than filters which have higher resistances. In most systems, resistance is deliberately added in the form of a perforated plate, pre-filters, or after-filters for the purpose of obtaining a uniform distribution of air. The resistance, including the baffles or after-filters, is constant and generally ranges from 0.15 to 0.25 in. of water at the usual velocities of 300 to 400 fpm. Such plates or filters, however, cannot compensate for defects in the duct layout ahead of the cleaner. Suitable screens of no coarser than 16 mesh should be installed across all outdoor air entrances to prevent insects, leaves, bits of paper, and similar material from entering the cleaner. Where lint is present in appreciable quantities, devices for lint removal should be installed ahead of the cleaner.

Electronic air cleaners of the ionizing type are efficient, low-pressure-drop devices for removing fine dust and smoke particles. They are available in fixed collector-plate and moving collector-plate types. The fixed collector plates are often coated with a special oil as an adhesive. Cleaning is generally accomplished by washing the cells in place with hot water from a water hose or by means of fixed or moving nozzle systems. The bottom of the equipment is made water tight and provided with a drain. In one moving-plate type, the grounded elements on which the dirt collects are mounted so as to form a travelling curtain which intermittently passes through a reservoir containing a fireproof chemical adhesive. The unit is equipped with wipers which remove the collected dirt from the plates. It then settles as sludge in the bottom of the adhesive reservoir from which it is removed periodically.

Electronic Air Cleaners of the stationary plate type are sometimes used without any adhesive treatment on the plates. Under such conditions the precipitator becomes an agglomerator which is followed downstream by a secondary filter, and the dry agglomerates produced in the precipitator are allowed to blow off and be caught by the downstream filter. The use of an automatic replaceable-media filter for catching these agglomerates results in an overall combination which provides a high degree of cleaning efficiency and also the freedom from maintenance associated with an automatic filter of this design. When handling certain types of atmospheric dust, the ionizing wires and struts may require periodic cleaning.

Electrical forces drive all particles to the collecting surface but cannot hold them there. In fact, after a particle touches the collecting surface, the electric force reverses and tends to pull it off, and the dust is held only by adhesion. It is, therefore, very important to be sure that either the dust is naturally adherent or that the plates are always covered with adhesive. The exception is given in the preceding paragraph describing the role of dry plates or agglomerators.

Space Charge

Dust which passes through an ionizer and is charged but not removed carries the electrical charge into the space. If continued on a large scale, this will build up a *space charge* in the space which tends to drive this charged dust to the walls.[14] Thus, an electronic air cleaner which, for any reason, charges but does not remove the dust, can blacken walls faster than if no cleaning device were used.

SELECTION AND MAINTENANCE

To evaluate filters and air cleaners properly for a particular application, two factors should be carefully weighed: (1) the degree of air cleanliness required and (2) disposal of the dirt after it is removed from the air. These factors affect initial costs, operating costs, and the extent of maintenance that will be required. Savings from reduction in housekeeping expenses, protection of valuable property and equipment, ability to carry on dust-free manufacturing processes, improved working conditions and even health benefits, should be credited against the cost of installing and operating an adequate system. The capacity and physical size of the unit required may emphasize the need for low maintenance cost. Operating costs, predicted life, and efficiency are more important than first cost, because air cleaning is a continuing process.

While electronic air cleaners have a higher first cost, they exhibit very high efficiencies in cleaning atmospheric air, due largely to their ability to remove fine dust which shows no gravitational effect. They are equally effective on coolant oil mists from high-speed cutting and grinding machines. System resistance remains unchanged as dirt is being collected, and the resulting residue is disposed of directly to prepare the equipment for further duty. The charged-media type electronic air cleaners are less effective than the ionizing type when compared on an individual test basis. However, they incorporate mechanical filtration with electrostatic precipitation and thus provide the effectiveness of a dry type air filter should an electrical outage occur.

Recent developments in extended surface dry type filters using very fine fiber glass wool webs or other materials, have brought the efficiency of these filters well into the range of the electronic or electrostatic types. First costs of these filters are lower than for electronic types, but higher than for panel types. Operating and maintenance costs are higher than for either panel types or electronic air cleaners. Pressure drop is greater and slowly increases during its useful life. Choice should be based on considerations of both first costs and operating costs as well as the degree of cleaning efficiency.

An advantage of the automatic filters of both the moving-curtain and replenishable-media type is the small amount of attention which they require. Such devices are therefore recommended for consideration where large volumes of air are being handled, where the installation is remote, or where reliable and frequent attention to filters cannot be assumed. The relatively constant pressure drop of this type of filter is also an advantage. The first cost is substantially higher than that of unit filters, but the saving in maintenance cost tends to offset this disadvantage.

Viscous-impingement unit filters do not have efficiencies as high as can be expected from dry types of unit filters, but their first cost and upkeep are generally low. They require more careful attention than the moving-curtain type if the resistance is to be maintained within reasonable limits. If higher efficiencies are required, the dry type filters or electronic air cleaners should be given consideration.

Table 1 lists some applications of various types of filters classified according to their efficiencies (AFI test methods).

FILTER INSTALLATION

Many air cleaners are available in units of convenient size for handling when installing, cleaning, or replacing. Such units are usually designated as unit filters. A typical unit filter may be 20 or 24 in. square and from one to several inches thick, and may be either of the dry or viscous-impingement type. In large systems, the frames in which these units are installed are bolted or riveted together to form a filter bank. Automatic filters are constructed in sections offering two or three choices of widths and generally range in height from 3 to 15 ft in 4 to 6 in. increments. Several sections may be bolted together to form a filter bank.

Air cleaners are commonly installed in the outdoor-air intake ducts of buildings, and generally in the recirculating and bypass air ducts as well. Cleaners are logically placed ahead of heating or cooling coils and other air-conditioning equipment in the system to protect them from dust. The dust arrested by the filters in an air-intake duct is likely to be mostly particulate matter of a greasy nature, while lint may predominate in dust from within the building.

The published performance data for all air filters are based on *straight-through* unrestricted air flow. Filters should be installed so that the face area is at right angles to the air flow whenever possible. Eddy currents and dead air spaces should be avoided, and air should be distributed uniformly over the entire filter surface, using baffles or diffusers if necessary.

Failure of air-filter installations to give satisfactory results can, in most cases, be traced to faulty installation or improper maintenance or both.

The most important requirements of a satisfactory and efficiently operating air filter installation are:

1. The filter must be of ample size for the amount of air it is expected to handle. An overload of 10 to 15 percent is regarded as the maximum allowable. When air volume is subject to increase, a larger filter should be installed.
2. The filter must be suited to the operating conditions, such as degree of air cleanliness required, amount of dust in the entering air, type of duty, allowable pressure drop, operating temperatures, and maintenance facilities.
3. The filter type should be the most economical for the specific application. The first cost of the installation should be balanced against efficiency and depreciation as well as expense and convenience of maintenance.

The following recommendations apply to filters installed with central fan systems:

1. Duct connections to and from the filter should change size or shape gradually to insure even air distribution over the entire filter area.
2. Sufficient space should be provided in front as well as behind the filter to make it accessible for inspection and service. A distance of 2 to 3 feet will be required depending on the filter chosen.
3. Access doors of convenient size should be provided in the sheet-metal connections leading to and from the filters.
4. All doors on the clean-air side should be lined with felt to prevent infiltration of unclean air. All connections and seams of the sheet-metal ducts on the clean-air side should be as airtight as possible. Any filter bank must be caulked to prevent bypass of unfiltered air. This is most important when high efficiency filters are used.
5. Electric lights should be installed in the chamber in front of and behind the air filter.
6. Filters installed close to an air inlet should be protected from the weather by suitable louvers, in front of which a large mesh wire screen should be provided.
7. Filters, other than electronic air cleaners, should have permanent indicators to give a warning when the filter resistance reaches too high a value.
8. Electronic air cleaners should have an indicator or alarm system to indicate when high voltage is off or shorted out.

Safety Requirements

Safety ordinances should be investigated when the installation of an air cleaner of any considerable size is contemplated. Combustible filtering media may not be permitted in accordance with some existing local regulations. Combustion of dust and lint on a filtering medium is possible, though the medium itself may not burn.

ADSORPTION OF VAPORS OTHER THAN WATER

Foreign gases in the atmosphere selectively adsorbed by charcoal include many of the organic gases, some of the gaseous constituents of combustion, alcohols, ketones, and gaseous products of putrefaction.

Charcoals differ widely in adsorptive capacity. Those which have marked adsorption characteristics, such as properly

Table 1 ... Typical Applications of Filters Classified By Efficiency

Efficiency, wt% (AFI)	Efficiency, Dust Spot% (Atmospheric)	Typical Applications and Limitations
35–50	<10	Window air conditioners, protection of heat exchanger from lint accumulations; relatively ineffective on smoke, settling dust, and pollen.
50–70	10–20	Window air conditioners, packaged air conditioners, domestic warm air heating; effective on lint; somewhat effective on common ragweed pollen (generally under 70 percent); relatively ineffective on smoke and staining type particles.
70–85	20–25	Air conditioners, domestic heating, central systems; fairly effective on ragweed pollen (generally over 85 percent); effective as prefilter for final cleanup filters for white room, pharmaceutical, etc.; relatively ineffective on smoke and staining particles.
85–95	25–40	Same as immediately preceding but with greater degree of effectiveness; recommended minimum for make-up air for paint spray; somewhat effective in removing smoke and staining type particulate.
>95	35–60	Effective on finer airborne dust and pollen; reduce smudge and stain materially; slightly effective on fume and smoke; ineffective on tobacco smoke. Used in building recirculated and fresh air systems; some types used in domestic heating and air conditioning; used as prefilters to high efficiency types.
>95	60–85	Effective on all pollens, majority of particles causing smudge and stain, fume, coal and oil smoke; partially effective on tobacco smoke. Used same as for 35–60 percent range but better protection. Some types reasonably effective on bacteria.
100 (Approx.)	85–99	Very effective on particles causing smudge and stain, coal and oil smoke and fume. Highly effective on bacteria. Uses the same as for 60–85 percent group but better performance. Suitable for hospital surgeries, pharmaceutical preparation areas, and controlled areas.[15] Quite effective on tobacco smoke.
100 (Approx.)	99+	This group includes, among others, the DOP rated filters and some electronic types. Electronic types used on general ventilation in special applications. DOP rated types provide the best protection available against bacteria, radioactive dusts, noxious dusts, all smoke and fume; used as clean-up filter with one or two stages of prefilters; suitable for all classes of clean rooms.[16,18]