

UNCLASSIFIED

AD 296 236

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

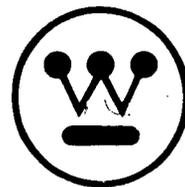
/

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

A 63-1-4 296236

Westinghouse

296 236



STIA
RECEIVED
FEB 12 1963
TISIA

DEVELOPMENT OF A SPECIFICATION FOR A 75 CFM
GAS PARTICULATE FILTER UNIT FOR REMOVING
THE CBR CONTAMINANTS OF WARFARE FROM THE
AIR SUPPLIED TO FAMILY SHELTERS

Contract No. DA18-108-CML-7029

17 September 1962

**DEVELOPMENT OF A SPECIFICATION FOR
A 75 CFM GAS PARTICULATE FILTER UNIT FOR REMOVING
THE CBR CONTAMINANTS OF WARFARE FROM
THE AIR SUPPLIED TO FAMILY SHELTERS**

Final Report to

**Commanding Officer
U. S. Army
CBR Engineering Group**

Attn: Mr. G. H. Kadel, Project Officer

Army Chemical Center, Maryland

Contract No. DA18-108-CML-7029

17 September 1962

**Westinghouse Electric Corporation
Portable Appliance Division
246 East Fourth Street
Mansfield, Ohio**

in

Conjunction with

**Westinghouse Research Laboratories
Churchill Borough
Pittsburgh, Pennsylvania**

AD Accession No. Unclassified
Westinghouse Electric Corp., Mansfield, Ohio
DEVELOPMENT OF SPECIFICATIONS for 75 CFM
Gas Particulate Filter Unit For 1. Air Purification
Removing the CBR Contaminants of
Warfare from the Air Supplied to
Family Shelters. - D.B.Price
F.P.Byrne
O.H.Kriege
Final Report, 17 Sept.'62, 85 PP - 12 Illus - 3 Tables
CONTRACT DA18-108-CML-7029
Report on the Development Program
which evolved a Specification
and prototype for a 75 CFM
Gas Particulate Filter and
Blower Unit for OCD

AD Accession No. Unclassified
Westinghouse Electric Corp., Mansfield, Ohio
DEVELOPMENT OF SPECIFICATIONS for 75 CFM
Gas Particulate Filter Unit For 1. Air Purification
Removing the CBR Contaminants of
Warfare from the Air Supplied to
Family Shelters. - D.B.Price
F.P.Byrne
O.H.Kriege
Final Report, 17 Sept.'62, 85 PP - 12 Illus - 3 Tables
CONTRACT DA18-108-CML-7029
Report on the Development Program
which evolved a Specification
and prototype for a 75 CFM
Gas Particulate Filter and
Blower Unit for OCD

AD Accession No. Unclassified
Westinghouse Electric Corp., Mansfield, Ohio
DEVELOPMENT OF SPECIFICATIONS for 75 CFM
Gas Particulate Filter Unit For 1. Air Purification
Removing the CBR Contaminants of
Warfare from the Air Supplied to
Family Shelters. - D.B.Price
F.P.Byrne
O.H.Kriege
Final Report, 17 Sept.'62, 85 PP - 12 Illus - 3 Tables
CONTRACT DA18-108-CML-7029
Report on the Development Program
which evolved a Specification
and prototype for a 75 CFM
Gas Particulate Filter and
Blower Unit for OCD

AD Accession No. Unclassified
Westinghouse Electric Corp., Mansfield, Ohio
DEVELOPMENT OF SPECIFICATIONS for 75 CFM
Gas Particulate Filter Unit For 1. Air Purification
Removing the CBR Contaminants of
Warfare from the Air Supplied to
Family Shelters. - D.B.Price
F.P.Byrne
O.H.Kriege
Final Report, 17 Sept.'62, 85 PP - 12 Illus - 3 Tables
CONTRACT DA18-108-CML-7029
Report on the Development Program
which evolved a Specification
and prototype for a 75 CFM
Gas Particulate Filter and
Blower Unit for OCD

TABLE OF CONTENTS

	<u>Page</u>
List of Tables	V
List of Figures	VII
Abstract	1
Introduction	2
Phase I Feasibility Study	3
A. Definition and Analysis of Problem	3
B. System Parameters	3
C. Components Search	4
D. Filtration	4
Phase II Design and Fabrication of Prototype	6
A. Components	6
1. Blower Unit	6
2. Gas Particulate Filter	7
3. Duct	8
B. Packaging	8
C. Cost Estimate	8
1. Influence of Marketing on Costs	9
D. Drawings	9
Phase III Test and Evaluation	10
A. Blower Unit Performance Tests	10
1. Blower	10
2. Hand Crank Drive	10
3. Motor Drive	10
4. Framing and Support	10
5. Noise Level	10
6. Transportation Test	10
B. Gas Particulate Filter Performance Tests	10
1. Prefilter	10
2. Particulate Filter	11
3. Gas Filter	11
4. Transportation Test	11
C. Power Input by Humans	11
D. Gas Particulate Filter Unit System Performance Tests	12
E. Performance Specification	12
Conclusions and Recommendations	13
Appendices	
Recommended Performance Specification	Appendix A
Filtration Analysis - Dr. F. P. Byrne, Dr. O. H. Kriege	Appendix B
DOP and Rough Handling Tests - Particulate Filter	Appendix C
Gas Filter Testing at Army Chemical Center	Appendix D
System performance Tests	Appendix E
Transportation Tests	Appendix F

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
I	Hand Crank Dynamometer Test	14
II	Hand Crank Speed <u>vs</u> Blower Speed	14
III	Hand Crank Endurance Test	15

LIST OF FIGURES

<u>Figure No.</u>	<u>Page</u>
1. Blower Unit	16
2. Blower Performance - 1400 RPM	17
3. Blower Performance - 1800 & 2200 RPM	18
4. Blower Performance - 2800 RPM	19
5. Blower Performance - 3400 & 3800 RPM	20
6. Gear Box Interior	21
7. Blower Unit - Wall Mounted	21
8. Gas Particulate Filter	21
9. Prefilter and Particulate Filter	22
10. Gas Filter	22
11. Gas Particulate Filter - Wall Mounted	22
12. Blower Unit Operated by Two People	22

ABSTRACT

An intensive development program was carried out to develop specifications for the CBR Gas Particulate Filter Unit. All available components and air purification methods were evaluated in light of end use requirements. Design concepts and parameters were established after careful consideration of required performance and economics. Based on this program, a recommendation is made for the performance specifications of the CBR Gas Particulate Filter Unit.

It is our belief that adherence to this specification will insure the procuring of Gas Particulate Filter Units of consistent quality, and at reasonable cost to the user.

INTRODUCTION

The Office of Civil Defense has recognized the need for maintaining a habitable atmosphere within a family shelter under conditions of fallout, or attack by chemical or biological agents. As part of the program to provide performance specifications for such shelters, the office of Civil Defense, acting through the Army Chemical Center, contracted with Westinghouse to provide the specifications for supplying the habitable atmosphere. In addition, Westinghouse agreed to build a prototype which would demonstrate the practicability of these specifications at a cost within reach of the average family.

A habitable atmosphere must contain no chemical, biological and radiological (CBR) agents, must have sufficient oxygen for comfortable maintenance of life and a minimum of carbon dioxide and odors. In addition, a livable comfort index is essential. There are a number of ways to maintain such an atmosphere. These were reviewed and evaluated for both practicability and economics. This evaluation confirmed the viewpoint that a blower combined with a filter system was, at this point in time, the most practical and economical system for providing the habitable atmosphere. Thus, the main objective became the providing of a performance specification for a CBR filter-blower unit for family fallout shelters.

For widespread adoption of a unit meeting these specifications, reasonable cost and consumer appeal are essential. The first needs mass production techniques with emphasis on the use of off-the-shelf components and interchangeable parts. The second is a complex of ease of installation, proper packaging, minimized weight and size, and operation at a low noise level. In addition, government and industrial standards, where applicable, must be met. The design and fabrication of a prototype meeting all these requirements thus became the second objective.

These objectives were accomplished. This report describes their accomplishment and is organized according to the three development phases outlined in the contract as follows:

- Phase I Feasibility Study - Investigate and recommend an air purifying system, establish the design concept, conduct a search of available components, and establish the system parameters.
- Phase II Prototype - Build a prototype meeting the proposed performance specifications.
- Phase III Test and Evaluation - Test and evaluate the prototype, and write the final recommended performance specifications.

PHASE I FEASIBILITY STUDY

A. Definition and Analysis of Problem

To understand this problem in its entirety, and before considering a gas particulate filter unit, the problem was defined as follows:

To provide, for two weeks, a habitable atmosphere in a small shelter containing ten people (140 man days), which atmosphere would not be contaminated with chemical, biological or radiological agents.

A habitable atmosphere is one which contains an adequate amount of oxygen and a minimum of carbon dioxide and odors. The relative humidity and shelter temperature should combine to a reasonable comfort index.

Consideration was first given to a sealed shelter wherein oxygen would be supplied from cylinders, potassium superoxide, a potassium chlorate candle, or an electrochemical system. Carbon dioxide and odors would be removed by suitable absorbers - such as soda lime and activated charcoal. For each of these oxygen supply systems, the cost was well above the target figure of \$200. In addition, the rapid rise in the comfort index which these systems would exhibit - unless air conditioning at an additional cost were provided - would result in conditions becoming excessively uncomfortable (for 10 people) within a short time. Thus, it became clear that an atmosphere supplied by a hand-cranked blower (with power drive, if power were available), in conjunction with a gas particulate filter system, would be the most practical and economical. However, for up to 24 man-days of shelter requirement, use of cylinder oxygen would be within reason. Further details are in Appendix B.

With this established, the logical next step was the development of reasonable system parameters for the gas particulate filter unit.

B. System Parameters

Important system parameters were established:

1. Blower Performance - A blower design was required which would draw 75 cfm of purified air through an effective gas particulate filter. Since it was estimated that the resistance of the gas particulate filter would be 1.3" wg or less, it was decided that the available static pressure of the blower should be 3" wg to include an allowance for filter dirt loading, duct losses, and shelter pressurization.

2. Muscular Work Input - The horsepower input requirement of the hand crank drive was established at 0.08 horsepower maximum at rated output. This was an important parameter to be established, since it dictates the required efficiencies of the drive components.

It was readily apparent that the system efficiency would have to be high in order to produce the required output.

3. Required System Efficiency - Applying the equation (1) for fan efficiency:

$$\text{Efficiency} = \frac{\text{Air HP}}{\text{Brake HP}}$$

$$\text{Efficiency} = \frac{.0001575 \times \text{cfm} \times \text{pressure}}{0.08}$$

$$\begin{aligned} \text{Substituting: cfm} &= 75.0 \\ \text{pressure} &= 3.0 \end{aligned}$$

$$\text{Required System Efficiency} = \underline{44.2\%}$$

4. Pressure Drop of Filters - The maximum combined pressure drop of the prefilter, particulate filter, gas filter, and canister was set at 1.3 inches of water at 75 cfm.

C. Components Search

With these parameters established, an industry search for required components was considered a necessary step in this development program. Inquiries were sent to 20 blower manufacturers, 19 filter manufacturers, 13 gear manufacturers, and 10 duct manufacturers. As the development progressed, numerous other manufacturers were contacted for required components. The full range of the search extended from components to materials and parts, and included such items as V-belts, pulleys, gasket materials, lubricants, gears, bearings, cord sets, hardware, standard rolled steel products, pipe and duct and related fittings, forgings, processing equipment, clutches, air meters, extrusions, and steel drums.

The industry components search failed to uncover many of the "off-the-shelf" components. Of the major components, only the electric motor was readily available. The blower required special fabrication to meet the requirements. Filter material was available but the filter-containing components had to be designed for the prototype.

D. Filtration

Radiological and biological agents were, for the purposes of this study, considered to be associated with particulate matter ranging in size from 0.3 to several hundred microns. Chemical agents were considered to be either vapors or aerosols. While the aerosol might be stopped initially by a particulate filter, it was felt that it would eventually bleed through as a vapor. Thus, this divided into two problems - the removal of particulate matter and the removal of vapors.

(1) Mechanical Engineers Handbook, 5th Edition, Lionel Marks, McGraw-Hill

1. Removal of Particulate Matter - The use of precipitron techniques for the removal of particulate matter was abandoned because of the power requirement. A sand filter was considered because of the low cost of sand and its ready availability. However, for adequate filtration, the pressure drop was excessive, particularly if the sand became damp. Consequently this approach was dropped. This left commercial glass fiber as filter material. Such material will remove 99.97% of particles as small as 0.3 microns, but quickly becomes loaded. Consequently a disposable inefficient pre-filter was considered necessary to remove the large particles and to protect the main filter. Thus, for the removal of particulate matter, a glass-fiber pre-filter and a glass-fiber particulate filter were considered necessary.

2. Removal of CW Agents - Consideration was given to a dynamic system wherein the incoming air would be heated to a temperature at which CW and BW agents would be destroyed. This was too expensive. Various types of sorbents were considered. Activated carbons made from coconut shells, pecan shells and other "live" sources were considered. These had low capacity for CW agents. Molecular sieves have a low capacity and yield their best results only at very low temperatures. Silica gel becomes rapidly saturated with water and loses its effectiveness. Of all sorbent materials, ASC impregnated charcoal has the higher capacity for CW agents. Consequently this material was recommended.

Further details are in Appendix B.

PHASE II DESIGN AND FABRICATION OF PROTOTYPE

Throughout the design and fabrication of the prototype, particular attention was given to cost. Much analysis and planning was devoted toward evolving components suitable to mass manufacture at low cost.

A. Components

1. Blower Unit

a. Blower Component - The blower component was built by the Torrington Manufacturing Company who are highly experienced in the design and manufacture of small centrifugal blowers. The centrifugal type was chosen because it can develop the required static pressure and air flow volume with high efficiency. The operating speed (2800 rpm) was established high enough to permit the efficient use of backward curved blades - but not so high as to increase structure, bearing, vibration, and drive problems. Backward curved blades have advantages over radial or forward curved blades in providing non-overloading power characteristics (drive motor will not be overloaded by wide fluctuations in filter dirt loading), providing lower noise levels, and providing maximum power requirements at maximum efficiency.

Tangential blowers were considered, but were rejected because of their lower efficiency and higher cost at the rating required.

The prototype incorporates roller bearings with long life capabilities in order that extensive testing would not be endangered by blower failure. The blower was designed for 5,000 hours of continuous operation.

b. Hand Crank Drive - This was designed with molded Delrin spur gears and oiled nylon bearings for low cost and quiet, smooth operation. Only initial lubrication is required. The crank handle was designed to disengage if turned in the wrong direction.

c. Motor Drive - The motor is a NEMA 48 frame split phase unit for low cost, low weight and size, and ready availability from several sources.

d. Drive Clutch - A V-belt connection is used between the blower and motor and also between the blower and hand crank. This affords greater noise dampening between components and flexibility in later varying drive ratios (For different system blower characteristics, if desired).

When motor driven, the hand drive is completely disengaged thus preventing needless gear churning, gear wear, noise, and crank arm rotation. Conversely, when operated by the hand drive, the motor drive is completely disengaged, thus the friction loss of the motor bearings is not a drag on the muscular input.

The V-belt drive provides the clutching by means of manual changing of V-belt pulley center distances. When the motor belt is tight for driving, the hand drive belt is loose and disengaged, and vice versa. Easy manual shifting from motor to hand drive can be made in a few seconds, without danger, and by any housewife or "non-mechanic."

e. Framing and Support (Blower Unit) - Rolled steel angle iron for maximum strength at minimum weight and cost. The framing also provides the wall or base support. Two lengths of angle iron make the complete frame, thereby maximizing the use of common parts.

The complete blower unit is shown in Figure 1. Figure 6 shows the gear drive and Figure 7 the blower unit as it appears when wall-mounted.

2. Gas Particulate Filter

a. Canister - A modified 30-gallon drum proved ideal as a canister or container for the filters. It is low in cost, readily available from existing suppliers, and serves as its own shipping container. The round shape is structurally resistant to abuse, the full removable cover allows ready access to filters, and the drum requires a minimum of floor area. The drum, with filters enclosed, is shown in Figure 8 and wall-mounted in Figure 11.

b. Prefilter - The prefilter, shown face mounted to the particulate filter in Figure 9, serves to remove large particles from the air stream and thus protect and prolong the useful life of the particulate filter. This filter should not be an efficient filter, as it could load up too fast and restrict air flow. Being a low efficiency, coarse furnace type filter, the NBS dust efficiency test is not applicable - but if applied, the efficiency would be less than 15%. The media is American Air Filter Company's AIRmat furnace type media.

c. Particulate Filter - The particulate filter (Figure 9) is equivalent to the particulate filters tested by Arthur D. Little, Inc., in Contract No. DA18-108-405-CM1-871, and therefore meets all specifications. The filter frame size was reduced from 24 x 24" to 12 x 12", and the rated air flow reduced from 1,000 cfm to 75 cfm. Available sources of supply for this filter include Mine Safety Appliance Company, Cambridge Filter Corp., and Flanders Filters, Inc. The prototype incorporates a filter obtained from the Mine Safety Appliance Company, and is verified to be equivalent to the filters submitted by Mine Safety and tested by Arthur D. Little, Inc.

d. Gas Filter - The cylindrical design of this filter was arrived at after an unsuccessful attempt to employ a flat bed filter. The flat bed filter - 16-5/8 inches in diameter with a 1 inch bed depth - was tested at rated flow and exhibited pressure drop ranging from 1.37 to 1.63 inches water gauge (verified by the National Bureau of Standards). This pressure drop was higher than could be tolerated, and the cylindrical design (Figure 10) was evolved to reduce the pressure drop and at the same time increase the sorption capacity. This unit was filled with ASC Charcoal MIL-C-13724-Grade I.

All of these filters were built by Mine Safety Appliance Company, who are competent in the fabrication of specialty filters.

3. Duct

a. Gas Particulate Filter - Provided with inlet and outlet fittings (See Figures 8 and 11) which will accept either 4 inch steel pipe or standard 5 inch round furnace duct. See alternative below.

b. Blower Unit - This inlet will accept standard 5 inch round furnace duct. See alternative below.

c. Alternative - When wall mounting the gas particulate filter and blower unit at opposite ends of a duct hole (approximately 4 inch diameter) provided through the shelter wall, cuff gaskets are provided on the blower intake and gas particulate filter outlet which effect a seal against the shelter wall around the wall opening. Thus separate duct is not required.

B. Packaging

The gas particulate filter requires no packaging since the canister is a very good shipping container. However, the inlet and outlet fittings were provided with caps to prevent entrance of contamination.

The blower unit was provided with special packaging. The packaging design is shown on drawing SDA-1154-D13 (included with the working drawings).

C. Cost Estimate

The following cost estimate on the blower unit and the gas particulate filter is presented on the basis of Government procurement cost:

Unit Requirement	100	1,000	10,000	Over 100,000
*Cost Motor Driven Blower Unit each	\$ 634.39	\$ 141.91	\$ 77.37	\$ 71.29
*Cost Manual Blower Unit each	616.00	125.20	61.05	54.80
*Cost Gas Particulate Filter each	203.55	85.86	66.77	58.94
Tools, Blower Unit	34,385.00	35,360.00	34,410.00	34,410.00
Tools, Gas Particulate Filter	4,800.00	4,800.00	5,300.00	5,300.00

*Includes Tool Expense

In addition, it would be desirable to present a cost estimate based on consumer procurement cost through existing non-governmental distribution channels. Following is a discussion of the cost variables in this area.

1. Influence of Marketing on Costs - Marketing costs will often exceed the manufacturer's cost of building the product, if the product must be mass marketed.

The CBR gas particulate filter unit is a consumer item not unlike an appliance, requiring mass distribution, selling and service. The costs of taking a product to market through consumer distribution systems are high. Even with discounting, which has become common today, it would be reasonable to expect consumer cost at twice the Government procurement cost.

D. Drawings

Shop drawings were prepared on the gas particulate filter unit, including assembly drawings, suggested installation instructions and packaging drawings. Refer to Bill-of-Material Drawing No. SDA-1154-D4 for detailed drawing information.

PHASE III TEST AND EVALUATION

A. Blower Unit Performance Tests

1. Blower - Figures 2, 3, 4, and 5 show the performance of the blower at various speeds, including the performance at rated speed (2800 rpm). It is obvious from these curves that this blower could be adapted to other output conditions by merely increasing or reducing the speed. Under "Conclusions and Recommendations," we suggest this blower unit be seriously considered for large shelters, in addition to the home shelter program.

2. Hand Crank Drive - Table I shows the results of Dynamometer tests on the hand crank drive at various hand crank and blower speeds. Note that at rated output (75 cfm, 3.0" wg) the brake horsepower of the hand drive was measured at 0.081, thus achieving the 44% system efficiency objective. Table II shows the relationship between crank speed and blower speed.

The gear box incorporated into the hand drive has been life tested in excess of 600 hours with no noticeable wear or deterioration of parts.

The molded Delrin gears and oiled nylon bearings incorporated into this unit have proved to be unusually quiet and smooth operating.

3. Motor Drive - When operating the blower unit at rated capacity, the split phase 1/6 HP motor draws 175 watts and 3.2 amperes at 115 volts. The motor is operable from 105 to 130 volts.

4. Framing and Support - Tests conducted with the blower unit wall mounted, Figure 7, shows the framing and support to be very rigid and structurally adequate.

5. Noise Level - The blower unit operates at an extremely low noise level. Against a background noise level of 66 Decibel the noise level two feet directly in front of the blower unit is 69 Decibel when motor driven and 69 Decibels when hand cranked. This test dramatically demonstrates the unusual quietness of this unit. As previously mentioned, the molded gears and bearings contributed to this low noise level. However, the V-belt drive, providing an effective sound barrier between components, is perhaps the greatest contributor to low noise level.

6. Transportation Test - The blower unit packaging design was successfully verified. The results of the Transportation Test are included in Appendix F.

B. Gas Particulate Filter Performance Tests

1. Prefilter - The pressure drop across the prefilter is approximately 0.02 inches of water and it is unaffected by rough handling.

2. Particulate Filter - The pressure drop across the particulate filters was checked at 0.46 inches water and the DOP penetration was less than 0.03%. DOP tests were run at the Army Chemical Center on two units, before and after rough handling, and the results, in Appendix C, show little change in DOP penetration before and after rough handling, and in no case did the penetration exceed 0.03%.

3. Gas Filter - Gas filters were tested at the Army Chemical Center for CW agent retention and for rough handling. The rough handling tests were successfully passed. The filters were shown quite effective in removing GB vapor and provided at least two hours protection at a GB vapor concentration of about 3 mg/liter.

In all tests except one, the filters within experimental error collected 44 grams of Freon 12 before breakthrough. In the one exception, the filter was shown to have absorbed a considerable amount of moisture, and after purging and drying, successfully passed the test. We would suggest that a negative ion detector (See Report on Contract DA18-108-CML-6549) be used because of its greater sensitivity, instead of the infra-red instrument for detection of filter breakthrough.

Chloropicrin (PS) results gave a breakthrough time of approximately 23 minutes before and after rough handling, and the amount of PS absorbed was approximately 800 grams. These results were considered satisfactory.

The variations in the Cyanogen Chloride test results precluded any valid conclusions since a small sample lot was available.

Further details will be found in Appendix D.

4. Transportation Test - Transportation tests were run on the gas particulate filter. The results are shown in Appendix F.

C. Power Input by Humans

The results of the dynamometer test on the hand crank drive are shown in Table I. In addition, people at random were asked to crank the unit in order that a measure of their endurance could be made. The results of this investigation are shown in Table III. It is noteworthy that persons C, H, and I tired rather quickly. Their physical condition was not necessarily the important cause of tiring. Rather, psychophysical factors could be involved. It is difficult to get a true measure of the ability of people to expend energy cranking a life depending device unless the test conditions create the incentive for survival that would certainly exist under warfare conditions. Therefore, we can only conclude that most people will be able to crank the blower, particularly under survival conditions.

The blower unit can be easily cranked by two people, as is shown in Figure 12. Sharing the work load in this manner will enable more people (such as children) to contribute to blower operation.

D. Gas Particulate Filter Unit System Performance Tests

The unit was tested in accordance with Performance Specification Section II, Part b, Paragraph 20 (See Appendix A). The unit delivered 75 cfm against a back pressure of 1.9 inches of water. See Appendix E for the complete results of this test.

Tests were not conducted on the gas particulate filter unit where the requirements represented common commercial practice, when these tests are destructive and would serve no useful purpose at this time. In this category were the tests for fire resistive heat stable materials and the corrosion test.

E. Performance Specification

The Performance Specification we recommend for controlling the performance and quality of CBR Gas Particulate Filter Units procured thereunder, is fully detailed in Appendix A. The working specification which was supplied by the Government as an Appendix to the contract served as a guide throughout the development of the gas particulate filter unit.

CONCLUSIONS AND RECOMMENDATIONS

The final design and performance of the gas particulate filter unit meets the specifications set forth in Appendix A. The design evolved is well suited to mass production, and its simplicity insures greater reliability. The units are compact and yet flexible for adaptation to various shelter constructions.

Specifically we wish to recommend:

1. The blower unit be used without the gas particulate filter in fallout shelters, substituting existing available prefilters or gravity filters instead. The gas particulate filter would still be used for CBR shelters, where protection from these additional types of warfare would be desired.
2. Provide multiples of the gas particulate filter and/or the blower unit for community shelters. Costs would be favorable, and no other system would provide the high degree of reliability, since manual operation can be employed, if necessary. Also, there may be a psychological advantage in having these manual units available - even if the probability of having to resort to manual operation is small.
3. Changing the performance level of the blower unit (by changing pulley and belt sizes) to suit shelter needs of higher cfm or static pressure requirements (See blower performance curves, Figure 2, 3, 4, and 5).
4. Changing the performance level of the filter system to suit shelter needs of higher protection requirements, or to suit shelter needs of higher air delivery and static pressure requirements, by increasing the number of filter units employed. As an example, two filter units arranged in parallel would provide more than double the protection of one filter unit, and the pressure drop across these two filter units would only be 1/2 the pressure drop across one unit. Therefore, a single blower unit would be capable of delivering more air against a higher back pressure within the shelter.
5. Considering the application of auxiliary sources of 60 cycle electrical supply, such as 1,000 watt generator sets (available from Sears Roebuck at \$125.00).
6. Conducting more study on the psychological and physiological considerations of blower manual operation. We strongly recommend the gas particulate filter unit prototype be subjected to a shelter use test.

TABLE IHAND CRANK DYNAMOMETER TEST RESULTS

	Test #1	Test #2	Test #3	Test #4	Test #5
Blower Speed, RPM	2800.	2800.	2200.	1800.	1400.
Crank Speed, RPM	64.	64.	50.	41.	31.
Static Pressure, inches water	0	3.0	0	0	0
Torque, oz ft.	125.	107.	83.	63.	45.
Brake Horsepower	0.095	0.081	0.049	0.031	0.017

TABLE IIHAND CRANK SPEED VS BLOWER SPEED

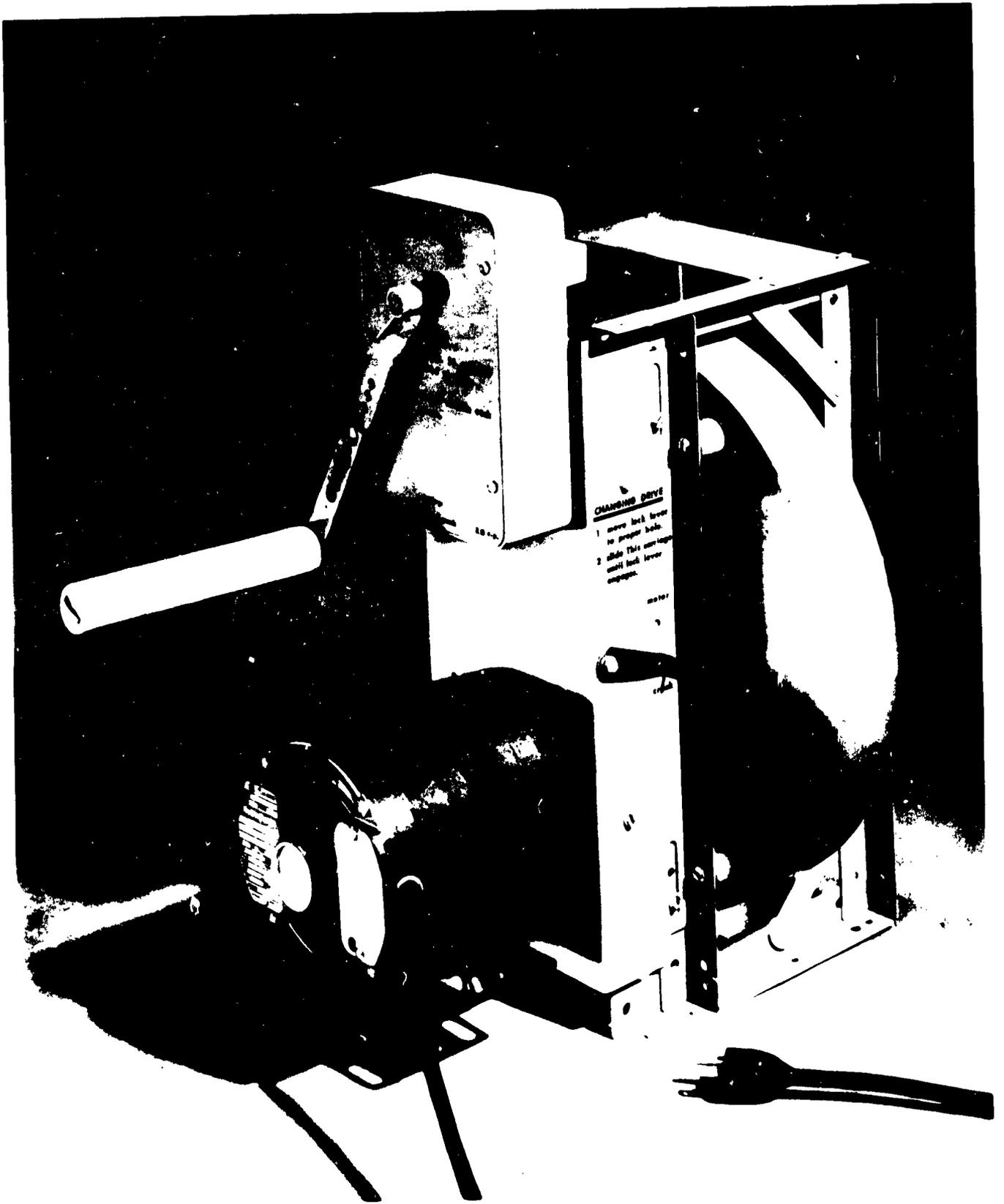
Blower RPM	2800	2600	2400	2200	2000	1800	1600	1400	1200
Crank RPM	64.	59.	54.	50.	45.	41.	36.	31.	27.

TABLE IIIHAND CRANK ENDURANCE TESTConditions

Blower Wall Mounted
 Crank Axis $38\frac{1}{2}$ inches above floor
 55 RPM Crank Speed
 2400 RPM Blower Speed
 Blower Wide Open (No static pressure)

Results:

<u>Code Name</u>	<u>Sex</u>	<u>Approx. Age</u>	<u>Approx. Wgt.</u>	<u>Approx. Hgt.</u>	<u>Crank Time</u>	<u>Comments</u>
A	M	31	160#	5'10"	1 hour	O.K.
B	M	45	150	5'8"	20min	O.K.
C	M	25	150	5'8"	11 min	Tired
D	M	28	165	6'1"	25 min	O.K.
E	M	45	145	5'8"	10 min	O.K.
F	M	45	140	5'8"	20 min	O.K.
G	M	54	160	5'10"	20 min	O.K.
H	F	32	135	5'6"	4 min	Tired
I	F	32	135	5'6"	3 min	Tired
J	F	50	140	5'5"	10 min	O.K.
K	F	50	140	5'6"	10 min	O.K.
L	F	47	110	5'2"	$6\frac{1}{2}$ min	O.K.



Graph No. 13211 Date 5-10-62 P. H. P. H.S.

Test Code FMI-702 NEMA RPM 1400

Test No. 13189-T P. H. P. P-5016

AIR PERFORMANCE OF WESTINGHOUSE C.B.R. BLOWER DYNAMOMETER TEST AT 2700 RPM CALCULATED TO 1400

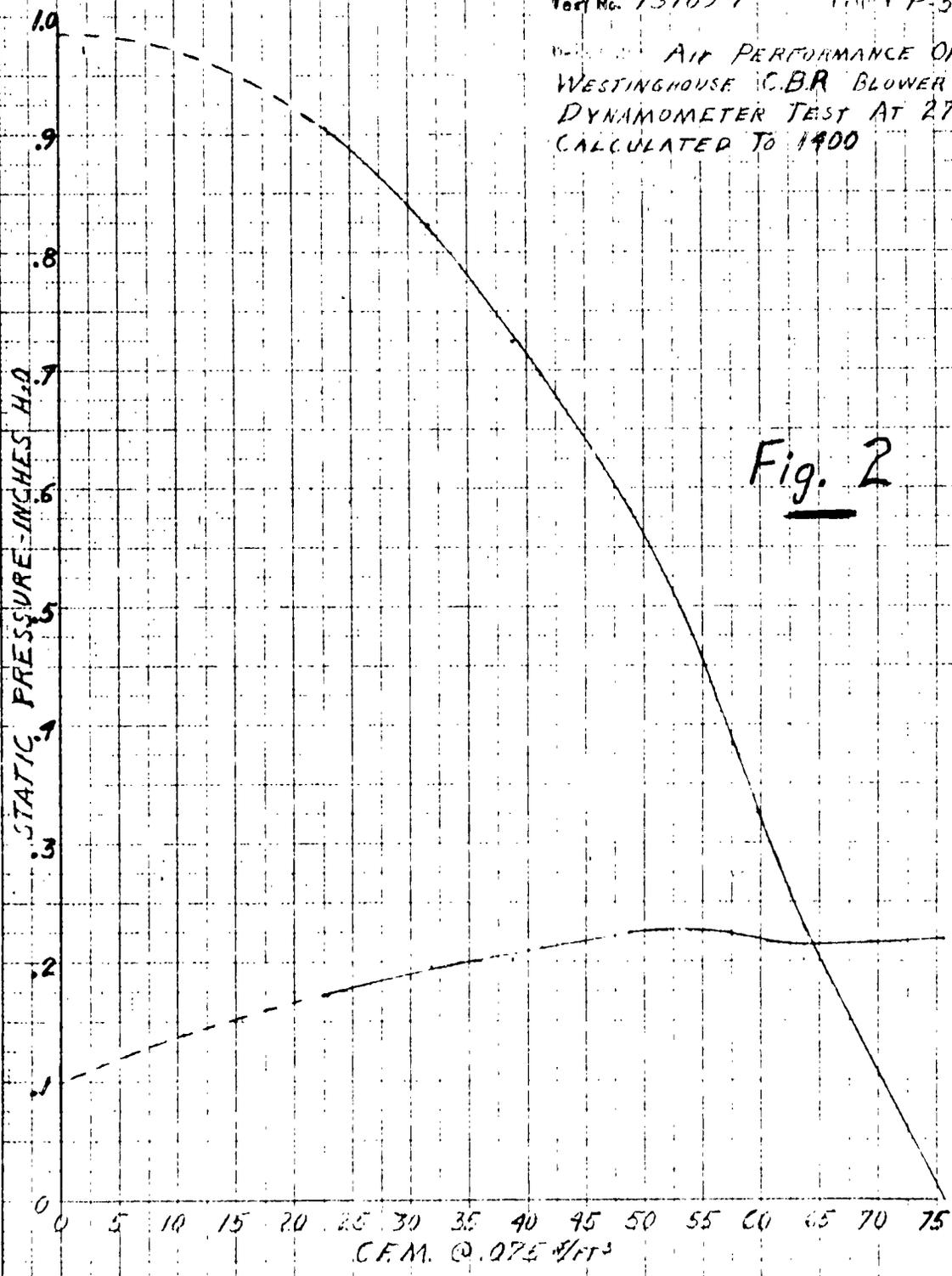


Fig. 2

0.010
0.008
0.006
0.004
0.002
B.H.P.

Air Inlet Pressure Factor of 1.0

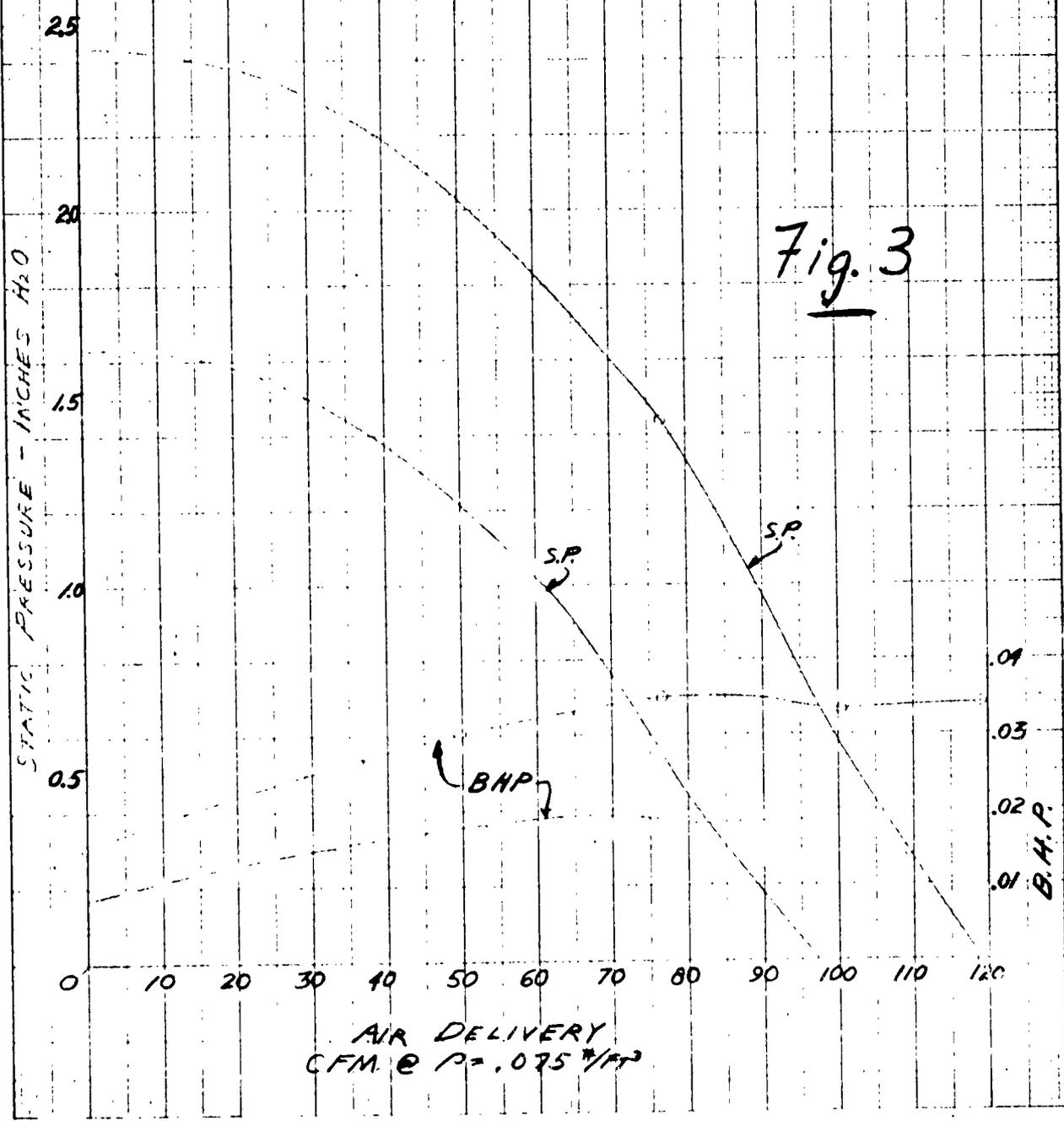
Graph No. _____ Date 7-19-62 By _____

Test Code _____ RPM 1800
2200

Test No. _____ Report No. _____

Figure 3 AIR PERFORMANCE OF WESTINGHOUSE CBR BLOWER
CALCULATED FROM LEAKMETER TEST AT 2200 RPM.

○—○—○ CALCULATED TO 2200 RPM
— CALCULATED TO 1800 RPM



Air Impeller Laboratory Test Report

Graph No. 13198 Date 5-10-62 Drawn By DRS

Test Code FMI-702 NEMA RPM 2800

Test No. 13198-T Project P-5016

Illustration AIR PERFORMANCE OF WESTINGHOUSE CBR BLOWER NUMBER A.15596

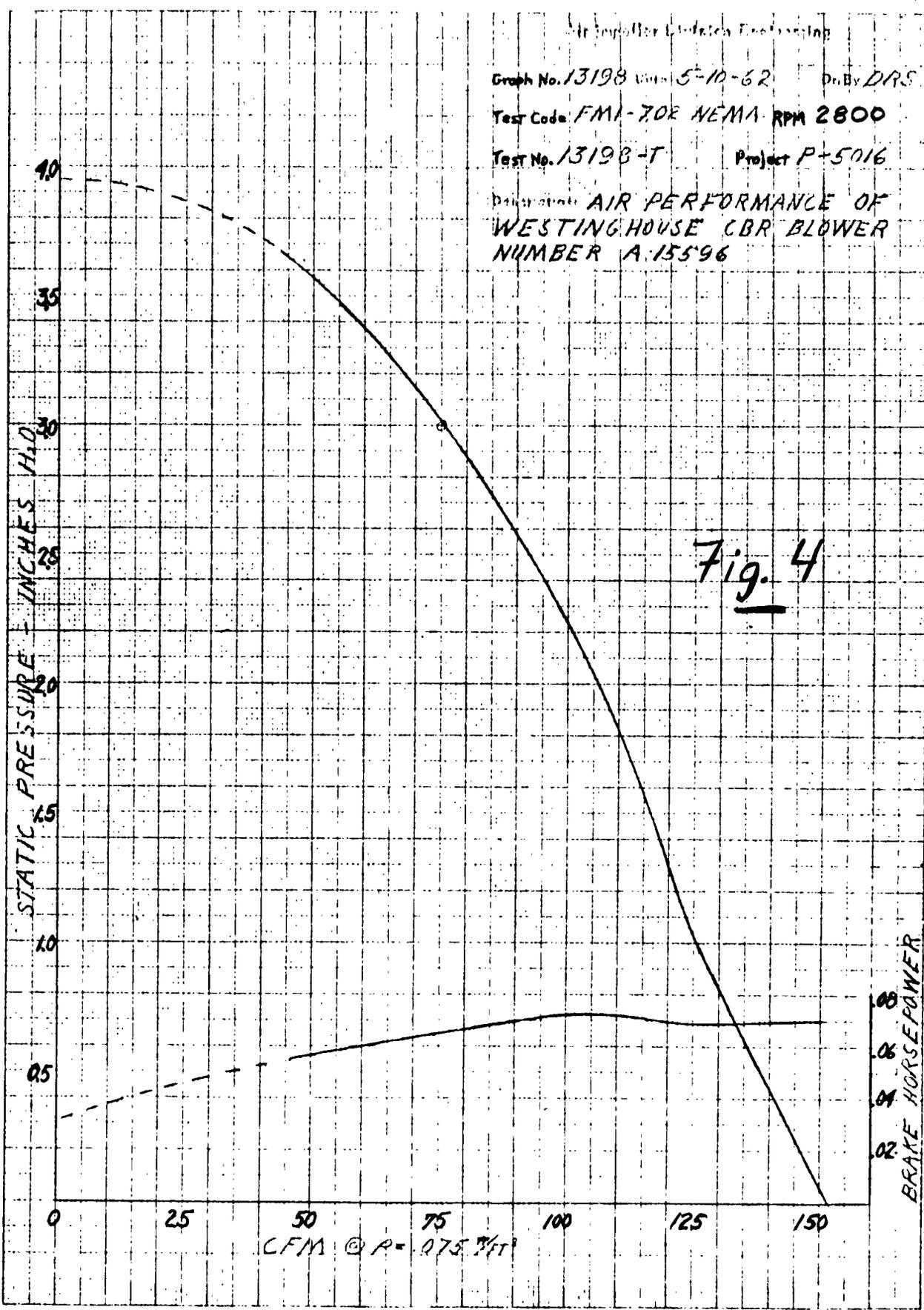


Fig. 4

Air Propeller Division Engineering

Graph No. 13210 Date, 5-10-62 Dr. By DRS

Test Code FMI-702

RPM 4200
3700

Test No. 13198-T

Project P-5016

Description: AIR PERFORMANCE OF
WESTINGHOUSE C.B.R. BLOWER
CALCULATED FROM DYNAMOMETER
TEST AT 2700 RPM

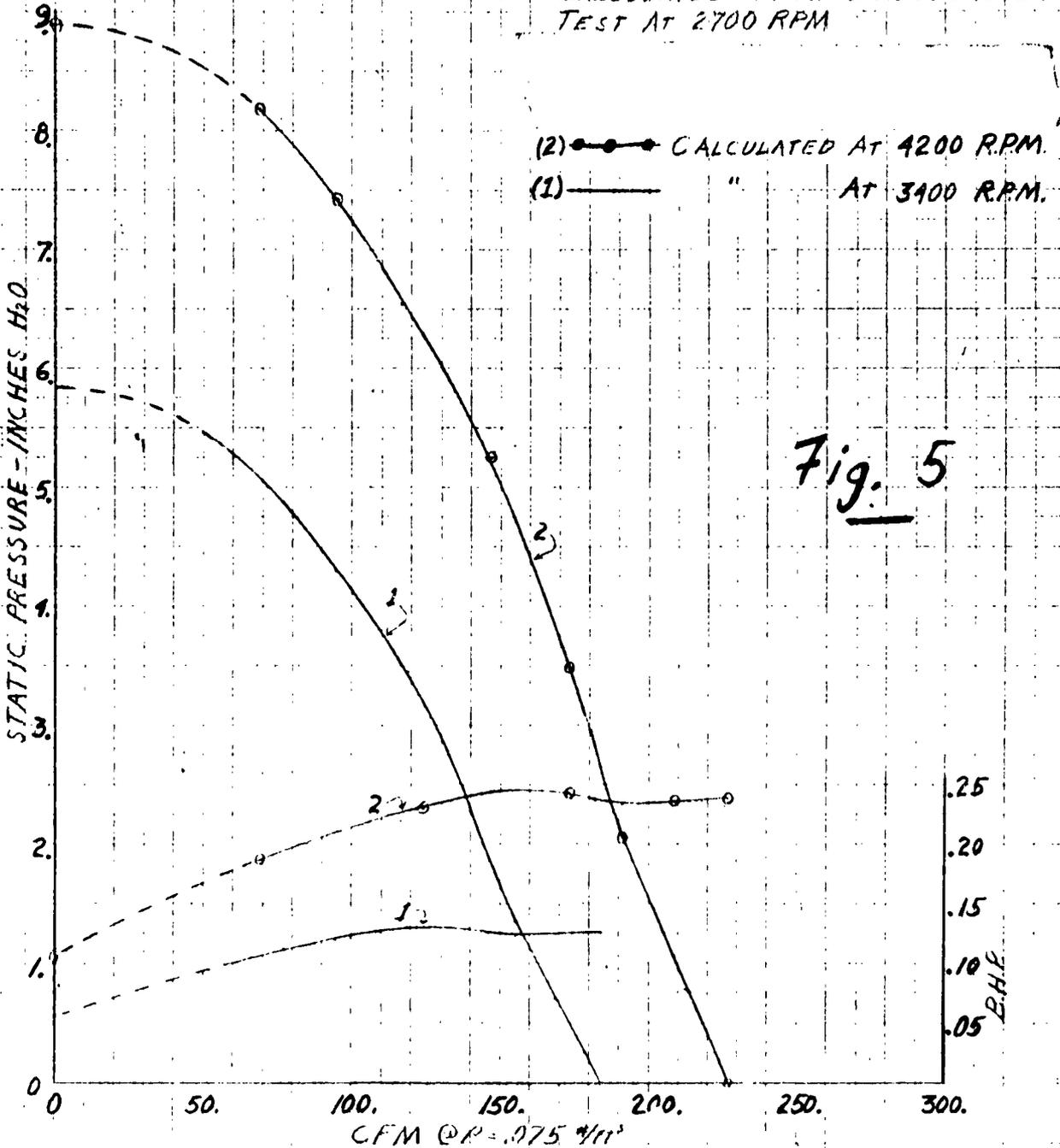
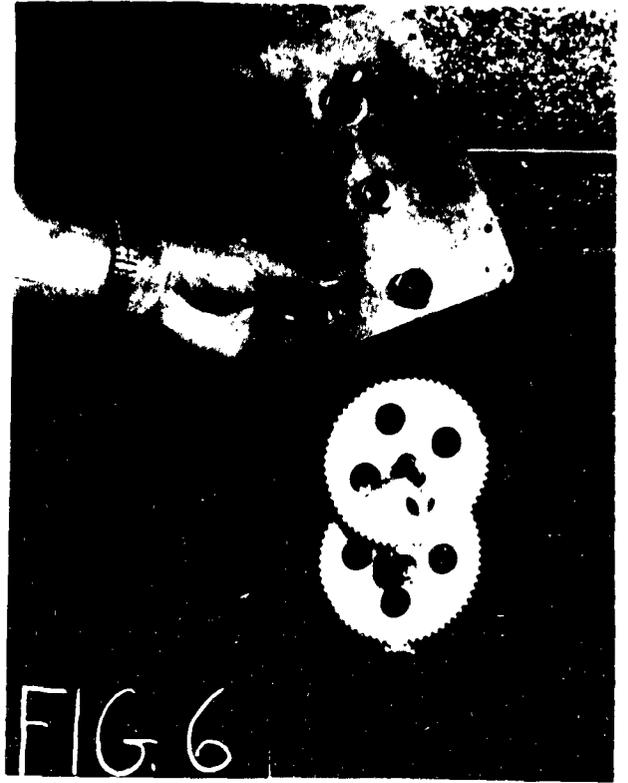


Fig. 5



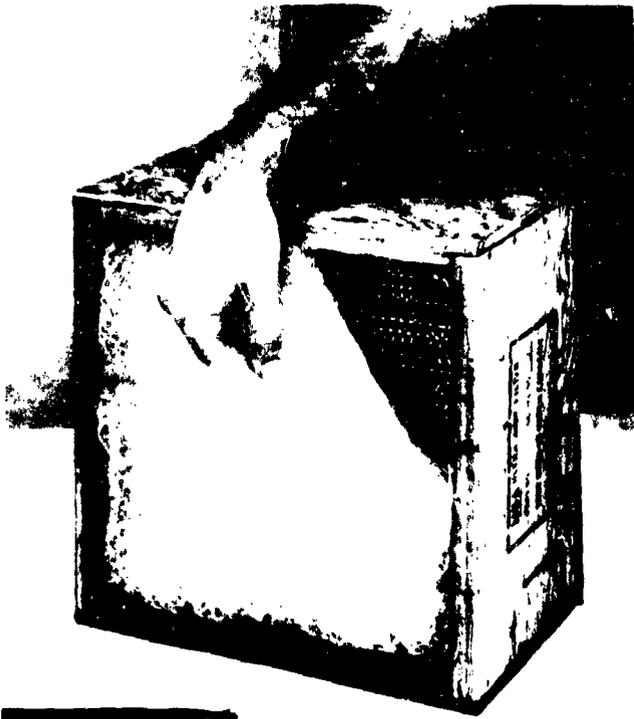


FIG 9

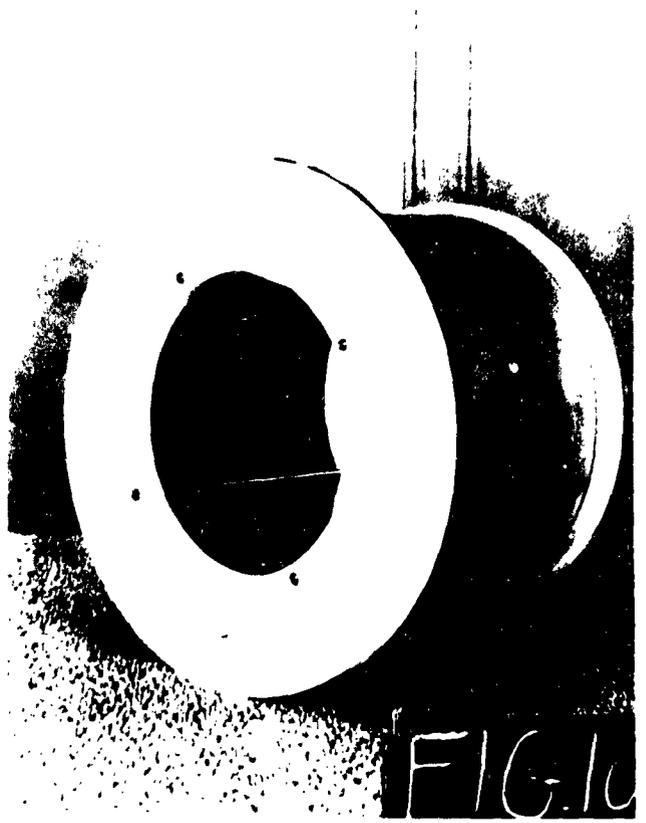


FIG. 10



FIG. 11



FIG. 12

APPENDIX A

1. A 75 cfm gas particulate filter unit is required for removing the CBR contaminants of warfare from the ventilated air supplied to family shelters.
2. The enclosed draft of performance specification requirements for a 75 cfm (CBR) gas particulate filter unit has been prepared in outline form to provide guidelines and establish a basis for evaluating candidate air purifying units.
3. Drawings SDA-1154-D4 and subsidiary drawings will be furnished by OCD upon request for use as reference only. Although a filter unit of this design was used to establish this specification, it should not be assumed that compliance with these drawings will assure the manufacture of filter units meeting this specification.
4. Manufacturers are encouraged to design their own filter units to meet this performance specification. However, those who may not wish at this time to design their own can use the design delineated in the note section of the specification. Nevertheless, regardless of the design used, the specification requirements will be overriding and must be met. (See performance specifications attached).
5. Tests will be performed and certified by an independent test laboratory approved by OCD or by the manufacturer. Tests performed by the manufacturer must be witnessed and certified by a qualified Federal Inspector. It is the responsibility of the supplier to have the filter tested and certified.

PERFORMANCE SPECIFICATION FOR A 75 CFM CHEMICAL, BIOLOGICAL, AND RADIOLOGICAL
(CBR) GAS PARTICULATE FILTER UNIT

I. Purpose:

This specification is designed to enable procurement of commercially produced filter units to fill the quantitative needs of the OCD, Army, Navy, and Air Force.

II. Requirements:

a. General: Standardized nomenclature shall be used to describe the gas particulate filter unit and the components thereof.

b. Gas Particulate Filter Unit. The filter unit shall:

(1) Be made of fire resistive heat stable materials in accordance with Test 1, Section III. In addition, noncombustible rigid materials shall be used as main support and enclosure members, to include filter framing.

(2) Employ materials that are free of all objectionable odors.

(3) Consist of a separate gas particulate filter and a separate blower unit.

The gas particulate filter shall include the following components:

- (a) Inlet
- (b) Prefilter
- (c) Particulate Filter
- (d) Gas Filter
- (e) Outlet
- (f) Canister
- (g) Mounting Bracket
- (h) Clamp(s)
- (i) Gaskets
- (j) Cuff
- (k) Instructions
- (l) Packaging

The blower unit shall include the following components:

- (m) Inlet
- (n) Blower
- (o) Motor
- (p) Hand Drive
- (q) Framing
- (r) Outlet
- (s) Cuff
- (t) Base
- (u) Instructions
- (v) Packaging

(4) Be properly packaged to withstand rough handling normally incident to shipping. Must pass Test 2, Section III.

(5) Be properly constructed to withstand rough handling normally incident to installation and operation.

(6) The gas particulate filter shall be on the influent end of the filter unit, and the filters shall be arranged from the influent end in the order listed in (3) above.

(7) Be constructed so that the components can be easily attached to or detached from one another to facilitate servicing.

(8) Be designed so that gas particulate filters may be arranged in parallel to form multiple banks. Be designed so that blower units may be mounted side-by-side to form banks. This will permit batteries of purifying components to be formed to meet large air volume requirements.

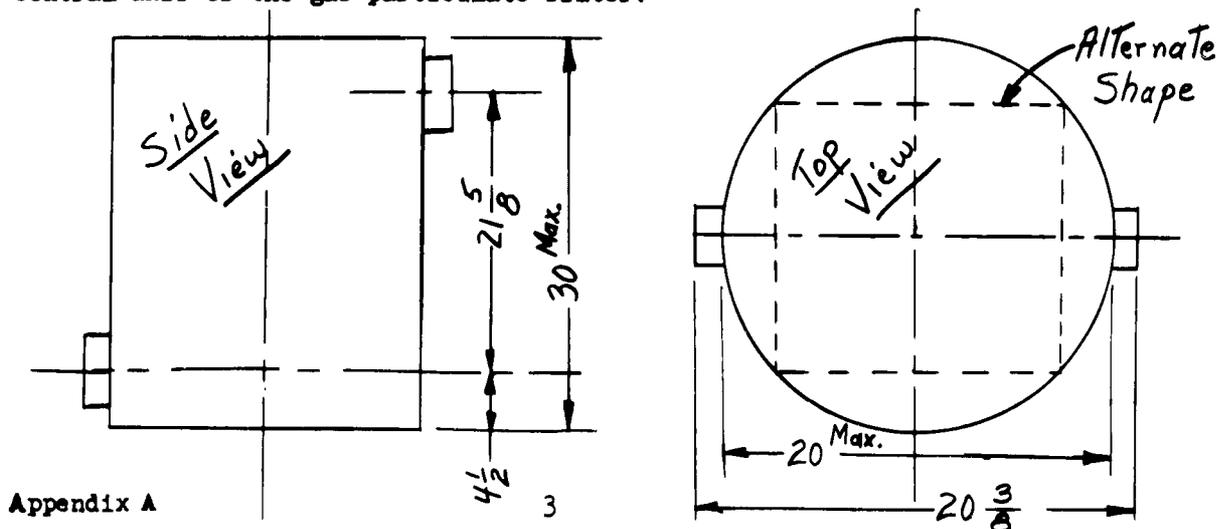
(9) Withstand climatic conditions expected to be normally encountered within the United States.

(10) Be designed so that components which are subject to contamination can be easily separated from the filter unit and placed into readily available containers (such as paper or plastic bags) before removing from the area in which they are installed. These containers will be utilized to prevent the spread of contamination contained in or on these components.

(11) Standard dimensions of the gas particulate filter unit shall include:

(a) Blower Unit - No dimension across the projected cross section perpendicular to the long axis shall exceed 20 inches. The long axis shall not exceed 30 inches.

(b) Gas Particulate Filter - No dimension across the projected floor area of the filter shall exceed 20 inches, excluding duct fittings. The height shall not exceed 30 inches. The axis of the inlet shall be in a horizontal plane, $21\frac{5}{8}$ inches above and parallel to the axis of the outlet. The axis of the outlet shall be $4\frac{1}{2}$ inches above the floor when the gas particulate filter is floor mounted. The outer faces of the inlet and outlet shall be perpendicular to the axes of the fittings, and the faces shall lie in parallel planes, $20\frac{3}{8}$ inches apart. The vertical plane thru the axes of the fittings must pass thru the central axis of the gas particulate filter.



Appendix A

(12) Be constructed so the gas particulate filter may operate in any position.

(13) Be designed so that individual blower units or gas particulate filters may be mounted on a concrete wall or floor.

(14) Be constructed so that all components can be easily handled, manipulated, assembled, and installed by unskilled workers.

(15) Be designed so that when the blower unit or the gas particulate filter is mounted on a concrete wall, the gas particulate filter outlet and the blower inlet achieve an air tight seal against the wall surface around the periphery of the end of the fitting. This will permit mounting a blower unit and a gas particulate filter at opposite ends of a hole through the shelter wall and achieve a closed air duct without the use of separate ducting.

(16) The outlet on the gas particulate filter shall be joined air tight to the effluent plenum.

(17) If gaskets are used, be provided with gaskets the width of which is essentially equal to the width of the surface to be sealed. Gasket ends shall be notched or rabbeted and the entire mating surfaces cemented to form an air tight seal. Gaskets shall be tightly secured to components by cement or mechanical means. Gaskets shall be made of suitable elastomeric material which will not deteriorate and become ineffective under continued compression.

(18) Withstand 7 day exposure to $88 \pm 5\%$ relative humidity at 113 ± 5 degrees F. ambient without corrosion exceeding 5% of the total surface area of each part or component.

(19) Provide sufficient seals within the gas particulate filter to prevent bypass of contaminated air when tested in accordance with test 4 Section III.

(20) Deliver at least 75 cubic feet of purified air per minute against a static back pressure of 1.7 inches of water, when the blower unit and gas particulate filter are connected by a straight one foot long 5 inch diameter furnace duct, said ducting tightly sealed to the fittings, with the inlet on the gas particulate filter open to the atmosphere (air density 0.075 lb./ft³) and when the power input to the filter unit does not exceed 0.08 H.P. applied to the hand drive input, or when the filter unit is motor driven.

(21) Indicate to the user when the blower unit is delivering greater than 40 cfm. The indication shall be readily visible during hand drive operation.

(22) Be provided with adequate use instructions thereon which are visible during hand operation. These shall instruct the user - "For manual operation under fallout conditions, operate the hand drive at least 5 minutes each hour per person at an air flow above 40 cfm. During an attack by chemical or bacteriological agents, operate continuously to maintain a pressure inside the shelter at least 0.1" of water gage above atmospheric."

(23) Be constructed so that when the blower unit is wall mounted and located so the axis of the inlet lies in a horizontal plane 30 inches above floor level, the axis of the manual drive will be $38\frac{1}{2} + \frac{1}{2}$ inches above floor level.

(24) Have minimum noise level without incurring excessive cost.

(25) Not weigh more than 150 pounds.

(26) Be attractively styled without incurring excessive cost.

(27) Incorporate required design practice for safety.

(28) The filters shall be accessible for replacement.

c. Components:

(1) Prefilter. The pressure drop across this filter shall not exceed 0.05 inches water gauge at rated flow. The filtering medium shall be dry type noncombustible, and shall exhibit a dust efficiency commensurate with household furnace filters. The prefilter shall not be deleteriously affected when rough handled in accordance with Test 3, Section III, or when handled during packaging, unpacking, and installation. The face area shall be at least 100 square inches. Minimum bed depth 1.0 inch. Density shall be homogeneous throughout.

(2) Particulate Filter.

(a) Efficiency - When tested at rated air flow against Dioctyl phthalate (DOP) concentration of 0.3 micron mean diameter homogeneous particles in accordance with Test 4, Section III, shall not permit a penetration of more than 0.03%. The pressure drop for this filter shall not exceed 0.55 inches water gauge at rated flow.

(b) Resistance to Handling - Shall be protected from damage during the handling incidental to packaging, unpacking, and installation.

(c) Rough Handling Resistance - Shall not be deleteriously affected when rough handled in accordance with Test 3, Section III, and shall still meet the requirement of Paragraph (a) above.

(d) Resistance to Climatic Changes - Shall not be deleteriously affected by Test 5, Section III and shall still meet the requirements of paragraph (c) above.

(e) Resistance to High Humidity - Shall not be deleteriously affected by Test 6, Section III.

(f) Resistance to Mildew - Certification that the filter medium is mildew resistant shall be required of the vendor, or the filter medium shall be tested as specified in Test 7, Section III. When tested in accordance with Test 7, the filter medium shall not support the growth of or be deleteriously affected by mildew.

(g) Water Repellency - Certification that the filter medium is water repellent shall be required of the vendor, or the filter medium shall be tested according to Test 8, Section III. The filter medium shall support a water column of 15 inches for 5 minutes without allowing any penetration.

(h) DOP Breakdown - Filter medium shall be tested to determine effects of exposure to DOP in accordance with Test 9, Section III. At the end of 30 minutes, the DOP penetration shall not be increased by more than 200% over the initial penetration, and the resistance to air flow shall not be increased by more than 100%.

(i) Resistance to Spot Flame

1. When subjected to Test 6, Section III, "breakthrough" shall not occur in less than 5 minutes after application of the flame.

2. When subjected to Test 6, Section III, there shall be no evidence of combustion on the downstream face of the filter.

(3) Gas Filter

(a) Performance Against Gas - When tested under Test 10, Section III, the gas filter shall sorb the following quantities of the indicated gases before permitting passage of a physiologically significant concentration of the agent under test. Freon gas life shall be determined by Test 11, Section III.

TEST CONDITIONS

	Min. Sorption Grams (1)	% RH	(2) Conc., mg/l	Moisture in Filter	Min. Temp. of Test Run °F	Ref. Sect. III Test
Chloropicrin	700	50	16	2.0% Max.	70	10
Hydrocyanic Acid	150	50	10	2.0% Max.	70	10
Phosgene	300	50	10	2.0% Max.	70	10
Arsine	420	80	10	Humidified @ 80 ± 3% RH	70	10
Freon 12	55	12 (3)	5.4	At equilibrium w/test air	65	11

(1) Sorptions for chloropicrin and freon were experimentally determined, the remainder were calculated on the basis of 9 pounds of Specification MIL-C-13724A Charcoal.

(2) A variation of ± 5% will be allowed. However, the gas life results of the filter shall be corrected to the concentrations listed. This will be known as the corrected gas life.

(3) Test may be run at any RH between 6% and 18%, however the gas life after rough handling must lie on or to right of line $y = -1.154 \times 10^{-4} X + 4.35 \times 10^{-2}$.

(b) Sorbents - A sorbent having performance characteristics equal to ASC Charcoal MIL-C-13724, Grade I, has been used to produce a filter having an acceptable gas performance.

(c) Pressure Drop - Shall not exceed 0.7 inches water gage at rated flow.

(d) Rough Handling Resistance - The gas filter shall not be deleteriously affected when rough handled in accordance with Test 3, Section III, and the Freon performance (Test 11, Section III) shall not be less than 90% of that exhibited before rough handling.

(4) Blower - The blower shall be operable by electric motor and auxiliary hand drive. The noise level is to be the minimum possible without incurring excessive cost.

Wide fluctuations in static pressure across the blower shall not cause overloading of the motor drive.

(5) Motor - The motor shall be operable from 105 to 130 volt 60 cycle AC electrical supply. Provision shall be made for electrically grounding the motor frame. The motor shall be provided with at least 8 feet of 3 conductor electrical supply cord terminating in a grounding type wall plug. The motor and cord must be recognized by Underwriters' Laboratories, Inc. Removal of the motor from the blower unit shall not impair operation of the blower unit by the hand drive.

(6) Hand Drive - Shall be of low friction loss and economical design. The noise level shall be of the minimum possible without incurring excessive cost. The hand drive shall not be a hazard when the blower unit is motor operated. The proper physiological balancing of required muscular force and distance shall be considered to maximize ease of operation. The hand drive shall be operable by either one hand or two hands simultaneously. Two people shall be capable of operating the hand drive simultaneously.

(7) Framing - Adequate framing shall be provided the gas particulate filter and the blower unit to protect components, to prevent injurious contamination, and provide structural rigidity.

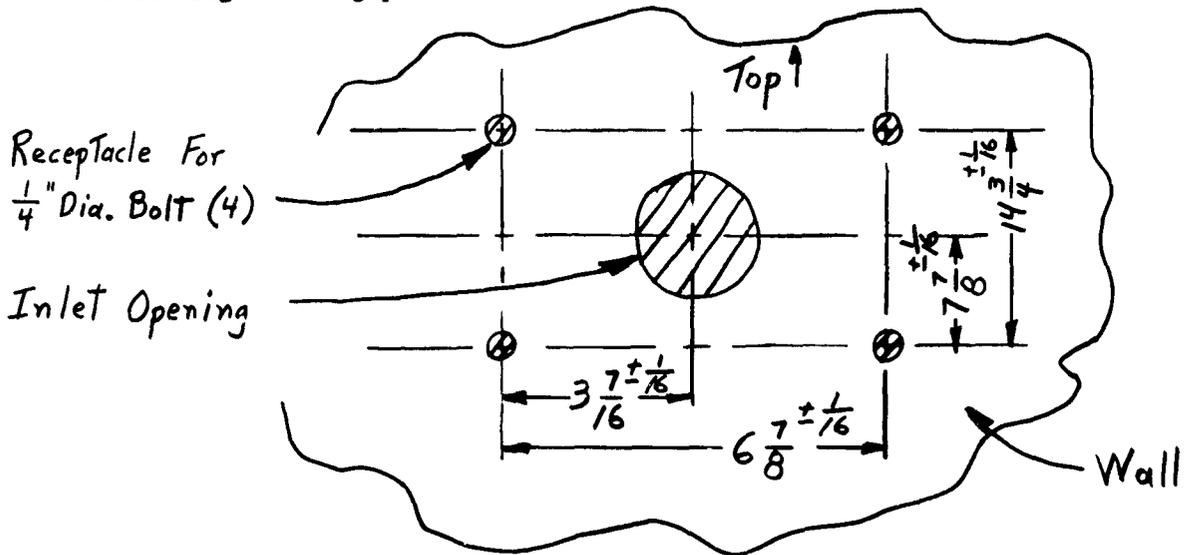
(8) Fittings

(a) Gas Particulate Filter - The inlet and outlet fittings shall accept standard threaded 4 inch steel pipe and standard 5 inch round furnace duct.

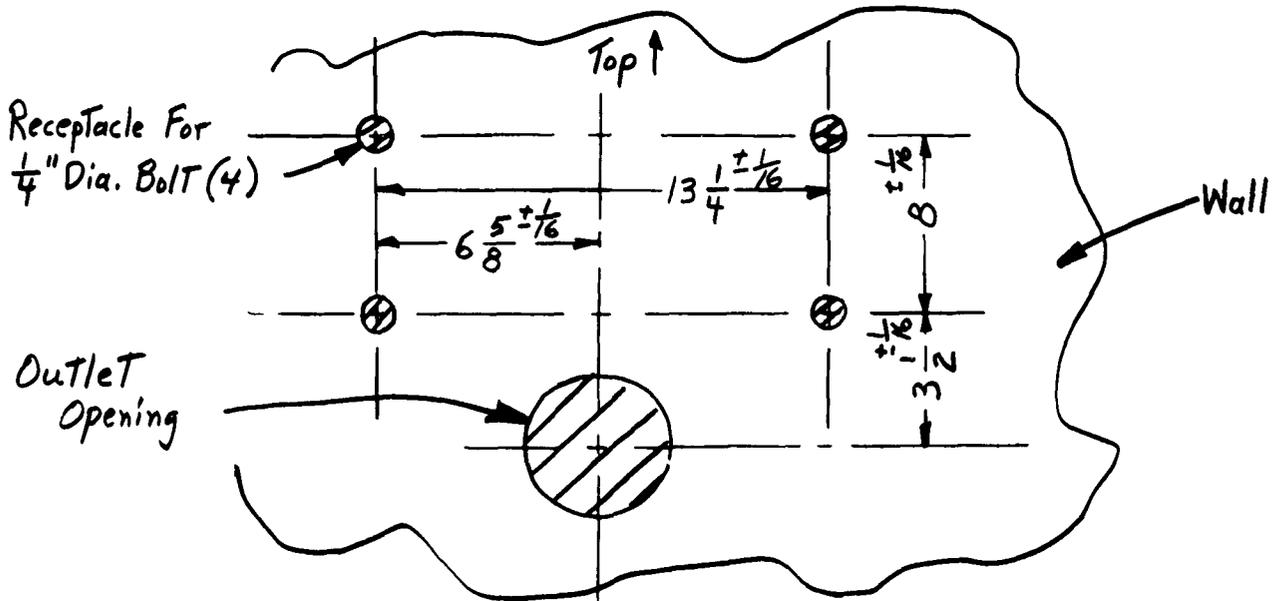
(b) Blower Unit - The inlet fittings shall accept standard 5 inch furnace duct. The outlet may be determined by the supplier, but must accept transitions which could be specially provided in the future.

(9) Base

(a) Blower Unit - Must be mountable to wall provided with the following mounting provisions:



(b) Gas Particulate Filter - Must be mountable to wall provided with the following mounting provisions:



(10) Instruction Must be provided with adequate installation, use, and care instructions.

III. Test Methods and Procedures:

1. The flame of a bunsen burner shall be adjusted to have a 3/4 inch length of yellow flame with no blue cone. Two successive 30 second applications of the tip of the flame shall be made to exposed outside surfaces of the gas particulate filter unit, with a one minute interval between the applications. The surface or adjacent materials shall not continue to burn or glow for more than one minute after application of the test flame. The gas particulate filter unit shall still be operative at completion of this test.

The unit shall be exposed to 212°F. for seven (7) hours. Following this exposure the gas particulate filter unit shall still be operative.

2. Federal Specification PPP-P-600, Sections 3.1, 3.2.2, 3.3.2, 3.3.5, 4.5.2, 4.5.2.1, 4.5.2.2.

3. MIL-STD-282, Method 105.9. The duration of the test shall be 20 minutes at a 1/4 inch amplitude.

4. MIL-STD-282, Method 102.9.1 or equivalent test.

5. The particulate filter will be exposed to the following environmental conditions:

Arctic	- 65°F.
Desert	+116°F., 10% R.H.
Tropical	+113°F., 88% R.H.

Expose for one week to each of the above conditions in completing one (1) test cycle of three (3) weeks duration. The complete test is to consist of three (3) cycles, the order of exposure in the cycles being varied as follows:

Cycle 1 - Arctic, Tropical, Desert
Cycle 2 - Tropical, Arctic, Desert
Cycle 3 - Arctic, Desert, Tropical

At the end of the 9 week period, a careful check will be made for warping, cracked cement, etc. The rough handling Test 3, Section III, followed by DOP and pressure drop tests, will be made to complete this test.

6. UL-STD. 586

7. Specification CCC-T-191, Method 5751.1

8. MIL-STD - 282, Method 603.1

9. MIL-STD - 282, Method 502.1.1 Use a suitable test chamber. Each sample (100 sq. cm.) shall be exposed to DOP at 85 lpm for 30 minutes. DOP readings at flow rate of 85 lpm shall be taken at 0, 5, 10, 15, 20, 25, and 30 minute intervals during the exposure process.

10. Specification MIL-C-13724A except that test will be made on 75 cfm gas filters at rated flow.

11. Freon Test.

a. Outline of method. The filter is conditioned for $\frac{1}{2}$ hour at 140°F then placed in the test apparatus where a mixture of air and freon at a concentration of 5.4 mg/l (1,000 ppm) is heated to $125^{\circ} \pm 3^{\circ}\text{F}$ is passed through the filter at 75 scfm. This flow is continued for 10 minutes or until the absolute humidity of the freon-air stream becomes constant at a point between 0.005 and 0.015 lbs/lb. When the test starts a continuous sample of the effluent air is monitored by a gas analyzer. The observed life of the filter is the time from the beginning of the test to the time the effluent concentration reaches 0.27 mg/l (50 ppm).

b. Apparatus. The apparatus used in this test shall be similar to that shown in Figure 1 (Enclosure 4). A fan, capable of delivering 75 cfm at 125°F with a 2" static pressure, blows air through a closed loop of 4" pipe or duct. The loop contains an air straightener, an orifice, control valves, a 1050 watt heater, and a test chamber. The heater operates intermittently to keep the air at $125^{\circ} \pm 3^{\circ}\text{F}$.

c. Test Gas. Freon Gas, Compressed, F-12, Federal Specification BE F-671a.

Calibration Gas. 0.1% (1,000 ppm) Freon F-12 in nitrogen, analyzed to nearest 0.001%. (Matheson Co., Inc., East Rutherford, New Jersey, or equal).

d. Procedure

(1) Turn on gas analyzer, tuning position, to warm up instrument.

(2) Insert filter in preheat and dehumidifying apparatus, adjust air flow until the resistance across the filter equals 3 times the resistance at 75 cfm and preheat for $\frac{1}{2}$ hour at 140°F (time may be reduced to 15 minutes if heater is already warm and little dehumidification is needed).

(3) After filter has been preheated, turn on blower and heater in test apparatus.

(4) When temperature in test apparatus has reach $125^{\circ}+$ remove filter from preheater and install in test apparatus. (Allow at least 10 minutes for equilibrium to be restored).

(5) While equilibrium is being established, turn on infra-red sensing element and vacuum pump and analyzer; turn on calibration gas turn on freon (vent position), and set timer at zero.

(6) Adjust freon flow to 2124 cc/min., then shut off control switch.

(7) Adjust air flow through gas analyzer to 2.6 cc/min., and zero analyzer.

(8) Adjust air flow in loop for 75 scfm by setting control valves.

(9) Turn freon on vent, turn on calibration gas and calibrate analyzer to 50 ppm.

(10) Check freon flow (venting), air flow in loop and through analyzer. At the end of the 10 minute equalizing period turn on timer switch, and begin test (move freon control switch from vent to test position).

(11) Turn off timer switch after effluent concentration has dropped below 50 ppm.

(12) Record data.

(13) Remove filter when test completed.

Elapsed time, approximately: 15 minutes for test, $\frac{1}{2}$ hour for preheat. For continuous testing preheat time will vanish after initial warm-up.

e. Acceptance/rejection criteria. The freon gas life and moisture content of the test air for each filter will be plotted. Any as received filter that falls on or to the left of the line $y = -1.154 \times 10^{-4} X + 4.35 \times 10^{-2}$ will be rejected. Any rough handled filter that falls on or to the left of the line $y = -1.154 \times 10^{-4} X + 4.45 \times 10^{-2}$ will be rejected.

Enclosure 4

Appendix A

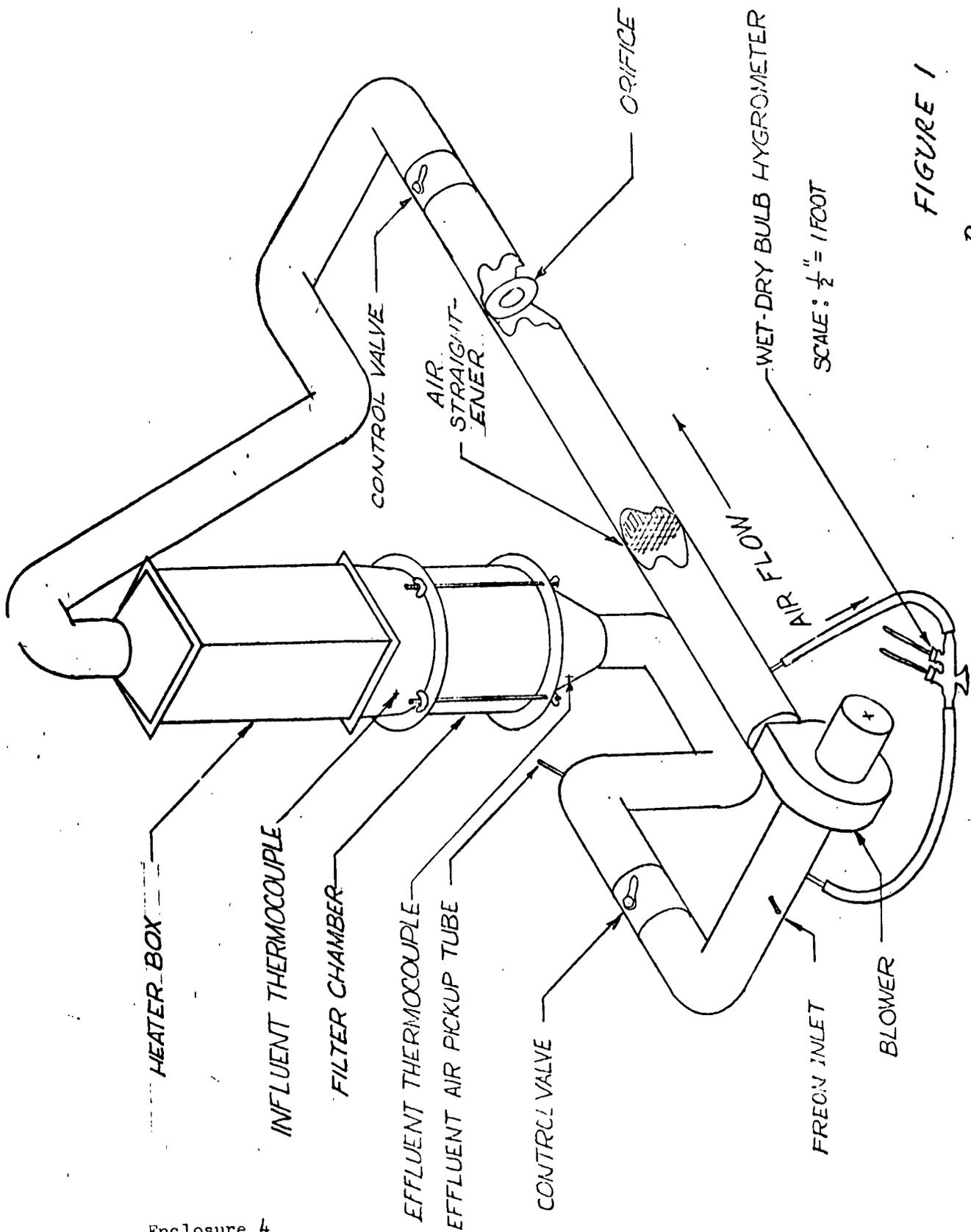


FIGURE 1

Small, 6 Oct, 1962

APPENDIX B

Provision of a Habitable Atmosphere for Family Fall-Out Shelters

F. P. Byrne and O. H. Kriege

Introduction

In family fall-out shelters one of the most important requirements is a habitable atmosphere. A habitable atmosphere is one which contains an adequate amount of oxygen and a minimum of carbon dioxide and odors. The relative humidity and shelter temperature should combine to a reasonable comfort index.

To assure ourselves that a filter-blower system was the most practical and economical for removing CBR agents from the atmosphere, we defined the problem and evaluated various systems that fell within this definition. Once this was done the logical development of performance specifications followed.

Definition of Problem - To understand this problem in its entirety it was defined as follows: - To provide for two weeks a habitable atmosphere in a small shelter containing ten people, which atmosphere would not be contaminated with chemical, biological, or radiological agents. To understand these terms a brief description of the kinds of war represented by each term will be given.

Biological warfare can be waged quite effectively against crops, animals, and man. The warfare against crops and animals is important and serious, but protection against this warfare is of a different nature and

and is not the subject matter of this contract. Consequently we are concerned only with biological warfare against man. This warfare can be either covert or overt.

In the covert type infection can be spread through various sources. For example, by sending disease carriers through the population or by infecting the water supply. Eventually this type of infection leads to an epidemic. Protection against this kind of biological warfare is a special problem involving all of the public health services and again is not the subject matter of this report.

In overt biological warfare, which is the subject matter of this report, the agent is usually dispersed as an aerosol or a cloud under favorable conditions. For example, at night when the humidity is high, or on a very cloudy day, because of the very effective killing of organisms by sunlight. According to Fothergill (Advances in Chemistry Series No. 26, Non-military Defense, Chemical and Biological Defenses in Perspective), the smaller the aerosol particle the more effective the organism, because the human respiratory system doesn't filter very small particles. Aerosols tested have been as small as 0.3 microns in diameter. Thus in protecting against this kind of warfare it appears that very small aerosol particles should be removed from the atmosphere.

Chemical warfare agents were first introduced on a massive scale in World War I. In common use were blister gases of the mustard type and choking and blood gases. During World War II nerve gases were developed. These are more lethal, their detectability is limited, and the unsuspecting

Appendix B

victim may have a lethal dose before he is aware of it. Protective devices are available for these agents but it should be pointed out that in this area there is an armament-armor contest and the protection medium supplied for the known agents may not be effective at all for some unknown agents, the nature of which has not been revealed.

In the Army Publication, "The Effects of Nuclear Warfare", the radioactivity produced by an atomic explosion is arbitrarily divided into two phases. The first phase is the radioactivity transmitted in the first minute after detonation of the bomb. Protection against this kind of radioactivity, according to this publication, is more a matter of proper shielding than filtration of particulate matter and is not the subject matter of this report. The second type of radioactivity is associated with the particulate matter formed during the bomb explosion. Shielding is also necessary to protect against this radioactivity, but filtration of the air is equally important and it is with this filtration that this report is concerned. This particulate matter arises from bomb residues and earth surface materials. The amount of material produced depends on the bomb size and the nearness of the bomb to the earth's surface at detonation. The particle sizes range from fractions of micron to several hundred microns and the fall-out patterns depend mostly on nearness of detonation to surface, wind velocity, and particle sizes. The larger particles fall fairly rapidly, the small, depending on bomb size and height of the bomb explosion, may remain aloft for years.

Three possible solutions to th's problem are considered. The Appendix B

first is a sealed system in which oxygen is supplied to the shelter and waste carbon dioxide, odors, and moisture are removed. The second solution is to supply filtered air and a third solution would be a compromise of the other two. The main criterions in suggesting a system for a shelter housing ten people are cost and effectiveness. The cost, on recommendation of the Army Chemical Corps, was to be held as near as possible to \$200.

Sealed Systems - The figure used for the oxygen needs of a sedentary adult was 0.85 cubic feet per hour at standard temperature and pressure. Four systems for supplying this oxygen were considered; as cylinders of compressed gas, canisters of potassium superoxide or as candles of potassium chlorate, and fourthly as an electrolytic system using the sodium sulfate cycle designed for use on Navy submarines. The second and fourth systems provide oxygen and at the same time the necessary reagents for the removal of carbon dioxide. Cost figures for the first three are in Table I.

Table I
Cost of Atmosphere Purification for Sealed Shelter

<u>System</u>	<u>Protection Man Days</u>	<u>Units of Oxygen Supply</u>	<u>\$ Cost</u>
Cylinder Oxygen + Absorbent	12	1	125
(cylinders 244 cu ft capacity)	24	2	175
	36	3	225
	48	4	275
	96	8	500
	144	12	700
Potassium Superoxide	3	1	150
Potassium Chlorate Candle	6	1	70

Appendix B

Since cylinder oxygen is the least expensive oxygen source, costs for this system are presented in more detail in terms of man-days. The cost figures quoted include the cylinder, the regulating valve, and a carbon dioxide absorber such as soda lime, barrel lime, or potassium hydroxide. It also includes a charcoal absorber for odors. If the family unit consists of two or three people it will be noted that for 28 or 42 man days the cost for habitable air is fairly close to the \$200 goal set as the cost maximum.

Disadvantages of the cylinder oxygen system are storage requirements, the large amount of steel required and the possible explosive danger from defective or mishandled cylinders. For the 10 persons, 14 day shelter or 140 man-days of protection, the cost is in the neighborhood of \$700.

The potassium chlorate candle is somewhat less expensive in terms of man-days of protection supplied. It suffers from the disadvantage, however, in that small amounts of chlorine are also liberated along with the oxygen and to sensitive people this may cause some discomfort.

The electrolytic system requires a rather large capital investment. Some 7000 watt hours of generating power are necessary for 10 cu. ft. of oxygen. A motor generator combination with a fossil fuel supply would probably require a capital investment in the neighborhood of \$1000. For the small family shelter this may be a difficulty. For larger community type shelters, perhaps it is something that could be considered.

Another consideration in the sealed shelter is the rise of temperature and humidity resulting from loss of body heat and moisture from the occupants. Pashkis ["A National Shelter Program" obtainable Appendix B

from P. O. Box 577, New York 27 (February 1962)] has estimated that depending on shelter volume per occupant these factors become troublesome within one to three days.

In general, it can be concluded that for the individual family shelter for ten people, a sealed shelter is impractical for long term occupancy in that all of the systems would cost more than the target price of \$200 and would become quite uncomfortable leading possibly to heat prostration of some of the occupants because of the rise in temperature and humidity. Thus it is clear that a ventilating system involving a filter-blower unit is the most practical solution to this problem and that a low-cost mass produceable item is mandatory.

Before proceeding to a definition of the parameters of such a system it might be well to consider some of its shortcomings. The disadvantages of a filtered air shelter are that this system would be inoperative during fire storms and cannot be scaled down for short term occupancy or for small families. In addition it must be assumed that there will always be an accessible passage from the shelter to the outside air. It also must be assumed that the air will not contain a lethal agent which the purifier fails to remove.

An answer to this may be a semi-sealed shelter which incorporates the advantages of both the sealed and open shelter but at a slightly higher cost. In addition to a CBR air purifier such as is described below there would be a source of oxygen in the shelter. This would provide for emergency use during fire storms or in the event that the air intake was temporarily plugged. Reference to Table I will give an idea of what would need

Appendix B

to be spent for this sealed shelter protection. It is presumed that the need for an auxiliary oxygen supply would be of short duration after which the air purifier described below would be used in the normal manner.

Air Filtration System

The filtration system must be designed to remove particulate matter ranging in size from 0.3 to several hundred microns, and vapors. The smaller sizes are associated with particle sizes of matter used to disperse biological agents, the larger sizes are associated with the dispersal of radioactive fallout. Chemical agents are dispersed as vapors or aerosols. The latter might be removed by a particulate filter, but in time may bleed through slowly because of their vapor pressure. Thus it became clear that two filter systems would be required. One for removing particulate matter and one for CW agents.

Particulate Filtration - One of the first systems considered was a precipitron technique wherein entering particulate matter is converted to electrically charged particles and then collected on electrically charged plates from which they are later washed. There are two objections to this. One is the power requirement. The other would be the disruptive effect of radioactive particles which may neutralize or reverse charges and cause dust to be prematurely released from the collector plates.

Another system involved the use of a sand bed filter. This appealed because of its low cost and high fire resistance. The pressure drop, Δp , was calculated for a bed 1 inch thick and 1.58 square feet in area for 10 mesh sand (0.065") at an air flow of 75 cfm according to the Appendix B

following equation. (Chem. Eng. Handbook, Perry, p. 354)

$$p = \frac{180\mu L (1-\epsilon)^2 V_o}{g_c \epsilon^3 \phi^2 D_p^2}$$

where μ is the viscosity, L is bed depth, ϵ the void content, V_o the superficial velocity based on empty chamber cross section and was taken as 0.79 ft/sec. for this system, g_c is a conversion factor ϕ a shape factor and D_p is the average particle diameter. The pressure drop for this system calculates to be 0.29 in. of water per inch of sand. This looked promising until it was found that packing and humidity variations alter the flow pattern through the material and significantly affects the pressure drop across it. Also, it was considered extremely difficult to obtain material of a uniform particle size, which is also important for filtration efficiency. Thus this approach was also abandoned.^{1,2,3}

This left only glass fiber filters. The industry survey, described above, revealed that filter material capable of removing particles as small as 0.3 microns was available in frames which were highly fire resistant. However, a practical consideration revealed that such a system would become quickly loaded with the larger particles in an actual defense situation. Consequently it was felt that the need for an inefficient disposable pre-filter was justified for the removal of the large particles and the protection of the particulate filter.

-
1. The Effectiveness of Sand as a Filter Medium, American Industrial Hygiene Association Journal 19, April (1958).
 2. Sand Filtration for Airborne Radioactive Products, J. Public Works, p. 94-5 (1957).
 3. Hanford Report HW-30142, Lyle H. Zahn (1953).

Appendix B

Thus, the particulate filter would consist of a coarse pre-filter to remove large particles and a more efficient filter to remove the fine particles.

Gas Filtration - Considerable thought and effort was spent on the CW filter system. We started with consideration of a pyrolysis system which would not only decompose the CW agent, but would have the added bonus of eliminating BW agents. It was felt that chemical agents in general would not survive treatment at high temperature without some decomposition, particularly if substantial amounts of water are present and that this would be a superior way to eliminate chemical agents and to place a major obstacle in the way of designing a super-stable chemical agent. For this pyrolysis technique it was felt that one second of exposure at 400°C should destroy all biological and chemical agents. This means a volume of approximately 1 cu. ft. would have to be raised to and held at the desired temperature. A fossil fuel burner could supply the required heat; however, a heat exchanger would be needed to cool the purified air. This system would be quite expensive for a family shelter and would be considerably in excess of \$1000.

Various types of sorbents are considered as a substitute for ASC charcoal to remove chemical warfare agents. There are many types of activated carbon made from coconut shells, pecan shells, coal and other carbonaceous materials. Many of these carbons are very hard materials which are quite resistive to abrasive action. They are used in a wide variety of industrial applications to remove odors, tastes, colored impurities and other undesirable contaminants. These activated carbons have

Appendix B

not been extensively tested to determine their ability to remove chemical warfare agents under normal warfare conditions; however, it is possible that one or more of these materials may be a satisfactory substitute for ASC charcoal provided it meets the performance specifications detailed in this report. In addition there is the problem of supply in the event of an emergency or effective blockade as at least some of these materials are imported.

Molecular sieves were considered as a sorbent for chemical warfare agents; but these materials have a low capacity and require very low temperatures to achieve their highest sorption efficiency. Silica gel was also studied; however, it is rapidly saturated with water vapor making its application in the CBR air purifier impractical.

This leaves only the specially treated ASC charcoal, which has been traditionally used in both World Wars for the removal of CW agents, as an "off the shelf product" immediately available. However the specifications for CW sorption are of the performance type and, as indicated above, other systems may be developed later or present systems may qualify. In specifying the amount of charcoal or its equivalent to be used in the final device, it is realized that a calculated risk is taken and that full military protection is not given. However, it is felt that it will offer such protection that the delivery of CW agents would be unduly expensive for the effect achieved, if these agents are removable by the filter system with the sorption unit.

Conclusion

The air filtration system thus consists of three filters. A

Appendix B

coarse pre-filter to remove large particles, with which most of the radiation would be associated, a particulate filter to remove all other particles to 0.3 microns diameter and finally a gas filter to remove CW agents. These filtration materials are now available. The performance specifications, in Appendix A, are based on these materials and are thus realistic.

CMLMC-EA-11-1

3 June 1962

SUBJECT: Results of Tests on Particulate Filter, 75 CFM, Work Order 3626

TO: Commanding Officer
U. S. Army Cml C Engineering Command
ATTN: CBR Defense Division
Army Chemical Center, Maryland

Confirming telephone conversation of 2 July 62, test results are as follows:

Before rough handling

Serial	Resistance	D.O.P. %
3	.48"	.012

After rough handling, 15 Min.

Serial	Resistance	D.O.P. %
3	.46"	.013

FOR THE COMMANDER:

J. N. AMBROSE
Director of Operations

CMLMC-EA-11-1

29 May 1962

SUBJECT: Results of Tests on One (1) each Filter, 75 CFM, Sketch
SDA 1154-05, Performed on Work Order 3626, Particulate
Filter No. 4

TO: Commanding Officer
U. S. Army Cml C Engineering Command
ATTN: CBR Defense Division
Army Chemical Center, Maryland

Confirming telephone conversation of 29 May 62, test results are
as follows:

Rated flow, 75 CFM, as received -

<u>Resistance</u>	<u>D.O.P. %</u>
.37"	.028

After rough handling 15 minutes -

<u>Resistance</u>	<u>D.O.P. %</u>
.36"	.030

R. A. HISCOX
Major, Cml C
Commanding

U. S. ARMY CHEMICAL-BIOLOGICAL-RADIOLOGICAL
ENGINEERING GROUP
Army Chemical Center, Maryland

SMUCE-CEC

2 January 1963

CYANOGEN CHLORIDE TEST METHOD
FOR 75 CFM OCD GAS FILTERS

1. Outline of Method.

A mixture of air and cyanogen chloride (CK) with a CK concentration of 4 milligrams per liter is passed through the Office of Civil Defense (OCD) 75 CFM Gas Filter at a 75 Cubic Foot per Minute (CFM) air flow rate. A sample of the filter effluent gas constantly bubbles through a pyridine-starch indicator solution. Bubblers are continuously replaced until a color change from blue to colorless or light yellow occurs within 2 minutes 45 seconds / 15 seconds. The "observed life" is the time interval between initial gas contact with the filter and the installation of the final bubbler. The cyanogen chloride concentration influent to the filter is found by a Volhard Titration. Filter life is then corrected for a CK concentration deviation from the specified 4.0 milligrams per liter.

2. Apparatus.

a. A diagram and listing of the test apparatus are given in Figure 1 and Table I. The individual components are listed and described at the end of this section.

b. Air and Framework Section.

(1) Because the agent is toxic, a ventilated hood houses the CK injection hardware, a spray chamber and the gas line from the blower. Flexible 5" diameter tubing connects the spray chamber to a plenum which provides a mounting position for the gas filter. A 10" diameter stove pipe duct from the blower unit to the hood exhaust completes the air system skeleton.

(2) Pressure drop studies with a calibrated orifice and draft gauge indicate the proper effluent air damper setting to produce a 75 CFM flow rate when a test filter is clamped within the plenum.

(3) The spray chamber is a 10" diameter stainless steel cylinder fitted with a 10" to 5" reducer at one end. Total length is 24". Supported in the larger cylinder by 10" OD concentric rings is a 5" diameter cylinder about 15" long.

"Appendix D"

2 January 1963

(4) Near each end of the smaller cylinder are two 5/8" x 5" slots. The plastic tubing through which the CK passes is positioned axially within the cylinder by spacers anchored to the cylinder and snugly clamping the tubing.

b. The Cyanogen Chloride Injection System.

(1) Liquid CK is forced into the spray chamber when compressed laboratory air travelling through the longer of two glass tubes bubbles through the liquid agent, subsequently vaporizing the liquid. The air-CK vapor exits through the shorter glass tube connecting with the plastic tube anchored within the spray chamber.

(2) Installed between the air source and the agent are an H_2SO_4 -Drierite Absorption train (2-2 and 2-3 respectively) a pressure stabilizer (2-4) and a gas flowmeter (2-6) controlled by a stopcock valve (2-5). The CK source, a portable bottle refrigerated except during testing (2-7) is immersed in a water-ice bath (2-8) to keep the liquid below its boiling point ($17^\circ C$).

(3) Lines in this system are of 3/8" glass and tygon. Glass clamps (2-9) and glass joints permit easy isolation of the CK supply for storage during test shutdowns.

(4) During early tests with the CK injection system, clear crystalline formations were observed growing on the glass rod immersed in the CK solution. Believed at first to be ice, the growth indicated possible hydrolysis of the agent's chemical stabilizer. Pressure buildup in the CK container, due to water entry, was clearly a safety hazard, so the H_2SO_4 -Drierite absorption train was installed. The formation, nevertheless, persisted. Therefore, the crystals must have been solid CK (F. P., $-5^\circ C$) formed when the rush of air from the delivery tube channeled through the agent. When the crystals reached the liquid surface, growth would occur at the end of the delivery tube subsequently blocking it and causing bubbling to cease.

(5) For these reasons, a taller supply bottle and higher liquid level were introduced. Also, a delivery tube having a dispersion ball on its lower end was employed to reduce the channeling effect. The dispersion ball was glass welded to the tube segment since the plastic connections tried disintegrated or deformed in the CK liquid. When the liquid level was allowed to drop no lower than one-inch during the tests no further crystalline formations were noted.

c. The Influent Sampling Line.

The influent sampling line mounted on the plenum adapter inlet is connected to the laboratory vacuum system to draw flowmeter-monitored filter influent gas at 1/2 liter per minute through two rubber-stoppered bubblers containing the CK absorption solutions. This is shown in Figure 1. Two absorption trains connect to the vacuum by a 3-way stopcock valve, the first to aid in purging the line and the second for sampling. Glass joints held together by clamps allow for easy setup and breakdown of this system component for use in repetitive testing and chemical analysis. Miscellaneous glass and rubber tubing, and two glass stopcocks complete this line.

d. Effluent Sampling Line.

(1) Effluent sampling employs two bubblers in parallel. Monitoring and controlling the draw-off are a flowmeter and a stopcock valve. Another three-way stopcock directs flow through one indicator branch allowing immediate switching to the other when a "breakthrough" color change is indicated.

(2) Connections from either side of the blower exit duct to each of the bubblers were 1/4" copper tubing. The balance were of glass and rubber.

e. Other Apparatus.

A timer and a psychrometer complete the apparatus.

f. Apparatus List.

(1) Motor (1-2). Howell Electric Motor Co. Type I unit rated at 1 HP, 3,450 RPM, operating on 3 ph, 60 cy current.

(2) Blower (1-2). Model 5ACom with 5A45 fan size, 60 cy, 3 ph, 3.4 amperes, 220 volts. L. J. Wing Manufacturing Co., New York, New York.

(3) Draft Gauge (1-5, 1-7). Ellison Industrial Draft Gauge. 3" H₂O pressure range.

(4) Flowmeters (3-2, 4-2). Fischer and Porter Flowmeter Tube. No. 02-8-20-5/36.

(5) Flowmeter (2-6). FP 2F 1/4 20-5 tube.

(6) CK Container (2-7). Pyrex, 8 gallon.

- (7) Bubblers (3-3). 30 ml capacity, brand unknown.
- (8) Spacers (1-10), brand unknown.
- (9) Bottles (2-1, 2-2). Pyrex, 8 gallons.
- (10) Timer (not shown). Superior Electric Time Co., Springfield, Mass.
- (11) Piping is 3/8" steel, tygon and glass.
- (12) Assorted valves are two- and three-way glass stopcocks, except 2-0, 3-0 and 4-0, which are laboratory sources.

3. Reagents and Materials.

a. Reagents.

Unless otherwise specified, only ACS reagent grade chemicals and distilled water shall be used throughout the tests. Blank determinations shall be run in parallel with the tests and corrections applied when significant.

b. Starch-Pyridine (CK Indicator).

Mix 200 ml pyridine-iodine stock solution and 400 ml 0.1% starch solution with 1 liter of distilled water. Add 0.05 N arsenite solution carefully until blue color disappears, then add 0.01 N iodine solution until the blue color returns. Use 12 ml additional 0.01 N iodine solution, and fill with distilled water to form a 2 l volume. The reading with a Klett Colorimeter Filter #42 should be 300 ± 15. Transfer the solution to a glass-stoppered bottle and keep away from light. Make a fresh solution daily.

c. Alcoholic Sodium Hydroxide.

Add slowly 40 gm of sodium hydroxide (containing not more than 0.002% chlorine) to 1 liter of water to make a 1N solution. At the beginning of the test add 10 ml of the 1N solution to 10 ml of 95% ethyl alcohol to each of two bubblers.

d. Nitric Acid.

Dilute concentrated nitric acid to contain approximately 35% nitric acid by combining equal volumes of concentrated acid and water. The acid should be free from lower oxides of nitrogen. If the acid is colored, boil before dilution. Store the 35% acid in brown glass-stoppered bottles.

e. Silver Nitrate, 0.025N.

Dissolve 4.25 gms of silver nitrate per liter of water and store in a brown or black bottle. Standardize the solution against potassium chloride (or sodium chloride) by the modified Volhard procedure. Dry the salt (chloride) for at least 2 hours at 150°C before use. If suitable material is not available, prepare it by recrystallization and drying of potassium chloride. To standardize, make a solution of approximately one gram weighed to the nearest 0.1 mg of potassium chloride per liter and use aliquot portions of 50 ml each for the analysis. Determinations should be made in duplicate. The water used in preparing the solution and in making the analysis must be comparatively free of chlorides. With each analysis a blank determination must be made and the correction applied. Calculate the normality of the silver nitrate solution as shown in 6a.

Volhard (modified Method).

Standardize the silver nitrate as follows: To the prepared aliquot of potassium chloride (see above) add a few drops of phenolphthalein and sufficient nitric acid (3d) to dispense with the color. From a burette, add 20 ml (an excess) of silver nitrate. Four or five ml of nitrobenzene are added and shaken vigorously for at least 1 minute. Add a few ml of ferric alum (3g) indicator and back titrate the solution with the potassium thiocyanate solution (3f) until the development of the first permanent red-brown color. Record the volumes of silver nitrate and potassium thiocyanate and determine the net ml of silver nitrate solution as shown in 6a.

f. Potassium Thiocyanate 0.025N.

(1) Dissolve 2.4 gm of potassium thiocyanate in distilled water and dilute to 1 liter. Shake thoroughly.

(2) The normality can be found in the following way: Four 100 ml of distilled water into a 200 ml flask; pipette 25 ml of silver nitrate solution (3e) into this flask; add 10 ml of nitric acid (3d) and 2 ml of ferric alum solution (3g). Titrate with potassium thiocyanate and set aside for 5 minutes. If color disappears, continue to titrate with a small amount of KCNS until the color holds. Calculate the normality of potassium thiocyanate as shown in 6b.

g. Ferric Ammonium Sulfate Solution.

Add to 360 ml of distilled water 453 gm of ferric ammonium sulfate. If necessary, warm to get all the crystals in solution. Cool and store in a brown bottle.

4. Test Procedure.

a. Initial Considerations.

(1) After setting up the equipment, except for the CK supply as shown in Figure 1, check obvious leak sources in the system. Also monitor the hood for leaks, using smoke capsules or their equivalent.

(2) Turn on the blower (1-2). Establish a 75 CFM flow rate with the damper (1-3), a calibrate orifice (1-4) and a draft gauge (1-5), when a 75 CFM OCD Filter (1-6) is in the plenum (1-1). Note the reading on draft gauge (1-5) and the damper position.

(3) Set up the CK source (2-7) in a water-ice bath (2-8). Fill the supply bottle to a convenient level about 4" below the top and mark it so each test can be referred to the same datum. Periodically drain some water, replacing the volume with ice. Check the glass joints for possible leakage. If necessary, keep the lines from sagging by using burette clamps attached to a nearby ringstand.

(4) Shut off the blower. Remove the test filter, and insert another which is to absorb CK during concentration tests. Do this as quickly as possible. Turn on the blower. If gauge (1-5) does not correspond with 75 CFM, move the damper so that this flow rate is achieved. Turn on the lab hood air and set up the psychrometer to monitor the relative humidity in the hood.

(5) The blower and hood will remain in operation at all times when cyanogen chloride is connected as shown in Figure 1, for the low vapor pressure of CK will allow toxic gas to evaporate continuously. An exception to this is during the brief period while the filters are being changed as in paragraph 4a(4).

b. Concentration Tests.

(1) To establish a 4 milligram per liter CK concentration, choose an air flow rate (2-6 reading), filling the stabilizer with liquid until its level permits bubbling to begin at pressures slightly below this air rate reading. Subsequently, the flowmeter reading (and stabilizer level, if necessary) will have to be varied until chemical analysis of influent gas is in the 3.9 - 4.2 mg/l range. The parameters for U. S. Army CBR Agency testing are given in Appendix I.

(2) Fill each of 4 quantitative bubblers (3-3) with 20 ml of alcoholic sodium peroxide solution (See section 3c). Insert the bubblers

in two parallel series connecting the first, or purging train, between the flowmeter (3-2) line and one path from the sampling inlet valve (3-4). Connect the second, or sampling train, to the other line from valve 3-4. Glass connectors (3-5) link sampling and purging line components with the vacuum and sampling inlet. Valves 3-4, 3-0 and 4-0 should be "off."

(3) After setting up the CK source and water bath, turn off the blower and valves 2-0 and 2-5. Adjust valves 2-1 and 2-5 to obtain a constant flowmeter reading. Note bubbling in the stabilizer (2-4), the CK source (2-7), and the H_2SO_4 bottle (2-2). At this time, use a Halogen Leak Detector to check the system for leaks.

(4) Turn on the lab vacuum line 3-0, adjusting the rate through flowmeter 3-2 to 500 milliliters/minute with valve 3-1. Bubbling in cylinders 3-3 indicates a leak in the line. Next, turn valve 3-4 to permit absorption by the purging train. Purge for about two minutes, then again turn 3-4 off. Disconnect the purging train from the stopcock and flowmeter leads, and connect the sampling bubblers to the flowmeter line (clamp 3-5c). Premature bubbles indicate leaks. Discard the solution from the purging bubblers. At this time, take a ten-minute concentration sample.

(5) Start the timer, and at the same time turn stopcock 3-4 to draw gas through the sampling line. Adjust valve 3-1 to maintain the 500 ml/minute draw rate through flowmeter 3-2. At the end of ten minutes shut off valves 2-0, 2-1 and 2-5 and stopcock 3-4 and determine the CK concentration by chemical analysis. Remove the bubblers. It is unnecessary to turn off the vacuum between successive tests.

(6) Repeat this procedure as often as it is necessary to determine the concentration variables, adjusting the air pressure and stabilizer liquid level if required. To maintain the liquid datum within 1 inch, add new CK about every 3 1/2 - 4 hours. Air pressure should be the only parameter requiring study.

(7) At the end of a test period, close valves 3-4, 2-0, 2-5 and 2-1. Disconnect the CK bottle from the system by removing clamps 2-9, placing the ends of the CK tubing together and re-clamping. Allow air to blow through the filter for ten minutes, then turn off the blower. The filter used in finding the concentration may remain seated in the plenum. It is not necessary to allow the hood to remain on during shut-down periods.

(8) Record the flowmeter reading (2-6), liquid level, relative humidity, and CK concentration. When the 4.0 mg/l concentration can be reproduced, filters may be tested.

c. Filter Testing.

(1) Set up the system so that concentration variables correspond with those for which the 4.0 mg/l concentration was found. Turn on the blower and the hood, set up the psychrometer, and ready the CK injection system and influent sampling line for use. Set up the effluent sampling line. If the filters are to be tested at a given R. H., either (1) humidify hood air, or (2) wait until hood humidity reaches the desired value.

(2) Fill five or six 20 ml bubblers with 15 ml of pyridine-starch indicator solution (See section 3b), and attach bubblers to each effluent line.

(3) Valves 2-0, 2-1, 3-0 and 4-0 should be "off" initially. Turn valves 3-4 and 4-3 to the "purge" position, then turn on valves 3-0 and 4-0. Adjust valves 3-1 and 4-1 so that flowmeters 3-2 and 4-2 each indicate a 500 ml/min flow. Feed compressed air and CK into the line through valves 2-0, 2-1 and 2-5. Purge the line briefly, then turn off the CK (2-5), the compressed air (2-1) and the blower.

(4) Remove the filter used in the concentration studies and place it in the hood. Insert a previously weighed and conditioned filter in the plenum. Switch valves 3-4 and 4-3 "off," and replace the spent bubbler with a fresh one.

(5) Since the damper position to effect a 75 CFM flow for the filter to be tested has been noted, move the damper to that position, if necessary. (A constant damper setting was found to be adequate for in-house testing.) Start the timer, turning the blower and switching valves 3-4 and 4-3 to "sample" positions at the same time. At this time, also, turn compressed air (2-1) and CK (2-5) valves to positions where experience has shown the 4.0 mg/l concentration should be effected.

(6) Take a 10 minute concentration sample. At the "break times" where the indicator turns from blue to colorless, switch instantly from one bubbler to the other, replacing spent bubblers at each break. Record the break times to the nearest 0.1 minute, until 2 color changes occur within 2 minutes \pm 15 seconds. The interval from the initial gas contact with the filter to installation of the final bubbler is the "break time."

(7) After "break time" is found, shut off all valves, isolate the CK source, wait 10 minutes, then switch off the blower. Remove the filter and store it for a time in the hood. Correct the break time (See

section 6d) if the concentration is not 4.0 mg/l, provided that it is in the 3.9 to 4.2 mg/l range. Those tests made with concentrations outside this range must be considered invalid.

(8) When a new test is to be made, proceed in the manner described above.

5. Determination of Cyanogen Chloride Concentration by Chemical Analysis.

Volhard Titration.

The equivalent factor relating the normality of the KCNS to the standardized AgNO_3 must be determined before the calculations for concentration may be made. This factor may be used so long as the same solutions are used and eliminates the requirement for determining a blank with each analysis. To determine the equivalent factor, run a blank determination using the same amounts of absorbent solution (40 ml) and carry out a blank titration using all solutions and reagents as described below. Calculate the equivalent factor as shown in 6c. Pour the contents of the absorbent solution tubes from the concentration determination into a 500 ml ground glass-stoppered Erlenmeyer flask. Wash the tubes and bubbler assemblies carefully. Add the washings to the solution in the flask. Keep the volume small, approximately 250 ml. Add a few drops of phenolphthalein indicator solution and make the solution slightly acid with diluted nitric acid (3d). Add 50 ml (an excess) of silver nitrate solution (3e) and shake the flask. Add 8 to 10 ml of nitrobenzene, stopper the flask and shake vigorously for at least 1 minute. This will coagulate the silver chloride precipitate. Add a few ml of ferric alum indicator solution (3g), and back titrate the solution with the potassium thiocyanate (3f) until the first permanent red-brown color is developed. Calculate the concentration for cyanogen chloride as shown in 6c.

6. Calculations.

a. Normality of Silver Nitrate Solution.

$$(1) N = \frac{\text{gm KCl}}{(\text{Net ml AgNO}_3)(0.0746)}$$

$$(2) \text{Net AgNO}_3 = (\text{Total ml AgNO}_3) \\ - (\text{ml KCNS})(R) \\ - (\text{Solution Blank})$$

$$(3) R = (\text{ml AgNO}_3) / (\text{ml KCNS})$$

Where N = Normality and V = Volume.

b. Normality of Potassium Thiocyanate Solution.

$$(1) \text{ Normality} = (\text{gm of AgNO}_3) / (\text{mls KCNS}) \left(\frac{169.06}{1000} \right)$$

$$(2) N_{\text{KCNS}} = (V_{\text{AgNO}_3}) / (V_{\text{KCNS}})$$

c. Cyanogen Chloride Concentration by Chemical Analysis.

$$(1) \text{ Equivalent factor, E} = (\text{ml AgNO}_3) / (\text{ml KCNS})$$

$$(2) \text{ CK conc. in mg/liter} = \text{ml AgNO}_3 - (E)(\text{ml KCNS})(N_{\text{AgNO}_3})(61.5)$$

c. Corrected Filter Life.

$$L_c = (L_o)(C_o) / (C_s)$$

where:

(1) L_c = corrected life.

(2) L_o = observed life.

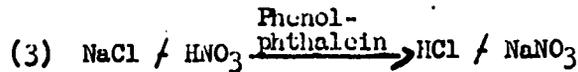
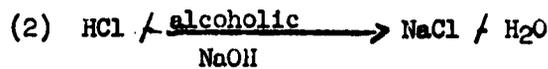
(3) C_o = observed concentration.

(4) C_s = specified concentration (4 mg/l).

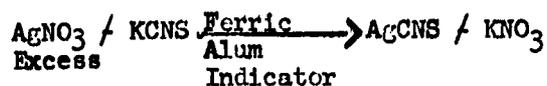
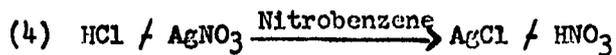
This correction applies only to concentrations within the 3.9 - 4.2 mg/l range.

7. Chemistry of the Process.

a. Cyanogen Chloride	CK	CNCl
(Chemical Name)	(CBRA Symbol)	(Chemical Formula)

b. Concentration Determination.

2 January 1963



(5) Cyanogen Chloride (CK) concentration in Milligrams/Liter

$$(a) = 61.5 \frac{(V_{\text{AgNO}_3} N_{\text{AgNO}_3} - V_{\text{KCNS}} N_{\text{KCNS}})}{V_s}$$

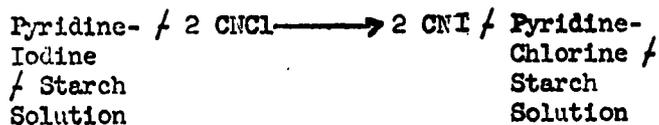
$$(b) = 61.5 (V_{\text{KCNS}})(\text{Equivalent Factor})(N_{\text{AgNO}_3} - N_{\text{KCNS}})$$

(c) V = volume in milliliters.

(d) V_s = sample volume in liters.

(e) N = normality.

c. Breakthrough Determination.



Blue
Solution

Clear or Lt. Yellow
Solution



PFC CHARLES E. KRUMM
Chemical Engineer
CBR Defense Division

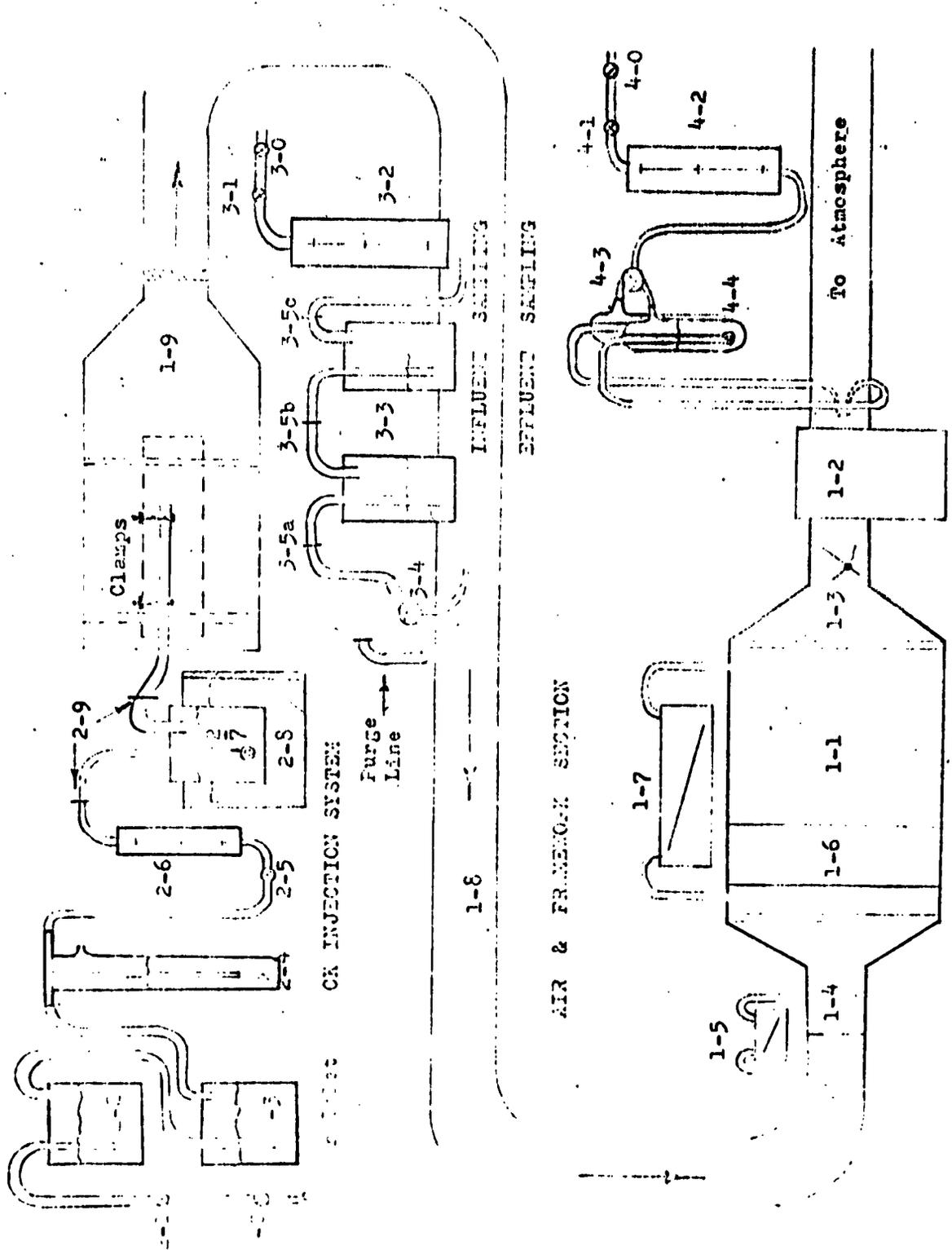


FIGURE 1. SCHEMATIC DIAGRAM FOR CK TESTING

TABLE I

APPARATUS SHOWN IN FIGURE I

1. Air and Framework Section
 - 1-1 Flenum
 - 1-2 Motor and Blower
 - 1-3 Flow Control Damper
 - 1-4 Calibrated Orifice
 - 1-5 Draft Gauge
 - 1-6 Filter, 75 CFM (Office of Civil Defense)
 - 1-7 Draft Gauge
 - 1-8 Flexible Ducting
 - 1-9 Spray Chamber

2. Cyanogen Chloride Injection System
 - 2-0 Valve, Air, Lab Supply
 - 2-1 Valve, Air, Needle
 - 2-2 Sulfuric Acid
 - 2-3 Drierite
 - 2-4 Stabilizer
 - 2-5 Valve, Stopcock
 - 2-6 Flowmeter
 - 2-7 CK Supply Bottle
 - 2-8 Water-Ice Bath with drain
 - 2-9 Glass Clamps

3. Influent Sampling
 - 3-0 Valve, Vacuum, Lab Supply
 - 3-1 Valve, Vacuum
 - 3-2 Flowmeter
 - 3-3 Concentration Sampling Bubblers
 - 3-4 Valve
 - 3-5 Glass Clamps

4. Effluent Sampling
 - 4-0 Valve, Vacuum, Lab Supply
 - 4-1 Valve, Vacuum
 - 4-2 Flowmeter
 - 4-3 Valve, 3-way Stopcock
 - 4-4 Bubblers

Appendix I

The U. S. Army CBR Agency has produced a concentration of 4.0 mg/l for a 75 CFM unit. With liquid level 0-1 inch below the "Pyrex" trademark on an 8 gallon container, a reading of 9.2 - 9.4 on flowmeter 2-6, at humidities from 30 - 80%, gave the required concentration.

2 January 1963

SMICE-CEC

"Appendix D"

RESULTS OF CYANOGEN CHLORIDE TESTS
ON 75 CFM OCD GAS FILTERS
PERFORMED ON WR 62-807

Filter No.	Orig.	Weight, G		DB OF	WB OF	RH	Gas Life Min.	Date Tested
		Dry	Humid.					
6	8830	8577		73	60.8	48	5.0 (1)	7 Nov 62
3 (2)	(3)	8588		70	59	51	17.4	14 Nov 62
4	8733		9560	79	74	79	4.1	9 Nov 62
5	8830		9711	77.5	73	80	4.3	16 Nov 62

Cyanogen Chloride (CK) concentration: 4 mg/l
Air Flow: 75 cfm

Notes:

- (1) Life not valid because of variation in test conditions. Filter was humidified to 80% and test started before deviation in procedure was discovered.
- (2) Purged of Chloropicrin and dried before testing for CK.
- (3) Not recorded.

U. S. ARMY CHEMICAL-BIOLOGICAL-RADIOLOGICAL
ENGINEERING GROUP
Army Chemical Center, Maryland

SMJCE-CEC

10 December 1962

CHLOROPICRIN TEST METHOD FOR 75 CFM OCD GAS FILTERS

1. Outline of Method.

A mixture of air and chloropicrin (PS) with a chloropicrin concentration of approximately 16 milligrams (mg) per liter is passed through the 75 CFM OCD Gas Filter at an air flow rate of 75 cubic feet per minute (CFM). A continuous sample of the filter effluent gas passes through a pyrolyzer tube and is then bubbled through a solution of starch and potassium iodide. When the indicator turns from colorless to blue, a break-point has been reached. The bubbler is repeatedly replaced with a fresh one until the color change occurs within 2 minutes \pm 15 seconds. The "observed life" is the time elapsed from the setting of the timer until the installation of the bubbler. The chloropicrin concentration of the air-gas mixture influent to the filter is determined by a Volhard Titration. Filter life is then corrected for a chloropicrin concentration deviation from the specified 16 mg per liter.

2. Apparatus.

a. The apparatus employed in this test consists essentially of the following:

(1) A plenum which provides a mounting position for the gas filter and has a provision for drawing air at a measured rate through the filter under test.

(2) A source of chloropicrin and a means for introducing measured quantities of the agent into the main air stream.

(3) A sampling line in the prefilter ductwork used to obtain chloropicrin-in-air concentrations by chemical analysis.

(4) A sampling line in the effluent stream providing a means to determine the "break point," or the time at which the gas filter ceases to prevent effectively the passage of chloropicrin. A diagram and listing of the test apparatus are given in Figure 1 and Table I. The individual components are listed and described at the end of this section.

b. Air and Framework Section.

(1) Because chloropicrin is toxic, a ventilated hood houses the PS injection hardware, a spray chamber and the gas line from the blower.

Flexible 5" diameter tubing linking the spray chamber to the plenum, and a 10" diameter stove pipe ducting from the blower unit through the hood to the open atmosphere complete the air system skeleton.

(2) Pressure drop studies with a calibrated orifice and draft gauge indicate the proper effluent air damper setting to produce a 75 CFM flow rate through the plenum when a test filter is clamped within the plenum.

(3) The spray chamber is a 10" diameter metal (stainless steel) cylinder fitted with a 10" to 5" reducer at one end. Total length was 24 inches. A 5" diameter cylinder about 15 inches long, and supported near each end in the larger cylinder by 10" OD concentric rings, as shown:



can move transversely in the larger unit. Bolts on the air and PS piping (Figure 1) anchor the chamber along two 5/8" x 5" slots on the small cylinder's influent end so that the nozzle assumes an axial flow position. Proper positioning is determined by inspection. With a proper piping layout the small cylinder may be placed far back in the chamber to lessen the possibility of PS leakage.

b. The Chloropicrin Injection System.

(1) The chloropicrin injection system is built around a Spraying Systems Co. air-liquid siphon-type nozzle. PS enters the liquid side by suction flow from the lower of two bottles kept at a constant liquid level by siphon feed from an elevated source. Compressed air from the laboratory entrains and vaporizes the liquid PS and forces the mixture through the nozzle aperture as an atomized mist.

(2) Two valves regulating the laboratory air supply, a regulating valve setting up a desired constant pressure, and a pressure gauge are in the air line. The chloropicrin section includes a glass stopcock and a short orifice segment. A 1.1 mm capillary tubing orifice is inserted to permit operation in the liquid head-concentration range listed in the manufacturer's nozzle specifications and at the same time gain a finer control of the concentration through an increased operating pressure range.

(3) Brass or steel pipe, 1/4" in diameter, compose the air line, while glass, tygon tubing and brass form the PS leg. Copper is unsuitable for use in contact with PS since it is readily corroded. Tygon, although usable, becomes softened in time and needs occasional replacement. The brass segment in the PS line is used to provide mating surfaces for the bolts positioning the spray chamber and to connect with the nozzle mounting.

Because PS left in the line overnight causes some corrosion to the brass, the line requires a cleaning before each day's tests; however, little corrosion is noted after a day's testing. Use of Teflon or other sturdy, non-corrosive, threadable material for the entire PS line might be well advised for prolonged testing.

(4) A proper fluid head seems to be a critical factor in reproducing chloropicrin concentrations. Exploratory tests at the U. S. Army CBR Agency made in the absence of a flow or liquid level controller indicate that:

(a) The siphon feed used (Figure 1) needs occasional repriming; hence it is not uncommon to witness the fluid head at times below the one inch level arbitrarily set for in-house testing.

(b) Successive concentrations at a given pressure and humidity decreased monotonically with time, although two or three replicate runs were often found. Filter tests, therefore, were begun at concentrations slightly higher than desired to allow for this effect. Installing a good level or flow controller should overcome these defects.

c. The Influent Sampling Line.

The influent sampling line mounted on the plenum adapter inlet vacuum draws flowmeter-monitored filter influent gas at 1/2 liter per minute through two rubber-stoppered bubblers containing PS absorption solution. This is shown in Figure 1. Two absorption trains connect to the vacuum by a 3-way stopcock valve, the first to aid in purging the line and the second to take a sample. Glass joints held by glass clamps allow for easy setup and breakdown of this system component for use in repetitive testing and chemical analysis. Miscellaneous glass and rubber tubing, and two glass stopcocks complete this line.

d. Effluent Sampling Line.

(1) Effluent sampling employs two parallel combinations of pyrolizers and bubblers in series. Monitoring and controlling the draw-off are a flowmeter and a stopcock valve. Another three-way stopcock directs flow through one indicator branch allowing immediate switching to the other when a "breakthrough" color change is indicated. Leads from the pyrolizers are connected to a powerstat.

(2) Connections from either side of the blower exit pipe to each of the pyrolizers were 1/4" copper tubing. The balance were of glass and rubber.

e. Other Apparatus.

A timer and a psychrometer complete the apparatus.

f. Apparatus List.

(1) Motor (1-2). The motor is a Howell Electric Motor Co. Type I unit rated at 1 HP, 3,450 RPM, operating on 3 ph, 60 cy.

(2) Blower (1-2). The blower, model 5ACom with 5A45 fan size, operates from 60 cy, 3 ph, drawing 3.4 amps at 220 v. It is made by L. J. Wing Manufacturing Co., New York, N. Y.

(3) Draft Gauge (1-5, 1-7). These are Ellison Industrial Gauges having a 3" H₂O pressure range.

(4) Stainless Steel Nozzle (2-1). The air nozzle, type 120, and fluid nozzle, 60100, together with the nozzle mounting are from the Spraying Systems Co., Bellwood, Illinois.

(5) Regulating valve (2-10). The valve is Type 20AG33 from the C. A. Norgren Co.

(6) Flowmeters (3-2, 4-2). Two Fischer and Porter flowmeter tubes, No. 02-1/8-20-5/36 are used.

(7) PS Containers (2-2). Two Pyrex 6 gallon capacity container hold the PS.

(8) Powerstat (4-5). A type 116, single phase unit with 120 v, 50 - 60 cy input powerstat is made by Superior Electric Co., Bristol, Conn.

(9) Timer (not shown). A Standard Electric Time Co., Springfield, Mass., timer is used.

(10) Piping is steel 1/4", tygon, glass.

(11) Assorted valves are two- and three-way glass stopcocks.

(12) Bubblers (3-3) were of 50 ml capacity, brand unknown.

3. Reagents and Materials.a. Reagents.

Unless otherwise specified, only ACS reagent grade chemicals and distilled water shall be used throughout the tests. Blank determinations shall be run in parallel with the tests and corrections applied when significant.

b. Starch Solution (Iodine Indicator).

Mix 0.5 gm of soluble starch with sufficient cold water to make a thin slurry. Add slurry slowly to 1 liter of boiling water. Continue boiling for 1 minute; cool and transfer the solution to a glass stoppered bottle. Add 5 ml of mercury.

c. 2% Potassium Iodide.

Dissolve 10 gm of potassium iodide in 500 ml of distilled water and store in a glass-stoppered, light-protected bottle.

d. Alcoholic Sodium Peroxide.

Add slowly 20 gm of sodium peroxide (containing not more than 0.002% chlorine) to 250 ml of chilled water packed in ice. The unused solution can be kept on ice for 1 day, after which time it should be discarded and fresh solution be prepared. Just prior to making a test 20 ml of 95% ethyl alcohol (see paragraph 3a) is placed in each bubbler to which is added 10 ml of the aqueous sodium peroxide solution.

e. Nitric Acid.

Dilute concentrated nitric acid to contain approximately 35% nitric acid by combining equal volumes of concentrated acid and water. The acid should be free from lower oxides of nitrogen. If the acid is colored, boil before dilution. Store the 35% acid in brown glass-stoppered bottles.

f. Silver Nitrate, 0.025N.

Dissolve 4.25 gm of silver nitrate per liter of water and store in a brown or black bottle. Standardize the solution against potassium chloride (or sodium chloride) by the modified Volhard procedure. Dry the salt (chloride) for at least 2 hours at 150°C before use. If suitable material is not available, prepare it by recrystallization and drying of potassium chloride. To standardize, make a solution of approximately 1 gm, weighed to the nearest 0.1 mg, of potassium chloride per liter and use aliquot portions of 50 ml each for the analysis. Determinations should be made in duplicate. The water used in preparing the solution and in making the analysis must be comparatively free of chlorides. With each analysis a blank determination must be made and the correction applied. Calculate the normality of the silver nitrate solution as shown in 6a.

Volhard (modified) Method.

Standardize the silver nitrate as follows: To the prepared aliquot of potassium chloride (see above) add a few drops of phenolphthalein and sufficient nitric acid (3e) to dispense with the color.

From a burette, add 20 ml. (an excess) of silver nitrate. Four or five ml. of nitrobenzene are added and shaken vigorously for at least 1 minute. Add a few ml. of ferric alum (3h) indicator and back titrate the solution with the potassium thiocyanate solution (3g) until the development of the first permanent red-brown color. Record the volumes of silver nitrate and potassium thiocyanate and determine the net ml. of silver nitrate solution as shown in 6a.

g. Potassium Thiocyanate 0.025 N.

(1) Dissolve 2.4 gm. of potassium thiocyanate in distilled water and dilute to 1 liter. Shake thoroughly.

(2) The normality can be found in the following way: Pour 100 ml. of distilled water into a 200 ml. flask; pipette 25ml. of silver nitrate solution (3f) into this flask; add 10 ml. of nitric acid (3e) and 2 ml. of ferric alum solution (3h). Titrate with potassium thiocyanate until first permanent reddish brown color is produced. Shake vigorously and set aside for 5 minutes. If color disappears, continue to titrate with a small amount of KCNS until the color holds. Calculate the normality of potassium thiocyanate as shown in 6b.

h. Ferric Ammonium Sulfate Solution.

Add to 360 ml. of distilled water 453 gm. of ferric ammonium sulfate. If necessary, warm to get all the crystals in solution. Cool and store in a brown bottle.

4. Test Procedure.

a. Preliminary Arrangements.

(1) Draw chloropicrin through a fine powdered asbestos filter to remove iron oxide eroded from the shipping containers. The suspension of Fe_2O_3 in impure PS breaks up when the liquid is in motion (i.e., when being filtered or run through tubing) only to reform at low liquid velocities. It forms a sludge on tubing walls and tends to clog the orifice. Distill the PS to remove the solid particles as well as oxides of nitrogen giving the liquid a yellow cast if the degree of PS use warrants it.

(2) Next check the equipment for leaks. Monitor air currents in the hood and in working areas adjacent to it using smoke capsules or their equivalent. Check obvious leak sources: pipe, glass and rubber connections, e.g. test the system with a Halogen Leak Detector immediately after PS is first introduced.

(3) Turn on the blower unit (1-2). Establish a 75 CFM flow with the aid of the flow control damper (1-3), a calibrated orifice (1-4) and a draft gauge (1-5), with a 75 CFM OCD filter in the plenum (1-1). Note the reading on the draft gauge (1-5), and the damper position. Switch off the blower.

(4) Set up the chloropicrin feed line with a head (2-8) which is one inch below the spray nozzle (2-1). Keep the liquid level in the lower bottle (2-2a) constant at, or about, 6 inches by siphoning additional PS from 2-2b (Figure 1) as needed. Valve 2-5 is normally closed, and 2-6 and 2-7 are normally open when the PS is fed.

(5) Remove the test filter and insert another which serves as a PS sponge during initial concentration tests. Turn on the blower. If gauge 1-5 does not correspond with 75 CFM, note the old damper position then move the damper so that this flow rate is achieved. Turn on the lab hood, air, and set up the psychrometer for checking the relative humidity in the hood.

b. The Concentration Variables.

(1) Establish an influent PS concentration of 16 mg/l by trial and error. Appendix I lists the concentration parameters found by the U. S. Army CER Agency in its test series.

(2) Fill each of 4 quantitative bubblers (3-3) with 20 ml of alcoholic sodium peroxide solution (See section 3d). Insert the bubblers in two parallel series, connecting the first or purging train between the flowmeter (3-2) line and one path from the sampling inlet valve (3-4). Connect the second, or sampling train, to the other line from valve 3-4. Glass connectors (3-5) link sampling and purging line components with the vacuum and sampling inlet. Valves 3-0 and 4-0 should be off, and valve 3-4 should be "off" to both purging and sampling lines.

(3) Open valves 2-0 and 2-9 and adjust air pressure shown by regulator 2-10. Open the PS feed line (2-3) as the main gas line and sampling line are briefly purged. Check nozzle operation by using a mirror or by inserting a dry paper towel in the nozzle path. At this time, use the leak detector to check for system leaks.

(4) Turn on the lab vacuum line (3-0), adjusting the flow through flowmeter 3-2 to 500 milliliters/minute with valve 3-1. Bubbling indicates a leak in the line that should be immediately corrected. Next, turn valve 3-4 on to permit absorption by the purging train. Use this line for about 2 minutes, then turn 3-4 "off" to both trains. At this time a concentration sample is to be taken.

(5) Disconnect the purging train from stopcock and flowmeter leads, and connect the sampling bubblers to the flowmeter line (clamp 3-5c).

Premature bubbles indicate leaks. Discard the solution from the purging bubblers. Start the timer, and at the same time turn stopcock 3-4 to draw gas through the sampling line. Adjust valve 3-1 to maintain the 500 ml/minute draw rate through flowmeter 3-2. At the end of two minutes shut off valve 2-3 and stopcock 3-4 and determine PS concentration by chemical analysis. Remove the bubblers. It is not necessary to turn off the vacuum between successive tests.

(6) Repeat this procedure as often as it is necessary to determine the 16 mg/l concentration, adjusting the air pressure if required, and maintaining a liquid head of 1 inch. Air pressure should be the only parameter requiring study.

(7) At the end of a test period, close valves 3-4, 2-0, 2-3, 2-6, 2-9, 3-0 and 3-1. Allow air to blow through the PS filter for ten minutes, then turn off the blower. The filter used in finding the concentration may remain seated in the plenum. It is not necessary to allow the hood to remain on during shutdown periods.

(8) Record the air pressure (2-1), liquid head (2-8), relative humidity, orifice specifications (2-4) and PS concentration. When the 16 mg/l concentrations can be reproduced, filters may be tested.

c. Filter Testing.

(1) Set up the system so that concentration variables correspond with those for which the 16 mg/l concentration was found. Turn on the hood, set up the psychrometer, and ready the PS injection system and influent sampling line for use. Set up the effluent sampling line. If the filters are to be tested at a given R. H., either (1) humidify hood air, or (2) wait until the hood humidity reaches the desired value.

(2) Attach leads from the two pyrolyzers (4-5) to the powerstat (4-6), varying its reading until the pyrolyzer wires retain a faint pink color. Fill five or six ml. bubblers with 15 ml. of the starch indicator solution (See section 3) and attach bubblers to each pyrolyzer. The blower can now be turned on.

(3) Turn valves 3-4 and 4-3 to the "purge" position, then turn on valves 3- and 4-0. Adjust valves 3-1 and 4-1 so that flowmeters 3-2 and 4-2 indicate a 500 ml/min flow. Feed compressed air and PS into the line through open valves 2-0, 2-9 and 2-3, after noting that 2-6 and 2-7 are open and that PS liquid head is one inch. Purge the line briefly, then turn off the PS (2-3) and compressed air (2-9).

(4) Turn the blower off and quickly remove the PS laden filter used for concentration testing and place it in the hood. Insert a previously weighed and conditioned filter in the plenum. Switch valves 3-4 and 4-3 "off" to the purging and sampling trains, and replace the spent bubbler with a fresh one.

(5) Since the damper position to effect a 75 CFM flow for the filter to be tested has been noted, the damper may be moved to that position if it is necessary. (A constant damper setting was found to be adequate for all U. S. Army CBR Agency tests.) Start the timer, turning on the blower and switching the influent and effluent sampling valves 3-4 and 4-3 to "sample" positions at the same time. At this time, also, turn on the compressed air (2-9) and PS (2-3) valves to positions where experience has shown the 16 mg concentration will be effected. The procedure outlined in this paragraph should be administered as quickly as possible.

(6) Take 2 minute concentration samples throughout the test, keeping the timer running if it is also to be used for influent sampling. At the "break times" where the indicator solution turns from colorless to blue, switch instantly from one bubbler to the other, replacing spent bubblers at each break. Record the break times to the nearest 0.1 minute. Continue until 2 color changes occur within 2 minutes ⁴⁵ seconds ₁₅ seconds. The interval from the beginning of the PS injection to the installation of the last bubbler is the "break time." Shut off all valves, wait 10 minutes, then switch off the blower. Remove the filter and store it in the hood. Correct the break time (See section 6d) if the concentration is not 16 mg/l.

(7) When a new test is to be made, proceed in the manner described above.

5. Determination of Chloropicrin Concentration by Chemical Analysis.

Volhard Titration.

The equivalent factor relating the normality of the KCNS to the standardized AgNO_3 must be determined before the calculations for concentration may be made. This factor may be used so long as the same solutions are used and eliminates the requirement for determining a blank with each analysis. To determine the equivalent factor, run a blank determination using the same amount of absorbent solution (40 ml) and carry out a blank titration using all solutions and reagents as described below. Calculate the equivalent factor as shown in 6c. Pour the contents of the absorbent solution tubes from the concentration determination into a 500 ml ground glass-stoppered Erlenmeyer flask. Wash the tubes and bubbler

assemblies carefully. Add the washings to the solution in the flask. Keep the volume small, approximately 250 ml. Add a few drops of phenolphthalein indicator solution and make the solution slightly acid with diluted nitric acid (3e). Add 50 ml (an excess) of silver nitrate solution (3f) and shake the flask. Add 8 to 10 ml of nitrobenzene, stopper the flask and shake vigorously for at least 1 minute. This will coagulate the silver chloride precipitate. Add a few ml of ferric alum indicator solution (3h) and back titrate the solution with the potassium thiocyanate (3g) until the first permanent red-brown color is developed. Calculate the concentration of chloropicrin as shown in 6c.

6. Calculations.

a. Normality of Silver Nitrate Solution.

$$(1) N = \frac{\text{gm KCl}}{(\text{net ml AgNO}_3)(0.0746)}$$

$$(2) \text{Net ml AgNO}_3 = (\text{total ml AgNO}_3) - (\text{ml KCNS} \times R) \\ - (\text{Solution blank})$$

$$(3) R = \frac{\text{ml AgNO}_3}{\text{ml KCNS}}$$

b. Normality of Potassium Thiocyanate Solution.

$$(1) \text{Normality} = \frac{\text{gms. of AgNO}_3}{\text{mls. of KCNS} \times \frac{169.89}{1000}}$$

OR

$$(2) \frac{V_{\text{AgNO}_3}}{V_{\text{KCNS}}} = \frac{N_{\text{KCNS}}}{N_{\text{AgNO}_3}} \quad \begin{array}{l} V = \text{Volume} \\ N = \text{Normality} \end{array}$$

c. Chloropicrin Concentration by Chemical Analysis.

$$(1) E = \frac{A}{B}$$

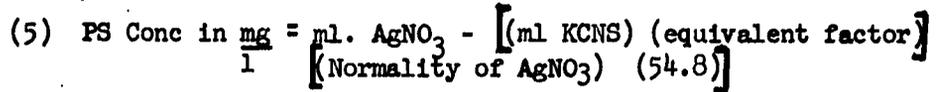
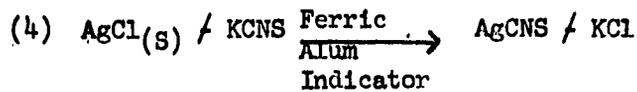
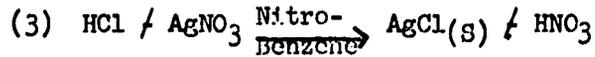
(a) E = equivalent factor.

(b) A = ml of AgNO₃.

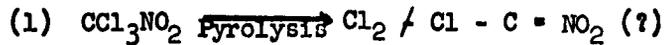
(c) B = ml of KCNS.

$$(2) C = A - (BXE) (N \times 54.8).$$

10 December 1962



c. Breakthrough Determination.



Clear
Solution

Blue
Solution



PFC CHARLES E. KRUMM
Chemical Engineer
CBR Defense Division

Appendix I

The U. S. Army CBR Agency has produced a concentration of 16 mg per liter for a 75 CFM unit. This concentration was obtained by using one siphon-type nozzle, an air pressure of 23 p.s.i.g., a fluid head of -1 inch of chloropicrin, and an orifice (capillary tubing: 1.1 mm bore, 1-1/8" long).

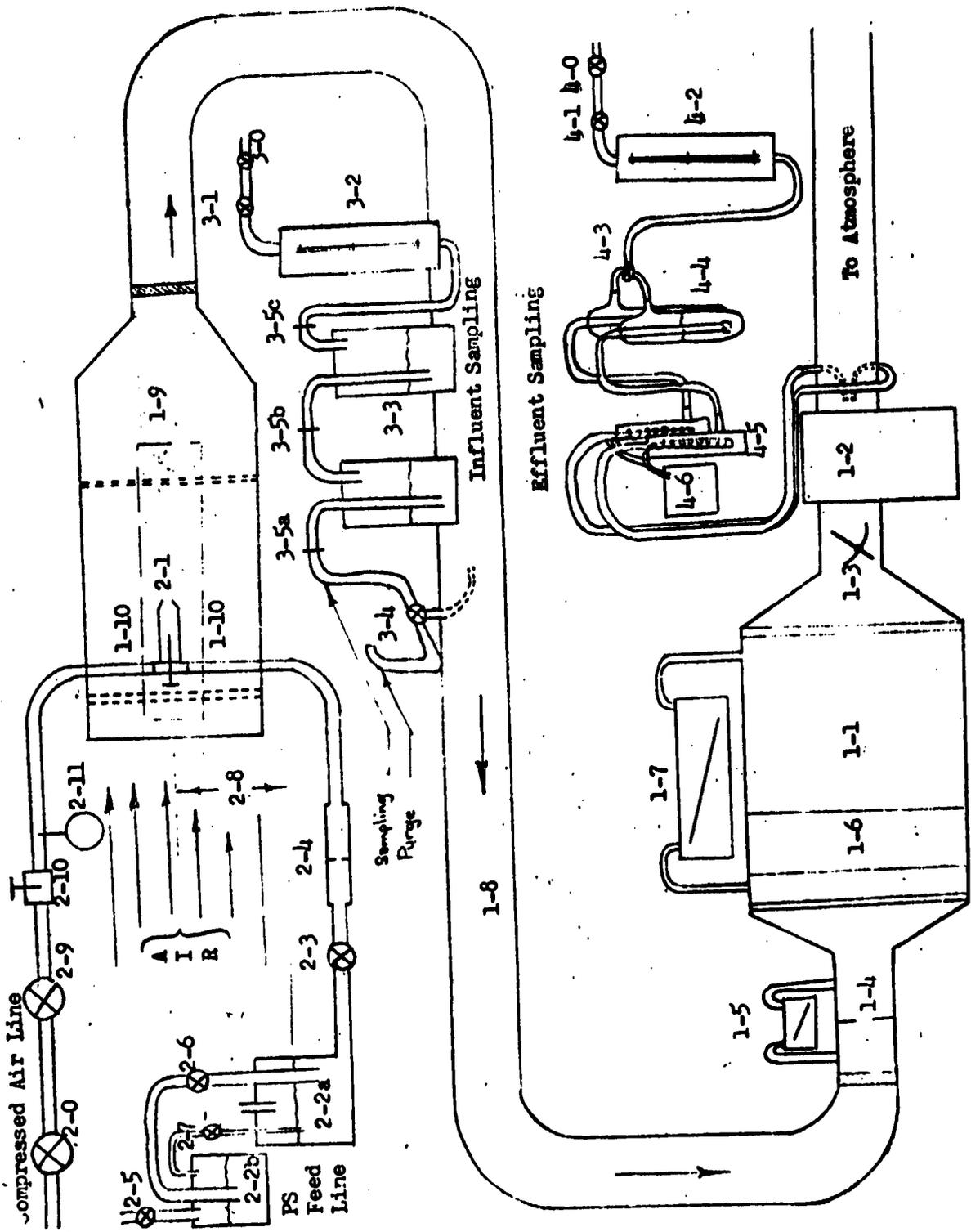


FIGURE 1. SCHEMATIC DIAGRAM FOR PS TESTING

TABLE I

Apparatus Shown in Figure 1

Air and Framework Section

- 1-1 Plenum
- 1-2 Motor and Blower
- 1-3 Flow Control Damper
- 1-4 Calibrated Orifice
- 1-5 Draft Gauge
- 1-6 Filter, 75 CFM (Office of Civil Defense)
- 1-7 Draft Gauge
- 1-8 Flexible Ducting
- 1-9 Spray Chamber
- 1-10 Bolts

Chloropicrin (PS) Injection System

- 2-0 Valve, Air, Laboratory Supply
- 2-1 Nozzle, Siphon Type
- 2-2 PS supply bottles
- 2-3 Valve, liquid
- 2-4 Orifice (Capillary Tube)
- 2-5 Valve, Siphon, Normally closed
- 2-6 Valve, PS Siphon, Normally open
- 2-7 Valve, PS Siphon, Normally open
- 2-8 Liquid Head, (shown negative in figure)
- 2-9 Valve, Air
- 2-10 Valve, Air, Regulating
- 2-11 Gauge, Air Pressure

Influent Sampling

- 3-0 Valve, Vacuum, Lab Supply
- 3-1 Valve, Vacuum
- 3-2 Flowmeter
- 3-3 Concentration Sampling Bubblers
- 3-4 Valve
- 3-5 Glass Clamps

Effluent Sampling

- 4-0 Valve, Vacuum, Lab Supply
- 4-1 Valve, Vacuum
- 4-2 Flowmeter
- 4-3 Valve, 3-way Stopcock
- 4-4 Bubblers
- 4-5 Pyrolizers
- 4-6 Powerstat

Appendix D

15 November 1962

RESULTS OF CHLOROPICRIN TESTS
ON 75 CFM OCD GAS FILTERS
PERFORMED ON WR 62-807

Chloropicrin (PS) tests under Specification MIL-C-13724 (except that the PS concentration was 16 mg/l and the flow rate was 75 cfm) were run on three gas filters with the following results:

<u>Filter No.</u>	<u>Rough Handled</u>	<u>PS Conc. mg/l</u>	<u>Corrected Break Time Min.</u>	<u>RH %</u>	<u>PS Sorbed g</u>
1	Yes	16.67	23.1	55 63	816
2	Yes	15.89	24.4	44	826
4	No	16.42	22.7	54 55	790

Incl 3

Appendix D

EVALUATION OF THE 75 CFM OCD RADIAL FLOW GAS FILTER

GB gas life tests have been performed on the 75 cfm OCD Radial Flow Gas Filter.

GB vapor was dispersed by a nozzle atomizer into an airstream moving at the rate of 2000 l/min (about 70 cfm) in such a manner that all of the contaminated air passed through the filter.

Groups of fruit flies and mice served as biological indicators of GB leakage on the downstream side of the filter.

In addition, the effluent air was sampled every 30 minutes throughout the test and as soon as a biological response was observed in the fruit flies.

The first test, a pilot study, was terminated after 300 gms of GB was presented to the filter during a period of 210 minutes (0.71 mg/l) and 400 gms during 60 minutes (3.3 mg/l). During this test, no indication of GB leakage was evident.

The additional filters were tested against GB vapor to determine the breaking point. The airborne concentration was maintained between 2.5 and 3.3 mg/l until GB leakage was evident.

The data summarized in Table 1 indicates that the OCD gas filter is quite effective in filtering GB vapors at a concentration of about 3 mg/l for at least a two-hour period.

The few moments between the biological response of the fruit flies (sensitive species) and the mice (resistant species) suggest that once leakage starts the breakdown in filter efficiency is rapid. The LC50s, for several exposure times, are shown in Table 2 for fruit flies and mice to indicate specie differences in susceptibility.

Table 1

EFFECTIVENESS OF THE 75 CFM OCD RADIAL FLOW GAS FILTER AGAINST CB VAPOR

Filter No.	CB mg/l	Time to Death		Leakage Concentration (Two minutes after filter died) mg/cu m	Total Agent Dispersed gm	Estimated Breakage Time minutes
		Fruit Flies	Mice			
2	2.9	157	162	22	850	120-150
3	3.3	126	135	18	785	120-125
4	2.5	153	158	21	760	120-150

Table 2

TOXICITY OF CB TO FRUIT FLIES AND MICE

Exposure Time min	LC50 mg min/cu m	
	Fruit Flies	Mice
2	3.3	210
20	5.8	450
200	10.3	920

HEADQUARTERS
U.S. ARMY CHEMICAL - BIOLOGICAL - RADIOLOGICAL
ENGINEERING GROUP
Army Chemical Center, Maryland

IN REPLY REFER TO:
SMUCE-CEC

8 October 1962

FREON TESTS OF THE
75 CFM OCD GAS FILTER

The use of Freon 12 for gas filter testing is an attractive means of quality verification since it is essentially a non-destructive test. Due to the low boiling point of Freon, the filter may be purged after a test by merely blowing hot air through the filter until the adsorptive process in the filter has been reversed and the gas escapes into the atmosphere. A purging temperature of 150°F has been found to be sufficient to effectively purge the Freon from the filter without lowering the effectiveness of the charcoal bed for further use. The Freon life of a filter may be correlated to the life of the filter when subjected to a toxic agent within the limits of experimental accuracy.

The apparatus used for the development of this particular test is essentially a closed system of ducting with a blower, heater and the filter placed in it by suitable transition pieces. Accurate instrumentation of the humidity, Freon flow, temperature, air flow and pressures is necessary in order to produce consistent results. It is essential that the operator can produce and reproduce a desired condition for testing and the necessity for adequate controls of the conditions cannot be overemphasized. Since the amount of moisture in the filter and the system has a gross effect on the Freon life of the bed, a pre-heat and dehumidifying purge of the filter should be made on a separate blower and heater before the test. The purging apparatus that was used in conjunction with the tests consisted of a 1200 CFM blower and a heater (see plate 5). The blower was throttled down until a pressure drop of 1.3 inches through the filter was obtained. The temperature of the air entering the filter was 140°F. When additional drying was needed, the influent air temperature was raised to 160°F.

A ½ hour pre-heat was necessary before testing in order to attain the desired moisture content in filters that stood overnight in the building. A 2-hour purge was needed to remove all detectable traces of Freon from a filter after a test.

After drying and pre-heat, the filter is then placed in the test apparatus and the air circulated until an equilibrium condition is reached before the test is made.

The heater box in the test apparatus contains three 350 watt PTF 10 Finstrip heaters and they have been satisfactory in maintaining the desired temperature of 125°F ± 3°F. Two of the heaters are connected

Appendix D

9.17

to a variac, forming a base load, and the other is regulated by a thermostatic switch. After some experimentation by the operator, the voltage on the base load heaters may be regulated to nearly maintain the desired temperature keeping the floating at a minimum since the thermostat will not sense changes less than 5 or 6 degrees F.

Attempts to control the humidity in the system have been, for the main part, unsuccessful. Since the closed loop of the system does not contain much air a very small amount of water is required to raise the humidity a large amount. A water spraying device was installed in the system, but the time lag for the hygrometer response was so great that by the time any change was noted, water was dripping out of the system. Injecting a measured amount of water into the system was tried with some success, but the time required for equilibrium to be re-established was excessive. Generally, the system will contain the water that the filter brings into it plus the water contained in the air in the loop. If the filter is dried thoroughly, the humidity of the system will be lower than that of the ambient air, and as long as conditions can be accurately measured, the filter life can be predicted. A drying salt was not tried because the pressure drop required would exceed the available head. The best method of moisture control is to pre-heat and dry the filter on the purging apparatus as previously described.

The air flow is controlled by the use of two butterfly valves located on the influent and effluent side of the filter. With this method, it is possible to maintain a constant pressure on the air passing through an orifice, calibrated at 75 CFM and placed in the system to permit duplication of the calibration conditions. An air straightener is located in the ducting ten diameters upstream of the orifice to help equalize the extremely turbulent flow exhausting from the centrifugal blower. The pressure drop through the orifice is corrected to standard conditions and the temperature of the air entering the orifice is measured by a thermocouple directly upstream of the plate. Pressure above atmospheric is measured by a V-tube water manometer, and the water content of the air is obtained by the use of a wet and dry bulb hygrometer across the inlet and outlet of the blower.

A Beckman Infra-Red Gas Analyser is used to indicate the breakthrough of the Freon. Before the test begins, the analyser is zeroed and then calibrated with a Freon mixture of 50 ppm Freon in nitrogen. The calibration gas should be run through the Beckman until the moment that the test begins to reduce the possibilities of a discrepancy in breakthrough concentration. When the test is started, the solenoids automatically shut off the calibration gas and allow the filter effluent to be analysed. The sample pickup hose is cut to length so that the time delay for the Freon mixture to reach the filter is approximately the same as the time delay for the effluent gas to reach the Beckman - eliminating, it is hoped, a systematic error that would otherwise amount to about 12 seconds. The timer is automatically stopped when the breakthrough concentration is reached.

The Freon flow is metered by a needle valve placed downstream of a precision bored rotameter which is kept at a constant pressure. The Freon is controlled by the use of two solenoid valves; one of them routes the Freon into the inlet side of the blower (test) and the other vents the gas to the outside of the building. A double-throw switch controls the solenoids, enabling the flow of Freon to be adjusted without contaminating the filter. When the correct conditions are established, the switch is moved to the test position; the Freon is then introduced into the airstream and the timer is started simultaneously. At the same instant the pickup for the Beckman Infra-Red analyser is switched from the calibration gas to the effluent side of the filter. Solenoid valves control this routing in a manner similar to the one used for the Freon control.

Three filters and the original mock-up were available for testing with Freon, and at least three tests were run on each filter. It is felt that these tests were sufficient to establish the criteria for testing and produce a general pattern representative of the characteristics of the filter design.

The mock-up filter was dropped during the construction of the test apparatus and was visibly damaged in the center of the bed for about one third of the circumference (see plate 1). The dent is approximately $\frac{1}{4}$ of an inch deep at the point of maximum impact. The first test of this filter revealed no significant deviation from the expected life of an undamaged filter, but after the Freon was purged from the filter at approximately twice normal flow and re-tested a significant loss in Freon life was noted. Further tests at varying humidities showed that this filter had the same humidity-gas life slope as the good filters, but had a lower life in all cases. It is suspected that the high flow purge and the normal handling of the filter caused the charcoal around the dent to redistribute, and possibly some channeling in the bed occurred. The mock-up filter was built only as an aid in setting up fixtures and test equipment. Pieces were not fully glued together nor was any attempt made to seal the plywood with the white epoxy paint which was used on the prototypes. Since the mock-up was on hand it was tested out of curiosity but no conclusion may be drawn from its results. From this point on, all of the filters that were tested were subjected to at least $\frac{1}{2}$ hour of high flow purging conditions. None of the other filters showed a significant decrease in life as a result of this purging treatment.

Filters Number 1 and 2 were tested in "as received" condition for a total of eight tests and were then rough handled in a vertical position per paragraph 4.5.2 Specification MIL-F-50040. These tests were run at varying humidities and for the range 0.010 to 0.020 lb. moisture/lb. dry air a general decrease in Freon life of 7.5 seconds for an increase of 0.001 lb. moisture/lb. dry air was exhibited. Filter Number 3 was rough handled before testing and no significant deviation in life was found after repeated tests and purges. The same moisture vs Freon life slope was followed for the range tested. The mock-up filter also followed this relationship after the first test was run; but as before mentioned, the Freon life was considerably lower than the other filters.

After the initial tests on Filters 1 and 2 were made, these filters were sent out for the rough handling treatment. Upon return, Filter #1 was pre-heated in the closed loop of the test apparatus while #2 was put in the purging unit. Number 1 Filter was found to have soaked up a large quantity of water during the shipping and the water content of the system had to be estimated because it was off scale on the psychrometric chart ... in fact, water was condensing on the walls of the hygrometer and it is felt that complete saturation of the air had been attained. The ensuing test, as expected, did not last very long; but nevertheless the time still very nearly adheres to the pre-determined curve. Systematic errors would have a great effect here.

Filter #2 was dried and then tested, and the loss in life due to the rough handling tests was less than 10%. Filter #1 was purged and dried and retested; loss in Freon life was also less than 10%, and it is felt that filters are sufficiently sturdy to give adequate performance after being subjected to normal shipping and installation handling.

The greatest source of error in the Freon tests for the 75 CFM filters was in the measurement of the water content of the air in the system. Sometimes after a test was started, the wet or dry bulb temperature would suddenly change as much as 2° F. This would naturally leave some doubt as to which value should be chosen or perhaps some arbitrary selection in between the two values should be made. A glance at a psychrometric chart would clearly demonstrate what a serious effect on the water content of the air this might have. The net result could conceivably vary the Freon life of the filter by as much as 8 seconds.

Another source of error was the measurement of the flow of Freon through the rotameter since the calibration of the rotameter was made at 70° F and no additional calibration curves were available. Ambient conditions generally were somewhat in excess of the calibration temperature (up to 30° F) and naturally the temperature of the Freon cylinder would also be similar. This causes the temperature of the gas passing by the rotameter ball to be higher than as calibrated, consequently an error of unknown magnitude would creep in. It is not felt that too serious an error is introduced by ignoring this variable.

Experimental errors in the measurement of the air flow should not be greater than 4% of the flow depending on the accuracy of the orifice meter and Ellison Draft Gauge supplied by QAG. Other errors in the instruments should be regarded as insignificant in comparison to the aforementioned possible discrepancies.

The Freon life of all the filters tested, with the exception of the water saturated test of Filter #1, is in excess of 225 seconds. The Freon concentration in air used in the tests was 1,000 parts per million (this is the same concentration that has been used by the CBR Agency for the past few years as a tentative standard), and the breakthrough was indicated at 50 ppm. A freon concentration of 1,000 parts per million equals.

5.4 milligrams of Freon per liter of standard air.

Data from the tests, graphs, diagrams and pictures of the test apparatus will be found on the following pages.

A handwritten signature in cursive script that reads "David Carroll".

PFC DAVID CARROLL

EQUIPMENT AND INSTRUMENTATION USED FOR TEST

FREON FLOW:

1. 0-125 psipressure regulator. (Norgren).
2. Bourden-type pressure gauge, 0-15 psig.
3. Calibrated rotameter (Fischer & Porter Co., Tube # FP-1/8-25-005 with float # TA-18.)
4. Needle-type metering valve (Hoke 4 RB 281).

LOOP PRESSURES:

1. Orifice pressure, 10" U-tube water filled manometer (Meriam Instrument Co.)
2. Pressure drop through orifice, -0.05 to 0.5" of H₂O inclined manometer (F. W. Dwyer Mfg. Co.).
3. Pressure drop through filter, -0.2 to 2.0" of H₂O inclined manometer (F. W. Dwyer Mfg. Co.).

HUMIDITY AND TEMPERATURE:

1. Wet and Dry bulb Hygrometer (Fisher).
2. Loop temperatures; Platinum, Platinum-Rhodium thermocouples.
3. Millivolt potentiometer (Leeds & Northrup, Cat, # 8691).

OTHER CONTROLS:

1. Variac (Scientific Glass Apparatus Co., Inc.).
2. Solenoid valves (Skinner Electric Valves).

SMJCE-CEC

4 October 1962

GAS ANALYSIS:

1. Beckman L/B Infrared Analyser, model 15A.
2. Crammer running time meter.
3. 10 millivolt recorder (Minneapolis-Honeywell, Mod. 143K10-VH-11-LLV-20).

EQUIPMENT:

1. Miscellaneous ducting & Elbows (6").
2. 3 Finstrip heaters, PTF-10 (120 volt, 350 watt).

TEST PROCEDURE, 75 SCFM FILTER

1. Turn on Beckman, tuning position.
2. Insert filter in preheat and de-humidifying apparatus and preheat for $\frac{1}{2}$ hour at 140°F (time may be reduced to 15 min. if heater is already warm and little dehumidification is needed).
3. After filter has been pre-heated, turn on blower and heater in test apparatus. (Heater set at 125°F .)
4. Remove filter from pre-heater and install in test apparatus. (Allow at least 10 minutes for equilibrium to be restored.)
5. While equilibrium is being established, turn on infra-red sensing element and vacuum pump on Beckman; turn on recorder power; turn on calibration gas; turn on freon (vent position), and set timer at Zero.
6. Adjust freon flow to 21.24 cc/min, then shut off control switch.
7. Adjust air flow through gas analyzer to 2.6 cc/min, and zero Beckman (control gate).
8. Adjust air flow in loop for 75 SCFM by setting butterfly valve.
9. Start recorder tape, turn freon on vent, turn on calibration gas and calibrate Beckman to 50 ppm.
10. Check freon flow (venting), Air flow in loop, Beckman, turn on timer switch, and begin test (move freon control switch freon vent to test position).
11. Turn off timer switch after pointer on recorder has dropped below the 50 ppm concentration.
12. Record data.
13. Remove filter when test completed.

Elapsed time, Approximately: 15 minutes for test, $\frac{1}{2}$ hour for pre-heat. For continuous testing preheat time will vanish after initial warm-up.

RESULTS OF FREON TESTS

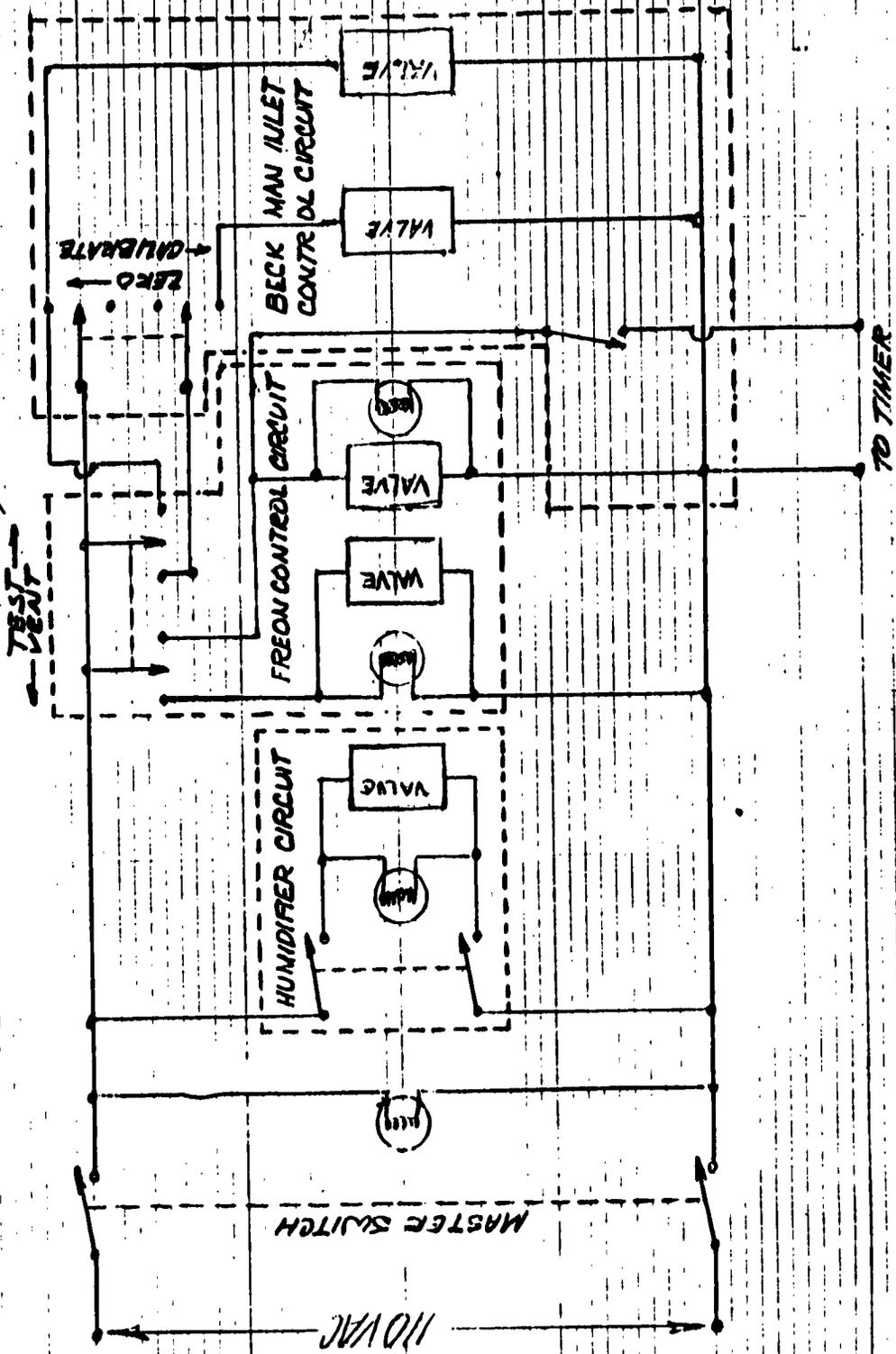
<u>Filter No.</u>	<u>H₂O Content of Air lb/lb</u>	<u>Life, sec.</u>	<u>Freon Adsorbed Gm*</u>
1	0.0191	253	48.4
1	0.0117	320	61.2
1	0.0138	289	55.3
1	0.0101	334	63.9
1	0.0132	290	55.5
1**	0.0091	314.5	60.2
1**	0.037+	41.9	8.01
2	0.0120	289	55.3
2	0.0085	316	60.5
2	0.0168	251	48.0
2**	0.018	231	44.2
2***	0.005	343	66.6
3	0.0108	318	60.9
3	0.0196	255	48.8
3	0.0152	291	55.6
00 Mock-up	0.0187	256	49.0
00	0.0224	144	27.5
00	0.0105	252.2	48.2
00	0.0152	213	41.7

* Calculated wt = $253 \text{ sec} \times \frac{\text{min}}{60\text{sec}} \times \frac{212.4 \text{ l}}{\text{min}} \times \frac{5.4 \text{ mg}}{\text{l}}$
 = 48.4 gm

** After rough handling per spec MIL-F-50040, p 4.5.2.

*** After rough handling per spec MIL-F-50040, par. 4.5.2 and two weeks in oven started @ 150°F and reduced to 125°F as moisture decreased.

CIRCUIT DIAGRAM FOR 75 CFM
 FILTER TEST PANEL, (FREON)



Appendix D

DATE: 1962
 5 OCT 1962

SAMPLE TEST
FOAM

75 SCFM RADIAL FILTER FREON TEST

FILTER # _____

AMBIENT CONDITIONS:

temp. _____ deg F

humidity _____ %

barometric press. _____ in. Hg

LOOP CONDITIONS:

temp. of influent air = _____ mv. X 1/0.0235 + _____ °F

temp. of effluent air = _____ mv. X 1/0.0235 + _____ °F

dry bulb temp. _____ deg. F

Wet bulb temp. _____ deg/F

water content of air _____ lb/lb X 10⁻²

TEST CONDITIONS:

pressure drop at orifice _____ in. H₂O

pressure drop at filter _____ in. H₂O

pressure head at orifice _____ in. H₂O

freon 12 pressure 5.3 psi

variac setting _____

freon rotameter setting _____

Beckman rotameter setting 2.6

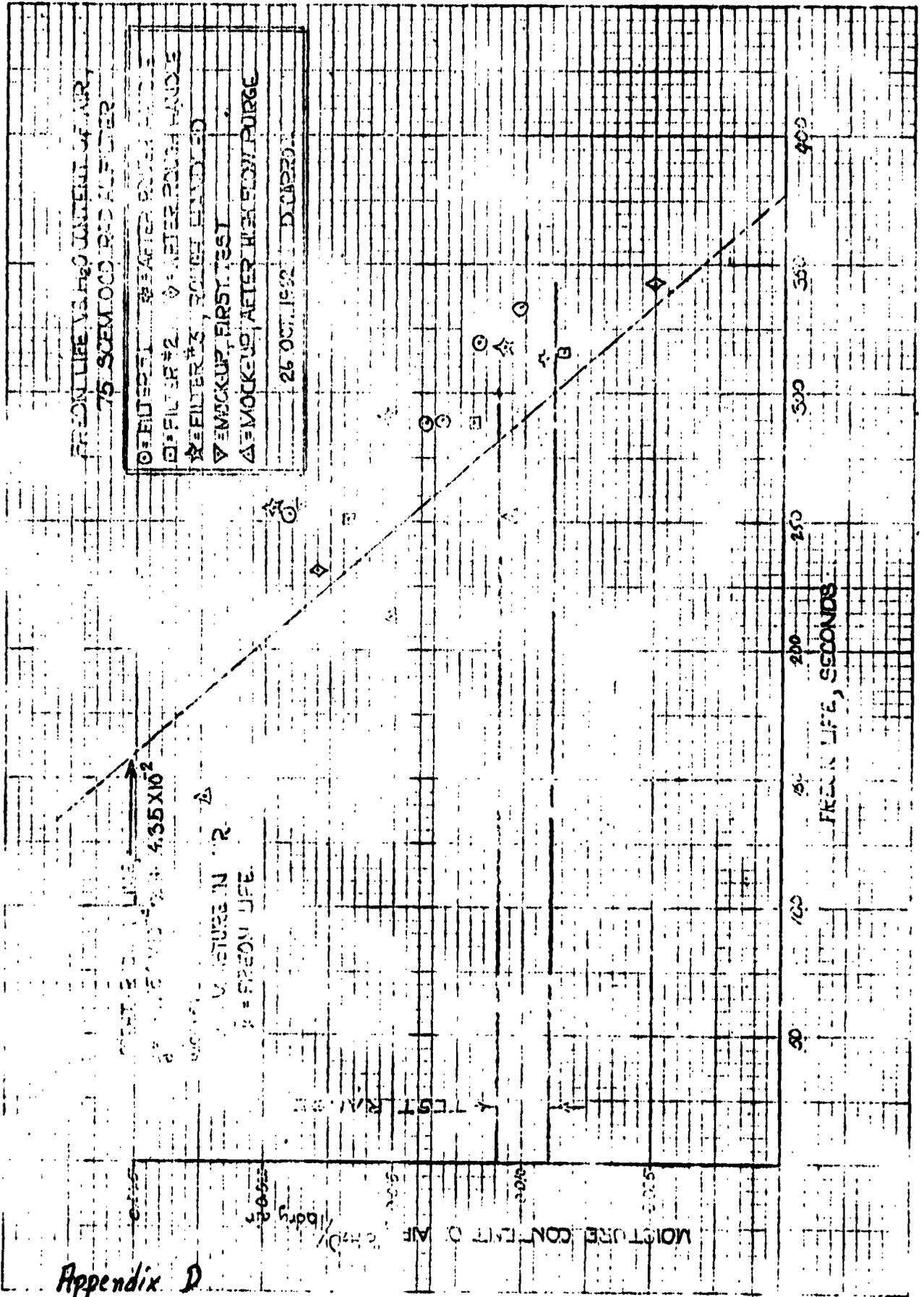
Beckman setting at 50 ppm _____, at 1000 ppm _____

start pre-heat at _____ hours

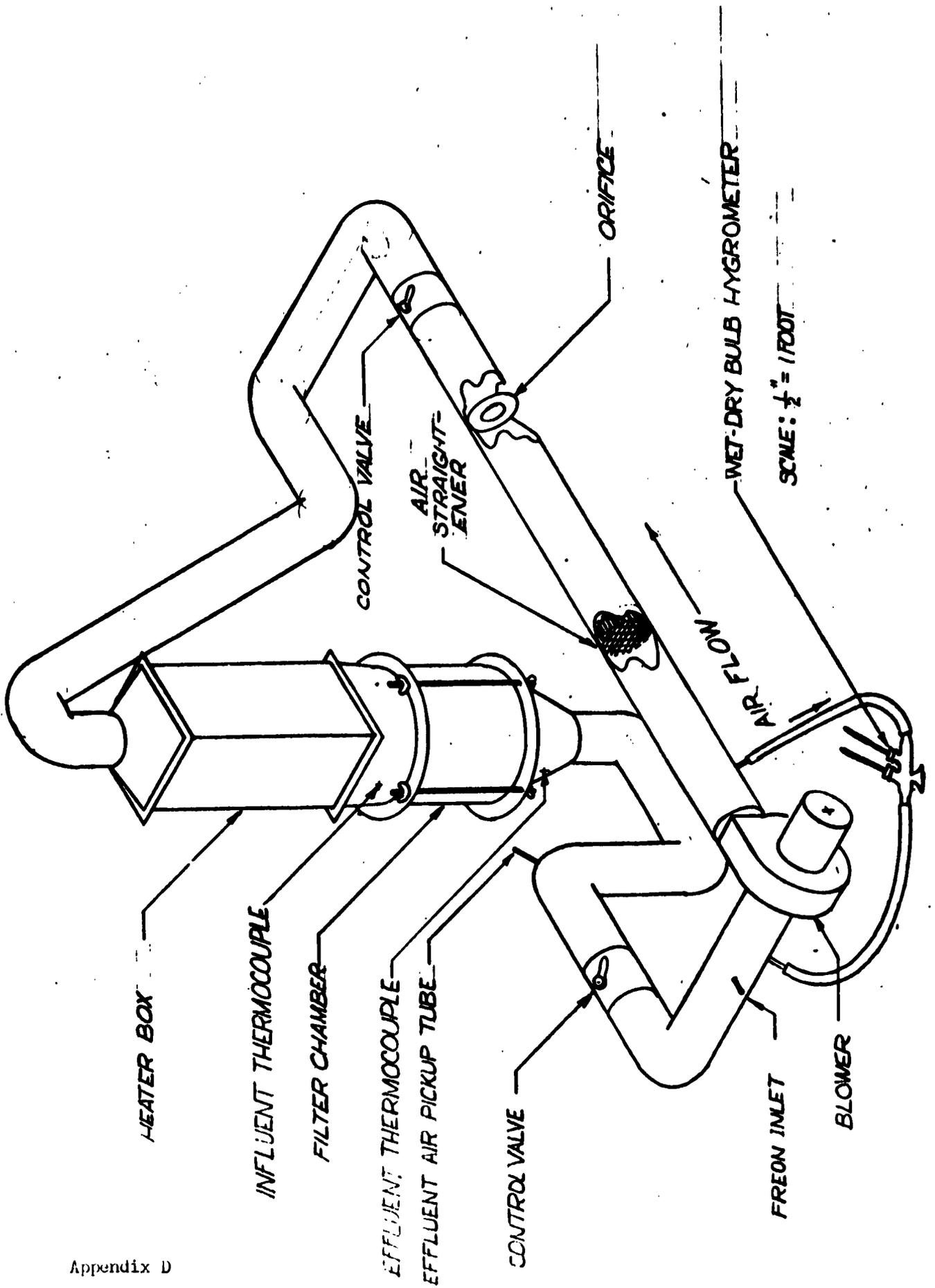
start test at _____ hours

BREAKTHROUGH OCCURRED IN _____ SECONDS

COMMENTS:

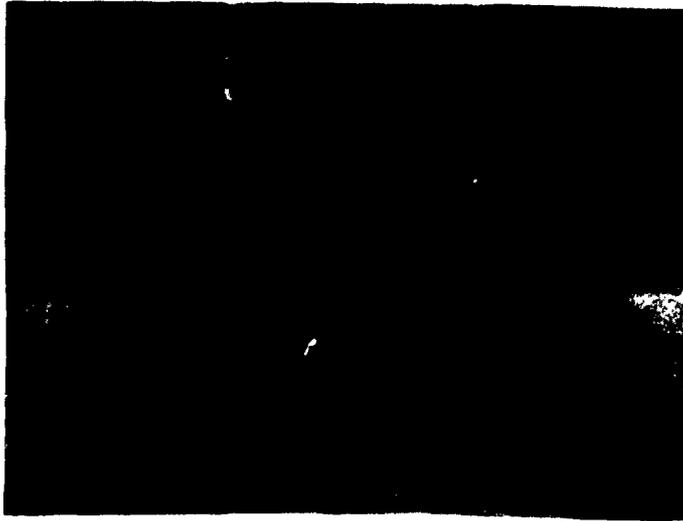


Appendix D



Appendix D

PLATE 1



Damage done to mock-up filter
during construction of the
Freon test apparatus.

Lip of filter is $1 \frac{7}{8}$ " high.



PLATE 2

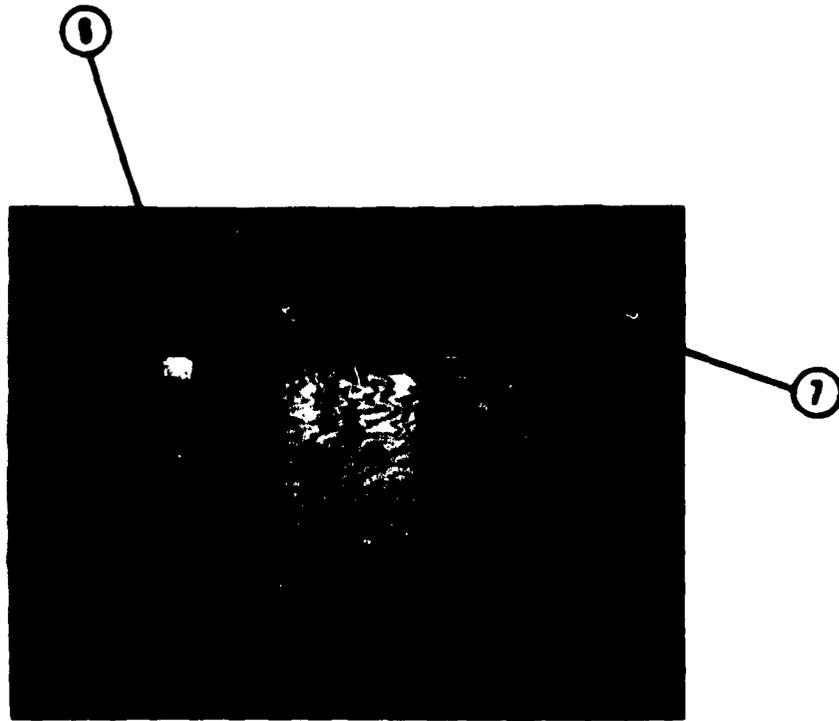
FREON TEST APPARATUS & BECKMAN



1. Centrifugal blower
2. 12" scale, directly above scale is a thermocouple lead and the orifice pressure taps.
3. Beckman infrared gas analyzer.
4. Air control valve.
5. Heater box, filter chamber may be seen directly below.

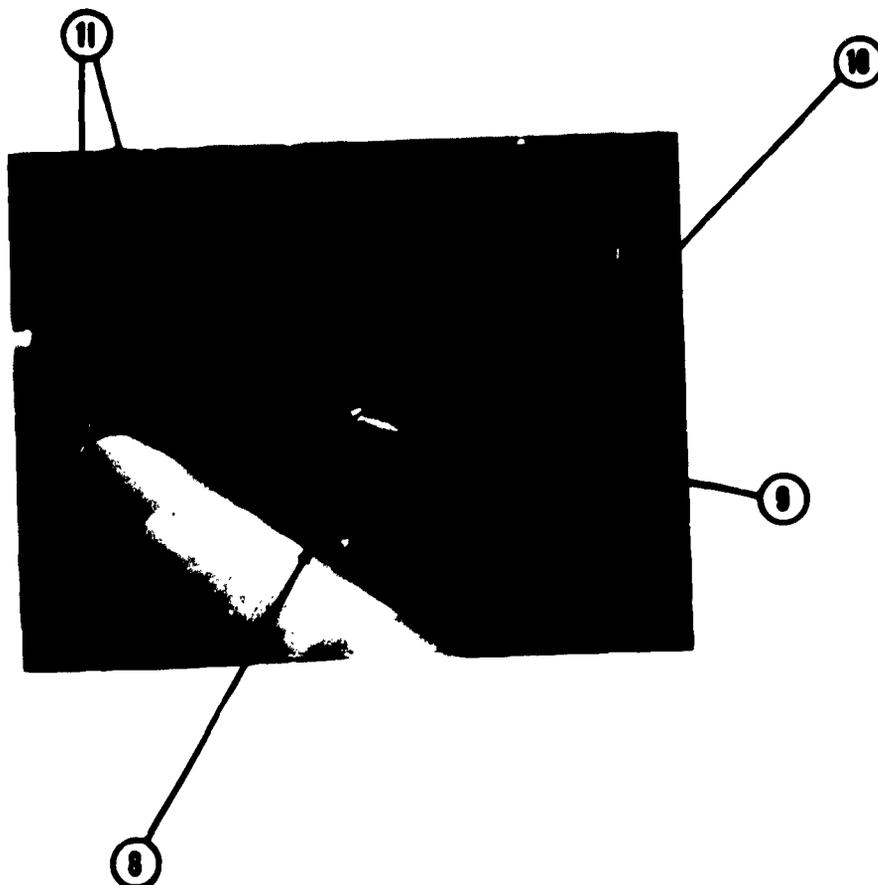
PLATE 3

THE MAIN CONTROL PANEL



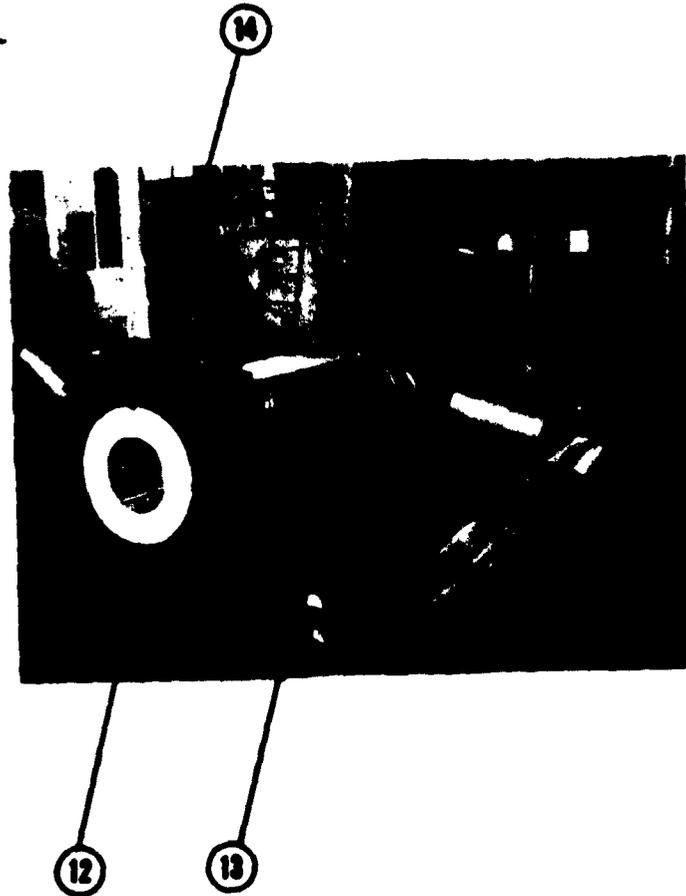
6. Freon metering valve, directly below is the rotameter.
7. Solenoid valves that control the Beckman pickup.

PLATE 4
BEHIND THE MAIN CONTROL PANEL



8. Air pressure regulator for humidifier spray nozzle, directly to the left is the air pressure gauge and the air control solenoid.
9. Humidifier nozzle, to the right is the air sample pickup for the Beckman, and to the left is the second airflow control valve.
10. Freon tank, pressure regulator, and pressure gauge.
11. Hygrometer connections on inlet and outlet side of blower.

PLATE 5
PURGING AND DRYING UNIT



- 12. Filter installed on effluent side of heater box for purging or drying.
- 13. GE Halide Leak detector. . .indicates when purge is complete.
- 14. Complete filter unit installed on wall of test chamber ready for use.

SYSTEM PERFORMANCE TEST

Date: 8/14/62
D. Price

Conditions:

Blower unit and gas particulate filter connected by two foot length of 5 inch diameter furnace duct. Static pressure of blower adjusted to 3.0 inches water gauge by means of an orifice placed midway in duct. All joints taped air tight. Gas particulate filter inlet open to atmosphere. Blower unit discharge to atmosphere. Air density 0.075 lb. /ft³.

Results:

CFM	75.
Blower RPM	2800.
Pressure Drop Across Gas Particulate Filter	1.1 inches water
Brake Horsepower (Crank)	0.08
Static Back Pressure Reserve	1.9 inches water

TRANSPORTATION TEST

7/24/62
R. La Budde

Procedure and Equipment

The procedure is outlined in Federal Specification PPP-P-600. The required tests include a vibration test and a drop test. The apparatus used in these tests is shown on page 2. The blower unit and the gas particulate filter belong to the weight test group for product weighing under 100 pounds (blower unit weight 39 lbs., gas particulate filter weight 63 lbs.).

Results

Blower Unit - The blower unit, with packaging per drawing SDA-1154-D13, was drop tested in accordance with the specification. The drop height applied was 24 inches. The blower unit successfully passed this severe drop test with no damage.

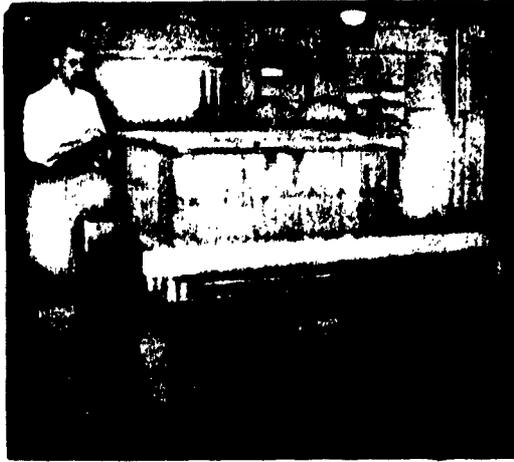
A vibration test was not run on this unit. However, this test is not severe in comparison to the drop test, and there should be no difficulty in passing this test.

As a practical test, the unit was shipped by commercial carrier (truck) from Mansfield, Ohio, to the Chemical Center and arrived without damage.

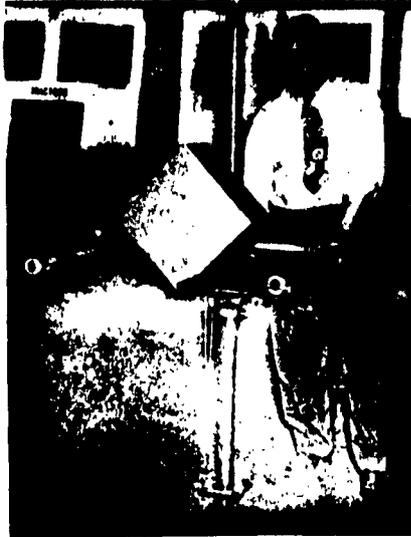
Gas Particulate Filter - The gas particulate filter was not formally transportation tested per Federal Spec. PPP-P-600 because only one prototype was available, and it was required intact for other testing. We would not expect failure from this test. Nevertheless, if damage were to occur, it could be readily corrected by modified packaging.

As a practical test, this filter was shipped uncrated by motor freight from Mansfield, Ohio to Edgewood Arsenal, Maryland. It was then tested for DOP penetration, as received, followed by a rough handling test per method 105.9 MIL-STD-282. The filter passed these tests, and the results are included on page 3 of this appendix.

Vibration testing machine



This vibration test determines the ability of the packaged product to withstand vibrational shocks encountered during transportation. Conditions simulated include: resonance, flat car wheels, rail joints, rough road bed or roadways, card sidesway, etc.



This drop tester is used to simulate the shocks incident to the handling and transportation of packaged products under 100 pounds.

17 October 1962

Results of Rough Handling Tests of
75 CFM Gas Particulate Filter
Performed on WR 62-805

	<u>Resistance</u> <u>in. wg</u>	<u>DOP</u> <u>Penetration</u> <u>%</u>
As received	1.10	0.020
After 15 min. @ 1/2" amplitude	1.12	0.024
After 20 min. @ 1/2" amplitude	1.13	0.026
Recheck	1.13	0.026

Remarks:

This filter was shipped uncrated by motor freight from Mansfield, Ohio to Edgewood Arsenal, Md. It was then tested as received followed by a rough handling test of 20 minutes @ 1/2" amplitude per method 105.9 MIL-STD-282. DOP tests were made at 75 cfm. The purpose of this test was to determine the effectiveness of the interior seals to resist rough handling. The penetration of less than 0.03% indicates a satisfactory performance.