NRL REPORT NO. C-3172

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FILTER PAPER STUDIES I
EFFECT OF REPLACING ESPARTO WITH YUCCA FIBER (C)

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NAVAL RESEARCH LABORATORY
COMMODORE H. A. SCHADE, USN, DIRECTOR
WASHINGTON, D.C.

FILTER PAPER STUDIES I
EFFECT OF REPLACING ESPARTO WITH YUCCA FIBER (C)

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Problem No. 32C04-05 September 11, 1947

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PREFACE

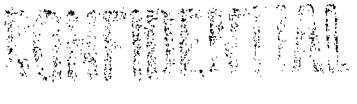
This Naval Research Laboratory Report consists of two Research and Development Reports written by Harold W. Knudson of the Hollingsworth and Vose Company, East Walpole, Massachusetts, on Navy Contract No. N6 ori-34.

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," First Quarter 1946, dated April 15, 1946. (Referred to as the N-1 Trial.)

"Research and Mill Trial on the Development of a Domestic Substitute for Esparto Fiber in the Navy Type H-60 Filter Paper," Second Quarter 1946, dated July 25, 1946. (Referred to as the N-2 Trial.)

This report concluded the work on contract No. N6 ori-34. Filter paper studies are being continued by the Hollingsworth and Vose Company and additional reports will be published when received.



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ABSTRACT

This is an interim report describing in detail two mill runs and the associated laboratory work on the effects of replacing esparto with yucca fiber in the Navy H-60 filter paper. It is shown that a satisfactory filter paper can be manufactured using the domestic yucca fiber. The presence of rayon in the filter paper is shown to be objectionable. The effect of "flexing" the filter paper requires further study.

RESEARCH AND MILL TRIAL ON THE DEVELOPMENT OF A DOMESTIC SUBSTITUTE FOR ESPARTO FIBER IN THE NAVY TYPE H-60 FILTER PAPER (N-1 TRIAL)

INTRODUCTION

The present H-60 filter paper used in the Navy gas mask was largely developed through an NDRC contract held by A. D. Little, Inc., Cambridge, Massachusetts. However, the Naval Research Laboratory, Washington, D. C. took an active part in the direction and supervision of this work. Most of the development work leading up to the adoption of this filter paper by the Navy was done at the West Groton Mill of the Hollingsworth & Vose Company, East Walpole, Massachusetts.

The paper that was finally adopted, known as H-60 Filter Paper, had a base composition approximately as follows:

A. Stock. 80%
- Causticized Esparto. 60%
- Cut Cotton Flock 35%
- Hemp 5%

B. Additive. 20%
- Blue Bolivian Asbestos.....100%

Milban-D, a fungicide, was added to improve the resistance to mildew. The finished sheet was later treated with Drifilm to lay down a silicone resin on the fibers. This made it water repellent to the extent that the paper would support a static head of water greater than twenty inches for relatively long periods of time.

The need for further work on this filter paper is indicated by the fact that esparto is imported from Africa, and in wartime this source is somewhat uncertain. Therefore it was considered highly desirable to develop a domestic substitute for this fiber.

Accordingly a Navy Contract, N6 ori-34, was placed with Hollingsworth & Vose Company for this purpose. This contract was written to cover two trial runs of paper on the regular mill equipment together with the necessary laboratory work leading up to and following the runs. The first run was scheduled for the first quarter of 1946 and the second run for the second quarter of 1946. This report covers the first trial run designated as N-1 Filter Paper, H & V Lot 9449.

LABORATORY WORK

Selection of Fiber

For several reasons attention was centered on yucca fiber as a domestic substitute for esparto. Briefly these reasons may be summarized as follows:

1. The fiber is native to this country and grows in abundance in the Southwestern states.

2. Previous work on the part of this company indicated that the average fiber diameter of yucca was about the same as for esparto (0.008 - 0.009 mm) although the range of fiber diameters was somewhat greater than for esparto. The average length of the yucca fiber is more than twice that of the esparto fiber, but that is not thought to be a limitation.

3. Some experience had been gained in cooking and preparing the yucca fiber from a previous attempt to use this fiber in the older type H-42 Navy filter paper.

4. The fiber resists hydration and responds to the causticizing treatment familiar to the paper trade for increasing its "freeness". In this respect it is different from some of the other fibers of this class such as rice straw, wheat straw, and caroa.

5. An adequate inventory of this material was on hand to carry out the work.

Preliminary Work on Yucca Fiber

Although an earlier trial had been made using yucca in the H-42 type of Navy filter paper, there was no experience to indicate that the fiber could be cleaned up and causticized to a "freeness" required to meet the much more rigid specifications of the H-60 type of filter paper.

Accordingly samples of the cooked stock were treated in the laboratory to learn the best procedure to follow in the mill. An examination of this stock revealed considerable amounts of sand, dirt and other non-fibrous contamination which could not be washed out successfully through the washing screens in the beater. This indicated that it would be desirable to run the yucca stock over the paper machine once or twice before mixing with the other fibers. This would also provide additional opportunities to pass the stock through the sand traps and Centrifiners.

Since the "freeness" of the stock largely determines the air resistance of the paper, it was considered important to causticize the yucca by the Krayfelt treatment to as nearly the same degree as was used for the esparto.

Two-gram hand sheets of the regular causticized esparto stock showed an air resistance under standard conditions of test of 10 mm water. In order to match this, two-gram hand sheets were made up from yucca stock causticized for 30 minutes at varying concentrations of caustic soda. The consistency used was 5 parts solution to 1 part of stock. In all cases, the stock was washed in the laboratory beater until free from the caustic before the hand sheets were made. In Table I are recorded the data of this work.

TABLE I

Caustic Soda Treatment of Yucca Stock vs Air Resistance

Concentration Caustic Soda (%)	Air Resistance (mm H_2O)
0	50
10	16
15	12
18	10
20	10

It is evident that the optimum concentration of caustic is between 15-18 percent. Accordingly, an 18 percent solution of caustic soda was used in this treatment in the mill operation.

Substitute for Cotton Flock.

Cut cotton flock was normally used in the esparto paper to help disperse the asbestos fiber and soften the sheet. In view of the present cotton shortage and the unfavorable ceiling prices, all attempts to secure cotton flock for this run failed. A reasonable substitute was found in rayon flock. This material, 1.5 denier cut 1/8th inch long, was blended with beaten cotton linter pulp in varying amounts to approximate the cotton flock. On the basis of laboratory hand sheets, these fibers in the ratio of 2 parts rayon flock to 1 part cotton linter pulp seemed to be roughly equivalent to the cotton flock in softness and air resistance,

This choice was further substantiated when handsheets were made up using this blend of fibers with the causticized yucca and prepared asbestos. Best penetration-air resistance performance was obtained from the handsheets made in the laboratory beater according to the formula detailed under "The Mill Run" of this report.(page 5). Some of the data on these handsheets are recorded in Table II

TABLE II

Performance of Handsheets

Sample	DOP* Penetration %	Air Resistance (mm H_2O)
1	0.12	105
2	0.10	110
3	0.055	114
4	0.035	125

* Measured by NRL Smoke Penetration Meter E2 or E2R1, NRL Instruction Manual A 825A, "Instructions for Canister Tests, Part II Filters, Section A, Smoke Penetration", 13 July 1945.

In all cases these samples before flexing had a higher penetration reading and a higher air resistance than the recorded value. Flexing in this case was accomplished by drawing the sample back and forth a few times over the edge of a desk top. Unfortunately no accurate data was recorded of this effect because it was thought to be due to the somewhat poorer formation of the handsheets than is realized on the paper machine.

However this effect was later observed (although to a less extent) on the machine samples also, so it may suggest some further study. The slight hydration of the cotton linter pulp may be a possible explanation for this effect.

Preparation of Yucca

The yucca plant as it was furnished to this mill apparently had been harvested by pulling the plant out of the sandy soil by its roots. A large amount of sand and other foreign material is therefore associated with the raw material. In the case of the previous attempt to use yucca (H-42 Filter Paper) it had been shown that much of this sand was carried through to

the finished paper and that it was definitely objectionable and impaired tne smoke filtering properties. It was decided, therefore to make a special effort to see if the fiber could be cleaned up satisfactorily.

The following operations were followed in the preparation of the yucca.

The Pre-Cook

Thirty-five hundred pounds of the raw yucca was loaded into the boiler and mixed with 7 parts water to 1 part stock. To this was added 175 pounds caustic soda (5% based on the dry weight of the stock). This was cooked two hours at 25 pounds steam pressure after which it was flushed with hot water and drained while the stock remained in the boiler.

The Cook

The stock was then diluted with more water to a ratio of 5 parts water to 1 part stock assuming that water in the amount of 75% of the original weight of the stock was retained. To this was added 525 pounds of caustic soda and 210 pounds of sodium sulfide (15% and 6% respectively based on the dry weight of the fiber). This was cooked at 50 pounds steam for 6 hours, after which it was dumped from the boiler and allowed to drain.

First Washing

This material was then transferred to a beater and washed until free from caustic. One to two hours may be required for this operation.

Machining (No. 1)

The yucca stock was then run over a Fourdrinier paper machine and dried. On its way to the machine the stock was made to flow over a sand trap and through a pair of Centrifines to remove as much foreign material as possible. There was still some contamination at this point which indicated that a second machining would be desirable before mixing the yucca with the other fibers.

Causticizing

This paper was then furnished to a boiler for the causticizing treatment. On the basis of the dry fiber, enough caustic and water were added to supply an 18% caustic solution in the ratio of 5 parts solution to 1 part of stock. This is a cold treatment and the stock was merely rotated in the boiler for approximately 30 minutes after which it was dumped and furnished to the beater.

Last Washing

Because of the large amount of free caustic in the stock at this point it was necessary to wash the stock in the beater thoroughly. Warm water was used for about one hour of the washing cycle and cold water for an additional one to two hours.

Machining (No. 2)

For purposes of removing more sand and foreign material, it was decided to run the stock over the sand traps, through the Centrifines and over the machine once again in preparation for the final furnish to the beater. This time the paper was not run over the dryers but was removed as wet broke. The additional sand and foreign material removed made

this operation worth while. At this point the yucca was ready to be mixed with the other fibers and furnished to the beater for the final time. The yield of prepared yucca fiber was only 300 pounds (less than 10%), but this is not be be considered representative of regular production. There is a certain minimum loss of fiber for any normal quantity of fiber treated in this way. Naturally the percentage yield will be much higher the larger the batch. In the case of esparto, the average yield was about 25 percent of the raw material. It is thought that the yield of yucca will be approximately the same.

THE MILL RUN

Manufacturing Data

As a result of the laboratory work, the following furnish was used:

Blue Bolivian Asbestos	18%
Causticized Yucca	52%
Viscose Rayon Flock	20%
Cotton Linter Pulp	10%
	100%

The asbestos was furnished to the beater first and given a hard beat for about 10 minutes. This resulted in a good dispersion of asbestos which showed no lumps of fibers when diluted with water and observed in a glass cylinder. The beater roll was then raised and the stock circulated in the beater while the remaining materials were added. After twenty minutes the mixing was judged complete and the stock was dropped to a chest from where it was pumped to the Fourdrinier machine for making the final product.

The amount of asbestos furnished to the beater was just insufficient to meet the smoke penetration specifications so a small additional amount of beater asbestos was fed to the stock on its way to the machine. By means of adjusting this continuous feed, the air resistance and smoke penetration of the finished sheet were controlled.

No special difficulty was encountered in handling this paper over the machine. The formation and general appearance were good. As far as the yucca fiber is concerned it was felt that this run demonstrated the fact that this raw material could be handled and cleaned up in the regular paper making equipment available at this mill.

Performance of the Paper

Typical of the physical tests on this paper are the data tabulated below:

TABLE III

Average Values of Physical Tests

Caliper	.035 in.
Weight	136 lb
Tear	
Length	24 g
Cross	32 g
Tensile	
Length	2.25 lb
Cross	1.75 lb
Moisture	4.3 %

This paper was extremely soft and could be creased without showing signs of breaking. In this respect it is quite superior to the regular H-60 paper.

Of special interest in this work are the smoke penetration and air resistance characteristics. For purposes of this study several samples covering a range from high to low resistance are included in the following table. All smoke penetration and resistance measurements were made on the NRL Smoke Penetration Meter E-2 at flows of 85 1/m.

TABLE IV

Performance and Efficiency of Mill Run Samples

Sample	DOP Penetration (%)	Resistance (mm H O)	Efficiency* (%)
1	0.115	106	2.77
2	0.110	108	2.74
3	0.100	110	2,73
4	0.052	118	2.78
5	0.022	125	2.92
Good Esparto Sample	0.050	110	3.00

*Percent Efficiency = $\frac{-\log P}{R} \times 100$

where P is the DOP Smoke penetration expressed in decimals rather than percent, and R is the resistance across the sample in mm of water under the standard conditions of test.

The samples of Table 4 were not flexed but were subjected to the action of several "nips" on the calender stock following the drying cans.

From Table 4 it will be observed that the quality of the yucca paper is such that it will meet existing Navy Specifications for type H-60 Filter Paper, but that it is not quite as good as the esparto paper. This is thought to be due not as much to replacing the esparto with the yucca as to replacing the cotton flock with the rayon flock. Further evidence to support this contention was discovered when it was learned that all samples of this run "broke" to DOP smoke relatively fast. After a very short initial exposure the penetration was observed to increase more rapidly with time of exposure than is normal for this type of paper. On several occasions in the past this same behavior was thought to be noted with the Army type 5 paper which also contains rayon flock. Insufficient data are on hand to demonstrate this clearly, so it is mentioned here only as a possible explanation.

That the sheet was well formed and free from sand pits and "pin holes" was shown by the fact that there was no inversion of the smoke penetration with decrease in the test flow rate. The so-called "pin hole effect" was not observed in any of the samples tested. Typical of the penetration-flow rate performance are the data given below for one sample:

TABLE V

Penetration-Flow Rate Performance of a Sample

Flow Rate (l/m)	DOP Penetration (%)	Resistance (mm H_2O)
85 1/m	.022	125
42.5	.016	62
32	.014	47

RECOMMENDATIONS

In view of the fact that it was possible to clean up the yucca fibers and handle the material with common paper making equipment, it is recommended that further work be done with this fiber during the second quarter of 1946 with a view toward improving the performance of the filter material.

Further work is also suggested to determine whether or not rayon flock is objectionable. Although it is a convenient flock to use and it imparts softness and good folding qualities to the paper there is some evidence that it may cause the filter to "break" rapidly with increase in exposure to smoke.

The improvement of this paper when flexed suggests that some fibers in the furnish were more or less hydrated. It is recommended that samples from later trials be examined for this effect in an effort to determine what fibers might be objectionable.

FORWARDING OF SAMPLE TO NRL

One roll of this N-1 Filter Material was waterproofed and sent to the Naval Research Laboratory, Washington, D. C. for examination.

RESEARCH AND MILL TRIAL ON THE DEVELOPMENT OF A DOMESTIC SUBSTITUTE FOR ESPARTO FIBER IN THE NAVY TYPE H-60 FILTER PAPER (N-2 TRIAL)

INTRODUCTION

This report covers the work done under this contract from April 1 to June 30, 1946. A statement of the general objectives together with an outline of the previous work done is contained in an earlier report covering the N-1 trial dated April 15, 1946.

The mill trial reported here is designated as the N-2 trial, H & V Lot No. 9544, dated June 17, 1946.

On the basis of the N-1 trial it was decided to continue work on the yucca fiber with a view toward improving the performance over the N-1 paper.

LABORATORY WORK

After checking the N-1 paper, it was felt that the rate of "break" to DOP smoke was higher than normal. Because of the smooth rod-shaped character of the rayon flock in this paper, the rayon was suspected as contributing to this effect. The effect of the rayon flock was not confirmed very accurately on the basis of hand-sheet data, but after consulting with NRL it was decided to proceed with the N-2 run omitting any rayon flock.

Cotton flock was the obvious choice to make for this substitution. The regular H-60 furnish calls for a purified cotton flock which was available during the war from Claremont Waste and Manufacturing Company, Claremont, New Hampshire. However, because of unfavorable OPA ceiling prices and raw cotton ceiling prices, their equipment has been modified for other purposes. The only source of cotton flock which could be located was Rayon Processing Company, Central Falls, R. I. They could supply only an unpurified flock, so samples were obtained for laboratory evaluation.

Their grade which most nearly matched the Claremont flock was designated as "Kingcote" 60A2. The physical dimensions as observed under the microscope appeared to be identical. However, the unpurified material appeared to have a wax-like coating on the fibers and wet out only with difficulty. In the presence of 0.1 percent Aerosol or a very dilute solution of sodium hydroxide the fiber was wet sufficiently to handle in the laboratory beater. Bleaching solution showed no advantage over either of the above solutions and was more troublesome to handle.

In practice it was shown that the residual caustic in the causticized yucca was sufficient to make possible the direct addition of this flock to the beater. It was not determined how completely the wax was removed, but hand samples containing the new flock indicated there was no deleterious effect.

On the basis of this preliminary work a mill trial was arranged calling for the same furnish as the regular H-60 paper substituting yucca for the esparto fibers and using the Kingcote 60A2 cotton flock.

PREPARATION OF THE STOCK

The experience gained during the N-1 mill trial indicated that the preparation of the yucca fiber was satisfactory in every respect. Consequently, no change was made in the procedure set up for the earlier run. The operations followed were exactly like those detailed in the preceding report except that the amount of stock was doubled. The steps are listed below and can be found discussed in detail in the report on the N-1 trial.

1. The Pre-cook
2. The Cook
3. First Washing
4. Machining (No. 1)
5. Causticizing
6. Last Washing
7. Machining (No. 2)

Approximately 6500 pounds of the raw yucca was used and resulted in a little over 600 pounds of prepared fiber. This yield was slightly higher than that for the N-1 trial. It is expected that the present 10 percent yield might be doubled in actual production.

(Note: It should be mentioned that the 5 tons of yucca purchased from the Mine Safety Appliances Company stock-pile has now been used up. If further work with this fiber is anticipated, more yucca should be purchased from this source.)

THE MILL RUN

Manufacturing Data

Each of two beaters was furnished with the following:

300 #	Causticized yucca	53.0%
150 #	Cotton flock	26.5
25 #	Prepared hemp	4.6
90 #	B.B. asbestos	15.9
565 #		100 %

The asbestos was furnished to the beater first and given a hard beat for about 10-15 minutes. No fiber lumps could be observed at the end of this time when the asbestos was diluted and viewed through a glass cylinder.

The beater roll was then raised and the stock circulated in the beater while the rest of the furnish was made to the beater. The yucca was added first, hemp second, and cotton flock last. The mixing was judged complete after twenty minutes and the stock was dropped to a chest from where it was pumped to the Fourdrinier machine for making the paper. Very little additional asbestos was required from the auxiliary asbestos feed.

The paper handled much the same over the machine as the regular H-60 grade. Formation and general appearance were good.

Performance of the Paper

The physical tests on this paper are tabulated below:

TABLE I

Average Values of Physical Tests

Caliper	0.037 in.
Weight	143 lb
Tear	
Length	24 g
Cross	24 g
Tensile	
Length	1.88 lb
Cross	1.44 lb
Moisture	3.6 %

If these tests are compared with the tests on the N-1 paper it will be observed that the N-2 paper is somewhat weaker in tensile and tear. This in part is due to the higher percentage of flock in the N-2 paper and also to the fact that slightly more pressure was used on the single calender nip. The higher pressure resulted in a softer sheet with a higher smoke filtering efficiency.

Table II shows the smoke penetration and air-resistance characteristics of this paper. The data are arranged in the order of increasing resistance and represent the average of several readings. Standard conditions of tests were used at a flow rate of 85 1/m using the NRL E2 Smoke Penetration Meter.

TABLE II

Performance and Efficiency of Mill Run Samples

Sample	DOP Penetration (%)	Resistance (mm H_2O)	Efficiency* (%)
1	.090	108	2.82
2	.075	111	2.81
3	.072	113	2.78
4	.064	114	2.80
5	.053	116	2.82
6	.046	119	2.80
7	.043	120	2.81
8	.040	121	2.81
Good Esparto Sample	.050	110	3.00

*Percent Efficiency = $\frac{-\log P}{R} \times 100$

where P is the DOP smoke penetration expressed in decimals and R is the air resistance across the sample in mm of water under standard conditions of test.

From Table II it will be observed that the penetration-resistance characteristics of this paper meet the existing Navy specifications for type H-60 Filter Paper. It cannot be claimed that this shows as good performance as some of the best esparto paper, but it is believed to be almost as good as the average esparto paper made in regular mill production. The yucca is somewhat more difficult to refine and process than the esparto, but this work indicates that it is commercially possible to substitute yucca for the esparto in this paper and yet maintain good penetration-resistance characteristics. Although the physical strength of the N-2 paper is slightly less than the regular H-60 paper, no difficulty is anticipated in handling or fabrication.

Effect of Flexing

In order to test further the effect of "flexing" of this paper, samples were exposed to DOP smoke under standard conditions before and after "flexing."

(Note: Flexing as used here refers to drawing the paper samples back and forth a few times over the corner of a desk top or similar object).

The data are recorded in Table III below. Some samples were selected which had higher than average "efficiency" in order that any increase in "efficiency" would not be misleading. It will be observed that samples 11-15 inclusive were flexed and tested some five weeks after the date of manufacture and the effect of flexing is still present. The fact that the efficiencies of Samples 11-15 before flexing were not as high as the samples selected in group 1-10 is partly explained by the fact that the samples came from different rolls. Samples 16-18 are included for comparison because the Army Type 6 paper was made from esparto and shows somewhat the same effect.

The increase in performance is outstanding and it would seem that further work on this aspect should be considered.

TABLE III

N-2 Filter Paper Manufactured 6/17/46
Performance Before and After Flexing

Date Flexed	Sample	DOP Penetration (%)		Resistance (mm H_2O)		Efficiency (%)	
		Before	After	Before	After	Before	After
6/17/46	1	.070	.064	110	101	2.83	3.16
	2	.060	.050	110	102	2.93	3.23
	3	.050	.038	114	102	2.90	3.35
	4	.051	.048	113	104	2.91	3.20
	5	.065	.050	110	103	2.90	3.20
	6	.052	.048	112	100	2.93	3.32
	7	.055	.044	113	102	2.89	3.29
	8	.070	.056	109	101	2.89	3.22
	9	.058	.054	113	102	2.87	3.20
	10	.065	.080	110	94	2.90	3.30
7/25/46	11	.066	.070	116	100	2.74	3.15
	12	.072	.068	115	104	2.73	3.05
	13	.072	.090	112	97	2.81	3.14
	14	.098	.092	108	97	2.79	3.13
	15	.100	.098	110	97	2.72	3.10
7/25/46	16	.088	.088	103	92	2.96	3.32
Army Type	17	.088	.087	102	96	2.99	3.19
Mfg. 5/27/46	18	.090	.086	102	95	2.99	3.22

Flow Rate versus Penetration

Mechanical imperfections in the paper as well as poor distribution of asbestos fibers is most conveniently observed by testing for the "pin-hole effect." The penetration is measured at several flow rates. If pin-holes or other imperfections are present, the penetration will not decrease in a normal way with decreasing flow rate, but will remain the same or increase. Table IV below shows a normal decrease in penetration with flow rate and is evidence of good formation and good distribution of asbestos. Samples of "flexed" paper are included to show that there is no serious mechanical disarrangement of the fibers after flexing.

TABLE IV

Performance vs. Flow Rate

Sample	85 1/m		42½ 1/m		32 1/m	
	Pen. (%)	Res. (mm H_2O)	Pen. (%)	Res. (mm H_2O)	Pen. (%)	Res. (mm H_2O)
Not Flexed	.068	112	.055	56	.037	43
Flexed	.055	108	.042	54	.025	41
Flexed	.052	107	.046	54	.026	41

Effect of DOP Exposure

When samples of the N-1 paper were tested for "break" to continuous exposure of DOP smoke, a rather high rate of break was observed. This was pointed out in the N-1 report and confirmed by test at NRL. For the purpose of showing the difference in the rate of "break" between the N-1 and N-2 samples, the two are compared in Table V. Data for the N-1 paper were taken at NRL.

TABLE V

Performance on Continuous Exposure to DOP Smoke

Exposure (mm H_2O)	N-1 Paper		N-2 Paper	
	Penetration (%)	Resistance (mm H_2O)	Penetration (%)	Resistance (mm H_2O)
0	.102	128	.070	114
½	.104	128	.065	114
1	.110	129	.074	115
2	.120	131	.070	115
3	.130	133	.080	115
4	.135	134½	.074	116
5	.140	135½	.078	116
6	.150	137	.084	116
7	.155	138	.078	116
8	.165	139	.085	116
9	.165	139	.090	116½
10	.170	140	.090	117

There can be little doubt but that the N-2 paper "breaks" more slowly. It will be observed further that the resistance of the N-2 paper builds up much more slowly. Whether or not this effect can be attributed to the presence of the smooth rod-shaped rayon flock in the N-1 paper is not certain, but it is the most satisfactory explanation at the present time.

It can also be stated that samples of the N-2 paper showed nearly the same behavior to DOP exposure after flexing as before flexing. During a 10 minute exposure, one sample of flexed paper "broke" from .072% to .098% while the resistance increased from 104 mm to 106 mm. This may be interpreted as further evidence that flexing does not harm penetration characteristics of the paper.

RECOMMENDATIONS

Based on the present evidence, it is recommended that rayon flock not be included in any furnish for the Navy Type H-60 filter paper. It is believed that this smooth fiber in the paper gives rise to a faster rate of "break" with continuous exposure to high concentrations of DOP smoke.

It is further recommended that yucca fiber as described in the N-1 and N-2 reports be designated as a substitute fiber or an alternate fiber for the esparto fiber called for in specifications covering the Navy Type H-60 filter paper.

It is also suggested that some survey be made to determine what quantities of yucca can be harvested in this country each year and what stand-by equipment might be necessary.

Since it has been pointed out that flexing definitely increases the efficiency of both the esparto type and yucca type papers, it would seem desirable to pursue this investigation further and possibly design some equipment for flexing this paper under controlled conditions. No existing paper making equipment seems capable of performing this function.

There is reason to believe that the ultimate combination of fibers has not yet been discovered which will give the highest penetration efficiencies. Further research and development work may lead to other domestic substitute fibers for esparto in Type H-60 filter paper and may also lead to the development of paper with still higher penetration efficiencies.

FORWARDING OF SAMPLE TO NRL

One roll of this N-2 Filter Material was waterproofed and sent to the Naval Research Laboratory, Washington, D. C. for examination and tests.

Naval Research Laboratory
Technical Library
Research Reports Section

DATE: 12 April, 2000

FROM: Mary Templeman, Code 5227

TO: **Code 6100 Dr. Murday**

CC: Tina Smallwood, Code 1221.1 to

SUBJ: Review of NRL Reports

Dear Sir/Madam:

1. Please review NRL Reports C-3226, C-3299, ~~6054~~, 3983, 3611, 3610, C-3394, C-3225, and C-3172 for: AD-C060 912

   ☑ Possible Distribution Change
   ☐ Possible Change in Classification

Thank you,

Mary Templeman

Mary Templeman
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The subject report can be:

☑ Changed to Distribution A (Unlimited)
☐ Changed to Classification _____
☐ Other:

James L. Murday 4/13/00
Signature Date

Please note documents have been declassified, but word "CONFIDENTIAL" Received 4-28-00