so far as cleanliness in a house or building is concerned, because much of the finer dust remains suspended in the air and is removed from the building by the circulating air. However, since some of the fine dusts, especially smoke and fume particles, are undoubtedly deposited by means other than settling, such as electrical or thermal precipitation[4, 5] and by contact, the ability to remove small particles is desirable in an air cleaner if it can be obtained at a reasonable cost.

VISCOUS-IMPINGEMENT TYPE FILTERS

The viscous-impingement type of filters consist of relatively coarse media constructed of a suitable fiber, screen, wire, mesh, metal stamping or plates, or a combination of media. The filter may be of the unit type manually-cleaned, the replaceable type, or the automatic moving-curtain type.

The medium in a viscous-impingement type filter is usually a fiber pack for non-automatic types, or a series of metal plates for automatic self-cleaning types. In either case, the medium is treated with a viscous substance, often an oil or grease, called the *adhesive* or the *saturant*, intended to retain dust particles which come in contact with it. Also, in either case, *the arrangement is such that the air stream is* broken up into many small air streams, and these are caused to change direction abruptly a number of times in order to throw the dust particles, by momentum, against the adhesive. Several desirable characteristics of an adhesive for air cleaners of this type are: (1) its surface tension should be such as to produce a homogeneous film or coating on the filter medium; (2) the viscosity should vary only slightly with normal changes of temperature; (3) it should prevent the development of mold spores and bacteria on the filter medium; (4) the liquid should have high capillarity, or ability to wet and *retain the dust at all operating temperatures*; (5) *evap*oration should be slight; (6) it should be fire resistant; (7) it should be odorless.

Various fibrous materials have been used as filtering media in unit filters of the viscous-impingement type. These include glass fiber, steel wool, similar *wool* of non-ferrous metals, wire screen, animal hair, hemp fibers, and other materials. In such filters, the medium is often packed more densely on the discharge than on the approach side, in order to increase the dust-holding capacity. This results in a selective arrestance of dust with the larger particles nearer the approach face. The *arrangement also permits some penetration of lint into* (but not through) the filter, so that the amount of lint which can be tolerated on the filter is also increased. Due to plane surface area the viscous-impingement type filter, however, may be inferior to some dry types if the air carries a high percentage of lint.

The resistance of air filters obviously increases with the rate of air flow through them. Face velocities of about 300 fpm, and resistances in the range from 0.1 to 0.2 in. water, when the device is new and clean, are usual for ventilation system filters.

Filters designated as high-velocity units are also available. In most instances these filters employ a uniform media pack and give best performance at velocities about 500 fpm. Impingement type air filters should hold a substantial amount of adhesive so that the dirt collected by the filter will be retained. The design and construction should also provide a goodly proportion of free space through the media so that high velocities can be used without excessive resistances. The design should assure that the media throughout the thickness of the filter will be effectively utilized and therefore, the filter should be designed to minimize the formation of a clogging dirt mat on the filter face. High-velocity filters are apt to be adversely affected if the amount of lint in the air to be cleaned is excessive.

The resistance of filters increases with dust or lint loading, and it is the resistance due to this cause that ordinarily necessitates servicing. The rate of loading obviously depends upon the amount as well as the kind of dust in the air, and for this reason, periods between servicing cannot be predicted with certainty. Manometers are often installed to measure the pressure drop across filter banks and thereby indicate when the filter requires cleaning. The pressure drop tolerated differs between operators and system designs. The resistance of a filter bank can be kept desirably low by periodically servicing some, but not all, of the units in the bank at one time. It is to be noted that a decline in efficiency may be the limiting factor in filter life rather than increased resistance due to load.

The method of cleaning viscous-impingement unit filters differs for different types of filters and kinds of dust. Much dry dust or lint can often be removed by rapping the filter.

Throw-away filters are constructed of inexpensive materials, and are designed to be discarded after one period of use. The frame is frequently a combination of cardboard and wire.

Cleanable filters usually have metal frames. Various cleaning methods have been recommended including: air jet, water jet, steam jet, washing in kerosene, and dipping in an oil. The last may serve both to clean the filter and add the necessary adhesive.

It is not mandatory that unit filters be removed from their metal frames for cleaning outside of the system. Cleaning of unit filters in place is feasible by means of hot water sprayed from a hose or by means of fixed nozzles to accomplish washing and adhesive application. Where filters are cleaned in place, provision should be made to collect and drain the water so as to prevent leakage from the filter housing.

Moving-Curtain Viscous Filters

Moving-curtain air filters are available in two main types. In one type the filtering medium making up the curtain is considered "permanent" and means are provided to remove the dust from the curtain mechanically. In the other type the curtain consists of a roll of viscous-coated fibrous filter medium which *is not permanent* but which is replaced after accumulating its dust load. Filters with moving cloth media, not viscous coated, are available essentially for lint removal.

The medium in the permanent, mechanically cleaned, moving-curtain type consists of a series of specially formed metal plates mounted on a pair of chains. The chains are mounted on sprockets located at the top and bottom of the filter housing, so that the filter medium can be moved as a continuous curtain up one side and down the other side of the sprockets. The arrangement is such that, at the bottom, the medium passes through a bath of special oil which both serves to remove the dirt from the plates, and acts as an adhesive when the cleaned plates next pass through the air stream. The plates forming the filtering medium or curtain usually overlap each other, and due to their special shape, form many small air passages between them. These air passages turn abruptly one or more times in order to give the impingement effect.

The medium in the replaceable moving-curtain type filter is supplied in roll form, one roll being sufficient for one to two years of operation in typical applications. The medium forming the moving curtain is unrolled from the supply roll

at the top, is moved down across the air stream where its dust load is accumulated, and then is rewound on a roll at the bottom. Replacement is accomplished by inserting a clean roll of medium at the top and disposing of the loaded dirty roll. In typical replacement medium, moving-curtain filters a signal is provided to indicate the end of the medium roll has reached the airstream. Usually provision is also made to stop the automatic curtain-moving mechanism before the end of the curtain is reached.

An electrically driven rotating device is usually supplied with a moving-curtain filter. The device may be set to move the curtain periodically, or a special switch, actuated by pressure drop, may be used to govern its motion. In operation, the resistance of an automatic filter will remain approximately constant as long as proper operation is obtained. A resistance of ½ in. water at a face velocity of 500 fpm is typical of this class.

DRY AIR FILTERS

The media in dry filters are usually fabrics or fabric-like materials. Media of wool felt, cotton batting (both glazed and unglazed), cellulose fiber, and other materials have been used commercially. The medium in a filter of this class is usually supported by a wire frame in the form of pockets or V-shaped pleats in order to increase the area exposed to the passage of air. A 2-ft-square unit may contain from 15 to 30 sq ft of medium.

Dry air filters, by virtue of the large area of medium used, have a comparatively high lint-holding capacity. The efficiency of dry type filters is usually higher than that of viscous impingement filters, while the life of the former based on dust-holding capacity, may be lower. Dust tends to clog the fine pores or openings of dry filters more quickly, thereby causing a higher rate of resistance rise than for viscous impingement filters. Efficiency with very fine particles equivalent to that of electronic air cleaners is not uncommon with certain types of dry filters. A comparatively deep bed, ½ to 1 in. thick, of filtering media having individual fibers in the order of 1 micron in diameter, is required for such high efficiency.

Dry filters may consist of a cleanable medium held in permanent frames, or a throw-away or replaceable filtering medium held in permanent frames, or the entire filter may be of the throw-away type. Usually the filtering medium alone is replaced after having collected its full dust load.

ELECTRONIC AIR CLEANERS

Two principal types of electronic air cleaners are available for air filter application: (1) ionizing type collectors where particles are given a definite charge by passing through an ionization zone, and (2) charged-media type collectors where the energized collecting medium induces a charge on the particles.

Ionizing Type Electronic Air Cleaners

Electronic air cleaners use electrostatic precipitation principles to collect particulate matter (see Fig. 1) but operate on much lower voltages than the type commonly used on industrial stacks. The *designation* Electronic Air Cleaner has been standardized to distinguish the class of electrostatic precipitator which alone is suitable for cleaning ventilating air.

In a typical case, a potential of 12,000 volts may be used to create the ionizing field, and some 6000 volts between the plates upon which the precipitation of dust occurs. These voltages, which are capable of momentary shock to personnel similar to that of a spark plug, necessitate some safety measures. A typical arrangement provides means for making the equipment inoperative when any door affording access to high-voltage parts is opened. Operation can be resumed only after all doors are closed. The voltages necessary for operation of the equipment are usually obtained by means of electronic high-voltage direct-current power packs operating from a 110–120 volt, 60-cycle, single-phase building service. Electric power consumption is about 10 watts per 1000 cfm, plus the approximately 40 watts required to energize the rectifier tube heaters.

Air cleaners of this type offer negligible resistance to air flow and, therefore, care must be exercised in arranging the duct approaches on the entering and leaving sides of the cleaners in order that the air flow may be distributed uniformly over the cross-sectional area. The efficiency of the electronic air cleaner is sensitive to air velocity, and the device itself has much less tendency to rectify the air stream 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.

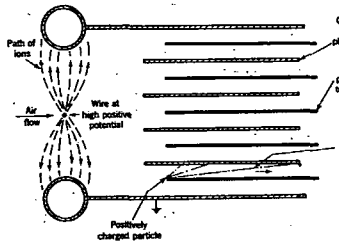

Fig. 1 . . . . Diagrammatic Cross-Section of Ionizing Type Electronic Air Cleaner

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