STATIC ELIMINATORS - A COMPARATIVE REVIEW
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Atomic Energy Control Board
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SUMMARY

This report examines the possible commercial methods of eliminating or reducing static charge in various typical applications. The technical background to the operation of static eliminators is discussed. The various industrial uses of static eliminators are examined and the comments of industrial users analyzed. An outline of the various available products is given.

TECHNICAL BACKGROUND

Electrical and nuclear static eliminators both work by generating sufficient ions to neutralise the surface charge. Inductive and chemical static eliminators operate by providing a conductive path which enables the static charge to be dissipated to ground. Nuclear static eliminators usually have Po-210 sources, although a few products are available with Am-241 sources. Devices using Po-210 have useful life-times of about one year. Electrical static eliminators have useful life-times of five to ten years depending on their use and maintenance. Electrical devices with their associated high voltage power supplies might present an inherent safety risk if used in areas with flammable or explosive atmospheres, and may also cause damage to sensitive electronic components.

INDUSTRIAL USE

The printing industry is a major user of static eliminators but most of the problems arising from static can be solved without recourse to anti-static devices by maintaining humidity levels of over 40% and ensuring the feedstock is not too dry. Printing of non-conductive, hydrophobic material does require the use of static eliminators, and for this application inductive and electrical devices seem to be adequate.
The photographic industry uses static eliminators, usually in the form of ionised air guns, to remove dust from negatives. It also uses them to prevent static streaking as unprocessed film is removed from its covers. A new product which generates ions by an emission effect rather than a corona discharge is meeting with some success in the photographic industry. Piezoelectric devices and ionised air blowers can both be used satisfactorily for cleaning negatives.

The electronics industry has considerable static problems but is still experimenting to find the most satisfactory way of dealing with them. New electronic equipment is being designed with increased shielding and grounding to protect sensitive components.

The availability of radioactive anti-static brushes and small scale devices for laboratory or in-home use appears to be increasing.

CONCLUSIONS

With the exception of explosive or flammable atmospheres and in the electronics industry, electrical static eliminators are as effective as the nuclear devices and cost less. For small scale applications piezoelectric devices appear to be adequate although they are initially more expensive. However, users sometimes have personal preferences for the more convenient nuclear static eliminators.
CONTENTS

1. INTRODUCTION

2. TECHNICAL ASSESSMENT
   2.1 Introduction
   2.2 Generation of Static Charge
   2.3 Methods of Static Elimination
      2.3.1 Humidity, Coating & Sprays
      2.3.2 Inductive Devices
      2.3.3 Electrical Devices
      2.3.4 Nuclear Devices
   2.4 Comparison of NSE's and ESE's
      2.4.1 Useful Life-times
      2.4.2 Efficacy of the Devices
      2.4.3 Safety
      2.4.4 Unwanted Side-effects
      2.4.5 The Special Case of Sensitive Electronic Devices
   2.5 Conclusion

3. PRODUCTS AVAILABLE FOR STATIC ELIMINATION
   3.1 Introduction
   3.2 Chemical Static Eliminators
   3.3 Inductive Static Eliminators
   3.4 Electrical Static Eliminators
   3.5 Nuclear Static Eliminators
      3.5.1 The 3M Product Line
      3.5.2 Herbert Products Nuclestat Product Line
      3.5.3 Brush Type Nuclear Static Eliminators
   3.6 Comparative Pricing
   3.7 Conclusion
4. USERS OF STATIC ELIMINATORS

4.1 Introduction

4.2 The Printing Industry
   4.2.1 The Printing Press
   4.2.2 Comments from the Printing Industry
   4.2.3 Printing Polyethylene Film
   4.2.4 Gravure Presses
   4.2.5 Conclusion

4.3 The Photographic Industry
   4.3.1 Undeveloped Film
   4.3.2 Handling of Finished Negatives
   4.3.3 Comments from the Photographic Industry
   4.3.4 Conclusion

4.4 The Electronics Industry
   4.4.1 Manufacture of Photomasks for Printed Circuits
   4.4.2 Production of Integrated Circuits
   4.4.3 Electronic Equipment
   4.4.4 Conclusion

4.5 The Chemical Industry
   4.5.1 Liquid Chemical Handling
   4.5.2 Powder Handling
   4.5.3 Conclusion

4.6 Other Applications of Static Eliminators
   4.6.1 Textiles
   4.6.2 Preparation of Dental X-Rays
   4.6.3 Feather and Down Separation
   4.6.4 Analytical Balances
   4.6.5 Floor Coverings
   4.6.6 Domestic Uses

4.7 Future Prospects

5. SUMMARY OF CONCLUSIONS

References
1. INTRODUCTION

A static charge occurs when two materials come into contact and then separate. In general electrons are transferred from one surface to another when separation occurs causing an electrostatic charge, the mechanism of this electron transfer is complex. This electrification effect depends on a difference in the affinity of surfaces for electrons. Good conductors, such as metals, will lose their charge immediately if they are adequately grounded; whereas poor conductors, such as plastic, paper and fabrics hold the charge for long periods of time. The polarity of the static charge generated on each of the materials involved and an approximation of the magnitude of the charge can be obtained by locating the positions of the materials in the Triboelectric series (1). The further apart in the series the materials are located, the more readily is the static charge generated.

Uncontrolled static charge can cause a variety of problems. These problems fall into five general categories:

1. Dust and dirt attraction
2. Fire and explosion hazards
3. Handling problems
4. Personnel shocks
5. Product damage

The magnitude of the problem varies, depending on the particular operation and the environment in which the operation is being carried out. In some situations static charges certainly occur, but do not interfere significantly in the efficiency of the operation and so no remedy is required. In other situations however, serious problems can be caused by the presence of static charge, in these situations some form of static reduction or elimination has to be employed.
It is the purpose of this report to examine the possible commercial methods of eliminating or reducing static charge in various typical applications. The information presented is based on an analysis of interviews with users of static elimination devices located within a 150 miles radius of Ottawa, and on discussions with the technical personnel of the major companies who manufacture such equipment. The principal areas from which users were selected were the printing, photographic and electronics industries; limited numbers of users in other groups were contacted. In total, twenty-four users, four equipment manufacturers and five equipment distributors were contacted.
2. TECHNICAL ASSESSMENT

2.1 Introduction

In order to evaluate the performance of nuclear static elimination devices (NSE's), and to compare them with alternative non-nuclear methods of static elimination, the following topics will be discussed:

i) How static charges arise and the problems they cause.

ii) The methods by which these problems can be alleviated and the mechanisms by which these methods operate.

iii) A comparison of NSE's and electrical static elimination devices (ESE's), both from the standpoint of their mode of operation and from their relative effectiveness.

It should be emphasized that static elimination in real-life situations is often a question of finding empirical solutions to the problems. The choice of method used is usually made on the basis of subjective criteria rather than on critical technical analysis, the deciding factor always being "will it work for me?".

2.2 Generation of Static Charges

When two dissimilar materials, which were originally in contact, are separated they are likely to be found to possess different electrostatic charges. The phenomenon arises from the exchange of surface electrons between the two surfaces when they are in contact. As a broad generalization the material with the greater electron affinity will, at any given moment in time, possess a greater share of the available sur-
face electrons. An empirical series called the triboelectric series has been devised.

<table>
<thead>
<tr>
<th>Triboelectric Series(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos</td>
</tr>
<tr>
<td>Glass</td>
</tr>
<tr>
<td>Human hair</td>
</tr>
<tr>
<td>Nylon</td>
</tr>
<tr>
<td>Wool</td>
</tr>
<tr>
<td>Fur</td>
</tr>
<tr>
<td>Lead</td>
</tr>
<tr>
<td>Silk</td>
</tr>
<tr>
<td>Aluminum</td>
</tr>
<tr>
<td>Paper</td>
</tr>
<tr>
<td>Cotton</td>
</tr>
<tr>
<td>Steel</td>
</tr>
<tr>
<td>Sealing wax</td>
</tr>
<tr>
<td>Hard rubber</td>
</tr>
<tr>
<td>Acetate rayon</td>
</tr>
<tr>
<td>Nickel-copper</td>
</tr>
<tr>
<td>Synthetic rubber</td>
</tr>
<tr>
<td>Orlon</td>
</tr>
<tr>
<td>Saran</td>
</tr>
<tr>
<td>Polyethylene</td>
</tr>
<tr>
<td>Teflon</td>
</tr>
<tr>
<td>Silicone rubber</td>
</tr>
</tbody>
</table>

The lower the position a substance is in the series, the more likely it will be to obtain electrons. When two surfaces are suddenly separated the material that is the lower in the series will, instantaneously, possess a negative charge relative to the other surface. If the material is a conductor (e.g. a metal) the charge will very quickly be distributed throughout the whole surface, and if connected to a ground, the charge will be dissipated. On the other hand, when one or both of the surfaces are insulators problems may arise. In this case the charge will not be readily dispersed; the magnitude of the charge difference will depend upon the pressure applied to the surfaces while they are in contact (e.g. friction forces) and upon the speed with which separation occurs. The
greater the pressure or friction and the faster the separation, the larger will be the charge difference.

In practical applications the charge possessed by the surface is measured as an electrostatic voltage. This voltage (V) is a function of the charge generated (Q) and the capacitance (C) of the system of which the surface is a part. This may be expressed as

\[ V = \frac{Q}{C} \]

The problems created by static charges are as varied as the processes that generate the charge in the first place. Some of the more common problems encountered are summarized in Table 1. These problems may cause annoyance, loss of productivity, poor product quality and increased operating costs. This has lead to the development of a wide variety of static elimination devices of varying degrees of sophistication.
## TABLE 1

**SUMMARY OF INDUSTRIAL PROBLEMS ARISING FROM STATIC**

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>NATURE OF PROBLEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing</td>
<td>- Improper paper or plastic feed</td>
</tr>
<tr>
<td></td>
<td>- Jogging of material at the end of printing process</td>
</tr>
<tr>
<td></td>
<td>- Fire hazard from flammable solvent based inks</td>
</tr>
<tr>
<td></td>
<td>- Shocks to personnel from presses</td>
</tr>
<tr>
<td>Photo processing</td>
<td>- Film clings in dryer</td>
</tr>
<tr>
<td></td>
<td>- Dust on negatives and lenses spoils image</td>
</tr>
<tr>
<td></td>
<td>- Static streaks on negatives</td>
</tr>
<tr>
<td>Electronics</td>
<td>- Dust can spoil negatives used for printed circuit manufacture</td>
</tr>
<tr>
<td></td>
<td>- Charge can damage or destroy integrated circuits</td>
</tr>
<tr>
<td>Plastics</td>
<td>- Clinging of product impedes delivery, packaging, etc.</td>
</tr>
<tr>
<td></td>
<td>- Dust in mould can cause flaws</td>
</tr>
<tr>
<td></td>
<td>- Personnel shocks on removing large objects from moulds</td>
</tr>
<tr>
<td></td>
<td>- (see also Printing)</td>
</tr>
<tr>
<td>Chemicals</td>
<td>- Powders cling when air-veying and handling</td>
</tr>
<tr>
<td></td>
<td>- Fire hazards with solvent vapours in coating processes</td>
</tr>
<tr>
<td>Textiles</td>
<td>- Ballooning of fibres in spinning mill</td>
</tr>
</tbody>
</table>
2.3 Methods of Static Elimination

The aim of static elimination is the reduction of the electrostatic potential on a surface. This may be accomplished by providing a conductive path to ground (passive methods) or by neutralising the charge by positive or negative ions (active methods). There are essentially four techniques used:

Passive:
- a) making the surface conducting and/or providing a sufficiently humid atmosphere
- b) inductive devices

Active:
- c) electrical devices that generate positive and negative ions in a high voltage corona air discharge
- d) nuclear devices that produce ions by $\alpha$-radiolysis air.

2.3.1 Humidity, Coatings and Sprays

The conductivity of air increases as the relative humidity is raised. In many applications humidity control is the most satisfactory method of eliminating static problems. Relative humidities of 40% to 50% are usually found to be satisfactory\(^2\). Many insulating materials are somewhat hydroscopic (e.g. paper, natural fibres) and by absorbing moisture may become sufficiently conductive to allow adequate charge dissipation. It is also true that many artificial materials such as synthetic fibres and plastics are hydrophobic, and handling these materials usually gives rise to some degree of static which may be
sufficient to impede the manufacturing process. Humidity control may alleviate some of the problem but it may also be precluded by practical or economic considerations. In the Canadian winter the very low external temperatures may make it inadvisable to maintain such high inside humidities because of potential structural damage to the building\(^2\).

The use of conductive surface films, usually applied in the form of a spray, will often reduce static charge to manageable levels. Various commercial products are available e.g. Chapman's Stop-Stat Spray, Simco-Netro-Stat. There are, however, a number of applications where this approach cannot be used (e.g. where the spray can damage the surface or when a surface has to undergo further processing steps).

2.3.2 **Inductive Devices** \(^3\) \(^4\)

Inductive eliminators are devices that initiate a discharge as a result of an induced electrostatic field. They can be subdivided in two types: soft brush-like eliminators which are used in contact with a charged surface, and those which are spaced from the surface. Both types are grounded.

The first type, represented by metallic soft-bristled brushes (usually called "tinsel"), can be used where the surface will not be damaged by the bristles. When the grounded brushes ride on a charged surface, the field intensity in the close gaps can be quite high, so that the discharge is usually in the form of multiple sparks. These sparks can initiate Lichtenberg discharge on the surface leaving large irregular areas of both positive and negative charge. Thus while the integrated charge might be almost neutral, this does not indicate the true state of surface charge. Experimental measurements using this type of eliminator have shown that charged paper (e.g., such as found in printing) passing through the tinsel at a speed of 1.3 m/sec could
be reduced to a charge density of $1 \mu\text{C/m}^2$ (4). While this level of charge is quite acceptable for many applications, the irregularly charged areas left on the sheet can cause problems (e.g., by attracting dust). In addition, sparks generated at contact points may be detrimental in some applications (e.g., by exposing undeveloped photographic film in automatic film processors). There is also a chance that contact between the surface and the brush could create charge on the surface which may well have previously been neutral.

The spaced (non-contact) inductive eliminator generally provides more uniform charge neutralisation; it consists of a series of grounded points positioned above the charged surface. The charged surface induces an opposite charge on the points, which creates a high electric field in the vicinity of the points. Because of the high field intensity, surface electrons become accelerated and cause ionising collisions, avalanches and, at sufficient field intensity, electrical breakdown of the air.

Inductive eliminators require a certain field intensity to perform effectively; because there is no unified theory of breakdown in non-uniform fields it is not possible to calculate from first principles the field intensity required. Satisfactory operation of the device requires solution by experiment, empirical deduction and by using some theoretical inferences. (This generalization is also true of static elimination using "active" devices). In general, discharge will only be initiated if field strengths are of the order of 0.5 to 1 MV/m (this voltage is known as the threshold or breakdown voltage) and induced by surface charge densities of the order of 1 to 2 $\mu\text{C/m}^2$. Inductive devices are incapable of reducing charge below these values and therefore cannot be used in situations which demand more thorough charge removal (e.g., problems of dust attraction, the manufacture of sensitive elec-
2.3.3 \textbf{Electrical Devices}

Electrical static eliminators generate ions close to the charged surface, the field between the surface and the eliminator will then attract ions of the appropriate sign and cause neutralisation of the surface charge. The ions are generated in a corona discharge, usually maintained on an array of points by a high A-C potential (see Fig. 1). Voltages of the order of 3000 to 12000 V A-C are commonly used. In commercial applications the current available to the emitter is limited electrically to avoid accidents should an operator touch the emitter. Some electrical devices use D-C corona discharges for specific static elimination problems.

There is a product on the market (Ener-jet), which generates ions by a field emission effect rather than by maintaining a corona discharge between an emitter and a grounded shield. In essence the operation of these devices is the same as that described above. The same company produce a "negative-ion" emitter in which the emitting needle is maintained at between -16,000 and -18,000 V D-C. The negative ions produced at the emitter will be repelled into the surrounding atmosphere; drift velocities of the order of 100 ft/min (0.5 m/s) are claimed for this device\textsuperscript{(5)}.

For small scale, localised static problems there are piezoelectric devices on the market. A piezoelectric crystal is connected to a needle point emitter. When the crystal is compressed a high potential is generated at the emitter causing local ionisation of the air, and ions of the same polarity as the emitter will then be emitted into the surrounding
FIGURE 1  The Main Types of Static Eliminators

a) **Electrical Static Eliminator**
   - Insulator
   - Grounded shield
   - Corona discharge

b) **Piezoelectric Device**
   - Pressure applied
   - Piezoelectric crystal
   - Pressure relaxed

- Pressure applied
- Piezoelectric crystal
- Pressure relaxed

- Radio-isotope

- Charged surface
atmosphere. Relaxation of the pressure on the crystal causes a potential of the opposite polarity to be generated at the emitter and a stream of oppositely charged ions will be produced.

2.3.4 Nuclear Devices

The principle of static elimination by nuclear devices is the same as that for the electrical devices, namely the generation of positive and negative ions sufficient to neutralise the surface charge. The mechanism of ion formation is, however, different.

NSE's use α-particles (high energy helium ions, He\(^{2+}\)) which are emitted during the radioactive decay of certain radioisotopes. The isotopes of choice are Polonium-210 and Americium-241. On emission from the surface of the radioisotope, α-particles initially undergo elastic collisions with air molecules and rapidly lose energy. Only when their energy has been reduced below about 1 kev do the inelastic collisions take place which lead to the ionisation of the air molecules. In air the area where ionisation is most likely to occur is about 3 to 4 cm from the source (the Bragg zone\(^{(6)}\)). In this respect nuclear devices differ from their electrical counterparts, where the zone of maximum ionisation is much closer to the device. It can be argued that this results in more efficient local charge neutralisation in practical situations, as physical design constraints usually require a clearance of 2 to 4 cm.

The ionising power of α-particles at close ranges is the property that makes α-emitting radioisotopes so toxic to living organisms.
The danger in this particular case arises from the ingestion of sub-microscopic particles containing the radioisotope which will then cause severe localised damage to tissues with which they are in contact. For this reason the isotope must be immobilised by some form of encapsulation. Two methods are presently used in sources supplied with NSE’s. The 3M technique involves absorbing Po-210 in small inert ceramic microspheres, which are then bonded to an aluminum substrate with a radiation resistant epoxy adhesive\(^{(7)}\). The other technique is used for both Po-210 and Am-241 and involves sandwiching the isotope between very thin gold and silver foils; encapsulation is completed by high pressure cold-welding\(^{(8)}\). This is the process used by the Nuclear Research and Development Company, whose sources are marketed in devices produced by Herbert Products Inc.

2.4 Comparison of NSE’s and ESE’s

Both nuclear and electrical devices are produced in similar product lines:

i) Simple bars - used in applications where the amount of static charge is not excessive, such as moving tapes and films, and medium speed printing presses.

ii) Combination units - a nuclear or electrical device preceded by a passive inductive device. The inductor reduces the charge to a level at which the active device can effectively remove the remainder. These combination units are used in high speed applications.

iii) Air blowers - employing the static eliminator to ionize a stream of air which is then blown over the area to be neutralised. Large blowers are capable of neutralising an area up to 2\(\text{m}^2\). Smaller air nozzles can be used to deal with small areas of localised charge.
2.4.1 Useful Life-times

Americium-241 has a half-life of 433 years and so devices containing such sources essentially have an unlimited life-time. Polonium-210 has a half-life of 138 days and the devices are usually marketed on a yearly lease basis. This leasing system has the potential of allowing control over the disposal of the decayed source.

Electrical devices theoretically have an unlimited life-time. However the conditions created in a corona discharge, sometimes exacerbated by the presence of trace substances in the ambient air, can cause slow deterioration of the needle points because of corrosion, and this leads to reduced efficiency. The high electrical fields employed can cause the attraction of dust particles to the emitter points, which in extreme circumstances will lead to electrical breakdown. Regular cleaning of the emitters is therefore necessary to maintain peak efficiency.

Figures provided by one manufacturer on the efficiency of an electrical device and a nuclear device under identical test conditions show that both devices lose efficiency with time. The data are presented as half-life plots in Figure 2. Because complete details of the tests carried out were not made available, no assessment of the relative efficiency of the two devices can be made. The information that can be drawn from the plots in Figure 2 is that the electrical device has an apparent half-life of just over three years, showing evidence of some form of deterioration. It is surprising that the nuclear device shows such a long apparent half-life (456 days, the half-life of Po-210 is 138 days). No explanation can be offered for this apparently contradictory result, without invoking speculative hypotheses (such as degradation of the source bonding material).
For a first-order decay the following relationship holds:

$$\ln \frac{X_t}{X_0} = -0.693 \frac{t}{t_\frac{1}{2}}$$

where $X_0$ is equal to the intensity at time zero, $X_t$ is the intensity at time $t$, and $t_\frac{1}{2}$ is the half-life.

**a) Electrical Device**

$t_\frac{1}{2} = 1160$ days

**b) Nuclear Device**

$t_\frac{1}{2} = 456$ days
2.4.2 Efficacy of the Devices

Nuclear devices are generally more compact than the electrical devices and do not require power cords and power supplies unless they are used with an air blower. They are therefore easier to locate in awkward positions and are more readily repositioned to take into account changing static-charge conditions. Provided the Po-210 devices are changed annually there is less risk of their not functioning; electrical devices require a conscious act to switch them on.

It is generally accepted that electrical devices have more static elimination power on a size-for-size basis than NSE's. Herbert Products Inc., which markets both NSE's and ESE's, have found that for a given situation their electrical devices were about 35% more efficient than the equivalent NSE\(^{(9)}\).

2.4.3 Safety

The question of health hazards posed by the radioactivity of nuclear devices is not considered in this report. If this consideration is omitted there is one area where nuclear devices are to be preferred for safety reasons, and that is where an explosion or fire hazard exists. Although some makes of electrical static eliminators have Underwriters' Laboratory Approval for use in Class 1 Group D atmospheres\(^{(10)}\) the question of inherent safety has to be asked. The corona discharge, when functioning as designed, does not possess sufficient energy to ignite flammable air/vapour mixtures. However, any high voltage electrical equipment possesses a finite, if small, possibility of malfunction. The presence of high voltages could therefore cause an explosive spark if insulation breakdown occurred. Nuclear devices, on the other
hand, are inherently safe with respect to explosion hazard.

2.4.4 **Unwanted Side-effects**

Both NSE's and ESE's have the potential of causing exposure of undeveloped photographic film; nuclear devices by $\alpha$-radiation, and electrical devices by the light emitted from the corona discharge. The problem with NSE's can be overcome by making sure that the device is positioned facing the non-emulsion side of the film as $\alpha$-particles will not penetrate the thickness of the film. The effectiveness of charge elimination is not altered since an insulating surface acquiring a charge will acquire an equal and opposite charge on the other side. Removal of the charge from one side will therefore dissipate the charge induced on the other side. Electrical devices are supplied with light screening baffles to prevent film exposure; such screens, however, will cut down the efficiency of the device.

A corona discharge will create small amounts of ozone from oxygen in the air, these amounts are far greater than those formed by $\alpha$-radiolysis$^{(11)}$. There is the possibility that some discomfort may be caused to operators working close to such devices if they are exposed to ozone for extended periods of time. Certain materials (notably rubbers) are also attacked by ozone.

2.4.5 **The Special Case of Sensitive Electronic Devices**

Some kinds of electronic devices (notably C-MOS's and FET's) are very sensitive to stray over-voltages. Electromagnetic radiation generated by the high fields present in ESE's can induce sufficient over-voltages in high impedance circuits to cause destruction of
sensitive components. High voltage transformers also induce "spikes" in main circuits which could cause damage to sensitive electronics connected to the same circuit\(^{12}\). In the production of microcircuits it is not possible to know if a static eliminator (necessary to remove all static charges from the work area) is also producing sufficient electromagnetic radiation to cause damage.

2.5 Conclusion

At the present time the process of static elimination in the industrial environment is far from being an exact science. Even at the research level, work is still being done on the precise mechanisms of static build up and its control. There is no question, however, that both NSE's and ESE's, as presently available, do perform an adequate job of eliminating static in the work environment. Because the characteristics of the devices differ, particular devices may be preferred in specific applications. Apart from the potential of health hazard due to the radioactivity of nuclear devices there appear to be no technical disadvantages inherent in their mode of operation. The electrical devices can present technical problems in some situations. Induction devices are not as effective as NSE's or ESE's but may be adequate in some applications.
3. PRODUCTS AVAILABLE FOR STATIC ELIMINATION

3.1 Introduction

Static elimination products may be broken down into four categories:

i) Chemical static eliminators
ii) Inductive static eliminators
iii) Electrical static eliminators
iv) Nuclear static eliminators.

They are used in a variety of different applications, in some cases different types of static eliminators may be used singly or in combination. The various manufacturers tend to aim their products at specific market places but never to the exclusion of other uses.

In this section the various products available will be considered with detailed consideration being given to nuclear devices and products competing directly with them.

3.2 Chemical Static Eliminators

These can take two forms, those additives incorporated into the product, usually man-made fibres, to decrease their propensity to generate static electricity, and those products applied as an external coating to increase surface conductivity. The internal additives, usually polyalkylene ethers, gave rise to Dupont's Antron III, an anti-static nylon which is probably the most significant anti-static fibre
in the market place\(^{(13)}\). External chemical anti-static compounds are supplied by over thirty suppliers and/or manufacturers in North America. The compounds come either as a concentrated liquid or as an aerosol spray, depending on the particular application. It appears that the sprays are widely available on the consumer market place under many different private labels for use primarily as record and film cleaners.

3.3 **Inductive Static Eliminators**

There are seven companies supplying inductive static eliminators to the industrial market plus additional manufacturers of "Tinsel" which can be used for static elimination. Table 2 summarizes the products available.

Inductive devices generally start working at electrostatic voltages of 5kV or greater. Manufacturers do not claim that they reduce charge to zero but rather to "acceptable levels", or recommend that they are used in conjunction with an ESE or NSE. They are widely used in high speed operations such as high speed printing presses and the handling of plastics.
### TABLE 2

**MANUFACTURERS OF INDUCTIVE STATIC ELIMINATORS**

<table>
<thead>
<tr>
<th>Company</th>
<th>Product Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herman Sticht Co.</td>
<td>&quot;Magic Wand&quot;</td>
<td>Bar with tufted copper wire</td>
</tr>
<tr>
<td>Western Brush Co.</td>
<td>Western Static Eliminator Brushes</td>
<td>Spiral wound copper wire with brass wire bristles</td>
</tr>
<tr>
<td>Simco Corporation</td>
<td>Type IS-2</td>
<td>Bar with tufted wires</td>
</tr>
<tr>
<td>Simco Corporation</td>
<td>Type HD</td>
<td>Bar with needles</td>
</tr>
<tr>
<td>The Portland Company</td>
<td>Chapman 075</td>
<td>Designed for use with ESE's</td>
</tr>
<tr>
<td>The Portland Company</td>
<td>Static Eliminator Brush</td>
<td></td>
</tr>
<tr>
<td>Achilles-Nonspark</td>
<td>Coated plastic</td>
<td></td>
</tr>
<tr>
<td>Gasotron</td>
<td>Tufts of wire</td>
<td></td>
</tr>
<tr>
<td>3M</td>
<td>&quot;105&quot;</td>
<td>Steel springs</td>
</tr>
</tbody>
</table>
3.4 **Electrical Static Eliminators**

There are two major manufacturers of electrical static eliminators selling in Canada although there are other manufacturers in the United States. The Canadian market place appears to be dominated by The Simco Company of Lansdale, Pennsylvania and Herbert Products Incorporated of Westbury, New York. Both companies have a range of products designed for different applications. The products fall into the following groups:

i) **Bars**
   - Simco Company
     - Type ME - up to 180" long, "shockless"
     - Type SS - up to 180", enclosed for dirty applications
     - Type MESB - up to 180", metal encased
     - Type XP - up to 180", "explosion proof"
   - Herbert Products
     - J-S Curastat

ii) **Circular bars**
    - Simco Company
      - Type MEC - diameter 5", 7", 9" and 11"
    - Herbert Products
      - circular Curastat

iii) **Pinpoint units**
    - Simco Company
      - Type OP
    - Herbert Products
      - cartridge Curastat
    - Consan Pacific
      - Ener-jet - see section 2.3.3 for description
iv) Air guns, nozzles & blowers
   - Simco Company
     - wide range of products
   - Herbert Products
     - range of products
   - Consan Pacific
     - Ener-jet - see section 2.2.3 for description

It should be noted that Consan Pacific's Ener-jet products are relative newcomers to the Canadian market place although they have been available in the U.S. for about twelve years. There are other manufacturers in North America but only those mentioned above seem to have made any impact in the area surveyed.

3.5 Nuclear Static Eliminators

The market for nuclear static eliminators is dominated by 3M Canada Ltd. The only other suppliers to the Canadian market place at the present time are Herbert Products, and Fisher Scientific who are distributing small brush type units and grids made by Hollywood Films International for use in balances.

3.5.1 The 3M Product Line

The 3M Company manufacture a full line of nuclear static eliminators which all use micro-encapsulated Po-210 sources. The product descriptions are summarized in Table 3.
### 3M COMPANY PRODUCT SUMMARY

<table>
<thead>
<tr>
<th>Product Code</th>
<th>Description</th>
<th>Size</th>
<th>Isotope Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>203</td>
<td>Pinpoint</td>
<td>3.5 cm diameter</td>
<td>10 mCi</td>
</tr>
<tr>
<td>204</td>
<td>Pinpoint</td>
<td>3.2 cm diameter</td>
<td>5 mCi</td>
</tr>
<tr>
<td>206</td>
<td>Circular</td>
<td>6&quot; &amp; 4&quot; diameter</td>
<td>40 &amp; 25 mCi</td>
</tr>
<tr>
<td>315</td>
<td>Bar - combined inductive &amp; nuclear</td>
<td>6&quot; to 84&quot;</td>
<td>2 mCi per inch</td>
</tr>
<tr>
<td>210</td>
<td>Bar</td>
<td>6&quot; to 84&quot;</td>
<td>2 mCi per inch</td>
</tr>
</tbody>
</table>

**Air Delivery**

<table>
<thead>
<tr>
<th>Product Code</th>
<th>Description</th>
<th>CFM at PSI</th>
<th>Isotope Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>902</td>
<td>Air gun</td>
<td>6</td>
<td>10 mCi</td>
</tr>
<tr>
<td>902F</td>
<td>Air gun with filter</td>
<td>2.5</td>
<td>10 mCi</td>
</tr>
<tr>
<td>905</td>
<td>Air blower</td>
<td>157</td>
<td>40 mCi</td>
</tr>
<tr>
<td>906</td>
<td>Air nozzle</td>
<td>7.4</td>
<td>20 mCi</td>
</tr>
<tr>
<td>908</td>
<td>Air nozzle</td>
<td>30</td>
<td>10 mCi</td>
</tr>
<tr>
<td>907</td>
<td>Air source</td>
<td>75</td>
<td>40 mCi</td>
</tr>
<tr>
<td>909</td>
<td>Air blower</td>
<td>50</td>
<td>40 mCi</td>
</tr>
</tbody>
</table>

Product 315, a combined inductive and nuclear static eliminator is designed for high speed applications. Product 907, an air source, is designed for explosive areas where the electrical pump may be situated outside the room, the pump being connected to the air source by a flexible plastic hose. The other products are very much multi-purpose products, the ease of locating and relocating being important selling features. All the 3M products are leased on an annual renewal basis.
3.5.2 Herbert Products Nuclestat Product Line

Herbert Products market only bars in the Nuclestat line and a spokesman for the company in New York stated that the company currently sells both Po-210 and Am-241 sources. They are trying to phase out the Am-241 sources because of its long half-life and the possibility that the company might have a long term moral responsibility for the radioactive source.

The sources in the Herbert Products bars are made with the radioactive isotope being sandwiched between gold foil. The bars are available in lengths from one inch to 120 inches. Although Herbert Products use a lease arrangement in the U.S., in Canada they only sell outright.

3.5.3 Brush Type Nuclear Static Eliminators

There have been available in Canada brushes, from one centimetre up to about ten centimetres in width, with radioactive sources in them. The appearance of the sources indicates that they originate from the same manufacturers as the sources in the 3M and Herbert products. However, the only company actually distributing such brushes in Canada at the present time is Fisher Scientific who supply brushes supplied to them by Hollywood Films International. These brushes have only just been included in the Fisher Scientific catalogue and little information is available. It is also the case that certain brushes with radioactive sources may be purchased by mail order from photographic equipment suppliers in the U.S.
3.6 Comparative Pricing

It is difficult to compare prices directly since 3M Canada lease their NSE's and do not sell them outright, Herbert Products sell their NSE's outright, and all the electrical products are sold outright. Table 4 lists comparative prices of a typical electrical unit price and the annual leasing fee for a nuclear unit at 1978 prices.

<table>
<thead>
<tr>
<th>TABLE 4</th>
<th>ESE*</th>
<th>NSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar 24&quot;</td>
<td>$190</td>
<td>$440</td>
</tr>
<tr>
<td>36&quot;</td>
<td>$220</td>
<td>$507</td>
</tr>
<tr>
<td>78&quot;</td>
<td>$393</td>
<td>$751</td>
</tr>
<tr>
<td>Circular 4&quot;</td>
<td>$435</td>
<td>$429</td>
</tr>
<tr>
<td>6&quot;</td>
<td>$510</td>
<td>$457</td>
</tr>
<tr>
<td>Air gun</td>
<td>$203</td>
<td>$130</td>
</tr>
</tbody>
</table>

*The price quoted for ESE includes a power pack, in the case of the air gun more than one unit may be run off the same power pack.

Inductive devices are generally cheaper than ESE's. The only electrical product which falls into a different price range is Consan Pacific's Ener-jet system. In this system sufficient outlets, connectors and power supply for a 36" printing press would be about $2,300 whereas a similar two bar (feed and delivery) installation would be about $440 for typical electrical units or $1,174 per annum for two combined nuclear and inductive static eliminators.

The estimated life of electrical static eliminators is over five years, given proper maintenance; the nuclear units last only one
year and the Ener-jet system is unconditionally warranted for three years so it is expected its life time is well in excess of this. It can be seen that over a three, or even two year period the nuclear devices are the most expensive.

For the small scale applications the smallest 3M device is a 3.2 cm disc costing $126 in 1978; devices supplied by Fisher Scientific start at $6 for a 1" brush or $12 U.S. for a flat anti-static device with a grid (designed to be installed in analytical balances). These can be compared to piezoelectric devices which start in price at about $24.

3.7 Conclusion

There are a variety of products available in the market place. In the area of ESE's, Simco and Herbert seem to dominate the market place. For NSE's, 3M have a commanding lead over Herbert Products, the only other company supplying industrial NSE's in Canada. As far as can be ascertained none of the companies supplying NSE's or ESE's have manufacturing facilities for these products in Canada. 3M Canada do not sell their radioactive devices but lease them on an annual basis so that they are returned to the company at the end of a twelve month period. Herbert Products sell their radioactive devices outright in Canada, although they operate a leasing program in the U.S.

Small brushes are available in Canada from Fisher Scientific on an outright sale basis. It seems that it is also possible to buy brushes from the U.S. by mail order but the companies in the U.S. supplying brushes on this basis have not been identified as this does not seem to be a widespread practice.
4. USERS OF STATIC ELIMINATORS

4.1 Introduction

In this section the types of problems that static electricity creates in the industrial environment are discussed, with a brief note on problems and products in the domestic situation. The problem is significant in a limited number of industries. Although static occurs in many everyday operations (e.g., walking across a nylon carpet), its occurrence is only of significance when it interferes with operations in the area. Comments were gathered from talking to people in industry and are brought together to produce a picture of the requirements for static elimination devices as the user sees them.

The overall picture that emerged was that in the printing and photographic industries the problems of static are recognized and generally attributed to lack of environmental control (humidity and dust levels). The electronics industry, while recognizing the problems static can cause, does not seem to have yet developed an overall "attitude", people in this industry still seem to be experimenting with alternative solutions; designing the potential problem out of the equipment or getting rid of the static charge by some means. In the chemical industry static has been a long recognized problem and in most cases adequate solutions are available. In explosive or flammable atmospheres the picture is not clear. Nuclear devices do not seem to be widely used, but for technical reasons are to be preferred to electrical devices if any kind of device is installed at all.
4.2 The Printing Industry

4.2.1 The Printing Press

There are numerous potential problem areas in the printing industry. The problems can begin at the point where the paper feeds into the presses. If the feedstock paper carries a static charge, improper feeding, or in the worst case jamming, of the press may result. As the feedstock passes through a web offset press the web itself develops a static charge, which could if touched give personnel a shock. At the same time the paper can develop a charge which can prevent the sheets stacking evenly as they come off the press.

The humidity of the operating environment has a significant influence on the potential for static problems. The reasons for this are discussed in section 2.3.1. If a print shop is unable to maintain and control proper temperature and humidity it may have intermittent problems depending on the climate, the problem is more severe in the dry, cold winter months.

The problem is also influenced by the "aging" or "conditioning" of the paper prior to use, and by the weight of the paper. The "aging" process is simply a way of allowing the paper to equilibrate with the humidity of the surrounding environment which should be at least 40% humidity\(^\text{(14)}\). As a general rule if the paper has been aged or conditioned so that it has sufficient moisture content, the conductivity of the paper is sufficient to considerably reduce, if not eliminate, problems caused by static. However some press rooms cannot take sufficient time to effectively age their paper.
These problems may be combatted in various ways:

i) by aging the feedstock,

ii) by maintaining reasonable humidity levels in the press room,

iii) by the installation of some static elimination device.

Inductive devices, electrical or nuclear devices may be used effectively. Ionised air blowers can be directed onto sheet-fed paper, bars can be mounted onto the press before and/or after the printing process.

4.2.2 Comments from the Printing Industry

The printing industry probably represents the largest number of potential users of anti-static devices. It is an industry where there are many small print shops. It seems that these small print shops are the ones who have the greatest problem with static. Large print shops with multiple high speed presses are in a better position to have adequate humidity control which eliminates, or reduces to insignificance, potential static problems. The nature of the feedstock is also an important factor; the high volume print shop is in a better position to refuse feedstock from their suppliers if it is obviously too dry. Light weight feedstock present problems and these are usually overcome by the use of ionised air blowers on the air feed, which can speed up the operation of the press. None of the major manufacturers of printing presses build in active anti-static devices but they are usually available as an optional extra. Suppliers of printing presses indicated that is an option requested only occasionally. Many print shops install devices themselves and do so in such a way that, if necessary, one anti-static device can be moved from one press to
another depending on the feedstock being used.

There is no question that, to the small print shop, static is a periodic source of irritation and inconvenience. Conversations with several establishments in this category produced the same story - "we've tried everything!". Most small shops spoken to have tried, or are trying a nuclear static eliminator. The general reaction is that the NSE works but does not seem to do a better job than the electrical device it usually replaces and it is a lot more expensive so that the lease will probably not be renewed. In many cases the blame for their problem is placed on their premises. It is difficult to maintain the necessary level of humidity in an older building.

4.2.3 Printing Polyethylene Film

The most serious problems in the printing industry occur when the feedstock is not paper but a highly non-conductive and hydrophobic material such as polyethylene sheeting. In this situation the problems are the same as those encountered in paper printing, but severely exaggerated as no charge is leaked away through the material. It is also often the case that the printed plastic material is going to be used in a subsequent packaging process and must be static free so that it will feed cleanly into the packaging or other process equipment. In this case the material may be chemically treated to remove static before the printing process begins but static elimination devices are still required at all stages of the process to ensure a static free final product.
Electrical and inductive bars are in general use. One representative of the industry interviewed stated that the combination of chemicals and anti-static bars was adequate in all but the driest of conditions, at which time a piece of tinsel draped over the equipment would give enough additional inductive static elimination to prevent problems.

4.2.4 Gravure Presses

In gravure presses the metallic inks used may be unevenly attracted to the surface of static charged paper giving an uneven effect. It is also true that the inks used are often based on flammable solvents giving rise to a fire or explosion hazard if static sparking is permitted to occur. Absorption of the solvent during the printing process permits static charge to leak away after the printing process. But static can still be a problem prior to the printing process if the paper stock has not been adequately conditioned, (i.e., is too dry).

Concern over flammable solvents used in gravure presses seemed to be non-existent, the attitude being that if the humidity was adequate there was no danger from static. No exceptional precautions were perceived as being required to eliminate static in the presence of these solvents.

4.2.5 Conclusion

The overall picture of the printing industry is that of an industry with readily surmountable static problems. In normal print-
ing of paper the solution is to condition the paper and operating environment so that any static that develops can leak away without interfering with the printing operation. In the case of the printing of hydrophobic material anti-static devices must be used but there is no evidence to suggest that NSE's do any better job than ESE's although there are people who exhibit personal preferences for particular types of devices.

4.3 The Photographic Industry

Static is a problem at two particular points in the photographic processing industry, the first point being when the undeveloped film is removed from its protective coverings for processing and the second point is when the finished negative is prepared for printing. The handling problems associated with the finished negative affect not only the preparation of prints or copies, but also film for projection.

4.3.1 Undeveloped Film

In the case of undeveloped film small static bursts imprint light tracks on the unprocessed film. These tracks can ruin an entire frame of 35 mm film. Ionised air blowers or inductive devices can be used to solve the problem. Bars can only be used when positioned on the underside of the film, as α-particles from NSE's and light from the corona discharge of an ESE can both damage certain types of high-speed undeveloped film.

4.3.2 Handling of Finished Negatives or Transparencies

Static charge can hold dust particles on the surface of the
negative or transparency and these dust particles may cause serious blemishes in the print or transparency made. The charge on the film may be generated when the film passes through the rollers of a film processor, or as it is unwound off a reel or simply when it is handled for inspection purposes. In the single negative situation anti-static sprays, piezoelectric devices and brushes can be used. Brushes can themselves present a problem when used to remove dust by leaving a static charge which attracts dust back again. In the commercial situation it is generally felt that the ideal is to keep dust levels to a minimum, something which depends on the age and design of the building and its air conditioning/ventilation systems. Failure to maintain this type of environmental control can be compensated for by the use of some type of static eliminator or a combination of cleaning device and static eliminator. Ionised air blowers, bars, and point eliminators can all be used depending on operator preferences.

4.3.3 Comments from the Photographic Industry

The commercial photo-processing laboratories who were interviewed told the same story. They had had 3M devices in their film cleaners but did not find them altogether satisfactory, principally because they appear to stop working after about six months. These establishments are planning to install Ener-jet systems because they anticipate that Ener-jet will do just as good a job as the 3M devices and that in the long run it will be cheaper.

Two other, smaller scale, photographic processing units were also users of the 3M products, both stressing the use of ionised air guns to blow dust off negatives. One of these establishments was also planning to install an Ener-jet system to combat a severe dust problem, this was to be used in conjunction with the 3M devices.
4.3.4 Conclusion

The general picture was one where the commercial photo-processing laboratories having tried the nuclear static eliminators were intending to replace them. The non-commercial, more specialized photographic units were, on the whole, very much in favour of the nuclear devices using them in ionised air blowers. The only reason anyone gave for not using the electrical devices was that they "...understood you could get a shock from them." A major non-commercial photographic unit specializing in copying film did, however, say that in their opinion the electric ionised air blowers were the best, thus it seems that an ESE can do an adequate job although people do have personal preferences for other devices.

4.4 The Electronics Industry

Of all the industries represented in this study this was the least clear cut when it came to establishing the need for static eliminators. It seemed that there were a variety of operations during the manufacture, use and testing of electronic equipment where static could be a major problem.

4.4.1 Manufacture of Photomasks for Printed Circuits

In the manufacture of printed circuits a photomask has to be prepared, it is essential that this be dust free and, as was discussed in the previous section, handling for inspection can be sufficient to generate enough static to attract dust. The maintenance of "clean" (dust free) areas is the normal way of dealing with this problem in the electronics industry. When this is not adequate, some kind of ionised
air blower can be used together with grounding of the operative, and
the use of conductive working surfaces.

Another problem reported by the electronic industry concerned
the use of ESE air blowers. If there was poor maintenance of the
device, dust particles may accumulate on the needles and eventually
cause current leakage through the polyethylene insulator leading to
carbonisation. Carbon particles could then become detached and blown
onto a photomask. While this problem was only mentioned by one elec-
tronics company there is no reason to suppose it could not occur else-
where. NSE's are not likely to suffer from this particular problem.

4.4.2 Production of Integrated Circuits

The masks used for photo-etching of silicon chips are suscep-
tible to the same problems as those described above in paragraph 4.4.1.
In addition to this, the electric fields associated with the high-
voltage corona discharge in ESE's can induce low-voltage disruptions in
an integrated circuit; some devices have breakdown voltages of less than
100 V. Should this occur during the manufacturing process serious dam-
age can occur to the circuits. Integrated circuits are also susceptible
to damage by direct sparking from static - similar precautions to those
described in section 4.4.1 have to be taken.

4.4.3 Electronic Equipment

Static discharges can harm some types of complex electronic
equipment (see section 2.4.5). Everyone in the industry accepts the
vulnerability of C-MOS and FET devices to static discharge; but no clear
picture emerged of the preferred way of dealing with these problems. Manufacturers concerned with the vulnerability to static of a finished piece of equipment strive to design the equipment to protect it against such damage by extensive shielding and grounding. In the actual manufacturing process grounding of the worker and work station is standard, the only additional piece of equipment used is usually an ionised air blower to bathe the work surface. Experts suggest that the use of ESE's may be a little risky as the electric field associated with a corona discharge, and pulses from the high voltage power supply can be picked up by equipment in the area; this could be sufficient to cause damage to sensitive equipment (see section 2.4.5). The manufacturers themselves do not have the same reasoned approach to the problem although they do express a preference for the nuclear devices, usually saying they have been recommended by other (U.S.) manufacturers.

4.4.4 Conclusion

There is reason to suppose that the electronics industry is one where NSE's are more desirable than ESE's. Users of NSE's were certainly pleased with their performance and there are valid technical reasons for preferring them to ESE's. The only question that is still unanswered is to what extent any static eliminating device is necessary. Indications are that their use could decrease reject rates during the manufacturing processes, although grounding of worker and work station may be enough to give an acceptable reject rate. As far as protecting equipment in use the trend seems to be towards integrating protection into the equipment's design, the ultimate aim being to eliminate the need for any kind of external anti-static protection.
4.5 Chemical Industry

The vast majority of static problems encountered in the chemical industry have long been recognized and dealt with satisfactorily before NSE's came on the market. There is a problem of charge separation (or the development of static charge) between product handling equipment and the product itself. This occurs with both liquids and solids and is of concern in the industry.

4.5.1 Liquid Chemical Handling

Precautionary measures often have to be taken when pumping or handling liquid products. Often it is sufficient to ensure that the equipment is well grounded. It is a particular problem in the petrochemical industry where flammable or explosive products are being handled. The approach in these situations is, in addition to ensuring grounding of the equipment, to keep the conductivity of the fluid as high as possible normally by the addition of anti-static additives\(^{(15)}\).

4.5.2 Powder Handling

In powder handling systems, the precaution of adequate grounding of hardware is essential but it may not be adequate as the powder may still acquire charge while it is in motion. Explosions have been known to occur because of this phenomenon\(^{(15)}\). Studies in this area seem to be directed to finding out where the static discharges are most likely to occur for given design of handling equipment. The use of an ion source to neutralise charge does not seem to be common practice, although examples are known\(^{(5)}\).
4.5.3 Conclusion

The only areas where NSE's may have an application is near explosive or flammable materials. One user of NSE's was found to be using it on P.V.C. sheeting used to wrap explosives for delivery to the Arctic. Under normal circumstances a non-conductive wrapping material would not be used in conjunction with explosive material. In general inductive devices are adequate to reduce static charge to a level below which sparking will not occur.

4.6 Other Applications of Static Eliminators

4.6.1 Textiles

On modern high speed looms static charging of the thread as it unwinds at high speed from the bobbins has long been a problem with non-conducting artificial fibres. This problem has in some part been alleviated by the addition of internal anti-static additive to the fibres themselves (see section 3.2). Humidity control and anti-static devices are also used.

4.6.2 Preparation of Dental X-Rays

It was, at one time, thought necessary to prevent static from spoiling dental x-rays either by streaking when the cover was removed from the undeveloped film or by dust. Equipment now being supplied for processing dental x-rays is so designed to reduce the problem to a minimum and makes the use of anti-static devices unnecessary. Equipment for processing dental x-rays incorporating NSE's is, however, no longer available. It was not found to be very satisfactory and other equipment was found to be perfectly adequate.
4.6.3 Feather and Down Separation

The task of separating feather and down for quality control purposes has, until recently been done manually, a very slow and laborious procedure performed only for the purpose of establishing quality standards. A mechanical device has recently been introduced in the Standards Branch of Consumer and Corporate Affairs. In low humidity conditions it was found that the device would not function properly without an anti-static device being built into it. A nuclear static eliminator was chosen as it was felt that the corona discharge area of an electrical device would become quickly clogged with feathers, causing electrical breakdown. This is not a widespread application of NSE's but is of significance because it is probable that standards for feather and down products will be legislated in the near future and the standards will be measured by the particular design of machine incorporating a nuclear static eliminator. There are four such machines in Canada at the present time with a fifth likely to be installed in the near future.

4.6.4 Analytical Balances

It is necessary to keep the pans of micro balances dust free to ensure accurate weighing. Brushing the pans risks creating static charge which will reattract the dust. In fact any static charge must be avoided to keep the dust problem under control and this dictates the use of an anti-static device. Bathing the balance in ionised air or installing a small anti-static device inside the weighing cabinet are both possible. Electrical devices with their associated wires are clumsy and inconvenient whereas the small nuclear devices are very convenient. It is for this type of application that the nuclear anti-static brushes are well suited. There is no reason to suppose that piezoelectric devices would not be equally adequate, and these are available in a brush form.
A major supplier of scientific equipment estimated that they supplied about twenty anti-static devices a year, incorporating a nuclear source both as brushes and grids. People using these products tend to do so without considering the fact that, in theory, it should no longer be functioning properly at the end of a year; they continue using them without complaint for considerably longer periods.

4.6.5 **Floor Coverings**

Walking across non-conductive flooring can build up fairly substantial amounts of static which is discharged as soon as the person touches a conducting surface. This can be uncomfortable and, if the surface through which the discharge takes place is sensitive equipment, it can be damaging. Anti-static carpeting can be produced in various ways; fibre with internal anti-static agents may be used; the finished carpet can be chemically treated with anti-static chemicals or fine metal wire may be woven into the carpet. Conductive plastics have been developed which can be used for mats to drain away static charge over smaller areas.

4.6.6 **Domestic Uses**

Static is never really more than an inconvenience in the home but various products are marketed for in-home use. In the clothes dryer static develops causing laundry to cling together; sprays and chemically treated sheets are available to deal with this. Stereo and photographic enthusiasts encounter problems of static which can be caused merely by handling, attracting dust to the surface of the record or negative. There are sprays, cleaning cloths, brushes and piezoelectric devices readily available on the retail market to reduce
static in these cases. As in the industrial environment the use of a humidifier can reduce any generalized static problems associated with non-conductive floor covering.

4.7 Future Prospects

Conversations with suppliers of NSE's and ESE's indicate that sales effort is being directed towards the potentially high volume areas of the printing and photographic industries. The evidence of the limited survey undertaken for this report is that while NSE's will continue to be leased by people in these industries it will not, in general, be on a repeat basis because they are more expensive and do not appear to perform any better job than the alternative products. There will undoubtedly be some customers who will prefer them and renew their leases because NSE's are in general a more convenient product to install and maintain in good operating condition.

The use of NSE's in the electronics industry may be expected to grow as more companies discover their advantages. The size of this total market is small relative to the printing industry and it is not a market towards which the major suppliers have directed any intensive selling effort.

In the chemical industry, while inductive and electrical devices may be adequate for most purposes, in hazardous atmospheres the use of NSE's should be preferred for safety reasons. As yet there is no evidence to suggest they have made a significant impact. It is a potential growth area for NSE's if customers rate the problem sufficiently severe to warrant the installation of any device at all.
For small scale uses, increases in use of NSE's may be expected as the brushes become more readily available but piezoelectric devices are also becoming more common. The relative pricing is such that in general the brushes are cheaper than the piezoelectric devices, but this does not allow for the necessity of repeat purchasing of brushes as the source decays. The advent of video discs for in-home use could cause a substantial increase in demand for small scale static eliminators.
5. SUMMARY OF CONCLUSIONS

In the industrial situation static can be a problem wherever a non-conducting product is being handled, or brought in contact with another material. It is in those areas outlined in the previous chapter, that the problem is of sufficient magnitude to have the potential to disrupt operations.

This report by no means deals with the only areas where static occurs, but those dealt with are those of significance in the area of study or where there is a real potential for NSE's to be used. Floor coverings and domestic uses of anti-statics have been discussed only briefly as they are not considered to be of any major importance here.

It was found in this study that nuclear static eliminators did have characteristics which made them a more convenient product to use. These may be summarized as:

i) self contained with no attendant wiring or power source,

ii) active at all times without the operator having to connect a power supply,

iii) can be made very small and compact,

iv) are the preferred products for explosive or flammable atmospheres and near sensitive electronic equipment.
In spite of the abovementioned advantages it was found that nuclear static eliminators have nothing to offer the printing industry that electrical devices cannot offer with the exception of convenience. The same would appear to be true for the photographic industry. In those industries electrical devices appear to be capable of doing a perfectly adequate job.

The electronics industry may, for technical reasons, be better served in certain applications by nuclear static eliminators but this does not as yet seem to be a particularly widely held view by the industry itself.

In explosive or flammable atmospheres nuclear devices are to be preferred for safety reasons. The extent to which such devices are necessary could not be determined by this study but indications are that their use is fairly limited.

For small scale applications there is no reason to suppose that the increasing range of piezoelectric devices available cannot meet the needs of users.

There will continue to be some very specialized applications, such as feather and down separation, that can only be served by nuclear devices but these do not represent a large number of potential users.

In those areas where nuclear devices are to be preferred for technical reasons (electronics, explosive or flammable atmospheres) more detailed study would be required to establish how extensive is the problem of static electricity.
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