The Measurement of Air and Gas Flow and Pressure as Applied to Modern Municipal Incinerators

Abstract

The performance of an incinerator depends on the control of the air flow to the stoker zones and overfire nozzles, the furnace draft, and the pressure drop across auxiliaries. The author describes simple, rugged pressure taps for fans, ducts and chambers, which provide the input to instrumentation. The objective is to provide the incinerator operator with relative values of flow for guidance.

As 9 to 10 lb of air may be supplied to an incinerator for each lb of refuse burned, and the air must be proportioned depending on fuel condition, flow instrumentation is necessary to guide the incinerator operator.

Most incinerator operators are not interested in absolute values of flow, but need relative values, as in percent of maximum flow. The measuring equipment and the installation is thus simplified, and can be made more rugged and reliable than precise test equipment.

Measurements in Current Usage

Depending on the degree of automatic control and instrumentation desired, any one or all of the following measurements may be indicated, recorded, or fed into the measured variable input of a controller in an automatic control loop.

1. Undergrate combustion air flow,
2. Overfire combustion air flow,
3. Discharge pressure of underfire air fan,
4. Discharge pressure of overfire air fan,
5. Air pressures in undergrate zones,
6. Air pressures in overfire air manifolds,
7. Furnace draft,
8. Gas pressure drop across heat recovery and/or gas scrubbing devices, and of induced draft fans, downstream of the furnace,
9. Chimney draft.

Air-Flow Meters

The flow of air past a restriction causes a momentary increase in velocity, which is associated with a decrease in static pressure. By inserting taps or tubes in the duct ahead of and behind the restriction at strategic points, and connecting the tubes to a differential pressure-sensitive gage, the elements of a flowmeter are produced. The pressure differential increases with the square of the flow velocity. The flowmeter can be calibrated in quantitative flow units or merely adjusted to read relative flow from 0 to 100 per cent.

Fan Inlet

A fan with unducted inlet may be provided with a pressure tap as shown in Fig. 1. The pressure in the tap is zero when the fan is stopped, and decreases below zero as the air flow increases. The tap is connected to the low pressure port of the measuring gage, while the high pressure port of gage is left open to the atmosphere. This arrangement is the least expensive but has the disadvantage of being mounted outside the fan inlet protecting screen and is possibly subject to accidental displacement.

Other arrangements for fan inlets are shown in Fig. 2. A circular orifice plate is shown in Fig. 2a for a single-inlet fan. Simple plate dams along one side of each inlet of a double-inlet fan are shown in Fig. 2b. A circular orifice plate or two dam plates may be used, as shown in Fig. 2c. Note, however, that all three arrangements involve additional cost of extending or hooding the fan inlet. With all of these fan inlet suction measurements, the flow measuring instrument input element is connected to the device on the low pressure side only and the high pressure side is vented to atmosphere.

Air Ducts

In air ducts, such as the fan discharge ducts, a simple baffle plate can be installed in the duct, approximately equal to half the height of the duct, as shown in Fig. 3.
By providing a flexible coupling between the pitot tube and the transmission lines, a traverse of the duct can readily be made to determine the optimum insertion depth and the pitot tube can then be fixed in that position.

**Pressure and Flow of Flue Gas**

The measurement of flue-gas draft and flow can be made by means of any of the primary elements discussed for air and inserted in the flue gas duct after the furnace, or by measuring the drop in pressure across a restriction to the gas flow (i.e. waste heat boiler, economizer or dust collector) downstream of the furnace. Exhaust-gas flow, however, is the most difficult flow measurement application on the incinerator for three reasons:

1. This is a dusty, moist gas and pressure taps will tend to plug. For this reason it is extremely important that the connection to the furnace or duct be made sufficiently large and with cleanout provision.

2. If the two pressure sensing points are at widely different temperatures, the resulting difference in density of the gas in the connecting lines to the instrument will create an error in measurement. For this reason, avoid measurement across spray chambers or other locations where gas temperature changes radically.

3. If taken across a restriction to gas flow, the fouling tendencies of the dirty gas will cause the restriction to increase with time, therefore changing the differential measurement for a given rate of flow.

For the reasons stated above, the usefulness of this measurement as an indication of quantitative flow is limited and care should be taken in this application.

Fig. 6a shows the connection for use on plain furnace

**Fig. 4 Venturi Section in Fan Discharge**

The tubes connect to the top of the duct and communicate to the air inside the duct by holes of \( \frac{3}{4} \) inch diameter. The upstream tap registers a higher positive pressure, while the downstream tap registers a lower positive pressure. The pressure drop suffered by the air stream while flowing past the baffle is partially lost and must be made up by a slightly higher pressure at the fan discharge.

This device can be readily modified in the field by varying dimension \( A \), if the actual operating air flow is found to be radically different from that originally calculated.

The venturi section shown in Fig. 4 is more efficient than the plain baffle, but is more difficult to fabricate. The loss in pressure of the air in flowing past the restriction is largely regained downstream of the section.

The pressure taps are shown in midstream.

For measuring static pressure in an air duct, the duct connection shown in Fig. 5 is suggested.

Another suitable device is the pitot tube which is described in many textbooks and handbooks. Due to its relatively small projected area, the pitot tube will create the least resistance to flow of all the devices thus far discussed and is relatively inexpensive. One drawback with the pitot tube is that at the velocities expected, the underfire and overfire air ducts will generate such small differentials as to limit selection of the measuring device to one capable of accuracy at very low ranges of input.

Another adverse feature is in that the pitot tube is not adjustable for range and, therefore, the differential pressure generated at a given flow is fixed.

The length of the pitot tube selected should allow a penetration of approximately \( \frac{3}{4} \) of the depth of the duct.

For measuring static pressure in an air duct, the duct connection shown in Fig. 5 is suggested.

Another suitable device is the pitot tube which is described in many textbooks and handbooks. Due to its relatively small projected area, the pitot tube will create the least resistance to flow of all the devices thus far discussed and is relatively inexpensive. One drawback with the pitot tube is that at the velocities expected, the underfire and overfire air ducts will generate such small differentials as to limit selection of the measuring device to one capable of accuracy at very low ranges of input.

Another adverse feature is in that the pitot tube is not adjustable for range and, therefore, the differential pressure generated at a given flow is fixed.

The length of the pitot tube selected should allow a penetration of approximately \( \frac{3}{4} \) of the depth of the duct.

By providing a flexible coupling between the pitot tube and the transmission lines, a traverse of the duct can readily be made to determine the optimum insertion depth and the pitot tube can then be fixed in that position.

**Pressure and Flow of Flue Gas**

The measurement of flue-gas draft and flow can be made by means of any of the primary elements discussed for air and inserted in the flue gas duct after the furnace, or by measuring the drop in pressure across a restriction to the gas flow (i.e. waste heat boiler, economizer or dust collector) downstream of the furnace. Exhaust-gas flow, however, is the most difficult flow measurement application on the incinerator for three reasons:

1. This is a dusty, moist gas and pressure taps will tend to plug. For this reason it is extremely important that the connection to the furnace or duct be made sufficiently large and with cleanout provision.

2. If the two pressure sensing points are at widely different temperatures, the resulting difference in density of the gas in the connecting lines to the instrument will create an error in measurement. For this reason, avoid measurement across spray chambers or other locations where gas temperature changes radically.

3. If taken across a restriction to gas flow, the fouling tendencies of the dirty gas will cause the restriction to increase with time, therefore changing the differential measurement for a given rate of flow.

For the reasons stated above, the usefulness of this measurement as an indication of quantitative flow is limited and care should be taken in this application.

Fig. 6a shows the connection for use on plain furnace.
walls. The anchor plate maintains the position of the pipe and helps to form a seal. However, plastic cement is also recommended to prevent air infiltration which could cause a false reading. The set-back at the hot face of the wall reduces the heat flow to the pipe and helps prevent clogging by fly ash or slag.

Fig. 6b is a similar arrangement for a wall with sheathing. A flange on the sheath adds stability to the structure.

The pressure connection outside the duct, when air or clean gas are encountered, is shown in Fig. 7a. For dirty gas the pressure tap shown in Fig. 7b is recommended, as it includes a moisture and dust trap. Both connections have cleanout plugs for rodding the pipes and for blowing them clean.

**Pressure Measurements**

Connections to furnaces and ducts for pressure measurement should be made in the same manner as described for flow measurement. That is, the taps should be of sufficient size to prevent closing off by fouling, and to permit ease of cleaning. Pressure measurements currently found useful as operating guides include: underfire and overfire fan discharge pressures, undergrate zone pressures, furnace draft, and induced draft fan inlet pressure. The drop in pressure across the heat recovery devices, such as the waste heat boiler and airheater or economizer, is an extremely useful measurement in that it serves as an indication of the cleanliness of that device and as such, indicates to the operator when soot blowing is required. Certain gas-scrubbing devices of the mechanical type require rather close control of the pressure drop through the device for efficient operation. In this case, the differential pressure instrument can be used either to indicate to the operator the need to change the number of units in the gas stream or to feed into an automatic controller to automatically change the gas flow path.

**Instruments**

Generally, in measuring air and gas flows one is dealing with differential pressures in the order of a very few inches of water, at most, at maximum flows. Since this differential pressure varies as the square of the flow, it is apparent that at low flow rates, one is measuring a few hundredths of an inch of water. For this reason, it is important that the instrument or controller selected be sufficiently sensitive to detect these very low inputs. The most widely used input element for these low ranges is a slack diaphragm. The active area of the diaphragm should be large enough to assure positive input forces to the instrument. The instrument should preferably be the force balance, rather than motion balance, type.

**Application**

The single most important factor in flow and pressure measurement is the selection of the primary element location. The point of measurement must be remote from changes in flow direction and as far as possible from points of turbulence. The pressure taps must be installed so they do not project into the flow stream, as this would result in a velocity head being added to the static pressure and the measurement would, therefore, be incorrect. The taps should be so located as to be in a plane normal to the gas flow stream. Just as important is the selection of a tap location which can be readily reached for inspection and cleaning. The size of pipe and/or tubing used between the primary elements and the instrument will vary with the length of pipe and the displacement of the input element in the instrument.

Instruments, if field-mounted, should be installed at a comfortable working height above the floor and should
be accessible for calibration and maintenance. Sensing lines should be arranged for simple connection of test manometers or gages for calibration of the instrument.

Conclusions

It can be seen that although the flow and pressure measurements described above are relatively simple and oft proven instrumentation applications, their usefulness as operating guides will be directly proportional to the instrument quality and the care taken in locating and installing measurement devices.

Acknowledgment

The sketches are reproduced by courtesy of the Republic Flow Meters Company, Chicago, Illinois.