

ASTM STUDIES OF FILTER TEST METHODS

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Two filter media performance test methods are now in the "round-robin" phase of standards development under the auspices of ASTM F-21.20 Gas Filtration Subcommittee. These procedures are potentially applicable to evaluating respirator filter media and air-purifying elements. They appear to offer distinct advantages over several current 30 CFR 11 test methods. This report summarizes the development and present status of F-21.20 voluntary consensus standard test methods for (1) determining filter media fluid flow characteristics in terms of pressure drop as a function of face velocity and (2) determining initial filter efficiency as a function of challenge aerosol size and face velocity of test.

Setting the scope for filter media performance test methods proved to be a difficult job for F-21.20, as it involved consideration of the impressive list of factors shown in FIGURE 1.

During the early stages of test method development, F-21.20 realized that it would not be able to include all these desirable features in one technically sound standard. Since a procedure for determining the efficiency of loaded media would have to be closely related to the method adopted for characterizing clean media performance, work on a loaded media test method was deferred.

There was strong sentiment for developing bench-scale methods for estimating media performance without having to resort to full scale equipment configurations. The subcommittee also preferred using the same test stand for both resistance and efficiency determination. In addition, we wanted test methods which would allow ready comparison of different types and configurations of media in common terms - in order to eliminate the apples and oranges state of affairs prevalent today in filter media performance data. Finally, F-21.20 filter media test methods would have to lend themselves to use in quality control, product development, basic research, product selection, specification and acceptance testing.

Not wishing to throw out the baby with the bath water, F-21.20 acquired and reviewed many available procedures for characterizing filter media performance. These are listed in FIGURES 2 and 3. In addition to all these, numerous papers - including those turned up by APCA and EPA literature searches, on fluid flow measurement, optical particle counting, aerosol generation, isokinetic sampling and so on, were studied for relevancy and usefulness.

After much discussion and many sessions of devil's advocate role-playing, close investigation of pertinent articles, surveys of commercially available equipment, preliminary "hands-on" experience with new techniques - such as the guarded ring apparatus - or lab trials with candidate devices, F-21.20 arrived at a consensus which resulted in the current draft test methods for fluid flow characterization and initial efficiency determination.

Rather than subject you to the lengthy texts of these two test **methods**, I'd like to highlight the features of **each**, at least as **F-21.20 members** see them.

First, the draft standard test method for determining media fluid flow **characteristics**:

The major technical considerations with any flow resistance standard are fivefold: flow **measurement**, pressure drop **measurement**, specimen mounting techniques, data collection and **reporting** and provision for correction to standard conditions. The draft now being completed includes a number of special features, in addition to addressing these five areas:

- (1) Use of coupon samples.
- (2) Criterion for determining whether media should be handled by the procedure option for incompressible media.
- (3) Requirement for flow measurement with devices conforming to **ASME specifications**.
- (4) Optional procedure, based on the guarded ring technique - as illustrated in FIGURE 4 - for use with compressible media, flat panels of pleated media and unconstituted bulk media. (Briefly, this technique employs a parallel, evenly distributed air flow directed perpendicularly through the sample. Within the apparatus the air flow is divided into "guard" and measuring areas concentrically positioned. The two areas have separate air supplies and air flows are regulated so that the differential pressure between guard and measuring areas is zero. This in effect, seals the sample and prevents edge leakage.)
- (5) Description of functional properties of media in terms of face velocity (**v**), fluid viscosity (**u**), specific resistance (**C**) and pressure drop (**Delta P**). $\Delta P = CVu$
- (6) Requirements for test room conditioning as regards control of temperature, pressure and humidity.
- (7) Suggested design for test stand
- (8) Discussion of the use of a laminar flow element
- (9) Statistical guidance on specimen sampling
- (10) **Requirements** for media conditioning
- (11) Flow measurement calibration procedure
- (12) Techniques for preventing edge leakage

- (13) Suggestions **for** measurement of lofty media thickness under flow conditions
- (14) Techniques for mounting and supporting test specimens
- (15) Options for either single or multiple-point determination of fluid flow characteristics.
- (16) Procedure for reducing data to standard conditions of **temperature** and pressure (altitude)
- (17) Provision for graphic presentation of multi-point data
- (18) Procedure for calculation of inertial and viscous permeability coefficients for describing media with non-linear flow behavior
- (19) Preliminary guidelines on data precision

Second, the preliminary procedure for **determining** clean media efficiency:

When it comes to describing the key features of **F-21.20's** preliminary test procedure for initial media efficiency, the story becomes a little more complex - by virtue of the tentative status of the procedure as well as the difficulties associated with previous attempts to provide reproducible filter media efficiency test **methods**.

Any efficiency test method, however, will consist of three components - aerosol generation, including conditioning; aerosol transport and sample extraction; and detection. The preliminary procedure being investigated by **F-21.20** utilizes a solid, monodisperse aerosol as a challenge test agent and a **single** channel, forward-light-scattering optical particle counter for detection.

(A) Monodisperse vs. Polydisperse Aerosol

F-21.20 decided to use a monodisperse aerosol rather than a polydisperse one for two reasons:

- (1) use of a monodisperse particle reduced the potential error due to non-isokinetic sampling and line losses
- (2) use of a monodisperse aerosol eliminated the need for relatively expensive and sophisticated multi-channel analyzers in the detection phase

(B) Aerosol Generation Technique

Selection of an aerosol generation technique was probably the most difficult part of **the** test method development work. F-21.20 surveyed commercially available devices, including spinning **disc**, vibrating orifice and fluid atomizer designs; examined generator performance specifications and consulted with **manufacturers**. Two factors finally influenced F-21.20 against the use of these relatively sophisticated devices:

(1) aerosol **concentration**, flow rate and particle size could not each be controlled independently

(2) F-21.20 **members** who had "**hands-on**" working experience with some types of monodisperse aerosol generators were dissatisfied with their routine operation, particularly in terms of a **method** suitable for QA applications. Furthermore, objective **confirmation** of both aerosol size and distribution would still be needed. (When monodisperse aerosol generators are themselves used for calibrating optical particle counters size and distribution are assumed based on calculation from generator operating **conditions**.) This need for independent verification of aerosol **size/distribution** would require the detection system(s) to both count and size the aerosol - a significant consideration in looking at the cost of equipment needed for the proposed method.

F-21.20 finally returned to consideration of aerosol generation by atomization using simple nebulizers - an approach which has an extensive use history. **Nebulization** of suspensions of pre-sized uniform latex spheres offered a simple, direct and possibly inexpensive method. These spheres are available in a CMD range of 0.087 μm to about 900 μm .

While this approach is not without its own peculiar interferences - from doublets and residues - techniques have been reported in the literature for their elimination. In addition, one F-21.20 member had had direct experience **with this** technique in a QC application and had found it **satisfactory**.

(C) Aerosol Dilution, Drying and Neutralization

Regardless of aerosol generation system, the aerosol would require dilution, drying and conditioning of its charge to a reproducible level. This is usually done in a single operation in commercially available generators by transporting the aerosol through **commercially** available tube sources of Krypton 85 using flow rates appropriately matched to the desired face velocities of test. A similar approach would be used by F-21.20 in its media efficiency test method.

(D) Test Stand and Sampling System

A tentative test stand design, shown in FIGURES 5 through 10, was developed for use in the preliminary **interlaboratory** study. Ducting and mounting section dimensions were **specified** to assure a uniform velocity profile across the face of the sample. The size and **configuration** of the aerosol sampling and transport system was specified to minimize line losses. The materials of construction for the test stand were chosen for ease of fabrication. The need of isokinetic **sampling** remains to be

confirmed. (Preliminary work in one lab did appear to indicate that concentration may be sensitive in this **regard.**) Other **modifications** in design of materials used for the test stand may be necessary. The results of the "**round-robin**" now in **progress**, should provide guidance in this area.

(E) Detection System

Selection of a detection system was greatly simplified by the use of pre-sized monodisperse aerosol. The task of sorting out the capabilities and limitations of commercially available optical particle counters was greatly reduced since a very thorough review, prepared by one of the technical committees of APCA, was made available to **F-21.20** by the author. The detection system selected by **F-21.20** would use the same **forward-light-scattering** single channel analyzer for alternately counting upstream and downstream concentrations per unit time. Use of a single channel OPC was **preferred**, since this helped to keep test equipment costs to a minimum, and when used in conjunction with uniform latex spheres, reduced considerably the complexity of detection system calibration.

(F) Cost Estimate

Test stand fabrication was expected to cost less than \$1,000; single channel analyzers, possibly between **\$3,000-\$4,000**. Uniform latex spheres, sufficient for ten hours of testing, were anticipated to cost no more than **\$25.00** per diameter. Nebulizers are readily available and quite inexpensive.

So much for the **ASTM** filter media test methods themselves. There are, however, several considerations which deserve our attention, in applying **F-21.20** filter media test methods to air-purifying respiratory protection:

(1) The interlaboratory reproducibility of both **F-21.20** test procedures is in the process of being established. **Round-robin** samples were to include one respirator filter media for which **ASTM E-34.14** already has interlaboratory silica dust and sodium chloride performance data. Results of the **F-21.20** interlab should indicate to what extent these new test methods offer improvement over existing procedures with respect to reproducibility.

(2) **F-21.20** test methods characterize the performance of filter media and as such would be applicable to respirator filter media or particulate air-purifying elements, but not to devices **themselves**.

(3) The **F-21.20** initial media efficiency standard will not specify which aerosol **diameter(s)** are to be used in media characterization. Monodisperse aerosols representative in size of respirable **particulates** would have to be selected for use in respirator filtration applications.

(4) The **F-21.20** initial media efficiency test method will stipulate the use of a solid aerosol, while media characterization for use in respiratory protection may require utilization of **liquid**, fibrous or wetted solid **aerosols**.

(5) It may be possible to characterize various types of media or air-purifying elements with multi-point Delta p vs. face velocity and efficiency **vs.** face velocity and aerosol size data **first**, then select critical data points for use in QC-specifications-certification. Critical data points might be based on size/velocity or Delta **p/velocity** parameters which result in either (a) greatest air-purifying element penetration or resistance or (b) highest potential for adverse physiological consequences - or **both**.

(6) **Finally**, F-21.20 has not yet tackled development of a test method for loaded media. With respect to air-purifying elements for respiratory protection, selection of representative challenge aerosols as predictors of **end-use** performance may be quite difficult. Characterization and duplication of workplace particulates in terms of size, distribution, shape, charge, physical state, reactivity concentration, ambient temperature, humidity and pressure might all be necessary to afford reproducible and meaningful results. Incremental field-loading of **air-purifying** elements, followed by lab testing using ASTM methods, may offer a viable alternative.

This concludes the end of the formal, planned presentation on ASTM filter test methods. However, Dr. Oppold has asked each of the workshop participants to comment on four additional **topics**. What follows is entirely my own opinion, and both unrelated and unendorsed by ASTM or F-21.20.

With regard to respirator filter technology sufficient data exist to indicate **that**:

(1) the performance of **particulate** respirator filter elements substantially influences the overall level of protection provided by both powered and non-powered particulate air purifying respirators

(2) a fair number of variables have potential to influence filter element performance

(3) respirator filter test methodology used in 30 CFR 11 or developmental systems such as **NaCl**, does not provide sufficiently reproducible results, due, in **part**, to the high number of incompletely specified test conditions

(4) filter element performance involving electrostatic **mechanisms** may deteriorate due to exposure to elevated temperature, humidity, solvent vapors or oily residues, but also exhibits unique penetration/resistance performance relationships

(5) Filter elements functioning solely through mechanical mechanisms can exhibit relatively high penetrations during loading until a more efficient particulate filter is deposited

(6) a real need for thorough characterization of filtration **performance** and standardized test methods for evaluating and reporting the functional properties of filters

(7) field-loading of filter elements in conjunction with before and after lab evaluation of filtration performance against respirable challenge aerosols may offer a satisfactory approach for evaluating the **end-use** performance characteristics of particulate air-purifying filters

(8) those workplace environments in which protection afforded by particulate air-purifying filter elements may be considerably less than anticipated on **the** basis of 30 CFR 11 approval tests

On the other **hand**, I believe that insufficient data exist to indicate:

(1) whether **ASTM f-21.20** filter test **methods** described here today are adequately **reproducible**, offer improvement over existing procedures and are adaptable to evaluating filter element performance

(2) the extent to which potentially significant variables influence respirator filter performance at the flow patterns and filter face velocities specified by device **design**, under the end-use environmental conditions against broadly different types and concentrations of hazardous particulates likely to be encountered in the workplace

(3) the extent to which laboratory-produced aerosols are representative of the hazardous species encountered in the workplace (mists, pesticides, paint spray, etc.)

(4) whether laboratory test methods can adequately reproduce end-use particulate environments for evaluation of the performance of functioning filters

(5) what particle size range is physiologically harmful, not merely respirable, and whether this critical size range varies substantially with the nature of the hazardous species

(6) what levels of breathing resistance are, in fact, medically or psychologically unacceptable for negative pressure air-purifying devices

(7) what flows of breathing air are acceptable for different levels of work load

(8) what maximum temperature and humidity exposure periods filter elements should withstand without functional deterioration

(9) those workplace environments in which the performance of existing particulate air-purifying filter elements is seriously inadequate, reasonably suspect, adequate or more than adequate

(10) for those workplace environments in which the performance of existing particulate air-purifying filter elements are either seriously inadequate or reasonably suspect, the number of users potentially affected and the probable severity of health consequences

(11) what minimum use period filters should provide in various environments

As for research needs, it is **not** difficult to list a number of areas which seem to need more or less immediate attention:

- (1) filter performance at **particulate** concentrations substantially lower than approval test levels
- (2) electrostatic filter environmental stability
- (3) filter performance against fibrous and other irregularly shaped or size-distributed **particulates**
- (4) filter performance against mixed physical state particulates (COE)
- (5) filter performance against high and low resistivity particulates
- (6) filter performance against oily mists and residues (pesticides)
- (7) filter performance against reactive particulates (isocyanates)
- (8) role of filters in air-purifying element performance against liquid systems of intermediate BP/VP

Priorities should be assigned on the basis of anticipated severity and frequency of potentially adverse health effects to users if filter performance deficiencies continue. It may also be appropriate to take into account the anticipated technical difficulty in defining and correcting filter performance deficiencies in comparison to the effort which would probably have to be expended in developing other modes of user protection.

Lastly, regarding methods for improving both international coordination and cooperation. Certainly this International Workshop sponsored by NIOSH is a very important first step. I congratulate Dr. **Oppold** and his staff for giving international cooperation such a fine start. **But--where** do we go from here in the area of filter **media** for respiratory protection?

First of all, the **ASTM F-21.20** methods described here are still in draft form. The subcommittee is open to input from anyone who wishes to offer technical **comment**. We would especially appreciate information about other test methods (1) which may be adaptable to filter **media** characterization, (2) which differ in principle from those approaches already examined or (3) which differ in practice from our collective experience or expectation.

I encourage those of you who may be in a position to comment constructively on **F-21.20** methods and/or participate in inter-laboratory trials of proposed test methods to join ASTM and the **F-21** Filtration Committee.

Since I am not yet familiar with the status of respirator filter media technology outside the U.S., I can only guess that it is limited and quite possibly incompletely identified. I had hoped that the Filtration Society might see its way towards locating and coordinating work on respiratory filtration - especially information on end-use performance - on an international basis, but the current Chairman Wells Shoemaker was not at all encouraging in this **regard**, primarily because these activities are beyond the scope of the organization and the fact that there is no paid staff to carry out administration.

Some international exchange might be possible through **ISO**, but participation can be expensive. In addition ISO Committees have had **difficulty** in attracting international participation even in some technical areas which enjoy major commercial **interest**. Attempts to work through ISO in the filtration area have been **unsuccessful**. There is an ISO **Committee** for Personal Protective **Equipment** and Clothing but its Respirator Subcommittee is inactive and **unassigned**. While it seems that an appropriate mechanism for international cooperation and coordination does exist in **ISO**, interest in supporting this activity seems to be lacking.

Finally, the American Industrial **Hygiene** Association, even though a U.S. organization, does have a fair number of international members - but, at the present time, the technical committee structure and scope is ill-defined and participation is voluntary, unsupported financially or administratively and limited in member **duration**.

Consequently, I welcome any suggestions the other workshop participants will have for international cooperation and coordination.

FIGURE 1 - SETTING THE SCOPE FOR FILTER MEDIA TEST METHODS

I. Types of filter media to be accomodated:

Paper **Non-wovens**
Pleated media
 Woven textiles Lofty batts
Flat panels
 Knit textiles Wire screen
Unconstituted bulk media
 Felts Foam (activated **carbon, etc.**)

II. Types of media applications to be accommodated in terms of end-use face velocities, particle size and loadings:

Engine and turbine inlet air filters
Air-conditioning and ventilating filters
Industrial air and gas-cleaning fabric filters
Respirable air-cleaning filters

III. Types of performance information desired:

Pressure drop at one or more face velocities
Laminar and turbulent flow characteristics
Clean media efficiency at various face velocities against
 a range of challenge particle sizes
Loaded media efficiency against a range of challenge particulate
 sizes and/or types of dust loadings

IV. Size, cost and sophistication of the filter media test stand and associated

equipment to assure that procedures would be practicable and acceptable to:

Media manufacturers
Filter fabricators
Filtration equipment producers
Filtration equipment users
Regulatory agencies

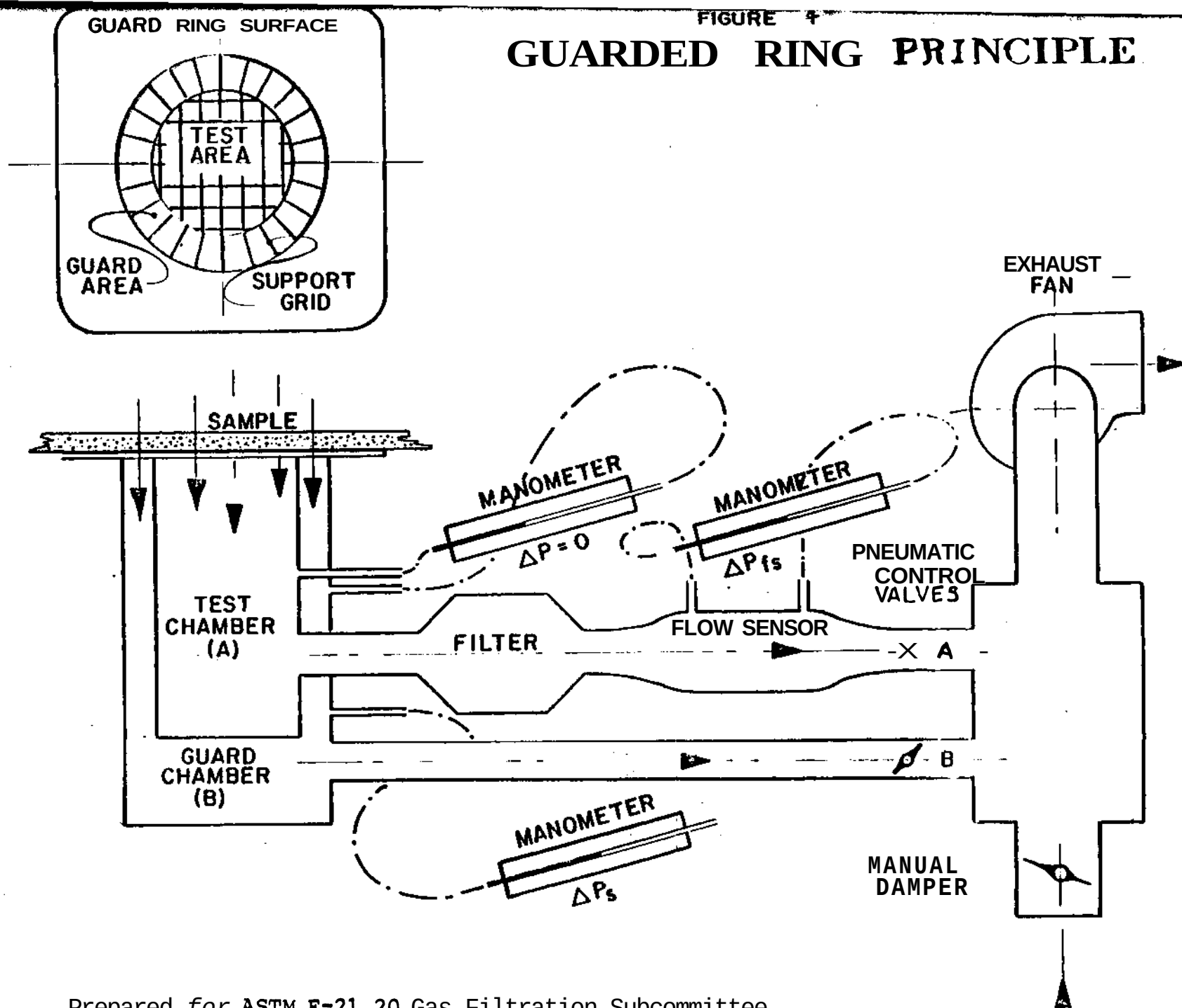
FIGURE 2 - EXISTING PROCEDURES FOR CHARACTERIZING FILTER MEDIA FLUID FLOW PERFORMANCE

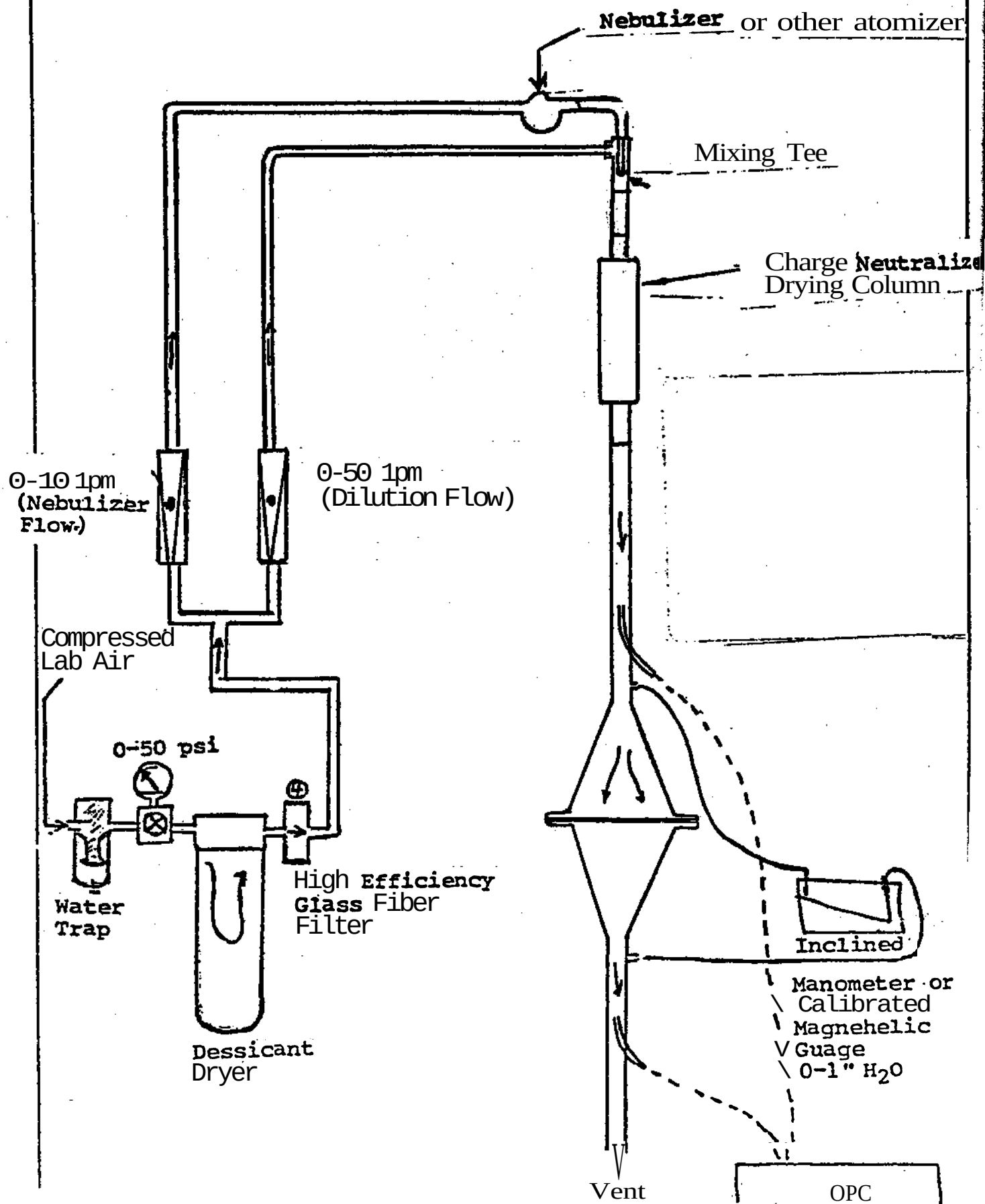
ASTM TEST METHODS:	D 202-76	Sampling and Testing Untreated Paper Used for Electrical Insulation
	D 376-70	Standard Specification for Holland Cloth
	D 461-70	Standard Methods of Testing Felt
	D 726-71	Standard Methods of Test for Resistance of Paper to Passage of Air
	D 737-75	Standard Method of Test for Air Permeability of Textile Fabrics
	D 1117-74	Standard Method of Testing Non-Woven Fabrics
	D 2752-72	Test for Air Permeability of Asbestos Fiber
FEDERAL SPECIFICATIONS	191-5450 (1968)	Permeability to Air, Cloth; Calibrated Orifice Method
	191-5452 (1968)	Permeability to Air, Cloth; Falling Cylinder Method
	191-5460 (1968)	Permeability to Hydrogen Gas, Cloth
TAPPI	T 460-68	Air Resistance of Paper - Falling Cylinder Method
OTHER SOURCES:	Owens-Corning	Media Flow Resistance Tester (L.F.E.)
	Johns-Manville	Method for Determining Air Permeability of Lofty, Compressible Media
FOREIGN STANDARDS:	French Norm FN 95352	Powder Metallurgy Determination of Fluid Permeability of Sintered Porous Parts
	Swedish NSIMT 262-1970	Method for Determination of Air Permeability of Insulating Materials According to the Guarded Ring Principle

**FIGURE 3 - EXISTING PROCEDURES FOR CHARACTERIZING FILTER
MEDIA EFFICIENCY PERFORMANCE**

ASHRAE Standard 52-76	Air-Conditioning and Ventilating Filters
SAE 726	Internal Combustion Engine Air Intake Filters
30 CFR 11	Particulate Air-Purifying Respirator Approval Tests
Mil. Stand. 282 ANSI 510	DOP Testing of High Efficiency Filters
BS 4400 BS 3928	NaCl Test Methods for Respiratory Protective Devices and Filters
BS 2831	Methylene Blue Testing of Filters

GUARDED RING PRINCIPLE

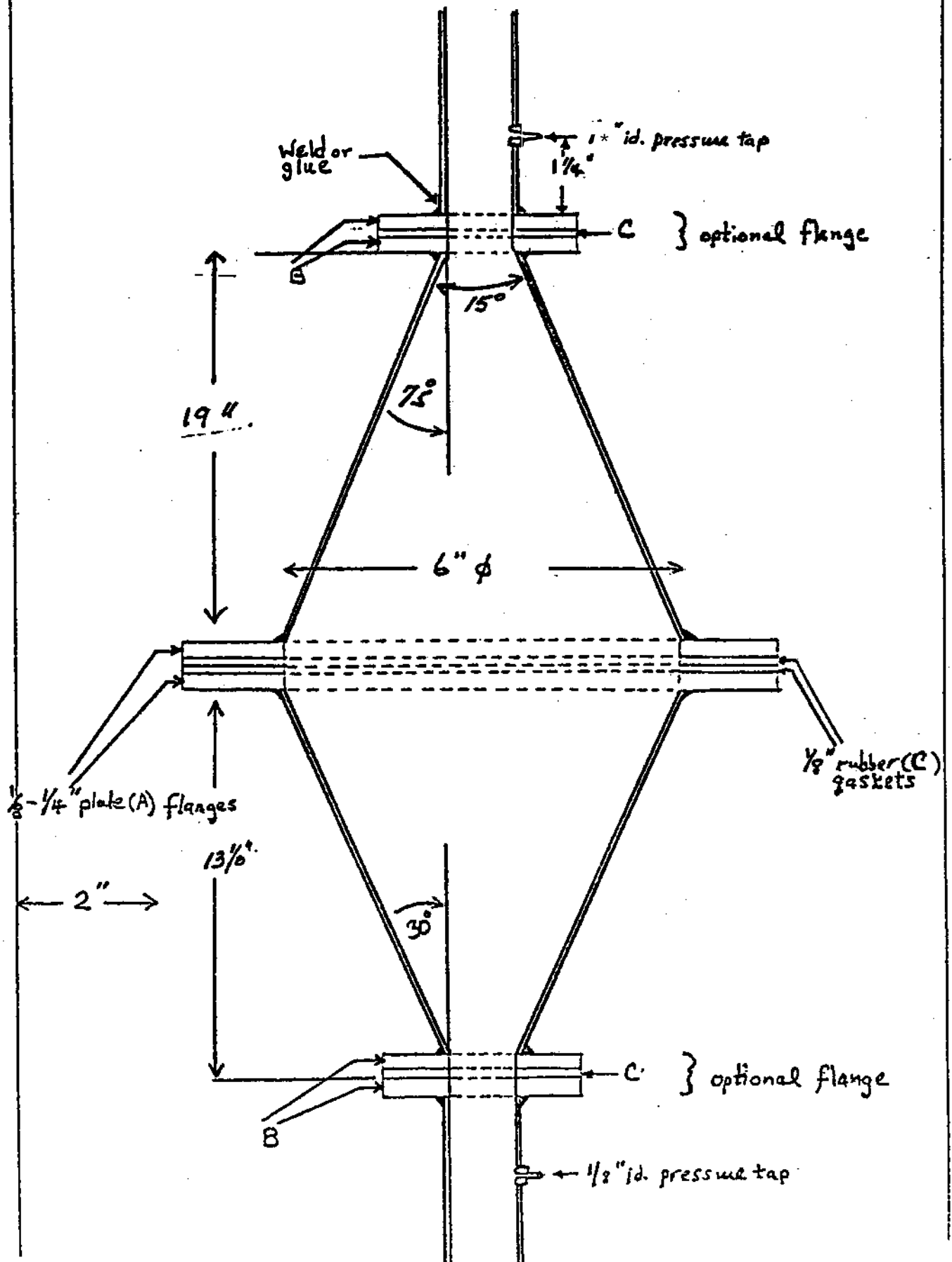




FILTER HOLDER SIDE VIEW

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FIGURE 6



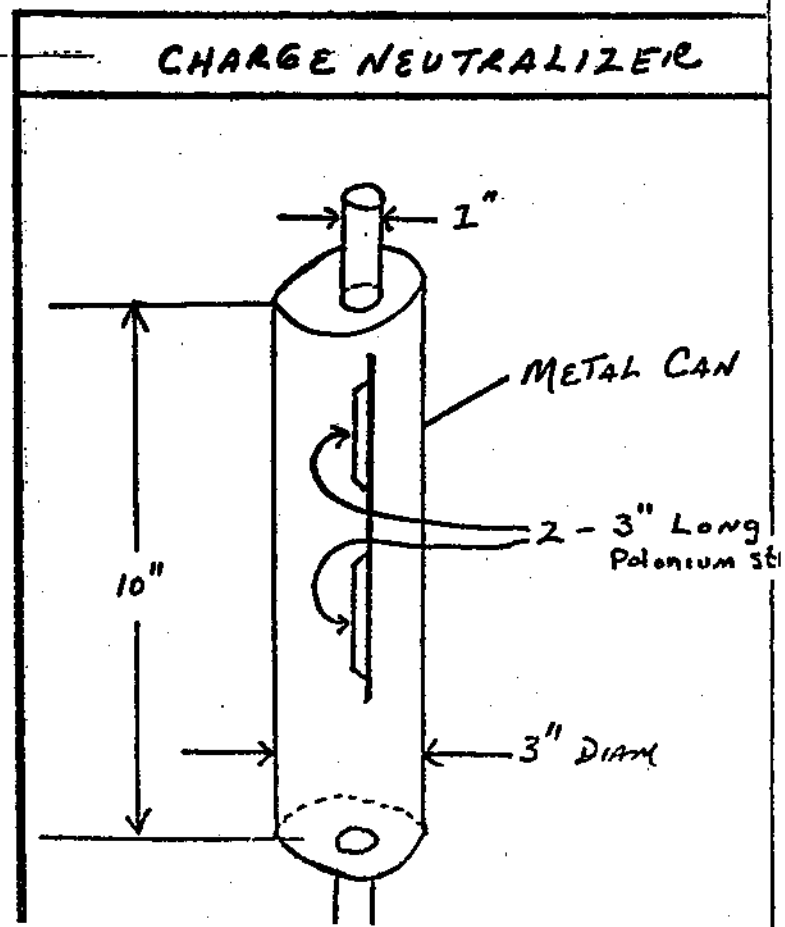
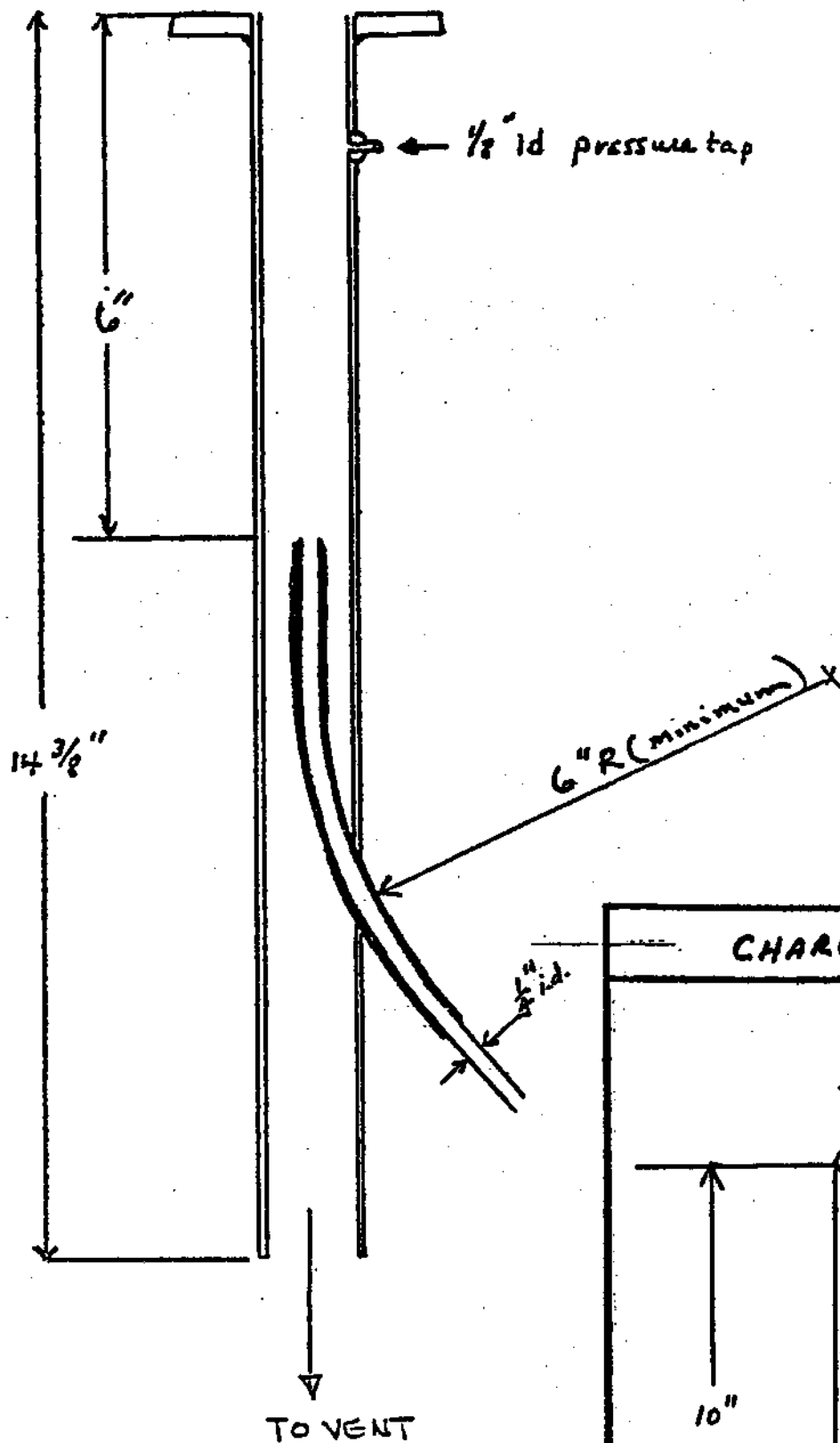


FIG 10

