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FILTER PAPER STUDIES III

EFFECT OF pH AND ADDED ELECTROLYTES

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NRL REPORT NO. C-3226

FILTER PAPER STUDIES III

EFFECT OF pH AND ADDED ELECTROLYTES

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Hollingsworth & Vose Company
East Walpole, Massachusetts

Approved by:

Dr. P. Borgstrom, Superintendent, Chemistry Division

Problem No. 32C04-05 January 28, 1948

NAVAL RESEARCH LABORATORY
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PREFACE

This Naval Research Laboratory report consists of two Research and Development reports written by the Hollingsworth and Vose Company, East Walpole, Massachusetts, on Navy Contract No. N-6-ORI-209. These reports are identified as follows:

> Research and Mill Trial on the Development of a Domestic Substitute for Esparto Fiber in the Navy Type H-60 Filter Paper, Third Quarter of Contract No. N6 ORI-209, referred to as the N-5 Trial.
>
> Research and Mill Trial on the Development of a Domestic Substitute for Esparto Fiber in the Navy Type H-60 Filter Paper, Fourth Quarter of Contract No. N6 ORI-209, referred to as the N-6 Trial.

This report concludes the work under Contract No. N6-ORI-209. Filter paper studies are being continued by the Hollingsworth and Vose Company under Navy Contract No. N7-ONR-430 and additional reports will be published when received.

CONTENTS

ABSTRACT

This is an interim report describing in detail two mill runs and the associated laboratory work on the effects of pH and added electrolytes on Navy filter paper. It is shown that both pH and added electrolytes influence the performance of the paper. Additional work is planned on the effects of each of these variables. Filter papers with exceptionally high filtering efficiencies have been made in the laboratory from a furnish consisting only of causticized wood pulp and Blue Bolivian asbestos. This simplified furnish eliminates to a large extent the DOP break and relaxation effects encountered previously with mixed-fiber papers.

RESEARCH AND MILL TRIAL ON THE DEVELOPMENT OF A DOMESTIC SUBSTITUTE FOR ESPARTO FIBER IN THE NAVY TYPE H-60 FILTER PAPER (N-5)

INTRODUCTION

This report covers the work done for the third quarter of Contract No. N6-ORI-209. A statement of the general objectives and an outline of previous work accomplished is contained in past reports of this series.*

The mill trial reported here is designated as the N-5 trial, H & V Lot No. 9979, dated May 5, 1947.

On the basis of repeated good results obtained on paper made solely from causticized kraft and asbestos, it was decided to work on a furnish of this type.

LABORATORY WORK

The unusual freeness of causticized kraft fibers indicated that little difficulty would be encountered in accomodating sufficient asbestos in a sheet while maintaining a reasonable caliper and resistance.

A summary follows of handsheet performance data obtained from furnishes of, 80% Causticized kraft and 20% Blue Bolivian asbestos. These handsheets were made from this stock prepared in a laboratory beater.

TABLE I

Handsheet Performance Data

Sample	DOP Penetration (%)	Resistance (mm H_2O)	Efficiency (%)	Flexed DOP Penetration (%)	Flexed Resistance (mm H_2O)	Flexed Efficiency (%)
1	.012	130	3.02	.005	124	3.47
2	.006	130	3.25	.004	124	3.54
3	.010	123	3.25	- -	- -	- -
4	.012	123	3.19	.010	105	3.81

* Knudson, H. W., "Filter Paper Studies I. Effect of Replacing Esparto with Yucca Fiber," NRL Report C-3172, September 1947.
Knudson, H. W., and Pasternack, S. J., "Filter Paper Studies II. Effect of Replacing Esparto with Wood Pulp Fiber," NRL Report C-3225, January 1948.

The above samples show exceptionally good initial filtering performance, probably as good as any recorded at this company. The effect of flexing is evident and probably could be partially duplicated by spray treatment.

This paper also had a very low rate of "break" as evidenced by the data in Table II.

TABLE II

Effect of DOP Exposure on Performance of Handsheet

Time (Min)	DOP Penetration (%)	Resistance (mm H_2O)
0	.010	123
1	.010	123
2	.012	123
3	.012	123½
5	.012	124
8	.012	124½

This rate of "break" was unusually slow. In interpretation of these data allowance should be made for possible variations in smoke concentration, fatigue of photo cell, and change in "owl" reading. A similar sample when flexed before "break" testing acted in the same manner.

Results of an asbestos distribution test, i.e. Performance vs Flow Rate is recorded in Table III.

TABLE III

Performance vs Flow Rate

Sample Flow Rate (l/m)	DOP Penetration (%)	Resistance (mm H_2O)
85	.008	120
42½	.004	60
21¼	.002	30

A well formed sheet with good asbestos distribution has a penetration that decreases with flow rate. From the data in Table III this paper showed the best asbestos distribution and mechanical perfection thus far encountered in this work.

In laboratory production of handsheets it has been noticed that sheets made of the same furnish but from different batches had different filtering efficiencies. Attempts to standardize materials, handling procedure, and sheet-formation procedure had failed to stop the variations. Of the possibilities investigated it appeared that the factors in most need of attention were condition of the asbestos and the mixing of the stock.

From a literature survey it was found that asbestos is affected by electrolytes. It was reported that salts having strongly adsorbable anions available in solution would tend to agglomerate the asbestos, and salts having strongly adsorbable cations available in solution would help disperse the asbestos. A patent to that effect was issued in 1933.†

In laboratory tests it was found that asbestos treated with a salt having available adsorbable cations (aluminum chloride, $AlCl_3$) did visually open up the asbestos fiber bundles and did help to disperse the asbestos in water.

Following is a summary of handsheet performance data obtained from furnishes of 80% causticized kraft and 20% Blue Bolivian asbestos (treated). The asbestos was treated with 1% aluminum chloride ($AlCl_3 . 6H_2O$) on the weight of asbestos. The stock was prepared in the laboratory beater, and handsheets were made in the usual manner.

TABLE IV

Performance Data of Handsheets Containing Treated Asbestos

Sample	DOP Penetration (%)	Resistance (mm H_2O)	Efficiency (%)	Flexed DOP Penetration (%)	Flexed Resistance (mm H_2O)	Flexed Efficiency (%)
1	.008	137	2.98	.005	121	3.55
2	.008	144	2.83	.005	123	3.50
3	.005	147	2.93	.002	128	3.67
4	.007	135	3.07	.006	115	3.68

The above samples show very good performance. Though efficiencies seem slightly lower than those of the sheets made with untreated asbestos, it is believed that the efficiencies calculated above are not too accurate due to the inaccuracy of the smoke meter at the extremely low penetrations.

Table V shows the rate of "break" with exposure to DOP smoke on these sheets.

TABLE V

Effect of DOP Exposure on Performance of Handsheets Containing Treated Asbestos

Time of Exposure (Min.)	DOP Penetration (%)	Resistance (mm H_2O)
0	.005	121
1	.005	121½
3	.005	122
5	.005	122
8	.005	122½

It appears that rate of "break" is not hindered, and may actually be decreased, by the treatment of the asbestos with aluminum chloride.

† Tucker, George R., U. S. Patent 1,907,616, May 9, 1933

Table VI is a record of performance vs flow rate used to check asbestos distribution and sheet formation.

TABLE VI

Performance vs Flow Rate of Handsheets
Containing Treated Asbestos

Sample Flow Rate (l/m)	DOP Penetration (%)	Resistance (mm H_2O)
85 l/m	.009	108
$42\frac{1}{2}$	.006	54
$21\frac{1}{4}$	.002	27

The asbestos distribution and the sheet formation as indicated by the data are very good. It appears that treating the asbestos with aluminum chloride does not hinder asbestos distribution in the sheet and does not hinder sheet formation.

On the basis of the preceding data it was decided to make a run using only causticized kraft and Blue Bolivian asbestos. In view of the assistance in asbestos distribution offered by aluminum chloride, without hindrance to filtration properties, it was further decided to treat the asbestos with 1% aluminum chloride ($AlCl_3.6H_2O$) on a weight basis.

THE MILL RUN

Preparation of Stock for Mill Trial

The preparation of the causticized kraft was carried out according to a standard procedure followed at this mill as outlined in the N-3 trial run. ‡

Manufacturing Data for N-5 Trial

One beater was furnished with the following:

710 lb	Causticized kraft	88%
100 lb	Blue Bolivian asbestos	12%
810 lb		100%

The asbestos was furnished to the beater first and given a hard beat for about 20 minutes. One pound of aluminum chloride ($AlCl_3.6H_2O$) was added to the beater, and the asbestos was beaten for an additional 20 minutes. The degree to which the asbestos was defibered was carefully checked. Further beating did not defiber the asbestos to any observable degree.

The beater roll was then raised and the causticized kraft was added. No further beating was done, but the stock was allowed to circulate for at least 30 minutes to insure thorough mixing. At the end of this time the stock was "backed-up" in the Jordan (sent through under pressure with the Jordan plug backed off), to further insure good mixing,

‡ NRL Report C-3225

and was sent to the machine for felting into paper. Approximately 5% more treated asbestos was added to the stock from the auxiliary asbestos feed line as the stock was fed to the Fourdrinier.

In an effort to minimize calendering, all but one calender roll was jacked up permitting the use of one light roll as compared to three light rolls used in the N-4 trial run.

The paper was sprayed with a wetting agent as indicated below. No great difficulty was experienced in formation and handling of the paper over the machine.

Performance of the Paper

The physical tests recorded in Table VII are for the 5% spray-treated paper.

TABLE VII

Physical Tests of Spray-Treated N-5 Paper

Caliper	0.044 in.
Ream Weight	157 lb
Tear	
Length	32 g
Cross	32 g
Tensile	
Length	1.0 lb
Cross	0.75 lb
Moisture	3.5%

The values in Table VII are average values for the sprayed paper, and their use must be tempered with the knowledge that tear and tensile tests are not too accurate in these low ranges

Table VIII is a record of performance characteristics of the paper as it was sampled directly from the machine over a period of about two hours.

TABLE VIII

Performance Data of Samples Taken Directly from Paper Machine

Conditions of Manufacture	DOP Penetration (%)	Resistance (mm H_2O)	Efficiency (%)	Flexed DOP Penetration (%)	Flexed Resistance (mm H_2O)	Flexed Efficiency (%)
No spray - 5% asbestos added	.050	130	2.54	.040	116	2.92
5% spray - 5% asbestos added	.035	113	3.06	- - -	- - -	- - -
	.035	112	3.08	- - -	- - -	- - -
	.020	122	3.03	- - -	- - -	- - -
	.020	117	3.16	- - -	- - -	- - -
	.018	122	3.06	.024	107	3.38
	.018	125	2.99	.022	118	3.11
	.024	120	3.02	.030	114	3.10
	.025	114	3.16	.040	103	3.30
	.040	110	3.08	.040	104	3.27

The increase in efficiency due to spray treatment is evident, however, further increases in efficiency may be realized by flexing the spray-treated samples.

Based on initial performance it appears that causticized kraft can be successfully substituted for the mixed fiber furnishes used heretofore.

On further study, this paper was noted to have the properties of very slow rate of "break", no relaxation with aging, good asbestos distribution, and good mechanical formation.

Effect of DOP Exposure

Table IX shows the effect of DOP exposure on smoke penetration.

TABLE IX

Effect of DOP Exposure on Performance of N-5 Trial Sample

Time of Exposure (Min.)	DOP Penetration (%)	Resistance (mm H_2O)
0	.045	119
1	.046	120
2	.046	120
3	.046	120½
4	.046	121
5	.046	121
6	.046	121½
7	.046	121½
8	.047	122

This paper exhibited the slowest rate of "break" of any paper made in the mill under this contract. The reasons for observed difference in rate of "break" on different papers are unknown; however, the mixed-fiber filter papers did exhibit higher rate of "break" than did this paper made of causticized kraft and asbestos. This would indicate that either a fiber or a combination of fibers used in the mixed-fiber furnishes was responsible for the higher rate of "break".

Relaxation with Aging

The relaxing effect upon aging (increased penetration accompanied by small decreases in resistance) was checked, and typical results are recorded in Table X.

TABLE X

Effect of Aging on Performance

Interval after manufacture	DOP Penetration (%)	Resistance (mm H_2O)
2 hours	.030	113
3 days	.035	115
17 days	.034	110

There is no doubt that relaxation did not take place in this paper. Though there is a difference in both penetration and resistance of the samples tested at the various times, a comparison of the data taken in any two test periods shows a difference no greater than that normally encountered between data taken in one test period. The differences appear to be due to sampling at different machine positions and machine times. It appears that from the relaxation standpoint the simplified furnish of causticized kraft and asbestos produces a paper that is superior to any thus far made under this contract.

Performance vs Flow Rate

Paper having good asbestos distribution and mechanical formation will have a penetration that decreases with decreased rate of flow.

TABLE XI

Performance vs Flow Rate

Sample Flow Rate (l/m)	DOP Penetration (%)	Resistance (mm H_2O)
85	.045	117
42½	.034	60
21¼	.018	30

From Table XI it seems that good asbestos distribution and good mechanical sheet formation were realized. However, it appears that in the mill run asbestos distribution was not as good as that obtained in the production of laboratory handsheets.

The handsheets formed in the laboratory were made from the same furnish as was used in this mill run. Either poor mixing was realized in the mill run or some unknown influence hampered asbestos distribution. However, in view of the special precautions taken during this run to insure good mixing it appears that probably the latter reason is more substantial.

RECOMMENDATIONS

Based on the very good filtering efficiency, the exceptional resistance to "break" and the lack of relaxation with aging obtained with this paper, it is recommended that work be continued on a furnish of the N-5 type, causticized kraft and asbestos.

It is further recommended that additional work be concentrated on preparation and handling of the stock, particularly the asbestos, and that the control of all variables up to and over the machine be studied and standardized. From present studies it appears that asbestos is affected markedly by pH and certain electrolytes. Work should be continued on these important variables.

RESEARCH AND MILL TRIAL ON THE DEVELOPMENT OF A DOMESTIC SUBSTITUTE FOR ESPARTO FIBER IN THE NAVY TYPE H-60 FILTER PAPER (N-6)

INTRODUCTION

This report covers the work done for the fourth quarter of Contract No. N6-ORI-209. A statement of the general objectives and an outline of previous work accomplished is contained in past reports.*

The mill trial reported here is designated as the N-6 trial, H & V Lot No. 36, dated June 23, 1947.

On the basis of repeated good smoke filtration results obtained with paper made solely from causticized kraft and Blue Bolivian asbestos it was decided to continue work on a furnish of this type with the objectives of increasing the tensile strength and increasing the filtration efficiency of the final sheet.

LABORATORY WORK

Results of Some Earlier Runs

The N-5 mill run, containing only causticized kraft and Blue Bolivian asbestos, produced a filter paper that easily met smoke filtration specifications, but the tensile strength was low and might cause difficulty in fabrication of the filter in the Navy gas-mask canisters. The N-3 and N-4 papers, containing causticized kraft and Blue Bolivian asbestos plus cotton flock, rayon flock and rope, had appreciably higher tensile strengths by virtue of the rope fiber incorporated into them. On the basis of these past runs it was felt that enough rope could be added to an N-5 type furnish to increase materially the tensile strength of the sheet without any appreciable loss in filtering efficiency. By a comparison with the N-5 paper an evaluation could be made of the effect of the rope on the sheet.

As stated in the N-5 report, various batches of the same type of furnish have produced sheets with different efficiencies though handling procedure had been standardized. It was felt that some variables of the system were escaping control. Also as previously stated, it was found that the behavior of asbestos slurries was markedly affected by pH and various electrolytes. It was felt that a better understanding and closer control of the erratic behavior of asbestos would tend to eliminate some of the variations in the filter paper.

"Freeness" Measurements

The major portion of laboratory work during this quarter was spent on a detailed study of the effect of pH and various electrolytes on asbestos, and on asbestos and

* NRL Reports C-3172 and C-3225

causticized-kraft slurries. Very few definite reproducible results were obtained; however, several observations can be stated.

As a control of asbestos, it has been standard practice to measure the length of time ("freeness") necessary to screen water from a definite volume of asbestos slurry at a given concentration on a standard screen using a conventional paper-makers' piece of test equipment, a Roger's Freeness Indicator. The actual properties of the asbestos measured in this piece of equipment are not definitely known, but it is believed that the measurements obtained are indicative of properties affecting the filter paper. It has been found that on the same batch of asbestos, "freeness" readings could be varied as much as ten-fold by changing the pH as little as two or three units. These changes in "freeness" cannot be reproduced at will, nor have they always occurred at a particular pH. It has been found that the addition of certain electrolytes, aluminum chloride ($AlCl_3$) for example, will change the "freeness" readings markedly, and that maximum and minimum "freeness" readings may be encountered at various pH readings. These pH readings do not necessarily coincide with the pH readings at the maximum and minimum "freeness" readings of asbestos slurries not containing $AlCl_3$. It has also been found that the concentration of the added electrolyte affects the "freeness."

Many dispersing, wetting, and cationic agents were tried, and all affected the behavior of asbestos in water and affected the "freeness" readings. Sufficient information is not available to make any general statements or to explain the observed behavior. Unfortunately it is also impossible to explain what changes in properties are indicated by changes in "freeness" measurements.

Slurries of causticized kraft and asbestos showed very minor changes in "freeness" with changes in pH or with the addition of electrolytes, however the small increases or decreases in "freeness" seem to coincide with those obtained with asbestos slurries similarly handled.

pH Studies

To study the effect of pH on the final properties of the filter paper, a series of handsheets were made at the pH ranges most representative of the extremes in asbestos behavior. All sheets were made from a furnish of 80% Causticized kraft and 20% Blue Bolivian asbestos, Three separate batches were adjusted to pH ranges of 3, 5, and 9 and each batch was maintained at its particular pH until formed into handsheets. Typical "freeness" data of asbestos, and asbestos and causticized kraft at the different pH readings are listed in Table I.

TABLE I

"Freeness" Data vs pH

pH at Formation	Consistency (Wt. %)		Freeness (Sec)	
	Asbestos	Asbestos Causticized Kraft	Asbestos	Asbestos Causticized Kraft
3	0.2	0.5	552	240
5	0.2	0.5	567	254
9	0.2	0.5	1980	256

The above data show, though not as markedly as several other examples encountered, the possible variations in "freeness" with changes in pH. It is of interest to note that only minor changes occurred in the "freeness" readings of the asbestos-causticized kraft slurries.

Typical smoke-filtration performance performance of the sheets formed at the various pH ranges is recorded in Table II.

TABLE II

Performance vs pH

pH at Formation	DOP Penetration (%)	Resistance (mm H 0)	Efficiency (%)	Flexed DOP Penetration (%)	Flexed Resistance (mm H 0)	Flexed Efficiency (%)
3.0	.085	100	3.07	.040	100	3.40
3.0	.150	93	3.03	.085	90	3.42
3.0	.180	90	3.05	.100	87	3.44
3.0	.025	109	3.31	.022	105	3.49
5.0	.028	110	3.25	.028	100	3.55
5.0	.032	105	3.33	.030	96	3.67
9.0	.11	99	2.99	.10	96	3.13
9.0	.080	100	3.10	.060	97	3.32
9.0	.065	104	3.07	.045	102	3.28
6.0*	.060	89	3.62	.035	86	4.02
6.0*	.075	86	3.68	.060	83	3.88
6.0*	.050	91	3.62	.032	89	3.93

* Asbestos treated with 1% aluminum chloride.

From the above data it appears that pH does influence filtering efficiency. It would appear that at a pH of approximately 5.0 the best sheet was produced. However, realizing the possibility of the erratic behavior of asbestos these results are not assumed to be conclusive. It is of interest to note the exceptionally high filtering efficiencies of all the samples tested.

The last series of sheets recorded in Table II were formed at a pH of approximately 6. The asbestos in these sheets was treated with 1% aluminum chloride ($AlCl_3 \cdot 6H_2O$) on the weight of asbestos. The efficiencies recorded for this series were exceptionally high, probably the highest ever encountered at this mill in either mill paper or experimental handsheets. Paper with such high efficiencies cannot be duplicated at will even in the laboratory, although handling procedure is standardized.

Upon checking rate of "break" with exposure to DOP smoke on the handsheets made at various pH values, it was found that all the sheets exhibited the same behavior, i.e., little or no "break" during the test periods of approximately 10 minutes. This exceptionally slow rate of "break" is a property that has persisted since the elimination of the mixed-fiber type furnish.

Table III is a record of performance vs flow rate at different pH values, used to check asbestos distribution and sheet formation.

All of these samples show a normal decrease in penetration with a decrease in flow rate. This would indicate that good asbestos distribution and good sheet formation were

TABLE III

Performance vs Flow Rate at Different pH Values

pH at Formation	Sample Flow Rate (l/m)	DOP Penetration (%)	Resistance (mm H_2O)
3	85	.092	96
3	42	.068	48
3	21	.038	24
5	85	.072	92
5	42	.056	48.5
5	21	.032	24
9	85	.12	94
9	42	.097	47
9	21	.045	24

realized. It would be extremely difficult to differentiate one sample as being better than any other. For all practical purposes the samples are assumed to be approximately alike on an asbestos-distribution and sheet-formation basis.

THE MILL RUN

Preliminary Considerations

On the basis of the preceding data and discussions, it was decided to make a run using causticized kraft, Blue Bolivian asbestos, and rope fiber. A small amount of rope fiber would be added to increase the tensile strength of the sheet, but not enough to injure smoke filtering efficiency. Since such exceptionally high efficiencies were realized when asbestos was treated with aluminum chloride, 1% aluminum chloride ($AlCl_3 6H_2O$) was to be added to the asbestos.

In the actual machine run, it was decided to change progressively the pH of the stock as it is pumped to the machine and to check the various properties of the sheet as formed in the different pH ranges.

Since this trial was to precede a lengthy mill production run of a similar filter, the Army H-64 filter which is run at pH above 8, it was felt that this run should be limited to pH considerations of less than 8. This decision was also influenced by the possibility of flocking out gelatinous aluminum hydroxide formed from the aluminum chloride at high pH. This flock might slow down the stock on the machine and might prove injurious to the paper.

Preparation of Stock for Mill Trial

The preparation of the causticized kraft was carried out according to a standard procedure followed at this mill as outlined in the N-3 trial run.

Manufacturing Data

One beater was furnished with the following:

710 lb	Causticized kraft	82%
100 lb	Blue Bolivian Asbestos (Treated)	12%
55 lb	Rope fibers	6%
865 lb		100%

The asbestos was furnished to the beater first and given a hard beat for about 20 minutes. One pound of aluminum chloride ($AlCl_3 \cdot 6H_2O$) was added to the beater, and the asbestos was beaten for an additional 20 minutes. At the end of this time the asbestos was well defibered.

The rope was then added and the asbestos and rope were beaten for approximately 10 minutes. At the end of this period the rope was defibered and well dispersed.

The beater roll was then raised and the causticized kraft was added. No further beating was done, but the stock was allowed to circulate for at least 30 minutes to insure thorough mixing. At the end of this time the stock was dropped to a chest where the pH was adjusted to 8 with caustic soda. Then the stock was pumped to a Fourdrinier machine for felting into paper. Approximately 5% treated asbestos was added to the stock before it entered the machine head box.

To minimize calendering, all but one calender roll were jacked up permitting the use of but a single roll.

The paper was sprayed with a 5% solution of wetting agent. The pH was lowered by the addition of muriatic acid to the machine chest. No difficulty was experienced in the formation and handling of the paper over the machine.

Performance of the Paper

The physical tests recorded in Table IV are for spray-treated samples taken during the run. Average values are presented of representative samples at the various imposed operational conditions.

TABLE IV

Physical Tests of Spray-Treated N-6 Paper

Conditions of Manufacture	Caliper (in.)	Ream Weight (lb.)	Tear L (g)	Tear C (g)	Tensile L (lb)	Tensile C (lb)	Moisture (%)
1 Nip, pH 8.0	.050	171.0	32	40	2.5	1.9	7.5
2 Nips, pH 6.4	.036	145.5	24	24	2.4	1.7	6.2
2 Nips, pH 5.3	.031	129.0	16	24	1.9	1.5	4.7

The variations in the recorded tear and tensile strengths seem considerable, but the major portion of the difference is traced directly to the variations in the ream weight. Table V shows the tear and tensile strengths of these sheets calculated for a ream weight of 150 pounds.

Though differences in tear and tensile strengths are indicated, it would be impossible to make any generalization since tear and tensile tests are not very accurate in these low

TABLE V

Calculated Physical Characteristics at Constant Ream Weight

Conditions of Manufacture	Ream Weight (lb.)	Tear L. (g)	Tear C. (g)	Tensile L. (lb)	Tensile C. (lb)
1 Nip, pH 8.0	150	28	35	2.2	1.7
2 Nips, pH 6.4	150	25	25	2.5	1.8
2 Nips, pH 5.3	150	19	28	2.2	1.7

ranges; however, tear strength seems to decrease with pH. Apparently the small amount of rope incorporated into this furnish increased tensile strength above specifications, and it is felt that from a strength consideration no difficulty would be encountered in fabrication of the filter in the Navy canister.

Table VI is a record of performance characteristics of the sprayed paper as it was sampled directly from the machine run over a period of about two hours.

TABLE VI

Performance Data of Sprayed Samples Taken Directly from Paper Machine

Conditions of Manufacture	DOP Penetration (%)	Resistance (mm H_2O)	Efficiency (%)	Flexed DOP Penetration (%)	Flexed Resistance (mm H_2O)	Flexed Efficiency (%)
1 Nip, pH 8	.100	120	2.50	.100	111	2.71
1 Nip, pH 7.5	.150	114	2.48	.150	104	2.72
1 Nip, pH 6.9	.240	108	2.43	.240	98	2.68
2 Nips, pH 6.4	.070	120	2.63	- - -	- - -	- - -
2 Nips,pH 6.2	.090	114	2.68	- - -	- - -	- - -
2 Nips, pH 5.3	.022	133	2.75	- - -	- - -	- - -
2 Nips, pH 5.3	.038	130	2.63	.050	120	2.74
2 Nips, pH 5.3	.068	112	2.83	- - -	- - -	- - -
2 Nips, pH 5.3	.082	106	2.91	- - -	- - -	- - -
2 Nips, pH 5.3	.065	115	2.77	- - -	- - -	- - -

The above data show considerable variations in penetration, resistance, and efficiency. During the machine run it was impossible to maintain consistently any of the properties of the sheet. Throughout the run the machine had to be adjusted and readjusted for changes occurring in the stock while the pH was changed.

Filtering efficiencies appeared to be increasing as pH dropped from 8 to 5. From pH 8 to approximately pH 6.5 the finished sheet did not meet filtration specifications. At pH below 6.5 the paper did meet specifications. However, the introduction of 2 nips on the calender stack at pH below 6.5 may have been partially or totally responsible for the increases in filtering efficiency. The exact reason for the change may be masked, but the fact remains that as pH changed there was also encountered a change in filtering efficiencies.

> Note: From the Army run it was found that the best Army paper was made at pH 10 to 10.5. In this range the sheets excelled in resistance and penetration, and on a standard ream weight the tensile strength was at a maximum. During the run, tensile strength and filtration properties did occasionally fall below specifications, and each time it was found that the pH was below 9.5. If the pH were adjusted to 10 or more, these difficulties would disappear within an hour or two, but usually not immediately.

From these facts it would appear that there are optimum pH ranges in the formation of this type of filter. In general the latter half of the run produced a sheet that was superior. This paper met specifications for strength, resistance, and penetration.

On further study it was found that this paper exhibited a very slow rate of "break", no relaxation with aging, good asbestos distribution, and good mechanical formation.

Effect of DOP Exposure

Table VII shows the effect of DOP exposure on performance.

TABLE VII

Effect of DOP Exposure on Performance
of N-6 Trial Sample

Time of Exposure (Min.)	DOP Penetration (%)	Resistance (mm H_2O)
0	.044	117
1	.044	117
2	.044	118
3	.046	119
4	.046	119
5	.048	120
6	.047	120

That the very slight "break" recorded above was due primarily to deformation of fibers in the sheet during the test at high flow rates was shown by backing a sample with gauze and testing. The results of this test are recorded in Table VIII.

It appears that this paper exhibited little or no "break" upon exposure to DOP smoke.

TABLE VIII

Effect of DOP Exposure on Performance
of Gauge-Backed N-6 Trial Sample

Time of Exposure (Min.)	DOP Penetration (%)	Resistance (mm H_2O)
0	.028	128
1	.027	128
2	.028	129
3	.029	130
4	.028	131
5	.028	132
6	.028	132

Relaxation with Aging

The relaxing effect upon aging (increased penetration accompanied by small decreases in resistance) was checked, and typical results are recorded in Table IX.

TABLE IX

Effect of Aging on Performance

Interval after Manufacture	DOP Penetration (%)	Resistance (mm H_2O)
No Interval	.068	112
1 Day	.076	111
4 Days	.050	113

Though there appear to be variations in both resistance and penetration on the recorded samples, these differences are caused by sampling at different machine positions and machine times. It is certain that relaxation did not take place in this paper during the period observed.

Performance vs Flow Rate

Mechanical perfection and good asbestos distribution are indicated by a normal decrease in penetration with decrease in rate of flow through the sample. The results of the study are recorded in Table X.

TABLE X

Performance vs Flow Rate

Sample Flow Rate (l/m)	DOP Penetration (%)	Resistance (mm H_2O)
85	.064	114
$42\frac{1}{2}$	.046	57
$21\frac{1}{4}$	.024	28.5

From the above it is apparent that very good asbestos distribution and mechanical formation were realized during this run.

RECOMMENDATIONS

In view of the facts that filter paper made from causticized kraft, rope fibers, and Blue Bolivian asbestos met specifications of smoke filtration and physical strength, did not relax with aging, and did not "break" upon exposure to DOP smoke, it is recommended that work be continued on a furnish of this type.

From this run it was found that pH did affect the final properties of the sheet; hence, information should be obtained to substantiate the optimum stock pH range, and the maintenance of this range should become standard practice.

Certain electrolytes do have a marked effect upon the sheet, but the degree of influence, whether good or bad, is not definitely known. Work should be continued to study the effect of electrolytes on "freeness" readings and on the final sheet.

As evidenced by initial efficiencies above 3.5 obtained occasionally with handsheets, many improvements in the present machine-made paper are possible. It is recommended that attempts be continued to increase the efficiency of the present machine-made paper.

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