

STEAMING RATE
7 PROBLEMS WITH HIGH TEMPERATURE INCINERATOR

GASES IN THE SUPERHEATER AREA

by

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Abstract

The advent of the modern, energy recovering, solid waste disposal facilities has brought with them new operational problems, which had to be corrected as their effects became apparent. Concern with corrosion in the superheater section has probably had a more deterring effect on the acceptance of modern power plants utilizing solid waste as a fuel than any other factor, until the difficulties encountered were alleviated. That the problems can be overcome has apparently not been recognized by many engineers.

This paper addresses itself specifically to advanced type mass burning stokers with integrally designed steam generators. The problems and causes of corrosion in the superheater section of modern incinerator boilers are analyzed and recommendations are made as how to minimize and possibly to eliminate altogether problems of the described nature, which are in many cases simple and not difficult to correct.

In view of occasional difficulties with superheater and boiler corrosion problems encountered in the past, most of which were not clearly understood, it is hoped that this paper will contribute to encourage new applications of energy recovery from solid waste. Research and development grants should be considered for optimum performance and reliability.

Introduction

Concern about the possibility of superheater corrosion has long been considered an obstacle to energy utilization from burning of solid waste. Many modern power plants of this type were installed during the past decade in Europe and considerable information is available on their performance as well as on their occasional corrosion problems. A symposium on "Corrosion in Refuse Incineration Plants," was held in Duesseldorf the 7th and 8th of April 1970. Further, the Battelle Memorial Institute of Columbus, Ohio has made a study under an EPA grant entitled, "Corrosion Studies in Municipal Incinerators." Much of this information has contributed to the recognition of the basic causes of corrosion in incinerator boilers.

Since then many superheater corrosion problems seem to have been overcome and other, recurring ones have been repaired, shielded and are in many cases considered to be part of the normal wear and tear of the plant operation and have frequently become a part of the annual or semi-annual repair and maintenance schedules and, as a result have become a part of the undesired downtime.

The true composition of the solid wastes, delivered to the incinerator consisting of household garbage, trash, plastics, worn-out tires or other industrial or commercial wastes is unpredictable and must be received "as is" for conversion into steam for energy or process utilization while the residual inert materials and ashes are recycled for recovery of valuable ferrous and non-ferrous metals.

To be realistic, the stoker, boiler and its components should be capable of handling any reasonable range of solid waste compositions, which should not cause any corrosion damage to the boiler or the superheater. With this in mind it will be useful to visualize what really takes place during the refuse feeding and combustion process that could result in damage to various parts of the energy recovery equipment and what might be done to overcome such problems.

Design Requirements for Optimum Combustion Performance

Solid waste incinerators designed for heat recovery in the form of superheated steam must be designed as an integrated system train from the feed chute to the stack connection.

Vital factors influencing optimum combustion performance consists essentially of the following parts:

- a. Refuse feeder
- b. Stoker
- c. Boiler furnace
- d. Superheater
- e. Economizer

Top performance can be anticipated when these five sections are especially designed and coordinated to meet the specified requirements.

Influence of Refuse Composition on Stoker Operation

Refuse as-received will be wet or dry. If it contains a high percentage of paper with a low moisture content it will ignite much sooner than wet refuse containing a high amount of grass clippings, which are not alone difficult to burn, but also may cause cascading over the grates, resulting in smothering of the main burning zone and causing rapid distillation of volatiles in the furnace. Such gases can be very corrosive.

a. Refuse Feeder--To overcome corrosive gas formation, the refuse feeder must be designed to prevent refuse from sliding. The refuse feedchute serves as a seal to prevent false air infiltration through the incoming refuse mass. The feeder mechanism must be a refuse metering device which must be positively responsive to a furnace temperature sensing device interlocked with the stoker actuating device. In this manner unpredictable furnace temperature variations are stabilized and will result in a uniform furnace burning rate and gas flow, assuring that the steam flow will follow the demand rate within a very close tolerance.

b. Stoker--The refuse metered to the stoker by the feeder ram in response to the furnace temperature controller must be fed in a thin layer for rapid ignition. The stoker must distribute and agitate the incoming refuse to the firing zone with the proper proportion of air at all points of the grate surface and with a minimum of dust carry-over into the gas stream. To achieve a thin fuel bed for proper air distribution the grate must be wide. A specific stoker design developed as a result of many years of experience has taught that grate front loadings for units with capacities in the order of 907 metric tons (1000 U.S. tons) per day or more, should not exceed 34.6 million KJ/hr per meter width (10 million BTU/hr per foot width), moisture loadings not to exceed 1190 kgs/hr per meter width (800 pounds/hr per foot width) and inert material and ash loading should be limited to 850 kgs/hr per meter width (1570 pounds/hr per foot width).

The figures indicated are not applicable to all stokers and may have to be revised downward in other cases depending on the effectiveness of the refuse distribution over the grate and the agitation achieved with a minimum of particulate carry-over by the process of combustion. For smaller units such input rates will be further restricted for optimum performance and for minimum corrosive effects on the superheater and boiler surfaces.

A good air distribution over the combustion zones is attained mainly by means of a high stoker grate bar resistance on the inlet side, to supply the air equally to the underside of matted materials, such as rugs, tires and paper masses. Such proportional air distribution further contributes effectively to the control of boiler tube corrosion. The stoker agitation should achieve continuous overturning of the refuse fed to cause uniform burning from the bottom up and not alone burning on the surface of the refuse bed. Drop-off ledges to cause agitation of the burning bed should be avoided, as they can cause a high percentage of dust to be released into the furnace gas stream, and may also result in undesirable slag build-up on the grate which, in turn, may restrict the proper air flow to the fuel.

The air distribution under the grate should consist of at least five compartments per section to provide the correct amount of combustion air for each zone of combustion. Each compartment with its separate plenum chamber damper, should be individually adjustable, as well as interlocked together, to permit proportional air adjustment depending on the seasonal heating value changes. Grate release rates should not exceed 3,974,600 KJ/hr

per square meter (350,000 BTU/hr per square foot). The rear or lower section of the grate should be utilized to permit final release of all smoldering combustible material before the discharge of inerts and ashes into the quench tank.

Over this rear grate section the rear watercooled arch should extend to guide the smoldering gases forward into the high temperature furnace section to assure complete burn-out of every fraction of non-aqueous combustibles.

c. Boiler Furnace--The boiler with welded waterwalls, effectively cooling the sidewalls down to the grate level, should be designed to match the firing equipment in every respect. At the grate level the tubes should be protected against abrasion from sharp metal parts, stones, etc. The furnace throat area in which the main combustion takes place should be designed for a low gas velocity not to exceed 3.66 meters (12 feet) per second. The proper dimensioning of the furnace and lay-out of its proportions is vitally important to achieve the best combustion performance. Overfire air nozzles are located at the front waterwall as well as at the rear furnace waterwall. Without overfire air, the flame volume expands and the gas travels straight up at a velocity of 3.66 meters (12 feet) per second. For a furnace 30.5 meters (100 feet) high the gas residence is therefore $8 \frac{1}{3}$ second and the flame would reach all the way up and beyond the furnace exit screen tubes. Any form of visible flame is not burned out and contains therefore corrosive fractions.

However, with the introduction of high intensity overfire air, downward directed at the front and horizontally directed from the rear furnace waterwall, a highly turbulent, rolling motion of the flame is achieved, which reduces the visible burning zone of the flame to well below one half of the furnace height. The gas travel pass, instead of rising straight up will now spiral its way up through the furnace thus effectively increasing the gas residence time in the primary furnace by 100 to 150%. In this manner the stratification of gases is greatly reduced, the CO formation is practically eliminated, and the primary furnace heat absorption is greatly improved. Even with such design precautions, the furnace height should be determined by limiting the heat input release not to exceed $372,570 \text{ KJ/m}^3$ ($10,000 \text{ BTU/ft}^3$) of primary furnace volume.

When limiting heat release rates to this extent, the particulate carry-over rate is still high enough to cause adherence of soft particles to the superheater tubes if these are placed directly in back of the upper furnace screen tubes. For this reason it is recommended to lead the furnace gases downward through an open pass and to cause a complete reversal of the gas stream at the bottom of the second pass whereby a high percentage of coarse fly-ash is dropped out into a large fly-ash hopper. A much cleaner gas mass enters now through the lower rear screen tubes into the superheater section. The gas stream carries not alone considerably less particulate matter at this point but the radiant heat absorption in the open pass has also decreased the gas temperature to a point where the particulate matter

has been cooled sufficiently below its ash softening temperature to minimize its adherence to the superheater tube surfaces, permitting longer annual operating periods between boiler shut-downs.

d. Superheater—Information on superheater performance and the causes of overheating, slag deposits and corrosion on its gas side have been studied at many installations and it may be concluded that superheaters perform best if conservative designs are applied with parallel flow instead of counterflow steam temperature rise in the last stage (high temperature) of superheating with intermediate desuperheating to assure a closely controlled superheater outlet temperature. Outlet temperature should be limited not to exceed 700°K (800°F) to avoid the use of exotic alloy steel tubes which are not alone very expensive, but must also be kept on hand at the plant as delivery schedules for such tubes may be excessively long and may cause prolonged shut-downs of a boiler.

Many superheater problems do not arise during normal operation but are easily caused during start-up periods. The following operational guidelines should be considered to minimize start-up corrosion problems:

1. Superheater is dry until boiler water reaches 373°K (212°F).

- a) Superheater tubes will reach gas temperature during this period which may cause tube deformation.
- b) Overheated tube surfaces will burn-off deposits and protective coatings.
- c) During initial start-up, until full furnace temperature is attained unburned volatiles containing CO, H₂O, HCl, SO₃ and other corrosive components will attack hot superheater metal surfaces.
- d) Uncooled superheater tubes are especially vulnerable to stratified gas streams during start-up period.
- e) Boiler waterwall tubes containing hot circulating boiler water are not subject to such corrosive attacks. [<533°K (500°F)]
- f) As soon as boiling takes place in the steam drum, sudden shock-like cooling of the superheater tubes takes place and causes severe stresses in tube support attachments.
- g) Even when using alloy steels for the superheater tubes, the problem is not solved but the tube life is only extended for a longer period between replacements, if the following precautions are not followed.

2. Recommendations for protection of superheater tubes during start-up period.

Superheater tubes in incinerator boilers may be considered more vulnerable to corrosion than any other boiler section, especially if they are subject to frequent start-ups. The use of non-drainable superheaters should be avoided since venting during the warm-up period may cause difficulties due to entrapped water in some tube loops. In contrast a horizontal superheater is easily drained and vented and steam can be bled off as soon as the boiler water reaches the boiling point.

Due to the much slower heating-up of refuse fired boilers the superheater tubes are subjected to a much longer exposure to the rising furnace gas temperatures which represents a critical period for possible corrosive attack.

In plants, where multiple incinerators are installed, saturated steam may be drawn from a operating boiler to keep the superheater tubes cool and free from stresses during the start-up period. Once the boiler under start-up has begun to generate its own steam, the superheater section should be vented continuously until the boiler is put into service.

It is also important to keep a close watch on the stack temperature as gas temperatures below the dewpoint [$<450^{\circ}\text{K}$ (350°F)] may cause corrosion. Utilization of start-up or auxiliary burners will assist in heating up the boiler much more rapidly thus reducing the period of exposure of possible superheater tube corrosion and consequently prolonging their life expectancy.

3. Effects of combustion in the furnace on superheater tubes during normal operation.

- a) The life of the superheater tubes is endangered not only during the start-up period until full steam flow through the tubes has been established, but the damage can also occur during continuous operation resulting from poor combustion conditions, excessively deep refuse beds, lack of proper undergrate air distribution and insufficient over-fire air penetration through the burning zones.
- b) The furnace gas temperature must be reduced by radiant absorption in the primary and secondary furnaces to a point below 1033°K (1400°F), before entering the superheater to prevent heavy fly-ash slag deposits which can be removed only by means of power tools during semi-annual shut-down periods. A multipass boiler design has proven to alleviate this problem to a minimum.

c) Assure uniform refuse feed rate and distribution to stoker to obtain a thin fuel bed that will ignite and burn rapidly and continuously under controlled furnace temperature conditions. Pile up of solid waste displaces the fire and causes distillation of volatiles which, if not quickly ignited, will cause severe corrosion. CO formation is the best indicator of incomplete combustion. Where CO can be measured corrosion is apt to occur. To overcome incomplete combustion three preventive design steps must be taken:

aa) All smoldering gases from the nearly completed combustion in the area at the rear end of the stoker must be reheated and ignited in the high temperature combustion zone for final burn-out to reduce to a minimum the occurrence of traces of non-aqueous condensibles.

bb) The violently burning solid waste mass at the front end of the stoker must receive intensive and highly penetrating, turbulent, and over-fire air jet streams, preheated for rapid completion of combustion, thus eliminating the presence of any CO or other harmful corrosive constituents in the main gas stream.

cc) As the furnace is operated under a slight negative pressure infiltration of air other than that supplied by the forced draft fan, must be eliminated. Air leakage at the feed chute section can cause heavy slag formation, while false air entry at the point of residue discharge can cause wide fluctuations in the stack gas composition and its CO₂ content thus resulting in combustion instability and reduced overall efficiency.

The intensity and distribution of the overfire air as previously described will greatly reduce the harmful constituents in the gas stream, reduce the fly-ash carry-over and greatly prolong the life of the superheater and boiler tubes assuring long "on-stream" availability of the steam generating incinerator during the full annual season.

Sootblowers can also be a source of trouble both in the superheater and boiler sections. Excessive sootblowing has a sandblasting effect on directly exposed tubes and may penetrate through the protective oxide

coating on the tubes thus imperiling the bare metal by corrosive attack and severe pitting. For this reason alloy shields or welded studs covered with silicon carbide should be applied to the tubes at points in close proximity to the sootblower blast.

Uneven distribution caused by low gas velocities over the tube sections will result in unbalanced heating of the tubes and may cause stress corrosion primarily at tube bends.

e. Economizer--Probably the least troublesome section of the steam generator is the economizer which should receive at all times preheated feedwater at 394°K (250°F) from the deaerating feedwater heater. This temperature effectively prevents deposits of condensation on the gas side of the tubes. Ash deposits in this area are generally soft and easily blown off. Stationary rotary sootblowers in this section do not impinge directly on the tubes and therefore do not require special shielding.

Precautions must be taken to maintain a minimum boiler and economizer water temperature during boiler outages to avoid moisture accumulation in the fly ash deposits on the tubes which may cause heavy corrosion. A heated boiler will also keep the superheater tubes dry.

Research and Development

Much work has already been done in the field of solid waste fired steam generators to obtain the reliability and availability of modern fossil fuel fired steam generators.

At the present time 4.2 MPa (600 psi) steam pressure and 700°K (800°F) is achievable without difficulty for continuous operation of solid waste burning incinerators. Research and development work should be directed toward still further improvement of the combustion intensity and elimination of corrosive and otherwise harmful constituents of the gas stream.

Gas analysis itself will not tell the story. The research work necessary should determine, directly at all points in the furnace, where corrosive attacks take place. The simplest and most effective way to test for corrosion is to prepare a superheater lance which can be inserted and mounted systematically in a pre-determined pattern throughout the furnace area. Saturated steam can be bled through this lance and regulated to the desired superheat temperature. In this manner dangerous zones in the furnace, where corrosive gases exist, can be spotted and their elimination can be achieved by either improving the air supply for more thorough combustion or to increase the rate of the furnace turbulence.

Much research work needs also to be done with the refuse feeding method. Where most presently operating incinerators attempt to demonstrate a continuous feeding method, a quantitative metering operation is rarely accomplished and causes in most instances masses of solid waste to be dropped

on an existing intensely burning fuel bed. The end effect is vaporization of volatiles under pyrolysis conditions causing a wide range of very corrosive gases to be distilled off before reaching their individual ignition temperatures. Some of these gases escape from the furnace without igniting and show up later at the boiler outlet as non-aqueous condensibles. Such uncontrolled burning results naturally in a widely fluctuating steam generating rate which is difficult to match a required demand rate by a steam customer. The heterogeneous nature of the solid waste fuel cannot achieve control of the burning rate unless the wide variation of the heating value is monitored to regulate the fuel feed rate. This, in turn, can only be accomplished by sensing the furnace temperature to be measured continuously. The impulse of the slightest temperature difference is then translated into a feeder control mode thus effectively limiting the steam flow rate to well within $\pm 5\%$. Further research in this area could possibly accomplish additional improvement of the capability and flexibility of solid waste burning incinerators to follow the steam demand rate at a yet much closer tolerance.

Pilot plant models have proven that scale-up to full size units can be very deceptive and may result in disastrous experiences. Research and testing should be done under controlled conditions in existing plants if optimum performance is to be accomplished.

Conclusion

Ample performance records from many European, Asian and American plants in continuous operation, prove that the superheater problems can be controlled by proper start-up and operational procedures. However, poor supervision and maintenance can be detrimental to the life of the equipment. Even the best equipment selected can deteriorate rapidly under inadequate management.

Instrumentation and its proper maintenance is vitally important and must be observed, checked and rechecked daily for best performance. The record of the furnace and stack gas composition will be a good indicator to prevent corrosion in the superheater section of the boiler. Vigorous observation of all instruments and regular inspection of boiler sections will ensure a greater performance availability of the steam generating equipment.

The heterogeneous nature of solid waste is hardly changed by front-end separation of a small percentage of ferrous and non-ferrous metals, the inert contents of the solid waste remain practically the same and so do the moisture and combustible contents. Back-end separation achieves practically the same resource recovery in a putrescible-free manner at only a fraction of the energy required.

The all important goal is still unchanged--to dispose of the solid waste and to generate revenue producing energy and saleable by-products with a minimum of energy expended and a maximum of reliability achieved.