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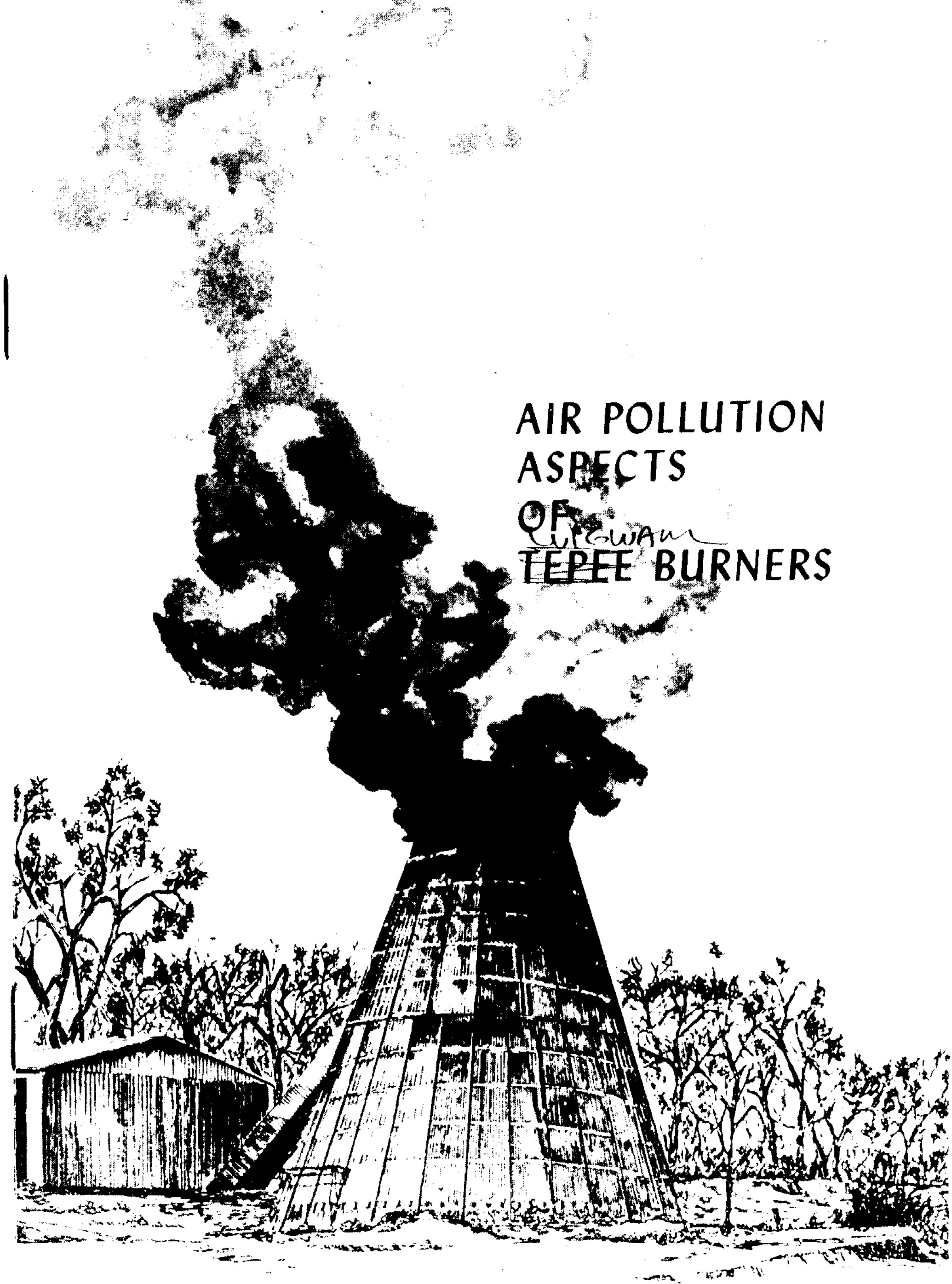

# AIR POLLUTION ASPECTS OF ~~TEPEE~~ Wigwam BURNERS

Public Health Service Publication No. 999-AP-28

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

# AIR POLLUTION ASPECTS OF TEPEE BURNERS USED FOR DISPOSAL OF MUNICIPAL REFUSE

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# ABSTRACT

This report covers an evaluation study of air pollution emissions based upon an extensive literature search and field trips to 15 tepee burners in six states. Smoke as a function of composition and rate of charge was observed, and the effect of burner charging methods, construction, and operational procedures on smoke emissions recorded. None of the tepee incinerators observed in operation meet normal visible emission limitations of air pollution control ordinances of most municipalities. Nuisance problems from fly-ash fallout can be expected within distances of up to 1,290 feet downwind from an operating tepee.

# INTRODUCTION

During the last several years, a large number of tepee-type industrial waste burners have been adapted to municipal refuse disposal and used across the country. Numerous public complaints prompted municipalities and states to ask the Public Health Service for an opinion on the advisability of using tepee burners for municipal refuse disposal. The Technical Assistance Branch, Division of Air Pollution, Public Health Service, consequently, undertook a study (including air pollution emissions and some economical aspects) to evaluate the use of tepee burners for disposal of municipal refuse. Based upon the results of the study, the Public Health Service does not consider the use of tepee refuse burners as a suitable method for the disposal of municipal refuse.

The evaluation study, which is reported herein, was based upon an extensive literature search and field trips to 15 refuse burners in six states. Smoke as a function of composition and rate of charge was observed, and the effect of burner charging methods, construction, and operational procedures on smoke emissions recorded. The information presented is intended to assist municipalities not now using tepee refuse burners in determining the ability of the tepee burner to fulfill their needs, both in refuse disposal operations and in air pollution control; and furthermore, to give municipalities that presently operate burners data they can use to improve burner operations and reduce air pollution emissions.

# CONCLUSIONS AND RECOMMENDATIONS

A number of cities of less than 100,000 people use tepee burners for disposal of municipal refuse. Field observations of 15 tepee burners used for disposal of domestic and/or industrial waste indicate that none of the tepee incinerators observed in operation meet normal visible emission limitations of air pollution control ordinances of most municipalities, i.e., an allowance of a visible emission as dark or darker than Number 2 Ringelmann or the equivalent opacity for periods not greater than from 3 to 8 minutes in any 1 hour. Also nuisance problems from fly-ash fallout can be expected within distances of up to 1,290 feet downwind from an operating tepee, and at possibly greater distances depending upon wind speed and burner operating conditions. For these reasons, it is necessary both to bring tepee burners now in use up to the highest possible standards of performance and, wherever possible, to replace them with better methods of municipal refuse disposal.

Where communities continue to operate tepee burners, the following guidelines are recommended for improving combustion in the tepee burner and for reducing incidence of nuisance complaints, regardless of other air pollution measures in effect.

1. The burner should not be built within 1,500 feet of the nearest property line (equivalent to approximately 200-acre site).

2. The surrounding property should be zoned agricultural or heavy industrial.

3. The burner should be charged by means of a covered conveyor belt.

4. A receiving building with a floor conveyor should be used for charging refuse to the conveyor belt.

5. Materials that produce heavy smoke when burned, i.e., rubber, plastics, asphalt or leather products, should be removed from the conveyor charge and disposed of by landfill.

6. Refuse should not contain more than 15 to 20 percent (by weight) garbage, and the garbage should be mixed uniformly with dry combustible refuse.

7. The capacity of the underfire air blower should ensure complete combustion so that the ash will be cold during cleanout operation. (The manufacturer should provide instructions for use that will ensure complete combustion.)

8. The ash should be pushed just outside the burner doors where it can cool and be wetted before being placed in a sanitary landfill.

9. The burner and equipment should be inspected and repaired under a continuous maintenance program.

Not listed above, but found to be of crucial importance in effective operation of the tepee refuse burner is an operator who is highly conscientious in the performance of his duties.

## CONSTRUCTION AND OPERATION OF A TEPEE BURNER

The tepee burner is so called because of its similarity in shape to an Indian tepee. The size of a burner may vary from 10 feet in diameter by 12 feet high to 90 feet in diameter by 97 feet high. A typical size for the 15 tepee burners inspected was 52 feet in diameter by 57 feet high. (See Figures 1 through 6.) The base of the tepee burner is normally secured to a concrete ring foundation, and the walls are usually 16-gauge steel. Many tepees have an inner-wall liner of corrugated steel for protection from heat. The 15- to 20-foot diameter dome of the tepee is normally equipped with 2-1/2-mesh steel wire for collection of large particles of fly ash. A large number, e.g., 50 to 75, adjustable- or fixed-draft doors about 10 inches wide by 20 inches high are located at the base of the burner to provide overfire air for combustion. Most tepee burners are also equipped with forced-draft blowers and underground piping to the burner grate. Double doors large enough for a dump truck to pass through provide access for charging the tepee with combustible waste and for removing ash.

Three methods are used for charging refuse to the tepee burner: (1) by steel conveyor belt, (2) by bull dozer with a movable blade, and (3) by elevated truck chute. (See Figures 1 through 4.) Table 1 describes each of the tepee burners inspected, and Table 2 shows a summary of grate and door types and kinds of refuse burned based on feed methods.

The fastest charging requiring the least operating personnel is the elevated-truck-chute method. The incoming truck loaded with refuse backs onto an elevated platform to the tepee charge chute and dumps the refuse onto the chute and into the tepee. Incoming truck loads of refuse may vary from one to four per hour.

A typical operating schedule observed during the study was from 7:00 a.m. to 6:00 p.m., 6 days per week. The first operation of the day is removal of the ash residue from the previous day. The ash is loaded on a truck and hauled to a landfill. Ash removal from the tepee may take from 30 to 60 minutes. After the tepee is charged with municipal-type refuse, the charge is ignited, and the underfire air blowers are turned on.

The more popular type of charging observed during this study was the dozer method. The incoming truck dumps the full load of refuse in front of the open doors of the tepee. A large dozer pushes the refuse onto the burning pile in the center of the tepee. The dozer blade is raised vertically as the dozer moves forward. At most of the dozer-fed tepees, the large dozer was operating about half and the large double doors were open approximately three-fourths of the operating day. A smaller dozer was usually used while the large dozer was serviced or repaired.

The typical conveyor-feed system for a tepee includes both a covered 4-foot-wide conveyor belt and a receiving house, perhaps 40 by 60 by 20 feet high. The base of the loading house is often 10 to 15 feet above the floor of the tepee burner. The belt conveyor enters the tepee about half-way between its base and dome and extends into the center of the tepee. Incoming trucks unload refuse onto the floor of the receiving building. A small dozer pushes refuse onto a separate floor conveyor, which transfers the refuse to the inclined conveyor feeding the tepee. This type of charging system offers a better controlled, uniform feed. The large unloading doors on the tepee are

Table 1. DESCRIPTION OF TEPEE REFUSE BURNERS INSPECTED

| Feed method | Burner size (diameter x height), feet | Burner age, years | Burner use | Auxiliary equipment in use | Clean-out procedures |
|---|---|---|---|---|---|
| Dozer | 53 x 57 | 5.5 | Municipal waste | 2 blowers | Push out cold ash |
| Dozer | 45 x 50 | 2.2 | Industrial waste (everything) | none | Push out hot ash |
| Dozer | 53 x 57 | 2.2 | Industrial waste (wood and paper) | none | Push out hot ash |
| Dozer | 67 x 72 | 2.2 | Industrial waste (mostly wood & paper) | none | Wet down, push out ash |
| Dozer | 53 x 57 | 2.3 | Industrial and municipal | 2 blowers | Push out hot ash |
| Dozer | 67 x 73 | 2.5 | Industrial (wood and paper) | none | Push out warm ash |
| Dozer | 67 x 73 | 2.4 | Municipal (some industrial) | 2 blowers | Carry out hot ash |
| Dozer | 53 x 57 | 3.0 | Municipal | 2 blowers | Push out hot ash |
| Dozer | 53 x 57 | 3.6 | Municipal | 2 blowers | Push out hot ash |
| Conveyor | 80 x 87 | 1.5 | Municipal | 1 blower | Push out cold ash |
| Truck chute | 45 x 50 | 1.5 | Industrial-municipal | 2 blowers | Push out hot ash |
| Dozer | 40 x 43 | 3.8 | Municipal | none | Push out hot ash |
| Conveyor | 67 x 73 | 1.2 | Municipal | 2 blowers | Carry out hot ash |
| Conveyor | 53 x 57 | 3.0 | Municipal | 2 blowers | Push out hot ash |
| Dozer | 53 x 57 | 4.0 | Municipal-industrial | Afterburner and scrubber | Push out ash |



Table 2. TEPEE BURNER COMPARISON BASED ON FEED METHOD

| Feed method | Number of burners | | | | | | |
|---|---|---|---|---|---|---|---|
| | Total | Kind of refuse burned | | | With underfire grate | | With usable doors |
| | | Municipal | Industrial | Both | Installed | Operating | |
| Conveyor | 3 | 3 | 0 | 0 | 3 | 3 | 3 |
| Truck chute | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| Dozer fed | 11 | 5 | 1 | 5 | 10 | 5 | 3 |
| Total | 15 | 8 | 1 | 6 | 14 | 9 | 7 |

closed during charging and burning to afford better control of overfire air entering the louvers at the base of the tepee.

Although the charging of refuse may stop at about 5:00 p.m., the burning continues at a reduced rate for another 8 to 12 hours. The forced-draft blowers are left operating to provide the necessary underfire air to complete combustion. Although the ash residue is normally removed each morning, in some tepee burners ash is removed only once or twice a week. In most of the ash unloading operations, no unburned garbage was detected.

# AIR POLLUTION FROM TEPEES BURNING MUNICIPAL REFUSE

There are six main operating variables that can affect the combustion efficiency adversely, thus increasing air pollution emissions of a tepee refuse burner: (1) charging methods, (2) burner construction, (3) burner operating practices, (4) composition of charge material, (5) charging rate, and (6) tepee clean-out operation.

## EFFECT OF VARIOUS CHARGING METHODS

Dozer. As indicated previously, control of the overfire air in a tepee burner requires that the large loading and unloading doors be closed. The overfire air should enter only through the louvered openings at the base of the tepee in a tangential pattern, which induces the combustion products and fly-ash to move clockwise around the fire. This flow pattern holds the combustible material in suspension and promotes more efficient combustion. When the doors are open, the circular motion of the draft stops and the combustion gases cool. As a result more smoke and fly-ash are emitted from the top of the tepee burner, and fly-ash and dust blow through the open doors. Whenever a dozer is charging a tepee burner, the large double doors of the tepee must necessarily be open. Operation at near capacity or above, therefore, requires open doors almost constantly.

From an air pollution standpoint, the use of a dozer to feed refuse to a tepee is a very poor method (Figures 1 and 2). Table 3

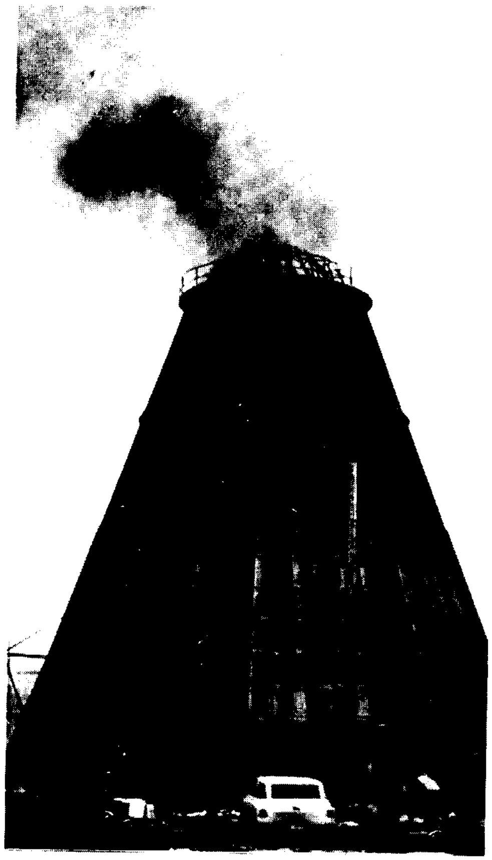

Figure 1. Typical dozer–fed refuse burner. Charge is damp paper and wood. Note refuse guides attached to protect tepee entrance, prevent doors from being used.

lists the visible emissions observed from two typical dozer-fed tepee burners. Burner No. 1, burning wood and dry paper, operated with a discharge plume of greater than 40 percent equivalent opacity for 45 minutes during 1 hour's observation. The underfire air blowers were not operating, a typical practice for tepees burning paper and wood. Even with the underfire air blowers operating full time, Burner No. 2 emitted heavy smoke and a resulting discharge plume greater than 40 percent equivalent opacity when burning domestic refuse.



Figure 2. Tepee refuse burner being fed by dozer. Note torn door opening and operator driving unprotected into fire.

Elevated Truck Chute. An elevated truck-chute burner (Figure 3) is an even less acceptable means of burning refuse than the dozer-fed burner from the aspect of air pollutant emissions. When refuse is dropped on the burning pile, the fire is smothered and the refuse burns with a heavy discharge of smoke and fly-ash. By the time the fire is burning well again, another load is dropped, and the smouldering and smoke recur.

Only one-truck-chute fed tepee was observed in operation. Visible emissions from this burner (Table 4) varied from 4 to 5 Ringelmann No. when leather, paper, and wood were burned and between No. 3 to 3-1/2 when only paper and wood were burned. Two forced-draft blowers continually supplied underfire air to this burner.

Conveyor. Combustion is more complete in a conveyor-fed tepee, (Figure 4) than in the dozer- or truck-chute-fed burners because of a more uniform feed rate and better control of overfire air. Although the visible emissions listed in Table 5 for Burner No. 1 were generally greater than 40 percent equivalent opacity, they did not exceed 65 percent. The effect of excess overfire air can be seen in the opacity readings for Burner No. 2. When the unloading doors were open during the charging of wood and paper boxes, the discharge

Table 3. VISIBLE EMISSIONS OBSERVED FROM TWO TYPICAL DOZER-FED TEPEE BURNERS

| Time | Average Ringlemann[a] No. or percent equivalent opacity | Color of plume | Material charged |
|---|---|---|---|
| Burner No. 1 | | | |
| 9:00 - 9:15 a.m. | 3-1/2 | Grey | Wood and dry paper |
| 9:15 - 9:30 | 3 | Grey | Wood and dry paper |
| 9:30 - 9:45 | 2-1/2 | Grey | Wood and dry paper |
| 9:45 - 9:50 | 2 | Grey | Wood and dry paper |
| 9:50 - 9:55 | 1-1/2 | Grey | Wood and dry paper |
| 9:55 - 10:00 | 1 | Grey | Wood and dry paper |
| 10:00 - 10:15 | 3-1/2 | Grey | New charge of wood and dry paper |
| Burner No. 2 | | | |
| 2:30 - 2:45 p.m. | 50 | White | Domestic refuse |
| 2:45 - 3:00 | 60 | White | Domestic refuse |
| 3:00 - 3:15 | 100 | White | New charge, domestic refuse plus wet garbage |
| 3:15 - 3:30 | 80 | White | New charge, domestic refuse plus wet garbage |

[a]No. 5 Ringlemann is a solid grey or black plume or a plume which entirely obscures vision. No. 1 Ringlemann is a light grey plume or a plume which reduces visibility through the plume by 20% (Equivalent opacity of 20% - equal to opacity of a grey plume of No. 1 Ringlemann).



Figure 3. Truck-fed tepee refuse burner. Charge is of dry paper, wood, and minor industrial waste.

Table 4. VISIBLE EMISSIONS OBSERVED FROM A TRUCK-CHUTE-FED BURNER

| Time - p.m. | Average Ringlemann No. [a] | Color of Plume | Material charged |
|---|---|---|---|
| 9:00 - 9:15 | 5 | Black | Leather, paper, and wood |
| 9:15 - 9:30 | 4 | Dark grey | Leather, paper, and wood |
| 9:30 - 9:45 | 3-1/2 | Dark grey | Paper and wood |
| 9:45 - 10:00 | 3 | Dark grey | Paper and wood |

[a]No. 5 Ringlemann is a solid grey or black plume or a plume which entirely obscures vision. No. 1 Ringlemann is a light grey plume or a plume which reduces visibility through the plume by 20% (Equivalent opacity of 20% - equal to opacity of a grey plume of No. 1 Ringlemann).

plume was a No. 5 Ringelmann. When the doors were closed, the opacity of the plume dropped to between a No. 1-1/2 and 3-1/2 Ringelmann. **Underfire air was utilized in both conveyor-fed tepee burners.**

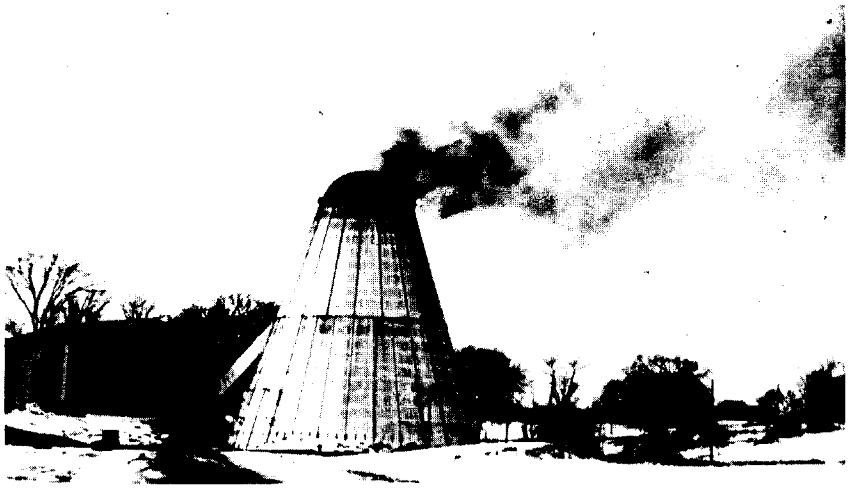

**Figure 4. Conveyor-fed municipal refuse burner during startup operation. Charge is dry paper, wood, and small amount of garbage. Represents peak emissions during field visit to this site.**

## EFFECT OF TEPEE BURNER CONSTRUCTION

Proper tepee burner construction and maintenance is a prerequisite to optimum burner operation and minimum air pollution. Most of the construction difficulties arise around the forced air system, which must be installed for adequate combustion. Of primary importance is the location of the grates and the method by which they are placed in the burner floor. The grates (8 to 12) should be placed very close to the center of the burner so that they will be covered completely as the combustible material falls from the conveyor chute. If the grates are located at the edges of the burning pile, they are virtually ineffective since the forced air is more likely to channel through several grates while avoiding the bulk of the pile.

To avoid tearing the grates from the burner floor with the clean-out dozer, the grates should be set in a ring of concrete approximately 20 to 30 feet in diameter, depending upon the burner size. The concrete should not have reinforcing material in it so that it can expand and contract freely without cracking. It should have beveled edges so that the clean-out dozer blade will easily ride over the surface. The remaining floor area should be dirt.

Most tepee burners observed did not have a forced-draft blower that could move a sufficient flow of combustion air through heavily packed refuse piles. The only blower installation that appeared to work



Table 5. VISIBLE EMISSIONS OBSERVED FROM TWO TYPICAL CONVEYOR-FED TEPEE BURNERS CHARGED WITH HOUSEHOLD REFUSE

| Time | Average Ringelmann[a] No. or percent equivalent opacity | Color of plume |
|---|---|---|
| Burner No. 1 | | |
| 11:30 - 11:35 a.m. | 40 | White |
| 11:35 - 11:40 | 50 | White |
| 11:40 - 11:45 | 55 | White |
| 11:45 - 11:50 | 60 | White |
| 11:50 - 11:55 | 55 | White |
| 11:55 - 12:00 | 60 | White |
| 12:00 - 12:05 | 65 | White |
| 12:05 - 12:15 | 55 | White |
| 12:15 - 12:25 | 50 | White |
| 12:25 - 12:30 | 45 | White |
| Burner No. 2 | | |
| 3:20 - 3:35 p.m. | 5 | Black[b] |
| 3:35 - 3:40 | 4-1/2 | Black[c] |
| 3:40 - 3:45 | 3-1/2 | Dark grey |
| 3:45 - 3:50 | 3 | Dark grey |
| 3:50 - 4:05 | 2 | Light grey |
| 4:05 - 4:20 | 1-1/2 | Light grey |

[a] No. 5 Ringelmann is a solid grey or black plume or a plume which entirely obscures vision. No. 1 Ringelmann is a light grey plume or a plume which reduces visibility through the plume by 20% (Equivalent opacity of 20% - equal to opacity of a grey plume of No. 1 Ringelmann).

[b] One load of paper and cardboard boxes added by dozer.

[c] Dozer loading stopped and unloading doors closed.

effectively had a rated capacity of 15,000 to 20,000 cubic feet of air per minute. The tepee burner manufacturers should themselves confirm or deny this figure by means of simulated tests on heavily packed piles. When the blower capacity is not sufficient, the air flows through one grate or stops completely. In some cases, the duct openings are clogged with ash and molten metal.

A number of municipalities have purchased tepee burners of a lower capacity than needed in order to reduce the initial capital expense. In time, the burners become increasingly overloaded, resulting in burner damage beyond feasible repair, and in increased emissions of smoke and fly-ash. This type of damage arises in two forms: first,

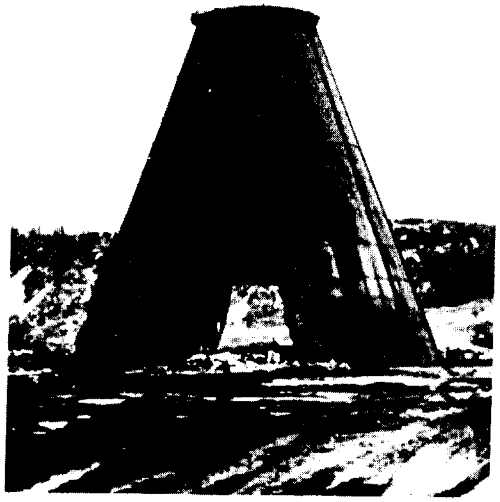

Figure 5. Dozer-fed tepee refuse burner with torn walls, no screen on top, no doors, and unprotected blowers. Burner is less than 4 years old.

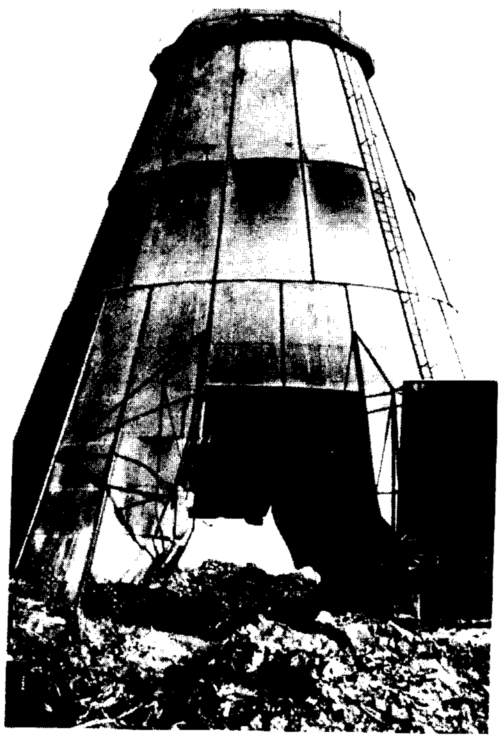

Figure 6. One of four dozer-fed tepee burners of comparable condition, each slightly over 2 years old.



the walls twist and crack from being overheated; second, the walls and doors are often hit and torn by the clean-out dozer because of limited dozer maneuverability. In addition, combustion efficiency is reduced because of the shortage of underfire combustion air. These factors result in greater smoke and fly-ash emissions. The burner operator then finds that the lifetime of the burner has dropped to 5 years or less. Note the age of the burners shown in Figures 5 and 6.

In most tepee refuse burner installations, the dome opening at the top is covered by 1/4-inch-wire mesh to prevent large fly-ash particles from leaving the burner. The fly-ash may clog the screen and limit the amount of combustion air passing through it. Some manufacturers have covered part of the dome with 1/2-inch screen to let more air and more fly-ash pass through. The undesirability of this type of screen is demonstrated by a picture (Figure 7) of fly-ash (emitted in a 5-hour span from this type of dome) in a footprint on fresh snow, 1,000 feet downwind from the burner. A possible solution would be to place a 1/2-inch horizontal screen below the 1/4-inch dome screen to keep all fly-ash larger than 1/2-inch in diameter from clogging the 1/4-inch screen.

Most burner operators using conveyor belts obtained satisfactory operation by using a 4-foot-wide steel belt, which has been found to handle most refuse with a minimum of hand charging. A steel belt is

Figure 7. Fly-ash collected in 5 hours, in footprint in fresh snow 1,000 feet downwind from conveyor-fed refuse burner.

not very likely to tear or break and should last the life of the burner. It is also built to promote continual flow of refuse to the burner without occasional blockages along the belt passage.

## EFFECT OF TEPEE BURNER OPERATING PRACTICES

A tepee burner is no better than the reliability of the operator. In 1 day an operator can burn holes in the walls, tear off the doors by hooking them with the clean-out dozer, or tear out the grates with the dozer blade (Figures 5 and 6). On the other hand, when the operator is conscientious, the burner can be expected to last for the depreciation period of 10 years with a minimum of repairs. At not more than a third of the sites visited could the operators have been described as conscientious workers; in every case where the operators were not conscientious, the burners were emitting excessive smoke and fly-ash. This is not to say that in every case in which the burner is in poor condition, the operator is not conscientious; the burner condition is also dependent upon the operating instructions provided by the owner.

For more effective air pollution control, the operator should adhere to certain operating practices. He should regulate the feeding rate of the conveyor system so as not to smother the fire. He should keep materials that adversely affect the quality of combustion from being charged into the burner (see next section). Finally, he should be extremely careful when moving the ash from the burner during the clean-out operation to keep particulate matter from blowing onto the property of others.

## EFFECT OF VARIOUS CHARGES AND CHARGING RATES

The extent of air pollution at a burning site is highly dependent upon the type of material being burned and the rate at which this material is charged to the burner.

Composition of charge. Some materials should not be charged into a tepee refuse burner. Others should be charged only as a small percentage of a homogeneous mixture. Table 6 lists the types of materials that should and should not be fed into a tepee burner. All plastic, rubber, asphalt, and leather goods burn with a resulting smoke emission of a No. 5 Ringelmann or a 100 percent equivalent opacity regardless of the method of charge. Almost every experienced tepee burner operator questioned during the field observations felt that these materials should not be burned in a tepee. Most of the operators segregated this material and disposed of it by landfill. A typical example is shown in Figure 8 of a tepee burning plastic materials.

If the refuse contains garbage over 15 to 20 percent by weight, and if this percentage is not mixed fairly uniformly with dry refuse, heavy smoke emissions, i.e., No. 4 or 5 Ringelmann, will generally occur. In practice mixing wet and dry refuse uniformly at the tepee site is not feasible with either the truck-chute or dozer-type charging technique, but can be done either manually or by use of a small dozer, in a conveyor-fed unit equipped with an unloading house having a floor conveyor. In the latter case the density of smoke is not significantly more than that from burning dry refuse. Wherever possible, however,



Table 6. EFFECT OF VARIOUS MATERIALS ON TEPEE REFUSE BURNER OPERATION

| Material | Maximum recommended percent of material in charge | Basis of recommendation | Practical experience of nine municipal operators |
|---|---|---|---|
| Dry Wood | 100 | - | - |
| Dry paper | 100 | - | - |
| Damp paper | 30 | Tends to smother pile; makes for unsatisfactory hot clean-out operation. | Damp material cuts down on burner capacity; must be charged sparingly. |
| Brush, logs | 100 | - | - |
| Ashes | None | Ashes from home use placed in charge produced Ringelmann No. 3 to 4 smoke. | Very little effort to separate ashes from charge. |
| Plastic products (polyvinyl chloride, etc.) | None | Produces Ringelmann No. 5 or 100% equivalent opacity smoke accompanied by nauseating odors. | Eight of nine municipalities recognized adverse effects and put plastic products in landfill.[a] |
| Rubber products | None | Produces Ringelmann No. 5 or 100% equivalent opacity smoke, sometimes accompanied by odors. | Eight of nine municipalities recognized adverse effects and put rubber products in landfill.[a] |
| Asphalt products (tar paper, linoleum tar blocks, etc.) | None | Produces Ringelmann No. 5 or 100% equivalent opacity smoke. | Eight of nine municipalities recognized adverse effects and put asphalt products in landfill.[a] |
| Leather products | None | Produces copious quantities of Ringelmann No. 5 smoke lasting for hundreds of yards downwind. | Only occurs around leather product corporations. |
| Raw garbage | 15 | Tends to smother pile; makes for unsatisfactory hot clean operation; may cause extensive odors. | All conveyor-fed burner operators recognize that only small amounts of garbage may be mixed homogeneously with dry combustible material. If possible, dispose of all garbage by other means. |

[a]The ninth municipality paid little attention to tepee burner operations and did not attempt to control charge composition under any circumstance.

raw garbage should be buried in a sanitary landfill or passed through garbage grinders for discharge to a waste disposal plant.

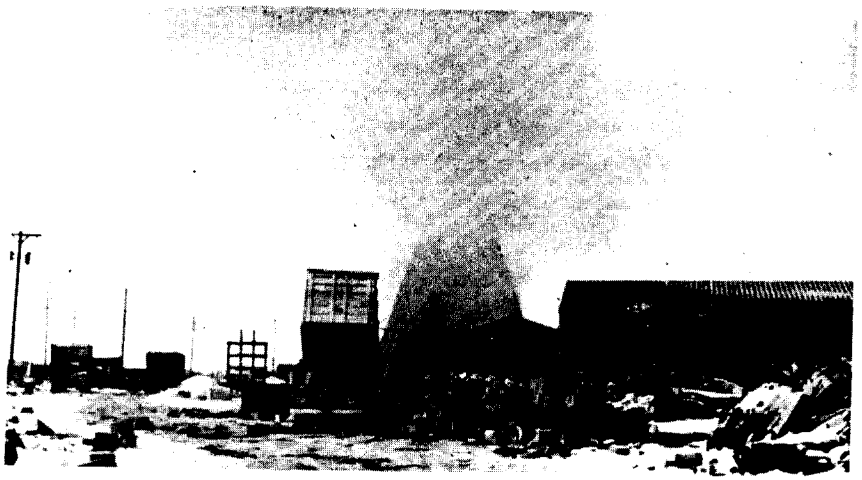

Figure 8. Emissions from burning plastic and polyvinyl chloride from electric wire.

If the charge contains more than approximately 30 percent damp material mixed uniformly with dry combustible material, the pile will smolder, yielding an undesirably large amount of smoke and a pile of hot ash for the clean-out operation. In addition, the buildup of a large pile of charge will cut down the forced air draft through the pile, which, will further impede the combustion rate. In summary, burner efficiency decreases and smoke emissions increase with increased water content in the charge.

Rate of charge. The rate at which refuse can be charged to a tepee burner to effect a minimum emission of smoke is dependent mainly on the size of the burner and the amount of available underfire air. Overcharging a tepee burner, which occurs if the feed system is not closely regulated, results in increased smoke emission because of insufficient underfire air. A continuous feed to a tepee burner allows the operator to control both underfire and overfire air to effect more complete combustion and reduced emission of smoke and fly-ash. The conveyor is the only feed system capable of a continuous, fairly uniform rate of charge.

## EFFECT OF CLEAN OUT OPERATION

Hardest to control in the tepee refuse burner operation from the aspect of smoke and fly-ash emissions is the clean-out process since, under the best of circumstances, there appears to be no suitable way to remove the ash without some emission of fly-ash.

Although the ash should be cold when removed from the tepee



burner, unfortunately, in a majority of cases the piles are hot. Figures 9 and 10 show typical hot clean-out operations. The heated air around and in the ash being moved will rise, carrying with it large amounts of dust and fly-ash. Figures A-1 and A-2, in the Appendix, show examples of dust collected on sticky paper downwind from a hot clean-out operation. More dust fell during the 20- and 30- minute sampling of clean-out than during 5- and 8- hour sampling during regular operation at approximately the same distances (Figures A-3 through A-6 in Appendix).

Figure 9. Hot clean-out operations of two separate dozer-fed tepee burners.

Only if the burner has not been overloaded or charged with wet material and if the forced draft through the pile has been sufficient, will the ash be cool during the clean-out operation. As it is removed from the burner, the cold ash may be sprinkled lightly with water to keep the dust emission to a minimum. Pictures of the clean-out operation, showing hot ash carried and pushed out (Figures 9 and 10), should be compared with the picture showing cold ash pushed from the burner (Figure 11).

Figure 10. Hot clean-out operations of two separate conveyor–fed tepee burners.



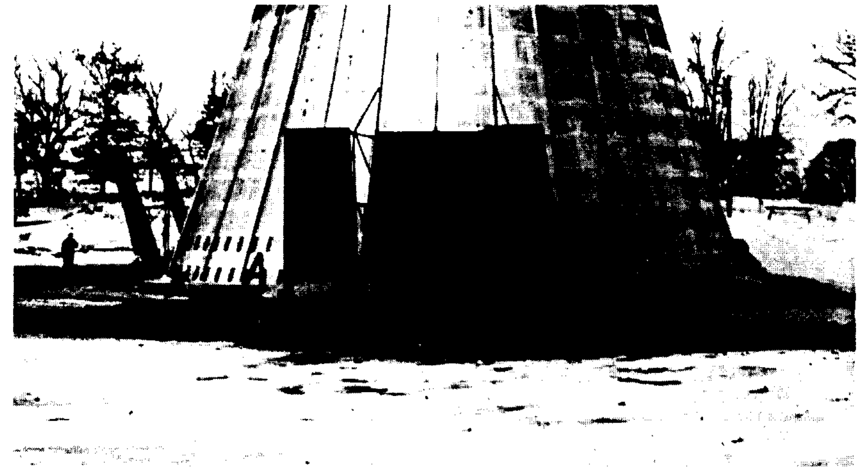

Figure 11. Relatively cold clean-out of conveyor–fed tepee burner.

## ECONOMIC AND OPERATIONAL COMPARISON

There are several disadvantages to operating the dozer-fed tepee burner. A large dozer operating in a tepee often tears the door edges with the shovel or blade or rips the forced draft fan ducts from the burner floor (Figures 5 and 6). After this occurs several times, the burner owner deems it uneconomical to replace the doors and grates as is borne out by the fact that 50 percent of the dozer-fed burners inspected were without forced air and over 70 percent did not have usable doors (Table 2). Conveyor-fed-burner owners need not worry about this problem since they can use small, more readily maneuverable dozers to clean out the burner in the mornings; and more important, they only use the dozer about 1 hour per day, thus saving operating cost and wear on the dozer.

Another disadvantage to operating the dozer-fed tepee burner may be categorized as an industrial hygiene problem. The dozer operator spends his time driving in and out of the burner, often without tractor cabs, and is exposed to large amounts of dust and heat (Figure 2). He could easily be injured by exploding pressure cans, for example, or by stalling his tractor in the flames of the fire.

The dozer-fed burner is more expensive to operate than the conveyor-fed burner as is shown in Table 7. These operating costs do not include the cost of the land, basic tepee burner, and personnel, which are assumed to be the same for each method of disposal.

Table 7. COMPARISON OF ESTIMATED COST OF DOZER- AND CONVEYOR-FED TEPEE BURNER OPERATIONS[a]

| Cost item | Dozer-fed, dollars/year | Conveyor-fed, dollars/year |
|---|---|---|
| Conveyor with 40- by 60-foot storage building | - | 5,000 - 6,000[b] |
| Large dozer | 13,520 - 19,760[c] | - |
| Small dozer | 2,600 - 3,120[d] | 7,800 - 9,360[e] |
| Total cost per year | 16,120 - 22,880 | 12,800 - 15,360 |

[a]Cost data compiled from participating burner operators.

[b]Cost includes operating costs plus initial investment ($30,000 to $40,000) depreciated in 10 years.

[c]Based upon 40 hours per week operation at a cost of $6.50 to $9.50 per hour. Cost includes operating costs plus initial investment ($12,000 to $15,000) depreciated in 2 to 3 years.

[d]Based upon 10 hours per week operation at a cost of $5.00 to $6.00 per hour. Cost includes operating costs plus initial investment ($6,000 to $8,000) depreciated in 5 years.

[e]Based upon 30 hours per week operation at a cost of $5.00 to $6.00 per hour. Cost includes operating costs plus initial investment ($6,000 to $8,000) depreciated in 5 years.

The high operating cost of the dozer-fed burner is based upon $6.50 to $9.50 per hour of operation for the large dozers and $5.00 to $6.00 per hour of operation for the small dozers. The hourly operating rates are typical for either rented or owned dozers. The cost is high, for the dozers have a lifetime that will not normally exceed 3 years because of the extremely large amounts of dust that pass through the engine.



The yearly cost of the conveyor, on the other hand, will be only slightly higher than its yearly depreciation rate since very little money is needed for maintenance. The lifetime of the conveyor belt should exceed the life of the tepee burner The conveyor installations can also feed 25 to 35 percent more material in a working day without overloading the burner; the resulting more nearly uniform burning rates in turn reduce air pollution emissions.

## LAND USE REQUIREMENTS

In order to determine land-use requirements for tepee-refuse-burner installations, sticky-paper stands were set up downwind of a number of burners at various distances to collect dust and fly-ash. Each stand contained a horizontal sheet of sticky paper and a strip of sticky paper wrapped around a bottle to show the direction from which collected dust was coming.[1,2]

Review of the dustfall samples and the visual observations taken in the field, indicates that the nearest boundary should be a minimum of 1,500 feet from the burner, a distance equivalent to having the burner located in the center of a square plot of about 200 acres. Figures A-3 and A-4 in the Appendix, show actual-size pictures of the fly ash at varying distances up to 1,300 feet from two separate tepee burners. These samples represent from 5 to 8 hours of fallout. The fallout was actually heavier than appears in the pictures for the smallest particles have been "screened out" of the pictures by the reproduction method used in printing.

The fly-ash fallout in all samples taken from 0 to 1,290 feet downwind of the burners was significantly undesirable. To extrapolate this fly-ash data to a distance from the burner that would insure a desirably low level of fallout is not possible since a desirable distance would depend upon the affected terrain and the meterological conditions of the area. In some cases the nearest boundary should be as much as 2,000 feet from the burner, an area comparable to a square plot of about 365 acres. The burner site would not be wasted, for it would be used for sanitary landfill of noncombustibles, ash, rubber, plastic, and leather products. A 200-acre plot could serve as a sanitary landfill for approximately 32 years for a population of 50,000, based on a fill depth of 7 feet or as a landfill for tepee-burner residue for a period of approximately 80 years under the same conditions.

The boundary distance from the burner also depends upon the land use of the surrounding country. It would be inadvisable to place the burner within city limits or within areas not zoned agricultural or heavy industrial.

Figures A-5 and A-6 in the Appendix show the directional dustfall obtained by wrapping sticky paper about a jar. In all cases, the greatest particulate concentration on the paper came from the direction of the tepee refuse burners.

These pictures of particulate fallout are not representative of the greatest concentration possible at each respective location since maximum dust load is a function of maximum wind speed and minimum dispersion conditions and these pictures only represent the dust concentration that will normally fall downwind when the wind speed is between 10 and 20 miles per hour.

# EQUIPMENT AVAILABLE TO CONTROL FLY-ASH AND SMOKE EMISSIONS

Tepee burner manufacturers have done some research in air pollution control equipment, but do not now consider such equipment economically feasible. Some manufacturers estimate an adequate control system for fly-ash and smoke would cost from $20,000 to $40,000 or as much as the cost of the installed burner. The commercial equipment manufacturers hope that costs can be reduced by design improvements and will probably market equipment in the future.[3]

One burner operator built his own collection device, an afterburner followed by water scrubbers, which was observed as part of the field investigation. It produced very little visible smoke (less than 30 percent opacity) during 1 hour of operation, during which it was charged with three packer-loads of municipal refuse. This control system could probably be reproduced for approximately $20,000 to $30,000.

# COMPARISON OF TEPEE REFUSE BURNER WITH OTHER MUNICIPAL WASTE DISPOSAL METHODS

From the aspect of air pollution control, the two most effective methods for disposing of municipal refuse are sanitary landfill and refractory-type multiple-chamber incinerators. Many smaller communities, however, continue to use tepee burners.

## TEPEE INITIAL COST

The initial investment for a tepee refuse burner depends upon the design capacity of the burner. Typical price ranges for fully equipped and installed burners are shown in Table 8. Each price range composites the cost of the burner (including double wall, forced air system, and double doors), the conveyor system, and the refuse-receiving building, but does not include the price of a cleanout dozer. In general, two men can operate a tepee refuse burner.



The costs for each burner size (Table 8) vary as much as $10,000 and depend upon the shipping costs, installation costs, refuse-receiving building size, and manufacturer's cost. A typical cost for a tepee burner equipped with a conveyor, receiving building, and cleanout dozer, serving a community of 50,000 population is between $90,000 and $100,000.

Table 8. PRICE RANGES OF COMPLETELY INSTALLED CONVEYOR-FED TEPEE REFUSE BURNERS FOR VARIOUS RATED CAPACITIES[a]

| Capacity, tons per day | Diameter, feet | Price range, dollars[b] |
|---|---|---|
| 45 | 45.0 | 43 - 50,000 |
| 60 | 52.5 | 50 - 55,000 |
| 80 | 60.0 | 60 - 65,000 |
| 100 | 67.5 | 70 - 80,000 |
| 120 | 75.0 | 84 - 90,000 |

[a]Based on cost data supplied by two major burner manufacturers.
[b]Does not include cost of dozer.

## SANITARY LANDFILL

The most practical method of refuse disposal for many medium and most small communities is the sanitary landfill operation. It has been estimated that 1 acre will accommodate the refuse of 10,000 people for 1 year if the recommended procedure of operation is followed and refuse is compacted to a finished depth of 7 feet.[4] Operating cost for this method ranges between $0.70 and $1.50 per ton of refuse.[5] The initial cost of land could be returned to the investor after the landfill was completed. In many cases, land value will increase because of the improvement made by the land-filling operation. Equipment costs (large dozer plus small equipment) for a sanitary landfill serving a community of 50,000 people would be about $20,000.

## MULTIPLE CHAMBER TYPE

Building a refractory-type multiple-chamber incinerator is often warranted when the distance from the community for a sanitary landfill site is more than 10 to 15 miles, or the cost of hauling is more than $1.50 per ton. Waste transfer stations, however, allow sanitary landfills to operate at haul distances greater than 20 miles. The cost of a refractory-type multiple-chamber incinerator that could serve the needs of 100,000 people would range from $375,000 to $1,200,000.[6] This range is based on an estimated cost of from $2,500 to $6,000 per ton of 24-hour burning capacity and the assumption that 1.5 to 2.0 tons of refuse are produced daily per 1,000 people.[6] For a community of 50,000 people, an incinerator built to handle 150-tons-per-day refuse would be needed to process a refuse load of 100 tons per day. This size is based upon a 16-hour working day, which would be more typical for a smaller community. Thus, the estimated cost for a refractory-type multiple-chamber incinerator serving 50,000 people (based upon $5,000 per ton of capacity) is $750,000.

## COST COMPARISON

The operating costs, including ash disposal and amortization of equipment, for a multiple-chamber incinerator would be between $5 and $6 per ton of refuse burned.[7] Operating costs per ton of refuse for a sanitary landfill range from $0.70 to $1.50[5]; costs for a comparable size tepee burner range from $0.85 to $1.50. Operating costs for the tepee burner are based upon data obtained from participating burner operators plus additional cost added for operating a sanitary landfill of 30 percent normal capacity to dispose of noncombustibles and ash. For purposes of comparison, it is assumed that the costs for hauling refuse to the incinerator or landfill site are $0.50 per ton for multiple-chamber incinerators, $1.00 per ton for sanitary landfills, and $1.50 per ton for tepee burners. A higher rate is applied for hauling to tepee burners than to landfill sites because the tepee burners should be placed outside of a community and a sanitary landfill is often located within a city limit.

A comparison of typical operating costs (including investment, depreciation, and labor) and hauling costs for various methods of waste disposal is shown in Table 9 for a community of 50,000 (4 pounds of waste per day per person - or a total of 100 tons of waste per day).

The very approximate cost data in Table 9 should be used for general comparisons only since costs may vary considerably from one geographic location to another. The data in Table 9 do show, however, that refractory-type multiple-chamber incinerators are considerably more expensive to operate in smaller communities than either tepee burners or sanitary landfills. The data also indicate a slightly higher operating cost for tepee burners than for sanitary landfill operations. Also, the initial cost of a tepee burner is approximately 5 times higher than that of a sanitary landfill.


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Table 9. COMPARISON OF OPERATING COSTS FOR VARIOUS METHODS OF WASTE DISPOSAL FOR A COMMUNITY OF 50,000

| | Multiple-chamber incinerator | Sanitary landfill | Tepee burner |
|---|---|---|---|
| Operating cost, dollars per ton of refuse[a] | 5.00 - 6.00 | 0.70 - 1.50 | 0.85 - 1.50 |
| Hauling cost, dollars per ton of refuse | 0.50 | 1.00 | 1.50 |
| Operating cost, dollars per year[a] | 182,500-219,000 | 25,500-54,700 | 31,000-54,700 |
| Hauling cost, dollars per year | 18,200 | 36,400 | 54,700 |
| Total cost, dollars per year | 200,700-237,200 | 61,900-91,100 | 85,700-109,400 |

[a]Includes amortization of equipment.

# ACKNOWLEDGMENTS

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Valuable assistance and information was provided by manufacturers of tepee burners. Special acknowledgment is made of the contribution of Larry E. Crane, Chief, Solid Wastes Training Section, Training Program, Public Health Service, in the review of this report.

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3. Private communication with tepee burner manufacturer. Feb. 24, 1965.

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6. When should a community consider incineration as a method of refuse disposal? New Jersey State Department of Health. Public Health News. Oct. 1960.

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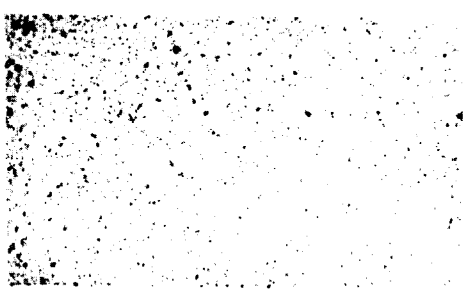
# APPENDIX

Background sample collected from upwind burner.

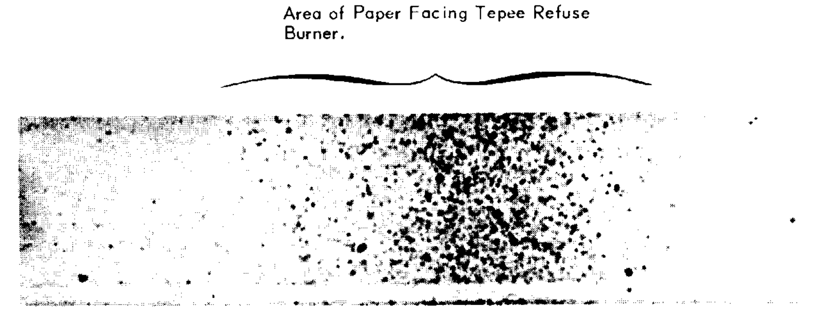
20–minute sample collected 260 feet downwind of burner.



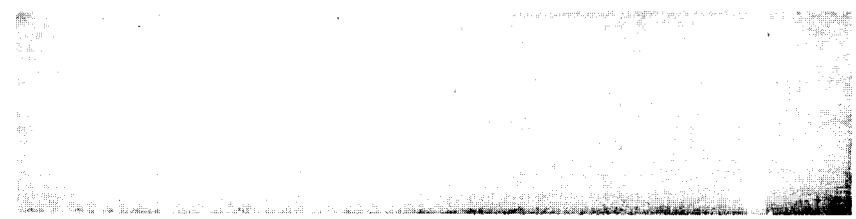
30–minute sample collected 200 feet downwind of burner.

Figure A–1. Horizontal sticky paper samples showing particulate collected during clean-out operation. Hot ash was carried from both burners by dozer scoop. Scale is full size.

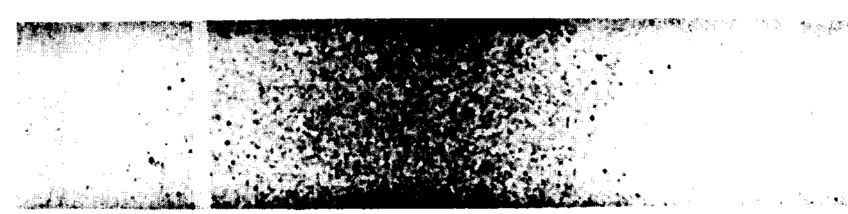





20–minute sample collected 260 feet downwind of burner.



Background sample collected upwind from burner.



30–minute sample collected 200 feet downwind of burner.

Figure A–2. Directional sticky paper unwrapped from bottles showing particulate collected during the clean-out operation. Hot ash was carried from both burners by dozer scoop.

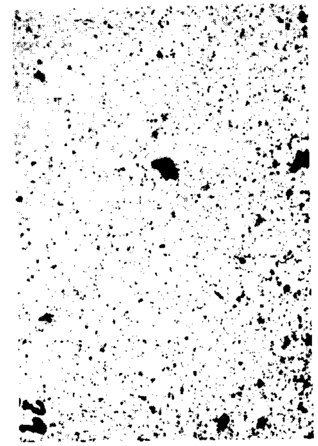

Background sample collected 230 feet upwind of burner.

Sample collected 400 feet downwind of burner.

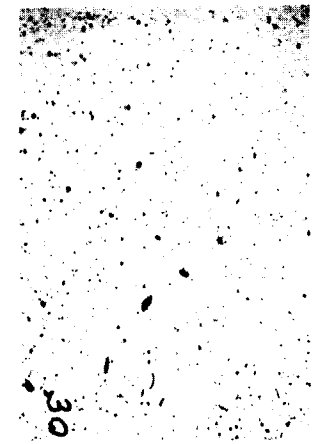
Sample collected 600 feet downwind of burner.

Sample collected 1,000 feet downwind of burner.

Figure A–3. Horizontal sticky paper samples showing particulate collected in 5 hours at various distances downwind of conveyor–fed tepee refuse burner. Scale is full size.




Sample collected 220 feet downwind of burner.



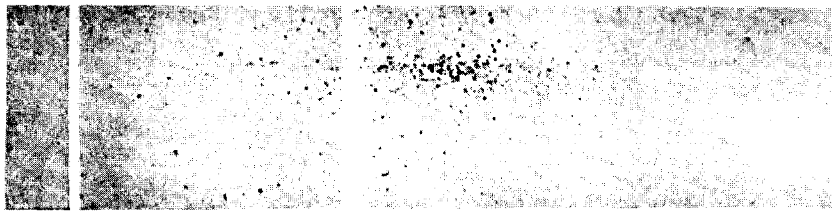

Sample collected 430 feet downwind of burner.


Sample collected 650 feet downwind of burner.

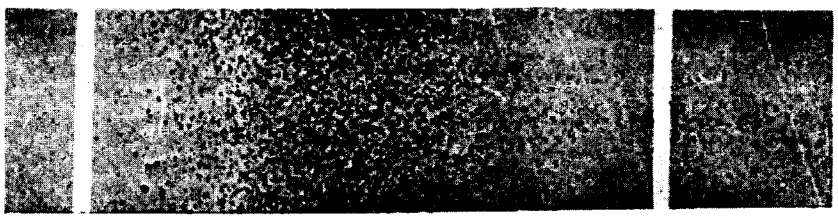

Sample collected 1,290 feet downwind of burner.

Figure A–4. Horizontal sticky paper samples showing particulate collected in 8 hours at various distances downwind of conveyor–fed tepee refuse burner. Scale is full size.

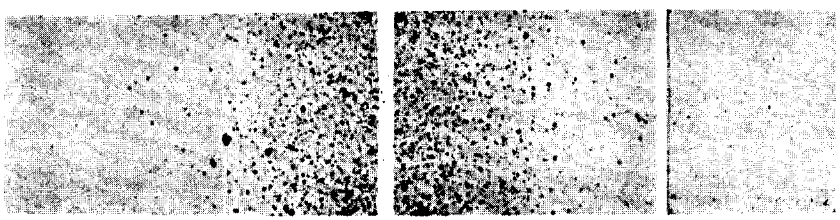
Area of Paper Facing Tepee Refuse Burner.



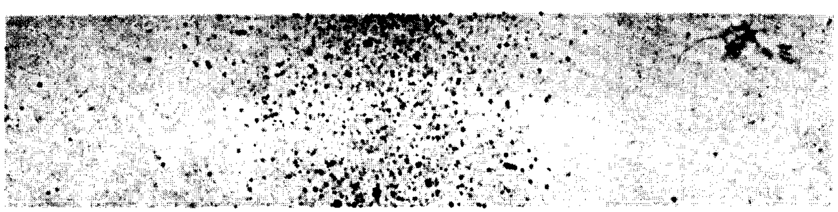
Background sample collected 230 feet upwind of burner.



Sample collected 400 feet downwind of burner.



Sample collected 600 feet downwind of burner.



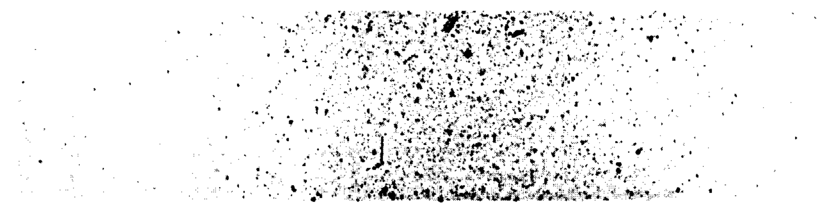
Sample collected 1,000 feet downwind of burner.

Figure A-5. Directional sticky paper unwrapped from bottles showing particulate collected in 5 hours at various distances downwind of a conveyor-fed tepee refuse burner.

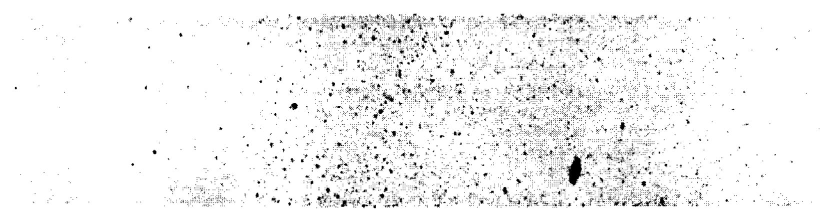


Area of Paper Facing Tepee Refuse Burner

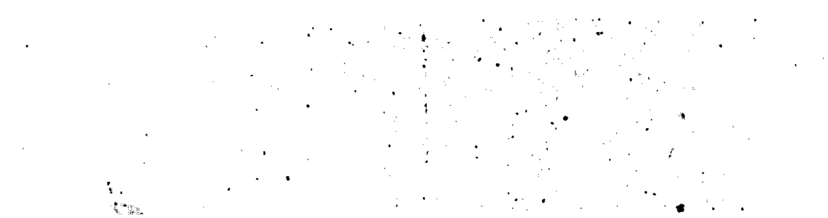
Background sample collected 75 feet upwind of burner.



Sample collected 175 feet downwind of burner.



Sample collected 700 feet downwind of burner.



Sample collected 1,050 feet downwind of burner.

Figure A-6. Directional sticky paper unwrapped from bottles showing particulate collected in 7 hours at various distances downwind of a dozer-fed tepee refuse burner.



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BIBLIOGRAPHIC: Kreichelt, Thomas E. Air pollution aspects of tepee burners. PHS Publ. No. 999-AP-28. 1966. 35 pp.

ABSTRACT: This report covers an evaluation study of air pollution emissions based upon an extensive literature search and field trips to 15 tepee burners in six states. Smoke as a function of composition and rate of charge was observed, and the effect of burner charging methods, construction, and operational procedures on smoke emissions recorded. None of the tepee incinerators observed in operation meet normal visible emission limitations of air pollution control ordinances of most municipalities. Nuisance problems from fly-ash fallout can be expected within distances of up to 1,290 feet downwind from an operating tepee.

ACCESSION NO.

KEY WORDS:

Air Pollution
Municipal Refuse
Equipment
Tepee Burner
Operation
Charges
Emissions
Cost
Efficiency

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