**Building Science Education Solution Center – Combustion Safety**

Proficiency Level 4: Analyze

**Learning Objectives 4.1:**

* Examine the remediation options available for making home combustion safe for indoor air appliances.

**Lecture Notes 4.1:**

The following section goes into detail on information about remediation measures for combustion safety for indoor air appliances, as introduced in section 3.3 of this module.

Reference:

Pages 27 through 32 of Measure Guideline: Combustion Safety for Natural Draft Appliances Using Indoor Air (<https://www.nrel.gov/docs/fy14osti/61326.pdf>)

The following section on remediation for combustion safety has been summarized from the measure guideline referenced above. For the full text, please visit the link.

If remediation has been determined to be necessary, and the cost estimation identifies it as the more favorable option, the next step is to identify and implement the remediation measures required to address the failed combustion safety testing. Remediation is an advanced step that should only be conducted by an HVAC technician with proper training. The goal of remediation is to ensure that:

1. Combustion gases from the appliances are exhausted to the outside through code compliant vent systems.
2. Adequate combustion air is provided to the appliances.
3. The installation passes the test-in and test-out requirements.

Although the module so far has saved the remediation process to the very end of the combustion safety testing after test-out, remediation can take place after any of the previous steps: after the code compliance inspection, after test-in, after implementing any planned upgrades, or after test-out.

**Remediation to Address Inadequate Combustion Air:**

If the volume of air for combustion and ventilation calculated using either the Standard Method or the Known Air Infiltration Method (as applicable to the airspace being tested) is inadequate, and makeup air has been provided, additional house air volume needs to freely communicate with the appliances. Common methods for increasing the volume of air include:

* Installing louvers in doors that separate the appliances from other spaces in the house (see NFPA 54 Section 9.3.2.3, <https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=54>).
* Providing transfer openings for return air from bedrooms and other areas separated by a door from a central return (see Florida Mechanical Code 2010, Section 601.3, <https://codes.iccsafe.org/content/FLIEBC2010/chapter-6-alterations-mdash-level-1>).
* Adding combustion air openings to the outdoors.

As mentioned in Section 3.3 of this module, a contractor who can perform these modifications should be consulted first to determine project cost. If any failing combustion appliances are going to be replaced, the appliance should be turned off. Other upgrades to the residence can proceed as long as there are not any additional unsafe conditions unrelated to that appliance.

**Remediation after Combustion Testing Failures:**

If the house fails at test-in or test-out due to appliance combustion or ambient CO level issues, a trained HVAC technician should correct the problem before additional work can be performed. If the house fails at either of these tests due to long spillage time, these failures must be addressed through remediation before continuing with any planned house upgrades. The remediation measures above, meant to address inadequate combustion air being supplied to the appliances, should be considered first, followed by these additional remediation measures as further options:

* Replace existing doors that separate the appliances from other spaces in the house with full louvered doors if installing louvers in those doors does not fix the issue.
* Seal return air ducts passing through the space housing the appliance.
* Seal supply duct leakage to the outdoors such that it is less than 6% of the total system flow.
* Replace high flow intermittent exhaust with low flow continuous exhaust meeting bathroom and kitchen requirements.
* Provide additional jump ducts in the attic or crawlspace to balance internal operating pressures, so the mechanical room changes less than 1 Pascal (Pa) with reference to the outside during HVAC operation.
* Provide supply-only ventilation ducted to the air handler return sized for dryer makeup air and interlocked with the dryer.
* Provide additional ducted returns direct to the air handler fan cabinet from spaces isolated from central returns. Increase the size of the central return filter grilles to reduce the face velocity to 300–500 feet per minute and reduce operating pressure on the return system.
* Supply makeup air as required by NFPA 54 Section 9.3.1.5. Off-the-shelf conditioned makeup air systems can also be used for lower flows matching residential needs. Intermittent operation adds little to operating cost.
* Convert from exhaust-only ventilation to balanced ventilation.
* Provide an engineered solution, such as a powered vent.

If a remediation path is chosen after test-in, a contractor who can perform these modifications should be consulted, and remediation should take place before the originally planned house upgrade is performed. If remediation is unsuccessful, but the failing combustion appliances are to be replaced, the house upgrade can proceed as long as an unrelated unsafe condition is not detected. However, under no circumstances should the house be left in an unsafe condition after test-out.

**Detail on a Sample of Remediation Options:**

The following section summarizes how to implement several of the remediation options described above.

1. Installing louvers in doors that separate the appliances from other spaces in the house:

Openings used to connect indoor spaces shall be sized as follows according to NFPA 54 Section 9.3.2.3. For these purposes, an open door is not considered an opening.

* If the spaces being combined are on the same story, each opening must have a minimum free area of 1 square inch per 1,000 Btu/hour of the total input rating of all appliances in the space, but not less than 100 square inches. One opening is required at the top and one at the bottom of the enclosure, and the minimum dimension of either opening must be at least 3 inches.
* If the spaces being combined are on different stories, the volume of the spaces on different stories are considered as communicating spaces, where such spaces are connected by one or more openings in doors or floors having a total minimum free area of 2 square inches per 1,000 Btu/hour of the total input rating of all the appliances.

In both cases, the required size of the opening in the door is based on the net free area of louvers or grilles covering the openings. If the net free area is unknown, use 25% of the opening’s area for wood louvers, and 75% for metal louvers or metal grilles. Louvers and grilles shall be fixed in the open position.

2. Sealing return air ducts and the furnace cabinet:

First, seal all joints, penetrations, and openings in the cabinets of the air handling unit. Use metal tape or suitable gaskets on service openings and permanent seals on fixed joints and seams. A list of suitable materials used for duct sealing can be found in Section 8 “Materials for Duct Sealing” of the referenced document. All air handling units should be mechanically attached to other air distribution system components.

Next, provide continuous sealed ductwork from the living space directly into the blower housing for the forced air furnace or other air handler. Maintain at least the cross-sectional area of the return inlet and size the liner or duct to meet the manufacturer’s required airflow without restriction. Furnace returns without the manufacturer’s information must provide at least 2 square inches of total cross-sectional area for every 1,000 Btu of output. (See Proctor and Chitwood 2011 “Efficiency Characteristics and Opportunities for New California Homes” <https://efiling.energy.ca.gov/GetDocument.aspx?tn=65226&DocumentContentId=10844>).

Then, mechanically fasten the duct to the furnace cabinet and at the connection to the interior. Tape all cabinet service openings and joints. Seal all joints and seams with mastic and mesh tape meeting Underwriters Laboratories (UL) 181-M, or foil tapes meeting UL 181 A-P and UL 181 B-FX. Sealant foam approved for use as a firestop in combustible construction is acceptable at the connection to the interior construction materials.

No return air can be taken from a garage, boiler room, furnace room, or unconditioned attic. Line any enclosed support platform or building cavity with continuous, durable, air impermeable material and seals that show a flame spread index of 25 or less and smoke development index of 50 or less when tested to American Society for Testing and Materials (ASTM) E 84 or UL 723, or use a standard material listed for use in duct systems. (i.e., sheet metal, duct board, and flexible duct).

After finishing the sealing, visually inspect the air handler to verify that the following locations have been sealed. These include:

1. Seams, joints, and openings at the fan cabinet, furnace cabinet, the cabinet section with the air conditioner coil, and connections to return and supply plenums.
2. Refrigerant line and other penetrations into the forced air unit.
3. Air handler door and other service panels, using tape or adjusting an approved gasket for sealing (no permanent sealants).
4. Plenum and duct seams.
5. Return plenum joints at filter grille and to the back side of interior finish materials.
6. The gap between any duct and duct chase where it passes out of the combustion space.

Lastly, perform a smoke test to confirm completion or compliance of duct and cabinet sealing work:

1. With the furnace fan and service disconnect off, set up for fan pressurization of the duct system for the furnace or air handler located in the combustion space. Close registers to limit smoke entry to the interior. Seal the grilles and registers necessary to reach +25 Pa inside the ducts in the specific combustion space.
2. With the duct pressurization fan running, inject theatrical fog or equivalent nontoxic smoke into the fan inlet while observing smoke coming out of the ducts and cabinet. Mark the spots and stop adding smoke.
3. Seal all joints, penetrations, and seams where smoke came out, use foil tape or an approved gasket on service openings in the cabinet, and place permanent seals on all other openings.
4. Inject additional smoke and inspect the seals. If smoke continues to come out of the return plenum or cabinet, turn off the pressurization fan and open the air handler fan cabinet to access and seal the remaining return leaks in the combustion space.
5. There must be no return leaks. Return air from outside the combustion space must be brought to the furnace fan through continuous airtight ducts.
6. The furnace duct section is sealed when smoke no longer comes out of any openings in the combustion space. Note any smoke coming out of the burner area, heat exchanger, or vent connector for follow up service.

3. Adding combustion air openings to the outdoors:

Outdoor combustion air or a combination of indoor and outdoor combustion air is permitted by the code when openings are sized appropriately. The appropriate size of openings to the outdoors are based on the appliance input and adjusted by the indoor volume communicating with the appliances. Combustion air openings to the outdoors can also be used to mitigate interference that exhaust fans, clothes dryers, and kitchen ventilations can have on the operation of combustion appliances. See NFPA 54 Sections 9.3.3 and 9.3.4 for more details.

4. Converting from exhaust-only ventilation to balanced ventilation:

In homes that employ exhaust-only ventilation, a balanced ventilation solution such as an air-to-air heat exchanger or enthalpy exchanger can be used. For purposes of combustion safety, a less costly option is to supply makeup air as described above in “3. Adding combustion air openings to the outdoors.”

5. Providing an engineered solution:

A professional engineer can perform an assessment of the installation and determine if a powered vent system or other approach can be used for remediation.

**Problem Set 4.1:**

1) Answer the following questions about remediation.

a) When can remediation be implemented in the process of evaluating combustion safety?

b) In the event of combustion safety failure at test-in or test-out, under which circumstance can remediation measures be implemented before needing to contact a trained HVAC technician?

 i) During failure due to appliance combustion.

 ii) During failure due to ambient CO levels.

 iii) During failure due to long spillage time.

2) For a home that has three combustion appliances on the same floor with input ratings of 75,000 Btu/hour, 50,000 Btu/hour, and 35,000 Btu/hour, installed across two adjoining rooms, if louvers are to be installed in the connecting door, how large in square feet should the net free area of the openings in the door be?

3) Choose one of the sample options in section 7.5 of the “Guidance for Combustion Safety using Indoor Air,” and explain how you would use that option to perform remediation on a residence in your local area.