UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

# REPORT TO UNIDO ON
# MEETING OF INTERNATIONAL ATOMIC ENERGY AGENCY STUDY GROUP ON IMPREGNATED FIBROUS MATERIALS

HELD IN BANGKOK, THAILAND, FROM 20-24 NOVEMBER 1967

BY

CHIEN CHU

CHEMICAL ENGINEER

BERNARD PH. ESSELINK

POLYMER TECHNOLOGIST

BANGKOK, 1968

not for publication

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# F O R E W O R D

Following an exchange of cables with UNIDO, Vienna, Dr. Chien Chu and Ir. Bernard Ph. Esselink as UNIDO representatives attended the meeting of the International Atomic Energy Agency Study Group on Impregnated Fibrous Materials held at the Office of the Atomic Energy for Peace, Bangkok, 20-24 November 1967. The Government of Thailand agreed to release them from their assigned duty with the Technological Research Institute (Applied Scientific Research Corporation of Thailand) for the period of the meeting so that they might attend as the official representatives of UNIDO. This paper gives their joint report on this meeting, together with the Programme of the Study Group, a list of the papers actually read, and a listing of the representatives and observers who attended the meeting.

# REPORT TO UNIDO ON MEETING OF INTERNATIONAL ATOMIC ENERGY AGENCY STUDY GROUP ON IMPREGNATED FIBROUS MATERIALS

By Chien Chu and Bernard Ph. Esselink

## 1. The IAEA Study Group Meeting

Products of natural wood have many shortcomings such as liability to decay, high moisture absorption and often poor dimensional stability and low strength. These limitations have restricted uses of wood to a few commercial species, which become very expensive with their dwindling supply. Many species of low grade wood find little uses although they are cheap and abundant in our tropical forests.

Impregnation of wood with monomers and polymerization in situ by irradiation or thermal catalyst processes produce a wood plastic combination (WPC) with improved physical properties such as high strength, low water absorption, good dimensional stability, mold and insect resistance, and sometimes even flame resistance from certain kinds of polymers or additives to the polymer. Thus the modified wood has wider applications than the original low grade wood. The same principle applies to bamboo, rattan, fibre board and wood veneers. Research and development on polymer containing fibrous materials have been made in many countries in recent years.

The IAEA Study Group Meeting on Impregnated Fibrous Materials sponsored jointly by the International Atomic Energy Agency and the Office of Atomic Energy for Peace of Thailand had a successful session during 20-24 November 1967. The meeting was attended by 25 participants from thirteen countries and five UN agencies besides 14 observers from relevant government agencies, universities, industries, and UN agencies in Thailand. Twenty-six papers were presented in the meeting. Various WPC samples of many countries were displayed during the session.

At the meeting the status of the WPC technology was reviewed and the method and techniques of impregnation and polymerization were compared, both out of technical point of view and from the economic side. The economics of WPC in comparison with other materials were discussed. Recommen-

dations were made for future research work on the development of WPC and cooperation in this research work.

In conclusion, the session of IAEA on impregnated fibrous materials in Bangkok is highly significant in advocating international cooperation especially from developed countries for advancement of atomic energy for peace and to introduce new fibrous products industries in developing countries.

## 2. Manufacture of WPC

The manufacture of WPC can be done in two steps. First the impregnation of the wood with monomer and after this the polymerization of the monomer in such a way that it adheres to the wood fibre. As monomers, methyl methacrylate, styrene and vinyl acetate are used. Trials on the use of other cheaper monomers have been done in many countries, but this is still in an experimental stage.

### 2.1 Impregnation of the wood with monomer.

In general, impregnation of wood with monomer is carried out first with evacuation of air out of the wood by applying vacuum, after which the monomer is forced under nitrogen pressure into the wood cavities. Low density wood is more porous than high density wood and therefore easier to impregnate.

### 2.2 Polymerization of the monomer.

#### 2.2.1 Thermal catalyst process.

Together with the monomer a catalyst is incorporated and the polymerization is initiated by heat treatment of the wood in ovens or autoclaves. This method has a disadvantage of high catalyst costs and high temperature involved. The initial capital investment is low and therefore a flexible production on moderate production scale is feasible.

#### 2.2.2 Polymerization by irradiation.

Irradiction by gamma radiation from Co-60 at a dose range of 1-2 megarad may initiate the polymerization. Another possi-

bility is irradiation by linear electron accelerators. Both methods, however, need a very high initial capital investment and therefore the method can only be realized with a high throughput of wood product.

Research on the thermal catalyst process and the irradiation process is continuing and finally economics will decide which method is preferred. With both methods, the effect of the heat of polymerization on the strength of the wood fibre is a matter for further research.

## 3. Practical applications

At present one commercial application of the production of WPC by the irradiation method is known in the USA. The American Novawood Company produces five million pounds of WPC annually. The process involves mainly the impregnation of wood with methyl methacrylate and radiation with a dose range at 1.1-2.0 megarads from Co-60. The total investment including the impregnation and irradiation facilities was about US $ 500,000.

Furthermore, the American Machine and Foundry Co. produces billiard cues by the thermal catalyst process.

In general, however, commercial development of WPC is still in its infancy. The approach for the developed countries and the developing countries should be quite different. In developed countries the need for decorative wood for buildings (parquet floor, decorative walls, artistic furniture, etc.) is big and there are also many special applications (golf clubs, billiard cues, etc.) The developing countries are more in need of low cost housing materials which are resistant to weathering, molds and insects. Their production of monomers is just starting and could be orientated to the new direction. One possible development is the integrated production of vinyl chloride and vinyl acetate for impregnation of fibrous materials such as fibre board, veneers, woodcraft and bamboo products.

## 4. Possibilities for developing countries

### 4.1 Fibre board

Fibre board is considered as being one of the promising building materials for developing countries. The board is easy to impregnate

with monomer. Also impregnation of only the outer layer can be made, after which a kind of sandwich construction is obtained with polymerization.

4.2 Bagasse board

Bagasse has been utilized in many developing countries (Republic of China, Philippines, India, etc.) for the production of low cost bagasse board as housing material. The weathering and insect resistance is low and a bagasse plastic combination can bring a considerable improvement. Research on bagasse plastic combination is done in Taiwan with good results. However at present the costs are still too high, which can be improved most probably by the use of cheaper monomers.

4.3 Bamboo

The Southeast Asian region is endowed with many species of bamboo. Thailand has a specie of giant bamboo with a culm diameter over 4". Bamboo harvest usually has a three-year cutting cycle. It is considered as the poorman's timber and is favoured by farmers for its quick growth and short harvesting cycle besides its numerous household uses.

On the mainland of China big bamboo poles, impregnated with tung oil and naturally cured, had been used as gas pipes and brine pipes in the production of rock salt in Szechuan Province. Such bamboo pipes owed their useful life to tung oil impregnation.

Research work on the bamboo plastic combination (BPC) in Taiwan shows good prospects in commercial development. The permeability of bamboo to monomer impregnation is so good that no nitrogen purging is necessary. Perhaps plasticisers such as dehydrated castor oil may be added to reduce monomer cost and to produce a pliable bamboo product, which may find application as durable strong low cost housing material.

4.4 Rubber wood

Rubber wood has fairly good physical strength, but is liable to rot quickly. Thus rubber wood has little value to rubber plantations. A process has been developed in Ceylon for the manufacture of fibre board from rubber wood. Preliminary study on WPC from rubber wood has been made by the Atomic Energy Commission of Thailand. Feasibility study and weathering tests of WPC products from rubber wood could be

conducted by regional cooperation with international assistance. WPC standard window frames and flooring from rubber wood may find a wide market for low cost housing.

4.5 Woodcraft articles and furniture parts

Production of woodcraft articles and furniture parts is quite labour intensive. These products have a great potential market in developed countries and can be regarded as a big export potential of developing countries. With government promotion, woodcraft articles and furniture parts can be made from a wide range of local wood and processed in a central impregnation and radiation plant for finishing, grading and modern packaging for export by private exporters. The central processing plant would charge only for the impregnation and radiation processing and packaging besides providing working capital and technical assistance to rural workshops for selection of wood, tools and designs based on foreign market trends.

## 5. Conclusions and recommendations

The IAEA Study Group Meeting recognized the fact that low cost housing materials for developing countries is one of the major world problems. Therefore this development was stressed as important and all participants of the meeting agreed to direct future research in this direction. As promising materials the bagasse board, fibre board and the bamboo were mentioned. Regional cooperation with respect to these materials was strongly recommended. Attention was drawn to come as soon as possible to natural weathering and climatic testing. These tests can be compared with accelerated weathering testing of the same materials, to be carried out in developed countries (Finland offerred to do these tests.)

In general the feeling was expressed that the WPC as a building material, although still in its infancy, is one of the most promising materials for the future.

Annex 1

# STUDY GROUP OF IMPREGNATED FIBROUS MATERIALS

## PROGRAMME

Monday, 20 November 1967

Session I - Introduction

A. Opening of Study Group

B. Introductory Papers

Session II - The Supporting Technology

Tuesday, 21 November 1967

Session III - Status and Technology of Polymer containing Fibrous Materials in the Western Hemisphere

Session IV - Status and Technology of Polymer containing Fibrous Materials in the Eastern Hemisphere

Wednesday, 22 November 1967

Session V - Fibrous Materials as a Natural Resource in the Far East

Thursday, 23 November 1967

Session VI - Potential Markets for Polymer-containing Fibrous Materials in the Far East.

Session VII - Programmes for Developing Polymer-containing Fibrous Materials as National Resources in the Far Eastern Countries

A. General Discussion (Entire Study Group)

B. Formulation of Research and Development Programmes (Study Group split into Committees).

C. General Discussion (Entire Study Group)

Friday, 24 November 1967

Session VII - Continued.

Session VIII - Summary and Conclusion

A. Review accomplishments of Study Group

B. Prepare summary of Study Groups activities

C. Prepare guidance for IAEA on Future Study Group

Annex 2

# PAPERS PRESENTED AT THE STUDY GROUP MEETING ON IMPREGNATED FIBROUS MATERIALS

A. General introduction

"History of impregnation techniques with fibrous materials", Dr. H. Tarkow, U.S. Forest Product Laboratory, Madison, Wisconsin, U.S.A.

"Wood-plastic combination by monomer impregnation and radiation polymerization", Dr. Tibor Czvikovszky, Plastic Research Institute, Budapest, Hungary. (At present only the contents and the bibliography of this article is available)

"Selected bibliography: fibrous material-polymer composites", (Composed by William E. Mott and George J. Rotariu, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington D.C. 20545)

B. Economic

"Impregnated fibrous materials, Economic Considerations", Eric Rotkirch, Ekono, Helsinki, Finland.

"Potential markets for wood plastic composites in the Far East-Japan", Toru Hirayama, Central Research Laboratory, Showa Denko. K.K., Tokyo, Japan.

C. Supporting technology

"Degradation of polymers by ultra-violet light", D.T. Turner, Camille Dreyfus Laboratory, Research Triangle Institute, Research Triangle Park, N.C., U.S.A.

"Emulsion graft polymerization to wood by $\gamma$ radiation", Masao Gotoda.

"Factors affecting the impregnation of bagasse and other Far Eastern fibrous materials", Ung-Ping Wang, Radioisotope Lab., Union Industrial Research Institute, Ministry of Economic Affairs, Republic of China.

"Monomer - polymer chemistry and the impregnation process", Vivian Stannett, Chemical Engineering Department, North Carolina State University, Raleight, N.C. 27607, U.S.A.

"The permeability of wood in relation to its structure and penetrability by fluids", Eric L. S. Ellwood and Richard J. Thomas, School of Forest Resources, North Carolina State University, Raleigh, North Carolina U.S.A.

"Radiation engineering in the polymerization of monomers in fibrous materials using a radio isotope source", A.J. Felice, Atomic Energy of Canada Ltd., Commercial Products, Ottawa, Canada.

"Radiation engineering in the polymerization of monomers in fibrous materials: accelerators", F.L. Dalton & J.D. McCann, Wantage Research Laboratory (AERE), Grove, Wantage, Berkshire.

"Fibrous material resources in Asia and the Far East", D.L. Stacey, FAO, Bangkok.

D. Papers on the status and technology of polymer-containing fibrous materials in the different countries

Australia — "The prospects for irradiated wood-polymer composites in Australia", J.G. Clouston, Australian Atomic Energy Commission, Lucas Heights, Australia.

China — "The status and technology of polymer-containing fibrous materials in the eastern hemisphere - Taiwan", Ung-Ping Wang, Radioisotope Laboratory, Union Industrial Research Institute, Ministry of Economic Affairs, Republic of China.

Eastern Europe — "The status of wood-plastic combination research in Europe", T. Czvikovszky and J. Dobo, Research Institute for Plastics, Budapest, Hungary

Finland — "Status and technology of impregnated fibrous materials in Finland", J.K. Miettinen. Department of Radio Chemistry University of Helsinki, Finland.

India — "Status and technology of polymer-containing fibrous materials in India", V.K. Iya, Isotope Division, Bha-bha Atomic Research Centre, India.

Japan — "Status and technology for wood plastic composites (WPC) in Japan", Toru Hirayama, Central Research Laboratory, Showa Denko. K.K., Tokyo, Japan.

Philippines — "The status of research on plastic impregnated fibrous materials in the Philippines", Leticia S. Bonoan, Philippine Atomic Research Center, Philippine Atomic Energy Commision, Manila.

South Korea — "The status and technology of polymer containing fibrous materials in the eastern hemisphere - Korea", Chwa-Kyung Sung, Office of Atomic Energy, Seoul, Korea.

Sweden — "Status and technology of polymer-containing fibrous materials in Western Europe with special reference to Sweden", P.O. Kinell and P. Aagaard, the Swedish Research Councils Laboratory, Studsvik, Nykoping, Sweden.

Thailand — "Wood resource of Thailand", Pong Sono, Forest Product Research Division, Royal Forest Department, Bangkok.

"Some investigation on Radiation-polymerization in Thailand", M.L. Anong Nilubol and Somkiart Greethon, Office of Atomic Energy for Peace, Bangkok.

U.S.A — "Impregnation and polymerization methods and systems used in the production of wood-polymer materials", William E. Mott and George J. Rotariu, Division of Isotopes Development, U.S. Atomic Energy Commission, Washington D.C. 20545.

Annex 3

IAEA STUDY GROUP MEETING

ON

IMPREGNATED FIBROUS MATERIALS

BANGKOK, 20-24 NOVEMBER 1967

Final List of Participants and Accommodation Representative

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