COLLECTING AND BURNING NONCONDENSIBLE GASES

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INTRODUCTION

Kraft pulp mills are typically characterized by a distinct foul odor. This odor is caused by sulfur compounds, referred to as Total Reduced Sulfur (TRS). These gases are generated in Kraft pulping process. TRS can also be generated in direct contact evaporators, in recovery boilers, and in lime kilns. The major constituents of TRS gases include hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulfide (CH_3SCH_3), and dimethyl disulfide (CH_3SSCH_3).

TRS gases are emitted from several processes in the Kraft pulp mill. The highest concentrations come from the digesters, evaporators, turpentine system and condensate stripping system. Lesser concentrations are emitted from the brown stock washers, condensate tanks and liquor storage tanks. The vent gases are collectively referred to as Noncondensible Gases (NCG).

The first attempts to contain these odorous gases were in the late 1950's. Initially systems collected and transported all forms of NCG in a single pipeline with a fan for motivation. Additional ambient air was added to ensure the TRS concentrations were below the lower flammability limits. This was not always successful, especially with concentrated gases coming from digesters and evaporators. The results were that many early systems experienced fires or explosions.

In the early 1970's advances were made to keep the NCG undiluted. With the smaller gas volumes steam ejectors could be used to motivate the NCG. These systems virtually eliminated explosions in NCG systems and became the precursor for the present day accepted method for handling NCG.

NCG also contains other pollutants, such as turpentine and methanol. These gases are classified as Hazardous Air Pollutants (HAPs). Environmental regulations require the collection and destruction of HAPs.

The steam ejector-based NCG systems have been so successful and reliable that environmental regulations in the United States require all Kraft mill concentrated NCG systems to operate above 99% uptime.

NCG COMPOSITION

NCG can be separated into three categories depending upon the composition. These are:

- Low Volume High Concentration (LVHC) NCG, also known as Concentrated NCG (CNCG)
- High Volume Low Concentration (HVLC) NCG, also known as Dilute NCG (DNCG)
- Stripper Off-Gases (SOG)

Chip bin gases (CBG) from the continuous digester are a hybrid category. They are typically collected with the HVLC NCG, but require special conditioning due to high TRS concentration excursions.

Typical LVHC NCG concentrations are shown in Table 1. These gases come from batch digester blow heat recovery systems, turpentine recovery systems, continuous digester flash steam condensers and evaporator vacuum systems. The actual composition will vary widely from system to system dependent on a number of variables. From time to time the composition will vary within the same system.

TABLE 1. Typical LVHC NCG Analysis

Source	%TRS (Vol)			$\%O_2$ (Vol)		
	Min	Avg	Max	Min	Avg	Max
Batch Digester	0	10	70	1	2	5
Continuous Digester	0	1	3	1	3	10
Turpentine (Batch)	0	2	10	4	12	20
Evaporator	1	20	70	1	5	8
Combined	0	8	70	2	3	6

It should be noted that in LVHC NCG, the TRS gases and HAPs make up only about 8% of the volume. The largest component of NCG is air that has been depleted of 50% or more of its oxygen.

The main source of air in a LVHC NCG system is leaks into the collection system, as it operates at slight vacuum. Some dissolved air is also released from the white and black liquor. The oxygen is depleted by reacting with reducing agents, such as Na_2S, in the liquors that it contacts.

NCG PROPERTIES

Corrosivity

All forms of NCG, but particularly LVHC NCG, are highly corrosive to carbon steel. Normally the NCG is saturated with water vapor resulting in condensation within the collection system. Some of the TRS gases, especially H_2S and CH_3SH are acidic, and will absorb in this condensate. The combination of this acidic condensate and the oxygen present in the NCG can be very corrosive to carbon steel. Thus carbon steel must be avoided in NCG collection systems.

The methanol and turpentine present in the NCG, along with other minor constituents, are very strong solvents that can dissolve or soften plastics or resin in Fiberglass Reinforced Plastic (FRP) piping. Therefore plastics or FRP should also be avoided in NCG collection systems. Furthermore FRP could easily fail during a fire started by NCG ignition.

Both 304 and 316 series stainless steel have proven to be resistant to NCG corrosion. These are the preferred materials of construction for NCG systems. Gasketing should be TFE (Teflon) based.

Toxicity

NCG is highly toxic and has been responsible for deaths and injuries in the pulp and paper industry. The toxicity of hydrogen sulfide is well known. At 20 ppm it causes irritation of the eyes and respiratory tract. Thirty minutes of exposure at 500 ppm causes severe sickness. Exposure at 1000 ppm for 30 minutes is fatal. The other components of NCG are similarly toxic. TRS concentration in a LVHC NCG system is commonly 100,000 ppm or greater.

Great care must be taken in the design and construction of systems for handling NCG due to its toxicity. Gas leaks, especially in enclosed areas, must be avoided. Venting must be controlled such that when there is an upset condition the gases are released in a safe manner well away from personnel. Vent stacks should be as high as reasonably possible and clear of any buildings, platforms and ladders where personnel may travel as well as clear of any ventilation air intakes.

Flammability

TRS, methanol and turpentine are flammable in the presence of sufficient oxygen. If contained in a pipeline or vessel they can also be explosive. Table 2 shows the combustion properties of the main components of NCG.

TABLE 2: Combustion Properties of NCG in Air

	Flammability Limits			
	Lower (% Vol)	Upper (% Vol)	Flame Speed ft/sec (m/sec)	Auto-Ignition Temp °F (°C)
H_2S	4.3	45.0	1.5 (0.46)	500 (260)
CH_3SH	3.9	21.8	1.8 (0.55)	
CH_3SCH_3	2.2	19.7		400 (206)
CH_3SSCH_3	1.1	8.0		572 (300)
Alpha-pinene	0.8	6.0	2.0 (0.62)	487 (253)
Methanol	6.7	36.5	1.5 (0.50)	867 (464)

The Lower Flammability Limit (LFL) is the lowest concentration of gas (by percent volume) that will burn when mixed with air. At concentrations lower than this level there is insufficient gas to sustain combustion.

Similarly, the Upper Flammability Limit (UFL) is the highest concentration of gas that will burn when mixed with air. At concentrations higher than this level there is insufficient oxygen to sustain combustion.

Unfortunately, the terms LFL and UFL only explain the situation in theoretical terms. In reality, as emitted, TRS gases are mixed with air that has most of its oxygen depleted. As such, the gases may still not be flammable at these points. Figure 1 illustrates this situation.

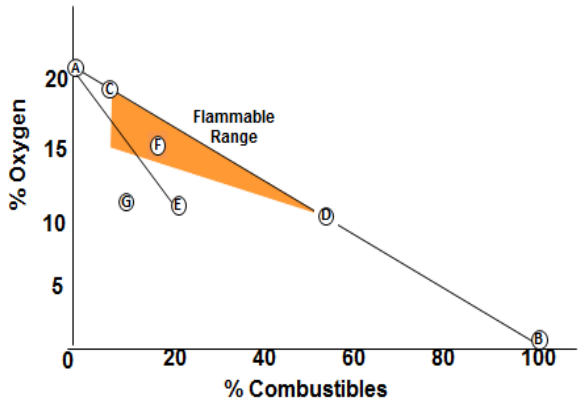


Figure 1. *Flammable range of NCG*

This figure is based on test data and the assumption that mixed TRS gases, which also contain other combustibles such as MeOH and turpentine, are flammable over the

range of 2% to 50% for all combustibles. The exact shape of this curve is not fixed, and will vary depending on the TRS components present.

Point A on Figure 1 is pure air with 21% oxygen and 0% combustibles. Point B is pure combustibles with 0% oxygen. The two points C and D on Line AB represent the LFL and UFL respectively.

The shaded area under Line CD represents the range of concentrations that are flammable. For example, Point E represents a typical LVHC NCG mixture that is well outside the flammable range. However, as air is added, the mixture moves along Line AE towards Point A. At some point the gases will enter the flammable range.

In the past, attempts were made to reduce LVHC NCG concentrations below the flammablity limit by diluting by a factor of 20 to 1 with air. As a result the mixture ended up at Point F, which is outside the flammable range. However, if the system was under-designed, or if an upset occurred which reduced this dilution ratio, the gases would end up in the explosive range. Once at a flammable concentration a fire or an explosion could occur.

Another design concern with NCG is the flame propagation speed. Table II lists velocities for the various constituents. This is a measure of how fast a flame will advance in an unrestricted area with sufficient oxygen. It should be noted that the flame propagation speeds listed in Table II are based on pure compounds in pure air.

The flame propagation speeds for sulfur gases and turpentine are relatively slow. However, when restricted in a piping system, a flame front will be accelerated by the expansion of the gases as they are heated during combustion. Velocity of the NCG flow should be kept at least 7 to 10 times these flame propagation speeds near the incineration point.

It should also be noted that turpentine can more readily form a combustible composition than the TRS compounds. For this reason it is critical to minimize the quantity of turpentine entering the NCG system.

IGNITION SOURCES

Three elements must be present before a fire can occur. The first two, namely a combustible material (TRS) and sufficient oxygen, have already been discussed. The final item is an ignition source.

Collection or transport fans have often provided the ignition source for NCG system fires. This could be from static sparks, hot spots on the casing if rubbed by the impeller, by a hot impeller shaft due to a bearing failure, or by sparks created by foreign material hitting the impeller.

Another potential cause of fire is welding. Lines and vessels containing NCG should be clearly labeled so that they are not accidentally cut or welded upon, and can be shielded from any overhead welding sparks.

If welding is necessary, all lines or vessels thought to contain NCG should be thoroughly purged and then checked for combustibles before welding is permitted. Care must also be taken to ensure that welding sparks are not drawn in through vacuum relief devices.

As TRS is known to adsorb onto, and then desorb from metal walls, welding should be done immediately after purging and testing for combustibles.

Static electricity can also provide a spark to ignite NCG. All lines and vessels containing NCG must be properly grounded. Otherwise, a static charge may build up, resulting in a spark or static discharge. Several explosions have been traced to this mechanism.

Turpentine can provide a second mechanism for static discharge. If turpentine vapor enters an NCG system, such as during loss of water flow to a turpentine condenser, then some of that turpentine will condense in the piping along with the water vapor also present.
As water and turpentine are immiscible, they will separate in the pipeline. If the interface between the two immiscible liquids is subjected to a shear force, the friction between the two liquids can generate a static spark that can ignite the turpentine.

Such a shear force can occur if these liquids enter a fan or cascade from a horizontal pipe run down a vertical pipe run. Some explosions have been attributed to this mechanism.

LVHC NCG SYSTEMS

LVHC NCG comes from both continuous and batch sources. Continuous sources are continuous digesters, turpentine recovery systems, multiple effect evaporators and foul condensate storage tanks. Batch sources include batch digester blow heat recovery systems.

The NCG volumes to be collected vary greatly from mill to mill, and from time to time within each mill. Table III shows the expected ranges of LVHC NCG flow from various sources. It is always best to design on actual test data. If this is not available, then conservative values should be used. Line sizes should be chosen to give a low pressure drop at peak flow conditions. If in doubt as

to line size, design larger in the collection lines and smaller for the lines near the incineration points.

TABLE III Concentrated NCG Volumes

Source	Ft^3/Ton Pulp	m^3/Tonne Pulp
Batch Digester	200 - 400	5.2 – 10.4
Continuous Digester	150 - 300	3.9 - 7.7
Turpentine System (Batch)	40 - 80	1.0 - 2.0
Evaporators	50 - 200	1.3 - 5.2

Note: *Volumes are actual at 60 °C (140°F) and saturated with H_2O.*

Collected NCG are typically at 60 °C (140 °F) or cooler. If the gases are hotter then consideration should be given to cooling them before transporting them to reduce volume, turpentine content, and moisture content.

Referring again to Figure 1, LVHC NCG at Point E is outside the flammable range due to lack of oxygen. Therefore, the system should be designed to prevent ingress of air into the system. This is done by sealing all parts of the system to make them airtight.

However, a sealed system can be exposed to high pressure or vacuum under upset conditions. Most storage tanks or evaporator hotwells are not designed to withstand significant pressure or vacuum. Therefore they must be protected by both pressure and vacuum relieving devices in order to prevent damage to the vessels during upset conditions.

Keeping the NCG outside the flammable range will insure a safe system at most times. However, during upset conditions, especially during start-ups and shutdowns, it is possible for air to enter the system and create a potentially flammable mixture.

For this reason it is necessary to eliminate all possible ignition sources during the design and operation of the system. Thus steam ejectors are preferred over fans to motivate LVHC NCG.

The vacuum that an ejector pulls varies inversely with gas flow. Thus it is possible to pull a high vacuum under low flow conditions. This may result in a vacuum relief device opening and allowing air into the system. A pressure control valve is used on the ejector suction to control the upstream vacuum. Alternatively NCG can be circulated from the outlet to the inlet of the ejector to manage the upstream vacuum.

Steam ejectors have additional advantages. It is possible to size the ejector and the piping downstream of the ejector such that the steam flow to the ejector ensures a line velocity safely above the flame propagation speed of TRS gases, even under low NCG flow conditions.

Since steam is an inert gas, it is possible to design the ejector such that the steam flow will help dilute the NCG to a point outside the flammable range.

Referring once again to Figure 1, if for some reason the NCG coming to the ejector is in the flammable range represented by the darkened triangle, the steam flow may dilute the resulting steam-NCG mixture back out of the flammable range.

To maintain the high NCG line velocity and the steam as a gas, it is imperative to keep the steam in the system from condensing. This requires that all steam lines, and all NCG lines after the ejector, be properly insulated to minimize steam condensation.

If a condenser or scrubber is used after the ejector, and the steam does condense, then some other means of ensuring line velocity should be provided. If not, there is the potential for the NCG to burn back into the transport line whenever the gases get into the flammable range.

Even when care is taken to keep the gases outside the flammable range, and care is taken to remove ignition sources, there is still a possibility that a fire may occur. To minimize any potential damage flame arresters should be installed at critical points. Flame arresters are designed to prevent the spread of a fire and to minimize pipeline and equipment damage. Typically flame arresters should be placed at each LVHC NCG source and at each incineration point.

To minimize damage from a fire or an explosion in the NCG line, line size rupture discs are installed. Typically, rupture discs have been placed at each LVHC NCG source and near the incineration points. Similar to the placement of NCG vents, rupture discs should be located to ensure that the gases are vented in a safe location if a disc ruptures.

The collection of NCG from continuous sources is relatively straightforward. See Figure 2. The vessels from which the gases are being collected must be kept airtight and properly sealed. Each vessel should be adequately protected from pressure and vacuum and protected by a rupture disc and a flame arrester.

Special attention must be given to overflow lines on these vessels. To avoid the ingress of air they must be sealed. The seal must be sufficient to ensure that pressure

or vacuum excursions are relieved through the pressure/ vacuum breaker rather than through the overflow line.

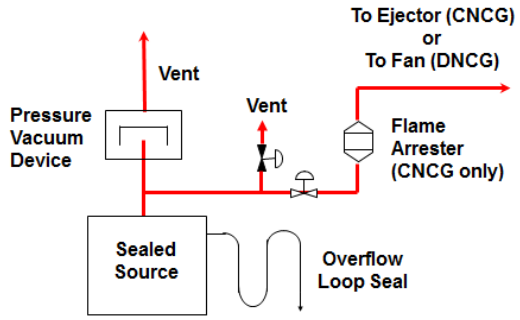


Figure 2. *NCG Collection – Continuous Source*

Additional care must be taken with the collection of NCG from batch digesters. Between blows there is virtually no NCG flow. At the start of a blow there is a momentary peak flow. As the blow progresses, this flow decreases until it reaches zero at the end of the blow. In many cases, there is another small peak NCG flow at the end of the blow when the digester blows clean.

In the past, one method to smooth these variations in flow was the use of a gasholder of either a diaphragm or an inverted-bell type. These gasholders were expensive to build, dangerous to operate and difficult to maintain. Gasholders are not used in modern NCG systems.

Batch digester blow heat recovery systems should be operated under positive pressure at all times, to prevent the ingress of air. If air gets into the accumulator and condensers, it becomes part of the NCG to be collected. This results in a very high NCG flow and a decrease in condenser efficiency at the start of the subsequent blow, invariably leading to venting of steam and NCG to the atmosphere. Also, the addition of oxygen into the LVHC NCG system may create a mixture that is in the flammable concentration range.

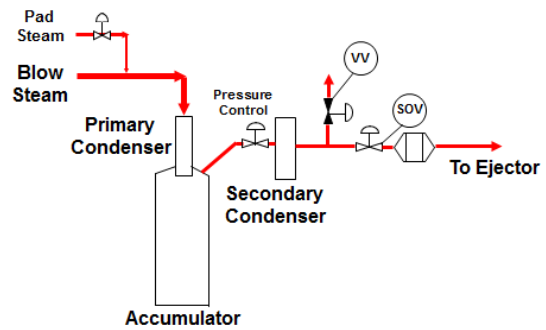


Figure 3. *NCG Collection - Batch Gases*

Positive pressure is maintained in the system by use of pressure control between the primary and secondary condensers. Padding steam is also added between blows to the accumulator, blow tank or condensers to maintain a slight positive pressure. See Figure 3 for the arrangement.

It is essential that the blow heat recovery system be properly sized and operated. If this is not done, even a well-designed LVHC NCG system will not be capable of effectively collecting NCG from the blow heat recovery system. Furthermore, it most likely will result in excessive oxygen being added to the LVHC NCG system.

Pressure relief is also required at the blow heat recovery system NCG source. This will prevent large quantities of steam from entering the NCG system and overloading the ejector system if the blow heat recovery condensers fail to perform.

In some systems batch gases are kept separate from continuous NCG sources until downstream of the ejectors. This does not help collect from an improperly designed blow heat recovery system. This adds expense and complication to the NCG system and therefore is not recommended. In a properly designed system a single ejector can be used and gases are combined ahead of the ejector.

Figure 4 shows a concentrated NCG transport system.

PIPING DESIGN AND LAYOUT

Consideration in the design of NCG systems must be given to the condensates that form in the lines. The NCG are normally saturated with water vapor and some water will condense in the lines. Therefore, it is necessary to slope the lines so that the condensate formed does not build up and block the flow of NCG through the line.

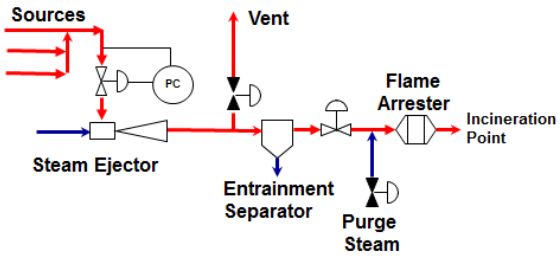


Figure 4. *LVHC NCG Transport*

Low point drains and separators are also required. The condensates formed are very foul and should be collected and treated. They can contain turpentine, which can accumulate and separate into a layer above the condensate.

The layout and positioning of block valves at the incineration point on both the NCG line and the steam purge line is a critical part of the design. Any condensate that collects behind these valves will be injected into the incineration device when the valve is opened. This condensate will be instantly vaporized and could snuff out a kiln or incinerator flame, causing a vent to the atmosphere. In a rarer, but more extreme case, it could cause a minor explosion, damaging the equipment.

The condensate collection system must be designed so that it can never be pressurized. If it does become pressurized, condensate can be forced back up the collection lines, and into the incineration device, possibly leading to an explosion.

The motivating steam ejector should be as close to the point of incineration as possible. This results in a majority of the system operating under vacuum. Thus if a leak does occur, it does not result in the release of NCG and the possible gassing of personnel.

An entrainment separator or mist eliminator is located after the ejector to remove any water droplets and condensate before the gases are injected into the incineration point.

The NCG then goes through a final flame arrester and into the kiln, boiler or incinerator for destruction. If the kiln, boiler or incinerator are not available for incineration, the gases should be safely vented upstream of the incineration point.

From time to time it will be necessary to vent the gases to the atmosphere. All vent lines should be made as high as practically possible and should release the gases straight up and away from buildings and platforms.

NCG SCRUBBING

Some mills have found it advantageous to scrub the TRS from the NCG before the gases are burned. Scrubbing the TRS may be necessary to reduce SO_2 emissions if the NCG are burned in a boiler, or an incinerator. In mills where NCG are burned in lime kiln, the additional sulfur may contribute to ring formation in the kiln. Scrubbing the NCG may minimize this problem.

The scrubbing medium is white liquor or caustic solution. The ionizible sulfur gases, H_2S and CH_3SH, are easily removed from the NCG by a chemical reaction. There is insignificant removal of the non-ionizible gases, CH_3SCH_3 and CH_3SSCH_3.

When fresh caustic is used as the scrubbing medium it is recirculated to minimize chemical consumption.

When hot white liquor is used for scrubbing, it is normally used on a once-through basis to minimize changes to the liquor temperature and concentration, and to minimize fouling. The NCG is heated up to near the white liquor temperature, and often sent to a gas cooler to reduce the gas volume and reduce condensation in the line downstream of the scrubber.

To avoid the cooler, some mills have used cooled white liquor for scrubbing. However, the heat exchanger used to cool the white liquor is often subject to severe scaling.

Historically packed columns have been used for these scrubbers. Fouling of the packing can occur, particularly when the scrubbing medium is white liquor. Spray columns have more recently been employed for this duty with minimal loss in efficiency.

Depending on the scrubbing media used and the NCG streams scrubbed, overall TRS removal efficiencies from as low as 40% to as high as 95% have been reported, although an overall TRS removal of about 65% is typical.

HVLC NCG SYSTEMS

Sources of HVLC NCG include brownstock washer hoods and seal tanks, knotter hoods, liquor storage tanks, brownstock storage tanks, oxygen delignification systems, slakers, mud filters, causticizers and black liquor oxidizers. Practically speaking, this includes all locations where air can come in contact with the black liquor.

HVLC NCG is normally outside the flammable range due to low concentration of TRS (see point F on Fig. 1). HVLC NCG systems are typically designed to run at 25% of the LFL or less. HVLC NCG is normally collected and transported in a common pipeline and motivated with a fan. If the flow is low enough, it is still desirable to use an ejector. Typically an ejector is only practical on a partial system.

As with LVHC NCG, the total volume of HVLC NCG to be handled varies greatly. Flows of between 180 to 900 m^3 per ton (6,000 to 30,000 ft^3 per ton) of pulp are typical.

Brown stock washer hoods on vacuum drum washers are the largest single source of HVLC NCG. It is necessary to properly seal the washer hoods to the vats, and to train the operators to keep the inspection doors closed. Suppliers have developed better fitting hoods to keep the washer hood gases to a minimum. Design volumes for modern, low flow hoods are 1,300 m^3/hr per drum or less.

Newer systems recirculate filtrate tank vents back to the washer hoods in order to reduce gas volume. Similarly, air for air doctors can be taken from the hood to avoid additional ambient air entering the system.

Pressure washers and diffusion washers have much lower volumes of gas to handle.

HVLC NCG collection from large, flat top storage tanks must be carefully designed. In most cases these tanks were not designed to take any pressure or vacuum. When they are tied into a collection system they will be subjected to the system vacuum. These sources often require air sweeps to protect the tankage, however the air sweeps add to the volume of gas to be collected.

As with LVHC NCG, these gases are normally collected at 60°C (140°F) or cooler. In instances where the HVLC NCG are hot and saturated with moisture, coolers are used to reduce their volume and moisture content. This has the added benefit of minimizing turpentine content upstream of the fan if any is present at the sources.

Heaters can be used to raise the dilute NCG temperature above the saturation temperature, thus drying the gases out. Generally the gases are heated to a temperature at which they are below 50% humidity. Having a dry gas is necessary if the gas will eventually go through mild steel equipment such as ducting at the incineration point, or into a recovery boiler.

Under no circumstances should LVHC NCG be added to HVLC NCG, especially if the LVHC NCG stream may contain appreciable turpentine vapor. This type of mixing risks the formation of a flammable gas composition.

As in the case of LVHC NCG systems, the pipelines for HVLC NCG systems should be properly sloped and drained. A moisture separator should be installed upstream of the fan suction and near the incineration point. A flame arrester is typically included near the incineration point.

A few mills monitor the concentration of combustibles in the HVLC NCG system to ensure that the gases are always well below the LFL. If the combustible concentration rises above 50% of the LFL during system upsets, then the system is vented or shutdown until the problem is corrected.

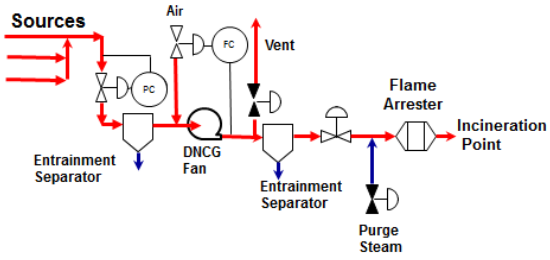


Figure 5. *HVLC NCG System*

A system for handling dilute NCG is depicted in Figure 5.

CHIP BIN GAS SYSTEMS

The gases from continuous digester chip bins are normally similar to HVLC NCG, however at times they can contain large amounts of turpentine, VOCs, and TRS. The gases are typically treated to remove combustible compounds before being transported to an incineration point. The chip bin gases are often handled as a separate stream from the LVHC NCG or HVLC NCG. Most often they are added to the HVLC NCG system after treatment, provided that the HVLC NCG flow is large enough to provide adequate dilution.

In the United States, environmental regulations require the NCG from chip bins to be collected if process flash steam is used for steaming. Collection is not required if fresh steam is used for steaming.

Collection of chip bin NCG (CBG) is illustrated in Figure 6. Chips are steamed in the chip bin to preheat the wood and remove air before they enter the steaming vessel. This steam can drive volatile compounds, such as turpenes, out of the chips. This situation is aggravated when too much steam is used, or if the steam breaks through the chip bed due to low chip bin level.

Large quantities of turpentine vapor may be present in chip bin gas. One Kraft mill in the southern United States that pulps pine has reported recovering up to 1 kg (2 lb./ton) of turpentine per ton of pulp from the chip bin gas. Even when only terpene-free wood is being processed, the chip bin gases require treatment due to the excessive volume and high TRS content that may be experienced when process flash steam "breaks through" the chip layer in the chip bin.

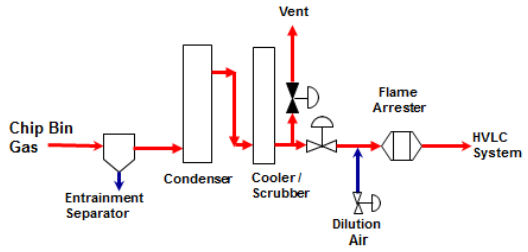


Figure 6. *Chip Bin Gas Collection*

Proper treatment of chip bin gas includes cooling, condensing and scrubbing to remove as much turpentine as possible. A typical system will include a separator to remove chip fines, followed by an indirect cooler/condenser, followed by a packed column scrubber using cold water.

Even at temperatures as low as 30°C (87°F) and atmospheric pressure, the vapor pressure of the alpha-pinene fraction of turpentine is high enough to create an explosive mixture. Therefore, dilution air is added to ensure a safe mixture is being transported. Fans should be avoided when the CBG is handled separately from the HVLC NCG system.

Once the chip bin gas has been cooled, scrubbed and diluted, it can be treated as any other HVLC NCG stream.

STRIPPER OFF-GAS (SOG) SYSTEMS

In most cases the stripper off-gas is removed as a mixture of 50% methanol and 50% water, by weight, at about 99°C (210°F). Due to the high temperature and water content of this stream, it must be transported in a separate piping system, as it is a "very condensable gas" (see Figure 7).

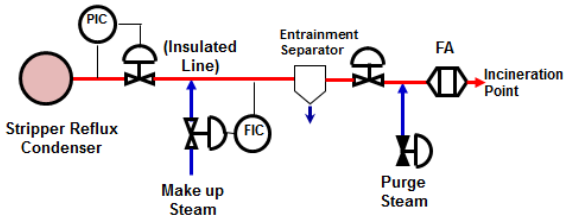


Figure 7. *Stripper Gas System*

The stripper system pressure is typically the motive force to deliver the gases to the incineration point. It is necessary to insulate and heat trace the SOG line in order to prevent condensation.

It is also necessary to steam purge the entire line to remove all air before any methanol rich gas is introduced. This is done by a steam makeup line.

Steam is added downstream of the stripper pressure control valve on flow control by measuring the flow at the incineration end of the line. This ensures a minimum velocity in the line during start-up, shutdown and low flow conditions. As the SOG is very concentrated and noxious, this avoids any venting of the gases during normal operation of the system. Another method of eliminating vents is to liquefy the SOG and handle it as a liquid.

BURNING NCG

In order for the TRS and HAPs in NCG to be properly destroyed by combustion, three conditions must be met. These are:

- Temperature of 870°C (1600°F)
- Residence time of 0.75 sec.
- Excess oxygen (O_2) content of 3-4%

These should be considered basic conditions, and if any of them are exceeded, the others can be reduced. That is, if the temperature is higher than 870°C (1600°F), then reducing retention time and/or lowering the excess oxygen content will still provide good destruction. For example, some new, high efficiency kilns are capable of meeting TRS emissions at excess oxygen content as low as 2%.

There are three locations in a pulp mill where these conditions exist: the lime kiln, power boiler and recovery boiler. A dedicated separate incinerator can also be installed to destroy NCG.

Lime Kiln

The lime kiln has traditionally been the first choice for burning NCG. It has the advantage that most of the SO_2 formed is absorbed on the lime mud and returned to the liquor cycle.

In many mills the lime kilns are overloaded and have low levels of excess O_2. An overloaded kiln is less effective at TRS destruction.

Modern, high efficiency kilns are designed to run at about 0.5% excess oxygen. This is normally not enough O_2 to completely destroy TRS.

One drawback of using the kiln for TRS destruction is that, in some cases, burning NCG in the lime kiln has contributed to, or accelerated, the formation of kiln rings. This is particularly true when the NCG flow fluctuates or when the mill experiences poor lime mud washing.

The LVHC NCG should be introduced into the kiln through a separate nozzle, mounted on the kiln hood, to minimize the effect on the main flame. This nozzle must be cooled in order to prevent preignition of the gases while still in the nozzle. In addition, during NCG system shut down with the kiln operating, the cooling jacket prevents heat damage to the nozzle. Air, steam and water have all been successfully used as cooling media. NCG can also be injected through a dedicated port in the main fuel burner of the kiln, although this is not recommended.

The NCG absorbs light in the UV range and can give a false loss of flame signal if the NCG passes in front of a UV flame detector. Thus the NCG nozzle should be placed well away from the flame detectors and at a location that minimizes the interaction with the main flame.

The HVLC NCG is not normally burned in the lime kiln due to its large volume. Smaller HVLC NCG flows may be successfully substituted for primary or secondary air, or added through a dedicated nozzle.

Power Boilers

Boilers have become a popular incineration point for burning NCG. Due to the relatively large size of the boiler it is a generally a trouble-free incineration point. However, burning NCG in a boiler will increase the boiler SO_2 emissions, creating another environmental concern.

Further, if the back end of the boiler is less than 160°C (320°F), then H_2SO_3 acid precipitation can occur and severe corrosion may result.

Studies have shown that considerable amounts of SO_2 are absorbed on the ash from coal or bark, if either of these fuels is used in the boiler. This can reduce the SO_2 emitted from the burning of NCG.

The LVHC NCG is introduced into boilers through separate nozzles, similar to those used in kilns. In many cases existing ports can be used for the nozzles. In other cases it is necessary to penetrate the boiler wall in order to place the nozzles.

The NCG flow may be split into two or more parallel lines before entering the boiler. This is done to balance the flow of NCG into the boiler. However, if this is done, great care must be taken to ensure a balance of flow to each nozzle, in order to prevent flame backs due to low gas velocity at one nozzle. The HVLC NCG can be introduced into the boilers as part of the primary or secondary air, or if the flow is small enough, through a dedicated nozzle. Care must be taken when adding or removing the HVLC NCG flow to the boiler in order to prevent upsets in airflow to the boiler.

Recovery Boilers

The recovery boiler is theoretically the best place to destroy NCG as the sulfur gases are destroyed and recovered as Na_2S in the smelt. However, due to its importance in the recovery cycle, the potential for catastrophic explosion due to water entering the unit during operation, or explosive gas build-up during shut down, there has been reluctance in the past to use the recovery boiler for NCG incineration.

In recent years incineration in the recovery boiler has become much more commonplace. Several mills are now burning LVHC NCG and HVLC NCG in recovery boilers and there is a trend toward expanding this practice.

The Black Liquor Recovery Boiler Advisory Committee (BLRBAC) has published "Recommended Good Practice for the Thermal Oxidation of Waste Streams in a Black Liquor Recovery Boiler". It is available on the BLRBAC Website, www.blrbac.com. The guidelines outline separate methods for burning LVHC NCG and HVLC NCG in recovery boilers. For LVHC NCG this includes the use of a dedicated burner and burner management system with a pilot and auxiliary fuel. For HVLC NCG the guidelines specify that the gases be cooled to 43°C (110°F) to remove moisture and then reheated to at least 66°C (150°F) to result in a gas that is less than 50% relative humidity.

At some mills stripper off-gases are being condensed to a liquid and blended with the heavy black liquor to the recovery boiler.

Incinerators

It is also quite common to burn NCG in a dedicated incinerator. The big advantage of the separate incinerator is that it takes the gases out of a piece of operating equipment and eliminates the complications associated with burning NCG in an operating unit in the mill. Most incinerators use conventional fossil fuel burners, although some are self sustaining with the heating value of the waste gases being burned and do not require auxiliary fuel except at startup.

The major disadvantage of the incinerator is its high capital and operating cost. These units have been installed as both the primary and secondary incineration points. The trend is away from using the incinerator as the primary incineration point if it is a consumer of fossil fuel. Quick start-up units have been developed as secondary incineration points that avoid continuous consumption of auxiliary fuels.

Due to the SO_2 emission, in most cases the incinerator is followed by an SO_2 scrubber, adding further to the capital and operating costs.

Another byproduct of incineration is sulfuric acid mist (SAM) which can give high opacity. Some mills have successfully added additional control devices, such as wet electrostatic precipitators, to reduce SAM.

Recently, some mills have added package boilers to the incinerators to recover the heat from incineration as steam. The relatively slower cooling of the combustion gases in the boiler results in higher sulfuric acid formation.

Stripper off-gas, due to its high MeOH content, has a very high fuel value and can be used as a primary fuel for incinerators. This reduces the incinerator operating cost by supplying most of the fuel requirement. However, SOG also contains ammonia which can increase NOx emissions. In recent years, two-stage incineration has been used to minimize NOx generation.

If the HVLC NCG flow is reasonably low, it may also be burned in the incinerator. In some cases it is substituted for combustion and cooling air to reduce fuel requirements.

Regenerative Thermal Oxidizers

Regenerative Thermal Oxidizers (RTOs) are viable devices for incinerating NCG. These units generally have very low operating costs and very high uptime. Several mills are successfully using RTOs to incinerate LVHC and HVLC NCG.

Other Considerations

Several other factors affect the choice of an incineration point for NCG. These are usually site specific. The age, size and operating condition of the incineration locations available are important.

As a general rule, the higher the capacity of the location selected the better as the NCG will have less impact on the operation of the larger equipment.

The uptime of the equipment used to burn NCG is very important. A boiler or kiln that is off line frequently, or for long periods of time, is a poor choice. The environmental regulations in the United States currently require an uptime of 99% for burning LVHC NCG and 96% for HVLC NCG. It is virtually impossible to do this unless there are backup locations for NCG incineration.

Recent regulatory action in the United States makes it necessary to start the NCG systems prior to starting the processes that generate the gases, and collection must continue until the gas generating processes are completely shut down. There are no longer any venting allowances during periods of process “startup, shutdown, or malfunction” (SSM). The result is an extended startup time for digesters and evaporators, as air is vented from the process equipment through the LVHC NCG system.

The relative locations of the NCG sources and the point of incineration are also important. This affects the length, and hence the cost, of the pipe line required to carry the gases. Generally shorter piping runs are advantageous.

IMPACT

Installation and operation of NCG systems have an impact on the rest of the mill operation. The largest impact usually comes from the digester blow heat recovery system.

To collect the NCG it is necessary for the blow heat system to contain and condense all the blow steam. Consequently, steam and methanol that would otherwise be vented are recovered as hot foul condensates. The recovered heat must be reused or discarded.

Many mills are now using recovered blow heat to heat water or pre-evaporate black liquor, while others install cooling towers to remove the excess heat. Also, the methanol collected can increase the BOD load to the effluent treatment system forcing mills to add aeration capacity or install foul condensate stripping systems.

Capturing and burning the reduced sulfur gases in the kiln or recovery boiler, or scrubbing (with white liquor) the TRS gases or the SO_2 formed by incineration, will increase the liquor sulfidity. That may upset the mill sulfur balance, necessitating a change in mill makeup chemicals away from saltcake and toward caustic soda or sodium carbonate.

It may be necessary to update and improve the operation of the turpentine recovery system and the multiple effect evaporators in order to make them compatible for NCG collection. For instance, the practice of bleeding air into

the evaporator vacuum system in order to control vacuum is not compatible with NCG collection.

Finally, the places where NCG is burned can no longer be looked upon only as production devices. They must also be considered pollution control devices. It is not uncommon for a mill to run a kiln or a boiler strictly for the purpose of burning NCG, even when the production capacity is not needed.

CONCLUSION

In order to reduce odorous and hazardous air pollutants from Kraft pulp mills, environmental regulations require that noncondensible gases containing TRS and HAPs be collected and incinerated. These gases are very corrosive, highly toxic, and if mixed with air, potentially flammable.

Consequently, great care must be taken in the design, construction, operation and maintenance of these systems. Fortunately, the technology exists to build NCG systems that are safe, efficient and reliable.

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