Practical Field Guide: Combustion Safety Checklist

This reference guide accompanies and supports the Combustion Safety Checklist. Note that each line item in the checklist is defined and explained in this Field Guide.

Throughout the Guide and on the Checklist, there are items marked with 💣. This symbol indicates a hazardous condition that may be life threatening and warrants immediate notification of the homeowner and immediate repair. This Guide covers some of the information regarding those hazardous conditions. If you encounter a situation corresponding to a 💣 hazardous condition, and you are unsure of what you should do, seek additional assistance.

Checklist identification information

Name: Write the name of the homeowner
CAZ_____: Each home has one or more combustion appliance zones (CAZ). A CAZ is an area in which the appliance or appliances are located. This could be a room, a garage, an attic, a mechanical room, a crawlspace or basement. Write the name of the location this checklist applies to.
Address and phone: Write the address of the home & phone number.
Date: Write the date of the checklist completion.

Combustion/Dilution Air For Confined Spaces

Confined Space: A confined space is any space that has a volume less than 50 cubic feet per 1000 Btu/hr total input for that space.

The combustion and dilution air is calculated using NFPA 54, National Gas Code. If the area you are working indicates other code requirements, then those criteria should be used.

On the Checklist, write your answer in the *before* column if this checklist is done *before repair*. Write the answer in the *after* column if this checklist is done *after repair*.

Lines 1.A. through 1.K.
A. Record input rating in Btu/hr for each appliance in the CAZ space. This information can be found on the information plate attached to each appliance. Make sure you are recording the input rating. If an appliance does not have a plate, assume the following: water heater: 1000 Btu/hr per

gallon; wall furnaces: 35,000 Btu/hr for a single side and 60,000 Btu/hr for a double side with two burners; forced air furnaces: 25,000 Btu/hr per burner. An alternative measurement method is to clock the gas meter and use gas pressure and orifice size.

B. Add the total Btu/hrs recorded in A.

C. Record the needed volume. Total Btu/hr recorded in B. times 0.05.

D. Record the volume of the combustion appliance zone (CAZ). Multiply the length times the width times the height.

E. Answer the question. If C is larger than D, then the volume is not large enough for the appliances listed in B. If D is larger than C and is not a confined space, it is large enough for the appliances listed in B.

F. Is the CAZ weatherized like the home? For example, if it is a basement that is weatherized like the home, as often is the case, and it has been sealed from the living space above, then the space is considered to be a confined space even if it has enough volume. (NFPA 54)

G and H. Are there currently any combustion air inlets? NFPA 54 requires two. One opening (upper) should be within 1 foot of the ceiling and one (lower) within 1 foot of the floor. Calculate the area of each *(see table below for areas found in round pipe).*

Below is a guideline from NFPA 54 to calculate properly sized inlets according to where and how combustion and dilution air is supplied to the CAZ.

NFPA 54 Approaches to supply combustion/dilution air.

All Combustion Air Is From Within the Building:

If this method is used, special attention must be given to draft pressures. Often appliances are located in a closet or in a small basement. Combustion air can come from the living area of the house as long as the portion of the house that the combustion air is being drawn from is the volume needed and cannot be closed off by a door. You cannot have your openings into a small room or hall that is connected to a larger volume but the room or hall door can be closed.

Openings: 2 are required and one shall be within 12" of the top and one within 12" of the bottom of the CAZ.

Minimum Free Area: 1 sq. in. per 1000 Btu/hr of the total input rating of all gas equipment in the CAZ, but not less than 100 sq. in.

in each**.** The minimum dimension of an air opening shall be not less than 3 inches.

All Combustion Air Is From Outdoors:

Openings: 2 are required and one shall be within 12" of the top and one within 12" of the bottom of the CAZ. The openings shall communicate directly, or by ducts, with the outdoors or spaces (attic or crawlspace) that communicates with the outdoors.

Minimum Free Area:

1. Directly communicating with the outdoors**:** 1 Sq. in. per 4000 Btu/hr of the total input rating of all gas equipment in the space.

2. Vertical ducts communicating with the outdoors**:** 1 Sq. in. per 4000 Btu/hr of the total input rating of all gas equipment in the space.

3. Horizontal ducts communicating with the outdoors: 1 Sq. in. per 2000 Btu/hr of the total input rating of all gas equipment in the space.

Sizing the Openings: The total Btu/hr input of all equipment in the space divided by 4000 or 2000 or 1000 Btu per Sq. in. (as the case may be) will give the required size for each opening. Ex: 125,000 total Btu input divided by 4000= 31 Sq. in. is required in each opening. Using the table below you will need 7" Dia. pipes. If the free area is not known because of louvers or screen, 2 X 31= 62 Sq. in. for each opening. Using the table below you will need 9" Dia. pipes.

4. One permanent open within 12 in. of the top of the enclosure where the equipment has clearances of at least 1 in. from the sides and back and 6 in. from the front to the appliance. The opening shall directly communicate with the outdoors or shall communicate through a vertical or horizontal duct to the outdoors or spaces (crawl and attic) that freely communicate with the outdoors, and shall have a minimum free area of:

a. 1 sq. in. per 3000 Btu per hr for the total input rating of all the equipment located in the enclosure and
b. Not less than the sum of the areas of all vent connectors in the confined space.

If combustion air does not meet these NFPA 54 or local gas code requirements, then no work should be done until these conditions are met. *This is a safety violation.*

AREA AND CIRCUMFERENCE OF ROUND PIPE IN INCHES					
Dia.	Area	Circ.	Dia.	Area	Circ.
4	12.6	12.6	14	153.9	44.0
5	19.6	15.7	16	201.1	50.3
6	28.3	18.8	18	254.5	56.5
7	38.5	22.0	20	314.2	62.8
8	50.3	25.1	22	380.1	69.1
9	63.6	28.3	24	452.4	75.4
10	78.5	31.4	26	530.9	81.7
12	113.1	37.7	28	615.8	88.0

J. If either I Upper is larger then G or I Lower is larger than H, then the combustion air inlets are too small and your answer will be yes.

K. Is the current combustion air restricted in any way? Ex: Dirty screens, taped over, crushed pipe, insulated over, etc.

If you answered yes to any of the above questions, then additional combustion/dilution air is required.

LINE 2

Vent Pipe Damage or Leakage

If there are any signs of leakage, damage or disconnects, this must be repaired prior to or in conjunction with any work on the house. If there is carbon or rust present it should be noted. Carbon can mean carbon monoxide production. The rust can indicate future problems. Rust on top of the water heater can indicate that the vent pipe is rusting on the inside and may have caused blockage within the vent. Make sure you inspect the portion of the vent that is in the attic. Attic, crawlspace, basement and garage air has been found to easily get into the condition space. It is suggested that vent damage, leakage or disconnects should be dealt with as though they were inside the conditioned space. This condition is similar to having a cracked heat exchanger. The combustion gases are mixing with house air with or without carbon monoxide and *can become lethal at any point.*

When the vent is damaged or disconnected or has large vent leaks, it should be treated as a *hazardous situation*. The homeowner should be notified and the vent fixed prior to or in conjunction to any other work done on the house.

LINE 3

Vent Pipe Installation and Termination

Check to be sure that the vent pipe(s) is installed properly and terminate properly. Size, connections, height, vent cap, and location are all very important during your inspection of the venting system.

LINE 4

Gas Leaks

If gas fumes are smelled or gas leaks detected, do not fire any combustion appliance. *You are in a HAZARDOUS SITUATION!* Turn them off. The leaks must be fixed prior to or in conjunction with air sealing the house shell or duct system.

LINE 5

Outside Temperature Measurement

Measure the outside temperature so that you will be able to select the correct vent draft standard. Care should be taken when measuring temperature so that the sun or masses that store heat do not affect it.

LINE 6

Combustion Appliance Zone (CAZ)
Maximum Depressurization Test

This set-up is only a guide. It *will not* cover all houses but will work for most. *It should never be use to replace good sound judgment.*

How to Conduct the Test

1. Record base pressure for the CAZ. You are concerned about pressure differences caused by mechanical means (duct leakage, exhaust fans, and interior door closure) and do they cause the CAZ to depressurize more than -3.0 Pascals [-0.012" wc] below base pressure. **Negative pressure in the CAZ caused by temperature and building air leakage can itself cause vent backdrafting.**

2. Turn on the furnace, heat pump or air conditioner fan, (air handler fan).

3. Turn on all exhaust fans, including attic and crawlspace power vent fans, radon fans and dryers.

4. Close all interior doors.

5. Close supply registers and any other openings that can be closed in the CAZ.

If the homeowner can close these, then they should be closed during this test. It is not a question of whether the homeowner operates the home this way. The question is, *can* they? If they can, that's the way we want to test to assure safety to the best of our ability.

6. Go to each closed door and determine if air is being drawn from the mainbody of the house into the room. If this is the case open that door. *Something in that room wants to draw air from the combustion appliance zone—so let it.* If air is flowing from the closed room into the mainbody of the house, then leave the door closed. The room is pressurized and forcing air out of the house through leak sites in the room. This leakage is contributing to the possible negative pressure in the mainbody of the house.
Exception: If smoke goes into the CAZ, leave the door closed. If smoke is coming out of the CAZ open the door. *There is something in the mainbody of the house, (duct leakage, interior door closure or exhaust fans), that wants to draw air from the CAZ and the vent pipes. Let this occur—open the door.*

7. Measure the pressure difference CAZ WRT outdoors. We will call this *P1*.

8. Turn off the air handler fan.

9. Open all interior doors that have exhaust fan behind the door and open the CAZ to house door. Re-smoke each door and open all doors that air is being drawn into the closed room from the main body.

10. Leave all the exhaust equipment on.

11. Measure the pressure difference CAZ WRT outdoors with the CAZ door to the house open. The door open measurement will be called $P2^{open}$.

12. Measure the pressure difference CAZ WRT outdoors with the CAZ door to the house closed The door closed measurement will be called $P3^{closed}$.

Which step has the largest magnitude negative pressure, step #7 or #11 or 12, (P1, P2**o**, or P3**c**)? This is the answer to Line 6. *This set-up will be the maximum depressurization case set-up for this house during combustion safety testing.* (Exception to this is when you feel there is something in the house this set-up did not account for.)

If the CAZ WRT outdoors is depressurized to a larger magnitude than -3.0 Pascals [-0.012"wc] below base pressure, {example: -4.2 Pascals [-0.017"wc]}, pressure relief is needed.

LINE 7

Non-Sealed Combustion Appliance Fire-Up

DO NOT fire-up the appliances if a large magnitude negative pressure (-8.0 pascals/-0.032 wc) exists CAZ WRT outdoors. Flame rollout might occur and result in a fire.

Carbon monoxide should be measured at the same time as draft if any appliance is backdrafting prior to this fire-up. *Turn off the appliance if it is producing 200 ppm or greater. You are in a HAZARDOUS SITUATION!* The reason this measurement is so important is backdrafting has been found to cause large carbon monoxide concentrations in some houses.

While the house is in the maximum depressurization set-up, fire up the furnace, vented heater, or water heater. If a furnace and the water heater share a common vent then only fire the lowest Btu/hr input appliance. Test it first and then fire the largest and test. The lowest Btu appliance will have the hardest time drafting by itself. When testing the water heater first, confirm if the A/H fan should be on.

LINE 8

Flame Roll-Out

When the appliance fires, observe the furnace burner area and the access doors at the bottom of the water heater for flames rolling out of the burner ports and up the front of the furnace or out of the access doors of the water heater.

If there is flame rollout, it should be treated as *a HAZARDOUS SITUATION* and must be fixed prior to or in conjunction with any work to be done on the house.

LINE 9

Spillage of Combustion Gases

How to conduct the test

After one minute of run time check each appliance for spillage of combustion gases. Check the furnace and water heater at the draft hood using your hand or a smoke generator. Make sure you check the entire length of the furnace draft hood and all the way around the water heater draft hood.

If there is spillage after one minute, it must be fixed prior to or in conjunction with any work being done on the house.

Special Information: You can open the CAZ to the outdoors by a door or window to determine if spillage is caused by depressurization in the CAZ, produced by duct leakage, interior door closure, exhaust equipment, or a combination of them. If the spillage quits once the CAZ is opened to the outdoors, it was caused by a low pressure in the CAZ. If the spillage continues, it is caused by blockage of some kind.

LINE 10

Flame Change in the Furnace

How to conduct the test

After a minute or so the furnace fan is going to come on. When it comes on, observe the flames on the burners. If they change (wave or flicker) when the fan comes on, that is a good indication there is a crack in the heat exchanger.

This should be treated as a *HAZARDOUS SITUATION* and the homeowner should be notified prior to your leaving the house.

If the flames change when the furnace fan comes on, it must be properly

tested and fixed if necessary prior to or in conjunction to with and work being done. This observation does not confirm that the heat exchanger is safe or unsafe. It should only be used as an indicator. Make sure in all cases that the heat exchanger is inspected with a mirror as best as possible.

LINE 11

CARBON MONOXIDE (CO) IN THE CAZ

How to conduct the test

Make sure that the calibration of the CO tester is current. Have your CO tester running and monitor its readout continually throughout the testing. After five minutes of appliance runtime, measure the CO in the CAZ. If it is greater than 35 ppm, then ventilate the CAZ. Opening a door or windows or exhausting the area with a fan can do this. Be sure to turn off the fan before continuing to test. If you find CO in the CAZ, it is smart to check which appliance is producing it.

If an appliance is producing 200 ppm CO and is spilling or backdrafting, or if ambient air reaches 35 ppm CO you should turn off the appliance and stop testing until the appliance is fixed! You are in a *HAZARDOUS SITUATION!*

LINE 12

Draft Testing

Carbon monoxide should be measured at the same time as draft, if any appliance has been backdrafting during the five-minute period. This is done because it has been found that in some houses backdrafting can cause large carbon monoxide production.

How to conduct the test for gas fired appliances

Drill a hole (5/16") in the vent pipe(s) of conventional and mid-efficiency furnaces and water heaters only (*not* in sealed combustion appliances). Place the hole 24" from the draft hood if possible. Install draft probe(s) in the vent(s) holes. After five minutes of run time measure the draft pressure, Vent WRT CAZ. Each gas fired appliance should be able to produce the minimum acceptable draft pressure either in Pascals or inches of water column (WC) at the outdoor temperatures listed below. (Data for oil fired appliances is listed below gas fired appliances.)

Minimum Acceptable Draft Pressures	
Outside Temperatures	Draft Pressures
below 20 degrees F	-5.0 pascals/.020" wc
20 to 40 degrees F	-4.0 pascals/.016" wc
40 to 60 degrees F	-3.0 pascals/.012" wc
60 to 80 degrees F	-2.0 pascals/.008" wc
above 80 degrees F	-1.0 pascals/.004" wc

If any gas fired appliance can not reach the above draft pressures, it must be fixed prior to or in conjunction with any work done on the house.

How to conduct the test on oil fired appliances

Oil Furnaces And Boilers: Oil furnaces and boilers require two draft measurements: 1.) "overfire" draft and 2.) at the vent pipe.

"Overfire" Draft

1. Drill a 1/4-inch hole in the fire door or, if feasible, remove one of the bolts holding the fire door lining to the door. This hole is used for the "overfire" draft reading.

2. Place draft probe into the test hole.

3. Allow the furnace or boiler to operate for five minutes.

4. Measure the "overfire" draft pressure, Overfire WRT CAZ.

Minimum Acceptable "overfire" Draft pressure
-5.0 pascals/-0.02" wc
If the firebox ("overfire") draft pressure runs less than –5.00 pascals/-0.02" wc, smoke and odor may occur in the CAZ.

Vent Pipe Draft

1. Drill a 5/16" hole in the vent pipe at least 12" from the breach and no closer than 12" to the damper where possible.

2. Place draft probe into the hole in the vent pipe.

3. Allow the furnace or boiler to operate for five minutes.

4. Measure the draft pressure, Vent WRT CAZ.

Minimum Acceptable Draft pressure

Most residential oil burners with firing rates not above 1.5 gallons per hour (gph) need vent pipe draft between -10.0 pascals/-0.04" wc and –15.0 pascals/-0.06" wc

The above vent pipe pressures are needed to maintain a "overfire" draft pressure of -5.0 Pascals or -0.02" wc.

If any oil burner cannot reach the above vent draft pressures, this must be fixed prior to or in conjunction with any work done on the house!

Information: The reason for drilling a 5/16" hole and not some other size is there are caps that are made to fill a 5/16" hole (Dryer Instruments). When filling these holes in "B" vent after testing, use RTV caulk to seal the inner hole. The “B” Vent Manufactures’ Association requires this.

LINE 13

Carbon Monoxide (CO) In the Flue Gases

How to conduct the test on gas fired furnaces with a draft hood

After five minutes of run time, insert the CO detector barrel 6" into each exhaust port of the heat exchanger and measure the parts per million (ppm) in each, one at a time. The port having the highest reading is the ppm concentration for the furnace.

Maximum Acceptable PPM in the Flue Gases
100 PPM

How to conduct the test on gas fired furnaces with induced draft

After five minutes of run time, insert the CO detector barrel into the same hole you made for draft and measure the parts per million (ppm) in the vent.

Maximum Acceptable PPM in the Flue Gases
100 PPM

How to conduct the test on gas fired gas fired water heaters

After five minutes of run time, insert the CO detector barrel 6" into one

side of the baffle inside the flue of the water heater *(not the vent)* and measure the parts per million (ppm). Then repeat the measurement in the other side of the baffle. The side having the highest reading is the ppm concentration for the water heater.

Maximum Acceptable PPM in the flue gases of water heaters
100 PPM

How to conduct the test on oil fired furnaces and boilers

After five minutes of run time, insert the CO detector barrel 6" into the vent pipe hole you made for taking draft pressure and measure the parts per million (ppm).

Maximum Acceptable PPM in the flue gases
100 PPM

If any appliance is producing greater than 100 ppm in the flue gases, this should be repaired prior to or in conjunction with air sealing of the shell of the house or duct system.

LINE 14

Heat Rise Test

How to conduct the test

1. Drill a hole in the return and supply plenum a least 12" upstream and downstream of the air handler fan, before a return or supply take-off when possible.

2. Place a temperature probe in each hole.

3. Make sure there is a clean filter in the system.

4. Measure the temperature in supply and return.

5. Subtract the return temperature from the supply temperature. That is the heat rise for this furnace.

The heat rise for each gas furnace should be on the plate on the furnace. If the plate is missing it should be a least 40 degrees F and no greater than 80 degrees F. If the temperature is outside this range or the range on the

furnace plate, then service is needed. If the heat rise is too high before repairs, make sure the return or supplies are not too small after your repairs.

Re-set water heater temperature and dump hot water until water is below 120 degrees F!

LINE 15

Unvented Appliance Carbon Monoxide (CO) Test

This testing is not done to tell the homeowner that an unvented space heater is presently safe because it is not producing CO. **No house should be airsealed in any way if the house has an unvented space heater or vent free fireplace!** This testing is to serve our clients and to inform them when an unvented appliance is producing CO.

Gas Cook Stoves
Gas cook stoves are unvented appliances. Each burner, oven and self-cleaning mode should be tested for CO production after 5 minutes of runtime for each.

How to conduct the tests

Burners: Place a 2-qt. pot of cool water on each burner as you test them one at a time. Fire the burner and measure CO at the rim of the pot after 5 minutes of burn time.

Oven: Turn on the oven for five minutes and then measure CO at the exhaust port of the opening. Most exhaust ports are located at the top, centered on the control panel.

Self-Cleaning Mode: Turn on the self cleaning mode and again measure CO at the exhaust port of the oven after five minutes of self-cleaning.

Maximum Acceptable CO Production for any part of a cook stove
50 PPM

If the stove is producing greater than 50 ppm during any of the above testing, the stove should be repaired prior to or in conjunction with air sealing of the house shell or duct system!

Health Effects of Carbon Monoxide (CO)

Concentration		Exposure time and symptoms
PPM	%	
9	0.0009	Maximum allowed ambient by EPA
35	0.0035	Maximum for 8 hour exposure
200	0.02	Headache in 2 to 3 hours
400	0.04	Life threatening after 3 hours
800	0.08	Dizziness, nausea, convulsion in 45 minutes Death within 2 to 3 hours
1600	0.16	Headache, dizziness, nausea in 20 minutes Death within 1 hour
3200	0.32	Headache, dizziness, nausea in 10 minutes Death in 30 minutes
6400	0.64	Headache, dizziness, nausea in 2 minutes Death in 10 to 15 minutes
12800	1.28	Death in 1 to 3 minutes

Reference: NBS Technical Paper 212