MONROE ELECTRONICS

# Application Note APNE-0009
# 268A Applications

## Forward:

**Charge plate monitors have been around in various forms since 1985. This application note deals specifically with the Monroe Electronics Model 268 Charge Plate Monitor. Originally designed to test the performance of ionizers, its functions have been adapted to many other uses over the years. In this document you will find step by step instructions to use this instrument to not only test ionizers to the EOS/ESD standards, but also test such items as wrist straps, floors, smocks and other ESD materials. Included, too, are instructions on utilizing the Model 268 for ESD demonstrations and education. We at Monroe would like to thank our customers who provided much of the information on these alternative applications as they searched for ways to improve their ESD programs.**

## CAUTION

**When charged, the plate voltage can be in excess of 5000 volts with respect to ground. Although the charges and potentials are below those that are normally detected by human senses, A SHOCK HAZARD EXISTS.**

- **If you are handling the plate assembly or conducting a test that involves touching the plate, <u>expect a shock</u>.**
- **Do not charge large capacitors with this device.**

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# 268A Applications

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# I. Introduction

1. The Monroe Electronics Charged Plate Analyzer (Monitor) Model 268A meets test equipment requirements of the Electrostatic Discharge (ESD) Association, Inc. current standard EOS/ESD-S3.1-1991, “Standard for Protection of Electrostatic Discharge Susceptible Items – Ionization”. The standard addresses specific requirements for the equipment categories of Room Ionization, Laminar Flow Hood Ionization, Worksurface Ionization and Compressed Gas Ionization (Guns and Nozzles). Procedures are given for measuring, at specified locations, the positive and negative charged plate discharge times as well as the positive and negative offset voltages obtained from a zeroed and uncharged plate.

2. The 268A Analyzer is used in conjunction with the above ionization standard to:
   a) Select effective ionizers and ionization systems.
   b) Certify effective ionization when equipment is first installed, and then on a periodic basis.
   c) Reduce or eliminate airborne particles and particle deposition on surfaces.
   d) Reduce or eliminate the incidents of ESD damage to electronic components.
   e) Reduce production line downtime.

3. Considerations regarding variability in charged plate discharge times and offset voltages.
   a) The EOS/ESD-S3.1-1991 standard specifies neither acceptable charged plate discharge times nor acceptable offset voltages. These values must be individually determined by the user based on her/his knowledge of the working environment, and the ESD susceptible devices being handled.
   b) Charged plate monitors (CPMs) from different manufacturers will not necessarily provide the same results under identical conditions because of electrical (i.e. components and circuitry), and mechanical (e.g. metal vs. plastic case) differences not described or specified in the standard. Likewise, different models of CPMs from the same manufacturer are subject to similar variability of results.
   c) Ionization equipment and CPMs must electrically and physically be set up exactly the same each day under the same environmental conditions (temperature, humidity, etc.) in order for testing results to be valid.

4. In addition to providing detailed instructions for using the 268A Analyzer to perform basic tests as specified by the ionization standard, the test procedures given in this application document provide other useful test methods of utilizing the 268A. Methods are given for evaluating materials, mats, floors, containers, footwear, etc. as well as evaluating tribocharging of materials and humans, and to demonstrate the effects of induction charging and voltage suppression.

5. The Charged Plate Analyzer Model 268A separates into two sections connected by a ten-foot cable. The top part containing the metal plate and fieldmeter may be placed at

the measurement location, while the bottom part may be placed at a convenient operating location remote from the detector. To separate the two sections, release the two side latches near the rear of the unit and lift up at the rear of the top section.

## II. Model 268A Features

1. A ¼ - 20 threaded hole (Figure 1) is provided on the underside of the top section for convenient tripod mounting.

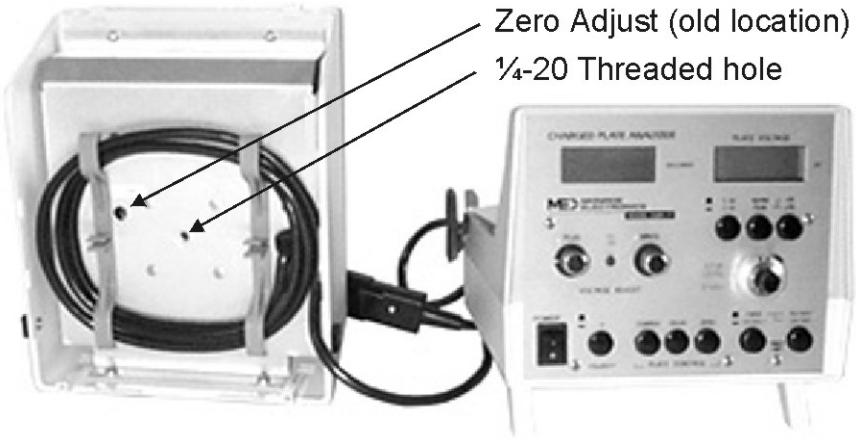



**Figure 1**

2. Two foldout legs are provided underneath the bottom of the control unit to elevate the front of the cabinet for easy meter viewing.

3. Controls (Figure 2) are grouped by function. Switches on the front panel are alternate action push-push types with the exception of the three used for "PLATE CONTROL". These are mechanically interlocked so that only one function can be selected at a time.

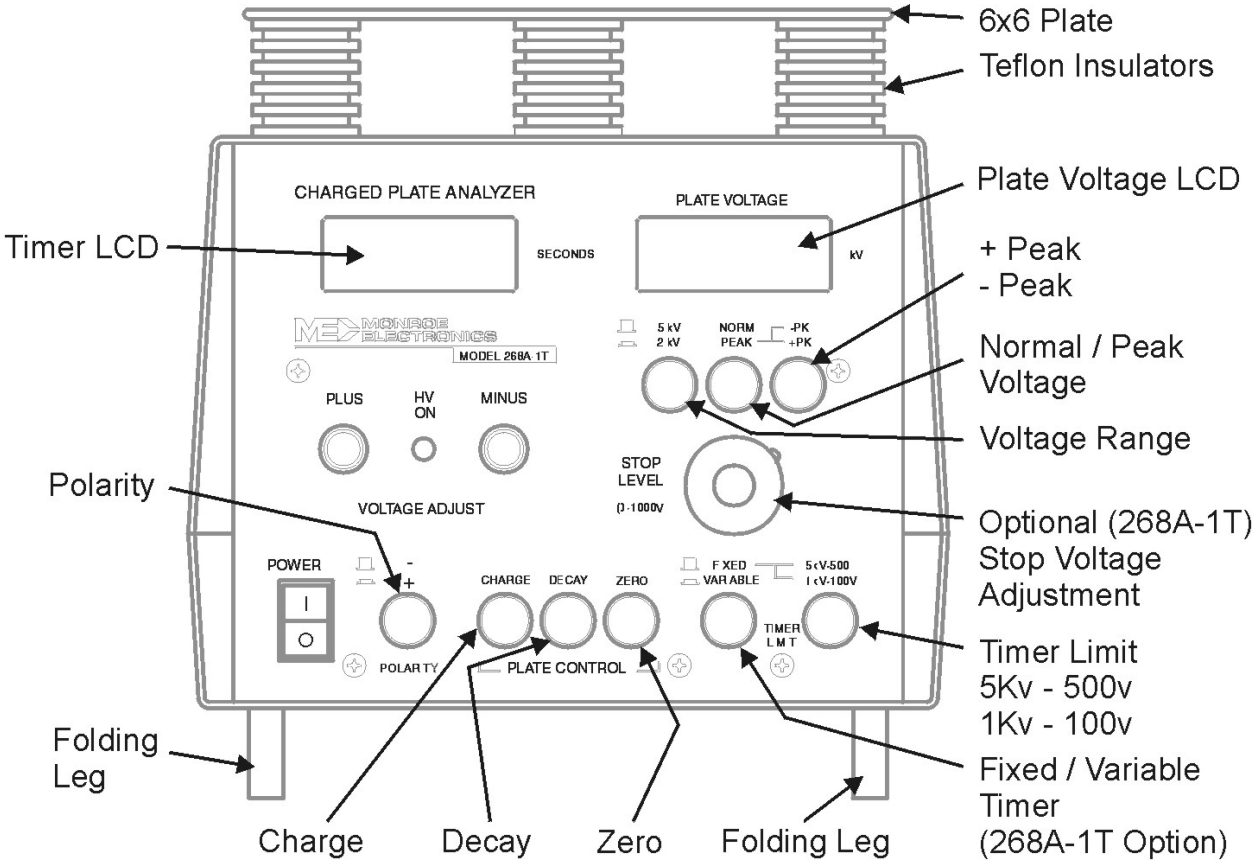



**Figure 2**

4. The three pushbutton switches directly beneath the "PLATE VOLTAGE" meter relate to meter range and function.

5. The three switches at the lower center of the panel labeled "PLATE CONTROL" affect the charge/discharge condition of the plate.

6. The "PLUS" and “MINUS” “VOLTAGE ADJUST” control knobs, the "HV ON" red LED indicator and the "POLARITY" pushbutton switch relate to the polarity and magnitude of the initial charge voltage on the plate.

7. The "TIMER LIMIT" switch sets the start/stop voltage limits for the timer.

8. The "OUTPUT" BNC connector on the back panel (Figure 3) allows an oscilloscope, XY recorder or data acquisition system to be connected to the output of the fieldmeter. The voltage signal here is 0.001 times the actual voltage on the plate, regardless of the settings of the meter range and function switches.

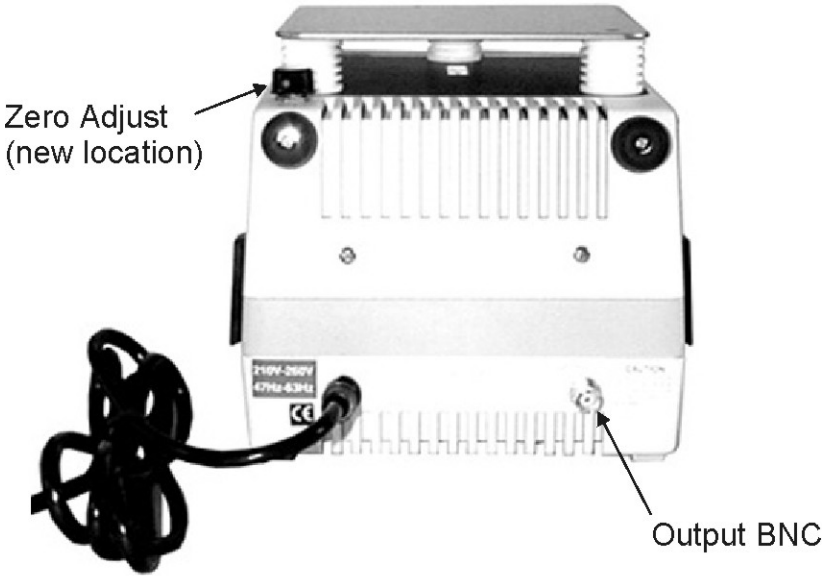



**Figure 3**

9. Two small holes are provided in the plate (Figure 4) for the attachment of standard or miniature banana plugs, useful for measuring induced charge or decay rate on personnel.

**Figure 4**

10. **IMPORTANT NOTE!** In order to maintain proper operation of the floating plate, it is essential that the support insulators be kept scrupulously clean:
    **a)** Do not touch or handle the insulators.
    **b)** Do not wrap the line cord around the insulators.
    **c)** Store the instrument in its protective case when not in use, in a clean, dry location.
    **d)** Clean the insulators when self-discharge of the charged plate exceeds 10% of the set voltage within 5 minutes at relative humidity of less than 50%. At higher than 50%, air begins to ionize readily and surface leakage currents increase. Self-decay time can be expected to decrease below 5 min. regardless of how clean the insulators are.
    **e)** *DO NOT USE SOAP, DETERGENT OR TAP WATER TO CLEAN THE INSULATORS.* Clean the exposed surfaces of the insulators with pure 70% isopropyl rubbing alcohol using a soft toothbrush. The unit should be inverted while doing this to minimize the amount of liquid entering the case. Allow the insulators to air-dry before using or storing the instrument.

## III. Basic Operation – Discharge Time Test

1. ***The Discharge Time Test*** is required for compliance, in part, to EOS/ESD-S3.1-1991, "Standard for Protection of Electrostatic Discharge Susceptible Items – Ionization" for all ionization systems. Required testing locations are specified in the standard.

2. ***Separate*** the 268A top plate and bottom meter sections, and position each as necessary. Depress the ZERO pushbutton in the PLATE CONTROL section (this ensures no voltage is on the plate by connecting it to ground through a 10 kΩ resistor). Connect the 268A power plug to the proper source (117V or 220V), and press "|" at the top of the POWER switch to turn it on. Black numerals in the LCD meter displays indicate that power is on.

3. ***Zero the fieldmeter.*** The 268A does not require frequent zero adjustment due to its "chopper stabilized" circuitry. If possible, allow 30-min. warm-up time for the electronics to stabilize so that zero drift is minimized while taking measurements. When the ZERO pushbutton is depressed with the 5 kV/2 kV pushbutton depressed in the 2 kV position, and the NORM/PEAK pushbutton released in the NORM position, the PLATE VOLTAGE should display .000 ± .002 kV (0 ± 2 volts). If the PLATE VOLTAGE is greater than ± 2 V, the following solutions may be applied:

    a) The fieldmeter may be mechanically zeroed by adjusting the ZERO potentiometer in the top plate section with a small screwdriver (see Figure 1).

    *Note: Newer 268A versions have the zero adjustment located on the top of the plate section at the rear of the plate (see Figure 3).*

b) The zero offset voltage may be algebraically subtracted from each subsequent PLATE VOLTAGE reading.

4. ***Select a range.*** We will use the 2 kV range for this example. Depress the 5 kV/2 kV pushbutton under the PLATE VOLTAGE meter display.

5. ***Select Normal Discharge Time Test*** mode by releasing the NORM/PEAK pushbutton (next to the 5 kV/2 kV pushbutton).

6. ***Select timer limits.*** Depress the TIMER LIMIT pushbutton to activate the timer between 1kV and 100V. If the 5 kV range had been selected above, the TIMER LIMIT pushbutton should be selected to activate the timer between 5kV and 500V.

   *Note: This application is written for the Model 268A. Monroe Electronics also manufactures a Model 268A-1T, which has a variable timer-stop option that allows the stop voltage to be adjusted from 0V to 1000V).*

7. ***Select a polarity.*** We will select positive (+) polarity for this example. Depress the POLARITY pushbutton to select positive. The Discharge Time Test is normally also repeated at each location with the negative (-) polarity selected (release the POLARITY pushbutton).

8. ***Charge the plate.*** Depress the CHARGE pushbutton. The red HV ON light indicates that the high voltage supply is on. The PLATE VOLTAGE display will indicate some positive voltage. Adjust the “PLUS” VOLTAGE ADJUST knob to a minimum PLATE VOLTAGE of approximately 1kV + 10% (1100 volts).

9. ***Allow the plate to decay.*** Depress the DECAY pushbutton. In the absence of ions, the plate will decay very, very slowly. In a balanced or negative ion field, the plate will decay at a more rapid rate.

10. ***Record the elapsed time interval.*** As the plate voltage crosses the +1000 volt level, the timer will start. As the plate crosses the +100 volt level, the timer will stop and indicate the elapsed time interval in seconds between these two levels. The timer will reset when the plate is recharged for the next test.

11. ***Change the polarity and repeat test.*** Repeat steps 8. through 10. with the opposite polarity selected.

## IV. Basic Operation – Offset Voltage (Ionizer Balance) Test

1. ***The Offset Voltage Test*** is required for compliance, in part, to EOS/ESD-S3.1-1991, "Standard for Protection of Electrostatic Discharge Susceptible Items – Ionization" for all ionization systems except Pulsed DC emitter types. Required testing locations are specified in the standard. The internal timer is not associated with these measurements. The internal high-voltage charging source is not normally used.

2. ***Separate*** the 268A top plate and bottom meter sections, and position each as necessary. Depress the ZERO pushbutton in the PLATE CONTROL section (this ensures no voltage is on the plate by connecting it to ground through a 10 kΩ resistor). Connect the 268A power plug to the proper source (117V or 220V), and press "|" at the top of the POWER switch to turn it on. Black numerals in the LCD meter displays indicate that power is on.

3. ***Zero the fieldmeter.*** The 268A does not require frequent zero adjustment due to its "chopper stabilized" circuitry. If possible, allow 30-min. warm-up time for the electronics to stabilize so that zero drift is minimized while taking measurements. When the ZERO pushbutton is depressed with the 5 kV/2 kV pushbutton depressed in the 2 kV position, and the NORM/PEAK pushbutton released in the NORM position, the PLATE VOLTAGE should display .000 ± .002 kV (0 ± 2 volts). If the PLATE VOLTAGE is greater than ± 2 V, the following solutions may be applied:

   a) The fieldmeter may be mechanically zeroed by adjusting the ZERO potentiometer in the top plate section with a small screwdriver (see Figure 1).

      *Note: Newer 268A versions have the zero adjustment located on the top of the plate section at the rear of the plate (see Figure 3).*

   b) The zero offset voltage may be algebraically subtracted from each subsequent PLATE VOLTAGE reading.

4. ***Select a range.*** Since the ideal offset voltage is zero, we will use the 2 kV range for best accuracy. Depress the 5 kV/2 kV pushbutton under the PLATE VOLTAGE meter display.

5. ***Select Normal Offset Voltage Test*** mode by releasing the NORM/PEAK pushbutton (next to the 5 kV/2 kV pushbutton).

6. ***Allow the plate to "float".*** Depress the DECAY pushbutton. In general, the plate should be allowed to "float" for at least 1 minute, or as necessary to allow the voltage reading to stabilize (5 minutes max.).

7. ***Record and adjust the offset voltage.*** To balance your ionization system or blower, adjust it until the voltage reading is as close to zero as practical. Depress the ZERO pushbutton to reset the plate for the next test.

## V. Basic Operation – Peak Offset Voltage (Ionizer Balance) Test

1. ***The Peak Offset Voltage Test*** is required for compliance to EOS/ESD-S3.1-1991, "Standard for Protection of Electrostatic Discharge Susceptible Items – Ionization" for Pulsed DC emitter type ionization systems. Required testing locations are specified in the standard. Peak mode is also useful for many other types of electrostatic testing which will be described later in these application notes. The internal timer is not associated with these measurements. The internal highvoltage charging source is not normally used.

2. ***Separate*** the 268A top plate and bottom meter sections, and position each as necessary. Depress the ZERO pushbutton in the PLATE CONTROL section (this ensures no voltage is on the plate by connecting it to ground through a 10 kΩ resistor). Connect the 268A power plug to the proper source (117V or 220V), and press "|" at the top of the POWER switch to turn it on. Black numerals in the LCD meter displays indicate that power is on.

3. ***Zero the fieldmeter.*** The 268A does not require frequent zero adjustment due to its "chopper stabilized" circuitry. If possible, allow 30-min. warm-up time for the electronics to stabilize so that zero drift is minimized while taking measurements. When the ZERO pushbutton is depressed with the 5 kV/2 kV pushbutton depressed in the 2 kV position, and the NORM/PEAK pushbutton released in the NORM position, the PLATE VOLTAGE should display .000 ± .002 kV (0 ± 2 volts). If the PLATE VOLTAGE is greater than ± 2 V, the following solutions may be applied:
   a) The fieldmeter may be mechanically zeroed by adjusting the ZERO potentiometer in the top plate section with a small screwdriver (see Figure 1).

      *Note: Newer 268A versions have the zero adjustment located on the top of the plate section at the rear of the plate (see Figure 3).*

   b) The zero offset voltage may be algebraically subtracted from each subsequent PLATE VOLTAGE reading.

4. ***Select a range.*** Since the ideal offset voltage is zero, we will use the 2 kV range for best accuracy. Depress the 5 kV/2 kV pushbutton under the PLATE VOLTAGE meter display.

5. ***Select Peak Offset Voltage Test*** mode by depressing the NORM/PEAK pushbutton (next to the 5 kV/2 kV pushbutton). The PLATE VOLTAGE meter display will hold at the highest voltage attained for the selected polarity.

6. ***Select a peak polarity.*** We will select positive (+) peak polarity for this example. Depress the –PK/+PK pushbutton (next to the NORM/PEAK pushbutton). The Peak Offset Voltage Test is normally also repeated at each location with the negative (-) peak polarity selected (release the –PK/+PK pushbutton).

7. ***Allow the plate to "float" to its peak.*** Depress the DECAY pushbutton. In general, the plate should be allowed to "float" for at least 1 minute, or as necessary to allow the reading to reach its peak value (5 minutes max.).

   *Note: The initial voltage will remain displayed until a higher voltage is reached.*

8. ***Record and reset the peak-offset voltage.*** Depress the ZERO pushbutton to reset the plate for the next test. Release and depress the NORM/PEAK pushbutton to reset the peak detector.

9. ***Change the peak polarity and repeat test.*** Repeat steps 7. and 8. with the opposite peak polarity selected.

10. ***Balance the Pulsed DC Ionization System.*** Adjust the ionization system until both positive and negative peak readings are as close to each other as practical. Depress the ZERO pushbutton to reset the plate for the next test.

## VI. Discharge Time (Decay) Tests

### A. Flooring, Floor Mats and Table Mats

1. Set up 268A Analyzer according to **Basic Operation – Discharge Time Test**, steps 1. - 6.

2. Have test person put on known good footwear or heel grounder.

3. Plug wrist strap banana plug into top of metal plate (Figure 5).

***CAUTION***

*When charged, the plate voltage can be in excess of 5000 volts with respect to ground. Although the charges and potentials are below those that are normally detected by human senses,* ***A SHOCK HAZARD EXISTS.***

- *If you are handling the plate assembly or conducting a test that involves touching the plate,* ***expect a shock****.*
- *Do not charge large capacitors with this device.*

**Figure 5**

4. Attach wrist strap to person. This person should be standing with both feet on a good insulator (e.g. a few layers of clear polyethylene) adjacent to the grounded flooring, floor mat or table mat under test.

5. Depress POLARITY pushbutton to select positive polarity.

6. Depress CHARGE pushbutton.

7. Adjust “PLUS” VOLTAGE ADJUST knob to a minimum PLATE VOLTAGE of 1.100 kV.

8. Depress DECAY pushbutton.

9. Have test person step onto test surface with one foot. Observe timer meter reading as charge is dissipated, usually in less than 1 second.

10. Release POLARITY pushbutton to select negative polarity.

11. Repeat steps 6. – 9. for “MINUS” voltage.

**B. Footwear and Heel Grounders**

1. Set up 268A Analyzer according to Basic Operation – Discharge Time Test, steps 1. – 6.

2. Have test person put on footwear or heel grounders under test.

3. Plug wrist strap banana plug into top of metal plate (Figure 5).

4. Attach wrist strap to person. This person should be standing with both feet on a good insulator (e.g. a few layers of clear polyethylene) adjacent to a grounded metal surface.

5. Depress POLARITY pushbutton to select positive polarity.

6. Depress CHARGE pushbutton.

7. Adjust “PLUS” VOLTAGE ADJUST knob to a minimum PLATE VOLTAGE of 1.100 kV.

8. Depress DECAY pushbutton.

9. Have test person step onto grounded metal surface with one foot. Observe timer meter reading as charge is dissipated, usually in less than 1 second.

10. Have test person once again stand with both feet on insulator, but facing opposite direction.

11. Repeat steps 6. – 9. with other foot.

12. Release POLARITY pushbutton to select negative polarity.

13. Repeat steps 6. – 11. for “MINUS” voltage.

**C. Gloves and Finger Cots**

1. Set up 268A Analyzer according to **Basic Operation – Discharge Time Test,** steps 1. – 6.

2. Have test person put glove or finger cot under test on one hand.

3. Plug wrist strap banana plug into top of metal plate (Figure 5).

4. Attach wrist strap to person’s other arm. This person should be standing with both feet on a good insulator (e.g. a few layers of clear polyethylene) adjacent to a grounded metal surface within easy reach of the test hand.

5. Depress POLARITY pushbutton to select positive polarity.

6. Depress CHARGE pushbutton.

7. Adjust “PLUS” VOLTAGE ADJUST knob to a minimum PLATE VOLTAGE of 1.100 kV.

8. Depress DECAY pushbutton.

9. Have test person touch grounded metal surface with glove or finger cot under test – a slight, non-hazardous shock may be felt. Observe timer meter reading as charge is dissipated, usually in less than 1 second.

10. Release POLARITY pushbutton to select negative polarity.

11. Repeat steps 6. – 9. for “MINUS” voltage.

**D. Testing Smocks**

1. Set up 268A Analyzer according to **Basic Operation – Discharge Time Test,** steps 1. - 6.

2. Have test person put on smock under test.

3. Plug wrist strap banana plug into top of metal plate (Figure 5).

4. Attach wrist strap to person's arm, over smock. If smock has snaps, detach cord from wrist strap and attach it directly to smock snap. Person should be standing with both feet on a good insulator (e.g. a few layers of clear polyethylene) adjacent to a grounded metal surface within easy reach.

5. Depress POLARITY pushbutton to select positive polarity.

6. Depress CHARGE pushbutton.

7. Adjust "PLUS" VOLTAGE ADJUST knob to a minimum PLATE VOLTAGE of 1.100 kV.

8. Depress DECAY pushbutton.

9. Verify that 268A PLATE VOLTAGE reading is close to voltage on smock: Use a fieldmeter like the Monroe Digital Stat-Arc™ 2, Model 282, to read voltage on smock, and to verify that observed voltage is evenly distributed over all areas of smock.

10. Verify that smock has conductive wrist cuffs or that some part of the smock is in intimate contact with the person's skin. Have person touch grounded metal surface – a slight, non-hazardous shock may be felt. Observe timer meter reading as charge is dissipated, usually in less than 1 second.

11. Release POLARITY pushbutton to select negative polarity.

12. Repeat steps 6. – 10. for "MINUS" voltage.

**E. Testing Small Containers and Handling Materials (Using Grounded Test Person)**

1. This test can be used for all sorts of objects such as containers, tote boxes, flooring tiles, and samples of large objects.

2. Set up 268A Analyzer according to **Basic Operation – Discharge Time Test,** steps 1. – 6.

3. Place object to be tested on top the 6" x 6" plate.

4. Plug wrist strap banana plug into alligator clip, and attach clip to grounded metal object. Attach wrist strap to test person in normal manner.

5. Depress POLARITY pushbutton to select positive polarity.

6. Depress CHARGE pushbutton.

7. Adjust "PLUS" VOLTAGE ADJUST knob to a minimum PLATE VOLTAGE of 1.100 kV.

8. Depress DECAY pushbutton.

9. Verify that 268A PLATE VOLTAGE reading is close to voltage on object: Use a fieldmeter like the Monroe Digital Stat-Arc™ 2, Model 282, to read voltage on object, and to verify that observed voltage is evenly distributed over all areas of object.

10. Have person wearing grounded wrist strap touch object – a slight, non-hazardous shock may be felt. Observe timer meter reading as charge is dissipated, usually in less than 1 second.

11. Release POLARITY pushbutton to select negative polarity.

12. Repeat steps 6. – 10. for "MINUS" voltage.

    *(Note: By using a conductive compliant material between the object under test and the 6″ x 6″ plate, a better electrical contact can be achieved. This compliant material should be cut to same size as the plate.)*

**F. Testing Small Containers and Handling Materials (Using Grounded Test Electrode)**

1. This test can be used for all sorts of objects such as containers, tote boxes, flooring tiles, and samples of large objects.

2. Set up 268A Analyzer according to **Basic Operation – Discharge Time Test,** steps 1. - 6. Make sure the 268A front legs are in the retracted position and the plate is reasonably level.

3. Place object to be tested on top the 6” x 6” plate (Figure 6).

   *Note: If possible cut the test object to fit the plate dimensions. Larger test objects can be used, but these result in increased charge-decay times due to higher capacitance of the test object).*

**Figure 6**

4. Place an NFPA-99 five-lb. electrode with a compliant conductive rubber bottom piece (included in Monroe Model 283, Digital Surface Resistance/Resistivity Test Kit) on top the test object, parallel to the plate.

5. Plug one end of the grounding cord into the five-lb. electrode, making sure the other end does not touch anything.

6. Depress POLARITY pushbutton to select positive polarity.

7. Depress CHARGE pushbutton.

8. Adjust “PLUS” VOLTAGE ADJUST knob to a minimum PLATE VOLTAGE of 1.100 kV.

9. Depress DECAY pushbutton.

10. Verify that 268A PLATE VOLTAGE reading is close to voltage on object: Use a fieldmeter like the Monroe Digital Stat-Arc™ 2, Model 282, to read voltage on

object, and to verify that observed voltage is evenly distributed over all areas of object.

11. Touch the free end of the grounding cord to a grounded metal object. Observe timer meter reading as charge is dissipated, usually in less than 1 second.

12. Release POLARITY pushbutton to select negative polarity.

13. Repeat steps 7. – 11. for "MINUS" voltage.

*Note: By using a conductive compliant material between the object under test and the 6″ x 6″ plate, a better electrical contact can be achieved. This compliant material should be cut to same size as the plate.*

## VII. Triboelectric Charging Tests

### A. Effect of Relative Humidity on Triboelectric Charging Tests

- Relative humidity has a tremendous influence on the voltage generated during triboelectric charging tests. Voltages in excess of 10,000 volts can easily be generated under low humidity conditions such as normally exist indoors during cold winter months. The same charging tests performed during the summer in high humidity conditions may not generate voltages greater the 100 volts.

- To produce meaningful worst-case voltage generation results, triboelectric charging tests must be conducted at the lowest relative humidity possible in the working environment, down to 12 ± 3% RH. Charging tests conducted in environments less than 9% RH can actually result in less than worst-case voltage generation results.

*Note: The following tests should be performed with ionizers OFF except when needed to discharge objects used in the tests. As static voltages will be generated intentionally in some cases, sensitive materials should be removed from the area.*

### B. Peak Voltage On Human Body Generated From Walking

1. Set up 268A Analyzer according to **Basic Operation – Peak Offset Voltage Test,** steps 1. - 6.

2. Plug wrist strap banana plug into top of metal plate (Figure 5).

3. Attach wrist strap to person.

4. Depress –PK/+PK pushbutton to select positive polarity.

5. Depress DECAY pushbutton.

6. Have person walk back and forth a couple of times across surface under test (SUT) wearing footwear under (FUT) test. Highest positive voltage generated is displayed on PLATE VOLTAGE meter. If person charges negative rather than positive, meter will not indicate a change.

7. Depress ZERO pushbutton. Release and depress NORM/PEAK pushbutton to reset peak detector.

8. Release –PK/+PK pushbutton to select negative polarity.

9. Repeat steps 7. – 9. for peak negative voltage.

   *Note: This test can be also be performed without a wrist strap. Set up and conduct test as outlined above, but without wrist strap. Have person walk back and forth a couple of times across SUT wearing FUT, and touch metal plate while still moving. Peak voltage generated is displayed on PLATE VOLTAGE meter.*

**C. Charging of Gloves and Finger Cots**

1. Even if gloves or finger cots fail the decay test, they still might not tribocharge against other surfaces if they are antistatic.

2. Set up 268A Analyzer according to **Basic Operation – Offset Voltage Test,** steps 1. – 5.

3. Plug wrist strap banana plug into alligator clip, and attach clip to grounded metal object. Attach wrist strap to test person in normal manner.

4. Have person put glove on one hand or finger cots on 2 adjacent fingers.

5. Discharge glove or finger cots in front of air ionizer, then turn ionizer off.

6. Depress DECAY pushbutton.

7. Have person rub glove fingers or finger cots briskly across insulating material several times in attempt to build static charge.

8. Touch 268A metal plate with glove fingers or finger cots. Voltage generated on glove or finger cots is displayed on PLATE VOLTAGE meter, either positive or negative polarity.

9. Depress ZERO pushbutton.

10. Repeat steps 5. – 9. using antistatic material such as “pink poly” rather than an insulating object. Note that if voltage was generated using an insulating object, then voltage usually will also be generated using an antistatic material.

11. Discharge glove or finger cots in front of air ionizer, then turn ionizer off.

12. Have person rub glove fingers or finger cots briskly across 268A grounded metal plate several times in attempt to build static charge.

13. Depress DECAY pushbutton.

14. Touch 268A metal plate with glove fingers or finger cots. Voltage generated on glove or finger cots is displayed on PLATE VOLTAGE meter, either positive or negative polarity.

15. Note that if voltage was generated using an insulating material, then voltage usually will also be generated using a conductive material.

    *Note: The only way to really tell if static charge will build on gloves or finger cots in the workplace is to attempt charge generation using the actual materials they will come in contact with.*

    *Note: Air ionizer must always be used before testing begins to discharge material under test plus all charging materials, unless it is known that a material is conductive and grounded.*

## D. Charging of Other Materials

Flat or conformational materials can be tested for charging by cutting out samples, and then attaching them to the 268A metal plate before rubbing.

1. Set up 268A Analyzer according to **Basic Operation – Offset Voltage Test,** steps 1. – 5.

2. Plug wrist strap banana plug into alligator clip, and attach clip to grounded metal object. Attach wrist strap to test person in normal manner.

3. Prepare 6” x 6” samples of materials to be tested.

4. Discharge samples in front of air ionizer, and then turn ionizer off.

5. Clamp sample to metal plate using 4 binder clips, 3/4” width x 3/8” capacity (Figure 7).

6. Depress DECAY pushbutton.

7. Have person rub material on plate with the selected materials it is to be tested against. These could be materials it may come against in the workplace, or a standard material such as Teflon.

8. Voltage generated by rubbing the 2 materials is displayed on PLATE VOLTAGE meter, either positive or negative polarity.

9. Depress ZERO pushbutton.

10. Repeat steps 4. – 9. for remaining samples to be tested.

*Note: The only way to really tell if static charge will build on materials in the workplace is to attempt charge generation using the actual materials they will come in contact with.*

*Note: Air ionizer must always be used before testing begins to discharge material under test plus all charging materials, unless it is known that a material is conductive and grounded.*

## E. Charging of Materials by Pressure Sensitive Tape Removal

The materials that are actually going to be taped should be used for this test. Clear tape removal will usually charge the surface of another material, but ESD tape removal may or may not charge the surface of another material depending on the characteristics of the tape and the material.

1. Set up 268A Analyzer according to **Basic Operation – Offset Voltage Test,** steps 1. - 5.

2. Plug wrist strap banana plug into alligator clip, and attach clip to grounded metal object. Attach wrist strap to test person in normal manner.

3. Prepare 6” x 6” samples of substrate materials to be tested, and apply several single layer strips of pressure sensitive tape across the top surface of each sample, leaving a loose end to grab hold of.

4. Discharge taped samples in front of air ionizer, then turn ionizer off.

5. Clamp sample, taped surface up, to metal plate using 4 binder clips, 3/4” width x 3/8” capacity (Figure 7).


**Figure 7**

6. Depress DECAY pushbutton.

7. Have person grab loose end of first tape piece, and quickly remove it from clamped sample.

8. Voltage generated by separating the 2 materials is displayed on PLATE VOLTAGE meter, either positive or negative polarity.

9. Remove remaining pieces of tape, one at a time, at about the same speed as the first piece. Note that each additional tape piece removed should incrementally add to the total about the same voltage as the first piece removed.

10. Depress ZERO pushbutton.

11. Repeat steps 4. – 10. for remaining samples to be tested.

*Note: The only way to really tell if static charge will build on materials in the workplace is to attempt charge generation using the actual materials they will come in contact with.*

*Note: Air ionizer must always be used before testing begins to discharge material under test plus all charging materials, unless it is known that a material is conductive and grounded.*

## VIII. Demonstrations

*Note: Some of the following demonstrations require the use of additional materials and devices. Details can be found in the Appendix.*

### A. Triboelectric Series

1. Triboelectric charging occurs when different materials are rubbed together or separated from each other. Over the ages, several lists of materials have been compiled to illustrate the triboelectric series. Among the earliest, for instance, contained cat's fur and solid sulfur. When they are rubbed together, cat's fur becomes positive and sulfur assumes a negative charge. Thus, cat's fur is higher in the series.

2. The following triboelectric series applies to the materials used in these demonstrations:

| | |
|---|---|
| Plexiglas (disk) | Most positive |
| Nylon (cloth) |  |
| Aluminum (disk) | |
| Polyester (cloth) | |
| Teflon (disk) | Most negative |

*Note: The following tests should be performed with ionizers OFF except when needed to discharge objects used in the tests. As static voltages will be generated intentionally in some cases, sensitive materials should be removed from the area.*

## B. Electrostatic Fields

When charged (by rubbing one with another) these materials will each become surrounded by an electrostatic field. The polarity and relative intensity of the field may be demonstrated by approaching the floating plate of the Model 268A Charged Plate Monitor.

1. Set up 268A Analyzer according to **Basic Operation – Offset Voltage Test,** steps 1. - 5.

2. Depress DECAY pushbutton.

3. While holding two dissimilar disks (Plexiglas and Teflon for most dramatic effect) by their handles, tribocharge them by rubbing flat bottom surfaces together.

4. Slowly approach the floating plate to within an inch or so with one of the disks. Observe the voltage and polarity. Release the 5 kV/2 kV pushbutton if PLATE VOLTAGE goes higher than ±1.999 kV

5. Move the disk away and approach the plate with the other disk. The voltage should be opposite in polarity but of about the same magnitude if the distance is kept the same.

6. Move both disks near the plate at the same time. If the distance is carefully controlled a net voltage or field of zero can be demonstrated.

## C. Triboelectric Charging of Materials

The short triboelectric series given in **A. Triboelectric Series** above can be demonstrated using the technique in **B. Electrostatic Fields**. It will be necessary to discharge the insulating cloths and plastic disks with an ionizer between tests. The metal disks can easily be discharged by grounding.

## D. Triboelectric Charging of Static Dissipative Materials

Even materials generally considered to be ESD "safe" can be shown to charge when rubbed, and can easily charge objects they come in contact with.

1. Set up 268A Analyzer according to **Basic Operation – Peak Offset Voltage Test,** steps 1. - 6.

2. Depress the DECAY pushbutton.

3. Wipe a "pink poly" bag briskly across the plate. You should see a positive voltage peak displayed. If not, release –PK/+PK pushbutton to select negative polarity. Then release and depress NORM/PEAK pushbutton to reset peak detector and repeat the “pink poly” wipe across the plate.

4. Repeat this wiping action several times. The voltage should increase with each wipe.

5. Try this test with other static dissipative materials.

**E. Induction Charging**

Induction charging occurs when an ungrounded (floating) conductor enters an electrostatic field and then is momentarily grounded. When the field is removed, a charge of the same voltage magnitude but opposite polarity remains on the conductor.

1. Set up 268A Analyzer according to Basic Operation – Offset Voltage Test, steps 1. - 5.

2. Depress DECAY pushbutton.

3. Take one of the plastic disks and charge it by rubbing with one of the synthetic cloths.

4. Place disk on the 268A “floating” metal plate.

5. Observe the polarity and voltage on the PLATE VOLTAGE meter.

6. While wearing a properly grounded wrist strap, touch the metal plate with your finger and observe the PLATE VOLTAGE meter drop to near zero kV.

7. Remove finger from the metal plate, and then remove plastic disk. The PLATE VOLTAGE meter will read very close the same magnitude as the original voltage in step 5 but the opposite polarity.

   *Note: It is not necessary for the charged plastic disk to actually touch the metal plate for a charge to be induced on it. Try the following test.*

8. Set up 268A Analyzer according to **Basic Operation – Offset Voltage Test,** steps 1. - 5.

9. Depress DECAY pushbutton.

10. Take one of the plastic disks and charge it by rubbing with one of the synthetic cloths.

11. While wearing a properly grounded wrist strap, approach the plate with the charged disk. Observe the PLATE VOLTAGE meter. The voltage will increase as the distance between the disk and the plate decreases.

12. Stabilize the distance. Do not touch the plate with the disk. Note the polarity and voltage magnitude on the PLATE VOLTAGE meter.

13. Touch the 268A metal plate with your finger. Observe the PLATE VOLTAGE meter drops to near zero kV.

14. Remove finger from the plate while maintaining the distance from disk to plate.

15. Remove the disk and observe meter. The PLATE VOLTAGE meter will read very close the same magnitude as the original voltage in step 12, but the opposite polarity.

## F. Voltage Enhancement and Suppression

Voltage Suppression occurs when a charged object is brought in close proximity to a background surface. Total charge on the object cannot change, so the observed voltage reduces inversely proportional to the increased capacitance of the object to ground. Conversely, when a charged object is moved away from a background surface, the observed voltage increases inversely proportional to the decreased capacitance of the object to ground.

### **Demo A:** Increase Capacitance and Decrease Voltage

1. Depress the ZERO pushbutton in the PLATE CONTROL section (this ensures no voltage is on the plate by connecting it to ground through a 10 kΩ resistor). Connect the 268A power plug to the proper source (117V or 220V), and press "|" at the top of the POWER switch to turn it on. Black numerals in the LCD meter displays indicate that power is on.

2. Release the 5 kV/2 kV pushbutton under the PLATE VOLTAGE meter display to select the 5 kV range.

3. Release the NORM/PEAK pushbutton (next to the 5 kV/2 kV pushbutton) to select NORMAL mode.

4. Release the POLARITY pushbutton to select negative (-) for this example.

5. Obtain an insulated test lead with a banana plug on each end. Attach the lead from the 268A metal plate to an aluminum disk (see Appendix for disk details).

6. Discharge a flat Plexiglas surface in front of air ionizer, then turn ionizer off.

7. Hold aluminum disk in open air by its handle, and depress the CHARGE pushbutton.

8. The red HV ON light indicates that the 268A high voltage supply is on. The PLATE VOLTAGE display will indicate some negative voltage. Turn the "MINUS" VOLTAGE ADJUST knob clockwise to its maximum (≈7 kV).

9. Depress DECAY pushbutton.

10. Slowly bring aluminum disk near the Plexiglas surface. Observe the PLATE VOLTAGE display drop as disk nears Plexiglas surface. Place disk on Plexiglas surface and observe display as voltage drops dramatically.

11. Slowly pick up disk by its handle and observe the PLATE VOLTAGE display increases as disk moves away from Plexiglas surface.

**Demo B:** Decrease Capacitance and Increase Voltage

12. Set up demonstration as explained above in Demo A, steps 1. to 6.

13. Place aluminum disk on Plexiglas surface, and depress the CHARGE pushbutton.

14. The red HV ON light indicates that the 268A high voltage supply is on. The PLATE VOLTAGE display will indicate some negative voltage. Turn the "MINUS" VOLTAGE ADJUST knob clockwise to ≈3kV.

15. Depress DECAY pushbutton. Note that maximum PLATE VOLTAGE display does not change appreciably.

16. Pick up aluminum disk by its handle into open air. The PLATE VOLTAGE display will increase dramatically to nearly twice its original voltage (≈5-6 kV).

## G. Difference of Potential

A difference of potential (voltage) between 2 objects exists when they are charged to different voltages in relation to each other. If the 2 objects are both conductors and are brought toward each other, they want to equalize their charge. For high differences of potential, 2 conductors will equalize their charge by passing an electric arc through the air between them. The higher the voltage difference, the more dramatic the arc.

1. Depress the ZERO pushbutton in the PLATE CONTROL section (this ensures no voltage is on the plate by connecting it to ground through a 10 kΩ resistor). Connect the 268A power plug to the proper source (117V or 220V), and press "|" at the top of the POWER switch to turn it on. Black numerals in the LCD meter displays indicate that power is on.

2. Release the 5 kV/2 kV pushbutton under the PLATE VOLTAGE meter display to select the 5 kV range.

3. Release the NORM/PEAK pushbutton (next to the 5 kV/2 kV pushbutton) to select NORMAL mode.

4. Release the POLARITY pushbutton to select negative (-) for this example.

5. Obtain an insulated test lead with a banana plug on each end. Attach the lead from the 268A metal plate to an aluminum disk (see Appendix for disk details).

6. Discharge a flat Plexiglas surface in front of air ionizer, then turn ionizer off.

7. Place aluminum disk on Plexiglas surface, and depress the CHARGE pushbutton.

8. The red HV ON light indicates that the 268A high voltage supply is on. The PLATE VOLTAGE display will indicate some negative voltage. Turn the "MINUS" VOLTAGE ADJUST knob clockwise to ≈3 kV.

9. Depress DECAY pushbutton.

10. Pick up aluminum disk by its handle into open air. The PLATE VOLTAGE display will increase to about twice its original voltage, ≈5-6 kV.

11. With the other hand, pick up an uncharged aluminum disk by its handle and hold in open air.

12. Without touching the disks together, slowly move the uncharged disk edge toward the charged disk edge until you hear and/or see the electric arc.

13. Verify that 268A PLATE VOLTAGE (and attached disk) reading is close to voltage on the previously uncharged disk: Use a fieldmeter like the Monroe Digital Stat-Arc™ 2, Model 282, to read voltage on the bottom of the previously uncharged disk.

## IX. References and Related Documents


1. EOS/ESD association standard for Protection of Electrostatic Discharge Susceptible Items – Ionization, EOS/ESD-S3.1-1991.

2. Monroe Electronics, Inc. Operator's Manual, Charged Plate Analyzer, Model 268A, 1994.

3. W. Vosteen, "Alternate Uses for the Charged Plate Monitor", EOS/ESD Symposium Proceeding, EOS-18, 1996

4. G. Baumgartner, "ESD Demonstrations to Increase Engineering and Manufacturing Awareness", EOS/ESD Symposium Proceeding, EOS-18, 1996

5. EOS/ESD association standard test method for the Protection of Electrostatic Discharge Susceptible Items – ESD Protective Worksurfaces Charge Dissipation Characteristics, ESD STM4.2-1998.

6. ESD association standard test method for the Protection of Electrostatic Discharge Susceptible Items – Floor Materials and Footwear-Voltage measurement in Combination with a Person, ESD STM97.2-1999.

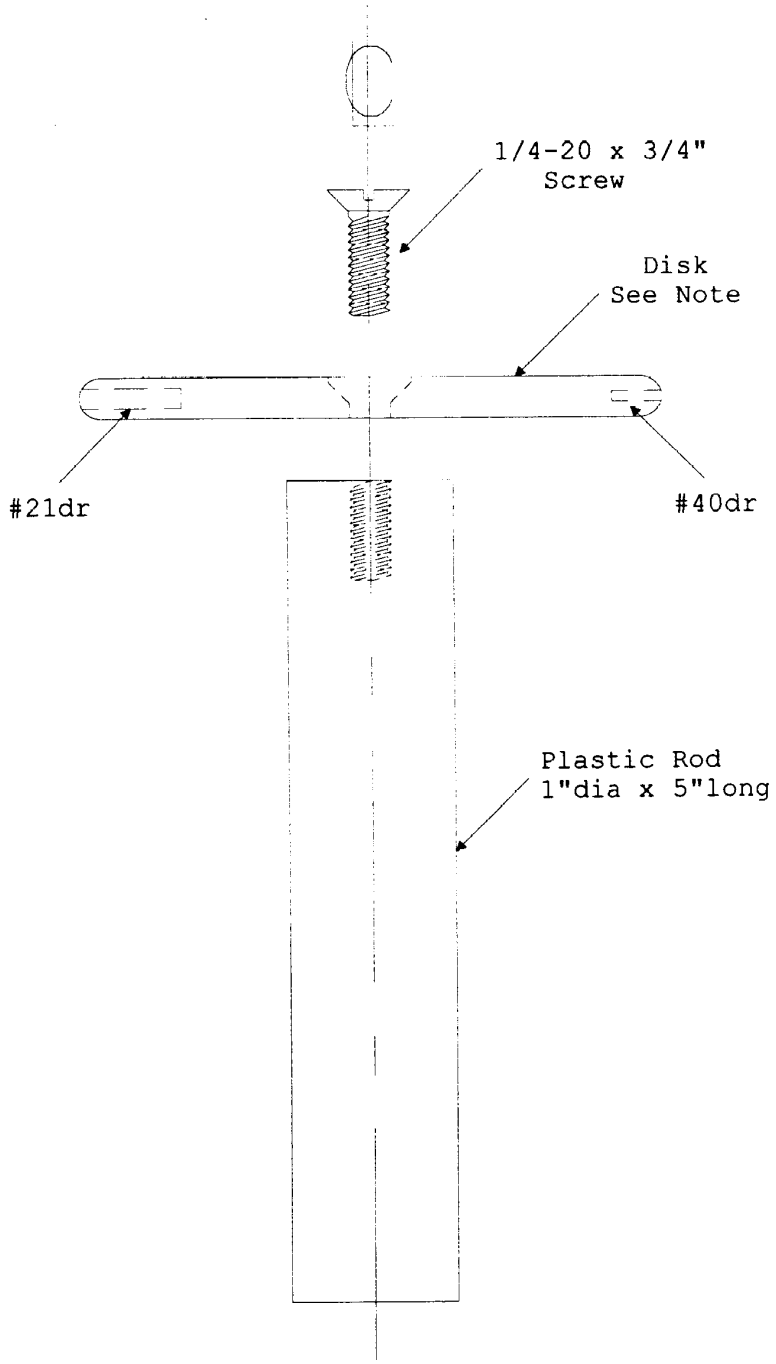
7. ESD association standard practice for the Protection of Electrostatic Discharge Susceptible Items – Periodic Verification of Air Ionizers (DRAFT), ESD DSP3.3-1997.

8. ESD association advisory for the Protection of Electrostatic Discharge Susceptible Items – Selection and Acceptance of Air Ionizers, ESD ADV3.2-1995.

9. ESD association advisory for the Protection of Electrostatic Discharge Susceptible Items – Triboelectric Charge Accumulation Testing, ESD ADV11.2-1995.

10. ESD association technical report for the Protection of Electrostatic Discharge Susceptible Items – ESD Glove and Finger Cots, ESD TR 03-99.

# X. Appendix




1) Make 4 disks: 2 aluminum, 1 Plexiglas and 1 Teflon. Disks are 3½" dia. and ¼" thick with full radius on the circumference and recessed ¼" flathead screw hole in center.
2) On aluminum disks, drill #40 and #21 holes in from circumference toward center. These should be about ¾" deep to accept banana plugs.
3) Attach a drilled (#7) and tapped (¼ - 20) Plexiglas rod (handle) to each disk with a ¼ - 20 x ¾" screw.