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Collection and burning of concentrated non-condensable gases: regulations, design and operation

Scope

Typical design and operating information concerning the collection and burning of concentrated non-condensable gases (CNCG) are included in this TIP. Aspects of the Cluster Rule regarding CNCG systems are also discussed.

These systems are also referred to as low volume, high concentration (LVHC) non-condensable gases (NCG).

It should be noted that there are also dilute non-condensable gases (DNCG), or high volume, low concentration (HVLC) NCG. These are not covered in this TIP. Stripper off gas (SOG) from steam stripping systems is also not covered in this TIP.

Definitions

NCG: Non-condensable gases are the gases that remain after water vapor has been condensed out of a vapor-laden stream. In pulp mills, NCG are emitted from digesters, evaporators, turpentine systems, strippers, brown stock washers and liquor storage tanks. They contain TRS, nitrogen, oxygen, and traces of methanol, turpentine, and HAPs, and are normally saturated with water vapor.

TRS: Totally reduced sulfur. The gases involved are hydrogen sulfide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulfide (CH_3SCH_3) and dimethyl disulfide (CH_3SSCH_3).

CNCG: NCG that are collected in concentrated form. These gases come from blow heat recovery systems, turpentine recovery systems, continuous digester flash steam systems, and evaporator vacuum systems and hotwells.

HVLC: NCG that come from sources such as brown stock washer hoods and are collected in dilute form.

Cluster Rules: A combined collection of air and water pollution control rules that are “clustered” together to ensure that an improvement in one does not result in deterioration of the other. That is, air pollution control cannot result in an increase in water pollution, and vice-versa. The Cluster Rules are designed to bring pulp mills up to MACT standards for HAPs.

HAP: Hazardous Air Pollutant

MACT: Maximum Achievable Control Technology.

LFL: The lower flammability limit is the lowest concentration of gas, by percent volume, that when mixed with air will burn. At lower concentrations, there is insufficient gas to sustain combustion.

UFL: Upper flammability limit is the highest concentration of gas, that when mixed with air will burn. At higher concentrations, there is insufficient oxygen to sustain combustion.

LDAR: Leak detection and repair. This is required on CNCG systems by the Cluster Rule.

SSM: Startup, shutdown and malfunction plan, previously required by the Cluster Rule, is now superseded by new MACT I rules promulgated July, 2012. Emissions during these periods are no longer allowed, and an SSM plan is no longer required

VOC: Volatile organic compound. An organic compound that will normally vaporize at room temperature.

BLRBAC (Black Liquor Recovery Boiler Advisory Committee): A volunteer organization promoting improved safety of chemical recovery boilers and their auxiliaries through the interchange of technical knowledge, experience and data on past and future recovery boiler incidents. www.blrbac.org.

Safety precautions

CNCG are highly toxic and are 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 CNCG are similarly toxic. TRS concentration in CNCG can be 100,000 ppm or greater.

Because these gases are toxic, great care must be taken in the design and construction of systems to handle these gases. Gas leaks, especially in enclosed areas, must be avoided. Adequate venting must also be provided, such that when there is an upset condition causing the gases to vent, the gases are released in a safe area and in a safe manner. Vent stacks should be as high as possible and clear of any buildings, platforms and ladders where personnel may travel, and well clear of any ventilation air intakes.

Consideration should be given to installing hydrogen sulfide detectors in areas, especially inside enclosed buildings, where leaks from the CNCG system may occur.

TRS, methanol and turpentine are flammable in the presence of sufficient oxygen, and if contained in a pipeline or vessel, can be flammable. Table 1 shows the combustion properties of the main components of CNCG.

Table 1. Combustion properties of NCG in air

	Flammable limits		Flame speed ft/sec (m/sec)	Auto-ignition temperature °F (°C)
	Lower (volume%)	Upper (volume%)		
H ₂ S	4.3	45.0	1.5 (0.46)	500 (260)
CH ₃ SH	3.9	21.8	1.8 (0.55)	
CH ₃ SCH ₃	2.2	19.7		400 (206)
CH ₃ S ₂ CH 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)

*Alpha pinene is a component of turpentine

CNCG is normally not flammable due to lack of sufficient oxygen to support combustion. Thus, CNCG systems must be designed and operated to prevent ingress of air. No open flames or welding should be allowed on or around the vessels or process lines of a CNCG system. All parts of a CNCG system should be properly grounded to prevent build up of static electricity, which could lead to sparking that could ignite the CNCG.

Special care must be taken with the turpentine recovery system. If this does not work correctly, turpentine can enter the piping system, where it will condense and build up as a liquid. Turpentine is able to reach a flammable concentration

more readily than TRS, and most explosions in CNCG systems have been attributed to turpentine. Thus, it is very important to keep turpentine out of the CNCG system. This is normally done by monitoring the temperature of the NCG coming from the turpentine recovery system. Turpentine condenses over a range of temperatures at atmospheric pressure; very little condenses above 200°F and very little turpentine remains in vapor below 120°F. Secondary condensers and gas coolers are installed to achieve a low NCG temperature from the turpentine and blow heat sources, keeping most turpentine out of the CNCG system. A common practice is to monitor NCG sources containing turpentine and alarm (or alarm and divert) the source from the collection system if the temperature rises above 160°F.

If maintenance work is required on all or part of the CNCG system, the affected part must be isolated, drained, purged with air or steam, and checked for the presence of toxic and flammable gases before entry or welding. As TRS is known to adsorb onto, and then desorb from metal walls, welding should be done immediately after purging and testing for combustibles. If possible, purging should continue throughout the repair period to keep gases diluted to below the LFL.

Composition and volume of CNCG

Table 2 shows a typical analysis for CNCG on a dry basis. These gases come from blow heat recovery systems, turpentine recovery systems, continuous digester flash steam condensers, evaporator vacuum systems, and hotwells. The actual composition will vary widely from system to system, and from time to time within the same system.

Batch digesters release about 0.6 lb/ton pulp of TRS. Continuous digesters release about 0.4 lb/ton. Evaporators release about 1.5 lb/ton (NCASI)

Table 2. Concentrated NCG typical analysis

	%TRS (volume)			%O ₂ (volume)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Batch Digester	0	10	70	1	2	5
Continuous Digester	0	1*	3*	1	3	10
Batch Turpentine Relief	0	2	10	4	12	20
Evaporators	1	20	70	1	5	8
Combined CNCG	0	8	70	2	3	6

Note: The balance of the gas will be nitrogen

*Values based on NCASI TB 849 (August 2002), however other experience indicates much higher concentrations

It should be noted that in CNCG, the TRS gases make up only about 8% of the volume. The largest component of CNCG is air that has been depleted of 50% or more of its oxygen. Although some air enters the system by dissolving in white and black liquors and is then stripped back out of them, most air enters through leaks in the system. The oxygen is depleted by reacting with reducing agents, such as Na₂S, in the liquors that it contacts. The data shown in Table 2 is for a “tight” system. It is recommended that seals in the system be audited on a periodic basis for ingress of air into the system.

The volumes of gases to be collected vary greatly from mill to mill, and from time to time within each mill. Table 3 shows the expected ranges of CNCG flow from various sources. It is always best to design based 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 (0.4 to 1.0 in. w.c. per 100 ft of pipe or 10-25 mm w.c. per 30 m of pipe) at peak flow conditions. If in doubt as to line size go larger in the collection system to reduce pressure drop, but smaller immediately ahead of the incineration points to maintain a safe velocity to avoid burn back into the piping.

Table 3. Concentrated NCG Volumes

CNCG Source	Volume ft ³ /ton pulp
Batch Digester	200-400
Continuous Digester	150-300
Batch Turpentine Relief	40-80
Evaporators	20-200

Note: Volumes are actual at 140°F and saturated with water

Collected CNCG are typically at 140°F (60°C) or cooler. If the gases are hotter than this, the volume of the water of saturation greatly increases the total volume of gas to be handled. This increases the line and equipment sizes required for transport. Consideration should be given to cooling CNCG if the temperature is above 140°F (60°C).

Materials of construction

CNCG is highly corrosive to carbon steel. These gases are normally saturated with water vapor, such that condensation occurs in the collection system. Some of the TRS gases, especially H₂S and CH₃SH are acidic, and will absorb in the condensate formed. The combination of this acidic condensate, along with the oxygen present in the CNCG, can be very corrosive to carbon steel. Therefore, carbon steel should be avoided in CNCG collection systems.

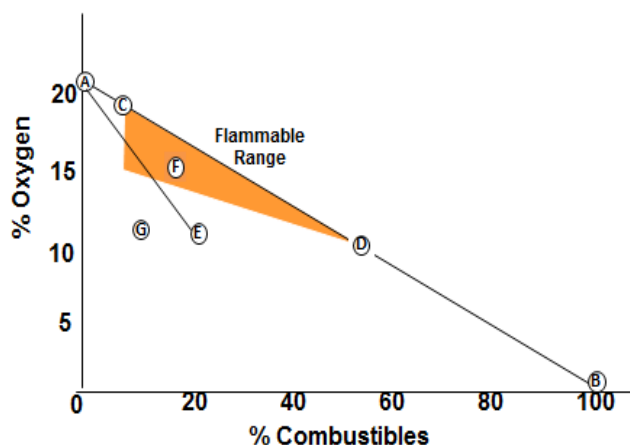
Other components of CNCG, especially turpentine and methanol, are very strong solvents and can dissolve or soften plastics or resin in Fiberglass Reinforced Plastic (FRP) piping, potentially leading to mechanical failure over time. Plastics and FRP are not acceptable materials for CNCG collection systems, because they are combustible materials, and transport gases that can be considered a fuel.

Stainless steel, typically 304 or 316, has proven to be corrosion resistant to CNCG and is the preferred material of construction for CNCG systems.

Gaskets should be selected for resistance to turpentine, methanol, and TRS compounds. TFE-based gaskets are typically used, as they are resistant to these CNCG components.

Flammable nature of CNCG

Unfortunately, the terms LFL and UFL only explain the situation in theoretical terms. In reality, CNCG gases, as emitted, are mixed with air that has most of its oxygen depleted, such that the gases are not flammable. Figure 1 illustrates this situation. It is based on typical 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.

**Fig. 1.** Flammable range of NCG.