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No. 348

PROTECTION OF WOODEN AIRPLANE PARTS AGAINST MOISTURE BY MEANS OF VARNISH

By E. B. Wolff and L. J. G. Van Ewijk

From "Verslagen en Verhandelingen van den Rijks-Studiedienst voor de Luchtvaart," Part III, 1925, Report M 14 A

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PROTECTION OF WOODEN AIRPLANE PARTS AGAINST MOISTURE BY MEANS OF VARNISH.*

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The objects of the experiments herein described were (a) to test the protection afforded by Valspar oil varnish against the absorption of moisture by wooden airplane parts and the consequent changes in their elastic properties and (b) to compare some of the best Dutch varnishes with Valspar. The varnishes were used in accordance with the directions given by the manufacturers.

Alongside the many advantages of wood for airplane construction, there are also some disadvantages, the most important ones being:

1. Its lack of homogeneity and the consequent great difference in its resistivity to tension, compression, shearing, shock, etc.

2. The great differences in strength in the different directions with reference to the grain. For light conifers, the strength with the grain is 20-40 times as great as across the grain. With these woods, therefore, the forces should be

* From "Verslagen en Verhandelingen van den Rijks-Studiedienst voor de Luchtvaart," Part III, 1925, pp. 75-92, Report M 14 A.

applied, as far as possible, in the direction of the grain.

3. Great sensitiveness to humidity changes, which affect not only the weight, but also the elastic properties and, accordingly, the characteristics of the whole airplane.*

Moreover, there is also the danger of decay, with a corresponding general loss in strength. The loads mentioned give rise to difficulties for the constructor in determining the stresses allowable. These loads are also important in practice and in the daily supervision of airplanes in flight. It is generally sought to diminish as much as possible the variations in the moisture content of the wood by the application of suitable protecting coats. Especially in the cases where very unfavorable circumstances are to be anticipated, or when the places where help can be obtained are far apart (as in long flights over uninhabited regions), journeys through very dry or very hot countries, remaining without suitable shelter in a very moist climate, it is necessary to protect the wood as much as possible.

* This is demonstrated by B. C. Boulton and R. L. Hankinson in their article on "Properties of Wood at 10% Moisture" (Aerial Age, Sept. 13, 1920, pp. 11-12) for red or Norway pine (Pinus resinosa), an American wood very similar to European pitch-pine, for which they obtained the following values:

Moisture content	Static Bending			Maximum crushing strength parallel to grain
	Fiber stress at elastic limit	Modulus of rupture	Modulus of elasticity	
%	lb./sq.in.	lb./sq.in.	lb./sq.in.	lb./sq.in.
15	7900	10900	1700000	6100
10	10600	13600	1830000	8110

From the records of long flights, it is known that, as the result of such conditions, the airworthiness is often greatly impaired and that an airplane is sometimes rendered useless. Even under ordinary conditions, such protection is important. The mechanical engineer, charged with the supervision of the airplanes in use, must be mindful of the fact that various parts can be so impaired by the effects of moisture, as to endanger the airworthiness of the whole airplane.

Oil varnishes are extensively employed for the protection of the wood and for this reason are exclusively considered in this article.

The terms "lacquer" and "varnish" are often confused, but it is desired to distinguish between them here. By "varnish" is meant a solution of gums or resins in oil or alcohol. We can thus speak of "oil varnish" or "alcohol varnish." Among modern resins, there are several which are called lacquers and which are obtained from certain tropical trees. These are especially hard. The term "lacquer" is therefore applied to hard varnishes, made from such resins, by solution in either oil or alcohol. By "shellac" is meant the pure resin, which is dried in the form of "shells" (See also A. W. Judge, "Aircraft and Automobile Materials," Pitman and Sons, London, 1921, and C. P. Van Hoek, "Handleiding voor de kennis der schildermaterialen en gereedschappen," Van Mantgem en de Does, Amsterdam, 1913.) The term "Oil varnish" will be used in this report.

In judging the quality of these varnishes, the following points are taken into consideration:

1. Impermeability to liquids.- It is important to have the greatest possible impermeability to liquids in any form (sea-water, gasoline, lubricating oil, etc.), so that the liquid content of the wood, and hence its properties, may vary as little as possible.

2. Resistance to corruption by the substances with which they come in contact. Moreover, they should not be much affected by atmospheric conditions.

3. Method of application.- They must be easy to apply to both exterior and interior parts (e.g., the inside of the wooden wings) and also to the more complicated wooden parts.

4. Resistance to distortion.- They must resist the distortions to which the parts are subjected, i.e., they must not crack or scale from vibrations or bending.

5. Resistance to injury.- During flight, damage may be done by rain, hail, etc.; and in landing, by sand or water. This resistance is of special importance for propellers, while the danger of injury of interior parts is not great. For some of these, the resistance to oil, gasoline, etc., is more important; for example, wooden parts used to secure the engine in the airplane, and the ribs of fabric-covered wings, where

scattered oil may penetrate the fabric and thus come in contact with the varnished wood.

The present report considers only the impermeability to liquids, no systematic data having yet been collected regarding the other points. In this connection, the following points may be noted. Moisture may be transmitted:

1. Through small holes in the coat of varnish. In order to avoid this, enough coats should be applied to insure the covering of all such holes.

2. By being absorbed by the varnish itself (either from the wood or from the outside) and then given off from the opposite side of the layer of varnish.

A further distinction can be made between the transmission of moisture in the gaseous and in the liquid form.

Method.- It may be remarked that in the subsequently described experiments, a beginning was made before the Report No. 85 of the American Advisory Committee for Aeronautics, "Moisture-Resistant Finishes for Airplane Woods," by M. E. Dunlap and the reports on "Varnish" by W. H. Lang (included in the "Report on the Materials Used in Aircraft and Aircraft Engines," by C. F. Jenkin, p.117, published by the Aeronautical Research Committee), were known, so that they could not be made in conjunction with the work of these investigators.

The tests were made on blocks of pitch-pine 15 × 15 × 6 cm

(5.91 × 5.91 × 2.36 in.). This kind of wood is well adapted for airplane construction. The test-blocks were made so big that the transmission of moisture through the varnish was only slightly affected by the moisture previously absorbed. For this reason, no thin pieces were used. Their weight varied from 600 to 750 grams (21.16-26.46 oz.). The total surface area of each block was about 800 cm^2 (124 sq.in.) and the total volume 1350 cm^3 (82.38 cu.in.). The corners were rounded, in order to lessen the danger of injury from dropping.

Since it appeared possible, from a preliminary series of tests, to render the wood almost completely moisture-proof by first painting and then adding several coats of varnish, it was decided to make more extensive tests in this connection.

Doubtless, it would have been advantageous for the tests, if it had been possible to make a perfectly tight coat in this manner. As customary in other tests, it would then have been possible to make the measurements on an accurately defined portion (unit area) of the test-block, while the standardization of the test-blocks and the determination of the moisture absorption for the different directions of the grain would have been thereby simplified. It would also be useful in practice to know that paint can form a perfectly moisture-proof coat.

From the further experimentation, it is obvious, however, that such imperviousness is impossible. Even three coats of white Ripolin paint and one coat of varnish proved only slightly more moisture-resistant than one coat of varnish alone. This shows that the absorption of moisture is not due to the presence of holes in the varnish, but to the process described in paragraph 2.

The protection afforded by varnish against increase or decrease in moisture content was tested as follows: Test-blocks were placed in closed vessels partly filled with water, some of the blocks being above the surface of the water and some below. The blocks above the water were therefore in air saturated with water vapor. The tests took place at 15°C (59°F) and at 45°C (113°F). Other blocks were placed in dry vessels which were heated to 35°C (95°F). The dry vessels were ventilated in the usual way and no other measures were adopted for influencing the moisture content of the warm air in them. The following tests were made:

a. In moisture-saturated air at 15°C (59°F);

b. In water at 15°C (59°F);

c. In saturated air at 45°C (113°F);

d. In water at 45°C (113°F);

e. In dry air at 35°C (95°F).

During these tests, which lasted from 500 to 1500 hours, the blocks were regularly weighed to within 0.5 gram (0.0175 oz.). The heating was interrupted during the night so that in tests b, d and e, the ratio of the lengths of the periods of high and low temperature was about 2 : 3. The object of these tests was to determine the effect of a tropical climate.

The total time covered by the experiments was 3-4 years, the order of procedure being as follows:

1. Preparation;
2. One week's drying;
3. Moisture test of 500 to 1500 hours (a, b, c or d);
4. Rest period in the laboratory;
5. Dry test of 500 to 1500 hours (e);
6. Rest period in the laboratory.

In order to determine to what extent the results were affected by the order of procedure, some of the blocks were subjected to the dry test (5), without the preceding wet test, and likewise some of the blocks, which had undergone all the tests, were again subjected to the wet test (3). Fig. 6 shows the weight changes of some of the blocks for the whole series of tests.

The blocks were prepared all together by the manufacturers in accordance with the specifications. Most of the blocks were accordingly given a coat of filler before varnishing. In a few instances, in order to obtain a more water-proof surface, the blocks were polished, after the separate coats, with powdered pumice, steel wool, etc. Three coats of varnish were applied in most cases. Where no statement is made to the contrary, it is to be understood that the protecting layer consists of a primer, filler and three coats of varnish.

Nine different kinds of varnish were tested:

1. Valentine's Valspar oil varnish, which was tested
   a) with Valspar primer and filler;
   b) " " " " a Dutch filler;
   c) " raw linseed oil, for the first coat.

2. Eight Dutch oil varnishes, which are referred to in the tables and diagrams as H_1, H_2, etc.

A rubber lacquer, which could be applied by brush, was similarly tested. A few tests were also made with a block on which the rubber coating was afterwards vulcanized. No tests were made with varnishes containing powdered aluminum, barium sulfate, powdered graphite or other substances of like nature. The varnishes tested were all "white varnishes," thus rendering it possible to examine the wood after varnishing, which is often an advantage.

The total number of test-blocks used was 195. Wet tests (1, 2, 3) were made with 149 blocks, including about 40 for each wet test (a, b, c, d); dry tests (1-6), with 46 blocks (e). For comparison, a few unvarnished blocks were subjected to wet and dry tests.

Results of the Tests

A. Wet tests.- Tables I-IV give the increases in weight for a number of the test blocks, these increases being represented graphically in Figs. 1-4. The time is given in hours on the horizontal axis, while the weight increases (in milligrams per square centimeter of the transmitting surface) are shown on the vertical axis. The hatched areas in these figures indicate the regions which include the results obtained for the various kinds of varnish. For the blocks forming the upper and lower limits of these areas, the percentages are recorded at the ends of the corresponding lines.

For comparison, the result of a longer test with Valspar is given in each graph, as likewise the weight changes in the rubber-coated and untreated blocks. Since the original weights of the test-blocks differed considerably, it was not possible to add a second scale on which to give the percentage changes. From these graphs the following conclusions can be drawn:

1. That the moisture absorption was small in all four cases, although distinct differences were found. The weight increase per unit of time was small from the beginning of each test. No limit was reached in the time occupied by the tests, but it is not improbable, however, that a constant weight would be reached after a longer time. Contrary to the results published by Lang (already referred to), no rectilinear relation was found between the weight of moisture absorbed and the time taken. With oil varnishes, the limiting values for 500 hours were:

For test a, from 0.00 to 6.88 mg/cm^2
(0.00 to .0016 oz./sq.in.)

For test b, from 3.13 to 11.25 mg/cm² (.0007 to .0026 oz./sq.in.),
" " c, " 5.63 to 16.88 mg/cm² (.0013 to .0038 oz./sq.in.),
" " d, " 11.88 to 25.00 mg/cm² (.0027 to .0057 oz./sq.in.);

2. That the varnishes tested differed but little from one another. The results obtained in these tests cannot be used to classify these kinds according to quality, because the differences are too small and, moreover, because the method of testing and the individual properties of the prepared blocks may have made a difference;

3. That, in the use of raw linseed oil, for the first coat, less protection was obtained than by the use of a primer and filler;

4. That the rubber lacquer tested gave less protection than the oil varnishes. This lacquer can be pronounced unsatisfactory for airplanes. The results obtained with this lacquer are given in the tables.

B. Dry tests.- Table V gives the weight decreases of a number of test-blocks during the dry tests. The hatched area in Fig. 5 shows the limits within which the results fall. Just as in the wet tests, there is here also a bending of the lines obtained by plotting the weight changes against the times. Here also no constant value was reached, although there is a sharper bend in the lines. For 500 hours, the limiting values were 32 and 45 mg/cm² (.0073 to .0102 oz./sq.in.).

In order to render it possible to compare the weight changes in the various tests, Fig. 7 gives the mean curves for the results plotted in Figs. 1-5, while Fig. 8 represents, by straight lines, the corresponding changes for a number of test-blocks. From these tests it follows:

1. That the resistance to drying is less than to the absorption of moisture;

2. That, just as in the wet tests, there were only slight differences between the oil varnishes tested.

General remarks.- It is obvious, from the diagrams, that the curves for the weight changes plotted against the time are all of the same character. Although the periodical temperature and moisture changes generally differ in practice from those in the experiments, a knowledge of these lines is important: first, for comparing the properties of different protecting coats with one another; second, for approximately estimating the changes which may be effected in wood by the use of a given protecting substance. When, however, a constructor desires to take advantage of such data, he must see that the protecting coat is very carefully applied, even to the interior parts, so that the estimated protection is really obtained.

Conclusions.- From the above tests we can draw the following conclusions:

1. The proper application of Valentine's Valspar oil varnish to pitch pine affords a very good protection against moisture and atmospheric influences. By "proper application" we mean that the wood must first be treated with a primer and filler and then, after careful drying, receive three successive coats of oil varnish.

2. It is not advisable to substitute a preliminary treatment with raw linseed oil for the treatment with a primer and filler, as better results were obtained by the latter method, especially at the higher temperatures.

3. The eight Dutch oil varnishes (commonly called "oil lacquers," even by the manufacturers) compare favorably with Valspar, the differences being very small in all cases.

4. The Dutch fillers generally gave better results than the Valspar filler, even when Valspar varnish was used, the differences, however, being rather small.

5. The rubber lacquer does not compare favorably with the oil varnishes and is unsuitable for airplanes. Only one kind was tested.

6. It is desirable to make further tests on the moisture resistance of protective coats. The following points should be tested:

a. The effect of other substances, in comparison with oil varnishes;

b. The effect of the kind of wood;

c. The effect of different primers, fillers, etc.

d. The effect of mixing powdered aluminum, graphite, barium sulfate, etc. with the varnish;

e. The resistance of protecting coats to wear and to oil, gasoline, etc.

f. The resistance of oil varnishes to the effect of strong light;

g. The standardization of tests for oil varnishes and other protecting substances for practical purposes;

h. The establishment of qualifications, to be required in specifications of such substances for use on aircraft.

Table I. Tests in saturated air at 15°C (59°F).

	Valspar with Valspar filler	Valspar with Dutch filler	Valspar with oil	H_1	H_2	H_3	H_4	H_4A	H_5	H_6	H_7	Rubber lacquer (lengthwise of grain)	Rubber lacquer (crosswise of grain)	Control test on 36-37	Ripolin paint + Valspar (lengthwise of grain)	Ripolin paint + Valspar (crosswise of grain)
Test No.	28 29	36 37	93 94	61	63	68	72	88	76	81	83	102	106	111	120	126
Original weight	551½	666½	610	620½	643	576	549	502	552	514	561½	591½	656½	789	590	689
Increase in weight (grams) after hr. 100	1.0	0.5	2.5	2.5	1.0	0	0.5	0	0	0	0	1.5	0.5	1.0	1.0	0.5
200	2.0	1.0	2.5	2.5	1.5	1	1.0	0.5	0	0	0	2.5	2.5	2.0	2.0	1.5
300	2.5	1.5	2.5	3.5	2.5	1	1.0	0.5	0	0	0	3.5	3.0	3.0	2.5	2.5
400	3.0	2.0	3.0	4.0	3.0	1	1.5	1.5	0	0	1	4.5	3.5	3.5	3.0	3.0
500	3.5	2.0	3.5	4.5	3.5	1.5	2.0	2.5	0	0	1.5	4.5	5.5	4.0	3.5	3.5
576														4.5	4.0	4.0
672														5.0	5.0	4.5
744														6.0	5.5	5.0
840														6.5	6.0	5.5
1344														9.5	8.5	8.0
1536														10.5	9.5	8.5

Table II. Tests in water at 15°C (59°F).

	Valspar with Valspar filler	Valspar with Dutch filler	Valspar with oil	H_1	H_2	H_3	H_4	H_4A	H_5
Test No.	26 27	34 35	91 92	59	66	67	71	87	75
Original weight	528½	684	613½	624½	651	586	542½	502	640½
Increase in weight (grams) after 100 hr.	2.5	1.5	6.0	0	2.5	0	1.0	0	1.5
200	4.5	3.0	9.0	0.5	4.0	1.0	2.0	0	3.5
300	6.25	4.0	10.0	1.5	5.0	1.5	2.5	0.5	5.0
400	7.5	5.0	11.0	2.0	6.0	2.0	3.5	3.0	5.5
500	9.0	6.0	11.5	3.0	7.0	2.5	4.0	4.0	7.5

Table II. Tests in water at 15°C (59°F) (Cont.)

	H_6	H_7	Rubber lacquer (lengthwise of grain)	Rubber lacquer (crosswise of grain)	Control test on 26-27	Control test on 26-27	Ripolin paint + Valspar (lengthwise of grain)	Ripolin paint + Valspar (crosswise of grain)	Rubber coating
Test No.	82	84	101	105	112	113	121	127	103A
Original weight	521	502½	601½	674½	780½	588	585	682	624
Increase in weight (grams) after hr.									
100	0	0.5	2.5	8.5	1.5	2.0	1.5	1.5	1.5
200	1.5	2.0	5.5	167.5	3.5	4.0	2.0	3.0	2.0
300	2.5	2.5	9.5	--	4.5	5.5	3.0	3.0	1.5
400	4.0	5.0	14.5	--	6.5	7.0	5.0	4.5	--
500	4.0	5.0	18.5	--	7.0	8.0	6.0	5.0	--
676					8.5	9.0	6.5	5.5	--
672					9.5	9.5	7.0	6.0	--
744					10.5	10.5	7.5	6.5	--
840					11.0	11.0	8.0	7.0	--
1344					15.0	15.0	11.0	10.0	--
1536					16.5	17.0	12.0	11.0	--

Table III. Tests in saturated air at 45°C (113°F).

		Valspar with Valspar filler	Valspar with Dutch filler	Valspar with oil	H_1	H_2	H_3	H_4	H_4A
Test No.		32 33	40 41	95 96	60	64	70	74	89
Original weight		521½	659	591½	638	632	563	605	536
Increase in weight (grams) after	hr. 100	3.5	1.0	2.5	2.5	1.5	0.5	1.0	2.0
	200	6.5	3.0	4.0	4.5	3.5	2.0	2.0	4.0
	300	10.0	5.0	9.5	6.5	5.0	3.5	3.0	5.5
	400	12.5	8.0	10.5	9.0	6.5	4.5	3.5	8.5
	500	13.0	12.5	15.0	10.5	7.5	5.5	4.5	11.5

Table III. Tests in saturated air at 45°C (113°F)-(Cont.)

	H_5	H_6	H_7	Rubber lacquer (lengthwise of grain)	Control test on 32-33	Control test on 32-33	Ripolin paint + Valspar (lengthwise of grain)	Ripolin paint + Valspar (lengthwise of grain)	Ripolin paint + Valspar (crosswise of grain)
Test No.	78	79	85	100	114	115	122	123	128
Original weight	643	558	507	519½	799	801	803	560	686
Increase in weight (grams) after hr.									
100	3.0	2.0	1.5	10.5	2.5	1.5	2.0	2.0	2.5
200	4.0	3.5	4.0	19.5	4.0	3.0	4.0	3.5	4.0
300	6.5	5.0	6.0	24.5	6.0	4.5	4.5	5.0	5.0
400	9.0	6.0	10.5	27.5	8.0	6.5	6.5	7.0	6.0
500	11.0	7.0	13.5	34.5	10.0	8.0	7.5	8.0	7.5
576					10.5	8.5	8.0	8.5	8.0
672					12.0	10.0	9.0	9.5	9.0
744					13.5	11.0	9.5	10.0	9.5
840					15.0	12.0	11.0	11.0	10.5
1344					19.5	16.0	14.0	13.5	14.0
1536					21.0	17.0	14.5	14.0	14.0

Table IV. Tests in water at 45°C (113°F).

	Valspar with Valspar filler	Valspar with Dutch filler	H_1	H_2	H_3	H_4	H_4A	H_6
Test No.	30 31	38 39	58	62	69	73	90	80
Original weight	540	684	600½	628	552	574	557	550½
Increase in weight (grams) after hr.								
100	6.0	4.5	8.0	5.5	0.5	0.5	0	4.0
200	11.0	7.5	10.0	9.0	3.5	3.5	0.5	8.0
300	15.0	10.0	13.0	11.0	6.0	4.0	1.0	11.0
400	18.5	13.5	16.0	13.0	7.5	7.0	1.5	13.5
500	20.0	17.0	19.0	15.5	10.0	9.5	2.0	14.5

Table IV. Tests in water at 45°C (113°F)-(Cont.)

	H_7	Rubber lacquer (lengthwise of grain)	Control test on 30-31	Control test on 30-31	Ripolin paint + Valspar (lengthwise of grain)	Ripolin paint + Valspar (lengthwise of grain)	Ripolin paint + Valspar (crosswise of grain)
Test No.	86	99	116	117	124	125	129
Original weight	510	569½	797	782½	614	576	681
Increase in weight (grams) after hr.							
100	--	1.5	7.0	6.0	5.0	5.0	5.0
200	--	28.0	9.0	9.0	7.5	7.0	7.5
300	--	40.0	12.5	13.5	8.5	9.5	8.5
400	--	54.5	16.5	16.5	11.5	11.5	11.0
500	--	63.5	19.0	19.0	13.0	13.0	12.5
576			20.0	20.0	14.0	14.0	13.5
672			23.0	22.5	15.0	15.5	15.0
744			24.5	24.5	16.5	16.5	16.0
840			27.0	26.5	18.0	18.0	17.5
1344			34.5	33.5	22.5	23.0	22.0
1536			37.0	37.5	25.5	24.5	24.0

Table V. Tests in dry air at 35°C (95°F).

	Untreated	Valspar with Dutch filler	H_1	H_2	H_3	H_4	H_4A	H_6	H_7
Test No.	99	36	61	63	68	72	88	81	83
Original weight	562½	680½	623½	645½	566½	541	500	510	558½
Wt. decrease (gr.) after hr. 100	25.5	5.5	8.5	7.5	14.5	17.0	6.0	17.0	18.0
200	46.5	--	--	--	--	--	--	--	--
300	54.5	30.5	33.5	25.5	45.5	30.5	28.0	35.0	40.0
400	60.5	--	38.5	29.5	--	--	--	--	--

Table V (Cont.)

	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_1	H_2
Test No.	59	66	67	71	75	82	87	58	62
Original weight	622	653	567	529	637	512	491	604½	630
Wt. decrease (gr.) after hr. 100	--	--	--	--	--	--	--	--	--
200	--	--	--	--	--	--	--	--	--
300	25.0	28.0	32.0	32.0	29.5	33.0	26.0	15.0	41.0
400	--	--	--	--	--	--	--	23.0	49.5
500	--	--	--	--	--	--	--	27.5	53.5
340	34.0	36.0		38.0		42.0	--	--	--

Table V. Tests in dry air at 35°C (95°F)-(Cont.)

	H_3	H_4	H_4A	H_7	Control test on 36	Ripolin paint + Valspar (lengthwise of grain)	Ripolin paint + Valspar (lengthwise of grain)	H_7
Test No.	69	73	90	86	110	118	119	84
Original weights	539	562	557	508	788	616	593	
Decrease in weight (grams) after hr.								
100	--	--	--	--	7.5	5.0	4.5	--
200	--	--	--	--	11.5	8.0	7.0	--
300	19.5	17.0	20.0	21.0	16.5	11.5	10.0	--
400	28.5	27.0	32.0	32.0	22.5	17.0	13.0	29.0
500	34.0	33.5	38.0	38.5	25.5	18.0	14.5	--
576					27.0	19.0	15.5	--
672					30.0	22.0	17.5	--
744					32.5	23.5	18.0	--
840					34.5	25.0	19.5	--
1344					42.0	31.0	24.0	--
1546					44.0	32.0	25.0	--

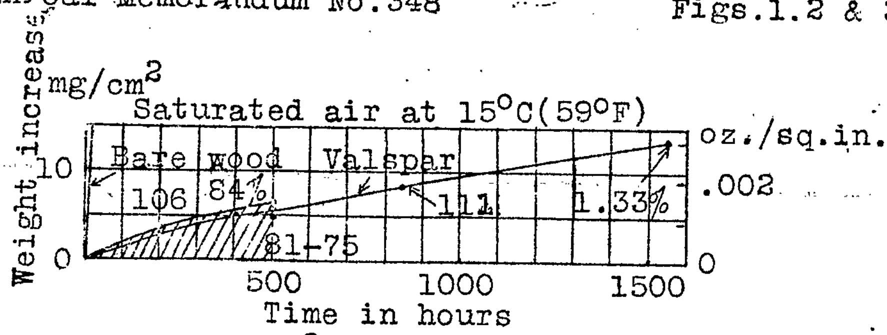

Fig.1 Weight increase (mg/cm²) plotted against the time in hours for the tests in saturated air at 15°C(59°F).

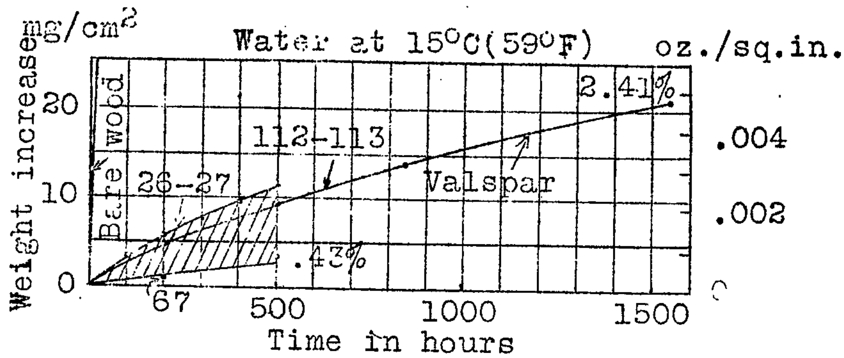

Fig.2 Weight increase(mg/cm²) plotted against time in hours for the tests in water at 15°C(59°F).

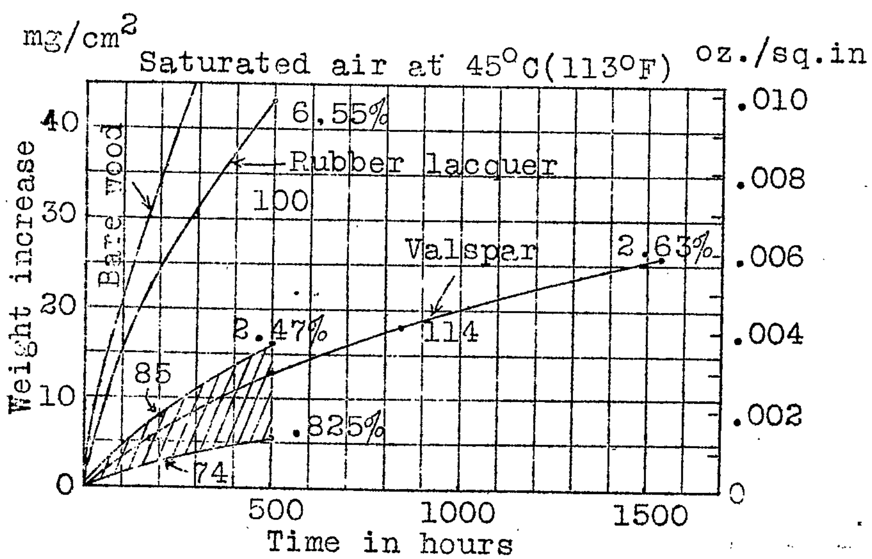

Fig.3 Weight increase (mg/cm²) plotted against time in hours for the tests in saturated air at 45°C(113°F).

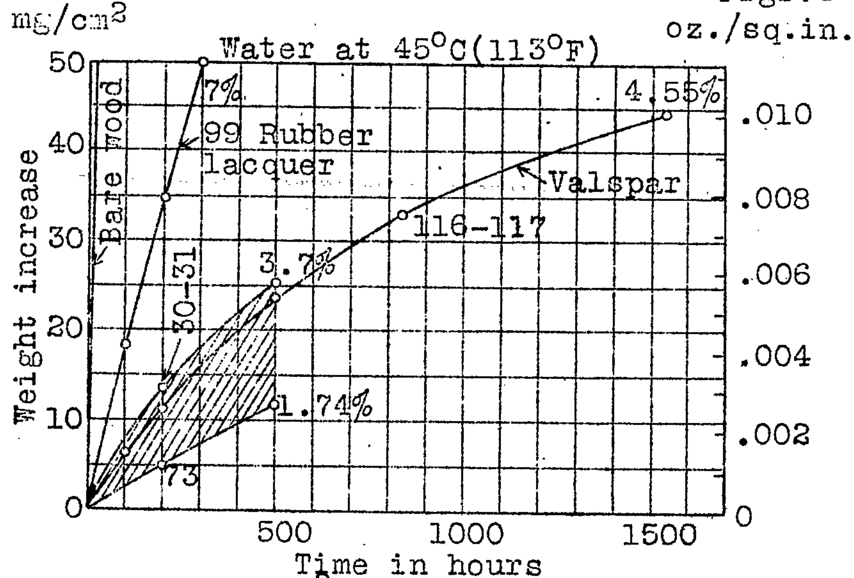

Fig.4 Weight increase(mg/cm²)plotted against time in hours for the tests in water at 45°C(113°F).

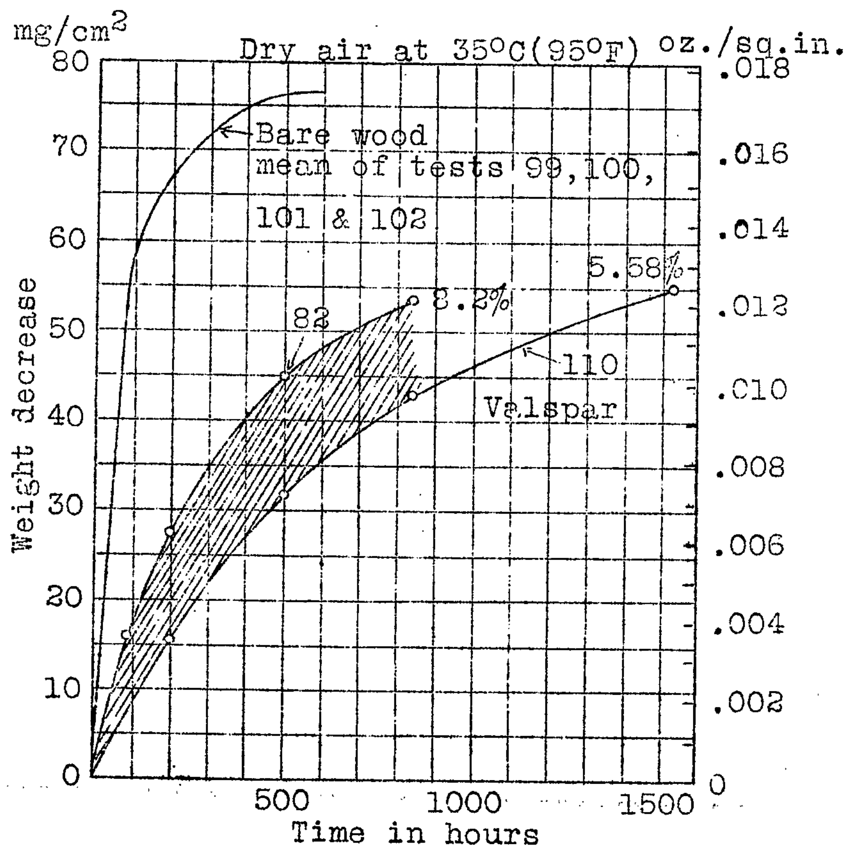

Fig.5 Weight decrease(mg/cm²) plotted against time in hours for the tests in dry air at 35°C(95°F).

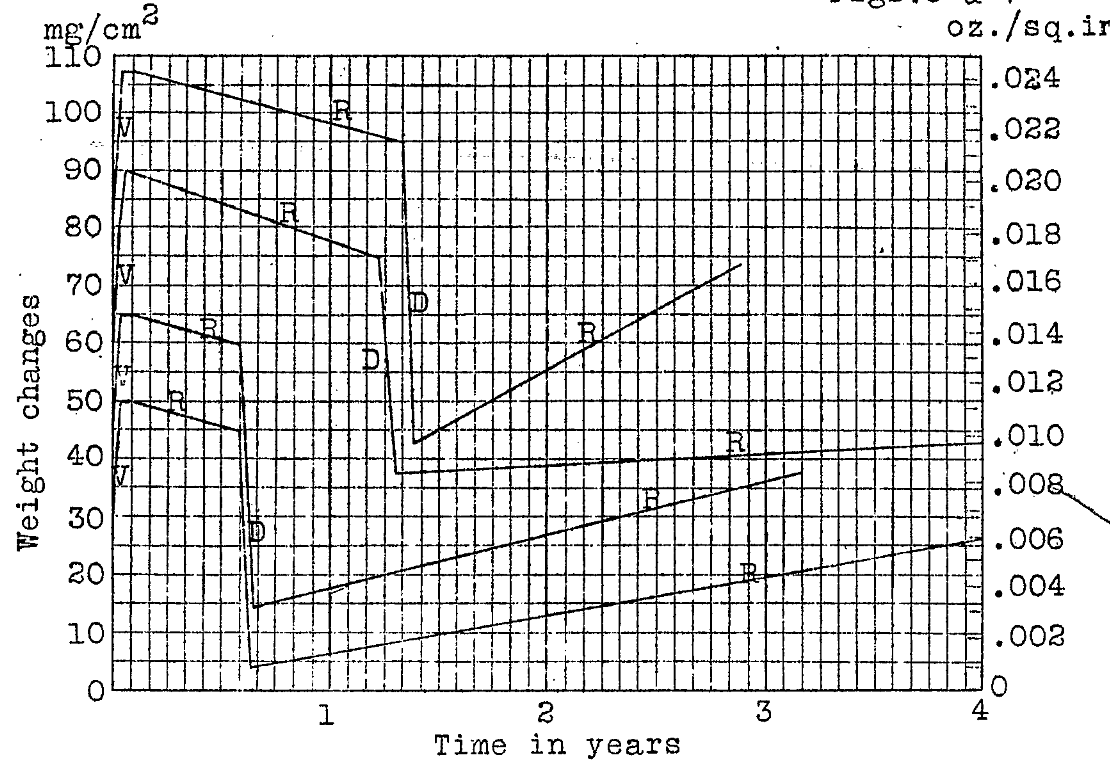

Fig.6 Weight changes (mg/cm²) of four test blocks plotted against the whole duration of the tests in years.

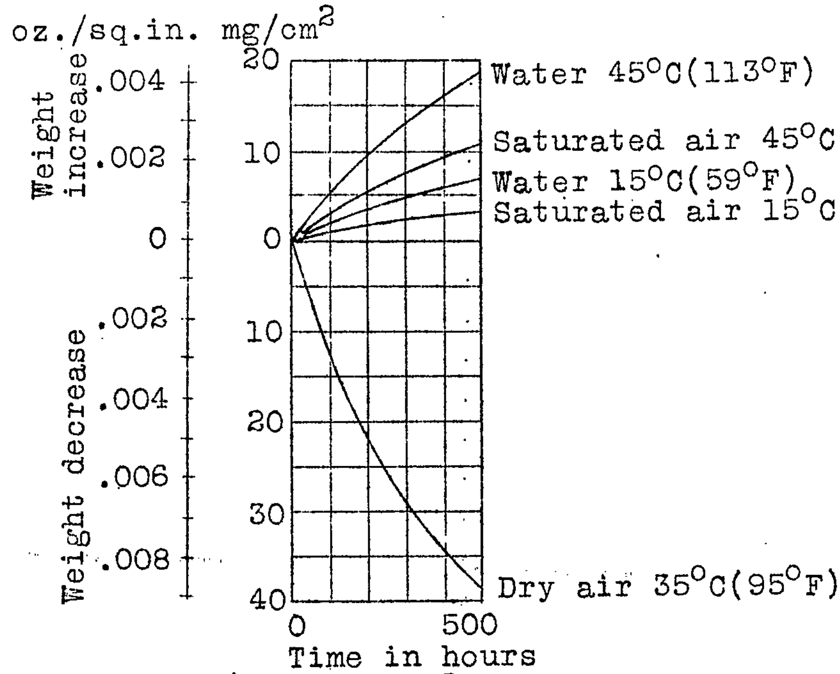

Fig.7 Mean weight alterations (mg/cm²) for the different tests plotted against the time in hours.

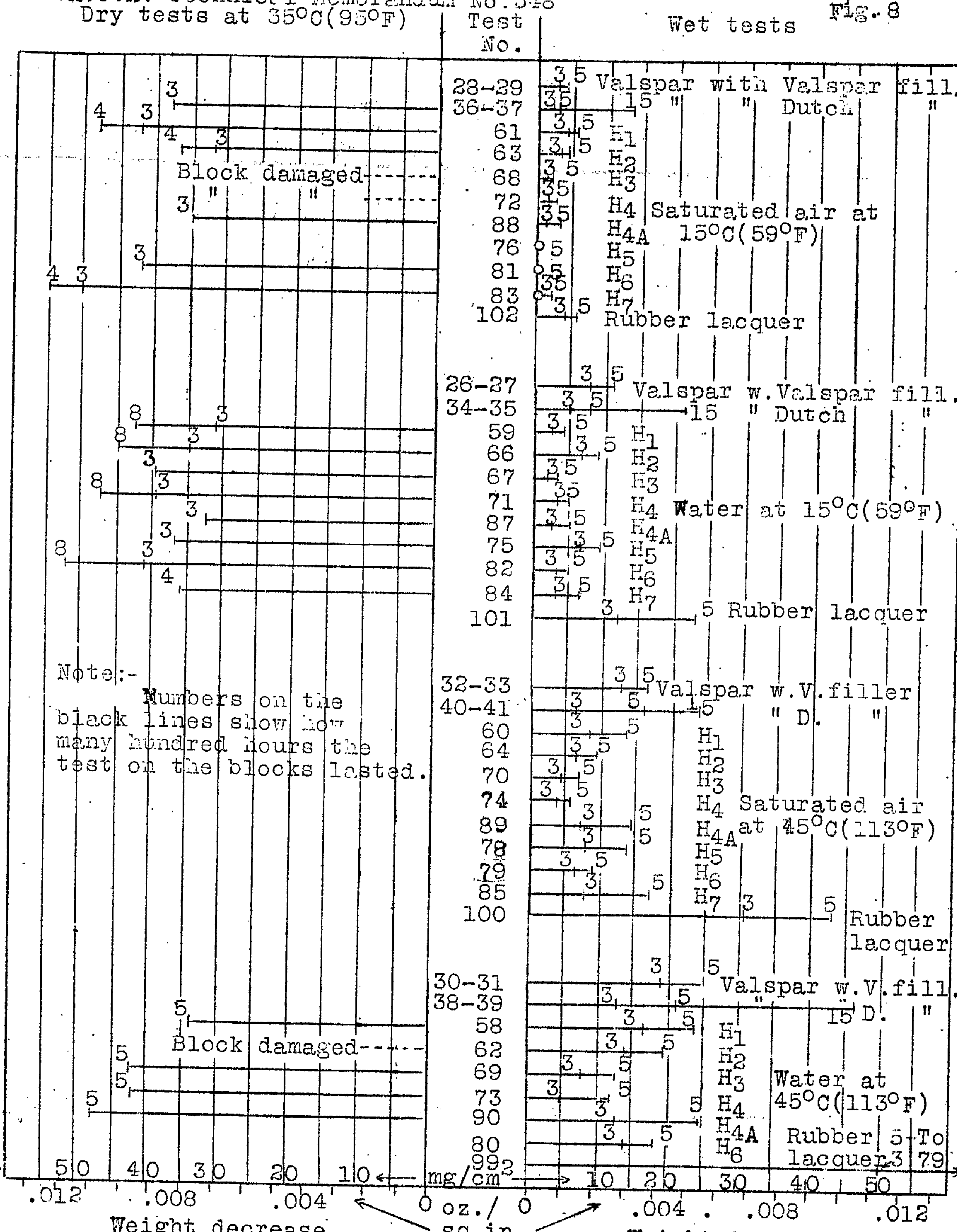
Dry tests at 35°C(95°F)
Test No.
Wet tests
28-29
36-37
61
63
68
72
88
76
81
83
102
Valspar with Valspar fill.
" " Dutch "
H1
H2
H3
H4
H4A
H5
H6
H7
Rubber lacquer
Saturated air at 15°C(59°F)
Block damaged
26-27
34-35
59
66
67
71
87
75
82
84
101
Valspar w.Valspar fill.
" Dutch "
Water at 15°C(59°F)
32-33
40-41
60
64
70
74
89
78
79
85
100
Valspar w.V.filler
" D. "
Saturated air at 45°C(113°F)
30-31
38-39
58
62
69
73
90
80
99
Valspar w.V.fill.
" D. "
Water at 45°C(113°F)
To 79
Note:- Numbers on the black lines show how many hundred hours the test on the blocks lasted.
50 40 30 20 10 mg/cm2 10 20 30 40 50
.012 .008 .004 0 oz./sq.in. 0 .004 .008 .012
Weight decrease
Weight increase

Fig.8