RPS
RADIATION PROTECTION SYSTEMS, INC.

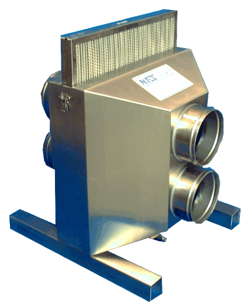
Engineering Data for Selecting and Using Portable HEPA Filtration Units and Accessories for Nuclear Applications

Rev. 2/2012



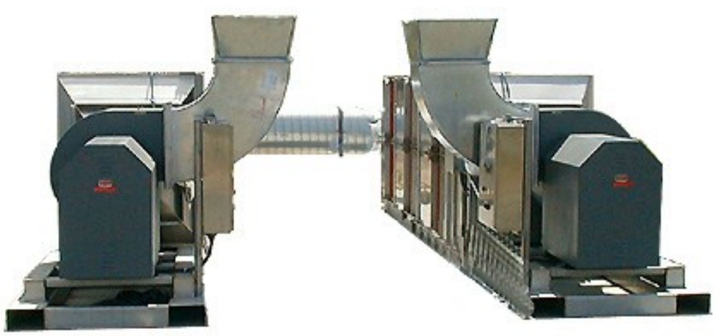








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FOREWORD

Radiation Protection Systems, Inc. (RPS) has been developing and implementing engineered controls for over 35 years, participating in both military and civilian nuclear programs commencing with development of the Naval nuclear programs of the 1950's and continuing today into the commercial power reactor field and the Department of Energy community. RPS continues to develop sophisticated techniques and engineering methods to confine, contain and control radioactive and hazardous contaminants. One major engineering control is portable air filtrations systems. When used properly, air cleaning systems effectively control contamination at its source, eliminating the spread of contaminants and minimizing exposure of personnel while increasing safety and efficiency.

These precepts are reinforced by the Nuclear Regulatory Commission and are set forth in the Code of Federal Regulations Title 10 Part 20 Subpart H, 20.1701 which states, "The licensee shall use, to the extent practicable, process or other engineering controls (e.g., containment or ventilation) to control the concentrations of radioactive material in the air."

This booklet provides basic information about the design, construction, testing, and application of RPS portable High Efficiency Particulate Air (HEPA) filtration and Carbon bed adsorber systems. It is a guide to selecting and using portable air cleaning systems, describing the basic principles that will assist the user in selection, setup and operation of a system that will suit their particular needs.

The recommendations in this booklet are based on criteria set by the ACGIH Industrial Ventilation Standards, the Nuclear Air Cleaning Handbook as wells as on the extensive experience of RPS personnel. When designed in accordance with these criteria and applied using accepted containment practices, a portable air filtration system is less costly and can be more effective than personal respiratory protection devices.

With todays increased pressure to reduce exposure, RPS' engineered controls offer a safe and cost-effective way to further minimize exposure and improve worker and workplace efficiency.

RPS

RADIATION PROTECTION SYSTEMS, INC.

Contents

SECTION I - HEPA FILTRATION AS AN ENGINEERING CONTROL

A. The Need for Engineered controls

The primary goal of a radiological engineering program is to provide controls which minimize radiation exposure of personnel without incurring high costs. A number of factors mush be considered when evaluating different methods. Factors include initial cost of equipment, cost to repair and service the equipment, the number of personnel and time required to use the method, effectiveness of controlling radioactive contamination, and effectiveness in reducing radiation exposure to personnel.

Personnel working where there are airborne radioactive particulates must be protected from inhaling the contaminants. Protection may be provided by respiratory protection devices or by controlling contamination at its source using engineering controls, such as HEPA filtration. Of the two approaches, engineering controls are more advantageous, offering cost benefits by reducing the spread of contamination, cleanup time, and radiation exposure. Also, the portable HEPA filtration system is cost-effective and maintains exposure as low as reasonably achievable (ALARA).

B. Facts

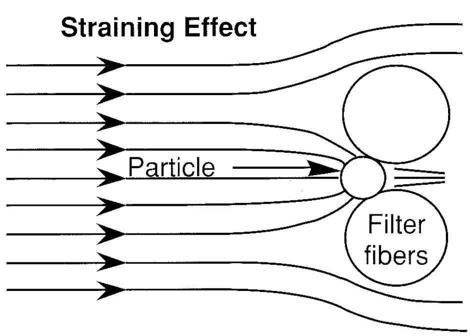
- The burden of control is removed from the worker. A comfortable environment allows him/her to perform more work of higher quality in a shorter time.
- Controlling contamination at its source reduces cleanup and the associated radiation exposure.
- Use of respiratory protection devices is minimized substantially, reducing cost for operation of an extensive respiratory program.

C. Advantages Offered by Portable HEPA Filtration

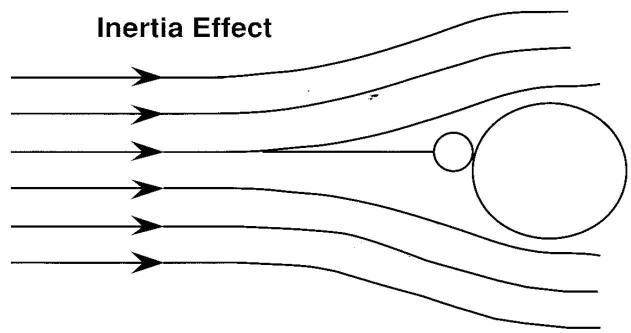
- Decreases cleanup and radwaste.
- Minimizes impact on adjacent work operation.
- Decreases laundry and respirator cleaning.
- Increases worker efficiency.
- Decreases personnel exposure.
- Provides better personnel safety.
- Reduced outage time.
- Reduced costs.

SECTION I - HEPA FILTRATION AS AN ENGINEERING CONTROL

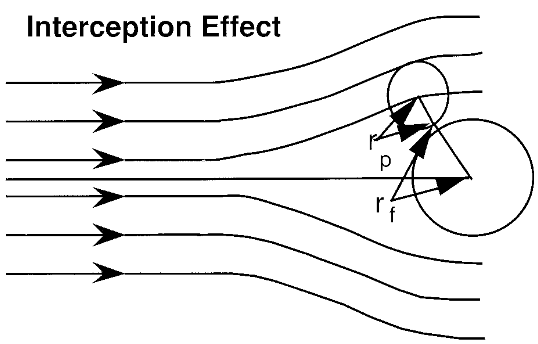
The mechanics of particulate filtration are discussed below. These effects represent the primary interaction of small airborne particulate within the filter media, resulting in their removal from the airstream.



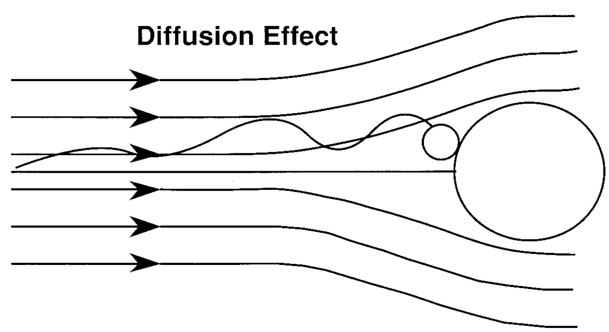
STRAINING (or sieving): Particles larger than the clearance between fibers cannot pass through and are collected on the media.



INERTIA (or impaction): Particles, due to their inertia, leave the airstream around fibers and impact the fiber directly. The particles are usually retained by adhesives.



INTERCEPTION: Particles are small enough to follow the airstream line around the filter but are intercepted by the fiber due to the dimensions of the fiber and the particle. (Their radii are larger than the distance between the airstream being followed by the particle and the fiber). The particles are retained by molecular attraction known as van der Waals' forces.

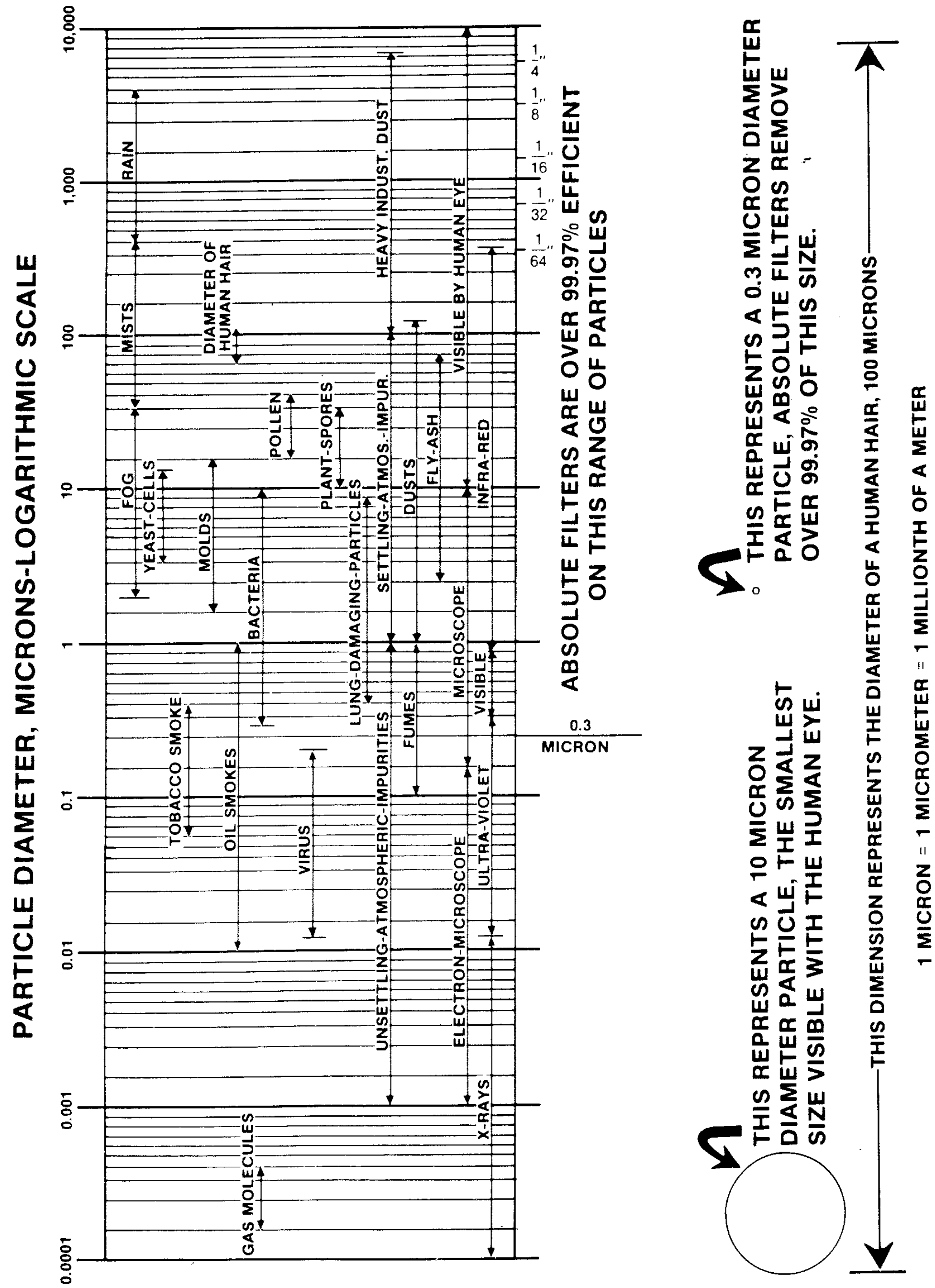


DIFFUSION (or super interception): Particles are small enough and have sufficiently low mass so that air molecules, which are continually in motion and are bombarding the particle, cause the particle to acquire a vibrational mode. Because of this vibrational mode, the particles have a good chance of coming in contact with the fibers. The smaller the particle, the stronger this effect is. For large particles, over one micron in diameter, this filtration mechanism has virtually no effect.

SECTION I - HEPA FILTRATION AS AN ENGINEERING CONTROL

D. Filtration Mechanisms and Common Air Contaminants (Continued)

Figure 2. Relative size Chart of Common Air Contaminants



SECTION II - DESIGN CONSIDERATIONS

A. Choosing the Right Portable HEPA Filtration System

A portable HEPA filtration system consists of a composite unit that includes a blower, filters, optional charcoal adsorbers, as well as connecting plenums, motor, motor controllers, flow control devices, and differential pressure gages. The remainder of the system is made up of interconnecting duct, adapters, and accessories such as hoods and diffusers. Two typical portable ventilation systems are shown in Figures 3 and 4.

To be sure you select the portable filtration system which best fulfills the demands of your facility, is adaptable to future needs, and provides long, reliable service, you should consider the following factors (grouped into three categories):

Performance

- Types of filter and gas adsorbers
- Flow rate requirements
- Static pressure requirements
- Environmental conditions
- Instrumentation
- Size and number of inlets

Configuration

- Size
- Weight
- Arrangement
- Mobility
- Handling
- Storage

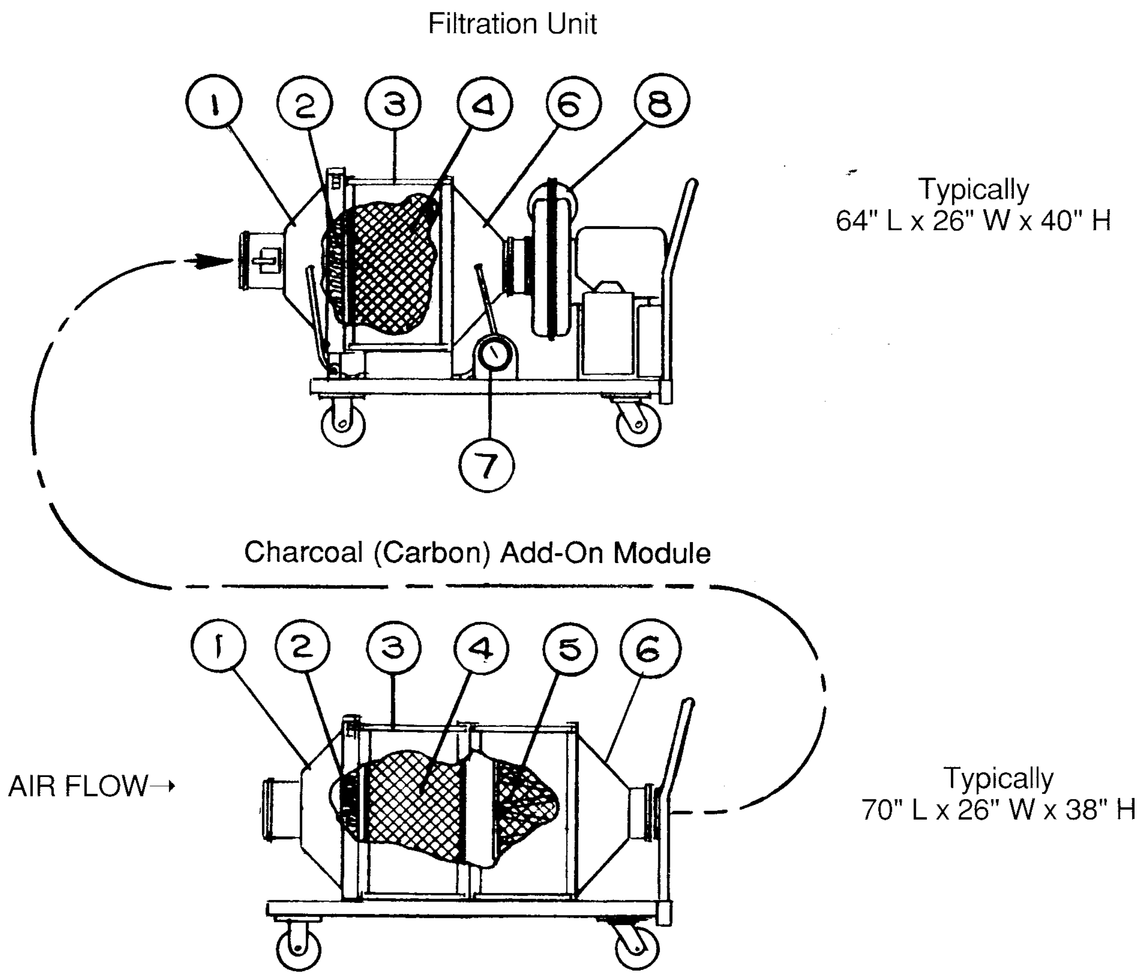
Construction

- Radiological considerations
- Material requirements
- Fabrication techniques

Careful evaluation of each of these will help you to establish your required system parameters. Information to help with the evaluation is presented in the following sections.

SECTION II - DESIGN CONSIDERATIONS

A. Choosing the Right Portable HEPA Filtration System (Continued)

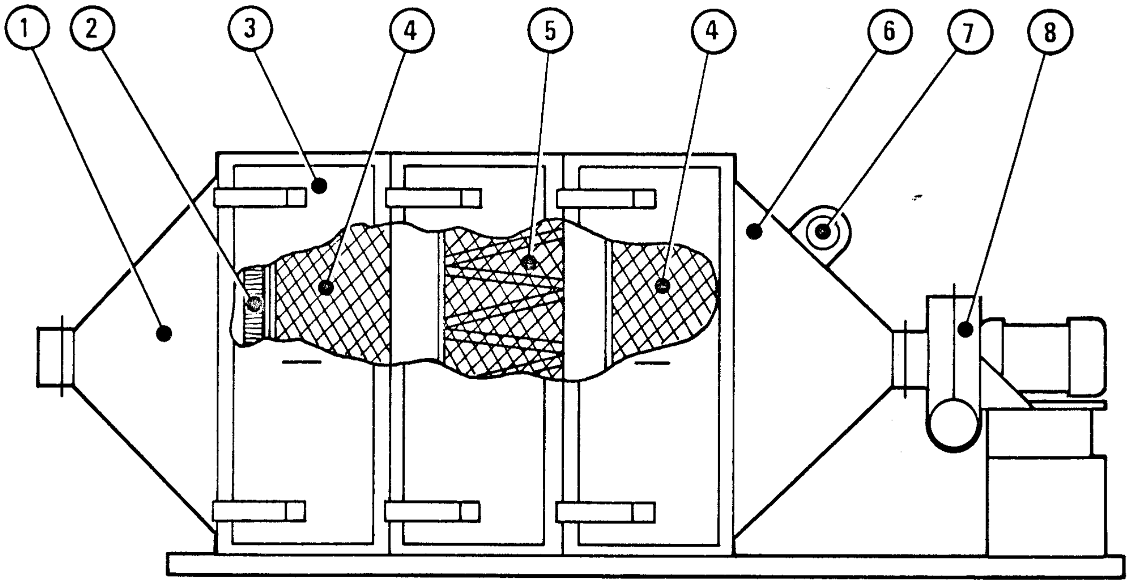


(1) **INLET PLENUM**	(5) **CARBON ADSORBER**
(2) **PREFILTER**	(6) **OUTLET PLENUM**
(3) **HOUSING**	(7) **DIFFERENTIAL PRESS. GAGE**
(4) **HEPA FILTER**	(8) **BLOWER**

Figure 3. Typical Portable HEPA Filtration Unit With a HEPA/Carbon Add-On Module

SECTION II - DESIGN CONSIDERATIONS

A. Choosing the Right Portable HEPA Filtration System (Continued)



Typically 130" L x 30" W x 36" H

1 INLET PLENUM
2 PREFILTER
3 HOUSING
4 HEPA FILTER
5 CARBON ADSORBER
6 OUTLET PLENUM
7 DIFFERENTIAL PRESS. GAGE
8 BLOWER

Figure 4. Integral Portable HEPA/Carbon Filtration Unit

B. Prefilters

Prefilters are the first in a sequence of components through which contaminated air passes to be cleaned. Prefilters are coarse filters used to collect the bulk of particulates, thus protecting and extending the service life of the more expensive downstream filters.

Prefilters are classified into several groups based on comparative removal efficiencies and configuration (Reference American Refrigeration Institute (ARI) 850-93). Because of their small space requirement and ease of replacement, groups I, and III prefilters are the types primarily used in portable filtration systems. Group II are less applicable, as they represent self cleaning, or self renewable filters not discussed here.

Prefilter performance testing is addressed in several industry standards, including the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 52.1, 52.2 and the ARI. Efficiencies are assessed by such factors as the weight of dust retained, dust spot efficiency and the new, minimum efficiency reporting value (MERV) rating addressed in ASHRAE 52.2.

SECTION II - DESIGN CONSIDERATIONS

B. Prefilters (Continued)

Group I prefilters, or panel filters, as they are commonly called, are shallow, tray-like assemblies containing coarse fiber media (glass, cotton, synthetics), or crimped metal mesh enclosed in a steel or cardboard casing. The media, or mesh, is usually coated with a tacky oil, or adhesive, to improve retention of trapped particles. The prefilters are available in disposable, replaceable, and cleanable types. Particulate removal efficiency ranges from 2% for 0.3µ (µ, or micron, = 1E—06 meters) particles to over 90% for 10µ particles. Pressure drop at rated flow across group I prefilters normally ranges from 0.1” water gage (wg) when clean to 0.5” wg when depleted.

Group III prefilters provide higher removal efficiencies for smaller particulate (smaller than 5 µ), have higher pressure drops and are usually of deep pleated, or extended surface, construction.

It is better to replace prefilters than to replace other filters in the system, because prefilters are the least expensive and changing the prefilter does not affect the system efficiency test (DOP test discussed later). For situations where heavy dirt or moisture accumulates on the filter, special prefilters may be grouped in a series to provide extra ability to remove the contaminants and protect the downstream filters. A sketch of a typical prefilter is shown in Figure 5.

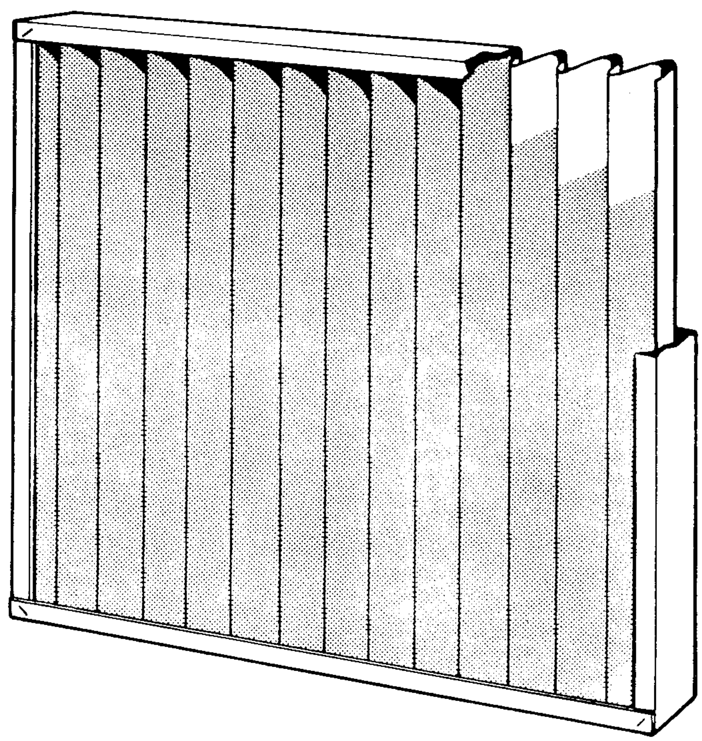


Figure 5. Prefilter

SECTION II - DESIGN CONSIDERATIONS

C. HEPA Filters

High Efficiency Particulate Air (HEPA) filters, the second component in the air cleaning sequence, are used to remove small particulates. **HEPA filters are 99.97% efficient or better for removing 0.3µ particles at rated flow.** Filter rating should be at 0.3µ particle size, since particles of this size are the most difficult to capture. This filter also captures particles in the 0.05µ to 5µ range, a primary concern in operations involving radioactivity since these particles tend to be retained in the lungs.

HEPA filters are classified by test requirements as either Type A, B, or C. Type A HEPA filters are only tested for overall penetration at 100% rated flow and are normally used in recirculating air systems where reduced flow is not usually experienced. Type B HEPA filters are tested for overall penetration at both 100% and 20% of rated flow and are normally used on once-through systems. The two flow test is designed to evaluate the filter for small imperfections, or pin-hole leakage. Type C HEPA filters are scanned over their entire downstream face to detect leaks. Scanning, a special leak test, is usually performed on filters used in clean rooms and clean benches. Type C HEPA filters are not usually used in nuclear facilites because of their high cost.

Type B HEPA filters are best suited for portable filtration in nuclear applications. Testing at both 20% and 100% of rated flow ensures that the filter is providing the required efficiency over the full range of flow, since portable filtration systems are often used at less than full flow.

HEPA filters consist of an external rigid casing with folded, paper-like filter media attached inside by special adhesives. **Face guards, usually 4 x 4 mesh hardware cloth, are recommended on upstream and downstream filter faces to protect the delicate filter media and prevent damage during handling and installation.** In addition, face guards increase the filter's resistance to racking, skewing, and shock.

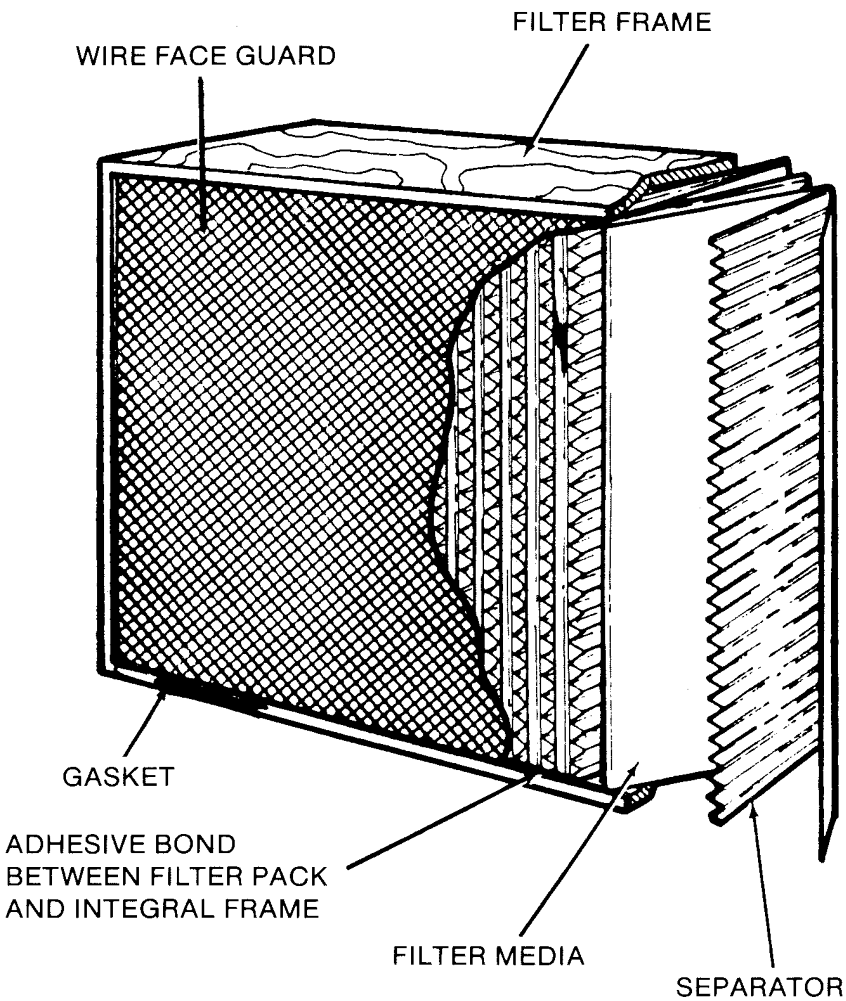
Gaskets used for sealing the filter to the ventilation system on the upstream and/or downstream face(s) also must be extremely efficient. The most effective gaskets are the fluid seal type and closed-cell neoprene type, with the closed-cell neoprene being the most common.

The differential pressure drop across a new HEPA filter is normally 1" wg or less at rated air flow. The differential pressure increases as the filter collects dust and, although the filter can withstand up to 10" wg differential pressure before rupturing, the filter should not, as a rule, be operated at differential pressures greater than 8" wg.

A sketch of a typical HEPA filter is shown in Figure 6.

SECTION II - DESIGN CONSIDERATIONS

C. HEPA Filters (Continued)



- **Efficiency is 99.97%**
- **Type A, B, & C filters**
- **Design features shown**
- **Change-out due to:**
  - **- Radiation levels**
  - **- Differential pressure**
  - **- Inadequate flow**

Figure 6. Typical HEPA Filter

NOTE: Case materials may be wood, metal, or other, based upon user requirements. Filter media will vary with design requirements and separators may not be present in some models.

SECTION II - DESIGN CONSIDERATIONS

D. Carbon Adsorbers

Most portable filtration systems contain prefilters and HEPA filters for removing air particulates. If radioiodine must be removed, the system should include charcoal adsorbers.

Carbon adsorbers, the third component in the air cleansing sequence, **remove radioiodine gas, a primary concern in nuclear air and gas cleaning**. Radioiodine may be in the form of elemental iodine (I^2) or organic iodine, principally methyl iodide (CH^3I). A distribution of 85% I^2 and 15% CH^3I is assumed for system design purposes. It is necessary to distinguish between the presence of I^2 and CH^3I because CH^3I must be in contact with the carbon adsorber media two times longer than if only I^2 were present. This contact time is known as "residence time". For I^2, residence time is about 0.10 seconds and for CH^3I, about 0.20 seconds.

To ensure effective sorption of organic radioiodine compounds, a minimum residence time of 0.25 seconds is recommended for design purposes to account for adsorbent bed thinning due to the unavoidable warpage and camber of screens used to hold the adsorbent. **All carbon adsorbers are rated at a given air flow with corresponding residence time and this information is one of the primary considerations in choosing an adsorber.**

Carbon adsorbers consist of a rigid external casing with a perforated sheet inner casing filled with activated carbon. Activated carbon (charcoal that has been heated in a steam atmosphere to clean out and enlarge the charcoal pores) is an effective adsorber because of the large surface area. One pound of activated carbon has a surface area from three to nine million square feet. Activated carbon should be impregnated with chemicals (usually I^2, KI, or TEDA) to improve its ability to adsorb radioiodine.

Adsorbers are designated by the Institute of Environmental Sciences (formerly The American Association for Contamination Control) as Type I (pleated bed), and Type II (tray or drawer). Adsorbers for long-term nuclear use, especially those adsorbers that are rechargeable, must be constructed of stainless steel because carbon steel corrodes.

The efficiency of adsorbers is affected by the following factors:

- Activation of the charcoal
- The type of impregnate
- Residence time
- Air flow rate
- Contaminants in the air stream, such as dust, paint fumes and solvents
- Moisture and humidity
- Temperature

SECTION II - DESIGN CONSIDERATIONS

D. Carbon Adsorbers (Continued)

At 0.25 second residence time, activated charcoal adsorbers are greater than 99% efficient for I^2 under all temperatures and humidity conditions. The adsorbers are 95% efficient for CH^3I at 85% or less relative humidity and 70º F (efficiency for removal of CH^3I decreases with increasing relative humidity).

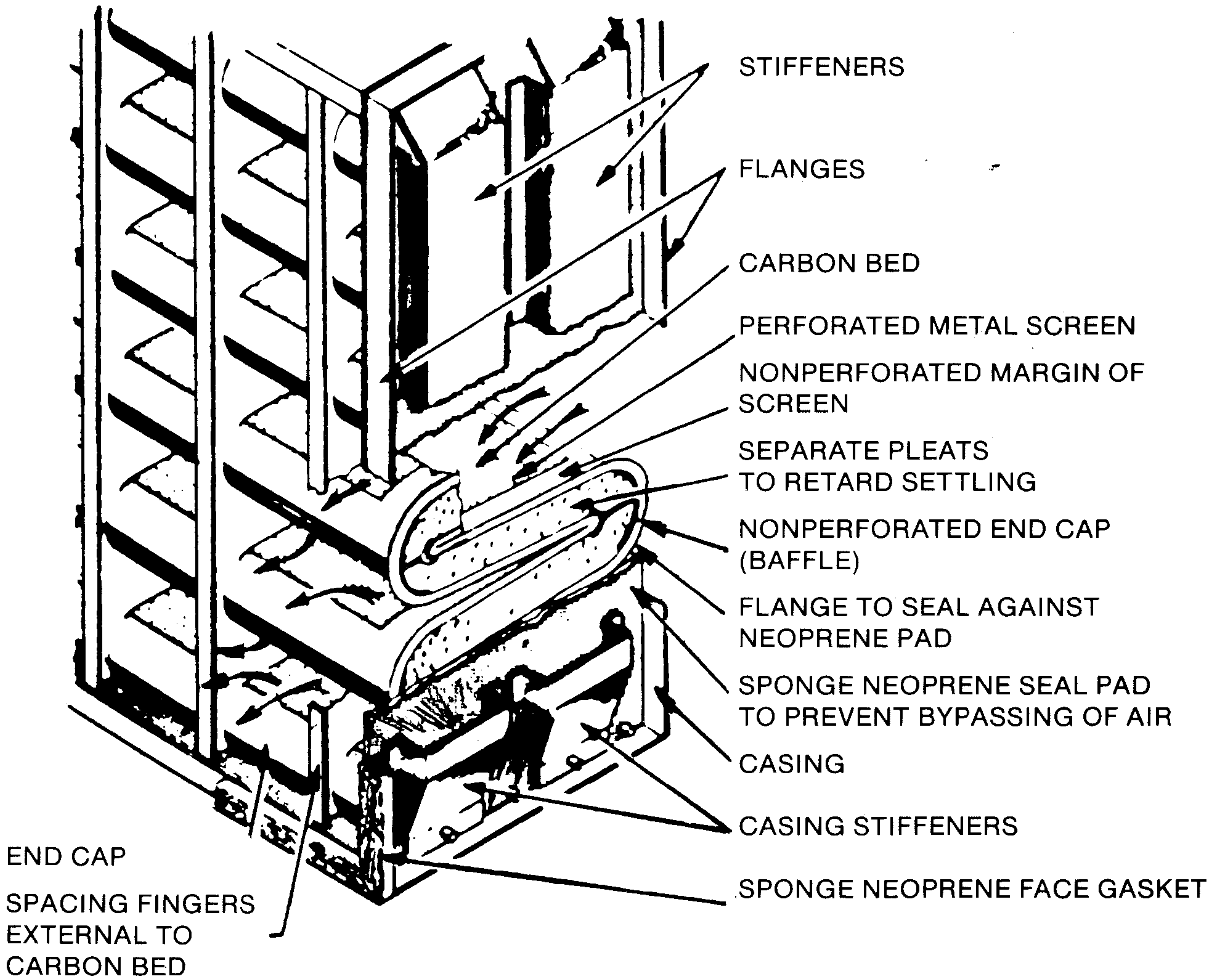
Gaskets are used to seal the upstream and/or downstream face of the adsorber. Mechanical efficiency of 99.9% is common for the adsorber seals, as determined using a refrigerant tracer gas. However, mechanical efficiency is not a measure of contaminant removal. It is only a measure of seal integrity and leak-tightness of the adsorber unit.

HEPA filters should always be installed upstream of the adsorber to prevent early depletion of the adsorber from dust accumulation. Since carbon adsorbers cost five to six times more than HEPA filters, protecting the carbon adsorbers is cost-effective. HEPA filters, or very high efficiency prefilters downstream of carbon adsorbers are also recommended to collect any radioactive charcoal fumes released from the adsorber.

A sketch of a typical carbon adsorber is shown in Figure 7. Schematics of typical carbon adsorber and HEPA filtration unit connections are shown in Section V.

SECTION II - DESIGN CONSIDERATIONS

D. Carbon Adsorbers (Continued)



- **Removal of:**
  - **-Elemental iodine (I^2)**
  - **-Organic iodine (CH^3I)**
- **Residence time of:**
  - **-0.25 seconds**
- **Design:**
  - **-Type I**
  - **-Type II**
  - **-Location**
- **Efficiency**

Figure 7. Cutaway of a 1-inch Pleated-Bed Carbon Adsorber

SECTION II - DESIGN CONSIDERATIONS

E. System Requirements

Because portable filtration systems must be compact, designing for optimum performance is not always possible. A gradual taper on the filter inlet and outlet, and a long straight inlet to the fan is ideal but not practical, since the unit would be excessively long. Therefore, some compromise must be made between optimum design and size. Flat plenums, with no taper, should be avoided because they channel the flow only through the center of the filter, which results in an excessive pressure drop. **Tapered plenums upstream and downstream provide the best results. Alternatively, space for air expansion and high performance blowers will substitute for a lack of inlet taper at an overall loss of optimum performance.**

Plenums and filter housing should be constructed of stainless steel. Although initial costs for stainless steel are higher, the ease of decontamination and longer service life more than offsets the expense.

Differential pressure gages across the prefilter/HEPA filter are recommended to indicate filter loading. The gages should have a range from 0" wg to 6-10" wg. A high pressure reading on the gage indicates that the filter should be replaced. Replacing filters only when necessary maximizes their usage.

Adjustable dampers should be installed in the inlet and/or outlet openings of the system to regulate system flow.

F. System Pressure Drop

The ability of the system to move air at a given rate depends upon the fan and the pressure loss through the system. System pressure loss is composed of fixed losses (at constant flow) and variable losses. The fixed pressure loss is the loss through installed ducting, transitions, filter housing (minus the filters), fan, inlets and exits. Variable pressure losses are losses through flexible hoses (may be added to the system to ventilate distant areas), prefilters, and HEPA filters (as they become loaded with dust). Carbon adsorbers normally maintain a fixed pressure loss, unless loaded with moisture which increases the pressure loss.

When choosing a portable system, make sure that the fan can develop high static pressures (sp-the measure of potential energy produced by the fan to move air through a filtration system). This allows the addition of long, flexible hoses for suction on remote work areas and provides sufficient differential pressure across the filter until it must be changed.

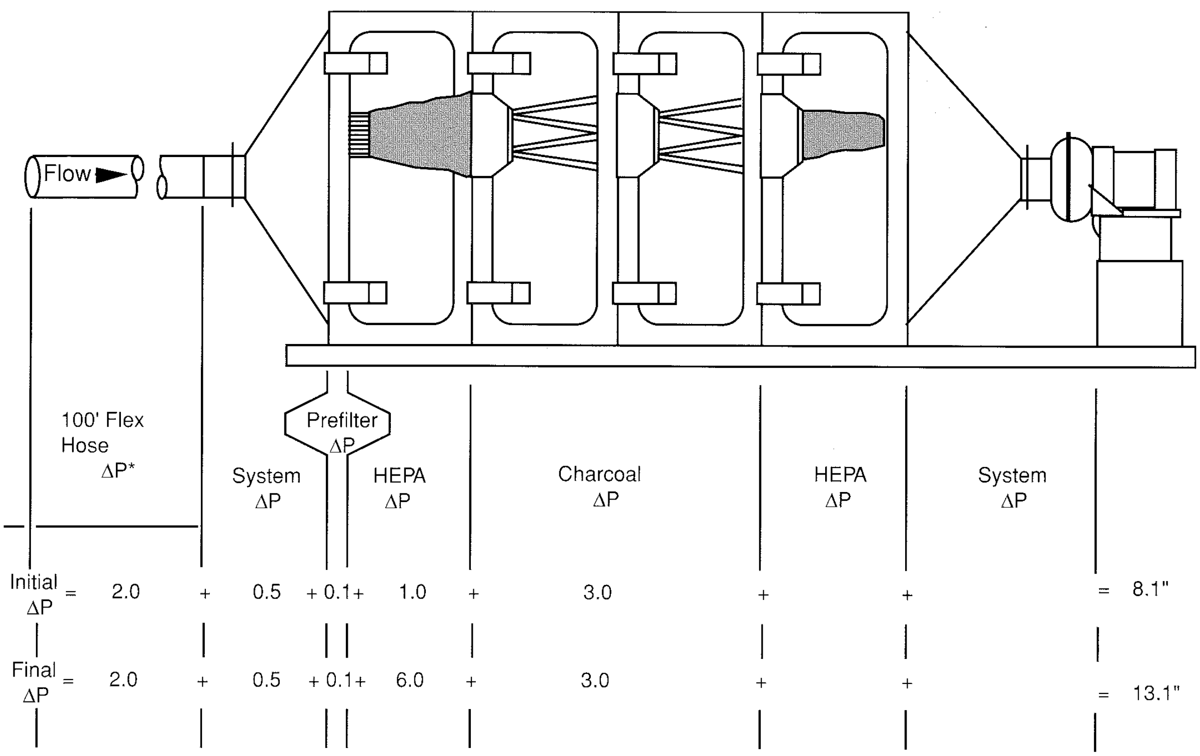
For example, consider a system which operates at 1000 cfm (see Figure 8). Assume the fixed pressure loss through the system is 1.0"wg. Add to this, the losses of 0.1" wg for a clean prefilter, 1.0"wg for the HEPA filter, and 2.0" wg for 100 ft. of flexible 8" hose (from Figure 9) at 1000 cfm.

SECTION II - DESIGN CONSIDERATIONS

F. System Pressure Drop (Continued)

The initial pressure loss in this system would be 4.1” wg. If the system operated until prefilter/HEPA filter loss is 6” wg (a 5” wg increase), a fan capable of 9” sp at 1000 cfm is required. Fans with less static pressure capability may not be capable of maintaining required flow rates or may require premature filter replacement. In addition, if radioiodine must be removed, the carbon adsorber and downstream HEPA filter would increase pressure loss further, requiring a more powerful fan.

Most standard carbon adsorbers are rated at approximately 1.5” wg loss at rated flow for 0.125 second residence time. This is equivalent to 3” wg pressure loss for the required 0.25 second residence time. The downstream HEPA filter would add another 1” wg loss, resulting in a loss of 4” wg for radioiodine removal. The fan for the example above would have to be capable of producing a total 13” sp at 1000 cfm.

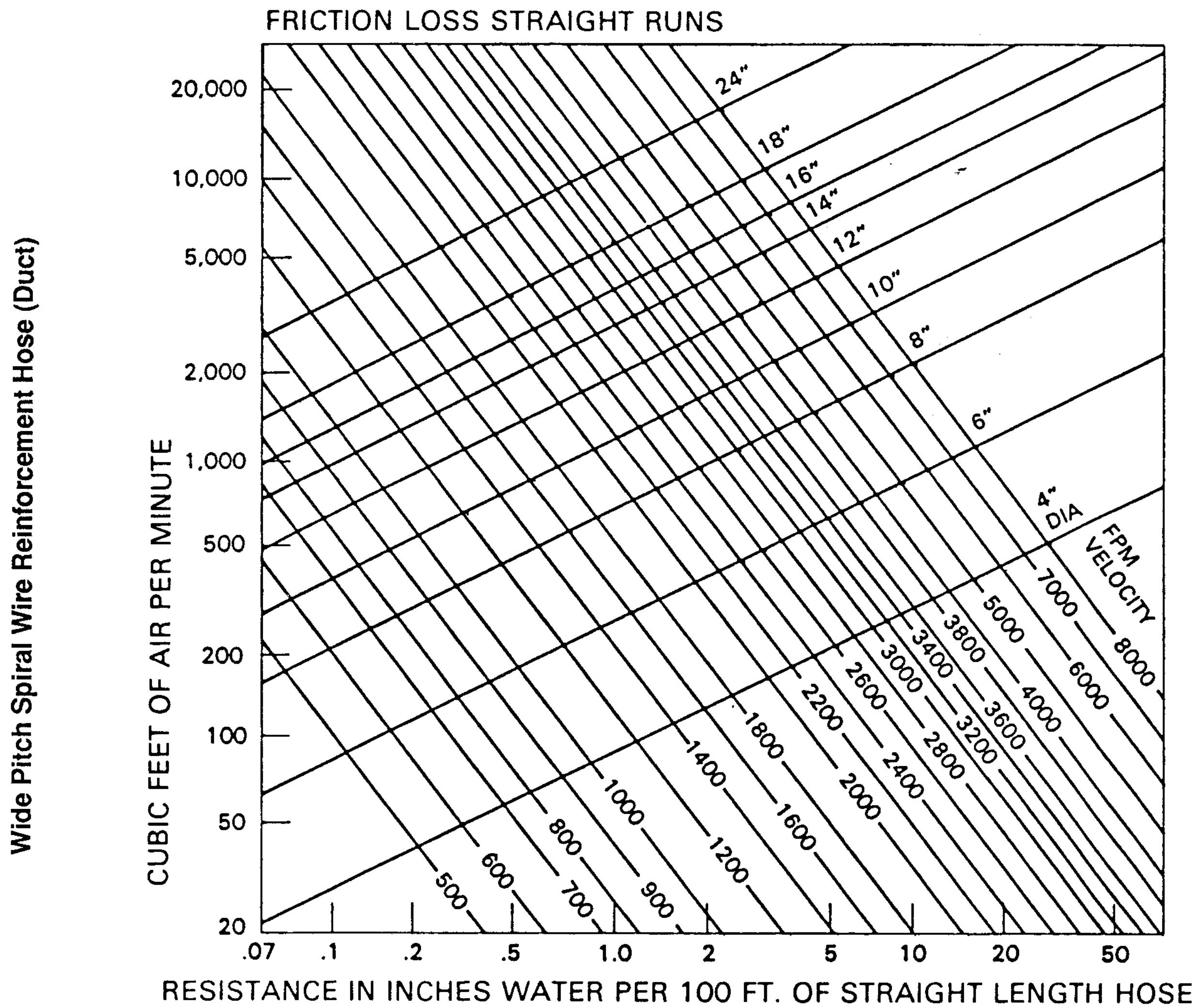


*NOTE: For each 90° or 180° bend add 6-8 times hose diameter to obtain equivalent hose length.

Figure 8. Typical HEPA Filtration System Pressure Drop at 1000cfm

SECTION II - DESIGN CONSIDERATIONS

F. System Pressure Drop (Continued)



For example on page 13; 1000 cfm thru 8" hose
Resistance = ~ 2.0" wg drop for 100 ft. hose
Velocity = ~ 2600 feet per minute

Figure 9. Flexible Hose Resistance Chart

SECTION II - DESIGN CONSIDERATIONS

G. Fans and Blowers

Special consideration must be given to selecting a fan for portable filtration equipment. **The fan must have flow characteristics which allow it to operate over a large pressure range to account for inherent system losses and increased pressure drops as filters collect dirt.** If the fan is inadequate, less than rated flow will occur as the filters become clogged, requiring premature filter replacement with corresponding additional cost, radiation/hazardous material exposure and waste. Refer to Figure 10 for graphic presentation of fan performance and associated filter replacement.

Centrifugal fans with backward inclined blades are best suited for flow rates up to several thousand cfm. These fans are non-overloading and provide high static pressure over a large operational range of flow. Above several thousand cfm, straight or radial blade centrifugal fans can be used. Centrifugal fans with forward curved blades should be avoided, since these fans develop relatively low static pressures and do not have non-overloading characteristics.

Axial flow fans should also be avoided since they are generally high volume, low static pressure fans. Some vaneaxial fans develop high pressures and may be used, but before you decide to use this design, you should study fan characteristics.

Direct drive fans offer a more compact design and reliable service, but belt-driven fans are also acceptable. Fans driven by three-phase motors should always be checked for proper direction of blade rotation when power is connected. When running backwards, the fan discharges some air, but only a small portion of the rated flow is produced.

Fans should always be located downstream of all filters to maintain negative pressures in the filter housing and to keep the fan clean. This way, any air leakage in the contaminated portion of the system is inward, preventing release of contamination. Also, shaft seals, on the shaft which drives the fan, prevent leakage of air around the shaft. The importance of the shaft seal is evident if airborne contamination is released in an area external to the fan. Since filtration is not provided downstream of the fan, contamination would be drawn into the fan and exhausted to the environment.

The performance from a 1000 cfm blower with a one (1) horsepower motor cannot be considered equal to a 1000 cfm blower with a five (5) horsepower motor. A one (1) horsepower motor unit cannot develop the static pressure losses that would be expected during the actual use of a portable filtration unit (see Figure 10). Assessing a blower based on a flow rate only, without consideration of the static pressure at which the flow is developed, is meaningless. A “1000 cfm” blower could mean 1000 cfm is moved at 0.5 in. wc static pressure, or at 5 in. wc static pressure.

SECTION II - DESIGN CONSIDERATIONS

G. Fans and Blowers (Continued)

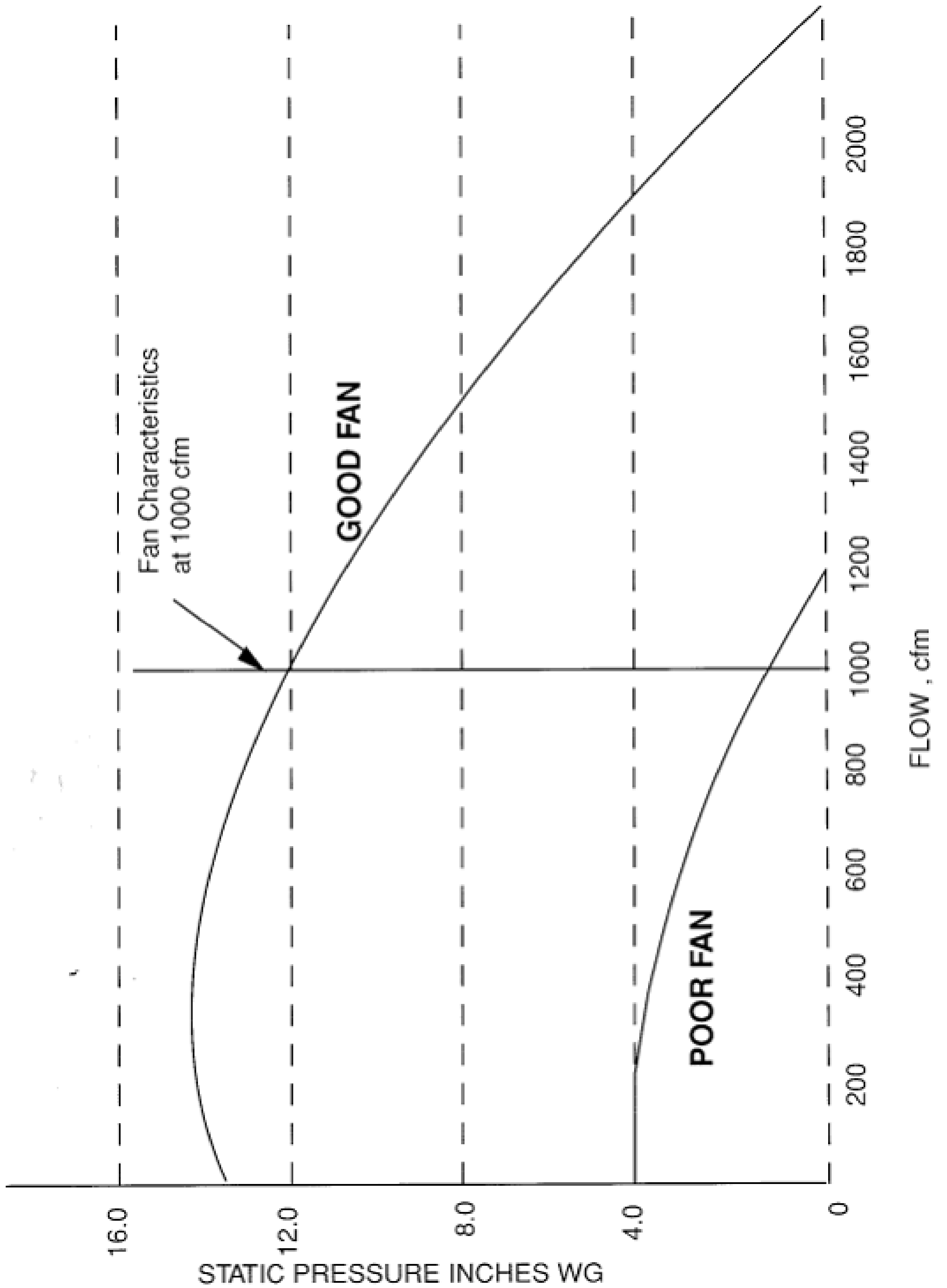
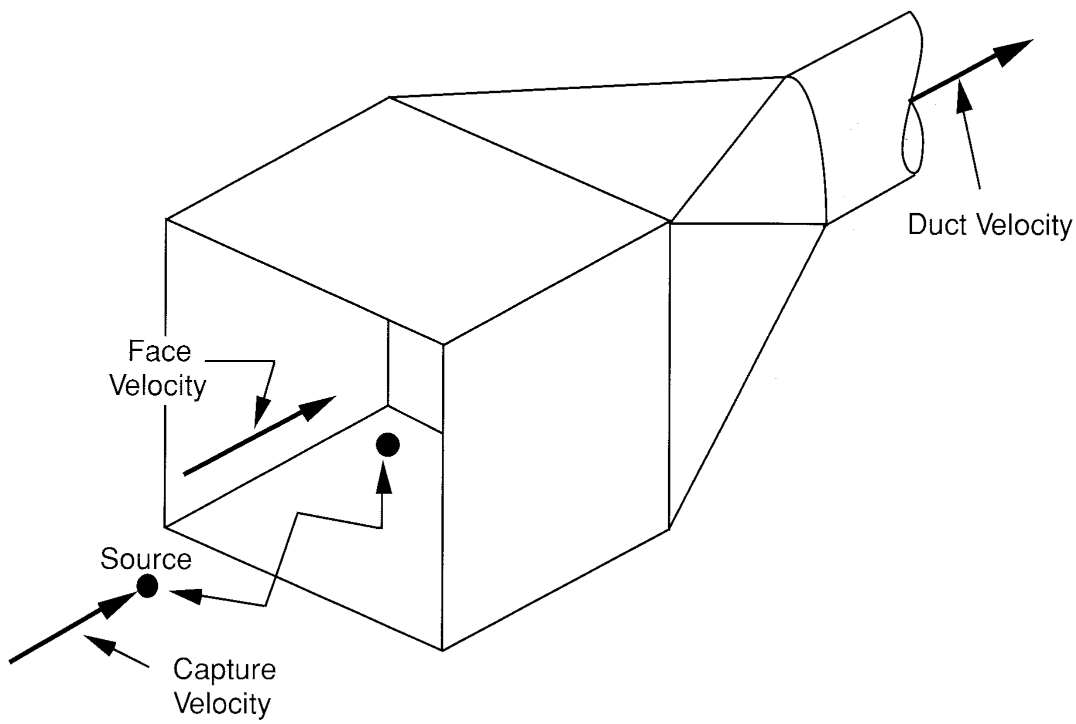


Figure 10. Typical Fan Performance Curves

SECTION II - DESIGN CONSIDERATIONS

H. Flow Rates

The air flow rate, or velocity, into a hood or work area when using portable ventilation is characterized by the capture velocity and duct velocity. The definitions of capture and duct velocity, and their relationship is shown in Figure 11. Capture velocity varies, depending on the size of the particles and the rate at which they are released into the air. For most situations, 125 to 200 feet per minute (fpm) capture velocity is satisfactory. Refer to table 1 for a range of capture velocities for various contaminant dispersion rates.



CAPTURE VELOCITY: Air velocity at any point in front of a hood or at the hood/hose opening necessary to overcome opposing air currents and to capture the contaminated air at that point by causing it to flow into the hood/hose.

DUCT VELOCITY: Air velocity through the duct cross section. When solid material is present in the air stream, the duct velocity must be equal to or greater than the minimum air velocity required to move the particles in the air stream.

Figure 11. Hood/Hose Nomenclature for Local Exhaust

SECTION II - DESIGN CONSIDERATIONS

H. Flow Rates (Continued)

Dispersion of Contaminant	Examples	Typical Capture Velocity (fpm)
Released with Practically no Velocity into Still Air	Evaporation From Tanks	50 – 100
Released at Low Velocity into Moderately Moving Air	Welding, Spraying Booths, Intermittent Container Transfer, Hand Tool Work on Contaminated Items.	100 - 200
Active Generation into Rapidly Moving Air	Spray Painting, Barrel Filling	200 – 500
Released at High Velocity into Very Rapidly Moving Air	Grinding, Abrasive Blasting	500 - 2000

Reference: ACGIH Industrial Ventilation

Table 1. Range of Capture Velocities

For ventilating work areas, 7 to 12 room volume air changes per hour are recommended. For example, a 10' x 10' x 10' room has a volume of 1000 cu. ft. At 12 changes per hour, this is equivalent to:

$$1000 \text{ cu. ft.} \times \frac{12 \text{ changes}}{\text{hour}} = 12{,}000 \text{ cu. ft. per hour}$$

Converting to normal flow rate units of cubic feet per minute (cfm) results in:

$$12{,}000 \text{ cu. ft. per hour} \times \frac{1 \text{ hour}}{60 \text{ minutes}} = 200 \text{ cfm}$$

To conserve thermal energy, recirculate discharge air through the filter system back to the work area/room, discharging only a small portion (typically 15%) of air to the environment. Also, provide a path for make-up air to the ventilated area to compensate for any air discharged.

SECTION II - DESIGN CONSIDERATIONS

H. Flow Rates (Continued)

Radiological and/or hazardous work areas should be planned so that air moves from the least contaminated to progressively more contaminated areas before finally entering the ventilation suction. This flow path prevents cross-contamination of work areas. Cross-contamination can also be prevented by maintaining a differential pressure of at least 0.05 to 0.10 in. wg between work areas. However, do not allow differential pressure to become so great that the negative pressure collapses the work area (e.g., a containment tent), or hinders safe door operations. Sufficient make-up air must be provided to work area to manage the pressure gradients and maintain a clean air sweep of the work area.

Approximate flow rates and velocity may be determined using the following formula:

V = Velocity (in linear feet per minute)
A = Area of opening (in square feet)
Q = Flow rate (in cubic feet per minute)

$$V = \frac{Q}{A} \qquad Q = V \text{ x } A$$

Additional information on air flow associated with the use of portable filtration is shown in Tables 2, 3, and 4 and Figures 12, 13, and 14. A rule of thumb that can be used to estimate the centerline capture velocity air flow for a flanged duct opening is shown in Figure 14.

HOSE SIZE (inches)	VELOCITY IN FEET PER MINUTE						
10	925	429	164	81	-	-	-
8	1420	512	175	84	-	-	-
6	2600	613	186	86	-	-	-
4	5500	699	193	88	-	-	-
	Face	3”	6”	9”	12”	15”	18”
	(DISTANCE FROM END OF HOSE ON CENTERLINE AXIS)						

∇
Rule of thumb for capture velocity of 150 fpm

Table 2. Effective Distance of Capture Velocity for 500 cfm HEPA Filtration System

SECTION II - DESIGN CONSIDERATIONS

H. Flow Rates (Continued)

HOSE SIZE (inches)	VELOCITY IN FEET PER MINUTE						
10	1850	858	329	162	95	62	-
8	2850	1025	350	167	97	62	-
6	5200	1226	372	172	98	63	-
4	-	-	-	-	-	-	-
	Face	3”	6”	9”	12”	15”	18”
	(DISTANCE FROM END OF HOSE ON CENTERLINE AXIS)						

Rule of thumb for capture velocity of 150 fpm

Table 3. Effective Distance of Capture Velocity for 1000 cfm HEPA Filtration System

Rule of thumb for capture velocity of 150 fpm

HOSE SIZE (inches)	VELOCITY IN FEET PER MINUTE						
10	3700	1716	658	325	190	123	87
8	5700	2050	701	335	193	125	87
6	10,500	2454	744	344	196	126	88
4	-	-	-	-	-	-	-
	Face	3”	6”	9”	12”	15”	18”
	(DISTANCE FROM END OF HOSE ON CENTERLINE AXIS)						

Table 4. Effective Distance of Capture Velocity for 2000 cfm HEPA Filtration System

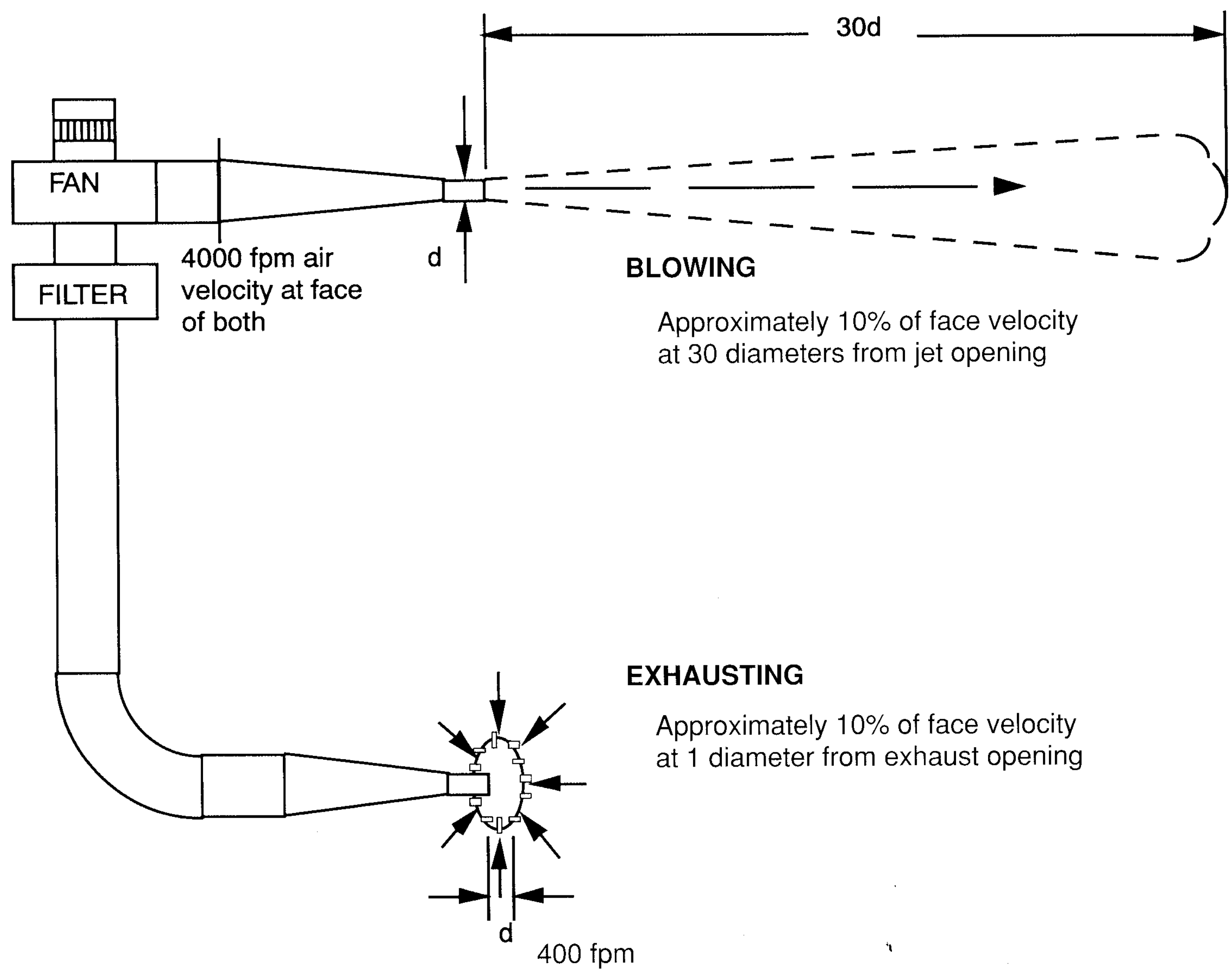
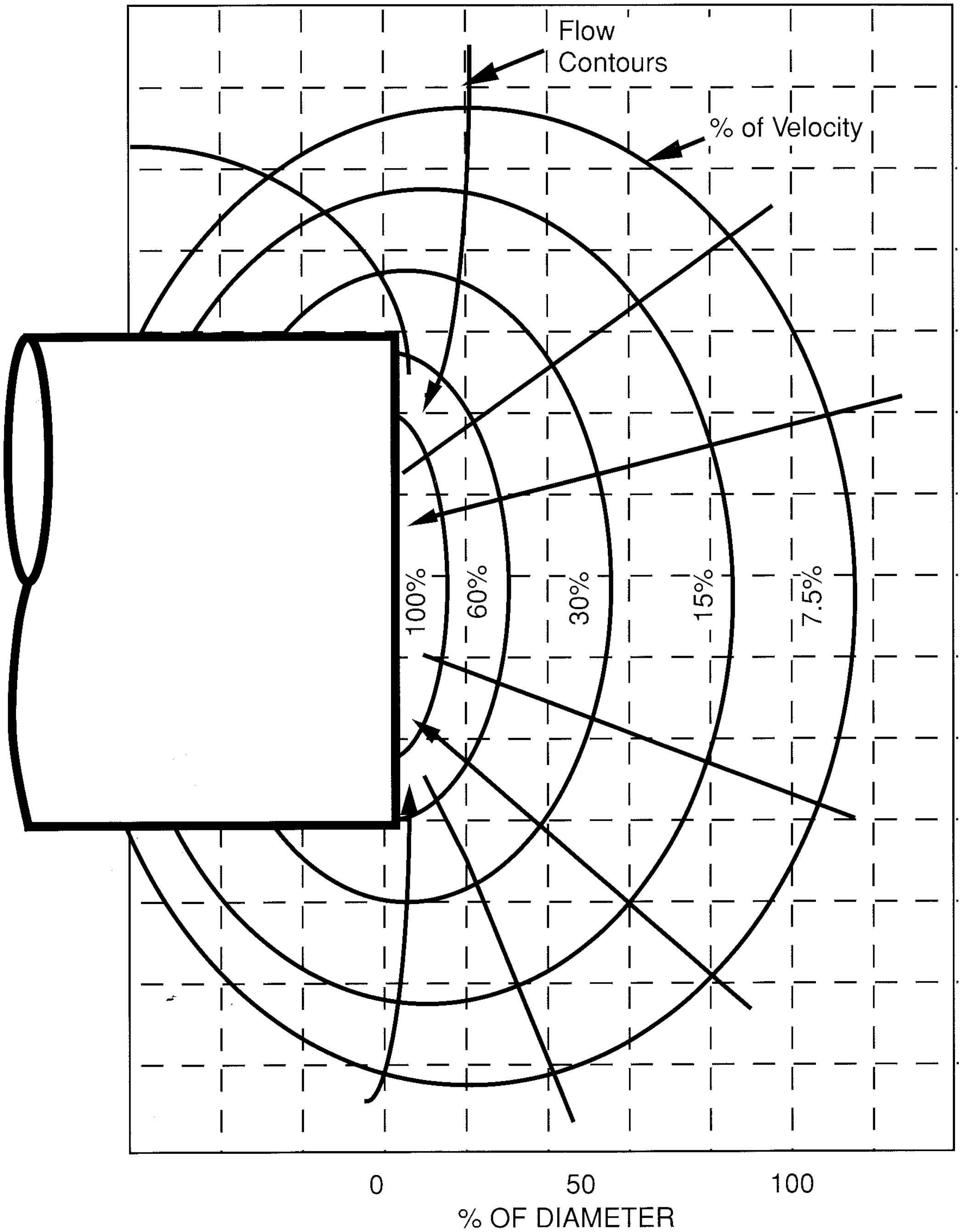


Figure 12. Fan Discharge vs. Suction Flow Characteristics

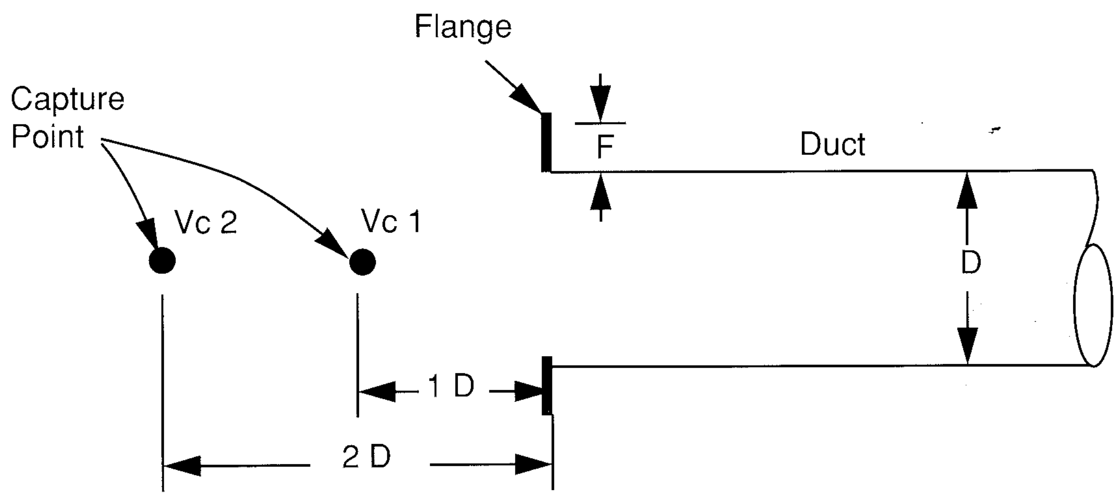
SECTION II - DESIGN CONSIDERATIONS

H Flow Rates (Continued)



13. Velocity Contours - Plain Circular Hose Inlet Opening - % of Opening Velocity

H. **Flow Rates (Continued)**



D = Duct Diameter in inches
F = ½ D
V = Velocity of air in duct

Center Line Capture Velocity Thumb Rule:

Vc 1 @ 1 D = 0.1V
Vc 2 @ 2 D = 0.01V

EXAMPLE:

D = 8” duct diameter
V = 1400 fpm velocity (500 cfm)
F = 4”
Vc1 = 1400 x 0.1 = 140 fpm
Vc2 = 1400 x 0.01 = 14 fpm

Figure 14. Rule of Thumb to Estimate Centerline Capture Velocity Air Flow for a Flanged Duct Opening

SECTION III - USING PORTABLE HEPA FILTRATION SYSTEMS

A. User's Checklist

The following checklist should be used to ensure proper operation of a portable HEPA filtration system.

- Check for presence of prefilter and HEPA filter.
- Check for obstructions in blower.
- Jog blower/motor and verify proper rotation.
- Ensure duct runs are as straight as possible with no kinks.
- Set dampers to desired position.
- Upon starting, check D/P gage; >0.9", <7.0".
- Check air flow volume: Is there enough?
- Ensure suction hose opening is ~ 1 diameter away from work for "hose only" applications.
- Consider using a funnel or partial containment to enhance air flow over work.
- Ensure air flows away from personnel and from least contaminated to most contaminated.
- For any operating unit, periodically check:

  - D/P gage reading; >0.9", >7.0"
  - Adequate air flow
  - Radiation levels
  - Hose condition (straight with no kinks)
  - Discharge point (Where is the air going?)
  - Damper positioning

B. Portable HEPA Filtration System Applications

The control of hazardous/radioactive contamination during operations where the potential for airborne activity exists can be substantially improved by utilizing properly designed portable HEPA filtration systems. Effective utilization of this engineered control captures contamination at the source, thereby minimizing its spread. Immediate reductions in usage of respiratory protection equipment, decon time, and waste generation are realized. Productivity is improved because the worker is less encumbered and more comfortable. The result – As Low As Reasonably Achievable (ALARA) objectives are met, performance span time is minimized, decon efforts, waste and costs are reduced.

SECTION III - USING PORTABLE HEPA FILTRATION SYSTEMS

B. Portable HEPA Filtration System Applications (Continued)

The examples shown in Figures 15 through 19 depict some practical and cost-effective uses of portable HEPA filtration systems.

- Dries out flow tubes.
- Removes radioiodine inventory when charcoal components are included.
- Provides capture velocity airflow into component to control spread of contamination.

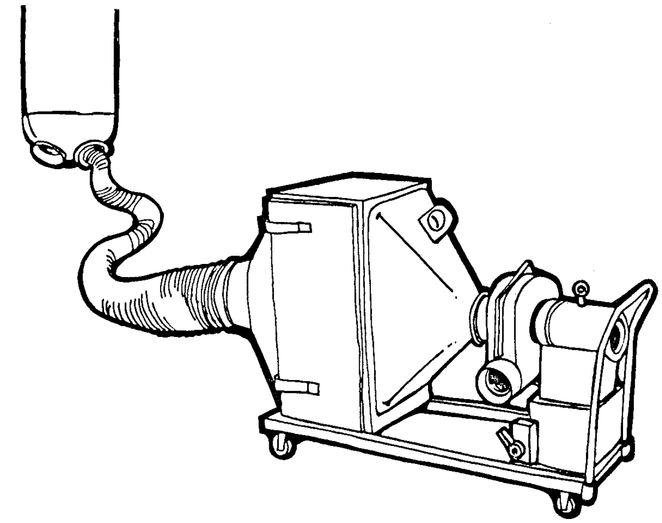


Figure 15. Stream Generators

- Isolated the worker during handling of contaminated materials.
- Eliminates the spread of contaminants. Packages the job and not the worker.

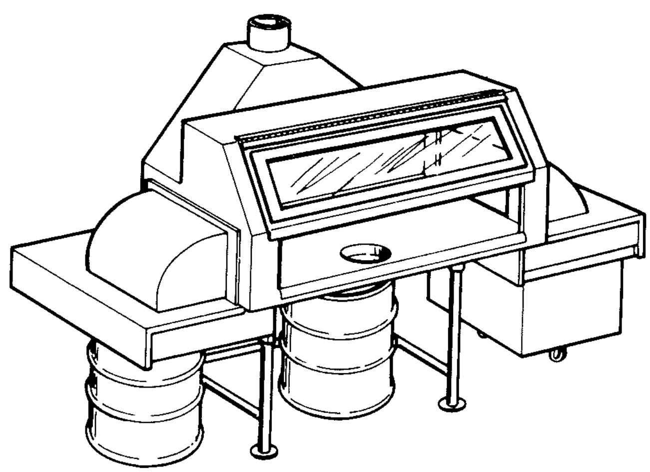
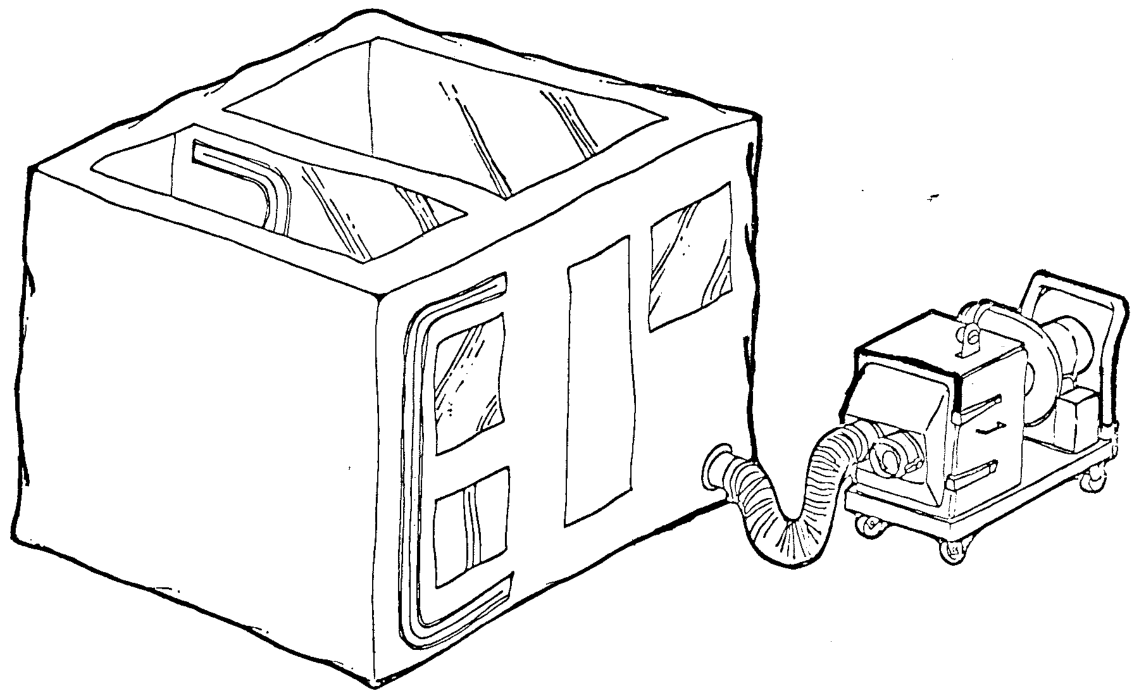


Figure 16. Glovebox/Ventilation Hoods

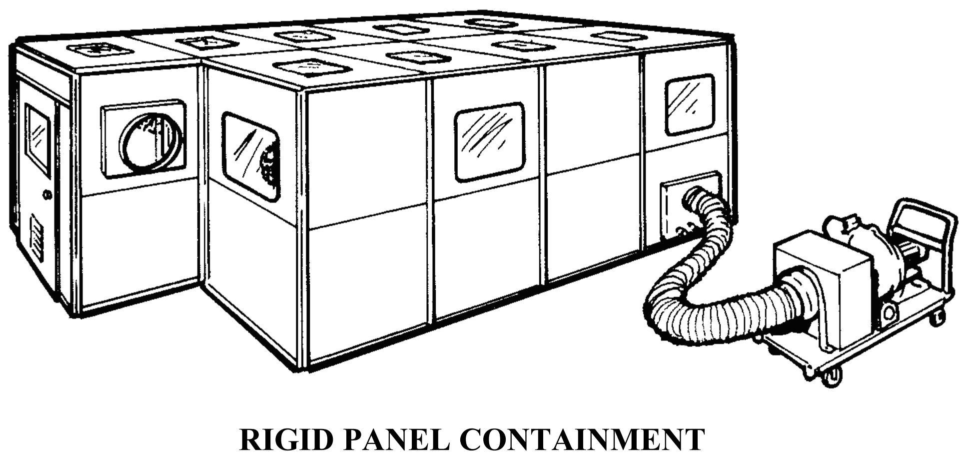
SECTION III - USING PORTABLE HEPA FILTRATION SYSTEMS

B. Portable HEPA Filtration System Applications (Continued)



CONTAINMENT TENT

- Provides localized control for contaminated work operations.
- Minimizes impact on adjacent areas.
- Reduces requirements for respiratory protection equipment.

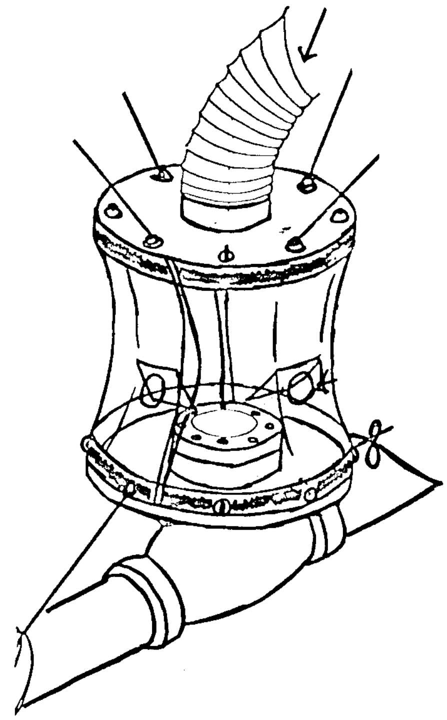


RIGID PANEL CONTAINMENT

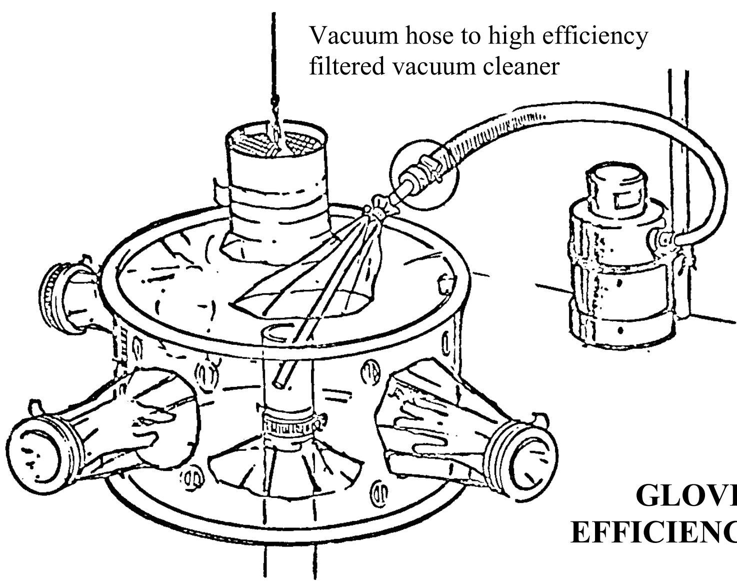
Figure 17. Temporary Containment Enclosures

B. Portable HEPA Filtration System Applications (Continued)

- Provides localized control for contaminated work operations.
- Minimizes impact on adjacent areas.
- Reduces requirements for respiratory protection equipment.



AIR-CON



GLOVE BAG WITH HIGH EFFICIENCY VACUUM CLEANER

Figure 27. Temporary Containment Enclosures (Continued)

B. Portable HEPA Filtration System Applications (Continued)

- Provides capture velocity airflow for radioactive contaminants present.
- Controls spread of contamination.
- Minimizes cleanup required.
- Reduces requirements for respiratory protection equipment.

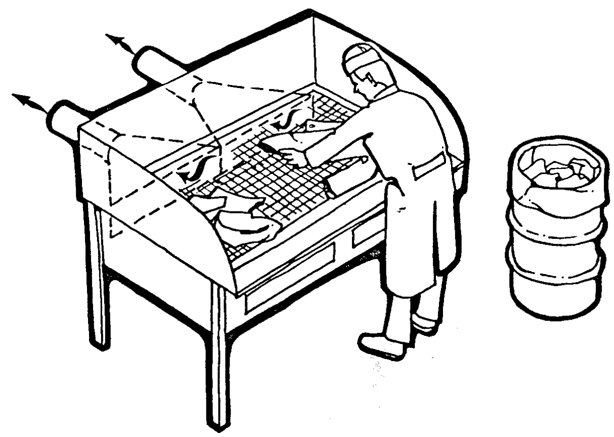
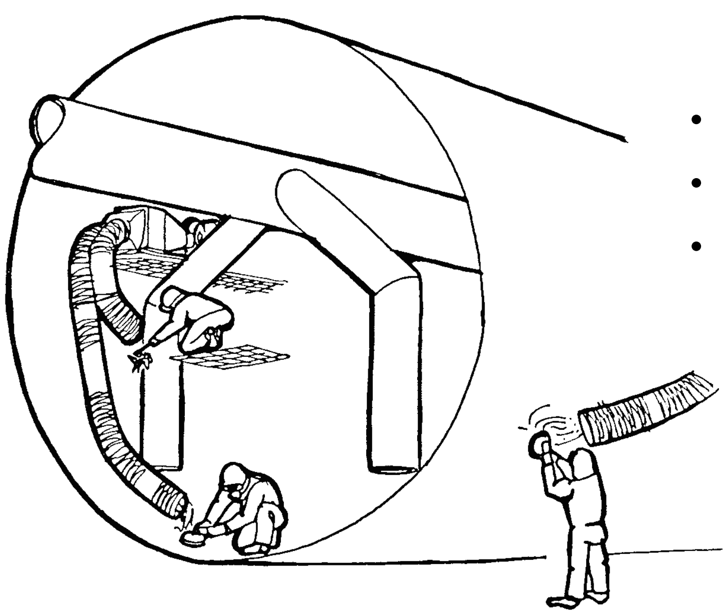


Figure 18. Materials Handling Benches



- Radioactive fume removal during flame-torch cutting operations.
- Fume removal during chemical cleaning/ decontamination operations.
- Radioactive particulate removal during abrasive blast stripping operations.

Figure 19. Plant Modification/Maintenance Operations.

SECTION III - USING PORTABLE HEPA FILTRATION SYSTEMS

B. Portable HEPA Filtration System Applications (Continued)

Other uses of portable HEPA Filtration units are as follows:

- Supplement to existing HVAC system.
- Evacuation of radioiodine from turbines and other primary components.
- Radioactive/Hazardous fume/particulate handling during welding, grinding and cutting operations.
- Area isolation via ability to create a desired flow condition.
- Maintain negative pressure on containment enclosures.
- Mock-up training in support of contamination control.

C. Aerosol Testing of Portable HEPA Filtration Systems

The portable HEPA filtration system should be aerosol tested after HEPA filters are installed or replaced to ensure proper installation. This test should not be confused with the efficiency test performed at the time of manufacture. Manufacturer tested HEPA filters must be 99.97% efficient for stopping 0.3µ particles at rated flow.

For system efficiency, 99.95% is acceptable. The 0.02% drop from the manufacturer's efficiency is attributed to both the difficulty of obtaining a 100% seal between the HEPA filter and filtration system/housing and to the use of portable field equipment.

In the United States, HEPA filters have been historically tested with DOP (Dioctylphthalate) aerosol. The manufacturer tests with a thermally generated, monodispersed DOP aerosol having a mean particle size of 0.3µ. More recently, PAO (poly-alpha olefin) has replaced DOP due to potential heath risks associated with DOP oil. While still commonly referred to as a DOP test, the term aerosol challenge test is more technically accurate.

When the filters are in the filtration system (field testing), usually a cold-generated, polydispersed aerosol having a mean particle size of 0.7µ is used. The field testing equipment usually consists of a unit to generate aerosol and a unit to measure the system's efficiency in removing the aerosol. While the system is running at its normal flow rate, aerosol is injected into the system upstream of the HEPA filter. The detection apparatus takes a sample of air from the upstream side of the HEPA filter and is adjusted to read 100% concentration. Then, a sample of air from the downstream side of the HEPA filter is taken. The downstream reading is the percent penetration through the filter. System efficiency is calculated by subtracting the percent penetration from 100%.

A flow chart illustrating aerosol challenge testing is shown in Figure 20 and a schematic of HEPA filter testing is shown in Figure 21.

SECTION III - USING PORTABLE HEPA FILTRATION SYSTEMS

C. DOP Testing of Portable HEPA Filtration Systems (Continued)

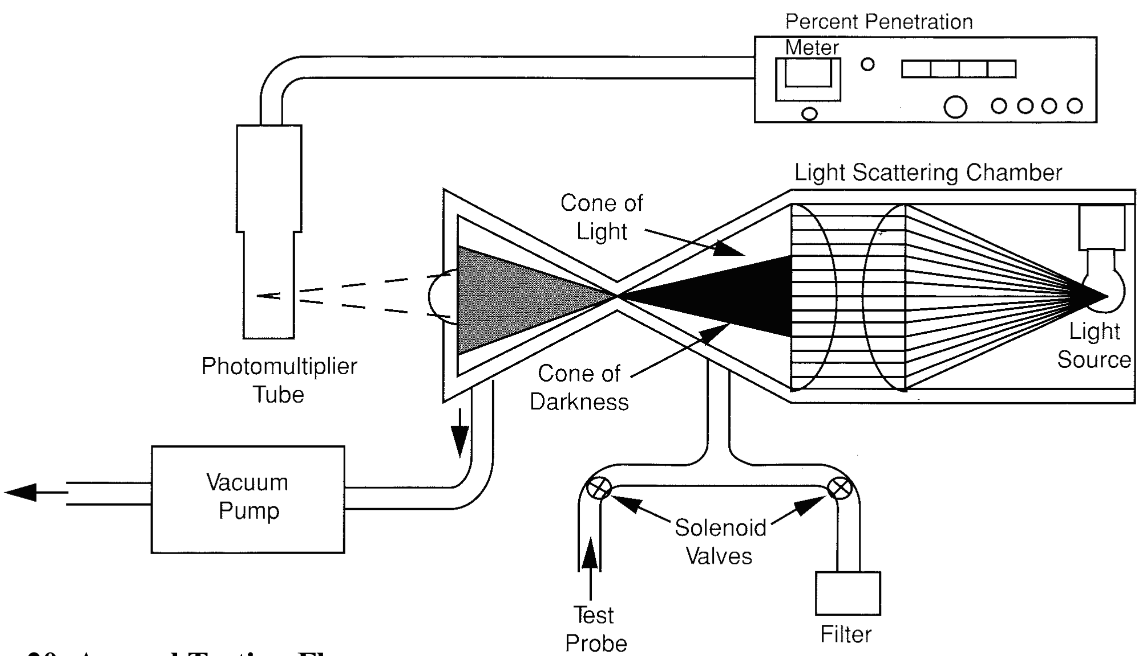


Figure 20. Aerosol Testing Flow

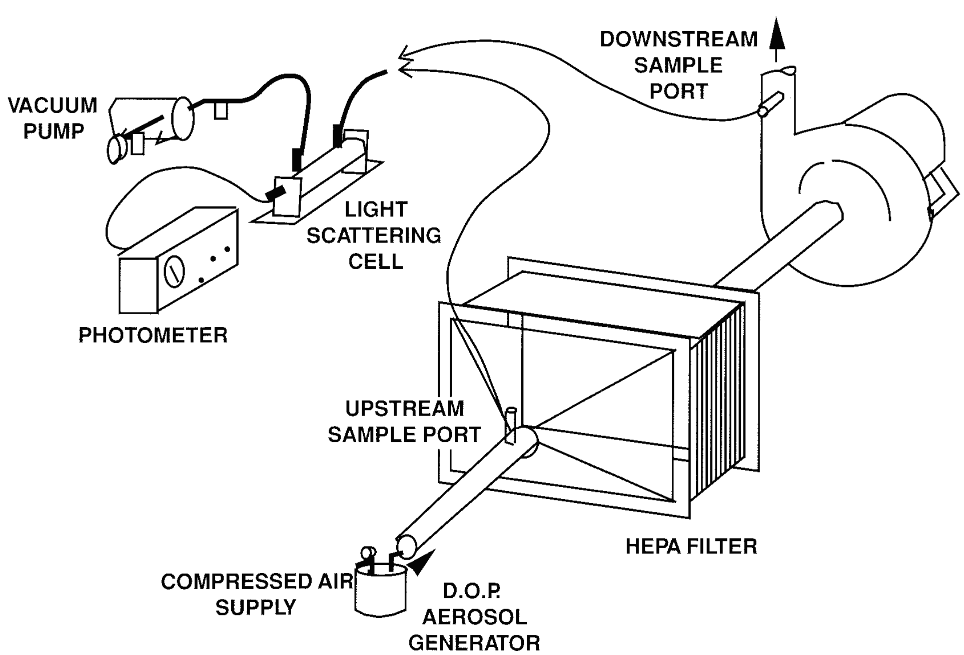


Figure 21. HEPA Filter Aerosol Test

SECTION IV - SAMPLE HEPA FILTRATION SYSTEM CALCULATIONS

A. Determining Flow and Velocity

From Section II, Subsection H, Page 20, the formula relating flow and velocity is:

Q = Velocity (in linear feet per minute)
A = Area of opening (in square feet)
F = Flow rate (in cubic feet per minute)

$$Q = \frac{Q}{A} = Q \times A$$

EXAMPLE:

What flow rate is required to achieve 150 lfpm (V) across an opening in a hood that measures 12” Hx32” L?

$$A = \frac{12x32}{144} = 2.66 \text{ sp. Ft;….. use 2.7 sq. ft.}$$

V = 150 Q= 150 x 2.7 = 405 cfm

EXAMPLE:

What is the velocity (V) of air traveling thru a 6”dia. Duct that has 500 cfm (Q) being withdrawn from it by a blower?

A = Π x R²; R = 3”, so Π x (3) = 28.3 sq.in.

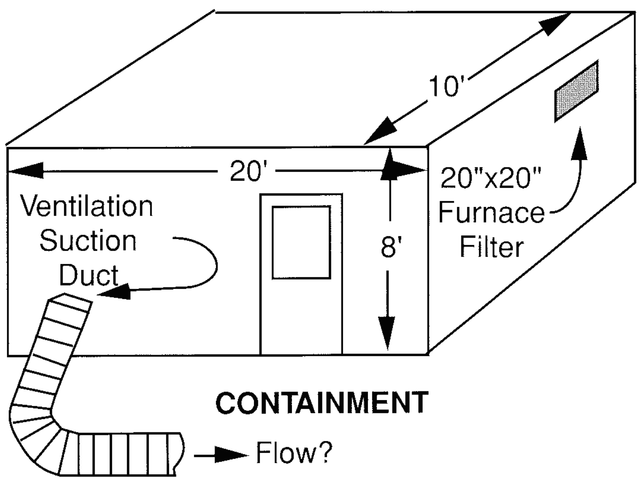
Use 28 sq. in.; so $A = \frac{28}{144} = 0.20$ sq. ft.

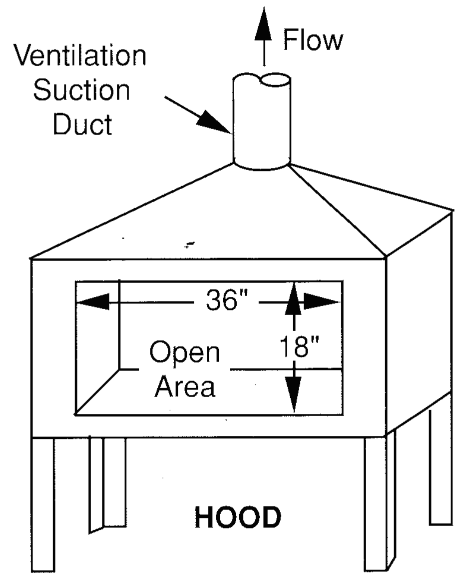
Q = 500 cfm; so $V = \frac{500(Q)}{0.20(A)}$

V = 2500 Linear Feet per Minute (lfpm)

SECTION IV - SAMPLE HEPA FILTRATION SYSTEM CALCULATIONS

B. Calculating Flow Rate and Duct Size





1. For the containment shown above, calculate the flow rate necessary for a ventilation system based on: (1) 12 room volume air changes per hour, and (2) capture velocity of 200 lfpm (linear feet per minute) through the furnace filter opening.

   (1) Tent volume = 20' x 10' x 8' = 1600 cu. ft.
   1600 cu. ft. x 12 vol. chg's per hr. = 19,200 cu. ft. per hr./60 min. = 320 cfm

   (2) Filter area = 20" x 20"/144 sq. in. = 2.78 sq. ft.
   2.78 sq. ft. x 200 lfpm = 556 cfm

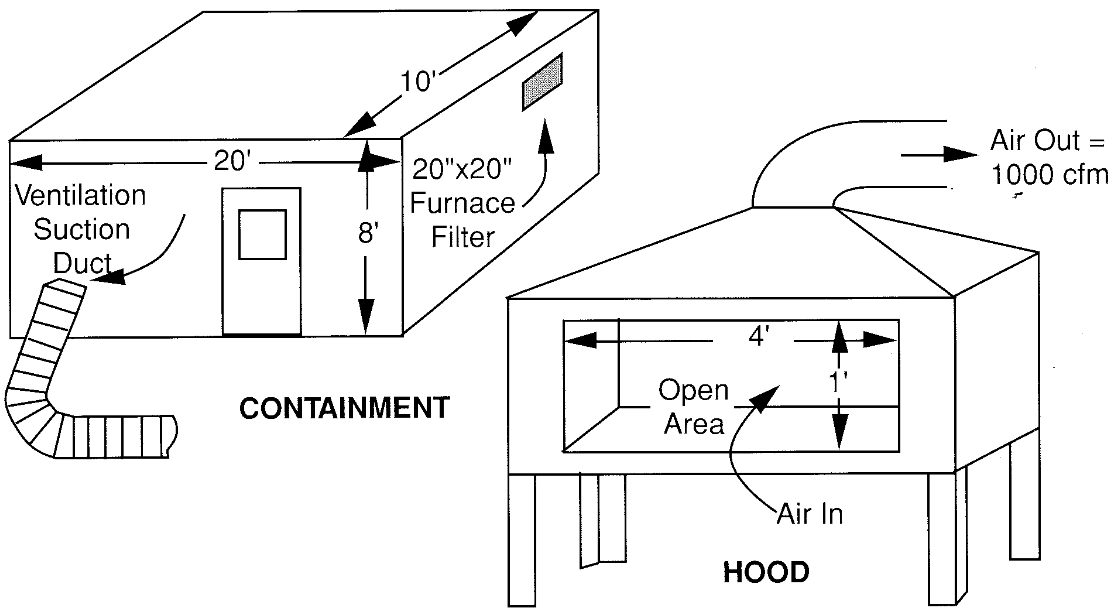
2. For the hood shown above, calculate the air flow rate in cfm required to maintain 200 lfpm through the open area. What is the smallest suction duct size you would use on the hood to maintain the duct velocity below 1500 lfpm…...6", 8", 10", 12", 14"?

   Hood opening area = 36" x 18"/144 sq. in. per sq. ft. = 4.5 sq. ft.; 4.5 x 200 lfpm = 900 cfm
   Duct area in sq. ft. = Π x R/144 sq. in. per sq. ft.
   Duct velocity in lfpm = cfm/duct sq. in. per sq. ft.
   For 12" Duct: [R=6] 6 x Π/144 = 0.79 sq. ft.; 900 cfm/0.79 sq. ft. = 1139 lfpm
   For 10" Duct: [R=5] 5 x Π/144 = 0.55 sq. ft.; 900 cfm/0.55 sq. ft. = 1636 lfpm

   12" is the smallest suction duct size required to maintain duct velocity below 1500 lfpm

SECTION IV - SAMPLE HEPA FILTRATION SYSTEM CALCULATIONS

C. Calculating Velocity and Flow Rate



1. What is the velocity of air moving into the hood shown above? Is this velocity adequate to provide capture velocity for contaminates released at low velocity into moderately moving air? (100-200 fpm required per Table 1)

(1) Area of opening = 4' x 1' = 4 sq. ft.

Air in = Air out = 1000 cfm

Velocity into hood = 1000 cfm / 4 sq. ft. = 250 fpm

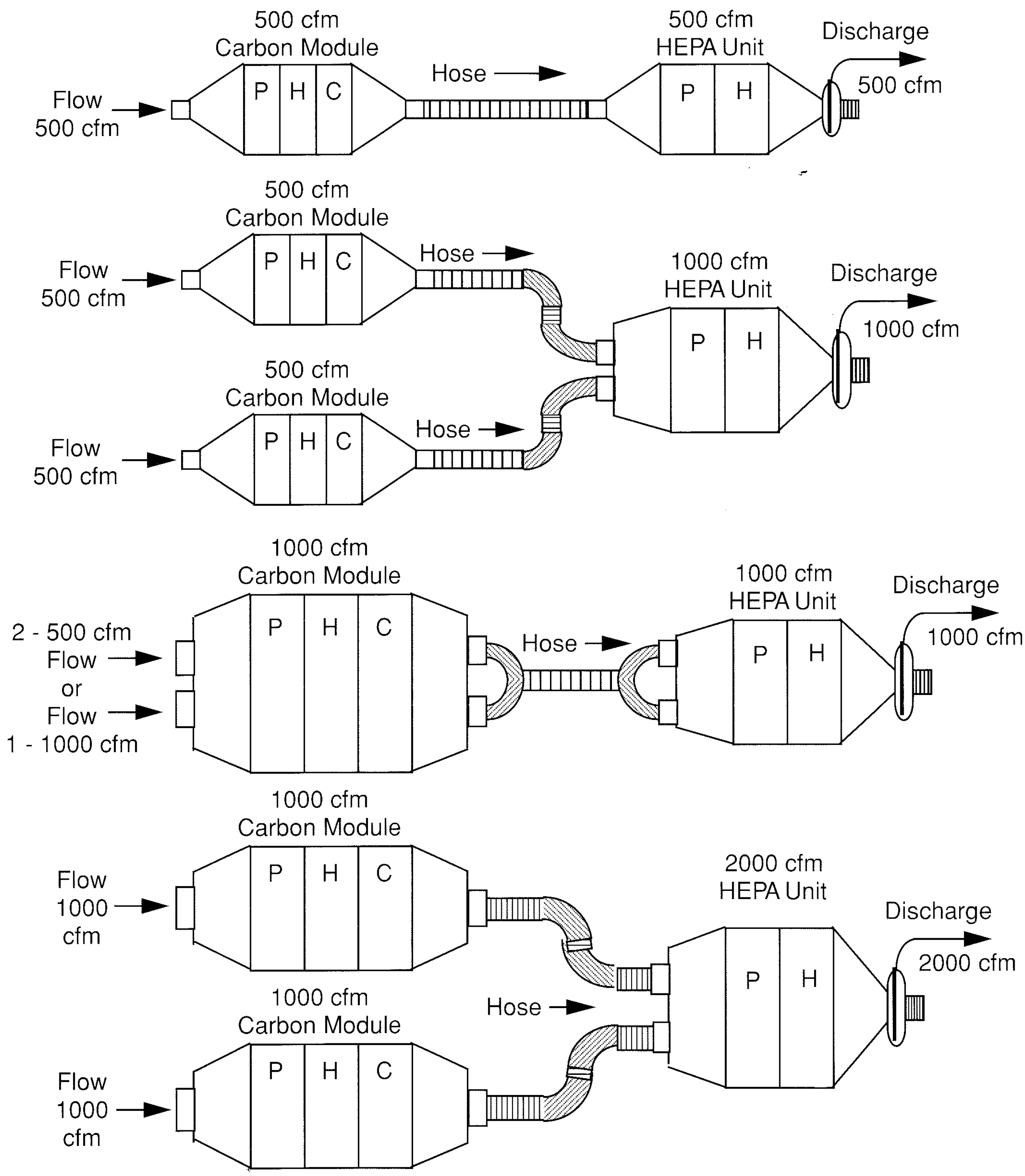
(2) This is adequate to provide capture velocity for the stated case.

2. What flow rate is required into the above tent through the 20" x 20" furnace filter in order to achieve a capture velocity of 150 fpm at the filter face?

$$\text{Flow rate required} = \frac{20" \times 20"}{144" \text{ sq. in./sq. ft.}} \times 150 \text{ fpm} = 417 \text{ cfm}$$

SECTION V - CARBON ADSORBER MODULE CONNECTION SCHEMATICS

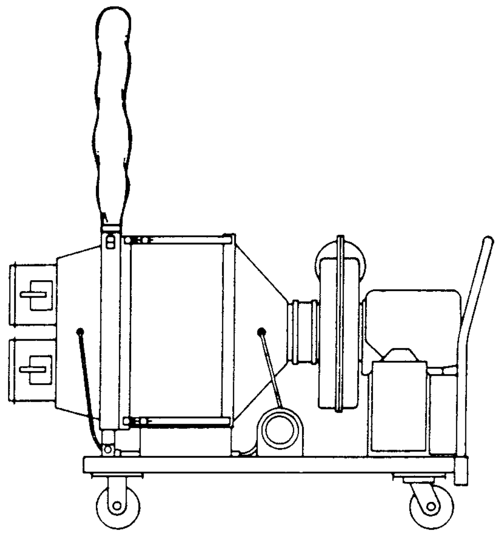
P = Prefilter; H = HEPA Filter; C = Carbon Adsorber



SECTION VI - TYPICAL HOUSINGLESS VENTILATION MODULE FILTER CHANGE-OUT PROCEDURES

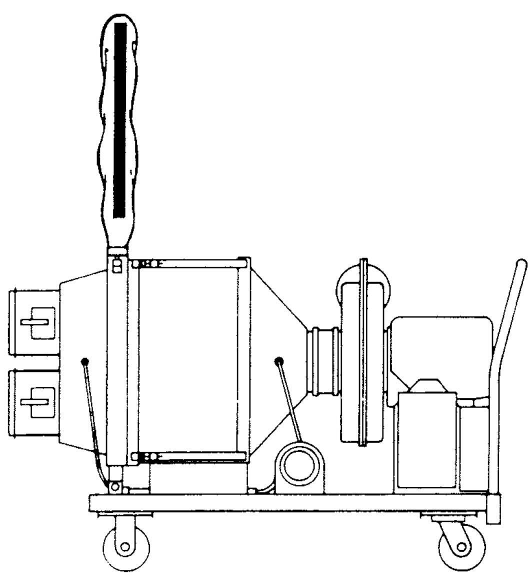
Prefilter Change-Out
(Models PFC(H)-500 & PFB(H)-1600 & 2500

Step 1



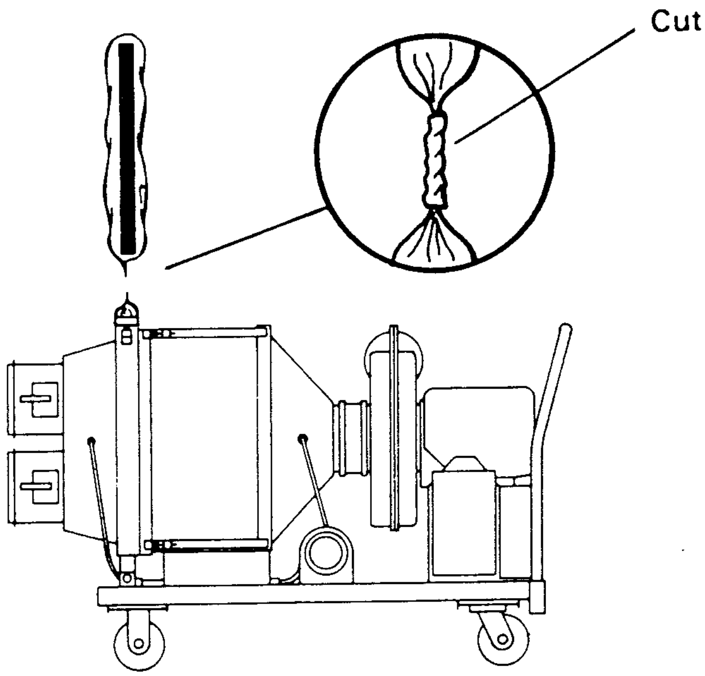
Survey inlet transition internals and decontaminate as necessary. Unfasten latches securing prefilter chamber cover and remove cover. Attach poly bag around chamber opening and secure with tape. Leave enough room for attachment of a second poly bag.

Step 2



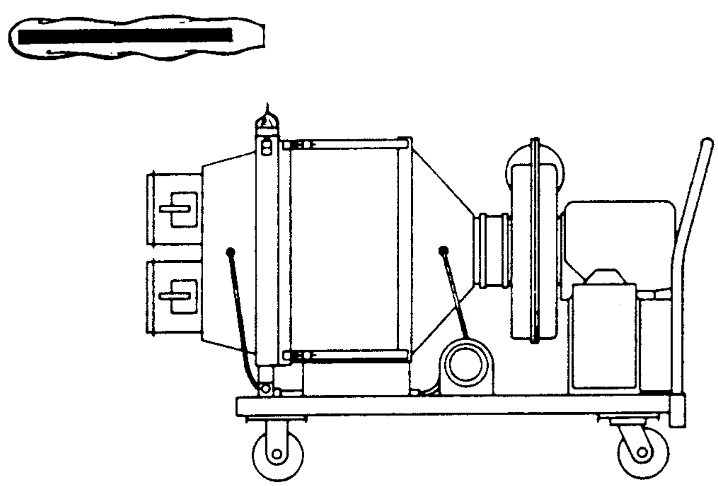
Reach into prefilter chamber through the poly bag, grab onto the removal handle, and pull the prefilter out into the extended bag.

Step 3



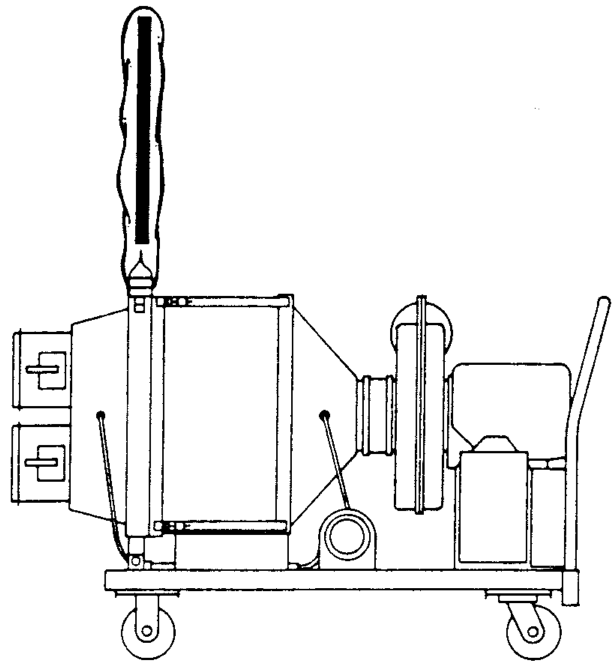
Seal the prefilter in the poly bag by gathering the bag at a point below the prefilter and taping. Cut through the taped joint leaving the end of the poly bag taped to the prefilter chamber opening. Place used prefilter aside for media change-out or dispose of it in accordance with established radiological practices.

Step 4



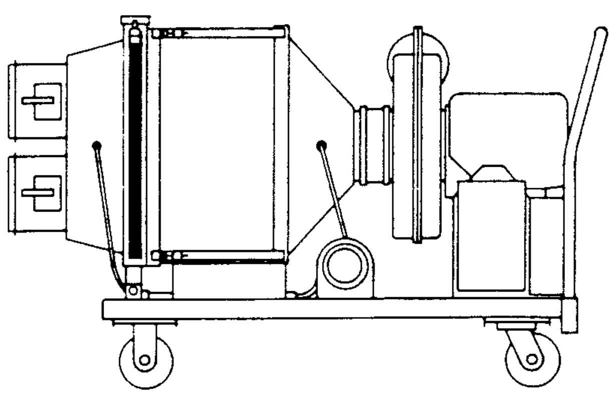
Place a clean prefilter inside a new poly bag.

Step 5



Attach the new poly bag with the new filter around the prefilter chamber opening and secure with tape at a point below the first bag.

Step 6

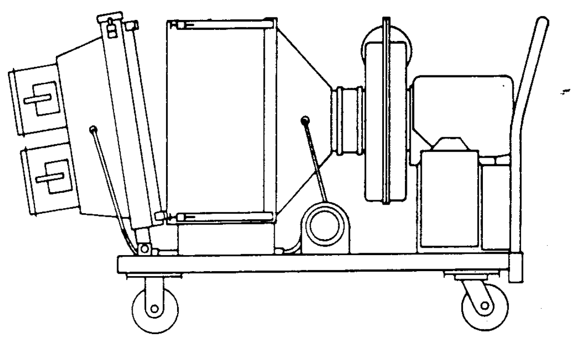


Remove the poly bag remnant from the prefilter chamber opening and place inside the new bag. Insert the new prefilter into the chamber, remove poly bag, and reinstall cover. Secure cover in place by fastening latch assemblies.

HEPA Filter Change-Out
(Models PFCX(H)-500 & PFB(H)-1600 & 2500

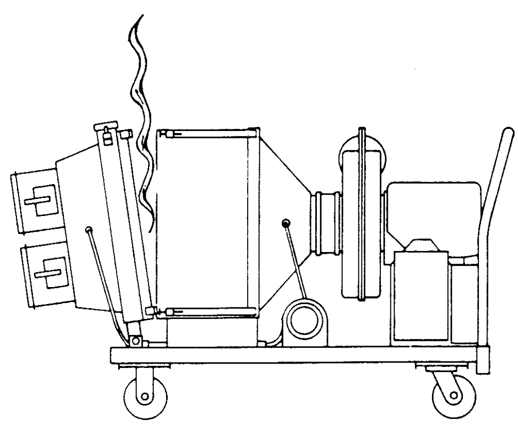
Prerequisite: Ensure prefilter change-out has been completed prior to start of HEPA filter change-out.

Step 1



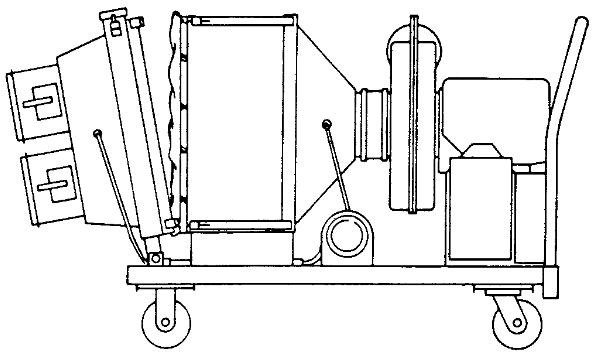
Disconnect unit from power source and carefully loosen the inlet transition mounting bracket bolts and clamp strap assembly T-bolts. Disengage T-bolts and gently pivot transition forward only enough to insert poly sheet.

Step 2



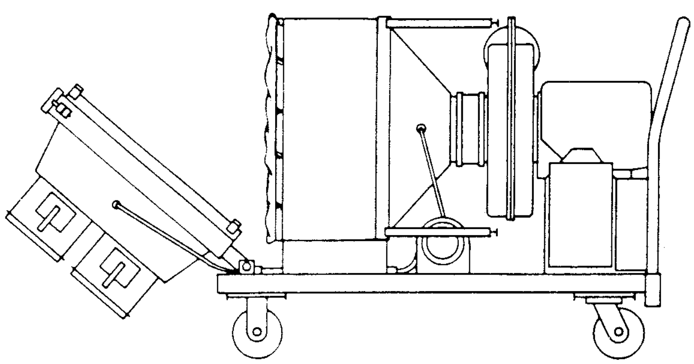
Insert poly sheet into the gap between the inlet transition frame and HEPA filter face. Poly sheet should be large enough to cover HEPA filter and extend over each side for taping. NOTE: When inserting poly sheet, be careful not to dislodge any matter that may be present on the HEPA filter face.

Step 3



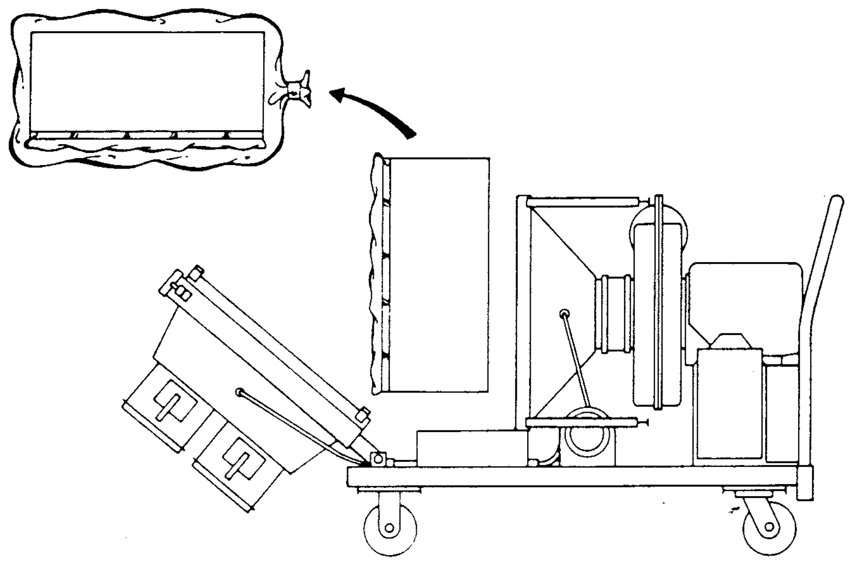
Fold poly sheet over HEPA filter top and side surfaces and seal to HEPA filter frame with tape. Use additional tape as necessary to cover any sharp edges that may rip poly bag packaging later (in Step 5.) Fold bottom flap of poly sheet up against HEPA filter frame and temporarily hold in place with tape.

Step 4



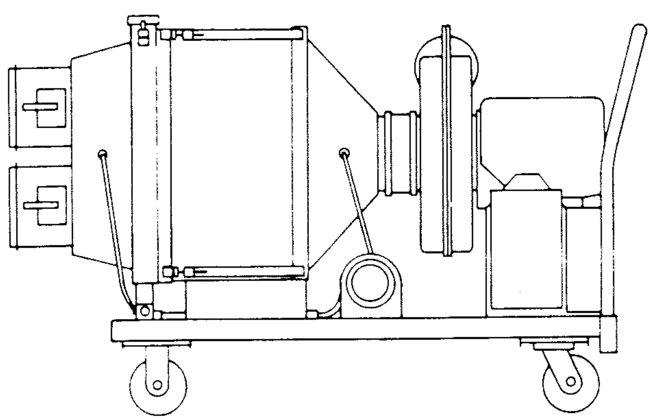
Pivot inlet transition and clamp strap assemblies out of the way, slide HEPA filter forward, and seal bottom flap of poly sheet to HEPA filter frames.

Step 5



Lift HEPA filter off cart platform and place in poly bag. Seal bag and handle in accordance with established radiological procedures. Survey internal surface of outlet transition and decontaminate as necessary.

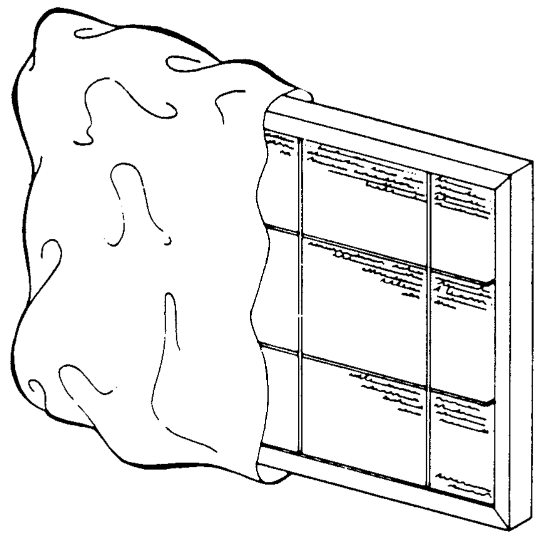
Step 6



Inspect both gasket seating surfaces and clean as necessary. Insert new HEPA filter into place and position transition by engaging and tightening clamp strap assembly T-bolts. Ensure pleats of filter are oriented vertically to prevent sagging of filter media. Tighten transition mounting bracket bolts. NOTE: To prevent filter gaskets from sticking to seating surfaces, it is recommended that the entire face of each gasket be coated with silicone grease (such as DOW Corning Molykote III or General Electric G661) before being installed.

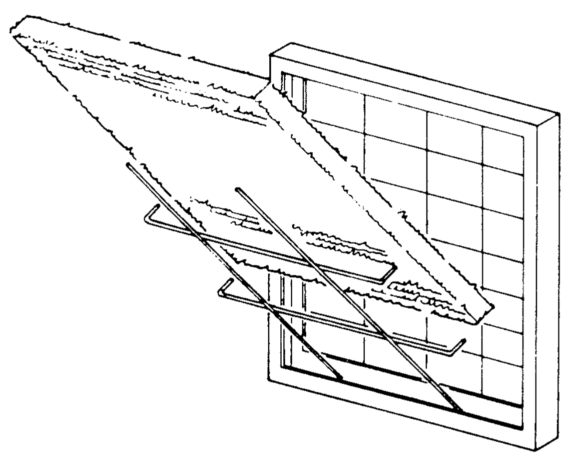
Prefilter Media Change-Out (<u>all models with reusable frames only</u>)

Step 1



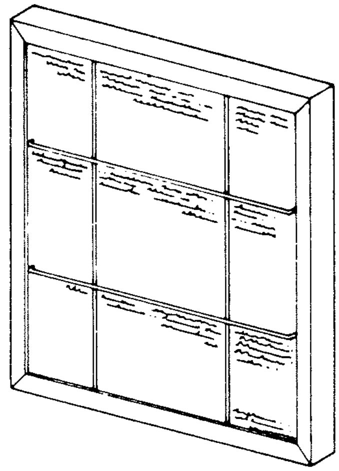
Remove used prefilter from poly bag and place in suitable work area.

Step 2



Disengage retaining grid and swing out of the way. Remove prefilter media, place in poly bag, and dispose of in accordance with established radiological practices.

Step 3



Decontaminate holding frame as required and insert a new prefilter media. NOTE: Ensure that the small mesh side of the media is in the downstream direction (side closest to the wire grid end of the holding frame). Swing retaining grid into contact with the media and engage with holding frame.

References

(a) Nuclear Air Cleaning Handbook, DOE HDBK-1169-2003

(b) ASME AG-1-2009 Code on Nuclear Air and Gas Treatment

(c) Nuclear Power Plant Air Cleaning Units and Components, ANSI/ASME N509, 2002

(d) Testing of Nuclear Air-Cleaning Systems, ANSI/ASME N510, 2007

(e) IEST-RP-CC001.3 / 1.5, 2010, HEPA and ULPA Filters, Institute of Environmental Sciences and Technology

(f) IEST-RP CC008.2, High Efficiency Gas-Phase Adsorber Cells, Institute of Environmental Sciences and Technology

(g) Military Specification MIL-F-51068, Filter, Particulate, High Efficiency, Fire Resistant

(h) Industrial Ventilation, A Manual of Recommended Practice, 26th Edition, American Conference of Government and Industrial Hygienists (ACGIH)

NOTES

RPS

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