THAI PLYWOOD COMPANY, LIMITED

APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

COOPERATIVE RESEARCH PROGRAMME NO. 35

INDUSTRIAL EXTRACTION AND UTILIZATION OF TANNINS

RESEARCH PROJECT NO. 35/4

DEVELOPMENT OF WATER-RESISTANT GLUES FROM TANNIN

REPORT NO. 2

EVALUATION OF THE PROPERTIES OF REINFORCED TANNIN-FORMALDEHYDE ADHESIVES FOR PLYWOOD

BY

SHAMNAN DEETESNA

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EVALUATION OF THE PROPERTIES OF REINFORCED TANNIN-FORMALDEHYDE ADHESIVES FOR PLYWOOD

By Shamnan Deetesna* and Bernard Ph. Esselink+

SUMMARY

Following an earlier report‡ on the economic evaluation of tannin-formaldehyde adhesives for plywood, a cooperative research programme started between the Thai Plywood Company, Ltd. and ASRCT. The target of the research programme is to prove the technical feasibility of reinforced tannin-formaldehyde adhesives in Thailand. The results are encouraging but research work will continue as the proper evaluation of the technical details is not yet finished.

I. INTRODUCTION

Reinforced tannin-formaldehyde adhesives (RTF adhesives) are used in Australia for the manufacture of marine plywood. These adhesives can compete economically with phenol-formaldehyde adhesives and the technical qualities regarding strength of the adhesive bond and weather-resistancy are equal or better than phenol-formaldehyde adhesives.

The formulation of the RTF adhesives is relatively simple. Wattle tannin (product from South Africa) is dissolved in water (50 per cent solution), 10-20 per cent of a reinforcing resin, resorcinol-phenol-formaldehyde resin (RPF resin), is incorporated in the formulation together with paraformaldehyde, a catalyst (NaOH) and a filler (wood flour). The adhesive is cured under the same working conditions as the

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* Thai Plywood Company, Ltd.

+ Industrial Chemistry Group, Technological Research Institute, ASRCT.

‡ "Economic evaluation of tannin-formaldehyde adhesives for plywood"; Report No. 1 on Research Project No. 35/4 (Development of water-resistant glues from tannin). ASRCT, unpublished report.

presently used hot curing plywood adhesives. The price is between the price of urea-formaldehyde and phenol-formaldehyde adhesives. (Esselink; Report No. 1 on Research Project No. 35/4.)

This kind of adhesives seems to have a future in Thailand as the need for a cheaper weather-resistant plywood glue is evident. Local utilization of tannins will be possible in the future. The Thai Plywood Company alone is using 40-45 tonnes/month phenol-formaldehyde adhesive for the manufacture of exterior plywood. Urea-formaldehyde is not weather-resistant under the tropical conditions of Thailand and therefore, its use is necessarily restricted for interior applications.

Discussions between the Thai Plywood Company and ASRCT resulted in this cooperative research project to investigate whether the Australian results (Plomley, 1966)* are applicable in Thailand.

Before starting the research a working programme was made, (Appendix I) and this programme was used as a guide but not followed chronologically. This was because a new experimental hot press was being installed in the laboratory of the Thai Plywood Company and no mechanical testing could be done before the beginning of June 1968.

II. MATERIALS AND METHODS

Appendix I sets out the working programme on the formulation and testing of the RTF adhesives. This working programme gives the details of the materials and methods used in the research work.

The raw material situation for TRF adhesives in Thailand is as follows:

(i) Tannins

At present, local tannins are used in negligible quantities by the local tanneries. The species which contain useful tannin are growing scattered over the country, the methods of harvesting are primitive and not systematic. For the application of the tannin on the tannery, the

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* Plomley, K.F. (1966).—Tannin-formaldehyde adhesive for wood. CSIRO Australia Division of Forest Products Technological Paper No. 39.

bark is soaked together with the hides in a basin and the result is a very poor leather.

For larger scale systematic recovery of tannins only mangrove tannin will be available in Thailand. The mangrove occurs in big quantities along the west coast of Thailand. However, discussions with an Australian expert (Dr. W.E. Hillis, private communication) revealed that mangrove tannin is not the best tannin to produce. It produces a poor quality red leather and for application in plywood adhesives, it is by far, inferior to wattle tannin.

Therefore, a reliable source of tannin will have to be developed in Thailand. Tannins are a cheap product(±5 baht/kg) as there exists a world over supply. Against this very competative price it will be hard to start local manufacturing of tannins, and in the near future imports of this material will continue.

(ii) Chemicals

Resorcinol, phenol, and formaldehyde are at present imported items. As they only represent a small percentage in the total glue formulation, this situation will not change in the near future.

Another possibility will be to import the ready made RPF resin from Australia. One adhesive manufacturer has shown considerable interest in exporting the resin to Thailand (NH Town, private communication). Samples of Thai veneer species were sent to this manufacturer to get the optimum glue formulation applicable under Thai conditions.

(iii) Fillers

Wood flour is by choice, the best filler for RTF adhesives and is used in quantities up to 15 per cent on dry tannin in the formulation. For this purpose both yang and teak wood flour are available in sufficient supply.

Another potentially interesting filler is coconut shell flour. This material is not yet available in Thailand in sufficiently reliable supply.

III. RESULTS AND DISCUSSIONS

As already mentioned, the working programme (Appendix I) has served as a guide for the research. A start has been made first with physical tests on the RTF adhesives* in which experiments were carried out to determine the influence of pH and the amount of paraformaldehyde on the physical behaviour (working life) of the RTF adhesives. The results of this work will be discussed under III (a).

Mechanical tests were then done on the RTF adhesives. First test boards were made with different adhesives. This will be discussed under III (b). These test boards were tested for their properties and the influence of the different variables will be discussed under III (c).

(a) Physical tests on RTF adhesives

(i) Influence of pH on the working life of RTF adhesives

With the aid of the Haake Rotovisco meter the viscosity increase of the RTF adhesive as a function of time was determined. In Figure 1, the viscosity ratio $\frac{\eta}{\eta_o}$ (η = viscosity at time t; η_o = viscosity at time = 0) is plotted against time and as function of pH.

Working life is taken as the time in which the viscosity is increased to four times, its initial value ($\eta/\eta_o = 4$).

This definition is based on the fact that the glue spreading machine usually starts with a glue mixture of 2,000 centipoises viscosity and above 8,000 centipoises viscosity, the glue is considered too thick for proper spreading.

From Figure 1 the following working life is found:

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* The experimental part of this work was done by Miss Warunee Yongskulroaj; fourth year student in Chemical Engineering, Chulalongkorn University.

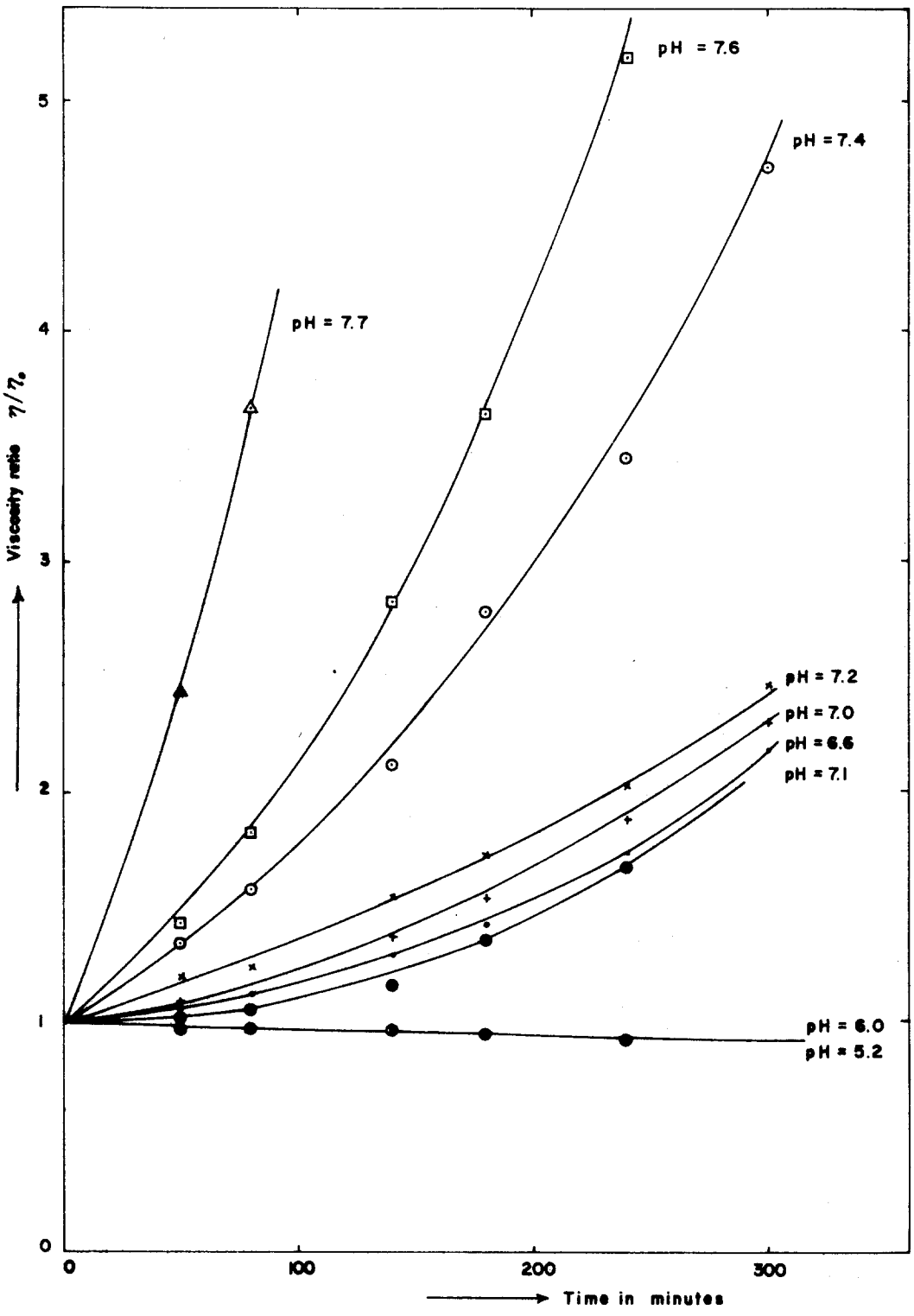

Figure 1.—Influence of pH on the viscosity ratio of RTF adhesives.

TABLE 1

WORKING LIFE AS FUNCTION OF pH

pH	Working life (minutes)
7.7	86
7.5	196
7.4	268
7.2 - 6.0	Longer than 300 minutes but lesser than 20 hours
6.0	Mixture does not react

As seen in Table 1 pH has a very big influence on the working life of the RTF adhesive.

(ii) Influence of the percentage of paraformaldehyde on the reaction speed of the RTF adhesive

Paraformaldehyde is used as the setting agent for the RTF adhesives. In Figure 2 the influence of the percentage of paraformaldehyde on the increase of viscosity with time of the RTF resin is plotted. The influence is seen to be significant. However, the optimum amount of paraformaldehyde will have to be determined on the basis of mechanical testing of the strength of the adhesive bond. From Figure 2 it can be concluded that a small amount of paraformaldehyde favours a long working life of the RTF adhesive.

(b) Mechanical testing of the RTF adhesives

The mechanical testing of the adhesives can be divided into three parts.

(i) Formulation of the RTF adhesives

Preparation of all components of the adhesive was done in the laboratory of TRI. The actual mixing of the components and the pH and viscosity measurements were done in the laboratory of the Thai Plywood Company.

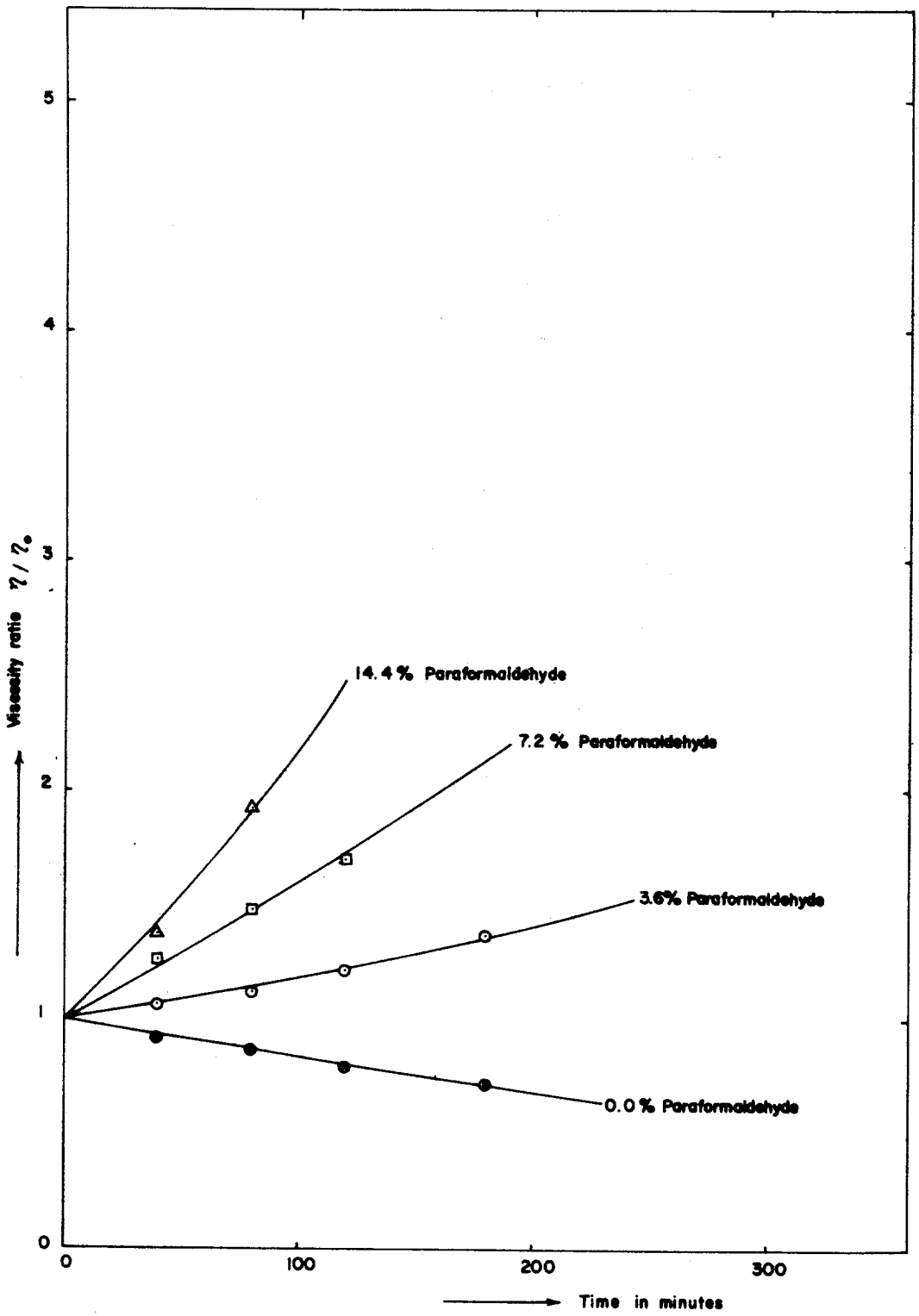

Figure 2.—Influence of the amount of paraformaldehyde on the viscosity ratio of RTF adhesives.

The formulation mentioned in the working programme (Appendix I No. 4) was used as the basic formulation.

		Per cent weight on dry tannin
Tannin extract 50% tannin (g)	66	200
NaOH 10% (ml)	3	0.9
RPF resin (g)	7.5	22.7
Paraformaldehyde (g)	2.7	8.2
Teak flour (g)	4	12.1

The pH and the viscosity of the glue mixture were measured directly after mixing.

All components were varied systematically in the above formulation: variations in tannin concentration (6.5), NaOH (6.4), RPF resin (6.6), paraformaldehyde (6.3), and wood flour (6.2) were made.

(ii) Preparation of the test boards

All the test boards were prepared in the laboratory of the Thai Plywood Company under the following conditions:

Veneer conditions

Kind of veneer:	Yang
Thickness:	1.6 mm
Moisture content:	± 10%
Construction:	Yang/yang/yang

Pressing conditions

Glue spread:	180 g/m^2 (single glue line)
Assembly time:	45 min (except in Test Report No. 1)
Cold press:	10 kg/cm^2 during 10 minutes
Pressing temperature:	130°C
Pressure:	14 kg/cm^2 (200 lb/in^2)
Pressing time:	6 minutes

The boards were conditioned in the testing room for 24 hours before the testing started.

(iii) Testing of the test boards

The tests were done according to the British Standard B.S. 1203: 1963 (specification for synthetic resin adhesives for plywood) and B.S. 1455:1963 (knife test). Test pieces were cut out of the test boards and subjected to:

Moisture resistance (MR test).—Immersing of the test pieces in warm water ($67 \pm 2^{o}C$) for 3 hours.

Weather and boil proof (WBP test).—Steaming in a closed vessel at 2.11 kg/cm^2 (30 lb/in^2), the test pieces being above the level of condensate or free water, 12 hours.

The following determinations were made on the test pieces:

Failing load: Reported as the average of the results for all five test pieces (one set of test pieces) in lbf/in^2.

Wood failure: Same as failing load

Knife test: Report on one glue line of the test piece.

The test board is up to standard when the failing load of the MR and the WBP test are 200 lbf/in^2 or higher.

The standard of the knife test is reached above point 5.

(c) Discussion of the results on the mechanical testing of the RTF adhesives

In Appendix II all test reports are collected. The results will be discussed below.

(i) Influence of the assembly time and the working life of the adhesive (Test Report No. 1, Appendix II).

The mixing of the adhesive was not done properly as the initial temperature of the glue was too high. However, it can still, be concluded that the optimum assembly time is between 30 and 60 minutes. For further experiments an assembly time of 45 minutes was chosen. The influence of the elapsed time (time after mixing the glue) is not very big. The small effect is most probably, caused by the higher viscosity of the glue which results in less penetration of the glue into the veneer.

(ii) Influence of the kind and amount of wood flour (Test Report No. 2, Appendix II)

Teak flour and coconut shell flour were varied in the formulation. The behaviour of the flours is extremely different. Teak flour has very big effect on the viscosity of the glue mixture and coconut shell flour hardly affects the viscosity. In all cases, 4 gramme wood flour (12.1 per cent on dry tannin) is the amount which gives the optimum value for the failing load. Teak flour gives slightly higher values for the failing load than coconut shell flour, but the difference is not significant.

(Note: In Test Report No. 2 two variables were observed together. The influence of the amount of resin will be discussed later.)

(iii) Influence of the amount of paraformaldehyde (Test Report No. 3, Appendix II)

The percentage of paraformaldehyde in the glue mixture was varied between 0 and 15.2 per cent on dry tannin. The minimum percentage of paraformaldehyde giving a satisfactory adhesive bond was 6 per cent.

(iv) Influence of the pH (Test Report No. 3, Appendix II)

Adjustment of pH of the glue to the required value was made right after the mixing of the glue. Up to pH = 7.5 no significant influence of the pH on the failing load value can be noted. Above this value (pH = 8.0 and pH = 8.5) a rapid decrease in strength can be noted.

(v) Influence of the percentage of tannin in the extract (Test Report No. 3, Appendix II)

No significant influence of the tannin concentration can be noted. The mixture with tannin concentration 55 per cent is too viscous for proper spreading on an industrial glue spreader.

(vi) Influence of the RPF resin (Test Report Nos. 2 and 4, Appendix II)

In Test Report No. 2, only the effect of the amount of RPF resin was determined. The minimum amount of reinforcing resin is 15 per cent on dry tannin. 22.5 per cent (7.5 g) resin gives slightly better results. In Test Report No. 4, quality and quantity of the RPF resin were subjected to investigation. The resins containing 20 per cent and

30 per cent resorcinol proved to give the best values for the failing load. The minimum amount of reinforcing resin is again 15 per cent on dry tannin. All the resins used were freshly prepared except in experiments no. 21-25, which were "old resin". Apparently, the shelf-life of the resins is sufficient because the failing load was not affected.

CONCLUSIONS AND RECOMMENDATIONS

The experiments have proven that the reinforced tannin-formaldehyde adhesives can produce strong weather-resistant bonds with Thai veneer. Further evaluation will be necessary however, because the optimum formulation is not yet established.

The working life of the RTF adhesives is too short. A proper solution has to be found. As the influence of pH on the working life is very great and influence of pH below pH = 7.5 is rather small, a low pH e.g. pH = 6.0-6.5 should be selected in order to get a longer working life. More experiments on the influence of pH will be needed.

The pressing conditions were not yet a subject of investigation. Optimalization of the pressing conditions will be useful and the target for further experiments.

More attention has to be paid to the viscosity of the glue mixture. Wood flour can serve as the regulating agent. A mixture of teak flour and coconut shell flour can be tried.

ACKNOWLEDGEMENT

Without the close operation between the Thai Plywood Company and the Technological Research Institute, ASRCT, the experiments could not have been done successfully. We thank the staff of the laboratory of the Thai Plywood Company for their help in all the routine work.

Also we thank Miss Warunee Yongskulroaj for her big contribution in the physical evaluation of the RTF adhesives.

APPENDIX I

WORK PROGRAMME ON THE FORMULATION AND TESTING OF REINFORCED TANNIN-FORMALDEHYDE ADHESIVES

Research Programme No. 35: Industrial extraction and utilization of tannins.
Research Project No. 35/4: Production of plywood adhesives from tannins.
Work Programme No. 35/4/1: Formulation and testing of the adhesives.

0. Introduction

Reinforced tannin-formaldehyde plywood adhesives are commercially produced and used in Australia. The reaction conditions and formulation are known from the article of Dr. K.F. Plomley in CSIRO Australia Division of Forest Products Technological Paper No. 39. However, no exact formulation is given in this article and Australian species of wood are used as veneer and fillers, which are different from the species commonly used in Thailand.

Most likely, adjustments in the formulations will have to be made due to the different working condition in Thailand. Furthermore, the optimum amount of reinforcing resin in the overall formulation has to be determined.

1. Object of investigation

1.1 Adjustment and evaluation of Australian formulations of the water-resistant plywood adhesives to the Thai condition.

1.2 Estimation of the optimum amount of reinforcing resin in the tannin-formaldehyde adhesives (both technical and economical).

2. Materials

2.1 Chemicals: Wattle tannin (South Africa), phenol, resorcinol, and formaldehyde. All imported.

2.2 Fillers: Yang flour, teak flour, coconut shell flour, tamarind seed testa flour, casava flour, etc. All locally available fillers.

2.3 Veneers: Yang and teak veneer and any other locally available species the Thai Plywood Company is using.

3. Preparation of the resorcinol-phenol-formaldehyde resin (RPF resin)

The following general formulation procedure of the RPF resin will be used:

React 1 mole of phenol with 1 mole of formaldehyde (as 40% solution) using sodium hydroxide catalyst (1.45% of the weight of phenol and dissolved in 3.5 times its weight of water). Heat the mixture for 60 minutes at 90°C. Cool to 70°C and add A grammes resorcinol with formaldehyde (molar ratio 1:0.67). Heat this mixture for 40 minutes and cool it to ambient temperature as rapidly as possible. The final product contains from 20-50 per cent resorcinol (depending on A), calculated on the weight of phenol and will have pH values from 7.9 to 7.5.

Prepare the RPF resin with different percentages resorcinol:

3.1 Take 20 per cent resorcinol on phenol

Formulation:

Phenol	94 g
Formaldehyde	75 ml (conc. 40%)
NaOH	4.75 ml (conc. 28.5%)
Resorcinol	18.8 g
Formaldehyde	8.5 ml (conc. 40%)

3.2 Take 30 per cent resorcinol on phenol

Formulation as 3.1 except:

Resorcinol	28.2 g
Formaldehyde	12.9 ml (40%)

3.3 Take 40 per cent resorcinol on phenol

Formulation as 3.1 except:

Resorcinol	37.6 g
Formaldehyde	17.1 ml (40%)

3.4 Take 50 per cent resorcinol on phenol

Formulation as 3.1 except:

Resorcinol	47 g
Formaldehyde	21.5 ml (40%)

4. Formulation of the reinforced tannin-formaldehyde adhesive (RTF adhesive)

Tentatively the following formulation will be used:

Dissolve 100 g wattle tannin in 105 ml water, first by soaking it for 2 hours (or more conveniently overnight) and then by heating to about 60°C. Cool the solution to room temperature and add 9 ml sodium hydroxide (10% solution). Add to this mixture the RPF resin (B gramme), followed by 8 g paraformaldehyde and 10-15 g wood flour (200 mesh). The proportion of the wood flour will depend on the amount of RPF resin and will adjust the viscosity of the mixture to 1,000-1,500 centipoise.

An evaluation of the many variables in the formulation process will be necessary. This evaluation can be done in two main steps and will be directed by the results of the testing.

4.1 Variation of the amount of RPF resin in the adhesive.

Prepare the RTF adhesives with B = 5, 10, 15, and 20 g of the RPF resins prepared in 3.1-3.4. Use either yang or teak wood flour, depending on the results of a preliminary test with both flours. Note in all cases the exact formulation and also the non-tannin per cent of the wattle tannin.

4.2 Variation of other variables.

4.2.1 Variation of wood flour.

Yang, teak, coconut shell, tamarind seed testa, tapioca flour can be used in variable mesh size (50-300 mesh).

4.2.2 Amount of paraformaldehyde.

The minimum amount of paraformaldehyde has to be determined.

4.2.3 Variation of the pH.

The pH will have an effect on the working life of the adhesive and therefore will be varied.

5. Physical testing of the RPF resin and the RTF adhesives

The following tests will have to be done with all the prepared resins and adhesives.

5.1 Determination of the pH.

The pH will have an effect on the working life and curing time of the adhesive and therefore has to be noted.

5.2 Determination of the consistency (viscosity).

The consistency changes is a measurement for the working life, spreading capacity etc. of the adhesives. The ASTMD 1,084 specifications will be used.

5.3 Determination of the working life of the adhesive.

The ASTMD 1338-1356 (1965) method will be used.

5.4 Determination of the storage life of the adhesive and resin.

Store the resin and adhesive under different condition and check each month the properties 5.1-5.3.

6. Mechanical testing

6.1 Preparation of the test boards.

Test boards will have to be made to determine the mechanical properties of the adhesives. The laboratory of the Thai Plywood Company is equiped for this purpose. On the small experimental hot press test boards (40 x 40 cm) can be made. The temperature and the pressure can be regulated on this hot press. The directions laid down in the Specification for Synthetic Resin Adhesives for Plywood, British Standard 1203: 1963 will be used. However, adaptation to the local situation has to be made. The variables in the preparation of the test boards will be:

6.1.1 Wood species.

The Thai Plywood Company uses both yang and teak wood veneer. Both species are to be used in the tests and conditioned to 5-10 per cent moisture content.

6.1.2 Amount and viscosity of the adhesive.

Initially 300-350 grammes adhesive per m^2 double glue line will be used. Viscosity 1,000-1,500 centipoise. After selection of the adhesive of a proper composition the optimum amount of applied adhesive will be determined.

6.1.3 Variation of the assembling time.

The assembling time will be varied between 15 minutes and $2\frac{1}{2}$ hours. (Use initially assembling times of 15, 30, and 60 minutes.)

6.1.4 Variation of the temperature.

Initially a platen temperature of 140°C will be used.

6.1.5 Variation of the pressure.

The platen pressure will be initially 200 lb/in^2.

6.1.6 Variation of the pressing time.

The pressing time will be varied between 5 and 12 minutes. Initially a pressing time of 8 minutes will be selected.

6.2 Testing of the test pieces.

Test pieces will be made out of the test boards according to the British Standard 1203:1963 (Specification for Synthetic Resin Adhesives for Plywood). The RTF adhesives belong to group of phenolic resins. Therefore, the following properties will be determined:

6.2.1 Dry tensile strength of the conditioned board.

6.2.2 Resistance to cold water.

6.2.3 Resistance to hot water or steam.

6.2.4 Resistance to micro-organism.

6.2.5 Additionally the knife test will be used for 6.2.1-6.2.4.

7. Equipment needed

7.1 For the chemical work involving the resin preparation and the adhesive formulation the following items are needed:

7.1.1 Glassware

Normal glassware which is available in the organic laboratory and the store room will be adequate.

7.1.2 Constant temperature bath.

7.1.3 Heating mantle.

7.1.4 Mechanical stirrer.

7.1.5 Balance.

7.1.6 Viscosity meter.

7.1.7 pH meter.

7.2 For the physical testing is needed.

7.2.1 pH meter.

7.2.2 Viscosimeter.

7.3 For the mechanical testing is needed.

7.3.1 Viscosimeter.

7.3.2 Balance.

7.3.3 A laboratory hot press, temperature range 100-150°C; pressure range 100-250 lb/in^2.

7.3.4 Conditioning equipment mentioned in British Standard 1203-1963.

7.3.5 Universal tensile strength testing machine.

7.3.6 Equipment for the knife test.

8. Chronological outline of the work phases

8.1 Prepare equipment and materials (see 9).

8.2 Undertake an initial experiment, which will include the following points of the working programme:

3.3; 4.1 using 20 g RPF resin and teak wood flour (200 mesh);

5.1-5.3; 6.1.1 using both teak and yang veneer; 6.1.2. 350 grammes adhesive per m^2 d.g.l.; 6.1.3 assembling time 15, 30, and 60 minutes; 6.1.4 temperature 140°C; 6.1.5 pressure 200 lb/in^2; 6.1.6 pressing time 8 minutes; 6.2.1; 6.2.2; 6.2.3; 6.2.5. Report the results.

8.3 Systematic execution of the working programme in which the results of 8.2 will be the guiding principle. This will include.

8.3.1 Preparation of the RPF resins analyses of the wattle tannin.

8.3.2 Preparation of the RTF adhesives (4.1).

The variations mentioned under 4.2 will be done in a later stage.

8.3.3 Physical testing according to 5.1-5.4.

8.3.4 Preparation of the test boards with each prepared RTF adhesive (6.1) and testing the boards on their mechanical properties.

8.3.5 Report and analyse the results and if necessary, proceed again with 8.3.1-8.3.5 to find the optimum conditions eventually with the variations mentioned in 4.2.

8.4 Report the results, conclusions, and recommendations. Include recommendation for enlargement to industrial scale.

9. Materials required

9.1 For the initial experiment (8.2) ± 2 kg adhesive is required for the mechanical testing. This includes ± 1 kg wattle tannin and small amounts of the materials mentioned under 2 of this working programme.

9.2 For the systematic execution of the working programme, most probably an amount of 20-30 kg adhesive will have to be prepared. The raw material list based on this figure will be.

Wattle tannin	10-15 kg
Resorcinol	± 1 kg

Phenol	± 2 kg
Formaldehyde	± 1 kg
Paraformaldehyde	± 1 kg

Fillers varieing amount, of each filler

Veneers teak + yang together ±250 m^2

Different chemicals in small quantities.

10. Special aspects

The working programme will be done as a joint effort between the Thai Plywood Company and the Technological Research Institute, ASRCT. The chemical work (3-5) will be done at TRI and the mechanical testing in the laboratory of the Thai Plywood Company.

APPENDIX II

TEST REPORT NO. 1

RPF resin (reinforced tannin-formaldehyde adhesive)

4 June 1968.

I. Formulation (glue mixing)

Wattle tannin	=	100 g
Water	=	105 g
Resin (20% resorcinol)	=	20 g
NaOH (conc. 10%)	=	9 ml
Paraformaldehyde	=	8 g
Wood flour (teak, 100 mesh)	=	15 g

Procedure

Dissolve wattle tannin in warm water (60°C) and then add the residual, mix (stir) until homogeneous.

II. Properties of the mixture

Passing time (min)	Viscosity (cP)	pH
0	525 at 40°C	7.3 at 40°C
60	2,175 at 33°C	7.0 at 33°C
120	3,900 at 31°C	6.7 at 31°C

III. Veneer conditions

Kind:	Yang (normal resin)
Thickness:	1.6 mm
Moisture content:	8%
Construction:	Yang/yang/yang

IV. Pressing conditions

Glue spread	=	180 g/m^2 (single glue line)
Assembly time	=	15, 30, and 60 min
Cold press	=	10 kg/cm^2, during assembly time
Temperature	=	130°C
Pressure	=	14.0 kg/cm^2 (200 lb/in^2)

V. Mark

Passing time (min)	Assembly time (min)	Mark
0	15	A-1
	30	A-2
	60	A-3
60	15	A-4
	30	A-5
	60	A-6
120	15	A-7
	30	A-8
	60	A-9

VI. Testing (according to B.S. 1203:1963 and B.S. 1455:1963)

MR test: Immersing in warm water (67 ± 2°C) for 3 hours.

WBP test: Steaming in a closed vessel at 30 lbf/in^2 the test pieces being above the level of condensate or free water, 12 hours.

VII. Results

Failing load: Report as the average of the results for all five test pieces (one set of test pieces), lbf/in^2 unit (lbf = pound force).

Wood failure: Same as failing load.

Knife test: Report or one glue line of test piece.

Mark	MR test			WBP test		
	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)
A-1	236.28	10	3	178.64	2	4
A-2	232.32	14	4	161.92	6	5
A-3	254.32	8	6	187.44	12	7
A-4	199.32	8	4	Delaminate	0	5
A-5	255.64	16	4	182.16	0	4
A-6	253.44	14	5	207.68	2	6
A-7	277.64	4	3	181.72	0	3
A-8	246.84	10	5	176.88	0	4
A-9	263.12	22	7	170.72	8	6

Note: Both MR and WBP test, standard of failing load are 200 lbf/in^2, and standard of knife test are above 5 points.

TEST REPORT NO. 2

Subject: RTF adhesives

Cooperation: Bernard Ph. Esselink, Mr. Shamman Deetesna

Place: Thai Plywood Laboratory

Date: 18 June 1968

I. Formulation (glue mixing)

Sample no. / Ingredients	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tannin extract (g) (50% tannin)	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66
10% NaOH (ml) (adjust pH to 7.2)	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
RPF resin (g) (30% resorcinol)	0	0	0	0	0	0	7.5	7.5	7.5	7.5	7.5	7.5	5	5	5	5	5	5	2.5	2.5	2.5	2.5	2.5	2.5
Paraformaldehyde (g)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
200 mesh teak flour (g)	3	4	5				3	4	5				3	4	5				3	4	5			
200 mesh coconut shell flour (g)				3	4	5				3	4	5				3	4	5				3	4	5
Viscosity at room temperature (cP)	850	3100	4410	550	600	575	1000	1750	4850	425	450	550	925	1900	2850	375	350	475	1100	1875	4250	425	475	675

II. Veneer condition

Kind:	Yang
Thickness:	1.6 mm
Moisture content:	10%
Construction:	Yang/yang/yang

III. Pressing conditions

Glue spread	=	180 g/m^2 (single glue line)
Assembly time	=	45 min
Cold press	=	10 kg/cm^2, 10 min
Pressing temperature	=	130^{o}C
Pressure	=	14 kg/cm^2 (200 lb/in^2)
Pressing time	=	6 min

IV. Testing (according to B.S. 1203:1963 and B.S. 1455:1963)

MR test: Immersing in warm water (67 $\pm$ 2^{o}C), 3 hours.

WBP test: Steaming in a closed vessel at 30 lbf/in^2, the test pieces being above the level of condensate or free water, 12 hours.

V. Results

Sample no.	MR test			WBP test			Remark
	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)	
1	216.04	0	6	139.48	0	5	Poor
2	256.08	0	3	174.24	0	3	
3	249.92	15	6	174.68	10	7	
4	200.20	0	2	139.04	0	3	
5	252.56	10	4	160.60	0	0	
6	218.68	10	6	176.00	10	6	
7	288.64	30	4	211.20	25	5	Pass standard
8	344.08	45	7	228.36	50	7	
9	300.52	30	4	210.32	35	5	
10	291.72	20	6	216.04	30	8	
11	231.88	10	5	202.04	15	6	
12	247.28	5	4	199.32	5	5	
13	213.40	5	7	178.20	20	7	Satisfactory
14	238.48	20	5	210.32	30	7	
15	239.36	22	4	190.08	24	7	
16	241.56	10	4	182.60	0	5	
17	266.20	20	6	212.08	30	8	
18	234.08	10	7	177.76	10	8	

Sample no.	MR test			WBP test			Remark
	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)	
19	168.52	0	1	162.80	5	2	
20	220.88	0	5	177.76	10	4	
21	227.04	20	0	148.72	0	2	
22	189.64	0	5	161.04	5	5	Poor
23	195.36	0	4	169.40	0	5	
24	174.24	20	5	144.76	5	6	

VI. Conclusion (suggestion on WBP test only)

1. Samples group 1-6 and 21-24 are poor, (amount of RPF resin is not enough).
2. Samples group 13-18, which have 4 g of teak flour and coconut shell flour, pass standard (Nos. 14 and 17).
3. Samples group 7-12 are satisfactory and all pass standard.
4. Optimum amount of teak flour and coconut shell flour is 4 g.
5. 7.5 g of RPF resin is the best one.

TEST REPORT NO. 3

Subject: RTF adhesives

Cooperation: Bernard Ph. Esselink, Mr. Shamnan Deetesna

Place: Thai Plywood Laboratory

Date: 28 June 1968

I. Formulation (glue mixing)

Sample no. / Ingredients	Changing in paraformaldehyde						Changing in pH						Changing in % tannin			Remark
	1	2	3	4	5	6	7	8	9	10	11	12	40% 13	45% 14	55% 15	
50% tannin extract (g)	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	
10% NaOH (ml)	3.0	3.0	3.0	3.0	3.0	3.0	0.0	1.0	2.0	3.9	8.5	14.5	3.0	3.0	3.0	
RPF resin (g)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	
Paraformaldehyde (g)	0.0	1.0	2.0	3.0	4.0	5.0	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	
200 mesh teak flour (g)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	
Properties of the mixture																
pH	7.2	7.0	7.0	7.1	7.0	7.0	6.0	6.5	7.0	7.5	8.0	8.4	8.0	8.1	7.9	
Viscosity (cP)	4800	3100	4400	3700	3300	4300	5500	3600	5800	3200	5200	5000	2200	2100	19400	

II. Veneer conditions

Kind:	Yang
Thickness:	1.6 mm
Moisture content:	10%
Construction:	Yang/yang/yang

III. Pressing condition

Glue spread	=	360 g/m^2 (double glue line)
Assembly time	=	45 min
Cold press	=	10 kg/cm^2, 10 min
Pressing temperature	=	130°C
Pressure	=	14 kg/cm^2 (200 lb/in^2)
Pressing time	=	6 min

IV. Testing

WBP test: According to B.S. 1203:1963 and B.S. 1455:1963.

V. Results

Sample no.	WBP test			Remark
	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)	
1	Delaminate	-	-	
2	Delaminate	-	-	
3	210.76	15	5	
4	220.88	50	7	
5	252.56	40	6	
6	242.44	55	8	
7	228.36	35	6	
8	220.88	60	9	
9	240.24	25	7	
10	229.24	75	9	
11	194.48	60	8	
12	125.84	10	5	
13	207.68	15	6	
14	223.52	55	8	
15	220.44	50	9	

TEST REPORT NO. 4

Subject: RTF adhesives

Cooperation: Bernard Ph. Esselink, Mr. Shamman Deetesna

Place: Thai Plywood Laboratory

Date: 12 July 1968

I. Formulation (glue mixing)

Changing in % of resorcinol.

Sample no. / Ingredients	0% resorcinol				20% resorcinol				30% resorcinol				40% resorcinol				50% resorcinol				Old resin*				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
50% tannin extract (g)	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66	66
10% NaOH (ml)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
RPF resin	2.5	5	7.5	10	2.5	5	7.5	10	2.5	5	7.5	10	2.5	5	7.5	10	2.5	5	7.5	10	7.5	7.5	7.5	7.5	7.5
Paraformaldehyde (g)	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
200 mesh teak flour (g)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Properties of the mixture at 32°C																									
pH	7.3	7.3	7.3	7.3	7.3	7.3	7.1	7.1	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.1	7.0	7.0	6.9	7.0	7.0	7.0
Viscosity (cP)	2100	1850	2300	5900	15500	17750	1650	1300	5200	4050	4700	1550	2900	13000	15000	11000	5500	4200	4100	12000	17750	6200	3300	7500	3800

* No. 21: RPF resin, 20% resorcinol, prepared 14/5/68; No. 22: RPF resin, 20% resorcinol, prepared 4/4/68; No. 23: RPF resin, 30% resorcinol, prepared 12/4/68; No. 24: RPF resin, 40% resorcinol, prepared 4/4/68; No. 25: RPF resin, 50% resorcinol, prepared 16/4/68.

II. Veneer conditions

Kind:	Yang (non sesinous yang veneer)
Thickness:	1.6 mm
Moisture content:	10.49%
Construction:	Yang/yang/yang

III. Pressing conditions

Glue spread	=	180 g/m^2
Assembly time	=	45 min
Temperature	=	130°C
Pressure	=	14 kg/cm^2 (200 lb/in^2)
Pressing time	=	6 min

IV. Testing

WBP: According to B.S. 1203:1963 and B.S. 1455:1963.

V. Result

Sample no.	WBP test			Remark
	Failing load (lbf/in^2)	Wood failure (%)	Knife test (point)	
1	139.04	10	4	
2	187.00	15	8	
3	230.12	20	7	
4	259.16	45	7	
5	261.36	35	6	
6	241.56	20	9	
7	221.76	35	8	
8	244.20	60	6	
9	205.92	10	6	
10	211.20	25	9	
11	219.56	50	8	
12	202.84	45	8	
13	178.64	30	7	
14	216.04	60	9	
15	269.28	40	7	
16	219.12	60	7	
17	159.72	20	9	
18	207.24	60	7	
19	215.16	40	7	
20	231.44	50	7	
21	209.00	60	9	
22	224.84	55	10	
23	220.88	70	10	
24	231.88	50	8	
25	199.76	45	9	