1-1-1966

Static Electricity - Why It Must Be Controlled

Statitrol Corporation

STATIC ELECTRICITY - WHY IT MUST BE CONTROLLED

There is much evidence of the effects of static ranging from spark-ignited fires costing thousands of dollars in property losses to the shock to one's nervous system from walking on a wool or nylon carpet. Many industries have been plagued with economic losses from statics generated in moving processes and have developed products for its control. Photographers know that even a small static charge on film causes dust to attract, resulting in costly imperfections. 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 further understanding of the methods by which static is generated. The clean room operator should recognize how static can seriously interfere with the ultimate clean product.

WHAT MATERIALS ARE AFFECTED?

We normally associate statics with plastics or nonconductive materials, but let's take a closer look. Any material — even an excellent conductor such as a piece of copper wire — can take on a static charge!

For example, a person walks across the vinyl floor of a clean room wearing nylon coveralls and plastic booties, picks up a piece of that copper wire from a formica counter top. At that instant the piece of wire takes on the same static charge as the person — which may well be over 20,000 electro-static volts! The wire (and the person) is now a precipitator or a magnet for dirt on the counter or in the air. The smaller the particle, the more mobility it has — and the more efficient that piece of copper wire becomes as a precipitator. The human body is a conductor, a good capacitor and, depending on the relative dryness in skin condition from one person to another, an excellent static generator.

HOW IS STATIC GENERATED?

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 intimate 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 plastic bags behaves in the same manner.

Appendix
1968

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.

METHODS OF CONTROL

I. 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 pound 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.

II. Grounding. Effective grounding and bonding of personnel and surfaces as a means of static control in a clean room is virtually impossible.

III. 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 their 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 homogenous manner throughout the area of the clean room.

AIR IONIZATION USEFUL IN AREA STATIC CONTROL

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.

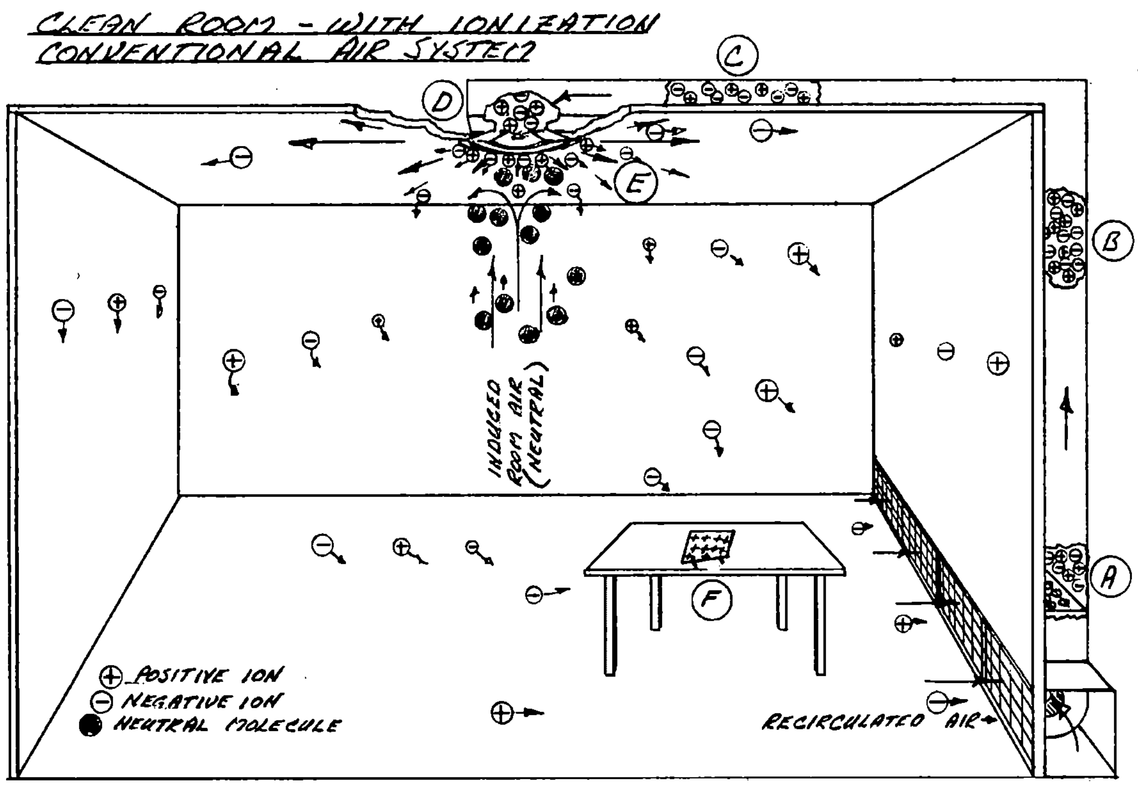
IONS ARE POSITIVE AND NEGATIVE

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

IONS — WHERE DO THEY GO, HOW LONG DO THEY LAST?

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 is severely reduced, depending 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 experiemnt 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 appear to be sufficient to force a high rate of decay in overall ionization.



(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

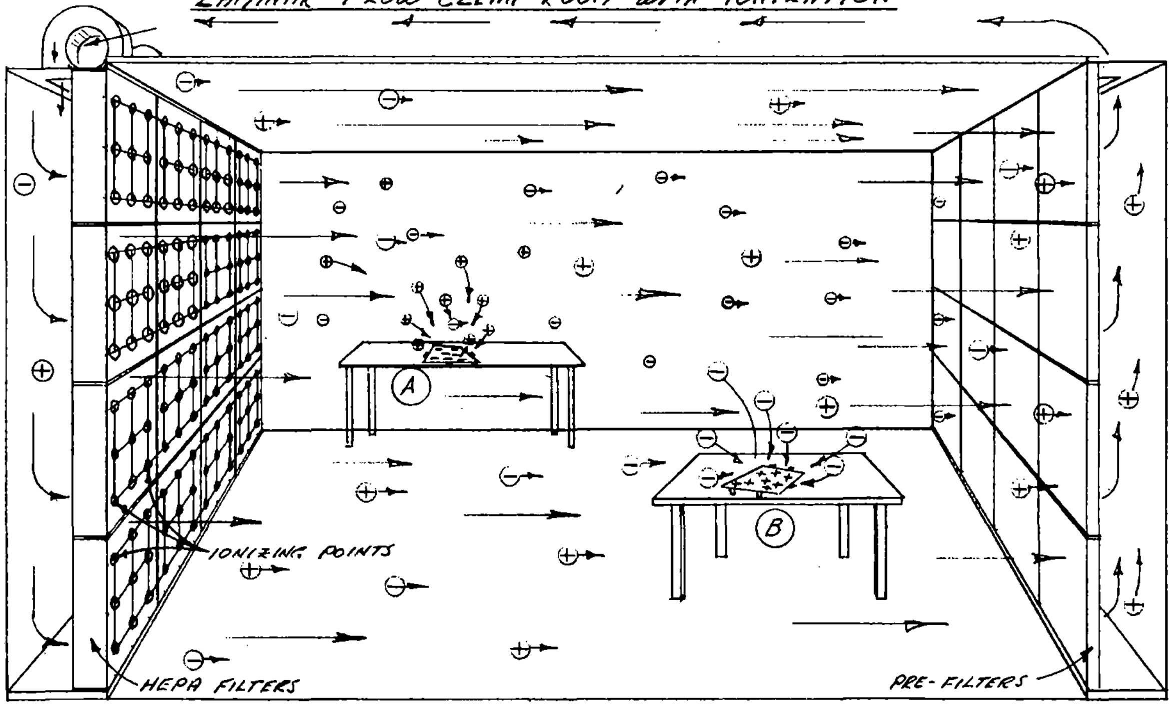
(F) LOW ION DENSITY AVAILABLE - SLOW NEUTRALIZING EFFECT

FIGURE I

Referring to Figure I, 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.

LAMINAR FLOW CLEAN ROOM OR CLEAN BENCH PRODUCES INHERENT ADVANTAGE

LAMINAR FLOW CLEAN ROOM - WITH IONIZATION



(A) NEGATIVELY CHARGED MATERIAL - ATTRACTING POSITIVE IONS.

(B) POSITIVELY CHARGED MATERIAL - ATTRACTING NEGATIVE IONS.

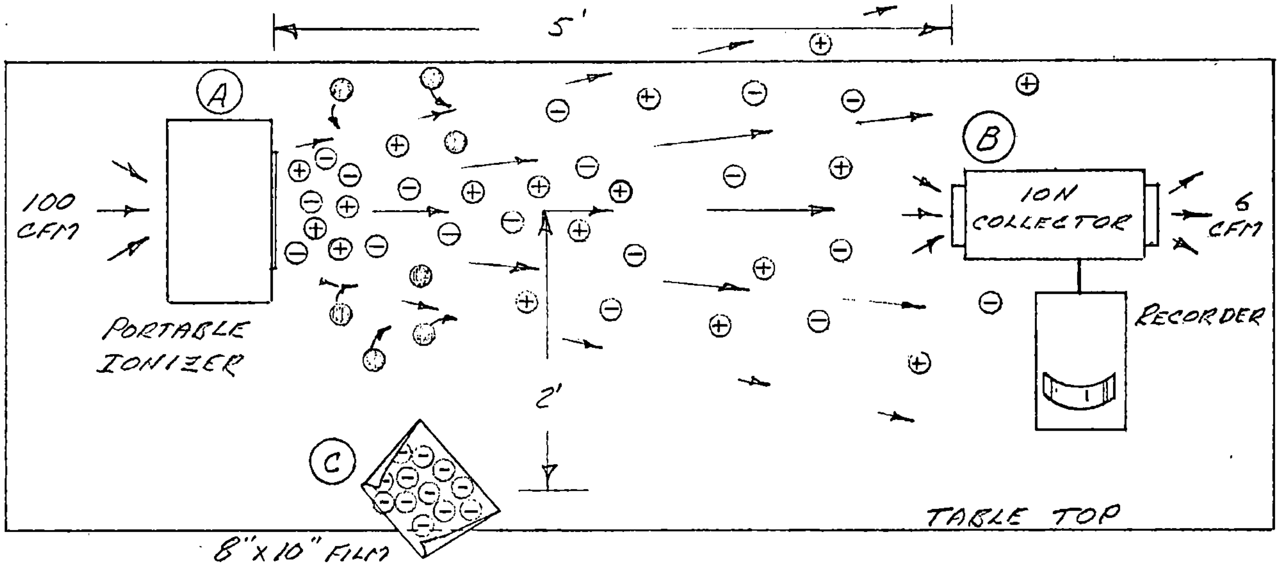
*NOTE - THE ABOVE CHARGED MATERIALS ARE NOT MAKING CLOSE CONTACT WITH TABLE TOPS CHARGES WILL NOT BE MEASURABLE ON FILM LAYING FLAT ON A SURFACE

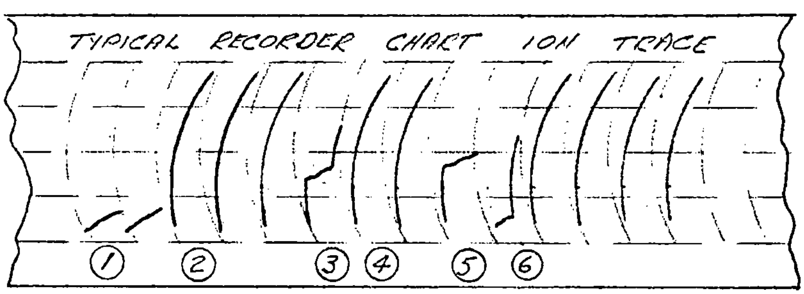
FIGURE II

In Figure II, is described 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 recombaination. This statement is not intended to be an endorsement of laminar flow clean rooms, but simply to point out their inherent advantage to the area ionization method of static control.

IONS MOVE TO STATIC POTENTIALS OF OPPOSITY POLARITY

PLAN VIEW - TABLE TOP DEMONSTRATION





(1) IONIZER OFF - BASE TRACE

(2) IONIZER ON - HIGH ION DENSITY AT (B)

(3) FILM AT (C) CHARGED TO 2000 VOLTS, ELECTROSTATIC, -NEUTRALIZES IN 10-15 SECS BY ATTRACTING ⊕ IONS OUT OF AIR STREAM.

(4) ION DENSITY AT (B) RETURNS TO HIGH LEVEL.

(5) SAME AS 3 - FILM CHARGED TO 30,000 VOLTS, NOTE - APPROX 1 MINUTE TO NEUTRALIZE

(6) ION DENSITY AT B RETURNS TO HIGH LEVEL

APPROXIMATES RANGE II
(REFER FIGURE V)

FIGURE III

The mobility of ions can be dramatically demonstrated by the simple experiment described in Fugure III. 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. 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.

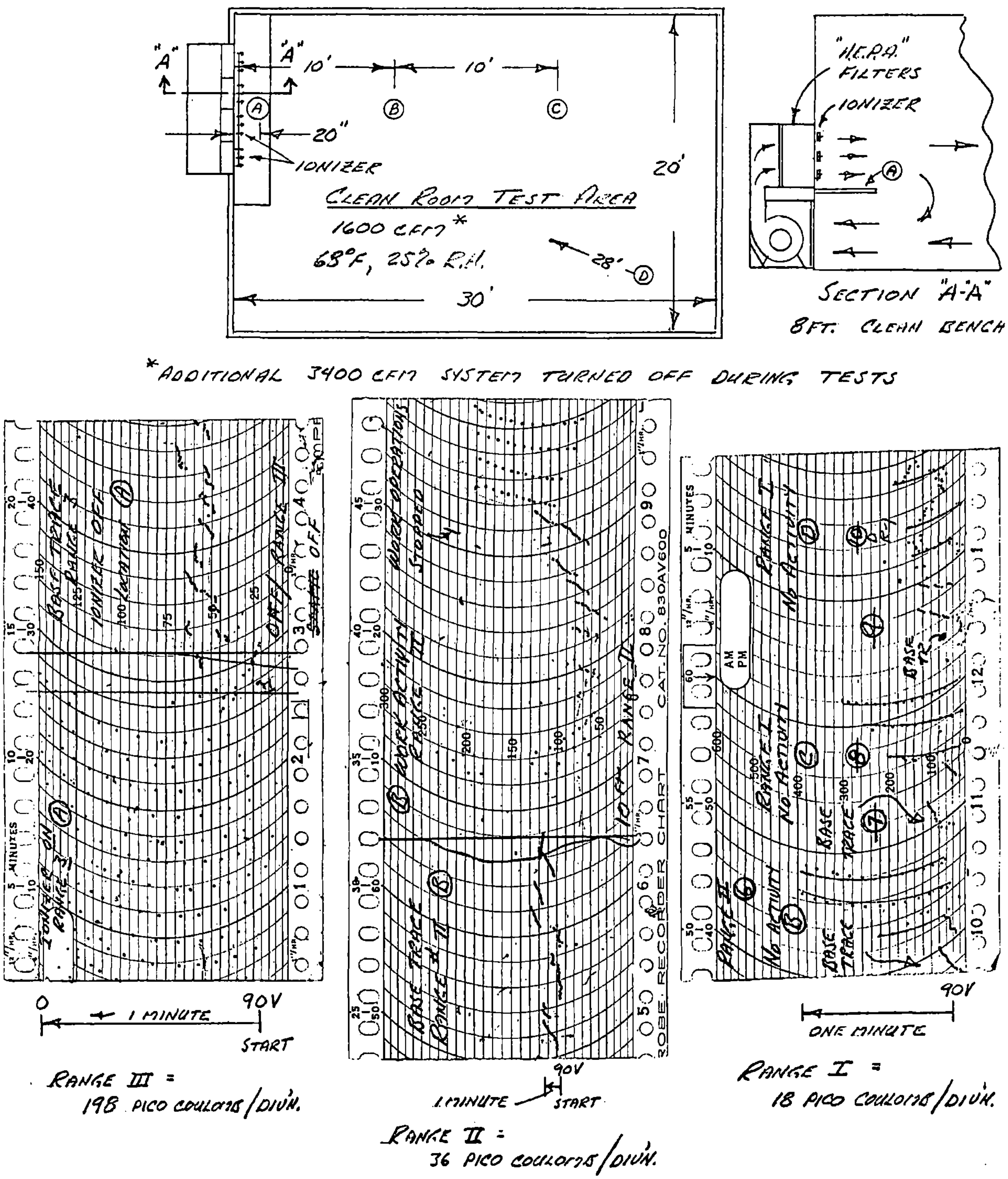
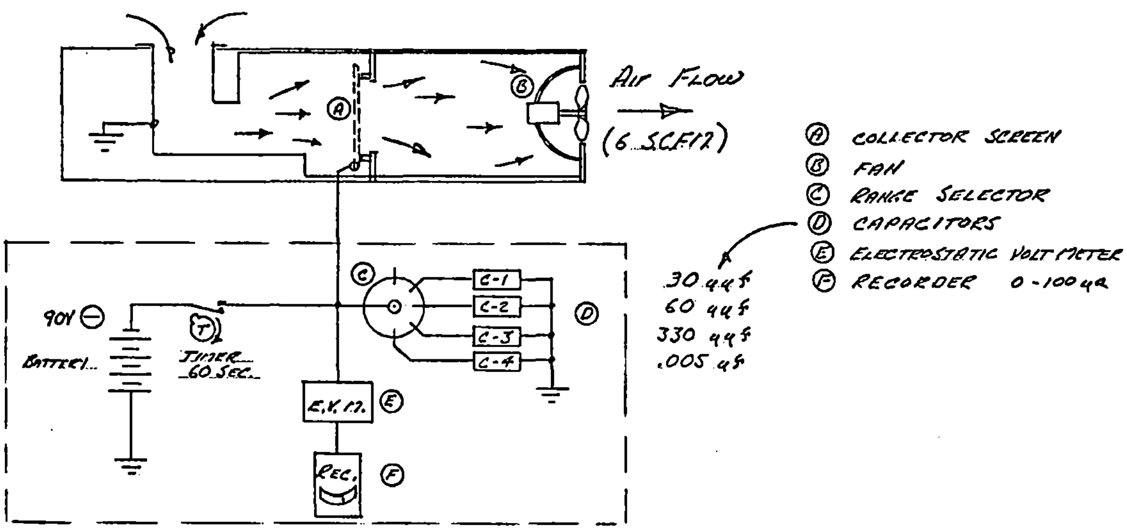


FIGURE IV

Referring to Figure IV, 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 plastic 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 chart.



IONIZATION DENSITY RECORDER

FIGURE V

SPECIFICATIONS - ION DENSITY RECORDER

RECORDER - Amprobe 0-100 micro-amp - Chart speed 12" per hour
Impressions at 5 second intervals
12 impressions per minute - chart travel - .2 inch
1 minute timer resets to 90 volts, negative.

Calibrated to record collector screen voltage at far right - 90 volt full scale deflection to far left - 72 volt or 18 volt scale span

COLLECTOR SCREEN VOLTAGES - 72 to 90 volt provides a "near 100%" ion collection efficiency.

AIR CAPACITY through collector screen - 6 SCFM

Q = Capacitance x difference of potential

Range I - Q = 30 pico farad x 18 volt = (full scale) 540 pico coulomb

Range II - Q = 60 pico farad x 18 volt = (full scale) 1080 pico coulomb

Range III - Q = 330 pico farad x 18 volt = (full scale) 5940 pico coulomb

Range IV - Q = .005 micro farad x 18 volt = (full scale) 90 micro coulomb

NOTE: Collector screen at 90 volts negative 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.

Location A shows a near "full scale" response on scale range 3. Detailed description of the recorder is shown in Figure V, 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 3.

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 Figure III.

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 feet, although at a low level, there is still a significant trace of ionization, demonstrating that static potentials between point D and the ionizer have been neutralized.

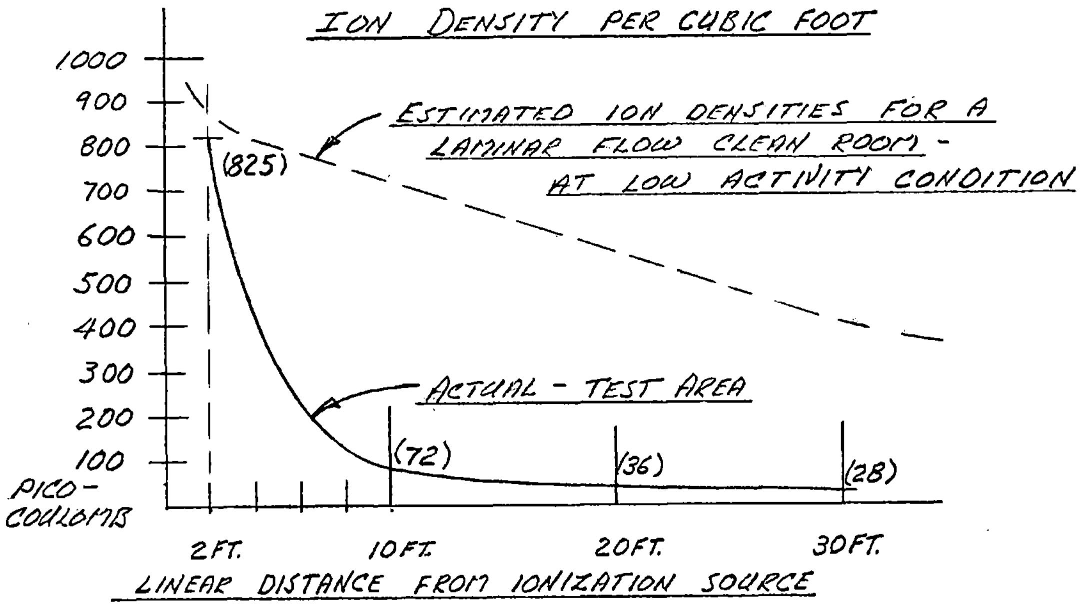


FIGURE VI

STATIC METER MEASUREMENTS

Object or Material	Surface Area	Measured Static	Distance From Ionizer	Time to Neutralize	Final Static
Man	?	7,000 V +	5 feet	7-10 Secs.	Zero
Vinyl	2 ft^2	50,000 V +	5 feet	10 Secs.	Zero
Aclar	2 ft^2	15,000 V +	10 feet	7 Secs.	Zero
Polyethelene	1 ft^2	5,000 V ±	10 feet	5 Secs.	Zero

Figure VI summarizes the recorder chart information.

The curve of estimated ion densities for a laminar flow clean room as shown in Figure VI is probably low. Air from the ionizer in the test area is mixing with large folumes 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.

STATIC METER MEASUREMENTS

Referring to the chart below Figure VI, it can be seen that even at distances of five and ten feet, 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.

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 three to five thousand volts; in other words, sufficient to create a spark that can be felt. A 400 volt potential is enough to cause a spark.

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

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. We suggest, 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.