

# IONIZED AIR FOR THE STATIC SAFE WORK ENVIRONMENT

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## Introduction

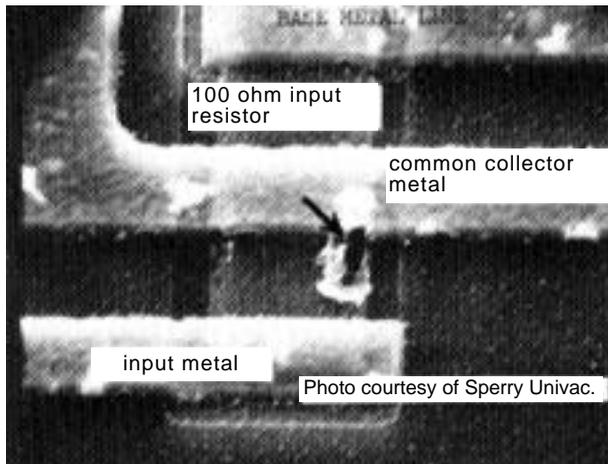
The electronics work environment must be protected from the catastrophic effects of static discharge and static fields. Two basic rules were established in previous technical publications<sup>1,2</sup> that if followed, prevent static damage of electronic components during assembly, testing, and field service of electronic equipment. Rule 1 states that static sensitive electronic components must be handled within a static safeguarded work environment. Rule 2 states that static sensitive components must be transported between static safeguarded work environments only in static shielding containers.

A static safeguarded work environment is an area free of all damaging levels of static voltage. The voltage on all conductors, including people, in the work area is controlled by grounding. Three pieces of equipment are used to implement this philosophy—the conductive floor mat, conductive table mat, and wrist strap. Since by definition, charge will not flow through a nonconductor, the nonconductors found in the electronics work environment cannot be effectively grounded. Candy wrappers, work order holders, coffee cups, the operator's clothing, etc. can all create static problems. Although restriction of these nonconductors from the static safeguarded work environment is a recommended solution, it has been the authors' experience that this is impossible to enforce. Static on these items must be neutralized with ionized air.

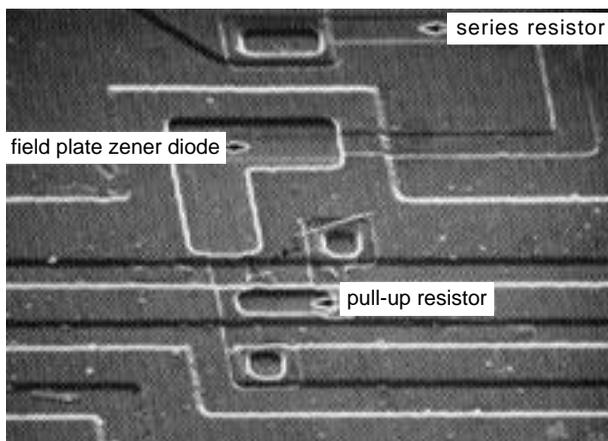
This paper describes how the unique properties of ionized air can be used to full advantage in dealing with charged nonconductors. A new test procedure capable of determining the efficacy of any ionized air source is also discussed.

## How Electronic Devices Are Damaged By a Nonconductor

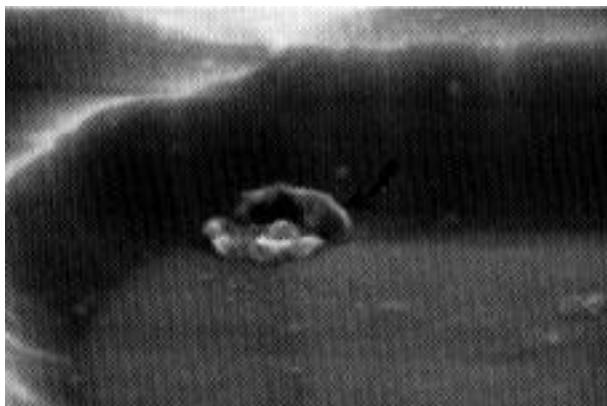
Static can damage electronic devices or components either by creating excessive voltage differences across the device, or by causing excessive current to flow through the device. Charged nonconductors generally affect devices that are most sensitive to excessive voltage. This would include MOS devices, which make up over half of all semiconductor ICs on the market today, as well as film resistors,<sup>3,4</sup> SAW (surface acoustic wave) devices<sup>5</sup>, capacitors in linear ICs<sup>6</sup>, and even some bipolar components. For example, metallization crossovers located in some bipolar ICs (Figure 1) render the devices voltage sensitive and thus susceptible to damage by charged nonconductors. Since this type of damage is directly related to the IC package densities of devices, its incidence is expected to become much greater in the near future.



**Figure 1.** Static induced breakdown in glassivation layer between metallization crossover and resistor in an ECL device (5600x) Photo courtesy of Sperry-Univac

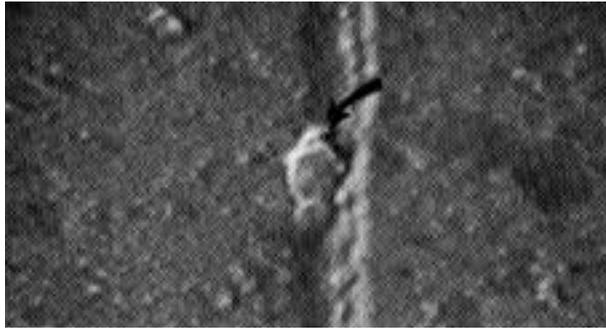


**Figure 2.** p-MOS character generator, pin 8 input protective network (620x)



**Figure 3.** Static damage to input pull-up resistor on p-MOS character generator caused by contact with a charged PVC work order holder (13 000x)

Voltage sensitive devices are not only damaged by direct contact with a charged nonconductor, but they are also very susceptible to the electric field surrounding such objects. Figure 2 shows a photomicrograph of input pin 8 to a p-MOS character generator with on-chip field plate Zener diode and series resistor input protection. Figure 3, which is a magnified view of the same device, shows static damage to the diffused pull-up resistor located immediately behind this protective network. This damage resulted when a charged (-10KV) nonconductive PVC work order holder was laid against the PC board on which the device was mounted. Figure 4 shows a static damage site on an SM110 CJ bipolar p-MOS integrated circuit. The device, unlike the character generator shown in Figures 2 and 3, was not actually contacted by the charged object. This IC was damaged by the intense electrostatic field surrounding a charged, nonconductive coffee cup brought to within 1 inch of its PC board. This resulted in the creation of an aluminum silicide path (electrical short) from the pin 4 input to V + during the breakdown at the edge of the thin gate oxide.

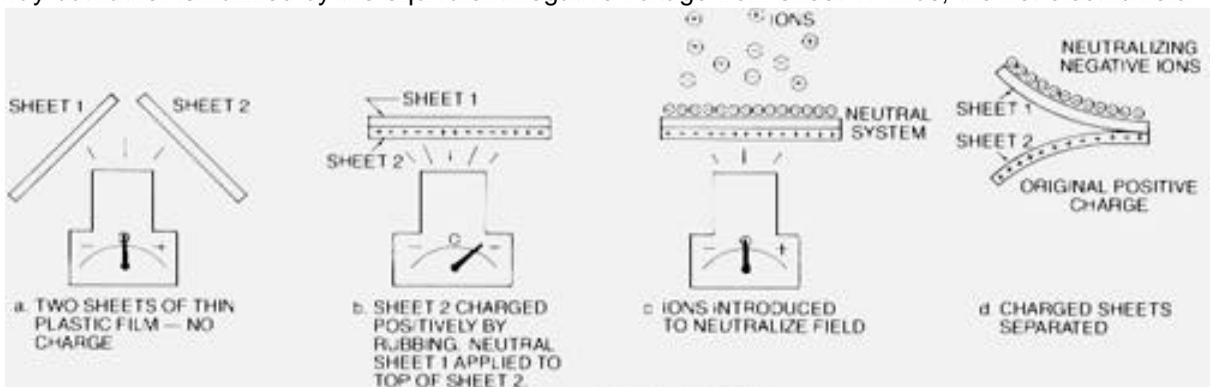


**Figure 4.** Static damage to thin gate oxide of an SM 110 CJ I C caused by exposure to the static field surrounding a charged coffee cup (20 000x)

### Neutralization of a Nonconductor

Static electricity can be defined as an excess or deficiency of electrons on a surface and is generated any time two materials come into contact and then separate. In the case of nonconductors, this charge can remain in “puddles” on the surface for hours or even days and build to higher levels with each subsequent contact and separation. The static voltage on nonconductors commonly reaches magnitudes of 500 to 1500 volts under relatively high humidity conditions<sup>7</sup> and often as high as 15,000 to 20,000 volts under dry conditions<sup>8</sup>. These static voltages can only be neutralized “in-situ” with ionized air.

Ionized air neutralizes voltage on a surface not by conducting charge away, but by adding ions of opposite polarity to the surfaced. The electric field from the charged surface continues to attract these ions until the electric field is neutralized. This neutralization process can be demonstrated with a static meter, a source of positive and negative ions, and two thin sheets of plastic film. Initially both sheets of film are neutral (Figure 5a). Sheet 2 is then charged positively by rubbing. The charged sheet is placed against neutral sheet 1, and the two sheets are held in front of the static meter (Figure 5b) with sheet 2 closer to the meter. The only purpose of sheet 1 (the neutral sheet) is to provide a removeable surface on which to place neutralizing ions. The meter still indicates the same positive voltage on sheet 2 since the thin nonconductive neutral sheet (sheet 1) does not appreciably affect the electric field. A source of positive and negative ions is then brought near sheet 1 (Figure 5c). The negative ions are attracted by coulombic forces to the surface of sheet 1 to neutralize the electric field from sheet 2. The meter will move to zero volts showing that due to the negative ions attached to sheet 1, the system of sheets is now effectively neutral. When the sheets are separated (Figure 5d), sheet 2 still shows the original positive voltage, but now sheet 1 shows an equivalent magnitude of negative voltage. When the sheets are placed together, the meter again reads zero volts. The positive voltage on sheet 2 is not conducted away but rather is nullified by the equivalent negative voltage from sheet 1. Thus, the net electric field



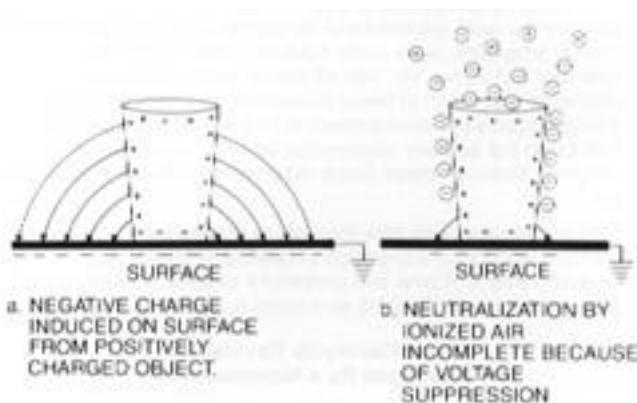
**Figure 5.** Neutralization of a nonconductor.

measured by the meter sums the positive electric field due to the original charge on sheet 2 and the negative electric field from the negative ions attracted to the surface of sheet 1. If sheet 1 had not been used, these neutralizing ions would have been attracted directly to the charged surface of sheet 2, permanently neutralizing it.

## Voltage Suppression

When a charged nonconductive object is placed on a work surface (Figure 6a), the bottom of the object will induce a charge of opposite polarity on the work surface. These positive and negative voltages will at least partially nullify each other as was the case with the positively and negatively charged plastic sheets in Figure 5c. This phenomenon is called voltage suppression .

Ionized air will neutralize only that voltage on the object which is not suppressed and thus still exhibits an electric field (Figure 6b). If the object which has been neutralized is removed from the table or turned over, any suppressed or unneutralized charge (for example the bottom of the cup in Figure 6b) will reestablish an electric field. It is therefore imperative to maintain a constant stream of ionized air in the work environment to completely remove the charge on nonconductors as they are brought into and moved about the area.



**Figure 6.** Voltage suppression effects on the neutralization of a nonconductor.

## Ionized Air Creation

Ionization occurs when sufficient energy is applied to any gas. The energy may be in the form of lightning, flame, induced charge, high voltage AC or DC electricity or radioactive emissions. In air, applied energy can cause an electron to dissociate from the outer orbital of an atom or molecule. The removed electron exhibits a negative charge and under normal conditions does not remain for long in a free, mobile state but rather attaches itself to a large particle in its vicinity. If this particle is a neutral air molecule, which is most often the case, a negative ion is formed.<sup>10</sup> The atom or molecule that originally lost the electron is termed a positive ion. The set of ions, one negative and one positive, is called an ion pair.

The control of static electricity with ionized air depends on the ability to place or direct ions into the influence of the electric field surrounding a charged object so that the field will attract ions of the appropriate sign to the surface. The most convenient way of doing this in the electronics work environment is by using a low pressure, low flow, air blower.

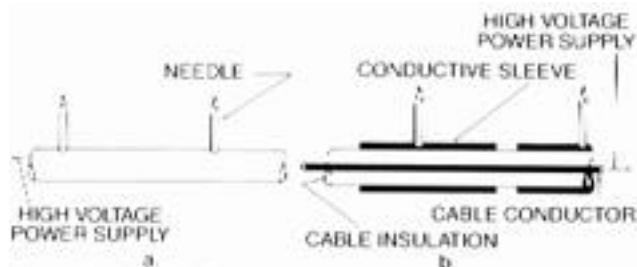
The speed of neutralization of charged nonconductors is a function of the number of ions the neutralizer can make available at the surface of the charged object. The greater the ion density, the faster the neutralization can occur. However, air ions are not long lived and recombination of these airborne positive and negative charges begins almost immediately, and continues until virtually all the ion pairs have neutralized one another. This usually occurs within a few seconds. Air turbulence is also a factor which increases ion recombination. Proper design of an ionized air blower depends, therefore, not only on high initial ion pair production but also on the existence of a rapid, nonturbulent air flow for effective ion delivery.

## Ion Pair Production By AC Electricity

Electrically powered static elimination equipment consists of an ion producing source and a high voltage power supply. The ion producing portion generally consists of one or more electrified needles that are held rigidly less than an inch from a grounded metal housing or proximity ground. High-voltage supplies of 3 to 8 kilovolts AC are used to power units of this type. On neutralizers where no conductive housing or proximity ground is used, power supplies of up to 20 kilovolts are necessary. The ionizing effectiveness of these devices is only a fraction of those having proximity grounds.

Ion generation from electrical static eliminators occurs in the air space immediately surrounding the highly charged needle points. Charge is continuously supplied to each needle point by the high voltage AC power supply. Self-repulsion causes this supplied charge to concentrate on the surface having the smallest radius of curvature or, in this case, the tips of the needles. When a high enough charge concentration has been developed, the resulting intense electrical field supplies the necessary energy to cause the air to ionize. Since the power supply is AC, these electrical air ionizers alternately produce positive and negative ions.

The neutralizing needles may be connected to their power supplies either directly or capacitively. Direct coupling of the needles to the high voltage supply results in what is termed a “hot” bar (Figure 7a). If any of the needles on a hot bar are accidentally shorted to ground during operation or, as frequently happens, high voltage arcing from one of the needle tips to ground occurs, the supply voltage will drop instantly, and the entire bar can become ineffective. “Hot” bars are not desirable in areas where personnel might accidentally come in contact with the needles or electrodes.



**Figure 7.** HIGH VOLTAGE COUPLING OF POWERED STATIC ELIMINATORS On a hot bar (a) the needles are directly attached to the power supply On a shockproof bar (b) the needles are capacitively coupled

A “shockproof” electrically powered static eliminator is produced by capacitively coupling the needles to the power supply. Often this type of coupling is accomplished by imbedding each individual needle in a conductive sleeve surrounding the high voltage transmission cable. The cable conductor acts as one plate of the capacitor, its insulator as the dielectric, and the outer sleeve to which the needle is attached as the other plate (Figure 7b). The shorting or arcing to ground of a needle on a shockproof” unit will not appreciably affect the efficiency of the rest of the bar If someone accidentally touches a needle, they will receive at most a sort of pin-prick discharge to the skin.

The sharpness of the needle points (smallest radius of curvature) is a key factor in the efficacy of electrically powered ion producers. The high voltage will, in time, dull the needle points of an electrical air ionizer and thus reduce its ionization ability. Corrosion, dust and dirt contamination of the needles also contribute to decreases in ion production A large manufacturer of such devices in the U.S. has reported that a new AC electrical static neutralizer can be expected to lose 14% of its ion producing ability during the first year

### Ion Pair Production By Radioactive Emission

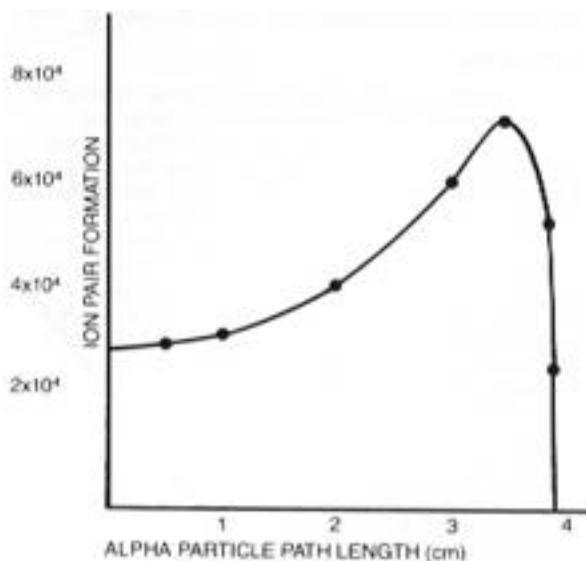
Modern radioactive emission ionizers produce ions by bombardment of air molecules with alpha particles. An alpha particle is equivalent to a helium nucleus, in that it is made up of two neutrons and two protons, and exhibits an atomic weight of 4. Although many radioactive isotopes emit alpha particles, polonium 210 ( $^{210}\text{Po}$ ) is the most popular ionizing source material since it decays by alpha emission directly to nonradioactive lead ( $^{206}\text{Pb}$ ) and does not emit undesirable beta and gamma daughter radiations. Each of the alpha particles from polonium 210 travels about 3.8 cm (1.5 inches) through air in a straight line path from the source. Ion pairs are formed as these 5.3 MeV (million electron volt) particles impart energy to adjacent air molecules by elastic and inelastic collision, and attraction.

Since the greatest density of ion formation is near the end of travel as the alpha particle is slowing down (Figure 8),” the majority of these ion pairs are created over one inch above the source surface. For this reason the radioactive source can be mounted far enough back in the blower housing so that the alpha particles themselves, although used to maximum ionizing effectiveness, are never released to the area outside the housing.

The half life of  $^{210}\text{Po}$  is 138 days, reducing the total number of alpha particles emitted from the source by about 84% after one year. However, the number of useable ion pairs created above a source in a given volume of air does not fall off at the same rate as the alpha emission. The reason for this is that excessive recombination occurs at higher alpha flux rates resulting in a diminishing number of ion pairs that can be removed quickly enough from the source area to be useful. The decrease in the number of available alpha particles that occurs with age results in far less per particle recombination so that after

one year, the effective neutralization ability of a radioactive emission neutralizing blower using  $^{210}\text{Po}$  decreases only about 20%. The sources in these devices, unlike the needle points in electrically powered air ionizers, are renewed at the end of each year's service.

### Ionization Current



**Figure 8.** Ionization-distance curve for 5.3 MeV alpha particle in air at standard temperature and pressure (STP)

If electrical charge moves from one point to another, it is said that a “current” is flowing. In the case of ionized air, this “current” flow is in the form of relatively large and slow moving ions. When the ion “current” interacts with a conductor, such as a metal plate, charge flow results across that plate in the form of free electrons. The phenomenon of air ion charge flow conversion to electron flow in a conductor is often referred to as “ionization current”. Since one electron flowing across the metal plate results from the interaction with one ion, ionization current can be used as a direct analytical measurement to determine ion flux at a location and thus static neutralizer performance.

### Experimental

The purpose of an ionized air blower in the electronics work environment is to neutralize electric fields on charged nonconductors as quickly as possible. To quantify the overall performance of an ionized air blower, both ion density and air flow must be measured at all points in the work area. An experiment was designed that provided a detailed map of the ionization current and air flow patterns for various ionized air blowers at selected points above the surface of a 2 foot by 4 foot table. In addition, static neutralization times were measured for several nonconductive items found in the electronics work environment and compared to the neutralization times calculated for these objects based on ionization current measurements from different blowers.

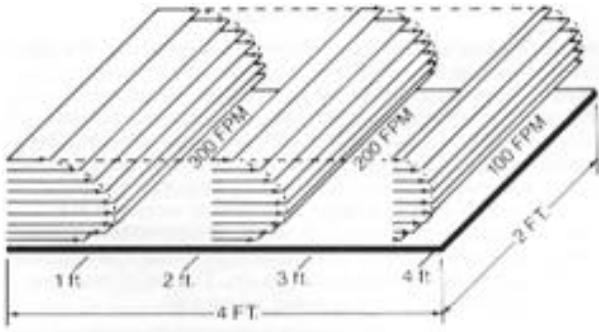
#### Air Flow Patterns

The air velocity and flow pattern uniformity from an ionized air blower are two critical design considerations in delivering sufficient numbers of the short lived ion pairs throughout the work area. Experimentally, it has been found that the air velocity should be at least 100 feet per minute to distribute ample ions to the farthest point in a 2 foot by 4 foot work station but not greater than 500 feet per minute down on the work surface since, at this velocity, small objects may be disturbed. The air velocity at the blower outlet may exceed 500 feet per minute if the blower is of such a design as to maintain its ionization efficiency without disrupting materials on the bench. A profile of an efficient air flow pattern over a typical electronic work table is shown in Figure 9.

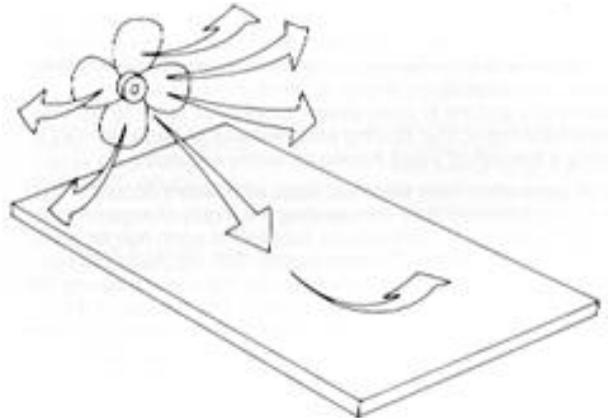
Air velocities were measured with an Alnor Type 8500 Thermo-Anemometer at various locations above the table surface to obtain three dimensional representations of air flow patterns in a work station. The bladed fan and the squirrel cage blower, two major types of fans in use today, were found to have very different flow patterns.

A bladed fan and its characteristic air flow pattern are shown in Figure 10. Much of the ionized air produced by such a device is wasted because of the multidirectional vortex-shaped flow. As will be seen later, this also contributes to significant nonuniformities in the side to side ion density in front of such a fan.

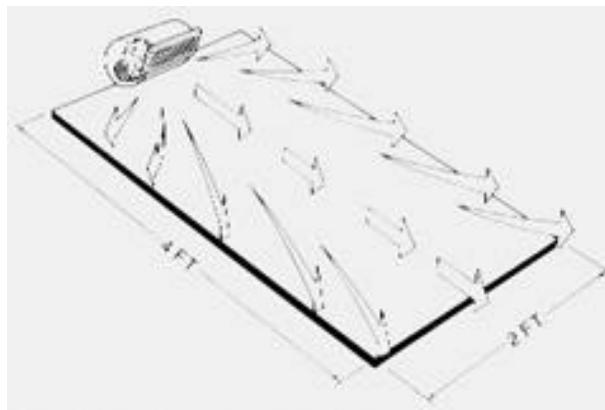
Figure 11 shows the air flow pattern from a squirrel cage type blower. Air exits more uniformly from such blowers than from the Laded fan devices. The air flow pattern from this type of blower is very similar to the optimum pattern shown in Figure 9.



**Figure 9.** Example of an efficient air velocity flow profile over a 2 x 4 work surface for transport of ionized air.



**Figure 10.** Bladed fan air flow pattern.



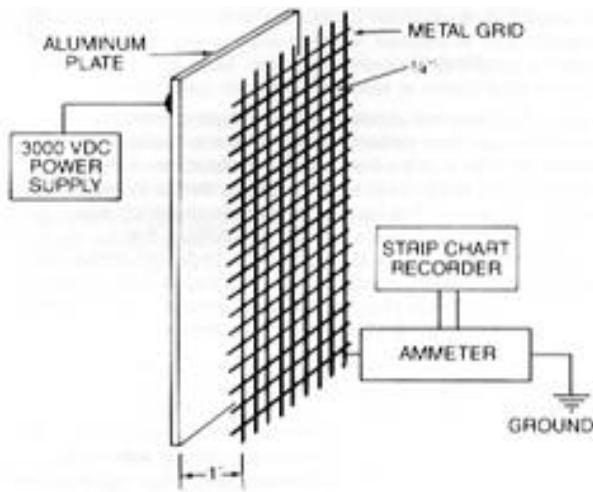
**Figure 11.** Squirrel cage blower air flow pattern.

Table 1  
**Ionized Air Blower Description**  
**Maximum Air Velocity at Various Distances from Blower (feet per minute)**

Blower	Method of Ion Production	6"	12"	24"	48"	Blower Type
A	High Voltage AC	400	250	160	100	Bladed Fan
B	High Voltage AC	200	200	120	80	Bladed Fan
C	High Voltage AC	800	600	450	400	Bladed Fan
D	Radioactive Emission	700	425	325	200	Squirrel Cage

### Ion Flux Measurement

A unique ion flux test method was developed that allows continuous and meaningful measurement of ionization current within a work environment. The components of the test system are pictured in Figure 12. The ion flux monitor (IFM) consists of a six inch square metal plate positioned behind and parallel to a six inch square 1/4 inch mesh metal grid. The metal plate at the rear of the IFM is continuously charged to +3,000 volts DC by a high voltage power supply. The metal grid defining the front sampling surface is connected through an ammeter to ground. Because this screen is grounded, it acts as an electric shield for the highly charged plate, limiting the sampled ions to those physically propelled into the IFM grid by the blower's air flow characteristics

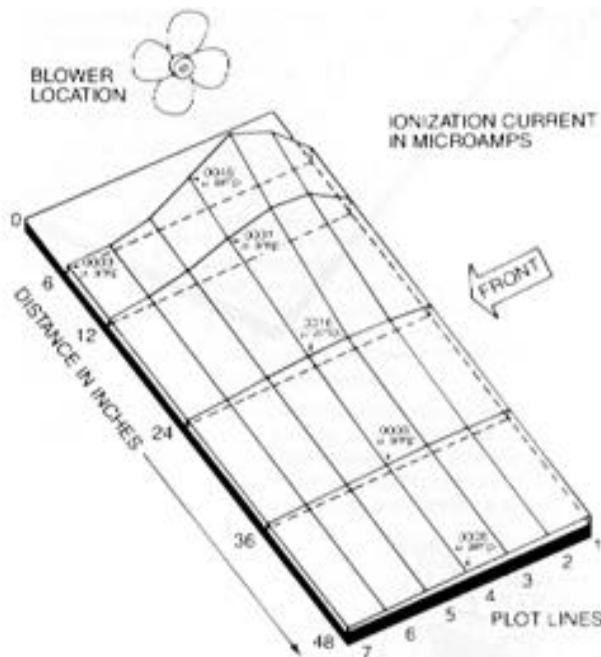


**Figure 12.** Ion flux monitor (IFM) test apparatus for the measurement of ionization current

As ionized air enters the front of the IFM through the metal grid, the negative ions are drawn immediately to the surface of the positively charged metal plate. The positive ions are repelled from the positively charged plate and are neutralized by accepting electrons from the grounded metal grid. This process, which continues as long as the ionized air is present, results in a continuous transformation of ion charge flow to electron charge flow within the IFM. The ionization current is monitored at the front grid (Figure 12), and the resulting signal fed from the ammeter into a strip chart recorder for a permanent record.

The IFM was placed at various positions across the width of the end of a work bench. The air blower under test was placed on a sliding support and centered on the table facing the IFM. The sliding support and air blower were then slowly and steadily pulled back from the IFM along the length of the bench at a rate of 1/4 inch per second by a small gear motor. By continuously monitoring the ammeter as the blower moved, a permanent record of the ionization current due to the ion flux at varying distances from each blower was obtained. These ionization current measurements were recorded at several positions across the two foot wide bench surface in front of each blower.

Four commercially available ionizing air blowers were tested using this ionization current monitoring technique. A description of each blower including its method of ion production, blower type, and the air velocity measurements made at varying distances from each, is given in Table 1. The seven positions across the bench surface along which the blower was pulled are called plot lines. The ionization current along these plot lines is plotted isometrically (Figures 13 through 16) for each blower and provides a three dimensional representation of the ion flux across the entire work surface.



**Figure 13.** Test Blower "A" ion flux.

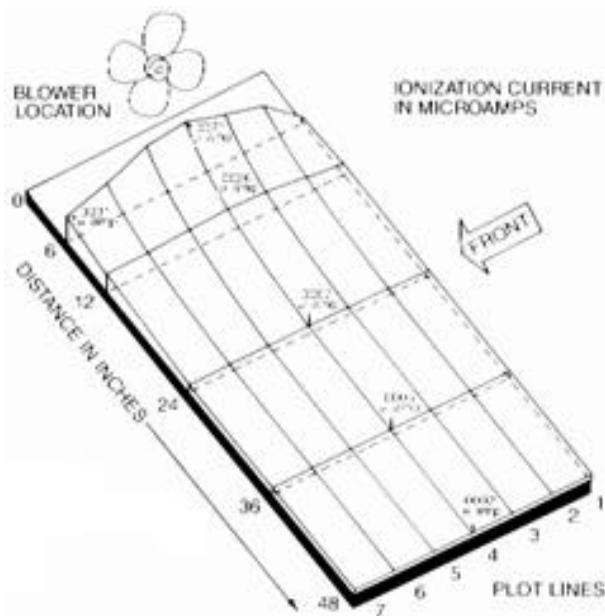


Figure 14. Test Blower "B" ion flux.

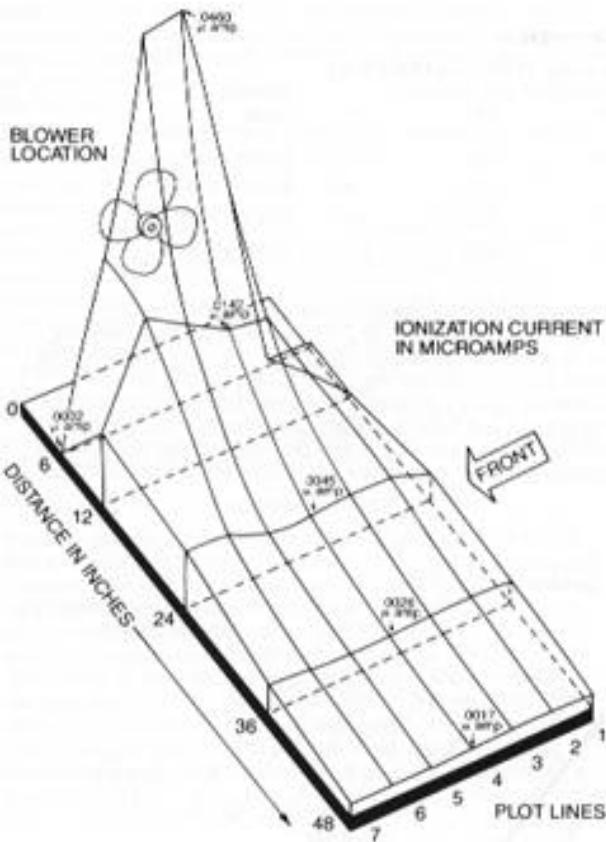


Figure 15. Test Blower "C" ion flux.

Table 2  
Ionization Current at Selected Locations  
Across Work Surface

Intercept Position (Distance x plot line)	Blower			
	A $\mu$ amp	B $\mu$ amp	C $\mu$ amp	D $\mu$ amp
6 inch x plot 1	.0016	.0010	.0002	.0022
6 inch x plot 4	.0046	.0071	.0460	.0310
6 inch x plot 7	.0003	.0031	.0002	.0032
12 inch x plot 1	.0017	.0014	.0003	.0023
12 inch x plot 4	.0031	.0026	.0142	.0122
12 inch x plot 7	.0001	.0023	.0084	.0034
24 inch x plot 1	.0010	.0015	.0030	.0020
24 inch x plot 4	.0016	.0007	.0045	.0036
24 inch x plot 7	.0005	.0008	.0068	.0035
36 inch x plot 1	.0007	.0004	.0022	.0012
36 inch x plot 4	.0006	.0005	.0026	.0022
36 inch x plot 7	.0006	.0004	.0032	.0020
48 inch x plot 1	.0003	.0002	.0015	.0010
48 inch x plot 4	.0006	.0002	.0017	.0019
48 inch x plot 7	.0003	.0003	.0016	.0013

As expected, the highest ion flux occurred nearest the blower in each case. In addition, blowers with the highest velocity air patterns exhibited the highest ion flux. Table 2 lists ionization current magnitudes at selected points for each blower

Figure 13 shows the skewed ion flux resulting from the nonuniform air flow pattern produced by the Laded fan in air blower "A". The numbers shown at the distance—plot line intercepts are the ionization current magnitudes in microamps at those locations. The back side of the work bench

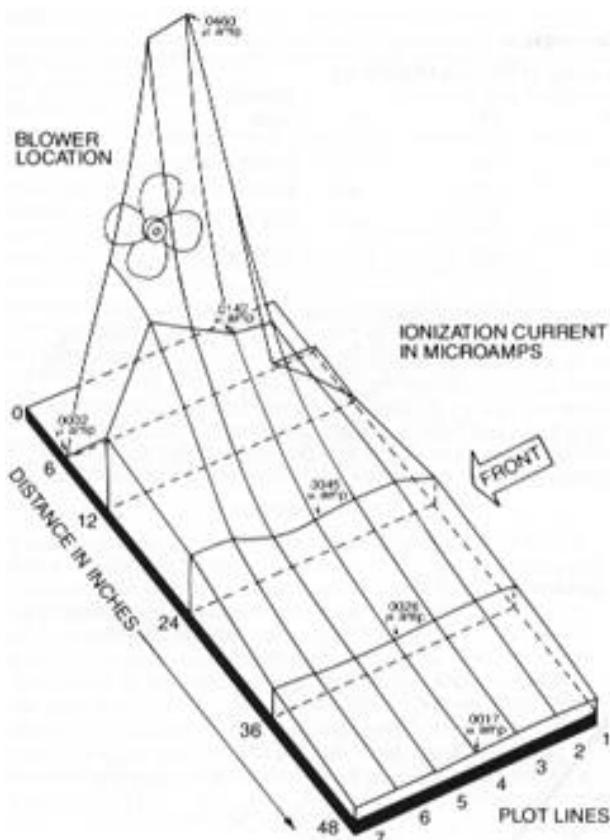


Figure 16. Test Blower "D" ion flux.

was virtually unprotected by this blower. In addition, the combination of low initial ion production, high turbulence and resulting recombination associated with bladed fans, and the low air velocity resulted in a substantial drop in the ion current at distances of over two feet from this blower

Air blower "B" (Figure 14) is also a Laded fan device. Because of the design of its housing, the air was forced out more uniformly than other fans of this type. This channeling effect, however, caused a substantial loss in air velocity (Table 1), and as a result, the effective ion delivery of this unit was lower overall than that of the other blowers tested.

Air blower "C", (Figure 15) showed a higher ionization flux over most of the table. As is typical of a Laded fan type device, however, skewing still existed. The high air velocity (Table 1), which tended to disrupt items on the table top and also made the blower distractingly noisy (Table 6), overcame to some extent the increased recombination effects due to the turbulence of the air in its flow pattern.

Air blower "D" uses a squirrel cage type blower to propel the ionized air into the work environment with a minimum of air turbulence. The air flow pattern for this blower was uniform and resulted in a balanced ion flux blanketing the full length of the table (Figure 16). The ionization current at the end of the table farthest from the blower was 10% higher than that

from blower "C", with 60% of "C's" air velocity at that point. Based on these ion flux measurements (Table 2), blower "D" would be expected to neutralize a charged nonconductor located at the farthest end of the table 10% faster than blower "C", three times faster than blower "A", and nine times faster than blower "B".

### Correlation of Ion Flux To Static Neutralization Time

Using the values of the ionization current given in Table 2, an estimate can be made of the time to neutralize a charged nonconductor at any given location within the work area. To make this estimate, it is first necessary to determine the effective capacitance of that object on the work bench. The method by which this effective capacitance measurement is made must take into account the portion of the object's voltage that is suppressed by the bench beneath it. This was accomplished by charging the object by rubbing, then placing it on top of a conductive work surface. The static voltage was measured around its perimeter and across its top, and the average voltage calculated. The object was placed into a closed "Faraday ice pail" which was connected to an electrometer for a direct measurement of its total charge in coulombs. By dividing the total charge in coulombs by the average voltage measured across the object's surface, the effective capacitance of several nonconductive objects that are commonly found in the work area were calculated (Table 3).

The neutralization time can be calculated by assuming that the unsuppressed charge on the body would be neutralized at a rate determined by the "ionization current" at the object's location. Based on experimental measurements of actual neutralization times (Tables 4 and 5), this assumption was found to be valid.

The neutralization time was calculated according to the relation:

$$t = \frac{C \cdot V}{I} \quad \text{Eqn. (1)}$$

where:  $t$  = time to neutralize the voltage (seconds)  
 $C$  = effective capacitance of object (farads)  
 $V$  = average static voltage over surface of object (volts)  
 $I$  = ionization current (amps) (from Table 2)

The time for neutralization was calculated for various objects in a static safeguarded environment (i.e. on a grounded table top) and is given in Table 3. These calculations were made for items located at the center of a 2 foot by 4 foot table under the influence of blower "D" (Figure 16), which exhibited an ionization current of 0.0036 microamps at that position.

In order to verify the accuracy of the ion flux data developed using the IFM measurement technique, direct measurements of the neutralization times for a nonconductor located at two different positions in a 2 foot by 4 foot work area were made for each of the four previously tested blowers using a Keithley Model 610C electrometer, and a Model 2503 static voltage probe and recorded on a strip chart recorder. These observed values of neutralization time were compared to the neutralization times calculated according to Equation 1, using the ionization current observed with the IFM.

A plastic box having an effective capacitance of 4 picofarads (Table 3) was charged by rubbing and placed onto the conductive work surface. The static probe was then lowered to within one half inch of the box. A cover was held over the outlet of the blower under test. The blower was turned on and allowed to reach full operating speed. The cover was removed, and the effective neutralization time constant  $\tau$ , (the time necessary to decrease the voltage on the box to 37% of its initial value) was determined from the strip chart recording. The neutralization curve was assumed exponential, and the neutralization time was taken as  $5\tau$ . This was repeated six times for each blower, and the average neutralization times determined.

Tables 4 and 5 compare both the theoretical and experimentally observed neutralization times of the small plastic box by each of the four blowers tested at two locations.

When the object was located at the far end of the work bench in the center (Table 4), blower "A" required over half a minute to neutralize the box. Blower "B" was unable to accomplish this neutralization in a minute and a half. Both blowers "C" and "D" at this position did a reasonable job of charge neutralization, but blower "D" accomplished this with 40% less air velocity.

When the small box was moved up toward the blowers and placed at the back of the bench, however, a very different performance was given by three of the blowers tested (Table 5). Blower "A" was only half as effective as it had been when the box was located at the far end of the table and required over a minute to neutralize the box. Unlike its performance at the first test location blower "B" did a good job of neutralization at this position. Blower "C" exhibited the poorest performance at this location requiring nearly 11/2 minutes to discharge the box. Only blower "D" was consistent in its performance at these two locations.

The theoretical neutralization time calculations based on the IFM measurements and the observed neutralization times correlate very well for all of the blowers. The IFM therefore, provides a useful analytical tool with which to monitor and aid in the optimization of the neutralizing performance of any ionized air source.

Table 3  
Effective Capacitance and Calculated Neutralization Times for Nonconductors In the Electronic Work Environment

Object To Be Neutralized	Effective Capacitance (picofarads)	Voltage (kilovolts)	Charge (coulombs)	Neutralization Time (seconds)
Coffee cup (styrene)	10	3	$3.0 \times 10^{-8}$	8.3
DIP Tube (plastic)				
(on table)	10	3	$3.0 \times 10^{-8}$	8.3
(in space)	3	3	$9.0 \times 10^{-9}$	2.5
Plastic box (2" x 3" x 7/8" high)	4	5	$2.0 \times 10^{-8}$	5.6
Cardboard box (2 1/2" X 5 1/2" X 3/4" high)	8	5	$4.0 \times 10^{-8}$	11.1
Flat chip carrier	7	7	$4.9 \times 10^{-8}$	13.6
Polystyrene wafer carrier	15	10	$1.5 \times 10^{-7}$	41.7

Table 4  
Static Neutralization Time For a Plastic Box Charged To 5,000 Volts Located at the Center of the Far End of the Work Area (48 inch distance, plot line 4).

Blower	Charge (microcoulombs)	Ionization Current (microamps)	Theoretical Neutralization Time (seconds)	Observed Neutralization Time (seconds)
A	0.02	0.0006	33.3	38
B	0.02	0.0002	100.0	93
C	0.02	0.0017	11.8	18
D	0.02	0.0019	10.5	16

Table 5  
Static Neutralization Time For a Plastic Box Charged to 5,000 Volts Located at the Back of the

**Table Near the Blower (6 inch distance, plot line 7).**

<b>Blower</b>	<b>Charge (microcoulombs)</b>	<b>Ionization Current (microamps)</b>	<b>Theoretical Neutralization Time (seconds)</b>	<b>Observed Neutralization Time (seconds)</b>
A	0.02	0.0003	66.7	76
B	0.02	0.0031	6.5	15
C	0.02	0.0002	100.0	85
D	0.02	0.0032	6.3	15

**Other Considerations**

In addition to neutralization effectiveness, there are other considerations in selecting an ionized air blower. These include characteristics such as ozone production, EMI emission, and noise levels. A comparison of these characteristics of the four previously tested blowers is given in Table 6.

AC electrical ionizing sources all produce more ozone than radioactive emission ionizers. Ozone concentrations of 0.01 PPM (parts per million) to 0.02 PPM will cause cracking of rubber that is under slight stress. The OSHA limit for ozone concentration in a breathing zone is 0.1 PPM, and some people have been found to be physiologically affected by continuous exposure to even lower concentrations. Table 6 shows the variability in ozone production that occurs among the four blowers evaluated.

Although all blower motors produce electromagnetic interference (EMI), electrical air ionizers also produce EMI at high frequency levels that could affect the operation of electronic equipment in the immediate area. The levels of EMI emission given in Table 6 were monitored at a distance of one meter from each of the four blowers.

The noise generated by an ionized air blower can be a significant factor since personnel are required to work beside these devices for long periods of time. All blowers emit sound at a level that appears dependent on air velocity and fan type. An increase in noise level of only 3 dB(A) (Table 6) is equivalent to a doubling of the acoustic power, or a sound level increase as perceived by the human ear of about 15%. The noise levels given in Table 6 were recorded 12 inches from the side of each blower (out of the air stream) to approximate the closest normal operator position.

Table 6  
**Comparison of Ionized Air  
Blower  
Characteristics**

<b>Blower</b>	<b>Ozone Production</b>	<b>EMI Emission</b>		<b>Noise Levels</b>
		<b>100 KHz</b>	<b>1 MHz</b>	
A	0.028 ppm	38 dB	17 dB	62dB (A)
B	0.230 ppm	65 dB	48 dB	61 dB (A)
C	0.055 ppm	74 dB	50 dB	72 dB (A)
D	*	*	*	59 dB (A)

\* below detectable limits

**Summary**

Static voltage on nonconductors in the electronics work environment can destroy or degrade sensitive electronic components. The only way to control static voltage on nonconductors is with ionized air. Ionized air neutralizes static voltage by adding sufficient ions of the appropriate polarity to the surface of a nonconductor to nullify the voltage field.

A unique ion flux monitor (IFM) was designed that accurately measures ion flux and thus the static neutralization efficiency at any position in front of an ionized air blower. It was found using the IFM test fixture that selection of the proper blower type is a very important factor in determining the neutralizing effectiveness of a blower. Bladed fans provide skewed air flow and ion flux patterns resulting in incomplete coverage for a typical work area. Squirrel cage blowers, however, provide less turbulent flow and better balanced ion flux patterns and are thus much better suited for propelling ionized air effectively. Significant differences in the performance of four commercially available ionized air blowers were shown both experimentally and theoretically based on measurements made of each unit's performance using the IFM technique.

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