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SYNTHETIC RESIN ADHESIVES ^{1/}

A Survey of Production,
Production Techniques and
World Trade

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1. SYNTHETIC RESIN ADHESIVES

Bonding of wood by adhesives is not a new technique. This art seems to have been well developed in ancient times. Carvings in Thebes dating back 3.300 years, depict the gluing of a thin piece of veneer to what appears to be a plank of sycamore.

The types of glue utilized by the Egyptians were gum Arabic from the acacia tree, eggs, semi liquid balsams and resins from trees. There was little advance in adhesives technology until the twentieth century, and woodworkers had to rely mainly on animal and vegetable based glues.

In the beginning of this century tapioca starch, proteins, soya beans and casein became important adhesives. These glues had in common a moderate water resistance and poor resistance to micro-organisms. The tapioca starch and soya bean meal became important for the development of the plywood industry. In the beginning of the 1930's the first completely synthetic resin for adhesives application, phenol formaldehyde, was invented and found a large-scale application in the plywood industry. This glue had good water resistance and could withstand outdoor weathering.

In this decennium also the amino resins used for adhesive purposes became commercially available and found their use in the plywood and furniture production, later also in the particle board production.

Later in the 1930's melamine and polyvinylacetate adhesives were developed. Resorcin-formaldehyde resins were developed during the World War II and found a usage in the production of laminated wood constructions and in boats. After the war a considerable number of types of synthetic resin adhesives have been developed and marketed.

The development of synthetic resins has led to an extension in the utilization of adhesives. Even when wood has been substituted by other materials within certain fields, the development of synthetic adhesives made possible an increased utilization of wooden materials. While the production of animal glues has decreased after World War II, the production of synthetic resin adhesives has had an enormous growth.

World production of amino and phenolic resins in 1967 probably amounted to 2.2 million tons net dry weight. Adhesive consumption by the wood-based panel industry approximates 1.6 million tons net dry weight. The total consumption by Western Europe in 1968 amounted to 1,165,000 tons, out of which 575,000 tons represent adhesives. Particle board and plywood production account for most of the consumption, and this sector also accounts for the bulk of the growth estimated at 10% per annum.

1.1 Thermosetting Resin Adhesives.

Amino resins (urea and melamine) and phenolic resins are thermosetting resins. These resins have found many end uses, but we are considering only the types for application as adhesives. The final glue line of the thermosetting resin adhesives is insoluble and unfusible. These characteristics have given the adhesives the term thermosetting.

The bulk of the amino and phenolic resin adhesives has found application in the plywood and particle board industries also in the furniture industry.

Within each of the groups, adhesives of different properties are available. The adhesives can be modified according to specifications to a certain degree.

Urea resin adhesive is manufactured from urea and formaldehyde, melamine resin adhesive is manufactured from melamine and formaldehyde and phenolic resin adhesive is manufactured from phenol and formaldehyde.

These adhesives have in common that they are all based on formaldehyde as one of the reactants.

1.1.1 Formaldehyde.

Formaldehyde is characterized as the old chemical work horse. A break down of end uses shows that formaldehyde goes into products like:

Urea resins
Melamine resins
Phenolic resins
Pentaerythritol,
Hexamethylene tetramine
Urea formaldehyde concentrates: industrial fertilizers
Polyformaldehyde
Ethylene glycol

Formaldehyde is in reality a gas with a boiling point of $- 21^{\circ}\text{C}$, and is usually absorbed in water to a 37% (by weight) liquid solution, also called formalin. Most processes for the manufacture of formaldehyde are based on methanol, the two main processes are:

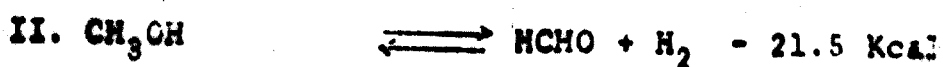
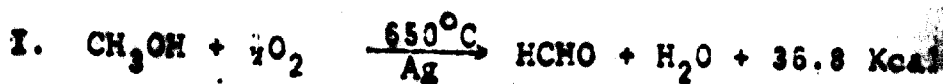
- 1) Converting methanol into formaldehyde with a silver catalyst - the silver process
- 2) Oxidizing methanol over a metallic oxide catalyst - the metal oxide process.

The processes are highly automated.

1.1.2 Flow Scheme

1.1.2.1 The Silver Process.

A mixture of methanol, water and air vapors is lead over a catalyst bed of silver crystals. Process temperatures are between 600 and 700°C . The following main reactions take place:



The first reaction is an exothermic oxidizing process, while the second is a dehydrogenation process of endothermic character. Methanol is converted to formaldehyde according to both

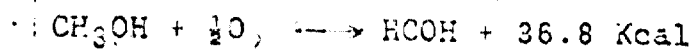
reactions and is recovered by absorption with water. Various side reactions occur, producing formic acid, carbon monoxide and carbon dioxide. The net reaction is exothermic and the temperature is maintained by a close control of the ratio between the air, the methanol and the water vapours from the evaporator.

Formaldehyde is commercially available as solution in a concentration of 37% - 40% by weight.

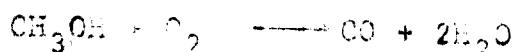
1.1.2.2 The Oxide Process.

In the oxide process metallic oxides are used as catalysts. These are usually iron or molybdenum oxides.

Gaseous methanol mixed with air passes over a fixed catalyst bed where the main reaction is:



In addition there is a side reaction:



Process temperatures are in the region of 300 - 400°C. The formaldehyde is recovered by absorption with water.

Several side reactions take place forming carbon dioxide and formic acid. Temperatures in the catalyst bed are controlled by the mole ratio methanol/air.

1.1.3 Production Equipment and Technique in the Production of Adhesives.

1.1.3.1 Liquid Glue, Condensate.

Liquid glue is manufactured in big reaction kettles. A resin plant consists of a reaction kettle equipped with turbo agitator and reflux condenser. The kettle is jacketed or equipped

with coils for heating or cooling and a thermometer. The thermometer is connected with an indicator, where the temperature can be controlled continuously.

The condensate can be concentrated in the kettle by distillation under vacuum. This requires a kettle built for operating under vacuum. A more effective way of concentrating the condensate is by evaporation in a thin-film dryer.

The equipment is usually stainless steel.

1.1.3.2 Powder Adhesives.

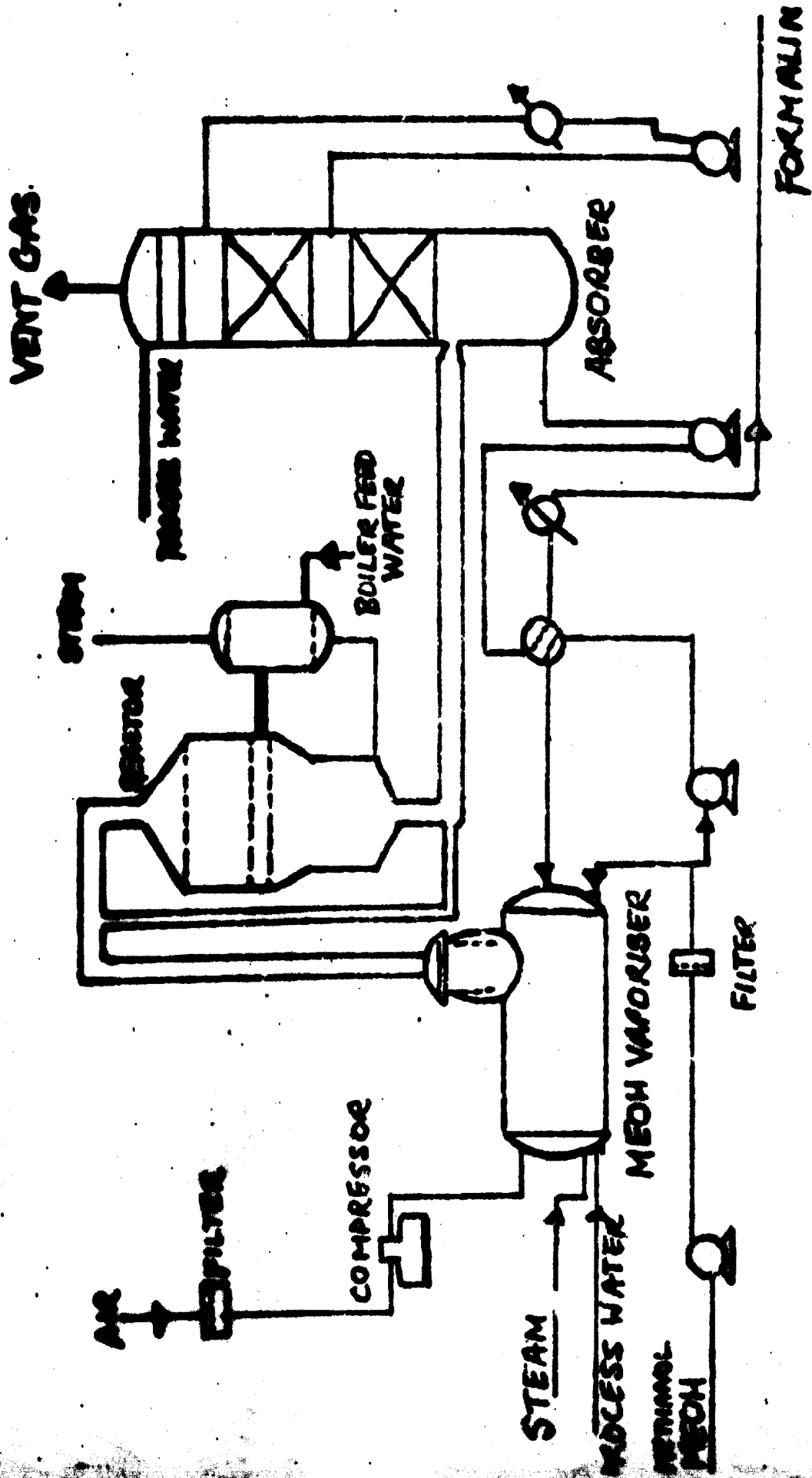
The production of powder adhesives is conducted in a spray dryer. The condensate is pumped into the spray dryer, caught by a rotating disk, which rotates at a speed of 6 - 8,000 rotations per minute. The resin is sprayed out as a very fine dust, which meets heated air at a temperature of 200°C, blown through the spray dryer by which water is evaporated. The air and the dried powder are separated in a cyclone. The powdered glue falls out and is bagged in polyethylene lined jute bags, ready for transportation over long distances, and for storing in warm climates.

1.1.4 Amino Resins.

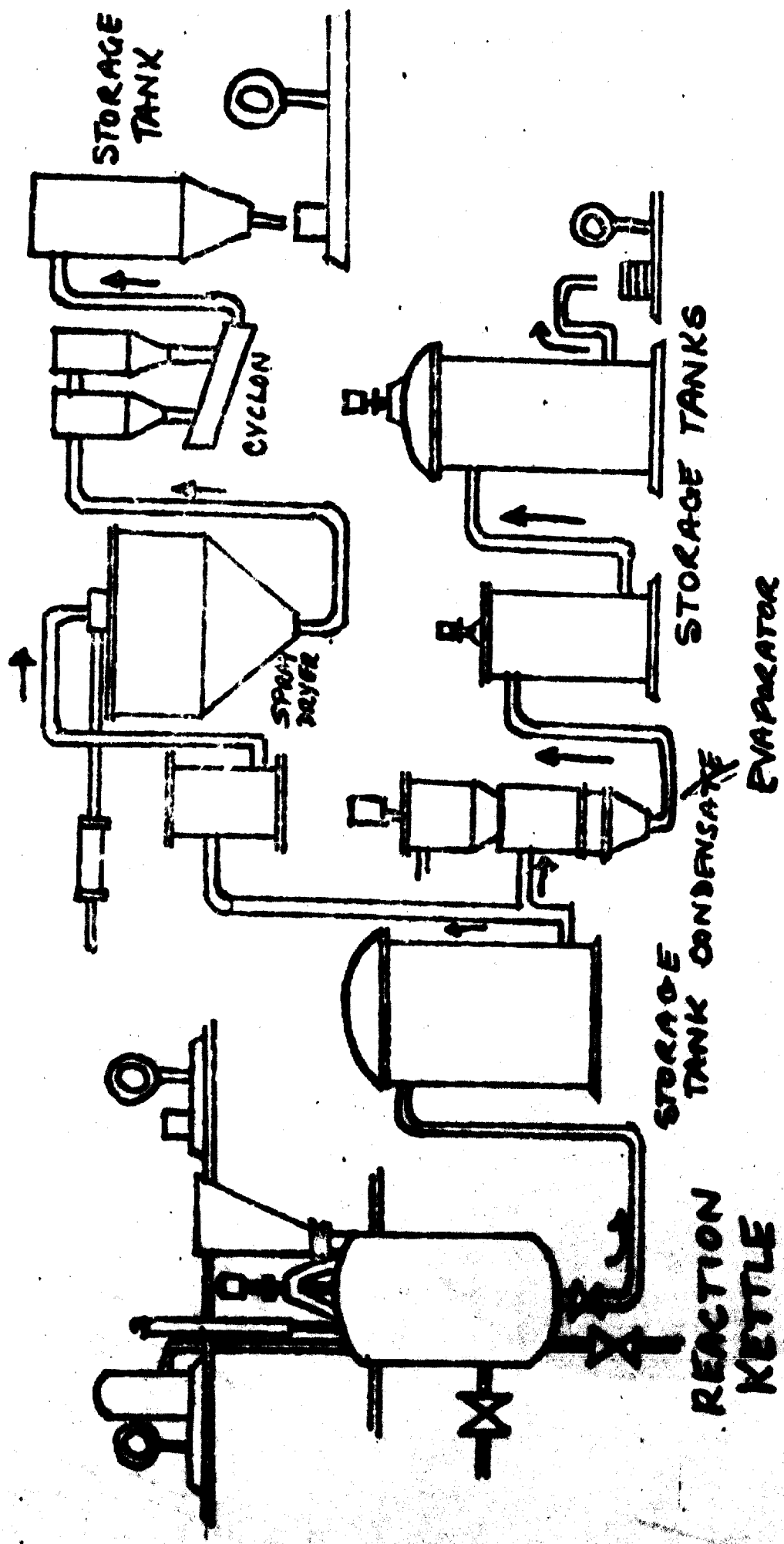
Raw materials for amino resins are urea, or melamine and formaldehyde.

1.1.4.1 Urea - General Description.

Ammonia and carbon dioxide are the feedstocks for production of urea in all commercial processes currently in operation. The reactions take place under temperatures in the range of 170 - 210°C and pressures in the range of 120 - 280 kg/cm².

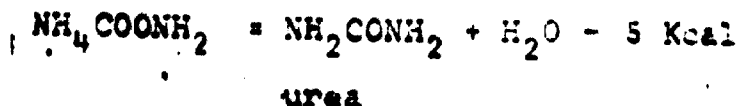
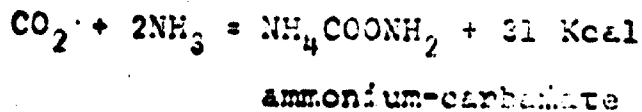


FORMALDEHYDE
FLOW-SYSTEM
SILVER CATALYST process



**SYNTHETIC RESIN PLANT
FLONSOH 5116**

First substantial amounts of ammonium carbamate is formed, but the effluent from the synthetic reactor also contains urea, water and excess ammonia. The principal reactions are:



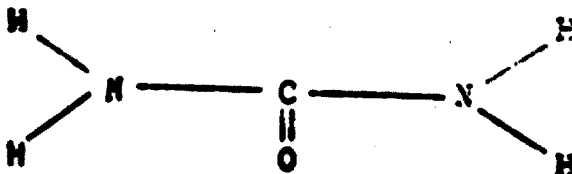
The first reaction is exothermic, while the second is endothermic.

Pure urea is a white, crystalline chemical in powder form with a melting point of 132.6°C. The technical grade is also quite pure, contains about 46% nitrogen and is commercially available in forms of granules, crystals, or flakes.

1.1.4.2 Production Techniques and Reaction Mechanisms.

The production of urea adhesives starts with mixing specified amounts of urea and formaldehyde into a reaction kettle. The reaction mechanism is complicated and a series of reaction products of different chemical compositions are formed. We are not going into details of chemical formulas in this connection, but it might be of advantage to get a brief idea of what happens when urea and formaldehyde react.

The urea molecule has the following chemical formula:



and may be illustrated like this, with four tentacles representing the hydrogen atoms:



The formaldehyde molecule has the following chemical formula:



and may be illustrated like this:



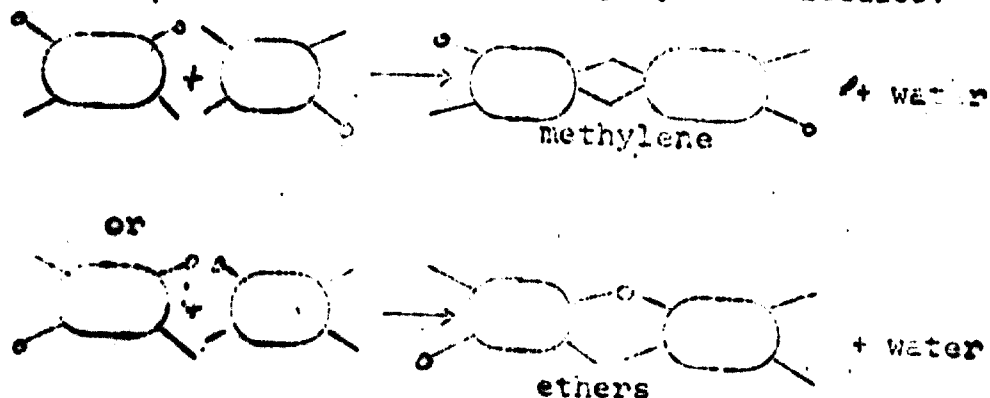
The first step in the reaction cycle when urea and formaldehyde react is that the urea molecule catches 1 - 4 formaldehyde molecules, the reaction product is methylurea:



etc.

When a tentacle in a urea molecule has caught a formaldehyde molecule, the molecular attraction weakens and consequently the formaldehyde molecules are added at a retarded rate. The last tentacle in trimethylurea is so weak that the formation of tetramethylurea is difficult and is possible only by presence of energy of formaldehyde in relation to urea.

The next step is the condensation or polymerization of methylol-urea to polymer molecules:



Two molecules melting together in this way under dehydration is called condensation.

Reaction between methylol groups gives ethers as a result and when one methylol group and one amino group react, formation of methylene is the result.

Condensation is conducted at 95 - 100°C and reaction speed is dependant upon pH, faster at a low pH.

Best results are obtained when the reaction is controlled at pH 5 - 6, acid condition.

During continued condensation large molecules or polymers of complicated cross-linked structures are formed.

These cross-linked structures may interreact and gelatinate (macromolecule).

To prevent the gelatination taking place in the reaction kettle the condensation must be closely watched and controlled at all stages of production.

The solids content of the condensate is only about 50% and water and methanol is distilled off or evaporated as previously described.

The finished resin adhesive has a solids content of 60 - 70%. The storage stability of such adhesives is two to three months.

In cases where longer storage stability is required, the liquid resins must be spraydried to a free flowing powder. The powder glue has a storage stability of about twelve months.

1.1.4.3 Properties.

1.1.4.3.1 Liquid form.

Urea-formaldehyde resin glue in liquid form and of normal specifications has low viscosity and low content of free formaldehyde and gives glue mixes combining long potlife and high reactivity at elevated temperatures.

It may be used for chipboard and for hot-bonding in the plywood and furniture-industry. Due to its low viscosity at least 5% flour extension (based on liq. glue) is necessary in order to give a convenient consistency of the glue mix.

Specifications:

| | |
|---------------------------|------------|
| Solids content: | 64,5-68,5% |
| Viscosity at 25°C (77°F): | 360-500 cp |
| Free formaldehyde: | 0,5-0,8% |
| pH: | 7,8-8,8 |
| Specific gravity: | 1,26 |

Storage:

The liquid glue should be stored in a cool place. At 20°C (68°F) it may be stored for approx. 3 months, longer at lower temperatures and shorter at higher temperatures.

1.1.4.3.2 Powder.

Urea-formaldehyde resin glue in powderform.

Specifications: (in 60% solution at 25°C)

Viscosity: 3000 - 5000 cp.

pH: 7,5 - 8,5

Preparing the liquid glue mix:

In general 1 part by weight of a resin of these specifications and 0,8 - 1 part of water will correspond to a suitable content of glue solids before addition of the hardener.

By using high-speed mechanical mixers, the water should be measured in first, then the powder added while the mixer is running.

In slow-speed mechanical mixers, about $\frac{1}{2}$ of the water is measured in first, then the powder. The dough is kneaded until all the glue is thoroughly mixed, after which the rest of the water is added while still stirring. Slow-speed mixers should be equipped with a wallscraper. The water should be at room-temperature 20°C (68° F), since colder water retards the mixing.

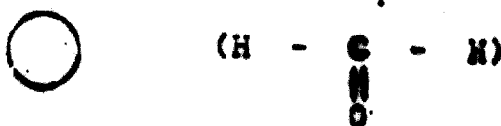
Storage:

The powder glue should be stored in a cool and dry place. At 20°C it may be stored for approx. 1 year. It absorbs moisture, and if the original bags have been opened, care must be taken to keep them well closed.

The phenol molecule has three carbon atoms, which can react with formaldehyde. The molecule may be described as a molecule with three tentacles:



As previously the formaldehyde molecule can be described as:



First step in the reaction when phenol and formaldehyde are brought together is that the phenol molecule catches 1 - 3 molecules of formaldehyde.

The reaction products are:

monomethylolphenol



dimethylolphenol



trimethylolphenol



The average amount of methylol groups per phenol molecule in the mixture is dependant upon the mole ratio of formaldehyde and phenol.

Mole ratio is usually between 1.3 to 1 and 3.0 to 1. At a mole ratio below 1 to 1 and reaction in acidic condition a so called Novolak is formed. This is cured only if excess formaldehyde is added, i.e. mole ratio is raised to more than 1.1 to 1.

The reaction is an exothermic reaction, a one step condensation, and takes place under alkaline conditions, pH of 8 - 9, and in temperature of 90 - 95°C. The speed of the reaction increases with a higher pH. The reactions are quite similar to those described for urea resins, and methylene and ether are formed.

The reaction products contain methylol side or end groups, which in turn interreact and form larger and larger molecules to macromolecules (curing).

Phenolic resins are divided into three groups according to the degree or stage of condensation or polymerization:

- A-stage (resol): . Mainly on the methylol stage. Soluble in alkaline solutions.
- B-stage (resitol): Cross linking of methylol groups starts. Partly soluble in alcohol or acetone.
- C-stage (resit): Complex cross linking of phenolic groups by methylene groups to cured resin. Completely impossible to dissolve.

To prevent the glue from gelling in the kettle, the production process must be controlled with utmost care throughout the whole condensation time. The viscosity and pH of the batch is to be watched closely and samples have to be taken at certain intervals.

A liquid resin is stabilized at a pH of 11 - 12, is soluble in water to infinite dilution. The resin may be stored for about 2 - 3 months, dependant upon temperature. Solids content is usually in the range of 43 - 50%. Phenolic adhesives are also spray dried and commercially available in free-flowing powder form.

Production equipment is similar to that used for the manufacture of urea resins.

1.1.5.1 Production Control and Customer Service.

As pointed out several times, the process has to be controlled at all stages of the

production cycle. The control and analyzing may be done by the operators or by special personnel. The final product is also to be checked according to standards and specifications. The laboratory must also be equipped to handle requests from customers when specific problems arise in the production line or when a specific product is to be developed.

1.2 Prerequisites for Establishing Plants for the Production of Resin Adhesives.

1.2.1 General.

This paper presents only a broad outline of production techniques, and the chemistry regarding the thermosetting resins. Those who are interested in a more complete knowledge on the subjects are advised to read some of the literature listed in the annexes.

The production processes for the thermosetting resins have generally been developed by research institutes and companies with advanced knowledge of chemical technology. Many patents have been granted. A manufacturer trying to establish his own knowledge by developing processes might have a hard time doing so without infringing patent rights, and also the work always will prove very costly.

Three ways are open in order to establish production in a country:

1. Establishment of a joint venture with a foreign company which provides know-how.
2. Local company buys complete process know-how and production equipment from foreign company.
3. Foreign companies are invited to establish business in the country.

In all cases favourable domestic conditions must be created. A good environment for investments is regarded to include political stability, steady development of the economy and good protection for foreign investments, including free repatriation of capital and free remittance of earnings.

It is further of great importance that adequate skilled labour, engineers and operators are available or can be trained.

Technology must also be guarded, or security provided by a system of patent laws.

It is believed that countries with established systems of patent laws and who have joined the Union of the Convention of Paris, stand a better chance to attract investments by business enterprises.

1.2.2 Market development.

A market, like a product has its life cycle. It is particularly true with regard to the thermosetting resin adhesives. In general the development in a certain market may be described to consist of five phases.

Phase 1. The demand is limited, but interesting, and big enough to invite introduction and service activities by foreign manufacturers.

Phase 2. Demand is increasing, volume is sufficient and calls for complete sales and service activities for customers.

Phase 3. Demand and consumption are developed to an interesting volume, not yet large enough for establishing local production, but of interest to competition by other suppliers. Prices tend to decline.

Phase 4. Consumption has increased to a degree that local production, based on imported raw materials, is an alternative to imports. At this stage local production cannot be competitive without trade regulations or subsidies from the Government.

Phase 5. Local consumption has increased to a volume which gives basis for local production of the raw materials. At this stage savings in freight and shorter transport favour local production, and additional trade regulations make import prohibitive.

It is apparent that no thumb rule exists telling exactly where conditions are favourable to start local production. Studies of local conditions, sources of supplies etc. are vital in this respect.

1.2.3 Investment Costs and Costs of Operation of Resin Plants or Integrated Formaldehyde Resin Plants.

Many factors must be taken into account when construction of a plant is considered.

The market environment, sources of raw-materials supply available supply of utilities, cost of transportation, inventory- and capital costs, to name a few factors worth considering.

Trade regulations and government policies might be an important part of the total picture and influence the final decision. Below are given general calculations indicating production costs and investment costs related to capacity. Costs may of course vary from plant to plant and from location to location.

A breakdown of the production costs for a plant in Northern Europe designed for 30,000 tons per year is approximately as follows:

Production cost of 1 ton of formaldehyde from a 30,000 tons per year plant:

| | |
|----------|----------------------------------|
| \$ 30.00 | 0.500 tons methanol at \$ 60/ton |
| \$ 0.15 | Catalysts and auxiliaries |
| \$ 0.75 | Utilities: Electricity 27 Kwh |
| | Water, cooling 30 m ³ |
| | Make-up water 1.1 m ³ |
| | Steam, start-up 1 ton/h |
| \$ 0.85 | Labour |
| \$ 2.10 | Maintenance |
| \$ 3.90 | Plant overhead |
| \$ 2.00 | Depreciations |
| \$ 39.75 | TOTAL |
| ===== | |

Production cost of 1 ton Urea/Formaldehyde Resin from a 30,000 tons a Year plant:

| | |
|----------|---|
| \$ 27.80 | Formaldehyde .0.9 tons at \$ 31.90/t |
| \$ 31.50 | Urea 0.45 " " \$ 70.00/t |
| \$ 1.10 | Utilities: Electricity 36 Kwh |
| | Water, cooling 15 m ³ |
| | Make-up water 4 m ³ |
| | Steam 1.1 ton |
| \$ 1.25 | Labour |
| \$ 2.50 | Maintenance |
| \$ 10.20 | Plant overhead (integrated plant) & royalties |
| \$ 4.50 | Depreciations |
| \$ 78.80 | |
| \$ 8.00 | Cost of investments & working capital |
| \$ 86.85 | TOTAL COSTS |
| ===== | |

Additional costs are delivery cost, research and development, taxes.

To complete the picture and give an example of the

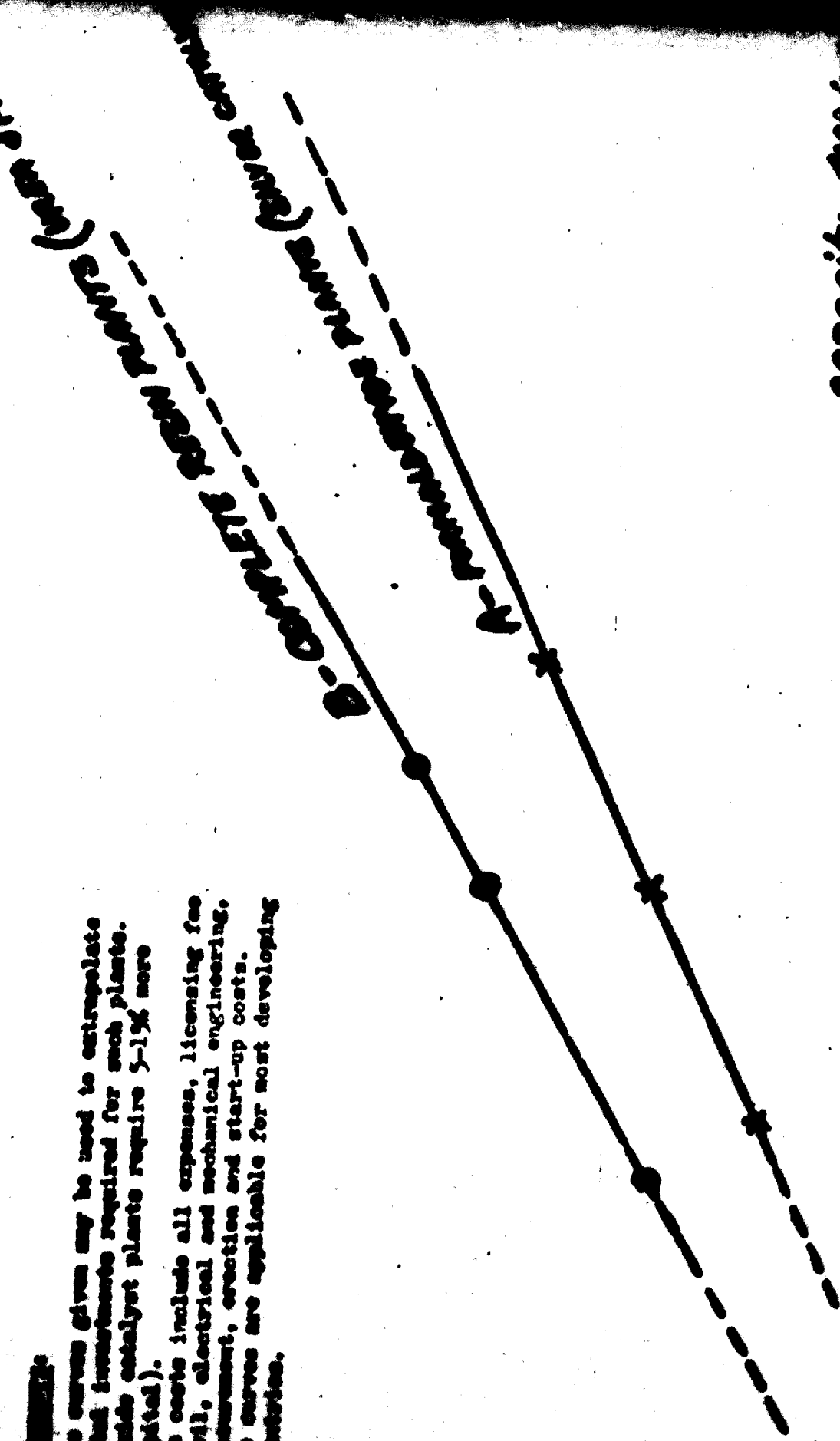
A. FORMALDEHYDE PLANTS

B. RESIN PLANTS - TWO TYPES OF FORMALDEHYDE RESINS , MAY BE PRODUCED, ONE BEING URSA TYPE

Notes:

The curves given may be used to extrapolate total investments required for such plants. (Urals catalyst plants require 5-15% more capital).

The costs include all expenses, licensing fee civil, electrical and mechanical engineering, procurement, erection and start-up costs. The curves are applicable for most developing countries.



Capacity - 1000 tons

See

PRODUCTION COST RELATED TO CAPACITY

- A. FORMALDEHYDE
- B. UREA FORMALDEHYDE RESIN
- C. PHENOL FORMALDEHYDE RESIN

Production cost is defined as the minimum sales price when all overhead, depreciations, and license fees are included.
Raw materials are based on bulk deliveries international port.
When transport costs must be added these applicable.

CAPACITY 100 TONS PER YEAR

relative importance of resin a study of the major factors affecting particle-board production costs is included. (This study was presented at Washington State University's Symposium on Particle-Board.)

1.2.4 Particle-board production costs.

1.2.4.1 Major Factors.

The major factors affecting particle-board production costs are raw materials, direct conversion costs, and losses due to waste from the press, finishing, cutting-to-size, and press down-time.

Table 1 identifies the specific elements that directly affect production costs (column 1, cost elements). The second column specifies the values assumed for purposes of illustration, representing what may be considered fairly typical values for manufacturing a 5/8" industrial board at a West Coast U.S. Plant. (Obviously most of these values will vary considerably from plant to plant). Total cost with cost elements at assumed levels was \$ 20.32.

The primary purpose in making this computation was not so much to show typical production cost, though \$ 20 per thousand square feet may be somewhat typical for 5/8" industrial boards on the west coast of the U.S. The primary purpose was to evaluate the relative significance of each cost element.

Table 1 also shows the amount total costs would be reduced if each cost element was reduced, one at a time, by 10% (all other cost elements held constant). (See column 3 "Cost Savings"). For example, press cycle time was assumed to be 5.8 minutes in this illustration. If press cycle time was reduced by 10%, and all other costs were held constant, total cost would be

this case be 18 times more productive than a 1% reduction in the cost of wax, downtime, finishing loss, or press waste.

Thus it can be seen that in this example the key variables affecting total costs are press cycle time and the cost of resin. The cost of wax at \$ 3.25 per 100 pounds, a downtime of 5%, a finishing loss of 2%, and press waste of 2% each have by comparison little influence on total costs.

1.2.4.2 Varying Cost Elements.

These same computations were redone with all cost elements at a level higher than that originally assumed, and then again at a lower level. Press cycle time was varied from 4.6 to 6 minutes, resin cost was varied from 4.5 to 5 cents, variable costs ranged from \$ 35 to \$ 65 per hour, etc. The result showed that varying these cost elements over a fairly wide range has little effect on the order of relative importance of the variables: press cycle time and resin cost remained the most significant factors throughout the analyses; while wax, downtime, finishing loss, and press waste remained the least important variables.

Table 1. - Simulated production costs of a 5/8" industrial grade particle-board at a West cost U.S. plant; and the effect on total production cost of a 1% reduction in individual cost elements.

| Cost Elements | Assumed value | Cost Savings |
|----------------------|-----------------------------|--------------|
| Press cycle time | 5.5 minutes | \$ 0.16 |
| Resin | \$0.0475/lb, 56% solids | 0.11 |
| Variable costs | \$ 60 per hour | 0.10 |
| Fixed costs | \$ 40 per hour | 0.07 |
| Wood | \$ 4 per O.D. ton | 0.05 |
| Panel finishing | 3 per MSF | 0.03 |
| Shipping preparation | 2 per MSF | 0.02 |
| Cut-to-size loss | 4% | 0.02 |
| Wax | \$ 3.25/100 lbs, 45% solids | 0.01 |

| Cost elements | Assumed value | Cost Savings |
|------------------|-----------------|--------------|
| Downtime | 5% | 0.01 |
| Finishing loss | 2% | 0.01 |
| Waste from press | 2% | 0.01 |
| Total cost | <u>\$ 39.32</u> | |

Our ability to generalize about the relative importance of these variables is helpful, but analysts at each plant should conduct this sort of analysis themselves to be most effective. Most importantly, the results can be used to guide expenditures for controlling key factors affecting production costs at each individual plant.

1.2.4.3 Cost Reports Age Quickly.

The usefulness of cost analysis is clearly limited unless cost analysis reports are made available to everyone who may be able to use them. Such reports must be current, available at least monthly, with a minimal amount of lag time. Like a daily newspaper, cost reports age quickly.

Equations used to compute total production costs

1. Raw material costs per MSF =
(lbs raw material/mat) (cost/lb solids)
(1000) square feet/mat
 2. Total raw material costs per MSF =
Wood cost/MSF + Resin cost/MSF + Wax cost/MSF
 3. Conversion cost/MSF =
(Fixed conversion cost + variable conversion cost)(press cycle time (1000)
(Production rate in sq.ft./hr)(1-pct downtime
(1-pct waste from press))
 4. Total cost per MSF =
Raw material/MSF + Conversion/MSF + panel
finishing/MSF (1-Finishing loss)(1-Cut-to-
size loss)
- + Shipping
MSF

2. World Production of Synthetic Resin Adhesives.

Synthetic resin adhesives of the phenolic and amino types have been produced for a rather short time.

Phenol formaldehyde adhesives and coatings were produced for the first time in 1909 in the U.S.A., in 1910 in Germany and in the United Kingdom, in 1916 in France, in 1922 in Italy, while Canada, Japan and Sweden took up production in 1923 and the Netherlands started production in 1934.

Urea formaldehyde adhesives were commercially manufactured for the first time in Germany in 1932. In the U.K. production came under way in 1934, France and the U.S.A. followed suit in 1936, the Netherlands started in 1940, Italy in 1942, while Canada and Sweden started their production in 1945. All European countries, except Denmark and Luxembourg, are believed to have production of synthetic resins of the phenolic or amino types for adhesive purposes. The U.S.A. and Canada are of course self sufficient.

In African countries there is production in the United Arab Republic (Egypt) and in South Africa. There are plans for starting up production in Algeria.

In the Latin-American region production is found in the following countries: The Argentine, Brazil, Chile, Colombia, Mexico, Nicaragua, Peru, and Venezuela.

In the Near East one will find production in Turkey and in Israel. The following other Asiatic countries have production: India, Japan, South Korea, Malaysia, the Philippines, Singapore, and Taiwan.

Further, Australia and New Zealand have production.

Practically all countries mentioned above have production of formaldehyde; some production units are integrated into urea and methanol.

2.2 Production and Consumption.

In surveying the production and consumption of synthetic resin adhesives of the different countries, and totals for the world, it is necessary to make estimates. Statistics of production and trade are not specified to a degree where figures are reliable. Most countries operate their statistics in broad commodity groups. SITC, Division 08 describes commodities like:

Regenerated Cellulose and Artificial Resins

Position 881.1 is: Products of Condensation, Polycondensation and Polyaddition (Phenoplasts, Aminoplasts, Alkyds, Polyallyl Esters and other Unsaturated Polyesters, Silicones).

The products which we are concerned about in this paper are the phenoplasts and the aminoplasts, and then only what is consumed for wood based panel production as adhesives.

One way of estimating the production of adhesives is to base the estimates on consumption of urea, melamine, phenol, formaldehyde or methanol where such figures are available.

Such estimates require knowledge of the end uses and the breakdown in end uses relevant to the different products in the countries or areas evaluated.

The safest basis for estimating the total consumption of urea and phenolic resins might, however, be the statistics of world production of wood based panels and boards. Such figures are compiled by FAO.

The table below gives estimated figures for the resin consumption by the plywood and particle board industries in specified regions, and the total for the world. Growth figures are also given for capacity and consumption.

| | Estimated | Consumption | Capacity | |
|------------------|--------------|-------------|-------------|-------------|
| | 1968 | yearly | yearly | yearly |
| | consumption | growth | growth | growth |
| | 1000 MT | 1968-1969 | 1966 - 1969 | 1966 - 1969 |
| | | % | Plywood | Part. Board |
| Western Europe | 694 | 19 | 3 | 12 |
| Eastern Europe | 142 | 7 | 3 | 6 |
| USSR | 208 | 16 | 6 | 22 |
| Africa | 14 | 14 | 9 | 20 |
| Asia & Near East | 250 | 13 | 12 | 6 |
| North America | 821 | 6 | 4 | 14 |
| Latin America | 48 | 22 | 6 | 24 |
| Oceania | 21 | 12 | - 2 | 10 |
| WORLD | 2.181 | + 16 | 6 | 18 |

In Western Europe total resin consumption by board manufacturers is estimated to be 694,000 metric tons net solids content. Approximately 585,000 tons were consumed by the particle board industry in 1968. The total increase in consumption per year is 19%, and the bulk of this growth derives from the particle board industry.

Urea formaldehyde resins comprise the largest part of the resin consumption. Estimates are that Western Europe in 1968 had a total consumption of approximately 675,000 tons net dry weight. By 1975 this amount is expected to reach 1.1 million tons. Adhesives will then account for 80% or about 880,000 tons. The larger consumption will continue to be by particle board and plywood industries, which in 1968 accounted for 85%.

The phenol formaldehyde resins had a growth of about 10% per annum from 1960 to 1968. Adhesives and bonding resins have been mainly responsible for this development. Production in 1968 estimated at 870,000 tons net dry weight, and requirements by 1975 will be 660,000 tons, a growth rate of 8% per annum. Adhesive application accounted for 10% of the consumption in 1968.

Eastern Europe has had a moderate growth both in consumption of adhesives and expansion in the board production capacity. USSR has had considerable growth, and this trend is expected to continue. USSR is known to have plans for a rather extensive expansion of particle board manufacturing facilities by 1972.

The total consumption of adhesive resins by countries in the African region is estimated at about 14,000 tons net dry weight. The plywood industry accounts for 68% of the total.

In 1966 the total production of plywood amounted to 266,000 m³ for the region. There was production in 35 mills in 14 different countries. By 1969 the total installed capacity amounted to more than 353,000 m³ in 43 mills, an increase of 9% per annum. An additional four countries had taken up production.

The mills are rather small and only eight of the countries have production in excess of 10,000 m³ of plywood per annum.

The biggest mills are found in Gabon and Nigeria. Utilized capacity is between 70 and 80% for the region.

The particle board production capacity increased by 81% in the period 1966 - 1969.

In 1969 the approximate capacity was 121,000 tons. 19 mills were producing in 14 countries. Eight new mills had been installed in seven countries during this period. Estimated utilized capacity was as low as 28% in 1969, against 41% in 1966.

The resin consumption may be expected to grow at least at the same rate for two or three years as in the last years, 14% per annum from 1966 to 1969, as utilization of capacity increases.

Resin consumption increases rapidly also in Asia and the Near East. The development is dominated by the rapid expansion in the plywood industry.

The plywood industry accounts for 90% of the total consumption by board and panel manufacturers. The rate of growth in consumption is at least 13% per annum as an average. The plywood and particle board industries seem to operate at a high level of utilization of capacity, but new units are under construction in many countries.

Expansion in the North American countries seems to have levelled off. Consumption has increased about 6% per annum. The Latin American region accounts for the highest growth rate. Consumption of adhesives increased by 22% per annum in the period 1966 - 1969.

Production capacity has increased by 6% per annum for plywood, while particle board capacity increased about 34%.

The particle board industry is operating at a rate of utilization of 33%, and the demand for resin adhesives will increase rapidly in years to come.

The region of Oceania also has a high growth of consumption, mostly dominated by the development of particle board.

3. International Trade in Synthetic Resins.

As previously pointed out, the statistics are not broken down by type of resin and end uses. U.N.'s commodity statistics give, however, an idea of how trade is flowing, and which countries are dominating the trade.

In table No. I is shown the main exporting countries. Figures are given for value and quantity. The EEC countries are the

main exporters of these products (products of condensation). Western Germany is the dominating country, followed by the Netherlands. The EEC-trade has increased 53% in volume and 45% in value from 1966 to 1969. The export from the U.S.A. and Canada consists of higher priced products. Exports increased 15% in volume and 18% in value from 1966 to 1969.

The EFTA countries have only one third of the volume sold by the EEC countries. The exports, however, seem to be relatively higher priced goods. Exported volume increased 33%, while value only increased 22% during the period 1966 - 1969.

The value of the export of other countries, as reported in these statistics is not significant.

The flow of the trade of condensation products is illustrated in the tables.

The importing countries are listed in regions. As will be seen from these tables, the bulk of the trade is within Western Europe. The U.S.A., Canada and Western Germany are dominating the trade with the Latin American countries.

The United Kingdom, Western Germany and France are important trade partners to the African countries. A closer study reveals that the trade mainly follows traditional patterns established long ago.

Western Germany, The United Kingdom, the U.S.A. and Italy are important trade partners also to the Asiatic countries.

As pointed out above, the statistics are not very detailed and conclusions based on these figures may be uncertain.

However, as is known by people in the trade, the urea- and phenolic resins are very much supplied according to the pattern revealed by the figures in these tables.

As the statistics are not broken down in detail, nothing can be concluded from the figures on the price trend. The main part of the cost structure is raw material cost. The critical cost of methanol and urea is the most important element.

The prices on the world market tend to change radically from time to time, following the trends of supply and demand. The price trend during the last ten years has a slight decline. This is partly a result of bigger units having come into operation and that transport cost is declining as a consequence of the development within the transportation sector.

A study of the tendencies in the development of the prices of resins for chipboard- and plywood-production in the European countries since 1965 shows a definite decline in most countries. Prices in 1969 in Western Germany are down by 6 points as compared to 1965 (1965 = 100).

Most countries are down 11 - 16 points, but in the United Kingdom prices seem to have been very stable.

The same tendencies are reflected in the import prices in most African and Asiatic countries.

In South American countries there are little fluctuation in prices. Apparently this reflects the fact that most of the countries have a very high price-level because of domestic production and customs barriers for the protection of domestic production.

Government policies and trade regulations effect the development of the forest industry in many countries. High customs barriers tend to hinder rather than promote development. It seems that when the governments objective is the development of forestry and industry related to forestry, adhesives, f.inst. might be considered as auxiliaries and consequently should be procured at cheapest possible prices.

Q = Quantity Unit: 1000 MT
 V = Value 1000 U.S.\$

REPORTING COUNTRIES:

| | 1 9 6 6 | | | 1 9 6 7 | | | 1 9 6 8 | | |
|-------------------------|---------|-------|--|---------|-------|--|---------|-------|--|
| | Q | V | | Q | V | | Q | V | |
| USA & CANADA | 122.8 | 151.4 | | 120.7 | 148.5 | | 141.6 | 178.6 | |
| THE COUNTRIES | 506.5 | 315.8 | | 602.8 | 360.1 | | 777.8 | 469.0 | |
| BELGIUM/LUXEMB. | 30.0 | 28.4 | | 35.7 | 30.2 | | 64.2 | 52.9 | |
| FRANCE | 32.7 | 38.4 | | 46.1 | 43.6 | | 63.0 | 53.1 | |
| WEST GERMANY | 277.2 | 144.6 | | 320.0 | 166.1 | | 361.1 | 192.3 | |
| ITALY | 60.2 | 26.0 | | 71.1 | 32.2 | | 91.8 | 40.5 | |
| THE NETHERLANDS | 100.4 | 78.4 | | 129.9 | 88.0 | | 197.7 | 127.2 | |

AREA COUNTRIES

| | | | | | | | | |
|-------------------------------------|-------|-------|--|-------|-------|--|-------|-------|
| UNITED KINGDOM | 191.0 | 131.4 | | 212.2 | 148.3 | | 255.1 | 160.9 |
| DENMARK | 98.7 | 76.8 | | 109.1 | 86.4 | | 115.3 | 84.0 |
| NORWAY | 6.4 | 4.8 | | 7.4 | 5.7 | | 8.7 | 6.2 |
| SWEDEN | 27.9 | 6.8 | | 28.1 | 7.4 | | 40.9 | 9.2 |
| AUSTRIA | 29.7 | 16.6 | | 32.6 | 16.9 | | 40.1 | 20.1 |
| PORTUGAL | 11.4 | 6.0 | | 15.7 | 8.4 | | 26.2 | 12.2 |
| SWITZERLAND | 0.9 | 0.5 | | 1.3 | 0.8 | | 1.1 | 0.9 |
| OTHER EUROPEAN COUNTRIES | 16.0 | 19.9 | | 18.0 | 22.7 | | 22.8 | 28.3 |
| (Spain, Finland, Yugoslavia) | 4.8 | 2.3 | | 6.8 | 2.9 | | 8.2 | 4.1 |

JAPAN

| | | | | | |
|--|------|--|------|--|------|
| | 17.9 | | 18.2 | | 27.2 |
|--|------|--|------|--|------|

10.20.90

Quantity
 Value

PRODUCTS OF CONDENSATION ETC.

| | WESTERN EUROPE | | EASTERN EUROPE | | U.S.A. CANADA | | AUSTRALIA OCEANIA | | | |
|-----------------|----------------|-------|----------------|-------|---------------|------|-------------------|------|------|------|
| | 1966 | 1968 | 1966 | 1968 | 1966 | 1968 | 1966 | 1968 | | |
| USA & CANADA | 122.8 | 141.6 | 55.8 | 58.2 | - | - | 28.0 | 34.1 | 4.0 | 6.0 |
| BELGIUM/LUXEMB. | 30.0 | 64.2 | 27.0 | 57.5 | - | - | 1.2 | 5.4 | - | - |
| FRANCE | 32.7 | 63.0 | 25.3 | 51.8 | 0.8 | 2.4 | 0.6 | 1.0 | 0.3 | 0.6 |
| WEST GERMANY | 277.2 | 361.1 | 209.3 | 265.7 | 8.7 | 11.7 | 6.6 | 9.7 | 4.6 | 5.8 |
| ITALY | 60.2 | 91.8 | 45.0 | 75.7 | 6.4 | 4.2 | - | 0.8 | - | 0.2 |
| GREECE | 106.4 | 197.7 | 86.7 | 171.7 | 1.3 | 4.7 | 1.3 | 1.7 | 2.4 | 0.9 |
| NETHERLANDS | 98.7 | 115.3 | 49.5 | 50.1 | 2.7 | 3.7 | 3.7 | 8.6 | 18.0 | 18.6 |
| DENMARK | 6.4 | 8.7 | 5.1 | 6.8 | 0.3 | 0.3 | - | 0.4 | - | - |
| IRELAND | 27.9 | 40.9 | 24.6 | 36.9 | - | - | - | - | - | - |
| FINLAND | 29.7 | 40.1 | 26.1 | 36.8 | 0.2 | 0.3 | 0.3 | 0.6 | - | - |
| AUSTRIA | 11.4 | 26.2 | 1.3 | 7.5 | 10.8 | 16.4 | - | - | - | - |
| PORTUGAL/SPAIN | 1.6 | 3.2 | 0.4 | 0.9 | 0.2 | 0.2 | - | - | - | - |
| SWITZERLAND | 16.0 | 22.8 | 12.4 | 17.3 | 1.4 | 2.3 | 0.3 | 0.4 | 0.3 | 0.2 |
| YUGOSLAVIA | 3.3 | 4.4 | 0.2 | 1.0 | 2.8 | 3.2 | - | - | - | - |

UN Commodity Statistics

10-30-70

Table 2

PRODUCTS OF CONDENSATION ETC.

QUANTITY = 1000 MT

| EXPORTING REGION | T O T A L | | LATIN AMERICA | | AFRICA | | ASIA AND THE PACIFIC | |
|------------------|-----------|-------|---------------|------|--------|------|-------------------------|------------------|
| | 1966 | 1968 | 1966 | 1968 | 1966 | 1968 | 1966 | 1968 |
| U.S.A. & CANADA | 122.8 | 141.6 | 17.5 | 21.3 | 2.8 | 1.9 | 13.8 | 19.6 |
| IRELAND/UK | 30.0 | 64.2 | - | - | 0.5 | 0.4 | - | 0.2 |
| FRANCE | 32.7 | 63.0 | 0.5 | 0.4 | 3.0 | 4.2 | 1.0 | 1.0 |
| WEST GERMANY | 177.2 | 361.1 | 11.7 | 19.6 | 8.1 | 12.3 | 23.3 | 28.7 |
| ITALY | 60.2 | 91.8 | 0.7 | 0.7 | 0.7 | 2.6 | 8.3 | 5.1 |
| NETHERLANDS | 106.4 | 197.7 | 4.7 | 4.8 | 3.6 | 5.1 | 4.1 | 6.3 |
| NETHERLANDS | 98.7 | 115.3 | 1.4 | 2.9 | 14.0 | 19.9 | 7.4 | 9.2 |
| DENMARK | 6.4 | 8.7 | - | - | - | 0.2 | - | 0.3 |
| GERMANY | 27.9 | 40.9 | - | - | 0.2 | 1.4 | 1.9 | 1.5 |
| SWEDEN | 29.7 | 40.1 | 0.5 | 0.4 | 0.2 | 0.2 | 1.3 | 0.3 |
| AUSTRIA | 11.4 | 26.2 | - | - | 0.2 | 0.4 | 0.1 | 0.8 |
| PORTUGAL/SPAIN | 1.6 | 3.2 | - | - | 1.2 | 0.3 | - | - |
| SWITZERLAND | 16.0 | 22.8 | 0.5 | 0.6 | - | 0.5 | 0.5 | 1.0 ³ |
| FINLAND | 3.3 | 4.4 | - | - | - | - | - | - |

Based on
UN COMMODITY
Statistics

10.30.70.

Table 3 a

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from Agricultural Wastes
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MEMO

TECHNICAL BACKGROUND

**A Survey of Production,
Production Techniques and
World Trade**

by

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The bonding of wood by adhesives is not a new technique. This art seems to have been well developed in ancient times. Carvings in Thebes dating back 3,200 years depict the gluing of a thin piece of veneer to what appears to be a plank of gumwood.

The types of glue utilized by the Egyptians were gum Arabic from the acacia tree, egg, semi-liquid balsams, and resins from trees. There was little change in adhesive technology until the twentieth century, and woodworkers had to rely mainly on animal and vegetable based glues.

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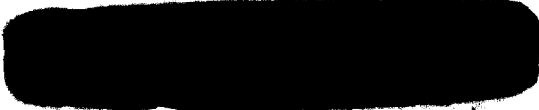
At the beginning of this century, tapioca starch, proteins, soya beans and casein became important adhesives. These glues had in common a moderate water resistance and poor resistance to micro-organisms. The tapioca starch and soya bean meal became important for the development of the plywood industry. At the beginning of the 1930's the first completely synthetic resin for adhesives application, phenol formaldehyde, was invented and found large-scale application in the plywood industry. This glue had good water resistance and could withstand outdoor weathering.

In this decennium also the amino resins used for adhesive purposes became commercially available and found their use in plywood and furniture production, and later also in particle board production.

Later in the 1930's, melamine and polyvinylacetate adhesives were developed. Resorcin-formaldehyde resins were developed during World War II, and found a usage in the production of laminated wood constructions and in boats. After the war a considerable number of types of synthetic resin adhesives were developed and marketed.

The development of synthetic resins has led to an expansion in the utilisation of adhesives. Even where wood has been substituted by other materials within certain fields, the development of synthetic adhesives has made possible the increased utilisation of wooden materials. While the production of animal glues decreased after World War II, the production of synthetic resin adhesives has increased enormously.

World production of amino and phenolic resins in 1967 probably amounted to 2.2 million tons net dry weight. Adhesive consumption by the wood-based panel industry approximates 1.6 million tons net dry weight. The total consumption in Western Europe in 1968 amounted to 1,165,000 tons, out of which 575,000 tons represent adhesives. Particle board and plywood production account for most of the consumption, and this sector also accounts for the bulk of the growth, which is estimated at 10% per annum.





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