

EFFECTS OF THE SELF-CLEANING OVEN
ON RESIDENTIAL AIR QUALITY

by

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A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

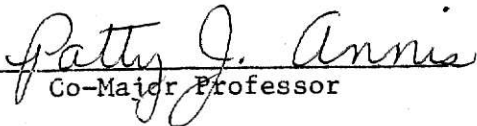
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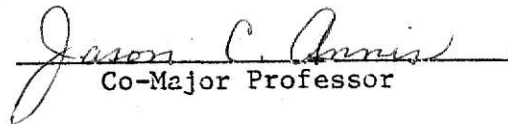
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INTRODUCTION

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 administering 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 index¹ 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.

¹A 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, vacuum 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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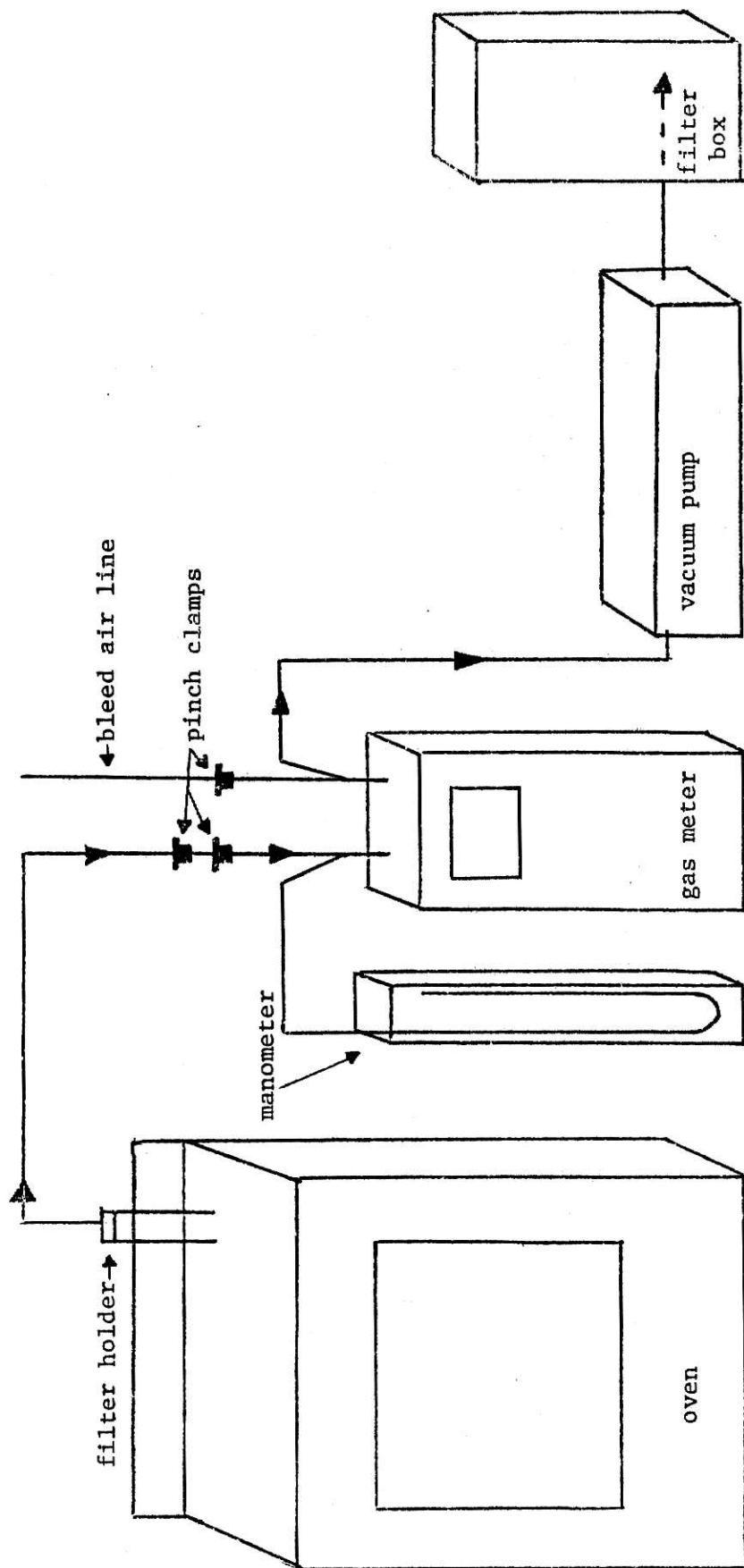


Figure I.
Arrangement of sampling system.

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 conversation 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.

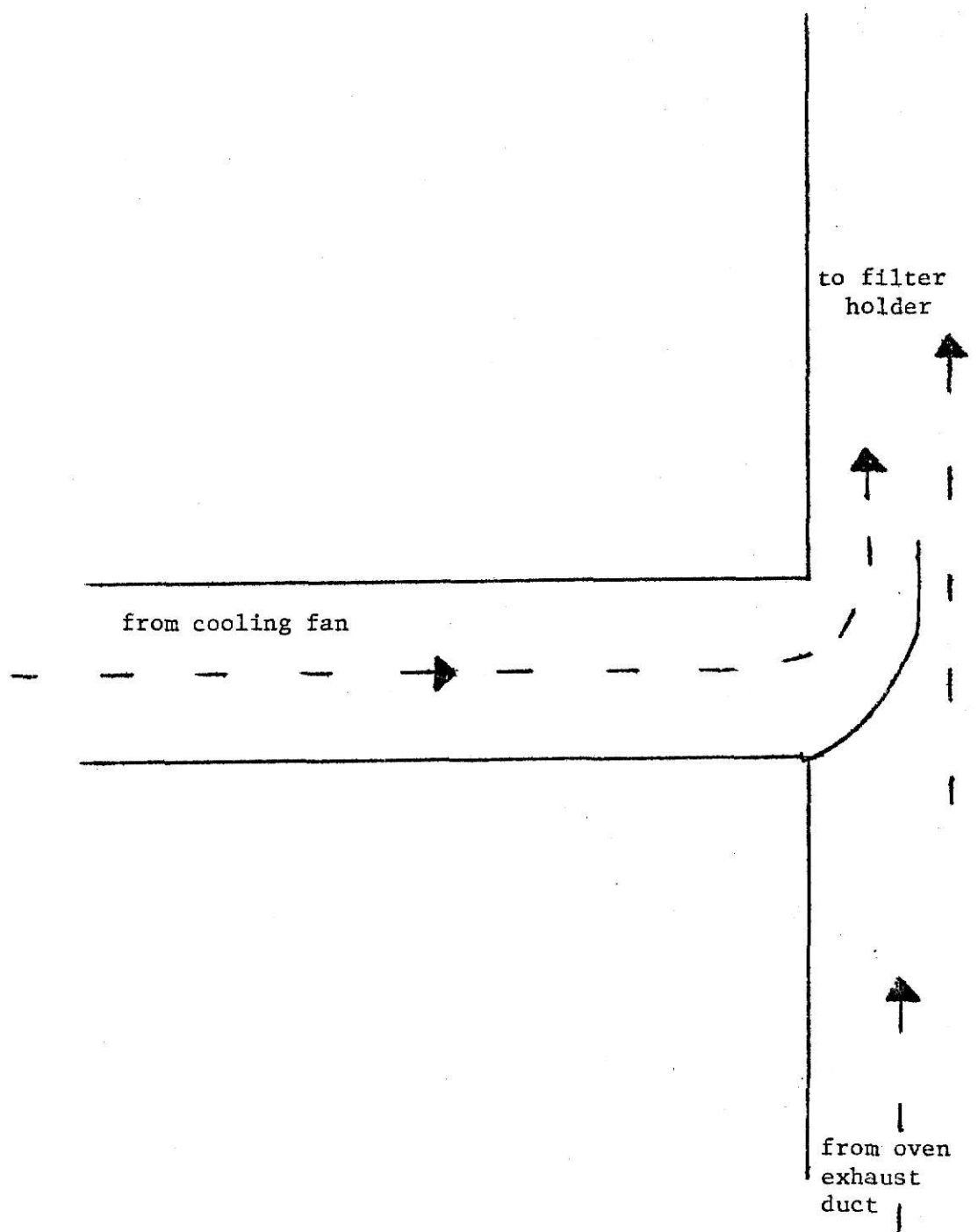


Figure II.

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 $0.001 \mu\text{A/mm}$ 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

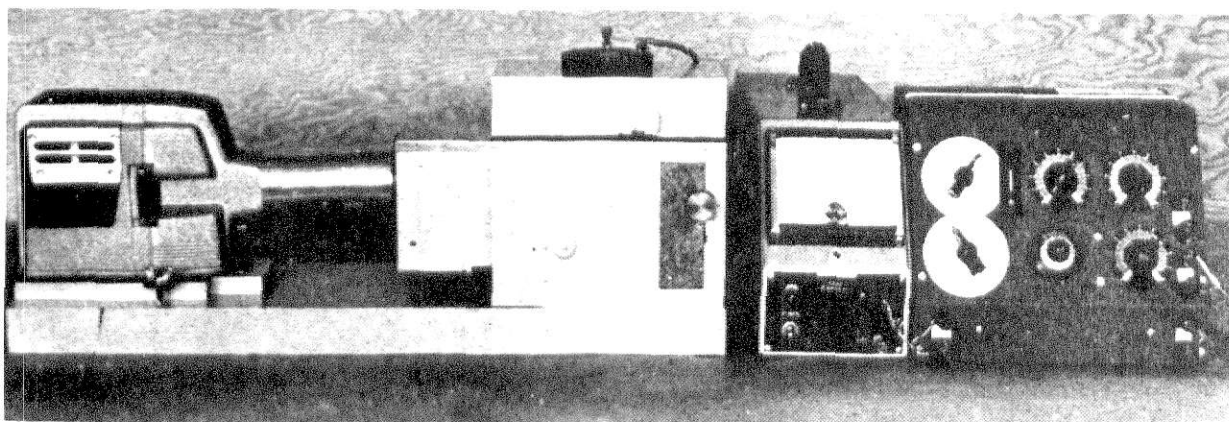


Plate I-A. Photometer.

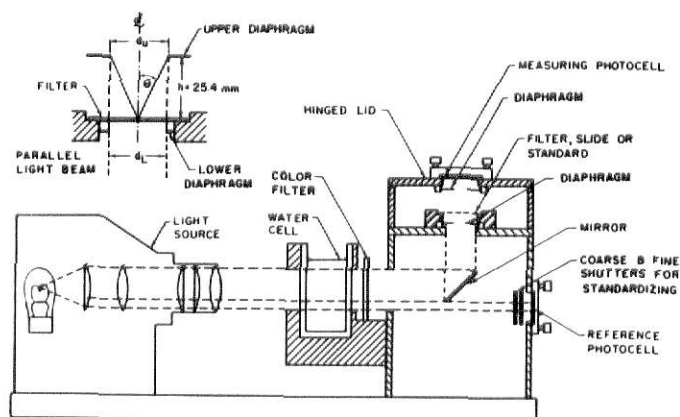


Plate I-B. Optical design of photometer.

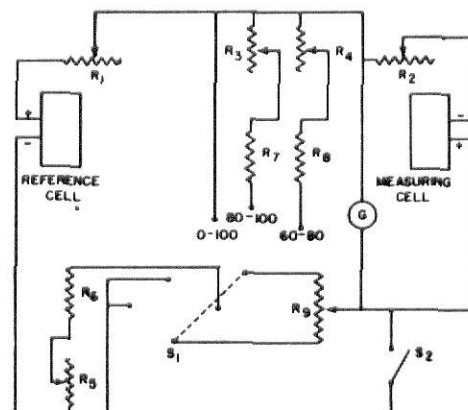


Plate I-C. Photometer circuit.

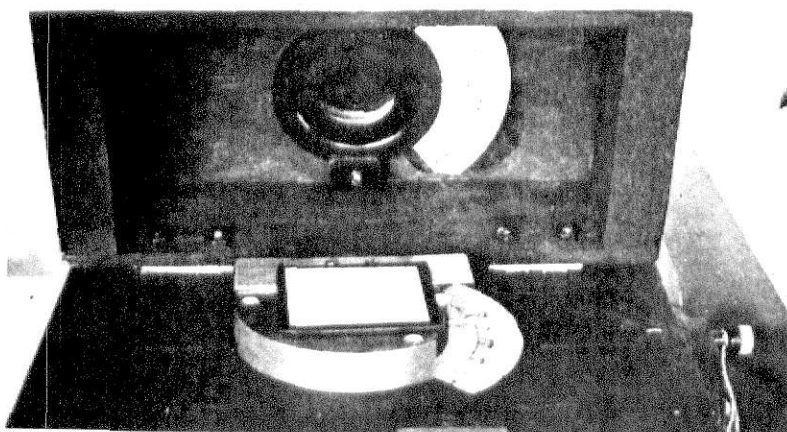


Plate I-D. Sample holder of photometer with standard in place.

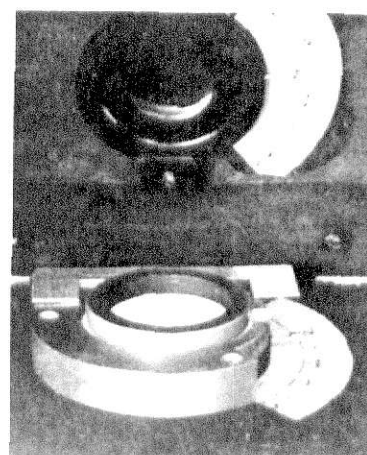


Plate I-E. Sample holder with filter in place.

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-selective 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.

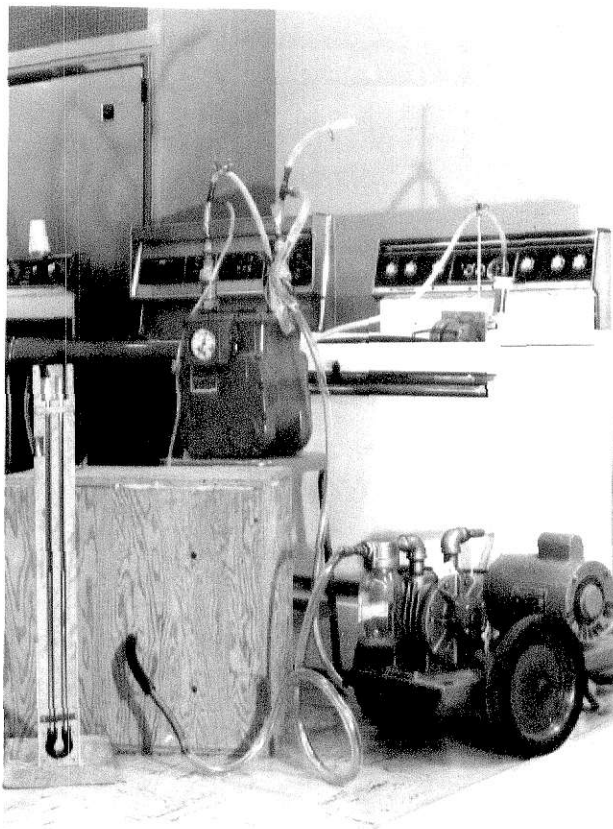


Plate II-A. Sampling system arrangement.



Plate II-B. Soiling of oven.

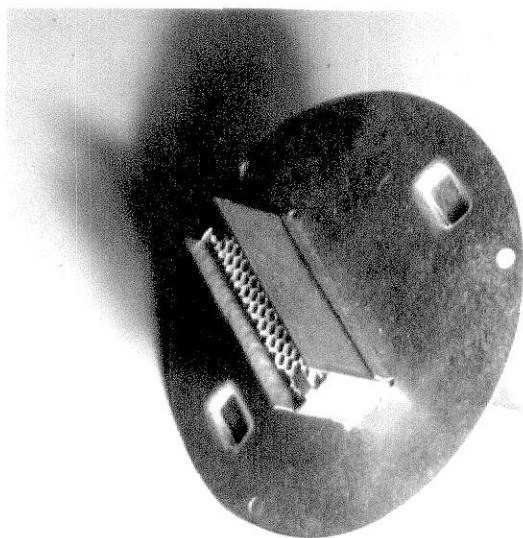


Plate II-C. Smoke eliminator.

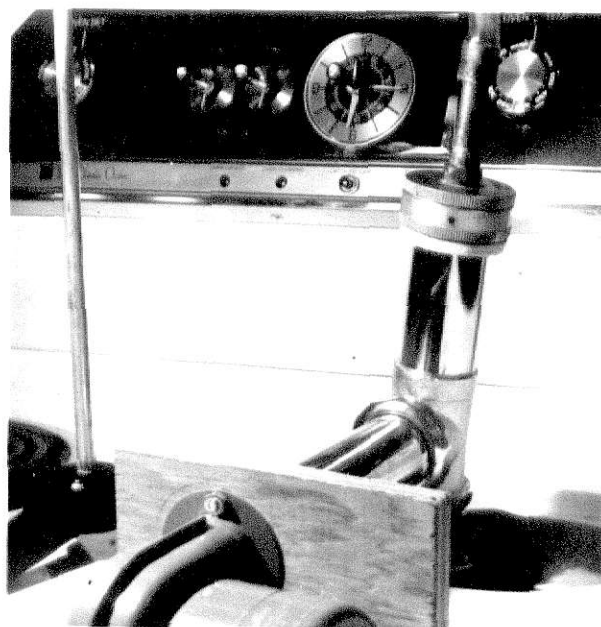


Plate II-D. Exhaust extension.

Because the number of sampling runs exceeded original expectations, a second batch of soil had to be formulated. The soil batches will be identified in the analysis section as first and second.

Procedures

Procedural philosophy

The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) 1972 Handbook of Fundamentals describes three basic methods of measuring air contaminant concentration: the particle number, weight, or light-scattering area per unit volume of air. Each method requires a specific analysis technique.

The method of counting particle numbers employs the capture of particles through various types of impingers, impactors, filters, or thermal or electrostatic precipitators. The counting is done under a microscope.

In the particle weight technique, air is drawn through filters, preferably membrane or glass-fiber, and a filter weight comparison is made before and after sampling. Other instruments such as impactors and electrostatic or thermal precipitators have been used with success.

The light-scattering area technique is based on the phenomenon that small particles scatter incident light in proportion to their projected area and a light-scattering coefficient, which depends on particle size, indices of refraction of particle and media, wave length of light, and angle of acceptance.

In this method air is sampled through membrane, glass, or asbestos-

fibered filters, which are analyzed with a photometer for the resultant difference in the light transmittancy of the filter paper. This method is particularly applicable, because the staining ability of dusts is a factor dependent on the light-scattering area per unit volume of air sampled (ASHRAE Handbook of Fundamentals, 1972), and because the resultant staining from air contaminants is a criteria for improving air quality.

The sampling technique of light-scattering area has advantages over weight measurement. The weight measurement technique ignores an important fact. Different aerosol systems have varying proportions of large particles that may comprise a small proportion of the total in terms of numbers, but a significant proportion in terms of weight. Furthermore, the pollution effect of fine particles is due to their light scattering quality regardless of their density or specific kind of pollution effect. That premise is true whether one considers the phenomenon of haze from suspended particles or the soiling effect created on a ceiling surface. Large particles, however, have an overwhelming influence on the calculated weight, but lack any significant power to scatter light. Since the light reflectance or light transmission measurement is a quantitative indicator of the light scattering potential of the sampled source, the cause of the pollution effect is reflected in the measurement technique (Hemon, et al., 1953). Thus, the standard light-scattering area method for testing particulate matter in the atmosphere as established by the American Society for Testing and Materials (1961) was followed in this research.

This sampling technique measures the level of staining contaminant in a gas and is a coefficient of haze (Coh) measurement. The air sample is drawn through a high-efficiency filter, and the relative light transmittancy of the filter paper before sampling, T_0 , and after sampling, T , is a measure of optical density (O.D.). The following equation represents this relationship:

$$\text{Coh}/1000 \text{ ft} = \frac{105 \text{ O.D.}}{Q/A}, \quad \text{Eq. (1)}$$

where:

$$\text{O.D.} = \log_{10} \frac{T_0}{T}$$

Q = volume sample, 10^3 ft^3

A = active filter area, ft^2

Consequently, one can determine the concentration of staining contaminant in a space by calculation of the Coh level in the air. As an example, a level of 3-4 Coh/1000 ft would produce a visible haze near lighting fixtures, but it would not be objectionable. A Coh level of 10-14, however, would be indicative of an objectionable haze (Sutton et al., 1964).

In this study the oven exhaust was sampled isokinetically at the oven's natural or natural plus induced air flow rate. By using a standardized comparative soiling and sampling technique, the researcher was able to calculate the amount of emitted smoke for each oven and evaluate performance of the oven.

Procedural development

Several runs of data were collected as a basis for standardizing

procedures. Each oven differed in design; consequently, the sampling schedule was not identical for all ovens.

The first step in the procedure was to determine the natural rate of air flow of each oven with the Hastings air velocity meter. For the Frigidaire and Hotpoint ranges, this included the induced air. Isokinetic sampling was desired, without increasing or decreasing the natural rate of air flow through the oven. Once this rate was established, a sampling timetable was set. The oven was soiled as described in the AHAM standard, cooled to room temperature, and was ready for the test run.

The sampling procedure varied only slightly among ovens. The Frigidaire and the Hotpoint were approximately the same, but differed from the Corning. For the Hotpoint and Frigidaire, the sampling filter head was placed on the oven exhaust pipe for the entire sampling period, excluding two one-minute periods used to change filters. Therefore, one could calculate directly the amount of smoke emitted during the entire period.

The Corning range differed from the other two ranges in that the smoke emission was too heavy to be sampled on a continuous basis. Instead, an intermittent sampling procedure was used. Through experimentation the critical points were determined, and these were incorporated into the sampling timetable. By graphing the data, a curve of concentration vs. time was drawn from which the total amount of emitted smoke was determined (Appendix A-7).

Another way in which the Corning range sampling procedure differed from the Hotpoint and Frigidaire was in a cooling system that was attached to the oven exhaust duct. The oven exhaust in the Corning was designed integrally with the backdrop of the range and induced a mixing of room air before discharge. In the Hotpoint and Frigidaire the exhaust was direct from the oven through the right rear surface unit. This factor, in combination with other range design features, caused the exhaust of the latter two ovens to be too hot to sample in the particulate state. Instead, the smoke passed through the filter as a vapor and melted the sampling tubing. To correct this problem a fan was attached to the sampling system at the exterior of the oven exhaust via a tee-joint pipe (Figure II). This tube was attached to the oven exhaust pipe which extended it and allowed enough air to be mixed with the oven exhaust to cool it to the temperature and state at which it could be sampled. The addition of the room air was accounted for in the final Coh measurement.

Test run procedures

Initial filter readings were taken with the photometer in the Fine Particle-Air Pollution Laboratory. These filters then were transported to the Justin laboratory, where they were used in the sampling system. A final photometer reading was taken immediately after sampling (Appendix A-1).

The procedures and detailed timetables of the sampling runs are listed in the appendix (A-2). Appendix A-3 is an example of the data record form used during the sampling schedule.

Following is a summation of the two basic types of sampling timetables or schedules:

I. Corning Schedule

<u>Time elapsed in minutes</u>	<u>Action taken</u>
0	Activate cleaning process and sampling process
20	Stop sampling process
23	Start sampling process
24	Stop sampling process
27	Start sampling process
27.5	Stop sampling process
31	Start sampling process
31.5	Stop sampling process
35	Start sampling process
36	Stop sampling process
47	Start sampling process
50	Stop sampling process
60	Start sampling process
120	Stop sampling process

This schedule totaled 120 minutes and used seven filters.

II. Frigidaire and Hotpoint Schedules

<u>Time elapsed in minutes</u>	<u>Action taken</u>
0	Activate cleaning process and sampling process
20	Stop sampling process
21	Start sampling process
41	Stop sampling process
42	Start sampling process
120	Stop sampling process

This sampling schedule totaled 120 minutes and used three filters

for all runs except the Frigidaire full-soil schedule, which was extended one hour and used four filters.

Because the exhaust extension on the Frigidaire and Hotpoint ranges induced a mixing of lab air and oven exhaust, the dust content of the lab air had to be accounted for and subtracted from the filter readings of the oven exhaust. Therefore, a lab air sample was taken during the sampling period in the Hotpoint and Frigidaire sampling schedule. Appendix A-5 accounts for the lab air samples.

The Coh measurement was the soiling index. By incorporating the information of the data record forms into the Coh equation, soiling indexes were calculated and statistically analyzed. Appendix A-4 illustrates the original sampling data, Appendix A-6 illustrates the Coh calculations, and Table 1 is a summary of these Coh levels or soiling indexes. Data in Table 1 provide the information for the first objective. Because a substantial amount of smoke was measured, the study was continued.

Selection of valid runs

From February through November 1976, 46 sampling runs were performed. Data for seven of those runs had to be discarded, and data for an additional six runs could not be used in statistical analysis.

Following are the circumstances that resulted in the discarding of data:

Filter Numbers of Discarded RunsReason for Discarding Data

Corning: 30-34
 Corning: 35-39
 Corning: 40-44
 Corning: 45-49
 Corning: 50-54

These runs were not used because the sampling schedule was still being changed and corrected. The runs, as taken, did not give an accurate or representative graph of Coh/1000 ft³ vs. time.

Hotpoint: 97-103

The researcher used the same timetable as for the Corning range. This resulted in filters too light to be read by the photometer. The sampling periods had to be extended to produce measurable stains.

Hotpoint: 110-113

The researcher failed to turn on the induced air blower, so the sampling run was stopped.

Listed in Table 1 are the valid sampling runs. Included are data from the six runs that were not used in statistical analysis.

Table 1. Summary of total smoke emission.

Range Brand	Run (Filter #)	Soil Level	Soil Batch	Total Amount of Emission (ex- pressed in Cohs)
Corning	55-61	Full-soil	First	1459.93
"	62-68	Full-soil	First	2100.29
"	69-75	Full-soil	First	1533.17
"	76-82	1/2-soil	First	461.31
"	83-89	1/2-soil	First	548.11
"	90-96	1/2-soil	First	654.27
"	240-247	Full-soil	Second	1453.62
"	254-261	Full-soil	Second	871.02

Table 1. Summary of total smoke emission. (continued)

Range Brand	Run (Filter #)	Soil Level	Soil Batch	Total Amount of Emission (expressed in Cohs)
Corning	180-187	----natural soil----		120.02
"	228-234	----natural soil----		214.73
Hotpoint	104-106	1/2-soil	First	16.22
"	107-109	1/2-soil	First	17.32
"	114-117	1/2-soil	First	16.55
"	118-121	Full-soil	First	25.19
"	122-125	Full-soil	First	31.26
"	126-129	Full-soil	First	91.90
"	130-133	1/2-soil	Second	23.75
"	134-137	1/2-soil	Second	31.50
"	197-201	1/2-soil	Second	7.01
"	202-206	Full-soil	Second	16.35
"	235-239	Full-soil	Second	32.68
"	248-252	Full-soil	Second	32.75
"	263-265	1/2-soil	Second	52.61
"	266-270	1/2-soil	Second	52.17
"	271-273	1/2-soil	Second	18.02
"	275-279	1/2-soil	Second	26.68
Frigidaire	138-141	1/2-soil	Second	25.98*
"	142-145	1/2-soil	Second	18.44*

Table 1. Summary of total smoke emission. (concluded)

Range Brand	Run (Filter #)	Soil Level	Soil Batch	Total Amount of Emission (expressed in Cohs)
Frigidaire	146-150	1/2-soil	Second	12.69*
"	151-156	Full-soil	Second	16.83*
"	157-162	Full-soil	Second	15.35*
"	163-170	Full-soil	Second	12.38*
"	171-175	1/2-soil	First	.86
"	176-180	1/2-soil	First	1.07
"	188-192	1/2-soil	Second	1.46
"	193-197	Full-soil	Second	8.96
"	207-212	Full-soil	Second	3.46
"	222-227	Full-soil	Second	7.58

*These are the first six runs of the Frigidaire. They could not be used in the statistical analyses.

The Frigidaire range was the only range of the three that was new and had not been used previously. Six runs of data were taken consecutively on that oven. Apparently, because of "baking off" of certain oils and binders found in the insulation of new ovens, the Coh levels of those six runs were biased and unrepresentative of the true total smoke emission. Figure III represents the decline in the Coh levels of this oven with increased usage. For a half-soil level of soiling, the

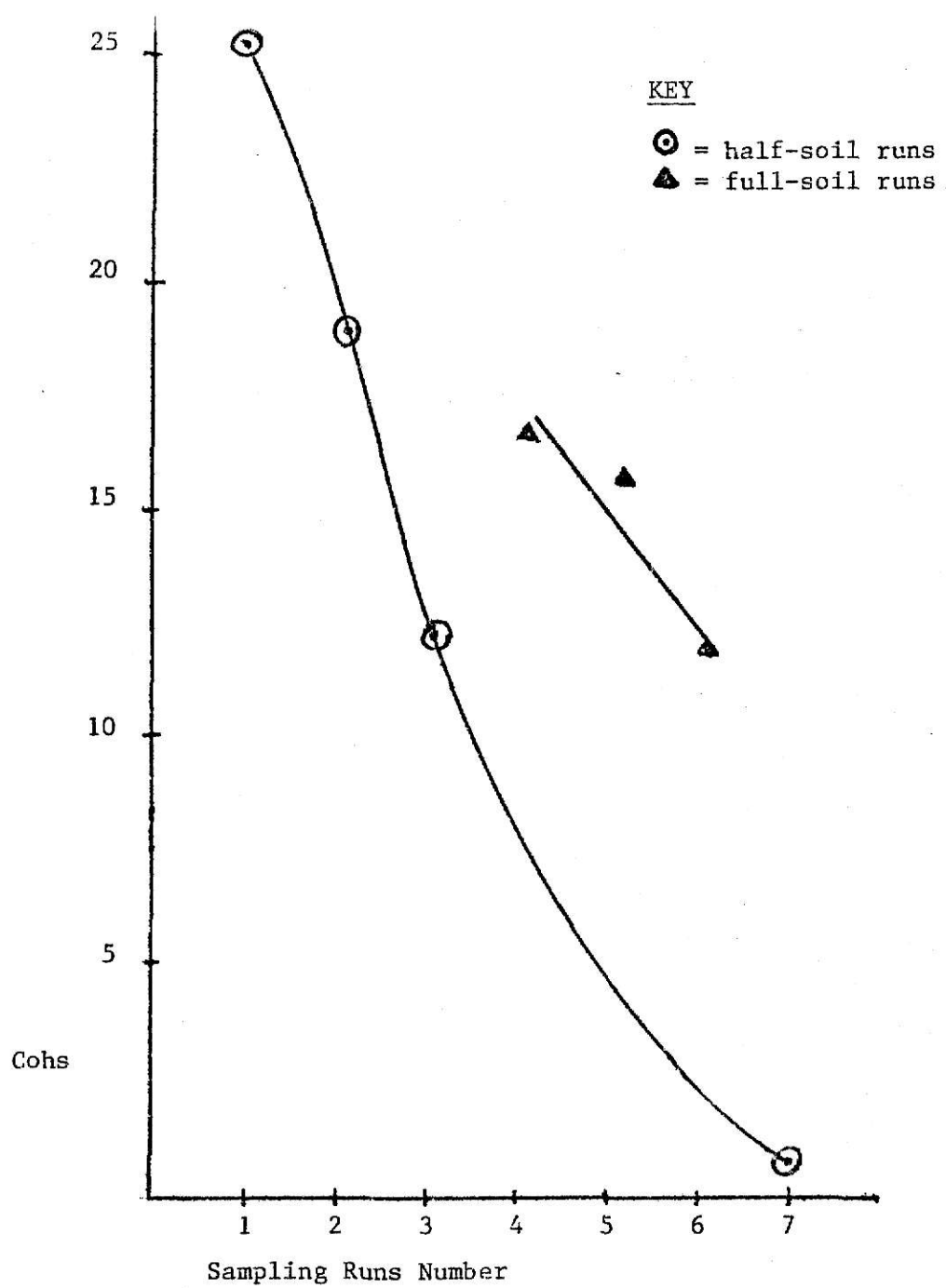


Figure III.

Total smoke emitted, preliminary Frigidaire runs.

Coh level fell from 25.98 total Cohs to 12.69 Cohs. As the level of soiling was then increased from half-soil to full-soil, the Coh levels increased but again the decreasing pattern of Cohs emerged.

This phenomenon was noted by Newell (1965) of the General Electric Company. In the conference paper presented at the 16th annual Appliance Technical Conference in Columbus, Ohio, he stated,

Another problem that had to be solved was the development of an oven insulation that was low in binder and oil and yet would not cause mechanical dermatitis to those who assembled the range on the assembly line. And this is contradictory because the chances of dermatitis are reduced when more oil and binder are used in the insulation, thereby eliminating much of the 'fly' that contributes to the dermatitis. Also the first several cycles of cleaning, bakes out the oil and binder and it is driven off in the form of smoke and odor. Both of these problems can be a nuisance. The smoke can soil the exposed areas of the range, especially the gasket, by condensing on it, and the odor can be very objectionable to the user.

Experimental accuracy

Because of several factors, the reproducibility of sample runs varied. The variation could be attributed partially to range design. The Hotpoint oven was extremely variable and produced a wide scatter in the data. The Frigidaire and Corning ranges were not as variable.

It appeared that variability in soil composition from run to run contributed most to the scatter of data. The soil consisted of nine items. Although it was mixed well, the soil samples were small, and different amounts of individual items could be in each. For example, it would have been almost impossible to get the same amount of hamburger, with the same fat content, or cheese in each sample unless one

weighed these ingredients separately. Because hamburger is coarsely ground and ingredients emit various amounts of smoke, it would be almost impossible to achieve good reproducibility.

Other sources of error could have been in readings of the balance, manometer, gas meter, or photometer. However, due to the actual variability of the soil, such error analysis would be meaningless.

RESULTS AND DISCUSSION

The initial statistical analysis was a comparison of the first and second batches of soil to determine if any differences existed. First an F-value was calculated to determine differences between the variances of the two populations of soil batches; one then could select the proper t-test. Table 2 is a summary of the variance calculations of the soil batches, Table 3 is a summary of the test for equality of variances, and Table 4 is a summary of the results of the t-test of the means of the soil batches. The null hypothesis was not rejected, so the first batch of soil was judged not to be significantly different from the second. Therefore, the data were grouped, and no distinction was made between first and second batches of soil.

The second objective was to compare the relative smoke eliminating effectiveness of the ranges as measured by total smoke emission (Coh). Table 5 is a summary of the calculated variances, Table 6 is a summary of the tests for equality of variances, and Table 7 is a summary of the results of the t-test. For both half-soil and full-soil conditions, the Corning range emitted significantly more smoke than either the Hotpoint or Frigidaire, and the Hotpoint emitted significantly more smoke than the Frigidaire.

The third objective was to compare the total smoke emission (Coh) to the level of soiling inside of the oven to test the effectiveness of the smoke eliminating system at two levels of soiling. Table 8 is a summary of the equality of variances, and Table 9 is a summary of

Table 2. Calculation of variances: difference between first and second soil batches.

Brand	Soil Batch	Soil Level	¹ Variance = s_j^2
Corning	First	Full-soil	122,841.69
Corning	Second	Full-soil	169,711.38
Hotpoint	First	1/2-soil	0.32
Hotpoint	Second	1/2-soil	287.78
Hotpoint	First	Full-soil	1,360.71
Hotpoint	Second	Full-soil	89.28

¹From Duncan (1953). See Appendix A-8 for sample calculations.

Table 3. Tests of equality of variance: difference between first and second soil batches.

Run Comparisons	¹ Degrees of Freedom	Calculated F-value ²	F-table value $\alpha=.05$	$\sigma_i^2 = \sigma_j^2$	$\sigma_i^2 \neq \sigma_j^2$
Corning-full-first vs. 2 Corning-full-second 1		1.38	18.5	Assume yes	No
Hotpoint-1/2-first vs. 2 Hotpoint-1/2-second 6		899.31	19.3	No	Yes
Hotpoint-full-first vs.2 Hotpoint-full-second 2		15.24	19.0	Assume yes	No

¹Degree of freedom, $n=N-1$.

²From Duncan (1953). See Appendix A-8 for sample calculations.

Table 4. Results of t-tests: difference between first and second soil batches.

Run Comparisons	Degress of Freedom	F-test Conclusions $\sigma_1^2 = \sigma_2^2$	Calculated t-value	t-table value $\alpha = .05$	Null Hypothesis $\bar{X}' = \bar{X}'$ i j
Corning (full-soil) first vs. second	3	yes	1.58	3.18 ²	Not rejected
Hotpoint (full-soil) first vs. second	4	yes	0.82	2.78 ²	Not rejected
Hotpoint (1/2-soil) first vs. second	8	no	2.11	2.45 ¹	Not rejected

¹Due to inequality of variances and sample size, the critical t was based on Duncan's (1953) theory, page 397-398. See Appendix A-8 for sample calculations.

²Used t-test for small sample size and equal variances, Duncan (1953), page 394.

Table 5. Calculation of variances: differences between ovens for both levels of soiling.

Oven Brand	Soil Level	¹ Variance = s_j^2
Corning	1/2-soil	9,339.62
Corning	full-soil	189,869.25
Hotpoint	1/2-soil	234.78
Hotpoint	full-soil	727.71
Frigidaire	1/2-soil	0.095
Frigidaire	full-soil	8.19

¹From Duncan (1953). See Appendix A-8 for sample calculations.

Table 6. Tests of equality of variance: differences between ovens for both levels of soiling.

Run Comparisons	¹ Degrees of Freedom	Calculated F-value ²	F-table value $\alpha=.05$	$\sigma_i^2 = \sigma_j^2$	$\sigma_i^2 \neq \sigma_j^2$
Corning (1/2-soil) vs. Hotpoint (1/2-soil)	2 9	39.78	4.26	No	Yes
Corning (full-soil) vs. Hotpoint (full-soil)	4 5	260.91	5.19	No	Yes
Hotpoint (1/2-soil) vs. Frigidaire (1/2-soil)	9 2	2,471.37	19.40	No	Yes
Hotpoint (full-soil) vs. Frigidaire (full-soil)	5 2	88.85	19.30	No	Yes
Corning (1/2-soil) vs. Frigidaire (1/2-soil)	2 2	98,311.79	19.0	No	Yes
Corning (full-soil) vs. Frigidaire (full-soil)	4 2	23,183.06	19.2	No	Yes

¹Degree of freedom, $n=N-1$.

²From Duncan (1953). See Appendix A-8 for sample calculations.

Table 7. Results of t-tests: differences between ovens for both levels of soiling.

Run Comparisons	Degrees of Freedom	F-test Conclusions $\sigma_i^2 = \sigma_j^2$	Calculated t-value	t-table value $\alpha = .05$	Null Hypothesis $H_0: \bar{X}_i = \bar{X}_j$ $H_1: \bar{X}_i - \bar{X}_j > 0$
Corning (1/2-soil) vs. Hotpoint (1/2-soil)	11	No	9.43 ¹	2.91 ¹	Accept H_1
Corning (full-soil) vs. Hotpoint (full-soil)	9	No	7.41 ¹	2.13 ¹	Accept H_1
Hotpoint (1/2-soil) vs. Frigidaire (1/2-soil)	11	No	5.17 ¹	1.83 ¹	Accept H_1
Hotpoint (full-soil) vs. Frigidaire (full-soil)	7	No	2.85 ¹	2.03 ¹	Accept H_1
Corning (1/2-soil) vs. Frigidaire (1/2-soil)	4	No	9.92 ¹	2.92	Accept H_1
Corning (full-soil) vs. Frigidaire (full-soil)	6	No	7.58 ¹	2.13 ¹	Accept H_1

¹Because of inequality of variances and sample size, the critical t was based on Duncan's theory (1953), page 397-398. See Appendix A-8 for sample calculations.

Table 8. Tests of equality of variance: differences between full and half level of soiling.

Run Comparisons	¹ Degrees of Freedom	Calculated F-value ²	F-table value $\alpha = .05$	$\sigma_i^2 = \sigma_j^2$	$\sigma_i^2 = \sigma_j^2$
Corning (1/2-soil) vs. Corning (full-soil)	2 4	20.33	19.2	No	Yes
Hotpoint (1/2-soil) vs. Hotpoint (full-soil)	9 5	3.10	3.48	Inconclusive (Assume Yes)	No
Frigidaire (1/2-soil) vs. Frigidaire (full-soil)	2 2	86.21	19.0	No	Yes

¹Degree of freedom, $n=N-1$.²From Duncan (1953). See Appendix A-8 sample calculations.

Table 9. Results of t-tests: differences between full and half level of soiling.

Run Comparisons	Degrees of Freedom	F-test Conclusions $\sigma_i^2 = \sigma_j^2$	Calculated t-value	t-table value $\alpha = .05$	Null Hypothesis $H_0: \bar{X}_i = \bar{X}_j$ $H_1: \bar{X}_i - \bar{X}_j > 0$
Corning full-soil vs. 1/2-soil	6	No	4.58 ¹	2.19	Accept H_1
Hotpoint full-soil vs. 1/2-soil	14	Inconclusive	1.16	1.76	Accept H_0
Frigidaire full-soil vs. 1/2-soil	4	No	3.33 ¹	2.92	Accept H_1

¹Because of inequality of variances and sample size, the critical t was based on Duncan's theory (1953), page 397-398. See Appendix A-8 for sample calculations.

the results of the t-test. Both the Corning and Frigidaire ranges emitted significantly more smoke at the full-soil level than at the half-soil level. On the basis of Hotpoint range data, the null hypothesis, which stated the means were equal, could not be rejected. This means that either the oven design did not eliminate smoke any better or worse at the half-soil level than at the full soil level, or there was too much data scatter. Although the null hypothesis could not be rejected, it cannot be assumed that the performance of the two ovens was the same. The sample size would have to be much larger to reach a reliable decision about accepting or rejecting the hypothesis.

The fourth objective was to relate the amount of emitted oven smoke to that of cigarette smoking. McNall, et. al., (1964) concluded one cigarette causes 5.5 Cohs/1000 ft or 7.48 smohs in a 1,360-cu ft room. To compare their data to the data just discussed, the latter data were converted to units of smohs.

One smoh (Coh level due to smoke) represents a quantity of staining contaminant equal to $1 \text{ Coh} \cdot \text{ft}^2$. The product of the average soiling index (Cohs/1000 ft) and the volume sampled (cubic feet) equals the quantity in smohs (equivalent to $\text{Coh} \cdot \text{ft}^2$). Table 10 lists the sample data in units of smohs. It also illustrates the sample data equivalency of cigarette smoking. This means that the smoke from the oven would be equivalent to the quantity of smoke from the number of cigarettes, as stated in Table 10. However, this is a quantity of smoke that would remain at the end of the sampling period, assuming no smoke had settled to horizontal surfaces or clung to vertical surfaces.

Table 10. Emission quantities compared to cigarette smoking.

Brand	Soiling Method	Soil Level	Total Smoke (in Smohs)	Equivalency in Cigarettes	For 1,360 cu ft room, % increase over		
					National Average inside residential air-l	Minneapolis inside residential air-l	
Corning	Artificial	Full	15.62	2.09	696	1914	
	"	"	22.47	3.00	1001	2754	
	"	"	16.41	2.19	731	2011	
	"	"	15.55	2.08	693	1906	
	"	"	9.32	1.25	415	1142	
	"	1/2	4.94	0.66	220	605	
	"	1/2	5.86	0.78	261	719	
	"	1/2	7.00	0.94	312	858	
	Natural		1.28	0.17	57	157	
	Natural		2.30	0.31	102	282	
Hotpoint	Artificial	Full	0.27	0.04	12	33	
	"	"	0.33	0.04	15	40	
	"	"	0.98	0.13	44	120	
	"	"	0.17	0.02	8	21	
	"	"	0.35	0.05	16	43	
	"	"	0.35	0.05	16	43	
	"	1/2	0.17	0.02	8	21	
	"	"	0.19	0.03	8	23	
	"	"	0.18	0.02	8	22	
	"	"	0.25	0.03	11	31	
	"	"	0.34	0.05	15	42	
	"	"	0.08	0.01	4	10	
	"	"	0.56	0.07	25	69	
	"	"	0.56	0.07	25	69	
	"	"	0.19	0.03	8	23	
	"	"	0.29	0.04	13	36	
	"	"	0.18	0.02	8	22	
	"	"	0.16	0.02	7	20	
	"	"	0.13	0.02	6	16	
	"	"	0.10	0.01	4	12	

Table 10. Emission quantities compared to cigarette smoking. (Continued)

Brand	Soiling Method	Soil Level	Total Smoke (in Smohs)	Equivalency in Cigarettes	For 1.350 cu ft room, % increase over	
					National Average inside residential air ¹	Minneapolis inside residential air ¹
Frigidaire	Artificial	Full	0.04	0.005	2	5
"	"	"	0.08	0.01	4	10
"	"	1/2	0.28	0.04	13	34
"	"	"	0.20	0.03	9	25
"	"	"	0.14	0.02	6	17
"	"	"	0.009	0.001	.4	1
"	"	"	0.01	0.001	.4	1
"	"	"	0.02	0.003	.9	2

¹Whitby, et. al., 1957.

The addition of smoke from the oven to the room air would result in an increase of total haze in the room. The increase that resulted from the test runs is listed as a percentage in Table 10; that increase is calculated using two levels of air quality. Whitby, et. al., (1957) reported the average soiling index (Coh/1000 ft) of inside residential air for major U.S. cities (national average) and Minneapolis, Minnesota. The Minneapolis average is similar to the average for Manhattan, Kansas, where the research was conducted. The ovens with the greatest and the least amount of smoke output represented an increase of 2,754% and 1%, respectively, over the average level of air quality in Minneapolis.

The original sampling data could have been figured as a smoh unit rather than the Coh unit. The difference between the two calculations is a constant factor of 0.0107 sq ft, the active filter area. Consequently, the unit chosen had no biased effect on analysis or results.

In order to increase the external validity of this study, three runs of data were conducted on ovens that were soiled by natural use. Those runs were made on two models of Corning ranges. One was model number R30DB, serial number 2103203405; and the other was model R30JB, serial number 2092303349. Table 11 is a summary of the food items baked or broiled in those ovens.

Table 11. Food items baked or broiled in naturally soiled ovens.

Oven	Food Items	Coh Level (Total Cohs)
R30DB	Two 8 oz. steaks One 12 oz. package of bacon Two 8 oz. cherry pies One 8 oz. chicken pot pie	120.02
R30DB	Three 12 oz. packages of bacon Three 4 oz. hamburgers One 8 oz. peach pie Two 8 oz. cherry pies	214.73
R30JB	An oven used in a class at Kansas State University. An undetermined amount of food was cooked in the oven. The type of foods baked consisted mainly of casseroles, starchy foods, and desserts and resulted in extremely large pools of "bakeover."	38.87

A statistical analysis was made of the data from the Corning range (model R30DB) to determine the difference between the natural soiling and the previously described half-soil level. Table 12 is a summary of the runs analyzed. Table 13 is a summary of variances, Table 14 is a summary of the equality of variances, and Table 15 is a summary of the t-tests.

Table 15 summarizes differences between the natural soiling and the half-soil level. Natural soiling was less than the half-soil level, and thus, less than full-soil level. That could be because the level of soiling, the components of the soil, or perhaps other unknown effects.

Table 12. Total smoke emitted: half-soil level vs. natural soiling.

Oven	Filter Numbers	Soil Level	Total Amount of Emission (expressed in Cohs)
Corning R30DB	76-82	1/2-soil	461.31
Corning R30DB	83-89	1/2-soil	548.11
Corning R30DB	90-96	1/2-soil	654.27
Corning R30DB	180-187	natural	120.02
Corning R30DB	228-234	natural	214.73

Table 13. Calculation of variances: difference between half-soil level and natural soiling.

Oven Brand	Soil Level	¹ Variance = s_j^2
Corning	1/2-soil	9339.62
Corning	natural	4485.94

¹From Duncan (1953). See Appendix A-8 for sample calculations.

Table 14. Test of equality of variances: difference between half-soil level and natural soiling.

Oven	Degrees of Freedom	Calculated F-value ¹	F-table value $\alpha = .05$	$\sigma_i^2 = \sigma_j^2$	$\sigma_i^2 \neq \sigma_j^2$
Corning 1/2-soil vs. natural	2 1	2.08	200	Assumed yes	no

¹From Duncan (1953). See Appendix A-8 for sample calculations.

Table 15. Results of t-test: difference between half-soil level and natural soiling.

Run Comparison	Degrees of Freedom	F-test Conclusion $\sigma_i^2 = \sigma_j^2$	Calculated t-value ¹	t-table value $\alpha = .05$	Null Hypothesis $H_0: \bar{X}'_i = \bar{X}'_j$ $H_1: \bar{X}'_i - \bar{X}'_j > 0$
Corning 1/2-soil vs. natural	3	Assumed yes	4.84	2.35	Accept H_1

¹From Duncan (1953). See Appendix A-8 for sample calculations.

The ovens were used until they were considered moderately soiled. The decision as when to clean them was made by the researcher and several aides, presuming that the average person would clean his oven at this level of soiling. This was a subjective decision, and there is wide variance in personal judgements as when to clean an oven.

Perhaps persons with a self-cleaning oven would be more inclined to postpone the cleaning process than those with a conventional oven. Because there is little physical exertion involved with operating the self-cleaning cycle, it seems probable that those with such an oven would not be as cautious about spills and may not clean the oven as often as those with a conventional oven. Therefore, it is possible that these naturally soiled ovens may or may not be representative of the average level of soiling in self-cleaning ovens. Even so, this in no way invalidates the decision to use AHAM standard soil formulation and level, because AHAM's recommendation is based on broad experience.

CONCLUSIONS AND RECOMMENDATIONS

The research thus conducted established some important implications. First of all, it established that some self-cleaning ovens adversely affect inside air quality. More importantly, it indicated that some range designs have little effect on air quality. Much depends not only on range design but also on the manner in which the appliance is used.

All three self-cleaning ovens emitted smoke during the self-cleaning cycle. By using the Coh measurement as a smoke emission control indicator, the oven's smoke-eliminating effectiveness was calculated and comparisons were made.

The Corning range produced significantly higher emissions than either the Hotpoint or Frigidaire, and the Hotpoint produced significantly higher emissions than the Frigidaire. That was true for both full-level and half-level soiling.

A comparison of smoke eliminating effectiveness of the ranges was made between half-level soiling and full-level soiling. The Frigidaire and Corning ranges both were more effective in eliminating the smoke at half-level than at full-level. For the Hotpoint no statistically significant difference occurred. The Hotpoint did not do any better or worse at one level than at the other although with a larger sample size, a more precise conclusion may have been possible.

A comparison was made between oven emission levels and a corresponding measure of cigarette smoking. The quantities of emission levels differed among ovens, ranging from an equivalent of 3.00 cigarettes for the worst oven to 0.001 cigarettes for the best oven.

Data collected revealed unusually high emissions of smoke from a new, previously unused self-cleaning oven. Levels of smoke did not decrease to "normal" operating levels until the oven was run through approximately seven cycles.

Recommendations for the consumer are:

1. Initiate several cleaning cycles in a new self-cleaning oven before using the oven.
2. Do not allow the self-cleaning oven to get extremely soiled before cleaning. Less soiled ovens are cleaned faster, if they have a variable time cycle, and are less damaging to inside air quality than heavily soiled ovens.
3. Use a ventilation hood to help rid the air of smoke, if the hood is vented to the outside or has filters to absorb the smoke.
4. There are big differences between brands; therefore, consumer input or information from friends may be valuable when at the point of purchase.

Recommendations for researchers are:

1. More research needs to be done to determine the relative effectiveness of different smoke eliminators and range designs.

2. Consideration should be given to use of more effective systems.
3. Research should be conducted to determine the health implications of such emissions, such as possible carcinogenic effects.

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APPENDICES

Appendix A-1. Photometer readings.

Filter Number	Photometer Standard	Initial Reading	Final Reading
55	850	968	837
56		991	735
57		975	30
58		960	24
59		999	459
60		956	778
61		947	680
62	800	910	800
63		936	676
64		959	318
65		985	43
66		969	214
67		923	702
68		924	672
69	800	932	841
70		949	737
71		930	447
72		958	120
73		958	303
74		963	790
75		942	704
76	850	956	870
77		971	785
78		959	624
79		961	612
80		973	727
81		990	877
82		995	811
83	850	984	894
84		980	693
85		1003 (estimate)	289
86		997	332
87		959	699
88		993	889
89		981	808
90	800	891	778
91		990	753
92		987	304

Appendix A-1. Photometer readings. (continued)

Filter Number	Photometer Standard	Initial Reading	Final Reading
93		925	214
94		971	647
95		927	786
96		924	664
104	800	971	761
105		954	858
106		917	861
107	800	942	690
108		941	886
109		929	869
114	750	970	762
115		942	843
116		886	828
117		956	926
118	800	983	697
119		965	791
120		904	844
121		908	873
122	800	962	562
123		957	832
124		936	871
125		985	962
126	700	993	160
127		988	832
128		949	846
129		996	943
130	700	930	608
131		979	908
132		998	914
133		932	898
134	700	941	507
135		945	872
136		957	904
137		967	941

Appendix A-1. Photometer readings. (continued)

Filter Number	Photometer Standard	Initial Reading	Final Reading
138	700	908	840
139		954	889
140		962	566
141		914	582
142	700	939	876
143		946	888
144		977	646
145		942	679
146		905	695
147		962	908
148		953	755
149		971	824
150		970	839
151	700	977	826
152		962	783
153		928	864
154		929	775
155		963	823
156		986	833
157	700	908	781
158		954	778
159		974	893
160		961	684
161		930	771
162		949	810
163	700	971	903
164		918	806
165		924	863
166		927	837
167		961	885
168		970	691
169		979	840
170		934	811
171	700	973	826
172		985	914
173		964	927
174		969	798
175		941	799

Appendix A-1. Photometer readings. (continued)

Filter Number	Photometer Standard	Initial Reading	Final Reading
176	700	951	641
177		905	823
178		913	848
179		869	686
180		940	807
181	700	954	907
182		860	742
183		983	819
184		949	795
185		995	887
186		917	877
187		971	858
188	700	908	801
189		930	852
190		945	907
191		977	853
192		988	884
193	700	980	670
194	700	970	831
195	700	984	917
196	800	946	741
197	800	936	799
198	800	972	831
199		965	950
200		971	947
201		935	920
202	800	941	714
203		925	736
204		962	852
205		920	853
206		955	885
207	800	940	863
208		981	873
209		948	885
210		918	702
211		945	747
212		940	783

Appendix A-1. Photometer readings. (continued)

Filter Number	Photometer Standard	Initial Reading	Final Reading
213	800	988	435
214		913	744
215		996	855
216		950	896
217		940	908
218		946	924
219		938	919
220		955	920
221		930	816
222	800	944	706
223	800	960	822
224	800	942	879
225	700	930	731
226	800	933	793
227	800	935	813
228	800	983	764
229	700	960	695
230	650	954	709
231	650	944	676
232	650	942	726
233	650	914	848
234	650	963	745
235	650	938	845
236		940	510
237		933	840
238		937	891
239		997	899
240	650	956	836
241		908	605
242		937	71
243		928	24
244		935	622
245		901	766
246		903	706
247		909	672

Appendix A-1. Photometer readings. (concluded)

Filter Number	Photometer Standard	Initial Reading	Final Reading
248	650	917	880
249		933	636
250		931	701
251		958	891
252		957	948
253		885	862
254	650	964	835
255		935	679
256		962	585
257		906	267
258		962	690
259		928	809
260		929	757
261		944	645
262	650	927	774
263		999	351
264		999	696
265		999	828
266		999	834
267	999	800	349
268		810	622
269		883	784
270		901	625
271	800	972	731
272		972	896
273		958	891
274		985	881
275	800	972	869
276		999	673
277		914	791
278		962	870
279		962	857

Appendix A-2. Test Procedures

The operational procedures for the Corning range remained almost the same in all sampling runs. Following is a schedule of operations that were conducted with that range:

1. Remove soil samples from freezer and put in glass cups to thaw.
2. After mixture is thawed, apply to oven walls as stated in the AHAM soil standard.
3. Bake soil on oven walls at 450° F. for one hour.
4. Allow oven to cool to room temperature, approximately one hour. Initial photometer readings of filter paper were taken in the Fine Particle-Air Pollution Laboratory.
5. Insert filter in sampling filter holder and tape filter holder to the cone that is attached to oven exhaust pipe.
6. Obtain gas meter reading.
7. Obtain atmospheric barometric pressure.
8. Initiate the cleaning and sampling processes by activating, simultaneously, the cleaning cycle, vacuum pump, and stop-watch. Use the stop-watch for calculating elapsed time.
9. Adjust bleed valves connected to the gas meter tubing to adapt the air flow to the predetermined natural flow rate, compensating for the gas pressure modifications as read from the manometer.
10. Stop the sampling system after 20 minutes have elapsed.

11. Remove filter from sampling holder and replace with a clean filter. Place soiled filter in a secure container.
12. Obtain the gas meter reading.
13. Start the sampling again after 3 minutes have elapsed.
14. Stop the sampling after 1 minute.
15. Obtain gas meter reading.
16. Remove filter and replace as before.
17. Start sampling after 3 minutes and sample for 30 seconds.
18. Stop sampling and obtain gas meter reading.
19. Replace filter, as before, with a clean filter.
20. After 3.5 minutes, initiate the sampling.
21. Sample for 30 seconds.
22. Obtain the gas meter reading.
23. Replace soiled filter with a clean filter.
24. Begin sampling after 3.5 minutes have elapsed and sample for one minute.
25. Obtain gas meter reading.
26. Replace soiled filter with a clean filter.
27. After 11 minutes, begin sampling.
28. Sample for three minutes.
29. Obtain gas meter reading.
30. Replace soiled filter with a clean filter.
31. Start sampling after 10 minutes.
32. Evaluate air flow to determine if it is within a desirable range. Make adjustments accordingly.

33. Sample for one hour, until 120 minutes in total have elapsed.
34. Obtain gas meter reading after the sampling is terminated.

Following are the schedules for the Hotpoint and Frigidaire ovens.

1.-4. These procedures are the same as for the Corning.

5. Insert filter paper in sampling holder and sample dust content in the laboratory environment for approximately one hour.

6. Discontinue sampling and obtain gas meter reading. Remove filter from filter holder and replace with a clean filter. Then place filter holder securely on top of the oven exhaust pipe.

7.-12. Same as for the Corning procedures.

13. Start the sampling again after a 1-minute pause.

14. Make adjustments in the air flow rate if necessary.

15. Stop sampling after 20 minutes have passed.

16. Obtain gas meter reading.

17. Remove soiled filter from filter holder and replace with a clean filter.

18. When 1 minute has elapsed, begin sampling again.

19. Make air velocity adjustments if necessary.

20. Sample until 120 total minutes have elapsed. (The Frigidaire full-soil sampling schedule was extended to 180 minutes with a one-minute filter change at 120 minutes).

21. Obtain gas meter reading.
22. Remove soiled filter. Replace with a clean filter.
23. Place the filter head adjacent to the oven exhaust pipe but not on the pipe.
24. Start sampling to obtain a filter sample of the dust content in the laboratory environment.
25. Allow air sampling for approximately one hour.
26. Stop sampling and record gas meter reading.

Air filters then were transported to the Fine Particle-Air Pollution laboratory where the final photometer reading was taken. Filters were handled with tweezers to prevent contamination.

Appendix A-3. Example of data record form.

Date: _____ Barometric pressure: _____
Time: _____ Comments: _____
Soil batch: _____
Soiling level: _____

Filter #	Total Time Elapsed	Sampling Time of Filter	Gas Meter Reading (cubic feet/min.)	Manometer Reading (inches of Hg.)
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Appendix A-4. Original sampling data.

Filter #	Total Time Elapsed		Sampling Time of Filter	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
	(Minutes: Seconds)	(Minutes: Seconds)				
55	0:00			553.17		
56	20:00	20:00		589.37	2.87	28.70
57	24:00	1:00		591.09	2.87	28.70
58	28:00	1:00		592.78	2.87	28.70
59	32:00	1:00		594.49	2.87	28.70
60	36:00	1:00		596.25	2.87	28.70
61	50:00	3:00		601.20	2.87	28.70
	120:00	60:00		704.21	2.87	28.70
62	0:00			708.39		
63	20:00	20:00		745.57	2.84	28.82
64	24:00	1:00		747.29	2.84	28.82
65	27:30	0:30		748.15	2.84	28.82
66	31:30	0:30		748.98	2.84	28.82
67	36:00	1:00		750.64	2.84	28.82
68	50:00	3:00		755.72	2.84	28.82
	120:00	60:00		861.84	2.84	28.82
69	0:00			888.96		
70	20:00	20:00		925.00	2.88	29.33
71	24:00	1:00		926.69	2.88	29.33
72	27:30	0:30		927.65	2.88	29.33
73	31:30	0:30		928.41	2.88	29.33
74	36:00	1:00		930.12	2.88	29.33
75	50:00	3:00		935.04	2.88	29.33
	120:00	60:00		1040.29	2.88	29.33

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed		Sampling Time of Filter	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
	(Minutes: Seconds)	(Minutes: Seconds)				
76	0:00			067.37		
	20:00	20:00		104.39	2.82	28.90
77	24:00	1:00		106.165	2.82	28.90
78	27:30	0:30		107.02	2.82	28.90
79	31:30	0:30		107.94	2.82	28.90
80	36:00	1:00		109.67	2.82	28.90
81	50:00	3:00		114.585	2.82	28.90
82	120:00	60:00		219.465	2.82	28.90
83	0:00			239.69		
	20:00	20:00		276.87	2.82	29.13
84	24:40	1:00		278.74	2.82	29.13
85	28:00	1:00		280.56	2.82	29.13
86	32:00	1:00		282.39	2.82	29.13
87	36:00	1:00		284.22	2.82	29.13
88	50:00	3:00		289.52	2.82	29.13
89	120:00	60:00		395.925	2.82	29.13
90	0:00			413.93		
	20:00	20:00		450.50	2.81	29.01
91	24:00	1:00		452.30	2.81	29.01
92	28:00	1:00		454.06	2.81	29.01
93	32:00	1:00		455.78	2.81	29.01
94	36:00	1:00		457.48	2.81	29.01
95	50:00	3:00		462.35	2.81	29.01
96	120:00	60:00		567.71	2.81	29.01

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed		Sampling Time of Filter	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
	(Minutes: Seconds)	(Minutes: Seconds)				
104	0:00			646.25		
105	20:00	20:00		664.19	3.07	29.05
106	41:00	20:00		681.84	3.07	29.05
	120:00	78:00		752.70	3.07	29.05
107	0:00			762.21		
108	20:00	20:00		780.49	3.03	29.03
109	41:00	20:00		797.72	3.03	29.03
	120:00	78:00		867.23	3.03	29.03
114	0:00			984.34		
115	20:00	20:00		002.19	3.06	28.86
116	41:00	20:00		020.01	3.06	28.86
117	120:00	78:00		090.27	3.06	28.86
	180:00	59:00		143.11	3.06	28.86
118	0:00			148.85		
119	20:00	20:00		166.59	3.05	28.74
120	41:00	20:00		184.78	3.05	28.74
121	120:00	78:00		253.70	3.05	28.74
	180:00	59:00		306.91	3.05	28.74
122	0:00			318.97		
123	20:00	20:00		336.92	3.07	29.09
124	41:00	20:00		354.43	3.07	29.09
125	120:00	78:00		423.84	3.07	29.09
	180:00	59:00		476.84	3.07	29.09

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed (Minutes: Seconds)	Sampling Time of Filter (Minutes: Seconds)	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
126	0:00		489.85		
127	20:00	20:00	507.91	3.05	29.00
128	41:00	20:00	525.21	3.05	29.00
129	120:00	78:00	594.92	3.05	29.00
	180:00	59:00	648.11	3.05	29.00
130	0:00		654.32		
131	20:00	20:00	672.36	3.09	29.00
132	41:00	20:00	689.73	3.09	29.00
133	120:00	78:00	761.04	3.09	29.00
	180:00	59:00	813.53	3.09	29.00
134	0:00		824.09		
135	20:00	20:00	841.91	3.07	28.97
136	41:00	20:00	859.64	3.07	28.97
137	120:00	78:00	928.76	3.07	28.97
	180:00	59:00	982.31	3.07	28.97
138	0:00		048.33		
139	20:00	20:00	191.96	8.78	29.05
140	41:00	20:00	336.45	8.87	29.05
141	120:00	78:00	904.33	9.13	29.05
	180:00	59:00	335.63	9.13	29.05
142	0:00		407.11		
143	20:00	20:00	551.82	9.04	29.01
144	41:00	20:00	693.79	9.11	29.01
145	120:00	78:00	245.76	9.11	29.01
	180:00	59:00	659.87	9.11	29.01

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed (Minutes: Seconds)	Sampling Time of Filter (Minutes: Seconds)	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
146	0:00		726.46		
147	20:00	20:00	868.27	9.14	29.05
148	41:00	20:00	009.32	9.28	29.05
149	120:00	78:00	566.89	9.16	29.05
150	180:00	59:00	994.21	9.12	29.05
	240:00	59:00	417.95	9.12	29.05
151	Lab air		417.95		
152	20:40	20:40	109.71	8.77	28.94
153	41:00	19:48	259.10	9.10	28.94
154	120:00	78:00	399.22	9.25	28.94
155	180:00	59:00	956.18	9.14	28.94
156	240:00	59:00	382.21	9.14	28.94
			811.96	9.04	28.94
157	Lab air		811.96		
158	20:00	20:00	211.88	8.90	28.97
159	41:12	20:12	356.84	8.90	28.97
160	120:00	59:00	500.90	9.11	28.97
161	180:00	59:00	058.52	9.28	28.97
162	238:56	58:56	479.52	9.32	28.97
			903.10	9.26	28.97
163	Lab air		903.10		
164	Lab air		233.55	8.72	28.89
165	Lab air		572.66	8.72	28.89
			800.80	8.74	28.89

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed (Minutes: Seconds)	Sampling Time of Filter (Minutes: Seconds)	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
166	20:00	20:00	944.21	8.84	28.89
167	41:00	20:00	088.01	8.93	28.89
168	120:00	78:00	643.48	9.10	28.89
169	180:00	59:00	061.79	9.15	28.89
170	240:00	59:00	485.34	9.20	28.89
171	Lab air		485.34		
172	20:00	20:00	019.33	8.98	29.34
173	41:00	20:00	161.59	9.22	29.34
174	120:00	78:00	303.34	9.21	29.34
175	180:00	59:00	856.85	9.24	29.34
			280.78	9.24	29.34
176	Lab air		256.50		
177	20:00	20:00	959.99	9.02	29.36
178	41:00	20:00	102.35	9.14	29.36
179	120:00	78:00	244.36	9.14	29.36
180	180:00	59:00	795.29	9.20	29.36
			220.24	9.10	29.36
181	0:00		236.64		
182	20:00	20:00	272.56	2.78	29.36
183	24:00	2:00	276.13	2.78	29.36
184	28:00	1:00	277.98	2.78	29.36
185	32:00	1:00	279.75	2.78	29.36
186	36:00	1:00	281.56	2.78	29.36
187	50:00	3:00	286.82	2.78	29.36
	120:00	60:00	393.58	2.78	29.36

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed (Minutes: Seconds)	Sampling Time of Filter (Minutes: Seconds)	Gas Meter Reading (cubic feet/min.)	Manometer Reading (inches of Hg.)	Barometric Pressure (inches of Hg.)
188	Lab air		280.72		
189	20:00	20:00	708.50	8.80	29.18
190	41:00	20:00	847.36	8.34	29.18
191	120:00	78:00	983.34	8.34	29.18
192	Lab air		518.24	8.36	29.18
			926.15	8.40	29.18
193	Lab air		926.15		
194	20:00	20:00	392.17	8.30	29.22
195	41:00	20:00	529.31	8.30	29.22
196	120:00	78:00	666.39	8.25	29.22
197	Lab air		218.04	9.14	29.22
			640.10	9.14	29.22
198	0:00		640.10		
199	20:00	20:00	657.75	3.03	29.18
200	41:00	20:00	674.89	3.02	29.18
201	120:00	78:00	742.38	3.02	29.18
	Lab air		797.10	3.02	29.18
202	Lab air		797.10		
203	20:00	20:00	980.67	2.67	29.17
204	41:00	20:00	997.39	3.05	29.17
205	120:00	78:00	014.71	3.02	29.17
206	Lab air		081.22	3.02	29.17
			208.70	2.69	29.17

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed (Minutes: Seconds)	Sampling Time of Filter (Minutes: Seconds)	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
207	Lab air		208.70		
208	20:00	20:00	372.95	2.69	29.13
209	41:00	20:00	512.34	8.81	29.13
210	120:00	78:00	655.86	9.00	29.13
211	180:00	59:00	213.61	9.33	29.13
212	Lab air		637.63	9.28	29.13
213	Lab air		957.10	9.28	29.13
214	Lab air		072.74	8.87	29.11
			487.35	8.87	29.11
no filter	0:00		487.35		
215	18:00	18:00	516.68		
216	21:00	1:30	519.15	2.23	29.11
217	23:30	1:30	521.58	2.23	29.11
218	28:30	2:30	525.50	2.23	29.11
219	35:00	4:00	532.70	2.57	29.11
220	46:00	8:00	547.29	2.75	29.11
221	59:00	12:00	569.01	2.73	29.11
	120:00	60:00	675.96	2.85	29.11
222	Lab air		675.96		
223	20:00	20:00	406.13	8.99	28.97
224	41:00	20:00	549.88	9.12	28.97
225	120:00	78:00	692.86	9.15	28.97
226	180:00	59:00	252.80	9.15	28.97
227	Lab air		665.55	9.20	28.97
			87.99	9.20	28.97

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed		Sampling Time of Filter	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
	(Minutes: Seconds)	(Minutes: Seconds)				
228	0:00			87.99		
229	20:00		20:00	124.34	2.82	29.05
230	24:00		2:00	128.09	2.82	29.05
231	28:00		1:00	129.96	2.82	29.05
232	32:00		1:00	131.85	2.82	29.05
233	36:00		1:00	133.71	2.82	29.05
234	49:00		4:00	140.73	2.82	29.05
	120:00		60:00	249.67	2.82	29.05
235	Lab air			249.67		
236	20:00		20:00	704.27	9.50	29.00
237	41:00		20:00	722.47	3.03	29.00
238	120:00		78:00	739.75	3.03	29.00
239	Lab air			806.48	3.03	29.00
				185.25	3.03	29.00
240	0:00			185.25		
241	20:00		20:00	225.84	2.77	29.00
242	24:00		2:00	229.29	2.77	29.00
243	28:00		1:00	230.99	2.77	29.00
244	31:55		0:55	232.54	2.77	29.00
245	35:30		0:30	233.52	2.77	29.00
246	39:30		0:30	234.30	2.77	29.00
247	47:30		3:00	239.40	2.83	29.00
	120:00		59:00	343.94	2.83	29.00

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time Elapsed		Sampling Time of Filter (Minutes: Seconds)	Gas Meter Reading (cubic feet/min.)	Manometer Reading (inches of Hg.)	Barometric Pressure (inches of Hg.)
	(Minutes: Seconds)	(Minutes: Seconds)				
248	Lab air			343.94		
249	20:00	20:00		889.01	8.65	29.05
250	41:00	20:00		906.92	3.04	29.05
251	120:00	78:00		924.48	3.04	29.05
252	180:00	59:00		994.33	3.04	29.05
253	Lab air			047.97	3.04	29.05
				462.87	9.20	29.05
254	20:00	20:00		462.87		
255	24:00	2:00		499.37	2.81	29.21
256	27:30	0:30		502.77	2.83	29.21
257	31:30	0:30		503.74	2.83	29.21
258	35:30	0:30		504.51	2.83	29.21
259	39:30	0:30		505.46	2.86	29.21
260	47:00	3:00		506.27	2.86	29.21
261	120:00	60:00		511.34	2.88	29.21
				619.68	2.81	29.21
262	Lab air			619.68		
263	20:00	20:00		916.36	8.22	28.84
264	41:00	20:00		933.82	3.03	28.84
265	120:00	78:00		951.14	3.03	28.84
266	Lab air			021.00	3.03	28.84
				270.31	9.70	28.84

Appendix A-4. Original sampling data. (continued)

Filter #	Total Time		Sampling Time of Filter (Minutes: Seconds)	Gas Meter Reading (cubic feet/min)	Manometer Reading (inches of Hg)	Barometric Pressure (inches of Hg)
	Elapsed (Minutes: Seconds)					
267	20:30	20:30	270.31	3.03	28.84	
268	41:00	20:00	288.60	3.04	28.84	
269	120:00	78:00	306.29	3.02	28.84	
270	Lab air		378.81	8.16	28.84	
			650.28			
271	0:00		650.28			
272	20:00	20:00	667.93	3.04	28.91	
273	41:00	20:00	684.89	3.04	28.91	
274	120:00	78:00	754.94	3.04	28.91	
	Lab air		191.82	9.12	28.91	
275	Lab air		191.82			
276	21:40	21:40	515.75	8.59	28.91	
277	41:30	19:30	535.50	3.06	28.91	
278	120:00	78:00	551.91	3.06	28.91	
279	Lab air		622.07	3.06	28.91	
			052.05	9.24	28.91	

Appendix A-5. Adjustment for lab air contamination, Hotpoint
and Frigidaire ranges.

Sample Run (filter #)	Lab Air Samples (filter #)	(Cohs/1000 ft)	Adjusted Filters (expressed in Cohs/1000ft)			
104-106	121,125,137	assume 0.2456	104 6.8144	105 2.8774	106 0.2166	
107-109	121,125,137	assume 0.2456	107 8.5914	108 1.5684	109 0.2528	
114-117	121,125,137	assume 0.2456	114 6.7794	115 2.9924	116 0.2553	117 0.0681
118-121	121,125,137	assume 0.2456	118 9.8304	119 5.4354	120 0.2725	
122-125	121,125,137	assume 0.2456	122 15.3064	123 3.9064	124 0.2932	
126-129	121,125,137	assume 0.2456	126 52.2644	127 4.9124	128 0.6103	129 0.2882
130-133	121,125,137	assume 0.2456	130 12.0024	131 2.0094	132 0.3596	133 0.1226
134-137	121,125,137	assume 0.2456	134 17.7924	135 2.1124	136 0.1828	
138-141	121,125,137	assume 0.2456	138 0.1154	139 0.0812	140 0.3874	141 0.2407
142-145	121,125,137	assume 0.2456	142 0.0784	143 0.0563	144 0.2621	145 0.2899
146-150	150	0.2319	146 1.0301	147 0.0478	148 0.0516	149 0.0283
151-156	151,156	0.2135	152 0.7206	153 0.1348	154 0.2075	155 0.0370
157-162	157,162	0.2540	158 0.6896	159 0.1546	160 0.1629	161 0.0511
163-170	165,170	0.2134	166 0.2634	167 0.1720	168 0.2008	169 0.0356
171-175	171,175	0.2336	172 0.1227	173 -0.0466	174 0.0043	

Appendix A-5. Adjustment for lab air contamination, Hotpoint
and Frigidaire ranges. (Concluded)

Sample Run (filter #)	Lab Air Samples (filter #)	(Cohs/1000 ft)	Adjusted Filters (expressed in Cohs/1000ft)			
176-180	176,180	0.3088	177 0.1414	178 0.0421	179 -0.0185	
188-192	188,192	0.1864	189 0.2240	190 0.0099	191 -0.0211	
193-197	197	0.2536	194 0.4783	195 0.0796	196 0.0458	
197-201	197,201	0.2034	198 4.3986	199 0.2701	200 -0.0112	
202-206	206	0.3057	203 6.7893	204 3.3293	205 0.2837	
207-212	207,212	0.3282	208 0.2292	209 -0.0059	210 0.0006	211 0.0499
222-227	222,227	0.2468	223 0.4853	224 0.0820	225 0.0453	226 0.0214
235-239	235,239	0.1742	236 17.2628	237 2.9798	238 0.2172	
248-252	248,253	0.0466	249 11.0554	250 8.3424	251 0.4922	252 0.0481
263-265	262,266	0.1045	263 28.2155	264 5.4955	265 0.3398	
266-270	266,270	0.1525	267 23.3975	268 7.6025	269 0.6985	
271-274	274	0.1734	271 8.2106	272 2.3186	273 0.3642	
275-279	275,279	0.2061	276 10.1909	277 4.3719	278 0.5386	

Appendix A-6. Coefficient of haze (Coh) calculations.

$$\text{Coh/1000 ft (soiling index)} = \frac{10^5 \text{ O.D.}}{Q/A} \quad \text{Eq. (1)}$$

$$\text{where: O.D.} = \log_{10} \frac{T_o}{T}$$

Q = volume sample, 1000 cu ft
 A = active filter area, sq ft
 T_o = initial light transmittancy
 T = final light transmittancy

This is also equivalent to:

$$\text{Coh/1000 ft} = \frac{10^2 \text{ O.D.}}{L} \quad \text{Eq. (2)}$$

$$\text{where: O.D.} = \log_{10} \frac{T_o}{T}$$

$$L = \frac{\text{flow (cu ft/min)} \times \text{sampling time in min}}{1000 \times \text{circular area of spot (sq ft)}}$$

T_o = initial light transmittancy
 T = final light transmittancy

Calculation Example: 107-109

$$\#107. \text{ O.D.} = \log_{10} \frac{942}{690} = 0.13520$$

$$\text{Meter vacuum} = 29.03 - 3.03 = 26.00 \text{ in. Hg}$$

$$Q_m = 780.49 - 762.21 = 18.28 \text{ cu ft}$$

$$Q_{F.A.} = 18.28 \cdot \left(\frac{26.00}{29.03} \right) = 16.37 \text{ cu ft}$$

$$L = \frac{16.37}{(0.0107)(1000)} = 1.530 \text{ tf}$$

$$\text{Soiling Index} = \frac{100(0.13520)}{1.530} = 8.837 \text{ Cohs/1000 ft}$$

$$\#108. \text{ O.D.} = \log_{10} \frac{941}{886} = 0.02616$$

$$Q_m = 797.72 - 780.49 = 17.23 \text{ cu ft}$$

$$Q_{F.A.} = 17.23 \cdot \left(\frac{26.00}{29.03} \right) = 15.43 \text{ cu ft}$$

$$L = \frac{15.43}{(0.0107)(1000)} = 1.442 \text{ tf}$$

$$\text{Soiling Index} = \frac{100(0.02616)}{1.442} = 1.814 \text{ Cohs/1000 ft}$$

$$\#109. \text{ O.D.} = \log_{10} \frac{929}{869} = 0.02900$$

$$Q_m = 867.23 - 797.72 = 69.51 \text{ cu ft}$$

$$Q_{F.A.} = 69.51 \cdot \left(\frac{26.00}{29.03} \right) = 62.25 \text{ cu ft}$$

$$L = \frac{62.25}{(0.0107)(1000)} = 5.818 \text{ tf}$$

$$\text{Soiling Index} = \frac{100(0.02900)}{5.818} = 0.4984 \text{ Cohs/1000 ft}$$

Total Cohs for #107-109:

$$\#107: 1.530 \text{ tf} \times 8.5914 \text{ Cohs/tf} = \underline{13.1448 \text{ Cohs}}$$

$$1 \text{ min off: } (1.530\text{tf}/20\text{min} + 1.442\text{tf}/20\text{min}) \div 2 = 0.0743 \text{ tf/min}$$

$$(8.5914 \text{ Cohs/tf} + 1.5684 \text{ Cohs/tf}) \div 2 = 5.0799 \text{ Cohs/tf/min}$$

$$0.0743 \text{ tf/min} \times 5.0799 \text{ Cohs/tf/min} = \underline{0.3774 \text{ Cohs}}$$

$$\#108: 1.442 \text{ tf} \times 1.5684 \text{ Cohs/tf} = \underline{2.2616 \text{ Cohs}}$$

$$1 \text{ min off: } (1.442\text{tf}/20\text{min} + 5.818\text{tf}/78\text{min}) \div 2 = 0.0733 \text{ tf/min}$$

$$(1.5684 \text{ Cohs/tf} + 0.2528 \text{ Cohs/tf}) \div 2 = 0.9106 \text{ Cohs/tf/min}$$

$$0.0733 \text{ tf/min} \times 0.9106 \text{ Cohs/tf/min} = \underline{0.0667 \text{ Cohs}}$$

$$\#109: 0.2528 \text{ Cohs/tf} \times 5.818 \text{ tf} = \underline{1.4708 \text{ Cohs}}$$

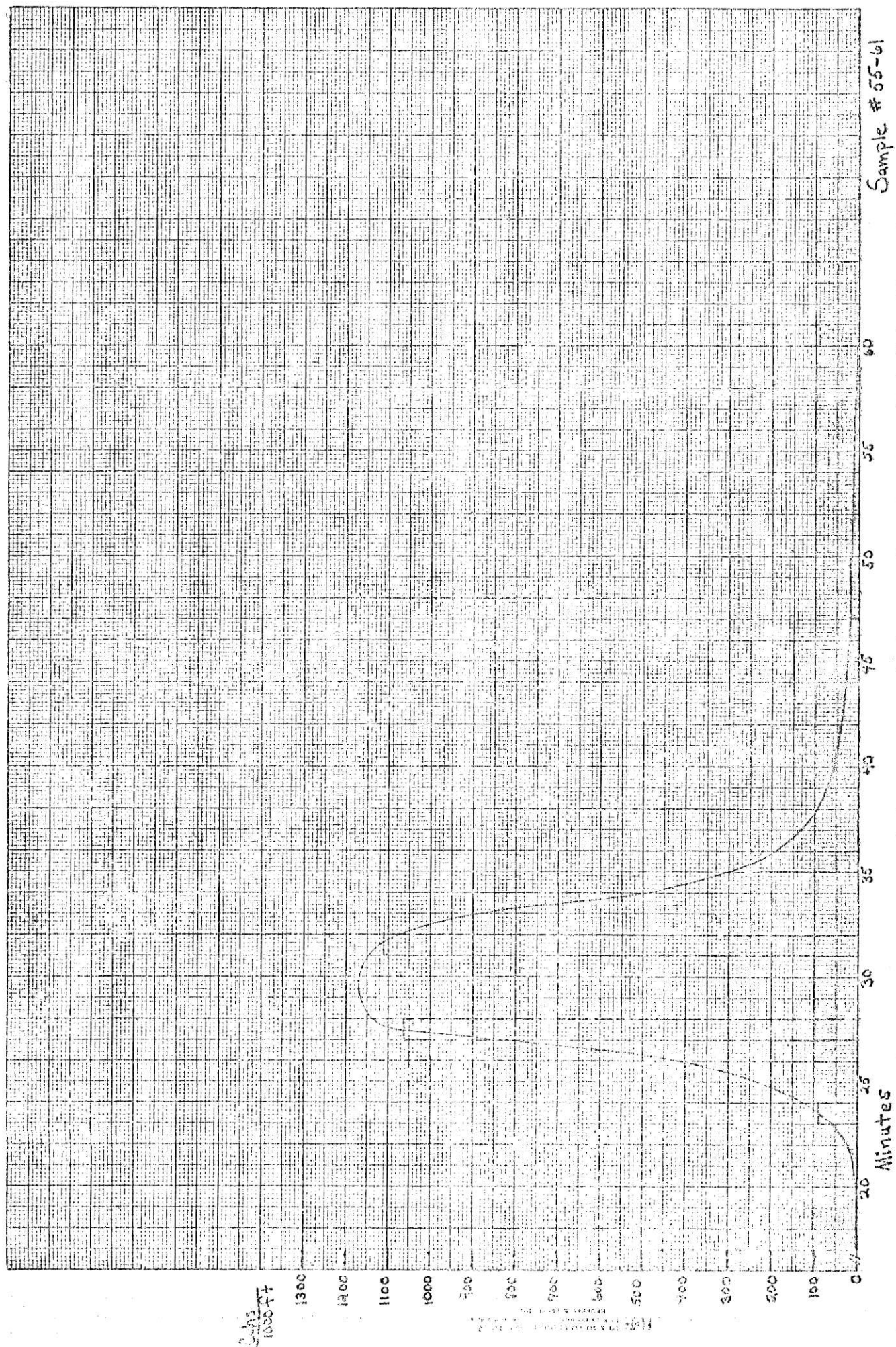
$$\text{Total} = \underline{\underline{17.3213 \text{ Cohs}}}$$

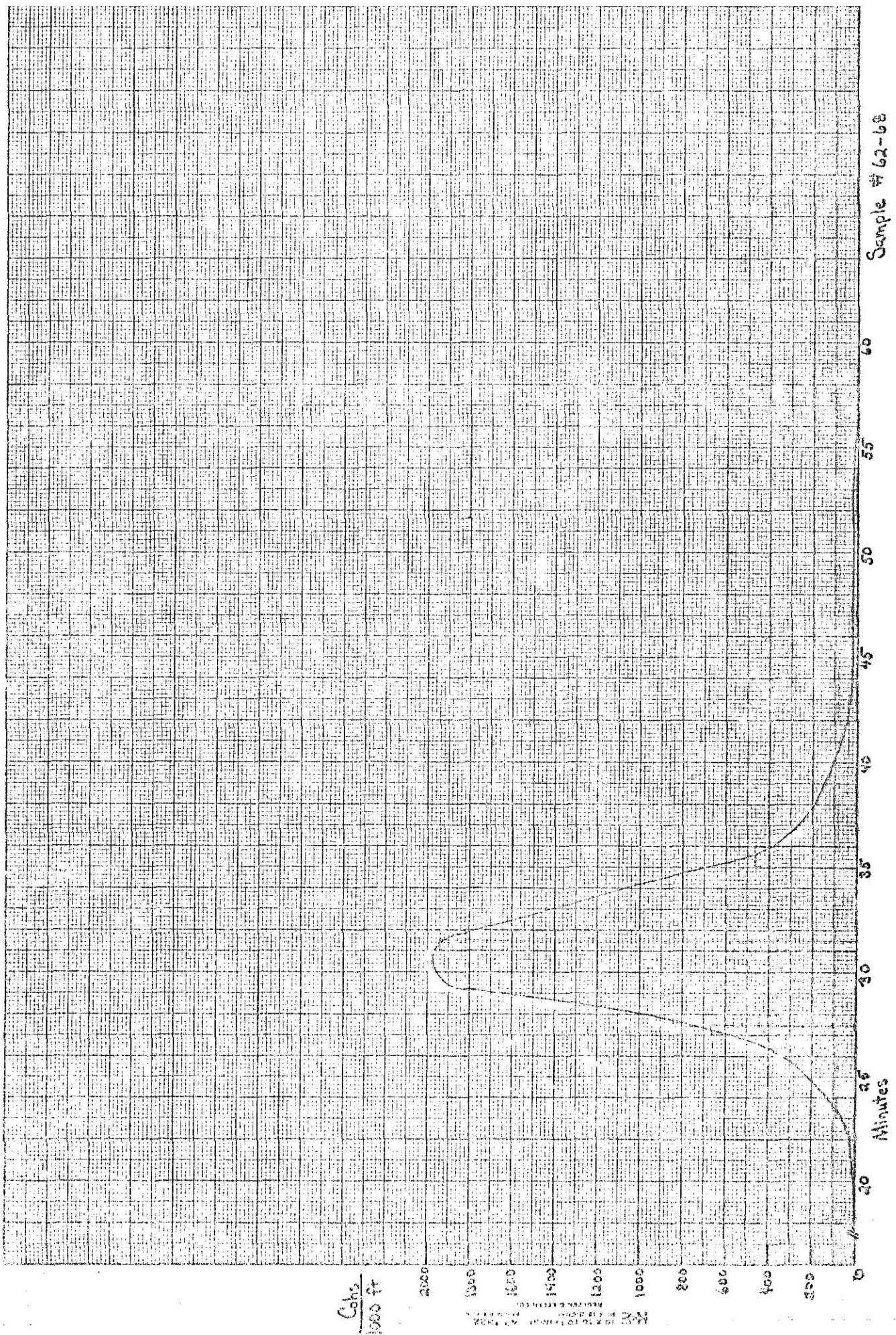
Appendix A-7. Graphs of Corning soiling data.

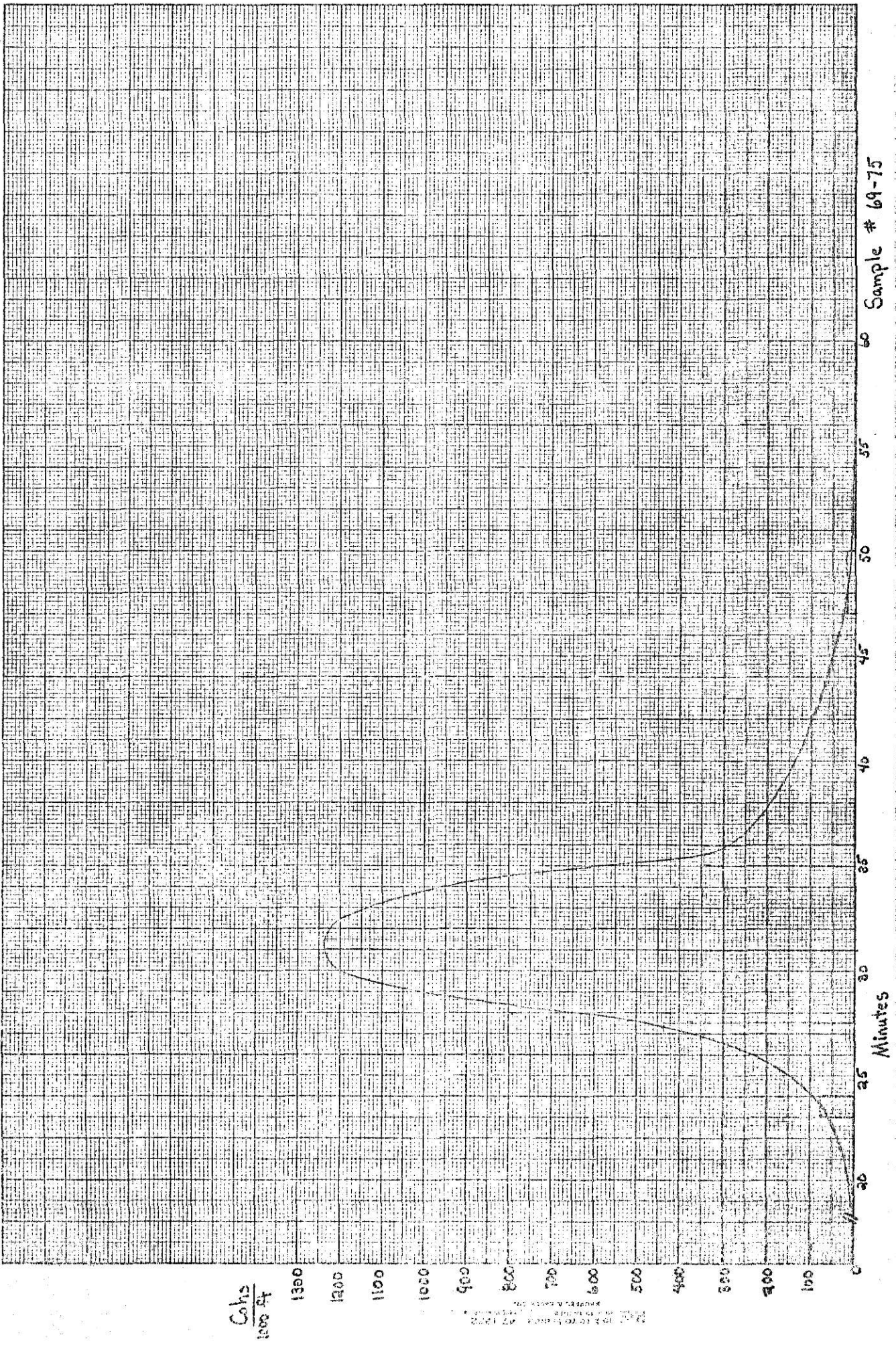
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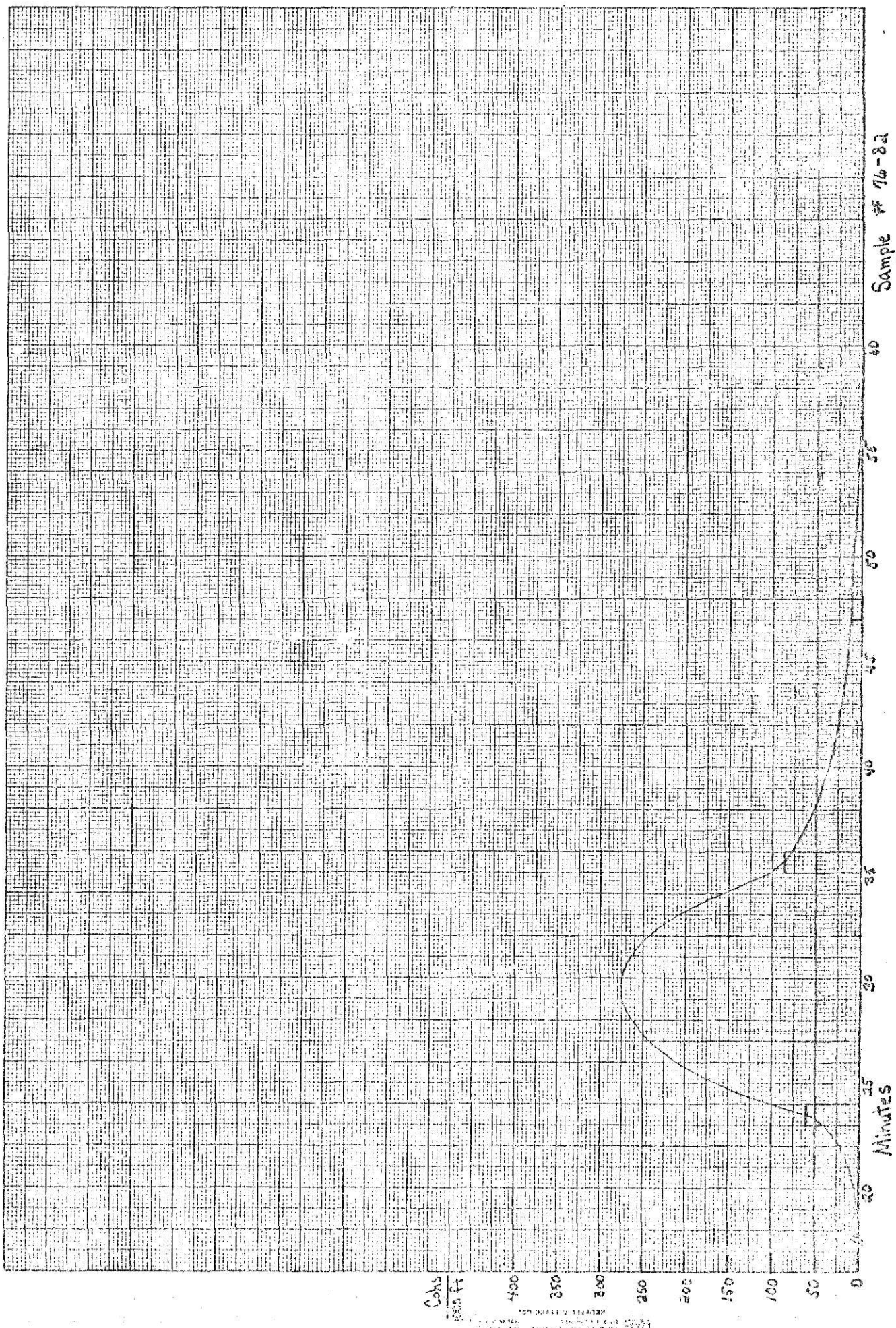


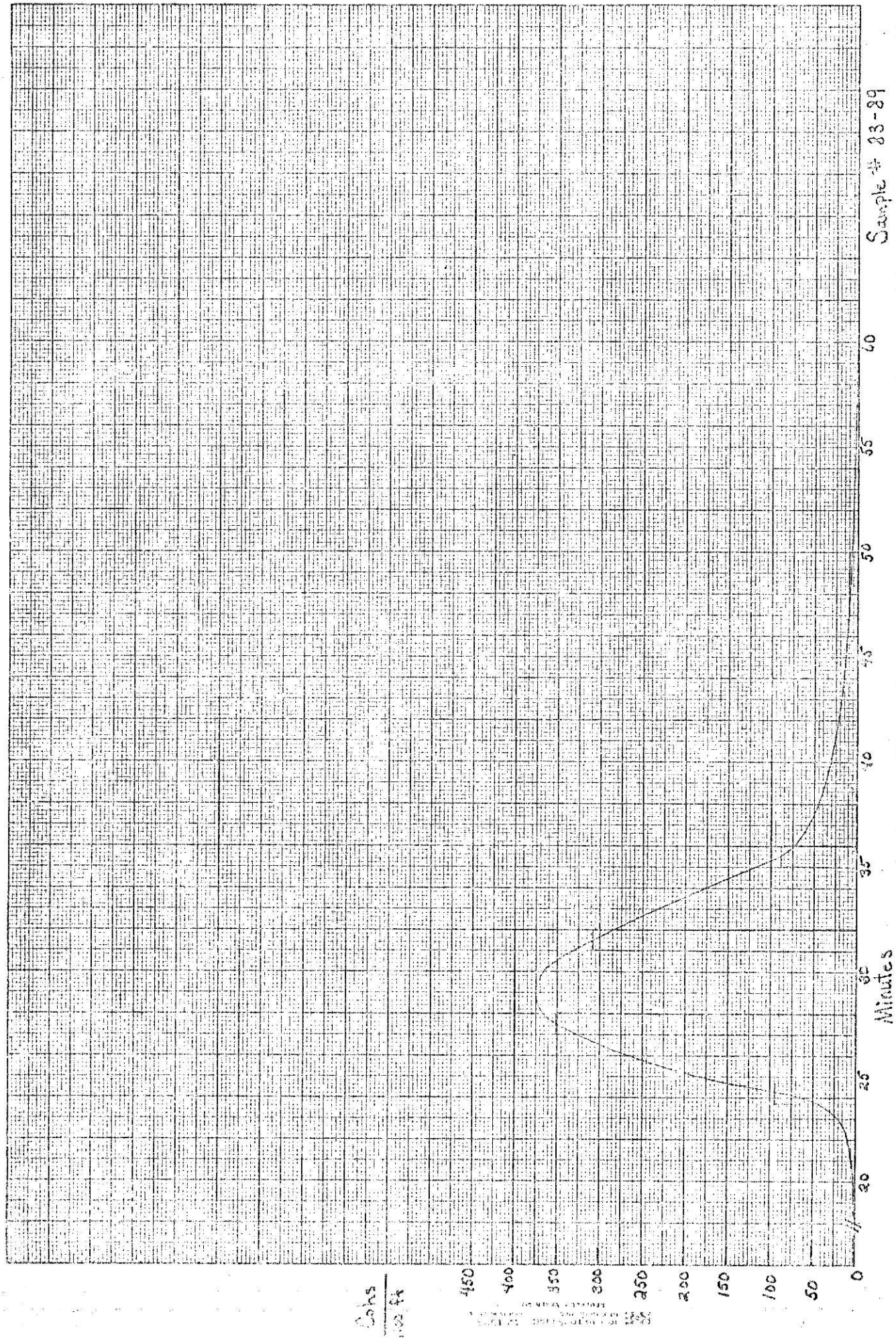


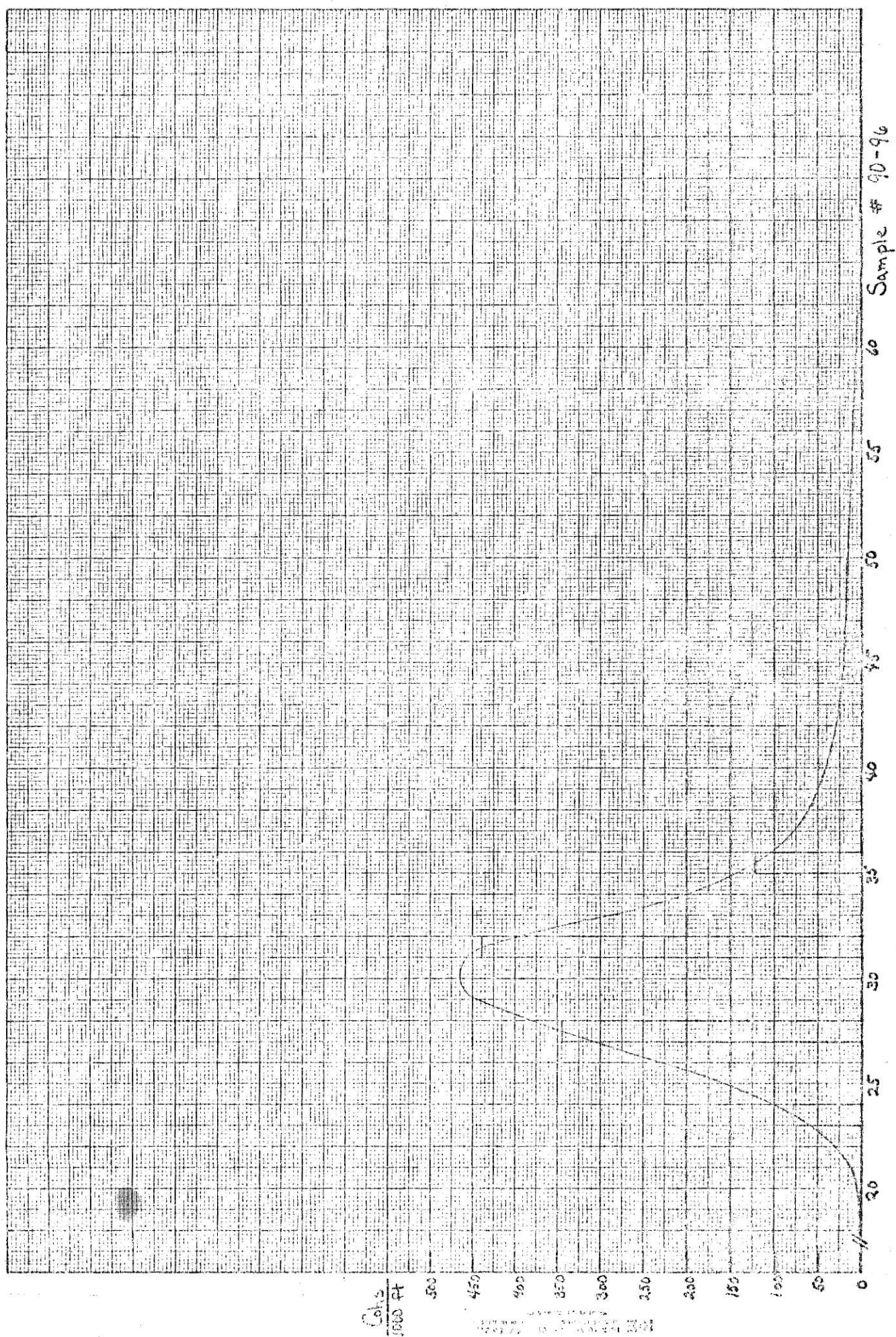
Cohs
100 ft

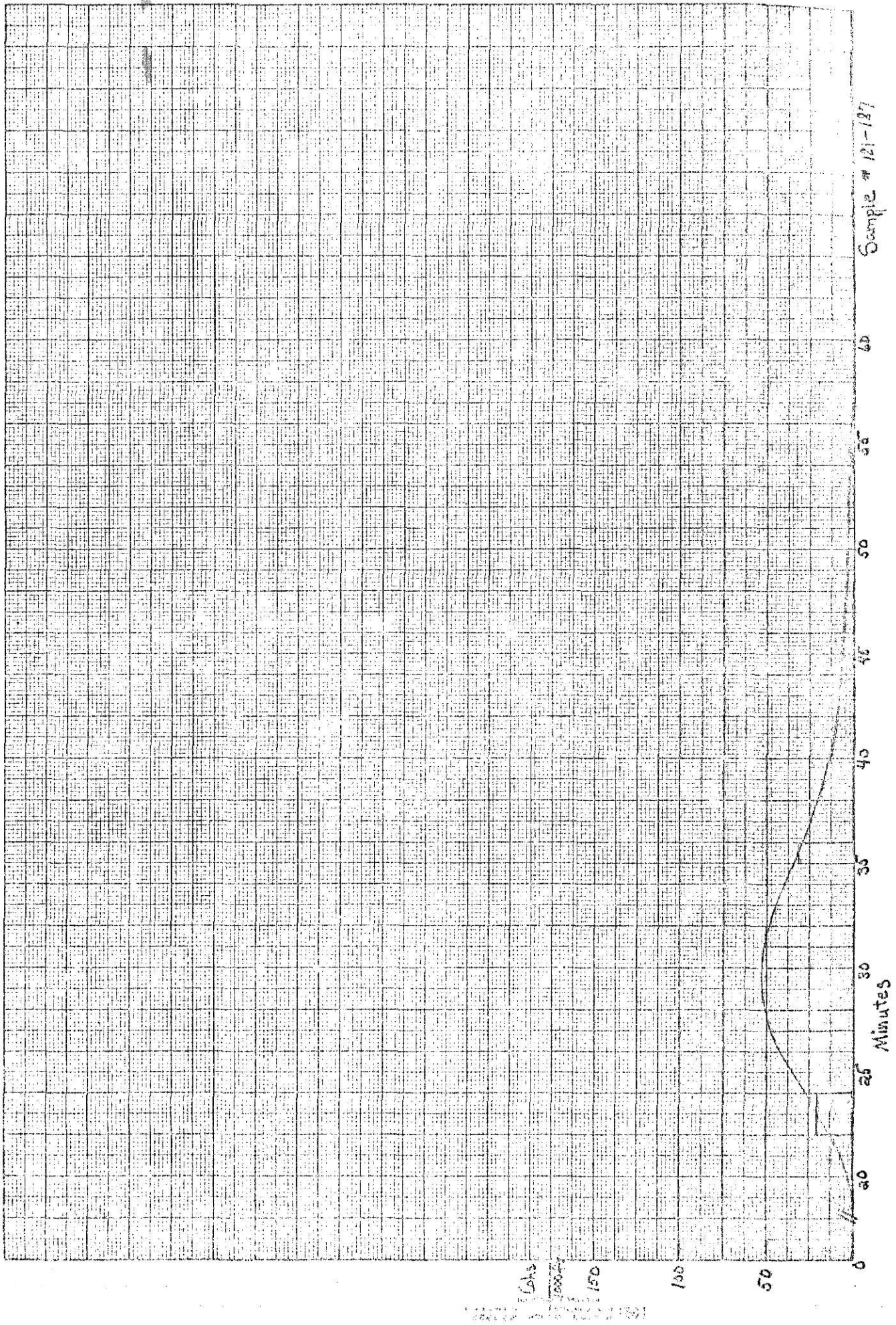
Sample # 69-75

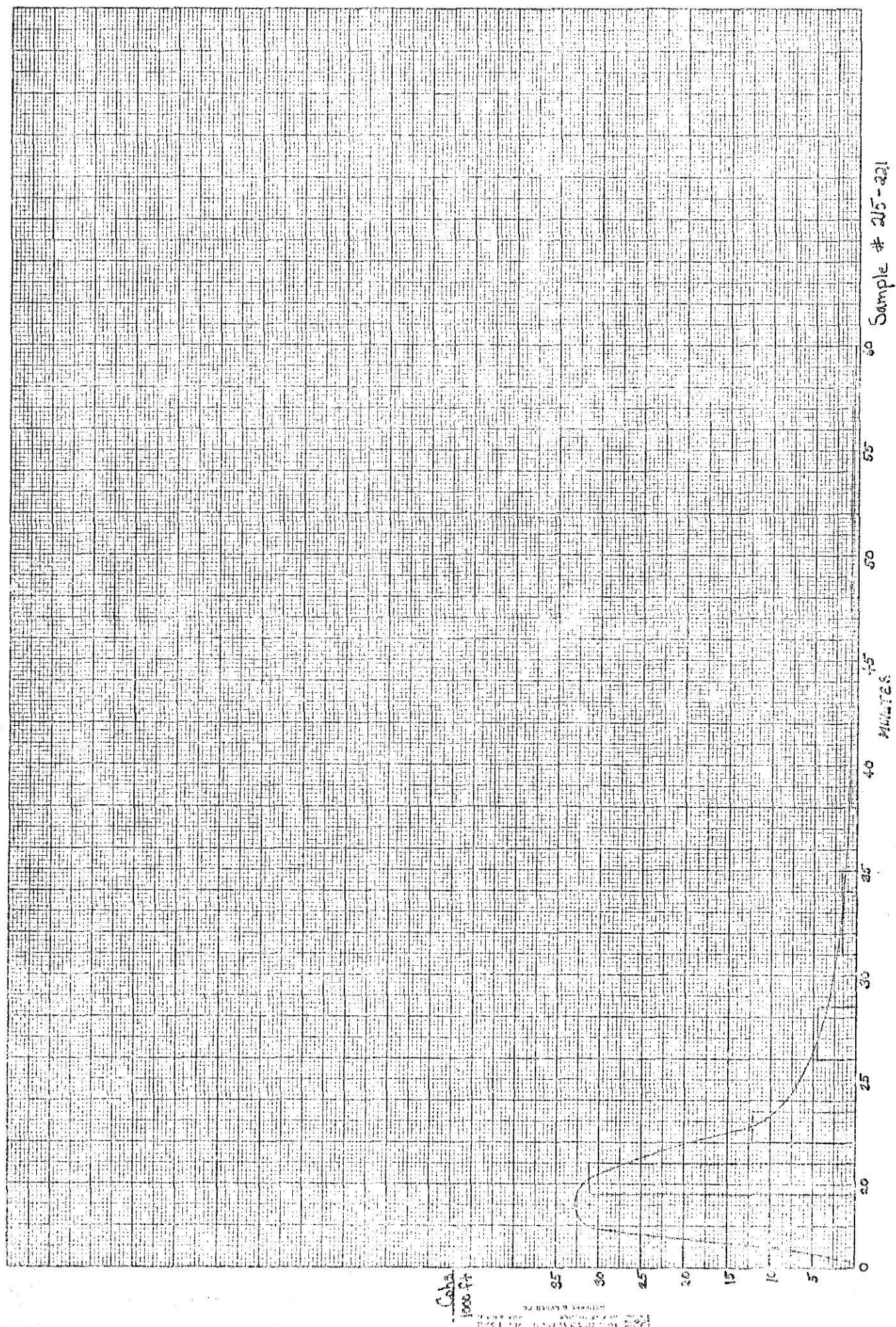
Minutes

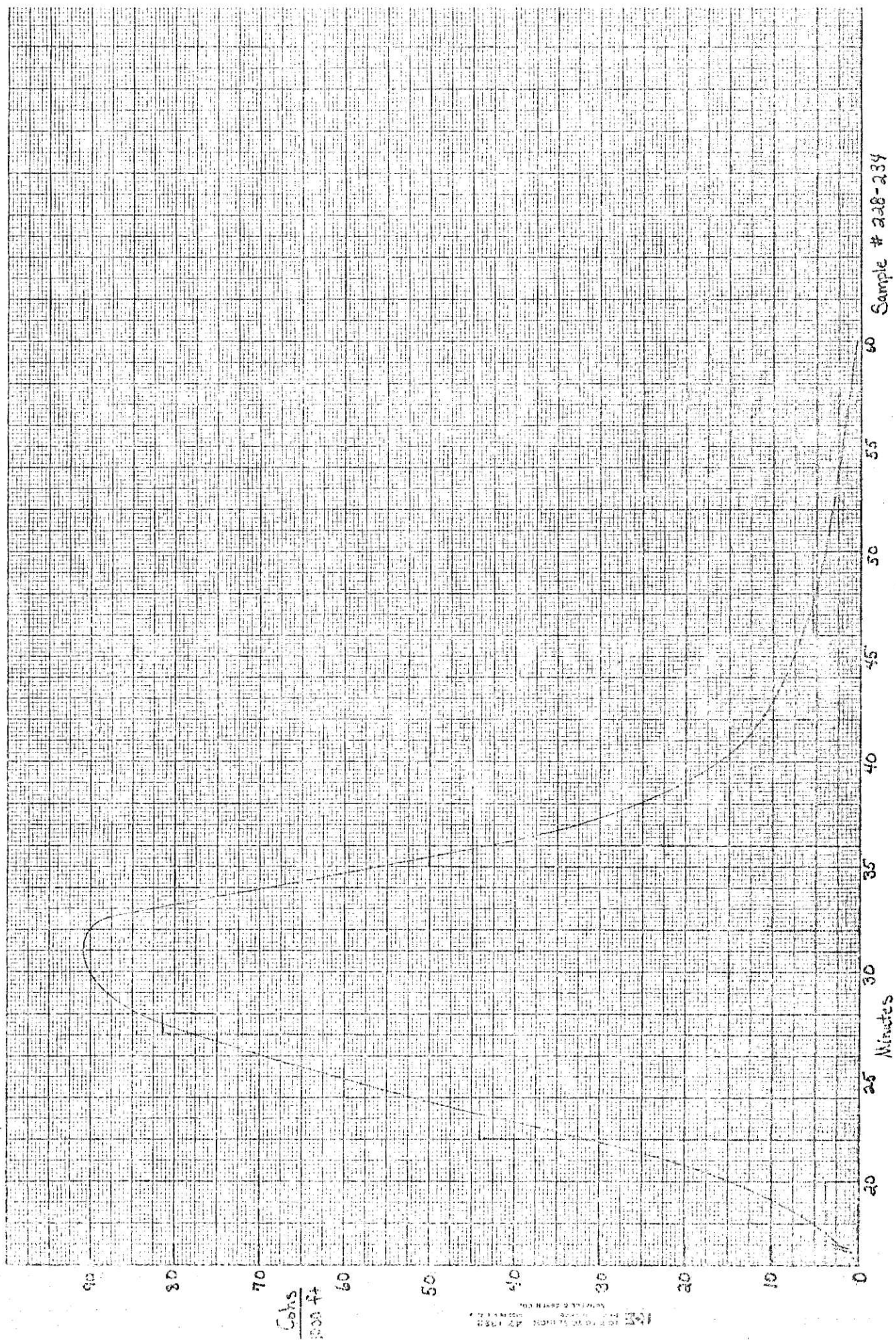


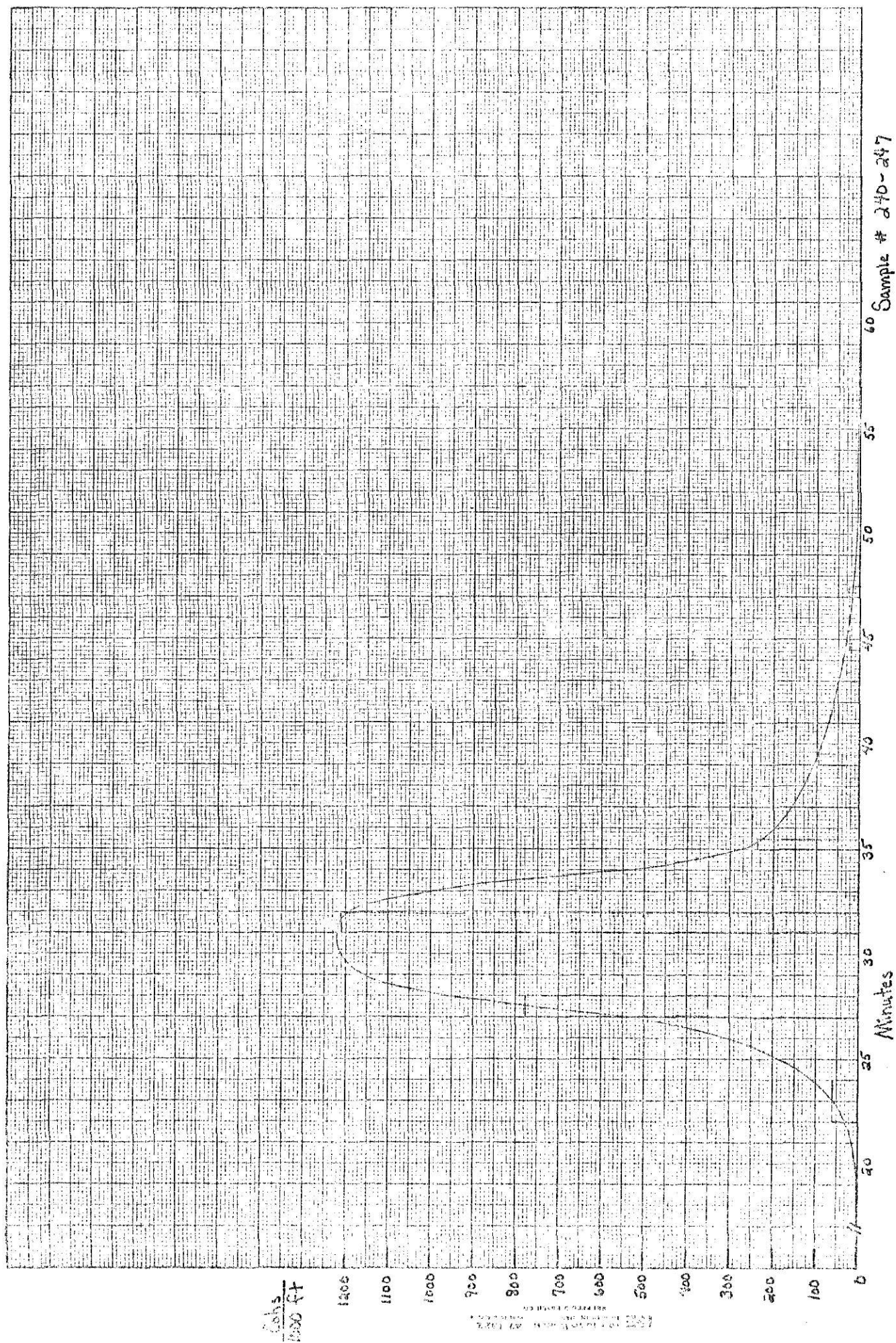


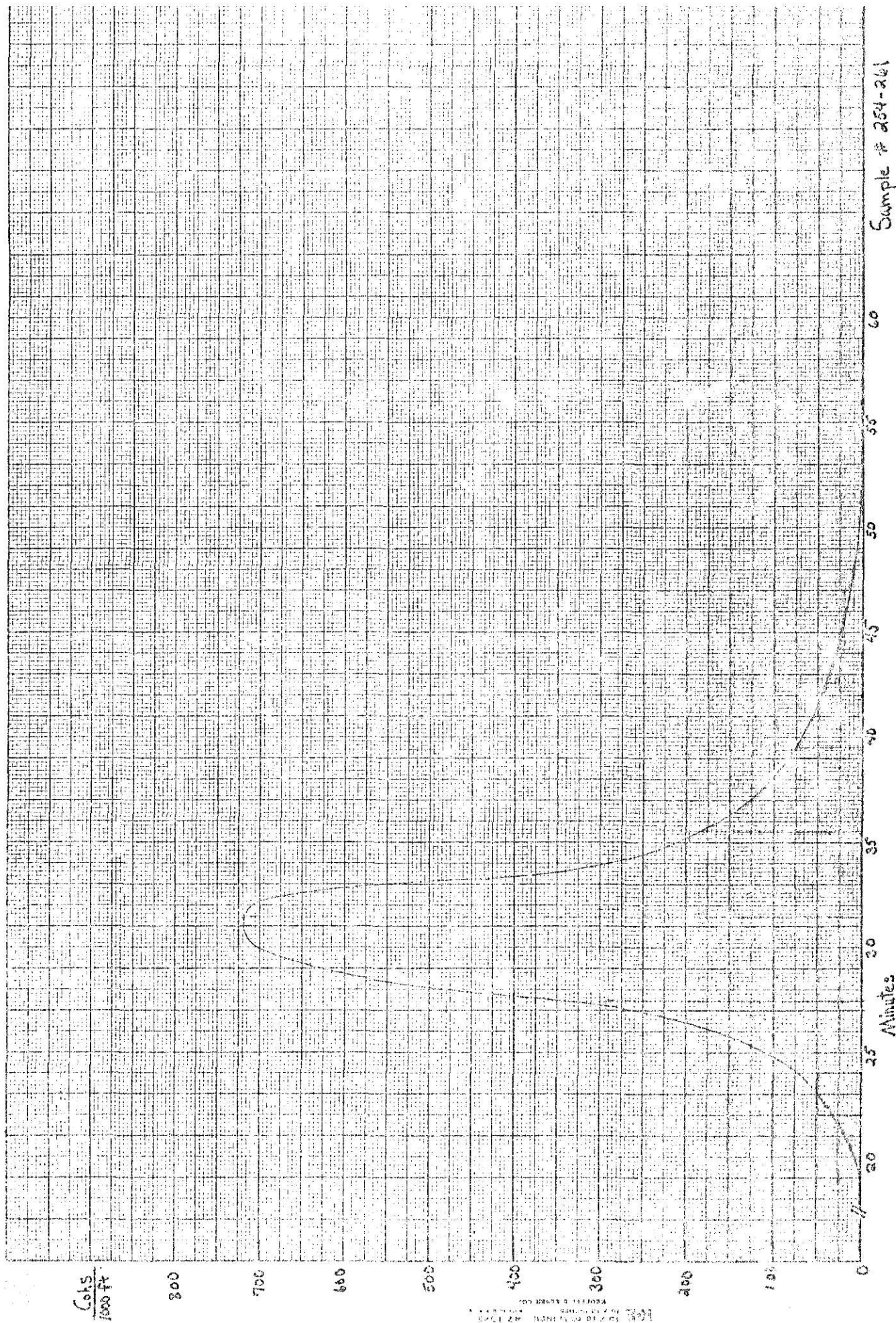












Sample # 254-261

Appendix A-8. Equations and examples of statistical analyses.

Testing of Variance¹

The F-distribution is the sampling distribution of the statistic $s_i^2 \sigma_j'^2 / s_j^2 \sigma_i'^2$, the ratio of variance.

$$\text{where: } s_i^2 = \frac{\sum X_i^2 - (\sum X_i)^2}{N_i}, \text{ an unbiased estimate of } \sigma_i'^2$$

$$s_j^2 = \frac{\sum X_j^2 - (\sum X_j)^2}{N_j}, \text{ an unbiased estimate of } \sigma_j'^2$$

$$n_i = N_i - 1 = \text{degrees of freedom}$$

$$n_j = N_j - 1 = \text{degrees of freedom}$$

Since the null hypothesis is $\sigma_i'^2 = \sigma_j'^2$, check $\frac{s_i^2}{s_j^2}$ against values in

F-tables². Obtain values of F for parameters, n_i and n_j where n_i corresponds to the " s^2 " used in the numerator of $\frac{s_i^2}{s_j^2}$.

Example: Test for equality of variance between Corning half-soil results and Hotpoint half-soil results.

$$H_0: \sigma_i'^2 = \sigma_j'^2$$

$$H_i: \sigma_i'^2 \neq \sigma_j'^2$$

$$s_i^2 = \frac{941,300.72 - 922,621.47}{2} = 9339.62$$

$$s_j^2 = \frac{8968.49 - 6855.49}{9} = 234.78$$

¹Equations from Duncan (1953), p. 402-404.

²Table J from Duncan (1953), p. 618.

Appendix A-8. Equations and examples of statistical analyses. (continued)

$$\frac{s_i^2}{s_j^2} = \frac{9339.62}{234.78} = 39.78$$

$$F_{.05, 2, 9} = 4.26$$

$$39.78 > 4.26$$

$$\text{Therefore, } \sigma_i'^2 \neq \sigma_j'^2$$

Testing the Difference between Means of Two Small Independent SamplesWhere σ_i' Is Assumed Equal to σ_j' .¹

$$t = \frac{d - d_o'}{s \sqrt{\frac{1}{N_i} + \frac{1}{N_j}}} \quad \text{Eq. (3)}$$

$$s = \sqrt{\frac{1}{N_i} + \frac{1}{N_j}}$$

$$n = N_i + N_j - 2$$

$$d = \bar{X}_i - \bar{X}_j$$

$$d_o' = \text{hypothetical value for } \bar{X}_i' - \bar{X}_j'$$

$$s = \sqrt{\frac{N_i \sigma_i'^2 + N_j \sigma_j'^2}{N_i + N_j - 2}}$$

Example: t-test for difference between full and half level of soiling for Hotpoint range.

$$H_0: \bar{X}_j' = \bar{X}_i' \quad H_1: \bar{X}_j' - \bar{X}_i' > 0$$

$$t = \frac{38.36 - 26.18}{s \sqrt{\frac{1}{10} + \frac{1}{6}}}$$

¹From Duncan (1953), p. 394.

Appendix A-8. Equations and examples of statistical analyses. (continued)

$$s = \sqrt{\frac{2113.02 + 3638.55}{14}} = 20.27$$

$$t = \frac{38.36 - 26.18}{20.27 \sqrt{\frac{1}{10} + \frac{1}{6}}}$$

$$= 1.16$$

$$t_{.05,14} = 1.761$$

$$1.761 > 1.16$$

Therefore, $H_0: \bar{X}_j = \bar{X}_i$ cannot be rejected.

Testing the Difference between Means of Two Small Independent Samples

Where σ_i^2 Is Not Equal to σ_j^2 .¹

If $N_i = N_j$, the value of "t" is calculated with Equation 3 with $n = N_i - 1 = N_j - 1$.

If $N_i \neq N_j$, separate "t"s are computed for each sample; and critical "t" is a weighted average of the two "t"s.

$$\text{statistic } t = \frac{\bar{X}_i - \bar{X}_j}{\sqrt{s_{\bar{X}_i}^2 + s_{\bar{X}_j}^2}}$$

$$\text{where: } s_{\bar{X}_i}^2 = \frac{s_i^2}{N_i}$$

$$s_{\bar{X}_j}^2 = \frac{s_j^2}{N_j}$$

¹From Duncan (1953), pp. 398-399.

Appendix A-8. Equations and examples of statistical analyses. (concluded)

$$\text{Critical } t = \frac{s_{\bar{x}_i}^2 t_i + s_{\bar{x}_j}^2 t_j}{s_{\bar{x}_i}^2 + s_{\bar{x}_j}^2}$$

$$\text{where: } t_i = N_i - 1$$

$$t_j = N_j - 1$$

Example: t-test for difference between half and full level of soiling for Corning range.

$$H_0: \bar{x}'_j = \bar{x}'_i$$

$$H_1: \bar{x}'_j - \bar{x}'_i > 0$$

$$s_{\bar{x}_i}^2 = \frac{189,869.25}{5}$$

$$= 37,973.85$$

$$s_{\bar{x}_j}^2 = \frac{9339.62}{3}$$

$$= 3113.21$$

$$t_i = 2.132$$

$$t_j = 2.920$$

$$\text{critical } t = \frac{311.21 (2.920) + 37,973.85 (2.132)}{3113.21 + 37,973.85}$$

$$= 2.19$$

$$\text{statistic } t = \frac{1483.61 - 554.56}{\sqrt{41,087.06}}$$

$$= 4.58$$

$$4.58 > 2.19$$

Therefore, H_0 is rejected; and H_1 is accepted.

May 18, 1976

Mrs. Patty J. Annis
Assistant Professor
Kansas State University
Department of Family Economics
Justin Hall
Manhattan, Kansas 66506

Dear Professor Annis:

In response to your inquiry of April 29, 1976, we offer you the following information:

Smoke Eliminator - The following is a categorization of devices available to range manufacturers. This categorization is by materials, only.

1. There are two types of catalytic solutions that may be applied to a base material:

- a) Palladium
- b) Platinum

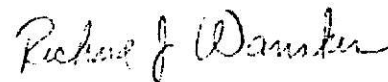
2. The above solutions are applied to the following base materials:

- 1. Ceramic
- 2. Asbestos
- 3. Stainless Steel
- 4. Stainless Steel and Asbestos combination

We hope this information will be helpful to your study. If we can be of further assistance, please let us know.

Sincerely,

TRW-CARR DIVISION



R.J. Wansker
Marketing Manager
Appliance/Consumer Electronics

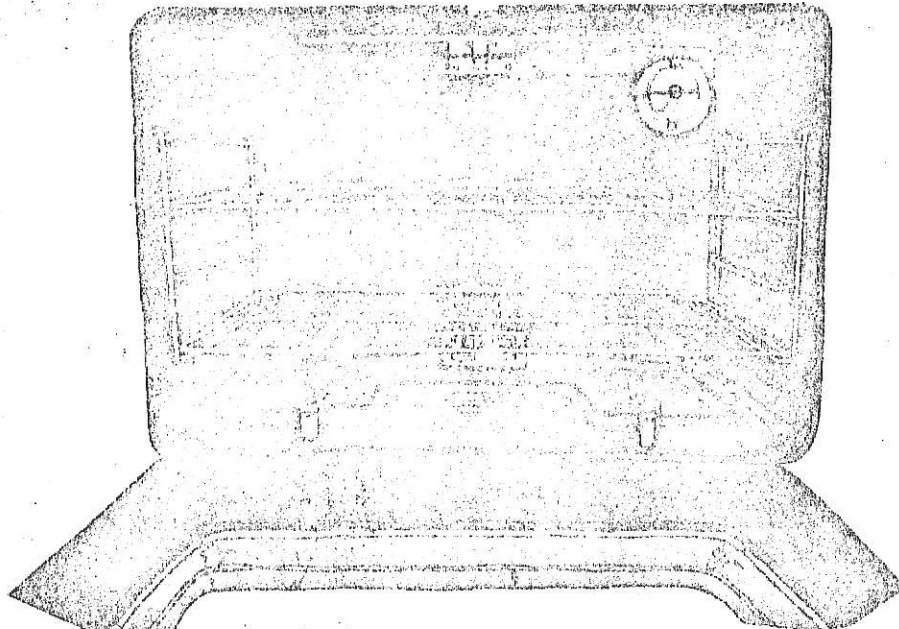
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General Electric's position on oven cleaning

D.W. Lynch, Vice President & General Manager, Range Products Division 95



Background. It is well known that the General Electric Company invented the "pyrolytic self cleaning" oven. It is not well known that General Electric was also involved in the original development of ceramic catalytic oven coatings as an alternate to "self-cleaning," and has continued to test extensively these and similar coatings, now referred to as "continuous cleaning" coatings. Therefore, we believe we are well informed on both approaches. Since we are introducing ranges utilizing a porous ceramic oven liner coating, we wish to make our position clear regarding these two methods.

The "Self-Cleaning" System. The "self-cleaning" oven is a fully automatic oven cleaning system. It cleans the entire oven interior including the oven door inner panel, oven door window, oven racks, and oven light covers. It will also clean heat resistant surface wall reflector pans as well as auxiliary oven panels, if they are placed in the self-cleaning oven.

The "self-cleaning" oven finish is an attractive, glossy porcelain enamel, resistant to food soil staining. The "self-cleaning" process uses heat and air to convert oven food-soil into a vapor. A smoke and odor eliminator in the vent cleans the vapor before it is exhausted. The only residue remaining is an occasional light ash which can be readily wiped out.

Self-cleaning ovens have more thermal insulation than standard ovens to keep surface temperatures down during the cleaning cycle. Therefore, during normal oven use, which is most of the time, they operate cooler and more efficiently. Depending on electrical rates, it costs about 9¢ to 11¢ for each oven cleaning cycle.

The "Continuous Cleaning" Coating. "Continuous Cleaning" is not a complete soil removal process but refers to ranges with special

porous ceramic coated ovens. These coatings are dark in color, rough in texture, somewhat low in abrasion resistance and have a high degree of porosity. This coating is not used on racks, windows, or oven light covers, which must be cleaned by hand.

The important point to realize is that both the porous ceramic or so-called "continuous cleaning" coatings and standard porcelain enamel lose some soil weight at oven bake temperatures. The significant difference between the two is that the dark porous ceramic surface tends to maintain its original appearance because of its soil-hiding or masking characteristics. This can be an advantage to people who do not use their oven frequently with heavy soil-producing loads, such as roasts and broiled meats. The worst problem for porous ceramic coatings is repetitious heavy soiling. This typically occurs on the oven bottom from spillovers of pies, casseroles, or heavy fat drippings. Such excess soiling exceeds the ability of the surface to absorb and mask.

General Electric's Position. We are concerned by the marketplace confusion between these two methods. This may result in unhappy customers, and will not be to the ultimate benefit of the range industry. We believe most salespeople are honestly trying to differentiate, but in many cases do not have the facts to do so. We are convinced the customer deserves better clarification than she is presently getting. With proper clarification, the advantages of each can be sold on its merits. "Self-cleaning" offers more and costs more. Porous ceramic or "continuous cleaning" provides a presentably clean look on coated oven surfaces only (except possibly the bottom) and costs less. In time, depending on usage, some permanent staining of the porous ceramic

surface can be expected.

In order to provide a choice, the General Electric Company will offer through its brands, selected models with the porous ceramic coating. On the oven bottom we will use a panel coated with standard porcelain enamel for easy removal and cleaning.

However, because of the confusion that has arisen around the "continuous cleaning" name, by frequent and incorrect identification with self-cleaning, General Electric will use a more descriptive term. Our term for the porous ceramic coating will be "Clean-Look" finish, because of its unique ability to hide levels of soil that would otherwise be unsightly on a standard oven liner.

We would welcome the use of this term by others in an effort to eliminate possible confusion in minds of the consumer.

General Electric continues to believe the "self-cleaning" oven is desired by most housewives interested in eliminating the oven cleaning chore. However, for those who want the lower cost "Clean-Look" oven finish, we think they should clearly know its limitations. Therefore, in addition to the name change, these limitations will be in our range literature and imprinted on the removable oven bottom panel. We believe dealers and customers will welcome this clarification, because it should result in satisfied users. We hope manufacturers and retailers alike will view this as a constructive and needed step in an industry noted for its fine contributions.



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EFFECTS OF THE SELF-CLEANING OVEN
ON RESIDENTIAL AIR QUALITY

by

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B.S., Kansas State University, 1975

AN ABSTRACT OF A MASTER'S THESIS

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This study was concerned with inside air quality. Effects of three self-cleaning ovens, each of a different brand, on residential air quality were determined by measuring the smoke emitted by the ovens during their self-cleaning cycle.

The soiling technique was adapted from the American Home Appliance Manufacturers soiling standard, ER-3. Two levels of soiling were used to analyze oven capacity to eliminate smoke from the by-products of the pyrolysis process.

The oven exhaust was isokinetically sampled; the sample filters were analyzed by the light-scattering technique. A photometer measured initial and final light transmittancy of the filter paper. This, with other sampling data, was used to calculate the soiling index (Coh/1000 cu ft) of the oven exhaust.

The soiling index was used to evaluate the smoke-eliminating capacities of the ovens. Statistically significant differences were found among ranges and between levels of soiling. The Corning range emitted significantly higher levels of smoke than the Hotpoint and Frigidaire ranges, and the Hotpoint range emitted significantly higher levels of smoke than the Frigidaire range. Significantly higher levels of smoke were emitted with full-soil than with half-soil for both the Corning and Frigidaire ranges. No significant difference occurred between levels of soiling in the Hotpoint range.

Using as a quantitative measure the product of soiling index and sampled air volume, smohs (Coh x sq ft), the oven smoke emission from

cleaning was related to an equivalent number of smoked cigarettes. The cigarette equivalency ranged from 0.002 cigarettes in the lowest smoke-emission run to 3.0 cigarettes in the highest, representing increases of 1% and 2,754%, respectively, over normal residential levels in a 1360 cu ft room in Manhattan, Kansas.

Recommendations concerning usage and purchasing of a self-cleaning oven are stated for consumers. Additional studies of the relative effectiveness of different oven smoke elimination systems and the health implications related to their usage are urged of researchers.