INSTRUMENTATION SYSTEMS FOR MUNICIPAL REFUSE INCINERATORS

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ABSTRACT
Operational requirements of today’s modern refuse incinerators make necessary the use of modern instrumentation techniques. This paper outlines the basic control systems which are used in modern incinerators. In addition, the utilization of the more sophisticated techniques of ratio and cascade control of interrelated variables are examined, as tools for more effective operation of incinerators.

INTRODUCTION
While a modern municipal incinerator is a fuel-burning furnace, it is unique in that the fuel (refuse) varies widely in content. A typical charge for a municipal furnace may contain paper, vegetable waste, glass, film, earth, paint, ink, plastics, cloth, ceramics, fish waste, petroleum, masonry, wax, animal waste, leather, dairy waste, metal, foil, wood and rubber. At any given time the refuse may contain from 0-100 percent of any of the above materials. In addition, the moisture content may vary from zero to saturation. The result is a rapidly and continually changing combustion condition which requires effective control of a number of variables in order to maintain stable operating conditions.

An incinerator must be controlled so that it will 1) effect complete combustion of the refuse, thereby reducing it to a minimum volume of materials that are non-offensive and easily disposable, and 2) prevent the release to atmosphere of offensive gases and smoke. The instrumentation systems described in this paper help the operator accomplish these two purposes under the varying fuel conditions outlined above at a minimum cost per ton of refuse burned. In addition, it helps to keep the incinerator and associated equipment from being damaged by high and/or rapidly fluctuating temperatures.

Fig. 1 is a schematic diagram of a typical incinerator. Refuse is fed to the furnace through a charging hopper A, dried and ignited on the drying stoker B and burned on the combustion stoker C. Primary (combustion) air is introduced under the stokers by an underfire forced draft fan D. Secondary (cooling) air is introduced through overfire air ports Q by overfire air forced draft fan E. The residue drops into the ash hopper F for disposal. The hot gases continue to burn in the combustion chamber G then enter the settling chamber H where reduced velocity causes the heavier fly ash particles to drop out. In the spray chamber J the gases are cooled to a safe temperature by water sprays. The gases are further cooled by dilution with air admitted by cooling air dampers K before passing through the dust collection equipment L, the induced draft fan M and out the stack. In the event of failure of the cooling system or other emergency conditions the emergency bypass damper P is opened allowing the hot gases to bypass the dust collector and induced draft fan.

In the earlier days of incineration, incinerator instrumentation consisted of a millivoltmeter indicating furnace temperature and draft gauge for indicating furnace...
pressure. However, with the enforcement of stringent air pollution laws such meager instrumentation can no longer do the job required. The basic instrumentation systems outlined in this paper represent the minimum requirements for the proper operation of today's modern incinerators.

**UNDERFIRE AIR CONTROL**

To effect complete combustion of the refuse an adequate amount of air must be introduced underneath the stoker. However, too much air will carry fly ash particles into the gas stream contributing to the air pollution load. In the past, an attempt has been made to control the pressure in the underfire air chambers beneath the stoker. Because of the non-homogeneous nature of the refuse on the stoker, the actual air flow of underfire air may vary considerably with the density of the refuse on the grate. In order to assure an adequate flow of underfire air it is desirable that the actual air flow be controlled. Fig. 2 is a schematic of such a control system. Air flow in the underfire air duct is measured and is controlled at a preset value. With such a control system, even though the resistance to air flow changes with the nature of the refuse on the grate, the flow of air will remain constant.

**FURNACE TEMPERATURE CONTROL**

To insure complete combustion of all volatile matter the furnace outlet temperature is usually maintained in the 1700 F - 1900 F range. This range may vary with furnace design and configuration and is indicative of the actual fire temperature. Furnace temperature is raised or lowered by controlling the amount of overfire air. If the temperature is allowed to drop too low odorous gases will escape into the atmosphere. If the temperature goes too high or varies too widely or too rapidly the furnace may be damaged. Fig. 3 illustrates the simplest form of furnace temperature control system. When dry refuse is being fed to the furnace a maximum amount of air will be allowed into the furnace to obtain the desired temperature. If the furnace feed is wet refuse the temperature drops because of the heat required to evaporate the additional moisture and the smaller amount of combustible material present. The control loop then acts to automatically reduce the quantity of overfire air. The combustible gases are not cooled by the excess air to the extent that they were before and the resultant temperature is restored to the control setting. As shown in Fig. 3 the temperature is sensed by a chromel alumel thermocouple mounted in sidewall or in the crown of the combustion chamber. The temperature signal from the thermocouple is compared with the desired temperature by the controller. The output of the controller positions the
overfire air damper by means of a modulating electric motor.

**FURNACE PRESSURE CONTROL**

With the furnace temperature control system continually varying the total air delivered to the furnace by the forced draft fans, a draft control system is necessary to maintain the proper pressure in the furnace. Fig. 4 illustrates a typical draft control system which regulates furnace pressure by controlling the speed of the induced draft fan. Pressure is measured at the combustion chamber sidewall by a pressure transducer. The pressure signal from the transducer is compared with the desired pressure by the controller which produces a signal to increase or decrease the speed of the induced draft fan as necessary. The type of actuator used depends on the particular type of speed regulating equipment furnished with the induced draft fan.

**COOLING CONTROL SYSTEM**

To prevent damage to the dust collector and the induced draft fan, the hot gases from the furnace (1700-1900 F) must be cooled to approximately 650 F. Cooling is generally accomplished by banks of water sprays and/or by dilution of the gas stream by outside air. The relative amounts of water and air are determined by weighing the water cost against the cost of the required induced fan capacity. For maximum flexibility of control, the control systems for water cooling and air cooling should be independent systems. Fig. 5 illustrates a typical spray chamber control system. Thermocouples mounted in the spray chamber outlet produce a signal proportional to the average temperature of the gas stream. The number of thermocouples used will depend on the size and configuration of the passageway. The average temperature signal is compared with a desired temperature by the controller. The output of the controller modulates in sequence the motorized valves that supply water to the spray banks, thus maintaining the desired temperature. High temperature alarm should be installed on this system to open the emergency bypass if the temperature exceeds a preset limit. As an added protection a pressure switch should be used to monitor the water pressure to initiate an alarm in the event of low water pressure.

Since cooling water is often costly it is desirable to keep an accurate record of water usage. Water flow can be measured by means of an orifice plate in the water supply line. The differential pressure across the orifice plate is proportional to the square of the flow and can be measured with a conventional flow transmitter. The signal from the flow transmitter is fed to a recorder totalizer.

If the configuration of the passageway makes it difficult to obtain a true average temperature reading it may be necessary to measure the temperature at a number of points in the passageway utilizing a device which controls the spray banks in accordance with the highest detected temperature.
The cooling air control system Fig. 6 is similar to the spray chamber control system. The signal from the controller modulates the damper motor thus regulating the amount of outside air that is introduced to the system at this point. In addition, an interlock switch on the dust collector inlet draft indicator will prevent the damper from opening if a positive pressure exists in the duct.

**DUST COLLECTOR CAPACITY CONTROL SYSTEM**

In some of the modern incinerators the multiple unit cyclone collector is used for incinerator fly ash control. Since cyclone collectors are most efficient at specific gas velocities, the number of collector units in operation should be determined by the velocity of gases through the furnace. This will keep the collector system operating at a maximum efficiency. Fig. 7 illustrates a control system which will achieve this result. Since the total flow of gases through the collectors is proportional to the speed of the induced draft fan, this speed is used to regulate the number of collector units in operation. The speed is measured by d-c tachometer generator. This speed signal operating through sequencing relays actuate 2-position damper motors to place in operation the proper number of collector units for most efficient fly ash control.

**PRESSURE INDICATION**

Draft indicators should be installed to measure pressure at the following points: 1) underfire air duct, 2) stoker compartments (one for each zone), 3) overfire air duct, 4) sidewall air duct if used (one each side), 5) sidewall low furnace outlet, 6) dust collector (differential across collector), 7) induced draft fan inlet, 8) dust collector inlet (with interlock switch).

**TEMPERATURE INDICATION**

It is desirable that the operator be able to monitor certain temperatures throughout the incinerator facility. Such temperatures may be monitored manually by means of a multipoint pushbutton type indicator or automatically by means of a multipoint recorder. Such temperature monitoring should include: 1) furnace outlet temperature, 2) settling chamber outlet temperature, 3) spray chamber outlet temperature, 4) dust collector inlet temperature, 5) dust collector outlet temperature, 6) stack temperature.

**FLOW INDICATION**

With more stringent enforcement of air pollution statutes incinerator operation must be more closely controlled. To operate the incinerator at peak performance, the operator should have available indications of critical air flows. These include underfire airflow to each stoker zone, total underfire air flow, and total overfire air flow. Such air flows may be continuously indicated and/or recorded or may be selectively indicated by means of a pushbutton precision indicator.
SMOKE DENSITY

In order to guard against the violation of air pollution requirements, it is desirable if not essential that the operator be continually informed as to the condition of the gases entering the stack. Smoke density monitors are used to continually measure the amount of smoke in the gas stream. Fig. 8 illustrates one type of smoke density monitoring system. The light source is installed on one side of the duct with the photocell unit on the opposite side. Stability of mounting of the light source and photocell and a clear unobstructed path from source to cell are essential. Accessibility for service, ambient temperature and other factors must be considered in choosing the best location. Smoke and fly ash passing between the light source and the photocell reduce the light transmitted to the photocell thereby reducing its output. The output of a photocell unit is fed to an indicating monitor with high density alarm. The output of the smoke density monitoring system can be and should be continuously recorded as proof of compliance of air pollution requirements. A smoke density monitoring system should be installed if possible in the duct between the dust collectors and the induced draft fan. Since a negative pressure exists at this point the need for air purging is eliminated.

ALARMS

An annunciator panel should be installed to alarm and identify the following functions: 1) high temperature-charging hopper, 2) high temperature – lower drying stoker bearing, 3) low pressure underfire air duct, 4) low pressure overfire air duct, 5) high temperature furnace outlet, 6) high pressure furnace outlet, 7) high temperature spray chamber outlet, 8) high temperature dust collector inlet, 9) low water pressure, 10) high smoke density, 11) high temperature stack.

CASCADE CONTROL

The control systems as outlined heretofore have been indicated as separate independent control systems. However, the interrelationship of the variables being controlled is such as to make desirable control systems which are likewise interrelated and interconnected.

For example, if smoke density increases it is probable that there is an insufficient amount of overfire air to effect the complete combustion of the carbon particles in the gas stream. An override control system as shown in Fig. 9 enables the smoke density system to take over control of overfire air in the event of high smoke density. This system increases the overfire air flow thus increasing the amount of air available for the reduction of smoke particles.

Furnace temperature is dependent on a number of factors, including the nature of the refuse being burned, the amount of underfire air and the amount of overfire air. Since the nature of the refuse being burned cannot be controlled this leaves furnace temperature dependent on two controllable variables, overfire air and underfire air. In the past, furnace temperature has been controlled by varying the overfire air only. However, much closer temperature control can be obtained by controlling the amount of underfire air as well as the amount of overfire air. Fig. 10 illustrates a cascade type control system which can be used to accomplish this purpose. The control signal from the furnace temperature controller in ad-

![Fig. 8 Smoke Density Recording System](image)

![Fig. 9 Smoke Density Override Control](image)
dition to controlling the overfire air dampers is fed through ratio stations to the underfire air flow controller. As the overfire air flow is increased, the underfire air is decreased thus effecting more rapid control action. The ratio stations furnish the necessary adjustability so that the ratio of overfire to underfire air is kept within the proper limits. An added benefit of such a system is that the air flow through the furnace is kept more uniform thus making it easier to more closely control the furnace draft pressure.

**PANELS**

Panel configuration and location will depend on overall incinerator design and operating philosophy. However, there is a trend toward installing an operating panel at each furnace and a main panel at the plant superintendent’s office. In general, the operating panel will contain all of the instrumentation related to furnace operation while the main panel will contain all of the instrumentation related to air pollution control.

**OTHER INSTRUMENTATION**

Since efficient operation of an incinerator is affected by prevailing atmospheric conditions it may be desirable to indicate outside air temperature, barometric pressure, wind velocity and wind direction.

Since cooling water usage may be as high as 275 gallons per ton of refuse burned, it may be economically desirable to clarify and recirculate the cooling water. The instrumentation required for the water treatment facility will vary with the type and extent of treatment.

The proper design of any control system must include provisions for emergency conditions such as loss of electrical power, excessive temperatures, fan failure, etc. The necessary interlocks must be included for maximum protection of the capital investment as well as the operators.

Judgment should be used in the selection and design of instrumentation systems for incinerators. For example, there is little or no justification for recorders where recording charts serve no useful purpose. All elements of the system must be carefully selected, considering such factors as location, environment, ambient temperature extremes and accessibility for service.

Effective incinerator operation involves the control of several complex interrelated variables. The utilization of such modern techniques as ratio and cascade control along with judicious use of conventional control techniques makes possible more effective control of these interrelated variables and thus more effective operation of municipal incinerators.