Overfire Air Jets for Incinerator Smoke Control

ELMER R. KAISER and JOSEPH B. McCAFFERY

ABSTRACT

Jets of air directed into the flames from incinerator fuel beds aid in completing the combustion of gases and suspended carbon particles. The location, sizing and pressurizing of the overfire air nozzles are important design considerations for air pollution control.

The paper reports on the investigation of the performance of overfire air jets in reducing smoke from a large incinerator furnace. Equations and recommendations are given for nozzle sizing, air pressures, air delivery rates and jet throw or penetration. A graph is included to aid in the selection of nozzles and air pressures for desired flow rates and penetrations.

INTRODUCTION

Incinerators with rectangular stokerized furnaces are provided with overfire air nozzles to prevent smoke through improved combustion and to control the furnace temperatures. Overfire air jets are commonly used on coal-fired furnaces [1] and on a variety of incinerators [2] [3].

The nozzles consist of pipes imbedded in the furnace refractories and are connected to air manifolds supplied by a blower. One or more dampers between the nozzles and the blower complete the assembly. The air is not preheated for incinerators.

Specifically, the air jets issuing from the nozzles project air a distance into the furnace known as the "penetration" or "throw," beyond which the velocity is too low to be useful. The terminal velocity selected for measuring the throw is 1000 to 1500 feet per minute (fpm), as measured in a cold furnace.

An air jet issuing perpendicularly from a furnace wall or roof entrains gas and propels gas and air as a mixture. The jet progressively widens and the velocity decreases with distance from the wall. A multiplicity of nozzles are usually used, often in rows.

Air jets assist combustion by mixing furnace gases and air by entrainment, as well as by delivering air (oxygen) to the center of the furnace. The flames issuing from a thick refuse fuel bed are deficient in oxygen because of the highly volatile organic matter. Air supplied from above corrects the deficiency and enables combustion to be completed. It is advisable to provide jets of air horizontally 18 to 24 inches above the fuel bed to introduce oxygen as soon as possible after the volatile matter is emitted, thus providing maximum time for burning. The jets should not impinge on the fuel bed. Air can also be supplied from above in a sweeping action over the fuel bed.

TESTS AT OCEANSIDE PLANT

Tests on overfire air jets were conducted at the Oceanside Refuse Disposal Plant, Oceanside, Long

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Island, New York, under a program supported by the Solid Wastes Program of the federal Public Health Service. The 300 ton-per-day Furnace No. 2 had 32 overfire air nozzles of 4-inch diameter, but often had a smoke emission of No. 1 to No. 1.5 Ringelmann density, as well as flame impingement on the boiler tube bank. The total amount of excess air was satisfactory, because the CO_2 content of the flue gas seldom exceeded 7 percent, dry volume basis. More excess air could not be tolerated because of its adverse effect on steam generation. It was necessary to utilize the available air more effectively.

Water-jacketed probes were inserted above the fuel bed for sampling the gases. The gas analyses revealed a scarcity of oxygen in the center of the furnace.

At the next shutdown each overfire air jet was investigated in the cold furnace to determine the throw, flow and static pressure ahead of the nozzles. Velocities were measured with a pitot tube along the centerlines of the jets, as evidenced by maximum velocities. Typical results are shown in Figure 1. The velocities declined rapidly within the first 4 feet from the nozzles, and then fell off more slowly with distance.

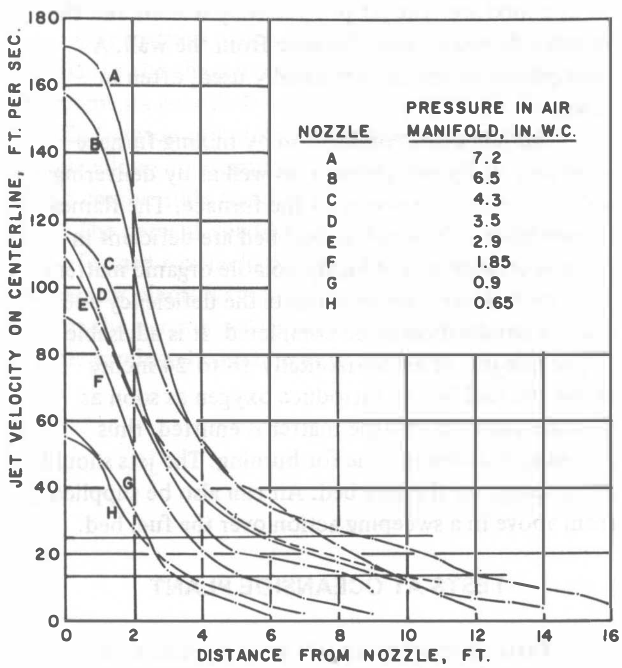

FIG 1 TYPICAL VELOCITIES IN AIR JETS FROM 4-INCH DIAMETER NOZZLES

The sidewall nozzles F, G and H were particularly weak and would not deliver air to the center of the furnace, a distance of 5 feet from the sidewalls, before the gases from the fuel bed would deflect the jets upward.

The average upward gas velocity from the No. 2 section of the rocking grate stoker, an area of 111 sq. ft., is 750 fpm. Because most of the flow is from fissures, flame velocities of 1500 to 2500 fpm are experienced. To penetrate to the central zone within a few feet of the top of the fuel bed, it is necessary that the air jet have a velocity of at least 1500 fpm (25 ft per sec).

Previously published design data for coal-fired furnaces were based on a terminal velocity of 1000 fpm (16.7 fps) and an efficient design of nozzle [1]. Bituminuous coal has a volatile matter content of only half that of refuse and is burned with less excess air.

By comparing the throw at 25 fps with the throw at 16.7 fps in Figure 1, it will be noted that the throw at 25 fps is only two thirds of the throw at 16.7 fps.

Inspection of nozzle design for overfire air on municipal incinerators indicates that the manifold-to-nozzle connection is a simple welded joint with an abrupt transition. The velocities in the air manifolds should preferably not exceed 2000 fpm, but the velocities in the nozzles will usually exceed 5000 fpm.

These factors combined in preparing the following conservative formulas:

The equation recommended for calculating the flow through an overfire air nozzle is

$$Q = 1096.5\,C\ \ A\sqrt{(p1 - p2)/w} \qquad (1)$$

in which Q = actual air flow, cfm.

C = 0.90

A = area of nozzle cross section, sq. ft.

$p1 - p_2$ = difference in pressure ahead of nozzle and furnace, in. w.c.

= manifold pressure and furnace draft, inches water column.

w = density of air at nozzle temperature and pressure, lb. per cu. ft.

The equation recommended for calculating jet throw (penetration) for a terminal velocity of 1500 fpm (25 fps) is

$$\text{Throw} = 0.75\ \ d\sqrt{(p1 - p2)} \qquad (2)$$

in which throw = ft from wall
d = nozzle diameter, inches
p1 - p2 = difference in pressure across nozzle, in. wc.

An ideal nozzle arrangement for test purposes would yield a higher distance of throw than given in Eq. (2), because the equation allows for practical considerations.

Figure 2 is a graph based on Equations (1) and (2) for the selection of nozzle sizes and air pressures. The graph is useful for new designs and for evaluating and correcting existing designs. For example, the increase in air penetration from the sidewall air nozzles of Oceanside Furnace 2 was accomplished without increasing the overfire air supply. Inserts of 3-inch pipe were fabricated with two 3½-inch pipe collars welded to serve as spacers. As shown in Figure 3 the pipe sleeve and one spacer were bell mouthed in a lathe.

Penetration of 5 ft from the 3-inch nozzles requires a manifold pressure of 5 inches of water. The resultant air flow is 400 cfm. The original 4-inch nozzle delivered 400 cfm at a pressure differential of 1.6 inches of water, but the throw was

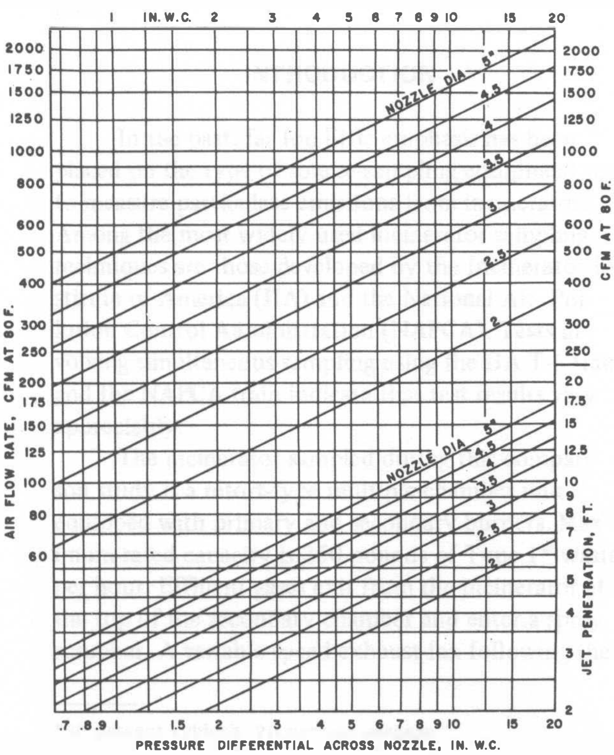

FIG. 2 AIR FLOW AND JET PENETRATIONS AT 1500 FPM AS FUNCTIONS OF NOZZLE DIAMETER AND PRESSURE DIFFERENTIAL

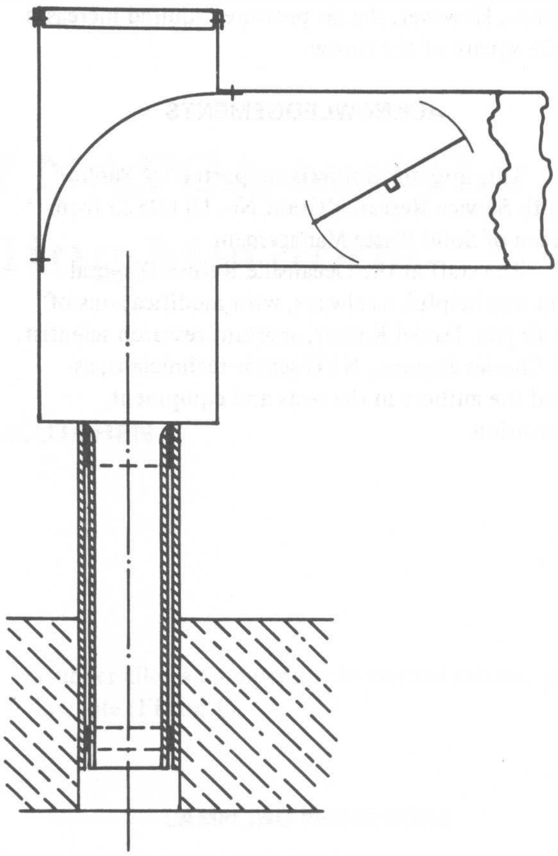

FIG. 3 MODIFICATION OF 4-INCH-DIAMETER NOZZLE WITH 3-INCH PIPE SLEEVE

under 4 ft. Had the manifold pressure been increased on the 4-inch nozzle to achieve 5 ft penetration, the flow would have been 530 cfm for each nozzle.

A damper with outside locking device is advisable ahead of each nozzle when the static pressure cannot be adjusted accurately by dampers in the supply manifold. A multiplicity of nozzles served by one fan can be balanced by adjusting the individual dampers with the aid of a draft gage and tap at each nozzle boot.

The improvement resulting from the increased penetration was a reduction in the color of the stack plume of Furnace 2 to a light haze. Air pollution had been reduced through improved combustion.

The investigation is continuing to achieve the best balance of air delivery from the sidewall and roof nozzles for the further shortening of the flames. Whether sidewall jet penetration beyond the center of the furnace is necessary will be explored. The interlacing of staggered jets from the two sidewalls would seem to have advantages for increased turbulence. However, the air pressure required increases as the square of the throw.

ACKNOWLEDGEMENTS

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The Charles R. Velzy Associates, Inc., collaborated on the technical features of the study.

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