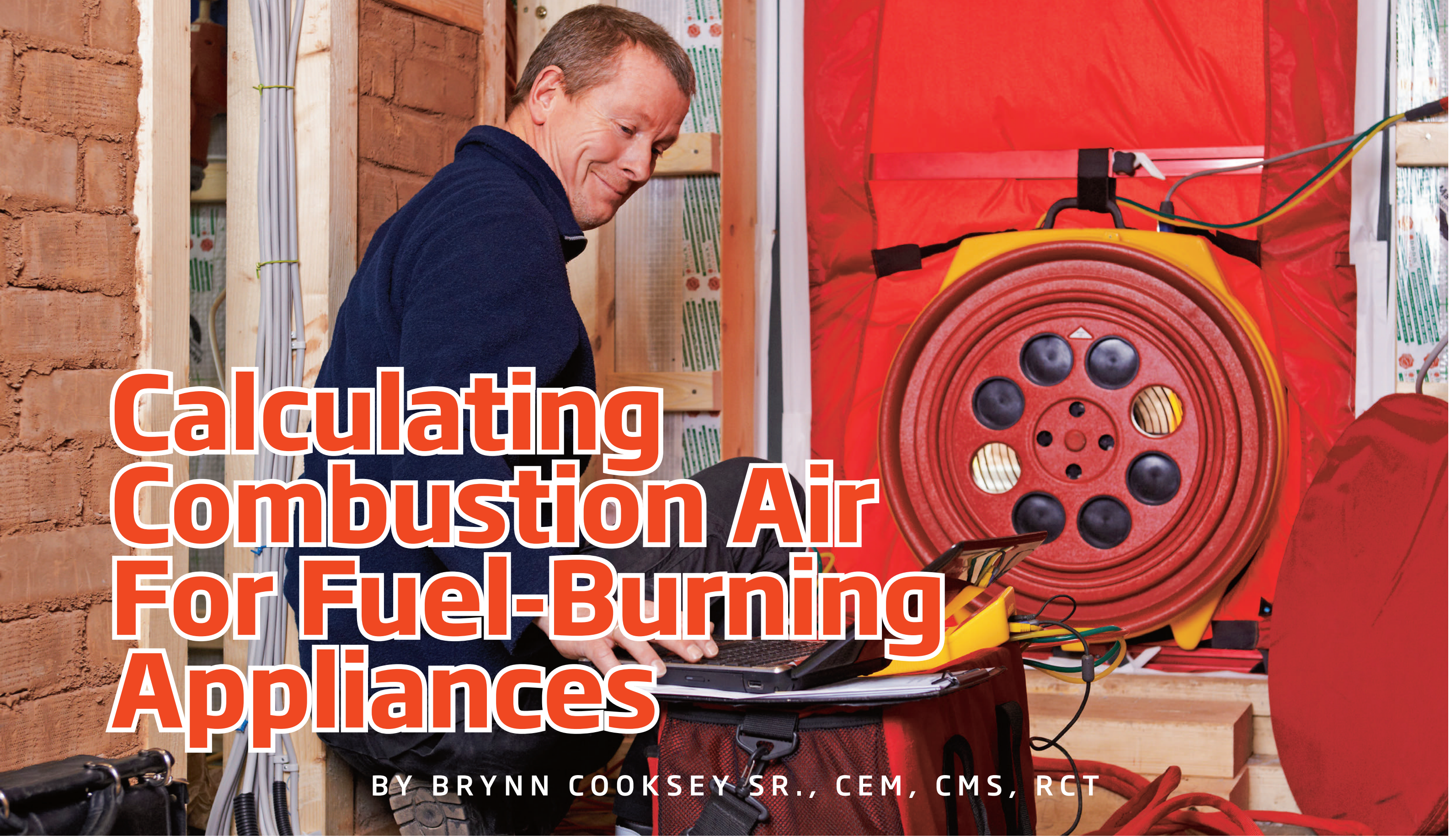


Calculating Combustion Air For Fuel-Burning Appliances

BY BRYNN COOKSEY SR., CEM, CMS, RCT

WITH PROPER DESIGN AND MAINTENANCE, COMBUSTION APPLIANCES CAN PROVIDE YEARS OF RELIABLE SERVICE

Combustion is defined as a chemical reaction that causes the rapid oxidation, or burning, of a fuel. The combustion process is used to liberate the stored energy contained in a fuel so that its chemical energy can be used as heat energy. In order for the combustion process to start and be sustained, it must have proportional amounts of fuel and air. It then must be introduced into a source of ignition.

To satisfy the air requirements for combustion, appropriate amounts of air must be made available to the fuel burning appliance in order for the burner to achieve complete combustion, which is the burning of all of the fuel particles in the fuel air mixture in the presence of ample amounts of air.

This article will cover the consequences of not having adequate combustion air, how to calculate combustion air requirements utilizing the indoor method and the mechanical supplied method, and how to implement combustion air based on the situation. The scope of this piece will be limited to the 2015 International Fuel Gas Code; however, one can also consult with other authorities that have jurisdiction over this topic for guidance and/or compliance.

Combustion air deficient

Combustion air is defined as "air necessary for complete combustion of a fuel, including theoretical air and excess air," according to the International Fuel Gas Code Commentary 2015. In order to achieve complete combustion, the service engineer must ensure that the fuel-burning appliance(s) have the appropriate volume of air based on the total Btu/hr. input of all of the fuel burning appliances within a common space. If the proper amount of combustion air is not supplied to the burner during the combustion process, then incomplete combustion will occur. Incomplete combustion will result in carbon monoxide generation, which is a colorless, odorless, tasteless, toxic gas.

Additionally, carbon monoxide has a heating value, so not achieving complete combustion is not only a danger, but is extremely wasteful, as well. In extreme cases, incomplete combustion can cause soot (unburned carbon) formation, which will act as an insulator and will retard heat transfer in the appliance's heat exchanger. Improper combustion air can also generate other harmful byproducts including toxic alcohols, ketones, aldehydes, nitrous oxides and other byproducts.

Accounting for combustion air is not just an option; it is a requirement, according to several code documents, manufacturers' installation instructions and other reference standards that are used in the HVACR industry. When accounting for combustion air, the service engineer has to determine "how much" combustion air needs to be supplied and also the "how to" of supply combustion air based on the application.

Combustion air can be supplied in many methods, and the method chosen by the service engineer must meet demands of the building or structure that the fuel burning equipment is located in. This article will cover the use and application of two of the most common combustion air techniques used in the HVACR industry: indoor air and mechanically combustion air.

Calculating combustion air

The quantity and delivery of combustion air deals directly with the style of and technology for the combustion heating appliances. Additionally, where the appliance is located within the structure may affect the technique of applying combustion air. There are five different methods for calculating combustion air. Combustion air can be calculated and supplied by using the indoor air of the space, all outdoor air, a combination of indoor and outdoor air, forced mechanical supplied combustion air, and other engineered and designed speciality methods.

Technicians often overlook combustion air, but when they do, it often leads to problems.

Indoor method

In order for the the indoor air method of delivery combustion air to be utilized, it must first meet a number of requirements that will allow this method to be implemented successfully. An appliance utilizing indoor combustion air is, in fact, utilizing a volume of air that located in the same area as the appliance(s). This method can be cost effective and easy to apply, especially when a building or structure is initially erected. The volume of the indoor air is supplied to the fuel-burning appliance via infiltration air or air that is traveling uncontrolled into a structure from the outside.

Essentially, the infiltration air travels to replace the air that is being utilized in the combustion process. For indoor combustion air to be a practical option, the dwelling or building must have a minimum of .40 ach, or air changes per hour. There must be a constant turnover of infiltration air for the fuel burning appliance to utilize at all times. To confirm if the indoor method of supplying indoor combustion air is a viable option, a blower door test must be performed where the service engineer can actually quantify the amount of infiltration air. The shell or envelope of the structure is the sole source of supplying combustion air and the service engineer must ensure that there is sufficient communication between the indoor and outdoor air before utilizing the option of indoor combustion air. As energy codes continue to become more stringent, there is a demand for tighter building construction and, as a result, the service engineer should look for the feasibility of utilizing indoor combustion air.

Another area of concern with combustion air utilized via the the indoor air method is that combustion air in most situations can be overlooked and the building owner may remodel the area with the fuel-burning appliance. This can pose a potential problem as the appliance is one located inside of a confined space, which is anytime an appliance is located where it has less than 50 ft^3 per 1000 BTU/hr. input.

A common industry problem occurs when the building owner may want to maximize space where a combustion appliance is located or that he or she may want to hide the fuel-burning equipment because it is not aesthetically pleasing. When this occurs, the building owner could have inadvertently eliminated the ability of using the indoor method using the sole space that the appliance is located in. This can cause an equipment performance problem, as well as a potential safety issues, because the appliance now has less combustion air available to support the correct fuel to air ratio for complete combustion. As a result, carbon monoxide is generated. The indoor method has some supporting countermeasures the service engineer can utilize granted the structure or dwelling has the appropriate amounts of infiltration air and if the spaces that are adjacent to the space can provide an ample volume of air to satisfy the volume requirements of 50 ft^3 per 1000 BTU/hr input.

To utilize combustion air from the indoors, the service engineer should follow all of the local codes, ordinances, and authorities having jurisdiction to determine if indoor combustion air is allowed and to determine how to apply it. The following can serve a guideline on how to implement utilizing combustion air from the indoors.

- Determine the structure's infiltration rate and verify that it qualified based on the requirements of the international fuel gas code, other published codes or standards, or manufacturers' installation instructions. If infiltration air is not acceptable, the indoor air method for calculating combustion air cannot be used.
- Add up the total input BTU/hr. of the appliances located in the space. Quite frequently other fuel burning appliances are located in the space, as the HVACR equipment and these appliances must be incorporated into the calculation for total BTU/hr. input. These appliances include but are not

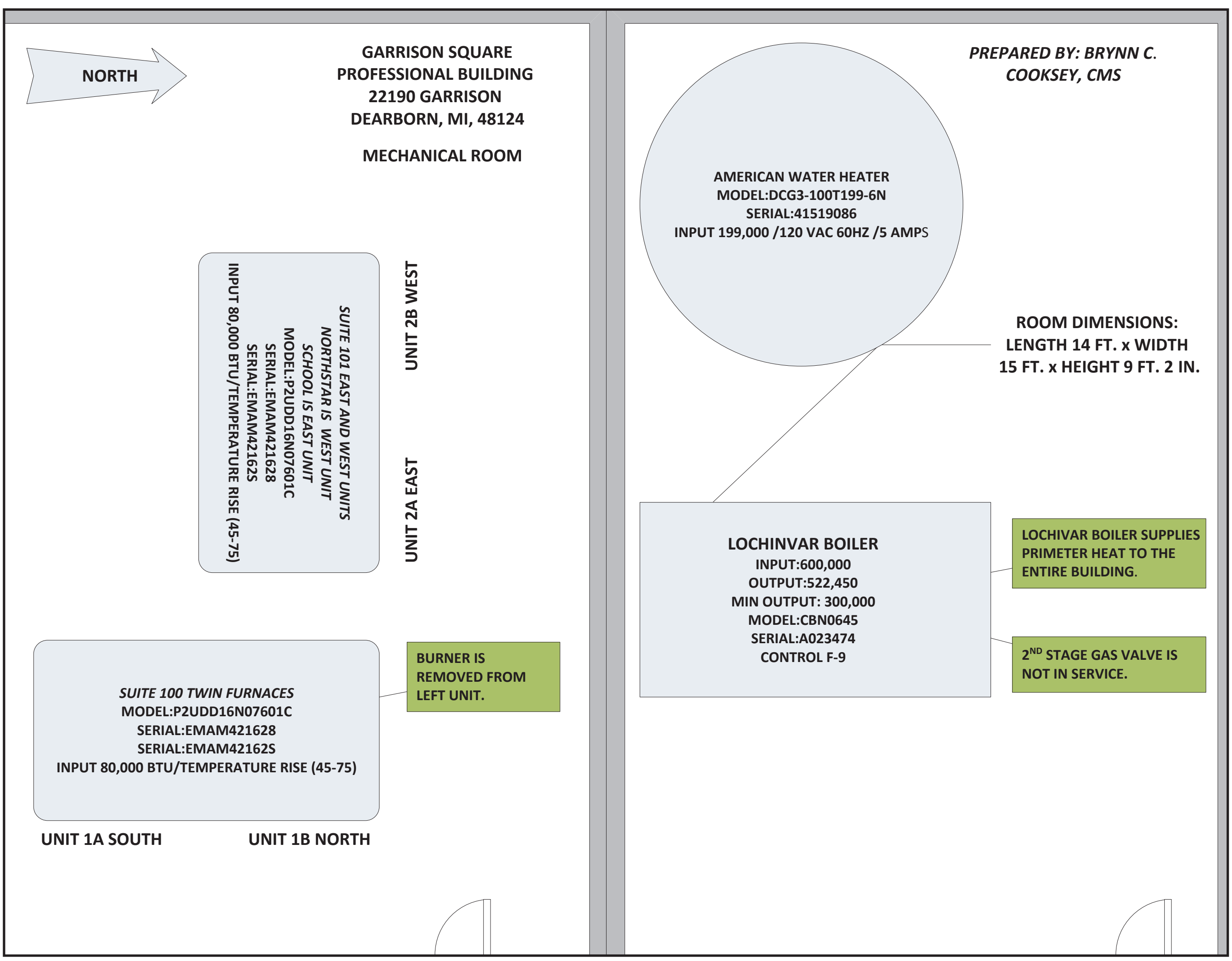
limited to water heaters, dryers, gas fire places, ovens or ranges.

- The volume of the space must equal 50 ft^3 per 1000 BTU/hr. in addition to the infiltration air requirements.
- If the volume of the space is sufficient and the infiltration air is acceptable, then the indoor air method for calculating combustion air can be utilized.
- If infiltration air is acceptable but the volume requirement is not met, then an adjoining space can be consulted to achieve the required volume for combustion air.
- If an adjoining space is going to be utilized, then the service engineer must calculate the size of the opening that will be required to communicate the air volume between the adjoining spaces.
- Despite the size that is utilized, there must be two openings on the wall joining the spaces and they should be located on the wall with a minimum of 12 in. from the top and bottom of the wall. The 12 in. from the top and the bottom promotes a natural convection air current that will take place between the spaces and promote communication between the spaces.
- Perform a combustion analysis, spillage, and a draft test with the structure in the worst-case depressurized condition. This worst-case depressurization of a structure is the where the structure is set up to operate in its worst conditions. Often this requires intentionally placing the structure into as negative of a pressure as possible. This takes place by closing off any positive pressure zones that may influence the performance of the combustion appliances. These test can confirm that the structure indeed can supply sufficient amounts of combustion air.

Mechanically supplied combustion air

There may become a point where combustion air may be impractical to obtain from the indoors, outdoors, or a combination of the two. In these situations, it may be a problem if the infiltration rate being improper, there is not enough volume of space, or with the openings of outdoor air becoming too large and impractical. In these situations, many service engineers will utilize mechanically supplied combustion air as a method of delivering the requirements of combustion air to support complete combustion.

To utilize mechanically supplied combustion air, the



It is recommended to set up a regularly scheduled maintenance plan to check for combustion air.

service engineer must determine the total input BTU/hr. of all of the appliances located inside of the space. Because the air is being influenced by a fan or blower, the physical size of the actual opening can be kept to practical limits. After the total input of all the appliances are tallied, the service engineer can utilize the calculations that are found in the International Fuel Gas Code. To support complete combustion for appliances using mechanical combustion air, the service engineer must specify a fan or blower that is capable of delivering .35 cfm per 1000 BTU/Hr. This method has a higher initial first cost, but it ensures the safe and efficient operation of fuel- burning appliances because it is not subjected to the leakage of the building envelope and shell, which could be inadvertently altered.

As with indoor air, the fan must be sized for the total BTU/hr input of all fuel-burning equipment and not just the HVACR equipment located int the mechanical room. Because all of the appliances are present and have the opportunity to operate simultaneously, the combustion air fan must be sized accordingly. The available combustion being delivered to a mechanical room should not double as a make up air requirement for exhaust fans. Make up air is a separate requirement and the two considerations should not be confused. Each engineering consideration should be separately addressed and accounted for. Additionally, there is a requirement for combustion air to electrically interlock the burner of the fuel-burning appliances with the the proof of operation of the combustion air fan or blower. Typically, on a call for the heat, the combustion air fan should start and prove that it is indeed working. After the interlock is satisfied, the burner of the combustion appliances is allowed to fire. Heating the combustion air should also be considered, as this will provide substantial energy savings. The warmer the combustion air is, the easier it will be for the fuel-to-air mixture to oxidize, which can yield some significant fuels saving. To utilize combustion air from mechanically supplied fans or blowers, the service engineer should follow all of the local codes, ordinances, and authorities that have jurisdiction to determine how to apply it. The following procedure can serve as a guideline on how to implement combustion air utilizing mechanical means.

- Add up the total input BTU/hr. of the appliances located in the space. Quite frequently, other fuel-burning appliances are located in the space and the HVACR equipment and these appliances must be incorporated into the calculation for total BTU/hr. These appliances include but are not limited to water heaters, dryers, gas fire places, ovens, range and etc.
- After calculating the total input determine the amount of air flow in cubic feet per minute that will be required to supply sufficient air to the combustion appliances.
- Apply the formula .35 cfm per 1000 Btu/hr. of input.

Example

Boiler is 1,000,000 Btu/hr.

Water Heater is 100,000 Btu/hr.

Total input is 1,100,000 Btu/hr.

CFM requirement is
1100 MMBtu/hr. x .35 cfm

CFM requirement is 385 cfm.

Select a fan with a rating of not less than 385 cfm.

Interlock the fan with the combustion appliances to prove that combustion air is indeed being supplied.

Implementation considerations

Whether looking at an internal combustion air application or mechanical combustion air solution, caution should be noted to prevent over sizing the combustion air. With the internal technique of combustion air, there is little to nothing that can be done. However, with a mechanical solution,

Contrary to popular belief, combustion air compliance is a code requirement.

there are some pitfalls that the service engineer can fall into if the following considerations are not taken into an account.

When considering solutions for combustion air, avoid grossly oversizing. Generally, all fuel burning equipment is designed to account appropriate amounts of excess air. Just supplying enough combustion air to meet the fuel burning appliance(s) BTU/hr input will satisfy the combustion air requirement. Grossly oversizing combustion air will show up as excessive excess air in combustion analysis testing. Excessive excess air can cause carbon monoxide generation and reduced efficiency, and it can also disturb some types of flame- sensing technologies. Excessive excess air

> **Combustion air is often overlooked and can cause serious problems if it is not considered.**

can increase the volume of the flue gases, which will increase their speed as they travel through the appliance's heat exchanger. As a result of the increase speed of the flue gasses, the heat exchanger has less opportunity to remove the heat from the exhaust gases—and less heat removed means less appliance efficiency. Additionally, the high excess air amount will cool the flame temperature down in the combustion zone of an appliance, and therefore promote the generation of carbon monoxide.

Finally, the excessive excess air can disturb some flame-sensing technology due to the flame signal being reduced because of the presence of excessive excess air. In this situation, the flame-sensing technology cannot see the flame because of the disturbance of excessive excess air, and this may cause intermittent appliance operation, such as nuisance trips and appliance lockout. As with any combustion appliance, it is typically recommended to set up a scheduled maintenance plan where combustion testing is performed on a regular basis.

Combustion air is often overlooked and can cause serious problems if it is not considered. It could be a potential equipment performance issue, as well as a health and safety issues. Despite popular belief, combustion air is a code requirement, and it must be considered. Combustion air can be delivered in multiple ways, including, internal combustion air, which is provided from the space, and mechanical supplied combustion air, which can be supplied from a blower or a fan. The service engineer should prevent grossly oversizing, as this can cause additional problems that can affect the safety of the reliability of the appliance. With the proper system design and maintenance plan, combustion appliances can provide years of reliable service.

For calculation sheets and other references, see the *RSES Journal* blog at www.rses.org/journal.aspx.

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