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The "Teepee" type wood residue incinerator, similar to many other sources, requires sampling at the point where the emissions enter the atmosphere. Because the location of the emission point is hazardous and unpleasant for the operation of a sampling probe, a portable, tilt-up column was developed which permitted installation, operation, and retrieval of the sampling train from ground level.

The sampling train used permitted determination of the size distribution and weight of the particulate emitted by this highly variable source.

AN EMISSION SAMPLING DEVICE INSTALLED, OPERATED, AND RETRIEVED FROM GROUND LEVEL

by

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K. R. W.

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INTRODUCTION

At the present time one of the air pollution problems which exists in the Pacific Northwest can be traced directly to the incineration of wood residues by the lumber industry. In the manufacture of lumber or plywood considerable waste material is produced. Presently one economical way to dispose of this residue is incineration. During the summer of 1964 a study was conducted by the Oregon State University Engineering Experiment Station for the Associated Oregon Industries, Forest Industries Air Quality Committee, in the Medford, Oregon area. In this report the magnitude of the air pollution caused by wood residue incineration is indicated: "The particulate emissions charged to the lumber industry varies from 90% to 96% of the total released from all sources" (1, p. 21) and, "The dustfall at the sampling stations therefore ranged from 10.9 tons per square mile per month to 68.9 tons per square mile per month above background with a mean of 46 tons per square mile per month. Since the State of Oregon considers anything greater than 15 tons per square mile per month above background as excessive in residential and commercial areas, the dustfall level was far from being acceptable during the sampling period" (1, p. 24). There are over 500

"Teepee" type incinerators located in Oregon only 30 of which are located in the Medford area (3).

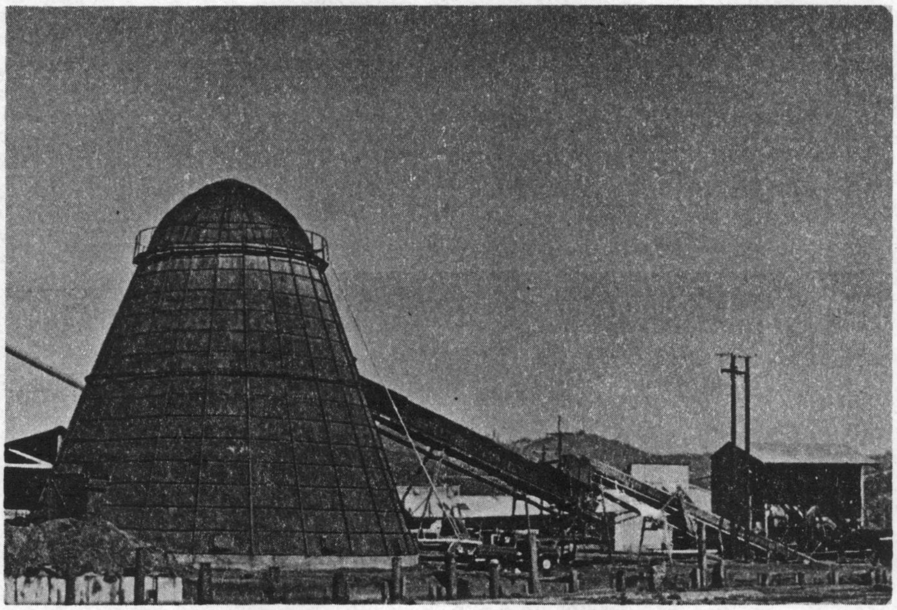

Figure 1. Typical "Teepee" type incinerator.

Due to the significant contribution of "Teepee" type incinerators to the air pollution in some communities, a study was conducted to learn more about the characteristics of the emissions from these incinerators. This is a report on the first step in this study of the solid particulate emissions from "Teepee" type wood residue incinerators. The total project, under the sponsorship of the Division of Air Pollution of the United States Public Health Service, includes study of the character, quantity, size distribution, transport characteristics, soiling properties, and visibility reduction effects of the solid particulates emitted under varying operating conditions. Subsequent research on methods to minimize particulate emission will be included in the total project (2, p. 2). When this project is completed lumber mill operators will be expected to invest in the instrumentation of their burners, such as the installation of recording pyrometers, combustion indicators, etc. The study will also enable them to justify the burner modifications necessary for relatively clean burner operation.

THESIS OBJECTIVE

The objective of this thesis was to develop a sampling device to collect a particulate sample from the burner exhaust gases. Examination of previous studies on "Teepee" type wood residue incinerators (4, p. 16-26) indicated a number of requirements for an ideal sampling device. In past studies the sampling apparatus consisted of a cinder collector which collected all of the particles which would not pass through a 50 mesh screen. This collector was placed at the base of the burner and tubing was installed up the side of the burner to the top. Velocity measurements were made by installing a pitot tube at the top of the burner. All of the installation and removal of equipment had to be done while the burner was cool. Most burners cool off enough during the night so that the equipment could be installed or removed early in the morning before the start of the days operation.

The sampling device necessary for the purposes of this project was required to:

1. Collect the complete particulate sample, not just those particles collected on a 50 mesh screen.
2. Collect samples over short time intervals because considerable difference in the particulate emission, as indicated by the appearance of the smoke plume, occurs

as the day progresses.

3. Eliminate the large number of man-hours involved in the installation and removal of the previously used sampling device.
4. Operate at an isokinetic sampling rate.
5. Reach into the burner far enough to extend beyond colder air coming up the side of the burner.
6. Divide the sample into portions which would facilitate gravimetric analysis and microscopic examination for characteristics and particle size analysis.
7. Have components which could be readily replaced to permit removal of one sampling train and replacement with another. This would allow the investigators to observe the time dependence of the emissions from the burner.
8. Collect the sample as near the top of the burner as possible to eliminate any long sections of tubing upstream of the collection components of the sampling assembly.

DEVELOPMENT PROCEDURE

Although there are a large number of methods currently being used in air pollution source sampling to separate particulate matter from a gas stream, one of the widely used methods is one developed by the Los Angeles Air Pollution Control District. The particulate laden air is drawn through a series of devices to trap the particulate. The heart of the Los Angeles Air Pollution Control District sampling train is a series of impingers, the first three placed in an ice bath to serve as a moisture trap as well as for removing particulate. In front of the impingers a screen filter or miniature cyclone is sometimes used to remove the larger particles. The impingers are followed by a filter to remove any remaining particles (5, p. 32). A membrane filter of the most widely used type has a pore size of 0.80 microns and stops virtually all particles remaining in the gas stream (8, p. 7). A sample train of this general type was decided upon for two reasons; it is a widely accepted, standardized sample train composed of inexpensive, readily available components and the particulate is generally collected in such a way that both microscopic and gravimetric analysis is possible.

In the previous studies made on "Teepee" burners the collection device was an Aerotech sampler. The collector was modified to collect only those particles which were stopped by a 50 mesh screen.

This collector was placed at the bottom of the burner and the sample was drawn to the collector through a two inch pipe. This pipe was installed on the side of the burner with the upper end in the center of the burner top. Problems with collection of particles on the inside of the pipe were encountered with this sampling setup (3). Neglecting the particles which passed through a 50 mesh screen was also a source of considerable error. The inaccuracies resulting from a long section of tubing leading to a sampling train, collecting a relatively small sample, led to the decision to locate the sampling train at the top of the burner. This decision to locate the sampling train at the top of the burner and the requirement for a short time period sample which could be continuously repeated required either an operator at the top of the burner or a means of placing the sampling probe and the sampling train at the top of the burner remotely. Because the top of a "Teepee" burner is an unpleasant and hazardous place to work, a method of installing, operating, and removing the sample train from the ground was chosen.

Based on these initial decisions to use a sampling train of the impinger, membrane filter type and to sample remotely from the ground, a sampling apparatus was built and tried. A column of three and four inch diameter aluminum irrigation tubing was constructed. The column was composed of 10 and 15 foot lengths of tubing to keep the column portable. Between each section of tubing and the next, junctions of aluminum pipe were made so that the column could be quickly bolted together at the test site. A base for the column was constructed from one quarter inch aluminum plate. The column was pivoted at one end of the base and a pickup truck held the other end of the base down. A tilt-up method rather than a telescoping column was chosen because the telescoped column would first have to be tilted up anyway and if the cable inside the tubing, for extending the column, became stuck or tangled while the column was in use the column would have been difficult to lower. By adding lengths of tubing the column length could be adjusted to 45, 55, or 65 feet.

The original sampling train was a simplification of the Los Angeles Air Pollution Control District system. An ice bath moisture trap was combined with a screen to collect the large particles. This was followed by two dry midget impingers and a one inch membrane filter. A small sample size is dictated by the decision to use impingers since the flow rates through them is somewhat limited. An aluminum box was constructed to house the sampling train and support the sampling probe. A wooden drawer-like base was used to hold the components. The original sampling train and housing are shown in Figures 2 and 3.

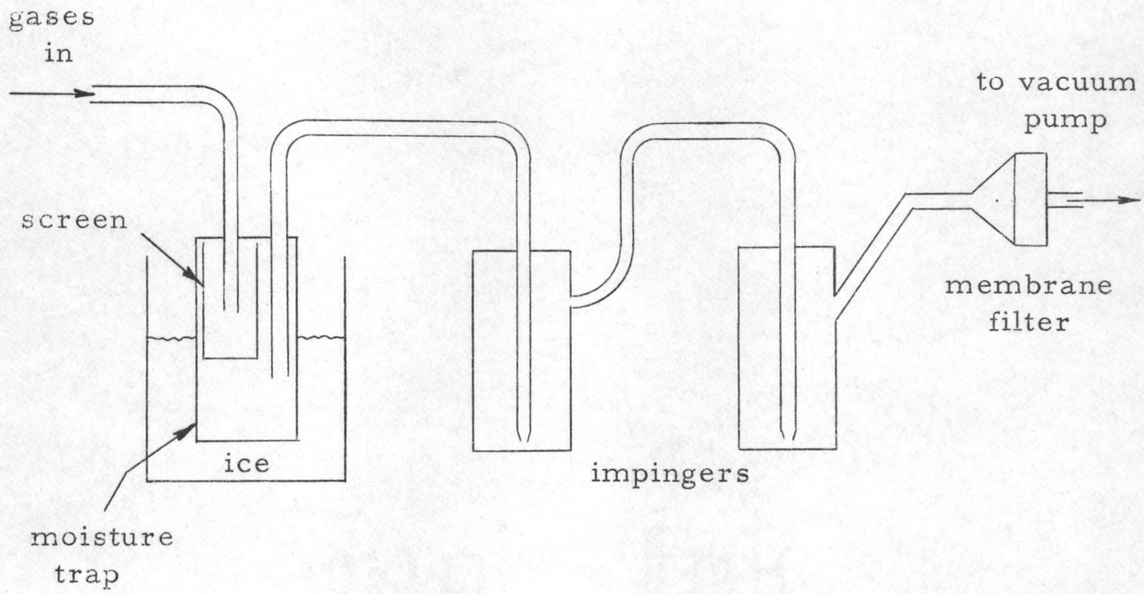

Figure 2. Schematic drawing of the original sample train.

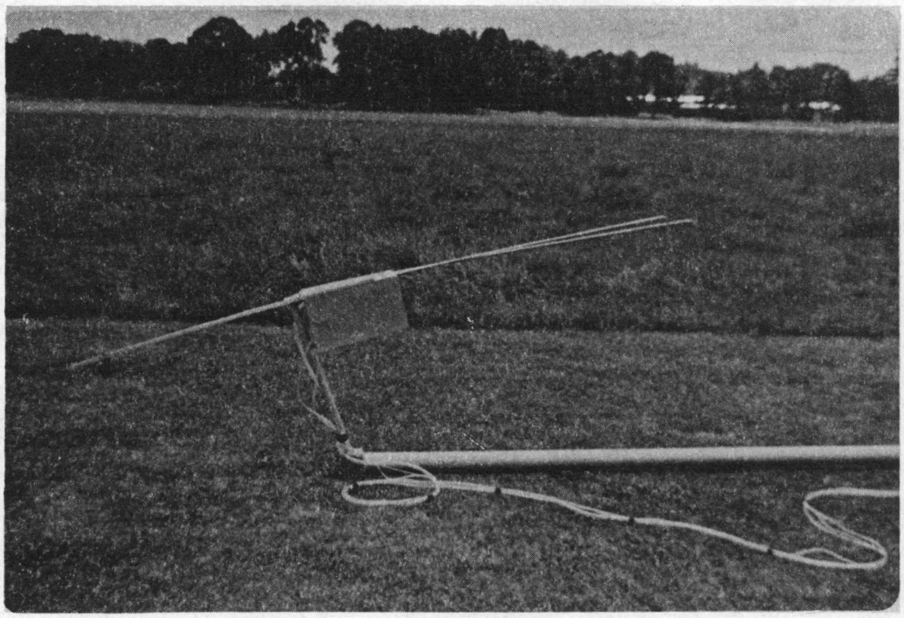

Figure 3. Original sampling train housing.

The only way to determine if the sampling train would collect the particulate satisfactorily and in a useable form was to try it. The mill selected as a test site was the Larson Lumber Company mill at the west edge of Corvallis, adjacent to the Oregon State University campus. The owners of the mill readily agreed to allow the use of their burner as a source of typical particulate for the development program. The mill is similar to the majority of the mills in the Willamette Valley in that the majority of the residue is Douglas Fir bark.

Initially there was some consideration given to being limited in sample time by clogging of the membrane filter. The opposite problem was experienced at the test burner, collecting enough sample to weigh. Testing a clean burner seemed to be the proper approach because results on both clean and smoking burners were required and smoking burners could be sampled by shortening the sample period if necessary.

A series of tests were completed using the original sampling train as shown in Figures 2 and 3. The first few tests revealed a number of necessary modifications. The degree of flexibility built into the original sampling train appeared to be unnecessary, so the box was shortened in length and the wooden tray eliminated. Because the Tygon tubing inside the box had melted, the box was completely lined with one inch of fiberglass insulation and the first ten feet of

Tygon tubing leading from the back of the box to the vacuum pump on the ground was replaced with aluminum tubing. A front for the box was also constructed and the sampling probe and pitot tube were installed on the top of the box rather than hung on the inside. The probes were also installed more rigidly than in the original design because they had rotated in their previous hanging mounting. The ice bath was placed in a thermos bottle liner to keep the ice from melting too quickly due to heat from other than the gas being drawn through the system. The box was mounted rigidly on the top of the column rather than permitted to pivot on a hinge. Once the ice bath was contained in the thermos bottle liner and the impingers located in such a way that any water in them could not flow to the membrane filter the need for the sampling train to be level during its trip to the top of the burner was eliminated. The modified sampling train and housing are shown in Figure 4.

The method of raising the column also needed some improvements. Initially a rope was tossed over a ring around the burner about 30 feet from the ground. Pulling on this rope would not supply enough force to lift the column. A pulley arrangement was used for awhile but still required considerable effort to raise the column. The final means selected to raise the column used a small boat trailer winch mounted on the column base. The cable from the winch went through a pulley halfway up the column then over the ring around

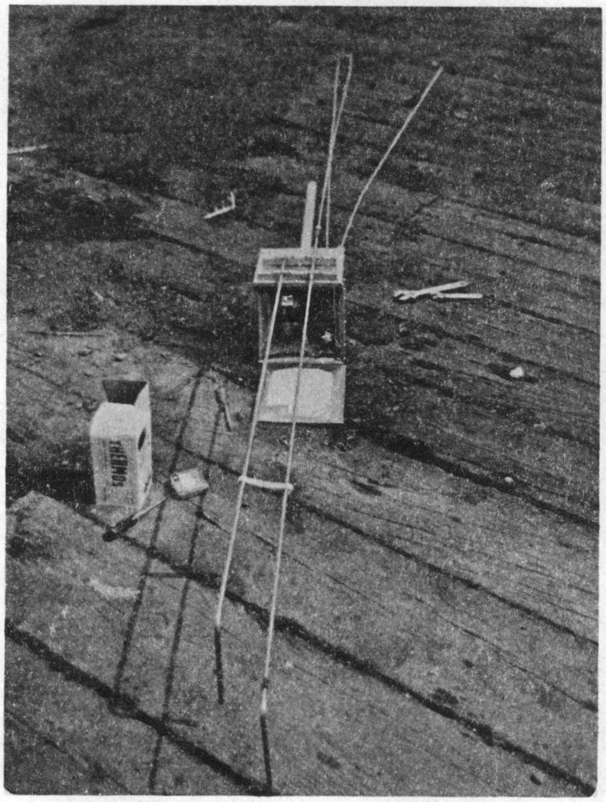

Figure 4. Modified sampling train assembly.

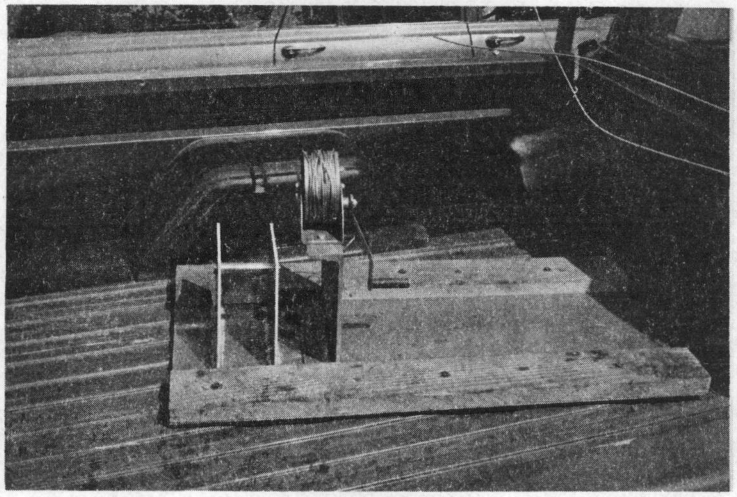

Figure 5. Column base.

the burner and to the ground. The base is shown in Figure 5 and the partially raised column in Figure 6. The wooden stiffeners on the base proved necessary to keep the base from swiveling under the pickup tire and bending when the wind blew the column toward the truck.

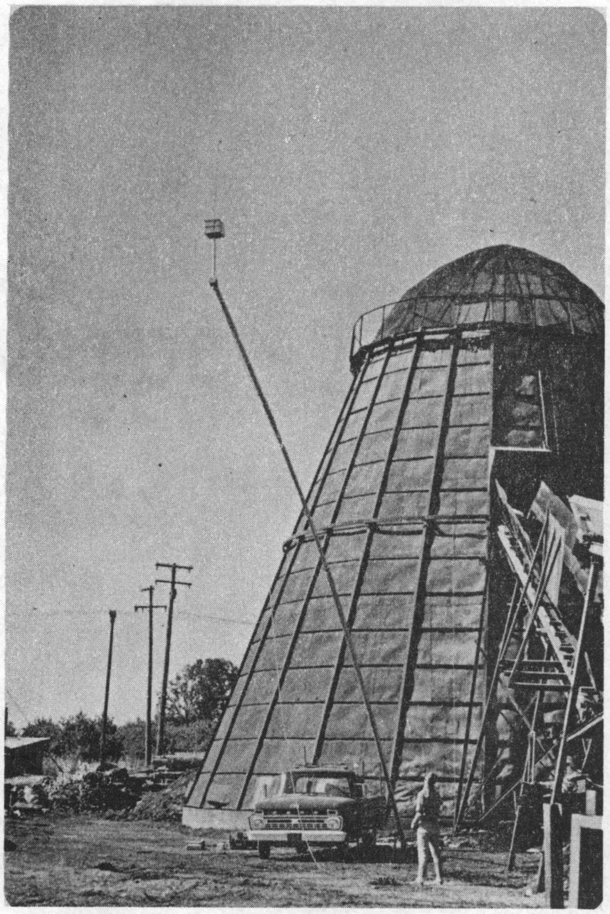

Figure 6. Partially raised column.

More tests were run and these tests led to modifications in the sampling train itself. The preliminary screen was replaced with one made of 100 mesh screen. Because little weight was gained by the second dry impinger it was removed. After more tests the remaining dry impinger was changed to a wet impinger and a second impinger added. The second impinger, operated dry, served mostly as a moisture trap. The total weights of the samples collected with this sample train were too low when one-tenth of a cubic foot per minute of gas, the flow rate suggested for midget impingers, was drawn through the sampling train. The sample weights collected were less than one milligram in weight. Because the Mettler balance used had a precision of 0.03 milligram (7, p. 11) an increase in total sample weight was desirable. The obvious means of collecting more sample was to draw more gas through the sampling train. The maximum flow rate obtainable through the sampling train and connecting hose with the available vacuum pump was three-eights of a cubic foot per minute. The jet tips in the impingers were replaced with plain glass tubing to obtain this maximum flow. Most of the pressure drop was observed to be across the membrane filter. A two inch filter holder was ordered and although it did not arrive early enough to be used in the development of the equipment using it for future tests will permit drawing three-fourths of a cubic foot per minute through the sampling train.

Acceptable sampling procedure requires that the sampling probe be of the proper area for a given sampling rate to sample isokinetically. In other words the velocity of the gas entering the probe must be the same as the gas velocity in the source being tested. If the velocity in the sampling probe is lower than the gas velocity in the source being tested, the concentration indicated by the sample will be higher than is actually the case. The particle size analysis on a sample which is taken with the sampling velocity lower than the gas stream velocity will indicate a coarser size distribution than exists in the gas stream being tested (9). With the required change in flow rate the area of the sampling probe had to be changed. This was done by fitting a larger diameter piece of tubing to the existing probe. In the early stages of the development of the sampling train attempts were made to measure the velocity of the gas stream in the top of the burner using a pitot tube and a micromanometer. A pitot tube is not a good device to measure such low velocities but the high temperature eliminates the use of devices such as anemometers. The velocity was observed to fluctuate considerably and an average velocity value of 600 feet per minute was obtained from the more extensive data in the previous studies (4, p. 31-48). This velocity value was matched at the sampling probe tip rather than attempting to continually vary the sampling rate to follow the fluctuating velocity.

The velocity of the gas stream can be checked by observing the time required by an observable parcel of smoke to rise from the flat screen to the dome shaped screen, and since this distance is known the gas velocity can be determined. This determination can best be accomplished with a pair of binoculars and a stop watch.

The temperature at the sampling point in the burner was continuously recorded through the use of a Chromel-Alumel thermocouple attached to the sampling probe. The voltage was recorded on a Heathkit recorder. This system operated satisfactorily from the start. A sample temperature recording is shown in Figure 7.

A number of additional tests were completed to make sure the sampling train would operate satisfactorily, that is collect enough sample to weigh and collect the particulate in a form amenable to microscopic examination. These additional tests were also used to develop an analysis procedure.

The first analysis procedure tried was to dry and weigh each element of the sampling train before and after the test. This procedure involved ten separate weighings on each sample train, the elements had to be handled in the field, and the particulate matter was in five different parcels, not making particle size analysis very easy. A better procedure was needed. The selected procedure was to clean and dry the sampling elements before each test. After the test was completed and the apparatus returned to the laboratory, the particulate was washed from each collecting element, except the membrane filter, with distilled water. A drop of the liquid was then placed on a microscope slide and a particle size distribution

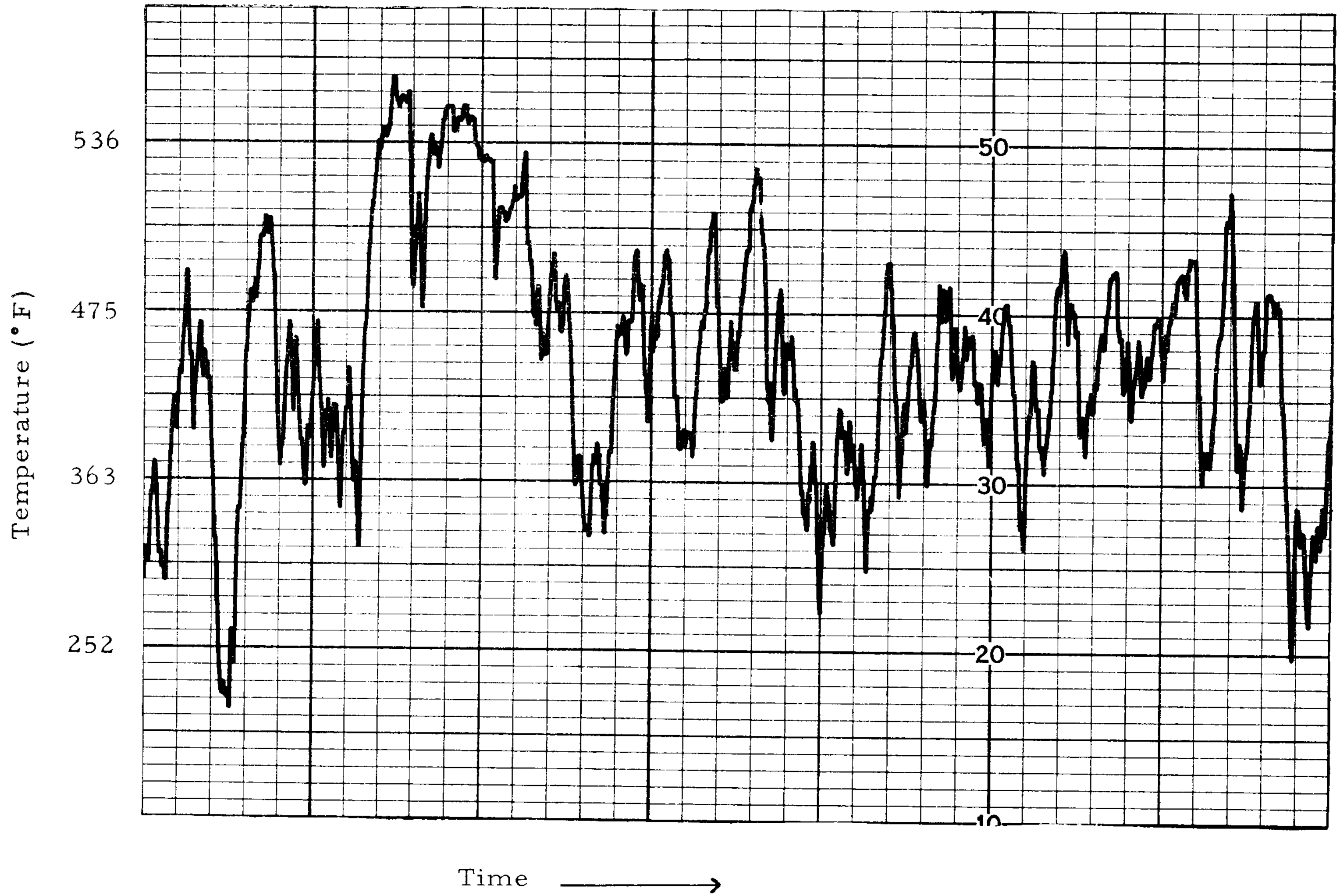

Figure 7. Sample temperature recording.

determined from this drop. The remaining liquid was evaporated in a dried, tared evaporating dish. The weight of the sample was then determined. Sample weights on the order of five milligrams were collected with the final sample train.

The microscopic examination of the collected particulate matter is an essential part of the analysis procedure. In future investigations there may be observable differences between the particulate from differently operated burners. Figures 8 and 9 show two examples of the larger particles collected.

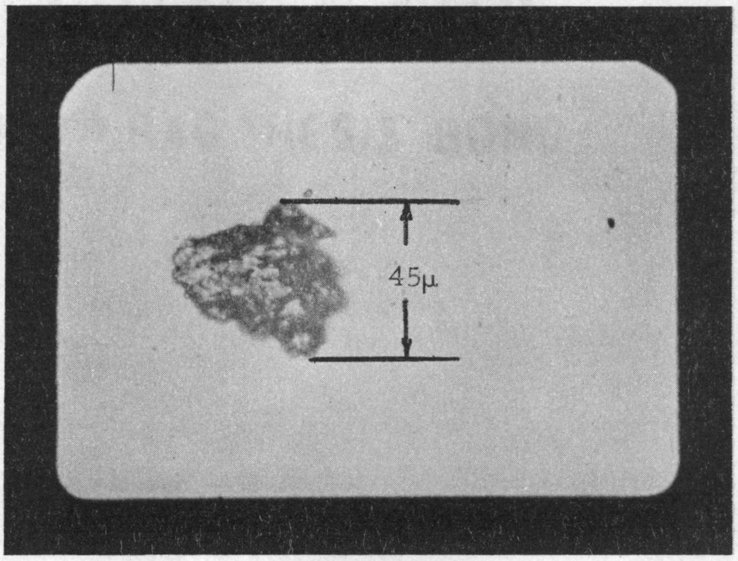

Figure 8. Large particle. 450X.

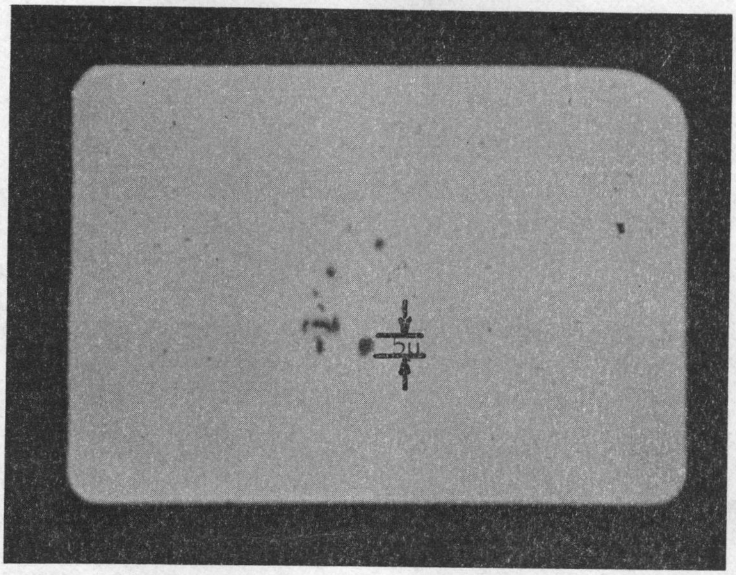

Figure 9. Smaller particles. 450X.

The small particles, which are mostly collected on the membrane filter, were treated for microscopic examination by making the filter material transparent by applying a drop of either acetone or immersion oil. An example of the small particles collected on the membrane filter can be seen in Figure 10. Although there appears at first to be a wide range in particle size on the membrane filter, closer examination reveals many particles of nearly the same size, about one-half micron in diameter, which have agglomerated on the filter surface. Similar observations of smoke composed of particles of nearly all the same size, again about one-half micron in diameter, were made in a study of grass field burning (6, p. 23). The larger particles collected in the other sampling train components appear to approximately follow a log mean distribution with a mean particle size on the order of 0.7 micron.

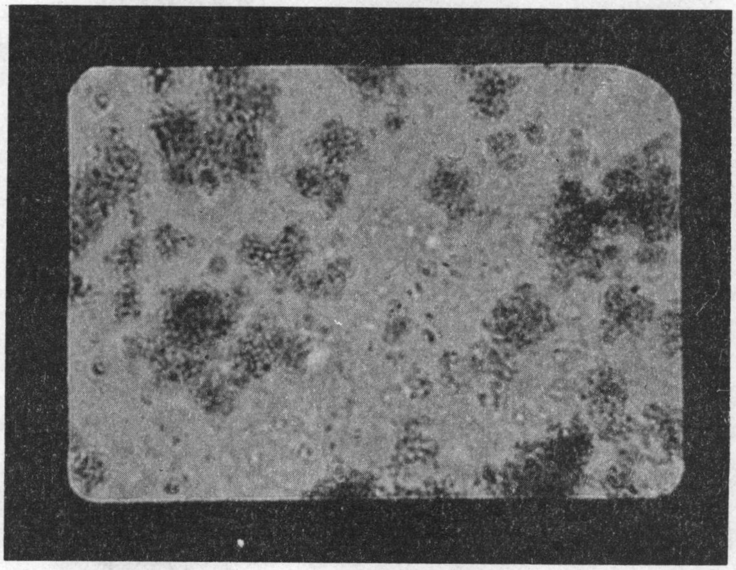

Figure 10. Particles collected on the membrane filter. 1000X.

The particles were sized using a Porton eyepiece for the microscope. This eyepiece has a series of clear and opaque circles and these are compared with the particles on the slide. For each microscope power the size of the particle corresponding to each circle is known and the particle size distribution can be found by observing a cross-section of the particles collected.

DISCUSSION OF COMPLETED SAMPLING ASSEMBLY

The completed sampling assembly meets each of the original requirements, some with a greater degree of success than others. The original requirements were:

1. Collect the complete particulate sample. All of the particulate matter was collected by the various components of the sampling train because with the last component being a membrane filter all of the particulate matter not collected by the other elements will be collected on the membrane filter.
2. Collect samples over short time intervals. On a clean burner the minimum sample time was approximately 30 minutes. On smoking burners the sample time may be shorter, if desired. The time to lower the column, change components, and replace in the burner was less than 15 minutes.
3. Eliminate the large number of man-hours involved in the installation and removal of the previously used sampling device. The only installation work which needed to be done when the burner was cool, using the new system, was to cut a hole in the dome shaped screen. It then took about 30 minutes to assemble the column and sampling train

and raise it into sampling position. This can be done at any later time and permits testing the burner and then removing all equipment immediately rather than being required to wait until early the following morning to remove the equipment.

4. Operate at an isokinetic sampling rate. To determine the gas velocity in the source and match it in the sampling probe entrance when testing a "Teepee" burner would be more difficult than in most stack sampling. The velocity is very low and the gas has not passed through any flow straightening sections. The use of hot wire anemometers are eliminated because of the high, fluctuating temperature of the gas. A vane anemometer is an integrating type instrument and the velocity fluctuations would not be observed with such an instrument. A vane anemometer would probably be the best device except that the high gas temperature is far above the usual operating temperatures for vane anemometers and difficulties with bearings could be expected. The pitot tube which was used is not a good velocity measuring device for such low velocities. Using the velocity values obtained in the previous studies as guidelines, as has been mentioned, and checking with visual observations was the method selected to measure

the velocity of the gas stream rather than striving for strict isokinetic sampling.

5. Reach into the burner far enough to extend beyond colder air coming up the side of the burner. On one sample run the thermocouple was attached halfway back on the probe, rather than at the tip. The temperature observed was about the same as had been observed when the thermocouple was attached at the tip, leading to the conclusion that the five foot probe length was adequate.
6. Divide the sample into portions which would facilitate gravimetric analysis and microscopic examination for characteristics and size analysis. This requirement of the test equipment was successfully met. The particles trapped in both the impingers and screen and filter could be examined under the microscope with only a minimum of preparation. A drying operation was all that was needed to determine the weight of the sample.
7. Have components which could be readily replaced to permit removal of one sampling train and replacement with another. Using impingers, membrane filters, test tubes, and baskets made of screen, all readily available and inexpensive, made it possible to have the necessary components to permit replacing the used ones with clean ones.

8. Collect the sample as near the top of the burner as possible to eliminate any long sections of tubing upstream of the collection components of the sampling assembly. This requirement led to the whole idea of placing the sampling train at the top of the burner. The five foot sampling probe leading into the first collection element was the minimum length of tubing possible.

The tilt-up column required two men to raise and lower it. One man operated the winch, raising the column while the other stood behind the column as it approached the hole in the screen and guided the sampling probe through the hole. A rope was attached halfway up the column for the purpose of guiding the column into the hole and keeping the column from being bent to the side by the wind.

The column is easily disassembled and transported on a pickup truck. A pipe rack was placed on the truck to hold the tubing while the other equipment such as the base and light plant was transported in the bed of the truck. The system is highly portable and with a little work could be carried to a roof top to sample from sources such as short boiler stacks or cyclones.

CONCLUSION

The development of this sampling apparatus, although developed for a specific source, introduces a new method of sampling to the air pollution field. Many errors may be committed in source sampling because of difficulties getting to the location to sample or because the conditions at the best available sampling site are so unpleasant that the operator permits errors in order to get a sample and get out. Although some error is possibly introduced by not being able to closely observe the sampling location, it is felt that this error will, in many instances, be less than the human error introduced due to extremely bad working conditions. The concept of holding the sampling apparatus on the end of a pole can assist in obtaining better samples from many sources. The working conditions will be more agreeable for the operator and less time and money will be spent in obtaining the samples.

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