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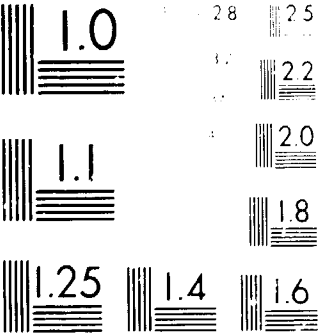
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United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.335/3/Rev. 1
30 September 1981

ENGLISH

Seminar on Wood Based Panels and Furniture Industries,
Beijing, People's Republic of China
23 March to 7 April 1981.

TECHNOLOGY AND EQUIPMENT OF A SMALL-SCALE WET-PROCESS HARD FIBREBOARD (HARDBOARD) PLANT *

by

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V.81-30286

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I. Introduction:

1. A brief introduction to the history of fibreboard production development:

The development of the fibreboard industry has not only made possible an integrated utilization of forest resources, but can also provide products having good physico-mechanical properties. Fibreboards have been widely used in furniture making, as a building material and in manufacturing other civil equipment. Consequently, the fibreboard industry has been developing, full of vitality, for the last half century. The development of the fibreboard industry may be broadly divided into three stages, namely the initial stage, the stage during which it was developing independently of the paper industry and the stage during which it was fully developing.

Initial stage:

Fibreboard produced in the early part of the twentieth century was mainly of the sound-absorbing and heat-insulating type used for interior finish in buildings. These were the by-products of the paper industry at that time and almost entirely soft fibreboard (i.e. insulating board) with a rather limited scope for use.

Development stage independant of the paper industry:

In the 1920's fibreboard production began to be separated from the paper industry to become an independant industry. New equipment and facilities to meet technological requirements kept on being created during this period, such as the explosive pulping process invented by Mason of the United States in 1924, the hot-grinding pulping process by Asplund of Sweden in 1932, the double-disc high speed mill invented by Bauer of the United States in 1935, and the four-drinier and the cylinder sieve machine appearing also in this period. During this period, the proportion of hard fibreboard began to increase gradually, and much greater attention was paid to the use of small poles and inferior grades of wood for raw materials.

Fully developed stage:

In the 1940's, specially after World War II, fibreboard was used extensively to make up for the lack of timber for reconstructing the war-devastated areas in many countries both as a raw material for the construction and for the furniture industries. As to the volume of world production, it rose from less than one million tons in 1945 to over four million tons in 1979. Technology and equipment was also further developed: the dry and semi-dry processes were introduced. In the middle part of the sixties medium density fibreboard was developed, and the testing and controls used during the manufacturing process were greatly improved. In addition, the problems related to the disposal of the wet-processing effluent were further solved. By now there are both a great variety of fibreboard products and a wide range of uses. It has been estimated that there are at least one thousand uses so far for hard fibreboard.

2. A brief introduction to the development of the fibreboard industry in China:

China began research on fibreboard and started production in 1958. Since that date, it developed the technology and production equipment and created a complete fibreboard industry system at a specific level of mechanization. There are currently wet-process hard fibreboard plants, dry-process hard fibreboard plants and soft fibreboard plants which have been designed and built without outside help; and already research has begun on the trial production of medium-density fibreboards. The capability exists already to design and establish plants with a technology and equipment to produce ten thousand cubic metres of medium-density fibreboard.

There exists in China at present no less than 240 big and small fibreboard plants. Those with a yearly production capacity of only 5.000 tons are widely distributed all over the country. The annual output increases year after year from less than 60,000 tons in 1960 to 440.000 tons in 1979. The small plants with an annual output of 5,000 tons produce 70 percent of the total output.

II. Definition and classification of fibreboard:

(1) Definition:

Fibreboards are panels obtained using wood or cereal stalks as the main raw material and fragmenting, refining, defibrating, forming, drying or hot-pressing these mechanically, utilizing the cohesive properties of the fibre itself and adding an adequate amount of chemicals to obtain boards.

(2) Classification of fibreboards:

There are several ways of classifying fibreboards, such as by production process, by density or by property and use, however, the most common method to classify fibreboards is by density of products.

By density:

Insulating board	density: 0.25 - 0.4 g/cm^3
Semi-hard fibreboard	density: 0.4 - 0.8 g/cm^3
Hard fibreboard	density: 0.8 - 1.2 g/cm^3
Very hard fibreboard	density: above 1.2 g/cm^3

By production process:

- Wet-process fibreboard
- Dry-process fibreboard
- Semi-dry process fibreboard
- Medium density fibreboard

By property and use:

- Ordinary fibreboard - fibreboard without any treatment
- Special fibreboard - fibreboard specially treated (as oil-impregnation or fire-resistant treatment).

III. Characteristics and Uses of Fibreboard:

(1) Characteristics of fibreboard;

a. It has a homogeneous texture, adequate strength, and shows little variance in longitudinal and crosswise strength; thus, it can be used without having to worry about fracturing, warping or deforming.

b. The dimensions of the surface and thickness of the board can be produced in different sizes according to uses, thus it is an ideal material to meet the requirements of construction and processing.

c. It possesses an acoustic absorbing and heat-insulating property and, through the addition of chemicals.where required, can be made into boards with functional properties (as fire-resistant and/or mould-repellent fibreboards).

d. It is suitable for further processing, such as machining or surface processing, bending, punching, etc.

e. It has a wide range of possible end-uses; and the residues can be re-used thus reducing the cost of products.

(2) Uses of fibreboard:

Insulating and semi-hard fibreboards:

Insulating and semi-hard fibreboards possess good acoustic absorbing, heat-preserving and insulating properties, therefore they are mainly used in building construction, especially in ceilings and partitions. They may also be used for packaging fragile materials such as glassware, electronic equipment and the like.

Hard fibreboard:

Hard fibreboard possesses a greater strength than hardwood. Some of its properties are superior to natural wood, consequently, it is widely used in furntiure making, as a framing material and for manufacturing civil equipment. Fibreboard that has undergone surface treatment has an even greater range of uses.

In China, ordinary hard fibreboard is mainly used for making concealed parts of furniture, however, printed or otherwise surface treated boards may be used as the face and side panels of furniture.

The thickness of standard hardboard is 3.2 mm. If calculated on the basis of this thickness and a density of 1 g/cm^3, the usable area per cubic metre (equal to one ton) of hardboard is equivalent to the total surface area of solid wood boards 11 mm thick that is obtained from 5.7 cubic metres of logs. 1/

1/ One ton of board requires 1.3 tons - or approximately 2 m^3 - of logs.

Medium density fibreboard:

Medium density fibreboard is a new type of board first developed during the middle part of the sixties which is light in weight, has great strength, is convenient for mortising, perforating, carving and use without edge banding, and is thus widely used for making high-grade furniture, as a building material and for different casings of electrical equipment.

The density of the medium density fibreboard made in China is 0.70 g/cm^3; its static bending strength is at least 230 kg/cm^2, its water absorptivity less than 25 percent, and its internal bond strength attains 6 kg/cm^2.

The principal materials used in fibreboard production are residues of wood processing and forest operations. This is one of the major ways to save timber. From the point of view of development of world forests, the bigger the population is, the greater is the amount of timber consumed and the less the forest resources will be. According to an estimate made by the Seventh World Forestry Congress, the consumption of wood products in the year 2000 will be double that of 1970. Therefore, the development of an integrated utilization of the forest resources in whatever region of the world is a very important measure which has to be promoted.

IV. TECHNOLOGICAL PROCESS AND MAIN CHARACTERISTICS OF SMALL-SCALE WET PROCESS FIBREBOARD PRODUCTION IN CHINA:

The characteristics of the wet-process hard fibreboard production are that it does not need any adhesives but mainly depends on its own chemical composition and fibre pattern to give it the strength and physico-mechanical properties of the fibres through the physical and chemical changes that occur during the mat forming, hot pressing, and heat treatment stages of the process. Thus, it saves chemical materials and reduces the cost of the end product. Furthermore, the finished boards do not contain any harmful chemicals.

Another characteristic of the wet-process is that the carrier used for transporting and forming the fibres into a mat is water, consequently it calls for a great consumption of water. Because the problems of disposing of the effluent has not yet been adequately solved, the development of the wet-process production has been somewhat limited. With the emergence of the various methods of using water in recent years (circulating water method, chemical, biotic, physical treatment, and closed and non-closed, etc.), the problem of effluent disposal for wet-process fibreboard was reasonably solved, thus, the prospects for using wet-process production are once again good.

In order to improve the quality of products obtained from the wet-process researches on the productive technology and equipment must be undertaken. The static bending strength of the hard fibreboard produced by small-scale wet-process production in China may attain or surpass 400 kg/cm^2, its water absorption is less than 25 percent. Such products are ranked among top-grade products; if necessary, various functional chemicals (fire-resistants, mould-repellants, preservatives, etc.) or tempering treatments (as oil impregnation etc.) may be utilized to produce fibreboards having special properties.

1. <u>Main technological stages in the production of hard fibreboard by the wet process.</u>

Raw materials → Chipping → Screening →
→ Washing → Hot grinding → Refined grinding →
→ Adding in water repellent → Mat-forming, pre-pressing → Hot pressing →
→ Heat treatment → Humidifying → Final products

<u>Main tasks of various stages</u>:

Chipping: To cut the various materials into chips of certain specified sizes thus to ensure a homogeneous pre-heating.

Screening: To screen out the oversized chips and the under-sized fines thus ensuring the consistency of chips with the technological requirements and to prevent them from affecting the quality of products.

Washing: To wash out the sand and mud from the chips or to screen out gravel and eliminate metallic parts thus protecting the disc of the defibrator and increasing the moisture content of the chips.

Hot-grinding: To soften the chips and separate them into fibre under the action of heat and the machine's discs.

Refined grinding: To further defibre the fibre bundles and coarse fibres so as to make them meet the technological requirements.

Addition of the water-repellent: In order to improve the resistance to water of the products.

Mat-forming pre-pressing: To produce fibreboard mats having a certain thickness and wet strength.

Hot-pressing: To form into fibreboard with certain cohesive strength through physico-chemical change in the mat under the action of heat and pressure.

Heat-treatment: It is the continuation of the hot-pressing process which allows the unfinished physico-chemical reaction of the hot-pressing to finish in the heat treatment chamber and thus improve the strength and water resisting properties of the products.

Humidifying: Through adopting the forced humidifying method, to make the moisture content attain an approximate equilibrium with that of the atmosphere and thus to reduce deformation during the use of the products.

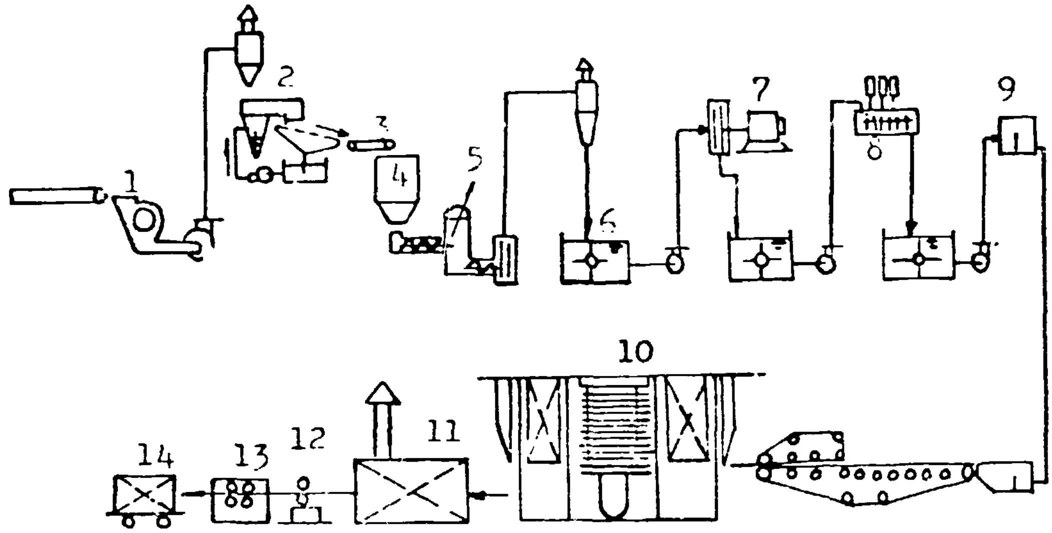


Fig. 1: Schematic diagram of technological flow of wet-process production (10 ton daily output).

Legend: 1. Chipper, 2. washer, 3. chips, 4. silo, 5. defibrator, 6. pulp storage tank, 7. refiner, 8. size vat, 9. high-level tank, 10. hot press, 11. heat-treatment chamber 12. edger, 13. humidifier, 14. final product.

2. Technological characteristics of small-scale wet-process hard fibreboard production in China:

Raw materials:

From the very first day that China started to develop its fibreboard industry, attention has been focused on the integrated utilization of the forest resources, particularly the rational use of residues of wood-processing enterprises, such as slabs, strips from sawmills and waste veneer and cores from plywood plants. In the vicinity of forests, even fuelwood and branches have begun to be used as raw material.

The principal species used for making fibreboard in China are Korean pine, dragon spruce, larch, birch, Chinese linden, northeast China ash in the north, and elm, Mason pine, Chinese fir, and Chinese sweet gum in the south.

In those areas with few or no forests, agricultural residues, such as cotton stalks in the cotton producing areas and hemp or wheat stalks in the north, bagasse in sugar-producing areas and bamboo in the south have already been brought into use.

As the types and forms of these materials differ, the data listed in Table I conveniently may be used for conversion.

Table I: Conversion factors of raw materials used.

Type of Material	Solid volume (m^3)	Waste wood stacked volume (m^3)	Wood chip stacked volume (m^3)	Weight conversion factor (kg/m^3)
Sawmilling residues	1.000	2.000	2.850	400
	0.500	1.000	1.425	200
	0.350	0.700	1.000	140
	2.500	5.000	7.143	1.000
Branches	1.000	3.333	2.843	450
	0.300	1.000	0.854	130
	0.351	1.170	1.000	158
	2.222	7.407	6.329	1.000
Fuel wood	1.000	1.429	2.667	520
	0.700	1.000	1.867	364
	0.375	0.536	1.000	194
	1.942	2.747	5.128	1.000
Forest thinnings	1.000	2.500	2.667	400
	0.400	1.000	1.067	160
	0.375	0.937	1.000	150
	2.500	6.250	6.667	1.000

Chipping:

Different types of chippers are used to chip the various kinds of wood materials. In a small plant where the scale of production is small and the forms of raw materials are numerous and varied, drum chippers are used, while in a comparatively large plant where the forms of raw materials are relatively uniform, disc chippers are used instead.

The cutting force of the rotating blade of a drum chipper is a circumferential force, while the acting force of the base blade is in a tangential direction with the moving trace of the flying blade, thus the shear effect cannot be well created and the quality of chips are consequently not as good as those produced by disc chippers.

Fibre is the basic material for producing fibreboard. The process existing between wood and fibre is chipping, the quality of which directly affects both the quality and quantity of the fibre. The general law affecting the quality of chips and the fibre is as follows:

$$m = \frac{M \times L}{M + L}$$

Where,

M = average length of original fibre in wood (mm);

L = length of chips (mm);

m = average length of fibre in chips (mm).

According to general experience the acceptable size of chips is 25 x 30 mm, and its appropriate thickness is 2.5 to 5 mm. In addition, the chips should be homogeneous to meet the technological requirements, so that they can guarantee the quality of the fibre obtained from grinding and defibration in order to increase the strength of the products.

Again, the form of fibre varies with the different species used while its length and diametre are other important signs to indicate its quality. The fibreous members in coniferous wood are called tracheids, with lengths about 1.5 to 3.7 mm, diametres about 20 to 40μ, and a cell-wall thickness of approximately 2 to 7μ. They make up approximately 95 percent of the coniferous wood. The structural construction of broadleaved trees is rather complicated, the length of the wood fibre is 0.5 to 3.0 mm, its diameter is 10 to 40μ, the wall thickness is 2 to 5μ, and its content does not exceed 50 percent whereas the rest of the material consists of different cells. The form of fibre of the coniferous wood is long and thin whereas that of the broadleaved wood is short and thick, so that the coniferous species are a better raw mateiial than the broadleaved species. However, our experience shows that if an appropriate combination of coniferous and broad-leaved species is chosen, high-quality fibreboard can also be produced. There is no strict requirement specified for the ratio of coniferous and broadleaved species, which may be adjusted according to actual conditions of production.

The chips cut into certain sizes require a moisture content of 35 to 50 percent which is the ideal moisture content beneficial to the pre-heating and defibering.

The requirements concerning bark content in the chips is that it should not exceed 10 percent, otherwise the performance and surface quality of the fibreboard will be affected.

Screening:

The purpose of chip screening is simply to separate out the oversized chips to be recrushed while the undersized dust and such other fine particles are eliminated, thus ensuring that only chips of certain specifications are fed into the defibrator and a qualified fibre pulp will be obtained from the homogeneous pre-heating.

Since there is a screen plate at the bottom of the drum chipper, the chipper itself possesses a screening effect, however, due to the impact the flying blade and screen plate exerts on them, the size of chips are extremely small which will cause relatively great losses if screened again, therefore they are not to be re-screened. As for the disc chipper, since it has no built-in screen plate, the chips cut out should be screened thus a screen and chipper must be installed with it.

Washing:

Washing with water performs a function that screening and magnetic separation cannot. It can eliminate the sand, mud and other impurities, such as stone, iron dusts and non-ferrous metals, through allowing them to deposit and be discharged, so as to protect the grinding discs of the defibrator against damage. Furthermore, washing chips with water raises their moisture content, thus facilitating their defibration.

Figure 2 shows in schematic diagrams the two most commonly used wood-chip washing equipment.

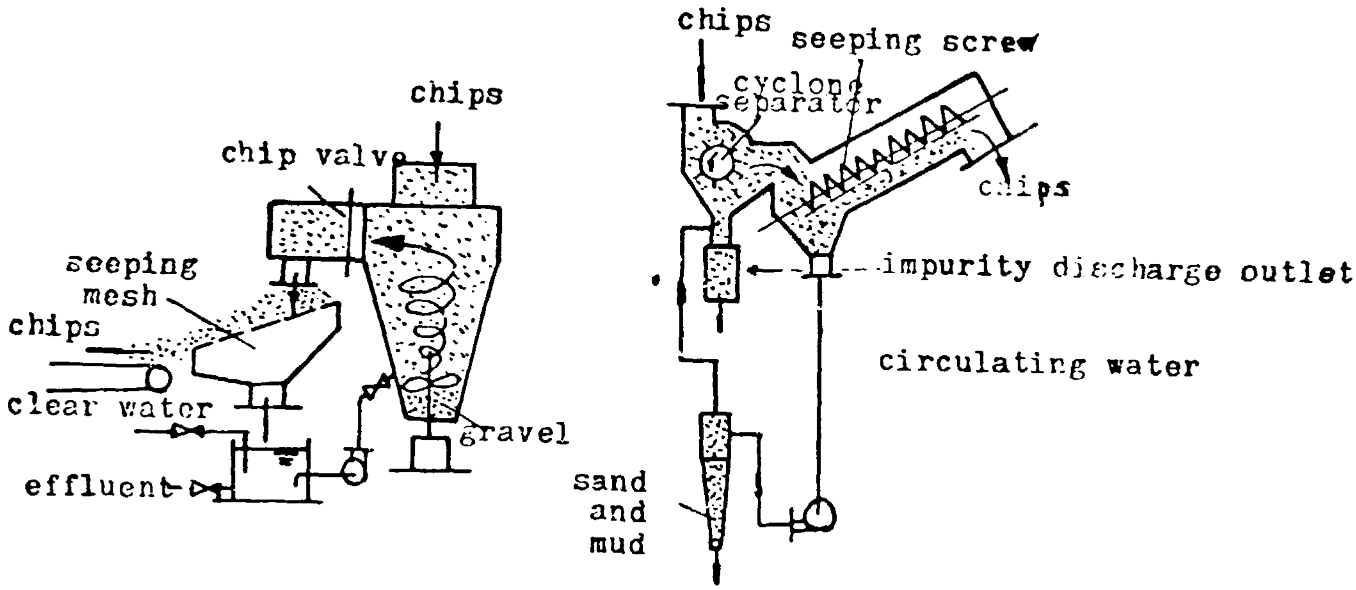


Fig. 2: Commonly used wood-chip washing equipment

Defibering:

Defibering is one of the most fundamental processes of fibre-board production. At the present time the main defibering equipment used are the two major types of defibrators (Asplund) and double-disc mills (Bauer). In China, attention has mainly focused on the development of defibrators because it is recognized that the defibering machine can produce high quality fibre, and compared to the double-disc mill and it is much easier to maintain and prepare. The defibrators produced at present in China which are appropriate for medium and small scale fibre board plants are models QM 6, QM 8 and the new model QM 9. Their characteristics are given in Table II below.

Table II: Characteristics of defibrators currently produced in China:

Item / Type	QM 6	QM 8	QM 9
Disc diameter (mm)	600	800	900
Power (kw)	110	245	275
Production capacity (t/day)	12-18	18-25	18-26
Fibre freeness (sec)	15-20	15-20	18-25

Prior to choosing adequate defibrating equipment it is necessary to grasp the appropriate defibrating technology. The temperature of the hot-grinding process, which carries out defibrating simultaneously with heating, appropriate for the softening of inter-cellular lignin as well as the hydrolysis of hemicellulose, is 160 to 180°C. Defibrating at this temperature not only can increase the fibre yield up to 95 percent but also will reduce the power consumption to 1/5 to 1/4 of that needed at 100°C.

Figure 3 shows the relationship between power consumption and temperature of defibering in the hot-grinding process

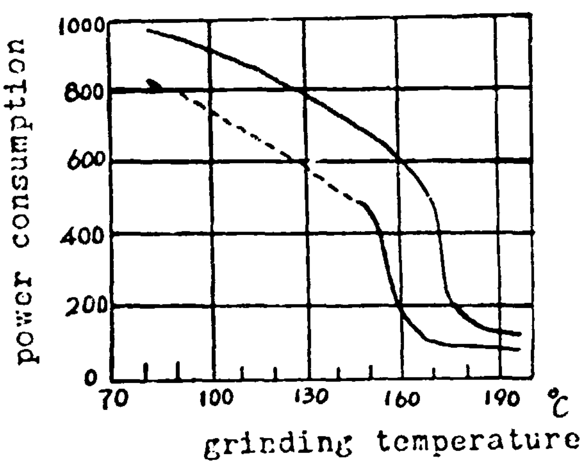


Fig. 3: Relationship between power consumption and temperature in defibering.

If the temperature is higher than 180°C, then the disolved and run-out material doubles with every increase of 8° C in the operating temperature. All the hemicellulose will be dissolved when temperature reaches 223°C. thus the fibre yield will drop down to under 70 percent at that temperature. Where a hot grinding temperature of 160 to 180°C is used, it is desirable to control the pre-heating time at 2 to 5 minutes according to actual conditions; if the time is too long the material dissolved will increase correspondingly and thus the total fibre yield will be affected.

Refining:

After the chips have been defibrated, with the defibrator, there normally remain some comparatively coarse parts of fibreous bundles and broken chips still not separated. It is a characteristic of the wet process that it needs no added adhesive but depends on its own feature of self-adhesion; the existence of these large fibre bundles and broken pieces will affect the adhesion strength of the fibre. Therefore, the purpose of refining is to further separate these large coarse "tows" and broken pieces so as to "fibrillate" and "fuzz" the fibre so as to increase the ratio between the surface area and polarity base and strengthen the seepage effect of the fibre, thus improving the interwoven adhesion of the fibre as well as the quality of products.

Water-repellent:

Fibres are hygrophilic by nature. Again, it is also a porous product; if it contacts the atmosphere, it is liable to absorb humidity. Therefore, in order to increase the water-repellent property of fibreboard, a water repellent should be added during the process, thus ensuring that the fibreboard will not be deformed or warped when it contacts the atmosphere.

There are a great variety of repellents, such as paraffin, resin, asphalt, synthetic resin, etc. Paraffin is the principal repellent used in China. There are two methods to add in the paraffin: one is to emulsify it and then add the emulsion to the fibre pulp, and the other is to feed the solid or liquid paraffin directly into the defibrator without any emulsification so that it may melt homogenously and be distributed on the surface of the fibre. This latter method is mostly used in the dry-process technology.

The paraffin emulsification method is mostly used in the wet-process production where paraffin is first emulsified and then added to the fibre pulp. This disperses the paraffin particles, increases the surface area and assures an even deposit on the surface of the fibre through the addition of a precipitating agent. There are a great variety of emulsifiers for the emulsification of paraffin, such as oleic acid, alkyl sodium sulfonate, stearic acid, synthetic fatty acid, etc. Among these the oleic acid and alkyl sodium sulfonate are relatively widely used in China; the latter being more economical. Much experience has been accumulated both in scientific research and production technology of the two paraffin-emulsification methods.

According to our experience in adding repellent in the wet-process production of fibreboard, the amount of paraffin used is 0.5 to 1 percent of that of the oven dry fibre; the particle size of the emulsified paraffin is 2 to 4μ; the density of the fibre pulp should be controlled at 0.8 to 2 percent, and the pulp temperature should be lower than the melting point of the paraffin; and finally, the pH value of the fibre pulp should be controlled at 4.5 to 5.

In addition, the precipitating agent used in China is aluminium sulphate which not only plays the role of breaking up the emulsification, but also can adjust the acid value of fibre pulp. In order to reduce the consumption of aluminium sulphate where the water is too hard (alkaline) small quantities of sulphuric acid or hydrochloric acid may be added to adjust the pH value of the pulp. Water soluble phenolic resin can also produce a firm adhesion effect on the fibre. This adhesive force will not be reduced by immersion in water, but instead the wet strength of the fibreboard will be increased. This is why some plants adopt the approach of adding a water-soluble resin.

Mat-forming:

Forming means the process of felting fibre into wet mats. There are two main types of wet-process forming: the fourdrinier forming and the cylinder sieve forming. The fourdrinier is the type that has been developed in China.

The purpose of forming is to felt the low density fibre dispersed in the pulp, through dehydrating by gravity, vacuum and pressure, into wet mats of certain thickness and wet strength. Figure 4 shows a schematic diagram of a fourdrinier.

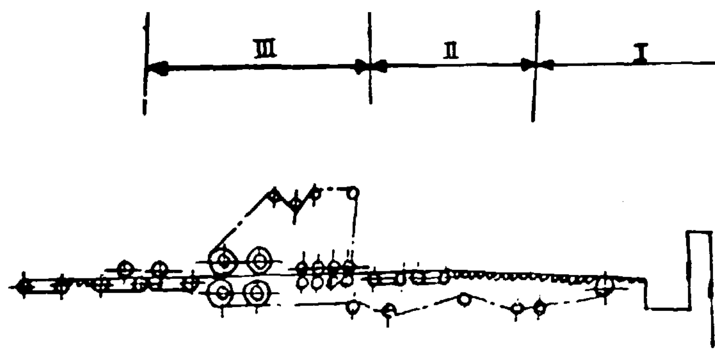


Fig. 4: Schematic drawing of a fourdrinier mat forming machine.

Legend: I.: Gravity drainage zone
II.: Vacuum dewatering zone
III: Pressure dewatering zone

Our experience shows that the forming density of fibre pulp should be controlled at 1.2 to 2 percent and the flow speed of fibre onto the pulp sieve should keep up with the speed of the fourdrinier, thus guarding against the emergence of stratified-flow effect affecting the quality of the mats. Where there is a 1 to 3° slope in the free gravity drainage section, the stratified-flow effect may also be avoided to prevent the stratification of mats. The frequency of the pulp beater should be controlled at 200 to 300 strokes per minute, the vacuum of the vacuum-dewatering stage should generally be controlled at 100 to 200 mm on the mercury column, the pressure of the roller line for pressure dewatering should be at 60 to 70 kg/cm, and the moisture content of the mats after forming should be about 75 percent.

Hot pressing:

The moisture in mats will be evaporated under the action of a combination of temperature and pressure and both physical and chemical changes will take place in the mats transforming them into a solid and compact sheet of fibreboard with a specific cohesion strength.

Temperature, pressure and time are the three key elements in the hot-pressing process, the concerted action which directly affects both the quality of the products and the quantity produced; best quality products will be obtained only if a suitable hot-pressing programme is selected, according to our experience, the generally acceptable hot-press curve with three-stage pressing along the lines of the cycle shown in Figure 5 should be used.

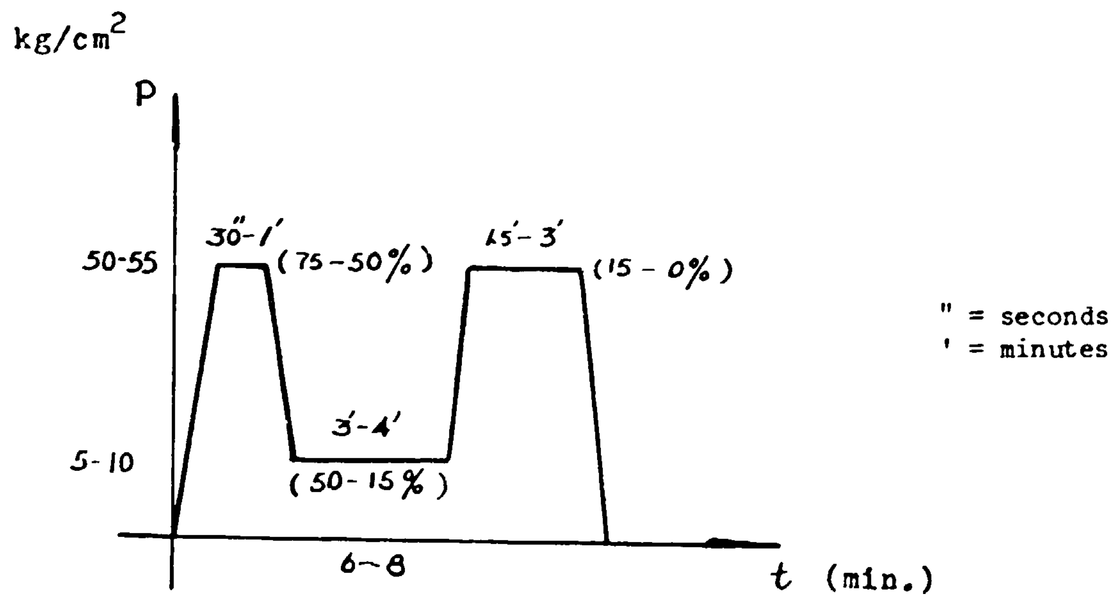


Fig. 5: Typical hot press curve for three-stage hot pressing of fibreboard.

The first stage is the high pressure drainage stage; the maximum unit pressure should be controlled at 50 to 55 kg/cm^2.

The second stage is the low pressure vapourization and drying; the unit pressure of this stage should be controlled at 5 to 10 kg/cm^2.

The third is the high temperature and pressure plastification stage; the unit pressure is similar to that of the first stage which may be controlled at 50 to 55 kg/cm^2.

Generally the hot-press temperature is controlled at 180 to 200°C, the time may be adjusted to suit actual conditions, the hot-press cycle is approximately 6 to 10 minutes and the duration of each period should also be changed with the variation of actual conditions, such as the type of raw material, characteristics of pulp and the requirements of the end products.

Heat-treatment:

Heat-treatment is the continuation of the heat reaction, allowing the unfinished physico-chemical reaction to proceed in the heat-treatment chamber to completion, so as to achieve the goal of improving the physico-mechanical property of the products. A particularly conspicuous result of the heat-treatment will be apparent where a hot-press technology of a short hot-pressing cycle and a lower hot-press temperature is used.

After heat-treatment fibreboard can increase its strength by 20 to 30 percent. The hot-press cycle can thus be shortened and the productivity of the hot-press increased while concurrently achieving the objective of improving the quality of products.

Though the heat treatment has a conspicuous effect on improving the product, it is not always effective if the technological conditions chosen fail to meet the requirements. The appropriate temperature of the heat-treatment should be controlled at 160 to 170°C, where the temperature is higher than 170°C a fire hazard exists, whereas if it is lower than 150°C, the effectiveness of the heat-treatment will then be affected. The moisture content of the fibreboard being heat-treated should not be over 5 percent, otherwise, a speedy hydrolysis and heat-decomposition will be effected, thus lowering its quality.

The duration of the heat-treatment may be adjusted according to actual conditions; it should not be too long, otherwise oxidization and heat-decomposition affecting quality will be induced into the fibre. Generally a duration of 3 to 5 hours is acceptable.

The heat-treatment chambers adopted in our country are of two types: the intermittent and the continuous. The temperature of the intermittent treatment is mostly at 160 to 170°C and the duration is 3 to 5 hours. The continuous treatment is further divided into the palisade and the suspended heat-treatment chambers, in which there are three temperature zones, namely, the pre-heating zone (80 to 160° C) and the high temperature zone (160° to 170° C). The continuous heat treatment chamber is generally 25 to 30 metres long and one fibreboard panel can be produced by it each 30 seconds.

Metres and instruments for measurement and control of temperature and a system for fire-prevention is installed in the heat-treatment chamber.

Humidifying:

The fibreboard, which is at an almost absolutely dry condition through hot-pressing and heat-treatment, will absorb moisture when exposed to the surrounding atmosphere; since there is the trace of the sieve on the back of wet-process hard fibreboard, the back surface area is larger than the smooth surface area, thus an interior stress is produced by the non-homogeneous absorption of humidity which causes the distortion and bowing of the board. In order to overcome this deficiency, an artificial forced humidification is generally adopted to force a speedy attainment of the equilibrium moisture content of the products corresponding to the atmospheric humidity.

The moisture content of the fibreboard after humidification should be a little lower than, or equal to, the atmospheric relative humidity which can be adjusted according to the various humidity conditions of different areas. Generally, the moisture content of the fibreboard produced in China is kept after humidifying at 6 to 10 percent.

There are two forced humidification methods, namely, the humidifying treatment chamber and the roller-press humidifier. The roller press humidifier is the most widely used method in China. When used, attention should be paid to the control of pressure and water temperature and the boards after humidification should be stacked for moisture balancing for more than 24 hours.
There are two types of humidifying chambers, the intermittent and the continuous, which are similar to the heat treatment chamber in construction. Attention should be paid to the control of humidity, temperature and time of treatment wherever the humidifying chamber is used. According to our experience, the temperature should be controlled at 40 to 60°C, the humidity should be kept at 80 to 90 percent, and the humidifying time should be about 5 hours; attention should also be paid to the corrosion by acidic organic gases in the humidifying chamber, thus measures should be taken to guard against corrosion.

Effluent disposal:

Much attention has been paid to the effluent disposal of the wet-process fibreboard production, and much research on the effective treatment of the effluent is being carried out. Many methods are presently used in China, and as a result of using the enclosed circulating water method and to the preliminary research results that have been obtained on this method in recent years, the amount of water consumed per ton of fibreboard is fundamentally controlled at 5 to 10 tons. This has really solved the problem of effluent disposal of the wet-process production. Compared with the other methods, it possesses the advantages of better results in disposing effluent, simpler equipment, less investment, more convenience to manage, and lower costs. We hold that this method is very effective for the small-scale wet-process fibreboard plant which lacks good financial means.

There are many similarities in industrial and agricultural productions and people's well-being in China and many other developing countries. Due to the lack of good industrial foundations, a certain backwardness in technology, the large area and population plus the uneven distribution of forest resources in China, a number of small-scale wet-process fibreboard plants suited to local condition have been developed, based on these characterists. These plants have contributed by producing fibreboard to lessen the gap between wood supply and demand, through a full utilization of forest resources and an integral use of the residues of the wood-processing enterprises. Also Chinese technical personnel and operating workers have been trained. A great deal of work has also been done during the last twenty years in summarizing the experience and in introducing techniques used by more advanced countries.

We hold that the scope of a productive enterprise should be determined by actual conditions, such as labour. financial resources, capital investment and marketing, and it is certainly reasonable to choose a suitable process and capacity.

In August 1978, FAO/UNDP investigated integrated wood processing industries in our country. They stated that the "small fibreboard plants of special interest to developing countries were seen in operation in China and this is one area in which the possibilities for transfer of technology could be quite good.

This size fits adequately the waste volume of many small to medium-sized sawmills cutting tropical mixed forests in developing countries.

It was not indicated whether the Chinese authorities are prepared to export these mills, but in principle, it should be possible. Good training for operatives, of course, could be given in the Chinese plants."

In a document published at the Fifth Session of the FAO Committee on Wood-based Panel Products, one of the author's important points of view was "The developing countries should not copy undiscriminatingly the type of development in advanced countries, or make a fetish of high mechanization, automation and computerization, but must establish their plants on the basis of the labour, capital and technical conditions of their own countries respectively."

It is believed by the Chinese authorities that the above statements are appropriate. The benefits of establishing small-scale plants in developing countries are: (1) low investment; (2) higher rate of employment; (3) convenient attachment to sawmilling or other wood-processing industries which results in the full utilization of residues; (4) simple and easy productive operation and equipment maintenance.

V. *BASIC EQUIPMENT AND ECONOMIC TARGETS OF A WET-PROCESS HARD FIBREBOARD PLANT*

(Hardboard) Plant with a daily output of ten tons:

1. The plant uses the wet-process technique for producing hard fibreboard (hardboard) the material of which may be residues of forest operations and other wood-processing industries. (See technological flow diagram on page 6).

   Production capacity: 10 tons per day
   Size of products: 1.000 x 2.000 x (2.5 to 5) mm

2. The building needed is 144 m long and 12 m wide, partly in high-rise construction, and the total construction area is 2.300 to 2,500 m^2, as shown in Fig. 6.

Fig. 6: Exterior of a small-scale fibreboard plant.

3. A fibreboard plant should store all the raw materials it needs for a production of three months, which should be stacked up separately according to different varieties and used in proper proportions. This point is very important to the planning and management of production.

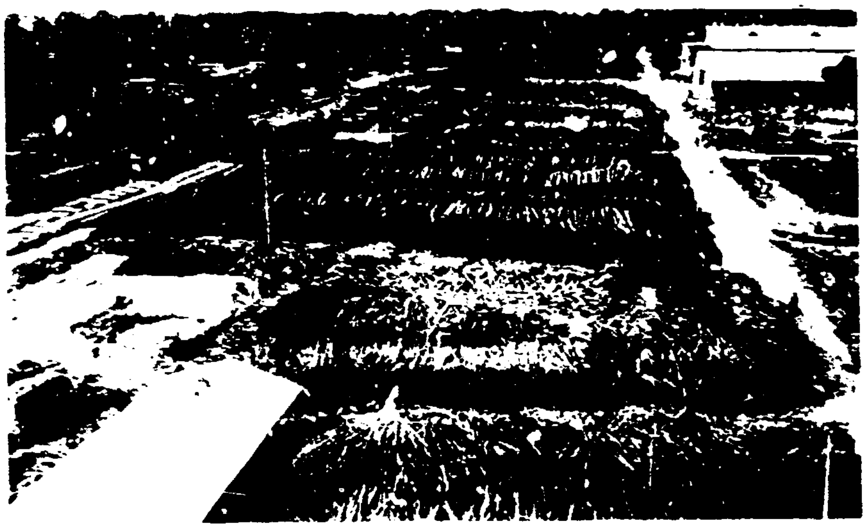


Fig. 7: A material storage yard.

Figure 8 shows the material preparation section of the plant, the feeding conveyor belt which is up to 30 m long and 400 mm wide, with residues from wood processing plants in the form of slabs, stored on both sides.

Fig. 8: Model PY 4030 feeding conveyor

5. The material-preparation section of the plant uses a drum chipper adaptable to the utilization of residues including all kinds of materials within the range not greater than three metres in length and 120 mm in thickness. The opening of the feeding roller at the feeder is controlled by hydraulic system and also there is a metal safety dog at the inlet. (see fig.9)

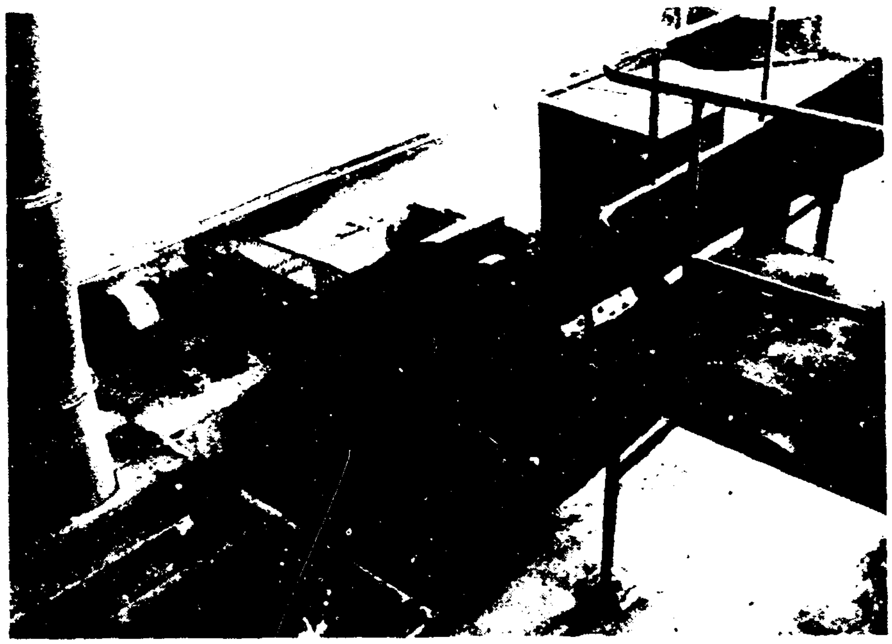


Fig. 9: Model GX-1200 drum chipper
Production capacity: 1.0 to 1.5 m^3/hour.
Diameter of the circular cutting blade: 1160 mm
Power: 40 kw

6. Chips cut by drum chipper are sent by a blower to a rectangular silo with a capacity of 150 cubic metres. This volume of chips is sufficient for the production of two shifts. At its base there is a screw discharger with adjustable speed which moves back and forth on a rail, as shown in figure 10.

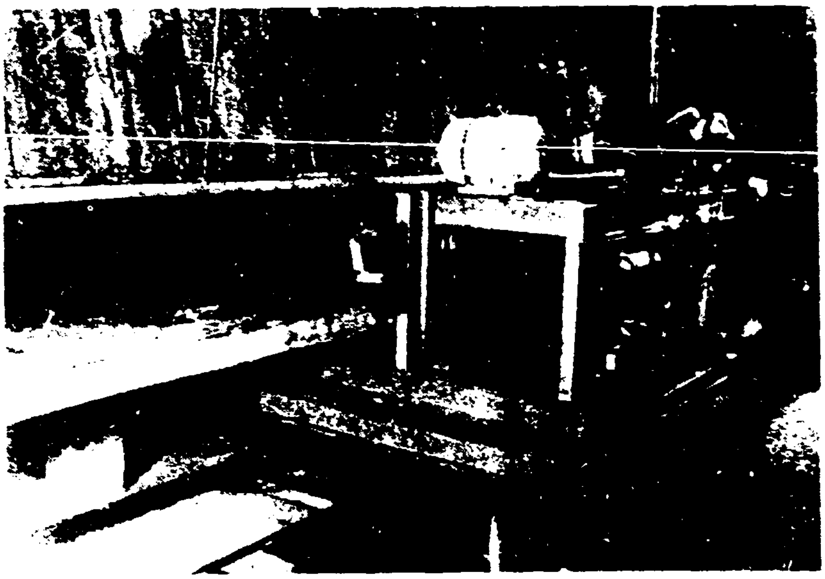


Fig. 10: Bottom of the silo and screw discharger of Model LS 200 screw discharger

Diameter of screw: 200 mm

Silo capacity 3.5 to 9.5 m^3/hour

Power: 2.7 kw.

7. Chips are sent into the washer at a temperature of 60 to 70°C, then fed into an oblique-bottomed tank to separate chips from the heavier materials such as gravel and metal particles which settle down to the bottom of the heavy-matter separator and are discharged through two alternating valves. The main body of the washer is shown in figure 11.

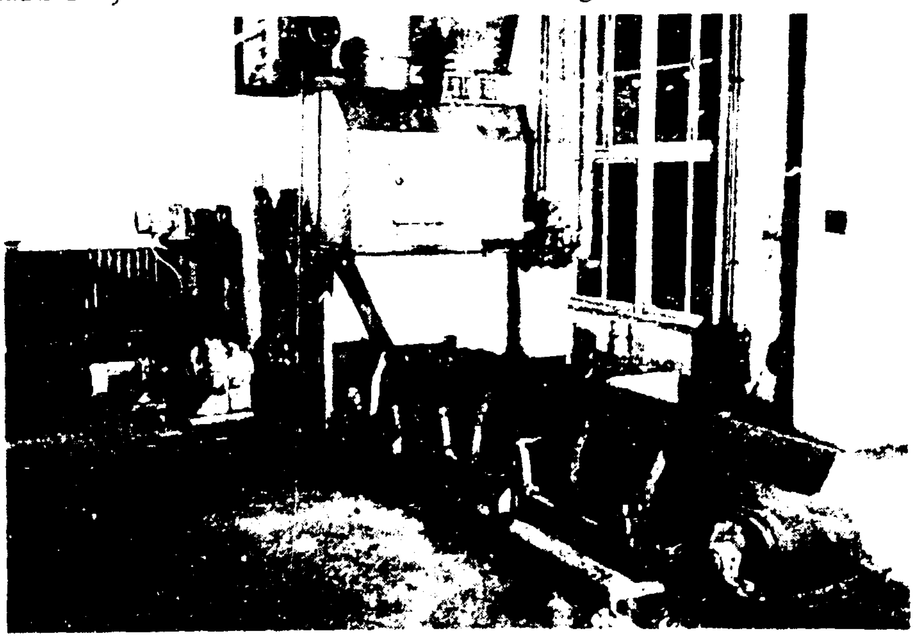


Fig. 11: Model MX chip washer

Production capacity: 4 to 8 m^3/ hour

Total power required for equipment: 5 kw

8. Chips will thus be rid of heavy matter such as gravel and metal particles, and their moisture and homegeniety will also be increased. They will then be sent into the Model SO-6 B silo with a 1.1 kw. magnetic vibrator, which has a capacity of 5.5 cubic metres and is connected with the defibrator shown in figure 12 (The funnel shaped part, in this photo is the silo).

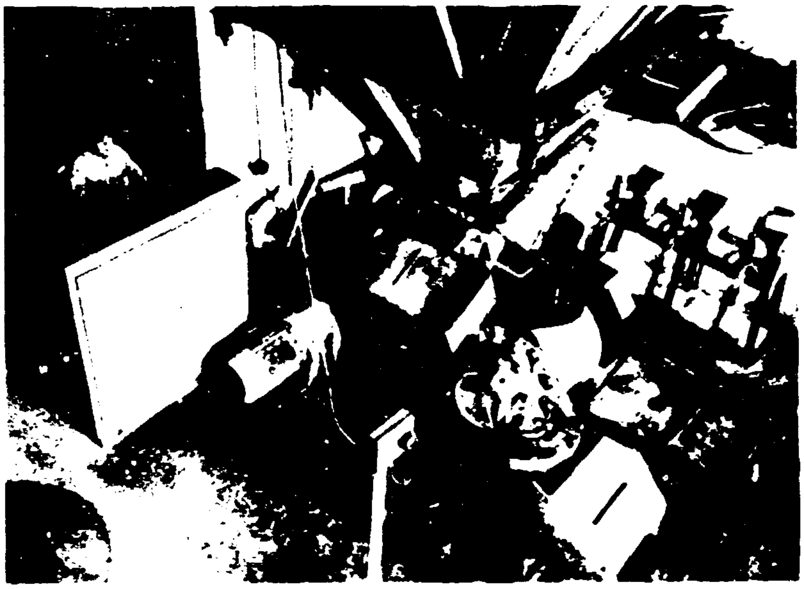


Fig. 12: Top part shows Model SO-6 B silo.

9. The defibrating system of the plant may use any of four models of defibrators, namely QM-6, SO-9, QM-8 and QM-9. Figure 13 shows a ∅ 800 (800 mm diametre) defibrator.

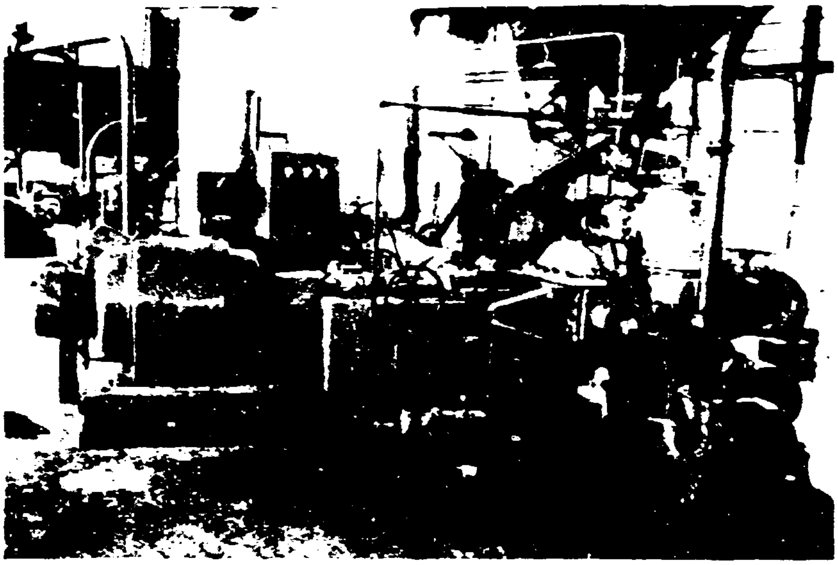


Fig. 13: Model QM-8 defibrator.

Production capacity: 8 to 25 tons per day

Diametre of disc: 800 mm

Rotational speed of disc: 735 r.p.m.

Power of main motor: 245 kw

Pre-heating steam pressure: 8 to 12 kg/cm^2

There also exists two other models of defibrators (the QM 6 and the SO-9) whose structures are similar to Model QM-8. Either of these three models should be used in co-ordination with the refiner, which means that the hot-ground coarse pulp can only meet the requirements of fibreboard production after having also passed through the refiner. There are two types of refiners: the Ø 600 and the Ø 800 (i.e. JM-6 and S13 refiners) which are similar in construction (see figure 14).

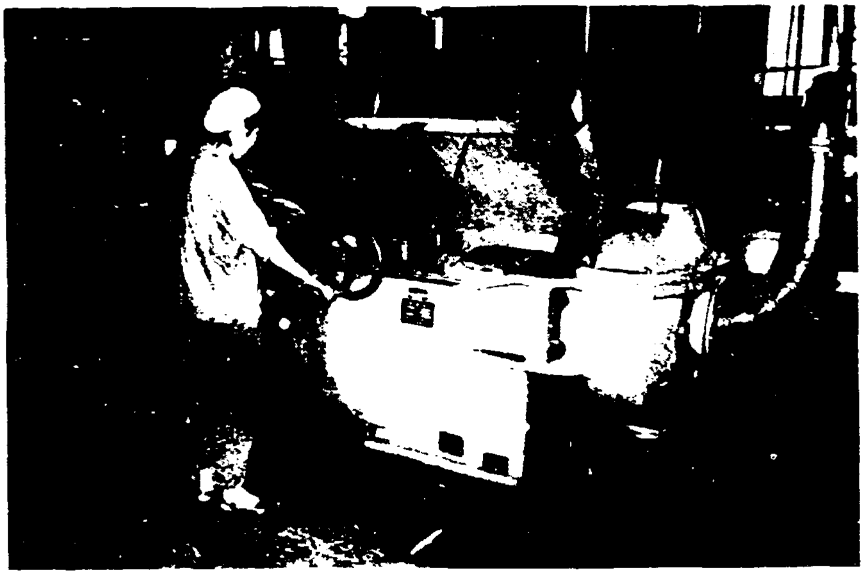


Fig. 14: Model JM-6 refiner
Production capacity: 20 tons per day approximately
Requirements for density of refined fibre: 8 to 15 percent
Diametre of disc: 600 mm
Power of electrical motor: 110 kw

This plant can also operate using the newly developed QM-9 (Ø 900 mm) defibrator which can prepare pulp meeting the requirements for fibreboard production in one operation by combining coarse grinding and refining. Figure 15 shows the main body of the QM-9 defibrator.

Fig. 15: Main body of Model QM-9 defibrator

Production capacity 18 to 26 tons per day of absolutely dry fibre.

Diameter of grinding disc 900 mm

Speed of grinding disc: 985 r.p.m.

Maximum adjustable clearance between grinding discs: 125 mm

Power of main motor 280 kw

Total weight of machine 3560 kg

Overall dimensions 6045 x 3767 x 5878 mm

The discs of Model QM-9 are divided into two grinding zones, namely, the coarse grinding zone and the refined grinding zone, as shown in figure 16.

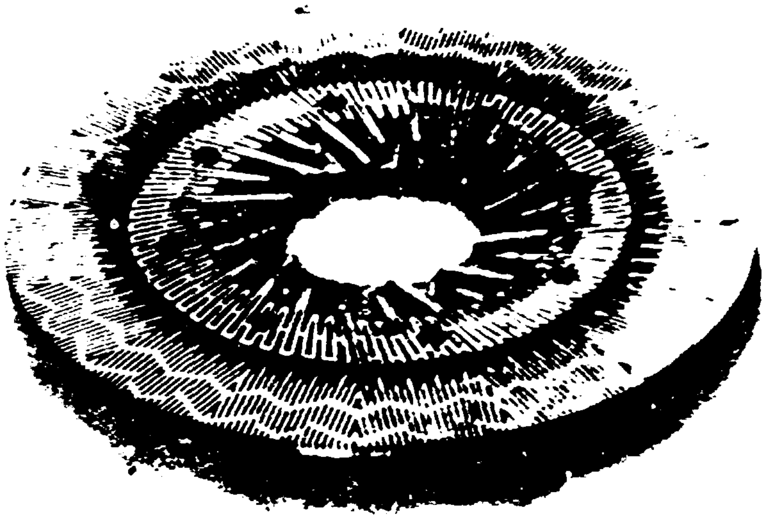


Fig. 16: Grinding disc of model QM-9 defibrator showing two grinding zones.

Model QM-9 defibrator has a rotating valve feeding system in co-ordination with vertical pre-heating;chips can be sent into the pre-heating cylinder progressively at a pressure of 6 kg/cm^2, Such a rotating valve is shown in figure 17.

Figure 17: Outward appearance of rotating valve for pre-heating

The model QM-9 defibrator has a vertical pre-heating cylinder and has incorporated with it a γ-ray material location control system. Chips can be steamed in the pre-heating cylinder at a steam pressure of 6 to 8 kg/cm^2 for 3 to 10 minutes. The vertical pre-heating cylinder which is shown in fibure 18, is 4 metres high, and has a diameter of 600 mm at the top and a diameter of 750 mm at the bottom.

Fig. 18: Vertical pre-heating cylinder with γ-ray material locator.

Model QM-9 defibrator is a new development which can do both the coarse and refined defibering on the same piece of equipment, thus when compared with past technology, the defibrator, coarse pulp storage tank and pulp pumps shown in figure 19 can be eliminated. In this way, not only is the technique and equipment simplified, but also the length of the plant can be shortened and the area occupied reduced.

Fig. 19: Outer appearance of model S11A pulp storage tank with a capacity of 45 cubic metres.

10. The plant uses a fourdrinier former. The principal technical data of the model S26C forming equipment are as follows:

Production capacity: 10 tons per day.

Mat-forming width: 960 to 1050 mm

Screen speed: 2 to 6 m/min.

Screen width: 1200 mm

Screen length: upper 5700 mm
lower 14600 mm

Total power 7 kw

Weight: 12000 kgs. approximately.

Figure 20 shows a model S26C fourdrinier board forming machine whereas figure 21 shows a model X-46 fourdrinier with a daily output of 25 tons of mats 1,300 mm in width.

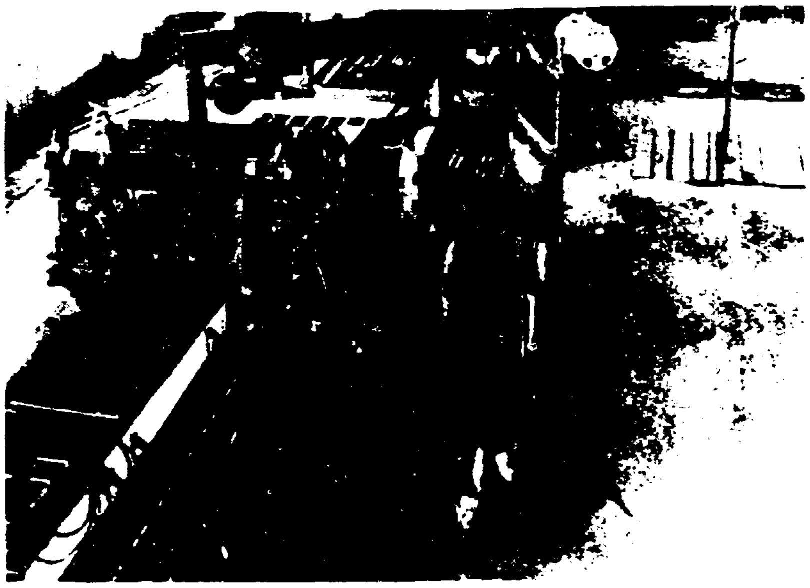


Fig. 20: Model S26C fourdrinier

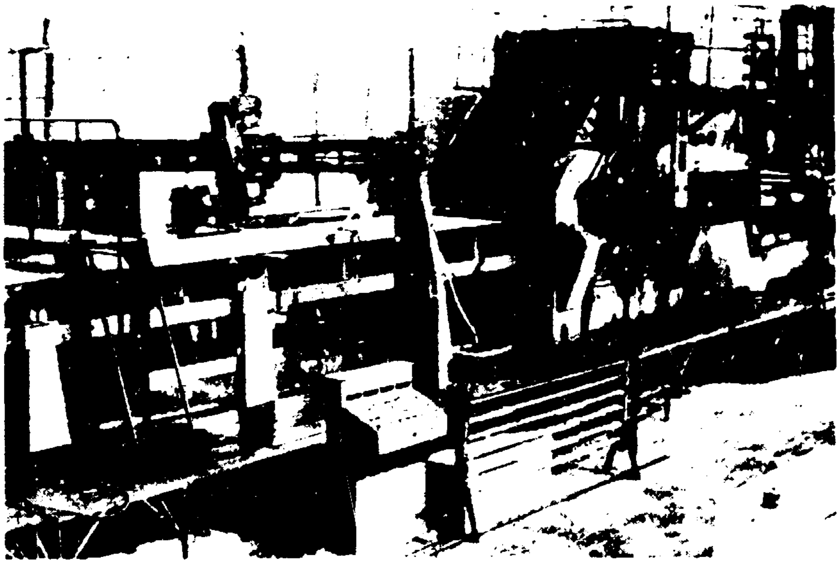


Fig. 21: Model X-46 fourdrinier

The moisture content of the mat is about 70 percent after forming and pre-pressing. Behind the couch roller of the fourdrinier there are a pair of longitudinal edgers and an automatic cross-cutting saw at an angle of 25° to the horizontal, which cuts the mat to the required length. It is then transported by a conveyor to the hot-pressing station.

Under the forming equipment and conveyor belt there are tanks for collecting waste mats to which the mats that do not meet the standards are sent by a tipper and from which they are then fed back to the pulp storage tank.

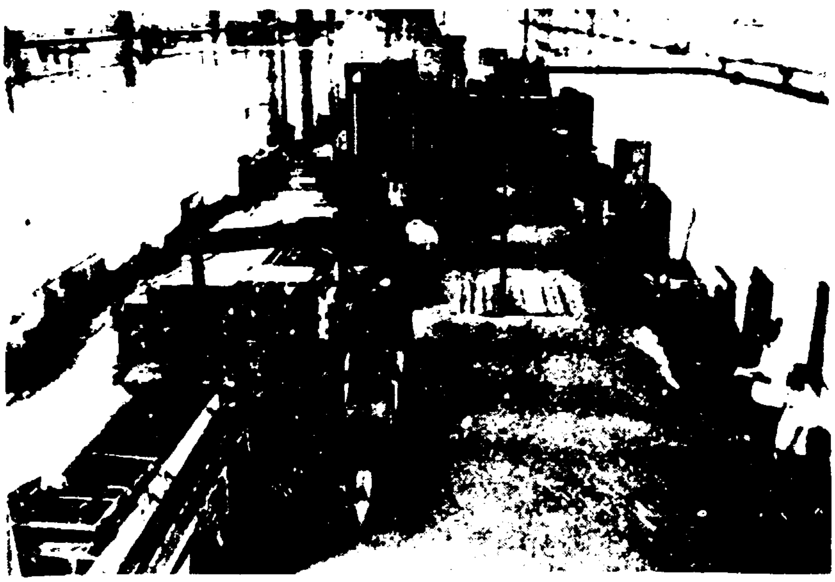


Fig. 22: Full view of the work sections of forming and hot pressing operations.

11. The hot press selected for such a plant is a 15-opening hot press with loader and unloader which is heated with saturated steam

at 20 to 22 kg/cm^2 (see figure 23).

Total pressure of hot press 1250 tons

Size of heated platen: 2250 x 1150 x 50 mm

Unit pressure: 60 kg/cm^2

Heated platen clearance: 90 mm

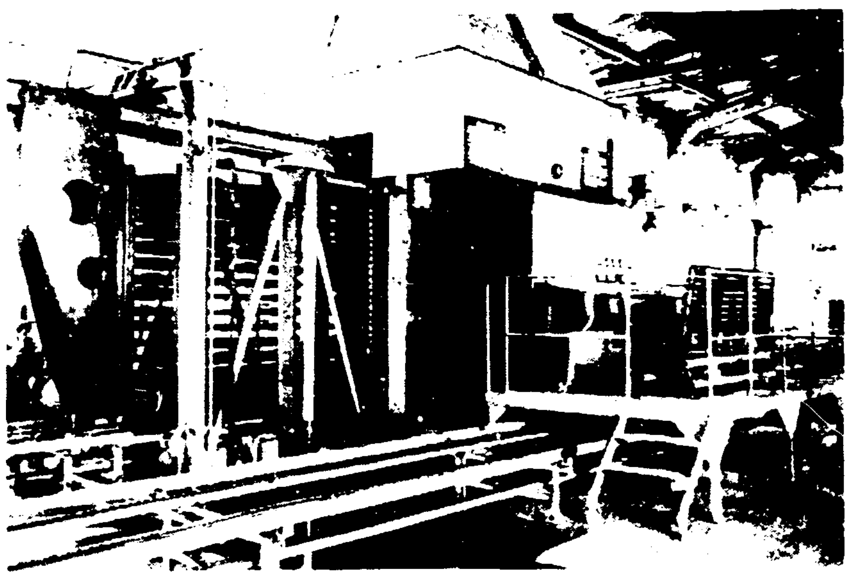


Fig. 23: SY 15-opening hot press

12. Fibreboards having passed through the hot pressing station are unloaded simultaneously by the unloader then separated from the cauls by the separator and sent for heat-treatment.

Two types of heat-treatment will be introduced here, one is the palisade progressive treatment chamber, as shown in figure 24. The principal technical data of this model RC-37 heat-treatment chamber are as follows:

Full length: 24 metres

Width: 5.2 metres

Height: 4 metres

Capacity: 354 fibreboard sheets can be handled at a time

Output speed: A sheet about every 30 seconds.

Temperature zone: three section temperature zone.

Steam consumption: 0.45 tons/hour

Fig. 24: RC-37 palisade heat-treatment chamber

The other type of heat-treatment is the suspended heat-treatment chamber, as shown in figure 25. The length of this chamber is 28 m, it can hold 320 boards at a time. It is divided into three temperature sections, namely, the pre-heating section which is 4 metres long and operates at a temperature of 80 to 160°C; the thermostatic section which is 20.5 metres long, operating at a temperature of 160 to 175° and the cooling section which is 3.5 metres long operating at a temperature of 175 to 80°C. Automatic temperature measuring and control systems and a fire extinguisher are installed in the chamber to ensure safe production.

Fig. 20: Suspended heat treatment chamber

13. The humidifying treatment is a technological process which should not be neglected in fibreboard production. This plant has a roller press humidifier: model JS-37 double roller humidifier as shown in figure 26,which has the following characteristics:

Feeding speed: 26 metres per minute

Maximum linear pressure of roller 55 kgs/cm

Power of motor: 3 Kw

Thickness of fibreboard that can be humidified: 2.5 to 5 mm

External dimensions 2022 x 1988 x 1800 mm

Weight: 4.2 tons

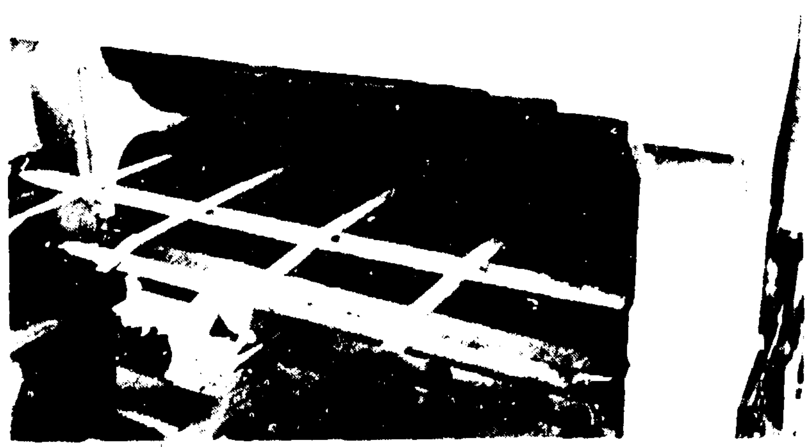


Figure: 26: Model JS-37 double-roller humdifier

Besides the above productive equipment, the plant is also provided with necessary instruments for testing and identification. A DS freeness tester is shown in figure 27 and a static-bending strength tester is shown in figure 28.

Fig. 27: DS freeness tester

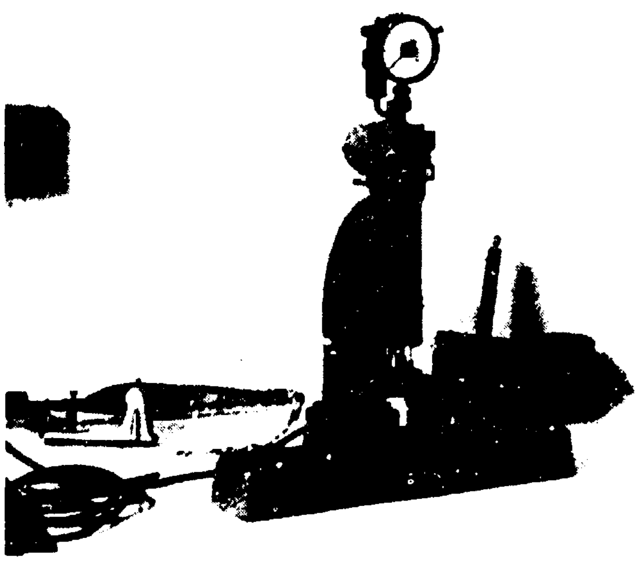


Fig. 28: model BJ-5 static-bending strength tester

The main techno-economic data of a small-scale wet-process fibreboard plant of this design are as follows:

Productivity per worker: about 90.5 T/yr (based on production workers)

Production capacity: 2.800 T/yr (based on 280 working days)

Cost of production: about 300 yuan per ton(based on the average costs of the majority of plants in China) (about US$ 200 per ton).

Some plants have added two hot-pressing plates into the 15-opening hot press and operate the hot-pressing cycle at a temperature of 200 to 210°C, thus reducing each pressing cycle to 7.3 minutes. The actual annual output may thus reach up to 6.500 tons. The cost of production per ton will thus be reduced to 280 yuan (US$ 187).

The above is a detailed description of the self-designed and self-constructed wet-process hard fibreboard plant with a daily output of 10 tons. In addition to this type of plant a wet-process hard fibreboard plant with an annual output of 8000 tons (25 tons per day) of panels 1.220 x 2440 x 2.5 - 5.0 mm has also been designed.

Main Economic Data of a Small-scale Wet-process Hard Fibreboard Plant

Item	Unit	Quantity	Remarks
Production capacity	T/yr	2800	daily output 10 tons
Size of panels produced	mm	1000x2100x2.5 to 5	
Consumption of wood	Solid m^3/yr	8.400	
Specific consumption of wood	T/T	1.322	
Maximum consumption of water	T/hr	28	Average 20
Maximum consumption of steam	T/hr	3.5	average 2.5
Installed capacity	kW	615.25	
Total weight of equipment	T	168.23	
Consumption of paraffin	T/yr	31	
Surface active agent	T/yr	2	or 6T of oleic acid, or 3T of ammonia spirit
Aluminium sulphate	T/yr	155	
Output per worker	T/yr	90.5	
Number of personnel		44	
Production workers		31	
Auxiliary workers		10	
Technicians		3	
Building area	m^2	2073.7	
Cost of unit product	Yuan/T US$/T	300 200	

Main Raw Materials Consumption and Its Percentage of the Total Costs For A Wet-Process Hard Fibreboard Plant with a Daily Output of 10 tons

Item	Consumption per ton of board	Percentage of 1/ total costs
Wood	1.30 T	10.81
Water	11.60 T	0.38
Electricity	350 kw.hr	10.50
Coal	1.20 T	14.00
Paraffin	11.0 kg	5.10
Oleic acid	2.1 kgs 2/	3.90 2/
Ammonia water	1.05 kgs	0.14
Aluminium sulphate	55 kgs	9.10
Total		54.0

1/ Based on a total cost of 300 yuan per ton of board (average costs of the majority of the plants).

2/ If alkyl sodium sulphonate is used as an emulsifier it will then be 0.54 percent of the total costs and the amount consumed will be 7.1 tons per ton of board.

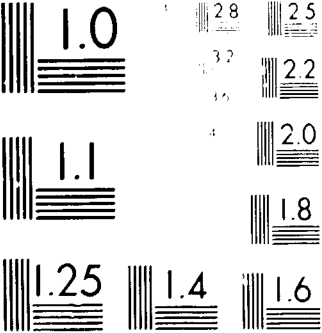
Chinese Technical Standards for Wet-Process Hardboard Manufacture

According to Chinese standards, ordinary hard fibreboards are divided into three grades as listed in the following table:

Physico-mechanical data	Unit	1st Grade	2nd Grade	3rd Grade
Density not less than	kg/cm^3	900	800	800
Static-bending strength (MOR) not less than	kg/cm^2	400	300	200
Water absorptivity not greater than	per-cent	20	30	35
Moisture content	percent	5-12	5-12	5-12

Exterior defects	1st Grade	2nd Grade	3rd Grade
Water stain	light	indistinct	distinct
Oil stain	not allowed	indistinct	distinct
Spots	not allowed	not allowed	light
Adhesive marks	not allowed	not allowed	light
Pressure traces	light	indistinct	distinct
Bulging, stratification, dampening, charring, splitting, corner-softening	not allowed	not allowed	not allowed

The standards require products to be identified by random sampling, with 0.3 percent of the total boards selected for each batch; however, not less than three samples should be re-examined. The average results of each sample should conform to the provisions in the above table.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LIMITED

ID/WG.335/3/Corr.1
22 April 1981

ENGLISH

United Nations Industrial Development Organization

Seminar on Wood Based Panels and Furniture Industries

Beijing, China, 20 March-4 April 1981

TECHNOLOGY AND EQUIPMENT OF A SMALL-SCALE WET-PROCESS HARD FIBREBOARD (HARDBOARD) PLANT

Corrigendum

Page 5, table I, headings of columns 3 and 4

For lamination read stacked volume

V. 81-24373