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Revision Memo

12/01	Added API Standard to reference list. Editorial revision to Fan paragraph. Added drop out door requirement to safety section. Editorial revision to Control of Combustion Air Flow paragraph. Clarification on Air Flow Measurement paragraph.
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SCOPE

This section covers the fan, ducting and related instrumentation required for a forced-draft burner system. Additional requirements for systems, which contain air preheaters, are covered in [Section VIII-K](#).

REFERENCES

DESIGN PRACTICES (BESIDES OTHER SECTIONS OF THIS SECTION)

[Section XIV](#) Fluid Flow

GLOBAL PRACTICES

GP 2-1-1 Equipment Noise Level Data Requirements

GP 7-1-1 Fired Heaters

GP 10-13-1 Special Purpose Centrifugal Fans

GP 15-1-1 Instrumentation for Fired Heaters

API STANDARD

650 Fired Heater for General Refinery Service Including Appendices

OTHER REFERENCES

R. Jorgensen, Editor, *Fan Engineering*, Buffalo Forge Company, Buffalo, NY (1961).

Heinz P. Bloch, *Process Plant Machinery*, Butterworth Publishers, Stoneham, MA (1989).

DESIGN SPECIFICATION REQUIREMENTS

Table 1 lists the necessary fan and ducting information in the form that it should be presented in the fired heater section of the design specification. This table lists all requirements *not* covered by the referenced Global Practices.

The required safety and control instrumentation should be shown on the design specification flow plan. Any necessary instrument connections should be shown on the fired heater sketch, so that these connections can be properly located.

BASIC DESIGN CONSIDERATIONS

BURNERS

Selection and arrangement of the forced-draft burners are covered in [Sections VIII-B](#) and [VIII-F](#). When sizing the fan and ducting, the designer must know the required air pressure at the burner inlet for the normal and maximum firing rates. This information is given in [Section VIII-F](#).

DUCTING

Air is ducted from the atmosphere to the fan inlet and from the fan exhaust to the forced-draft burners. **Figure 1** shows a typical ducting system.

Duct Arrangement - The ducting must be located so that:

1. Burners can be removed onstream as required in **GP 7-1-1**.
2. Personnel escape routes from the fired heater are provided.
3. There is adequate clearance for maintenance of equipment beneath the fired heater.

Fan Inlet - To prevent potentially damaging foreign material from entering the fan, the fan inlet duct (or the fan inlet itself, if no duct is used) must be covered with a screen of 1-1/2 in. mesh (wire spacing of 38 mm), as required by API Standard 673. Fine-mesh screens should not be used, since they tend to ice over in the winter or to become plugged with fine material. A rain shield should be called for in the Design Specification (see **Table 1A** or **1B**), if needed to prevent rain from entering the fan.

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BASIC DESIGN CONSIDERATIONS (Cont)

Fan Discharge - Ducting from the fan discharge includes (see **Figure 1**):

1. **Supply Duct** - Connects the fan exhaust and the distribution duct.
2. **Crossover Duct** - Connects the ducting systems of two fired heaters. This duct permits operation of two fired heaters with a single fan.
3. **Distribution Duct** - A manifold which must be sized to assure equal air flow to all burners.
4. **Riser Ducts** - Connect burners with the distribution duct.

Construction - Above-ground ducting should be constructed of carbon steel at least 3/16 in. (5 mm) thick and braced to minimize vibration. This must be noted in the Design Specification (see **Table 1A** or **1B**).

Dampers - An isolation damper must be installed in the crossover between two fired heaters (even if both fired heaters are in a common box, as POWERFORMING Unit fired heaters often are). The designer must note this in the Design Specification.

As required by **GP 7-1-1**, the following dampers must be installed in the ducting:

1. Tight shut-off dampers at each burner, upstream of the burner flange and operable from grade.
2. Discharge isolation facilities on any fan that can be shutdown for maintenance while the heater continues to operate.
3. If two or more fans discharge into a common duct, each fan must be provided with an automatic damper which prevents backflow through the fan when it is not in operation (similar to a check valve). This automatic damper may serve to satisfy Requirement 2.

Sizing - Duct size (cross-sectional area) for a specified air flow is fixed by the design air velocity. A low velocity will result in an excessively large and costly duct. Too high a design velocity will result in large pressure drop and high power costs. A design air velocity in supply and crossover ducts of 40 ft per second (12 m/s) has been found to result in ducting of reasonable size and pressure drop. Use of higher velocities is not recommended unless justified by an economic study.

Air velocity in the *distribution duct* - and in the *riser ducts*, if they feed more than one burner (see **Figure 1**) - must be low enough to assure equal air flow to all burners. This velocity may be below the optimum 40 ft per second (12 m/s) recommended above. Uniform air flow to the burners from the distribution duct is assured by limiting the velocity so that the dynamic head (velocity pressure) in the distribution duct is less than 5 percent of the static pressure required in the burner windbox at normal firing rate.

Pressure Drop - Pressure drop in the ducting must be calculated before the final fan design requirements can be established. Since the final ductwork arrangement and sizing are generally established by the contractor, the pressure drop calculations are also normally performed by the contractor during the detailed engineering stage and are checked by the Owner's Engineer. Duct pressure drop calculation procedures are given below, under **CALCULATION PROCEDURES**. Calculated pressure drop in distribution and riser ducts should be based on normal design air flow rate (heater design firing rate at design excess air rate divided by total number of burners).

FAN

The fan is the key element in a forced-draft system. Since fans are not usually spared, failure of a fan results in fired heater shutdown in a single fan installation, or in reduction of unit throughput if more than one fan is used to supply combustion air. Manufacturers will rarely guarantee a fan/driver combination for a run length consistent with the desired fired heater run length, which may be as long as 3 to 4 years. Therefore, to provide a fan/driver combination with the desired run length, critical design features, such as bearings and lubrication, must be carefully specified. **GP 10-13-1, Special Purpose Centrifugal Fans**, defines these design requirements.

In addition to reliability, the fan must be properly sized to provide the required air flow at the pressure required by the burners.

- ◆ **Number of Fans** - One fan per fired heater is sufficient except for critical units, such as atmospheric pipestills, where shutdown of the fired heater would necessitate shutdown of downstream units. In such critical units two fans should be provided, each sized for 50% of the normal air flow requirements. With one of the two fans in operation, the fired heater could be operated at about 85% of design capacity, rather than 50%, because of margins incorporated in the fan sizing criteria, and because the single fan will be operating at a lower head point on its characteristic curve.
- ◆ **In some non-critical units, a spare is provided when it can serve as a common spare between two or more heaters.**

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BASIC DESIGN CONSIDERATIONS (Cont)

Fan Specification - The specification of a fan to meet the requirements discussed above has two parts:

1. **General Requirements for Forced Draft Fans** - Most of these general fan requirements are covered by **GP 10-13-1** and **GP 7-1-1** and should not be repeated in the Design Specification. Those requirements not covered by Global Practices are given in **Table 1A** or **1B**.
2. **Criteria for Sizing the Fan** - To size a fan, its *rated point* must be specified. The rated point and the information needed to define it quantitatively are discussed below.

Fan Curves - **Figure 2** shows the static head versus flow characteristics for a typical constant-speed, centrifugal fan with backward curved blades. Backward curved blades are specified (as opposed to straight or forward curved blades), because the peak efficiency of a fan with backward curved blading occurs close to the point of maximum fan power, thus minimizing driver power.

As can be seen in **Figure 2**, the fan has a separate characteristic curve for each position of the variable inlet guide vanes, which are used to control air flow. The following are also shown on **Figure 2**:

1. **System Resistance Curve** - This curve shows the fan head needed to overcome the system pressure drop at a given air flow rate. System pressure drop includes the pressure to force air through the burners (see **Section VIII-F**), the ducting pressure losses, and losses in any sound dampers or flow metering devices. Thus, the system resistance curve is the *fan operating line*. Any increase in back pressure, such as would result from closing a burner damper, moves the system resistance curve upward. The system resistance curve is also higher when the fired heater is operating with some burners turned off, even though the total air rate is constant.

The *operating line* (system resistance curve) is defined as follows:

$$H = H_n \left(\frac{F_v^2}{F_{vn}^2} \right) = R F_v^2 \quad \text{Eq. (1)}$$

where: F_v = Volumetric flow, cu ft/min (dm³/s)
 F_{vn} = Volumetric flow at normal firing rate, cu ft/min (dm³/s)
 H = Static head at F_v , in. of water (kPa)
 H_n = Static head at normal firing rate, in. of water (kPa)
 R = System resistance = $\frac{H_n}{(F_{vn})^2}$

Note: Use summer design temperature and humidity, and correct for altitude (if necessary) in defining the operating line.

2. **Fan Operating Points** - These are intersections of the system resistance curve with the fan characteristic curves.
3. **Fan Rated Point** - This is *not* an actual operating point, but includes margins on both flow and head, as defined below. These margins are needed to provide a safety factor on fan/system performance and to assure that the fan is not normally operating with its inlet vanes fully open (i.e., without control).
4. **Fan Stability** - Fan operation is unstable near and to the left of the peaks of the characteristic curves. In this unstable region, any reduction in air flow (e.g., as would result from closing a burner damper) reduces the fan head, which then causes a further reduction in air flow, and so forth. To assure stable operation, the static head should show a continuous increase from rated air flow back to a nominal 60% of rated air flow.

Sizing - To provide a fan of proper size, the fan *rated point* must be defined (see **Figure 2**). At the rated point, the fan must provide the following:

1. 115% of the air flow (weight flow) needed for fired heater design firing rate and excess air.
2. 115% of the static head required to overcome the sum of the ducting pressure drop plus the pressure at the burner needed for *maximum* burner firing rate.

The fan must be sized based on design summer air temperature and relative humidity and at the altitude of the installation. No altitude correction is needed unless the installation is more than 1000 ft (305 m) above sea level. The calculations needed to establish the rated point are normally performed by the fired heater vendor, using information given in the Design Specification (**Table 1**). See **CALCULATION PROCEDURES**.

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BASIC DESIGN CONSIDERATIONS (Cont)

NOISE CONTROL

Noise emission from the fan and ductwork must meet the hearing conservation criteria defined in **GP 2-1-1, Equipment Noise Level Data Requirements**. To assure that these noise criteria are met, the fan/duct system should incorporate the following features (as noted in **Table 1**):

Elevation - The fan inlet should be 15 ft (4.6 m) above the first fired heater platform.

Insulation - Typically, aboveground ducting and fan casings require 2 in. (50 mm) or more of acoustic insulation (e.g., 80 to 100 lb/ft³ gunite - 1280 to 1600 kg/m³).

In addition to meeting the *hearing conservation* noise criteria, the noise contribution of the fan/duct system must be consistent with the *community* noise criteria for the particular installation. Since these requirements vary from installation to installation, the Mechanical Engineering Section of EETD should be consulted regarding establishment of fan/duct noise limits and the possible need for noise suppression features, such as inlet duct sound dampers, in addition to those mentioned above.

S SAFETY

Fired heaters equipped with forced-draft systems require certain safety features *in addition* to those for natural draft heaters. These are covered in **GP 15-1-1** and are summarized below:

- ♦ **Loss of Combustion Air** - Main fuel and pilot fuel must be cut off automatically and a warning alarm must be sounded if air flow is blocked, or if the fan fails. This can be accomplished by a low combustion air flow cut-off. If the heater is equipped with drop out doors, FD fan failure shall initiate a heater shutdown with a time delay. To override the shutdown signal, opening of the bypass damper and air door must be confirmed. Time delay shall be approximately 10 seconds.

Loss of Fan - The preferred measurement method is low fan speed.

Fired Heater Overpressure - The maximum internal pressure that a fired heater can withstand without structural damage is about 5 in. of water gauge (1.25 kPa). Since the fan is capable of delivering higher pressures, the fired heater must be protected from the overpressure which would result if the fired heater outlet were blocked. To prevent overpressure, the following features are required:

1. A high-pressure alarm, set to sound whenever the box pressure becomes slightly positive; say 0.1 in. of water (0.025 kPa).
2. Partial dampers in the flue gas ducting, in lieu of standard dampers. These partial dampers must be sized to provide a maximum pressure drop of 5 in. of water gauge (1.25 kPa) in the fully closed position with normal air flow. If partial dampers are impractical (such as when an air preheater is used), then a pressure relieving device must be provided to assure that heater box pressure does not exceed 5 in. of water (1.25 kPa). Sizing of pressure relieving doors is discussed in **Section VIII-K**.

Fired Heater Shutdown - Fans are to continue running when the fired heater is shut down by safety equipment, such as the pilot gas PLCO.

CONTROL OF COMBUSTION AIR FLOW

- ♦ To provide the proper excess air at varying heater firing rates, the air flow to the burners must be adjustable. Variable-position inlet guide vanes on the fan are the preferred means of controlling air flow. As the inlet vanes are closed, the entering air is given a spin in the direction of fan rotation. This spin results in reduced driver power required for a given air flow and static head (see **Figure 2**).

Other methods of controlling air flow, such as varying fan speed or use of a variable damper in the fan discharge, are not generally desirable. Throttling the fan discharge raises the system resistance curve (see **Figure 2**), thus requiring greater driver power for the same air flow and discharge pressure (downstream of the throttling damper) than does inlet guide vane control. Varying the fan speed requires a variable-speed driver or a variable-speed drive (e.g., fluid drive), both of which are more expensive than inlet guide vane control. Even when economics dictate use of a steam turbine driver, which is capable of variable-speed operation, constant-speed operation of the turbine in combination with inlet guide vane control is preferred, because a less complicated system results.

Inlet guide vane position may be controlled by any of the following:

1. **A local, manual positioner**, such as a hand wheel.
2. **A hydraulic or pneumatic positioner** controlled by a Manual Loading Station (MLS) from the control house. This approach is preferred when the indicator of the heater oxygen analyzer (if provided) is located in the control house. Using the oxygen indicator as a guide, the boardman sets the MLS at the position providing the desired excess air. Since burner windbox pressure is a measure of burner air flow (see **Section VIII-F**) it may be used as a check on fired heater air flow by installing a pressure indicator in the control house.
3. **An automatic control system**, which sets air flow as a function of firing rate to maintain a preset excess air level.

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BASIC DESIGN CONSIDERATIONS (Cont)

AIR FLOW MEASUREMENT

- ♦ Airflow measurement must be provided for all forced draft applications as well as special requirements, such as automatic air-fuel ratio control, which dictate that air flow be measured. A venturi in the fan inlet is the most practical device for this purpose. The venturi may also be located in the fan discharge provided that sufficient run length between the fan exhaust and venturi inlet is available for good metering.
- ♦ In some special applications, particularly retrofits, there may not be overhead or plot space available to provide venturis for airflow measurement. Orifice meters require too great a pressure drop relative to venturis, and single pitot tubes require a greater velocity for proper measurement than is typically available in air ducts. Multiple pitot tube arrays provide a solution that results in reasonable accuracy, although they are subject to plugging in dusty environments and should be used only when a venturi is not feasible.

CALCULATION PROCEDURES

REQUIRED WEIGHT FLOW OF DRY AIR AT GIVEN FIRING RATE

$$W_a = F_g (FG - 1) \quad \text{Eq. (2a)}$$

where: W_a = Air weight flow, lb/hr (kg/s) of dry air
 F_g = Gross fuel required, lb/hr (kg/s)
 FG = Lb flue gas/lb fuel (kg flue gas/kg fuel) (**Figure 12, Section VIII-M**)

or

$$W_a = 0.0008 Q_f \left(\frac{100 + EA}{100} \right) \text{ or Metric } W_a = 0.344 Q_f \left(\frac{100 + EA}{100} \right) \quad \text{Eq. (2b)}$$

where: Q_f = Heat fired, Btu/hr (MW) (LHV)
 EA = Percent excess air

VOLUMETRIC AIR FLOW AT SPECIFIED ENVIRONMENTAL CONDITIONS

Given: Summer temperature, relative humidity, and weight flow of dry air

Find: Volumetric flow rate, F_v

From psychrometric chart (**Figure 3A or 3B**) determine v = specific volume in ft³/lb (m³/kg) dry air

$$F_v = \left(\frac{v W_a}{60} \right) \text{ or Metric } F_v = v W_a \times 1000 \quad \text{Eq. (3)}$$

where: F_v = Volumetric flow rate, cu ft/min (dm³/s)

CORRECTING VOLUMETRIC FLOW RATE FOR ALTITUDE

$$(F_v)_{\text{corr}} = \left(\frac{1.0}{S_a} \right) (F_v)_{\text{sea level}} \quad \text{Eq. (4)}$$

where: S_a = Specific gravity for air at desired altitude, from **Figure 5A or 5B**

If the altitude is less than 1000 ft (305 m) above sea level, this correction can be neglected.