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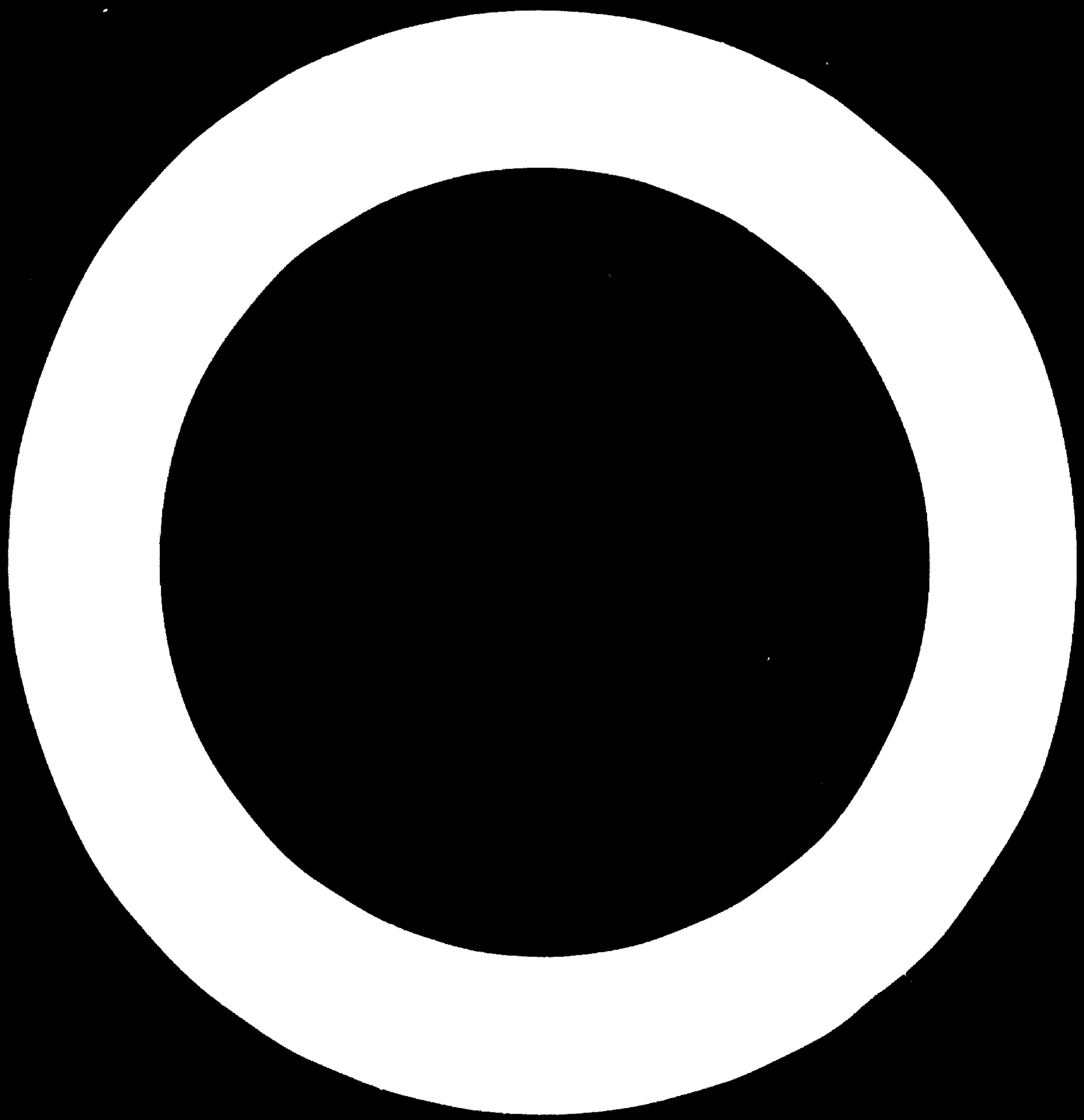
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

ADHESIVES USED IN THE WOOD PROCESSING INDUSTRIES

Report of a Workshop
Vienna, Austria, 31 October—4 November 1977



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INTRODUCTION

The Workshop on Adhesives Used in the Wood Processing Industries, organized by the United Nations Industrial Development Organization (UNIDO), was held at Vienna from 31 October to 4 November 1977. The main purpose was to analyse the various factors involved in the manufacture and use of the adhesives that are not only a prerequisite for, but also a major cost factor in, the production of wood-based panels, i.e. plywood, laminated boards, block-boards, particle boards, plymoulds, high-density plywood, plymetals and other wooden laminated products used in modern wood-processing industries (timber engineering, gluelam, furniture, joinery etc.), by:

(a) Determining the minimum requirements for adhesives production;

(b) Determining whether natural products occurring in developing countries could be used for the production of binding agents to replace a certain amount of high-priced imported synthetic resin, and recommending future research in this field;

(c) Assessing the various glue-spreading systems for application in developing countries;

(d) Recommending quality control and standards for those products.

The Workshop was attended by participants from developed and developing countries, who compiled data and guidelines on the above topics to be disseminated by UNIDO in the developing countries to potential investors, industrialists, financiers, government agencies and other regulatory bodies to ensure the development of viable wood-processing industries in the developing countries. The necessity for spreading such information was underlined by the participants in the World Consultation on Wood Based Panels which FAO convened at New Delhi in February 1975, who felt that it would allow developing countries to make fuller use of naturally occurring products as binders or extenders in the wood-based panel industry and to find the optimum ways of utilizing those products or even producing them, as well as synthetic adhesives, locally.

The Workshop was a follow-up of an Expert Working Group Meeting on the Production of Panels from Agricultural Residues that UNIDO convened at Vienna in December 1970, the purpose of which was to assist those countries that, though not self-sufficient in wood and wood products, had great quantities of unutilized agricultural residues and non-wood lignocellulosic material.

RECOMMENDATIONS

The recommendations of the Workshop are listed below in groups according to the bodies to which they were addressed.

Industry

1. Complete feasibility studies should be done before any investment decision is taken on the establishment of adhesive production facilities in developing countries.

Research institutes

2. Work on the development of tannin-formaldehyde resins, based on wattle, chestnut, mangrove, quebracho, coconut and other extracts, in the present and potential tannin-producing countries should be carried out by the tannin, resin-adhesive, plywood and particle board industries, so that maximum technical know-how is available for the project.

3. Greater attention should be paid to developing suitable preservative treatment processes for plywood.

4. Standard methods of measuring formaldehyde, both in the air and in ligno-cellulose-based panels, should be developed and steps taken to make them generally accepted.

Governments

5. In order to reduce the cost influence of the resin adhesive used in lignocellulose-based panels and consequently increase their potential use in low-cost housing and furniture, the following measures should be taken:

(a) If no local resin manufacture exists, import duties for resin adhesives, tannins and hardeners should be reduced;

(b) The maximum investment incentives allowed by the local legislation should be given to promote the establishment of adhesive manufacturing plants in developing countries because although the production of adhesives is capital intensive, their production locally would help to develop the plywood industry, which is labour intensive.

6. National standards bodies and the International Organization for Standardization (ISO) should take steps to ensure that standards for adhesive-bonded wood products do not exclude the use of adhesives based on tannin-formaldehyde resins and other natural products on grounds other than performance.

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7. If requested to do so, should give UNIDO technical assistance to present and potential tannin-producing countries to investigate and obtain efficient tannin-formaldehyde resins based on wattle, chestnut, mangrove, quebracho, coconut and other extracts.

8. UNIDO should sponsor a workshop exclusively on adhesives from natural products within the next five years. In the meantime, UNIDO should act as a co-ordinator of that research in this field. The laboratories involved in this research should submit a report on progress to UNIDO at the end of each calendar year. It is requested that UNIDO diffuse the information to interested parties.

9. UNIDO should commission a study to cover the subject of extenders and fillers.

10. Attempts by developing countries having scarce wood and wood wastes to utilize alternative raw materials hitherto unutilized, such as rice husks, coconut husks and straw involving appropriate research and development work, should be encouraged and supported by UNIDO.

11. UNIDO should compile a list of specifications and test methods issued by various countries and publish it as a follow-up to the Workshop's report. The list should include a glossary (in English) of terms used in the wood glueing industry.

I. ORGANIZATION OF THE WORKSHOP

1. M.M. Aref, Head of the Agro-Industries Section of UNIDO, opened the Workshop with an address of welcome in which he referred to the Lima Declaration and Plan of Action on Industrial Development and Co-operation (ID/CONF.3/31, chap. IV)1/ as it pertained to development, particularly in the wood-processing industry.

1/ Transmitted to the General Assembly by a note by the Secretary-General (A/10112).

2. The Workshop was attended by 23 participants from the following countries: Argentina, Australia, Federal Republic of Germany, Ghana, India, Kenya, Malaysia, Mexico, New Zealand, Norway, Paraguay, the Philippines, Switzerland, Turkey, the United Kingdom of Great Britain and Northern Ireland, and Yugoslavia. They comprised individuals, attending in their own capacities and not as representatives of their Governments, who occupy managerial or policy-making positions in wood-based panel industries, adhesives manufacturers, specialists from adhesive equipment manufacturers, and scientists from wood research institutes working in the field of adhesives.

3. Thirteen observers, whose background was similar to that of the participants, attended and took part actively in the Workshop. They came from the following countries: Austria, Federal Republic of Germany, Finland, Indonesia, Malaysia, Norway, Switzerland, the United Kingdom and the United States of America.

4. J. George was elected Chairman and J.C. Scharenberg Vice Chairman cum Rapporteur while A.V. Bassili and H. Eldag of the UNIDO secretariat served as secretaries to the Workshop. The following participants served as discussion leaders:

	Agenda item
J.C. Scharenberg	Economics of production of: (a) Synthetic resin adhesives; (b) Resins based on naturally occurring products.
K.F. Plomley	Utilization of naturally occurring organic products: (a) Past research; (b) Industrial application.
J. Reinhardt	Industrial application of synthetic adhesives for: (a) Ligno-cellulosic based panels; (b) Gluelam and timber engineering products; (c) Joinery and furniture products.
S. Senn	Equipment for application of: (a) Ready-to-use adhesives; (b) Adhesive-particle blending; (c) Adhesive spreading.
J. George	Testing procedures and equipment for adhesive testing.

5. The agenda given in annex I was adopted unamimously. Twelve papers were specially commissioned for the Workshop (annex II). English was the working language.

II. ECONOMICS OF PRODUCTION OF RESIN ADHESIVES

6. The two papers prepared for this topic were presented by their authors. These were "Economics of production of synthetic resin adhesives" by J. George (ID/WG.248/3) and "Economic aspects of tannin extracts as wood adhesive binders" by J. C. Scharenberg (ID/WG.248/7).[2/] The points made in the ensuing discussion are given below.

7. The economic feasibility of manufacturing resin adhesives for the ligno-cellulose-based panel industry in developing countries depends on the availability of raw material technology, domestic and export markets for the finished products, and investment costs related to the existing market.

Technical considerations

8. The principal resins needed by the wood-processing industries are:

Urea-formaldehyde (UF)
Phenol-formaldehyde (PF)
Urea-melamine-formaldehyde (MUF)
Resorcinol-formaldehyde (RF)
Phenol-resorcinol-formaldehyde (PRF)

These products can be made in the same reaction vessels, approximately under the same manufacturing conditions. Polyvinyl acetate (PVAc), hot melts, epoxies, acrylics, isocyanates, rubber-based adhesives etc., were not considered because of the small volumes involved.

9. UF resins are used in the manufacture of particle board and plywood for internal use (furniture, doors etc.); PF resins are for exterior use (sidings, concrete forms etc.) and MUF resins are for semi-exterior uses (walls, partially-protected terraces) where a full waterproof bond is not required. RF resins are cold-setting, fully waterproof adhesives for woodworking.

2/ See annex II. Another UNIDO document that deals with this topic is A.G. Seljestad, "Synthetic resin adhesives. A survey of production techniques and world trade" (ID/WG.83/8).

10. The main raw materials involved in the production of resin adhesives are urea, phenol, melamine and resorcinol, which can be obtained by petrochemical routes, and formaldehyde, which can be obtained by the oxidation and/or dehydrogenation of methanol, itself a petrochemical product. (See chapter IV for flowsheets.) Urea, phenol, melamine and resorcinol can be considered as 100 per cent solids for resin manufacturing purposes while formaldehyde can be obtained as a solid containing up to 98 per cent active ingredient, as a solution containing up to 55 per cent active ingredient, or as a UF concentrate with up to 85 per cent active ingredient.

11. Other raw materials may be:

(a) Natural products that react with formaldehyde (tannins etc.);

(b) Non-active extenders and fillers (wheat flours, walnut- and coconut-shell flour, sander dust etc.);

(c) Chemical hardeners and retarders.

When considering the feasibility of a resin manufacturing plant, only UF and PF need to be discussed as they constituted more than 95 per cent of the resins used for lignocellulose-based panel manufacture.

Marketing

12. Developing countries considering local resin manufacture should take into account the market available for the product, either domestic or export. The resin to be manufactured will be sold almost exclusively in the domestic market and the particle board and/or plywood produced can then be sold locally or exported.

13. One ton of particle board, trimmed and sanded, would consume approximately 60-100 kg of UF resin at 100 per cent solids, or 60-120 kg of PF resin at 100 per cent solids. The corresponding quantity of phenolic resin used for waferboard and strand board would be about half that, but its unit cost would be much higher.

14. The average consumption of resin by plywood is rather more difficult to generalize as it will vary according to the number of glue lines per board, thickness of each ply, quantity of extender used and type of wood being processed. Perhaps for UF-bonded plywood, sheets about 4 mm thick (3-ply construction) could be said to be average, and for PF-bonded plywood boards, 12 mm (5-ply construction) may be typical. Taking this into account for UF resins with 100 per cent extender added, the average consumption per cubic

metre would be approximately 20-25 kg of 100 per cent resin solids for the 3-ply construction while for PF resins with 20 per cent extender added, the average consumption may be estimated at 25-30 kg of 100 per cent resin solids for the 5-ply construction.

15. A market survey of particle board and plywood in each country, with these factors in mind, could determine the potential market by country for resin manufacturing.

Raw material

16. The local availability of raw materials for resin manufacture is probably very low or non-existent in small-market countries and therefore the resins would have to be imported from more developed countries.

17. Typical prices[3/] (November 1977) for these products are (per ton[4/] f.o.b.): paraformaldehyde, $700; formalin (37 per cent solution), $120 (equivalent to $300 at similar concentration to 92 per cent paraformaldehyde); UF concentrate (80 per cent), $160.

18. The approximate prices of the other raw materials are:

	(Dollars per ton)
Urea	130
Phenol	500
Tannin (quebracho and wattle)	450-500

The powdered UF and PF resins could be quoted at approximately $400 and $700 per ton, respectively.

19. Any resin manufacturing project must take into account:

(a) Import duty differences on resin adhesives and on the raw materials for their production;

(b) Freight rates on anhydrous raw materials and resin adhesives in powder form;

(c) Required technological degree of the resin-producing facility in relation to its installation cost;

3/ References to dollars ($) are to United States dollars.

4/ References to tons are to metric tons.

(d) Availability of relevant technology and skilled manpower to establish the resin plant, promote the product among users and service them technically;

(e) Complications arising from the transport of hazardous chemicals such as formaldehyde and phenol;

(f) Complications in the purchase of the different raw materials involved;

(g) Economies of scale.

20. Synthetic raw materials may be partly replaced by natural tannins if a careful study of comparative costs and availability under local conditions prove it to be economical. Tannins may be used as cure accelerators for phenolic resins in plywood production.

Investment

21. A plant for the production of resin adhesives could vary in size in accordance with the available market for the finished product. Its size would also have to be regulated by the costs of the raw materials available plus labour and fixed capital costs compared to the cost of imported resin adhesive. The cost of the latter would include taxes and duties that could be increased in order to protect local industry and/or the raw materials be granted preferential treatment.

22. The cost of the plant would vary considerably and no figures can be given. Each case should be evaluated in the light of local conditions and requirements. The smaller resin plants could operate successfully on paraformaldehyde or UF concentrate imported from overseas and/or 37 per cent formalin imported overland from neighbouring countries. The economics of transporting larger amounts of these products for larger sized resin plants would not allow them to operate successfully, so a formaldehyde plant would have to be installed to compete with imported finished resin at lower cost levels. A formaldehyde plant can be engineered for an annual capacity of 300 to 10,000 tons. Its cost would vary according to the process to be used.

III. UTILIZATION OF NATURALLY OCCURRING ORGANIC PRODUCTS

23. Two papers "Review of past research on utilization of naturally occurring organic products as replacement of synthetic phenolics in wood adhesives" by E. Kulvik (ID/WG.248/2) and "The formulation and industrial application of naturally

occurring polyphenol (tannin) adhesives in the wood based panel industry" by K.F. Plomley (ID/WG.248/6) and an annotated bibliography were submitted dealing with the utilization of naturally occurring organic products as wood adhesives. These are the points made in the first paper:

(a) Adequate supplies of methanol may be available in the near future. However, the long-term supply of phenol and resorcinol is considered to be less assured because benzene is increasingly in demand for other uses;

(b) The availability of phenols for wood adhesives over a long term could be better assured by modifying the synthetic resins with naturally occurring products. Intermittent and world-wide shortages and price increases of synthetic phenol and resorcinol have intensified the search for alternative lower-cost materials based on natural, non-petrochemical resources as replacement in adhesives for the woodworking industries;

(c) Research into the development of phenolic adhesives from naturally occurring sources has been reported from time to time. Such natural sources include:

The polyphenols of commercial vegetable tannins
The polyphenols of other wood and bark extracts
Lignin such as in spent sulphite liquor

All these have been suggested for partial or full replacement of phenol in PF adhesives for the manufacture of plywood and particle board. The use of some of these natural products for replacement of resorcinol in resorcinol-based adhesives and for acceleration of cure of PF adhesives has also been considered;

(d) The substitution of natural phenolics for synthetic phenols, especially from various tannin extracts, is reported to be an established commercial practice in a number of countries and significant economic advantages are reported to have been obtained by their use. Of particular interest are resources available within the adhesive-consuming country, thus benefiting both the domestic product and balance of payments of the country. There are useful natural sources of phenols available in many developing countries and particular attention should be given to identifying these sources and determining whether they could be used to replace a certain amount of synthetic phenolics;

(e) Spent sulphite-liquor adhesive formulations comply with certain standards for plywood and particle board but it is suggested that tannins have greater potential for replacement of synthetic phenol and resorcinol than lignin products;

(f) Although not having the high replacement potential of some condensed tannins, chestnut tannin has been shown to have value as a substitute for phenol. Replacement in the amount of 50 per cent for synthetic phenol in an ordinary, alkaline PF resin for plywood seems to be the maximum to meet the requirements according to BS 1455 (1972) for WBP gluing. In Malaysia, the chestnut-wood tannin modified adhesive resin is used industrially under the same conditions of plywood manufacture as the unmodified resin. It is also an inexpensive and effective accelerator for the cure of PF resins.

24. In discussion, interest was shown in mangrove tannin as a potential adhesive base. Past work had shown that an efficient plywood adhesive could be prepared although, because a higher proportion for fortifying resin was required, the cost of formulations was likely to be higher than for wattle tannin. Furthermore, variability in viscosity was a problem in commercial extracts.

25. The industrial use of quebracho tannin as a replacement for about 50 per cent of synthetic phenol in phenolic resins was reported from Argentina, although further work on this extract was warranted. Quebracho tannin was used industrially in Finland as a cure accelerator for phenolic resin plywood adhesives.

26. These are two of the points made in the second paper:

(a) The possibility of using the condensed tannins as substitutes for phenol and resorcinol in wood adhesives has been recognized for many years and over the last 25 years a considerable fund of information on the properties of tannins and the formulation and properties of tannin adhesives has been built up. This research has resulted in the commercial use of wood adhesives based on wattle bark extract and on quebracho wood extract;

(b) Adhesives based on commercial wattle tannin have been used in Australia for the manufacture of exterior grade plywood since 1960 and for particle board since 1969. Formulations have been developed for timber laminating under laboratory conditions, either cold or warm setting and using radio-frequency heating to cure the adhesive. Warm-setting formulations had been used commercially in South Africa. Wattle tannin is currently used industrially as a replacement for resorcinol in water-resistant starch adhesives for corrugated board in these two countries. Particle board adhesives based on quebracho extract has been used commercially in Argentina.

Other points were brought out in the ensuing discussion and are given in the following paragraphs.

27. A pilot plant has been installed in New Zealand for the manufacture of _Pinus radiata_ bark extract, specifically for adhesives. Condensed tannins are also being used to accelerate the cure of phenolic resin adhesives, replacing resorcinol.

28. Wattle tannin adhesives are being used as substitutes for PF and RF adhesives. As such they show high durability in exterior exposure and accelerated weathering tests and comply with relevant standards, which are based on the performance of the synthetic resin adhesives. Plywood and particle board bonded with wattle tannin adhesives pass the relevant specifications involving immersion in boiling water for 72 hours.5/

29. Weathering tests on plywood panels bonded with wattle tannin adhesives have been in progress for 15 years without bond failure. Accelerated aging

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5/ Standards Association of Australia (1963) - AS 087 Plywood for Exterior Use. Standards Association of Australia (1976) - AS 1,859 Flat Pressed Particle Board.

tests have been carried out on commercial particle board bonded with wattle tannin-formaldehyde (TF) in comparison with boards bonded with PF and UF. In a test consisting of immersion in water at 40°C for 24 hours and redrying for six days, the cycle being repeated up to 15 times, the performance of TF- and PF-bonded boards is similar and much superior to UF-bonded boards. Three years of humidity at 38°C result in a similar performance by TF and PF adhesives.

30. Unmodified tannin-based adhesives differ from the PF resin adhesives in the wood-glue moisture relationship. An understanding of this characteristic is considered to be highly important for the successful use of tannin adhesives. Rate of loss of moisture when in contact with wood is more rapid for tannin adhesives than for PF resins, and the minimum amount of moisture in the adhesive for flow in the hot press is higher. This could have important effects at all stages of the glueing process, as it influences glue transfer, prepress adhesion and bond quality. The situation is ameliorated by relatively small changes in formulation and by control of glueing, assembly and pressing conditions.

31. Currently, it is primarily cost rather than lack of technology and supply of suitable extracts that limits the use of tannin adhesives. This situation is likely to change, especially with a decrease in petroleum resources. It is recommended that research should be continued and directed towards the improvement of adhesive formulations based on available tannins and towards the discovery of new tannins with valuable properties. Also, information should be exchanged, especially with the developing countries and countries where an additional extraction industry could be set up and where the economics might be more favourable for the use of tannin adhesives.

32. The Workshop took note of the "Annotated bibliography on the research done on the use of naturally occurring adhesives for wood processing industries" by J. George (ID/WG.248/5)[6/]. Participants were requested to communicate to the UNIDO secretariat any recent work that might be incorporated in an addendum to the document or an up-dated bibliography to be published by UNIDO on similar lines.

6/ See also H. Augustin, "Annotated bibliography on the utilisation of agricultural residues and non-wood fibrous material for the production of panels" (ID/WG.83/16).

IV. SYNTHETIC RESIN ADHESIVES

33. Three papers on this topic were prepared and discussed, namely, "Industrial application and formulation of synthetic resin adhesives in the wood based panel industry" by J. Reinhardt (ID/WG.248/9); "Formulation and industrial application of synthetic resin adhesives in the gluelam beam and timber engineering industry" by H.C. Kolb (ID/WG.248/10); and "Formulation and industrial application of synthetic resin and special adhesives used in the joinery and furniture industries and other specialised wood products" by E.J. van der Straeten and T.I. Mynott (ID/WG.248/4).[7] The main points are summarized below.

34. Particle board and plywood manufacturing plants account for most of the current consumption of synthetic, formaldehyde-based adhesives. These synthetic adhesives use raw materials that are derived from the petrochemical industry, except for urea and melamine. Figures I to IV show the various routes from raw material to formaldehyde resins. These flowsheets illustrate that there should be few, if any, restrictions on the availability of the raw materials, particularly in regions where natural gas or crude oil is readily available. However, with the dwindling availability of crude oil and, to a lesser extent, coal, there is the possibility of raw material shortages. World prices for the raw materials are dependent on petroleum feed stock prices. The demand for crude oil is increasing and may exceed the supply. It is estimated that less than five per cent of the world's crude oil is currently used in the chemical industry. Availability and price of the raw materials are closely related, and provided that realistic resin prices can be achieved, it is anticipated that manufacturers of synthetic resin will be able to bid competitively for their raw materials. If realistic prices for resin cannot be achieved, the heavy chemical industry will divert its raw materials to outlets with a better return on capital and problems may arise on the supply and price of formaldehyde-based resins. Consequently, it is necessary to find alternative supplementary raw materials for the manufacture of wood adhesives.

7/ Other UNIDO documents dealing with this topic are J. Meriluoto, "The use of glues and other adhesives in furniture and joinery" (ID/WG.105/26/Rev.1) and J. Reinhardt, "Adhesives for wood" (ID/WG.200/3).

Figure I. Some raw materials from coal

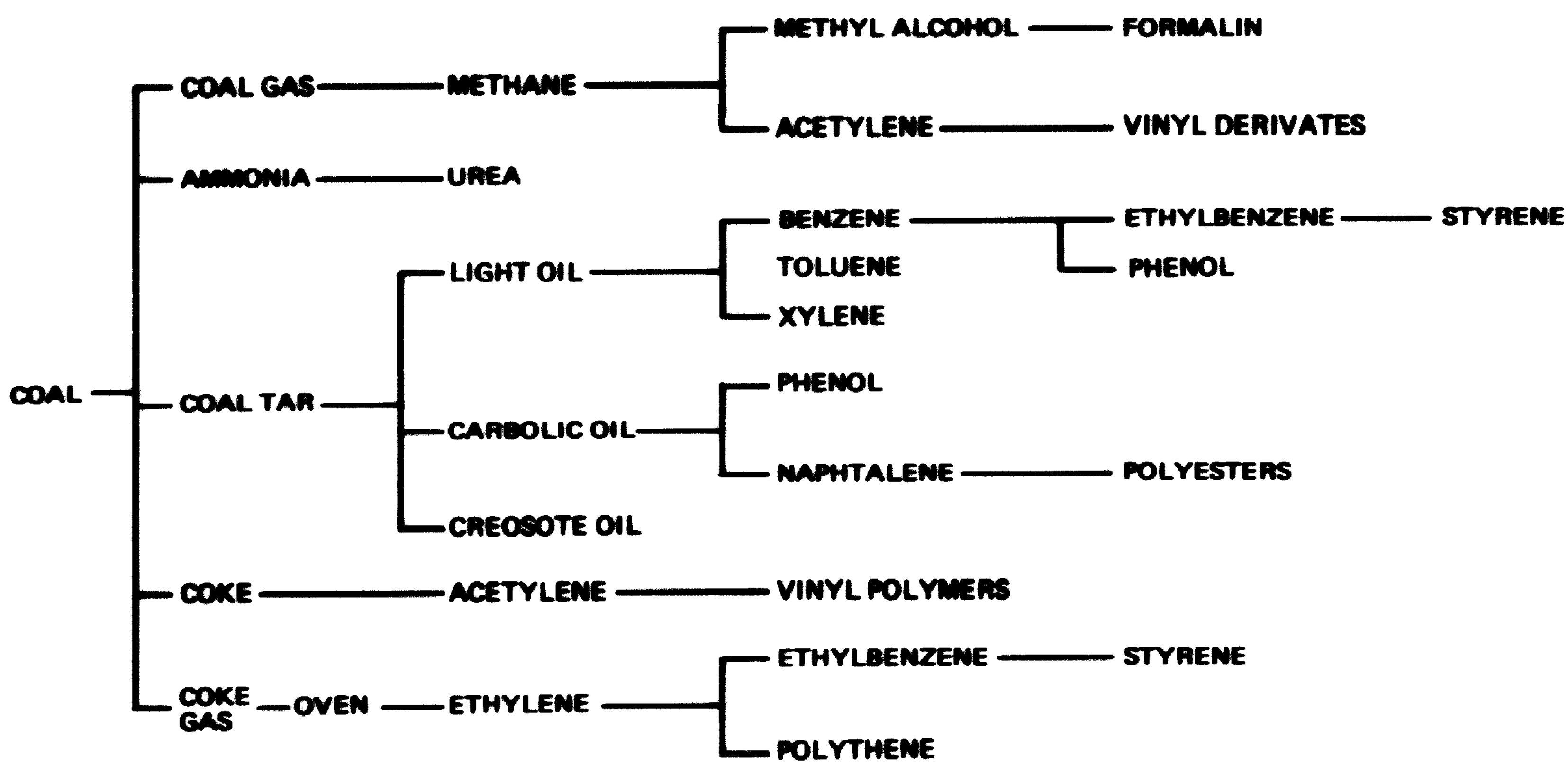


Figure II. Some raw materials from crude petroleum

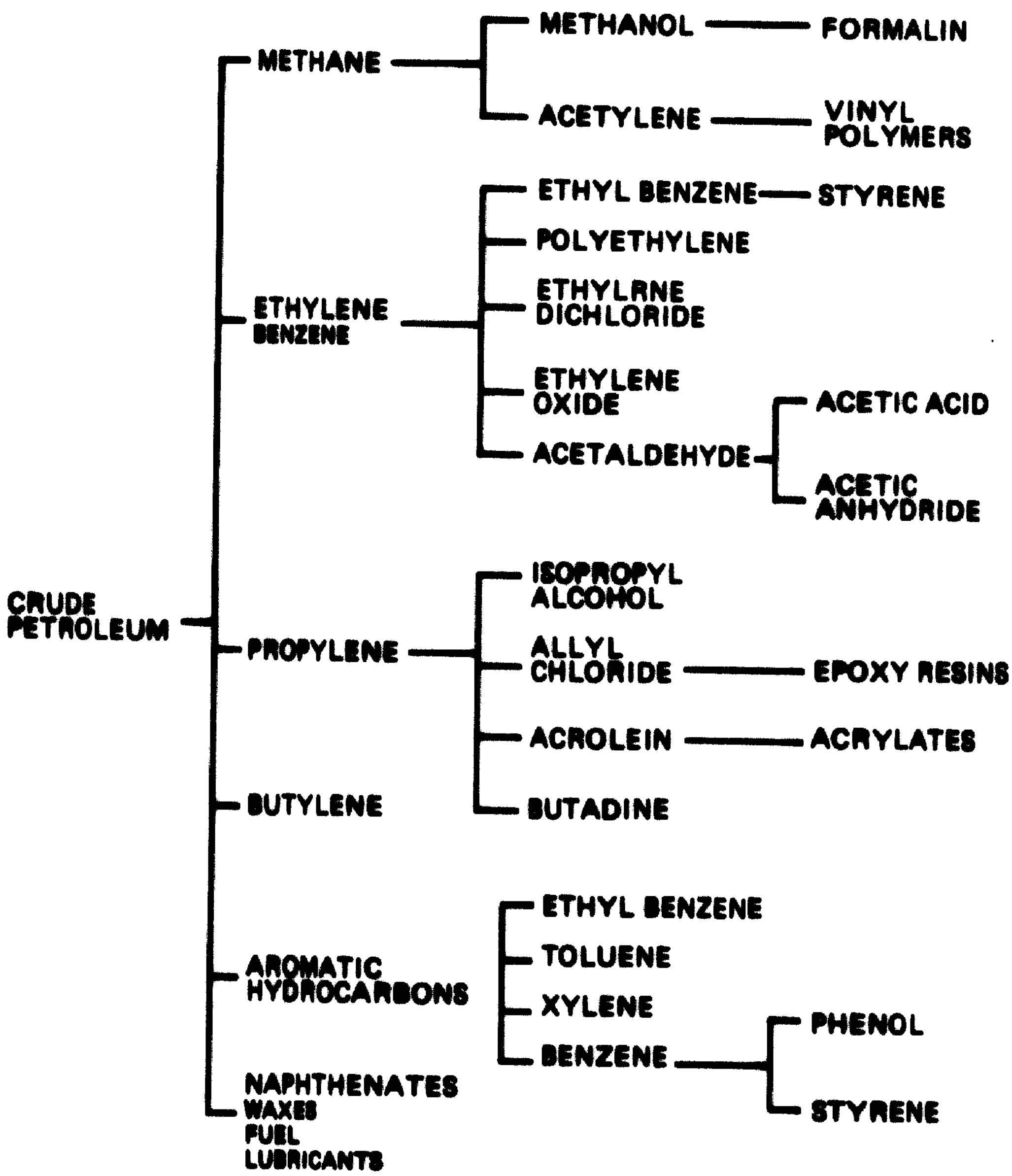


Figure III. Flow sheet for the manufacture of urea and melamine

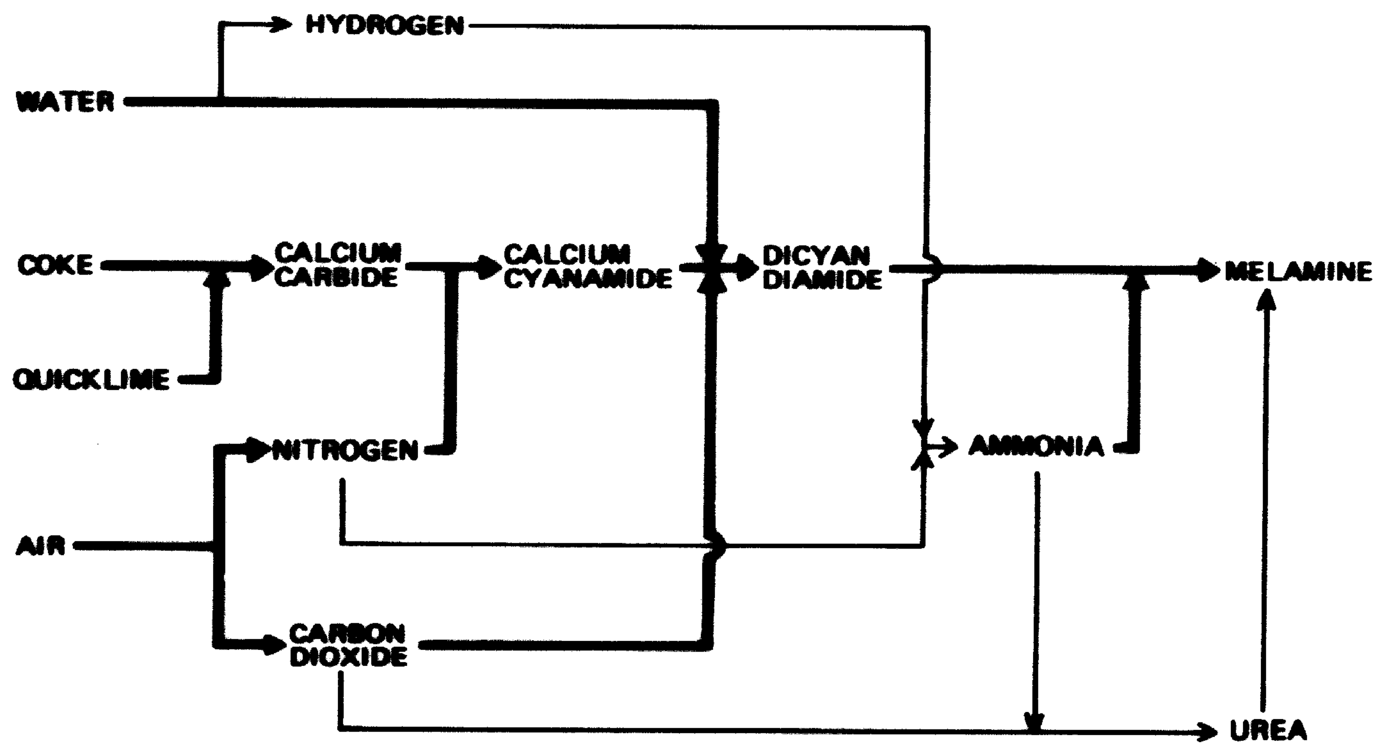
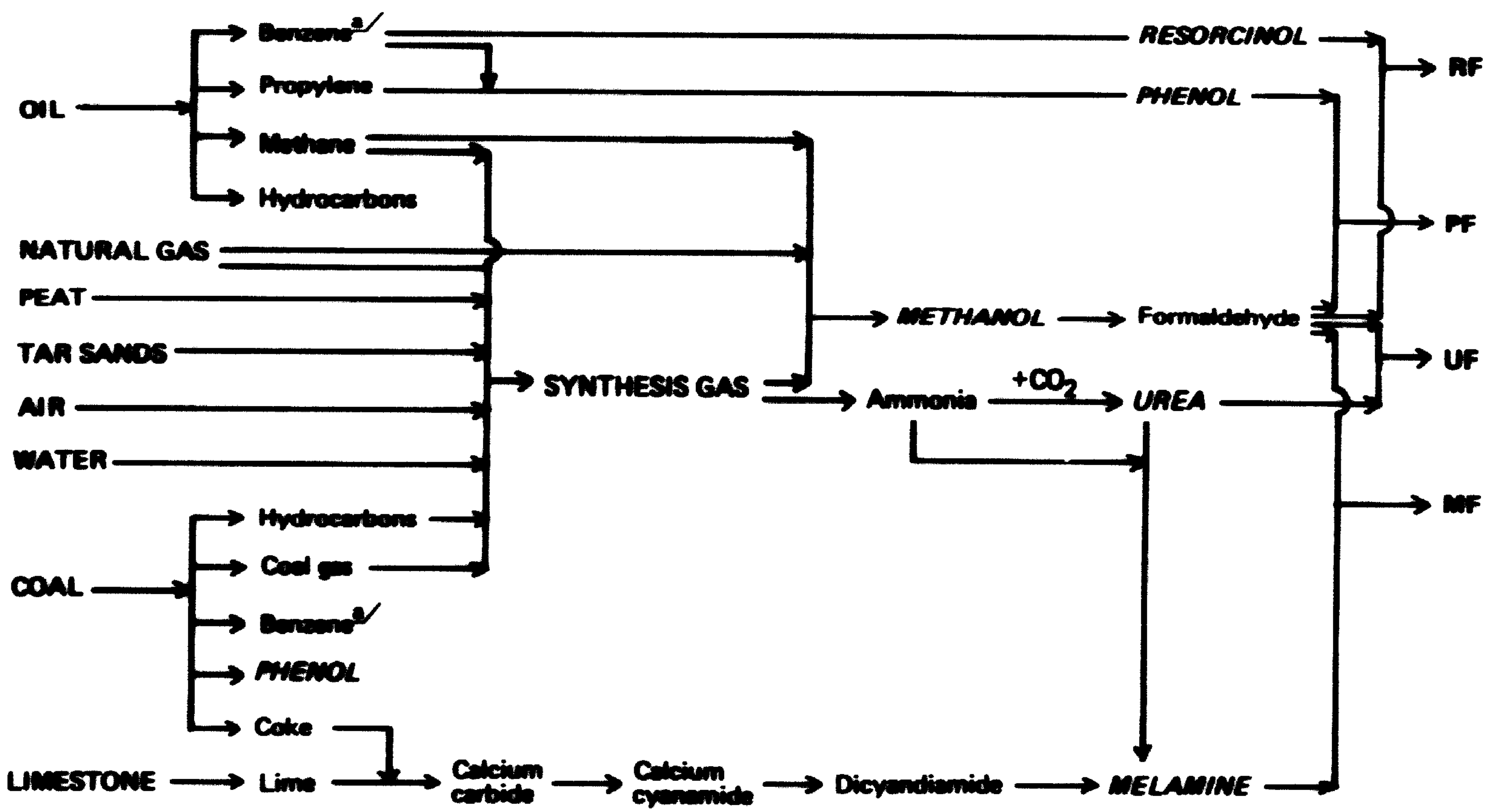


Figure IV. Synthesis routes to formaldehyde resins



a/ Benzene from either source can be used to produce phenol and resorcinol.

35. The custom of using wax (as an emulsion or molten) in the manufacture of particle board is justifiable beoause the addition of wax inoreases the rate of liquid water repellenoy of partiole board. Molten wax may also help to fix resin partioles on to the flakes in the production of flake board, and wax emulsion in general confers oertain "slip" properties in resin blenders and on oonveyors, forming stations and oauls.

36. Preservative treatment of panel products may be divided into two groups:

(a) Treatment against attack by insects;
(b) Treatment against attack by fungi.

Protection oan be achieved by:

(a) Treatment of the veneer or particles prior to adhesive application;
(b) Incorporation of preservatives into the adhesives;
(c) Post treatment of the glued, finished panel product.

There is no universal solution to the problem of the preservative treatment of plywood and particle board.

37. Additives for improving the inseot and fungus resistanoe of partiole board are used. For example, in the Federal Republio of Germany there are five approved preservatives for the protection of partiole board against fungi that meet the requirements of the Federal Institute of Materials Testing in Berlin (West).

38. The treatment of plywood is more diffioult. A oonsiderable amount of work has been oarried out by the Commonwealth Scientifio and Industrial Researoh Organization (CSIRO) in Australia, the Forest Produots Laboratory in the United Kingdom and preservative manufaoturers. The ideal preservative fulfilling all requirements (adhesive compatibility, proteotion against all hazards, and universal aooeptanoe for all legislation on human toxioity of the preservative) has not yet been developed. Greater attention should be placed on this work.

39. The Workshop's attention was drawn to the increasing publicity being given to the emission of formaldehyde from lignocellulose-based panels. Statements had been made that formaldehyde was a serious health hazard, even carcinogenic. Speakers stressed that no evidenoe existed to support such claims and pointed out that such statements could bring unjustified discredit on wood-based panel produots. In oonsequence, world trade in these materials oould be affected.

40. The speakers recognized that formaldehyde gas in air - even at levels as low as 1 part per million - produced temporary unpleasant physiological reactions.

41. Some countries were already introducing standards to limit the emission of formaldehyde from lignocellulose-based panels, especially particle board. The intention of those standards was to reduce the emulsion to amounts that, in general, would not cause discomfort in rooms containing even large amounts of lignocellulose-based panel products.

V. EQUIPMENT FOR APPLICATION OF ADHESIVES

42. Three papers prepared for this topic were presented and discussed. They were "Equipment for preparing ready-to-use adhesives" by S. Senn (ID/WG.248/12), "Mixing equipment for glue coating of wooden chips or irregular particles of similar shape" by K. Engels (ID/WG.248/13) and "Equipment for glue coating of adhesives in the wood processing industry" by H. Funke (ID/WG.248/11).8/ The main points are summarised below.

43. With regard to glue-mixing equipment for the particle board industry, mechanical methods should be used to avoid costly electronic control units while ensuring that the human element does not become a risk when blending the glue. The ready-to-use glue mix should contain all components and for safety and economic reasons no in-line mixing or separate application of the components on to the furnish is recommended. However, the separate application of wax could be an acceptable procedure.

44. The addition of starch, waxes, fungicides and other special additives are optional and depend on board requirements. Excessive mixing of the glue components should be avoided to prevent excessive foaming and to minimize the risk of insufficient glue solids application. The blending equipment for glue application on to the particles described in the papers reflects mainly the requirements of the developed countries. For developing countries, where plants usually have smaller capacities, investment and maintenance can be minimized by the use of only one blender for alternatively gluing face and core material. This is possible because of the shorter retention time offered by the modern blenders. Glue viscosity variations do not present a problem for modern equipment. Simple, accurate proportioning of glue to particles requires the presence of a reliable operator. The use of belt conveyors for

8/ Another UNIDO document that deals with the subject is E. van der Straeten and J. Reinhardt, "Selection of equipment for joining" (ID/WG.151/18).

transporting resin-coated particles would, in most cases, meet the needs of developing countries. Experience has shown that certain non-essential glue deck items, such as metering devices, fall into disuse shortly after plants become operational, which indicates the need for a careful determination of the items considered to be essential. Additional control systems can be incorporated at a later stage provided that the possibility has been borne in mind during the planning stages.

45. Experience has shown that other lignocellulosic raw material, e.g. bagasse, rice husks, coconut coir, can be coated with glue using existing equipment. Further development work is needed, however. Attempts to use these and other lignocellulosic raw materials should be encouraged by UNIDO.

46. The various glue applicators used in the plywood, gluelam and furniture industry are designed for specific products. Hence selection of equipment would be limited by the products manufactured. For plywood and veneering in developing countries, roller coating equipment is generally the most suitable because it tolerates a wide glue viscosity range and can apply a wide range of spread. The machine is also not sensitive to glue fillers with a certain grit content. The use of roller coaters makes it necessary to control veneer thickness to ensure even spreads. Thin veneers may require a reduction in glue viscosity to ensure correct passage through the rollers. With spray coating applicators, inefficient glue application occurs and up to a 50 per cent glue loss is experienced. Problems may be encountered when spraying filled resins. For furniture and joinery, glue-gun application may be used, but it is important to clean the guns regularly. In gluelam production, where high throughput is required, curtain coaters are recommended.

VI. ADHESIVE TESTING PROCEDURES AND STANDARDS

47. A paper entitled "Adhesive testing procedures and bonding strength testing equipment" by A. Frühwald (ID/WG.248/8) was presented and discussed. The main points are presented below.

48. Tests on uncured adhesives are mainly evaluation of viscosity, reactivity, pot-life, pH and solids. In the solids test a temperature of 140°-$150^{\circ}C$ is too high, because of weight loss from the condensation reaction and by pyrolysis. Lower temperatures are used within different time lapses.

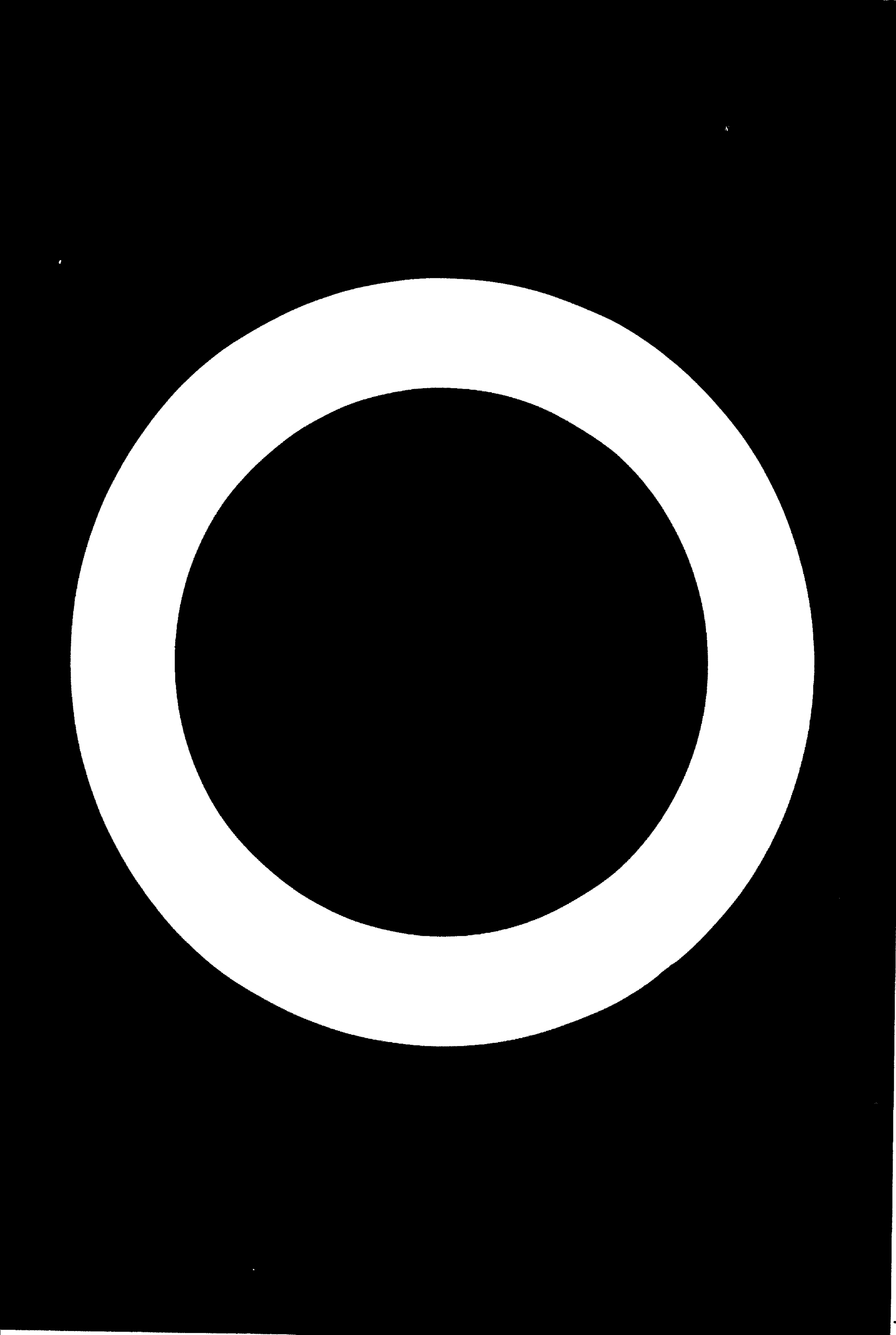
49. There is no general agreement on the validity of measuring the quality of plywood by wood failure versus shear tests.

50. In countries where wood species vary widely, shear values are usually taken as a measure of quality for hardwood species, while for softwoods, the wood failure values are taken. Some countries regard both values as necessary for plywood quality evaluation. The values of 100 per cent wood failure really give the value for the shear strength of the wood but not for the glue line. The only real relationship between these values would be that the shear strength of the glue line is greater than that of the wood; no other relationship is possible. In particle board, a strong correlation exists between shear strength and internal bond. It is recommended that for particle board standards, a shear strength test be considered for adoption as it is easier to carry out than an internal bond test.

51. Tests made on the same types of plywood, following standards set by the Federal Republic of Germany, Turkey and the United Kingdom, give different results. That was noted by different Asian nations that export to different countries, each with different standards; hence, an Asian Plywood Standard involving the use of wood failure and shear strength determinations was adopted in October 1977 at the Conference of Asian Plywood Manufacturers. Japan uses only shear strength as quality measurement, while in the United States both shear strength and wood failure values are specified.

52. International standards should be prepared and adopted for testing glue lines of plywood; it is reported that ISO has such a standard in preparation.

53. There is a need for non-destructive testing of panels since many boards are lost by destructive testing. In the United States, ultrasonic test methods are being used for plywood, particle board and gluelam as an effective continuous production quality control tool, although physical tests are also being carried out. The correlation between ultrasonic values and physical strength test values is being studied. However, ultrasonic devices would seem to be too advanced for many developing nations.



Annex I

AGENDA OF THE WORKSHOP

1. Election of officers and adoption of agenda.
2. Economics of production of:
   - (a) Synthetic resin adhesives;
   - (b) Resins based on naturally occurring products.
3. Utilisation of naturally occurring organic products:
   - (a) Past research;
   - (b) Industrial application.
4. Industrial application of synthetic adhesives for:
   - (a) Lignocellulose-based panels;
   - (b) Gluelam and timber engineering products;
   - (c) Joinery and furniture products.
5. Equipment for application of:
   - (a) Ready-to-use adhesives;
   - (b) Adhesive-particle blending;
   - (c) Adhesive spreading.
6. Testing procedures and equipment for adhesive testing.
7. Quality control procedures and standards for glued assemblies.
8. Adoption of the report.

Annex II

LIST OF DOCUMENTS

Documents prepared for the Workshop

Symbol	Title and author
ID/WG.248/1	Provisional agenda
ID/WG.248/2	Review of past research on utilisation of naturally ocurring organic products as replacement of synthetic phenolics in wood adhesives E. Kulvik, A/S Jotungruppen, Sandefjord, Norway
ID/WG.248/3	Economics of production of synthetic resin adhesives J. George, Indian Plywood Industries Research Institute, Bangalore
ID/WG.248/4	Formulation and industrial application of synthetic resin and special adhesives used in the joinery and furniture industries and other specialised wooden products E.J. van der Straeten and T.I. Mynott, CIBA-Geigy Plastics and Additives Company, Cambridge, United Kingdom
ID/WG.248/5	Annotated bibliography on the research done on the use of naturally occurring adhesives for wood processing industries J. George, Indian Plywood Industries Research Institute, Bangalore
ID/WG.248/6	The formulation and industrial application of naturally occurring polyphenol (tannin) adhesives in the wood based panel industry K.F. Plomley, Division of Building Research, CSIRO, Melbourne, Australia
ID/WG.248/7	Economic aspects of tannin extracts as wood adhesive binders J.C. Scharenberg, Compania Casco SAIC, Buenos Aires
ID/WG.248/8	Adhesive testing procedures and bonding strength testing equipment A. Frühwald, Institut für Holzphysik, Hamburg, Federal Republic of Germany
ID/WG.248/9	Industrial application and formulation of synthetic resin adhesives in the wood based panel industry J. Reinhardt, CIBA-Geigy Plastics and Additives Company, Cambridge, United Kingdom

ID/WG.248/10	Formulation and industrial application of synthetio resin adhesives in the gluelam beam and timber engineering industry H.C. Kolb, Otto-Graf-Institut, Stuttgart, Federal Republic of Germany
ID/WG.248/11	Equipment for coating of adhesives in the wood processing industry H. Funke, Fachhochschule Rosenheim, Rosenheim, Federal Republic of Germany
ID/WG.248/12	Equipment for preparing ready-to-use adhesives S. Senn, FAHRNI Institut AG, Zurioh
ID/WG.248/13	Mixing equipment for glue coating of wooden ohips or irregular particles of similar shape K. Engels, Draiswerke GmbH, Mannheim, Federal Republic of Germany
ID/WG.248/14	Agenda and programme of work

<u>Documents issued after the Workshop</u>

ID/WG.248/5/Add. 1, Add.2	Addenda to "Annotated bibliography on the research done on the use of naturally occurring adhesives for wood processing industries"
ID/WG.248/15	List of participants
ID/WG.248/16	List of documents
ID/WG.248/17	Report of the Workshop

The following studies on uses of wood have been prepared by UNIDO.

ID/70 (ID/WG.49/10/Rev.1)	Production techniques for the use of wood in housing under conditions prevailing in developing countries. Report of Study Group, Vienna, 17-21 November 1969 United Nations publication, Sales no. 70.II.B.32
ID/61 (ID/WG.49/5/Rev.1)	Production of prefabricated wooden houses Keijo N.E. Tiusanen United Nations publication, Sales no. 71.II.B.13
ID/72	Wood as a packaging material in the developing countries B. Hoohart United Nations publication, Sales no. 72.II.B.12
ID/79 (ID/WG.83/15/Rev.1)	Production of panels from agricultural residues. Report of the Expert Group Meeting, Vienna, 14-18 December 1970 United Nations publication, Sales no. 72.II.B.4
ID/108/Rev.1	Furniture and joinery industries for developing countries Part I: Raw material inputs Part II: Processing technology Part III: Management considerations
ID/133 (ID/WG.151/37/Rev.1)	Selection of woodworking machinery. Report of a Technical Meeting, Vienna, 19-23 November 1973
ID/154	Low-cost automation for the furniture and joinery industry H.P. Brion and W. Santiano
ID/180 (ID/WG.200/14/Rev.1)	Wood processing for developing countries. Report of a Workshop, Vienna, 3-7 November 1975
UNIDO/LIB/SER.D/4/ Rev.1 ID/188	UNIDO Guides to Information Sources No.4: Information sources on the furniture and joinery industry United Nations publication,
UNIDO/LIB/SER.D/9	UNIDO Guides to Information Sources No.9: Information sources on the building boards from wood and other fibrous materials
UNIDO/LIB/SER.D/31 ID/214	UNIDO Guides to Information Sources No.31: Information sources on woodworking machinery

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