WIDER SERVICE RANGE FOR A LIQUID WASTE INCINERATOR WITH A STAINLESS STEEL CONSTRUCTED WATER QUENCH

Roger Malone, P.E.
Dr. Wei Wang
Union Carbide Corporation

Paul Kuten, P.E.
Fluor Daniel, Inc.
Houston, Texas

Ron Desai, P.E.
Roop Bhan, P.E.
Callidus Technologies Inc.
Tulsa, Oklahoma

Pat Thomasson
Technical Consultant

ABSTRACT

This paper describes the unique design features incorporated in a miscellaneous liquid waste streams incinerator with a 304L stainless steel constructed water quench to accommodate the presence of organic chlorides in one of the waste streams and coke fines in another. This incinerator is expected to operate successfully and meet all emission limits and thermal performance requirements. This project demonstrated how an operating company, an equipment supplier and an engineering company can work together to identify problems and develop solutions that satisfy both operational and financial objectives.

Major issues of interest to industry are as follows:

1. Flue gas HCl and recirculating liquid chloride concentrations controlled in the downstream quench/scrubber system to ensure reasonable service life for the 304L stainless steel constructed quench system, venturi scrubber/separator, piping, crossover ducts, and pumps.

2. A downfired burner designed to provide cyclonic action, enabling the incineration of an organic waste liquid slurry containing coke fines.

INTRODUCTION

The miscellaneous waste streams incinerator is designed to handle two major continuous waste streams with their individual feed systems and spray guns, and six minor intermittent waste streams using a common feed system and a common spray gun. Some of the waste streams contain enough inorganic solids to necessitate the use of a venturi scrubber downstream for particulate matter removal. The purpose of this discussion is to describe an alternative to the use of exotic alloys or fiberglass reinforced plastic (FRP) for the wet section of an incineration system burning wastes containing inorganic salts and/or chlorinated hydrocarbons. Also described are design features incorporated to incinerate a liquid waste stream with solid coke particles as an alternative to hauling the waste away for disposal by others or installing a separate solid waste incineration system.

SUMMARY OF WASTE STREAMS

The two major continuous waste streams and the six minor intermittent waste streams are described below:

<u>Continuous Streams</u>

Description	Slop Oil	Residue
C4+	11%	30%
Aromatics	80%	63%
Coke Fines	2-9%	None
Inorganics	None	7%
Total	100%	100%

Description	Slop Oil	Residue
LHV (Kcal/Kg)	9,800	10,000
Viscosity (cp @ 38°C)	20	2
Sp. Gr.	0.96	.88

Intermittent Streams

There are six small intermittent streams being fed to the incinerator, one at a time. These streams variously contain C10+ paraffins, mineral oil, aromatics or water. One of the streams contains up to 3 wt% of organic chlorides and up to 2 wt% of inorganic solids while the waste oil and aqueous streams contain up to 5 wt% of inorganic solids. The lower heating value (LHV) is approximately 10,000 kcal/kg for all of these streams except for the aqueous stream, which has practically none.

PROCESS DESCRIPTION

As stated earlier, eight different liquid wastes can be destroyed in this incinerator; however, only two streams will be fired continuously. Among the six intermittent streams, only one will be fired at any given time. Thus, the burner is designed to fire three liquid waste streams simultaneously. Provision is also made to inject an aqueous waste stream directly into the thermal oxidizer.

All streams fired through the burner are exothermic in nature at the operating temperature. One of these streams, containing coke particles and contributing the largest heat release, is fired through the center of the flame holder cone. The other two streams are fired through guns offset from the center gun by a few inches. All streams are steam atomized. The fuel gas is fired through multiple tips located on the inside periphery of the burner tile.

A combustion chamber operating temperature of 2200°F with a residence time of about 4 seconds was chosen. In addition, the downfired configuration was selected to minimize the accumulation of solid particles in the oxidizer vessel.

Some fuel gas will be burnt at all times to maintain a constant flame in the burner and to stabilize burner operation. Even at the higher operating temperature, the system is still exothermic in that the heat released by the wastes and the fuel is enough to reach an adiabatic flame temperature above 2200°F. This necessitates quenching the flue gas to a temperature of 2200°F by injecting quench air into the thermal oxidizer. The use of air for quenching assures a high concentration of oxygen in the thermal oxidizer. This is expected to improve the burnout rate of coke fines.

The quench air is introduced with a swirling motion, with the same spin direction as that of combustion air in the burner. The combined swirling motion serves two purposes. It helps keep coke and other particulate matter from collecting on the oxidizer refractory and, more importantly, it keeps coke fines in turbulent suspension, improving the burnout rate. Should future field tests confirm that high burnout rates are being achieved, the temperature of the combustion chamber could be reduced to as low as 1800°F, thereby prolonging the life of the refractory lining.

Flue gases leaving the thermal oxidizer flow into a quench system located directly below the thermal oxidizer (Figure 1). This system consists of a water weir, a spray contactor and a quench tank. The flue gases flow through the contactor, where twelve spray guns, using mechanical atomization, spray finely atomized water into the flue gases. The amount of water sprayed in is nearly four times that needed to saturate the flue gases. The water weir, located above the contactor, maintains a constant film of liquid over the brick in the contactor, protecting the contactor vessel from the hot flue gases.

Saturated flue gases exiting the contactor flow into the quench tank through a downcomer. The mouth of the downcomer is kept very close to the liquid level, as this helps the flue gases approach their saturation temperature. The quench tank is designed for a very low vapor velocity to help disengage any entrained liquid from the saturated flue gases. Blowdown from the quench system is dictated by the waste streams being fired. If wastes containing chlorinated hydrocarbons are being burned, the blowdown is increased to limit chloride concentration in the quench recirculating liquid. The flue gases next go through a crossover duct to a vertical venturi scrubber.

The venturi scrubber is designed for a pressure drop of nearly 60 inches water column. A set of recirculating pumps provides the scrubbing solution, which is fed to the venturi through several nozzles. Make-up water for the whole system is fed into the venturi recirculating stream. This cools and dilutes the liquid stream going to the venturi and is designed to improve removal efficiency of HCl and particulate matter. A caustic soda solution is injected to help neutralize the HCl in the flue gas. Blowdown from the venturi recirculation system goes to the quench system as make-up liquid. Entrained water droplets in the flue gas exiting the venturi scrubber are removed downstream in a chevron type demister. The demister is located in a separator vessel, designed for a relatively low velocity to help disengage the droplets from the gas stream. The clean flue gases are discharged to the atmosphere by a vent stack located on top of the separator vessel. Figure 1 is a simplified flow diagram showing the flow configuration.

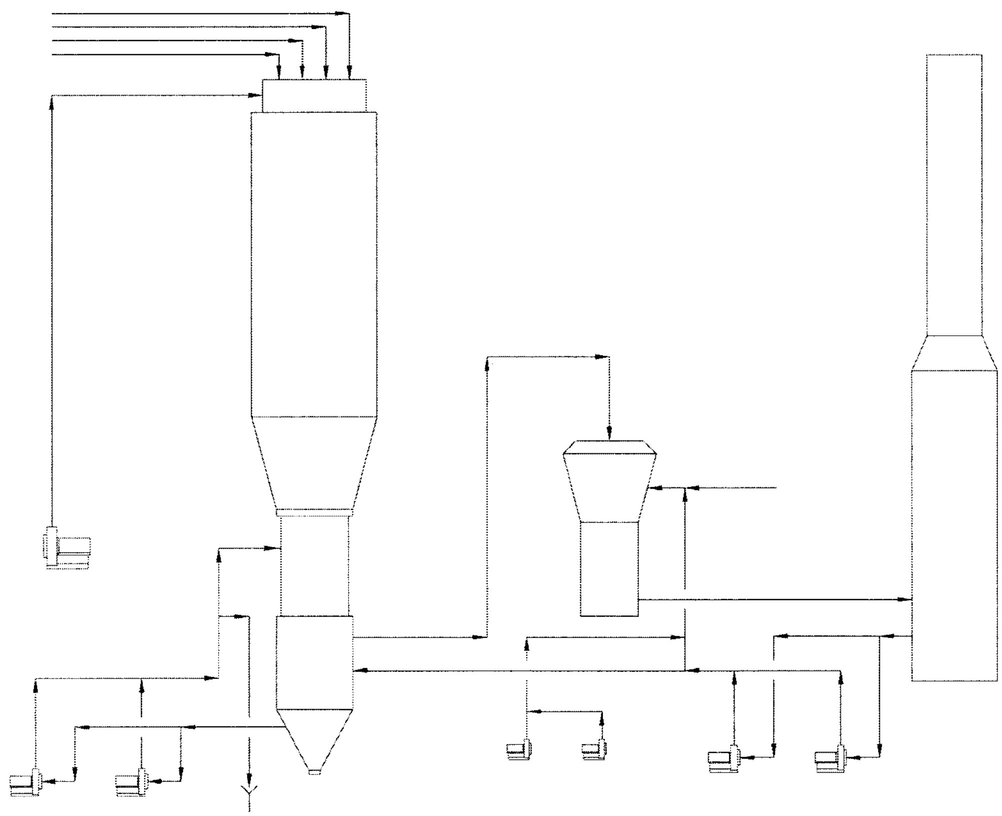

Figure 1. Simplified Flow Diagram

EQUIPMENT DESCRIPTION

In the burner, the liquid waste streams are steam atomized, with the atomization taking place externally to minimize plugging problems associated with internally atomizing spray guns firing solid bearing wastes. Except for the liquid waste spray gun nozzles and fuel gas tips, which are all higher alloy, the material of construction for the burner, including the combustion air plenum, is carbon steel. The burner throat is lined with a high alumina castable tile. Adjustable spin vanes are provided in the air plenum to give a cyclonic motion to the incoming combustion air. The intensity of spin imparted can be adjusted up or down by moving an external lever.

The thermal oxidizer is carbon steel fabricated with the cylindrical portion lined with a 90 percent alumina firebrick designed to better withstand an operating temperature of 2200°F. The firebrick is backed with a layer of insulating castable. The top and bottom cones of the oxidizer vessel are lined with a high alumina, phosphate-bonded plastic refractory backed with an insulating board. The selected refractory, in addition to its ability to withstand higher temperature, is expected to limit the potential for abrasion caused by the movement of particulate matter in the swirling air.

The oxidizer is vertical with the burner firing downwards through the top. The bottom of the oxidizer opens into the quench system located directly below. An external stairway structure is provided to facilitate access to various points, including the burner at the top.

The quench system consists of a water weir, spray contactor and a quench tank. The water weir is stainless steel fabricated and maintains a constant liquid flow along the entire circumference of the insulating bricks contained in the spray contactor below. The contactor has twelve spray gun assemblies using mechanical atomization. The brick inside the contactor, saturated by the liquid flowing down from the weir above, helps protect the contactor vessel from the hot flue gases. The quench tank, with the downcomer, is located below the contactor. All are fabricated from 304L stainless steel. The quench tank has a conical bottom to collect any solid materials dropping from the thermal oxidizer above. Liquid for the quench recirculating pumps is drawn from a point above the conical portion to prevent the flow of solid

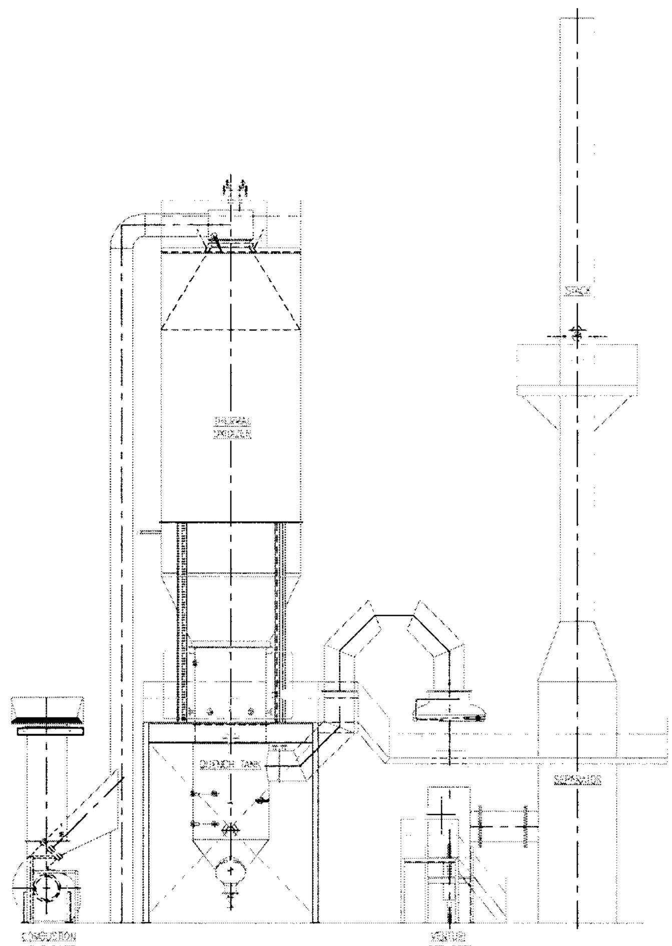

Figure 2. Equipment Layout

material to the pumps. A baffle/weir arrangement on the inside of the quench tank is provided to aid in the occasional removal of any floating, unburned material.

The crossover duct connecting the quench tank with the venturi scrubber is stainless steel fabricated, as is the venturi scrubber. Both the venturi recirculating pumps and the quench recirculating pumps with their associated piping are also 304L stainless steel fabricated.

The separator vessel downstream of the venturi scrubber includes a chevron type demister, designed to remove liquid droplets from the flue gas stream. The demister is provided with an elaborate wash system consisting of nine spray nozzles spraying upwards. This is expected to eliminate any salt build-up on the baffles. The vent stack is mounted on top of the separator and extends to a height of 75 feet. This height provides adequate distance above the burner service platform located on top of the downfired thermal oxidizer. Figure 2 is a simplified sketch showing the overall layout.

ALTERNATIVES TO STAINLESS STEEL QUENCH

Waste stream specification shows that one of the intermittent waste streams can have an organic chloride content of up to 3 wt%, which will be converted to HCl gas during the combustion process. The HCl gas eventually reacts with caustic soda forming salt (NaCl). At this chloride content, the austenitic stainless steel components in contact with the liquid can fail due to chloride stress corrosion cracking. From an engineering standpoint, FRP is the safest (and therefore the most frequently used) material of construction for the equipment in the wet section, namely, the contactor, quench tank, crossover duct and scrubber, and the stack. However, from the standpoint of operation, the FRP constructed components can suffer catastrophic failure due to a temperature excursion and can cause a long term shutdown of the incinerator. This was a matter of concern to the operating company since the incinerator is installed overseas. They were not comfortable with the idea of replacing FRP equipment thousands of miles away should a meltdown occur. Stainless steel, despite its flaws, was a preferred alternative because it would not experience a catastrophic failure and most damage would be readily repairable, at least in the short term.

Alternatively, one could have used a dry particulate removal device (ESP or a baghouse) operated at a flue gas temperature higher than the dew point of HCl, followed by a scrubber for the removal of HCl. From an operation standpoint, this system is more complex, therefore more difficult to operate; and with a baghouse or an ESP, there is again the risk of a long term shutdown due to a major failure. The design approach selected for this project struck the right balance between the need to keep the incinerator online by maintaining vessel integrity and the need to limit system complexity. Process conditions are created and controlled not to totally eliminate degradation but to reduce the rate of degradation, thereby increasing the service life of the stainless steel components.

CORROSION PROTECTION

HCl produced by burning one of the liquid waste streams is removed in the spray contactor section of the quench system by the caustic soda present in the recirculating liquid stream. Because the HCl removal efficiency in the quench section is not known, components in contact with the flue gas (which is saturated) are externally equipped with provisions for future installation of insulation and heat tracing materials. This is expected to reduce condensation and resulting corrosion. Since most of the HCl in the flue gas exiting the quench section is removed in the venturi scrubber, steel construction of equipment downstream of the scrubber would be adequate although stainless steel was used for this project.

CHLORIDE STRESS CORROSION CRACKING

As HCl is removed from the flue gases, the concentration of chlorides in the recirculating liquid increases. Higher concentration of chlorides, coupled with a liquid temperature of nearly 200°F, subjects stainless steel components to failure due to chloride stress corrosion cracking. It is not practical to create the conditions (such as removal of oxygen from the liquid or cooling the liquid to 140 C) that would eliminate chloride stress corrosion cracking; however, time to repair can be increased by controlling the chloride concentration in the recirculating liquid. This is accomplished by adjusting the blowdown rate.

For example, reducing the concentration of the chlorides in the liquid from 10,000 ppm to 1000 ppm (with the pH between 8.5 and 9.5) reduces the rate of chloride stress corrosion cracking enough to increase time to failure from 10,000 hours to well over 100,000 hours. (According to J. F. Lancaster's publication titled, "What Causes Equipment to Fail", Hydrocarbon Processing, January 1975).

FIRING OF COKE FINES

One of the continuous waste streams being incinerated is a slurry of liquid sludge with up to 9% by weight of coke fines, with a size distribution as follows: 50% of the particles between 10 and 20 microns, 35% between 20 and 50 microns, and 15% between 50 and 100 microns. The presence of coke presents a special problem in that coke has a relatively high heat content but no volatiles, making it more difficult to ignite. Unburned coke particles may create other difficulties, such as accumulation of slag on the walls of the incinerator, plugging in the quench spray system, and an increase in the CO and particulate emissions. Although there are different alternative ways of solids disposal by incineration, a dedicated solid waste incinerator was not a viable option due to the additional cost and complexity. Instead, the design team accepted the challenge of designing an up-graded liquid waste incinerator capable of handling the solid content in the waste stream.

TIME, TEMPERATURE AND TURBULENCE

The main features of a well designed combustion chamber are sufficient time, temperature, and turbulence in the presence of adequate oxygen content to achieve the targeted destruction efficiency of the materials being burned. For the coke particles, predicted burnout rates indicate that complete burnout of 100 micron coke particles requires approximately 3 seconds at 2400°F, 4 seconds at 2200°F, 5 seconds at 2000°F, and 6 seconds at 1800°F. A combustion temperature of 2200 F with a residence time of 4.0 seconds was chosen for this application. As stated earlier, the burner is provided with spin vanes to create turbulence to promote better mixing. The quench air is also introduced with a swirling motion to create more turbulence through the thermal oxidizer. Turbulence promotes mixing, which in turn enhances the process of combustion.

CONCLUSIONS

The two features that make this incinerator somewhat unique are that it is designed to burn coke fines contained in one of the liquid wastes and its quench system is stainless steel fabricated, even though one of the waste streams contains chlorinated hydrocarbons, which will produce HCl gas during the combustion process. The success of this unit will be measured by the following two criteria: a) the extent to which it is able to destroy the coke fines; and b) its ability to stay on-stream before any repair of the stainless steel components is necessitated by HCl or chloride corrosion. As with any other incinerator system, it will also need to meet the generally accepted emission standards for such incinerator systems.