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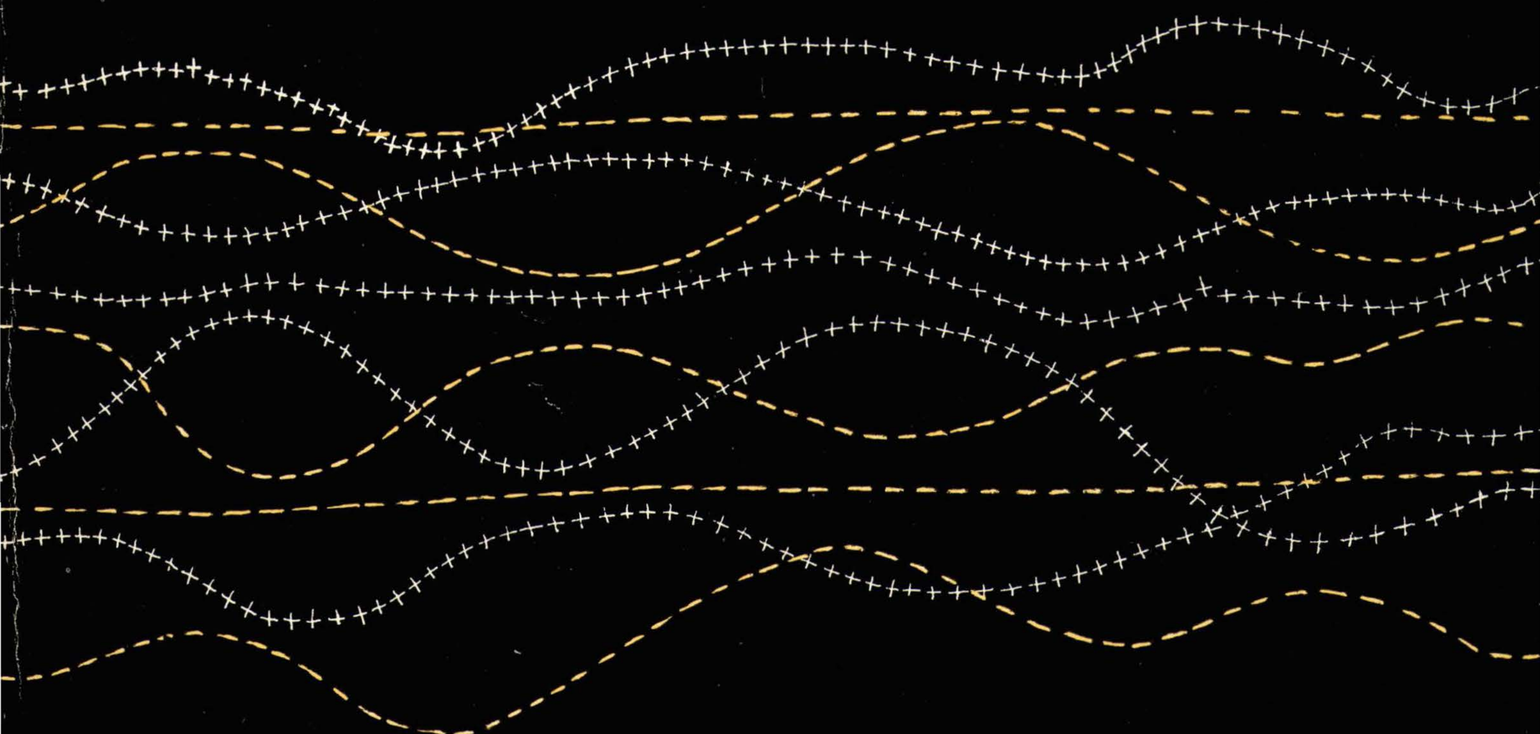
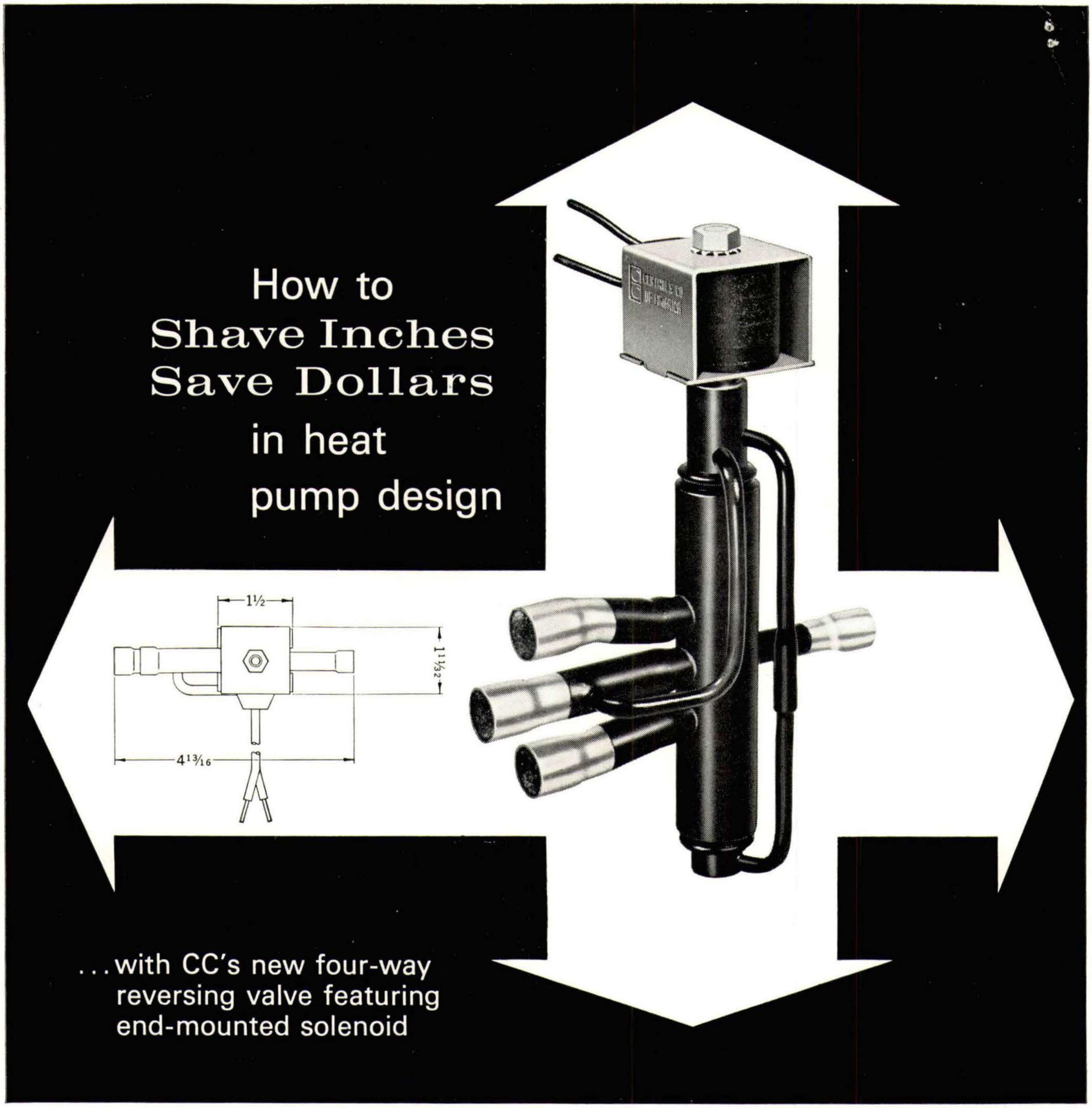
ASHRAE journal

American Society of Heating, Refrigerating and Air-Conditioning Engineers

DISTRIBUTION OF IONS BY AIR FOR EFFECTIVE CONTROL OF ELECTROSTATIC CHARGES: PEARSALL





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BULLETIN NO. P-2241

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"Wherever static is a problem"...

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depends upon application—unit should be placed within 3-5 ft. of static source.

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Convenient handle—set it anywhere.

LIGHTWEIGHT:

15 lbs.

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18 inches x 16 inches x 6 inches.

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Does not use radioactive material, but electrically emits tremendous quantities of electrons by high voltage.

NOISELESS:

The small fan does not create air circulation in the space—ions travel at high speeds to electrostatic potentials of opposite charge.

COOL:

No heat is generated in the unit—no tubes to burn out—service free.

- ★ **ANY TWO SURFACES RETAINING OPPOSITE STATIC CHARGES ARE ATTRACTED TO EACH OTHER.**
- ★ **ANY SURFACE RETAINING A STATIC CHARGE ATTRACTS DUST.**
- ★ **ANY TWO SURFACES RETAINING LIKE STATIC CHARGES WILL REPEL ONE ANOTHER.**
- ★ **STATITROL REDUCES OR ELIMINATES UNLIKE CHARGES!**

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STATIC CONTROL DIVISION

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DUANE D. PEARSALL
Member ASHRAE

There is much evidence of the effects of static electricity, ranging from the expenses of spark-ignited fires to static discharges caused by walking across carpets. Many industries have been plagued with economic losses from statics generated in moving processes, and have developed products for its control. Most of these applications involve static charges which are large enough to create sparks or strong enough to force relatively large particles to move through air to a surface on which there is a static potential. The clean room static hazard is more subtle, and therefore requires a greater understanding of the methods by which static is generated, since static can seriously interfere with the cleanliness of the ultimate product.

Distribution of ions by air for effective control of electrostatic charges

Static electricity is produced by the action of contact and separation of dissimilar materials. The technical explanation that has long been accepted describes the interaction of electrons between two surfaces as they come into contact. Upon separation, the electron will attempt to return to its source material, and the speed of separation of the two surfaces results in the electron remaining predominantly with the more resistive material. The more resistive material then has a surplus of electrons and is called negatively charged. The other material, being less resistive, now has a deficiency of electrons or is positively charged. Rubbing two materials together is simply a multiple contact and separation process creating higher levels of static potential. A metal part on a metal table or a stack of plastics bags behaves in the same manner.

From the description of the methods of static generation and the many materials involved, a generalization can be made. A clean room, because of the many non-conductive surfaces, is inherently an area susceptible to high static generation. It should be noted that the generation of static electricity cannot be prevented. We must, therefore, find ways of neutralizing or controlling it.

Duane D. Pearsall is President, Statitrol Corp, Denver, Colo. This paper was presented at the ASHRAE Region IX Conference in Denver, April 14-16, 1966.

METHODS OF CONTROL

Humidity

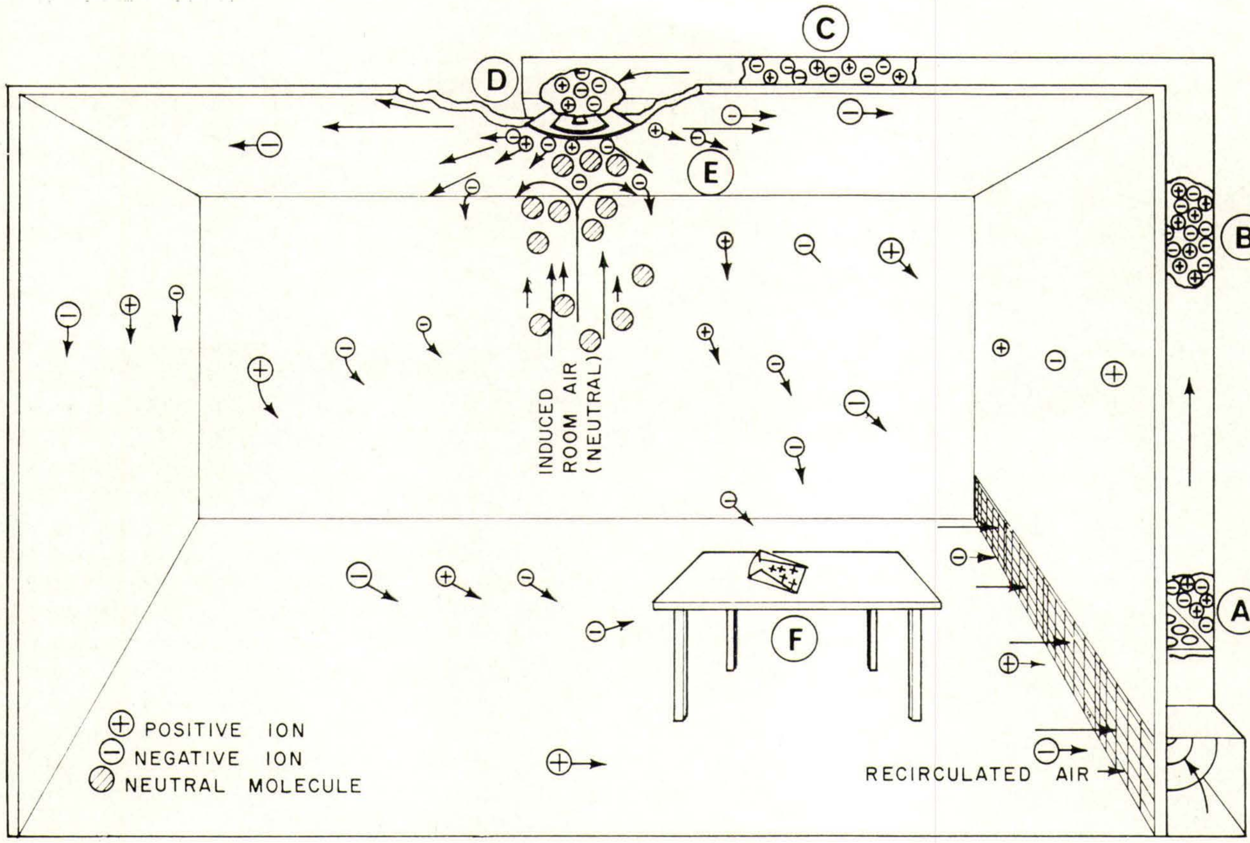
The most common method of controlling statics is to maintain a high relative humidity in the space. A high absolute moisture content in the air itself, in grains of moisture per lb of dry air, has little or no effect on static generation or dissipation. The effect of a high relative humidity creates, on the surfaces of materials in the space, a film of moisture which acts as a surface conductor draining off static charges. The higher the relative humidity in the space, the faster the rate of static removal.

The subject of moisture control involves many considerations. Adding humidity is relatively inexpensive, although its accurate control is difficult and its side effects may be undesirable.

The growing requirements in the aerospace industry, in particular, demand extremely low moisture levels, often necessitating dew points far below the freezing level to prevent damage to sensitive components which might corrode in storage or where moisture might condense on these parts as a part of a space vehicle operating at cryogenic temperatures.

Grounding

Effective grounding and bonding of personnel and sur-



(A) IONIZER AT FAN DISCHARGE VELOCITIES 800 TO 2000 F.P.M.

(B)(C) HIGH ION DENSITY - LOW LOSSES

(D)(E) AIR DIFFUSER - HIGH ION LOSS - BY SURFACE COMBINATION & COLLISIONS WITH NEUTRAL MOLECULES

(F) LOW ION DENSITY AVAILABLE - SLOW NEUTRALIZING EFFECT

Fig. 1 Clean room with ionization—conventional air system

faces as a means of static control in a clean room is virtually impossible.

Air Ionizers

For localized areas, ionizers using radioactive materials have been effective. Careful consideration should be given to radiation hazards and short half life which may render these devices ineffective.

An electric source of ionization in the form of static bars is also effective in localized areas, but the high voltage ionization creates ozone which has health hazard considerations. The industrial health divisions of state or public health departments are often willing to make tests if there is a suspected hazard involved.

The equipment used in this series of tests is a form of electric ionization which incorporates relatively low voltage levels in combination with air velocities to create a maximum ionization without the generation of ozone. More important, the ions are distributed in a relatively homogeneous manner throughout the area of the clean room.

AIR IONIZATION

Ionization is a term with which the clean room manager or owner should become familiar. Ionization is the process of multiple collisions of electrons with atoms or molecules of air. In order that a single moving electron may ionize an atom or molecule, it is necessary that the electron possess a certain minimum kinetic energy. The level of this energy is referred to as the ionization potential. Every electron with the minimum amount of energy will not necessarily ionize a gas through which it moves. In the case of the equipment described, electrons are accelerated by an electric field, creating an ionization coefficient sufficiently high not only to ionize the air moving in the immediate field of high intensity electrons, but also to accelerate the resulting ions to create further ionization at a distance of several inches from each point source.

With a collision of sufficient intensity by an electron or another ion, the molecule or atom is excited to the point of ionization where the energy absorbed by the atom allows an electron to leave the atom against the force which tends to hold it. An atom that has lost one or more electrons is said to be ionized and is one type of positive ion. The electron which is lost may, in itself, be considered under broad definition a negative ion. In general, an ion is an elementary particle of mat-

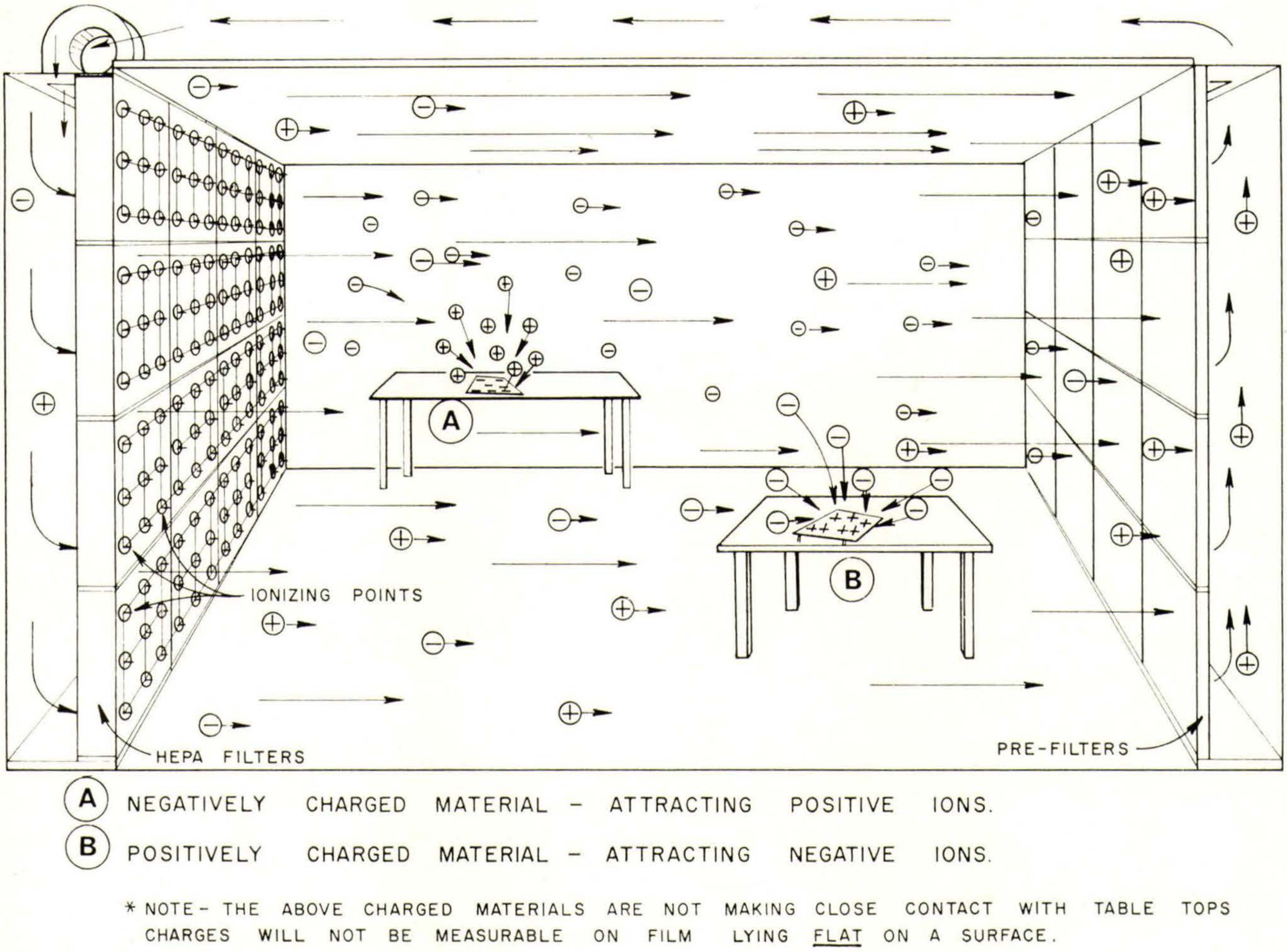


Fig. 2 Laminar flow clean room with ionization

ter or a small group of such particles having a net positive or negative charge.

Experimental evidence demonstrates that ionization disappears mainly through volume recombination from the attachment of electrons to neutral gas molecules to form the heavier and slower moving negative ions, which subsequently combine with positive ions. The rate of combination of positive and negative ions is proportional to the product of the two ion densities. It has been demonstrated that ionized air can be transported through grounded duct work under reasonably low turbulent conditions for hundreds of feet with relatively low losses. When air is discharged from a duct, as through a ceiling diffuser, the ion density may be severely reduced. This condition is dependent on the method of air diffusion.

The experiments demonstrate that a stream of ionized air discharged into a volume of neutral air results in a rapid loss of ionization by attachment to the neutral air molecules. A further conclusion might be reached from this same experiment that ionized air moving through a metal duct is affected only by the forces of recombination between opposite polarity ions and the surface of the grounded duct. Neither of these forces appears to be sufficient to force a high rate of decay in overall ionization.

Referring to Fig. 1, a clean room with air distribution through ceiling diffusers with the ionization source at the fan discharge shows a relatively economical type of system. However, the level of ionization is seriously reduced through recombination at the diffuser outlet, as well as interference with neutral air molecules as the air stream is introduced into the room. Nevertheless, the system might be entirely adequate for many clean rooms, depending upon the air change rate and the nature of the clean room product, type of activity, number of personnel, etc.

Fig. 2 illustrates a situation allowing maximum ionization and maximum static control. Recombination of ions is reduced to a minimum. The laminar flow clean room whether vertically discharged or horizontally discharged, becomes, from the ionization standpoint, a section of duct, since the air flow is the movement of a parcel of air through the room. Air motion is only relative to the objects and surfaces of the room. There is a minimum association with neutral air molecules and a minimum of recombination. This is the advantage of laminar flow clean rooms.

RESULTS OF TEST

The mobility of ions can be dramatically demonstrated by the simple experiment shown in Fig. 3. Using a small ionization source with a fan to carry the ions in an air stream from point A to point B, the ion can be forced out of the air stream by a static potential at point C.

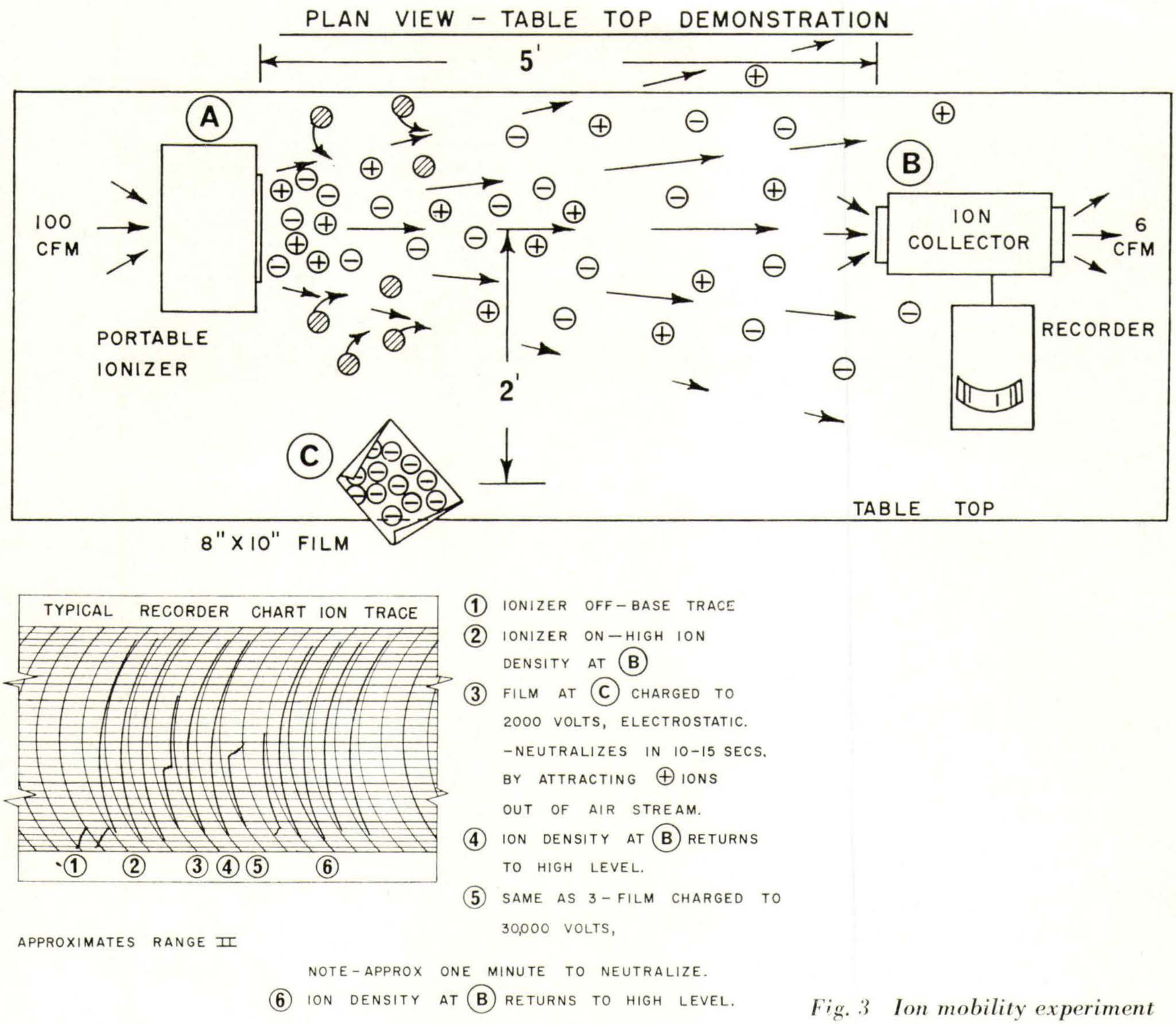


Fig. 3 Ion mobility experiment

As the static at point C becomes neutralized, the recorder at point B will show a return to the original ionization level carried by the air stream without interference.

Referring to Fig. 4, the clean room test area is not described in detail. The test area has additional clean benches and an air supply normally equal to three times the equipment shown. The area is principally used in the manufacture of plastics bags for use in packaging clean products and therefore must meet rigid specifications.

The test area does not demonstrate an area of maximum ion density, but does provide an excellent area to demonstrate the limits of ionization from only one clean bench. Note that air from the bench is recirculated in a conventional manner and all other air to the space has been turned off during the tests.

The ion density recorder was placed at locations A, B, C and D, respectively. Location A recording is shown on the left with the time beginning at the bottom of the figure.

Location A shows a near full scale response on scale range III. Detailed description of the recorder is shown in Fig. 5, with the values of ion collection shown for each of the four ranges.

The next reading shows a base trace with the ionizer in the off position on range III.

The center recording was made at location B using scale range II. The first trace is again with the ionizer off as a base trace. Note that the first several minutes at location B with the ionizer on shows a very low ion density, barely more than twice the base trace. This is because normal work activity was going on at the time with personnel working in the area of location B and between the ionizer and the recorder.

During this period, available ions were being attracted to static sources so that the recorder was showing only the absence of ionization. One and one half minutes after work activity was stopped the recorder reflects an ionization level of about 12 divisions on range II, demonstrating that the statics generated by work activity have been first neutralized. The ionization level at location B can then return to normal.

A table top demonstration of this characteristic is referred to in Fig. 3.

The recording on the right shows successively lower levels of ionization and the base trace on each range in locations C and D.

It is important to note that at a distance of 28 ft, although at a low level, there is still a significant trace

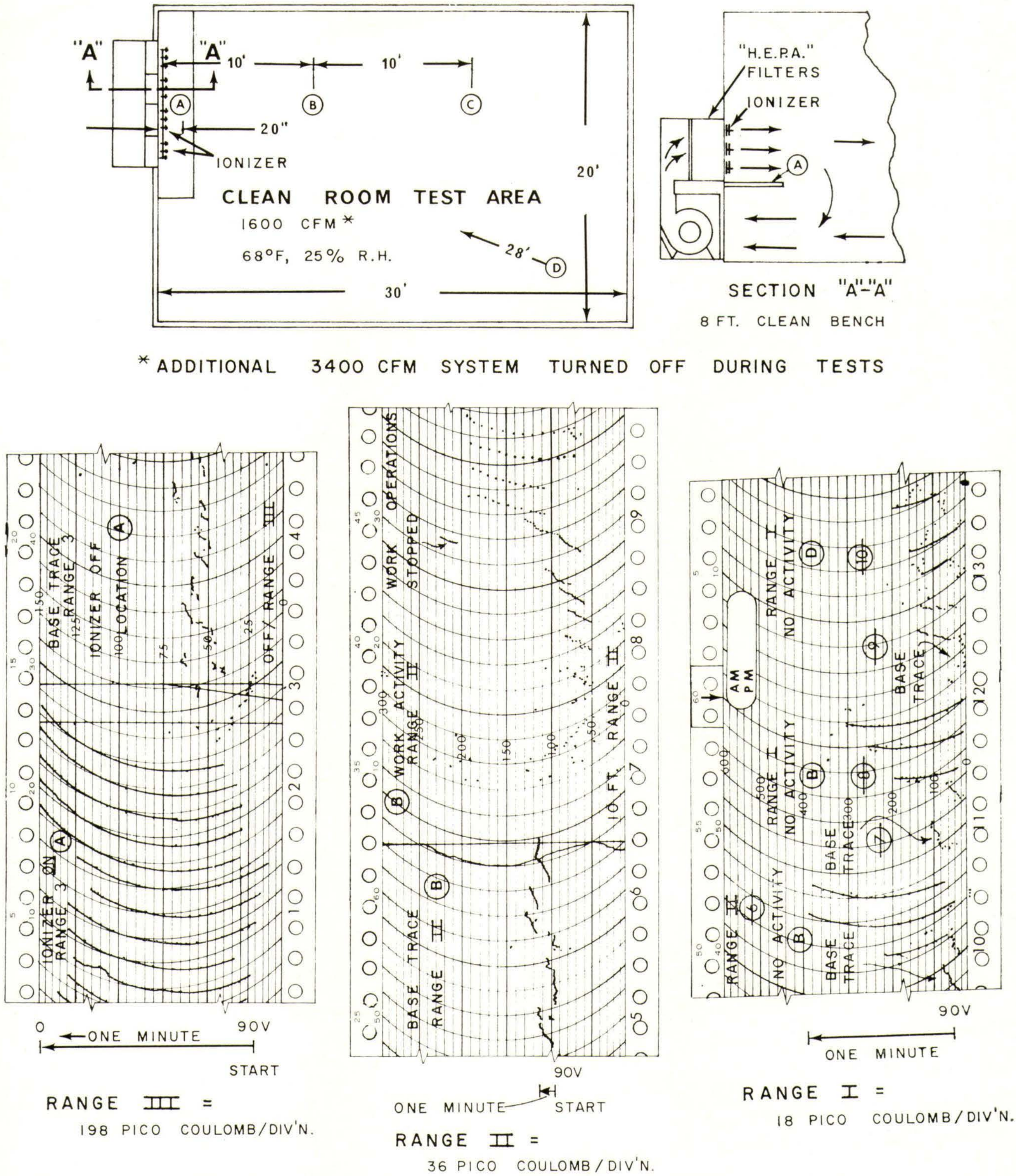


Fig. 4 Clean room test area and scale ranges

of ionization, demonstrating that static potentials between point D and the ionizer have been neutralized.

Fig. 6 summarizes the recorder chart information. The curve of estimated ion densities for a laminar flow clean room as shown in Fig. 6 is probably low. Air from the ionizer in the test area is mixing with large volumes of neutral air molecules, forcing substantially more losses than would be experienced in a laminar flow area.

However, note that in the immediate area of the clean bench and for a considerable distance beyond, statics are neutralized almost instantaneously.

Referring to the chart below Fig. 6, it can be seen that even at distances of 5 and 10 ft, rapid static neutralization is possible. The accuracy of the static meter used depends on the operator's judgment of the distance of the meter from the static surface and, therefore, the measured static values are only approximate. Nevertheless, the meter had an extremely fast response and the results are well demonstrated.

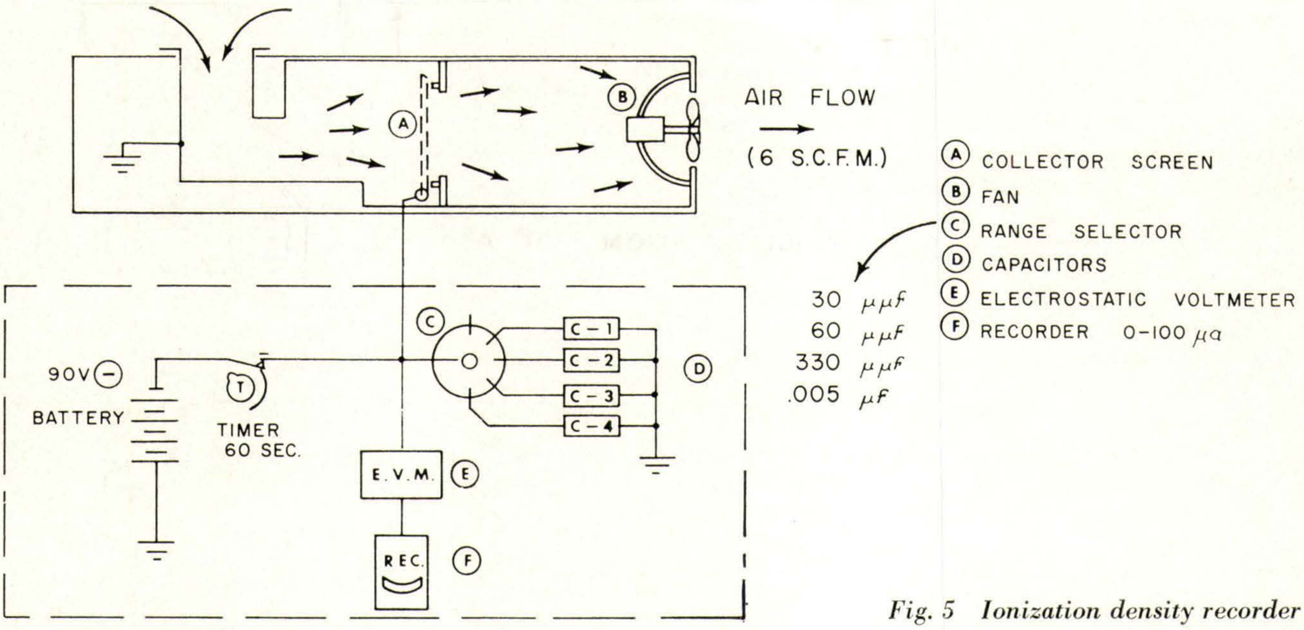


Fig. 5 Ionization density recorder

Specifications—Ion Density Recorder

Recorder—Amprobe 0-100 micro-amp—chart speed 12 in. per hr impressions at 5 sec intervals.
12 impressions per min—chart travel—.2 in.
1 min timer resets to 90 V, neg.
Calibrated to record collector screen voltage at far right—90 V full scale deflection to far left—72 V or 18 V scale span.
Collector Screen Voltages—72 to 90 V provides a "near 100%" ion collection efficiency.
Air Capacity through collector screen—6 SCFM
Q = capacitance × difference of potential
Range I—Q = 30 pico farad × 18 V = (full scale) 540 pico coulomb
Range II—Q = 60 pico farad × 18 V = (full scale) 1080 pico coulomb
Range III—Q = 330 pico farad × 18 V = (full scale) 5940 pico coulomb
Range IV—Q = .005 micro farad × 18 V = (full scale) 90 micro coulomb

Note: Collector screen at 90 V neg will record only positive ions if capacitors shielded to ground. Test recordings show total of both positive and negative since the case is used as reference ground.

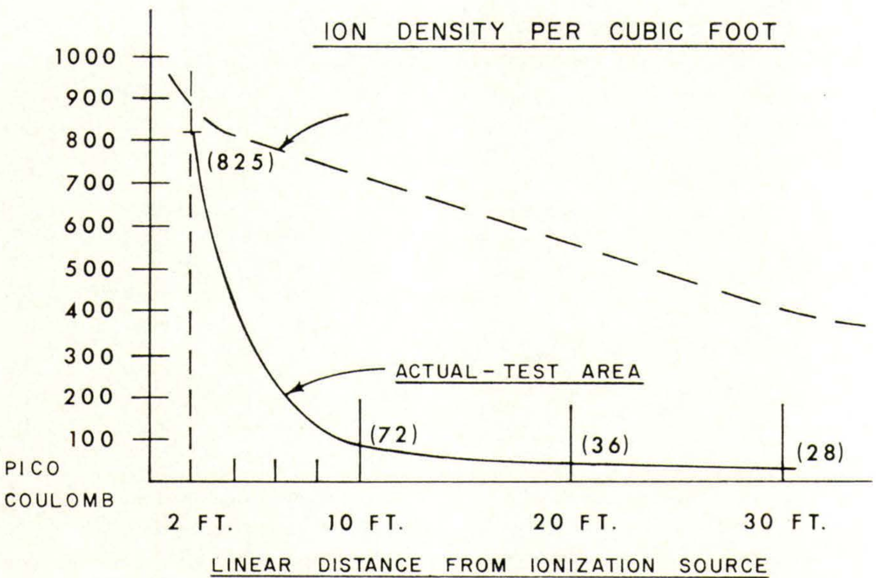


Fig. 6 Estimated ion densities for a laminar flow clean room at low activity condition

Static Meter Measurements

Object or Material	Surface area	Measured static	Distance from ionizer	Time to neutralize	Final static
Man	?	7,000 V+	5 ft	7-10 sec	zero
Vinyl	2 sq ft	50,000 V+	5 ft	10 sec	zero
Aclar	2 sq ft	15,000 V+	10 ft	7 sec	zero
Polyethyelene	1 sq ft	5,000 V±	10 ft	5 sec	zero

SUMMARY

The average clean room facility is not equipped with static measuring devices. The clean room operator usually does not recognize that static precipitates dirt like a magnet, and that static is virtually impossible to prevent. Without instrumentation, static will not be recognized unless the potential exceeds 3000 to 5000 v; in other words, a sufficient amount to create a spark that can be felt. A 400-v potential is enough to cause a spark.

Heavy dust particles will precipitate to static potentials as low as 1500 v. The infinitely small particles that today's clean room operator must avoid may precipitate to his product at potentials under 500 v.

The purpose of this article is to demonstrate that static potentials can be controlled or eliminated in any area of a clean room by creating an atmosphere essentially saturated with ions of each polarity. The control of statics is fundamental to an efficient clean room operation. These tests have demonstrated one method of creating electrical charges for effective static control. It is suggested, therefore, that the electrical characteristics of the clean room atmosphere be considered as a controllable variable in the same manner as we recognize humidity, temperature and air cleanliness as controllable variables.

APPENDIX A. IONIZATION DISTRIBUTION BY AIR-HANDLING SYSTEMS

The term air conditioning, in its broadest sense, implies control of any or all of the physical and chemical qualities of the air. As defined in Chapter 67, Comfort Air Conditioning, it is the process of treating air to control simultaneously its temperature, humidity, cleanliness and distribution to meet the comfort requirements of the occupants of the conditioned space.

There are no less than 300 technical papers relating to the physiological characteristics of ionization. Most of the papers suggest some value in the generation or control of ionization. We have found no information to suggest that ionization is unhealthy to the human environment.

This Appendix considers the possible use of bipolar ions distributed by air-conditioning ducts to reduce electrostatic charges in the conditioned space. If static charges on surfaces can be eliminated, then one of the forces causing dirt deposition on walls, ceilings or other surfaces is removed. However, before any practical use of ions can be made, it must first be established that these ions can be generated in quantity and then distributed in an economical manner.

The following brief test was conducted Tuesday, April 12, in a typical air-conditioned office space. Fig. A-1 shows the floor area of the entire sixth floor of the Denver Club Building. The core area of approximately 10,000 sq ft is served by a high-velocity air-conditioning unit of approximately 12,000 cfm.

The four ionizer discharge points are located at the fan outlet in an air velocity of 2600 fpm. Air velocity at point A is 5100 fpm and at point B it is 3220 fpm. At the terminus of each branch duct is a high-velocity sound attenuator box. The diffuser assembly is mounted directly to the box. For these tests, the core of the diffuser was removed for ease of air sampling. Since each of the boxes is manually regulated by a high-pressure valve, the system air distribution pattern was not disturbed.

Fig. A-2 is a summary graph of the averages of the recordings made at five different locations. Location 1 (Fig. A-1) is the closest sampling to the ionization source. In each test the air-sampling meter was placed on a 5-ft step ladder, 26 in. below the diffuser outlet. In each location a minimum 5-min recording was taken with the ionizer on, and a separate recording was taken with the ionizer off to establish a base trace at each location. The figure reflects the net difference in ion concentration per cu ft.

Fig. A-1 Floor area of the sixth floor of the Denver Club Building

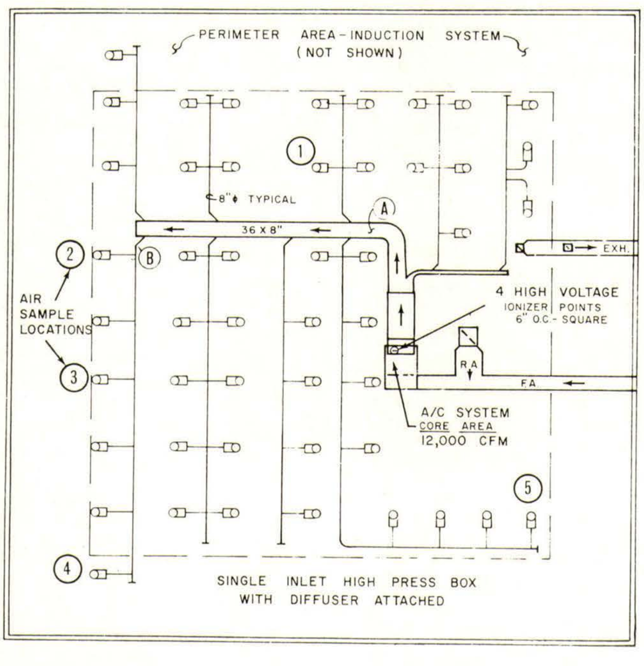
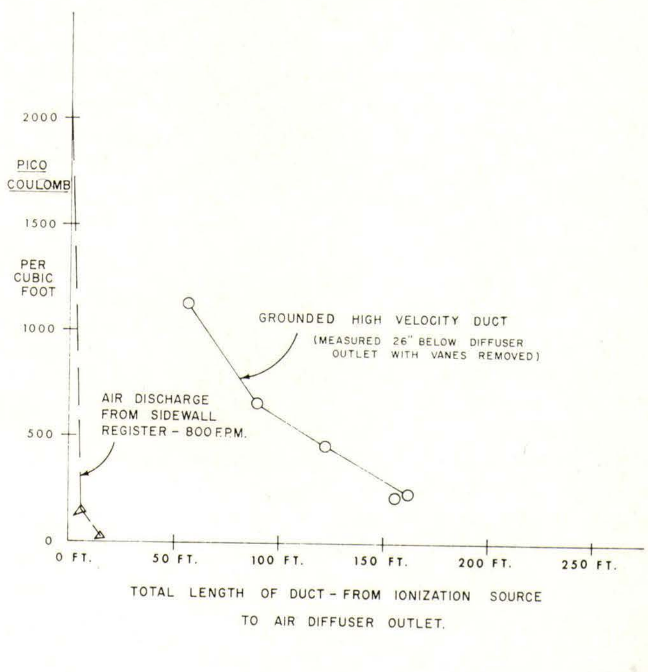


Fig. A-2 Ion density decay rate per lineal foot



With the high speed of the air, readings at the farthest diffuser location were almost instantaneous with the on or off condition of the ionizer.

At the far left of the figure there is a sharp curve representing decay in ion concentration from the outlet (800 fpm) of a portable ionizer for a distance of 15 ft with readings taken at 1, 6 and 15 ft.

The figure, therefore, demonstrates that a jet stream of air with a high concentration of ions will show an extremely rapid decay through interference and bombardment with neutral air molecules. However, it can be concluded that ions may be effectively transported through air ducts (even high-velocity ducts) for substantial distances with a reasonably high level of ionization available to be discharged into the space.

The following observations were made from this test:

(1) Only approximately 22% of the free area of supply air was being ionized. In other words, maximum ionization would occur with approximately 20 discharge points rather than four.

(2) Maximum recombination of ions will occur at surfaces or where the air is forced to converge. The high velocity boxes in this test were a major factor in the loss of ionization.

(3) A low-velocity duct designed with careful consideration for static regain would result in a lower loss in ion concentration per lineal ft.

The above test has been made only for the purpose of demonstrating that ions of both polarities can be transported through grounded ductwork with relatively low losses. The use of this principle in a practical sense either for physiological or for cleanliness reasons will have to be further substantiated through experience and additional testing. Nevertheless, we submit that the electrical characteristics of air can be controlled and, therefore, should be given serious consideration as a controllable variable.

ACKNOWLEDGMENT

The author wishes to thank Robert Bolasny, President, Scientific Enterprises, Inc, for his personal assistance and use of his clean-room facilities, and Abram Miller, Engineer, and the Denver Club Building management for their assistance and use of their building for the tests.

LINCOLN BOUILLON TO HEAD EXPOSITION ADVISORY COMMITTEE

ASHRAE President Lincoln Bouillon has been named Chairman of the Advisory Committee of the 18th International Heating and Air-Conditioning Exposition scheduled for January 30 to February 2, 1967 in Cobo Hall, Detroit, Mich. The Exposition, sponsored by the ASHRAE membership, will be held in conjunction with the ASHRAE Semiannual Meeting. Registration at the meeting is automatic registration for the exhibit, where over 450 manufacturers of heating, refrigerating, air-conditioning and ventilating equipment will display their products.

The Advisory Committee is composed of the heads of a number of professional and industrial associations in such fields as air conditioning, air pollution control, air moving, refrigeration, heating, cooling, fuel, architecture, consulting engineering and contracting.

ASHRAE representatives include Mr. Bouillon; Kenneth J. Wagoner, General Chairman of the Semiannual Meeting; Harry G. Gragg, Director and Regional Chairman of Region VI; and Robert E. Strand, President of the Michigan Chapter.

Other members of the committee are: John E. Schilling, President, Air-Conditioning and Refrigeration Contractors of America; John Sheperdson, President, Air-Conditioning and Refrigeration Wholesalers; John M. Clem, President, Air Filter Institute, Inc.; E. A. Cruse, (Member ASHRAE), Executive Vice President, Air Moving and Conditioning Assn, Inc; James H. Huguet, President, Air Pollution Control Assn; R. J. Rutherford, President, American Gas Assn, Inc; Charles M. Nes, Jr., President, The American Institute of Architects; John G. Hoad, President, American Institute of Consulting Engineers; J. D. Jillson, President, Anthracite Institute; John F. Pritchard, Jr., President, Board of Directors, Cooling Tower Institute.

Also, Robert S. Rickabaugh, Chairman, The Institute of Boiler and Radiator Manufacturers; Anthony L. Cherne, President, Mechanical Contractors Assn of America, Inc; Robert L. Horovitz, President, National Assn of Plumbing-Heating-Cooling Contractors; E. C. Bruce, President, National District Heating Assn; George D. McDaniel, President, National Oil Fuel Institute, Inc; Keith T. Davis, (Member ASHRAE), President, National Warm Air Heating and Air-Conditioning Assn; and Cecil W. Sullivan, President, Refrigerating Engineers and Technicians Assn, Inc.

E. K. Stevens (Associate Member ASHRAE) will manage the show, which is being conducted by International Exposition Co. For information and invitation tickets contact: International Exposition Co, 200 Park Avenue, New York, N. Y. 10017.

HEATING WITH LIGHTING REPORT

The Illuminating Engineering Society has published its findings on the idea of heating with lighting in a new IES Technical Committee report, "Lighting and Air-Conditioning". The report brings together the experience of many experts on this subject who are members of the IES Committee on Lighting and Air Conditioning.

The report is divided into five sub-sections: Electric Lamps as Heat Sources; Luminaires as Heat Sources; Lighting Systems as Heat Sources; Methods of Controlling Lighting Heat; and Systems for Controlling Lighting Heat. Line drawings are used to show such data as: light distribution classifications of luminaires; various test arrangements and results; effect of ceiling-to-luminaire relationship upon lighting system heat transfer; and other material.

Copies of the booklet may be ordered by writing to Publications Office, Illuminating Engineering Society, 345 E. 47 St, N.Y., N.Y. 10017. Prices are as follows: 1 to 24 copies, $.50 each; 25 to 99, $.40 each; 100 or more, $.30 each.