AD NUMBER

ATI209130

CLASSIFICATION CHANGES

TO

unclassified

FROM

confidential

AUTHORITY

12 Jun 1964 Grp-4 IAW document markings

AD-A800 520

AD-A800 520

CONFIDENTIAL
SECURITY INFORMATION

UNCLASSIFIED

UNCLASSIFIED

NRL REPORT 3983

FILTER PAPER STUDIES VIII
EFFECT OF
ASBESTOS FIBER TREATMENT

Harold W. Knudson and Robert D. Parsons

Hollingsworth and Vose Company
East Walpole, Massachusetts

Approved by
The Chemistry Division, NRL

June 12, 1952

UNCLASSIFIED

UNCLASSIFIED

PLEASE RETURN THIS COPY TO:

NAVAL RESEARCH LABORATORY
WASHINGTON, D.C. 20375
ATTN: CODE 2628

Because of our limited supply you are requested to return this copy as soon as it has served your purposes so that it may be made available to others for reference use. Your cooperation will be appreciated.

NDW-NRL-5070/2651 (Rev. 9-75)

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

APPROVED FOR PUBLIC RELEASE - DISTRIBUTION UNLIMITED

DOWNGRADED AT 3-YEAR INTERVALS
DECLASSIFIED AFTER 12 YEARS
DOD DIR 5200.10

UNCLASSIFIED

UNCLASSIFIED

CONFIDENTIAL

CONTENTS

PREFACE

This Naval Research Laboratory report is based on four Research and Development Reports written by H. W. Knudson and R. D. Parsons of the Hollingsworth and Vose Company, East Walpole, Massachusetts, on Navy Contract N7-ONR-430. These reports are identified as follows:

"Navy Gas-Mask Filter Materials; A Study of Asbestos Fibers," Ninth Quarterly Period of Contract N7-ONR-430, 12 October 1949

"Navy Gas-Mask Filter Materials; A Study of Asbestos Fibers," Tenth Quarterly Period of Contract N7-ONR-430, 12 January 1950

"Navy Gas-Mask Filter Materials; A Study of Asbestos Fibers," Eleventh Quarterly Period of Contract N7-ONR-430, 17 April 1950

"Navy Gas-Mask Filter Materials; A Study of Asbestos Fibers," Twelfth Quarterly Period of Contract N7-ONR-430, 5 July 1950

This report concludes the third year of the contract. All work reported here is based on laboratory investigations; no mill work was conducted. Filter-paper studies are being continued by the Hollingsworth and Vose Company under a renewal of the contract; this work will be largely confined to semiproduction mill runs. Additional reports will be published when received.

ABSTRACT

This is an interim report describing laboratory studies for the period of July 1, 1949 to June 30, 1950 on Blue Bolivian and Canadian chrysotile asbestos fibers as related to Navy gas-mask filter materials. The base-carrier fibers used were AA Fiberglas, causticized-viscose rayon, and causticized-kraft wood pulp. The use of asbestos of small-sized fibers, as contained in mill white water, results in less efficient filters than asbestos of larger-sized fibers. Filter efficiency is raised by increasing concentrations of Blue Bolivian asbestos, but it is reduced by increasing concentrations of Canadian chrysotile asbestos. Distribution of asbestos fibers in a filter is shown to affect its efficiency. Studies on the effects of calendering, high and low furnish consistencies, air resistance, and the pH of the furnish were also conducted.

PROBLEM STATUS

This is an interim report; work is continuing.

AUTHORIZATION

NRL Problem C04-28
RDB Projects NR 404-280 and NS 181-005

Manuscript submitted April 25, 1952

FILTER PAPER STUDIES VIII
EFFECT OF ASBESTOS FIBER TREATMENT

INTRODUCTION

Earlier work* under Contract No. N7-ONR-430 was chiefly concerned with developing a suitable domestic fiber as a substitute for esparto fiber in the filter material for the Navy gas mask (ND Mark IV). Greatest success was obtained by using a specially causticized rayon fiber (NRL Report C-3299). After several semicommercial mill trials, it was demonstrated that under present conditions the contractor could not manufacture the new-type filter material with consistent high quality.

On August 12, 1949, this problem was carefully reviewed at a conference between representatives of the contractor and the NRL project officer and other Laboratory personnel. These discussions brought out the fact that in many cases the lack of reproducibility might be a result of variables contributed by the asbestos rather than the base fibers. There is inadequate knowledge regarding the role of asbestos in the mechanism of aerosol filtration as applied both to the older (type H-60) paper as well as the newer-type rayon papers. It was decided, therefore, that the emphasis under the present ammendment to the contract should be placed on laboratory studies of asbestos as it relates to the problem.

RESEARCH PROGRAM

The past experiences of the contractor in producing asbestos-bearing filter papers offered considerable information that naturally influenced the choice of methods, materials, and techniques employed in this study. For instance, greater success has always been realized with Blue African or Blue Bolivian (BB) asbestos than with the more common and much finer Canadian or domestic types. This would indicate that the blue asbestos should be studied first.

Although the exact sequence of investigation is always difficult to predict on a problem of this nature, a program was outlined and followed as closely as time would permit. It included the investigation of:

a) the effect of asbestos-fiber size,

b) the effect of asbestos interfiber distances,

c) the effect of asbestos-fiber distribution.

* A list of previous NRL reports in this series appears on inside front cover

Asbestos-Fiber Size

Based on present information, it is believed that the diameter of the asbestos fibers in a filter mat largely determines the ability of the filter to remove aerosol particles from an air stream. For a given particle size, an optimum range of fiber diameters is believed to exist. Actually, all asbestos materials studied thus far contain fibers with diameters that vary over at least a ten-fold range; this condition was observed under an ordinary optical microscope. Experience has also shown that the ratio of fine fibers usually increases with mechanical action on the asbestos. The extent to which submicroscopic fibers are produced under these conditions is not known at present. When sheet formation occurs, some asbestos fibers are lost through the dewatering of the stock on the wire. Whether or not there is a selective retention of the coarser asbestos fibers in the web is unknown. Previous work, however, indicated that the presence of increasing amounts of asbestos fines in a filter mat is harmful to the efficiency.

Asbestos Interfiber Distances

From a practical point of view, the ratio of asbestos fibers to other fibers in the filter material for Navy gas masks has been largely determined by the particular kind of asbestos and by the ream weight and caliper of the paper. Little attention has been given to this subject. It should be possible, for instance, to form a paper twice as heavy with half the percentage of asbestos as a reference paper, or to form a paper half as heavy with twice the percentage of asbestos. In each sheet the total weight of asbestos would be the same, but the fiber-to-fiber distance would vary considerably. A similar effect might also be observed by varying the apparent density of a sheet with the same fiber composition. The extent to which the average distance between asbestos fibers affects the performance of a filter is unknown.

Asbestos-Fiber Distribution

Many type H-60 filter papers have shown abnormal relationship between (a) the "rate of breaking" and the DOP smoke exposure and (b) the flow rate and smoke-penetration characteristics. It has always been assumed that these abnormal relationships were due to nonuniform distribution of the asbestos fibers within the sheet. The extent to which this assumption is valid is unknown. Furthermore, no distinction is usually made between the effect of spotty concentrations of asbestos throughout the sheet and the effect of laminated layers that could exist near the bottom, center, or top side of the sheet.

ASBESTOS-FIBER SIZE

The contractor elected to study the effect of asbestos-fiber size first, and arrangements were made under the contract to borrow a Sharples Super Centrifuge from the Naval Research Laboratory. The integral part of this centrifuge, a hollow stainless-steel cylinder, is called a "bowl"; it is rotated by a motor at approximately 20,000 rpm. A slurry (solids in water) can be fed into the bottom of the bowl while it is in motion. Depending on the rate of feed and the size and specific gravity of the suspended matter, most of the solid fraction can be made to deposit on the inside of the bowl while the liquid flows out the top. Through this action it was hoped that some fractionation of asbestos could be realized to separate the coarser fibers from the finer ones.

BB Asbestos

During a regular production run of Army type-6 filter material, arrangements were made to reserve samples of commercially beaten Blue Bolivian asbestos as well as samples of asbestos fines collected in the "white water" from the paper machine. The white water represents the fluid that drains through the wire screen during the formation of the paper web. This liquid contains fibers (mostly asbestos) too fine to be retained by the wire screen or too fine to be filtered out by the paper web. It was believed that a source of asbestos fines such as this would represent predominately fine fiber diameters.

AA Fiberglas - Although the choice was somewhat arbitrary, AA Fiberglas was selected as the fiber most suited for the composition of the base furnish for these handsheet studies. This choice was poor since AA Fiberglas alone is an excellent filter and consequently masks the effect of added asbestos. In this investigation, however, the interest is in the comparative results obtained by variations of asbestos additions in a standard sheet rather than the actual efficiencies recorded for any single sheet.

To eliminate some of the variables, enough Fiberglas was beaten in one batch to provide stock for all handsheets. The technique followed called for measuring out uniform quantities of Fiberglas and adding enough asbestos from the various samples to bring the resistance up to the normal range of type H-60 paper. Table 1 is typical of the preliminary data collected.

TABLE 1
Effect of BB Asbestos-Fiber Size on AA Fiberglas Filter Performance

Sample	Asbestos Added	Resistance* (mm H_2O)	Penetration* (%)	Efficiency† (%)
1	None	128	0.001	3.91
2	None	70	0.057	4.54
3	Mill-beaten	112	0.001	4.50
4	Mill white water	93	0.024	3.93
5	Centrifuge effluent	104	0.002	4.51
6	Centrifuge bowl	93	0.007	4.57

*Measured by NRL Smoke Penetration Meter E2, E2R1, or E3. For operating instructions, see NRL Instructions Manual A825A; "Instructions for Canister Tests, Part II, Filters, Section A, Smoke Penetration," 13 July 1945

†Percent efficiency = $(-\log P)/R \times 100$, where P is the DOP penetration expressed in decimals rather than percent and where R is the resistance across the sample in mm of water under the standard conditions of test

From these preliminary data, it can be seen that the only asbestos additive that deviated appreciably from the others was No. 4 (Table 1); this sample contained mill white paper.

By the optical microscope it was observed that the centrifuged-asbestos-effluent fibers, in general, had smaller dimensions than the mill white-water fibers. This observation, however, was only qualitative at best. Fiber measurements (Table 2) were also estimated from electron photographs of mill-beaten Blue Bolivian asbestos.

TABLE 2
Fiber Size of BB Asbestos Samples

Sample	Source	No. of Counts	Average Diameter (Microns)
1	Mill-beaten	85	0.228
2	Mill white water	131	0.101
3	Centrifuge effluent	188	0.090

The white-water and centrifuge-effluent samples have approximately the same average diameters (Table 2). From an observation of samples 1 and 2, it would appear that some fractionation of the asbestos takes place during sheet formation on the paper machine. For the most part, the asbestos that is retained in a filter mat appears to be 2 to 3 times the diameter of the fibers that pass through the mat. The assumption that none of the finer fibers are retained in the sheet must not be made since the air resistance of the handsheet can be raised solely through the addition of large quantities of these small white-water fibers.

To prepare the AA Fiberglas as the carrier fiber or base sheet for additional asbestos samples, the material was wetted out and cut into short lengths (1/4 to 1/2 inch) with scissors; the pieces fill directly into the beater. The glass was then circulated for a few minutes with the beater roll up, thus preventing excessive shortening of the fibers. The Blue Bolivian samples were procured from mill production. Enough asbestos was added to the base filter material to bring the air resistance within the normal range of type H-60 paper.

Several series of handsheets incorporating the various samples of asbestos were made at different times; the quantity of Fiberglas used for each sheet was kept as constant as possible.

The values recorded in Table 3 represent the average of from 2 to 5 handsheets in each case. It should be pointed out that the average efficiencies reported in column (3) are the average of the efficiencies obtained from the individual handsheet measurements. In other words, the values in column (3) were not calculated from the values in columns (1) and (2) since the penetration is not a linear function of the resistance.

The four series of handsheets recorded in Table 3 were prepared on different occasions from different batches of cut AA glass. This circumstance accounts for the fact that base sheets in the different series do not have exactly the same resistance or efficiency. However, the variation of the different asbestos fractions within any one series is approximately the same as in any other series.

The efficiencies of the handsheets of Table 3 are averaged in Table 4 in the order of decreasing efficiency. Although there appears to be a decrease in efficiency for the average values as arranged in Table 4, the difference between the first four values is relatively small and is not thought to represent any significant difference in performance. Examination of the original measurements on the handsheets indicates a variation as great as 0.3 efficiency unit for any one type of asbestos. On the other hand, an unmistakable decrease in efficiency is apparent in all samples where mill white water was used for the asbestos. This reduction is thought to be real and significant.

TABLE 3
Effect of BB Asbestos Fiber Size on AA Fiberglas Filter Performance

Series	Asbestos Added	(1) Average Resistance (mm H_2O)	(2) Average Penetration (%)	(3) Average Efficiency (%)
0	None	109	0.003	4.14
1	None	70	0.057	4.54
1	Mill-beaten	112	0.001	4.67
1	Mill white water	93	0.024	3.93
1	Centrifuge effluent	83	0.028	4.67
1	Centrifuge bowl	93	0.007	4.57
2	None	62	0.100	4.84
2	Mill-beaten	87	0.018	4.33
2	Mill white water	110	0.025	3.42
2	Centrifuge effluent	85	0.017	4.48
2	Centrifuge bowl	81	0.020	4.54
3	None	66	0.043	4.77
3	Mill white water	99	0.024	3.67
3	Centrifuge effluent	80	0.017	4.70
4	None	59	0.27	4.40
4	Mill-beaten	111	0.006	3.98
4	Mill white water	103	0.100	2.86
4	Centrifuge effluent	105	0.016	3.77

TABLE 4
Average Efficiencies of AA Fiberglas Filters
with BB Asbestos Added

Sample	Asbestos Added	Average Efficiency (%)
1	None	4.64
2	Centrifuge bowl	4.55
3	Centrifuge effluent	4.36
4	Mill-beaten	4.33
5	Mill white water	3.47

Since the fibers in the centrifuge effluent had nearly the same diameters as those in the mill white water and were used in identical base sheets, a question naturally arises concerning their different filter characteristics. Further investigation and studies under the microscope clearly indicated that the white-water samples contained a generous amount of amorphous-like material that may be derived from the cellulose fibers rather than from the mineral fibers. Similar material was not noted in the centrifuge effluent, and it seems reasonable to assume that this foreign material in the white water only serves to plug the sheet and reduce its efficiency.

Rayon - The next carrier fiber chosen for investigation was causticized, bright viscose rayon; a filter mat composed only of these fibers is a much less efficient filter than one composed of AA glass. It was believed, therefore, that the effect of the various asbestos samples in a rayon sheet would indicate a trend in relation to the size, concentration, and distribution of the fibers.

The rayon carrier-fiber stock was prepared in the laboratory in the following manner: Each batch of bright viscose rayon consisted of three parts of 1-1/2 denier 1/8-inch cut and one part of 1-1/2 denier 1/4-inch cut. This mixture (4 percent consistency) was causticized for 30 seconds in a Waring Blendor in 7.50 percent sodium hydroxide solution at a temperature of 75°F; the speed of the blendor was regulated by a Variac which was set at 80 volts. After causticizing, the stock was then quenched in 5 times its volume of water and washed on a screen until the caustic was entirely removed.

The results of causticized viscose-rayon handsheets made with several Blue Bolivian asbestos samples are recorded in Table 5; each series represents different batches of causticized rayon.

TABLE 5
Effect of BB Asbestos Fiber Size
on Causticized-Rayon Filter Performance

Series	Asbestos Added	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
1	Mill-beaten	115	0.002	4.20
1	Mill white water	107	0.076	2.97
1	Centrifuge effluent	83	0.094	3.82
1	Centrifuge bowl	100	0.015	3.85
2	Lab-beaten	95	0.016	3.98
2	Mill white water	111	0.012	3.53
2	Centrifuge effluent	92	0.020	4.08
2	Centrifuge bowl	99	0.027	4.06
3	Lab-beaten	117	0.003	3.86
3	Mill white water	107	0.019	3.49
3	Centrifuge effluent	100	0.029	3.64

Since the mill white-water supply was not adequate if used to build up the entire resistance of the sheet, only part of this resistance was afforded by the white water. Regular-beaten asbestos was used to raise the resistance to 70 or 80 mm, and the white water furnished a resistance of approximately 20 mm in each sheet. The centrifuge effluent was incorporated in the same manner. From Table 5 it can be seen that apparently the only asbestos fraction detrimental to smoke filtration was the mill white-water sample. However, in series No. 3 there seems to be an indication that the centrifuge effluent could lower the efficiency.

To study the effects of the centrifuge effluent further, a run was made using handsheets with decreasing amounts of laboratory BB asbestos and increasing amounts of effluent so that each sheet would be built up to essentially the same air resistance. The effect of increasingly larger amounts of effluent in causticized-rayon based sheets is shown in Table 6.

TABLE 6
Effect of Centrifuge-Effluent BB Asbestos on Causticized-Rayon Filter Performance

Sheet Furnish	Centrifuge Effluent Added	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
1	No	101	0.069	3.71
2	No	69	0.24	3.80
2	Yes	111	0.048	3.05
3	No	30	6.0	4.06
3	Yes	93	0.23	2.87

The data in Table 6 definitely show that large amounts of centrifuge effluent have a bad effect on filtration properties. From this it would seem that extremely small Blue Bolivian asbestos fibers (as in the centrifuge effluent and mill white water) should be added in only limited amounts to viscose-rayon filter mats, if at all.

Kraft - Another type of carrier fiber was investigated to determine its effect on, and relation to, the filtering properties of Blue Bolivian asbestos. The study was made using a wood pulp, specifically Bloedel kraft pulp. To use this fiber in the most efficient manner as a filter mat, it was causticized as follows: A quantity of the kraft pulp was treated for several hours at room temperature in a 17.5° Bé solution of sodium hydroxide at a 1 to 5 ratio by weight. The fiber was then thoroughly washed and made up to a predetermined consistency.

The effect of Blue Bolivian asbestos-fiber size in a causticized-kraft filter sheet is recorded in Table 7. Each series reported represents a different batch of the carrier filter.

The fact that the kraft stock was under causticized (meaning that the fibers were not crinkled enough) accounts for the lower over-all efficiencies of series No. 1 (Table 7). The relative values in each series, however, show the same variations. The mill white-water and the centrifuge-effluent samples reduce the filtration efficiency of the sheet to about the same degree. This effect in causticized-kraft sheets is different from that of causticized-rayon sheets. It was demonstrated, however, that excessive amounts of either the mill white-water or the centrifuge-effluent asbestos fibers produce a sheet of decreased filtration efficiency when incorporated in rayon or wood-pulp filter mats.

TABLE 7
Effect of BB Asbestos Fiber Size on Causticized-Kraft Filter Performance

Series	Asbestos Added	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
1	Lab-beaten	99	1.04	2.00
1	Mill white water	101	1.31	1.89
1	Centrifuge effluent	89	2.61	1.86
1	Centrifuge bowl	109	0.72	2.08
2	Lab-beaten	109	0.089	2.81
2	Mill white water	106	0.20	2.62
2	Centrifuge effluent	85	0.61	2.69
2	Centrifuge bowl	114	0.11	2.94

Chrysotile Asbestos

Limited quantities of chrysotile-asbestos samples were obtained from mill production; they were ultimately augmented by laboratory-beaten asbestos which gave similar results.

AA Fiberglas - The effect of different chrysotile fiber fractions in AA glass filter mats is recorded in Table 8.

TABLE 8
Effect of Chrysotile-Asbestos Fiber Size on AA Fiberglas Filter Performance

Asbestos Added	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
Lab-beaten	110	0.001	4.47
Mill-beaten	113	0.002	4.38
Mill white water	73	0.33	3.48
Centrifuge effluent	99	0.006	4.31
Centrifuge bowl	97	0.011	4.39

A large quantity of white water (much more than the capacity of the sheet-mold tower) would have to be used to raise the air resistance to compare with the other samples. However, even at the low pressure drop recorded for handsheets made from AA glass and mill white water, it can be seen that the efficiency is much lower than all other asbestos samples studied. It may also be noticed that the laboratory-beaten-chrysotile and mill-beaten-chrysotile handsheets produced similar results.

Rayon - An investigation of chrysotile asbestos incorporated in a causticized-rayon mat was carried out in the same manner as the study of Blue Bolivian asbestos. The effect of different chrysotile fiber fractions in causticized-rayon filters is shown in Table 9.

TABLE 9
Effect of Chrysotile-Asbestos Fiber Size on Causticized-Rayon Filter Performance

Asbestos Added	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
Lab-beaten	110	0.26	2.29
Mill white water	70	1.88	2.53
Centrifuge effluent	105	0.49	2.22
Centrifuge bowl	95	0.36	2.63

Since the chrysotile fiber is small and difficult to retain, a large quantity of white water was needed to cause any resistance in the sheet at all. The mill white-water sample was not large, and as a result, the mill white-water sheets (Table 9) did not have the air resistance desired to compare properly with the other samples. The data, however, show that the centrifuge-bowl fraction produces sheets of higher comparable efficiencies than the other samples and indicate that the larger chrysotile fibers are more efficient in the filter mat.

ASBESTOS INTERFIBER DISTANCE

BB Asbestos

To study the asbestos interfiber distance in a filter mat, handsheets were made containing the same total weight of mill-beaten asbestos, but varying in the weight of the carrier fiber (AA glass). Several handsheets were made in each series of weights; data recorded in Table 10 are average values for these sheets in each weight series. The Fiberglas was prepared as previously stated in this report.

It can be observed from these data that with decreasing sheet weights (hence, increasing asbestos concentration) the resultant filtration efficiencies exhibit no significant trend. The variations noted can be attributed, at least in part, to the fact that in many cases the smoke-penetration values approached the sensitivity of the meter and thus made it difficult to obtain accurate readings. At the outset of this study, little variation in efficiency was expected by varying the interfiber distance of the asbestos in AA glass handsheets since AA glass itself removes a large percentage of the smoke. For this reason and because most of the handsheets in this series exhibited low penetrations, it was difficult to interpret the data. It is entirely possible that similar data collected on other carrier fibers, such as causticized-viscose and causticized-wood-pulp, will show a more definite trend.

TABLE 10
Effect of BB Asbestos Concentration on AA Fiberglas Filter Performance

Average Sheet Weight (grams)*	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
4.4	123	0.0005 †	4.30
3.9	116	0.002	4.05
3.7	118	0.001	4.40
3.6	116	0.001	4.19
3.5	113	0.001	4.37
3.4	106	0.0017 †	4.63
3.3	111	0.003	4.08
3.1	118	0.002	3.98
3.0	105	0.0035 †	4.25
2.8	106	0.002	4.43
2.4	108	0.0035 †	4.17
2.2	92	0.010	4.39
2.1	95	0.007	4.42
2.0	100	0.007	4.18
1.9	97	0.005	4.44
1.8	91	0.021	4.04
1.7	88	0.019	4.25

*Each sheet contained 0.3 gram of mill-beaten BB asbestos
†Estimated

To study the effect of Blue Bolivian asbestos concentration in a causticized-rayon filter sheet, handsheets were made containing the same weight of asbestos, but the weight of the carrier fiber (causticized rayon) was varied.

The data recorded in Table 11 are values for individual handsheets and show the effect of asbestos concentration in a causticized-rayon filter mat. The efficiency values indicate a trend in relation to asbestos concentration. As this concentration is increased, the smoke filtration becomes more efficient; another run was carried out to confirm this result. Several handsheets were made in two weight groups, and the results are given in Table 12.

From these data, it is also apparent that asbestos-fiber concentration has a definite bearing on filtration efficiency in this type of filter mat (causticized-viscose rayon).

The variable of asbestos concentration was studied with relation to causticized-kraft fibers. The effect of increasing the Blue Bolivian asbestos concentration in a causticized-kraft sheet is reported in Table 13.

TABLE 11
Effect of BB Asbestos Concentration
on Causticized-Rayon Filter Performance

Sheet Weight (grams)*	Resistance (mm H_2O)	Penetration (%)	Efficiency (%)
7.5	72	0.18	3.81
6.8	78	0.14	3.65
5.9	84	0.049	3.94
5.3	86	0.044	3.91
5.2	92	0.022	3.98
4.1	97	0.012	4.04
4.1	106	0.009	3.82
3.9	88	0.024	4.12
3.8	98	0.009	4.13
3.6	111	0.003	4.07
3.0	85	0.028	4.18
2.6	108	0.002	4.35
2.1	115	0.001	4.35
2.1	118	0.001	4.24

* Each sheet contained the same quantity of mill-beaten BB asbestos

TABLE 12
Effect of BB Asbestos Concentration
on Causticized-Rayon Filter Performance

Average Sheet Weight (grams)*	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
3.2	95	0.016	3.98
1.9	102	0.004	4.45

* Each sheet contained the same quantity of mill-beaten BB asbestos

TABLE 13
Effect of BB Asbestos Concentration
on Causticized-Kraft Filter Performance

Asbestos Added (cc)	Sheet Weight (grams)	Resistance (mm H_2O)	Penetration (%)	Efficiency (%)
48	4.3	73	1.50	2.50
48	4.0	72	1.25	2.64
48	3.9	90	0.47	2.59
48	3.4	95	0.24	2.76
48	3.1	74	0.80	2.84
60	4.6	103	0.25	2.52
60	4.2	90	0.36	2.71
60	3.4	98	0.18	2.79
60	3.2	107	0.10	2.80
60	2.1	119	0.030	2.96
60	1.9	116	0.027	3.08
65	4.4	125	0.058	2.58
65	4.0	109	0.13	2.65
65	3.3	145	0.006	2.91

In each of the three series reported in this table, the smoke-filtration efficiency increased as the asbestos fiber became more concentrated. There was a notable increase in efficiency between the highest and lowest weight sheets in each group.

Chrysotile Asbestos

The effect of chrysotile-asbestos concentration in causticized-rayon sheets is shown in Table 14. Handsheets were made in two general weight classes, and equal quantities of asbestos were added to each sheet.

TABLE 14
Effect of Chrysotile-Asbestos Concentration
on Causticized-Rayon Filter Performance

Average Sheet Weight (grams)*	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
4.2	97	0.34	2.55
2.4	141	0.25	1.93

* Each sheet contained 0.2 gram of laboratory-beaten chrysotile asbestos

The higher the concentration of chrysotile asbestos in a causticized-rayon filter mat, the lower its efficiency becomes (Table 14); Blue Bolivian asbestos acts in the opposite direction with the same type of carrier fiber.

ASBESTOS-FIBER DISTRIBUTION

The effect of poor dispersion for Blue Bolivian asbestos in an AA glass filter mat is recorded in Table 15. Asbestos was added to these sheets in a manner that would cause the fibers to bunch in several areas, but leaving other areas with comparatively few. In other words, no effort was made to disperse the asbestos fibers uniformly with the carrier fibers.

TABLE 15
Effect of BB Asbestos Dispersion on AA Fiberglas
Filter Performance

Asbestos Added	Asbestos Dispersion	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
None	----	71	0.045	4.60
Mill-beaten	Uniform	105	0.0015	4.65
Mill-beaten	Nonuniform	119	0.0065	3.71

It is apparent from Table 15 that uniform dispersion of the asbestos within the filter mat is an important factor in the filtration characteristics of the sheet. The agglomeration of asbestos fibers into several separate bundles within a sheet not only reduces the effective filtering power of the mat but also appreciably increases the air resistance of the over-all sheet. The results of this study, however, do not show the effect of a laminated sheet, i.e., a sheet in which the asbestos is found predominantly in one stratum of its thickness. Laboratory experimentation, however, has revealed that when this type of sheet is prepared its filtration characteristics are sometimes good. The technique involved in making such a sheet is rather troublesome and poorly reproducible.

The effect of Blue Bolivian asbestos-fiber distribution in causticized-rayon sheets is recorded in Table 16. The dispersion of asbestos fibers within the filter mat seems to be critical in its effect upon filtering properties.

TABLE 16
Effect of BB Asbestos Dispersion
on Causticized-Rayon Filter Performance

Asbestos Dispersion	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
Uniform	102	0.010	3.93
Nonuniform	121	0.017	3.19

The effect of asbestos-fiber distribution in a causticized-kraft sheet is shown in Table 17. Nonuniform dispersion of Blue Bolivian fiber throughout a causticized-kraft sheet definitely affects the filtration characteristics of that sheet.

TABLE 17
Effect of BB Asbestos Dispersion on Causticized-Kraft Filter Performance

Asbestos Dispersion	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
Uniform	109	0.089	2.81
Nonuniform	123	0.12	2.39

MISCELLANEOUS EFFECTS

Calendering

Causticized-rayon and causticized-kraft fibers were used as base sheets to determine the effect of calendering in relation to filtration efficiency. The calender used was a small hand-operated device with 1-3/4-in.-diameter steel rolls; pressure at the nip was regulated by a hand screw.

The kraft and rayon fibers were causticized and washed according to methods previously described. The Blue Bolivian asbestos used in these experiments was beaten hard for 10 minutes in the laboratory. The individual handsheets reported in Table 18 were tested for smoke penetration before and after calendering.

TABLE 18
Effect of Calendering on BB Asbestos Filter Performance

Carrier Fiber	Before Calendering			After Calendering		
	Resistance (mm H_2O)	Penetration (%)	Efficiency (%)	Resistance (mm H_2O)	Penetration (%)	Efficiency (%)
Kraft	90	0.47	2.59	116	0.10	2.58
Kraft	74	1.50	2.46	106	0.25	2.45
Kraft	76	0.82	2.75	112	0.17	2.47
Kraft	90	0.44	2.62	121	0.084	2.54
Kraft	75	0.94	2.70	125	0.13	2.31
Kraft	81	0.70	2.66	114	0.15	2.47
Kraft	72	1.25	2.64	113	0.13	2.56
Rayon	103	0.013	3.78	115	0.009	3.52
Rayon	112	0.006	3.77	113	0.006	3.73
Rayon	110	0.008	3.73	113	0.009	3.58
Rayon	104	0.011	3.81	113	0.007	3.67

These data show that calendering slightly lowers the efficiency of the two types of base sheets tested. This does not hold true, however, for the type H-60 filter, which will increase in efficiency after calendering. The reason for this behavior is not entirely clear. Calendering under production conditions may have a different effect on the various base sheets than was found in the laboratory.

Optimum Resistance

The next variable studied was the optimum resistance for the highest efficiency of two types of base sheets. The air resistance was varied by decreasing the quantity of BB asbestos incorporated in the filter mat.

The results obtained are shown in Table 19; each efficiency value represents one handsheet.

TABLE 19
Effect of BB Asbestos Concentration and Calendering on Filter Performance

Carrier Fiber	Asbestos Added (cc)	Before Calendering			After Calendering		
		Resistance (mm H_2O)	Penetration (%)	Efficiency (%)	Resistance (mm H_2O)	Penetration (%)	Efficiency (%)
Kraft	80	130	0.032	2.69	152	0.008	2.70
Kraft	75	125	0.038	2.73	143	0.011	2.77
Kraft	70	97	0.26	2.66	120	0.048	2.77
Kraft	65	81	0.70	2.66	119	0.068	2.66
Kraft	60	63	2.00	2.70	110	0.20	2.45
Kraft	55	62	2.00	2.70	117	0.15	2.41
Kraft	50	45	5.80	2.75	97	0.64	2.26
Kraft	45	40	7.80	2.77	100	0.80	2.10
Kraft	40	39	8.60	2.74	88	1.75	1.99
Kraft	35	30	15.4	2.70	74	4.50	1.82
Kraft	30	20	28.0	2.75	64	5.20	2.00
Kraft	25	16	38.0	2.62	49	13.0	1.81
Rayon	70	120	0.002	3.92	130	0.004	3.38
Rayon	65	108	0.006	3.91	116	0.006	3.64
Rayon	60	90	0.027	3.96	98	0.022	3.74
Rayon	55	79	0.10	3.80	85	0.081	3.64
Rayon	50	62	0.27	4.15	70	0.25	3.72
Rayon	45	61	0.32	4.10	70	0.26	3.68
Rayon	40	45	1.75	3.91	52	1.50	3.50
Rayon	35	30	7.60	3.73	35	5.60	3.57
Rayon	30	25	11.2	3.80	31	8.20	3.51
Rayon	25	22	16.0	3.64	30	14.0	3.17

As the air resistance was decreased, the sheets made from the causticized-kraft base furnish did not vary appreciably in efficiency before calendering. In other words, there appeared to be no optimum pressure drop at which a maximum efficiency occurred. After being calendered, however, the efficiency fell off with a decreasing pressure drop.

Using causticized rayon as a carrier fiber, a slight peak in efficiency occurred around a pressure drop of 62 (Table 19). This irregularity was previously noticed when handsheets with low air resistance were prepared. Upon calendering these sheets, it was observed that the rayon fibers were more difficult to densify than wood fibers. This phenomenon was primarily caused by the difference in the surface properties of the fibers. As a result, the air resistance was not increased the same amount by calendering as it was for the kraft sheets.

Consistency and Premixing

In the study of the consistency and premixing of the furnish, handsheets were made using the causticized-rayon and causticized-kraft stocks together with Blue Bolivian asbestos. In one case, the furnish was put into the handsheet tower which was then filled with water; this dilution of the furnish made a consistency of approximately 0.18 percent. In the other case, the stock was diluted to 0.50 percent consistency corresponding to that over the Fourdrinier wire in mill production. A Hamilton Beach mixer was used to disperse the fibers uniformly in some cases but in others no mechanical mixing was employed.

Several series of handsheets were prepared from each base furnish investigated. After being tested for smoke-holding properties, each sheet was ashed to determine the amount of asbestos remaining therein.

The results of varying the consistency and mixing the two furnishes are recorded in Table 20.

TABLE 20
Effect of Furnish Consistency and Furnish Premixing on BB Asbestos Filter Performance

Carrier Fiber	Pre-mixed	Consistency (%)	Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)	Average Asbestos Content (%)
Kraft	yes	0.18	126	0.034	2.73	16.8
Kraft	no	0.18	95	0.20	2.80	13.1
Kraft	no	0.50	72	0.81	2.90	13.2
Kraft	yes	0.18	139	0.058	2.36	13.2
Kraft	no	0.18	107	0.15	2.64	15.0
Kraft	no	0.50	69	1.72	2.55	11.5
Kraft	yes	0.18	109	0.023	3.34	-
Kraft	no	0.18	100	0.031	3.50	-
Kraft	no	0.50	70	0.27	3.72	-
Kraft	yes	0.50	93	0.086	3.32	-
Kraft	yes	0.18	123	0.030	2.89	-
Kraft	no	0.18	89	0.17	3.11	-
Kraft	no	0.50	63	0.97	3.21	-
Kraft	yes	0.50	98	0.090	3.11	-
Rayon	yes	0.18	107	0.009	3.78	10.2
Rayon	no	0.18	97	0.014	3.95	14.3
Rayon	no	0.50	82	0.064	3.95	14.4
Rayon	yes	0.18	107	0.009	3.77	13.1
Rayon	no	0.18	97	0.018	3.88	12.2
Rayon	no	0.50	78	0.095	3.89	12.4

From these data it is apparent that the consistency of stock over the wire as well as the action of a mixer can influence the efficiency of the filter to a varying degree that depends upon the furnish. When the causticized-kraft and the causticized-rayon furnishes were agitated in the mixer and formed into handsheets at 0.18 percent consistency, they tested lower in efficiency than sheets made under the other conditions. Use of the mixer and 0.50 percent consistency also seemed to have a detrimental effect. The best efficiencies resulted when 0.50 percent consistency was used with no mixer. It is also observed that under these conditions the air resistance is decreased appreciably. Despite the fact that Table 20 indicates that high consistencies produce more efficient sheets than low consistencies, the variations observed in air resistance were in part caused by the suction leg of the handsheet mold. The vacuum in the suction leg did change to a certain extent while the sheet was being formed because of the consistency used in the tower.

The ash determinations that were performed to find the actual asbestos content of the sheets did not seem to indicate a particular trend. However, in testing three of the four series for asbestos content, the sheets formed at 0.50 percent consistency (without mixing) contained a smaller quantity of asbestos than sheets formed at 0.18 percent consistency (with mixing). It is believed that ashing filters may prove extremely important in determining the action of the asbestos fiber over the wire and its drainage through the wire. However, the technique for ashing these samples must be improved.

Asbestos Beating Time

In an attempt to find the effect of shortening the asbestos fibers in causticized-kraft filter mats, several batches of Blue Bolivian asbestos were beaten from 1 to 10 minutes in the laboratory. This length of time was equivalent to approximately 24 minutes to 4 hours in a mill beater. The results obtained on handsheets made with causticized-kraft carrier fibers are given in Table 21.

TABLE 21
Effect of BB Asbestos Beating Time
on Causticized-Kraft Filter Performance

Beating Time (min)	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
1	109	0.031	3.29
3	96	0.069	3.31
5	116	0.027	3.08
10	114	0.063	2.99

Examination of the data indicates that the asbestos fibers can be over-beaten and may possibly cause the sheet to plug to a certain extent. The 1- and 3-minute samples of asbestos (equivalent to 24 minutes to 1-1/4 hours in the mill) have the most efficient smoke-holding properties. In examining this information, the beating cycle that has been used in the mill for asbestos appears to be within the most satisfactory time interval.

Reformed Machine-Made Filters

The highest-efficiency filter paper that has been made in the mill under contract N7-ONR-430 was N-11; samples of this paper and also of N-12 (NRL Report 3610) were disintegrated and reformed on the laboratory sheet mold. The handsheets made from these furnishes had the same basis weight as the original paper. A small amount of asbestos was added to the reformed handsheets to compensate for the loss through the wire. The filter performance of the mill N-11 and N-12 papers is compared with that of the reformed sheets in Table 22.

TABLE 22
Effect of Disintegrating and Reforming Machine-Made Filters

Filter	Treatment	Average Resistance (mm H_2O)	Average Penetration (%)	Average Efficiency (%)
N-11	None	115	0.002	4.19
N-11	Reformed	89	0.035	4.17
N-12	None	125	0.002	3.76
N-12	Reformed	101	0.011	3.94

The efficiency values shown here for the reformed sheets are essentially the same as those of the machine-made filters. This would indicate that reforming these stocks had little or no effect on the filtration characteristics. In other words, the inconsistencies between the N-11 and N-12 papers are not believed to be attributed entirely to the formation of the sheet on the Fourdrinier wire, but rather to the preparation of the base furnish.

Causticized-Rayon pH

Laboratory investigation revealed that the N-11 and N-12 filter papers were slightly different in pH values; one was more basic than the other (N-11 = 8, N-12 = 7). This difference was caused by incomplete final washing of the N-11 causticized rayon in the mill. The stock was normally washed down to a neutral condition (pH 7), but at times the washing was considered adequate at pH 8. A slight difference in pH was considered to be of no great importance to the filtration properties of the filter sheet. Some preliminary work was completed in the laboratory to find out to what extent the pH value of the furnish affected the filtration characteristics of the filter mat.

Two batches of viscose rayon were causticized in exactly the same manner except that they were washed with water to different pH values. One batch was washed to pH 10.0, the other to pH 6.7. Handsheets were formed from these two batches of causticized rayon by adding various quantities of BB asbestos to each; the data obtained are given in Table 23.

From these data, it will be noticed that a slight increase in efficiency is apparent when a higher pH furnish is used. Further study on washed-stock pH variation is necessary before any satisfactory conclusions can be reached.

TABLE 23
Effect of pH of Causticized Rayon
on BB Asbestos Filter Performance

pH	Resistance (mm H_2O)	Penetration (%)	Efficiency (%)
6.7	104	0.015	3.68
6.7	93	0.030	3.79
6.7	99	0.022	3.70
10.0	112	0.004	3.93
10.0	88	0.026	4.07
10.0	75	0.090	4.06

SUMMARY AND CONCLUSIONS

The general objective of the present contract was to investigate asbestos fibers and their relation to the carrier fibers in a filter mat. The contractor planned to subject the asbestos fibers to all tests and procedures deemed necessary for a more definite knowledge of their behavior and filtration characteristics.

Blue Bolivian and chrysotile asbestos were studied to determine their relation to AA Fiberglas, causticized-viscose rayon, and causticized kraft-wood-pulp carrier fibers. The fibers were photographed under an electron microscope, and measurements were taken of their dimensions. Asbestos fibers were partially fractionated in a Sharples Supercentrifuge, that is, the small-diameter fibers were separated from the medium-to-large-diameter fibers. White water from regular mill production (fibers that drain through the wire as the sheet is being formed) was also incorporated with the different carrier fibers.

Further studies on asbestos fibers included:

a) effect of calendering filter sheets,

b) effect of changing stock consistency over the wire,

c) effect of pressure drop in relation to efficiency.

The work on these items was carried as far as time would permit; further work on some would be profitable.

In general, the conclusions that have been reached from the study of asbestos fibers and their effect on a filter mat are summarized in the following paragraphs:

a) The use of mill-white-water and centrifuge-effluent asbestos samples in the three filter mats studied resulted in a decrease of filtration efficiency. The white-water samples showed the larger decrease in efficiency since cellulose-like foreign materials are necessarily part of the white water. Both asbestos samples were photographed under an electron microscope and were found to be almost identical in fiber diameter.

b) Variation in the asbestos interfiber distances, i.e., a change in the asbestos concentration of a filter mat, resulted in a definite trend toward an increase in the filter efficiencies as the concentration of Blue Bolivian asbestos was increased. On the other hand, as chrysotile-asbestos concentration was increased, a decrease in efficiency became apparent.

c) The distribution of asbestos fibers in a filter mat was shown to be important for maximum efficiency. The presence of large asbestos agglomerates within a sheet lowered its efficiency considerably. A uniform dispersion of asbestos in carrier fiber must be effected for high filtration efficiencies.

d) When causticized-rayon and causticized-kraft filter sheets were calendered in the laboratory, the results indicated either no change or decreased efficiencies.

e) Handsheets formed at high consistencies exhibited slightly better filtration efficiencies than sheets made at low consistencies. It will be observed, however, that variations in the operation of the sheet mold, specifically the suction leg, have a bearing on the results.

f) In the two types of furnishes studied (causticized-viscose-rayon and causticized-kraft-wood-pulp), there appeared to be no optimum pressure drop at which markedly higher efficiencies resulted, i.e., the efficiencies remained essentially constant as the air resistance was decreased.

g) Blue Bolivian asbestos can be over-beaten, thereby causing a decrease in the efficiency of causticized-kraft filters.

h) Machine-made filters have been disintegrated and reformed in the laboratory with no change in filtration efficiency. This fact indicates that sheet formation on the Fourdrinier machine is comparable to that on laboratory molds. Variations in machine-made filters are, therefore, attributed to variations in furnish rather than in sheet formation.

i) Limited experiments indicate that filters made from causticized rayon at pH 10.0 are more efficient than those made at pH 6.7.

ACKNOWLEDGMENTS

The authors express their appreciation to the personnel of the Protective Division of the Chemical and Radiological Laboratories, Army Chemical Center, Md., for the electron photographs of asbestos samples and for permiting the collection of mill asbestos samples during Army production runs.

* * *

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 ts

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~~:

- [x] Possible Distribution Change
- [ ] Possible Change in Classification

Thank you,

Mary Templeman

Mary Templeman
(202)767-3425
maryt@library.nrl.navy.mil

The subject report can be:

- [x] Changed to Distribution A (Unlimited)
- [ ] Changed to Classification __________
- [ ] Other:

James S Murday ______ 4/13/00

Signature Date

please note documents have been declassified, but word "CONFIDENTIAL" have not bee[n] ...

received 4-28-00