AIR FILTRATION

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1. GENERAL

1.01 This section discusses and provides standards for air filtration. These standards are provided for use in the design of new buildings or building additions that are intended to house telephone equipment that meets the requirements of Bell System Practice 800-610-164, "New Equipment-Building System (NEBS), General Equipment Requirements."

1.02 This section is being reissued to correct Table D. Change arrows have been used to denote information added or changed in this issue.

SCOPE

1.03 This section lists and discusses standards for air filtration in heating, ventilating, and air-conditioning systems installed in central office buildings. These standards are intended primarily for use in the design of new buildings or building additions for housing telephone equipment that meets the requirements of Section 800-610-164, "New Equipment-Building System (NEBS), General Equipment Requirements."

1.04 This issue contains new information about medium filters, references performance specifications for filters, and includes new guidelines for selecting filter systems that are related to the characteristics of the local environment.

2. EQUIPMENT MALFUNCTIONS DUE TO AIRBORNE CONTAMINANTS

2.01 Airborne particles can cause expensive malfunctions in Central Office equipment. Typical problems are the blocking of electrical contacts, leakage across insulating surfaces, and the corroding of metal surfaces. The ionic, liquid, and gaseous pollutants absorbed on airborne particles contribute to the degradation of equipment. Examples of central office equipment failures traced to dust and other airborne particles in various parts of the country are listed in Table A.

TABLE A

TYPICAL DUST-RELATED FAILURES OF CENTRAL OFFICE EQUIPMENT

TROUBLE REPORTED	LOCATION
Cracked relay springs	California
Sticking translator cards	Illinois
Film formation and metal pitting	New Mexico
Cracked jack springs	New York
Magnetic tape data errors	New York
Open sender-link contacts	Ohio
High crossbar contact resistances	Pennsylvania
Open SXS switch contacts	Connecticut

2.02 Above certain critical levels of humidity, each foreign particle on a metal surface acts as a center for moisture condensation and soaks the surface with the corrosive materials absorbed from the air. Fine particles of less than 1 or 2 microns collectively form large absorption surfaces for pollutants; such particles are responsible for most equipment soiling.

2.03 Dusts and aerosols vary widely in size and composition from location to location. Examples of those originating outside a facility are: fly ash, fragments of coke and other unburned fossil fuels, carbon black, iron oxide, quartz, silicates, and plant fibers. Examples of those originating inside a facility are (in addition to some of the above): textile, glass and paper fibers, chalk dust, paint fragments, particles from office copying machines, and miscellaneous organic debris originating from human activity in the building, such as lint and epidermal scale.

2.04 One noteworthy case of equipment malfunction caused by dust occurred at a 4M toll office. Thick layers of dust had accumulated on all of the equipment—even on flat spring relays enclosed in cabinets. Dust "trees" bridged the crossbar springs and contacts, as shown in Fig. 1. The use of apparatus cleaners had been discontinued years before, and no routine cleaning had been done since then. Individual troubles were corrected by burnishing contacts and blowing the loose dirt off; however, this latter practice is successful only if the BSPs for pressure cleaning are followed. Cleaning apparatus in this very dirty condition in this way usually results in a temporary increase in trouble rates at first. After a week or two the troubles should decrease to a satisfactory level and remain there.

Fig. 1—Dust Particles on Crossbar Switch Preventing Conduction Through Contact Pairs

3. AIR FILTRATION SYSTEMS REDUCE MALFUNCTIONS

3.01 Table B points up how effective air filters in a Central Office are in reducing the frequency of malfunctions. Studies of the corrosive action of dust on various metals used in telephone equipment (Fig. 2) show that filters that prevent coarse dust from settling out can drastically reduce tarnish rates, particularly on nickel and brass. High-efficiency filters and humidity controls offer additional protection to telephone equipment.

TABLE B

EFFECT OF AIR FILTERS ON EQUIPMENT PERFORMANCE IN A CENTRAL OFFICE

	TOTAL CONTACT TROUBLES	TROUBLES PER 100 LINES
Year prior to air-conditioning	945	10.10
One year after air-conditioning	313	4.77
Third year after air-conditioning	195	2.12

3.02 Both coarse and fine dust particles cause equipment troubles. Coarse particles are those desposited by gravity on horizontal surfaces; fine particles are those deposited independently of gravity on any surfaces. Most of the particles in a typical dust mixture are fine particles, while practically all of the mixture's weight is attributable to coarse particles. Fig. 3 shows a representative distribution of particles in the atmosphere.

3.03 Although many filters remove coarse dust particles effectively and have high efficiencies when rated by the weight percentage of dust removed from the airstream (arrestance), they do not materially reduce the number of fine particles. Since most discoloration of walls and ceilings in buildings is caused by fine particles, the cleaning effectiveness of a filter that concentrated on arresting coarse particles would be nil.

4. MECHANICAL FILTERS

4.01 Filters generally are classed as either primary, medium, or high-efficiency types. A primary

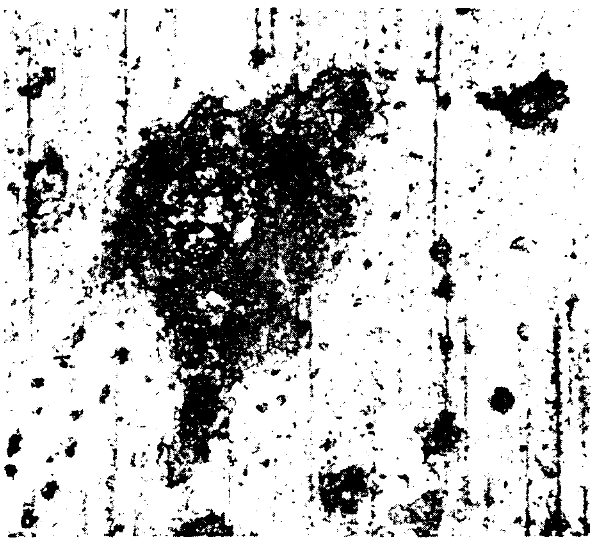

Fig. 2—Corrosion After 21 Days at 70°F and 75% R.H. of Clean Phosphor Bronze Surface by Dust Particles. Dust Sample Taken from ESS Office Magnification X200.

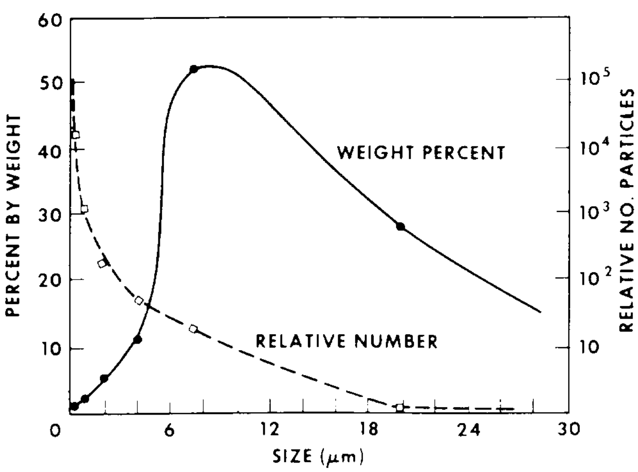

Fig. 3—Plot of Representative Particle Distribution in Atmosphere. Particles Below 2 Micrometers in Size Account for Small Percentage of Weight of Total Particles but Over 99% of Total Number. Such Fine Dusts are Responsible for Most Equipment Soiling.

filter is an inexpensive device that will remove larger particles from the air supply effectively or is used as a "roughing" filter or "prefilter" ahead of a high-efficiency system to prevent too rapid loading of these more efficient filters. Medium-efficiency filters (those having about a 30 to 60 percent "dust-spot" rating) do not offer much advantage over the better primary filters and generally are not recommended except where they can be used as direct replacements for low-efficiency primary types without modification of existing systems or standard KS-7406 installations.

4.02 The American Society for Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) rates filters either by weight percentage of a test dust removed (arrestance) or by dust-spot efficiency. Arrestance is used for primary filters; efficiency values usually fall between about 50 and 75 percent. The dust-spot values for primary filters range from about 8 to 15 percent. KS-7406 filters have at least 75 percent minimum arrestance and are better than most of the other "throw-away" types. High-efficiency filters are rated only by the dust-spot method; their efficiencies may be as high as 95 percent. Fig. 4 indicates the efficiencies of various filters graphically.

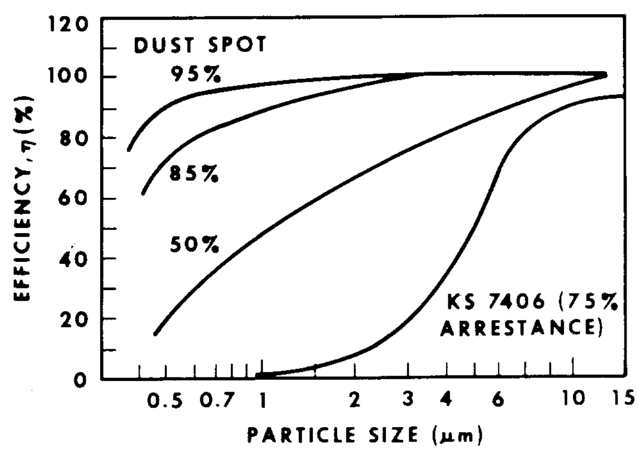

Fig. 4—Plot of Filter Efficiency vs Particle Size for High and Low Efficiency Filters

4.03 The performance differences of medium and high-efficiency filters depend on the amount and configuration of filter medium. The configuration restricts the flow of air entering and leaving the filter; this resistance, which remains constant for the filter's life, is the major loss factor. The better filters have a configuration loss of less than 0.25 inches of water at design flow rates. Performance loss also depends on the amount of filter medium and continues to increase as the filter becomes loaded with dust. Therefore, the overall resistance to air flow increases as the filter loads up with dust. At some critical load, sudden unloading will occur and the accumulated dust will pass into the office.

4.04 The low-efficiency or primary air filter types are rated by an ASHRAE arrestance value which, for the KS-7406, has an average of at least 75 percent. The ASHRAE atmospheric dust spot (D.S.) rating of this type is generally lower than 12 percent. The medium or intermediate-efficiency filter types have an ASHRAE D.S. rating of 30 to 60 percent. These filters are more effective against particles in the 2 to 5 micron size range. The third type, the high-efficiency filter, has ASHRAE D.S. ratings of 82 percent or higher. Such filters are effective for fine particles of 0.5 micron size or larger. All of these types of filters remove dusts and other aerosols from the air stream but do not remove vapors or gaseous contaminants.

A. Type I Filters (Primary)

4.05 The standard Bell System primary filter is the KS-7406 which commonly has glass fiber media enclosed in a rigid cardboard frame and supported between perforated thin metal sheets or wire screening. These KS-7406 filters are superior to the average glass "throwaway" filter. Sometimes two 2-inch filters are put together to give 4 inches of filtering media. This arrangement is not recommended since it does not do a better cleaning job than one thickness yet is more costly and difficult to change filters. Even worse, the arrangement is wasteful of energy needed for the air-conditioning fans. Dimensional variations and poor fits in the holding frame leave gaps around the edges which allow unfiltered air to bypass the filter. Air bypass problems are overcome by internally self-supported filters which have a wire loop frame embedded in the media (Fig. 5). The media are usually a synthetic polyester fiber or a mixed polyester and glass fiber. The selvage of excess media is compressed against the holding frame when placed in position, thus sealing any bypass paths. This type of primary filter can be put into present KS-7406 installations. Only a single thickness of filter is required. Normally, the compression of the selvage and the pressure of the air flow are enough to keep the filter in place, but the filter could be secured with shims if necessary. Internally self-supported media types would be particularly advantageous for side-loading filter installations. The filter units can be flexibly linked together so that a row of them might be inserted into the side holder without leaving the gaps for bypass air that frequently result when conventional glass fiber "throwaway" units are used in such an installation.

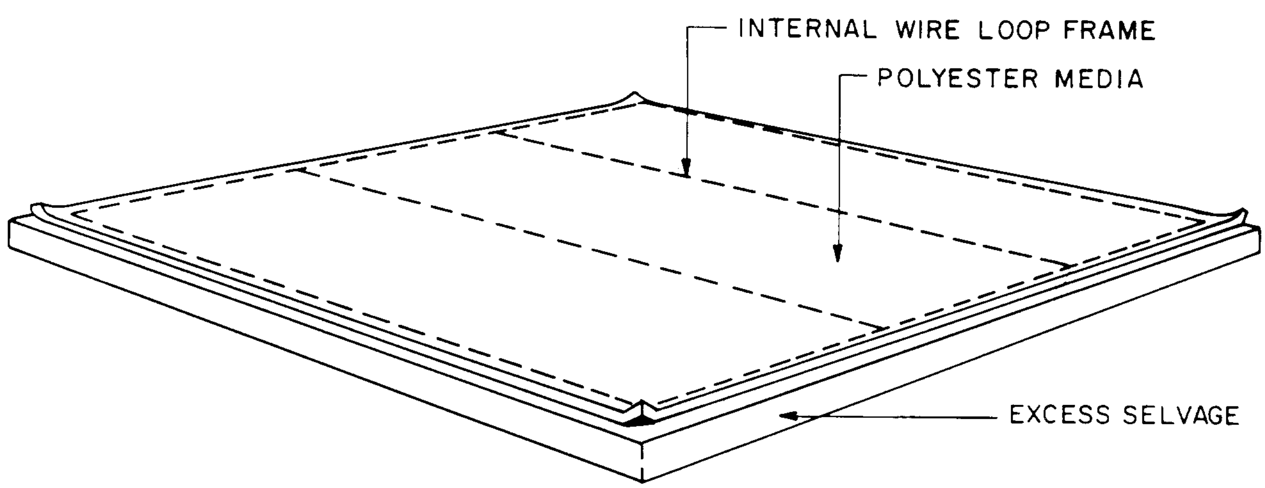

Fig. 5—Internally Supported Filter

4.06 There are other advantages associated with internally supported primary filters. Although they may be slightly more expensive, field studies indicate that they have a longer service life. ➧Moreover, the total installed cost may be less since only one thickness is used. The labor costs are less because of the ease with which replacement is made.➧

4.07 The pressure drop across the internally supported synthetic media filters as they become loaded with dust behaves differently from that of a conventional glass fiber filter. The increase in pressure drop is more gradual and does not tend to rise precipitously toward the end of service life. These new filters should be changed either when the pressure drop across the filter, measured at the same air flow rate as on the new filter, has increased by 0.4 inch of water or after a year if the pressure drop has not yet increased by that amount. ➧The 1-year life limit is recommended to prevent unloading of the filter during operation.➧

4.08 Type I primary filter media is also available in the form of rolls under the KS-7406 specification. This type media is employed in roll filters that are advanced manually or automatically. They sometimes find application either in large multistory buildings where one is located on each floor or in remote and unattended facilities. They are an acceptable primary filter assembly and require the same attention and provide the same limited filtration as "throwaway" units. Special attention should be given to the end-of-life period of automatic roll type filter assemblies to avoid a period when the media is stopped and overloading can occur or actually breaks and primary filtration ends altogether. ➧Tension of the filter media must be controlled to prevent necking of the media which prevents air bypass at the edge of the filter media.➧

B. Type II Filters (Intermediate or Medium)

4.09 There are two versions of intermediate or medium efficiency filters in general usage. The first is a pleated media filter (Fig. 6) having the same dimensions as the KS-7406, L1 and L2 filters that will fit installations designed for these KS types. It has an ASHRAE D.S. efficiency of 30 percent or more. The pleated media filter can replace glass or synthetic fiber units when the latter are not sufficient to provide satisfactory air quality in dirty environments. In cases where the KS-7406 filter is not adequate and the expense of installing a system for a higher efficiency system is not justified, the pleated media filters will be advantageous.

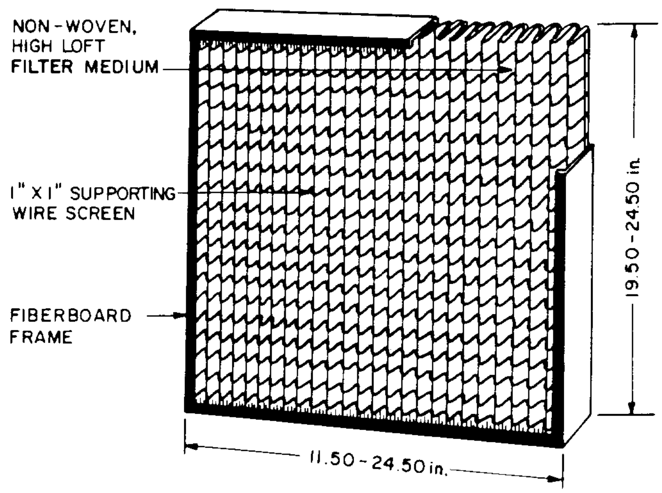

Fig. 6—Internally Supported Filter with Pleated Cotton Media

4.10 Unfortunately, this type of filter still has the rigid outer frame that the glass fiber "throwaways" have. Care must, therefore, be taken to seal edges and gaps between the units with tape or stripping if the filter frame does not have a sealing strip of its own. These filters are somewhat more expensive than primary filter types, but they cost less than other medium and high-efficiency filters that would require new holding frame installations as well. Note that pleated media filters are normally used without prefilters.

4.11 Field studies in the Monongahela office of Bell of Pennsylvania have confirmed the usefulness of these pleated media filters, and they are approved for Bell System usage where better air filtration than that provided by a Type I Filter is needed, but a Type III high-efficiency installation is not justified. In locations with prefilters and filters where the after filter is a field-loaded frame type in the medium efficiency range, the pleated media type can be used in place of both sets.

4.12 The second kind of Type II medium-efficiency filter comprises those filters which have ASHRAE D.S. ratings of 25 to 70 percent and will not fit a KS-7406 holding frame installation. There is wide variety in the construction and design of these filters. Many require unique holders that preclude the use of different filter brands. There are no particular advantages in using this second kind. However, if a system is giving satisfactory service, as shown by lack of dust and dirt problems in the office and by satisfactory equipment operation, it should be continued in service.

C. Type III Filters (High-Efficiency)

4.13 The third general type consists of the high-efficiency filters that have ASHRAE D.S. ratings greater than 80 percent. They are usually divided into two groups: "85" percent filters having an ASHRAE D.S. rating of about 80 to 88 percent; and "95" percent filters having ASHRAE D.S. ratings of 90 percent or higher. These are either the "supported" designs that may have a rigid construction or have the media fitted over wire basket supporting frames, or else the "nonsupported" designs, that are also called "sock" or "bag" filters. In the case of the latter, the media are held in position by the pressure of the air flowing through the filter. The different constructions of these two groups of Type III filters are illustrated in Fig. 7 and 8.

4.14 Basket supports for different brands of filters vary, thus restricting the choice of manufacturers. The nonsupported filters of different manufacturers will usually fit the same holding frames. If there is sufficient plenum depth, deeper nonsupported filters with higher dirt holding capacity can be used, providing the fan system has sufficient static pressure capacity. This may decrease the filter resistance without changing the installation. Use of face velocities and CFM rates below maximum design levels will give lower pressure drops through the filters which would save energy and provide longer filter life between filter changes. Filters in these two efficiency ranges can be interchanged if the air quality considerations demand or allow it. Because the holding frame installation for a "nonsupported" bag filter (Fig. 8) allows a greater flexibility in choosing filters, we recommend that they be used for new installations, other factors being the same.

4.15 Craft people should be aware of some precautions when working with Type III higher-efficiency filters. The media are very delicate and can be torn if care is not taken when filter units are replaced. With both the "supported" and "nonsupported" designs, there may be gaps that allow bypass air between the filter's frame and the holder's frame. Such gaps must be filled by tape or stripping if the full effectiveness of the installation is to be obtained. The media of the "nonsupported" designs are apt to wear away at the front of the bag if the bags flutter excessively in the air stream. The bags of these "nonsupported" designs should be kept from collapsing at low flow rates either by loops on their ends which hook over a support rod or by some other means.

4.16 Filters should be operated under the conditions recommended by their manufacturers. Normally, higher-efficiency filters should be changed when the pressure drop across them increases by 0.5 inches of water at the same air flow conditions as were present when they were installed. Where manufacturers recommend other criteria, these should be taken into account in the operation of the installation. Type III high-efficiency filters should normally have Type I as prefilters. The pressure drop across the prefilter should be measured independently of the high-efficiency filter banks so that the prefilters are changed at the proper times.

5. FILTER INSTALLATION AND MAINTENANCE

5.01 Proper filter installation and maintenance are important. Filters must be set rigidly and properly in their frames to eliminate any openings through which air can bypass the system. Fig. 8 illustrates a typical high-efficiency filter. When this type of filter is installed, the filter bags must be fully open and checked for rips or holes. Damaged filters must be replaced. Filters should be installed so that excessive vibration is avoided.

5.02 The manufacturer's instructions should provide guidelines for filter maintenance. In general, as filters become loaded with collected dust and dirt, their resistance to air flow increases to the point at which they should be changed. This point is determined by measuring the pressure drop across a filter and comparing this value with the maximum allowable pressure drop, designated by the manufacturer, at which the filter can operate. Relatively simple gauges are available for this purpose. The pressure drop of "panel" filters should be measured weekly; the drop across other types of filters should be checked about once a month. Typically, the annual operating cost is about 2-1/2 times the initial cost of the filters.

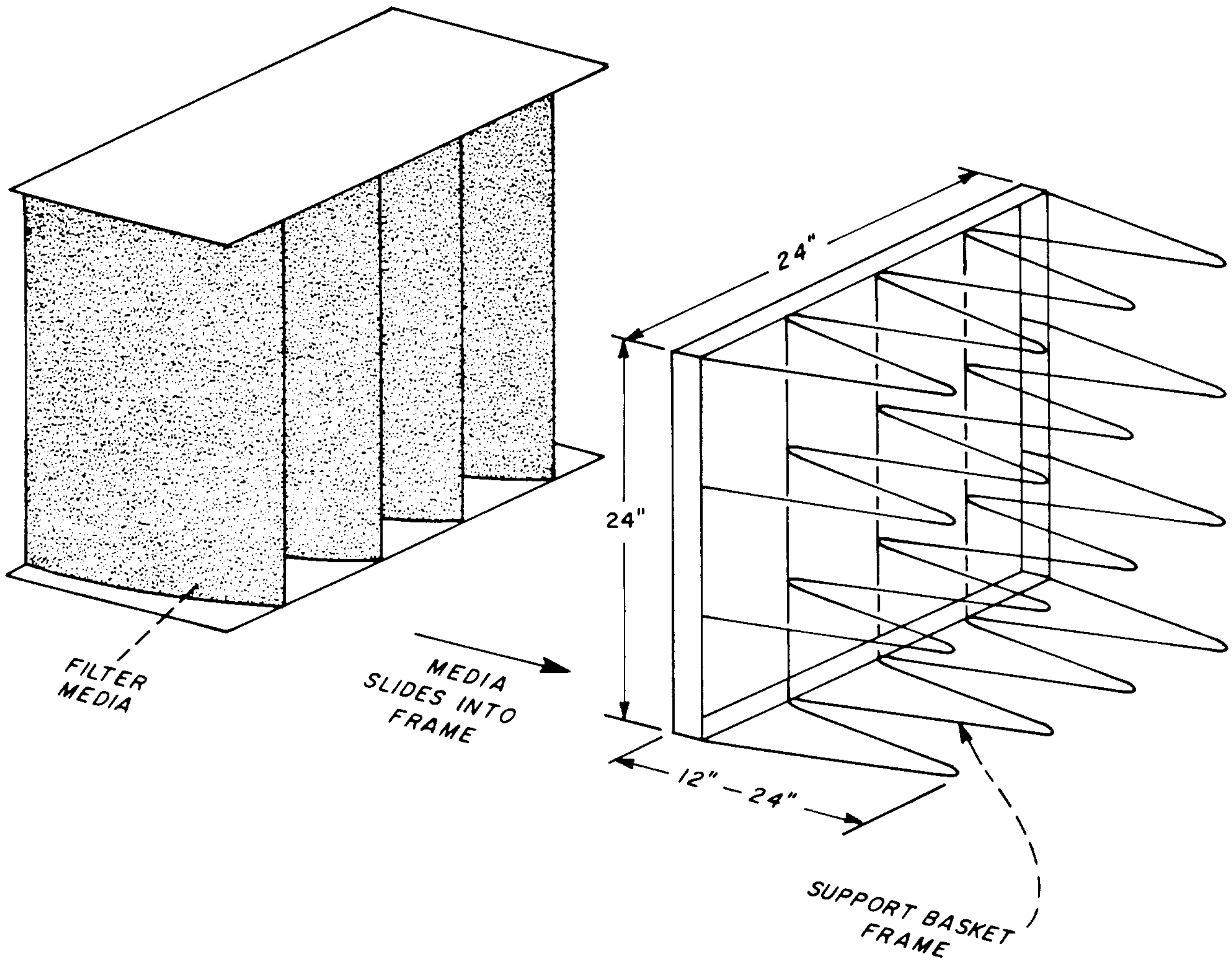

Fig. 7—Supported Filter

6. ELECTROSTATIC AIR FILTERS

6.01 High efficiencies in air filtration can be achieved without electrostatic filters, although electrostatic filters may be needed at locations where extremely large dust concentrations in the air would make it necessary to replace mechanical filters very often. "Prefiltering" with Type I filters is required because with electrostatic air-filters, large particles or flying insects may cause short-circuiting and snow or fine rain may cause electrical malfunctions. In electrostatic air cleaners, dust collects on adhesive-coated plates and must be washed off at intervals. In an electrostatic agglomerator filter system, dry plates are used; the particles that are collected are allowed to blow off into the air stream, where they are captured by storage filters. Because the agglomerated particles are much larger than individual particles, they tend not to clog the filter media as much; this may double or triple the filter's life.

6.02 Electrostatic filters are to be used only where they are absolutely necessary. ➧Their initial cost is always higher than that of mechanical filters, proper maintenance is critical to performance and precautions must be taken to prevent their high-voltage discharges from harming equipment, particularly memory and tape units.⬅ Shielding can be installed, for example, to keep the level of radiation from these high-voltage discharges within allowable limits at equipment sites. The ➧electro-magnetic⬅ radiation being emitted from electrostatic filters must be measured close to the filters and within the air ducts. For the procedures used to measure radiation, see Section 760-220-100,

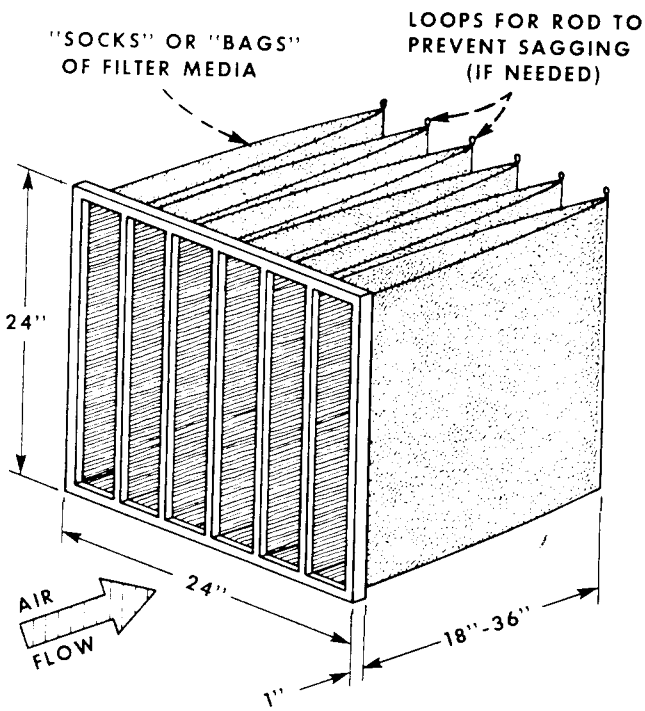

Fig. 8—High-Efficiency Filter for Removal of Fine Dust (Nonsupported Type III)

RFI Shielding and Section 760-220-110, EMP Shielding. If electrostatic filters are to perform satisfactorily, they must be maintained properly, and their operating conditions must be held closely to specifications.

7. AIR INTAKE CONSIDERATIONS

7.01 A knowledge of air circulation patterns in "street canyons" can help determine the best locations for air intake ducts in urban Central Offices. A typical corner building located where building height and street width are similar and where the mean wind direction is parallel to one of the two streets is shown in Fig. 9(A). The form of vortex development is shown in the side view, Fig. 9(B). The vortex creates significant differences in pollutant concentrations within the street canyons; concentrations of motor-vehicle pollutants at point 1 may be 10 times as high as concentrations at point 2, while concentrations at point 3 should be somewhere between these two extremes. The plan view, Fig. 9(A), shows the relative concentrations of pollutants—the longer, closely spaced lines indicating higher concentrations. From this it is evident that point 4 would be a better location for an air duct than point 1. Either of the two points 5 would be still better, provided that parking lots or building exhaust or stacks from adjacent buildings were not located near the intakes.

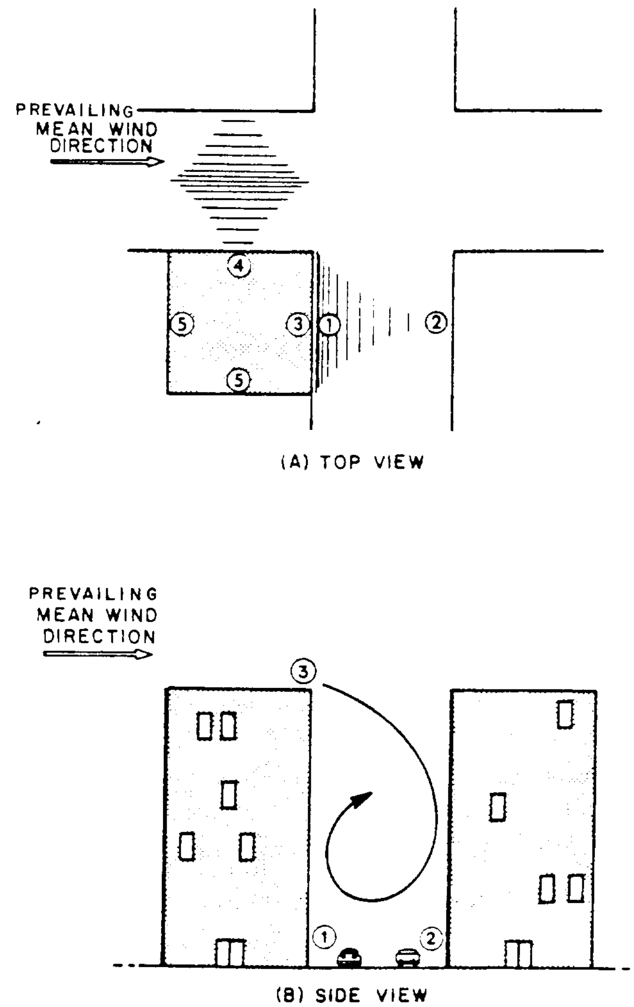

Fig. 9—Air Patterns at a Typical Urban Building

7.02 In many urban areas, sulfur dioxide is a major pollutant. Since sulfur dioxide usually is released into the atmosphere from stacks or ducts near the tops of buildings, some modification of the above analysis of street-canyon circulation may be necessary. Placing intake ducts midway up a building wall may be an acceptable compromise.

8. GASEOUS POLLUTANTS ARE NOT REMOVED BY FIBER FILTERS

8.01 In some areas of the country, such as those near large industrial operations, high concentrations of gaseous pollutants can cause problems of equal or greater severity than airborne particles; they can corrode equipment surfaces and relay contacts severely.

8.02 Gaseous pollutants usually are removed by activated carbon filters placed downstream of a high-efficiency filter. A typical tray-type unit with a capacity of 2000 cfm will have a pressure drop of 0.35 inch WG. A serpentine cell unit will have a pressure drop of about 0.20 inch WG.

8.03 It is desirable, of course, to avoid locating a telephone building in a contaminated environment, but considerations other than air pollution usually govern the selection of a site. If possible, building sites should never be located within a mile of an upwind pollution source. For those that must be so located, the building engineer must plan from the beginning for adequate air filtration.

8.04 The gaseous pollutants considered to be potentially most damaging to telephone equipment are sulfur dioxide and hydrogen sulfide. The three maps in Fig. 10 show the areas in the continental United States with high concentrations of these sulfur containing gasses. Sulfur dioxide results principally from industrial fuel combustion, hydrogen sulfide from "sour" crude oil and the manufacture of kraft paper. Nitrogen oxides from motor vehicles may form nitrate aersols in the environment. These aersols can be removed by high-efficiency filters.

8.05 The procedures for gaseous filtration are complex and differ with different gases. A study of the carbon filters being used at the microwave relay station at Artesia Junction, New Mexico, showed that they have been reducing the sulfide gas level in the station's air supply by over 83 percent. Each location has its unique problems; however, it is recommended that such specific problems be referred to the appropriate building engineering consultants.

9. ENERGY REQUIRED FOR FILTRATION

9.01 The percentage of total air-system energy required for the filtration portion of a central office air-conditioning plant is usually less than 10 percent. The watt-hour requirement for a typical filter system WH, can be determined by the relationship

$$WH = 0.24\ QSPT$$

where

Q = quantity of air to be filtered, cfm;

SP = static pressure; the energy required to move the specified quantity of air through the filter bank; also called filter resistance, inches of water

T = time, hours.

It can be found from the above relationship that the average cost of filtering 1600 cfm of air with KS-7406 filters is similar to the cost of operating a 150-watt light bulb. Since the energy and the cost required to operate the filter are directly related to the filter's resistance to air flow, special attention should be given to both the initial resistance and the resistance change during the life of the filter.

9.02 The relatively low energy requirements for all types of filter systems make it particularly advisable to maintain high filtration standards. This will produce significant benefits from improved equipment and building performance. ➧Efficient air filtration systems keep building interiors clean, one result of which is that ceiling illumination is increased by as much as 10 percent in a properly filtered environment. Also, because efficient systems allow the use of outside air in place of refrigeration for cooling, they can maintain proper environmental conditions at a significant saving in cost and energy.➧

10. FILTER SYSTEM SELECTION

10.01 The design of the filter system should be based on an assessment of the contaminating characteristics of the local exterior environment, the required interior environment, and the overall economics of the system during operation. The relatively low cost of filtration systems compared to the losses that can occur through service impairment or equipment malfunction resulting from contamination greatly diminish the economic considerations. For all building projects, filtration system expense is entirely acceptable although, naturally, attention should be directed to obtaining a quality filtration system at least cost.

10.02 Central office equipment designers have been advised that all equipment must

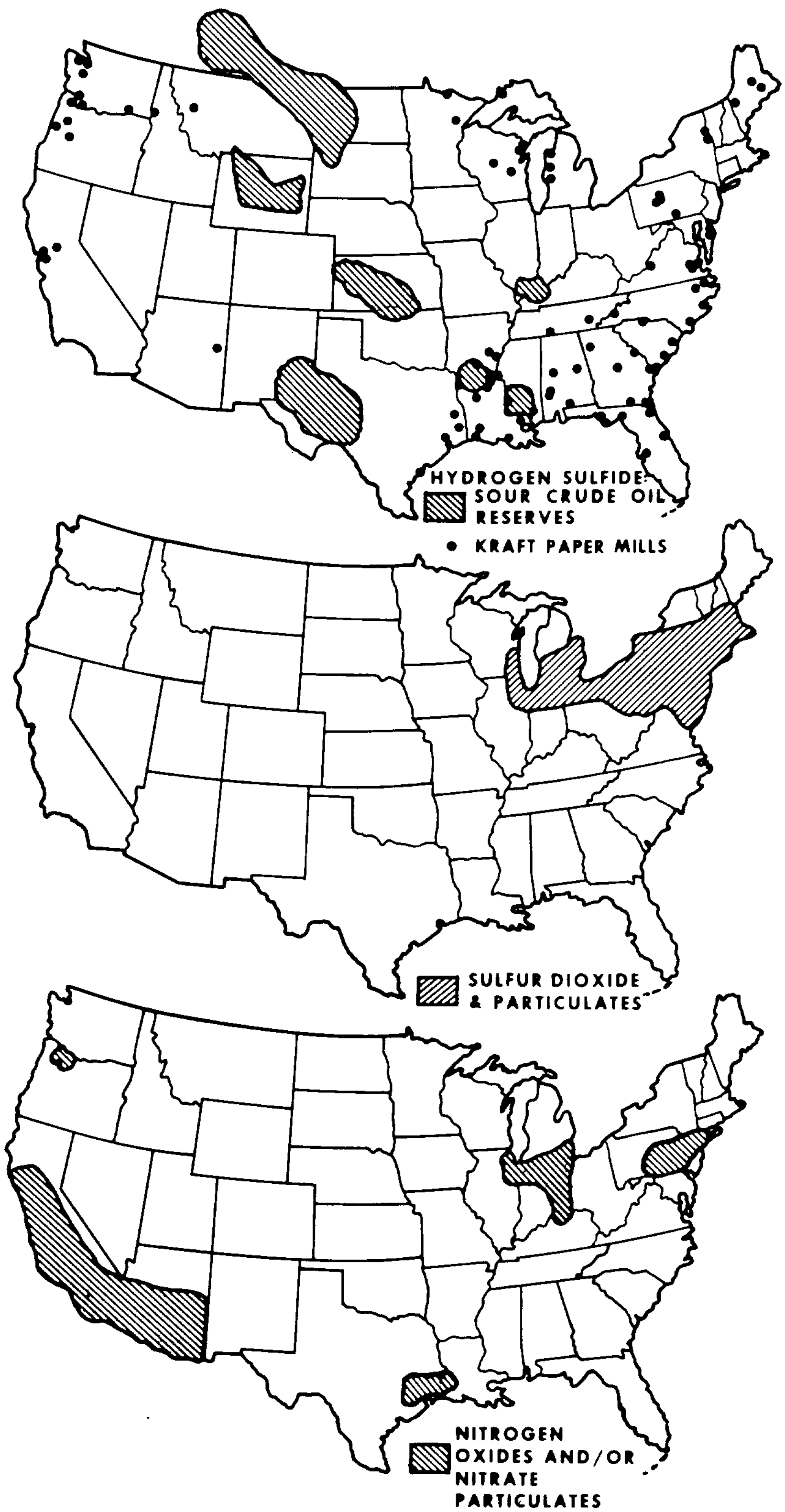

Fig. 10—Areas With High Concentrations of Gaseous Pollutants

remain operational when located in the atmospheric environments found within Bell System buildings. The environmental standards listed in Table C for equipment design cover the main environmental condition that equipment can experience when a central office is conditioned in accordance with the filtering and ventilation requirements of this section. These standards for contaminations are contained in Section 800-610-164 and in Technical Reference PUB51001 ➧for General Trade equipment.➧ It is the responsibility of the building engineer to see that central office environments meet or exceed these minimum values. The design of the appropriate filter system must take into account the local ambient contamination.

TABLE C

CONTAMINATION STANDARDS

CONTAMINANT	STANDARD CO
Particulate Matter	75 $\mu g/m^3$
Nitrate Particulate Matter	5 $\mu g/m^3$
Total Hydrocarbons	10 p/m
Sulfur Dioxide	0.20 p/m
Oxides of Nitrogen	0.30 p/m
Photochemical Oxidants	0.05 p/m
Hydrogen Sulfide	0.10 p/m

10.03 Setting the design criteria based on the local environment entails time-consuming analysis and measurement. Such results may show little need for filtration or may vary greatly depending on the time of day or year. Additionally, the sources of dust and contaminating particles may change with time at the location under study. Even environmental protection laws establish pollution levels that are beyond those considered safe for many types of equipment. Design criteria based on equipment performance is also subject to the uncertainties of future events. While considerable attention is devoted to the development of equipment that has high tolerance to dust and contamination, there is only limited assurance that all future equipment will be as robust as present electronic systems. Therefore, because of the uncertainties of future environments and equipment requirements, all buildings should have filtration systems that can accommodate changing criteria.

10.04 Table D gives guidelines for the air filters required for different types of telephone equipment offices in locations as indicated by the environmental characteristics in Table E. In using Table D a certain amount of judgment on the part of the operating company engineer is necessary since the technology of air filtration system selection has not yet advanced to the point where a mathematical equation will give numbers that will serve as absolute criteria for the filter types and efficiencies required under all individual circumstances.

11. DUST SPOT TRANSMITTANCE MEASUREMENTS

11.01 To aid in determining the type of local environment, modified American Iron and Steel Institute (A.I.S.I.) dust spot sampler manufactured by the Research Appliance Corporation can be used as a means of obtaining relative particle concentrations in terms of the Coefficient of Haze (COH). It is advisable to use a sampling interval of 24 hours to get a reasonable dust spot density under all but the heaviest dust loads with a sampling rate of 15 CFH (cubic feet/hour).

11.02 The exposed filter paper dust spots taken from the samples are examined using the dust spot transmittance method specified in ASTM D1704-61. The percent transmission is measured to determine the COHs/1000 feet, which represents the concentration of haze per 1000 linear feet of air sampled. One COH unit is the amount of dust necessary to cause a change of 0.01 in the optical density of the filter paper. The percent transmission is determined using a "% Transmission Meter" made by the Research Appliance Company. The equations needed to determine the COHs/1000 feet are presented below, along with definitions of terms.

$$\text{COHs/1000 ft} = \frac{\text{O.D.} \times 100}{\text{L}}$$

where

O.D. = optical density = Log ($\%T_o/\%T$)

$\%T_o$ = % transmission through the new filter paper. This is usually set to equal 100.

$\%T$ = % transmission through the dust spot on the exposed filter paper.

♦TABLE D♦

RECOMMENDED TYPES OF OUTRIDE AMBIENT AIR FILTER SYSTEMS

OFFICE	ENVIRONMENTAL CATEGORIES*			
	A	B	C	D
#1 ESS & Computer Centers with Low Personnel Activity	I or II (30)**	II (30)	II (30) or III (85)	II (30) or III (85)
Large Toll (#4ESS, #1ESS) & Computer Centers with High Personnel Activity	I or II (30)	II (30)	III (85)	III (85 or 95)
#2ESS & #3ESS	I	I or II (30)	I or II (30)	I or II (30)
Crossbar, CDO and Step Offices	I	II (30)	II (30) or III (85)	II (30) or III (85 or 95)

* See Table E.

** Figures in parentheses are the "dust spots" efficiency drops.

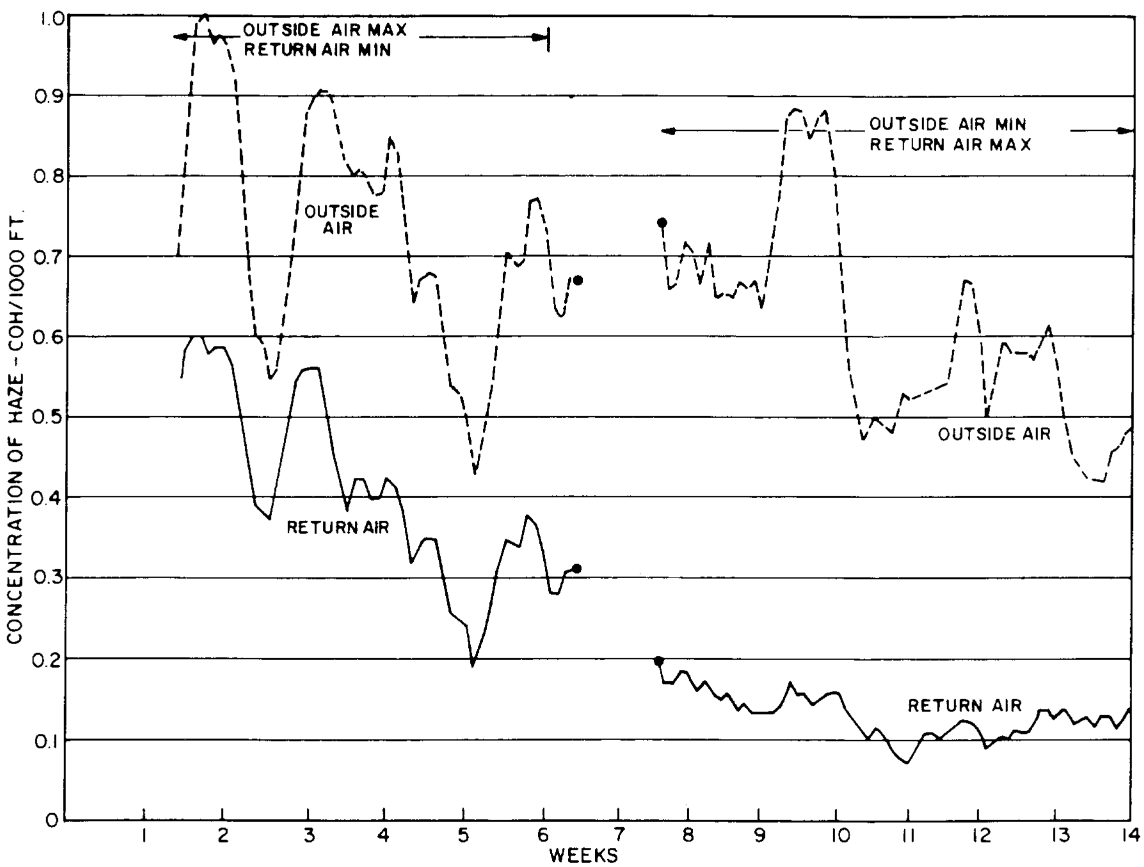

Fig. 11—Category C—Central Office Air Sampling Concentration of Haze/1000 Ft vs Time for 7-Day Moving Average

L = The amount of air that has passed through a spot of known size in a given period of time.

= sampling time (minutes) × air flow (CFM) × spot area (sq ft) × (1000)

11.03 The dust spot samples from a Category C location have been evaluated in terms of the calculated COHs/1000 ft. Examination of the raw data indicates that on a day-to-day basis, the COH values vary over a fairly large range in a seemingly random manner. This prevents the direct presentation of the COH data as a comparison of inside to outside air quality but a 7-day moving average is acceptable for data analysis. In this method, the first seven values in a series are averaged and the average value (in COHs/1000 ft) is plotted against the midday of the 7-day series. For the next average value, the first value from the original series is dropped and the eighth value is added. The resulting average value is again plotted on the midday of this new 7-day series. This process is continued until all the values in the series are used.

11.04 A Category C location was chosen for the investigation because of its frequent high levels of particulate contamination generated in nearby steel mills with their blast furnaces and coke ovens, along with the other types of heavy industry that cluster around such complexes. The central office circulation system is equipped with primary and secondary filter banks with Type II filters at both positions.

11.05 Fig. 11 shows the plot of the average COH values versus the midday of the 7-day cycle. The COH data for two conditions of the outside air louvers is shown. During the first condition, the recirculation ratio was set at maximum outside aiı intake with minimum return air. This results in a much higher level of particulate matter entering the filtration system, thus producing higher inside levels. In the second condition, the recirculation ratio was reversed such that the system was run at maximum return air with minimum addition of outside air. This results in only a low level of particulate matter entering the office, such that low COH readings are obtained.

11.06 At this Category C location, the standard pressure drop method was used to determine when the filters needed to be changed. It was found that the primary filter bank filters had to be changed every 4 months, while the secondary banks were only replaced at 9- to 12-month intervals. This would be expected since the primary filters were exposed to high outside dust levels while the secondary filters were exposed to partially filtered air. The test results clearly show the effectiveness of a well-designed filtration system and how the amount of outside air employed during operation influences cleanliness in the office.

11.07 Further examination of the COH data shows that filters can maintain an average of 0.150 COHs/1000 feet at the return air position. The inside air level would be even less than the return air level. Based on discussions with telephone personnel and visual examination of offices, the value of 0.200 COHs/1000 feet or less for the return air is considered to correspond to a reasonable indication of cleanliness. The data shows that dust spot sampling may be one useful way to measure the effectiveness of air filters in actual field locations. This method can also yield information that is useful in determining the type of filtration system necessary for a given geographical location. If a filtration system can supply an inside air quality level of less than 0.200 COHs/1000 feet for at least 80 percent of the time, then it should be adequate for the location.

12. PROCUREMENT OF FILTERS

12.01 Experience with the KS-7406 filters has shown that it is difficult to provide a specification for filters that will take into account all factors involved without expensive testing. It would be almost impossible to write a single specification that would cover all categories and types of filters described in this section. It is recommended that the filters defined by the characteristics given herein be obtained as general trade items using the ASHRAE standards as certified by the manufacturer. To obtain better control of filter products that will be purchased under local contracts, Specification X-74417, Mechanical Filters for Equipment Buildings, is available from the Engineering Records, Bell Laboratories, Holmdel, N.J. Included are performance requirements for: Types I, II, and III filters covering subjects such as: efficiency, pressure drop, media, design, construction, arrestance, air resistance, and workmanship. Letter request for the specification should be addressed attention: Mrs. Martha S. Garbarino (BTL-HO), copy to C.A. Russell (BTL-HO).

TABLE E

LOCATION ENVIRONMENT CATEGORIES

CATEGORY	TYPICAL ENVIRONMENT
A	Rural and Semirural areas with normally slight to moderate amounts of airborne dust and aerosols. (See Notes 1 & 2.)
B	Small towns and small cities with moderate to somewhat heavier amounts of airborne dusts and aerosols. (See Notes 1 & 2.)
C	Large cities and industrial locations with a high frequency of smoke or smog occurrences, having considerable amounts of smokes and dusts having medium (5-10μ) and larger (>10μ) sized airborne particles. (See Note 1.)
D	Large cities and industrial locations with a high frequency of smoke or smog occurrences, having large amounts of corrosive smokes and dusts having very fine (>1μ) sized airborne particles. (See Notes 1 & 3.)

Note 1: If there is heavy motor vehicle traffic in the neighborhood of a location, its category should be moved to the next higher type.

Note 2: Regions in the western U.S. with considerable wind blown dust should be moved to the next higher type.

Note 3: In some special cases where corrosive gases or sulfur vapors cause equipment problems, special filters such as carbon filters may be needed. In such cases Bell Laboratories should be consulted.

The present KS-7406 filters will continue to be made available by Western Electric, since these are superior to the average glass fiber throwaways.

12.02 Table F lists the various categories and types of filters that have been studied by Bell Laboratories in the laboratory or field and found to give acceptable performance. There are other manufacturers' products that have not been studied that also have acceptable performance.

13. REFERENCES

Section 069-703-801—"Cleaning Equipment Frames by Means of Compressed Air—Crossbar Offices—General," June 1972

Section 069-703-802—"Cleaning Equipment Frames by Means of Compressed Air—No. 1 Crossbar and Crossbar Tandem Offices," June 1972

Section 069-703-803—"Cleaning Equipment Frames by Means of Compressed Air—No. 5 Crossbar Offices, June 1972

Section 069-703-804—"Cleaning Equipment Frames by Means of Compressed Air—Nos. 4A and 4M Toll Switching Systems," June 1972

Section 760-555-150—"Atmosphere Environment for Telephone Equipment Space—General Considerations and Heat Release Data," (Sec. #2.03, "Filtration Requirements"), December 1969

TABLE F

FILTERS STUDIED BY BELL LABORATORIES

MANUFACTURER	TRADE NAME
TYPE I	
Internally Supported and Mixed Media Types	
Drico Industrial Corp.	Dustmaster
Precisionaire Inc.	
Pure-Air Filter Intl.	Perma Tac
Tri-Dek Filter Corp.	Tri-Dim 4-40
TYPE II	
Pleated Media Medium Efficiency Filters	
Farr Co.	30/30
TYPE III	
"Nonsupported" 85% Efficiency Filters	
American Air Filter Co.	Dri-Pak
Cambridge Filter Corp.	Hi-Flo Aerosolve
Continental Air Filters Co.	Conosac
Farr Co.	NS-100
"Supported" 85% Efficiency Filters	
Cambridge Filter Corp.	Rigid Aerosolve
Farr Co.	HP-100
"Nonsupported" 95% Efficiency Filters	
American Air Filter Co.	Dri-Pak
Cambridge Filter Corp.	Hi-Flo Aerosolve
Continental Air Filters Co.	Conosac
Farr Co.	NS-200
"Supported" 95% Efficiency Filters	
Cambridge Filter Corp.	Rigid Aerosolve
Farr Co.	HP-200

EM 1160, "Buildings: Air Filtration," AT&T File, April 10, 1969

X-74417, "Mechanical Filters for Equipment Buildings"

KS-7406—Primary Air Filters

Morton A. Bell, "A Guide to the Selection of Proper Air Filters," Heating/Piping/Air-Conditioning, Vol. 42, No. 9, September 1970

Robert A. Avery, "Air Filtration: Resistances, Energy, and Service Life, "Heating/Piping/Air-Conditioning, Vol. 45, No. 13, December 1973

H. W. Hermance, et al., "Relation of Airborne Nitrate to Telephone Equipment Damage, "Environmental Science and Technology, Vol. 5, pp 781-785, September 1971

"Standard Method of Test for Particulate Matter in the Atmosphere (Optical Density of Filtered Deposit)," 1971 Annual Book of ASTM Standards, Part 23

P. C. Chang, P.N. Wang, and A. Lin, "Turbulent Diffusion in a City Street," paper presented at Air Pollution, Turbulence, and Diffusion Symposium, Las Cruces, New Mexico, December 8, 1971

"Method of Testing Air Cleaning Devices," ASHRAE Standard 52-68, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., New York, N.Y., 1969

"ASTM Standards on Methods of Atmospheric Sampling and Analysis," ASTM D1704-61, 2nd. Ed., pp 89-96, American Society for Testing and Materials, Philadelphia, Pa., 1962.

14. AIR FILTRATION STANDARDS

1. Filter all incoming air and recirculated air from inside to remove airborne contaminants and debris and to prevent the buildup of fine dust suspensions in room air.

2. For new installations, design the central air system with Type I filter systems selected from Table E, but provide plenum space for Type III high-efficiency filters even though they are not yet required.

3. Locate new sites not in urban areas at least a mile from any upwind pollution source, or provide special filtration.

4. For new installations in urban areas, study the air current flow in street canyons to determine the best locations for air intakes.

5. Where problems resulting from gaseous air pollution are anticipated, contact the appropriate consultant to obtain filtering recommendations.

6. Use Type I filters as primary filters, placed singly in the filter frame.

7. The size of locking frames to mount KS-7406 filters shall be a 24-inch by 24-inch opening in the upstream face.

8. Install Type III high-efficiency filters where the following pollutant concentrations are exceeded: 100 microgram/cubic meter ($\mu g/m_3$) of suspended particles; 8 $\mu g/m_3$ of benzene-soluble organics; 7.5 $\mu g/m_3$ of nitrates; 15 $\mu g/m_3$ of sulfates.

9. Install Type III filters when the soiling index measured in the air intake stream exceeds 1.35 Cohs/1000 feet.

10. Install Type III filters, when required, of the unsupported type that fit the nominal 24-inch by 24-inch frame.

11. Use Type III filters, when required, that have a maximum configuration resistance of 0.50 inch of water.

12. Support the ends of high-efficiency filters when this is recommended by the manufacturer.

13. Operate the air system at a velocity of 400 ft/min measured on the face of the KS-7406 Type I filter media.

14. Specify magnahelix or inclined ▶draft gauges◀ for each filter bank in the system to determine operation and maintenance data.

15. Replace KS-7406 primary filters when the resistance increases to ▶0.4◀ inch of water. Replace Type II and Type III filters in accordance with manufacturer's instructions.

16. Where electrostatic filters are used, the maximum allowable peak level radiation shall be 1/2 volt/meter measured 12 feet from the filters and 600 microwatts/square meter for energy radiated into the air duct.