EFFECTS OF THE SELF-CLEANING OVEN
ON RESIDENTIAL AIR QUALITY

by

JANET M. HECHT

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Approved by:

Patty J. Annis
Co-Major Professor

Jason C. Annis
Co-Major Professor

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INTRODUCTION

The first federal legislative effort towards air quality control was in a 1955 act establishing "research and technical assistance" for the control of air pollution. The law was amended and the administrating agency restructured repeatedly, culminating in the 1970 Clean Air Act, which federalized the responsibility for air pollution control and empowered the Environmental Protection Agency (EPA) to establish national air quality standards (The Yale Law Journal, 1973).

The EPA has extensive regulatory powers, as reflected in the magnitude of expenditures required to comply with the agency's standards. Between 1973 and 1977, the EPA estimates that as much as $42 billion will be expended in the private sector to achieve compliance. The rationale for such large expenditures has been the protection of public health, not aesthetics. Yet Congress' concern for requiring those expenditures and extensive technological changes, in the name of health, stopped at the windowsill (The Yale Law Journal, 1973).

Because legislation requires the private sector to comply with standards for outdoor air quality, there has been emphasis on such research. Congress, however, has not emphasized indoor air quality; consequently, little research or concern for this dimension of the problem has been generated.

The average person spends about 80% of his time indoors. Those who are most susceptible to the deleterious effects of inside air pollution, such as the elderly or chronically ill, spend even greater amounts of time indoors (Benson, _et al_., 1972). Although many laws legally define air pollution in terms of outside concentrations, this does not exempt its occurrence indoors.

Indoor pollution results from infiltration of outdoor air and from internal generation of pollutants (Yocom, _et al_., 1971). Significant sources of air pollution can and do contribute to indoor pollution levels, which far exceed the outdoor stipulations established in such laws as the Clean Air Act of 1970 (The Yale Law Journal, 1973). That, coupled with the consideration of time spent indoors, qualifies the need for increased attention to be given to indoor air quality. That need was the impetus for this study in which an evaluation was made of the potential of the self-cleaning oven as a source of air pollutants.

Background Information

Physical description of particles

Smoking, cooking, and heating are three major sources of indoor pollutants in non-industrial buildings (The Yale Law Journal, 1973). The particulates generated from those activities adversely affect air quality according to their size. Visible particles, those with diameters of twenty microns or larger, settle on horizontal surfaces and contribute to housekeeping or cleaning problems. Invisible particles, under twenty microns in diameter, are little affected by gravity because of their small mass, Brownian movement, and electrostatic forces. This air-borne dust causes gradual soiling of interiors, since it remains suspended until there is contact with a vertical or horizontal surface (Brethour, 1966). Particles smaller than one micron tend to remain suspended indefinitely (Thomson, 1972). Preservation of the beauty and cleanliness of the home is aided by the removal of those staining contaminants (Sutton, et al., 1964).

Health effects

Indoor pollutants can be health hazards. The major concern about suspended particles is related to injury of the respiratory tract. Their size, toxicity, and ability to increase the effect of a harmful gas through aerosol transport determines their hazardous impact (Rai and Spielman, 1975).

Goldwater, et al., (1961) stated that years ago pathogenic bacteria were recovered from the air and dust surrounding patients afflicted with infectious diseases such as tuberculosis. The medical profession today is cognizant, also, of the air quality factor in treating the allergic patient. The removal of smoke, allergy-causing dusts, pollen, and air-borne bacteria is a common practice in the control of allergies. (Sutton, et al., 1964).

Research

There is little research on indoor air quality (Thomson, 1972). The author found no published studies of self-cleaning oven emissions in either the United States or foreign areas of literature review. Marchesani, et al., (1970) described the lack of indoor air pollution research as serious, and stated that it should be combated with an increased emphasis given to both major and minor sources.

Oven design

The first electric self-cleaning oven was marketed in 1963 by the General Electric Corporation. It was considered a landmark invention by many in the appliance industry, and its sales represent a significant share of the range market.

The self-cleaning oven differs from the conventional and the continuous-cleaning in that it has a specific cleaning cycle. During the 2-4 hour self-cleaning cycle, a pyrolytic process operating at 900° F (minimum) degrades the food soil inside the oven chamber to a small amount of ash residue. Accordingly, many design features of the traditional oven were changed to meet safety and efficiency standards of the appliance trade associations. In addition to different materials and controls, a smoke eliminator was necessary (Newell, 1965).

The smoke eliminator, an example of which appears in Plate II-C, was developed to cope with the by-products of the pyrolysis process. It may be described as a heated catalytic oxidation unit located in the oven vent system to eliminate smoke and odor produced by the degradation process (Casson, 1968). Hotpoint (Service Manual, 1975) claims that oxidation is achieved through the addition of heat and oxygen, which decompose the food soils, mainly into carbon dioxide and water vapor that should be of harmless amounts.

The construction of the smoke eliminator differs according to manufacturers. Wansker classified smoke eliminators by catalytic solutions (palladium and platinum) and by base materials (ceramic, asbestos, stainless steel, or stainless steel-asbestos combination) to which they are applied (Wansker, 1976).

Appliance industry publications (Casson, 1968; General Electric,______) claim that smoke and grease are eliminated from the oven vapor before it is exhausted into the kitchen. It would seem, therefore, that the self-cleaning oven, operating as designed, would have no negative impact on residential air quality. It was the purpose of this study to evaluate the amount of effluent, if any, from several self-cleaning ovens.

Objectives

The specific objectives of this study were to:

1. measure the soiling index[1] of the effluents of the self-cleaning oven; (If an indication of smoke was obtained from this measurement, the following objectives were to be pursued; if no smoke was found, the study would have been terminated.)

2. compare the relative effectiveness of smoke elimination systems of several ranges, using the soiling index;

3. compare the effectiveness of smoke eliminator systems at different levels of soiling load inside of the oven, using the soiling index; and

4. equate the amount of smoke emitted by the ovens to that emitted by cigarette smoking.

---

[1]A measure of the staining potential of smoke, as determined by light-scattering measurement; defined in Eq.(1).

EXPERIMENTAL ENVIRONMENT, EQUIPMENT, AND PROCEDURES

Test Environment

The research was conducted in the household equipment laboratory, Justin 327, at Kansas State University. This room is a combined lecture room and laboratory, with no doors or windows opening to the outdoors. The environment of this laboratory was relatively static throughout the nine-month period of testing.

Analyses of the filters were done in the Fine Particle-Air Pollution Laboratory at Kansas State University. This laboratory is used for air pollution and air quality studies.

Test Equipment

Test equipment included ovens, sampling apparatus, sample evaluation instruments, and accessories. The sampling system isokinetically sampled the oven exhaust by pulling it through a filter at the same velocity that it would normally emit from the oven chamber. The light-scattering area measurement technique was used to determine the amount of emissions. Equipment used included air flow meter, vaccum pump, gas meter, U-tube manometer, sampling filter, and photometer. That equipment, shown in Figure I and Plate II-A, measured the rate of air flow of the oven exhaust, pulled the air through the sampling tubing, registered the volume of sampled air, measured the partial vacuum in the gas meter,

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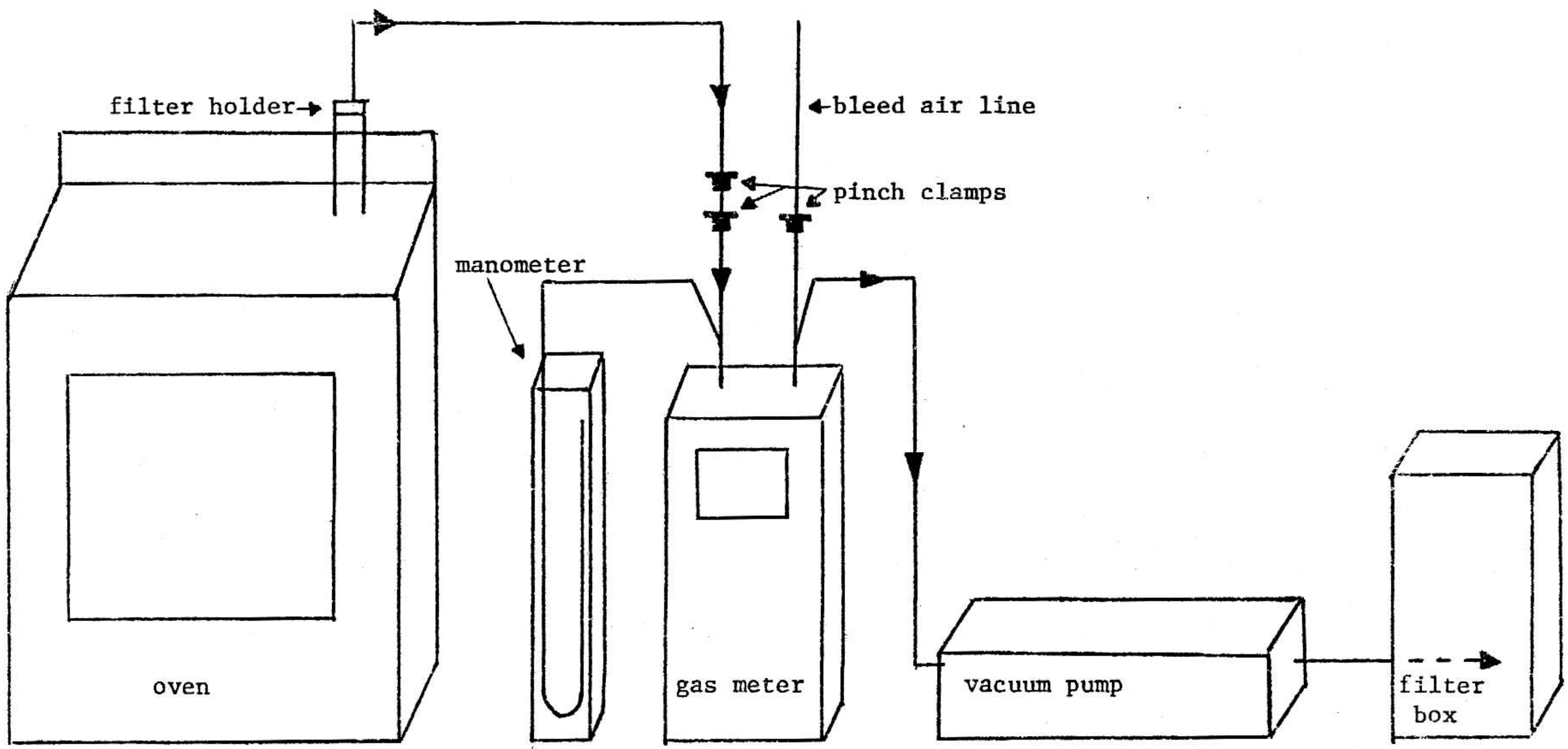

Figure I.

Arrangement of sampling system.

captured the emitted smoke particles on filters, and measured light transmittancy of the filter paper.

Ovens

Three different brands of ovens were used. All were self-cleaning ovens with a manually controlled cleaning cycle. One range was a 1973 Corning, model number R30DB, serial number 2103203405; one was a 1972 Hotpoint, catalog number RB754001WH, serial number ZN245486R; and the other was a 1976 Frigidaire, model number REG-38 serial number 51CL9193.

All three ovens employed the pyrolytic process in the cleaning cycle. Via a telephone conservation with Mr. Walter H. Blanck, Jr., of the Association of Home Appliance Manufacturers, information was obtained to document the kinds of smoke eliminators contained in the ovens. Mr. Blanck stated that the Hotpoint and the Corning range used basically the same kind of smoke eliminator and that it was different from the design used in the Frigidaire. He also stated that many of the oven manufacturers were beginning to use the same type of smoke eliminator as that installed by Frigidaire.

Vacuum pump and accessories

A Gast model 5K480 oil-less carbon vane, 1-hp vacuum pump with an a.c. capacitor motor was used to pull the air from the oven venting through the filtering system via a system of Mayon clear food tubing. The pump was connected to a gas meter with 1/2-in. I.D. tubing.

During the sampling of the Corning range, a standard Gast discharge muffler-filter was attached to the pump. This muffler was replaced by a custom-made high efficiency muffler and filter box for the experimental runs on the Frigidaire and Hotpoint ranges. This box was 18 in. x 18 in. x 4.5 in. and held a 3/4-in. sheet of fiber glass perpendicular to the flow of air. It much more efficiently filtered the vacuum pump exhaust and prevented the escape of graphite as the carbon vanes wore.

Gas meter

An American Meter Co. model AL 425 gas meter with a sweep dial was used to determine the quantity of air flowing through the sampling system. Three pinch clamps, acting as valves, were connected to the tubing attached to the meter. One was attached to a bleed air line, connected through a tee, to the tubing from gas meter to vacuum pump; and the other two were attached to the tubing from the filter holder to the gas meter. Figure I illustrates that arrangement.

Manometer

A mercury U-tube manometer measured the pressure inside of the gas meter. It was connected to the gas meter with Mayon clear food tubing of 3/16-in. I.D. The readings were in inches of mercury vacuum, below atmospheric pressure.

Sampling filters and holders

The sampling filters were manually cut from filter paper manufactured by the Mine Safety Appliance Company. They were of glass fiber with no binder, #1106BH, approximately 47 mm. in diameter.

These filters were held in a Gelman model 1220 filter holder, containing a stainless steel screen designed to prevent rupture of the filter during sampling. A spring-loaded sealing ring kept the filter in place and prevented air leakage from the sampling system.

The filtering device was attached to the oven venting in two ways, dependent upon the type of range. The Corning had a venting system that mixed room air with the oven exhaust before discharging through the oven backdrop. A cone-shaped adapter, approximately 5 in. in height, 2 x 3 in. at the base, and 2 in. diameter at the top was made of heavy construction paper. The cone was secured to the Corning range with Permacel heavy duty adhesive tape. The filter holder was then taped to this cone with Scotch No. 202 masking tape to prevent air leakage.

Another method of attachment was necessary for the Hotpoint and Frigidaire ranges because their oven exhaust temperatures were too high to permit velocity measurement or sampling. The exhaust venting of these ovens was through the right rear surface unit. An exhaust of 1.5 in. diameter metal tubing, seen in Plate II-D, was attached to the oven venting system. The 9.5-in. extension was connected by a tee-joint to a 6-in. long, 1.5-in. diameter metal tube which was attached to a Dayton model 2C782, 1/250 hp centrifugal blower. This blower was used to induce mixing of room air with the oven exhaust to cool it to a temperature capable of being sampled. Figure II illustrates the structure of this attachment.

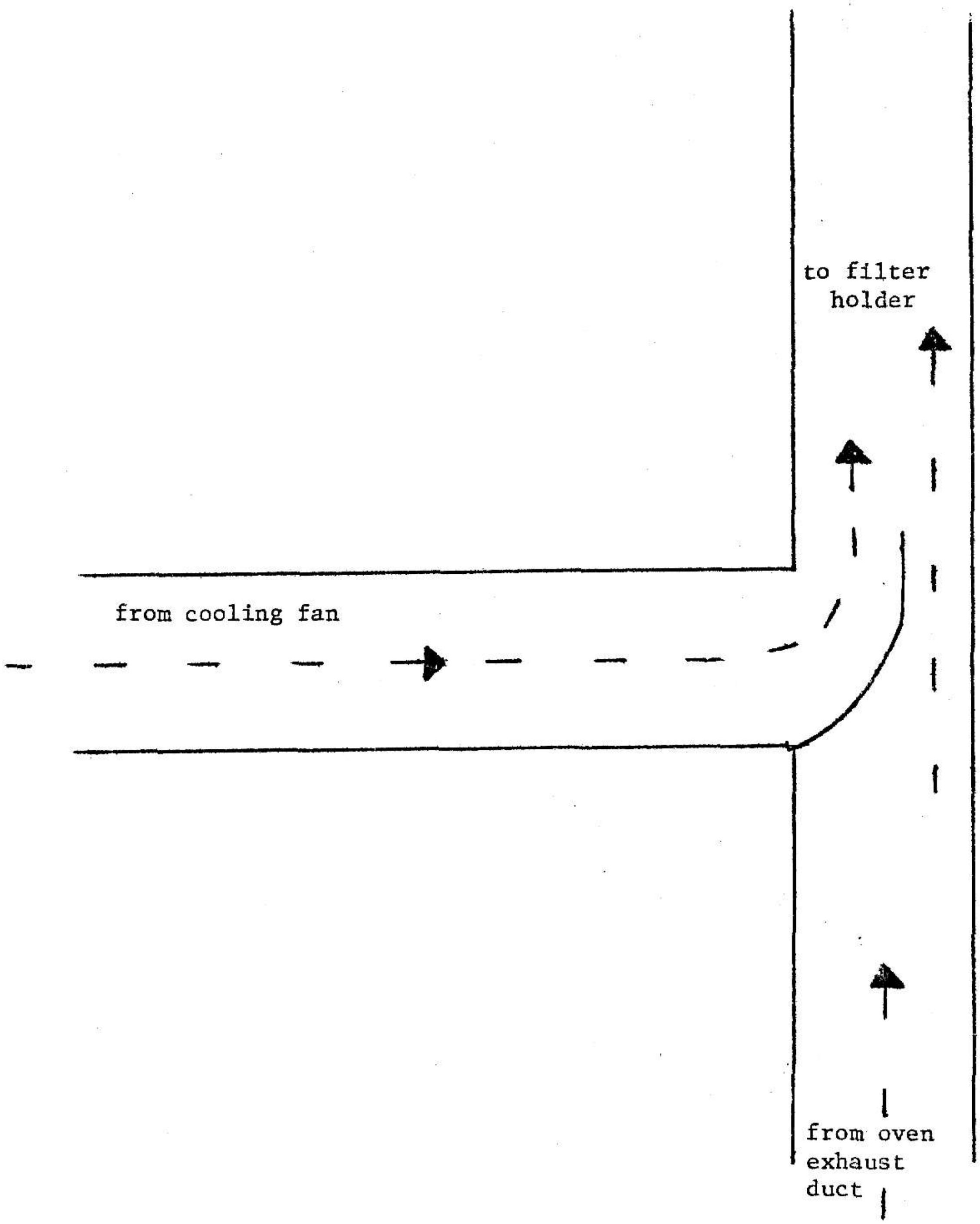

Figure II.
Structure of sampling attachment, Frigidaire and Hotpoint ranges.

Because of this modification in the venting system, a different sampling seal was used. A 0.25-in. extension made of foam rubber innersole was attached to the filter holder cap. This sampling head fit directly on top of the oven exhaust tube and required no taping to prevent air leakage from the sampling system.

Photometer

Plates I-A - I-E illustrate the design of the photometer that was used to measure the optical densities of the filter paper.

Plate I-B shows the collimated beam, from the light source, being split into two parts. One part is reflected onto the photocell and dust spot being measured, and the other beam is reflected to a reference photocell. Two shutters were placed in front of the reference photocell. The coarse shutter was made of a piece of filter enclosed by two pieces of sheet aluminum. The fine shutter was mounted in metal and adjusted by a fine pitch screw.

The two cadmium-sulfide photocells are connected in series as demonstrated in the circuit in Plate I-C. Measurement is made of the ratio of light falling on the measuring photocell to that on the reference cell. Current balance is indicated on a 0.001 μ A/mm sensitivity electronic null indicator.

In addition, two rheostats, R_1 and R_2 as shown in Plate I-C, were used to compensate for any residual mismatching of the photocells. Adjustments were made in these rheostats until there was a minimum of galvanometer movement. Another problem, drift, which could be caused by

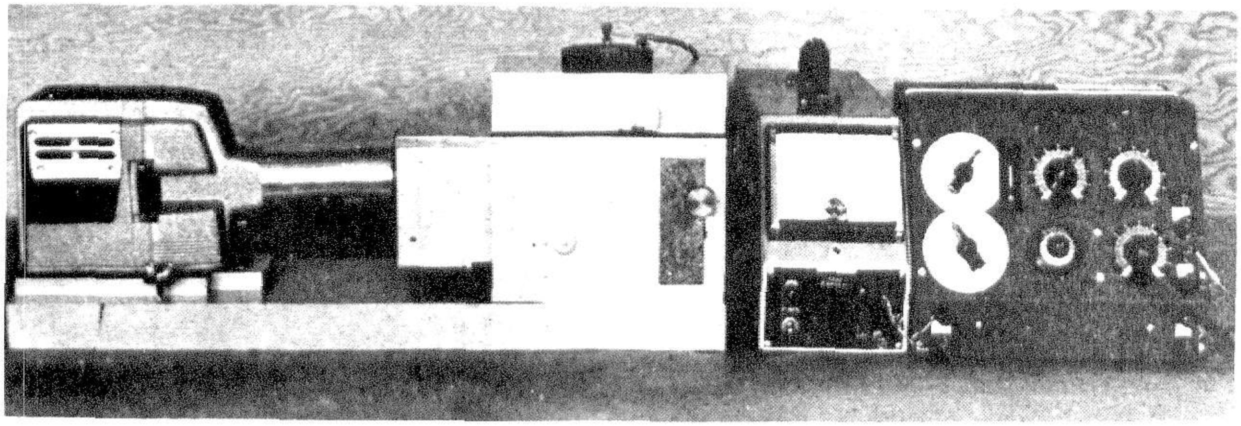

Plate I-A. Photometer.

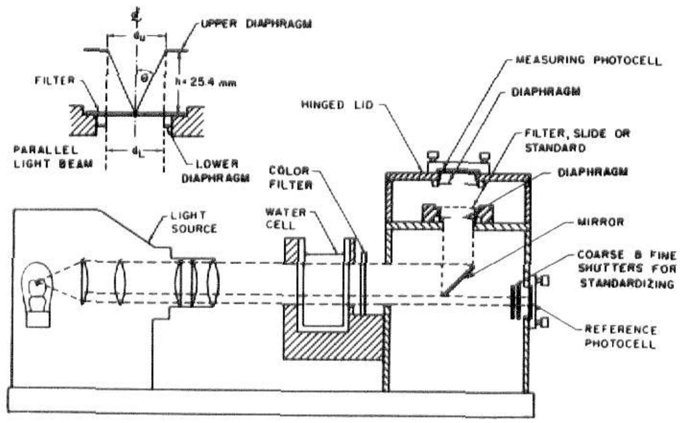

Plate I-B. Optical design of photometer.

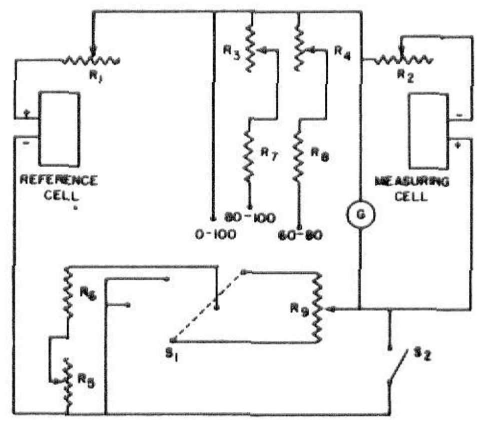

Plate I-C. Photometer circuit.

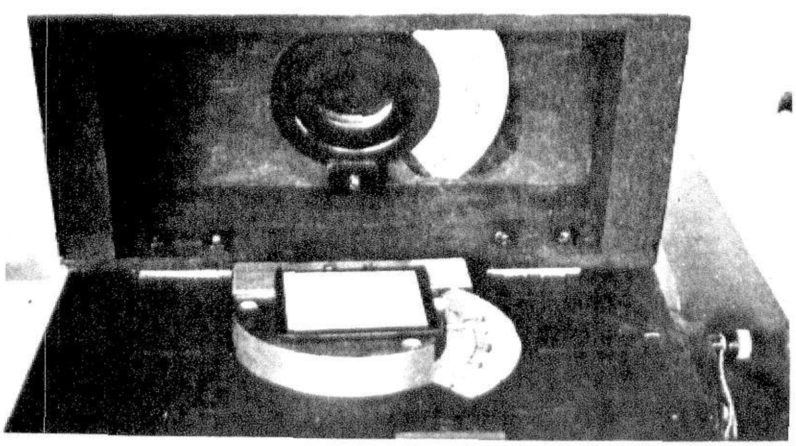

Plate I-D. Sample holder of photometer with standard in place.

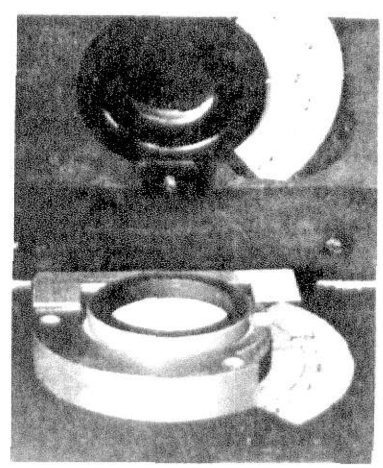

Plate I-E. Sample holder with filter in place.

unequal heating of the photocells, was minimized by using a water cell and by placing the light source away from the cells.

The sample holder, as shown in Plates I-D and I-E, was designed to hold 2x2 in. glass slide covers, 47mm disks of filter media, and 25mm wide microscope slides. The hinged lid was painted with non-relective black paint and was closed by a magnetic cabinet latch.

Another component of the photometer was the diaphragm. To control the size of the illuminated area on the filter, one was placed just below the filter holder. In order to control the angle of acceptance, one was placed just in front of the measuring photocell.

A 200-watt slide projector provided the light source. To prevent instability of the light source, the light path to the photometer box was enclosed completely (Whitby, et al., 1956).

Air Velocity Meter

A Hastings (Teledyne Hastings-Raydist, Hampton, Virginia) air meter, model B-22, serial number 196 with a Hastings directional probe of S-22A type, serial number 1489, was used to determine the air velocity of each oven exhaust air flow. This air flow rate was determined so that the sampled air rate would approximate that rate for which the oven was naturally designed, plus any induced cooling air.

Balance

A Harvard Trip balance (Ohaus Scale Corporation of Union, New Jersey) was used to weigh all soil samples. It had a capacity of two kilograms and thus was sufficient for this usage.

Test Soil

A standard self-cleaning oven soil and method of application, promulgated by the Association of Home Appliance Manufacturers (AHAM), was used. The AHAM standard ER-3 for pyrolytic self-cleaning ovens establishes "a uniform and repeatable procedure or standard method for measuring the cleaning performance characteristics of household electric self-cleaning ovens." The standard is written so that different brands and models of self-cleaning ovens may be evaluated with respect to significant characteristics in the use of the product (AHAM Standard ER-3, 1974). Because AHAM stated that this standard was reproducible and representative of elements that would be found in an oven during normal usage, it was selected for use in this research.

The mixture, as prescribed in standard ER-3, consisted of the following ingredients:

109.4 g fatty ground beef (Not less than 70% lean was used.)
1/2 cup grated cheddar cheese
1/2 cup milk
1/2 cup white sugar
1/2 cup cherry juice (canned sour pie cherries)
2 Tbsp. prepared instant tapioca
1 raw egg (without shell)
2 Tbsp. all-purpose flour
1/2 cup tomato juice

These ingredients were mixed in a glass bowl with an electric mixer for 45 seconds. The mixture was then weighed for equivalent amounts of one, two, and four teaspoons, respectively.

Four teaspoons of this soil mixture were applied evenly to the side walls, back, inner door, and floor of the oven with a 1.5-in. pastry brush. An additional two teaspoons were placed evenly over the oven bottom. This mixture was not to be placed on oven top, racks, or heating units. The method of application was followed as suggested; however, the teaspoon amount was converted to an equivalent weight to aid in reproducibility.

The sampling runs were conducted with both the recommended soil level applications and with one-half of the recommended amount to determine the effect of soiling load on emission levels; these treatments will be referred to as full-soil and half-soil sampling runs. Full-soil amounts were four and two teaspoons, weighing 17.05 g and 10.55 g , respectively, and half-soil applications were two and one teaspoons, weighing 9.20 g and 4.60 g , respectively. Plate II-B illustrates the physical appearance of an oven after it had been full-soiled, baked, and cooled.

Individually measured quantities (for a single test) were placed in Baggie sandwich bags and tied with wire wrappers. These bags were placed in a refrigerator storage bag designed to prevent moisture loss and placed in a freezer at 0° F.

The measurements of soil were thawed in a small custard cup, enclosed by plastic to prevent moisture loss, immediately before their application. When thawed the mixture was applied in the prescribed manner and baked on the oven at 450° F for one hour from a cold start. The oven was then cooled to room temperature and was ready for the sampling process.

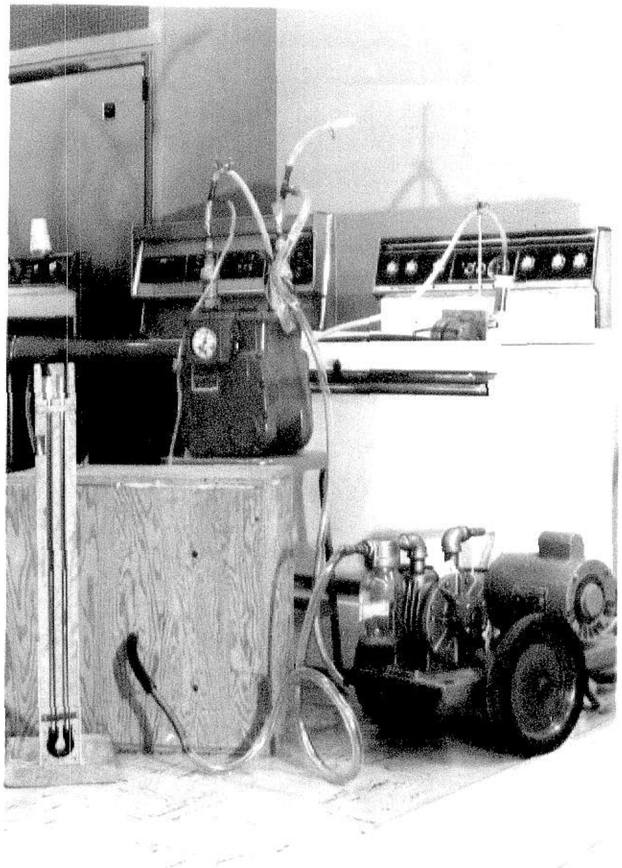

Plate II-A. Sampling system arrangement.

Plate II-B. Soiling of oven.

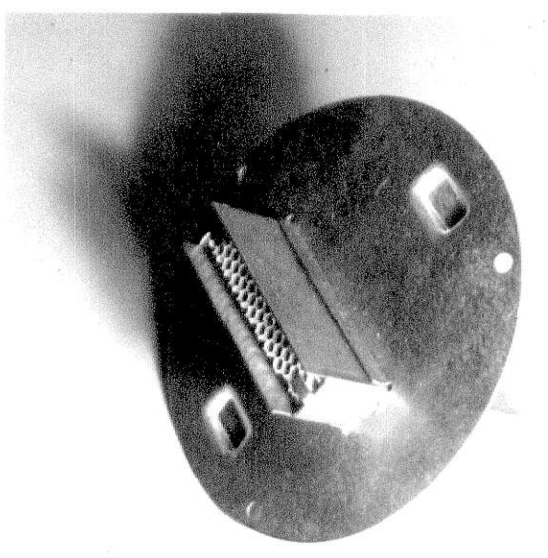

Plate II-C. Smoke eliminator.

Plate II-D. Exhaust extension.