

FIRE PROTECTION DESIGN CONSIDERATIONS FOR WASTE-TO-ENERGY FACILITIES

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ABSTRACT

This paper reviews design considerations required for fire prevention and suppression in resource recovery facilities using the mass burn technology. Potential hazards found in various areas are reviewed and the appropriate level of protection identified. Precautions and operating procedures required to minimize fires are also discussed.

FACILITY PROCESS DESCRIPTION

In a resource recovery facility of the "mass-burn" type, municipal solid waste is discharged from refuse packers or transfer trailer trucks directly into a waste storage pit (see Fig. 1). From the pit, the waste is fed into feed chute hoppers by one of two overhead cranes. These cranes are also used to mix and stack the refuse in the pit. Nonprocessable wastes and large items, such as refrigerators, are separated from the waste stream by the crane operator for off-site disposal. All other items are loaded into boiler feed chute hoppers without any shredding or processing.

Refuse is then metered by hydraulic rams onto the stoker grates. The action of the grate agitates the fuel bed continuously in a manner that provides thorough burnout. The hot ashes are then quenched in a water bath or ash discharger.

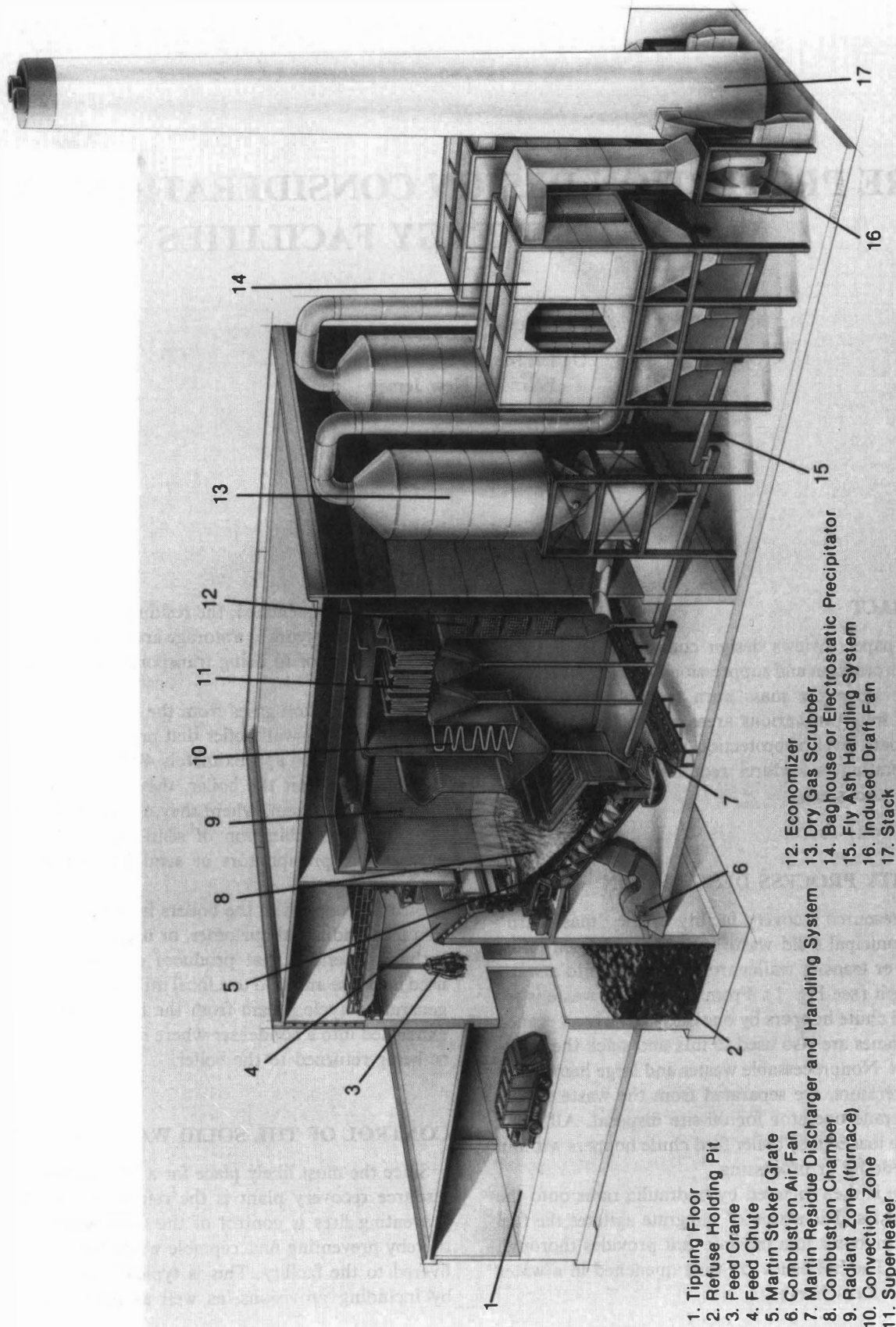
After being quenched, the residue is normally transported by conveyors to a storage area or loaded directly into trucks prior to being transported to a landfill for disposal.

Hot combustion gases from the burning refuse flow through a water-wall boiler that produces steam while cooling the gas to approximately 400°F (205°C). After the flue gases exit the boiler, they are ducted to the air pollution system, where they are typically cleaned by either a combination of semi-dry scrubbers and electrostatic precipitators or semi-dry scrubbers and fabric filters.

Steam produced in the boilers is usually sold either to a local industrial customer, or used in a condensing turbine generator that produces electricity which is used in-house and sold to a local utility. In the electrical generating cycle, steam from the turbine generator is exhausted into a condenser where it is condensed prior to being returned to the boiler.

CONTROL OF THE SOLID WASTE SUPPLY

Since the most likely place for a fire in a mass-burn resource recovery plant is the refuse pit, the key to preventing fires is control of the solid waste stream, thereby preventing unacceptable waste from being delivered to the facility. This is typically accomplished by including provisions, as well as penalties, in the



- 1. Tipping Floor
- 2. Refuse Holding Pit
- 3. Feed Crane
- 4. Feed Chute
- 5. Martin Stoker Grate
- 6. Combustion Air Fan
- 7. Martin Residue Discharger and Handling System
- 8. Combustion Chamber
- 9. Radiant Zone (furnace)
- 10. Convection Zone
- 11. Superheater

- 12. Economizer
- 13. Dry Gas Scrubber
- 14. Baghouse or Electrostatic Precipitator
- 15. Fly Ash Handling System
- 16. Induced Draft Fan
- 17. Stack

FIG. 1 A TYPICAL WASTE-TO-ENERGY FACILITY

service agreements prohibiting the delivery of unacceptable wastes including hazardous materials, explosives, chemical waste, kerosene, gasoline, etc. Private and public haulers, local government authorities and plant operators must work together to identify and prevent the delivery of unacceptable waste.

Educating haulers to identify and reject unacceptable waste prior to loading it into their vehicles is the most effective method of preventing delivery of unacceptable waste. When the trucks arrive at the resource recovery facility, a detailed inspection program begins in order to ensure that unacceptable waste is not unloaded into the refuse pit. Signs are posted at the scalehouse where collection vehicles are weighed (see Fig. 2). The signs constantly remind the drivers that certain types of materials are prohibited. Scale operators perform a visual inspection of materials in the delivery vehicles checking for unacceptable waste in open trucks or smoldering loads.

Periodically, vehicles are randomly selected for spot inspections. The trucks are required to dump their loads onto the tipping floor so trained operators can check them for unacceptable items. In most instances, trucks are randomly selected; however, the specific area of pickup or type of industry served are also considered. Haulers who have previously delivered unacceptable waste to the facility are checked more frequently.

Tipping floor personnel and crane operators visually inspect the refuse for hazardous materials, explosives, chemical wastes, kerosene, gasoline etc., as it is unloaded into the pit. Prior to loading it into the boiler feed hoppers, the refuse crane operator again inspects the waste as it is mixed. Any unacceptable waste found in the pit is removed by the crane operator for off-site disposal. Manual rather than automatic loading of the hoppers provides an additional level of inspection to ensure that unacceptable waste is removed.

REFUSE PIT/TIPPING FLOOR

The refuse pit is typically enclosed on all four sides, up to the charging level, by reinforced concrete walls (see Fig. 3). The thickness of the pit wall varies with the facility design, but should provide a minimum of 4 hr fire separation. The pit wall adjacent to the tipping floor is normally provided with 20–25 ft (6–8 m) high openings that enable refuse vehicles to discharge the waste directly into the pit. The tipping bay area should be provided with an automatic sprinkler system covering the first 20 ft (6 m) of the tipping floor adjacent to the refuse pit. This sprinkler system provides protection of the truck unloading area where refuse may



FIGURE 2

be spilled as well as providing the equivalent of a water curtain to contain a pit fire. The tipping bay area sprinkler system should be designed based on a minimum water density of 0.25 gpm/ft² (10 L/min/m²) [1]. This provides a discharge rate of at least 5 gpm/ft (62 L/min/m) of pit opening—approximately one and a half the 3 gpm/ft (37 L/min/m) [2] required for a water curtain. The pit wall, which extends above the tipping bays, collects the smoke and gases from a fire in the tipping area and prevents the heat from spreading into the refuse pit. This wall acts as a draft stop by banking up the heated air from a fire, allowing prompt operation of the automatic sprinklers.

In addition to allowing refuse vehicles to discharge, the pit wall openings provide access at grade level to manually fight a fire in the pit. Designs that require the pit wall to extend down to the tipping floor, used with sloped-tipping bays (see Fig. 4), should be avoided because this approach prohibits access for manual fire fighting.

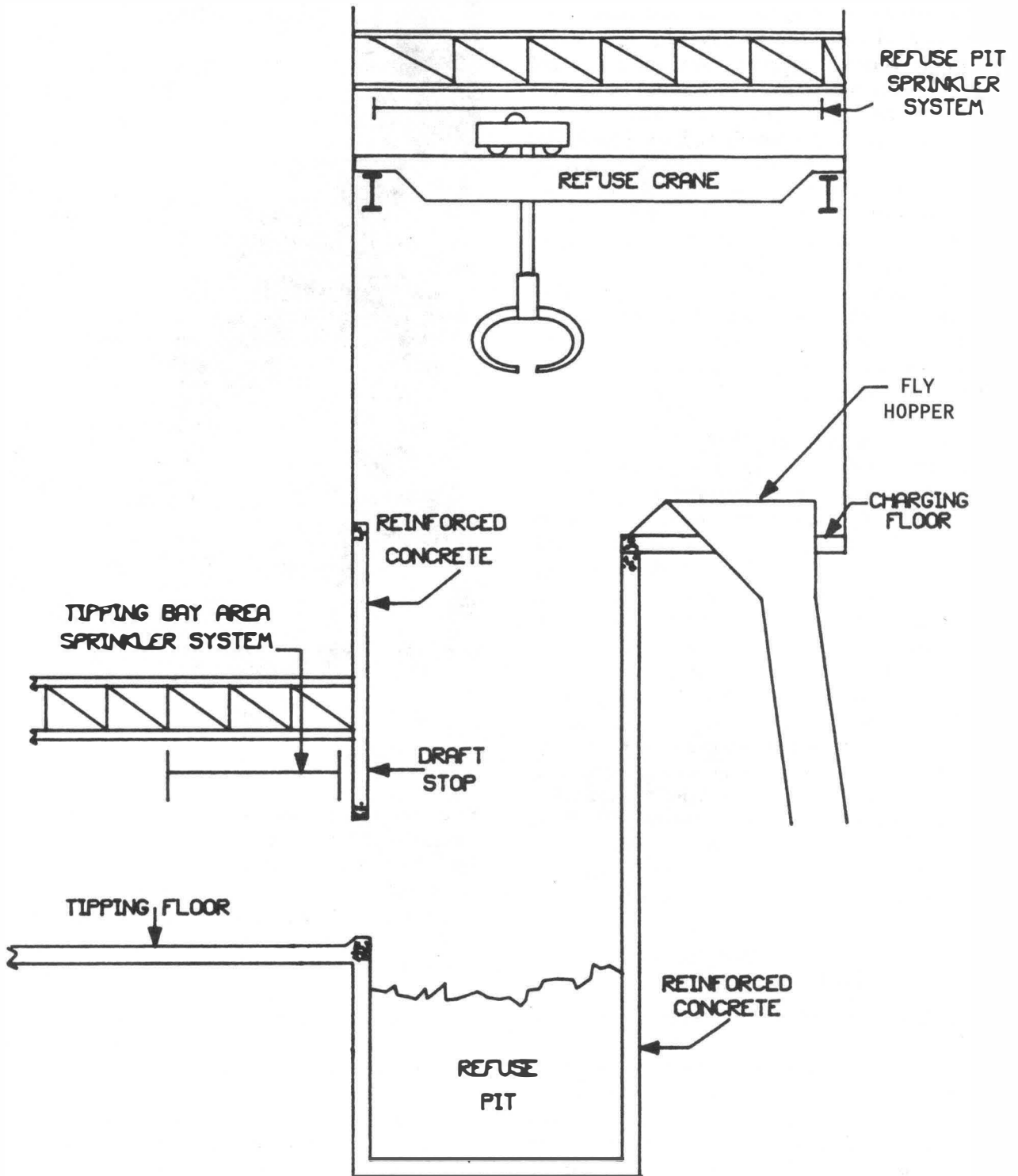


FIG. 3 REFUSE PIT CROSS SECTION

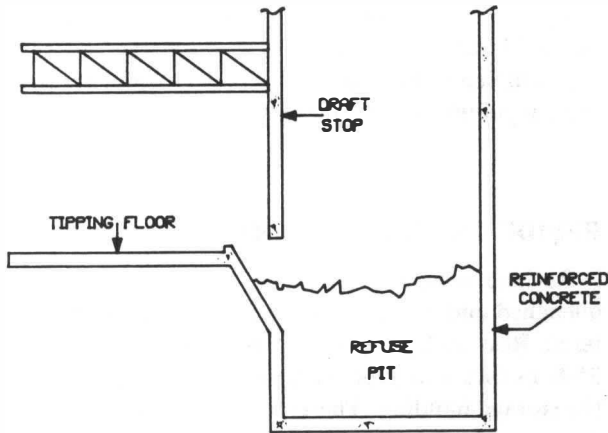


FIG. 4 TIPPING BAY CROSS SECTION

Facilities which store refuse on the tipping floor should be provided with an automatic sprinkler system over the entire area.

An automatic sprinkler system should be provided over the entire refuse pit, including the hopper and crane park area at both ends. In conjunction with the pit walls, this system and the tipping bay sprinkler system completely encloses a fire in the refuse pit.

To eliminate damage to the refuse pit sprinkler system from the crane's grapple, the system piping and heads must be located above the cranes. The system design must consider the vertical distance between the waste in the pit and the sprinklers heads. When sprinkler heads are located more than 40 ft (12 m) above the charging hoppers, the efficiency of the water-spray system is reduced because of the increased likelihood that drafts will carry heat away from sprinklers above the fire. This results in a delay in actuation of the sprinkler system or actuation of sprinkler heads remotely located from the area in which the fire is occurring. In addition, the system should be designed to protect the building steel by including nozzles located in the webs of exposed structural columns.

Manual monitor nozzles should be located on the charging floor (see Fig. 3). Each monitor should be capable of supplying 300 gpm (1150 L/min) [1]. A minimum of two nozzles should be strategically located so that an effective water spray can reach any portion of the pit. Manual hose stations should also be provided on both the charging and tipping floors. The combination of monitor nozzles and hose stations should be considered the primary means of fighting a pit fire. Since the refuse pit is continuously observed by the crane operator, a fire can be easily detected and extin-

guished using monitor nozzles and hose stations before the automatic sprinkler system is activated.

Boiler combustion air is normally drawn from the top of the refuse pit area. The makeup air is usually admitted to the tipping floor through louvers located low on the outside wall. The combustion air quantity will normally exceed the 10 cfm/ft² (3 m³/min/m²) requirements of a smoke exhaust system [3]. This provides the equivalent of a continuous smoke exhaust system for the refuse pit. In addition, the crane control pulpit should be provided with fresh air from outside the pit area to allow the refuse crane to be used to assist in the early stages of a fire or dig out the smoldering refuse after the fire is extinguished. A safe means of egress as well as breathing air apparatus must be provided to allow the crane operator to leave the area.

BOILER AREA

The boiler area of a resource recovery facility is a large single-story enclosure, more than 100 ft (30 m) in height with a very low combustible load. The major combustible load comprises electrical cable insulation and the hydraulic fluid associated with the boiler stoker. Cables are located throughout the area, routed in either steel conduit or in cable trays. Each stoker hydraulic system should either be provided with fire-resistant hydraulic fluid or be protected by a local deluge system with heat-actuated fire detectors. In order to prevent leaking hydraulic fluid from spreading over the floor, the hydraulic pumping station should be enclosed within a curb.

SCRUBBERS

Semi-dry scrubbers typically used on resource recovery facilities are generally constructed of carbon steel without the plastic or rubber linings commonly found on wet scrubbers. Consequently, no special fire protection is required.

FABRIC FILTER BAGHOUSES

Fabric filter bags can incur damage by flue gas temperatures, which exceed the material design temperature, and by fires initiated by high temperature fly ash particles or burning embers. To provide protection against combustion of the filter bags, the bag material should be designed for a maximum continuous temperature that corresponds to the maximum expected continuous temperature of the flue gas leaving the

This flue gas temperature is approximately 475–500°F (245–260°C).

The multipass design of some resource recovery boilers eliminates burning embers from reaching the fabric filter. Low velocities (See Fig. 5) associated with refuse boilers provide a flue gas residence time of approximately 24–30 sec before the gas reaches the fabric filter. This is four to five times longer than the nominal time it takes the fly ash particles to come into equilibrium with the flue gas stream. In addition, the multipass design provides four complete changes in direction that remove large fly ash particles, those that take the longest time to reach equilibrium temperature, from the gas stream.

Since baghouses are normally used in conjunction with a semidry scrubbers, located between the fabric filter and the boiler, they are constantly protected from burning embers and high temperature flue gas by the injection of a mixture of lime and water that reduces temperatures to approximately 275–300°F (135–150°C) while removing acid gases. In the unlikely event that the scrubber's water injection system should fail, baghouses should include a system that bypasses the high temperature flue gases around individual compartments [4].

The baghouse is separated into multiple compartments by noncombustible partitions that limit potential damage caused by fires. If the bag material used in the fabric filter does not have a design operating temperature exceeding 400°F (205°C), the baghouse should include an automatic sprinkler system or the compartment should be separated by partitions with a minimum of 30 min fire resistance.

ELECTROSTATIC PRECIPITATORS (ESPs)

If unburned byproducts of the combustion process reach the electrostatic precipitators, they can be ignited by electrical arcing. This problem has occurred in electrical power plants [4, 5], but is virtually eliminated in resource recovery boilers because they operate with excess air rates of 90–110%. In addition to supplying twice the amount of air required to burn refuse, boilers are designed with two separate combustion air systems: the underfire system, which comprises a series of plenum chambers beneath the stoker and admits primary combustion air at rates controlled to suit conditions at each section of the grate, and the secondary or over-fire system which injects air through high-pressure nozzles located at the front and rear walls of the furnace section of the boiler (see Fig. 5). The secondary air causes intense flame turbulence and pre-

vents stratification of unburned gases, such as carbon monoxide and hydrocarbons, assuring that all gases are completely burned in the boiler before reaching the air pollution control equipment.

RESIDUE HANDLING SYSTEMS

Residue produced from the boilers is thoroughly quenched and is comprised of 3–5% combustible material. Residue leaving the ash discharger contains 15–25% moisture as it is transported from the boilers to the storage building. Therefore, no special fire protection provisions are required.

TURBINE AREA

Large quantities of turbine lubricating oil pose the second greatest fire threat. Equipment that contains large amounts of lubrication oil, such as the lube oil reservoir and condition, should be provided with individual deluge systems using heat-activated fire detectors. Pipe ruptures and equipment leaks resulting in oil spills post significant fire risk. Oil could cascade down to ground level and spread. To protect against such occurrences, an automatic sprinkler system should be installed beneath the turbine operating floor (see Fig. 6). The sprinkler system coverage area should extend a minimum 20 ft. (6 m) beyond the lube oil piping and equipment.

Because failure of the bearings or seal could release a continuous oil flow, the turbine-generator bearings present a significant hazard. If it comes in contact with hot turbine parts, this oil could cause a severe fire. However, because of the potential for expensive damage from the unintentional operation of a system spraying cold water, extreme care must be taken in selecting and laying out the turbine bearing protection system.

An automatic pre-action sprinkler system which requires two positive indications of a fire prior to water discharge should be used to protect turbine bearings. First, a detector will sense a fire and open the pre-action valve, flooding the pipe with water. Second, the fusible link at the sprinkler head must open, discharging water to extinguish the fire. In order to minimize thermal shock, turbine casing areas that are subject to water spray should be protected by sheet metal shields.

Since the generators associated with the turbines are usually totally enclosed water/air cooled (TEWAC), a carbon dioxide fire protection and alarm system for the generator-exciter usually provided on hydrogen-

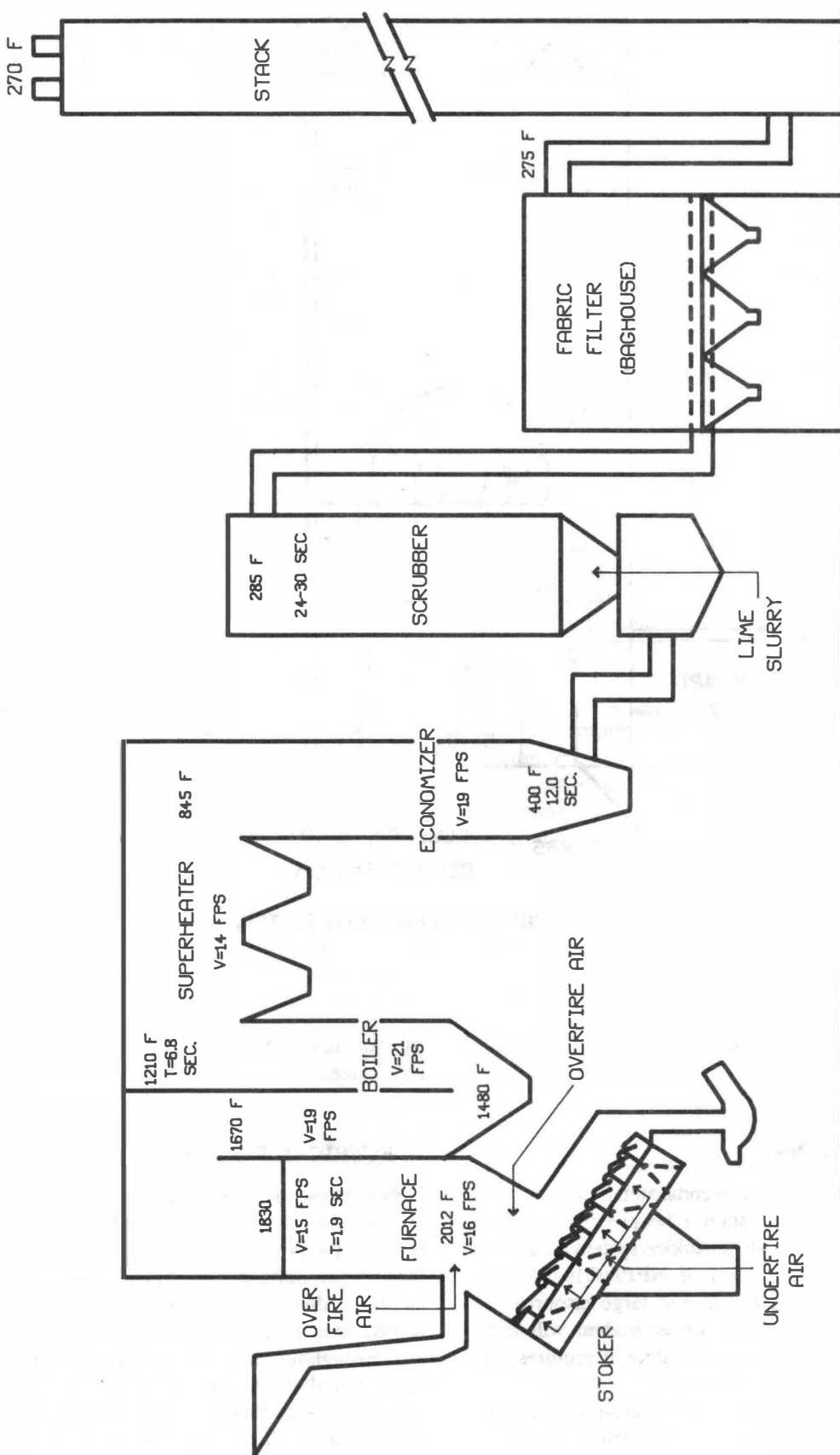


FIG. 5 BOILER / APC RESIDENCE TIME

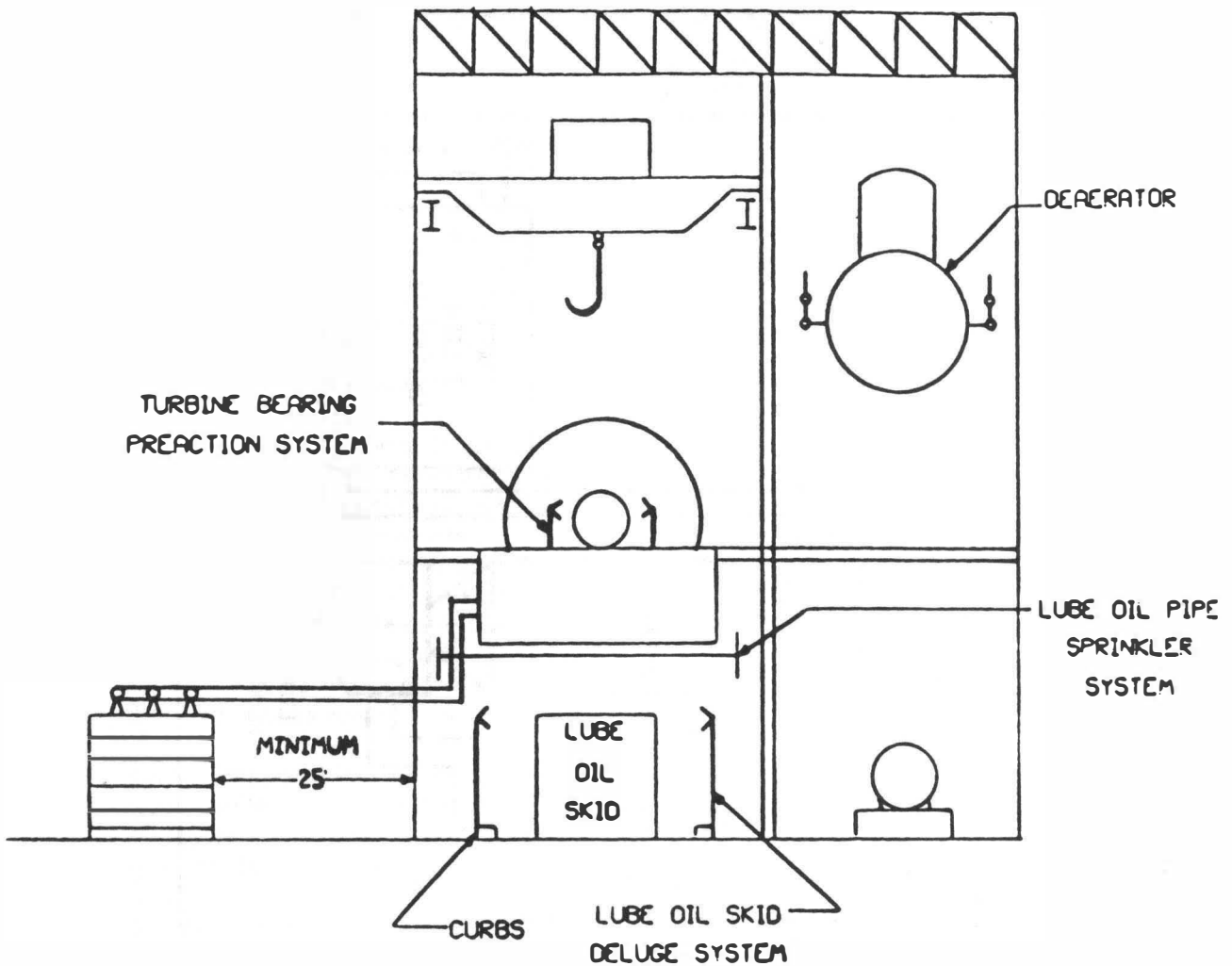


FIG. 6 TURBINE BUILDING CROSS SECTION

cooled units is not required for resource recovery facilities.

COOLING TOWERS

Unless the cooling tower is constructed only of non-combustible material, it should be provided with a deluge spray or automatic sprinkler system in accordance with the requirements of NFPA-214 "Water Cooling Tower". For medium and large resource recovery facilities, the cooling tower system will normally set the fire pump capacity since it requires the greatest suppression system demand.

For larger cooling towers, 20 min fire-resistant partitions that separate the cells would further minimize

the potential fire damage and the facility's water flow requirements.

ELECTRICAL ROOMS

Switchgear, unit substations and motor control centers should be isolated from plant areas containing large amounts of combustibles. Since dry-type transformers are normally used inside a resource recovery facility, cable insulation represents the majority of combustible material in electrical rooms. To lesser hazard throughout the facility, only fire-retardant cable insulation that has passed the Institute of Electrical and Electronic Engineers (IEEE-383) flame propagation test should be used. This test requires that ver-

tical cable be exposed to a 1500°F (815°C) flame source within 1/8 in. (3 mm) of the cable surface and requires that the cable self extinguish after the flame source is removed [5].

Each electrical equipment room should be provided with fire detection to provide an early warning. Portable fire extinguishers should be located inside and hose stations should be placed within each access to all areas.

Oil-filled transformers are used for main step-up transformers and occasionally for station auxiliaries on larger facilities. Located outside in the switchyard, these transformers should be separated from the facility and each other by a minimum of 25 ft (8 m) [4]. If sufficient space is unavailable, then the transformers should be separated by a 2 hr rated fire wall. A yard hydrant should be located within 150 ft (45 m) of the transformer.

The facility battery should be isolated from other areas of the plant and installed in accordance with the National Electric Safety Code. Since hydrogen is generated during recharging, the battery room's ventilation system must be designed to limit hydrogen concentration to less than one percent, which is one fourth of the lower explosive limit concentration [4]. The exhaust fan should be spark resistant and exhaust directly outdoors. An alarm should be installed in the event that the ventilation fan fails.

CONTROL ROOM

Because the control room represents the facility's central operating point, continued occupancy of this area is extremely important during any emergency.

The major combustible loading in the control room comprises wire insulation, located within individual control cabinets, and a minimal amount of paper required to operate the facility. Since personnel are located in the control room 24 hr/day and easy access is provided to all areas including the interior of the control cabinets, portable extinguishers and hose stations with adjustable fog-type nozzles furnish the appropriate level of protection. Designs which use the space above the suspended ceiling as a cable spreading area or have raised floors should be protected by either a halon or pre-action sprinkler system.

To ensure the absolute minimum response time, the control room and individual control panels should be provided with a complete fire detection system. The room should include a dedicated air-conditioning system with ductwork smoke detectors and should also

be positively-pressurized to prevent smoke entering from adjacent areas.

WATER SUPPLY

Since water represents the primary means of fire control, a reliable and adequate supply must be available at all times. The preferred water supply is a municipal water system meeting the following requirements [1]:

(a) Proven history of reliable service.

(b) Continuous adequate pressure without major seasonal or periodic fluctuations due to fluctuating user demands.

(c) A backup generator if the water supply depends upon electricity for powering pumps.

(d) The system must be capable of continuously supplying the largest sprinkler system demand plus 500 gpm (1890 L/min) for hoses.

(e) Two hour supply minimum at the required flow rate.

If the municipal water system meets all of the above requirements, with the exception of the minimum pressure needed, a pumping system should be provided to increase pressure to an adequate level. The system should comprise a diesel-driven fire pump and a jockey pump.

A diesel drive is needed because power outages, equipment faults or fires in electrical equipment may also affect an electrically-driven fire pump making it inoperable. The pump should normally be located in a separate pumphouse adjacent to the water supply. Providing it is completely enclosed by noncombustible construction, it can be located in the main building. Enclosures containing diesel-driven fire pumps and associated oil tanks should be provided with a wet-pipe sprinkler system as well as a separate detection system to provide early warning.

When the municipal water supply is inadequate, a 2 hr supply must be provided. A dedicated fire protection tank is normally used, but sources such as rivers, lakes, ponds or cooling tower basins may be considered. Reliability and cost are the primary criteria for selecting a water source. In evaluating rivers, lakes and ponds, it is necessary to determine fluctuations in the water level, as well as the potential for freezing and biological fouling. When considering the use of an enlarged cooling tower basin for storage, the cost of the increased basin size and pump structure as well as the chemistry of the water must be considered, since sewage treatment effluent and other waste water supplies are often used for cooling tower makeup.

YARD AREA

A yard loop encircling the main facility buildings should be provided, separate branches should be provided for protection of remote areas such as the scalehouse and cooling tower. Valves should be provided in order to isolate portions of the fire protection loop for maintenance and repair. Hydrants with individual isolation gate valves and curb boxes should be located at approximately 300 ft (90 m) intervals along the yard loop and all branches. The grizzly scalper building, residue building, scalehouse, switchyard, air pollution control equipment and cooling tower should be protected by exterior yard hydrants.

STANDPIPE AND HOSE STATIONS

Class III building standpipes and hose stations should be provided throughout the tipping floor, refuse pit, turbine, boiler, water treatment, and administration area. Located strategically at approximately 100 ft (30 m) intervals, stations should be provided with 75 ft (23 m) of 1½ in. (38 mm) hose to ensure that all areas can be reached by at least one hose stream. All interior hose stations require adjustable fog-type nozzles with shutoff because of the high-voltage shock hazard located throughout the facility.

PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers should be provided throughout the facility in accordance with the requirements of NFPA-10 "Portable Fire Extinguishers."

Halon fire extinguishers should be provided in the control room as well as other areas containing electrical equipment.

SUMMARY

Prior to construction, a thorough evaluation of all areas of a resource recovery facility must be performed by experienced design engineers in consultation with the insurance company and local code officials to determine the potential fire hazard and appropriate level of protection required. Standard approaches should be avoided because the local codes and the degree of risk varies between facilities.

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Key Words: Cogeneration; Fire Protection; Incineration; Mass Burn; Power Generation; Refuse