Designing Incinerators for Combustible Waste Management

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Module 1: Incinerator Design

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the primary structural components and functional chambers of a municipal-scale incinerator.
- **Select** the appropriate incinerator type based on waste composition and heat release constraints.
- **Calculate** required incinerator capacity and preliminary dimensions using standard design factors and draft formulas.

Executive Summary: Successful incinerator design requires balancing waste composition with strict thermodynamic and aerodynamic constraints. Engineers must prioritize Type I designs for general refuse to avoid the structural risks associated with high heat release, while ensuring all volumetric and velocity requirements meet minimum safety thresholds to facilitate complete combustion and proper draft.

Design Definitions

To apply the standards in this manual effectively, engineers must use consistent terminology for the following structural elements:

- **Incinerator:** A specialized structure designed to reduce refuse to inert gases and solids through controlled burning.
- **Furnace:** The primary assembly where combustion occurs, encompassing the ignition, mixing, and combustion chambers, as well as the charging hood.
- **Arch:** The refractory ceiling spanning the internal chambers.
- **Grate and Hearth:** The **grate** (typically cast iron) supports dry material burning, while the **hearth** (inclined firebrick or grate bars) is used for drying and burning wet material.
- **Chambers:** The **ignition chamber** initiates the burn; the **mixing chamber** (or downpass) blends gases; and the **combustion chamber** ensures final gas burnout.
- **Separation Walls:** The **bridge wall** separates the ignition and mixing chambers, while the **target wall** stands between the mixing and combustion chambers.
- **Draft Control:** Includes the **flue** (connection to stack), the **damper** (refractory slab for flow control), and the **damper box**.
- **Loading:** Refuse enters through a **charging hood** or a **charging throat** (an extension from the arch to the charging floor).

Incinerator Type Selection

Selection is driven by the moisture content and "rubbish-to-garbage" ratio of the expected waste stream:

- **Type I (General Purpose):** Designed for rubbish or a mixture (up to 35% garbage by weight). This is the standard for most installations.
- **Type II (Wet Garbage):** Designed for 65% wet garbage and 35% rubbish without auxiliary fuel.

⚠️ **Safety Constraint:** Do not use Type II incinerators for waste streams with high rubbish percentages. They are not designed to withstand the high heat release resulting from dry material combustion.

Capacity Determinations

Establish requirements based on an actual waste survey whenever practicable. For planning at average troop cantonments, use the following per capita daily estimates:

- **Rubbish:** 1.5 pounds
- **Non-edible Garbage:** 0.50 pounds
- **Edible Garbage:** 2.0 pounds

💡 **Design Tip:** Provide **25% excess capacity** over average hourly needs to account for irregular delivery schedules.

Example Calculation: If 4 tons (8,000 lbs) must be burned in 8 hours: (8,000 / 8) * 1.25 = **1,250 pounds per hour capacity**.

Basic Design Requirements

The system must be designed for the **severest expected conditions**, typically assuming a 100% dry material load to evaluate maximum heat release and gas volume.

Volumetric and Thermal Constraints

- **Heat Release:** Maximum **18,000 Btu per hour** per cubic foot of furnace volume.
- **Temperature:** Must ensure complete combustion but cannot exceed **1,600°F**.
- **Combustion Time:** Minimum **1.5 seconds** total gas residence time.

Velocity and Area Constraints

- **Combustion Chamber Velocity:** Maximum **15 fps**.
- **Mixing Chamber/Stack Velocity:** Maximum **35 fps**.
- **Effective Grate Area:** 0.022 sq. ft./lb (Type I) or 0.04 sq. ft./lb (Type II).

🧮 **Calculation Note:** When calculating the effective grate area, firebrick hearths are considered **60% effective**, while grate-bar hearths are **80% effective**.

Draft and Stack Height Formulas

Equation 1-1 (Stack Height):

$$H = \frac{D}{0.52 \cdot B \cdot \left(\frac{1}{T_a} - \frac{1}{T_s}\right)}$$

Equation 1-2 (Velocity Head):

$$\text{Velocity head} = \frac{0.119 \cdot B \cdot V^2}{14.7 \cdot T_s}$$

Equation 1-3 (Friction Loss):

$$\text{Friction loss} = \frac{(1.1 \times 10^{-6}) \cdot T_s \cdot W^2 \cdot L \cdot P}{A^3}$$

Where:

- **H** = Stack height above the grate (feet)
- **D** = Static stack draft (inches of water)
- **B** = Barometric pressure (psi)
- **Ta** = Atmospheric temperature (degrees F. absolute)
- **Ts** = Average stack-gas temperature (degrees F. absolute)
- **V** = Gas velocity (fps)
- **W** = Weight of gas including excess air (pounds per second)
- **L** = Stack height above flue plus length of flue (feet)
- **P** = Inside stack perimeter (feet)
- **A** = Average inside cross-sectional stack area (square feet)

Preliminary Design

Use the following factors to establish initial dimensions before performing a full design check.

Table 2-1. Preliminary Design Factors

	Type of Incinerator	
	I	**II**
Effective grate area per pound of refuse per hour (square feet)	0.022	0.04
Ratio of hearth area to grate area	1	1
Effectiveness of hearth area in terms of grate area (percent):		
Firebrick hearths	60	60
C. I. grate bars	80	80
Horizontal cross-sectional area of mixing chamber in terms of effective grate area (percent)	25	20
Horizontal cross-sectional area of combustion chamber in terms of effective grate area (percent)	60	30
Cross-sectional area of flue in terms of effective grate area (percent)	25	10
Cross-sectional area of stack in terms of effective grate area (percent)	22	10
Ratio of height of arch above grate to width of furnace not to exceed	1	1

Design Analysis

All construction requests must include a design analysis indicating:

1. The specific type of material to be incinerated.
2. The detailed basis for established capacity requirements.

Checkpoint Quiz

1. **Which incinerator type should be selected for a waste stream consisting of 60% wet garbage and 40% rubbish?**
   a) Type I
   b) Type II
   c) Either Type I or Type II
   d) Neither; auxiliary fuel is mandatory

Answer: (b). Type II is designed for waste streams containing up to 65% wet garbage by weight.

2. **If a firebrick hearth has an actual area of 100 square feet, what is its "effective area" in terms of grate area?**
   a) 60 square feet
   b) 80 square feet
   c) 100 square feet
   d) 125 square feet

Answer: (a). Per standard design factors, firebrick hearths are considered 60% effective in terms of grate area.

3. **What is the maximum allowable gas velocity through the combustion chamber?**
   a) 1.5 fps
   b) 15 fps
   c) 35 fps
   d) 60 fps

Answer: (b). The basic design requirements mandate a maximum of 15 fps for the combustion chamber, while flues and stacks allow up to 35 fps.

Purchase this course to see the remainder of the technical materials.