steam was not necessary as there was already a large amount of water present. The distillation was, therefore, carried on to the point where the distillate came over as a homogeneous liquid. The temperature was slowly raised until 100° C. was exceeded and steam under constant pressure was then injected into the tar. The ratio of oil to water in the distillate gradually decreased until only 25 per cent of the distillate was oil. The distillation was then stopped. The last portion of the distillate on standing solidified to a jelly-like mass because of the presence of paraffin. The residue in the still was liquid when hot and could be easily poured, but on cooling solidified to a hard brittle pitch which could be powdered in the fingers. Special experiments showed that not more than 2 per cent of the tar is lost as gas or vapors.

RESULTS

The following yields were obtained by this method of distillation:

No. 1—1100 g. Tar taken	Total Distillate	Oil	Per cent in Tar
1st Portion of Distillate.....	282 cc.	64 cc.	19.8 Water
Straight distillation.....	29 cc.	29 cc.	8.5 Light Oil
2nd Portion of Distillate.....			
Stirred with steam.....	1076 cc.	446 g.	40.5 Heavy Oil
RESIDUE (by difference).....			31.2 Pitch
No. 2—1175 g. Tar taken	Total Distillate	Oil	Per cent in Tar
1st Portion of Distillate.....	371 cc.	101 cc.	23 Water
Straight distillation.....			9 Light Oil
2nd Portion of Distillate.....			
Stirred with steam.....	920 cc.	372 cc.	32 Heavy Oil
RESIDUE (by difference).....			36 Pitch

The heavy oil from No. 1 contained 0.7 per cent acids figured as acetic acid. This was reduced to 0.3 per cent by washing three times with equal volumes of water.

CONCLUSION

In brief, the following method seems to be a desirable one for the production of crude wood-tar creosote on a semi-commercial scale: (1) Distill with direct heat until the distillate comes over as a homogeneous liquid well above the boiling point of water. (2) Raise the temperature and stir the tar with a steam jet; collect this latter portion of the distillate in a separate container and continue until the distillate contains solid paraffin.

If the above procedure is carried out carefully the heavy oil fraction should not contain more than one per cent acid and the pitch can easily be emptied without fear of coking in the still. Furthermore, a slight gain in time of distillation will result from the use of steam.

FOREST PRODUCTS LABORATORY
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SOME OBSERVATIONS ON THE INFLUENCE OF HUMIDITY ON THE PHYSICAL CONSTANTS OF PAPER¹

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Samples of paper taken for testing purposes at the mill and later at the point of destination may show

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rather surprising variations in their so-called physical constants. Paper is essentially a network of interwoven cellular fibers which may or may not be sized, loaded, calendered, coated or treated in other ways for special purposes, but the paper will still show the general physical characteristics of the individual fibers which make up the sheet and determine its quality.

INFLUENCE OF HUMIDITY ON STRENGTH

Since the individual fibers of a sheet of paper are hygroscopic, the whole sheet consisting so largely of fibrous material naturally possesses this quality, though to a lesser degree than the individual fibers. It is a common observation that on humid days a sheet of paper is more limp, stretches more and is less resistant to tearing and bursting than on dry days. The relative humidity of the atmosphere varies from 30 per cent in cold, dry weather to almost 100 per cent in foggy or hot, moist weather. Indoors, the relative humidity ranges are not so wide except that on a cold, dry day the relative humidity in a steam-heated room often falls to 20 per cent while in summer, with all the windows open, indoors it may be almost as high as that outdoors.

Herzberg¹ in his treatise on "Papierprüfung" gives data on the effect of varying humidities on the physical properties of paper. From a study of his data, it is evident that variations in the relative humidity of the atmosphere and consequent variations in the percentage moisture in the paper have a decided effect on the strength and stretch of paper. As the humidity falls, the breaking length is increased and the stretch decreased.

Herzberg in quoting from the work of G. Dalén states that for relative humidities between 0 per cent and 80 per cent, paper expands in direct proportion to the amount of moisture present. But when the relative humidity is between 80 per cent and 100 per cent, the expansion is somewhat over this proportion.

G. Dalén, after many experiments on the effect of varying humidities on the breaking length and stretch of papers, constructed a table of factors by which the results for breaking length and stretch obtained at relative humidity are to be multiplied to obtain the correct result for 65 per cent relative humidity. This table of factors has been published in Herzberg's book on page 18.

As a result of the investigations made at the testing laboratories in Germany, all papers for Government use are tested at the Royal Testing Laboratories at Gross-Lichterfelde, under a constant relative humidity of 65 per cent.

The Forest Products Laboratory has recently installed a constant humidity room in which to study the effect of variations in humidity on the physical properties of paper. The room is double-walled, 8 ft. 2 in. X 9 ft. 3½ in. X 7 ft. 6 in. high, and fitted with a constant temperature and constant humidity apparatus. Fig. 1 represents a diagrammatic sketch of the apparatus which consists essentially of a galvanized iron conduit A in one corner of the room and

¹ W. Herzberg, "Papierprüfung," p. 14.

reaching from the floor through the roof where it is connected with a motor-driven fan *B*. The outlet from *B* leads through heating coils *C* into flue *D* and back into the room. At the bottom of the conduit *A* is a settling tank *E* from which the pump *F* draws its supply of water and pumps it to the sprays *G*, the water dropping down into the tank *E*. Above the sprays are a series of eliminator plates *H*. The air compressor *J* delivers compressed air to the tank *K*, *L* is the humidity regulator, *M* is a thermostat, while *N*₁ and *N*₂ are diaphragm valves. *P* is an air outlet duct. *Q* is a steam supply line in which the steam is reduced to a pressure of 5 lbs. per square inch by means of a reducing valve.

FIG. 1—DIAGRAMMATIC SKETCH OF THE AIR CONDITIONING APPARATUS

During operation, the pump *F*, sprays *G*, compressor *J* and fan *B* are in constant operation. Air enters the opening in *A* as shown by the arrow, passes up through the sprays *G* and into the eliminator plates *H* where the entrained water is removed, then up through fan *B*, heater *C*, and flue *D* into the room and finally out into the atmosphere through flue *P*.

Before explaining the regulation of the temperature and humidity it is best to review some definitions. The "dew point" of air is that temperature at which it is saturated with a given amount of water vapor. If cooled below this temperature, some vapor will condense and dew will be deposited. The "dry bulb" temperature is the ordinary temperature of the air in the room as given by an accurately graduated thermometer. The "wet bulb" temperature is that given by a thermometer similar to that used for determining the dry bulb temperature, but having the bulb tightly covered with a piece of soft muslin or silk which is thoroughly wet and over which a current of air is passed.

Through the evaporation of water from the cloth, the wet bulb temperature is always lower than that of the dry bulb except at the dew point, when all three temperatures read alike. However, the wet bulb temperature is always higher than the dew point temperature except at 100 per cent relative humidity. The "relative humidity" is the ratio of the amount of water vapor in a given space, to the amount which the same space will hold when fully saturated at the same temperature and is expressed in per cent.

For a given amount of moisture per cu. ft. of air, the dew point is always the same, because at the dew point temperature, only, is the air saturated with that amount of moisture. If this air is heated, both the dry bulb and wet bulb temperature rise, the dry bulb more rapidly than the wet bulb, because the latter is cooled by the evaporation of water from its muslin jacket. As the air is heated, its capacity for water vapor is increased and, therefore, the relative humidity falls. By taking the difference between the wet and dry bulb thermometers, the relative humidity can be found by consulting a humidity chart or a set of tables.

The above-mentioned method of regulation is employed with the apparatus in use. Referring to Fig. 1, the air as it passes from the eliminators *H* is saturated with water vapor, *i. e.*, it is at its dew point. If no heat is added to or taken from the air it will pass through the fan and into the room at the same temperature as that which it had when leaving *H*, and the wet and dry bulb thermometers will both register the same temperature, namely that of the dew point. No evaporation can take place from the wet bulb thermometer because the surrounding air is already saturated and can hold no more moisture.

If now, the humidity regulator *L* is set for say 60 per cent relative humidity, then by means of the diaphragm valve *N*₁, steam is admitted to the heating coils and the air heated. As the temperature rises, the capacity of the air for water vapor increases and the relative humidity decreases. At 60 per cent relative humidity, the humidity regulator shuts off the steam from the heating chamber until the humidity in the room rises above that for which it is set when steam is again admitted to the heaters. The actuating mechanism in the humidity regulator is a silk thread which contracts and expands with the amount of moisture present in the room. Through this regulator the compressed air from *K* being at a higher pressure than the steam keeps the diaphragm valve shut. When the percentage humidity rises above that for which the regulator is set, the silk thread expands and shuts off the air pressure and steam is admitted to the heating coils.

For high relative humidities where it is necessary to keep the temperature of the sprays above that of the water from the supply pipes, the thermostat *M* operates the diaphragm valve *N*₂ which governs the admission of steam to the spray water as it enters the pump *F*.

An automatically operated wet and dry bulb thermometer or psychrometer was used to determine the relative humidity. The extreme ranges of humidity

we were able to secure with the cooling water at our command were 41 to 82 per cent.

TESTS OF COMMERCIAL PAPERS

The laboratory originally planned to include in this work a series of tests on commercial papers made under uniform conditions of mechanical treatment and from the same stock where the only variation would be one of ream weight. For papers made on any given furnish there appears to be a certain thickness (which decides the ream weight) from which the paper of unit maximum strength is produced. Some work has been done by Rehn¹ on the study of the influence of weight on strength of paper, which brings out some interesting points. It was hoped that samples, taken at the time of change in weight, representing papers of different ream weights made with the same mechanical treatment and from the same furnish, could be obtained from the mills. Unfortunately, some of the papers submitted showed such large variation in appearance, texture and color, that we feel sure they represent different runs, and this was substantiated by a study of the strength tests. This necessitated our omitting at this time any study of the effect on the physical constants caused by variation in ream weight.

The physical tests employed in arriving at a basis of comparison of the strengths of the papers studied under varying degrees of humidity were the following:

- 1—Ream weight.
- 2—Thickness.
- 3—Resistance to bursting; points per lb., points per 0.001 in. thickness.
- 4—Tensile strength, breaking length.
- 5—Stretch.
- 6—Resistance to folding.

1—The ream weight was taken on the 500 basis, sheets 24 in. $\times$ 36 in.

2—The thickness was measured by a spring micrometer.

3—The resistance to bursting was measured by the Mullen tester. By "points per lb." is meant the bursting strength in pounds required to burst one sq. in. of surface as determined by the Mullen test divided by the ream weight. By "strength factor" or "points per 0.001 in." is meant the bursting strength in pounds as determined by the Mullen test divided by the number of thousandths of an inch thickness of the paper.

4—The tensile strength in kilograms was determined by the Schopper tensile strength machine. The tensile strength varies with the kind of paper, the width of the strip and the thickness. A numerical expression for the tensile strength of the paper which depends solely upon the nature of the paper is called the "breaking length," and is independent of the thickness and the width of the paper, as these are considered in the calculation by which "breaking length" is determined. By "breaking length" is meant the length of a strip of paper, which, if suspended from a support, will break at the point of support due to its own weight.

¹ *The World's Paper Trade Review*, August 25, 1911.

5—The percentage stretch of the paper is obtained with the Schopper tensile strength machine at the same time as the tensile strength is taken.

6—The resistance to folding is measured by the Schopper folder.

These tests and their significance are, of course, familiar to the paper trade and are only cited to avoid any misunderstanding of the tabulated results. As is well known, machine-made papers are stronger in the machine direction which is indicated in the table by the minus sign (—) than across the machine direction which is indicated in the table by the plus sign (+). The stretch of machine-made paper is less in the machine direction (—) than across the machine direction (+).

In order to obtain average results five tests were made to determine bursting strength and five tests in each direction for tensile strength and stretch, and three folding tests both with and across the machine direction. If variable results were obtained 10 tests were made and the results averaged.

Four sets of commercial papers of totally different properties were examined. These will be designated as Series I, II, III and IV. Series I, known as ground-wood-sulfite papers, was supplied in 25, 30 and 34-lb. weights and was made according to the mill submitting these samples on a furnish of 30 per cent groundwood and 70 per cent sulfite pulp. These papers were of a "wild" formation and showed many shives.

Series II consisted of papers made on an all sulfite furnish in weights of 25, 40, and 60 lbs. These papers showed a "wild" formation, making it difficult to obtain uniform results.

Series III and IV represent kraft papers of two different shipments from the same mill. Series III consisted of samples of 25, 30, 40, and 50-lb. papers while Series IV consisted of 30, 40, and 60-lb. papers. Papers of Series III and IV showed a "wild" formation.

Before beginning the actual testing it was necessary to determine the length of time required for the papers to "season," *i. e.*, to reach the desired moisture content. Herzberg in his "Papierprüfung" states that the strips should be kept under the desired atmospheric conditions for at least half an hour before testing.

K. Fenchel and K. Cornely¹ state that "experiments on the rate of absorption and loss of moisture when pulp was transferred from an atmosphere at 50 per cent humidity to one of 70 per cent and then back again, showed that two hours were sufficient for the establishment of equilibrium with the moister atmosphere but on returning to the drier atmosphere, the original weight was not restored in so short a time." In these experiments the humidity was controlled by blowing the air through CaCl_2 solutions or through granulated CaCl_2 .

To see how long it would take for papers to become saturated under the conditions of the experiment sheets of newspaper, all-rag stationery, light and heavy weights of kraft wrapping paper, light and heavy

¹ *J. Soc. Chem. Ind.*, **32** (1913), 1103.

TABLE I
Humidity changed from 55 per cent to 70 per cent at 7:05 P.M.
Results given in Grams

Paper	HUMIDITY:	55 per cent 6:40 P.M.	70 per cent 9:00 P.M.	70 per cent 10:00 P.M.	70 per cent 10:37 P.M.
News.....		27.54	27.96	27.98	27.96
All Rag.....		17.79	18.00	18.00	18.01
Light Weight Kraft.....		13.18	13.34	13.37	13.37
Heavy Weight Kraft.....		20.28	20.53	20.52	20.56
Light Weight Water Finish.....		27.71	28.14	28.11	28.17
Heavy Weight Water Finish.....		47.48	48.18	48.14	48.09
Aspen Pulp.....		31.46	31.90	31.92	31.90

weights of "water finished" wrapping paper and a sheet of unsized aspen soda pulp were suspended from a string across the room and each sheet was weighed approxi-

mately every half hour on an analytical balance, until the weight became constant.

Table I shows the time required to season the paper when changing from 55 per cent relative humidity to 70 per cent. The change from 55 per cent to 70 per cent relative humidity was made at 7:05 P.M. The data show that in two and one-half hours all the papers had practically attained equilibrium. A striking feature of this test is that the heavily sized all-rag paper reached a state of constant weight about half an hour before the unsized aspen pulp. The light

TABLE II																			
PAPER		Humidity Per cent	Weight per ream Lbs.	Thickness In.	Bursting Strength	Points per Lb.	Points per 0.001 in. Thickness	TENSILE STRENGTH			BREAKING LENGTH			STRETCH			NUMBER OF FOLDS		
								—Kilograms— + Av.			—Meters— + Av.			—Per cent— + Av.			—Double— + Av.		
SERIES I—GROUNDWOOD-SULFITE PAPERS																			
25-lb.....	41	26.5	0.00300	12.8	0.482	4.25	3.7	1.8	2.75	5860	2820	4340	1.24	2.12	1.68	17	10	13	
	53	25.5	0.00286	12.2	0.478	4.26	3.5	1.72	2.61	5450	2700	4075	1.25	2.27	1.76	71	11	41	
	64	26.5	0.00293	12.0	0.447	4.09	3.48	1.62	2.55	5210	2500	3855	1.45	2.72	2.08	92	12	52	
	65	28.0	0.00312	12.8	0.457	4.10	3.36	1.48	2.42	5190	2400	3795	1.32	2.96	2.14	80	10	45	
	77	28.0	0.00326	12.0	0.429	3.68	3.08	1.44	2.26	4750	2220	3485	1.78	3.87	2.82	104	14	59	
	82	27.5	0.00298	9.4	0.342	3.15	2.64	1.16	1.90	4100	1860	2980	1.72	3.90	2.81	41	..	..	
30-lb.....	41	32.5	0.00354	17.0	0.523	4.80	4.60	2.62	3.61	6040	3340	4690	1.16	2.14	1.65	60	17	38	
	53	32.5	0.00364	16.6	0.511	4.56	4.55	2.52	3.53	5940	3220	4580	1.24	2.52	1.88	75	21	48	
	64	32.0	0.00358	14.6	0.456	4.08	4.12	2.24	3.18	5370	2760	4065	1.38	2.66	2.01	114	33	73	
	65	33.0	0.00316	16.0	0.485	4.42	4.38	2.36	3.37	5700	2980	4340	1.38	2.52	1.95	126	18	72	
	77	34.5	0.00368	14.4	0.417	3.92	4.26	2.04	3.15	5110	2600	3855	1.58	3.02	2.30	170	25	97	
	82	32.0	0.00340	11.8	0.369	3.47	3.16	1.66	2.41	4080	2120	3100	1.58	3.70	2.64	62	19	40	
34-lb.....	41	35.0	0.00404	17.0	0.486	4.21	5.08	2.86	3.97	5810	3460	4635	1.30	2.42	1.86	68	25	46	
	53	36.5	0.00410	17.5	0.479	4.27	5.00	2.70	3.85	5660	3030	4345	1.30	2.44	1.87	78	30	54	
	64	35.5	0.00400	15.75	0.444	3.94	4.38	2.50	3.44	4940	2820	3880	1.42	3.14	2.28	86	42	64	
	65	37.0	0.00400	16.20	0.438	4.05	4.72	2.58	3.65	5520	3040	4280	1.42	2.90	2.16	80	34	56	
	77	39.5	0.00412	16.6	0.420	4.20	4.24	2.44	3.34	4690	2700	3695	1.64	3.28	2.46	136	43	90	
	82	38.5	0.00416	14.4	0.374	3.41	3.44	1.94	2.69	3760	2175	2968	1.76	3.70	2.73	127	24	75	
SERIES II—ALL SULFITE PAPER																			
25-lb.....	41	23.5	0.00182	12.8	0.545	7.04	4.24	2.06	3.15	7320	3580	5450	0.96	1.56	1.31	44	36	40	
	53	25.5	0.00194	13.2	0.518	6.80	4.24	2.06	3.15	7330	3210	5270	1.24	2.35	1.80	..	..	..	
	64	26.0	0.00194	13.6	0.523	7.01	3.88	1.90	2.89	6890	3220	5055	1.28	2.60	1.94	134	46	90	
	65	22.5	0.00184	12.2	0.550	6.63	3.87	1.96	2.91	6700	3240	4970	1.00	2.60	1.80	122	45	83	
	77	25.5	0.00164	13.2	0.518	8.05	3.80	1.90	2.85	6240	3150	4695	1.42	3.02	2.22	201	..	..	
	82	22.0	0.00162	11.0	0.500	6.80	3.20	1.68	2.44	5520	2820	4170	1.52	3.48	2.50	..	..	..	
40-lb.....	41	43.5	0.00310	27.6	0.635	8.90	7.36	3.90	5.63	7100	3700	5400	1.04	2.30	1.57	63	120	91	
	53	44.5	0.00300	28.2	0.634	9.40	7.58	3.78	5.68	7200	3580	5390	1.12	2.68	1.85	79	78	78	
	64	43.5	0.00300	25.4	0.584	8.46	7.08	3.62	5.35	6550	3410	4980	1.06	2.94	2.00	251	217	234	
	65	44.5	0.00300	25.7	0.578	8.56	7.08	3.72	5.40	6840	3566	5200	1.10	3.06	2.08	293	354	323	
	77	45.5	0.00304	27.8	0.611	8.14	7.02	3.66	5.34	6480	3390	4935	1.38	3.40	2.39	649	337	498	
	82	46.0	0.00326	24.6	0.535	7.54	6.52	3.34	4.93	6100	3090	4595	1.50	4.32	2.91	326	114	220	
60-lb.....	41	63.7	0.00432	32.6	0.512	7.55	9.15	4.80	6.92	5990	3060	4525	0.92	1.85	1.38	66	40	53	
	53	62.0	0.00406	31.0	0.500	7.63	9.32	4.88	7.10	5940	3020	4480	0.92	2.26	1.58	152	83	118	
	64	70.5	0.00490	33.4	0.474	6.82	8.82	4.94	6.83	5510	3240	4375	0.98	2.58	1.78	631	94	362	
	65	63.5	0.00428	32.0	0.520	7.54	8.82	4.76	6.79	5775	2995	4385	1.00	2.42	1.71	357	238	297	
	77	69.0	0.00484	30.75	0.445	6.36	8.50	4.44	6.47	5360	3060	4210	1.20	2.86	2.01	671	265	468	
	82	68.8	0.00498	28.6	0.416	5.64	7.30	4.14	5.72	4680	2550	3615	1.30	3.40	2.35	515	208	361	
SERIES III—No. 1 KRAFT																			
25-lb.....	44	28.5	0.00276	22.2	0.779	8.04	5.00	3.08	4.04	7230	4410	5820	1.64	3.62	2.53	227	313	270	
	53	29.0	0.00276	20.8	0.718	7.50	4.96	2.68	3.82	7200	3860	5530	1.66	3.56	2.61	238	146	192	
	64	29.0	0.00270	21.25	0.733	7.76	4.75	2.86	3.81	6720	4110	5415	1.72	4.75	3.23	638	582	610	
	68	29.0	0.00266	20.8	0.718	7.82	4.60	2.67	3.63	6380	4260	5320	1.50	5.30	3.40	630	720	675	
	77	30.0	0.00262	21.5	0.716	8.21	4.46	2.70	3.58	6120	3790	4955	1.94	5.64	3.79	839	1036	937	
	82	29.0	0.00266	20.75	0.714	7.79	4.14	2.54	3.34	5160	3460	4310	2.30	6.54	4.42	111	..	..	
30-lb.....	44	31.5	0.00300	23.8	0.756	7.93	5.82	2.87	4.34	7650	3780	5715	1.75	2.90	2.32	309	131	225	
	53	32.0	0.00304	23.2	0.725	7.64	5.52	3.10	4.31	7290	3920	5605	1.84	3.48	2.66	357	81	219	
	64	32.0	0.00312	25.6	0.800	8.20	5.25	2.96	4.10	6950	3710	5330	1.92	3.92	2.92	705	391	548	
	68	31.5	0.00312	24.5	0.778	7.85	5.36	2.84	4.10	6800	3610	5205	2.10	3.88	2.99	1016	203	610	
	77	32.0	0.00300	22.4	0.700	7.47	5.05	2.72	3.88	6400	3520	4960	2.02	4.20	3.11	1148	397	772	
	82	33.5	0.00315	22.5	0.672	7.15	4.52	2.34	3.43	5160	2920	4040	2.26	4.34	3.30	1775	228	1000	
40-lb.....	44	42.5	0.00400	34.25	0.806	8.55	8.28	4.08	6.18	7900	3895	5900	1.90	4.88	2.89	436	214	325	
	53	43.0	0.00396	35.2	0.819	8.89	7.92	4.14	6.03	7550	3950	5750	2.02	5.54	3.78	619	407	513	
	64	44.5	0.00380	34.6	0.778	9.10	7.82	4.02	5.92	7320	3780	5550	2.22	5.92	4.07	901	578	740	
	68	43.5	0.00398	37.0	0.850	9.30	7.82	4.00	5.91	7360	3765	5562	2.23	6.40	4.31	1386	484	935	
	77	45.5	0.00390	35.2	0.774	9.03	7.20	3.90	5.55	6660	3600	5130	2.20	6.42	4.31	1913	1002	1457	
	82	46.0	0.00402	32.2	0.700	8.02	6.64	3.40	5.02	6030	3120	4575	2.56	6.60	4.58	3721	614	2167	
50-lb.....	44	53.5	0.00492	34.2	0.639	6.95	7.50	5.53	6.51	5800	4250	5025	1.35	4.27	2.81	212	347	250	
	53	54.5	0.00484	32.6	0.598	6.75	7.82	5.28	6.55	5880	4030	4955	1.48	4.32	2.90	340	514	427	
	64	54.7	0.00494	36.0	0.659	7.29	7.28	5.24	6.26	5670	4000	4835	1.74	4.82	3.28	547	665	606	
	68	54.5	0.00492	33.8	0.616	6.84	7.06	5.10	6.08	5550	3850	4700	1.62	5.06	3.34	545	1046	795	
	77	55.0	0.00494	34.2	0.622	6.92	6.66	4.80	5.73	5110	3610	4360	1.54	5.30	3.42	754	2752	1753	
	82	56.0	0.00498	29.8	0.532	5.99	6.30	4.50	5.40	4660	3340	4000	2.00	5.68	3.84	1369	2823	2096	
SERIES IV—No. 1 KRAFT																			
30-lb.....	44	33.0	0.00314	29.0	0.879	9.24	6.26	3.18	4.72	7640	3880	5760	1.64	3.04	2.34	443	253	348	
	53	35.0	0.00338	27.0	0.772	8.00	5.64	3.32	4.48	7240	4100	5670	1.74	4.00	2.87	451	304	378	
	64	32.0	0.00308	23.8	0.744	7.72	5.80	3.24	4.52	7220	3940	5580	2.08	4.50	3.29	1017	246	631	
	68	33.0	0.00322	26.5	0.803	8.24	5.62	3.08	4.35	7050	3860	5455	2.12	4.52	3.32	939	413	676	
	77	35.0	0.00302	26.5	0.758	8.77	5.48	2.76	4.12	6490	3380	4935	2.26	4.82	3.54	1213	399	806	
	82	34.0	0.00304	25.2	0.741	8.29	4.84	2.44	3.64	5800	2910	4355	2.44	4.86	3.65	3200	767	1980	
40-lb.....	44	40.5	0.00382	33.8	0.833	8.84	7.30	4.16	5.73	7550	4275	5912	1.50	4.72	3.11	381	445	413	
	53	40.0	0.00374	32.8	0.820	8.77	7.60	3.78	5.69	7830	3770	5800	1.72	4.66	3.19	583	385		

weight papers also tend to approach equilibrium somewhat sooner than the heavier papers.

The papers for each day's run were hung loosely from a cord strung across the room so that the air had free play around them and were left to season for at least 3 hours. Each set of papers was tested without interruption on the same day and all the conditions of testing were kept as nearly constant as possible.

RESULTS OF THE EXPERIMENT

The results of the tests under varying humidities are shown in detail in Table II, and graphically by means of curves. Keeping in mind the shivy character of the groundwood-sulfite papers and the wild formation of all of the samples of papers examined, these results can be considered only as indications. However, certain conclusions may be drawn which should be of interest.

Table II shows the average of the results obtained

FIG. 2—SERIES II: ALL SULFITE

in testing the different papers of Series I, II, III and IV at 41, 53, 64, 68, 77 and 82 per cent humidities. In order not to show too many curves only those for Series II on the all sulfite papers, and for Series IV on kraft papers are included in Figs. 2 and 3. The results for all the different weights of the papers in each of Series II and IV, for both the "points per pound" and for "breaking length," are plotted as the curves are practically parallel and form a composite curve.

CONCLUSIONS

I—The value of points per pound increases with the decrease in relative humidity. The increase between 40 and 65 per cent is fairly regular but the increase of the relative humidity above 70 per cent causes a large reduction in strength. Foreexample, on the groundwood-sulfite mixture, Series I, taking the strength at 65 per cent relative humidity as standard, the average variation for the three papers was 8 per cent for the humidity change from 41 per cent to 65 per cent while from 65 per cent to 82 per cent the drop was 21.5 per cent, giving a total variation in strength of almost 30 per cent from the strength at 65 per cent relative humidity. On the Series IV, No. 1 kraft, the variation from 44 per cent to 64 per cent relative humidity was 13.7 per cent, while from 64 to 82 per cent the difference in

FIG. 3—SERIES IV: NO. 1 KRAFT

strength was 11.9 per cent, the total variation in strength being nearly 26 per cent from that at 65 per cent relative humidity.

II—The same results seem to hold for the breaking length. Above 70 to 75 per cent relative humidity the strength falls more rapidly than between 40 per cent and 75 per cent. For the groundwood-sulfite mixture, Series I, again taking the values at 65 per cent as standard, the variation in breaking length between

41 per cent and 65 per cent relative humidities is 10 per cent, while an increase in humidity from 65 per cent to 82 per cent caused a reduction in the breaking length of 27.2 per cent, a total variation of over 37 per cent. For Series IV, No. 1 kraft, the variation in breaking length for the humidity change from 44 per cent to 64 per cent was 6.4 per cent, while with an increase in humidity from 64 per cent to 82 per cent the drop in breaking length was 19.3 per cent, a total variation of 25.7 per cent.

III—The stretch of the paper increases with increase in relative humidity, the variation being rather more regular than with points per pound and breaking length. For the groundwood-sulfite mixture, Series I, the stretch increased 17.0 per cent, with increase in relative humidity from 41 per cent to 65 per cent, and 31 per cent with increase in humidity from 65 per cent to 82 per cent. For the Series IV, No. 1 kraft, the stretch increased 20.4 per cent with increase in relative humidity from 44 per cent to 64 per cent, and 18.7 per cent with increase in humidity from 64 per cent to 82 per cent.

IV—The folding properties seem to be affected to a greater degree than any other property. For the groundwood-sulfite mixture and the all sulfite papers, the resistance to folding increased tremendously between 55 and 77 per cent relative humidity, a further increase in the moisture content, however, causing the folding strength to break sharply. With the kraft papers, the folding strength increased with the increase in humidity and at the most saturated condition used, *viz.*, 82 per cent, the papers showed far greater folding strength than at 77 per cent. For the groundwood-sulfite paper, Series I, the number of folds increased 153 per cent with a humidity increase from 41 per cent to 77 per cent. Above 77 per cent relative humidity the folding strength decreased, showing that the per cent of relative humidity giving greatest folding strength had been passed. For Series IV, 30-lb. paper, the number of folds increased from 348 at 44 per cent relative humidity to 1980 folds at 82 per cent humidity, an increase of 470 per cent, while the 60-lb. paper showed an increase of 588 per cent in the folding strength in varying the relative humidity from 44 to 82 per cent.

The results obtained are sufficient to show that when paper is bought and sold on strength specifications, more uniform results would be obtained if the relative humidity at the time of testing were specified.

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FURTHER STUDIES ON A NUMERICAL EXPRESSION FOR COLOR AS GIVEN BY THE IVES TINT PHOTOMETER

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In a previous paper by the authors¹ we described the results of some experiments in attempting to determine a numerical expression for color of paper as given by the Ives Tint Photometer. These experiments were made, (1) to determine if color indica-

tions as shown by the Ives Tint Photometer could be employed as a means of measuring the progress of beating, and (2) to observe the relation between the numerical expression for depth of color as read by the instrument, as compared with the grading for depth of color as observed by visual inspection. As reported in the previous paper we found it was possible to give a numerical expression for depth of color of papers comparable to visual grading where the variations were produced by either varying the amount of color or by holding the amount of dyestuff constant and varying the depth of color by variation in the hydration of the stock. The matter of scientifically and accurately recording color both as to hue and intensity is one of especial interest to those interested in paper research. A numerical expression for color is of value for purposes of scientific record and description, and for comparison and classification of papers and paper stocks. The best prepared papers may change in shade in a comparatively short time, due to changes of the paper stock itself or the fugitive character of the dyestuff.

Further experiments were made in order (1) to determine whether any shade matched visually in both hue and intensity with a different combination of dyestuffs would give the same tint photometer reading, (2) to study the darkening action caused by calendering of paper and whether such progressive darkening action could be numerically recorded, and (3) to study if there is a definite relation between the readings of the tint photometer and the glarimeter for successive increases in darkness and finish as produced by progressive calendering.

For description of the Ives Tint Photometer reference is made to our previous paper.

Through the courtesy of the Badische Company, New York City, some paper dyeings made on a furnish of 80 per cent groundwood and 20 per cent unbleached sulfite stock and sized with rosin size were obtained.

A paper which will be designated a "brown shade" using per 1000 pounds of stock,

Vesuvine BPX 4 lbs. Auramine Conc. 12 oz. Safranin T extra Conc. 4 oz.

was accurately matched both for shade and depth of color by a dyed paper using per 1000 pounds of the same stock,

Auramine Conc. 3 lbs. 2½ oz. Safranin T extra Conc. 2 lbs. 1½ oz. Victoria Green BF 1¼ oz.

and this dyeing will be designated as "brown match." These two dyeings matched well under both natural and artificial light and gave the following readings under the Ives Tint Photometer, the results being the average of 5 readings:

PARTS:	TINT PHOTOMETER READINGS			
	Red	Green	Blue	Black
Brown shade.....	73.7	37.1	31.0	158.2
Brown match.....	73.8	37.2	30.9	158.1

A "blue shade" was prepared using per 1000 pounds paper stock, consisting of 80 per cent groundwood and 20 per cent unbleached sulfite,

Methyl Violet N 3 lbs. 10½ oz. Victoria Blue B Conc. 1 lb. 10½ oz.

This was matched with a "blue match" using per 1000 pounds of the same stock,

¹ Paper, August 2, 1916, and THIS JOURNAL, 8 (1916), 711.