FANS AND BLOWERS FOR COMBUSTION PROCESS

INTRODUCTION

The burning of gas, oil, coal, or other combustible material requires air. When the end result of the burning is to be an efficient combustion process, in compliance with Federal and State Clean Air Act requirements, the volume of supply air must be reliably controlled. Insufficient air volume will result in wasted fuel and excessive particulate along with potentially explosive gases in the exhaust system. Too much air increases the amount of heat carried up the stack by the excess draft. Either extreme increases the cost and difficulty of controlling exhaust emissions.

NATURAL AND MECHANICAL DRAFT

Air can be supplied to the combustion process by *natural* or *mechanical* draft.

Natural draft simply refers to the use of a chimney or stack to induce an upward flow of air. The stack effect pulls air into the combustion chamber, as shown in Figure 1. The amount of airflow depends on the stack's height and diameter, the prevailing wind velocity, and the resistance of the burner mechanism or fuel bed itself. The demand for air-cleaning apparatus on combustion systems, particularly oil and coal, has increased the overall system resistance to such an extent that natural draft alone is seldom sufficient.

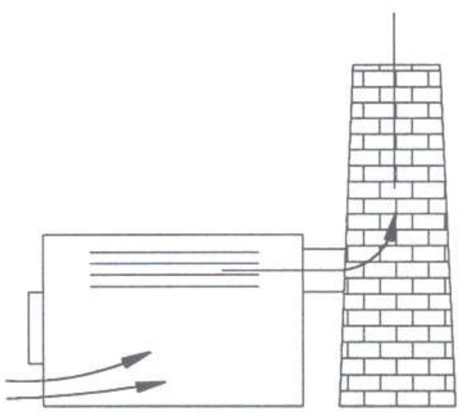

Figure 1 – Natural Draft

Mechanical draft refers to the use of fans or blowers to create airflow through the combustion area. When mechanical draft is incorporated, the chimney or stack is used primarily to direct the exhaust gases up and away where they will not be a nuisance. Because wind velocity and direction are less important, the combustion process can be much more carefully controlled.

Mechanical draft is accomplished in one of two ways: when air is blown or forced into the combustion chamber it is known as *forced draft* . . . see Figure 2; when the air is drawn through the combustion chamber it is called *induced draft* . . see Figure 3. When both forced and induced draft are used, the system is termed a *balanced-draft system.*

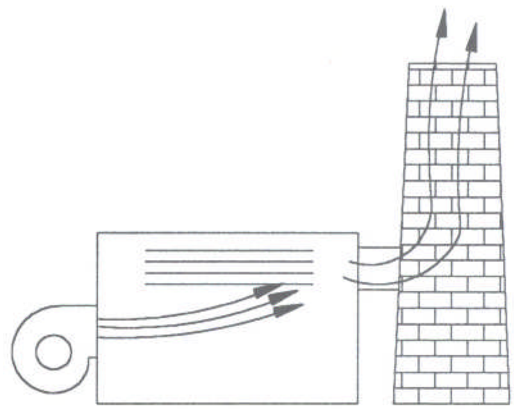

Figure 2 – Forced Draft

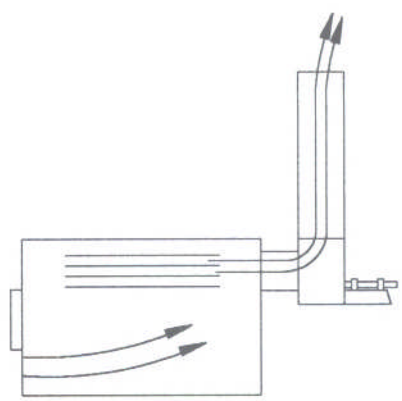

Figure 3 – Induced Draft

Generally, the fans or blowers used for induced-draft applications are larger and more expensive than those used for similar forced-draft applications. The combustion process itself creates gases and elevated temperatures that expand the exhaust airstream, requiring fans with greater volumetric capacity than would be required on the supply side of the combustion process to supply clean, ambient air. Also, the hot exhaust serves to lower the density of the airstream, so density corrections must be applied to the fan static pressure (SP) to overcome the actual system resistance. The fact that the exhaust or flue gases are hot often requires induced-draft fans to be of a construction suitable for higher temperatures.

The first induced-draft fans were applied to hand-fired, solid-fuel boilers where the combustion chamber had to be at a negative pressure to permit the operator to shovel in fuel.

When oil and gas became primary fuel sources, boiler designers were able to seal the combustion chambers. As a result, forced-draft fans became popular. The advantages were lower fan power and fans handling clean air (no corrosion or abrasion) at ambient conditions. These factors encouraged the use of airfoil fans, further reducing power consumption. This led to the almost universal use of pressurized firing in gas, oil, and pulverized coal boilers by the mid 1950s.

However, by the late 1 960s the combustion process industry had learned through experience that it was impossible to maintain an airtight quality in large (approximately 150,000 lbs./hr. and larger) industrial and power boilers. These units (some over 100 feet high) simply had too much thermal expansion. Fly ash and noxious and corrosive fumes were creating tremendous maintenance and personnel problems. This led to the development of balanced-draft systems, in which both forced-draft and induced-draft fans are used. (See Figure 4)

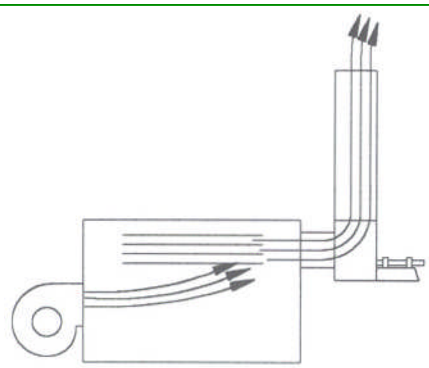

Figure 4 - Balanced Draft - Forced and Induced

Forced-draft fans and blowers are common for cast iron firetube and small water tube boilers. The fan or blower serves to provide the air and the velocity necessary for the fuel-to-air mixture to enter the actual combustion chamber. When used in conjunction with induced draft, the forced-draft fan is often called the primary air fan since it provides the primary combustion supply air. The induced-draft fan provides the airflow necessary to overcome system resistance and exhaust the flue gases.

Some combustion systems draw hot, perhaps dirty air from other processes. Forced-draft fans for such systems are called *gas recircula tion* fans, and must be selected for the rigorous conditions under which they will operate.

ALTERNATIVE FAN DESIGNS

Figure 5 shows a typical Pressure Blower for forced-draft application. This type of unit is normally direct connected to a 3600 RPM motor and develops pressure sufficient to overcome the total system resistance on small combustion systems. To minimize motor bearing load and starting current, the wheel is normally fabricated of high-strength aluminum. It is therefore limited to handling clean, often filtered air. Pressure Blowers are commonly used on small firetube boilers.

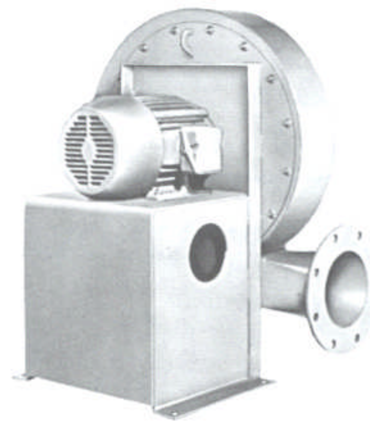

Figure 5 – Pressure Blower

Figure 6 shows a typical backwardly-inclined airfoil wheel commonly used for forced-draft fans on balanced-draft boilers. This type of fan is preferable because it typically is high volume, medium pressure and is usually the most efficient fan selection. Some airfoils, such as the **nyb** AcoustaFoil, are capable of stable operation throughout a complete, dampered range from wide-open to closed-off so the combustion rates can be closely controlled with inlet or outlet dampers.

On boilers that use hot, dirty gases for combustion supply, the gas recirculation fan most frequently selected is a radial-blade type. This type of wheel is considered to be the most “rugged” and will run at lower tip speeds. It is therefore less subject to abrasion than radial-tip or backwardly-inclined wheels. (See Figure 7)

Figure 6 – Backwardly-Inclined Airfoil Wheel

Figure 7 – General Industrial Wheel (Radial)

Radial-blade fans were at one time commonly used for induced-draft service. However, as pollution requirements have become more stringent and control devices have been added to reduce flue gas particulates (ahead of the induced-draft fan), radial-tip blade or even backwardly-inclined fans have become popular due to their higher efficiencies and higher volumetric characteristics. (See Figures 8 and 9) The exception to this is where high efficiency scrubbers are used and the pressure requirements are increased to where the radial-bladed fans are more suited.

Figure 8 – Radial Tip Wheel

Figure 9 – Flat Blade Backwardly-Inclined Wheel

The combustion of coal and most fuel oils will release sulfur fumes into the flue gas. If a wet scrubbing or cleaning apparatus is used, water vapor will combine with the sulfur to form sulfuric acid. This can place severe constraints on the fan types available to handle this highly corrosive gas stream. For this very reason, flue-gas-desulfurization (FGD) equipment is designed into the pollution control systems of many combustion processes. Another alternative to reduce the potential for sulfuric acid in the exhaust system is to mix lime or crushed limestone in a fluidized bed combustion process so the lime will neutralize the sulfur and stabilize the pH of the exhaust gases.

FAN SELECTION

Ideally, the fan in any combustion process will supply just enough air to completely burn all the fuel, and no more. This will help keep heated, but unused, air from going up the stack. Actually, this idea is approachable with gas burners but impractical with wood- or coal-fired combustion. Thus, nearly all air volume requirements for combustion processes are calculated to include some margin of excess air.

As stated in the introduction, insufficient air volume will result in wasted fuel and excessive particulate along with potentially explosive gases in the exhaust system. From this viewpoint it is better to include excess air volume. Some typical excess air percentages are shown in Figure 11 for reference only.

The amount of air required for theoretically perfect combustion is based on the portion of the combustible substances carbon (C), hydrogen (H_2), oxygen (O_2), and sulfur (S) contained in fuel. These are the only combustibles found in common fuels.

Air Required for Combustion		
	Combustible Substance	**Lbs. of Air Per Lb. of Combustible**
C	Carbon	11.5
H_2	Hydrogen	34.3
O_2	Oxygen	--
S	Sulfur	4.3

Figure 10

The ratio of air required for perfect combustion to a pound of each element in the fuel is shown in Figure 10. This ratio should be multiplied times the percentage of the element in the fuel, times the weight of the fuel to get the required weight of air, and then excess air must be added and the result must be corrected to the corresponding air volume per minute.

For example: Assume a fuel oil with 86.1% C, 13.8% H_2 , 0.1% S, and negligible free oxygen. The fuel oil weighs 6.8 lbs./gallon and will be consumed at a rate of 5 gallons each hour.

$$.861\text{ C} \times 11.5 \times 6.8 = 67.3 \text{ lbs. air}$$
$$.138H_2 \times 34.3 \times 6.8 = 32.2 \text{ lbs. air}$$
$$.001\text{ S} \times 4.3 \times 6.8 = .03 \text{ lbs. air}$$
$$\text{Total} = 99.53 \text{ lbs. air}$$

$$99.53 \text{ lbs.} \times 1.10 \text{ excess} \times 5 = 547.4 \text{ lbs./hr. air}$$

$$547.4 \div 60 = 9.12 \text{ lbs./min. air}$$

In a combustion supply application handling standard density air, this equates to (9.12 lbs./min. ÷ .075 lbs./ft.^{3} = 121.6 CFM).

Although there are a number of accepted methods for determining combustion air requirements . . . some rules of thumb, some exact calculations . . . they all rely on the actual portion of combustion constituents found in the fuel in question. Figure 11 lists some typical examples, but a full, accurate list would be impractical as there are hundreds of unique coal grades. In practice, the combustion system designer should determine the actual air volume requirements and the excess air margin based on an analysis of the fuel in question.

In addition to the fundamental volume specifications, combustion process fans, particularly larger fans, are often specified for two conditions . . . actual and test block. The actual condition is the calculated volume (including excess air) and pressure requirements. The test block condition is a theoretical duty that includes some safety factor beyond the actual volume and pressure requirements. The fan selection for the application should be capable of meeting both conditions with good efficiency, economy, and stability. Whenever possible, the actual condition should represent the most efficient point of operation for the fan selected for the application.

Fuel	Typical Excess Air Range (% Volume)	Typical Percentage of Combustibles (% Weight)			
		Carbon	Hydrogen	Oxygen	Sulfur
Fuel Oil	5-20				
No. 1		86.3	13.7	--	0.3
No. 2		87.2	12.9	--	0.5
No. 4		87.9	11.8	--	1.1
No. 5		87.9	11.3	--	1.8
No. 6		88.4	10.8	--	2.1
Natural Gas	5-15	70.6	22.7	1.4	0.3
Wood, Pine	10-25	54.3	5.6	37.9	0.1
Coal (ref. only)	10-60	85.0	5.4	5.8	1.5
Coke	10-30	80.0	0.3	0.5	0.6

Figure 11 - Typical fuel analysis of excess air requirements and amount of combustibles.

Typically, direct-drive fans are preferred to belt-drive fans. Direct-drive fan arrangements used are 4, 7, and 8.

To reduce volume and pressure to meet the actual design or reduced load conditions, inlet dampers or variable frequency drives are used. Variable speed offers the most efficient means of performance reduction, although the initial cost and equipment maintenance is greater than that of dampers. These must be evaluated on an individual job basis to determine whether the power savings will offset the greater initial price differential and added maintenance costs.

Belt-drive fans, Arrangements 1, 3, 9, and 10, can be selected for the most efficient operation at the actual operating conditions. It is usually enough that belted units simply have sufficient speed reserve to meet the speeds necessary to fulfill the test block condition by means of a change in drive sheaves.

The criteria for selecting the fan motor is usually specified per job. Often, the motor is sized to handle the hot test block conditions so the fan can be dampered for low load periods such as start-up or shut-down. This reduces the dampering, or turn-down, range required under actual conditions.

FAN CONSTRUCTION

Fans used in combustion processes, whether forced or induced draft, should be capable of meeting the following minimum requirements:

1. The fan pressure curves should be stable throughout the entire operating range of the system (actual and test block). Certain fans, such as most radials, the **nyb** Pressure Blower, and the **nyb** AcoustaFoil, are stable from wide-open to completely closed-off to offer the broadest possible control range.

2. The fan and all its components should be designed to meet even the test block condition without passing through the first critical frequency of the rotating parts. A common specification calls for the fan shaft's first critical speed to be 125% of the maximum operating speed.

3. The entire fan assembly should be rugged to withstand industrial service. Catalogs or drawings should contain complete material specifications.

4. Whenever possible the entire fan, motor, and drive assembly should be factory assembled, aligned, and test run to ensure smooth operation. The fan manufacturer should be capable of test running complete assemblies.

Induced-draft fans have further special requirements:

5. Where fan airstream temperature exceeds 300°F., the fan should include a shaft cooler and the bearing base should be separated from the fan housing.

6. The fan should be selected to handle the maximum particulate loading. **nyb** offers radial, radial-tip, and backwardly-inclined designs in a variety of alloys to handle a wide range of contaminated airstreams.

7. Fans handling particulate-laden airstreams should be furnished with shaft seals to protect the inboard bearings. Ceramic-felt shaft seals usually provide the best protection in these applications.

8. Fans handling particulate-laden airstreams should be furnished with a cleanout door and a drain to facilitate periodic cleaning. Various quick-opening, bolted, and raised, bolted cleanout doors and drain connections are generally available.

9. Blade liners, housing liners, and hard surfacing of blades and/or inlet cones may be desirable, depending on the particulate loading.

CONCLUSION

The proper specification and selection of fans for combustion processes require a careful communication between the system designer and the fan manufacturer. Given a clear understanding of the specification, the fan manufacturer can offer the appropriate fan type and accessories for the application.