Example 3: Determine if a 13-ft, 8 x 8-in. nominal-size flue is sufficient for a coal-heating unit rated at 0.03 in. of water draft at 400 F inlet temperature, fuel rate being 10 lb per hr of bituminous coal, with 10 percent CO_2.

Solution: From Fig. 9, a flue-gas rate of approximately 180 lb per hr is obtained. The available draft for a 180 lb per hr fuel rate, and an inlet temperature of 400 F, obtained from Fig. 6, is 0.056 in. of water. This indicates that the chimney is adequate.

The selection of chimney areas for liquid- and solid-fuel-burning devices is difficult because of the variability in efficiency of different models, the possibility that soot on the lining will restrict the chimney area, and the variation in combustion air requirements of different solid fuels. Figs. 6 and 7 show that a given chimney produces a maximum available draft and a maximum efficiency for some intermediate mass flow rate for any selected inlet flue-gas temperature. For mass flow rates lower than the optimum the greater cooling of the gases in the chimney causes lower available draft, whereas for mass flow rates above the optimum the greater friction losses reduce the available draft. A chimney for a given heating system should probably be designed to operate at its point of maximum efficiency and maximum available draft for its full rated output. A chimney would have an accelerating effect[10] on the combustion rate of a solid-fuel burning device if it were operating to the left of the optimum point in Fig. 6 because an additional increment in mass flow rate would increase the available draft a small amount and tend to increase the mass flow still more. On the other hand, a chimney operating to the right of the optimum point in Fig. 6 would tend to decelerate the combustion rate for any small increase in mass flow rate.

Data are not complete for the selection of proper chimney areas for heating plants of different capacities, but some information on the effect of cross-section area on the capacity of masonry chimneys is provided by recent tests[8, 11] on several chimneys with liners having nominal outside dimensions: 9 in. diameter, 12 in. diameter, 9 × 9 in., and 9 × 13 in. These tests showed that for flue gas rates up to 200 lb per hr, and entering flue gas temperatures from 200 to 1000 F, the 9-in. round liner provided an available draft equal to, or greater than, that produced by the other three larger liners. When the flue gas rate was increased to 320 lb per hr, the three larger liners produced a little more draft than the smallest one for entering flue gas temperatures above 600 F. Other data[9] show that metal chimneys with an internal diameter of 6 in. should not be used for mass flow rates greater than 130 lb per hr.

Table 2 shows approximate values of the mass flow rates and flue-gas velocities at the chimney inlet that produce the maximum available draft for masonry chimneys[8] of several conventional sizes and with an effective height of 15 ft. This table shows that a 9-in. round chimney is best suited to mass flow rates from 130 to 170 lb per hr, a 9 × 9-in. chimney performs best for flow rates from about 200 to 300 lb per hr, and a 9 × 13-in. and 12 in. round chimneys are best suited to flow rates above 300 lb per hr. These results were obtained with clean chimneys, so that conclusions about chimney areas require some modification if soot deposits are taken into consideration.

Soot deposits in chimneys reduce the effective area of the liner and may in some cases entirely close the passage. Soot deposits are likely to be greater in the horizontal passages in the heating plant, the breeching, and the smokepipe, than in the vertical chimney liner. An increase in the liner diameter of one inch above that required for a clean chimney will probably make adequate allowance for soot deposits in all but the worst

cases. Where smoky combustion is likely to occur and the mass flow rates on a clean chimney basis approach those listed in Table 2, the next larger commercial size liner should be used. Smoky combustion with oil-burning devices, particularly with vaporizing oil burners, is likely to be caused by inadequate draft which is often due to insufficient chimney height. For coal, inadequate chimney height or chimney area may be a contributing cause, but smoky combustion with coal is related to fuel characteristics and firing methods. Therefore, an increase in chimney area will usually not cure smoky combustion of a coal-burning device, but can be expected to lengthen the interval between cleanings.

New standard sizes of clay flue linings were recently developed by the industry and approved by the *American Standards Association*, in order to effect economies that can be derived from coordination of the dimensions of building materials. These linings are known as modular clay flue

TABLE 2. APPROXIMATE FLUE-GAS FLOW RATES FOR MAXIMUM AVAILABLE DRAFT IN MASONRY CHIMNEYS

Nominal External Liner Dimensions	Internal Area of Liner, Sq In	Flue Gas Temperature at Chimney Inlet, Fahr.					
		200	600	1000	200	600	1000
		Mass Flow Rate, LB/HR			Flue Gas Velocity at Chimney Inlet, FPM		
9 in. Dia.	38.5	170	150	130	175	250	300
9 in. x 9 in.	49	215	306	334	175	400	600
12 in. Dia.	78.5	290	Above 320	Above 320	150	—	—
9 in. x 13 in.	77	295	Above 320	Above 320	150	—	—

linings, and the dimensions and tolerances are summarized in *ASA* Standard A62.4-47. As the effective areas of these liners are somewhat smaller than those of the corresponding linings used previously, they cannot be used in certain municipalities where building codes specify minimum areas based on the older dimensions.

DRAFT REQUIREMENTS OF APPLIANCES

Typical flue-gas temperatures and drafts required at rated output for several kinds of domestic heating appliances[12] are contained in Table 3. Chimney height and chimney area for cast iron boilers are specified in the $I = B = R$ Testing and Rating Code of the *Institute of Boiler and Radiator Manufacturers*.

Mechanically-fired devices such as oil burners and stokers are equipped with blowers, and therefore, the chimney is not required to overcome the resistance of the fuel bed or burner. Nevertheless, a draft in the firebox, of about 0.03 in. of water, is considered desirable so that any small openings in the firebox or flue passages will result in leakage of air inward, and not leakage of combustion products outward. Firebox leakage should be kept to a minimum, however, since such leakage adversely affects heating plant efficiency.

Difficulty in obtaining enough draft for natural draft appliances is likely to occur for attic installations or in one-story houses without basements. Automatic oil-burning space heaters, floor furnaces, and warm air furnaces employing natural-draft vaporizing burners require a draft of 0.06 to 0.08 in. water for outdoor temperatures of 60 F. Taking into account the prob-