Prefabricated Chimneys

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Abstract

The paper reviews development of the prefabricated chimney, its use with incinerators, and the safety standards of the Underwriter's Laboratories. Several types of such chimneys are described, including residential, commercial and industrial. The wall construction is given for the range of sizes and heights. Prefabricated refuse chutes are an allied product.

Introduction

To most of us chimneys are commonplace, always there, brick upon brick, symbols of warmth and comfort, sentinels of industry, punctuating our skyline. Chimneys are basic to all phases of our living, our homes, our offices and our factories. Yet with all our progress chimneys showed little change from their first usage in 1200 A.D. to modern times.

Prefabricated chimneys, or chimneys constructed away from the job, have been in use for many years; the first may well have been made of clay pipe or sheet metal. The sheet metal "smoke pipe" is a prefabricated chimney, but is not the type of prefabricated chimney we will speak of in this paper. Our interest is in the factory-built chimney as listed with the Underwriters' Laboratories, chimneys with inside diameters from 10 to 36 in., lined with acid-resistant, load-bearing refractory materials. Continuity, however, we shall review the development of other prefab chimneys that led the way to the larger sizes.

In 1949 the National Fire Protection Association issued a booklet [1], which outlined the fire hazards of masonry chimneys and showed that the conventional brick chimney could be built to avoid fires, but could also cause fires because of many of the faulty but common installation practices.

The problem with conventional chimneys, and the subsequent high incidence of chimney fires, assisted in the motivation of Underwriters' standards for factory-built chimneys and the development of a number of chimneys that meet these standards. The first factory-built chimney was "the all-fuel chimney" as presented under the UL standards for Safety No. 103, suitable for coal, wood, oil or gas. There were two types:

1. Insulated. Utilizing a lining of metal or refractory, an insulating wall, and an outer jacket, as shown in Fig. 1.

FIG. 1 INSULATED-TYPE FACTORY-BUILT CHIMNEY
2. *Thermo-Syphon*. A multi-walled metal chimney utilizing air flow as insulation by drawing in air through an outer annular area, flowing the air down this channel through a manifold at the base of the chimney, then up an inner annular area and out the top as shown in Fig. 2. The differential temperature and densities create the thermal-syphon movement.

These types were tested under conditions severe enough to cause fire with some masonry chimneys. Nevertheless, the Underwriters' Laboratories required the outside surface of the chimney to be less than 90°F above ambient air under test conditions. This safer chimney provided a bonus factor; it was considerably less expensive than the brick-and-mortar chimney.

The next development was the introduction of a vent especially for gaseous fuels. Standards for gas vents, UL 441, were developed and a number of UL-approved vents appeared on the market. Most consisted of an inner lining or flue of aluminum, a small air space for insulation, and an outer jacket of galvanized steel. One vent utilized a refractory lining.

In 1959 a most important development occurred. The Underwriters' Laboratories tested and approved the first chimneys for medium-heat appliances, according to UL definitions, including such items as chimneys for annealing furnaces, charcoal furnaces, galvanizing furnaces, gas producers, steam boilers, other furnaces classified as medium-heat appliances, and commercial industrial-type incinerators. Chimneys of this type are listed under UL Guide No. 6011 3.13. They have a service temperature of 1800°F for continuous firing and 2000°F for intermittent firing.

The chimney is produced with inside diameters of 10, 12, 15, 18, 21, 24, 27, 30 and 36 in. id, with wall thicknesses of acid-resistant refractory ranging from 2 in. for the 10 in. id size to 4 in. for the 36 in. id size. It is produced with various outer jackets depending upon manufacturer: 28-gage aluminized steel, 26-gage galvanneal, 12-gage galvanized iron, 11-gage black iron and a variety of heavier gage metal jackets.

They are produced as 4 ft long straight sections together with fittings of various types, elbows, tees, floor supports and a variety of special items as a particular design may require. Typical components and fittings are shown in Figs. 3 and 4. Approval of this factory-built chimney depends upon many factors: freezing and thawing tests, corrosion resistance, thermal tests, shock tests (by spraying cold water in a hot chimney), strength tests of various components, and compression tests of the refractory.

This last test is most interesting and points out the care with which the Underwriters' Laboratories examines a product. It is their belief that this type of chimney must support its entire weight on the refractory, the jacket being an enclosing member only, lending no compressive strength. When tests are made, carefully fitted plates are designed to rest on the refractory only with no contact on the jacket at top or bottom platens of the test equipment. The test is made on a section that has been fired to 2000°F at the Underwriters' Laboratories. This is done to take into consideration the loss of compressive strength upon firing, which averages about 50 per cent. Of course, if the item is fired at a lower temperature, the loss will be less, but all tests at Underwriters' are conducted, as they should be, after maximum firing.

The load at failure is divided by 4 to give a 4-to-1 safety factor. Then 15 per cent of this remaining figure is removed to accommodate masonry variables. The remaining load is calculated as total feet of allowable stack height, which will range from 180 ft for a 10 in. id chimney to 135 ft for a 36 in. chimney. Lower heights are allowable over tee sections.

This whole concept is different from that of the refractory-lined steel stack which achieves its strength from the jacket material and utilizes lugs to secure the refractory to the steel shell. Such construction precludes the use of the refractory as a supporting member. In cases where lugs or other mechanical fixtures secure the refractory to the shell, the shell must bear the total load. Upon firing, hydraulic-type refractories will shrink up to 0.5 per cent or more when fired at 2000°F, and could separate into individual cylinders transferring the weight of the refractory to the shell.
There are various criteria for establishing the gage number of the steel casing. The National Fire Protection Association presents the following suggested gages [2]:

<table>
<thead>
<tr>
<th>Mfg. Steel Gage No.</th>
<th>Inside Area, sq in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Up to 154</td>
</tr>
<tr>
<td>14</td>
<td>154 to 201</td>
</tr>
<tr>
<td>12</td>
<td>201 to 254</td>
</tr>
<tr>
<td>10</td>
<td>Larger than 254</td>
</tr>
</tbody>
</table>

It is evident here that a chimney of this type with 18 in. inside diameter should have a 10-gage jacket to support the load.

Some specifications are in more detail, but present a similar picture. General Services Administration Specs, for instance, are given in Table 1.

These specifications require that a chimney of 24 in. or more shall have a ¼ in. jacket.

The chimneys listed with the Underwriters' Laboratories need not adhere to the jacket specification presented above, having been tested in accordance with a different criteria where the refractory must carry the load and where there are no lugs or fastening connecting the refractory to the jacket. It is common practice, however, to use heavier gage jackets when reduced guyings or other special considerations are required.
When one thinks of prefabricated, factory-built chimneys, it is often in association with an incinerator installation, particularly in a high-rise dwelling. It is here that some of the most interesting developments have taken place and where the true versatility and value of the factory-built chimney first came into focus. To understand how these developments came about it is necessary to review on-site incineration, its advantages, its problems and the solution of these problems.

It was during the early 1900's that refuse handling in apartment dwellings became a serious problem. Apartment-to-apartment collection became more costly to building owners, and street collection became costly to towns and cities. The single-flue incinerator was born. A small door at each floor made possible refuse charging to the flue by the tenant. The same flue carried the combustion gases from the incinerator in the basement. To improve combustion, auxiliary gas burners and overfire air jets with blower were recently added to the combustion chamber. Electric timers and controls made them automatic. The gas washer at the upper end of the flue cleaned the flue gases in some cases.

The importance of adequate flue sizes was not recognized until stoppages by refuse, especially cartons and umbrellas, were experienced. The National Fire Protection Association, recognizing the fire hazard and smoke problems, established standards for both flue size and service openings, which would minimize or eliminate clogging [3; p. 7, par. 2.4].

Hopper locks, charging gates at the base of the flue, multiple-chambered incinerators, and by-pass flues were also developed.

Because of the tendency for paper to float upward when charged during the burning period, and the lack of tenant co-operation with hopper locking, the two-flue incinerator is coming into favor. The larger flue is the charging chute, while a smaller flue is the chimney. The charging chute has a powered gate at the bottom to regulate the movement of refuse into the furnace and to prevent the flow of hot gas into the chute.

As building heights increased and mechanical ventilation became common, the escape of flue gas into the building was experienced at the upper floors. It is in this zone that the differential between flue pressures and building pressures is at a minimum, even with a properly designed building. This problem can be corrected, but first let us examine how a building achieves a more negative pressure than a flue: (1) exhaust fans, (2) air conditioning units, (3) forced draft boilers, (4) inadequate air supply to boiler or incinerator room, and (5) exfiltration.

This last item may easily be overlooked. A strong wind impinging on a building at a certain angle will draw air out of a building. Although well known, this fact sometimes appears improbable. It does exist, particular-
Gas Scrubbers and Draft Inducers

With air pollution codes becoming more effective and with limits on particulate matter becoming lower, it has become necessary to add scrubbers or dust removers of various types. When not equipped with induced draft fans, these devices require the addition of a draft inducer to the system. We now have the last link to complete effectiveness. A properly designed chute and chimney system can avoid smoke evolution on upper floors, and control expansion and contraction, which obviously becomes more serious as building height increases.

The most obvious location for a scrubber is adjacent to the incinerator where an attendant can more easily clean it and dispose of collected materials. There is one factor, however, that has been overlooked; the corrosive nature of the condensed products of combustion. A water scrubber lowers the flue gas temperature from 400 °F to 500 °F or even 160 °F, which reduces the draft effect and thus also creates another problem. Reduced temperatures at the stack inlet may allow the stack temperature, at some phase of burning and/or in some portion of the chimney (particularly in high rise), to fall below the dew point, resulting in condensation of moisture and some other gaseous materials. The wide variety of compounds possible with refuse burning makes it extremely difficult to select a proper chimney material. The factory-built chimneys are more resistant to acids than most any other material in use, but are not totally immune to deterioration by condensation.

To utilize the draft created by the 1400 °F incinerator exit temperature and to reduce corrosion by avoiding condensation, the scrubber should be placed at the terminal end of the chimney and should be designed to provide exit temperatures as high as possible. It is in its most advantageous location and allows for a very important modification that will eliminate the smoke on the upper floors.

It is essential to install a draft inducer at the top of the chimney, with a substantial surplus above building requirements to insure a more negative pressure even under unusual circumstances. This, however, may not necessarily eliminate upper floor smoke. To eliminate smoke evolution from the chute of a double-flue incinerator, a bypass is placed above the chute gates of the refuse chute to the incinerator stack to provide a definite negative pressure in the chute. One manufacturer has developed an incinerator system that eliminates the charging gate and thus requires no bypass. This is usually sufficient in relatively low buildings, but in high buildings it is often necessary to introduce a bypass near the top of the chute to insure more negative pressure in the chute. The draft inducer provides the third line of defense against building smoke. Any leaks will be “in leaks”; no portion of the chimney and chute system in the living areas will be under a positive pressure.

We now have the background. A properly designed chimney-chute system begins to evolve. The normal high-rise chimney system includes many items:

1. **Floor supports and expansion joints**: These make possible prefabricated chimneys in any building height, spread the load throughout the steelwork and provide an expansion joint with a double line of protection.

2. **Refuse chute sections**: These provide a square opening for accepting standard, available, service entrance (hopper) doors.

3. **One-hour fire-rated chase**: The three chimneys, boiler chimney, incinerator chimney, and refuse chute may be enclosed in a one-hour fire-rated chase according to Underwriters’ testing.

4. **Fittings**: A variety of fittings (elbows, tees, “Y” sections, and special fittings of all types) allow for efficient connection of incinerator and boiler with the respective chimneys. They also allow for the necessary bypasses.

5. **Low Cost**: We have so far presented the factory-built chimney as one that will out-perform the conventional
brick-and-mortar chimney. It also provides for the many features available with fittings and special sections at costs substantially below conventional chimneys.

6. Heat Purging: The optimum incineration system will include not only the frequent charging cycle, but also the frequent purging cycle. It is recommended that the refuse chute be purged frequently (as often as once per 24 hours as a portion of the 24-hour cycle). Door locks should be used. A frequent purge cycle allows for a short duration of purging during the least active early morning hours. This reduces tenant problems with locked doors. It also eliminates odors and problems from vermin. The top damper is opened during this purging cycle.

7. Draft Induction: Draft inducers properly located overcome static pressure losses in scrubbers and other equipment and maintain refuse chutes under the negative pressures required to avoid smoke evolution into upper floors.

The Separate Refuse Chute

We have limited our discussion this far to the chute-fed incinerator, but we cannot overlook the separate refuse chute. This system was designed to avoid the problems of smoke evolution at upper floors.

1. It required a two-hour, fire-rated enclosure for the refuse chute [3; pp. 12-36].

2. A separate refuse-chute termination room of two-hour, fire-rated walls, self-closing class B doors, and proper fire-fighting equipment are required to provide for the substantial fire hazard. [3; pp. 12-37].

3. Liquid purging: A purging ring must be installed on the top of the chute to provide for warm water detergent-disinfectant purging. The disinfectant reservoir is filled manually.

4. Manual transfer to incinerator: Refuse must be manually removed from terminal room and charged to the incinerator. This could lead to irregular and improper loading.

These chutes operate successfully when they are properly sized and attended, however, when the NFPA established standards for this type of unit, they designed a fire-safe system, as is their responsibility. They provided the 2-hour chase, Class B fire doors. They left the chute sizing to others. It is here that problems begin. Chutes are made of aluminum or stainless steel in sizes from 18 in. It is common practice to use 24 in. refuse chutes for residential trash chutes for buildings over 6 stories high. Chutes as low as 18 in. have been designed. The frequency of chute fires and clogged chutes is testimony that these chutes have been improperly sized.

When NFPA established the sizing for a flue-fed incinerator, they recommended a size that would not clog; they also stipulated the door size as a specific function of chute size. Unfortunately the doors or chute sizes were not specified by NFPA for the separate refuse chute. The result — chutes too small and doors to large.

The National Academy of Sciences – National Research Council [4] recommends that all refuse chutes have a minimum size of 27 x 27 in. or 729 sq in. They recommend a 30 x 30 in. chute, or 900 sq in.

If we want to avoid chute clogging, whether separate or chute fed, we should at least adhere to the minimum NFPA size of 484 sq inches for dwellings over 6 stories high. The door should be no more than one third of the cross-sectional area of the flue. For best results we should use the National Academy of Sciences recommendations. We have summarized the NFPA data for convenience, in terms of existing factory-built chimney sizes. These are given in Table 2.

<table>
<thead>
<tr>
<th>Service Opening</th>
<th>Minimum Flue Area, Square Inches</th>
<th>Minimum ID Factory-Built Chimney, Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Service Opening, one-family dwelling</td>
<td>144</td>
<td>15</td>
</tr>
<tr>
<td>One Service Opening, multi-family dwelling</td>
<td>196</td>
<td>18</td>
</tr>
<tr>
<td>Two to Six Service Openings</td>
<td>324</td>
<td>21</td>
</tr>
<tr>
<td>Six or More Service Openings</td>
<td>484</td>
<td>27</td>
</tr>
</tbody>
</table>

When factory-built chimneys are used as separate charging chutes, they provide extra safety with their 2000 F refractory lining. This massive lining also provides the sound deadening recommended by the National Academy of Science. In any event, all chutes should be properly sized.

The best combination, however, is still the chute-fed incinerator properly controlled with a chimney and chute as described in the paper. It saves space and is more economical.

References