

REMOVAL OF RAGWEED POLLEN FROM ENVIRONMENTAL ATMOSPHERE OF PATIENTS

THE EVALUATION OF AN ELECTROSTATIC PRECIPITATOR COMBINED WITH AN AIR CONDITIONER

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INTRODUCTION

THE etiology of ragweed pollinosis and ragweed asthma is known. One method of therapy—separation of the patient from the pollen—will result in complete relief of symptoms. At least tens of thousands, however, still suffer when *Ambrosia* pollinates. Not all these victims can voyage to mid-ocean or escape to other areas free of the offending agent. Another approach has been the development of devices designed to clear pollen from the air of the patient's room. Beginning with van Leeuwen in 1924,¹ investigators²⁻¹⁰ have described several types of equipment able to perform with varying success. Some of these authors have stressed technical difficulties and have envisioned more satisfactory clinical results when better machines become available. This article considers an electrostatic precipitator† which has been combined with an air conditioner.‡ This combination represents a logical answer to complaints that air cleaners without air conditioning are unbearable in hot weather.

MATERIALS

The apparatus in Fig. 1 consisted of an electrostatic precipitator† combined into one functional unit with a standard 0.5 horsepower room air conditioner.‡ In electrostatic precipitation,¹¹ an electrostatic field, intense enough to break down air into free ions, is produced. The positive ions attach themselves to air-

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borne particles principally by impaction. These charged particles then are drawn into a second, less intense field where they are attracted out of the air stream by the negative electrodes.

In the present model, the ionizer and the collector sections which are required have been integrated into a cell occupying about 0.5 cubic foot. The cell was placed so that it would intercept the recirculated air before it reached the cooling fins of the air cooler. This arrangement allows the air conditioner always to work at peak efficiency by keeping the heat transfer surfaces clean and by preventing condensate from forming on the collector plates and electrically degrading the insulation. The cell can be detached easily and cleaned by rinsing in warm water. With the usual atmospheric dust loading, such cleaning need be done only monthly. The ionizer section consists of fine wires separated

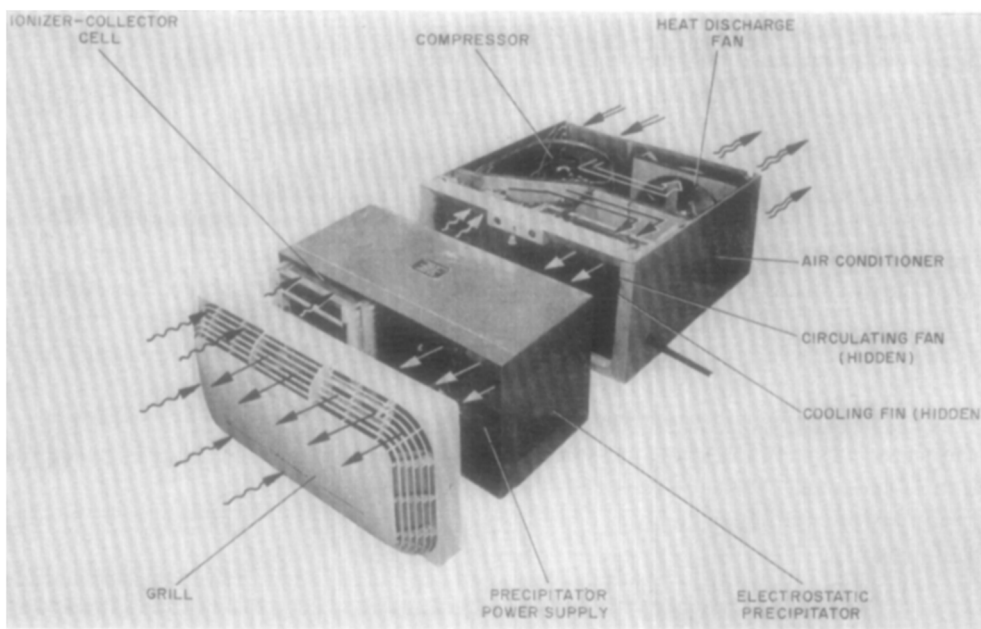


Fig. 1.—Assembly of electrostatic precipitator and air conditioner (exploded view).

equidistantly between large rods. A positive pulsating voltage of 14,000 peak volts is impressed between the wires and the ground rods to produce the intense electrostatic field. Immediately behind the ionizer is the collector section, a series of aluminum plates which are parallel to the air stream. Alternate plates are insulated from each other, and a positive direct potential of 6,000 volts is applied between adjacent plates.

The power for the precipitator is provided by a simple capacitively loaded half-wave rectifier driven from a step-up transformer which supplies 5,500 volts. In action, the collector cell serves as the capacitor in the power supply, while the ionizer acts as the electrical load by being connected across the rectifier. The unusual property of an ionizer—no current will flow unless a

voltage of greater than 8,000 is impressed on it—allows this connection. The voltage impressed on the ionizer is the sum of the capacitor's voltage and the alternating voltage from the secondary of the transformer.

For pollen collection, a standard 3 by 1 inch glass slide was coated by hand as thinly and evenly as possible with a 3:1 mixture of petrolatum and mineral oil. After exposure, the coated side was stained with a solution of 0.8 part 2 per cent aqueous basic fuchsin to one part glycerin, two parts 95 per cent ethanol, and two parts distilled water. Using a microscope ($\times 100$ magnification), a competent technician performed all counts by one of three methods: (1) the pollen on the entire slide was identified and recorded (this was the usual way); (2) 1 sq. cm. was studied and the count multiplied by a factor of 18.75 for comparison with an entire slide (outdoor counts); and (3) one transverse microscopic field was examined and the count multiplied by twenty-two fields (this technique was used only for the pollen-saturated slides in the second experiment).

Throughout the pollen season, a daily slide was exposed from noon to noon on a stand similar to that approved by the American Academy of Allergy.¹² This stand was on the roof of a thirteen-story building located within the hospital grounds. In all rooms fitted with precipitators, slides were usually placed at a position which provided for the least disturbance. This was the top of the lower sash of the window containing the unit. Such selection, however, did not represent the ideal place to trap pollen circulating between the patient and the air cleaner.

EXPERIMENTS

These experiments were devised with three purposes in mind: (1) to test the capacity of the apparatus to remove ragweed pollen from the air entering it, (2) to observe its ability to clear a room heavily laden with pollen, and (3) to determine its function under clinical conditions in the hospital, laboratory, and home.

In order to carry out the first aim, 0.2 gram of dry pollen (mixed *Ambrosia trifida* and *Ambrosia artemisiaefolia*) was introduced into the intake section of the precipitator while prepared slides completely covered the outlet. After five minutes the slides were removed, stained, and studied microscopically. A total of twenty-four slides was required to occlude the air exit.

In the second experiment, 1 gram of ragweed pollen was spread over a flat piece of paper (11 by $8\frac{1}{2}$ inches). Simultaneously at opposite ends of the laboratory, as depicted in Fig. 2, 2 grams of pollen was placed directly in front of two nonoscillating electric fans. Each fan had two 11 inch blades. Pollen slides from the six sites were obtained in the following sequence: immediately after the pollen dispersal, after 5, 10, 15, 75, and 165 minutes, and again after 24 hours.

The last group of observations involved patients sensitive to pollen. Those with ragweed asthma severe enough to warrant hospitalization were placed in one of two rooms located in separate hospital buildings. One room was 8 by 8

feet and the other was 12 by 14 feet. These rooms had private toilet facilities, and in each the bed was between the window which contained the precipitator-air conditioner and the door to the corridor. There was only one unit in each room and the windows were nailed down. All patients and hospital personnel involved were requested to cooperate in keeping the doors of the rooms closed. Patients from the Allergy Clinic who were acutely ill with ragweed pollinosis were advised to use the laboratory pictured in Fig. 2 as a possible aid for the

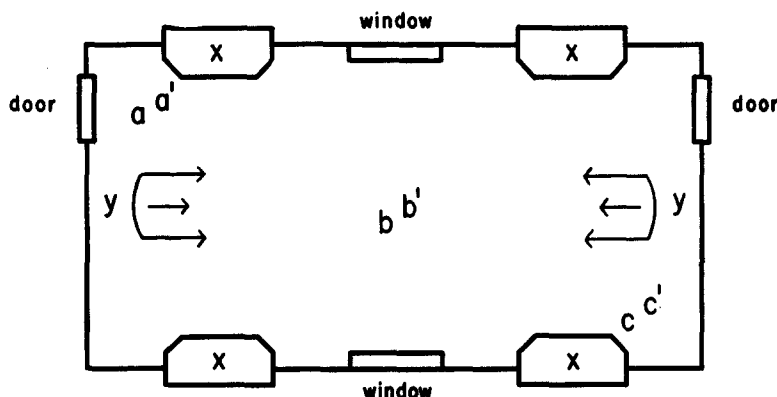


Fig. 2.—Laboratory room. The room contained various pieces of equipment and furniture and measured 28 by 14 by 9 feet, or 3,528 cubic feet. The fans were placed at six-foot heights. The units had the capacity to clear this room of circulating air in about five minutes. *x*, Precipitator-air conditioning unit; *y*, electric fan. *a*, *b*, *c*, Pollen slides, floor level; *a'*, *b'*, *c'*, pollen slides, four feet above.

relief of their symptoms. They were afforded chairs, reading matter, and freedom of the room as they desired. No further information was given. After a tenure in the room, they were examined at various intervals before leaving. Similar units were placed in six homes selected by a local representative of the manufacturer from a list of about fifty patients who were sensitive to ragweed and had not received sufficient relief of symptoms in previous years, despite therapy. Selection was based on suitability of room to the standard unit. Those selected lived in areas as far distant as thirty-four miles. After the units were installed, each patient was visited in order to explain operation of the equipment, and later on to obtain the opinions of each regarding the status of his symptoms and the desirability of the devices.

RESULTS

The first experiment demonstrated that the apparatus did remove all ragweed pollen from the air which entered it. No pollen was found on the slides, even when an estimated 75 million grains were presented to it at one time. The particular unit tested was one of those in the laboratory, and this unit had been in continuous operation, without cleaning, for twenty-five days.

In the second experiment, when the 2 grams of pollen was released into the laboratory, a dense yellow cloud was plainly visible with fingerlike projections advancing on each of the four window units. At the same time, however, some of the yellow particles settled on the floor and furniture, despite the circulating

fans. This deposition resulted in huge collections of pollen on all six exposed slides, as shown in Fig. 3. After five minutes, the counts revealed approximately a 98 per cent decrease, but in the intervals up to 160 minutes, the counts rose to variable heights. Twenty-four hours later, only a few pollen grains were present on four of the six slides (Fig. 3). At least one week, however, was required before the laboratory was completely free of pollen.

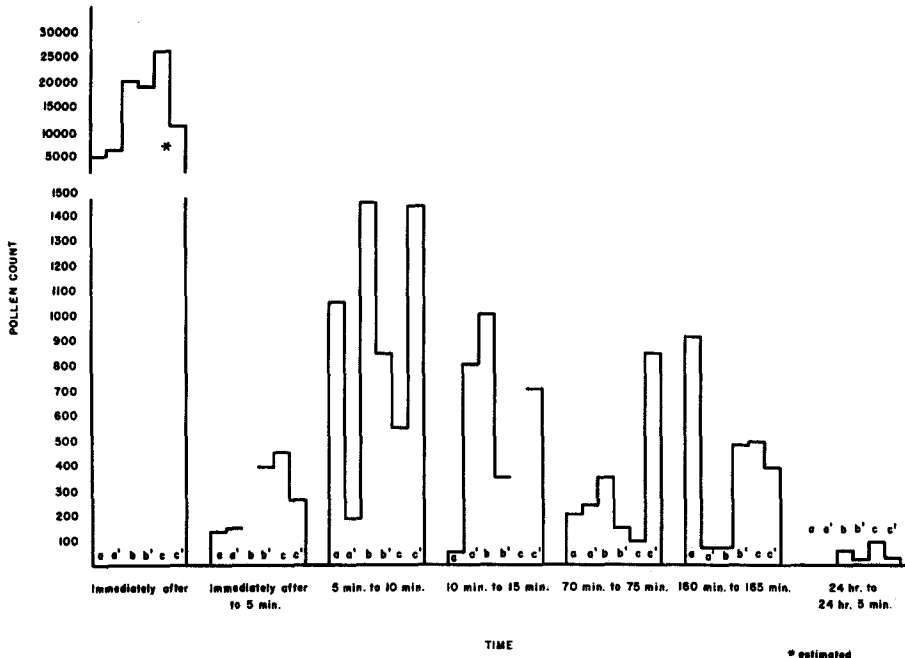


Fig. 3.—Counts after liberation of 2 grams of ragweed pollen into laboratory. Lower-case letters refer to location of pollen slides depicted in Fig. 2.

During this experiment, an unplanned set of observations was secured. Four men were participating in the tests and, by chance, two were patients with proved ragweed pollinosis. Both were asymptomatic before the experiment, for the time was December and New England was covered with snow.

A chronological set of observations was recorded as follows:

- 10:30 A.M. 2 grams of ragweed pollen dispersed into room.
- 10:33 J. I.: "Nose itchy," sneezing repeatedly, "head full."
- 10:35 R. P.: "Head full," "throat itchy."
- 10:40 J. I.: "Itching in my ears."
- R. P.: "Eyes itch," sneezing.
- 10:45 Examination of J. I. revealed moderate palpebral conjunctivitis; nasal turbinates edematous; pallid, clear mucoid discharge.
- 10:50 Examination of R. P. revealed mild peripheral bulbar conjunctivitis; nasal mucosa as above.
- 11:10 Both feeling better; less head stuffiness, but R. P. notes itchy throat.
- 11:30 Both asymptomatic.
- 2:00 P.M. 2 grams of ragweed pollen again blown into room.

2:03	J. I.: "Itching in eyes and nose." R. P.: "Nose stuffed."
2:10	Both sneezing frequently.
2:40	Both asymptomatic.

Throughout this period, the two nonallergic experimenters were free from symptoms.

The clinical studies revealed that none of the patients always obtained complete relief of their symptoms of pollinosis or asthma while in any of the equipped rooms. A few specific examples may serve to illustrate.

A 38-year-old housewife had had severe asthma from mid-August to killing frost since childhood. She had a positive skin test to ragweed. During the ragweed seasons of 1953 and 1954 she required hospitalization and cortisone in early September. She did well throughout the other months of the year. Hypo-sensitization to ragweed had never been markedly effective. She had experienced persistent asthma from Sept. 7, 1955, until her admission on September 23. She then required intravenous aminophylline and six subcutaneous injections of epinephrine during the first eighteen hours. On September 25 generalized inspiratory and expiratory wheezes were noted in the chest, and the nasal mucosa was boggy, pale, and contained a watery discharge. She gradually became more comfortable and required less medication. At noon on September 29, however, there were inspiratory and expiratory wheezes in all lung fields. Throughout the last six of her seven days of hospitalization, the patient complained frequently of being "cooped up" and "all alone," and the outer door was found ajar on three occasions. These events occurred despite the patient's expressed desire to do anything to get relief from the asthma, even remarking, "I'll go as far away as Arizona." Follow-up examinations of the patient found her asthma-free after November 1. The slides exposed daily in this room yielded a total of one ragweed pollen, but these slides were on top of the air cleaner. Her bed was placed between the door and the air cleaner.

A 48-year-old man who had proved ragweed asthma for ten years was admitted to the other hospital room on August 15 because of severe asthma. During the first twelve hours he received intravenous fluids containing aminophylline and epinephrine. He was comfortable during the next twelve hours, but in the early morning hours of August 17 he was awakened by cough and dyspnea. Generalized inspiratory and expiratory wheezes were found throughout his chest. By August 18 he again required intravenous medication which resulted in improvement, but inspiratory and expiratory wheezes were noted on August 20. Although he was not completely free of symptoms, he was discharged on August 21. At no time did he object to confinement in his room, but on at least two occasions visitors left his door open. No pollen counts were obtained during his hospital stay. During the next week, when the outdoor counts were higher, the slides in this room showed the following counts: 9,0,0,0,3,3, and 5.

Seven clinic patients who had ragweed hay fever, and who had symptoms in spite of hyposensitization, paid a total of eight visits to the laboratory during

the 1955 ragweed season. Four of these visits resulted in definite subjective and objective improvement. For example, one patient noted no itching of his nose or eyes and no tearing after sixty minutes in the room, but he still complained of blocked nasal passages. On examination, the perinasal erythema had subsided, and the watery nasal discharge had cleared. The fastest relief was obtained by another who was "able to breathe again" and showed less edema of the nasal mucosa after thirty minutes. Questionable or no relief was the result of the other four visits. None of the patients were worse.

A study of the pollen counts in Fig. 4 indicates that pollen was found on most of the slides in the homes and, to a lesser degree, on those in the laboratory, but in all cases these were considerably less than the corresponding outdoor counts. Three of the six home patients selected had pure ragweed

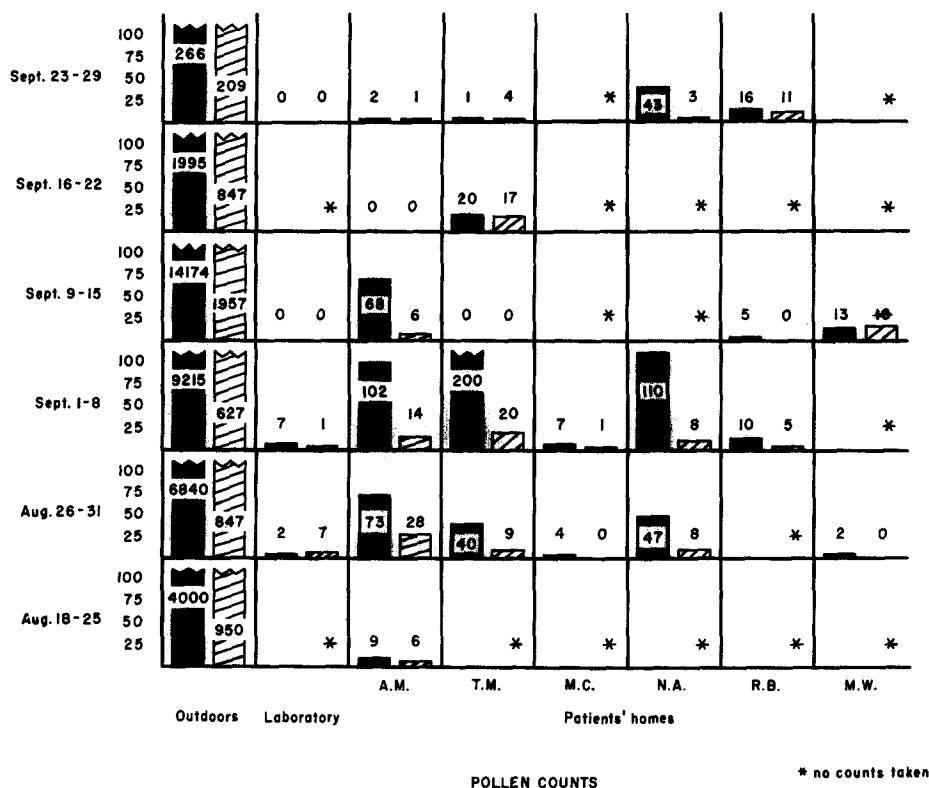


Fig. 4.—Comparison of pollen counts. Black bars represent counts of ragweed pollen. Cross-hatched bars denote counts of all other pollens.

pollinosis, while the other three had ragweed rhinitis and asthma, with the latter the more distressing condition. Patient A. M., whose home had some of the highest counts, had the entrance to the equipped room open during one visit. She had no significant relief of her symptoms of hay fever or asthma and had to be placed on one of the adrenocortical hormones during the last two weeks of the ragweed season. Patient M. C. had less asthma and rhinitis during the nights when she allowed the device to operate and was able to

reduce her bed pillows from three to one. She was not completely free of symptoms and continued her usual medications. During the daytime, the patient usually turned the unit off for fear of overloading the electrical system. M. W., another patient with pollen asthma, began to notice relief after the third night in the room, but he was not completely free of symptoms. He remained in the equipped room mainly at night, but never for a period longer than ten hours. He was careful to keep all exits tightly closed and to change his outer garments before entering the room. His unit was off until one hour before the room was occupied.

All three patients with "hay fever" alone were definitely improved while in the room with the precipitator. The abatement of symptoms in these three usually occurred after one hour in their rooms. N. A. admitted to three or four bad nights, but he considered this a milder season than usual. T. M. believed that he experienced the best season in the past twenty-three years. The third patient usually experienced comfortable nights while sleeping in his room. Shortly after leaving in the morning, his symptoms of rhinitis gradually returned and became very distressing by afternoon.

Initially, most of the patients were disturbed at night by the hum of the compressor, but after two or three nights this noise no longer was distracting. None of the patients otherwise objected to the presence or maintenance of the equipment.

DISCUSSION

The first experiment, in which 0.2 gram of dry pollen (mixed *Ambrosia trifida* and *artemisiaefolia*) was introduced into the intake section of the precipitator while slides completely covered the outlet, was the most revealing experiment. No pollen appeared on the slides, even though the precipitator had not been cleaned for twenty-five days. Without question, this particular precipitator will remove all ragweed pollen from the air directed to it. This unit also maintained all equipped rooms at a comfortable temperature and humidity. This precipitator-air conditioner, therefore, achieves the objectives of its design.

The full potentiality of the equipment was not realized. If a patient entered a room adequately fitted with this unit before the pollen season and remained there until that pollen season was over, he would doubtless remain completely asymptomatic. This course, however, is even less feasible than the ocean voyage.

Examination of the other experiments raises several questions. When a large quantity of pollen was blown into the laboratory shown in Fig. 2, it was obvious that all the released pollen was not air-borne to the precipitators at once. Quantities of it settled on the floor, counters, books, and articles of furniture. As this deposited pollen was stirred up, it became air-borne. The pollen counts in Fig. 3 add support to this observation. The two experimenters who had ragweed pollinosis are of interest. They promptly developed symptoms when ragweed was released into the laboratory, but they cleared while the ragweed counts were still high. J. I. has severe ragweed pollinosis, where-

as R. P. has only moderate symptoms during ragweed seasons. Yet their experiences during this controlled experiment in December were similar. These observations raise questions which cannot be answered with available data, but they do give rise to speculation.

Obviously, the pollen counts do not determine accurately the quantity of pollen present in a room. In the laboratory experiment there was extreme variability between counts at the same site in the same room. After twenty hours all counts were low, but accumulations of the pollen were seen in several areas of the laboratory for a week. The fact that J. I. and R. P. cleared even though pollen counts were still high might suggest that the air which they breathed did not contain as much pollen as the slide counts suggested.

Study of the patients who visited the laboratory, who were confined to the hospital, and who had units in their bedrooms at home was revealing. None enjoyed confinement in a closed room. They proved this in several ways. It was difficult to entice patients with symptoms of ragweed pollinosis to spend time in the laboratory. Those who came did not remain long, even though some showed marked improvement. Those in the hospital managed to keep their doors to the corridor open. Those with home units usually spent only their sleeping hours in the equipped rooms; several persisted in keeping the doors of those rooms open; and most did not run the units constantly. Even under such conditions, some degree of relief of symptoms was noted by the majority. Since the pollen counts in Fig. 4 often were not high, it might be stated that having doors open was of little importance. All of these units, however, were in windows, and in every instance the patient's bed was between the door and window. The pollen slide was always on top of the precipitator. Obviously, the air with any pollen in it admitted through the door would reach the patient before it did the air cleaner or the pollen slide.

Another point of interest involves the apparent discrepancy between the amount of relief received by those with ragweed pollinosis and by those with ragweed asthma. Again available data are insufficient to explain, and again speculation is in order. The preponderance of inhalants usually will be deposited on the nasal mucosa and eliminated by sneezing or ciliary action, but a demonstrable amount has been found in the lungs, as suggested by the experiments of Scott and associates.¹³ An aerosol containing a solution of a radioactive mineral from 0.5 to 1.0 micron in diameter was inhaled and exhaled in one respiration, and it was found that about 2 per cent was immediately exhaled. After seventy-one hours, approximately 32 per cent of the radioactive material had been removed via the bronchial tree, and the remaining 66 per cent presumably remained in the alveolus. When rats were forced to inhale radioactive matter of 1.0 micron or less and the fate of these particles was followed by means of Geiger counters and radioautographs of lung tissue sections, many particles were still present in the alveoli and alveolar ducts after several months. In a series of experiments on dogs, performed over a period of several years, Drinker and Hardenbergh¹⁴ also demonstrated slow elimination from the alveoli. They felt that although bronchiolar absorption

of particles undoubtedly occurs, both because of the surface area available and the anatomic barriers imposed, it was of little importance compared with absorption from the alveoli. By their methods of right lymphatic and thoracic duct cannulation and the simultaneous study of peripheral blood specimens, chemically and immunologically, in living dogs, followed by pathologic section of the lungs, they were able to follow the fate of the following substances introduced into the trachea: dog plasma, purified bovine serum albumin, crystallized egg albumin, hemoglobin, and Pyrex spheres 4.0 micra in diameter. They concluded that even after four hours there was minimal absorption of any of these substances from the alveoli. This was the finding despite production of increased lymphatic drainage from the alveoli by means of increased inspiratory pressure using artificial respiration. These experiments do not explain what happens to inhaled ragweed pollen. It should be pointed out, however, that the alveolar ducts have diameters to 40 micra and that some ragweed pollen in patients with prolonged exposure might reach the alveoli where absorption is slow. Perhaps only the contact of pollen with the nasal mucosa is important in ragweed pollinosis, whereas pollen deeper in the respiratory tree is more slowly absorbed and may play a role in the production of asthmatic symptoms.

SUMMARY AND CONCLUSIONS

1. An electrostatic precipitator, combined with an air conditioner into one functional unit, has been described. This precipitator was designed to remove particles 0.1 micron in diameter from the air presented to the unit.

2. Experiments were performed to determine this air cleaner's ability to remove ragweed pollen from air entering it and to ascertain its competence in clearing pollen introduced into a room. In addition, patients with ragweed pollinosis and ragweed asthma were studied in equipped rooms in the hospital, laboratory, and home.

3. This apparatus removed all ragweed pollen from the air presented to it. Clearing a room into which 2 grams of ragweed pollen was dispersed took more than a week. Much of the pollen settled on the floor, furniture, etc. This equipment does not have the capacity of stirring up every potential particle in the room into the air, but can only remove particles from the air presented to it. The combination with an air conditioner resulted in maintenance of a comfortable temperature in all equipped rooms, even during hot weather.

4. Patients with ragweed "hay fever" usually noted some relief of their symptoms after an hour's occupancy of one of these rooms. Those with asthma due to ragweed did not fare so well.

5. A possible explanation for this discrepancy was discussed, with emphasis being placed on particle elimination from the respiratory tract.

6. This air cleaner, therefore, accomplishes the purposes for which it was designed. Ideally, such equipment should free instantly any room from all particles (even those stuck to items of furniture) and should, in some magic

manner, manage to filter the air free of pollen, even though the patient inhales the air before it is filtered by the precipitator. Such ideal equipment probably will not appear in the near future. In the meantime, this precipitator in combination with an air conditioner will, in a reasonable period of time, free a room of pollen, keep the air of that room relatively free of pollen, and maintain the room at a comfortable temperature in hot weather if the unit is allowed to run and if the doors and windows of the room are kept closed most of the time. The need at present, therefore, is not for a more effective air cleaner, but for more effective use by the human beings in control.

REFERENCES

1. Van Leeuwen, W. S.: Bronchial Asthma in Relation to Climate, *Proc. Roy. Soc. Med.* 17: 19-26, 1924.
2. Leopold, S. S., and Leopold, C. S.: Bronchial Asthma and Allied Allergic Disorders; Preliminary Report of a Study Under Controlled Conditions of Environment, Temperature and Humidity, *J. A. M. A.* 84: 731-734, 1925.
3. Cohen, M. B.: The Prophylaxis and Treatment of Hay Fever and Asthma in Rooms Made Pollen- and Dust-Free by Means of Mechanical Filters, *J. Lab. & Clin. Med.* 13: 59-63, 1927.
4. Peshkin, M. M., and Beck, I.: A New and Simplified Mechanical Air Filter in the Treatment of Hay Fever and Pollen Asthma, *J. Lab. & Clin. Med.* 15: 643-649, 1929-1930.
5. Rappaport, B. Z., Nelson, T., and Welker, W. H.: The Effect of Air Filtration on Hay Fever and Pollen Asthma, *J. A. M. A.* 98: 1861-1864, 1932.
6. Gay, L. N.: The Treatment of Hay Fever and Pollen Asthma by Air-Conditioned Atmosphere, *J. A. M. A.* 100: 1382-1385, 1933.
7. Nelson, L., Rappaport, B. Z., and Welker, W. H.: The Effect of Air Filtration in Hay Fever and Pollen Asthma; Further Studies, *J. A. M. A.* 100: 1385-1392, 1933.
8. Vaughn, W. T., and Cooley, L. E.: Air-Conditioning as a Means of Removing Pollen and Other Particulate Matter and of Relieving Pollinosis, *J. ALLERGY* 5: 37-44, 1933.
9. Criepp, L. H., and Green, M. A.: Air Cleaning as an Aid in the Treatment of Hay Fever and Bronchial Asthma, *J. ALLERGY* 7: 120-133, 1936.
10. Friedlaender, S., and Friedlaender, A. S.: Effectiveness of a Portable Electrostatic Precipitator in Elimination of Environmental Allergens and Control of Allergic Symptoms, *Ann. Allergy* 12: 419-428, 1954.
11. Westinghouse Electric Corporation: Industrial Electronics Reference Book, New York, 1948, John Wiley & Sons, Inc., chap. 28, "Electrostatic Precipitation."
12. Durham, O. C.: The Volumetric Incidence of Atmospheric Allergens. IV. A Proposed Standard of Gravity, Sampling, Counting, and Volumetric Interpolation of Results, *J. ALLERGY* 17: 79-86, 1946.
13. Scott, K. G., Axelrod, D., Crowley, J., and Hamilton, J. G.: Deposition and Fate of Plutonium, Uranium, and Their Fission Products Inhaled as Aerosols by Rats and Man, *Arch. Path.* 48: 31-54, 1949.
14. Drinker, C. K., and Hardenbergh, E.: Absorption From the Pulmonary Alveoli, *J. Exper. Med.* 86: 7-17, 1947.