CHIMNEY SIZING FOR MASONRY FIREPLACES

Fireplaces of masonry construction are desirable features for many home buyers. A great many resources for design of these amenities can be found in building codes, institutional publications, internet postings, manufacturers' literature and in building trade manuals. The chimneys used for masonry fireplaces may be of traditional masonry with tile liners or of approved factory-built chimney designs. The size and height of fireplace chimneys, for proper operation with log fires or any other heat source, is dependent mainly in fireplace opening area in two ways. For a given opening size the shorter the chimney, the larger it must be. For a larger fireplace opening, the larger the chimney must be. Some simple rules of thumb specify that short chimneys must be one eighth ($1/8^{th}$) of the opening area, or one tenth ($1/10^{th}$) of the opening area, depending on chimney height.

In principle, a fireplace operates as a gravity ventilation hood. For proper operation it must capture and contain all smoke and combustion products and allow the chimney to carry them away. Assuming that a fireplace has adequate air for combustion and is not competing with ventilation fans or adverse indoor pressures, a fireplace/chimney system can be studied experimentally based on well known fluid flow and gas analysis principles. In the late 1960s this writer was involved in research and design of factory-built chimneys (those which comply with Underwriters Laboratories Standard UL-103). Along with these studies, an update of the chimney chapter of the ASHRAE handbook was under preparation.

One of the fireplace design studies was to show how a factory-built chimney could serve a conventional masonry fireplace. To this end, a fully instrumented masonry fireplace system was constructed with a factory-built chimney, using a radiant non-aerated yellow flame gas burner as a heat source. This burner consisted of a parallel grid of horizontal ¾ inch pipes each of which had multiple small holes along its entire length. This pipe burner assembly was located just above the hearth with the pipes placed where logs might be located.

The size of the test fireplace opening, as recalled by this writer, was three feet wide by two feet high, with conventional slanted sides and sloping back. The length of the burner pipes was probably about 2 feet to allow placement within the hearth area. The smoke chamber converged at its upper end for the adapter to the circular factory-built chimney.

All pipes operated together and were connected to the natural gas source through a rotameter for measuring flow. Being non-aerated the resulting flames were soft and yellow, with flame height depending on gas input. Flow of combustion air from the room source was comparable to expected flow with burning logs.

The flow rate of air and combustion products in the chimney was determined from temperature and combustion product analysis. Based on these fireplace tests along with theoretical analysis, a technical paper was submitted for publication in the ASHRAE Journal. This paper appeared in the February 1969 issue and may be reviewed by clicking the link at the end of this discussion. This discussion, which is an excerpted upgrade of the original paper can be copied, reproduced or used in any way the reader sees fit. Due to copyright restrictions the original article, which contains the theoretical basis for the fireplace charts, may not be reproduced without permission from ASHRAE. The terms of this permission are included with the linked article.

This paper also served as a reference for a short section in the ASHRAE Handbook chapter on chimney sizes for fireplaces. An excerpt from this paper first appeared as Chapter 26 of the 1975 edition, "Chimney Gas Vent and Fireplace Systems". Currently Chapter 30 of the "HVAC Systems and Equipment" volume contains the same text and figures as the 1975 chapter.

An occasion arose recently to review this earlier work, because this writer was never entirely pleased with the rendition of the chart entitled "Fireplace Sizing Chart for Circular Chimneys", which is currently Fig. 19 in the 2004 ASHRAE edition. First, the vertical "SIZE" lines on the right are so closely spaced as to make reading very difficult. Second, because of concerns that use of a factory-built circular chimney might be viewed as a cause of poor fireplace performance, the damper resistance parameter was assigned a very conservative value. It is stated in the article and in the ASHRAE text that the damper free area should, for best operation, be twice the chimney cross-section area.

From the drawings and specifications of framed dampers offered for use within a masonry fireplace, it is difficult to determine their free area. The dimensions given are mainly external sizes to enable the brick mason to size and construct the throat or smoke shelf accordingly. It is likely that actual installed free area of a damper seldom exceeds the chimney cross-section area. Experience with this chart has established that this applies equally to circular chimneys, to other inside chimney forms and to fireplaces with a damper free area roughly equal to chimney area.

From a fluid flow point of view, the throat and damper area is a contraction/expansion zone, or a sort of orifice. This is particularly true if the construction includes a typical smoke chamber as shown in Figure 1. In this typical construction all of the air, smoke and combustion products go from a large combustion area, through a contraction, causing some flow resistance. On exiting the throat or damper contraction, there is an expansion into the smoke chamber and a second contraction into the chimney proper. A numerical flow resistance factor, combining fluid acceleration equal to 1.0 and an orifice factor of 1.5 was assigned in the calculations used for the chimney sizing chart. The total, 2.5 appears in the bracketed term of equations (8) and (9) in the reference paper and is adequately conservative to allow damper free area to equal chimney area.

Damper or throat flow resistance affects fireplace performance far more than chimney shape or fireplace hearth area, as shown by tests conducted and by the theoretical analysis. The equations further confirm the rules of thumb relating opening area to chimney size for ordinary fireplaces, showing that the size of short chimneys must be much greater than for tall ones.

The sizing chart in both the ASHRAE handbook and in the reference paper is very hard to read. For purposes of this discussion, two new versions of the sizing chart are offered in Figures 2 and 3. Figure 2 has exactly the same information as the one in the article and is applied in the same way. It has better spacing for the right hand vertical size lines for more legibility. The arrow lines for the example compute front opening area using its width and height. The horizontal arrow line ends at a selected height (above the lintel) to choose either circular size diameter (lower scale) or flue area (upper scale).
For flue tiles, the chart is reasonably conservative, particularly because tile cross-section area is seldom exactly the same as that of a circular chimney, so that the tile section will generally be larger for a given frontal area. For this reason, of more area, compensation for a "hydraulic radius" factor is inconsequential.

The charts do not cover chimney offsets or internal corbels. However recalculation of the equation with an added one (1) velocity head (fixed resistance total of 3.5) indicates that even with a borderline size, increasing the chimney one size, or larger than the area called for will allow proper operation. The damper selected for the increased chimney size must again have an open free area equal to or greater than chimney area.

<u>Notes for Application of Charts</u>

a. For any chimney size or flue area selected, the damper and/or throat free area must be equal to or greater than the chimney internal area.
b. These charts apply to circular, square and rectangular chimney cross-sections. The applicable area for these is actual internal area, not nominal size.
c. For corner-opening or double-opening "see through" fireplaces the area of all such openings shall be included.
d. For frontal area-chimney height combinations falling on a line, use the next largest chimney size or increase chimney height.
e. If there is an offset or corbel in the chimney, use the next largest size to compensate for added flow resistance.
f. Chimney height effectively is the height above the lintel or highest part of the fireplace opening. The combustion zone below the lintel does not contribute to chimney draft.

These notes summarize the results of the experimental and theoretical analysis in the reference paper and apply to Charts Figure 2 and 3. They are given here to provide separate enlarged images of these charts.

Fireplace Efficiency

The results reported in the reference paper were from tests which also included data for finding conventional heating efficiencies by the flue loss method. These were calculated from gas analysis and temperature observations and compared with the known heat input to the gas burner. The yellow flames from the non-aerated burner emit heat radiation and also impinge on the fire brick walls to heat them for an additional radiant source, but most of the heat in the fuel goes up the chimney.

There was no effort in these tests to optimize or maximize heating efficiency. The carbon dioxide values found at low heat inputs were unreliable due to uncertainties of the Orsat analyzer at values of less than one percent. Above one percent, the heating efficiencies were from 10 to 13.5 percent. Log fires which are more strongly radiant may reach higher values. Also if the chimney is fully within the building envelope, conduction through its walls adds a small amount of additional heat.

A copy of the summary data sheet Fig. 4 is from a test made on 5/18/1967 and shows somewhat high values of efficiency "E" for CO_2 values from 0.30 to 0.85. The curve plotted as Fig. 5 should obviously end at the zero/zero intercept for CO_2 vs. input. The "E" % function in the brackets includes the natural gas fractional value of .095 for the latent heat loss, which is always included in this kind of efficiency calculation.

Gas temperature rise above the ambient level is more accurate than CO_2 values and plots as a straight line vs. Btu input. Gas flow numbers in the chimney at values of CO_2 less than one percent are probably slightly off. But the most interesting result of these tests is that mass flow peaks at 403 degree F rise at the rate of 1270 lb/hr and drops slightly at higher temperatures.

The upshot of this is that bigger hotter fires, with greater heat input do not increase chimney gas flow. They only raise gas temperature in the chimney and do not have much of an effect on efficiency, or on inlet air velocity in to the front opening.

A second reminder: To see the original copyrighted paper, click on the link below. The foregoing text and graphs however may be copied or used in any manner the reader sees fit.

Richard L. Stone
November 17, 2005

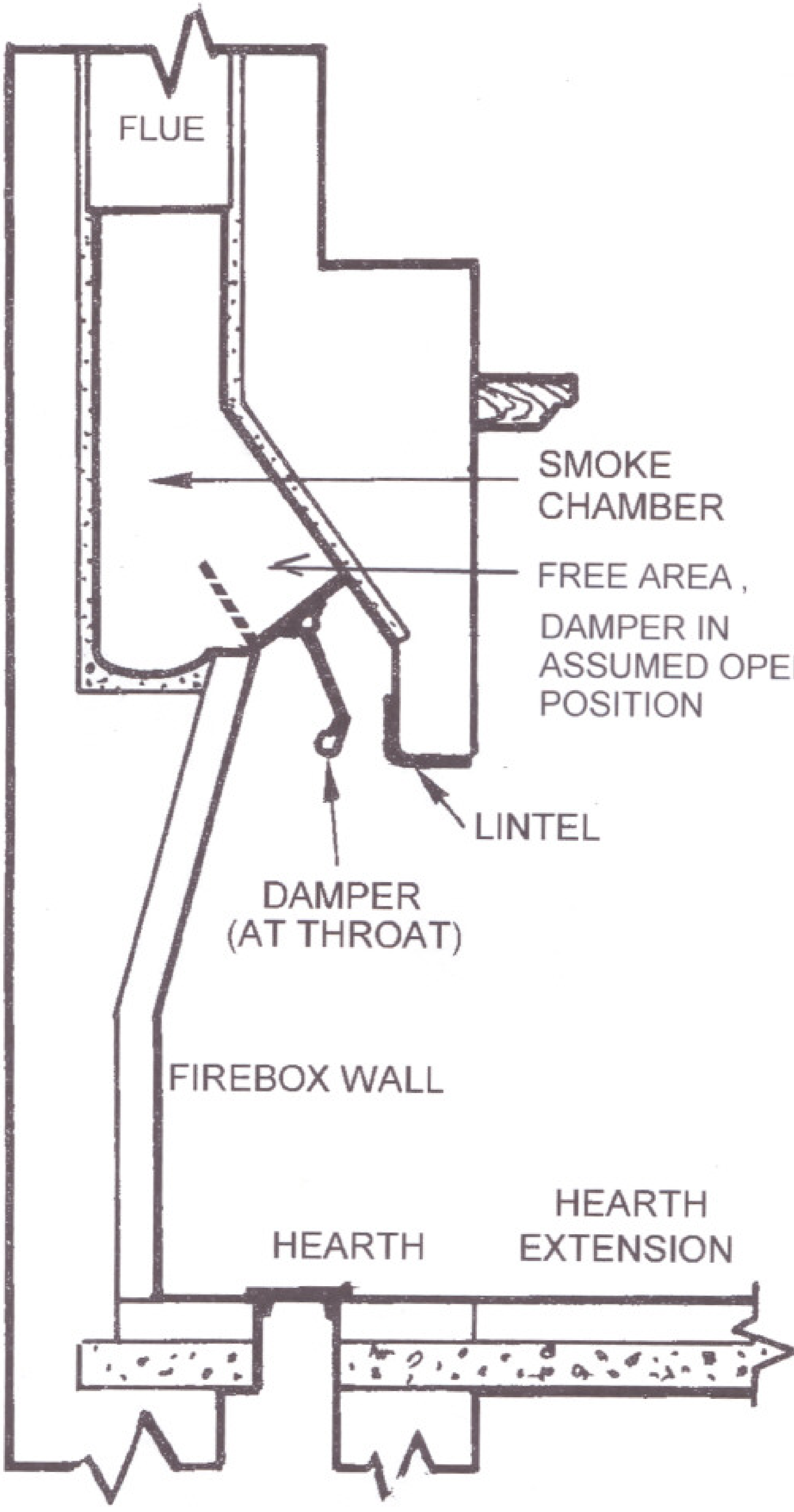
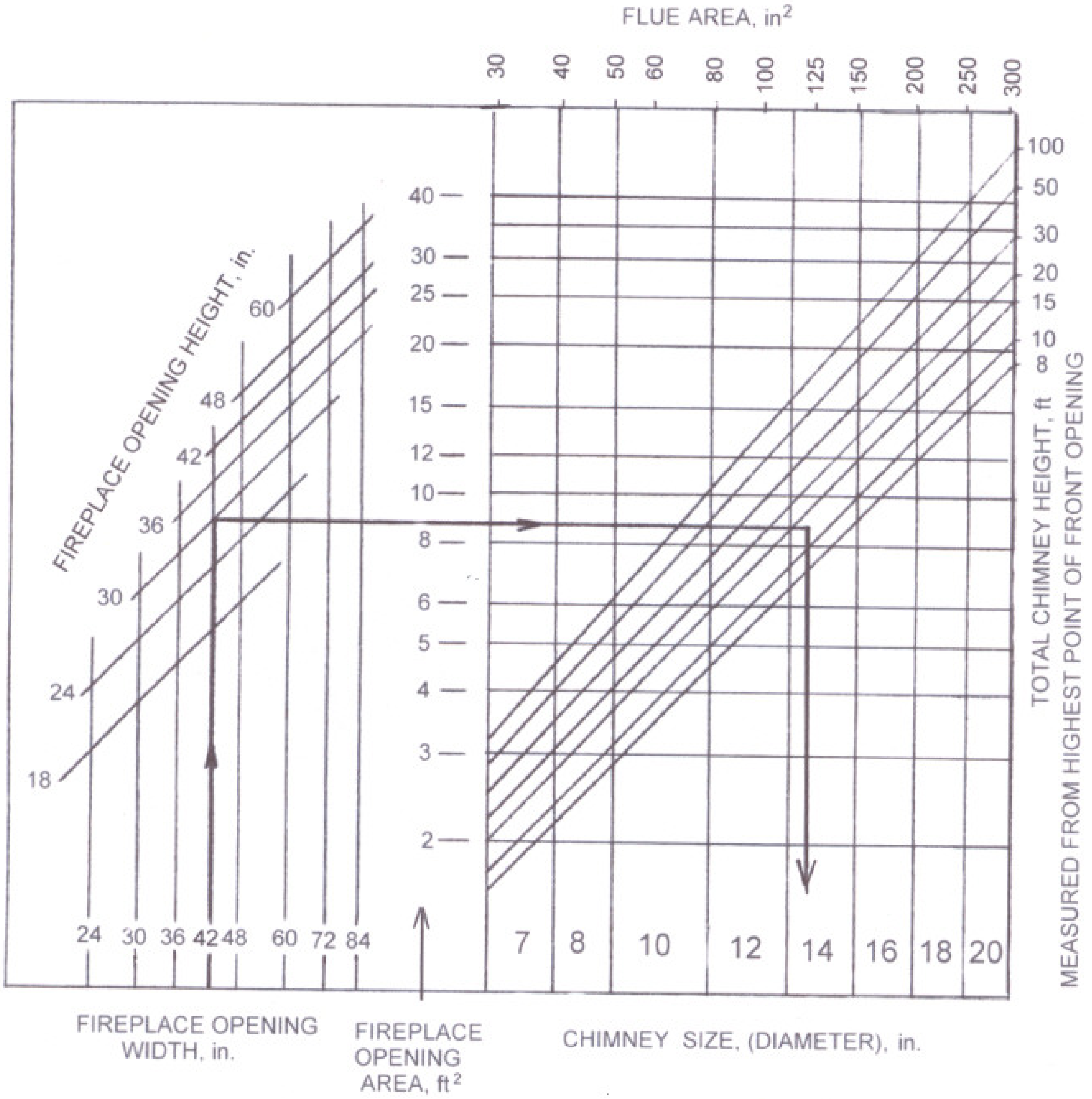


FIGURE 1, TYPICAL FIREPLACE CROSS SECTION



See "Notes" in the discussion

FIGURE 2 CHIMNEY SIZING CHART FOR FIREPLACES

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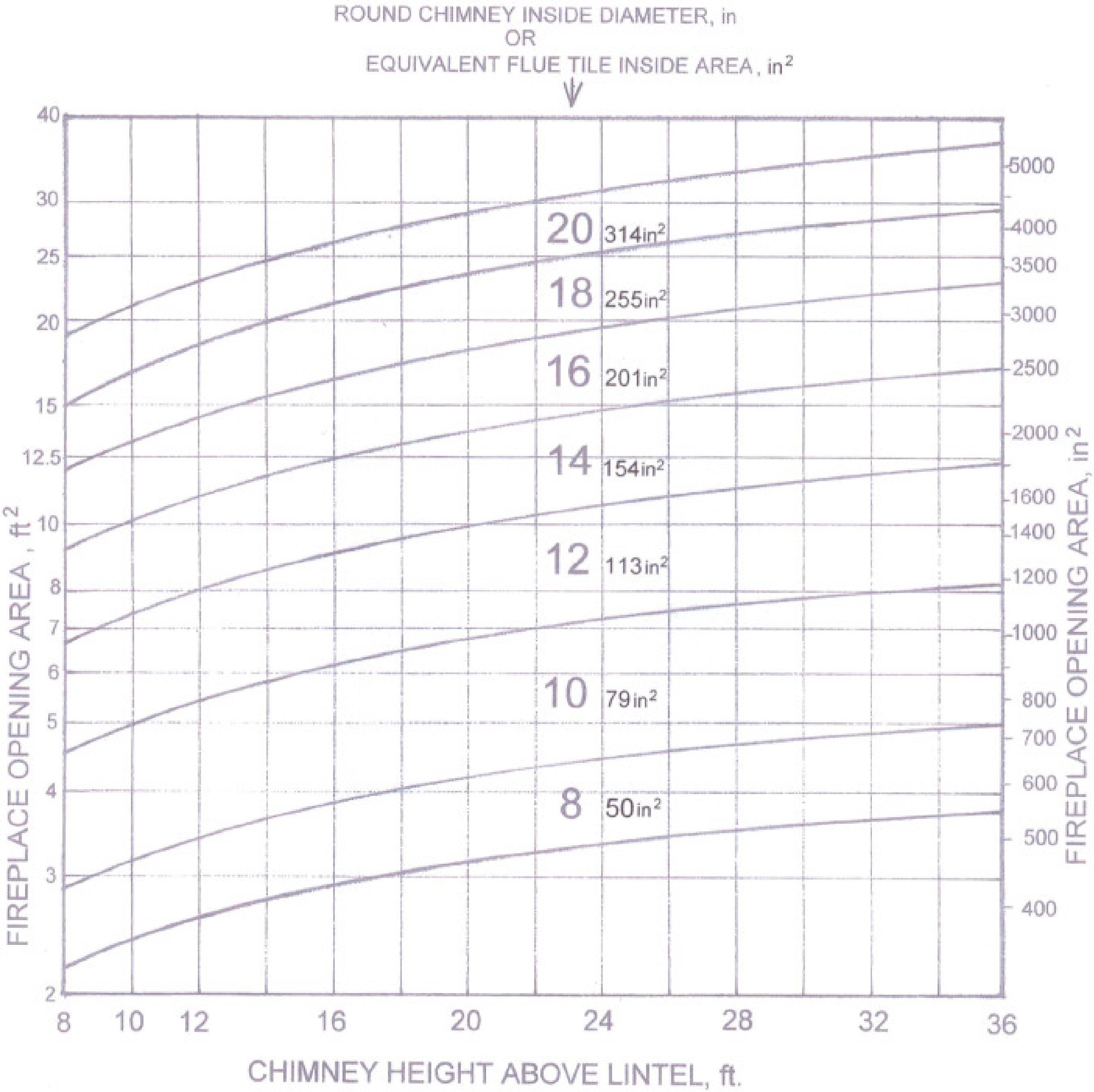
JUNE 2005



See "Notes" in the discussion

FIGURE 3 CHIMNEY SIZING FOR MASONRY FIREPLACES

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FIREPLACE TEST DATA*

VENT GAS RISE t	CO_2 %	BTUH INPUT I	w	Q (c_p=.25)	Q/I	E %	R. V.H.
89	0.30	30M	796.	17,740	.59	31.5	2.6
140	0.39	50M	1020.	35,700	.714	19.1	2.2
204	0.55	75M	1088.	55,500	.74	16.5	2.3
265	0.70	100M	1142.	75,700	.757	14.8	2.3
314	0.85	125M	1180.	92,500	.74	16.5	2.2
403	1.00	159M	1270.	127,000	.804	10.1	2.1
444	1.10	175M	1260.	140,000	.80	10.5	2.0
517	1.35	210M	1255.	162,000	.772	13.3	2.1
553	1.45	219M	1220.	168,500	.77	13.5	2.3

*RUN FP-7 26/27 APRIL 1967

$$w = 7.2 \frac{I}{10000}\left(.15 + \frac{11}{(CO_2)}\right) \quad LB/HR$$

$$Q = w c_p t$$ SENSIBLE HEAT FLOW IN BTU/HR

$$E, \% = 100(1 - .095 - Q/I)$$, HEATING EFFICIENCY

R = SYSTEM FLOW RESTANCE

FIGURE 4 CALCULATION SUMMARY

5-19-67

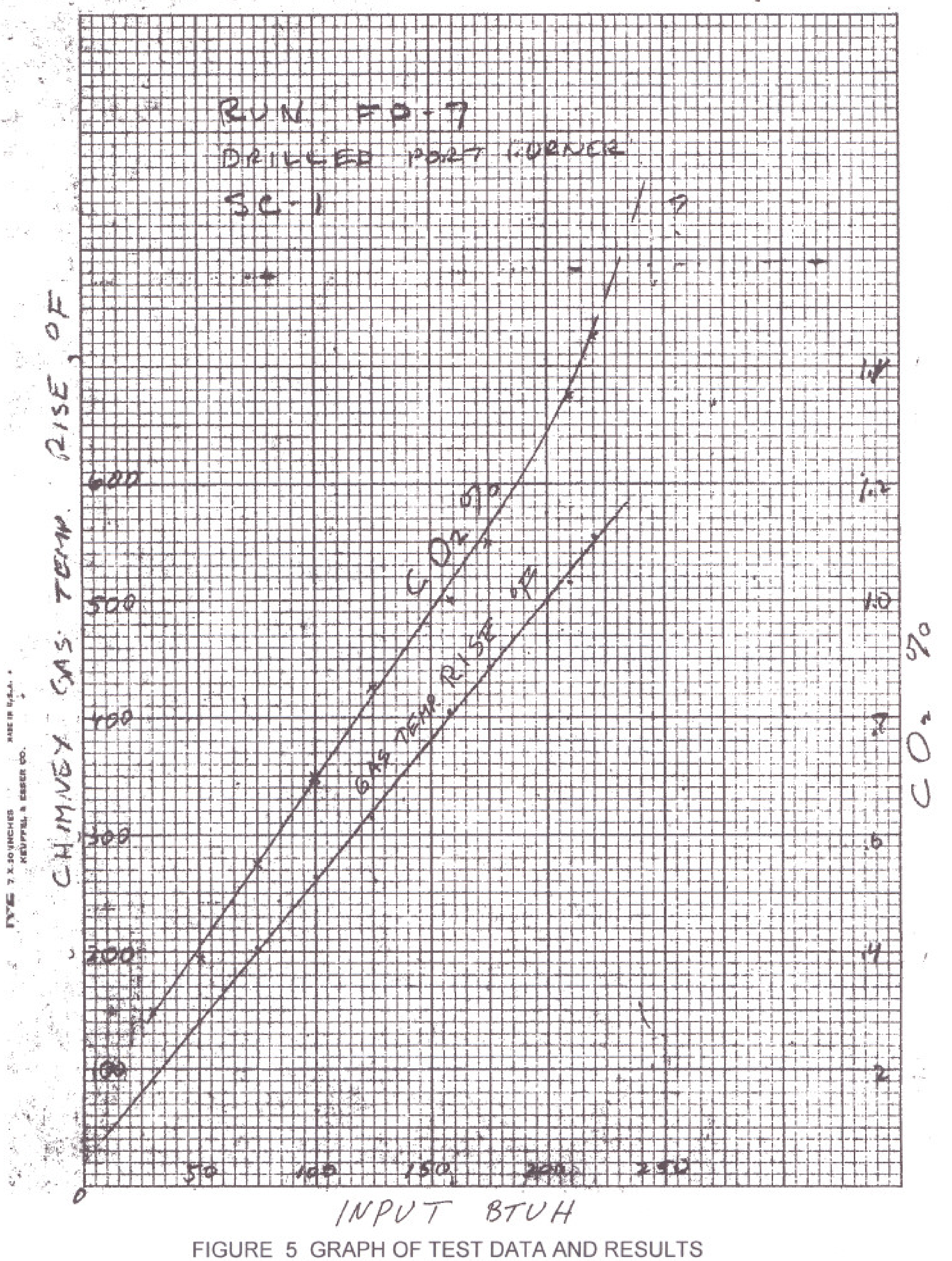

FIGURE 5 GRAPH OF TEST DATA AND RESULTS
IN FIGURE 4 CALCULATION SUMMARY