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Influence of the House on Chimney Draft

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Draft is the pressure difference between some point in a venting system and the surrounding air at the same level. It is common to consider draft with respect to outside air, when predicting the draft provided by residential chimneys. But the draft between the base of the chimney or firepot and the surrounding inside air is the one effective in venting connected appliances. Draft requirements and chimney design are usually based on conditions expected when connected appliances operate steadily at rated output, when the difference between draft with respect to outside and inside air may be unimportant. However, a number of appliances, for example, solid-fuel hand-fired furnaces or oil units with pot-type burners, operate at low fire much of the time. Even with gas or mechanically fired oil-burning units there is a period of non-steady flue gas temperature at the beginning of each on-cycle.

Some of the venting problems that arise under these conditions can be understood better by considering the relation between chimney draft and house pressures. In this paper, this relationship is examined and demonstrated by results of some field measurements. Its application to a specific case of venting failure with solid-fuel hand-fired furnaces is discussed. Included, too, are results of field measurements of draft during start-up of a furnace with a high-pressure gun-type burner.

VENTING FAILURE AT LOW FIRING RATE

In the spring and fall, when houses have low heat requirements, draft problems with heating units which can operate on low fire are not uncommon. Appliances under hand control such as oil burning space heaters or solid-fuel hand-fired furnaces, where the combustion rate

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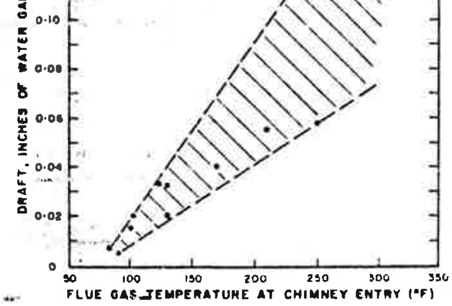
is modulated roughly to conform to heat requirements, are in this category. Sooting of flue passages with the former and venting failure and fume poisoning with the latter are sometimes reported. These venting failures are often ascribed to down-drafts or unusual atmospheric conditions.

However, in recent investigations in two widely separated housing developments, venting failures were reported during calm, mild periods, often during sleeping hours. The houses, 1½-story units with basements, had gravity warm air heating systems and hand-fired coal-burning furnaces venting into standard lined masonry chimneys located on an exterior wall. Chimneys were 25 ft high with 7⅛-in. square flues inside; smokepipes, about 12 ft long contained a plate damper. Pennsylvania anthracite coal was burned. Venting failure was not reported in similar bungalow units with chimneys located inside the house.

In mild weather ash pit dampers were generally left closed, and air for combustion was admitted through a manual slide in the firing door. Combustion was controlled by manipulating the smokepipe plate damper. Measurements of flue gas temperatures and chimney draft were taken in a number of houses with furnaces operating at low combustion rates. With the smokepipe damper closed, temperature drops of 40, 90 and 140 F occurred in the smokepipes with gas temperatures at the flue collar of 150, 250, and 350 F respectively. With the smokepipe damper open, temperature drops with the same gas temperatures at the flue collar were increased to 60, 150, and 220 F due to diluent air.

Fig. 1 gives results of the draft measurements related to flue gas temperatures at chimney entry. Values fall within the cross-hatched area; some spread is expected as measurements were taken under differing conditions of flue gas volume. Outside temperatures during the measurements were between 25 and 34 F. Basement temperatures were near 70 F. Draft at the smokepipe plate damper was not measured but would have been less than at the chimney by the amount required to overcome smokepipe pressure losses. Thus, under the conditions shown at the lower end of the graph, venting failure was imminent. Some of the factors contributing to these conditions are apparent, but the actual mechanism by which venting failure occurred can be fully explained

Fig. 1 Draft vs. flue gas temperature at chimney entry



only by considering the inter-relation of draft and house pressures.

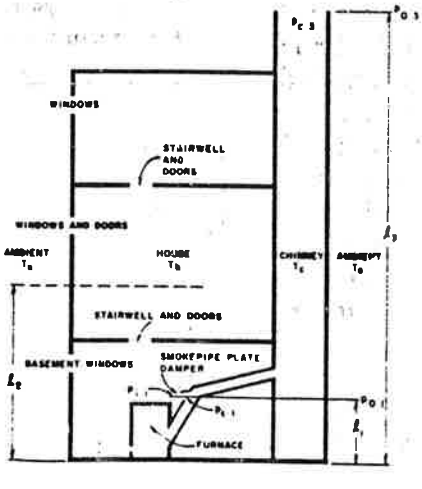
INTER-RELATION OF DRAFT AND HOUSE PRESSURES

Fig. 2 is a simplified diagram of a two-level house with basement and attached chimney. Elevation l_2 represents the level of the neutral zone where the absolute pressures inside and outside are equal. Elevation l_1 represents the location of any opening between the venting system and the house, such as a smokepipe plate damper, a barometric damper, or a draft hood. Venting failure occurs when the pressure in the venting system at this location, p_{c1}, is greater than the pressure in the house at the same level, p_{i1}. Since pressure p_{c3} at the chimney exit is equal to the outside pressure p_{o3} at the same elevation, l_3,

$$p_{c1} = p_{o3} + w_c (l_3 - l_1) + p_{fc} \qquad (1)$$

where

Fig. 2 Simplified diagram of 2-story house



w_c = mean weight of flue gas, lb per cu ft

p_{fc} = pressure loss in the chimney due to flow resistance, lb per sq ft

The outside pressure at elevation l_1 is

$$p_{o1} = p_{o3} + w_o (l_3 - l_1) \qquad (2)$$

where

w_o = mean weight of outside air, lb per cu ft

The chimney draft with respect to outside air at elevation l_1 is then

$$p_{o1} - p_{c1} = (w_o - w_c)(l_3 - l_1) - p_{fc} \qquad (3)$$

Similarly, the chimney draft with respect to inside air at elevation l_1, is

$$p_{i1} - p_{c1} = w_o (l_3 - l_2) + w_i (l_2 - l_1) - w_c (l_3 - l_1) + p_{fi} - p_{fc} \qquad (4)$$

where

w_i = mean weight of inside air, lb per cu ft

p_{fi} = pressure loss in the house due to resistance to flow between elevations l_1 and l_2

The resistance to flow between levels within the house is usually negligible and the difference between the chimney draft with respect to outside and inside air is

$$p_{o1} - p_{i1} = (w_o - w_i)(l_2 - l_1) \qquad (5)$$

Equation (4) shows that venting failure and spillage of flue gas into the house from openings at elevation l_1 will occur if

$$w_o (l_3 - l_2) + w_i (l_2 - l_1) \leq w_c (l_3 - l_1) + (p_{fc} - p_{fi}) \qquad (6)$$

Thus the location of elevation l_2, the neutral zone, has an effect on draft with respect to inside air and is related to draft failure. If elevation $l_2 = l_1$, the draft with respect to inside and outside air will be

equal at elevation l_1 and will be zero when the mean temperature of the flue gas in the chimney, T_c, is equal to the outside temperature, T_o, ignoring friction effects.

Similarly, if elevation $l_2 = l_3$, the draft will be zero when T_c is equal to the mean temperature in the house, T_i. If there is flue gas flow in the venting system, friction losses must be overcome. These limits of mean flue gas temperature, below which venting failure occurs, will be correspondingly higher. An increase in the mean flue gas temperature of approximately 10 F would normally be adequate to overcome these friction losses with the small flue gas volumes involved when venting failure is imminent.

Wind pressures may affect the neutral zone location, and, in addition, will usually have some direct effect on pressures at the chimney exit. Wind effects are beyond the scope of this paper. Under calm or low wind conditions, the level of the neutral zone will usually be at some elevation between l_1 and l_3 and will depend on the location and characteristics of the openings between the house and outside.

Data on the location of the neutral zone in houses are limited. Available records indicate that it may often be well above the mid-height of the heated structure. It follows that opening basement windows will have a beneficial effect on draft, but openings at upper levels may affect draft adversely. Appliances that exhaust air from the house have the same effect as openings above the neutral zone. In a tight house these might lower house pressures below outside pressures at all levels, creating an imaginary neutral zone above the heated structure. It will be recognized that the chimney itself represents one of the upper openings. In a tight house or enclosure the chimney might have an effect on the neutral zone similar to a mechanical exhaust unit.

The mechanism of draft failure described previously applies directly to conditions found at the housing developments referred to. It can be assumed that the neutral zone was at an upper level in the house, particularly at night when upstairs windows are open, and at times the mean flue gas temperature fell below the critical value defined by Equation (6). It is clear that to avoid this cause of venting failure the mean flue gas temperatures in the chimney cannot fall much below mean house temperature.

Several factors contributed to the lowering of mean flue gas temperature below this value. Low rates of combustion, dilution of flue gases at the smokepipe plate damper, and cooling of the flue gases in the long smokepipes resulted in relatively low flue gas temperatures upon entrance to the chimney. These temperatures were still higher, however, than the house air, and the effect of cooling the flue gas in exposed outside chimneys must be considered the ultimate cause of draft failure.

The temperatures at the exit of the chimneys where venting failure occurred were not meas-

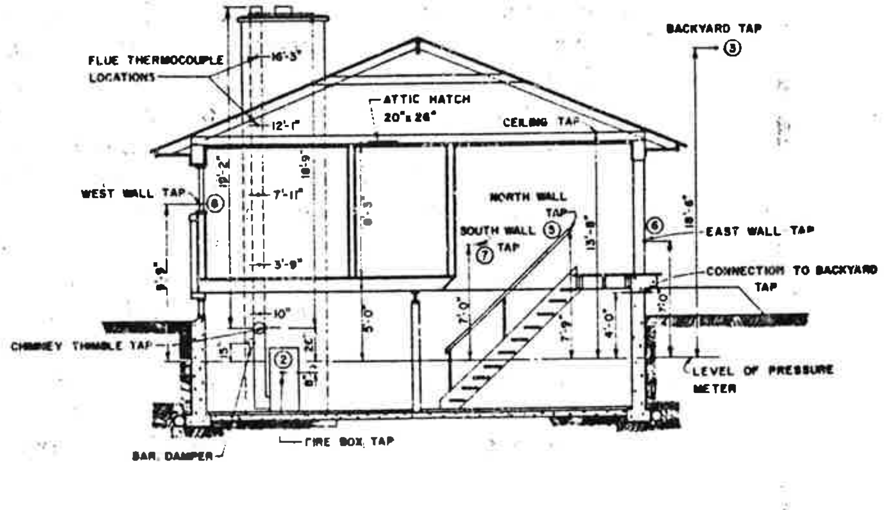
ured. Subsequently, however, some temperature records were obtained for three chimneys of similar construction venting oil burning furnaces. Two of these chimneys were on outside walls, one 27 ft and the other 19 ft high. The third was an inside chimney 22 ft high; 12 ft within the heated structure, 7 ft in the attic, and 3 ft above the roof. Following an 8-hr burner-off period, when outside temperature was 40 F, the flue gas temperatures at chimney exit were 47, 48, and 65 F, respectively. Venting failure of the type described, with solid-fuel hand-fired furnaces, is unlikely to develop when inside chimneys are used.

Similar venting problems can be expected when heating units burning other fuels operate at low or pilot fire during mild weather, although spillage of the products of combustion into the house might not be regarded so seriously. It follows that inside chimneys would also be advantageous in these instances. On the other hand, mechanical oil-burning furnaces operate at rated input on heat demand, regardless of the outside temperature, and the same problem of venting failure due to low flue gas temperatures does not occur. However, the draft condition during start-up of such furnaces, and the extent to which this is affected by the draft prior to start-up, are of special interest. Since the average temperature of gas in the chimney can be relatively low, the effect of house pressures on the chimney draft prior to starting of the burner is next considered.

MEASURING CHIMNEY DRAFT AND HOUSE PRESSURES

Measurements of chimney draft and house pressures were made in a single-story house with basement, heated by a forced warm-air system with high-pressure gun-type oil burner. The house had a floor

Fig. 3 Location of pressure taps and chimney thermocouples



area of 1200 sq ft and was well insulated, with plaster finish throughout. Storm windows and doors and weatherstripping were used. There was a covered hatch in the hall ceiling leading to a vented attic.

The chimney was on an outside wall and exposed to the weather on three sides. It was constructed of single layer brick with clay-tile flue liners and contained a nominal 8- by 8-in. flue serving the furnace and a nominal 8- by 8-in. flue serving a fireplace. The furnace room was open to the basement which was interconnected to the main floor through the return air system. The oil burner was equipped with a 0.75-gph nozzle and the air supply was adjusted to give No. 2 smoke spot with about 5% CO_2. The flue pipe was 6 ft long and contained a barometric damper, which was partly open even when the furnace was off.

Pressure taps were located in the cap of the combustion chamber sight-port to measure overfire draft, in the flue pipe at chimney entry to measure chimney draft, in the four outside walls and ceiling to measure pressure differences across the building enclosure, and at an outside pressure station in the backyard approximately 80 ft from the rear of the house. Pressure measurements were made with an electric capacity-type differential pressure meter. This provided a current output proportional to pressure, which was measured on a galvanometer-type recording milliammeter. The pressure meter was sensitive to pressure charges of less than 0.001 in. of water and was calibrated against a laboratory micromanometer having a corresponding accuracy. The zero-position of the meter, however, drifted with temperature and line voltage fluctuations and frequent checking was necessary.

Flue gas temperatures in the chimney, along the center of the

TABLE I

HOUSE PRESSURE VS. BACKYARD, ATTIC AND CHIMNEY AS AFFECTED BY HOUSE OPENINGS, WITH FURNACE OFF

Arrangement of Openings	Pressure Differences, In. of Water				
	Backyard (3)		Attic (4)		Chimney (1)
	$T_i = 72$ F $T_o = 27$ F	$T_i = 70$ F $T_o = 6$ F	$T_i = 72$ F $T_o = 27$ F	$T_i = 70$ F $T_o = 6$ F	$T_i = 72$ F $T_o = 27$ F
Openings closed	−0.005	−0.018	0.005	0.010	0.016
Basement window open	0.000	−0.003	0.016	0.025	0.027
Attic hatch open			0.000		0.011
Fireplace damper open		−0.023		0.006	

flue, and outside temperature were measured with copper-constantan thermocouples connected to a 16-point electronic temperature recorder. Location of the chimney thermocouples with respect to the center of the chimney thimble and location of pressure taps with respect to the level of the pressure meter are shown in Fig. 3. Inside air temperature was measured with a calibrated thermograph at one location only, in the living room approximately 2½ ft from the floor. This has been taken as the mean house temperature in subsequent calculations.

Table I shows, for two different outside temperature conditions, the effects of openings to the outside at different levels on house pressure (at the meter) relative to backyard, attic and chimney pressures. These records were obtained on relatively calm days, during periods when the furnace was off.

When there is no wind, the pressure reading obtained with the meter connected to tap 3 is equivalent to the pressure difference across the building enclosure at the level where the connection from inside to outside is made. If there is wind, the reading merely represents basement pressure with reference to the backyard tap. The reading obtained with the meter connected to tap 4 is equivalent to the pressure difference across the ceiling. The house chimney effect required to produce these pressure differences can readily be calculated from the difference in density between inside and outside air, and a neutral level established with reference to the pressure taps; although where the pressure differences are extremely low, small errors in pressure or air density can lead to significant errors in the calculation.

From the results for an outside air temperature of 27 F, the neutral level, calculated with reference to the attic pressure, is approximately 4 ft below the ceiling with the basement window shut, and approximately 12 ft below the ceiling with it open. This shift of the neutral level below the basement window can be explained by outside wind pressure. There is a corresponding increase in chimney draft with the basement window open. It is anomalous that the basement pressure measured with respect to the backyard tap did not increase to the same extent when

TABLE II

HOUSE PRESSURE VS. CHIMNEY AND OUTSIDE WITH FURNACE OFF AND ON

T_i = 70 F, T_o = 6 F	Pressure Differences, in. of water							
	Chimney (1)	Overfire (2)	Backyard (3)	Attic (4)	North (5)	East (6)	South (7)	West (8)
Furnace off	0.020	0.019	—0.018	0.011	—0.007	—0.010	—0.008	0.000
Furnace on	0.065	0.035	—0.023	0.007	—0.012	—0.013	—0.012	—0.004

the basement window was opened.

Opening the attic hatch raised the neutral zone to the ceiling level and had a corresponding effect in lowering chimney draft. A similar study of the results for an outside air temperature of 6 F indicates that opening the basement window lowered the neutral level approximately 7½ ft, while opening the fireplace damper raised it approximately 2½ ft.

Table II gives some additional pressure measurements, taken under the same conditions as those in Table I for an outside temperature of 6 F. Calculated neutral levels vary from 3½ ft below the ceiling with reference to the west wall to 1 ft below the ceiling with respect to the east wall, indicating some easterly wind effect. Similarly, the neutral level is 5½ ft below the ceiling with reference to the attic tap and at the ceiling with respect to the backyard tap. With the furnace on and other conditions the same, the neutral level is approximately 2 ft higher with reference to all taps, a result of the increased flow up the chimney.

It should be pointed out in connection with calculated neutral pressure levels, that the house had a total door and window crackage of about 260 lineal ft. Basement windows, not well weatherstripped, represented 35 ft. Living room windows were fixed and ventilation was provided by louvred openings with weatherstripped covers just above floor level, contributing 40 ft. Thus, there may have been more cracks immediately above and below the floor than is usual, and neutral levels may have been correspondingly lower.

Table III presents some further records of the effect of house openings on chimney draft under mild weather conditions. With the furnace off, opening of the basement window raised the draft about 0.006 in. of water, while opening the attic hatch lowered it by about 0.005 in. of water. With the furnace on, the effect of opening the window is somewhat greater, while opening the attic hatch has a lesser effect.

DRAFT DURING BURNER START-UP

Several tests were made with this same installation, in which the chimney or overfire draft was recorded during burner start-up. Fig. 4 gives the results following extended furnace-off periods at different outside temperatures. The accuracy of these measurements of transient draft has not been established. The galvanometer pen was delicately balanced to minimize drag, and the galvanometer was critically damped to eliminate over-

TABLE III

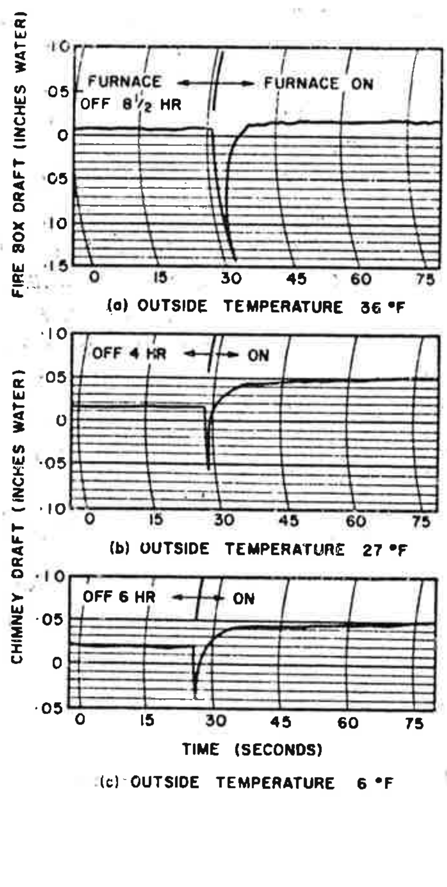
EFFECT OF HOUSE OPENINGS ON CHIMNEY DRAFT

$T_i = 72$ F $T_o = 36$ F	Chimney draft, in. of water	
	Furnace off	Furnace on
Openings closed	0.010	0.066
Basement window open	0.016	0.075
Fireplace damper open	0.005	0.063

shooting. Any errors are thought to be mainly in the measurement of extremes in pressure when pressures were rapidly reversed.

Fig. 4(a) indicates that substantial positive pressures can occur for a brief period in the fire box when the burner-blower first starts. Maximum pressure measured in this test was just under 0.15 in. of water. Draft failure in the fire box occurred for about 5 sec. In this instance, the furnace had been off overnight and the temperature in the center of the flue varied from 69 F at the bottom

Fig. 4 Draft during furnace start-up, following extended off periods



to 49 F at the top prior to burner start-up. The chimney draft was 0.010 in. of water, as shown in Table III. Fire box draft after burner start-up surpassed that prior to start-up in about 6½ sec.

Figs. 4(b) and 4(c) show the extent of positive pressure at the base of the chimney during burner start-up following extended periods with the furnace off. Temperatures from bottom to top of the chimney were 77 to 61 F and 70 to 43 F, respectively. Draft failure at the base of the chimney existed for about one sec in both instances. Chimney draft with the burner operating exceeded that with the burner off after 2½ sec. Draft build-up was relatively rapid in all cases.

There was a corresponding rate of increase in chimney flue gas temperature, as shown in Fig. 5 for the conditions of Fig. 4(c). The curves from top to bottom represent the temperatures at the thermocouple positions shown in Fig. 2, in order, from the bottom to top of the chimney. The print and chart speed of the temperature recorder were not sufficiently fast to show the precise pattern of temperature change during the first few seconds of furnace operation.

As mentioned earlier, the barometric damper was partly open even when the furnace was off. This no doubt led to higher chimney temperatures than would have occurred otherwise, during extended periods with the furnace off. The position of the barometric damper also affected the maximum pressures at the base of the chim-

ney and in the fire box during burner start-up. This can be seen in Fig. 6, which gives the results of chimney and fire box draft measurements with the barometric damper in its normal free position and taped closed. All results in this figure were obtained within a short period under essentially the same conditions.

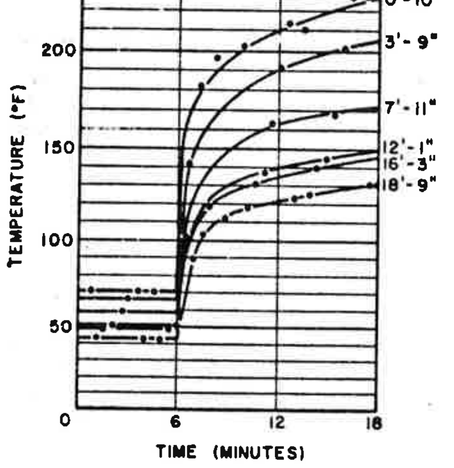
In each case the furnace was allowed to run for less than one min and the system allowed to cool until the chimney draft returned to its original value, with the barometric damper free, before beginning another on-cycle. The outside temperature was 5 F and the burner had been cycling normally before the measurements were taken, accounting for the relatively high chimney draft prior to each burner start.

Higher positive pressure occurred both in the fire box and at the base of the chimney when the barometric damper was closed, indicating that these pressures are relieved, to some extent, by gas flow out of the barometric damper. The rate of draft recovery was somewhat greater with the barometric damper closed, probably due to the higher flue gas temperatures in the chimney, as well as the greater difference between maximum pressure in the chimney or fire box and potential for draft. The position of the barometric damper in this instance had little effect on the period of draft failure, being less than 1 sec at the base of the chimney and 2 or 3 sec in the fire box.

In comparing the results in Fig. 4 with those in Fig. 6, it must be noted that the burner nozzle size was 0.75 gph for the former, but was changed to 0.65 gph for the latter, with a corresponding throttling of the air supply to the burner blower. Thus, both the higher draft before start-up and the reduced capacity of the burner blower probably account for the lower positive pressures and shorter periods of draft failure shown in Fig. 6.

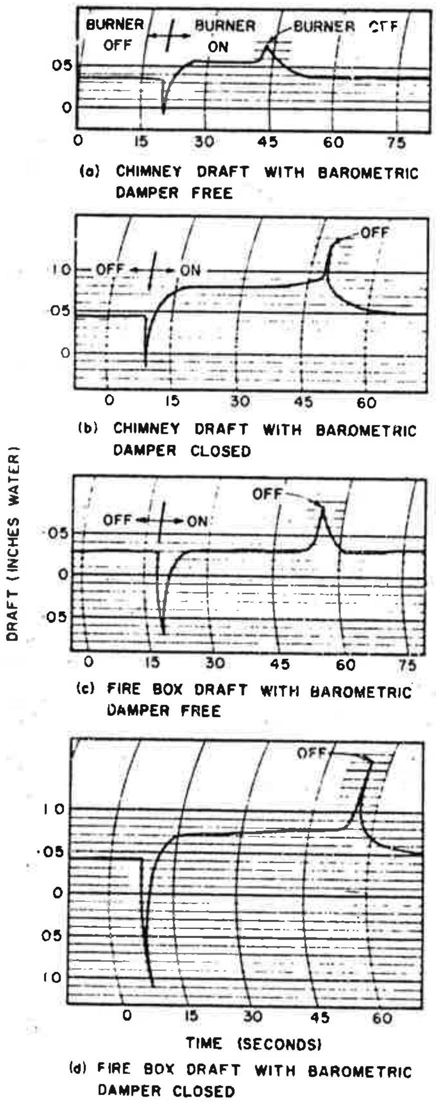
Sudden increase in draft at the moment the oil burner stops, in Fig. 6, is of academic interest. The rate at which the draft subsequently decreases is more important, since it relates to the draft available at the beginning of the next on-period. Fig. 7 is a record of chimney draft following extended burner operation, the beginning of which is shown in Fig. 4(b). The draft decreased rap-

Fig. 5 Chimney temperatures at furnace start-up



idly for the first few minutes but was still nearly 0.03 in. of water after 50 min. Previously, the draft had decreased to 0.016 in. at the end of a 4-hr off-period. In a comparable test with an outside temperature of 6 F, similar results were obtained. The draft fell from 0.065 in. to 0.04 in. in about 15 min but was still above 0.03 in. one hr after the burner stopped. Fig. 4(c) shows that the draft was 0.02 in. of water after a 6-hr burner-off period at this outside temperature. The rate of draft decrease will depend on several variables; these results are, therefore, specific to the installation tested.

Fig. 6 Draft during burner start-up following normal furnace operation with outside temperature at 5 F

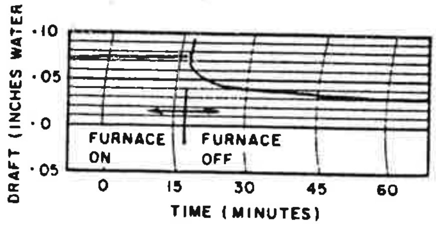


CONCLUSION

An analysis has been made of draft failure with residential heating units operating at low rates of combustion during mild, calm weather. It has been shown that under these conditions the relation between chimney draft and house pressures becomes important in determining when venting failure will occur. A simple equation expressing this relation has been developed. It shows that draft failure will occur if the mean flue gas temperature in the chimney falls below a value that depends on the neutral zone level.

Under the most unfavorable conditions, excluding the effect of

Fig. 7 Chimney draft after burner shut-down with outside temperature 27 F



ind, draft failure occurs when ie mean flue gas temperature in ie chimney is less than the mean ouse temperature. Measurements ave shown that this can occur ith masonry chimneys located at n exterior wall and exposed to the eather on three sides, but it is nlikely when chimneys of similar onstruction have a substantial roportion of their length located ithin the heated structure.

Measurements of chimney aft and house pressures in a sine-story house with an oil-fired urnace have demonstrated that raft, either with the burner on or ff, is increased by lowering the eutral zone and decreased by raisig it by an amount which correoonds to the change in house presure at the furnace. The effect of urnace operation on the level of ie neutral zone has also been hown. Measurements on a furnace vith a high pressure oil burner ave established that substantial ncreases in pressure occur in the ire box during start-up and that ositive pressures may exist for everal seconds.

Similar increases in pressure, of lesser magnitude, occur at the ase of the chimney. The amount of positive pressure and the period over which draft failure occurs depends, to some extent, on the draft available prior to start-up. It appears, also, to depend on the adjustment of the burner blower. Adjustment of the barometric damper affects the positive pressures developed, since it acts as a relief opening. Draft recovery after burner start-up was quite rapid in the installation tested, even following long burner-off periods. Development of draft, following initial draft loss on start-up, was perhaps aided by the burner blower.

It would be interesting to measure the development of draft on start-up with units relying entirely on natural draft for combustion air supply, especially under conditions where no prior draft was available.

The development of furnace units with instantaneous firing rates modulated in accordance with heat requirements, in contrast with on-off firing, has often been advocated to improve heating system performance. It may be noted that draft failure, similar to that described in this paper, is a potential problem with such units, while it is largely avoided with on-off firing as commonly employed.

ACKNOWLEDGMENTS

The author wishes to thank C. Wachmann for his participation in the analysis of draft failure and R. G. Evans, laboratory technician, for his assistance with the field measurements. The advice of Dr. N. B. Hutcheon, Assistant Director of the Division of Building Research, is gratefully acknowledged. This is a contribution from the Division of Building Research, National Research Council, Canada, and is published with the approval of the Director of the Division.

DISCUSSION

D. W. LOCKLIN, Columbus, Ohio: This paper emphasizes the fact that the house must be considered part of the entire combustion system. To improve this situation, there is likely to be a trend toward completely sealed combustion systems to separate the air intake and the exhaust products from the various phases. This trend has been developing in mobile homes and there are reasons for doing this also in residences, especially with the trend toward extremely tight construction.

AUTHOR WILSON: The house is a part of the overall venting and combustion system with most of our present-day heating systems. One of the ways to avoid some of the problems pointed out in this paper is to go to an isolated venting and combustion system.

G. APPLEGATE, Trowbridge, England: In my country, the extremely foggy and humid days have a considerable bearing on drafts. Have any tests been carried out in this country in this direction? Also, what was the orientation of the specific house, in the event that any wind tests were carried out?

AUTHOR WILSON: Tests have never been carried out with conditions of fog on the outside. These conditions do not arise often in our part of the country. With regard to the effect of wind, this is certainly one of the other major variables and one that deserves much more attention than it has received in the past. It is an extremely difficult type of investigation to make. We are attempting to get some useful information from field measurements and currently are examining an installation in which one of the objectives is to determine if the various ways in which wind affects draft can be segregated.

R. B. ENGDAHL, Columbus, Ohio (Written): An additional factor which should be considered in anthracite-fired systems is the effect of flue gas composition on gas density. Usually, it can be assumed that the chimney gas has a density equal to that of air. However, if an anthracite combustion system is tight, so that little dilution of the flue gases occurs, these may become appreciably more dense than air. Theoretically, a sealed system could give a CO_2 content of over 20% by volume. Having a molecular weight of 44, CO_2 weighs approximately 40% more than air. In almost all practical situations, this effect is negligible. But in the case of tight combustion systems burning carbonaceous fuels, especially anthracite or coke, it can be the deciding factor in chimney failure.

AUTHOR WILSON: I agree that in some instances refinements in the draft equations, such as the one suggested, are justified and should be incorporated.

PAUL R. ACHENBACH, Washington, D. C.: This paper illustrates clearly that a heated house acts like a chimney. For a number of years, the GUIDE has contained a statement that parallel flues in the same chimney should not be connected at the bottom because a U-shaped arrangement permits instability. This is in effect what exists here—two chimneys in parallel—one being the house and the other the real chimney with connections near the bottom. If the house itself has large openings near the top, it is more like a chimney.

As pointed out in the paper, the neutral zone can be lowered by increasing the openings near the bottom of the house and this suggests, at least as far as air circulation is concerned, that openings in the house should predominate in the lower floors.

In the case of wind, this same relationship does not necessarily hold true. However, it appears that the openings should still predominate in the lower part of the house but they should be exposed either to prevailing wind direction (the larger openings) or there should be openings to all exposures, so that the pressure in the lower part of the house would tend to equate with the outdoor pressure.

Another possibility is to provide a horizontal barrier at the first floor level so that the whole house can not act as a chimney. However, this is a step forward and an interesting description of how the house can act as a better chimney than the chimney does itself.

W. G. COLBORNE, Windsor, Canada: The kinetic energy or velocity head term should appear in Equation 1. Normally, this term cancels out because the change in velocity head is negligible compared to other terms of the equation. In this paper consideration is given to changes in the neutral zone which are measured in thousandths of an inch of water and also the draft conditions at or near venting failure. Should not the velocity head term be considered and discussed before it is neglected from Equation 1?

The cases in which the velocity head changes might be significant would be in an installation where the area of the flue pipe differed considerably from the area of the chimney; when considerable air is allowed into the flue pipe through the plate damper or through a draft regulator or draft hood; and where over-fire draft became a reference. In this case, the over-fire area is usually large and velocity therefore negligible while the chimney velocity may still be appreciable.

AUTHOR WILSON: A complete equation describing the inter-relationship of house and chimney draft should include a velocity head term. This paper is an introductory one and was intended to demonstrate the inter-relation of house and venting system as simply as possible. It is uncertain whether or not the velocity head term will be significant, but it should be considered.