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Electrostatic Space Charge System for Air Quality Improvement in Broiler Production Houses

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Abstract. Reducing airborne dust in enclosed animal housing has been shown to result in corresponding reductions in airborne bacteria, ammonia and odor. Technologies that have been shown to be effective for reducing airborne dust in animal areas include misting with an oil spray, water mists, extra ventilation, and electrostatic space charge systems. Increasing pressure from environmental groups to reduce PM-10 and ammonia emissions from animal housing has led to considerable interest by the poultry and swine industries for practical systems to reduce these air pollutants. This presentation will describe an electrostatic space charge system (ESCS) that was designed to reduce airborne dust and ammonia emissions from a commercial broiler production house. The ESCS for this application was based on patented technology that was developed over a period of several years to reduce airborne dust and pathogens and proven in numerous research trials in poultry hatchers and growout areas. A recently completed study in a small broiler breeder house showed the ESCS reduced airborne dust by an average of 60%, ammonia by 56%, total bacteria by 76%, and it reduced the number of Salmonella infected broilers produced from eggs gathered in the study. Preliminary results of the present study in a broiler production house during the cool months of November through April indicate the ESCS reduced airborne dust by an average of 55% and ammonia by an average of 8% in a house with built-up litter. Later studies will include litter that is fresh or not over a few months old which is expected to improve the effectiveness of the ESCS for ammonia removal since a higher percentage of the ammonia produced would be on the dust that is removed.

Keywords. Electrostatic, air quality, poultry, dust, ammonia

Introduction

Air quality relating to poultry production housing has been a major concern for years – primarily due to the close proximity of many poultry houses to residential and commercial areas. Of particular concern are particulate matter, ammonia, and odor. Producers on the other hand are primarily concerned with ammonia which can affect bird health and airborne disease transmission which can be greatly affected by airborne dust which carries microorganisms. While there is considerable research directed at defining the problem and scope of emissions, it is equally important that practical and economical control measures are examined.

Dust concentrations for poultry houses have been reported to vary from 0.02 to 81.33 mg/m3 for inhalable dust and from 0.01 to 6.5 mg/m3 for respirable dust (Ellen et al., 2000). Sources of dust that have been identified in broiler houses include feed, down feathers, excrements, microorganisms, and crystalline dust. There are several factors that are suggested to affect dust levels in poultry houses which include animal activity, animal density and moisture conditions (Ellen et al., 2000). Dust can contain large numbers of microorganisms that could have potential impact on human and bird health. Several studies have focused on dust levels in various animal housing and characterization of the dust components which include microorganisms, endotoxins (Wathes et al., 1997), and odors (Pearson and Sharples, 1995; Simpson et al., 1999).

Several approaches can be used to reduce dust concentration in animal housing areas. These include adding fat to feed, fogging with water, fogging with an oil-based spray, regular washing, ionization, electrostatic filtration, vacuum cleaning, filtration and recirculation, cleaning with wet scrubbers, purge ventilation, deep litter, and optimization of air inlet position. Reductions reported with these approaches ranged from 15% for weekly washing of pigs and floors to 23% with ionizers to 76% with a rapeseed oil spray (CIGR, 1994). Other reports of ionizer efficiency have ranged from 31% (Czarick *et al.*, 1985) to 67% (Veenhuizen and Bundy, 1990) to 92% (Mitchell, 2002b). Other studies (Madelin and Wathes, 1988; Carpenter *et al.*, 1986) have shown that reducing airborne dust levels by 50% can reduce airborne bacteria by 100 fold or more.

The Electrostatic Space Charge System (ESCS) described by Mitchell and Stone, 2000 has been shown to significantly improve air quality by reducing airborne pathogens and disease transmission in poultry. In recent, related broiler-breeder-house studies (Richardson *et al.*, 2003; Mitchell et al. 2002a) the ESCS technology was used to reduce airborne pathogens and bird to bird or bird to egg transmission by reducing airborne dust which carries the pathogens resulting in an average of 60% reduction of airborne dust, 56% reduction in ammonia and 76% reduction in airborne bacteria. The ESCS uses a simple, environmentally friendly process which is harmless to birds and humans to reduce airborne dust and associated microorganisms by charging the dust in an enclosed space and collecting it on special grounded collector plates or on the floor or walls of a room. The ESCS system has been shown to have effectiveness comparable to a 95% media filter for removing dust in laboratory experiments in hatching cabinets and equal or better effectiveness for removing airborne bacteria and Salmonella (Mitchell *et al.*, 2002b). Similar results were obtained with the ESCS in three field studies in commercial hatchers (Mitchell and Waltman, 2002). Salmonella transmission experiments with chicks exposed to Salmonella during hatching have shown that ESCS treatment of the hatching cabinet reduced cecal contamination at 7 days of age by an average of 3.4 logs (Mitchell et al., 2002b). Airborne *Salmonella enteritidis* (SE) experiments conducted in controlled environment transmission cabinets with and without an ESCS showed chicks exposed to a naturally generated aerosol of SE beginning at one week of age had no cecal contamination 8 days later (Gast, Mitchell and Holt, 1999). Experiments conducted in a 15 x 22 ft (3300 ft^3) isolation room with SE infected caged layers showed reductions of airborne SE of approximately 95% over a test period of 10 days when the room was treated with the ESCS (Holt, Mitchell and Gast, 1999). Another effect of the space charge -- besides reducing dust and microorganisms which are already airborne, is to keep surface dust near its source. For example, loose dust on the floor of a treated room would tend not to become airborne because as soon as it left the floor it would be charged and re-attracted to the floor. It is also known that long term exposure to airborne dust and pathogens in poultry houses is associated with chronic respiratory problems for workers, therefore, an additional benefit of reducing airborne dust and pathogens in poultry houses would be the improvement of air quality for workers.

There is a trend within the poultry industry for tighter house design and less frequent litter removal from poultry houses. These two factors have the potential to increase the ammonia concentration within poultry production facilities. The National Institute of Occupational Safety and Health (NIOSH) has established eight-hour exposure levels for humans at 25 ppm and the Occupational Safety and Health Administration (OSHA) has established it at 50 ppm. The level that is considered an immediate danger to life (IDLH) is 300 ppm. Symptoms of NH_3 poisoning in poultry include coughing, snicking, conjunctivitis, and dyspnea (Carlile, 1984). A general rule of thumb for the poultry industry has been to keep NH_3 below 25 ppm. However, prolonged exposure to even low levels of NH_3 could be detrimental to bird health and performance as poultry remain in this environment throughout the production period.

Control of NH_3 has been largely accomplished through ventilation. However, as fuel costs increase particularly during the winter months, poultry growers tend to minimum ventilate to reduce heating expenses. Another trend is less frequent complete house clean out resulting in birds being grown on built-up litter with the cake removed and the remaining litter top dressed with new bedding material. The combination of these trends can be detrimental to air quality in broiler houses if dust and NH_3 levels are not controlled, particularly during the brooding phase.

As the use of built up litter has increased, litter treatments have been developed to help control ammonia release from the litter pack. Litter treatments that are used by the industry include phosphoric acid, sodium bisulfate (PLT), ferrous sulfate, calcium phosphate and aluminum sulfate (alum). These treatments have been used with varying levels of success.

The primary goals of this research are to determine whether a practical electrostatic space charge system (ESCS) system can be developed and operated in a commercial broiler production house, and to evaluate the effectiveness of this technology for improving air quality in the house and for reducing emissions of dust and ammonia.

Safety Emphasis

The ESCS technology has been shown to reduce potentially harmful air pollutants such as dust, ammonia and pathogens in poultry areas resulting in healthier birds and providing a healthier environment for researchers and animal caretakers exposed to these areas. Successful application of this technology in broiler production houses would have the potential of improving disease immunity for broilers by reducing airborne dust, ammonia, and pathogens and it would reduce the respiratory hazards for animal caretakers and others who frequent the houses. The ESCS system has no harmful adverse effects.

Materials and Methods

ESCS Design and Layout: A custom designed ESCS system was designed and installed in a 500 ft x 40 ft commercial broiler house (Fig. 1).

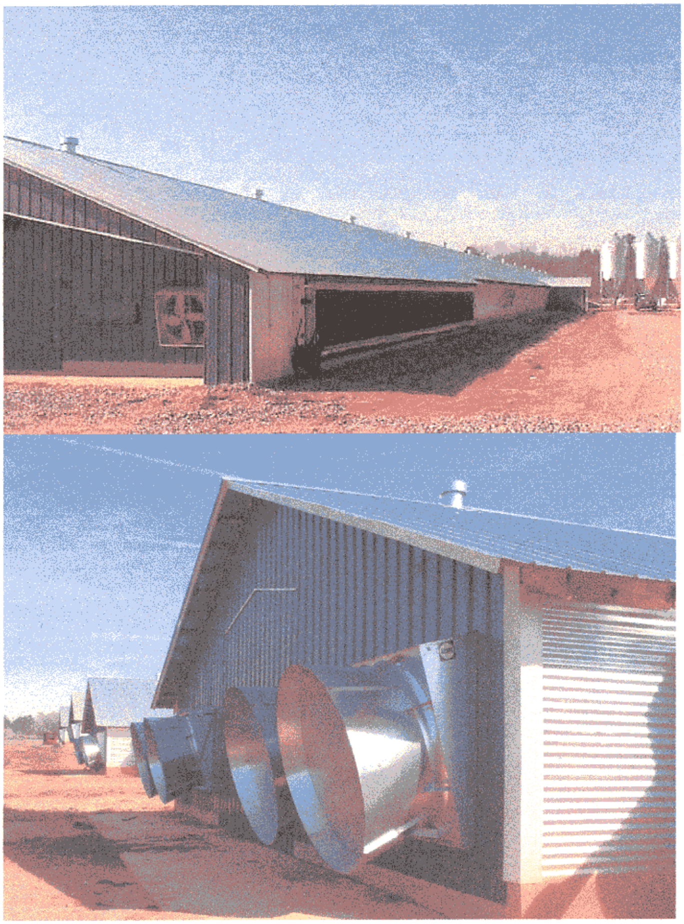

Figure 1. Broiler production house: Top is evaporative cooler end, bottom is tunnel fan end.

The system consisted of two rows of inline, negative air ionization units running most of the length of the house (Fig. 2). Separate high voltage, -30 kVdc, 2 mA capacity power supplies were used to supply -25 kVdc to the ion generators in each half of the house. The inline generators consisted of a conductive tube with sharp pointed electrodes at 1 in intervals pointing toward the litter. The tubing was attached to a grounded 1 in black iron pipe with Teflon insulators at 2 ft intervals. The iron pipe was located 3 in above the discharge points to provide a close proximity ground plane and to increase the negative air ion output (Mitchell and Stone, 2000).

Figure 2. Inline ionization units can be seen hanging from the ceiling on either side of the center of the house.

The inline generators were centered between the first row of waterers and the first row of feeders such that they were about 12 ft. from the sidewalls. Two hundred ft of inline generator were installed on each side such that it was centered between the center curtain (used for half house brooding) and the evaporative cooling pads on one end and between the center curtain and the tunnel ventilating fans on the other end. Winches were used to raise the iron ground plane pipe such that the discharge points were 7 ft above the litter (sufficiently high to walk under, but as low as possible to concentrate the charge near the birds where dust is being generated). An identical house adjacent to the treatment house was instrumented but operated as a control house without ionization.

Dust, Ammonia, Temperature, and Humidity Measurements: Dust, ammonia, temperature and relative humidity measurements were made at approximately 4 ft above the litter in the center of the house at different locations in the house. During the brooding period, measurements were made in the center of the brooding section. After brooding, when birds occupied the entire house, measurements were made either at the center of the downwind half of the house or just before the tunnel fan section. Dust and ammonia were typically measured at 10 min intervals and temperature and relative humidity were typically measured at 1 min intervals. Dust measurements were made with TSI DustTrak instruments (0.001 mg/m^3 to 100 mg/m^3) which had their own data loggers. Ammonia was measured with Draeger Polytron 1 electrochemical sensors (0 – 100 ppm) using Hobo data loggers to record the values. Temperature and relative humidity were recorded with Hobo data loggers. The ammonia sensors were calibrated with lab NH3 at 50 or 56 ppm each week.

Ventilation: Special efforts were taken to assure the treatment house and the control house were operated at the same temperature and ventilation rate. A separate central logging system used at the farm recorded operation of each fan along with temperatures throughout the house.

Results and Discussion

Preliminary results of the production house study for three flocks during the cool months of November through April indicate the ESCS reduced airborne dust by an average of 55%. This is comparable to the 60% reduction obtained in an earlier study in a small scale broiler breeder house (Mitchell et al., 2002a). Dust concentrations were generally low and ranged from 0.2 mg/m^3 to 1.9 mg/m^3. Charged dust could often be seen extending from the grounded water and feeder support cables in the treatment house (Fig. 3).

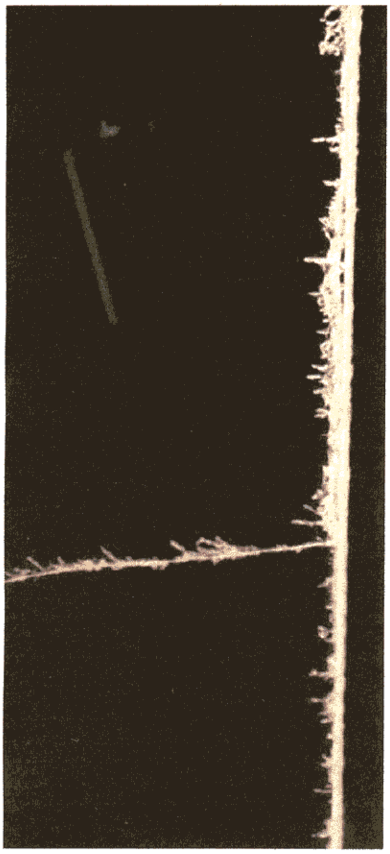

Figure 3. Charged dust extending from a grounded feeder support cable in the treatment house.

Ammonia was reduced only by an average of 8% in the house with built-up litter. This minimal reduction of ammonia is much lower than the 56% average reduction obtained in the earlier study in a small scale broiler breeder house (Mitchell et al., 2002a). Ammonia levels ranged from an average of 26 ppm to 76 ppm.

Results of a recent flock during the brooding period are shown in Figs. 4-6. Dust levels in the treatment house (PH7) were consistently lower than in the control house (PH8) and averaged 48% lower for this week (Fig. 4). Peak dust levels in the control house in the latter part of the week were noticeably higher than those in the treatment house.

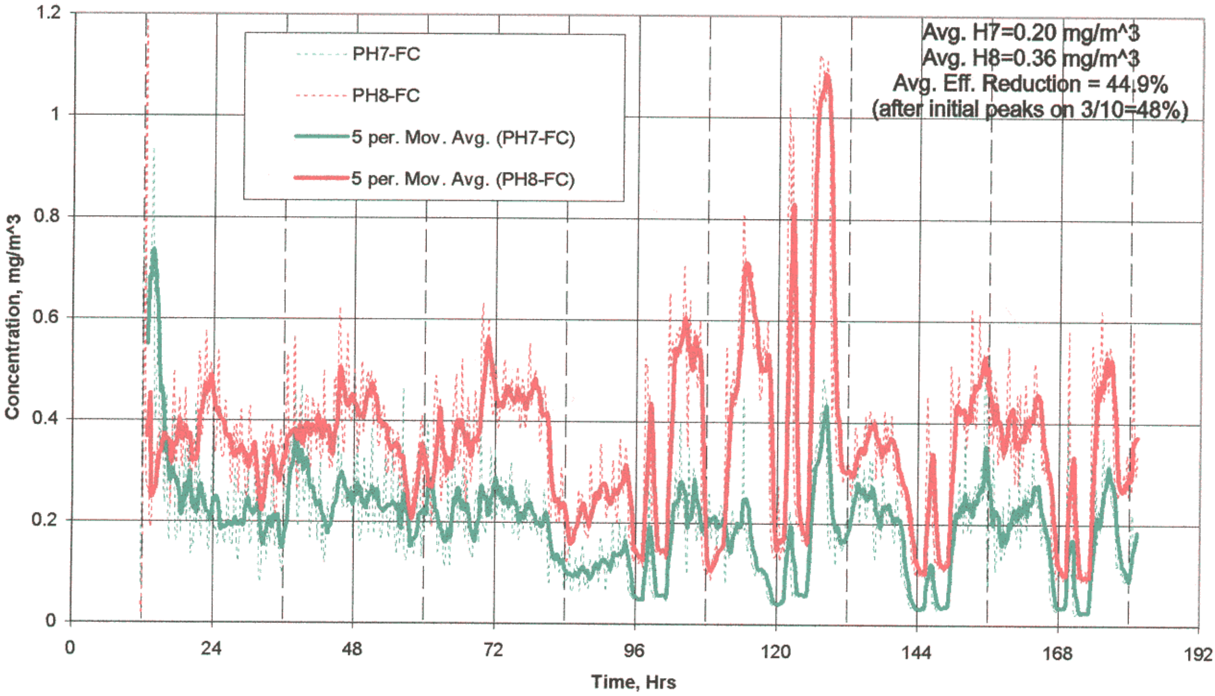

Figure 4. Dust concentration during approximately 1-wk (3-10 to 3-17-03) of a brooding period (Flock 5). Green curve is treatment, red is control.

Ammonia levels in the treatment house averaged 12% lower in the treatment house than in the control house with most of the reduction being during the evening hours when ammonia levels were highest (Fig. 5).

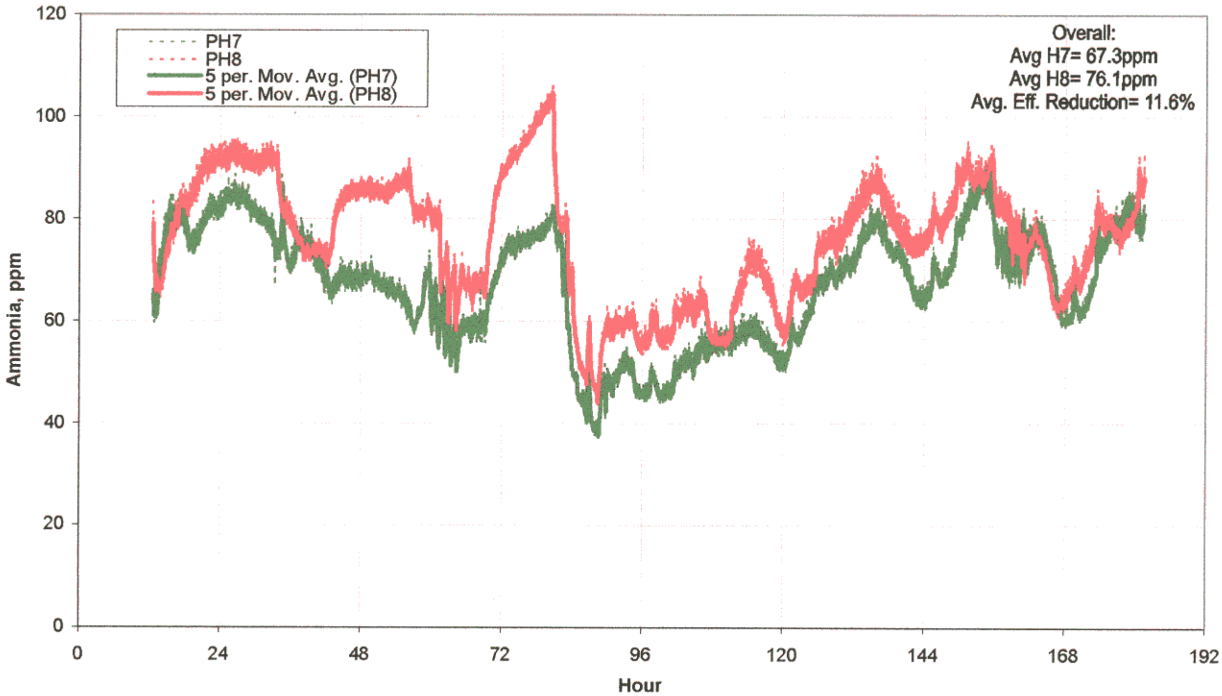

Figure 5. Average ammonia levels starting on day 5 for approximately one week (3-10 to 3-17-03) during the brooding period (Flock 5). Green curve is treatment house, red is control.

Temperatures and humidity in the two houses tracked fairly closely (Fig. 6).

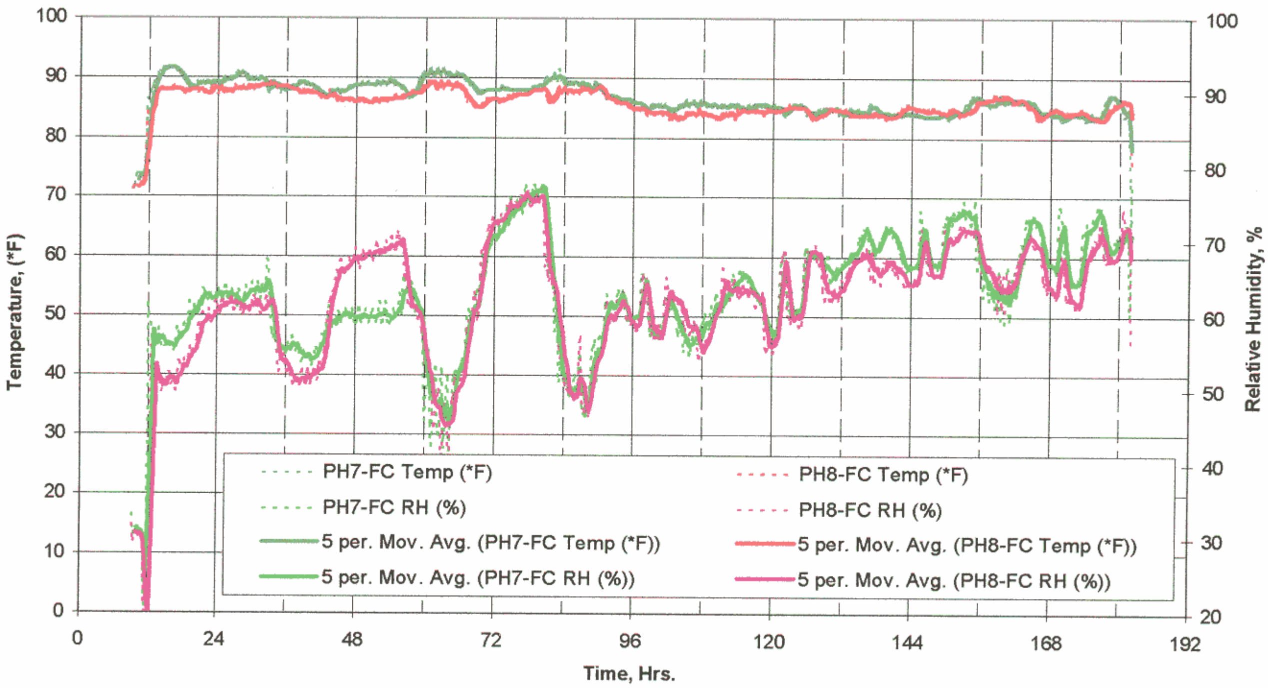

Figure 6. Temperature and humidity curves for approximately one week (3-10 to 3-17-03) during brooding period (Flock 5). Treatment house is PH7 and control house is PH8.

Although it is known that a certain amount of ammonia and odors are absorbed in poultry house dust, it is not known what percentage of total ammonia production this represents. An assumption in the present study was that reduction of airborne dust by the ESCS would result in a similar reduction in airborne ammonia. In an earlier study with broiler breeders and drier litter, ammonia was reduced by an average of 56% by an ESCS which reduced dust by an average of 60% (Mitchell et al., 2002a). In the present study with built-up litter over one year old, the ESCS has not reduced ammonia more than an average of about 12% in a given week during cool months of November through March. The reasons for this discrepancy are not clear. It may be that the amount of gaseous ammonia compared to the amount bound in the dust for the present study is much greater resulting in less opportunity for overall ammonia reduction by a dust reduction system. It may also be noteworthy that the ammonia levels in the present study have been 2-3 times higher than in the previous study while the dust levels in the present study have been 2-3 times lower than in the previous study – both of which would lend themselves to lower effectiveness of the ESCS in the present study. It should also be noted that PLT treatments on the litter just prior to chick placement were only able to control ammonia below comfortable limits of 25-35 ppm for 4 to 5 days, and ammonia levels during the last two or three weeks of growout tended to be much higher than this. It remains to be seen if fresh litter or litter that is not over about 3 months old will produce a higher ratio of dust-borne ammonia to gaseous ammonia in the broiler production house and thus lend itself to higher reductions with the ESCS.

. No differences in bird activity have been observed in the form of decreased water consumption, increased mortality, or behavior and no adverse effects of the continuous charge have been observed with the birds in the form of stray voltage or static discharge at the feeder and water lines. The incidence of static discharge to workers has also been minimal and similar to static discharges resulting from walking across a carpet in the wintertime and limited to those times when standing directly under the charger while touching a grounded chicken or piece of equipment.

Dust collection on the ESCS and subsequent need for cleaning has not been a major issue. It appears that cleaning of the equipment every week or two is sufficient to maintain desired high charge levels in the house. Telescoping brushes similar to those used to remove spider webs have been used to clean the ESCS with the power off. Cleaning time of the prototype system is about 1 hr. Designs are being considered which will minimize buildup of dust on the ESCS and reduce the cleaning frequency. Maintenance of the system has been minimal.

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