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MASTER

INTERIM MEMORANDUM REPORT
ON
FILTER DEVELOPMENT
AND
DISCUSSION ON AVAILABILITY
OF MATERIALS

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Authorizing Official
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INTRODUCTION

This is a preliminary report dealing with the work to date on the development of a filter paper and its fabrication into filters that can be used in the same service that is now supplied by filters from Chemical Corps for use in Atomic Energy Commission operations. These filters are suitable for use in filtering out harmful dusts or radioactive matter from the air which discharged from processes dealing with radioactive operations. The filters may also be used on the incoming cooling or ventilating air to eliminate airborne dirt. They can be used for continuous use in temperatures ranging up to about 250°F.

The result of this work has been the production at moderate cost of a suitable paper which has high filtering effectiveness. Methods for fabricating it into filter units have been worked out to the point where a private manufacturer can consider the set-up of a production operation. Although process of manufacture of the paper is special, its production need not be confined to the mill which has made the initial lots. It can be made in a number of small mills which produce special types of paper, and which are located in different parts of the country.

The main fiber furnish for the paper is a specially treated wood pulp of domestic origin. A vital part of the furnish in minor volume is an especially prepared asbestos.

Full size model filters have given excellent performance tests. These tests show efficiencies as high as 99.996 percent on atmospheric dusts and on artificially prepared test aerosols averaging .3 to .5 microns in diameter. Tests were made at an arbitrary capacity rating which gives a static resistance or pressure drop through the filter of one inch of water. Filters of higher or lower efficiencies with corresponding changes in static resistance can readily be made by slightly modifying the formula of the paper at time of manufacture.

PAPERManufacture

The filter paper is made from a combination of specially treated chemical wood pulp and blue Bolivian asbestos. The treatment imparts a softness and resiliency to the fiber which is favorable to the formation of a soft low resistance sheet of paper about forty-thousandths of an inch thick. The skill in making the paper lies in the chemical treatment and the proper distribution of the asbestos plus running on the paper machine to get the requisite softness and porosity accompanied by adequate strength and low resistance to the passage of air.

The paper furnish can be varied to suit the requirements of filtering efficiency. Exact proportions depend upon character of both the paper pulp and the asbestos. A good example would be about 85 percent paper pulp to 15 percent asbestos. The exact amount of the latter is determined by tests made while the paper is in process of manufacture. The asbestos is prepared in a separate beater. Most of it is added to the furnish at the start of the run. The rest is stored in a small tank to be dribbled into the machine chest as dictated by the performance tests of the sheet coming off the dry end of the machine.

The pulp is prepared by a mercerizing or causticizing treatment in which it is wet with caustic at a strength of twelve to eighteen percent dependent upon conditions. Following this treatment, it is carefully washed to practical neutrality and is ready for use.

Hollingsworth & Vose own a patent covering causticizing of paper pulp, and feel that this process falls within its claims. This patent will soon expire; meanwhile, it is felt that suitable arrangements, at least for government business, can be made either to operate the process or to purchase a pulp specially prepared for the purpose.

The asbestos used is imported from Bolivia and goes by the name blue Bolivian. It is carefully defibrillated and cut to proper length in a paper mill beater to produce the fine filaments which, in the paper, offer the necessary barrier to catch dust particles. The art in using asbestos is in its preparation to the proper size and length, and in operating the paper machine in such a way that the asbestos is properly distributed through the sheet. A substitute for the Bolivian fiber is a blue asbestos from South Africa. Bolivian, however, is preferred because it is more uniform from shipment to shipment. Both kinds are obtainable from asbestos brokers, although the supply is not plentiful as in the case of domestic or Canadian asbestos. Because the character of the fiber in each shipment may be variable, the exact amount used in the furnish must be determined after it is prepared. Preparation consists of beating or otherwise defibering in dilute water solution until the individual filaments are separated down to sizes averaging around a micron in diameter or less.

The development work on the paper has been done with the generous cooperation of Hollingsworth & Vose Company in their mill at West Groton. The paper must be made on a Fourdrinier machine and in mills which specialize in the soft saturating types of paper. Papers of this kind are run at a slow speed, and relatively speaking, in small lot orders. Large mills with high speed machines are not suited to producing this material.

A subsequent process of a light surface treatment of the paper with plastic emulsions to increase strength and resistance to abrasion is in the process of development, and while not vitally necessary, offers promise of imparting additional ruggedness.

Testing of Paper

The paper must be tested frequently during manufacture. Since it is intended to be comparable in effectiveness with the Chemical Corps filter paper, the Army's "smoke" testing equipment, which was available at the paper mill, was used for establishing manufacturing control. Other methods of testing have been worked out in this laboratory, but they are not suitable for the frequent quick spot tests that must be made in the paper mill during manufacture. Similar testing equipment will be required in any mill manufacturing the paper.

Under a later heading the specific test requirements are given.

Cost of Paper

The paper mill has not had sufficient experience in making this particular paper to permit a close estimate of cost. Fiber costs depend upon the cost of wood pulp plus cost of chemical treatment. Asbestos has been running twenty to twenty-five cents per pound, allowing for processing losses. The paper is expected to cost probably not over fifty cents per pound.

FILTER UNITSSize and Capacities of Units

The paper is formed into deep pleats with separators between them, and fastened by plastic adhesives into wooden frames. Filters have been made in the following sizes. Depth dimensions are before gaskets are put on:

	<u>Capacity - c.f.m.</u>
8" X 8" sq. X 5 7/8" deep	50
20" X 20" sq. X 8 7/8" deep	450
24" X 24" sq. X 5 7/8" deep	500
24" X 24" sq. X 12" deep	800

Capacities are based upon a resistance or pressure drop of one inch of water. Resistance varies directly with capacity. For instance, two inches of water for double the capacity; one half inch when operated at half capacity.

The type of construction of these filters and the fact that the material is a paper spanning across the opening limits the size because the paper must withstand static pressure. Test models of above sizes readily withstand an applied static pressure equivalent to over six inches of water. It is felt that a convenient upper size limit will be found to be about twenty-four inches wide by forty-eight inches long by twelve inches deep with an air capacity of slightly under two thousand cubic feet per minute.

Manufacturing Operations

For the wooden frames, 3/4-inch thick clear pine has been used on the 8-inch by 8-inch size, 7/8-inch on the 20 by 20-inch size, and a full inch on the 24 by 24-inch size. The frames have a half joint or a rabbeted joint at the corners, and are held by adhesives and by long wood screws or nails going into each side of the joint. The pleats and separators are anchored to the box on all four sides by a resin furnished by the Minnesota Mining and Manufacturing Company known as Adhesive 3M-EC 847. This material is stable against oxidation, and is more resistant to elevated temperatures than the rest of the materials in the filter.

The most suitable material for use in separators between the pleats is a paper of the type used for corrugating medium in the manufacture of corrugated shipping containers. It averages between nine and eleven thousandths of an inch thick. The type preferred for this operation is made of a fiber furnish of one hundred percent Southern kraft pulp, but straw corrugating medium and that made by the recently developed chemi-pulp process are acceptable.

These papers, when formed into corrugations for the construction of corrugated boxes, have flutes of several sizes. When used as pleat separators, a fluting resembling the largest size gives a space between pleats of a little over three-sixteenths of an inch. A slightly smaller fluting of a size about equal to the smallest size used in corrugated boxes is suitable for filters with pleats below five inches in depth.

This fluted corrugating medium is difficult to purchase already corrugated or fluted because in bulk, it does not roll, handle, or ship well. Moreover, when cut into the small pieces required for separators in assembling a filter, the corrugations nest together, and the handling of individual pieces is slowed down. It is preferable to buy the paper in rolls, to slit it to the proper width, and to run it through a small corrugator timed with the pleating machine in order to corrugate it only as fast as required. The machine for doing this is called a fluter, and is based upon a machine manufactured by the Chandler Machine Company of Ayer, Massachusetts for pleating or fluting cloth.

The following pages describe by text and illustration the steps in the manufacture of a filter as worked out under the development program. No attempts have been made to completely mechanize the operation because of the small scale on which it has been carried out. Jigs and miscellaneous equipment used are mostly built of wood, and construction has been carried only to a point sufficient to indicate how a production tool or simple piece of equipment can be made.

Briefly, the assembly operation consists of pleating the paper in a specially designed folding or pleating machine which, at the same time, inserts the separators simultaneously being fluted on another machine and fed by hand to the pleater. The pleat assemblies, of a size to make one filter, are then run through saws to trim the ends to exact dimension. The ends of the pleats are then primed and heavily spray coated with adhesive and the pieces of the wood frames likewise primed and brush or spray coated. With the proper amount of adhesive on all parts, the pleats in a jig are enclosed by the frame which is fastened by screws or nails. A final bead of plastic at the junction point of paper and wood plus the attaching of gaskets complete the job.

The following are the principal steps in manufacture:

1. Making Wood Frames
2. Preparing Adhesives, etc.
3. Slitting and Coating Gauze
4. Slitting Rubber Gaskets
5. Slitting Corrugating Medium and Filter Paper
6. Pleating and Inserting Separators
7. Sawing Ends of Pleated Assemblies
8. First and Second Spray Coating of Sawed Pleat Ends
9. Spray Coating of Frame Members
10. Assembling the Filter
11. Applying Plastic Bead
12. Cleaning and Smoothing Off Frames; Applying Gaskets
13. Testing
14. Inspecting, Painting, and Stenciling

These steps are discussed on the following pages for a twenty-four inch square filter rated 500 cubic feet per minute, which is a convenient size frequently produced. From these descriptive operations, a tentative man hour or labor cost is estimated basing figures on a man hour rate of \$1.50 per hour. These costs, together with material costs, are summed up under a subsequent major heading entitled "Costs."

1) Making Wood Frames

Up to the present time, these frames have been made of clear white pine for which a cost of \$35 per thousand is assumed for rough kiln-dried lumber purchased in quantity as five quarters or 1 1/4-inch thick. Allowing for waste, a frame requires 5 1/2 board feet costing about \$1.95. The operation of planing, cutting, and rabbeting is assumed to make the frames cost \$2.50 a piece, ready for assembling. As an alternate, the cost in one inch selected fir plywood should be less than \$2.00.

2) Preparing Adhesives, etc.

The adhesive 3M-EC 847, which is made by the Minnesota Mining & Manufacturing Company and is understood to be a Buna N and phenolic resin formulation, comes with a solids content of thirty-six percent. For use it is diluted to twenty-four percent solids, using a fifty-fifty mixture by weight of methylethyl ketone and toluol as diluents. The amount used in the construction of a filter is about one and two thirds pounds. As purchased, it costs about sixty-five cents per pound, and if diluted for use, allowing for waste, the cost is sixty cents per pound or \$1.00 per filter.

3) Slitting and Coating Gauze

Because of the extremely tacky nature of the adhesive making it difficult to brush-coat or to spray some surfaces, a procedure of applying the body of the adhesive in the form of a coated or saturated strip of gauze has been worked out. This is an alternative to brushing and spraying. Its value can be determined only by more experience than this small operation furnishes. The gauze is stiffened with starch as purchased, and costs about five cents per square yard. For use on this size filter, it would be slit into strips $5 \frac{3}{4}$ inches wide, making the four linear feet required for a filter cost something under two cents.

Photograph No. 1 indicates how the gauze may be drawn up from the adhesive solution between two doctor bars which imbed it in a plastic mass about one-sixteenth of an inch thick. This photograph aids in visualizing a simple device to pull the gauze from the roll through the adhesive and hang it in festoons about six feet high to partially dry ready for use. An operation requiring less than an hour for one employee at the beginning of each half shift period could easily treat enough material for one hundred filters at a cost, including gauze (but not adhesive which is covered elsewhere) of not over seven cents per filter for time and material.

Photograph No. 2 indicates how the material, semi-dried into a slightly tacky sheet, is applied in putting a filter together. This photograph happens to be on the assembling of an 8 by 8-inch filter.

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FIGURE 1 - COATING THE GAUZE

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FIGURE 2 - APPLYING THE GAUZE

A manufacturer of these filters would soon learn himself whether brush and spray application of the adhesive or the modified gauze method is best suited for his use in the final assembly steps.

4) Slitting Rubber Gaskets

Gasket material is a soft sponge rubber, one-quarter inch thick, made in the Middle West, and is called Tan Sponge. Its specifications will be discussed under a separate heading.

The material, which has been purchased at retail locally, costs sixty-cents per square foot. Gasketing one side of a filter requires two-thirds of a square foot at a material cost of forty cents. Large sheets are slit into required widths, i.e., 3/4-inch for an 8 by 8-inch filter and one inch for the larger sizes. Slitting is done in a simple device with a small revolving cutter attached to a motor running in a guided slot. The operation is rapid, and the time required for slitting, handling, etc., is less than five cents per filter, making the gasket cost ready for applying less than forty-five cents per unit. This would be for filters requiring gaskets only on one side. Gaskets on two sides, a usual requirement, double the cost.

5) Slitting Corrugating Medium and Filter Paper

The stock for separators will come in large rolls, and will cost about \$100 per ton delivered (equivalent to about \$1.50 per thousand square feet). The filter requires 140 square feet which would cost about twenty-one cents. Cutting labor should run less than ten cents per thousand square feet, making the total about twenty-two cents per filter.

The filter paper itself would come from the paper mill in rolls of proper width to go on the pleating machine, and allow one-half inch on each side for trimming after pleating. The filter requires about 140 square feet of paper plus five percent for trim and waste in pleating or 147 square feet total. The paper has a ream weight of 130 pounds. Allowing ten percent for wastage, the weight for one filter would be 6.4 pounds. At fifty cents per pound, this makes a cost of \$3.20 per filter.

6) Pleating and Inserting Separators

Photographs 8 and 9 show the pleating machine and fluter. The pleater is a rough but serviceable first model. The fluter consists of brass fluting rolls originally developed for pleating cloth. In Photograph 8 the fluter at the left has a roll of plain paper at the back of the machine passing through the rolls and hitting a microswitch to actuate a chopping knife which cuts the fluted piece to proper length.

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FIGURE 8 - PLEATER AND FLUTER

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FIGURE 9 - OPERATING PLEATER

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At the present low speed of the pleater, one operator can make eight pleats per minute, which means eleven to twelve minutes to make the ninety pleats required for one filter. This indicates a pleating cost of about sixty cents per filter, doubling the time to allow for interruptions from unknown causes.

7) Sawing Ends of Pleated Assemblies

The next operation is shown in Photograph No. 13. About ninety pleats are required to fill the twenty-two-inch space which is the inside dimension of the frame. There is a slight difference in the height of the corrugations in the separators made by the fluter, depending upon the stiffness of the paper and its moisture content at the time of using. This flute height determines the exact number of pleats. The capacity of the filter is only slightly affected by a slight change in the number of pleats. If the corrugated separators produce a wider gap than usual, there are fewer pleats and less paper in the filter. This results in a slight increase in resistance or pressure drop through the paper because the air velocity is higher. However, an increase in the space between the pleats decreases the friction loss of the air passing down into the space, which just about offsets the increase due to the smaller paper area. Conversely, if less height of flutes results in slightly less space, there is more paper area and the overall capacity is still not materially affected. This generalization is approximately true within practical limits.

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FIGURE 13 - SAWING

Arthur D. Little, Inc.

The required number of pleats is removed from the pleater and put into the jig shown in Photograph No. 13. The jig is resting on an improvised saw table with band saws properly spaced on each side so that when the jig is advanced, the saws will accurately cut the pleats to the required length.

The saw table is set on a slant because the saws do not cut well if they enter the paper in exact vertical line with the pleats. The saws in the picture are sixteen-inch models. A production operation should have larger saws with a greater gap so that the saw table can be set at a still more inclined angle; or, perhaps to achieve a better working arrangement, the saws could be set at an angle to allow the table to be level.

Much experimental work was done on best methods of trimming with rotary knife cutters and slitting knives and finally, saws of various tooth size, spacing and set, on a band saw. It has been found that a hard type of saw blade metal, having eleven or twelve teeth to the inch with little or no set, running at high speed, cuts cleanest and gives all-round best results.

This operation requires only a very few minutes, and might, on a time cost study, be considered to run into not over fifteen cents.

8) First and Second Spray Coating of Sawed Pleat Ends

Because the adhesive is difficult to brush out and the ends of the pleats are easily distorted, the adhesive to cover them is sprayed as shown in Photograph No. 15. Since the paper is absorptive, the operation should be done in two stages. The first coat is effective in sizing the surface and the second will build up a suitable thickness in which the pleats are imbedded for making the seal between the pleats and the sides of the filter frame. It should be noted in Photograph 15 that two ends of the frame, which have been previously coated, as described immediately below, are put into position, and the frames squeezed up to the proper dimension with the end clamping screws. Photograph No. 16 shows these ends being inserted into the jig.

The face of the paper which presses flat-wise against the other sides of the frame need not be spray coated.

9) Spray Coating of Frame Members

The frame members, spread flat on the table in groups, are given a fairly heavy coating of adhesive with the spray gun, covering the rabbeted joints as well as the face of the boards. Best results follow a procedure of doing this operation an hour or two before assembling in order that the adhesive take an initial set so that when used, it is more in the tacky stage rather than in the "runny" stage. A light priming coat, sprayed on the cut areas of the rabbeted joints, assures that the overall spray coat does not become absorbed into the rough joint.

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FIGURE 15 - SPRAYING AFTER SAWING

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FIGURE 16 - INSERTING ENDS OF FRAME

10) Assembling the Filter

The next operation is to take the pleat assembly with the ends sprayed, as per Photograph No. 15, and either give it and the end boards another spray coat or use the gauze mentioned under Operation 3, the application of which is shown in Photograph No. 2. The photograph happens to be that of an eight-inch filter being assembled in an early model of a wooden jig, but procedures are the same for a larger filter.

In assembling the boards by the gauze method, the filters and both sides of the gauze are given a quick sloppy brush coat of solvent, a fifty-fifty mixture of methylethyl ketone and toluol of the same make-up as that originally used for dilution of the adhesive. This produces a tackiness and softening which results in a binding together of all parts when the end board is screwed into place. The adhesive is so sticky and difficult to handle that a procedure of taking the gauze directly from the coating step, without a short period of drying to form a skin, and attempting to spread it on the pleated ends, proved unworkable.

If gauze is not used, the wood frames and ends of the pleats are given a sufficient adhesive application by spray, and are put together as in the other case. Frothy bubbles and drips or sags in the adhesive are points to guard against.

After the side boards are in place, they are screwed together as in Photograph No. 17, which shows the assembling of the twenty-four inch square filter.

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FIGURE 17 - ASSEMBLING

Photograph No. 18 shows the assembly of an 8 by 8-inch filter held in a metal jig which is a more accurate and workable operation. This photograph is included in order to indicate how the same idea can be applied to larger size filters with the metal sides, being built as flaps, attached to the sides of a square assembling platform. The flaps would fold back out of the way, but would be brought up into position with a foot treadle to put the proper pressure on all four sides of the frame, in order to bring the corners into tight contact and to assure a square box when the operation is finished.

A liberal estimate of the time required allows \$2.50 for this operation. Practice and better jigs should reduce this time.

11) Applying Plastic Bead

In order to anchor the pleated section to the frame with extra firmness and as an additional precaution against any possible pinhole leaks along the edge, a bead of the regular adhesive is run all along the inside of the frame on the top and bottom of the filter. It can best be done by putting the adhesive in a closed container from which it can be forced out by air pressure through a small pipe or nozzle suitable for applying a heavy bead. The operation must be done with care and is time-consuming because the adhesive flows erratically. It is estimated that to allow proper care, twenty minutes might be spent on each filter. This would include time for inspection.

FIGURE 18 - ASSEMBLING

12) Cleaning and Smoothing Off Frames; Applying Gaskets

Photograph No. 20 shows the gasket, having previously been cut into strips, being applied. For this purpose a solvent-type of neoprene cement has been found most suitable, after tests of several different types of cement. It is highly desirable to get a firm bond between wooden frame and the gasket so that if the filter is dragged along over the floor or elsewhere during installation, the rubber gasket will not be rolled off the edge.

Before applying the gasket, it may be necessary in some cases to plane off the top of the joints at the corners and to remove excess adhesive that has exuded at the corners when the side boards are squeezed into place. The smoothing off is done with a hand plane by taking off one or two light shavings. The cleaning up of the filter is done with a chisel or sharp blade after the adhesive has set up.

Applying the gaskets must be carefully done. From the small scale observations on this experimental work, it is estimated that not over twelve minutes of one employee's time would be used for the work under this heading, and that the cost would amount to thirty cents.

FIGURE 20 - APPLYING GASKETS

13) Testing

Testing is done by generating fine particles or aerosols and drawing them through the filter with a suction fan running at the operating capacity for which the filter is designed. The experimental testing apparatus used in the development work is shown in Photograph No. 21. In the photograph a 24 by 24-inch filter ready for testing is shown on the floor half way in a gap in the duct work. This filter will be raised into position, accurately set, and clamped tightly into place against the gaskets on both sides because the slightest leak to by-pass the test particles makes the test ineffective.

Directly behind the filter is a portable impactor which works on the principle of impinging a jet of air against a microscope slide in such a way that the dust from the air, owing to the jet action, is deposited on the glass. A sample of air from in front and behind the filter indicates the ratio of dust that is passed or the effectiveness of the filter. By properly choosing the time duration of the jet action, first, on the airborne dust in front of the filter and, second, with a clean slide, on the dust (if any) in the air passing through the filter, and by examining the slides on a high-powered microscope, the number of particles per cubic foot of air may be accurately determined. The relation between them is the filter efficiency.

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FIGURE 21 - TESTING EQUIPMENT

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The suspended particles may be artificially produced by spraying a measured quantity of methylene blue dye into the air, or in some cases, may be those naturally occurring in the air. The test air in this picture enters the pipe at a point away from the observer just behind the wooden trestle or horse that supports the main pipe. It makes a U-turn, and directly behind the gage is a spray nozzle which, through a hole at the bend, sprays a carefully measured quantity of dye solution under air pressure to produce a fine mist into the stream of air being sucked through by the blower at the extreme rear of the picture.

The dye solution, a carefully made solids composition, is metered to the nozzle by a Zenith accurate metering pump. The picture shows the solution in a beaker and directly below it the motor-driven metering pump which in turn is piped directly to the spray. Compressed air for spraying is supplied from a service air line, and the gage shown in front is used to regulate the quantity. The dye solution is so finely divided that the water quickly evaporates, leaving very fine crystals of methylene blue suspended in the air. The intensity of the suspension is governed by regulating the amount of liquid metered to the spray and by carefully measuring the entering air. To assure that the mist is all evaporated so that no liquid reaches the filter, the incoming air is heated by means of

electric heating elements suspended in the pipe. Energy amounting to about 2000 watts will raise 500 cubic feet per minute of ordinary room temperature (70°F) to about 110°F, which is sufficient. The equipment is provided with thermometer wells, sampling tubes and calibrated orifices with water manometers so that volumes and temperatures can be kept within a constant working range. Under "Specifications" the quantitative rate required for this form of testing is given.

The process of testing with the above described apparatus is slow because counting the dust particles under a high powered microscope takes time. While it gives accurate results, other methods under development will be quicker. One is the so-called smoke test apparatus.

For small scale testing of paper samples a smoke tester has been developed to a high degree of perfection. This apparatus generates aerosols or liquid particles by applying heat to various liquids under controlled conditions so that the fumes or smokes given off have a uniform particle size of three-tenths micron in diameter. These smokes in appearance roughly resemble cigarette smoke. The intensity or particle density of this airborne smoke can be measured quickly on instruments indicating the light scattering effect. Measurements of the airstream each side of the test sample of paper indicate the efficiency. The test is accurate and rapid.

The early equipment used for the purpose did not generate smoke in sufficient volume for testing a full size filter. Large size smoke generators are being worked out, and it is very probable that a similar device can be built or made available to this filter manufacturing operation. With such a set up, filters can be tested in a few minutes. It is therefore assumed that two men can test four filters per hour. This allows for lost time and lost motion between individual tests or between tests on batches of filters. The time cost would average seventy-five cents per filter.

14) Inspecting, Stenciling, and Painting

Inspecting under this heading would be a continuation of the care which must be exercised in the whole process of filter assembling. Final inspection following the test need only be for a general check-up for hand damage or some unusual feature.

Spray painting of the side boards will be optional upon request. Painting is not needed for appearance as the filters are usually installed in locations where they are not seen.

Because of the indefiniteness of what would be required of a large scale production, but in order to include coverage of all costs that might be required, a cost item for the operation of inspecting, painting, and stenciling is included. If ten minutes per filter are allowed, the cost is equivalent to twenty-five cents.

INDICATED COSTS

The costs given below are based upon the small production operation that has been carried on. Production steps carried on in connection with development work are spotty and costs extrapolated to indicate that an expanded operation is difficult to arrive at.

In the foregoing descriptive text, individual material and labor costs are given for various steps. Material costs are for material delivered to the plant, and include an allowance for wastage in processing. Labor costs are for direct labor only, determined from the man hours estimated at an hourly rate of \$1.50 as previously explained. Undistributed employee and plant overhead has not been included.

Costs for a 24" X 24" X 5 7/8" Filter - 500 c.f.m. capacity:

Wood frame ready for assembly	\$2.50
3M Adhesive, including solvents	1.00
Gauze (Coated)	.07
Gaskets - Retail price	.90
Separator paper, slit, ready for use	.22
Filter paper, ready for pleater	3.20
Pleating and inserting separators	.60
Sawing ends	.15
Inserting in spraying jig, spraying ends of flutes, spray coating inside of frame members, assembling filter, and screwing or nailing all joints - one hour (2 men)	2.50
Applying plastic bead	.25
Cleaning up and gasketing	.30
Testing	.75
Inspecting, Painting, and Stenciling	.25
	<u>\$12.69</u>

Many items in the above may appear generous in man hour requirements because much depends upon the scale of manufacturing, i.e., the number of filters of one size that can be carried through as a single batch. When applying overhead and undistributable plant costs to the above figures, this fact should be recognized.

SPECIFICATIONS - MATERIALS

This heading covers materials used, assembly techniques, and performance tests on finished filters. The specifications refer especially to the following capacities and outside dimensions. These sizes are the same dimensions as the filters now in use or proposed for various uses. Depths given are before gaskets are put on. Capacities are for tests on room air at resistance of one-inch of water for the following sizes:

8" X 8" X 5 7/8"	Capacity:	50 cfm
8" X 8" X 11 1/2"	"	100 cfm
20" X 20" X 8 1/2"	"	450 cfm
24" X 24" X 5 7/8"	"	500 cfm
24" X 24" X 11 1/2" *	"	800 cfm

* This dimension of 11 1/2" may be made 12" and pleat height left same or increased 1/2" in certain instances.

Filter Paper

This paper, as presently made, is a furnish of specially treated chemical wood pulp and blue Bolivian asbestos. The amount and distribution of asbestos, averaging around fifteen percent, is regulated to give a paper of the following characteristics:

<u>Thickness:</u>	Between the limits of .035 to .045" immediately after the calender stack. Stack to be operated to give light calendering.
<u>Ream weight:</u>	About 130 pounds.
<u>Tensile strength:</u>	1 3/4 pounds to 2 pounds per inch, machine direction.
<u>Resistance - inches of water:</u>	4.3 inches (110 mm.) at air velocity of 28 linear feet per minute (maximum increased resistance tolerated will be 10%).
<u>Percentage of penetration on a smoke tester generating particles of .3 micron diameter when operated at standard performance at above velocity:</u>	.1% (maximum)
<u>Percentage of penetration when operated at same velocity on reasonably dirty room air:</u>	.02% (approximate)

Subsequent surface treatment of paper is still under consideration. If used, it will improve the scuff resistance and increase tensile strength.

Separators

The corrugated paper separators may be made of any acceptable type of corrugating medium, as used by shipping container manufacturers. The several most satisfactory grades likely to be available are:

Southern kraft nine point

Straw nine point

Semi-chemical or chemi-pulp paper

These papers range from eight and one-half to eleven thousandths of an inch thick, and weigh about thirty pounds per thousand square feet. More costly paper less susceptible to dimension changes due to high humidity is still undergoing tests, and may prove preferable.

Separators should be corrugated or fluted in such a way as to give about eighty-five to ninety pleats for a twenty-four inch square filter frame which is twenty-two inches inside measurement.

Lumber

This should be commercial grades of thoroughly kiln-dried clear white pine free from knots, pitch streaks, or other imperfections, and would be satisfactory in the following finished dimensions. Single width boards (i.e. without matching or splices) would be used, except where finished width is eight inches or over. In such cases a fully glued double matched joint is not desirable, but may be used.

8" X 8" sizes:	finished thickness -	13/16"
20" X 20"	"	"
24" X 24"	"	"

In the case of twenty-four by twenty-four inch sizes, plywood may be substituted for white pine lumber. Plywood should probably be a full inch in thickness of so-called waterproof grade fir, good two sides. Thickness, whether three-quarters or one inch, has not been decided upon, and will be determined by experience. The material must be free of surface cracks at time of use. Individual pieces must have no internal cavities or cracks occurring at locations where possible air leaks could result. These cavities or cracks are caused by splicing the plies of veneer at time of manufacture.

All corner joints shall be half joints, whether in plain lumber or plywood, of the style shown in the various photographs.

Hardware

Choice between nails or screws is optional for corner joints. Sizes and lengths of either must be suitable for the different sizes of filter frames as will be decided later. If nails are used, they should be long coated box nails or some form of grooved shank nail.

Gasket Material

Until otherwise decided, all gasket material should be similar and equal to that presently being purchased from the Greene Rubber Company, a Cambridge, Massachusetts retail distributor.

Name: Style No. 2150 Tan Sponge Rubber

Formulation Characteristics:

62% natural rubber by volume
.5% free sulphur, maximum, by weight

Test Characteristics:

Maximum density: .02 pounds per cubic inch
Compression resistance: 2 to 7 pounds per square inch to compress to 75% of original thickness.
Recovery: When compressed to 50% of original thickness for 48 hours, recovery will be to 95% of original thickness in a time of not over one minute after removal of compressive load.

Gaskets must not be wider than the thickness of the filter frame lumber, but may be not less than 1/16 of an inch narrower.

Gasket Cement

A neoprene cement has been found most satisfactory for firm bond of rubber to wood. Any neoprene cement that under tests gives equally good adhesion will be acceptable.

Adhesive Cement and Solvents

The cement used for spraying the ends of the pleats and for coating the frame boards and the gauze (when gauze is used) should be Minnesota Mining and Manufacturing Company 3M-EC 847, diluted to 24% solids with commercial methylethyl ketone and toluol. Solvents are a fifty-fifty mixture. The same solvent combination should be used to brush-moisten adhesive coated surfaces when assembling filters.

SPECIFICATIONS - PERFORMANCE TESTS

Filter units would be tested at specified air capacity rating after completion, and would operate at performance rating in cubic feet per minute at a resistance or pressure drop of water of one inch or less.

Tests used in development work consisted of clamping the filter in a gap in a test duct so set up that a fan at the outlet could draw through the required amount of air. Resistance or pressure drop was measured by a water manometer. Under these conditions the velocity of the air through the filter medium itself would be approximately five linear feet per minute.

Performance as to penetration or filtering effectiveness was determined as follows: A finely divided suspension of methylene blue crystals was fed into the entering air at the rate of twenty-five milligrams per one hundred cubic feet of testing air.

The particle size of the suspension should be an average or predominating size of four-tenths micron diameter with eighty percent in the range between two-tenths and one micron.

By means of a jet impactor using the high velocity jet, the number of particles in the air upstream and downstream of the filter is sampled and counted by microscopic study of the slides magnified to about 1450 diameters.

Under the foregoing tests the particles passing the filter would not be greater than five thousandths percent (.005%) as determined by comparative particle counts. Counts in our tests were made by determining the particles visible on a reticle field of sixty-two square microns. Sampling period must be timed so that the deposited particles on the slide are intense enough to be readily counted but still not so sparse that they are too few to be representative. A satisfactory sampling time on the upstream air was found to be thirty seconds with the impactor drawing off 8.8 liters per minute, and on the downstream side fifteen minutes at the same air flow.

Air sampling should be done within the first few minutes of the period of test at rated capacity flow because, in some cases, the initial performance of the filter improves very rapidly as air-borne particles are deposited within the meshes of the paper.

The methylene blue particle suspension is made as follows, taking a 500 c.f.m. test as representative. Standard grade methylene blue dye is dissolved in water in a proportion of .25% solids. This solution is sprayed into the air stream at the rate of fifty cc. per minute. A Zenith motor-driven accurate measuring or metering pump was used. The incoming air passed through heating coils to increase its temperature to about 110°F. The spray nozzle used was made by the Spray Engineering Company, Somerville, Massachusetts, Number 2070, and was operated at an air atomizing pressure of thirty pounds per square inch.

Reference has previously been made to the developing possibility of using a different testing device, a full-size smoke generator which, with proper electronic devices, would greatly simplify the testing set-up and speed up the operation of testing.

DISCUSSION OF AVAILABILITY OF MATERIALS

This discussion deals with the availability of materials and equipment under present conditions, but also considers how war conditions might affect supplies.

Filter Paper

The kraft paper making fibers used in the last run of paper were a specially soft pulp from Canadian spruce treated in the paper mill which made the filter paper. While this particular pulp was selected because it was felt that it might be especially suitable, many commercial grades of northern type kraft fiber can be used. Southern kraft in still more abundant supply either alone or blended with northern kraft is also likely to be found suitable if the need arises. Kraft pulp supplies are so large that availability under all circumstances need give no concern.

The caustic treatment of the fiber utilizes commercial caustic in a process using either rotary cookers or open agitated tanks of types found in most of the paper mills that would be suitable for making the paper. The causticizing process is patented by the mill which has made the paper for this contract, but the patents are about to expire. No difficulty in a license by other mills on government work is anticipated. The types of mill suitable for making this paper are the small plants making specialty papers of the soft or saturating type. There are a number of paper mills that, located in diverse parts of the country, can be made suitable if not already fully equipped for the process.

The Hollingsworth & Vose Company, now supplying the Army, can readily supply the ordinary needs of the Commission. If the demand for paper should greatly increase or if competitive bidding is desirable, other mills would have to be shown how to make the paper and probably would ask for educational orders before they would be ready to make a firm bid on an order.

Asbestos

Blue Bolivian asbestos appears to work best in the process for manufacturing this paper. South African blue can be used, but varies in quality as between shipments, and is sometimes troublesome. Both fibers must be imported and both were in short supply and hard to get during the last war. In a time of up-set world conditions and interrupted shipping facilities or local mining operations, a scarcity may be expected. This can be guarded against by stockpiling in quantities sufficiently large to provide enough asbestos to make up at least twenty percent of the weight of the filter paper produced. Total requirements may be estimated from the fact that about six and a half pounds of filter paper are required for one 500 c.f.m. filter, twenty percent of which being asbestos would weigh 1.3 pounds.

The Chrysotile grades of asbestos now being marketed from the deposits along the Canadian border and especially over the line in Quebec province, and in lesser degree from our own operating deposits in Arizona; are not suitable for the manufacture of filter paper. Outside of Chrysotile, there are no known suitable grades of asbestos in the United States and Canada.

The trade demand in asbestos is for relatively long, soft silky fibers. The producers avoid the coarse or "harsh" occurrences of this mineral. One of the difficulties in applying Chrysotile to filter paper manufacture is the extremely small filament diameter. However, samples received at this laboratory during several years' work with asbestos indicate that in the Arizona deposits, a coarse type fiber is found that is more like the imported blues, and that it should be usable in filter paper.

If examination and tests of outcroppings and unworked parts of operating mines should find a suitable supply, the menace of failure of overseas supplies would be eliminated. To investigate the possibilities would require a field exploration followed by laboratory and then experimental paper mill runs to prove the point definitely.

Separator Paper

Papers of a type suitable are made in large volume, and are widely available. No concern over the supply need be felt.

Adhesives

Both the 3M cement, believed to be a formulation of buna N rubber and phenolic resin, and the neoprene cement for gaskets are made from standard materials that should always be available.

Gaskets

The material used contains natural rubber, but it is believed that equally good substitutes of synthetic or artificial rubber can be made if it should ever become necessary.

Testing Equipment

The only test equipment suitable for control testing of the filter paper during manufacture are the D.O.P. testers developed by the Army and Navy and which they loan to paper mills manufacturing for their use. The Hollingsworth & Vose mill at West Groton, which makes paper for both branches of the service, has been equipped with testing apparatus.

This apparatus was available for the runs of paper made for this contract. If the Commission is to proceed with independent production of its paper, it must secure the use of equipment of this type.

For testing finished filters, there will be required fan and duct work suitably designed for rapidly clamping the different sizes of filters in place, and passing a measured rate of air flow through them. This part of the equipment is simple, of low cost, and easily made. The instruments and process for taking the measurements to show the effectiveness or efficiency of performance are somewhat complicated. A set-up using a cascade impactor and counting samples of dust greatly magnified has been described.

The Chemical Corps uses a quicker method, comparing color staining on paper discs. A more recent development under consideration is an apparatus for generating a D.O.P. smoke on a sufficiently large scale to test a full size filter. This permits sampling to be done in the same type of detection apparatus as that used on the paper in the paper mills. If arrangements can be made to duplicate or build similar equipment, the testing operation will be low in cost and easily carried on.