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Collection and Incineration of High Volume-Low Concentration Pulp Mill Noncondensible Gases

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Abstract

High Volume-Low Concentration gases are collected at the Packaging Corporation of America (PCA) mill at Valdosta, Georgia. After collection and cooling, pulp mill HVLC gases are incinerated in one of two existing waste wood boilers which required no significant modifications in either equipment or operation. Successful collection of HVLC gases is dependent on having reasonable estimations of temperature and flow rates, evaluation of the streams for possible contaminants, and control of condensates generated during transport. Successful incineration of HVLC gases is dependent on judicious selection of incineration locations that can handle large volumes of HVLC gas on a continuous basis. Finally, safety must be given the highest priority in the design and operation of HVLC collection and incineration systems.

Introduction

During the past several years, many pulp mills have installed systems for the collection, treatment, and disposal of noncondensible gases (NCG) generated during the pulping process. Most recently, these systems have included provisions for the collection and disposal of High Volume–Low Concentration (HVLC) gases. The PCA mill in Valdosta, Georgia installed an HVLC collection and incineration system as a part of a larger project involving the addition of a new pulp washing line. The system was later modified to include a dedicated incinerator for incineration of these gases, together with other pulp mill noncondensible gases.

As the environmental climate continues to change, HVLC collection and incineration will continue to receive more attention. The collection of dilute gases requires specialized consideration, necessitating careful attention during all phases of the project. Through sound design, the safe and efficient collection of HVLC gases can be accomplished.

General Design Criteria for High Volume-Low Concentration NCG Systems

Pulp mill NCG sources can be broken down into three (3) categories. The first category is the LVHC gases; examples of typical sources are shown in Table I. The second category is the HVLC gases, examples of which can also be found in Table I. The third category is overhead vapors from a steam stripping system for foul condensate. These vapors are a mixture of methanol, water, and TRS gases.

Table I – Typical NCG System Sources

LVHC GAS SOURCES	HVLC GAS SOURCES
Turpentine Recovery Vent	Black Liquor Oxidation Vent
Blow Heat Recovery Vent	Soap Skimming Tanks
Evaporator Hotwell Vents	Black Liquor Storage Tanks
Foul Condensate Storage Tanks	Brown Stock Washer Filtrate Tanks
Continuous Digester Relief	Brown Stock Washer Hoods
	Knotter (Screen) Hoods
	Chip Bins
	Contaminated Condensate Tanks
	Air Stripping Equipment

The historical emphasis has been on the collection of the first and third categories of sources. Only new mills and major mill expansions have been required to include the collection of HVLC sources. However, new regulations will soon require all mills to include collection of HVLC sources as a part of their mill-wide NCG collection and disposal system.

Characteristics of High Volume–Low Concentration Gases

The pulp mill gas streams that are collected into the HVLC NCG system produce a gas stream that is predominantly air, but includes small amounts of compounds known collectively as Total Reduced Sulfur (TRS) and Volatile Organic Compounds (VOC). TRS compounds include hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide. VOC includes methanol, acetone, and turpentine.

The first and most important characteristic of HVLC gases is that the concentration of components in these streams falls well below the lower explosion limits (LEL). Still, the TRS compounds present are noxious and have a very low threshold of odor detectability, resulting in the need for their collection and disposal.

The second characteristic of HVLC gases is the high gas volumes associated with these sources. The total volume of the combined HVLC sources, often in the range of 15,000-20,000 m^3/hr and potentially much higher, requires that the gas treatment methods and the disposal methods be given careful consideration.

Collection of High Volume–Low Concentration Gases

For new pulp mills, the need for collection of HVLC gases from sources must be considered in initial design of the collection points. Storage tanks can be designed to be completely sealed from the atmosphere to minimize the volume of HVLC gases by not allowing excess air to be pulled into the tank by the gas fan. Source collection points should be designed to withstand slight vacuum conditions of up to 3 kPa gage.

Retrofits to existing systems can sometimes be difficult because source equipment was not originally designed to withstand vacuum conditions. In some cases it is possible to avoid modifying or replacing existing equipment by using a sweeping action to remove the HVLC gases from the equipment. This requires a second equipment vent, open to atmosphere, through which some air is drawn into the equipment. If the atmospheric and HVLC vents are properly located, HVLC gases can be effectively purged from the equipment without releasing any gas to the atmosphere. This does result in additional overall capacity required for the HVLC system due to the additional air added and should be used only if absolutely necessary.

In either case, new or existing sources, it is critical to have reasonable estimates of the expected flow and temperature of each HVLC NCG source. Failure to properly analyze the amount of gases that will be present can result in an expensive, oversized system, or worse, a system which is undersized and not capable of collecting all of the gases which are being generated from the various sources.

Treatment of High Volume–Low Concentration Gases

Treatment of noncondensible gases typically takes one of three forms. The first is scrubbing with white liquor or caustic to remove soluble TRS compounds. The second is removal of entrained fiber or foam using direct contact scrubbers, mechanical foam breakers or cyclone separators. Third is the use of indirect contact coolers which remove excess water vapor and other condensable from the gases and reduce the volume of gases to be handled downstream.

HVLC systems typically do not employ white liquor scrubbers. Since there is a relatively small amount of TRS compounds present in the gases, the benefit of removing these compounds does not justify the cost of providing a large scrubber. More commonly, direct contact scrubbers are used as fiber removal devices. Because of the possibility of foam carryover, HVLC sources should utilize either mechanical foambreakers or cyclone separators to prevent foam from entering the HVLC system.

The use of indirect contact coolers is quite common in HVLC systems. Many of the sources of HVLC gas listed in Table I will have normal temperatures in the range of 80-90° C. At these temperatures, the HVLC gases carry a significant amount of water vapor and have a large specific volume. For example, reducing the temperature of a typical HVLC gas stream from 90 °C to 50° C will remove 94% of the water vapor present and reduce the gas volume by 68%. This will result in less dead load from water vapor at the incineration point and will quite possibly reduce the size of piping and equipment downstream of the cooler, resulting in significant cost savings.

Motivation of High Volume–Low Concentration Gases

HVLC gases can be transported through the system using either steam ejectors or fans. Steam ejectors are preferred because there is little potential for generating a spark which in turn could ignite the HVLC gas. However, the typical high gas volume of an HVLC system precludes the use of a steam ejector, so fans are typically used. Care must be taken in the selection and installation of the fan in order to minimize the risk of an explosion should unusual conditions cause the LEL to be exceeded.

Incineration of High Volume–Low Concentration Gases

The three typical locations for NCG incineration include lime kilns, power or waste wood boilers, and dedicated incinerators. The high gas volumes in the HVLC system make it difficult to use the lime kiln as an incineration point. This is because the volume of gases to be incinerated is often a significant portion – possibly even a majority – of the total air requirements to the kiln. Using the lime kiln as an HVLC incineration point greatly reduces the flexibility of the kiln for its primary purpose.

Power boilers or waste wood boilers can easily handle large HVLC gas volumes and deserve consideration as prime candidates for points of HVLC incineration. To assist in maintaining good combustion efficiencies with these boilers, a steam coil air heater can be used on the HVLC gases prior to their introduction into the boiler. This also reduces the potential for corrosion in the carbon steel entry ducts.

However, when using a boiler as an incineration point, the presence of TRS compounds in the HVLC gases can have two negative effects. The first is the possible long term corrosion effects from the sulfur. The second is that the sulfur added from the HVLC gas stream will leave the boiler as SO2 in the stack gases. This may result in having to add new SO2 removal and/or analysis equipment to a boiler where none was previously required.

Increased emphasis on mill-wide air pollution controls will make dedicated incinerators increasingly more important in the coming years. An incinerator can be designed specifically to meet the needs of the HVLC gases. Further, the inclusion of HVLC gases in an incinerator which is also used to destroy LVHC and stripper overhead gases will complement the overall performance of the system. The high volume of low fuel content HVLC gas serves as combustion and cooling air for the other NCG streams. Conversely, the high heat value of the LVHC and stripper overhead streams greatly reduces the amount of fuel which would otherwise be required to incinerate HVLC gases alone.

The main disadvantages of choosing an incinerator as an incineration point are its requirements for significant initial capital expenditure and its continuing operating costs. The operating costs with respect to fuel can be greatly reduced if a high quality stripper overhead gas stream is available for use as a supplemental fuel.

Safety in the High Volume–Low Concentration System

The HVLC gases described earlier contain TRS compounds which can be hazardous to life and/or property, even at the low concentration present. A properly designed HVLC system will include the following features to address these safety concerns.

1. Mixing of different types of gas streams is not advised. The HVLC gases could dilute the LVHC gases into the explosive range where they become more dangerous to handle. Mixing of either HVLC or LVHC gases with stripper overhead gases may condense stripper overheads and can cause two-phase flows in piping and low NCG velocities.
2. Piping velocities should be maintained to ensure that gases are moving above the flame propagation speed of the TRS components. Typically these velocities should be several times the flame propagation speed of the gases. It is possible to design an NCG system with piping velocities above the flame propagation speed of TRS compounds, but not above the flame propagation speed of turpentine. Every effort must therefore be made to prevent any accumulation of condensate and/or turpentine throughout the system.
3. Piping systems must be further designed so that condensate is not allowed to collect in the piping. If allowed to collect in the piping, two problems can occur; 1) flow can be stopped due to a condensate "plug" and/or 2) turpentine can collect on the surfaces of any accumulated condensate. All piping low points, even small piping connections at the bottom of a pipe, must be drained into a sealed condensate collection tank.
4. Flame arresting devices should be installed at each incineration point. Care should be taken to choose and install flame arresters so that condensate cannot collect within the flame arrester. Also, flame arresters should be designed with large air passages which minimize pluggage and restriction to flow.
5. Pressure relief devices are also important at the individual sources and near the incineration points. High pressure means that either a restriction has occurred in the piping or combustion is occurring. Due to the hazards associated with high pressure, the system must be designed to recognize and react to the high pressure by venting the gases and alerting the operations personnel that venting has occurred because of high pressure. Pressure switches can be effectively used to monitor pressure within HVLC systems and are used with pressure relief safety devices like rupture discs.
6. Entrainment separation equipment is important to prevent entrained particles from blocking flame scanning equipment within the incineration locations. They can also be excellent locations for a low point drain within the piping. Entrainment separators minimize erosion damage, particularly when installed on the suction side of the HVLC system motive fan.
7. Local vent stations, either manual or automatic, should be provided to allow for proper operational flexibility as well as proper isolation for maintenance.

8. The use of a properly designed system of interlocks, "permissives", and control logic can prevent damage to the system and greatly reduce the potential for significant (and/or catastrophic) accidents. Safety features provided by the interlock system include:
   - The "fail safe" position of the system should vent the HVLC gases to the atmosphere. The failure position of control valves and other instruments should allow the HVLC gases to vent to the atmosphere if electrical control power or instrument air is lost, or if the system interlocks are activated.
   - Loss of flame as indicated by flame detection equipment will cause the system to vent to atmosphere. When a boiler is used as the incineration point, a minimum steam output is required to maintain HVLC gas incineration.
   - If a steam ejector is used as the motive force, then either low steam flow or low steam pressure will cause the HVLC gases to vent. If a fan is used, the fan speed should be monitored and HVLC gases should trip at the first signs of fan failure.
   - Low HVLC flow at the incineration point will cause the collected gases to vent.
   - High temperature in a collection line approaching the incineration point indicates a possible burnback and will cause the HVLC gases to vent to atmosphere.
   - High pressure at any source or near incineration points will cause the HVLC gases to vent. The causes of high pressure, such as line blockage or combustion, are important enough that redundant methods should be employed to ensure that the high pressure is relieved.

The Packaging Corporation of America HVLC System in Valdosta, Georgia

The HVLC system in Valdosta, Georgia was originally started up in April 1991. The system collects gases from seven sources. Six of these are new sources associated with a new pulp washing line. The seventh source is an existing batch digester evacuation system. Figure 1 is a flow diagram of the HVLC collection system as originally installed, including the incineration portion of the system. The pulp washer project also included the addition of new batch digester capacity. Therefore, it was necessary to install a new LVHC NCG system for the collection of the gases generated during the digester blows in addition to the new HVLC NCG system. A blow heat recovery system was also added to condense and utilize the heat released during the digester blows and to concentrate the NCG into a form which can be easily handled. The new HVLC NCG, LVHC NCG, and Blow Heat Recovery systems were all designed, supplied, and installed by A. H. Lundberg Associates, Inc. under a turnkey contract.

System Overview

It was initially determined that fiber carryover would not be a problem from any of these sources, so no direct contact scrubber was provided. Two sources were deemed likely to contain foam carryover, so mechanical foambreakers were added on these tank vents. The combined HVLC sources had a design temperature of 82° C. A cooler was installed to reduce the HVLC gas temperature to 49° C. This temperature reduction decreased the amount of water vapor in the gas by 87% and reduced the volume by 50%. Just as important, the downstream line size was reduced from 24″ to 20″ in diameter. This resulted in a significant cost savings since there was approximately 250 m of pipe installed downstream of the cooler. The decreased volumetric flow also decreased the required size of flame arresters and control valves, and reduced the motive fan horsepower.

Due to the high volume of the gases, approximately 10,000 m^3/hr even after the cooler, a fan was selected as the motive force for the gases. The fan, constructed of T-304 SS, is located near the bark boilers which were selected as incineration points. This allowed the vast majority of the system piping to remain under vacuum conditions so that any leaks would further dilute the already low concentration gases, and further, would not allow escape of the gases to the atmosphere.

Two bark boilers were selected as primary and secondary incineration points for the HVLC gases in the initial project. The boilers were selected because of their reliability – at least one was always in service – and because of their ability to absorb the total HVLC flow as a reasonable proportion of the total combustion air flow.

The HVLC system includes an air make-up system that allows the HVLC gas flow to act as a constant source of combustion air. HVLC sources seldom operate at a constant, steady flow rate. Rather, they swing widely depending on production rate, tank levels, and other mill processes. These swings would be difficult to absorb in any of the incineration points, possibly resulting in inefficient combustion. To avoid this situation, the design flow of HVLC into the incineration point is selected to be slightly higher than the total output from the HVLC sources. Atmospheric air is added to the system to meet the desired flow into the incineration point, providing a constant flow of combustion air for the incineration point.

In order to remove entrained moisture droplets, chevron style mist eliminators were installed immediately upstream of the motive fan, as well as at each incineration point. The separator in front of the fan is especially important in order to avoid erosion of the fan blades by water droplet impingement.

The modifications required to add the HVLC gases to the existing boilers were very minor. After consultation with the original boiler manufacturer, it was determined that the HVLC gases would be added to the Forced Draft Fan discharge duct prior to entering the air preheat section. This allowed the HVLC gases to be preheated along with the rest of the boiler combustion air. The only modification required to the boilers was a 20″ tie-in for the HVLC NCG duct into the boiler combustion air duct.

Within one day of starting the HVLC system, the entire system had been placed on line and was being operated by the mill operators. There was no noticeable effect on the boiler operation, either in terms of capacity or operability. Further, the amount of SO_2 released from the boiler stacks increased only marginally and was considerably lower than the normal amount of SO_2 generated when the boilers switch to use fuel oil as the fuel source.

Recent System Improvements and Additions

In October 1992, in conjunction with the installation of a new lime kiln, PCA installed a dedicated NCG incinerator at Valdosta. As is the case with many mills, PCA had continued to add NCG sources over the years as new systems were installed or in order to meet new requirements. The result was a system with four different collection systems with normal incineration at four different points. Because the new lime kiln was replacing two existing kilns which were LVHC NCG incineration points, it was necessary to find a new primary and secondary incineration point for these NCG streams. PCA elected to install a new dedicated incinerator as the primary incineration point. Figure 2 illustrates the various other system modifications and Figure 3 is a flow diagram of the incinerator. The new lime kiln would be the back-up incineration point for the LVHC NCG and for the stripper overhead gases, while the waste wood boilers continue to back up the incinerator for the HVLC gases. The new incinerator, as well as the modifications to the existing NCG system, was designed and supplied by A. H. Lundberg Associates, Inc. under a turnkey engineering contract.

By combining all of the NCG streams into a single primary incineration point, PCA was able to take advantage of the complimentary nature of the HVLC gases with the LVHC and stripper overhead gases.

The result is a system which does not require a tremendous amount of fuel to incinerate the HVLC and is also able to utilize the HVLC gas stream as combustion air for the other noncondensible gases.

Conclusions

The collection and incineration of High Volume–Low Concentration noncondensible gases generated in the pulp mill is likely to become very common in all pulp mills as new environmental regulations are issued requiring stricter air and water emissions compliance. The addition of HVLC collection systems should be considered integrally with other types of NCG systems in order to achieve the most efficient operation. Careful consideration should be given in the initial design phase to ensure that the HVLC system will have adequate capacity. New systems must also consider what level of treatment is required for the specific gases to be collected, particularly in the areas of contaminant removal and gas cooling. The selection of an incineration point must allow for the large quantity of low heat value gases contained in the HVLC gas streams. Finally, and most importantly, the HVLC system must incorporate safety features which will allow easy operation of the system and yet consider the fact that HVLC NCG is hazardous and can cause damage to life or property if not handled properly.