THE EFFECT OF CHEMICAL SOLUTIONS ON SOME WOODS.

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For many purposes such as vats, pipe lines, impellers, scrubbers, hoppers, trucks and battery separators, wood is required to resist chemical action, and it has long been known that all timbers are not equal in this respect. Thus for many purposes, especially vats, Kauri is preferred, whilst for battery separators Port Orford Cedar is largely used.

In order to gain some knowledge of the resistance of certain Australian timbers compared with that of Port Orford Cedar (*Cupressus Lawsoniana*), twenty-five local woods, all being commercially available, were selected, and one board of each was cut into twenty-four thin slats measuring approximately $2'' \times 0 \cdot 15'' \times 10''$ long. The timbers used were: Celery Top Pine (*Phyllocladus rhomboidalis*), Huon Pine (*Dacrydium Franklinii*), Port Macquarie Pine (*Callitris Macleayana*), Hoop Pine (*Araucaria Cunninghamii*), Queensland Kauri (*Agathis* sp.), Radiata Pine (*Pinus radiata*, *P. insignis*), Tallowwood (*Eucalyptus microcorys*), Blue Gum (*Eucalyptus saligna*), Spotted Gum (*Eucalyptus maculata*), Blackbutt (*E. pilularis*), Turpentine (*Syncarpia laurifolia*), Brush Box (*Tristania conferta*), Rosewood (*Dysoxylum Fraseranum*), Teak (*Flindersia australis*), Coachwood (*Ceratopetalum apetalum*), Red Carabeen (*Geissois Benthami*), Crab Apple (*Schizomeria ovata*), Corkwood (*Ackama Muelleri*), Bolly Gum (*Litsea reticulata*), Silver Sycamore (*Cryptocarya glaucescens*), Beech (*Gmelina Leichhardtii*), Yellow Carabeen (*Sloanea Woolsii*), Sassafras (*Doryphora sassafras*), N.S.W. Maple (*Villaresia* (*Chariessa*) *Moorei*), and Port Macquarie Beech (*Euroschinus falcatus*).

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The timbers were weighed, measured to 0·001″, and immersed in water and in the following aqueous solutions, all at atmospheric temperatures : 10, 25 and 50% sulphuric acid ; 5, 10, 25, and 50% nitric acid (sp. gr. 1·42) ; 10, 25, 50 and 100% hydrochloric acid (sp. gr. 1·16) ; 5, 10, 20, and 40% caustic soda ; 50 and 100% ammonia (sp. gr. 0·880) ; 50 and 100% glacial acetic acid ; saturated solutions of sodium carbonate, ammonium sulphate, sodium chloride, and 35% sodium sulphite. The experiment was commenced in February, 1933, and the slats were examined at intervals. The majority were left until August, 1935, when they were again weighed and measured.

The percentage swellings given in Table I were calculated on the original air-dry size with a moisture content of approximately 13%, and the results obtained with the different solutions can be compared with what may be regarded as the normal figures, namely those obtained by soaking in water. No measurements were made of the timbers immersed in 50% nitric acid, and in a number of other instances measurements were not practicable. Many of the figures obtained appear to be irregular ; thus with varying concentrations of, for example, sulphuric acid, swelling may vary directly or indirectly with acid strength, or the intermediate strength may produce a maximum or minimum swelling. Working with certain American timbers Hauser and Bahlman[1] also found irregular swelling at different concentrations with sulphuric acid and caustic soda. Caustic soda (40%) caused an increase of over 29% in the width of several woods, whereas with other timbers the swelling was under 2%. Consistently low swelling figures were obtained with ammonium sulphate.[2]

In comparing the figures for the different timbers it should be noted that they were not all cut in the same vertical plane ; the normal shrinkage and swelling of wood is approximately twice as much tangentially or " backed-

[1] S. J. Hauser and C. Bahlman : " Effect of Chemical Solutions on Various Woods Used in Tanks ", *Chem. and Metall. Eng.*, 1923, *28*, 159-162.

[2] A. J. Stamm (" Effect of Inorganic Salts upon the Swelling and Shrinkage of Wood ", *Jour. Am. Chem. Soc.*, 1934, *56*, 1195) has shown that the degree of swelling varies with different salts, depending largely upon their solubility, but in no case is any reduction of swelling between water and inorganic salt solutions indicated.

TABLE I.

Percentage Lateral Swelling Based on Air-dry Size, Obtained by Immersing Slats in Different Aqueous Solutions.

Timber.	H_2SO_4.			HNO_3.			HCl.				NaOH.				NH_4OH.		Acetic Acid.		Na_2CO_3.	NaCl.	Na_2SO_3.	$(NH_4)_2SO_4$	H_2O	Cut.*
	10%	25%	50%	5%	10%	25%	10%	25%	50%	100%	5%	10%	20%	40%	50%	100%	50%	100%	Sat. Sol.	Sat. Sol.	35%	Sat. Sol.		
Celery Top Pine ..	1·0	2·4	0·5	3·3	1·8	1·4	3·4	3·5	3·5			0·9	0·9	1·2	1·3	1·0	2·5	2·8	0·8	0·6	2·0	0·4	1·2	Q
Huon Pine ..	1·7	1·6	0·3	1·9	2·0	1·4	1·9	1·7	1·5	1·5	2·4	2·1	0·9		2·5	2·2	2·8	2·3	2·2	1·7	1·9	0·2	2·1	Q
Port Macquarie Pine	1·8	1·6	2·3	4·6	2·2	2·1	3·1	3·4	3·8	2·0	3·4	4·5	3·5		5·4	1·9	3·2	4·4	6·2	2·6	2·2	1·0	2·2	O
Hoop Pine ..	3·2	2·7	3·9	3·6	3·6	3·3	3·8	3·5	3·7	5·3	5·7	5·1	4·7	2·6	5·8	5·0	4·8	4·5	3·1	2·7	3·5	2·1	4·4	B
Queensland Kauri ..	3·6	3·5	1·6	4·1	2·8	2·0	2·2	3·8	2·6		3·4	2·1	6·2	1·6	3·9	2·5	4·3	6·5	2·0	2·9	2·5	1·6	3·6	O
Radiata Pine	3·5	4·0	3·8	5·1	2·8	4·3	2·8	3·4	3·9		4·6	3·2	4·9	5·8	5·2	5·8	5·2	6·5	4·0	3·0	3·4	2·3	4·8	O
Port Orford Cedar ..	2·7	2·2	2·1	2·9	3·1	2·2	1·6	2·4	2·7	2·9	2·6	2·5	1·9	1·7	3·3	3·1	3·4	3·0	2·8	2·3	2·3	2·0	2·7	Q
Tallowwood	4·7	5·1	7·0	4·9	4·7	7·2	4·1	4·3	7·3		7·2	14·9		12·6	7·7	9·8	8·7	8·9	4·8	5·0	6·9	3·0	6·4	O
Blue Gum ..	8·2	5·6	5·4	11·5	9·4	12·8	9·3	9·7	8·9		12·9	10·4	12·5	18·1	7·5	4·0	4·1	6·4	10·7	4·0	5·3	2·0	7·0	Q
Spotted Gum	3·2	2·2	2·1	2·7	2·8	6·3	6·4				10·9	3·9	6·2	5·4	3·2	4·2	3·2	5·2	2·9	2·5	3·2	1·2	2·9	Q
Blackbutt ..	6·1	5·1	7·2	7·4	7·5	6·3	8·8	7·1	7·7		9·6	11·8	24·2	29·5	10·3	10·9	8·6	10·7	7·2	5·0	6·9	3·6	6·0	B
Turpentine ..	6·8	3·3	3·7	6·5	7·5	7·7	6·3	6·5	6·7		6·7	6·5	3·4	7·0	7·2	7·4	7·0	6·1	6·7	4·7	6·7	3·3	7·1	Q
Brush Box ..	2·9	1·5	3·6	3·4	5·2	6·8	10·0	6·5	6·9		8·7	4·8	13·2	29·3	7·9	8·9	7·3	9·1	6·6	5·1	7·4	1·8	6·5	O
Rosewood ..	1·8	2·0	1·5	2·9	2·0	5·0	3·6	3·2	4·1		6·4	5·3	9·0		4·5	4·6	5·6	4·0	4·9	2·8	3·7	1·1	4·0	O
Teak ..	4·1	2·3	2·4	4·2	3·4	4·7	2·6	2·8	3·8		5·4	3·9	6·8	10·4	4·6	4·4	3·9	5·8	3·6	3·5	4·0	1·6	4·7	B
Coachwood ..	2·7	2·3	2·2	3·3	2·8	2·4	4·0				2·5	3·9			3·9	2·7	5·8	5·7	4·2	3·3	3·2	1·7	3·2	Q
Red Carabeen	2·9	2·2	3·7	3·0	3·3	3·1	3·2				4·5	7·0	4·3		4·4	2·6	3·2	5·8	4·1	2·3	2·7	1·6	5·6	Q
Crab Apple..	4·1	2·3	1·0	2·7	2·6	2·5	3·0				1·7	0·6		3·2	3·7	2·4	3·3	3·0	2·8	2·3	2·7	1·3	3·1	Q
Corkwood ..	9·8	3·7	3·3	5·3	4·3	5·7	4·0	4·5	4·8		13·7	12·9			3·6	3·0	3·6	3·4	4·2	7·6	1·9	0·6	8·0	O
Bolly Gum	5·2	1·5	3·2	4·0	2·9	5·9	3·7				8·1	6·3	6·7	15·8	2·7	6·2	3·7	4·2	3·6	3·4	5·7	1·0	4·0	O
Sycamore ..	5·7	5·3	4·8	7·0	7·3	6·7	6·8	6·2	5·6	9·0	9·5	9·8	11·8	10·0	8·8	8·5	8·1	8·9	8·4	7·0	6·4	3·2	7·4	B
Beech ..	1·3	3·7	2·9	7·0	2·8	3·5	3·1	2·2	2·8		2·1	8·8	6·6	7·7	4·8	5·0	6·2	6·3	5·3	4·3	7·5	1·7	3·2	Q
Yellow Carabeen ..	5·4	5·9	9·3	5·6	6·2	5·1	5·9	7·0	7·4		10·1	9·0	5·5	9·1	8·6	7·7	8·1	7·1	6·1	4·6	6·5	2·9	6·9	B
Sassafras ..	4·9	3·9	3·7	4·8	4·6	4·2	3·8	3·9	4·3		6·6	5·8	10·3	5·9	5·8	5·8	5·0	5·2	5·5	3·9	6·3	2·4	5·5	O
N.S.W. Maple	7·8	4·5	4·3	8·5	7·6	7·9	3·3				10·4	8·4	14·1	5·6	2·1	8·8	7·8	9·3	3·6	3·8	6·7	2·4	2·4	Q
Port Macquarie Beech ..	4·0	3·3	3·7	4·4	4·2	4·3	4·2						6·9	7·2	6·9	6·2	5·4	6·3	5·0	4·7	3·3	2·4	3·9	B
Mean ..	4·2	3·2	3·4	4·8	4·2	4·8	4·4	4·5	4·8	4·1	6·6	6·2	7·5	9·5	5·2	5·2	5·2	5·8	4·7	3·6	4·4	1·8	4·6	

* Q = Quarter-cut. O = Oblique. B = Tangentially cut or "backed-off."

off " as it is when quarter-cut. The direction of cut is shown in the table.

Apart from caustic soda, the highest mean figure was obtained with glacial acetic acid.

In Table II are given the various degrees of firmness of the woods after different periods of immersion. This determination was purely empirical, and was based on the resistance of the slats to bending in the fingers, but it can be regarded as affording an indication of the relative rigidity of the woods.

It is obvious that in general the " pine " timbers showed the greatest resistance to chemical action, and compare very favourably with Port Orford Cedar, whilst the majority of the " non-pine " woods were definitely inferior, notably Port Macquarie Beech, which failed lamentably.[3] The rigidity or otherwise of the slats as shown in the table does not tell the whole story ; many woods, including the Eucalypt hardwoods, and especially Tallowwood, which might have been expected to possess some resistance, became cracked and warped, particularly in caustic soda. Apart from the " pines ", Teak, Sassafras and Sycamore seemed to be generally most satisfactory. The effect of ammonia, acetic acid and the various inorganic salts was so little that it was not possible to discriminate between the different woods ; the results have therefore been omitted from the table. Any of the woods could be used satisfactorily in contact with these solutions, at any rate at atmospheric temperatures.

The effect of the more corrosive solutions can be summarised as follows, based on an examination of the slats after washing and drying :

Sulphuric Acid, 10%. Very little alteration noticeable ; all woods stiffened up and appeared to be strong.

Sulphuric Acid, 25%. Little external effect apparent, except that all woods darkened ; some of the hardwoods inclined to check.

Sulphuric Acid, 50%. All woods discoloured, and had appearance of being partially carbonised ; the " pines ", together with Teak, Sassafras, Coachwood, Beech, and Corkwood affected least in shape, others more or less warped. Tallowwood also badly split

[3] C. S. Robinson (" Wood as a Chemical Engineering Material ", *Jour. Ind. and Eng. Chem.*, 1922, *14*, 607) states that in general coniferous woods are most resistant to hydrochloric and other acids.

TABLE II.

Comparative Stiffness of Different Woods after Immersion for Varying Periods.

1 = Firm. 2 = Moderately firm. 3 = Brittle. 4 = Very brittle.

Timber.	H_2SO_4.			HNO_3.							HCl.							NaOH.						
	10%	25%	50%	5%	10%	10%	25%	25%	50%	50%	10%	25%	25%	50%	50%	100%	100%	5%	10%	10%	20%	20%	40%	40%
Celery Top Pine ..	1	1	1	1	1	1	1	1	1	3	1	1	1	1	1	2	3	1	2	3	1	3	2	3
Huon Pine ..	1	1	1	1	1	1	1	1	1	4	1	1	1	1	2	1	3	2	2	2	3	4	2	3
Port Macquarie Pine	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	2	2	2	3	3	4
Hoop Pine ..	1	1	1	1	1	1	1	1	1	3	1	1	1	2	2	1	3	1	2	2	3	4	2	4
Queensland Kauri	1	1	1	1	1	1	1	1	1	3	1	2	3	1	2	2		1	2	2	2	3	3	
Radiata Pine ..	1	1	2	1	1	1	1	1	1	3	1	1	1	1	2	2	3	2	2	2	2	3	2	4
Port Orford Cedar	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1		1	2	2	1	3	2	3
Tallowwood ..	1	1	3	1	1	1	2	3	4		1	1	2	1	2	3		1	1	1	4	4	4	
Blue Gum ..	1	1	2	1	1	2	4	3	4		1	1	2	1	1	3		1	2	2	2	2	4	
Spotted Gum ..	1	2	3	1	1	2	3	3	4		1	3	3	4	4	3		1	2	2	1	2	3	
Blackbutt	1	1	2	1	1	2	2	2	4		1	1	2	2	2	3		1	1	2	1	2	4	
Turpentine ..	1	1	2	1	1	1	2	4	4		1	1	2	1	2	3		1	2	2	2	2	3	
Brush Box ..	1	1	3	1	1	1	3	3	2		1	1	2	3	3	3		1	1	2	1	2	4	
Rosewood	1	1	3	1	1	2	3	3	3		1	1	2	2	3	3		2	3	3	3	4	3	
Teak	1	1	1	1	1	1	1	2	2		1	1	2	1	3	3		1	1	1	1	2	4	
Coachwood ..	1	3	3	1	2	2	4	3	3		1	3	3	4	4	4		1	2	4	3	3	3	
Red Carabeen ..	1	2	3	1	1	2	3	4	3		1	1	3	4	4	4		1	2	2	3	3	4	
Crab Apple ..	3	3	4	2	2	3	3	4	4		1	3	3	4	4	4		1	2	3	3	3	3	
Corkwood	1	2	3	2	2	2	3	3	4		1	2	2	3	3	3		1	3	3	3	3	3	
Bolly Gum ..	1	3	3	2	2	2	4	4	4		1	3	3	4	4	4		2	3	3	4	4	3	
Sycamore	1	2	3	1	1	2	1	2	1	4	1	1	2	1	2	1	3	2	2	3	3	3	2	4
Beech	2	1	3	1	1	2	4	3	2		1	2	3	2	3	3		2	2	2	4	4	3	
Yellow Carabeen ..	1	2	3	2	2	3	4	4	4		1	2	3	3	3	3		2	3	3	4	4	2	4
Sassafras	2	1	3	1	1	2	1	3	3		1	1	2	2	2	3		1	2	3	3	3	3	
N.S.W. Maple ..	1	3	3	1	1	3	3	3	3		1	3	3	4	4	3		1	2	2	4	4	3	
Port Macquarie Beech	4	4	4	3	3	4	4	4	4		4	4	4	4	4	4		4	4	4	4	4	4	
Period of immersion in months ..	30	30	30	30	14	30	7	30	3	14	30	14	30	14	30	14	30	30	14	30	14	30	7	30

and to a smaller extent Rosewood, Yellow Carabeen, Blue Gum, Blackbutt and New South Wales Maple.

Nitric Acid, 5%. All timbers bleached to a yellow colour; Port Macquarie Beech and Yellow Carabeen seriously warped, others scarcely affected and all appeared rigid, although some were inclined to be brittle.

Nitric Acid, 10%. Blue Gum and Spotted Gum roughened and checked; Bolly Gum badly corrugated; Port Macquarie Beech, Yellow Carabeen and New South Wales Maple considerably warped; remainder not altered in shape.

Nitric Acid, 25%. Practically all timbers cracked and distorted, with excessive shrinkage evident in Port Macquarie Beech, Blackbutt and Brush Box. All woods dried out rigid and stiff, but were brittle.

Nitric Acid, 50%. After three months the majority of the woods were so weak, when wet, that they were unable to support their own weight when held at one end horizontally, and they were removed. The coniferous woods and Sycamore were still firm, whilst timbers such as Tallowwood, Blue Gum and Crab Apple were so soft and spongy that they could not be handled without falling to pieces. All woods were bleached to a pale yellow. On drying all woods were more or less distorted and cracked.

Hydrochloric Acid, 10%. Little apparent effect except in Blackbutt, which was warped and cracked. All woods hard and rigid.

Hydrochloric Acid, 25%. Little alteration except Blue Gum, which showed slight corrugations.

Hydrochloric Acid, 50%. Most woods inclined to be brittle. Bolly Gum showed excessive shrinkage; Blue Gum and Blackbutt checked and warped; all timbers darkened and the majority became brittle, especially Port Macquarie Beech.

Hydrochloric Acid, 100%. All woods darkened considerably and appeared carbonised. Tallowwood and Blackbutt badly checked and warped, and Blue Gum and Spotted Gum to a somewhat less degree. The conifers, together with Sassafras and Corkwood, seemed to be least affected in shape.

Caustic Soda, 5%. The conifers and Teak were in best condition, whilst Rosewood, Port Macquarie Beech and Crab Apple were worst, being badly warped. Bolly

Gum and Brush Box showed excessive uneven shrinkage, amounting to over 32% and 20% respectively. All the timbers appeared tough and strong.

Caustic Soda, 10%. The conifers, with the exception of Celery Top Pine, which was warped, and Port Macquarie Pine, which showed considerable uneven shrinkage, appeared in fair condition. Port Macquarie Beech and Bolly Gum had shrunk badly, the latter by 46%, on the air-dry size. Rosewood, Corkwood and Coachwood were much warped and the remainder to a greater or less extent.

Caustic Soda, 20%. Practically all woods showed excessive shrinkage, especially Port Orford Cedar, Port Macquarie Beech, Bolly Gum and Huon Pine; all distorted and more or less warped, especially Tallowwood.

Caustic Soda, 40%. Excessive shrinkage evident in the majority of the woods, particularly in those mentioned previously. Queensland Kauri and Sassafras appeared to be least affected, but all were more or less distorted. Tallowwood was the worst of all, the surface being extremely broken and ragged, whilst Rosewood, Teak and Corkwood were not quite so roughened.

Ammonia, 50%. All woods darkened, but not otherwise seriously affected. Bolly Gum and Port Macquarie Beech showed excessive shrinkage and these, together with Rosewood, Crab Apple, Beech, Spotted Gum and Yellow Carabeen, were also warped.

Ammonia, 100%. As for 50% except that Bolly Gum was also corrugated. All woods appeared to be rigid and strong.

Acetic Acid, 50%. Woods practically unaffected except for slight corrugating of Bolly Gum and the " grain " being raised in Blue Gum and Spotted Gum.

Acetic Acid, 100%. Woods apparently unaffected and appeared to be even better than in 50%.

No special comment appears to be necessary for the other solutions, except that sodium sulphite had a moderate bleaching action, whilst ammonium sulphate ebonised some of the woods, especially Turpentine, Blackbutt, Tallowwood and Yellow Carabeen. Sodium carbonate in a few instances caused the wood surface to lift in small areas, particularly where the surface was cut with the stamps used for marking the slats. It has been noted on other occasions that where wood has been exposed to

washing soda under alternately wet and dry conditions it has become frayed and woolly.

Summary.

A number of woods, Australian with one exception, were immersed in various acids, alkalis and inorganic salts. In general the coniferous woods proved to be the most resistant to chemical action, whilst many of the hardwood and brush timbers were very inferior.