

## COLLECTING AND BURNING NONCONDENSIBLE GASES

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### INTRODUCTION

Kraft pulp mills are normally characterized by a distinct foul odor. This odor is caused by sulfur compounds, referred to as TRS (Total Reduced Sulfur), that are generated in pulp digesters when wood is cooked with Kraft liquor. TRS can also be generated in direct contact evaporators, in recovery boilers, and in lime kilns. The TRS gases involved are hydrogen sulfide ( $H_2S$ ), methyl mercaptan ( $CH_3SH$ ), dimethyl sulfide ( $CH_3SCH_3$ ) and dimethyl disulfide ( $CH_3SSCH_3$ ).

TRS gases that are emitted from digesters, evaporators, turpentine systems, strippers, brown stock washers and liquor storage tanks are referred to as Noncondensable Gases (NCG).

Attempts to collect and burn NCG were first tried in the late 1950's. The initial systems collected the gases in pipelines, using fans as motivators to move the gases. These systems usually diluted the gases with air to bring the TRS concentrations below their lower explosive limits. This was not always successful, especially with concentrated gases coming from digesters and evaporators, and many early systems experienced fires or explosions.

In the early 1970's, a system was developed in Sweden that kept the NCG undiluted and that used steam ejectors as motivators. This system has virtually eliminated explosions in NCG systems, and is now the accepted method for handling NCG.

The steam ejector based NCG systems have been so successful and reliable, that the Cluster Rule requires all Kraft mills to have NCG systems, and to operate them at 99% uptime.

### COMPOSITION OF NCG

NCG can be broken down into four separate categories, depending upon composition. These are: Concentrated NCG (low volume, high concentration (LVHC)); Dilute NCG (high volume low concentration, (HVLC)); chip bin gases; and stripper off gases (SOG).

Table I shows a typical analysis for concentrated NCG. 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.

It should be noted that in concentrated NCG, the TRS gases make up only about 50% of the volume. The largest component of NCG is air which has been depleted of 50% or more of its oxygen. Although some air enters the system by dissolving in white and black liquors and then stripping back out of them, most air enters through leaks in the system. The oxygen is depleted by reacting with reducing agents, such as  $Na_2S$ , in the liquors that it contacts. The data shown in Table I are for a "tight" system.

### PROPERTIES OF NCG

#### Corrosivity

NCG, especially concentrated NCG, are 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  $H_2S$  and  $CH_3SH$  are acidic, and will absorb in the condensate formed. The

combination of this acidic condensate, along with the oxygen present in the NCG, can be very corrosive to carbon steel. Therefore, carbon steel should be avoided in NCG collection systems.

Other components of NCG, especially turpentine and methanol, are very strong solvents and 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. Further, FRP should be avoided because of potential failure during a fire started by NCG ignition.

Stainless steel of the 300 series, typically 304 or 316, has proven to be corrosion resistant to NCG and is the preferred material of construction for NCG systems.

### Toxicity

NCG 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 NCG are similarly toxic. TRS concentration in concentrated NCG is 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.

### Explosivity

TRS, methanol and turpentine are flammable in the presence of sufficient oxygen, and if contained in a pipeline or vessel, can be explosive. Table II shows the combustion properties of the main components of NCG. The Lower Explosive Limit (LEL) is the lowest concentration of gas, by percent volume, that, when mixed with air, will burn. At lower concentration there is insufficient gas to sustain combustion. Similarly, the Upper Explosive Limit (UEL) is the highest concentration of gas, that, when mixed with air, will burn. At higher concentrations there is insufficient oxygen to sustain combustion.

Unfortunately, the terms LEL and UEL only explain the situation in theoretical terms. In reality, TRS gases, as emitted, are mixed with air that has most of its oxygen depleted, such that the gases are not explosive. Figure I illustrates this situation. It is based on some 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 has not been determined, and will vary depending on the TRS components present.

Point A on Figure I is the pure air case with 21% oxygen, 0% combustible. Point B is the pure combustible case with 100% combustible and 0% oxygen. The two points, C and D, on Line AB represent the LEL and UEL respectively.

The shaded area under CD represents the range of mixtures that are explosive. Point E represents a typical concentrated NCG mixture, which is well outside the explosive range. However, as air is added, the mixture moves along Line AE towards Point A. At some point, if enough air is added, the gases will enter the explosive range.

In the past, attempts were made to reduce concentrated NCG below the explosive 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 explosive 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. At this point, if an ignition source were present, such as a spark from a fan, then an explosion would occur.

Another characteristic of flammable gases is flame propagation speed. This is a measure of how fast the flame will travel through the pipeline or vessel once a fire is started. See Table II. The flame propagation speed for sulfur gases is relatively slow. However, the flame propagation speed for turpentine is extremely fast. The value reported in Table II for turpentine is currently being disputed by some experts in the field, who claim the speed is much slower. Regardless, explosions caused by TRS are usually minor, with minimum damage, while explosions caused by turpentine can be catastrophic.

It should be noted that the flame propagation speeds listed in Table II are based on pure compounds in pure air.

It should also be noted that while NCG systems are designed to handle the flame propagation speed of TRS, it is not practical to design against the flame propagation speed of turpentine. For this reason, it is very important to minimize the amount of turpentine entering the NCG system.

## **IGNITION SOURCES**

Before an explosion can occur, three things must be present. The first two, namely a combustible material (TRS), and sufficient oxygen, have already been discussed. The final item is an ignition source. Fans have traditionally provided an 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. Welding torches have ignited many NCG fires. Lines and vessels containing NCG should be clearly labeled so that they are not accidentally touched by welding flames or arcs. 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, eventually leading to a spark or static discharge. Several explosions have been traced to this mechanism.

Turpentine can provide a second mechanism for static discharge. If sufficient 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 decant in the pipeline. At this point, 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, which will ignite the turpentine. Such a shear force can occur if these liquids enter a fan, or if they cascade from a horizontal pipe run down a vertical pipe run. As before, several explosions have been credited to this mechanism.

## CONCENTRATED NCG (LOW VOLUME, HIGH CONCENTRATION) SYSTEMS

Concentrated NCG come from two types of sources, continuous and batch. Continuous sources are continuous digesters, turpentine recovery systems, multiple effect evaporators, and foul condensate storage tanks. Batch sources are blow steam condensers for batch digesters.

The volumes of gases to be collected vary greatly from mill to mill, and from time to time within each mill. Table III shows the expected ranges of concentrated 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 (0.4 to 1.0 inches w.c. per 100 ft. of pipe) at peak flow conditions. If in doubt as to line size, go larger.

Collected NCG are typically at 140°F (60°C) or cooler. If the gases are hotter than this, then consideration should be given to cooling them before transporting them.

The concentrated NCG, Point E on Figure I, are normally outside the explosive 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 pressure or vacuum. Therefore they must be protected by both pressure and vacuum relieving devices in order to prevent damage to the vessel during upset conditions.

Keeping the NCG outside the explosive 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, creating a potentially explosive mixture. For this

reason, it is necessary to eliminate all possible ignition sources during the design and operation of the system. Hence, steam ejectors, rather than fans, should be used to motivate the gases. Since the vacuum that an ejector pulls varies inversely with gas flow, it is possible to pull a high vacuum under low flow conditions. In that case, a vacuum breaker could open, allowing air into the system. To overcome this problem, a pressure controller is used on the ejector suction.

Steam ejectors have other advantages. It is possible to size the ejector and the piping downstream of the ejector, such that the steam flow to the ejector insures a line velocity greater than the flame propagation speed of TRS gases, even under low NCG flow conditions. It should be noted again that it is impractical to design against the flame propagation speed of turpentine. However, steam is an inert gas, and it is possible to design the ejector such that the steam flow will dilute the NCG to a point outside the explosive range. Refer to Figure I. If, for some reason the NCG coming to the ejector is in the explosive range, Point I, the steam flow will dilute the resulting steam - NCG mixture to Point J, which is outside the explosive range.

For the reasons discussed above, it is necessary 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 insure the steam does not condense. If a condenser or scrubber is used after the ejector, and the steam does condense, then some other means of ensuring line velocity and dilution should be provided. If not, then the NCG will burn back into the transport line whenever the gases get into the explosive range.

Even if care is taken to keep the gases outside the explosive range, and care is taken to remove ignition sources, there is still a remote possibility that a fire may occur. To

protect against this, flame arresters should be used at several points throughout the system in order to prevent the spread of a fire and to minimize pipeline and equipment damage. As a general rule, flame arresters should be placed at each NCG source, and at each incineration point. To prevent damage from an explosion in the NCG line, line size rupture discs have been used on the NCG line. Typically, rupture discs have been placed at approximately 100 ft. (30m) intervals on extended NCG lines. Care must be used when placing the rupture discs to insure that the gases are vented in a safe location if a disc ruptures. However, because the rupture discs are subject to mechanical failure due to fatigue rather than explosions, some mills are removing them, and some new installations are built without rupture discs on the transport lines.

The collection of NCG from continuous sources is relatively straightforward. See Figure II. Care must be taken to insure that the vessels from which the gases are being collected are airtight and properly sealed. Each vessel should be protected by a pressure/vacuum breaker and by a flame arrester. Special attention must be given to overflow lines on these vessels. Overflow lines must be sealed, to insure that during an upset condition, pressure or vacuum is relieved through the pressure/vacuum breaker, rather than through the overflow line.

The collection of NCG from batch digesters is much more difficult, due to the cyclical nature of the gas flow. Between blows, there is virtually no NCG flow. At the start of a blow, there is a momentary high flow. As the blow progresses, this flow drops off until it reaches zero flow at the end of the blow. In many cases, there is another small peak flow at the end of the blow when the digester blows clean.

In the past, these variations in flow were smoothed out using a gas holder of either a

diaphragm or inverted-bell type. These gas holders were expensive to build and troublesome to maintain. In modern NCG systems, gas holders are no longer required, except in rare situations.

Blow steam condensing systems should be operated under positive pressure at all times, to prevent ingress of air into the system. If air gets into the accumulator and condensers, it becomes part of the NCG to be collected. The result is a very high NCG flow, and a decrease in condenser efficiency at the start of the blow, invariably leading to venting of steam and NCG. See Figure III. Pressure is maintained in the system by use of pressure control on the NCG discharge line from the condensers, or by pressure control between the primary and secondary condensers. Padding steam is also added to the accumulator, blow tank or condensers between blows to keep the pressure and temperature up.

It is essential that the blow steam condensing system be properly sized and operated. If this is not done, very little NCG from the batch digesters will be collected.

Pressure relief is also required on the NCG line. This will prevent large quantities of steam from entering the NCG system and overloading the ejector system if the blow steam condensing system fails.

Batch gases must be kept separate from continuous NCG sources until at least downstream of the ejectors. If this is not done, the pressure swing in the batch gas line will upset the smooth flow of the continuous gases, causing frequent venting of the continuous gases.

Figure IV shows a concentrated NCG transport system.

Another consideration in the design of NCG systems is the condensate formed 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. Low point drains and separators are also required. The condensate formed is very foul. The Cluster Rule requires that these condensates be collected and treated.

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

Vent lines should not terminate in elbows, or have caps on the discharge. Water build-up in the vent line, due to rainfall or condensate, can be removed through sealed drain lines.

The motivating steam ejectors should be as close to the point of incineration as possible. A separator or mist eliminator is used after the ejector to remove any water droplets or 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 is not available for incineration, the gases should be safely vented upstream of the incineration point.

### **SCRUBBING NCG**

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<sub>2</sub> emissions if the NCG are burned in a boiler, or an incinerator. In mills where NCG are burned in lime kilns, the SO<sub>2</sub> formed may contribute to ring formation in the kiln. Scrubbing the NCG may alleviate this problem.

Scrubbing is normally done in packed columns, or spray columns, using either a caustic solution, or white liquor for scrubbing. The polar sulfur gases, H<sub>2</sub>S and CH<sub>3</sub>SH, are

removed from the NCG by a chemical reaction, while the non-polar gases, CH<sub>3</sub>SCH<sub>3</sub> and CH<sub>3</sub>SSCH<sub>3</sub> are removed by physical absorption.

If hot white liquor is used for scrubbing, the absorption of H<sub>2</sub>S and CH<sub>3</sub>SH is favored. However, the NCG is heated up, and must be sent to a gas cooler to reduce the gas volume and reduce condensation in the line. If cooled white liquor is used, the absorption of CH<sub>3</sub>SCH<sub>3</sub> and CH<sub>3</sub>SSCH<sub>3</sub> is favored. However, the heat exchanger used to cool the white liquor is often subject to severe scaling.

There are also specialized chemicals on the market that are designed to scavenge the TRS from NCG. These have proven very effective. However, their high cost excludes their use on a continuous basis, but they have been successfully used as a backup for TRS reduction when incineration is not available.

Depending on the scrubbing media used, and the NCG streams scrubbed, overall TRS removal efficiencies from as low as 40% to as high as 99% have been reported, although overall TRS removal of about 70% is typical.

### **DILUTE NCG (HIGH VOLUME, LOW CONCENTRATION) SYSTEMS**

Sources of dilute NCG are brownstock washer hoods and seal tanks, knotter hoods, liquor storage tanks, brownstock storage tanks, slakers, mud filters, causticizers, and black liquor oxidizers.

As with concentrated NCG, the total volume of dilute NCG to be handled varies greatly. Flows of between 10,000 to 30,000 ft<sup>3</sup> per ton (300 to 900 m<sup>3</sup>/tonne) of pulp are typical. Brown stock washer hoods on vacuum drum washers are the largest single source of dilute NCG. It is necessary to properly seal the washer hoods to the vats, and to train

operators to always keep the inspection doors closed. Suppliers are developing better fitting hoods to keep the washer hood gases to a minimum. Design volumes are now about 1000 cfm per drum.

Recirculating seal tank vents back to the washer hoods in order to reduce volumes has been successfully done. This reduces the volume to be collected here by about half.

Similarly, air for air doctors should be taken from the hood, thus recirculating this air and further reducing the volume.

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

Large, flat top storage tanks are another problem. In most cases, they were never designed to take any pressure or vacuum. When they are tied into a collection system, they will be subjected to either a pressure or a vacuum (or both from time to time). Safe design here is a real challenge.

Gases in this category are normally outside the explosive range due to low concentration of TRS (see point F on Fig. 1). Dilute NCG are usually mixed with air to further dilute them, transported in a common pipe line, and motivated with either a fan or a steam ejector.

In instances where dilute NCG are hot and saturated with moisture, coolers are used to reduce their volume and moisture before the fan or ejector. Heaters can be used to raise the dilute NCG above the saturation temperature and thus prevent condensation in the transport lines.

Under no circumstances should concentrated NCG be added to dilute NCG, especially a concentrated NCG stream that may contain considerable quantities of turpentine vapor.

As in the case of concentrated NCG systems, the pipelines for dilute NCG systems should be properly sloped and

drained. If a fan is used, a moisture separator should be installed upstream of the fan suction. If an ejector is used, a moisture separator should be installed on the ejector discharge.

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

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

## **CHIP BIN GAS SYSTEMS**

The gases from continuous digester chip bins (steamers) are really dilute NCG, but because they can contain large amounts of turpentine and TRS, they should be treated before transported or added to a dilute NCG system.

The Cluster Rule requires the NCG from chip bins to be collected if flash steam is used for steaming. Collection is not required if fresh steam is used for steaming.

Collection of chip bin NCG is illustrated in Figure VI. Chips are steamed in the chip bin to 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 chips due to low chip bin level. In any case, 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 2 lb. of turpentine per ton ( 1kg/tonne) of pulp from chip bin gas.

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. At temperatures as low as 87°F (30°C) and atmospheric pressure, the vapor pressure of the alpha-pinene fraction of turpentine is high enough to create an explosive mixture. Therefore, dilution air must be added to ensure a safe mixture is being transported. The use of cold water to recover turpentine can cause the temperature of the condensate going to the decanter to be too low for good decanting. In this case, it may be necessary to reheat the condensate before it goes to the decanter.

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

### **STRIPPER OFF (SOG) GAS SYSTEMS**

In most cases, the stripper off gas is removed as a mixture of 50% methanol and 50% water, by weight, at about 210°F (99°C). This stream, due to its high temperature and water content, must be transported separately as a concentrated NCG system (see Figure VII). The stripper typically runs under pressure, so an ejector is not required for motivation. It is necessary to insulate and heat trace the gas line in order to prevent condensation.

It is 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 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.

### **BURNING NCG**

In order for NCG to be properly destroyed by combustion, three conditions must be met. These are:

- Temperature of 1200°F (650°C)
- Residence time of 0.5 sec.
- Excess oxygen (O<sub>2</sub>) content of 3-4%

It should be noted that the Cluster Rule requires a temperature of 1600°F (871°C) and a residence time of 0.75 seconds in order to ensure destruction of other Hazardous Air Pollutants in the NCG.

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 1200°F (650°C), then reducing retention time, and/or lowering excess oxygen content, will still provide good TRS 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 places in a pulp mill where these conditions exist. These are the lime kiln, power boiler, and recovery boiler. A dedicated separate incinerator can also be used to burn NCG.

### **Lime Kiln**

The lime kiln has traditionally been the first choice for burning NCG. It has the advantage that most of the SO<sub>2</sub> 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<sub>2</sub>. Figure VIII shows the effect of excess O<sub>2</sub> levels on TRS emissions from a lime kiln. An overloaded kiln is not very effective at TRS destruction.

Modern high efficiency kilns are designed to run at about 0.5% excess oxygen. This is normally not enough O<sub>2</sub> 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, formation of kiln rings.

The concentrated NCG are normally introduced into the kiln through a separate nozzle, mounted on the kiln hood. 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.

The NCG gases absorb light in the UV range, and can give a false flame out signal if they pass in front of an UV flame detector. Therefore, the NCG nozzle should be placed well away from the flame detectors.

The dilute NCG are not normally burned in the lime kiln due to their large volume. If burned in the kiln, they are used as primary air and introduced either on the suction or discharge of the F.D. fan. However, in most cases, the volume of dilute NCG is larger than the kiln primary air flow, and thus the kiln cannot be used.

### **Power Boilers**

Boilers are becoming more popular as incineration points for places to burn NCG, as this point is relatively trouble free. However, burning NCG in a boiler will increase the boiler SO<sub>2</sub> emission, creating another environmental problem. Further, if the back end of the boiler is too cold (under about 320°F (160°C)) then H<sub>2</sub>SO<sub>3</sub> acid precipitation can occur, and severe corrosion may result.

Studies have shown that considerable amounts of SO<sub>2</sub> are absorbed on the ash from coal or bark, if either of these fuels are

used in the boiler. This can reduce the SO<sub>2</sub> emitted from the burning of NCG.

The concentrated NCG are 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 bend some water wall tubes in order to place the nozzles.

Often, the NCG flow is 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 on one side.

The dilute NCG are normally introduced to the boilers as part of the primary air, either before or after the primary air fan. Care must be taken when adding or removing the dilute NCG flow to the boiler, in order to prevent upsets in air flow 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<sub>2</sub>S in the smelt.

However, due to the nature of the recovery boiler, its importance in the recovery cycle, and the potential for catastrophic explosion due to water entering the unit during operation, or explosive gas build-up during shut down, the recovery boiler is generally not recommended as a place to burn NCG.

The Black Liquor Recovery Boiler Advisory Committee (BLRBAC) has recently 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](http://www.blrbac.com).

A few mills have tried burning concentrated NCG in recovery boilers, and have been

successful in doing so. With respect to dilute NCG, several mills are now doing this, and there is a trend to accepting this practice.

### **Incinerators**

It is now 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 one mill has successfully used a flameless oxidizer.

The major disadvantage of the incinerator is its high capital and operating cost. At present, few mills use an incinerator as a primary source of NCG incineration, although there appears to be a trend to do this. Several use incinerators as a backup to the primary point of incineration. Due to the SO<sub>2</sub> emission, in most cases the incinerator is followed by an SO<sub>2</sub> scrubber, adding further to the capital and operating costs.

Another byproduct of incineration is sulfuric acid mist (SAM), which can give high opacity.

Recently, some mills have added package boilers to the incinerators to recover the heat from incineration as low pressure steam.

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, reducing the incinerator operating cost, by supplying most of the fuel requirement.

However, SOG also contains ammonia, which can give high NO<sub>x</sub> emissions from incinerators.

In some cases, if the incinerator combustion air flow is greater than the dilute NCG flow, it is possible to burn the dilute NCG in the incinerator, although this is not normally done.

At least two mills are successfully using a Regenerative Thermal Oxidizer (RTO) to incinerate dilute 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 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 Cluster Rule requires an uptime of 99% for burning concentrated NCG. It is virtually impossible to do this unless there are two points for NCG incineration.

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

A final factor to consider is human nature. Few operating superintendents are willing to accept the responsibility of handling and burning NCG gases.

### **IMPACT**

Installation and operation of NCG systems has an impact on the rest of the mill operation. The largest impact usually comes from the digester blow heat recovery system. It is necessary for the blow heat system to collect and condense all the blow steam. Consequently, steam and methanol that was previously vented, are now recovered as hot foul condensates. The recovered heat must be reused or discarded.

Many mills are now using recovered blow heat to pre-evaporate black liquor, while others install cooling towers to get rid of it. Also, the methanol collected can increase the B.O.D. load to the effluent treatment system, forcing mills to add aeration capacity, or install foul condensate strippers.

Capturing and burning the reduced sulfur gases in the kiln, or scrubbing the SO<sub>2</sub> formed with white liquor, will increase the liquor sulfidity, and that may upset the mill sulfur balance, necessitating a change in mill makeup chemicals, away from saltcake, and toward caustic soda or sodium carbonate.

There is a new process available that will convert the TRS in NCG directly to sulfuric acid, which can be used to cut tall oil. This will help the overall mill sulfur balance.

It may be necessary to update and improve the operations of the turpentine recovery system, and 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 acceptable with NCG collection.

Finally, places where NCG are burned can no longer be looked upon as production devices only. 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 air pollution from Kraft pulp mills, environmental regulations require that noncondensable gases containing reduced sulfur gases be collected and incinerated. These gases are very corrosive, highly toxic, and if mixed with air, potentially explosive. Consequently, great care must be taken in the design, construction, operation and maintenance of these systems.

Fortunately, the technology exists to build noncondensable gas systems that are safe, efficient and reliable.

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**TABLE I**  
**Concentrated NCG Typical Analysis**  
**Normal Operation**

Source	%TRS (Vol)			%O <sub>2</sub> (Vol)		
	Min	Avg	Max	Min	Avg	Max
Batch Digester	20	50	70	0.5	2.0	5.0
Continuous Digester	12	60	80	1.0	3.0	10.0
Turpentine (Batch)	0.1	2.0	10	4.0	12.0	20.0
Evaporator	1.0	60	70	1.0	5.0	8.0
Combined	10	50	65	2.0	3.0	6.0

**Note:** The balance of the gas will be nitrogen

**TABLE II**  
**Combustion Properties of NCG in Air**

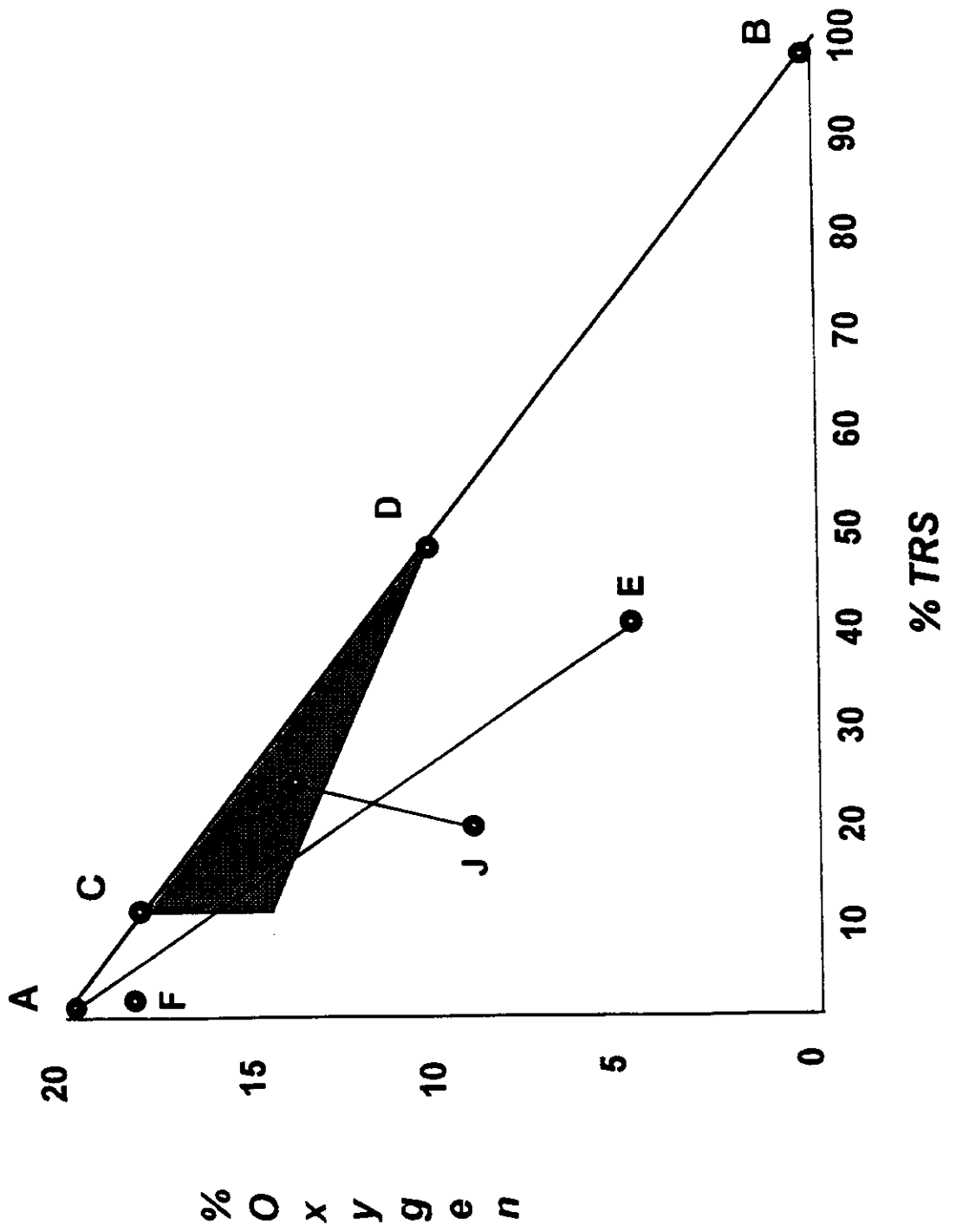
	Explosive Limits		Flame Speed ft/sec (m/sec)	Auto Ignition Temp °F (°C)
	Lower (Volume %)	Upper (Volume %)		
H <sub>2</sub> S	4.3	45.0		500 (260)
CH <sub>3</sub> SH	3.9	21.8	1.8 (0.55)	
CH <sub>3</sub> SCH <sub>3</sub>	2.2	19.7		400 (206)
CH <sub>3</sub> SSCH <sub>3</sub>	1.1	8.0		572 (300)
Alpha-pinene	0.8	6.0	500 (154)?	487 (253)
Methanol	6.7	36.5	1.5 (0.50)	867 (464)

**TABLE III**  
**Concentrated NCG Volumes**

Source	Ft <sup>3</sup> /Ton Pulp	m <sup>3</sup> /Tonne Pulp
Batch Digester	100 - 200	2.6 - 5.2
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 140°F and saturated with H<sub>2</sub>O.

# Figure I Explosive Range of NCG



**Figure II NCG Collection - Continuous Source**

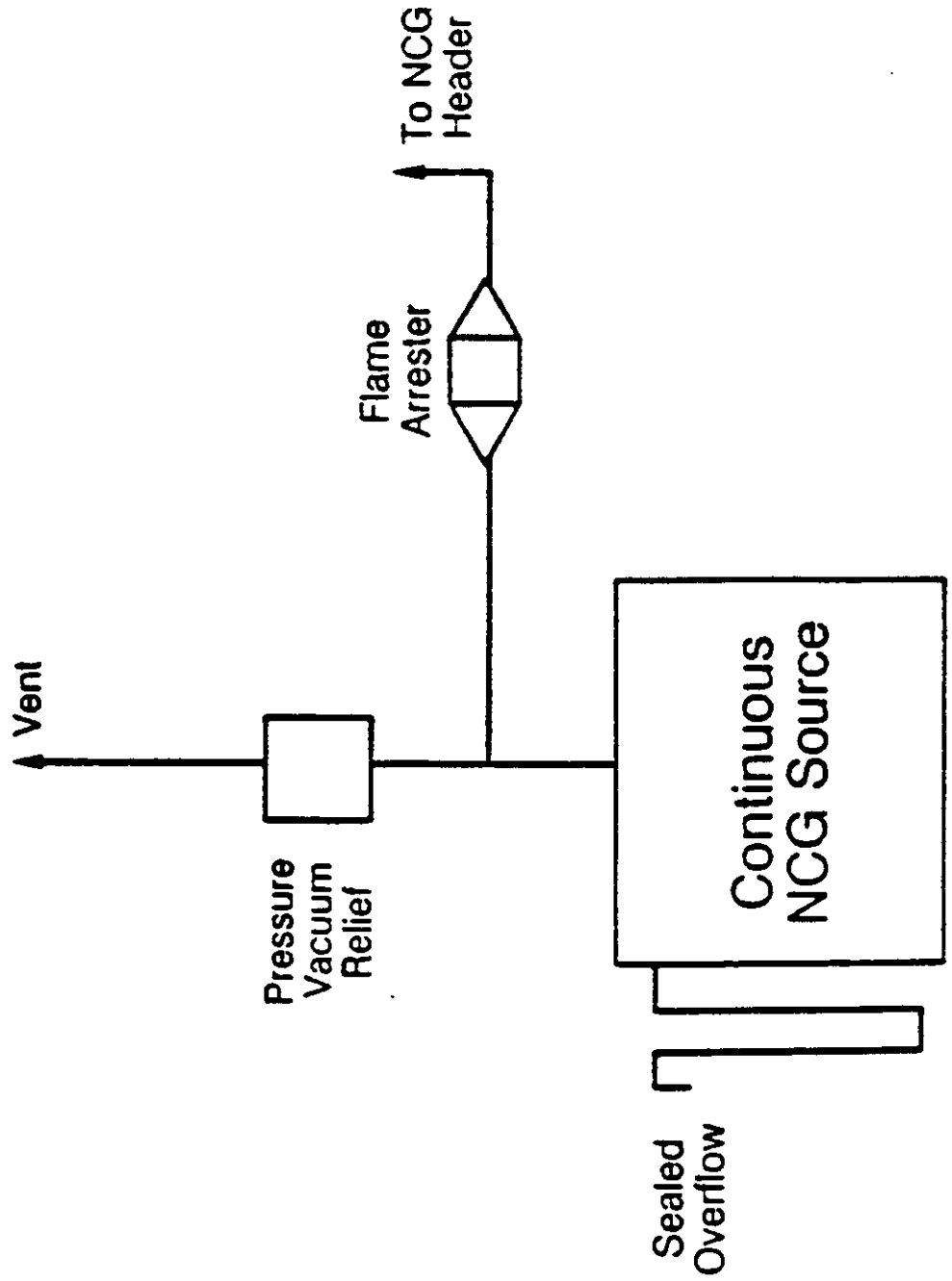


Figure III *NCG Collection - Batch Gases*

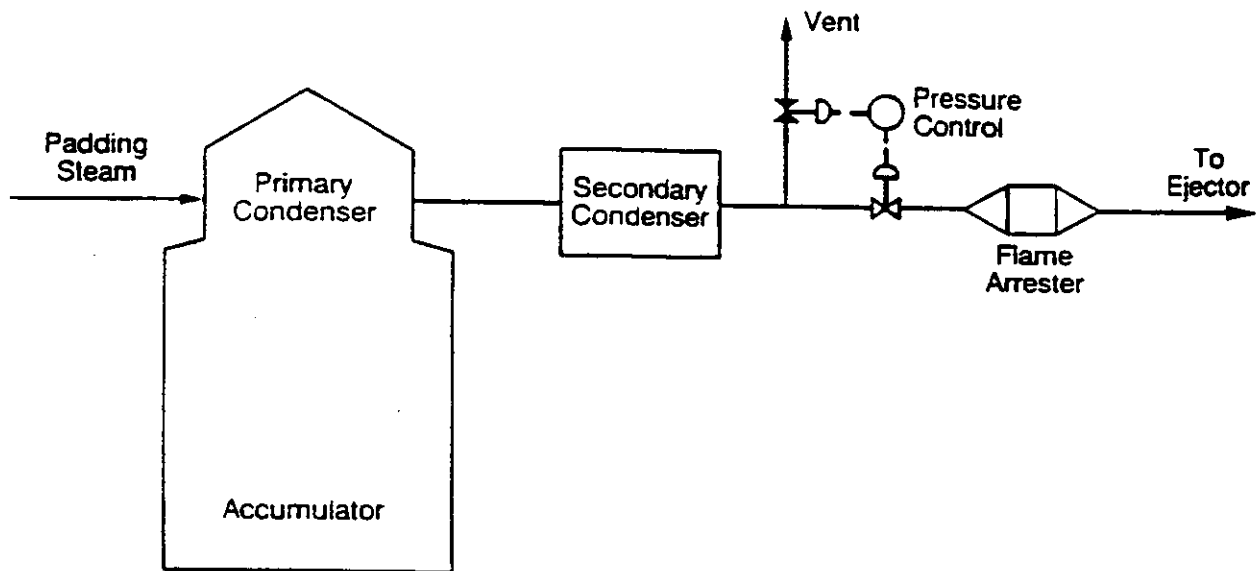
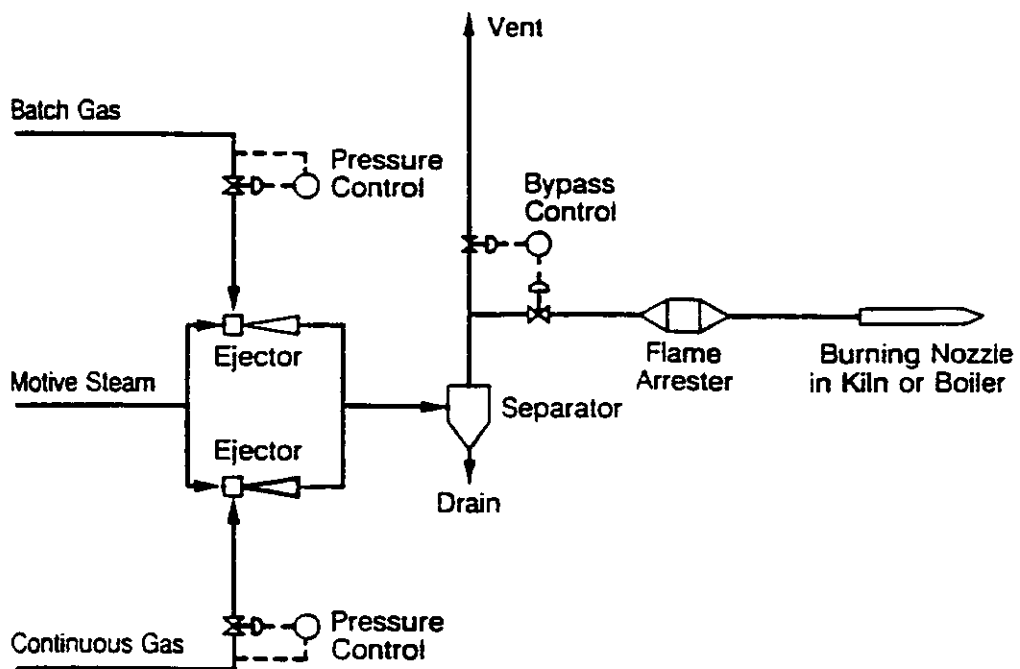
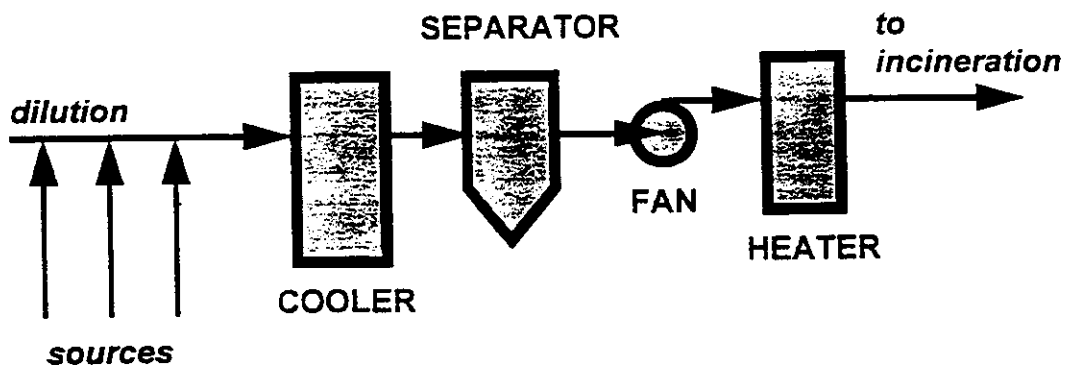


Figure IV *HCLV NCG Transport*

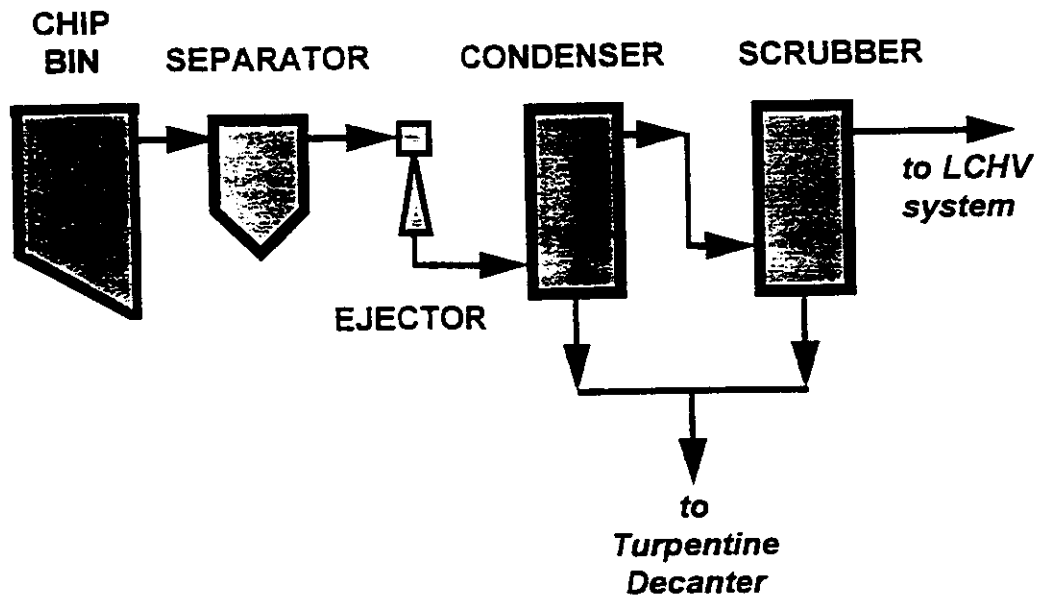




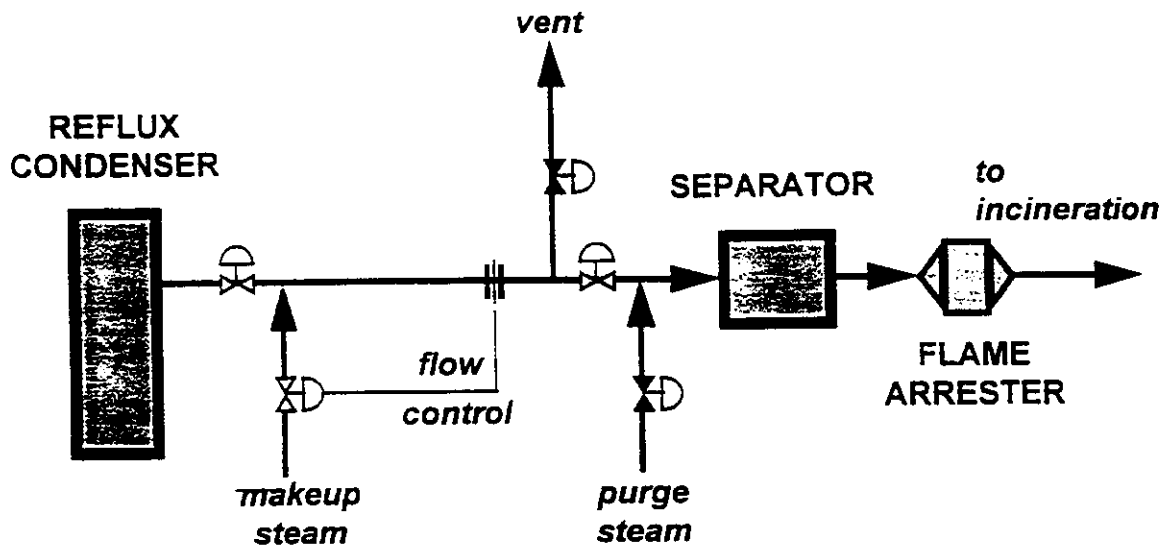
**Figure V LCHV System**



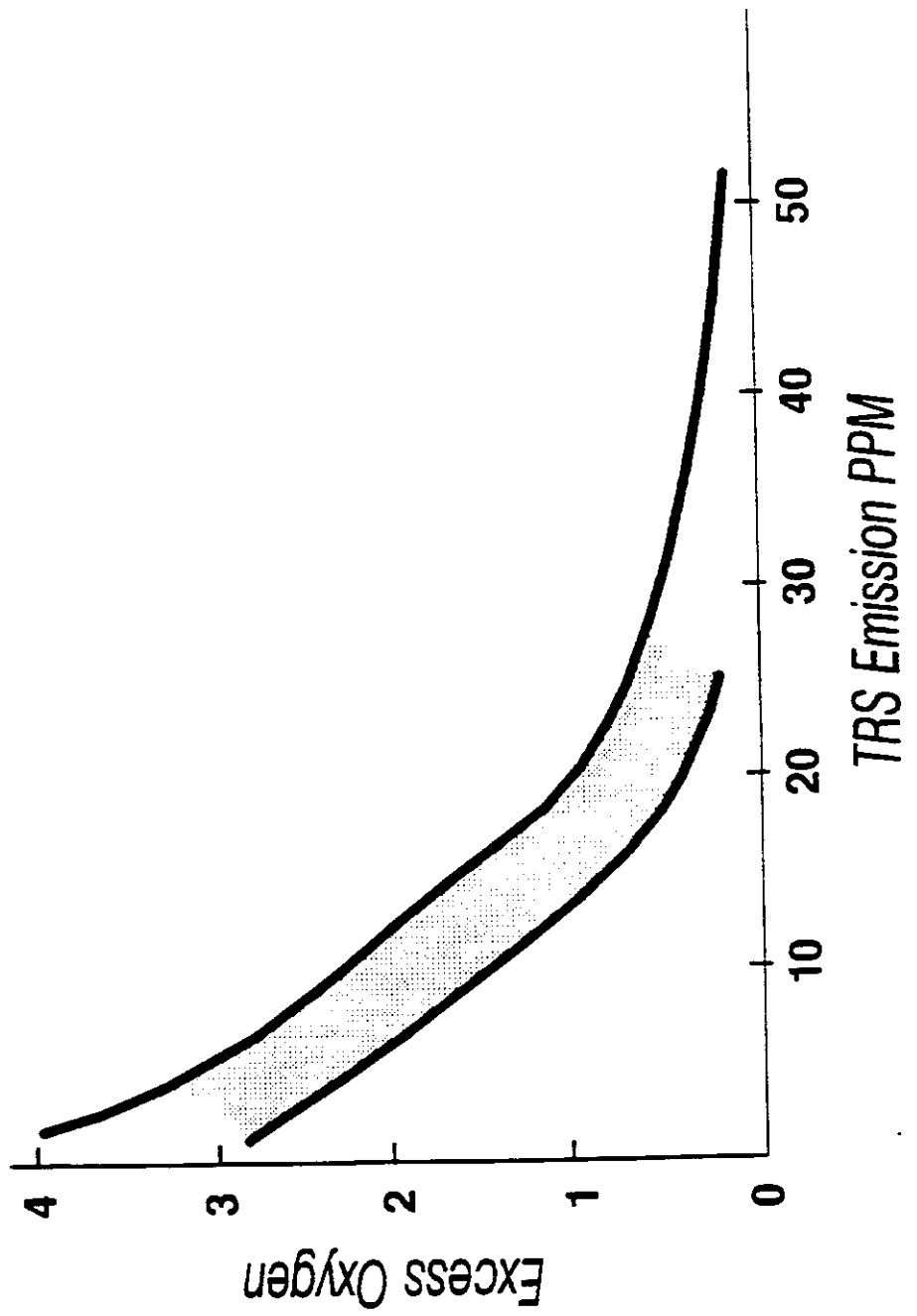
**Figure VI Chip Bin System**



**Figure VII** *Stripper Gas System*



**Figure VIII** Effect of Lime Kiln Excess Oxygen  
On Lime Kiln TRS Emissions



# **COLLECTING AND BURNING NONCONDENSIBLE GASES**

**TOM BURGESS**

**SENIOR MANAGER  
ENVIRONMENTAL TECHNOLOGY  
GEORGIA PACIFIC CORPORATION  
ATLANTA, GEORGIA**

## **TOTAL REDUCED SULFUR (TRS)**

<b>Hydrogen sulfide</b>	<b>H<sub>2</sub>S</b>
<b>Methyl Mercaptan</b>	<b>CH<sub>3</sub>SH</b>
<b>Dimethyl Sulfide</b>	<b>CH<sub>3</sub>SCH<sub>3</sub></b>
<b>Dimethyl Disulfide</b>	<b>CH<sub>3</sub>SSCH<sub>3</sub></b>

## **TYPES OF NCG SYSTEMS**

- **Low Volume, High Concentration (LVHC)**
- **High Volume, Low Concentration (HVLC)**
- **Chip Bin Gas**
- **Stripper Gas**

## **CONCENTRATED TRS SYSTEMS**

**Low Volume, High  
Concentration (LVHC)  
Systems**

## OTHER COMPONENTS OF NCG

Turpentine  
Methanol  
Water Vapor  
Nitrogen  
Oxygen

## NONCONDENSIBLE GAS ANALYSIS TYPICAL DATA

	<u>Avg</u>	<u>Min</u>	<u>Max</u>
% TRS	47	30	70
% H <sub>2</sub> O	6	4	10
% O <sub>2</sub>	3	0	20
% N <sub>2</sub>	44	14	78

NCG  
is

**CORROSIVE**

**MATERIALS OF  
CONSTRUCTION**

- **Mild Steel Corrodes Quickly**
- **FRP Experience is Mixed**
- **300 Series Stainless Steel Works Well**

NCG  
is

T   IC

**VENTS**

**Make them**

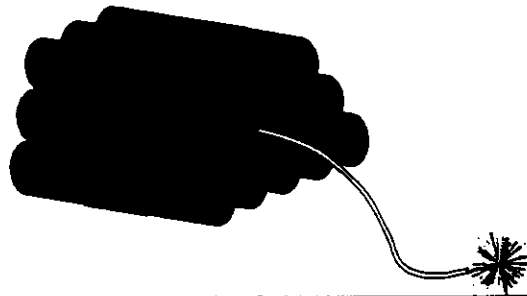
**HIGH**





NCG  
is

**EXPLOSIVE**



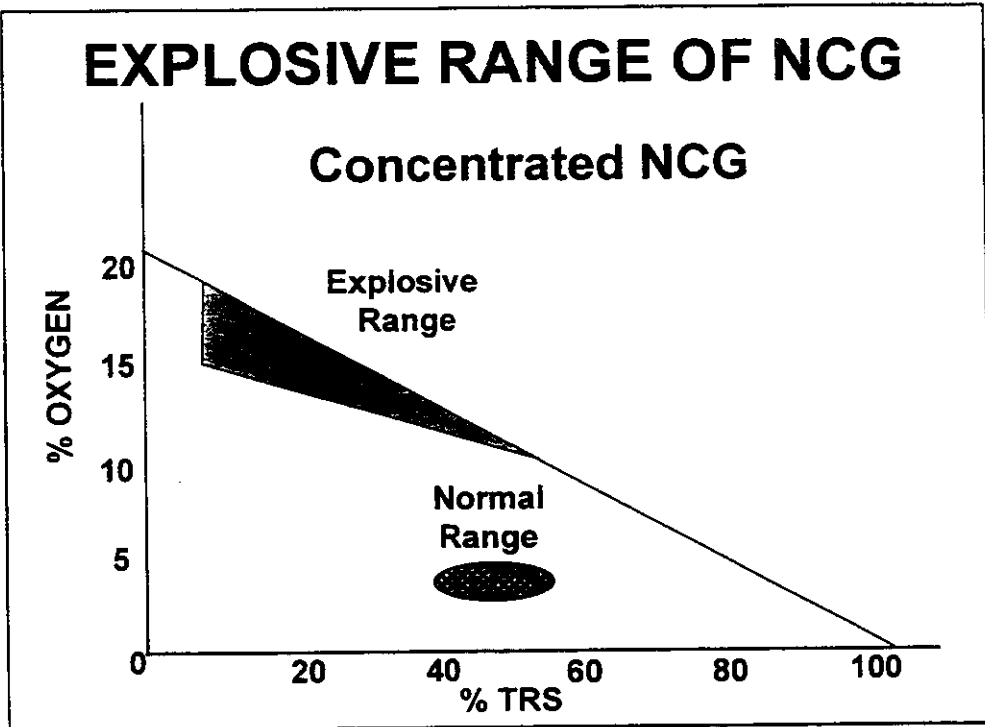
## COMBUSTION PROPERTIES

	FLAME SPEED	
	m/s	ft/s
H <sub>2</sub> S	-	-
CH <sub>3</sub> SH	0.55	1.8
MeOH	0.50	1.6
Alpha Pinene	150?	490?

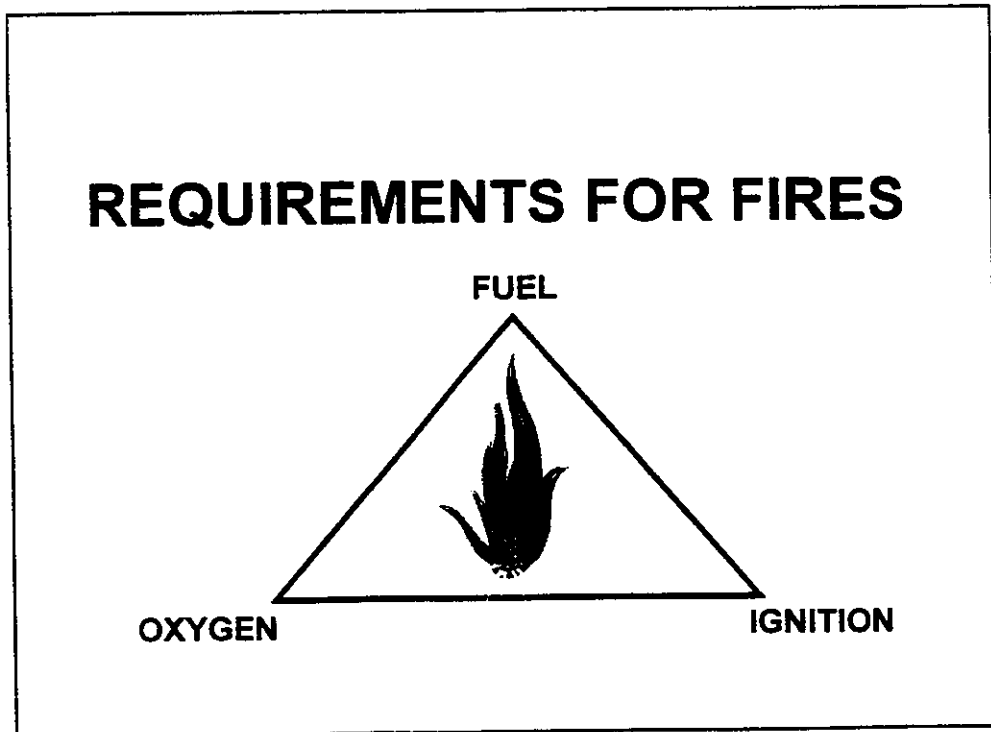
## COMBUSTION PROPERTIES

	LEL	UEL
H <sub>2</sub> S	4.3%	45.0%
CH <sub>3</sub> SH	3.9	21.8
MeOH	6.7	36.5
Alpha Pinene	0.8	6.0
TRS	2.0	50.0

## EXPLOSIVE RANGE OF NCG

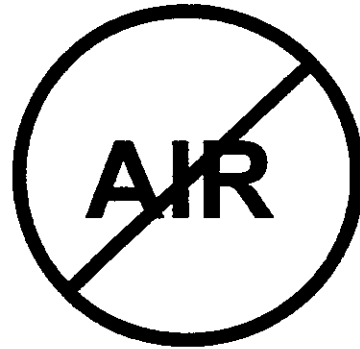


## REQUIREMENTS FOR FIRES



## **SAFE DESIGN**

**KEEP THE  
AIR OUT**



## **ELIMINATE IGNITION SOURCES**



**ELIMINATE IGNITION SOURCES**



**ELIMINATE IGNITION SOURCES**



## **CONCENTRATED NCG VOLUMES**

<b>SOURCE</b>	<b>ft<sup>3</sup>/ton</b>	<b>m<sup>3</sup>/tonne</b>
Batch Digester	100-200	2.6 - 5.2
Continuous Digester	150-300	3.9 - 7.7
Turpentine System	40 - 80	1.0 - 2.0
Evaporator Hotwell	50 - 200	1.3 - 5.2

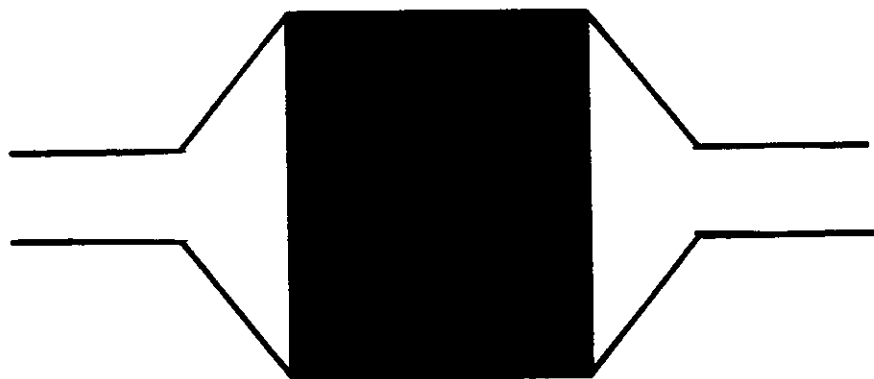
## **NCG EQUIPMENT**

- **FLAME ARRESTORS**
- **PRESSURE/VACUUM RELIEF**
- **RUPTURE DISCS**
- **MIST ELIMINATOR**
- **STEAM EJECTORS**
- **INJECTION NOZZLES**
- **CONTROL/DIVERT VALVES**

## **FLAME ARRESTERS**

- **PREVENTS SPREAD OF FIRE**
- **LOCATED AT EACH SOURCE AND AT EACH INCINERATION POINT**

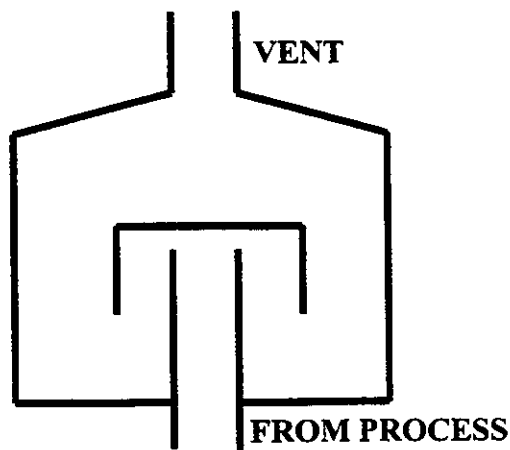
## **FLAME ARRESTERS**



## **PRESSURE/VACUUM RELIEF VALVE**

- **PROTECT VESSEL**
- **PREVENT AIR INGRESS**

## **PRESSURE/VACUUM RELIEF VALVE**





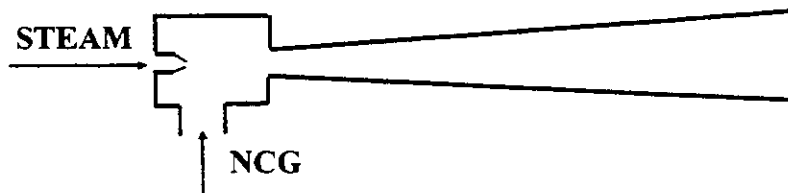
## **RUPTURE DISCS**

- **PROTECT LINE AGAINST EXPLOSION**
- **CARBON (GRAPHITE) OR STAINLESS STEEL**
- **SHOULD BE FULL LINE SIZE**
- **AT 100 FOOT INTERVALS**
- **MAY BE MONITORED**

## **MIST ELIMINATOR**

- **REMOVES WATER DROPLETS BEFORE INCINERATION**
- **NORMALLY HAVE VANE TYPE INTERNAL DESIGN**
- **MUST DRAIN PROPERLY**

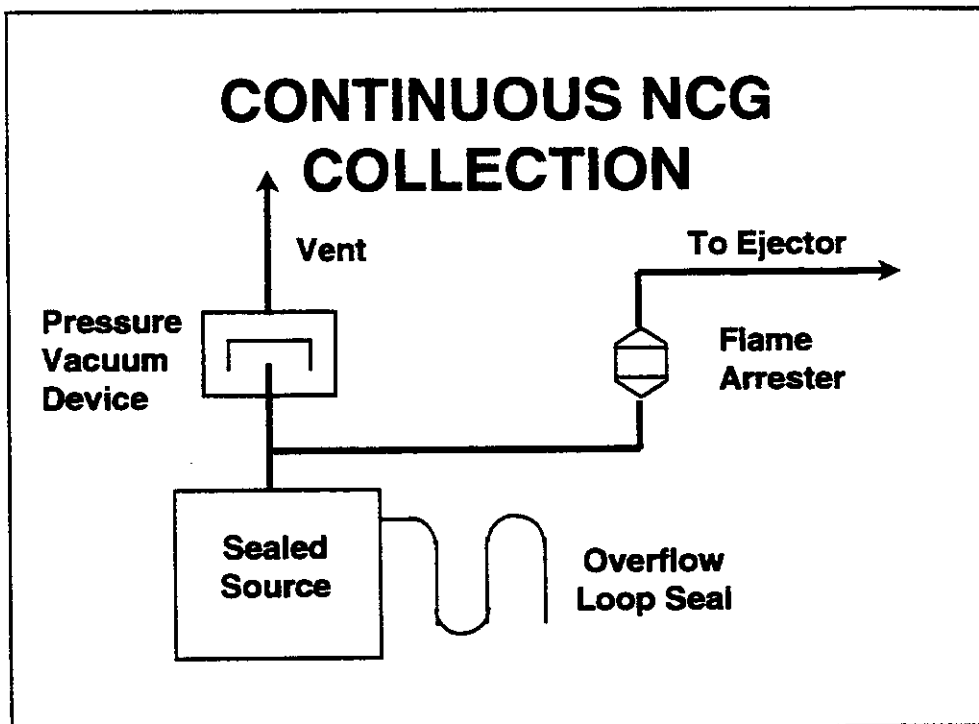
## STEAM EJECTOR



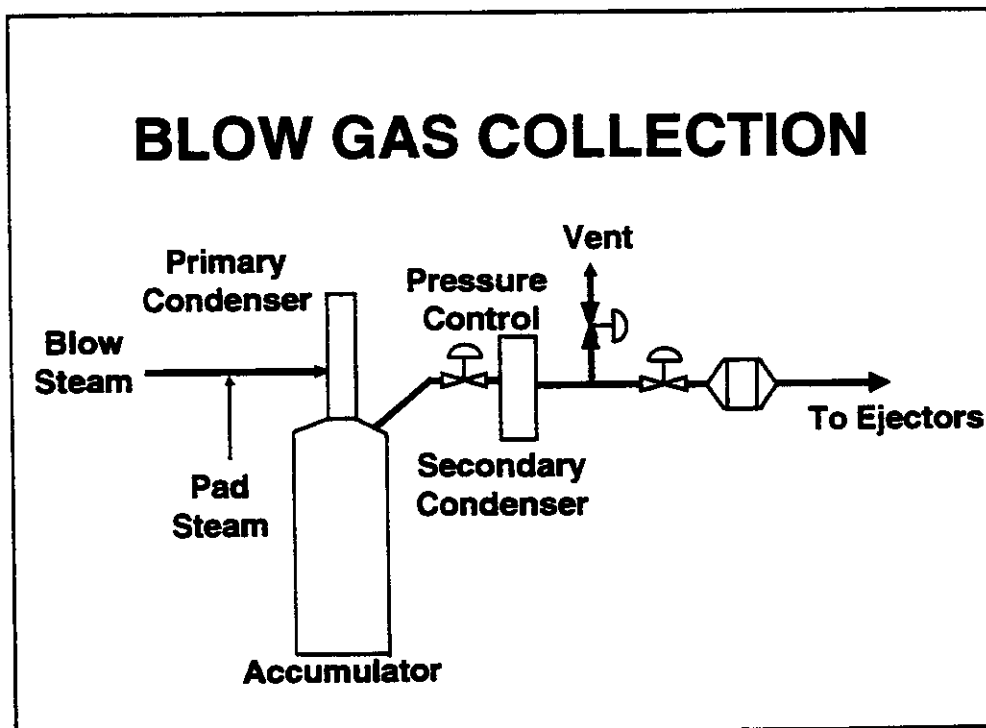
## INJECTION NOZZLE

- FORCES NCG INTO INCINERATION
- IT IS NOT A BURNER
- SHOULD BE COOLED TO PREVENT DAMAGE WHEN NOT IN USE

## CONTINUOUS NCG COLLECTION



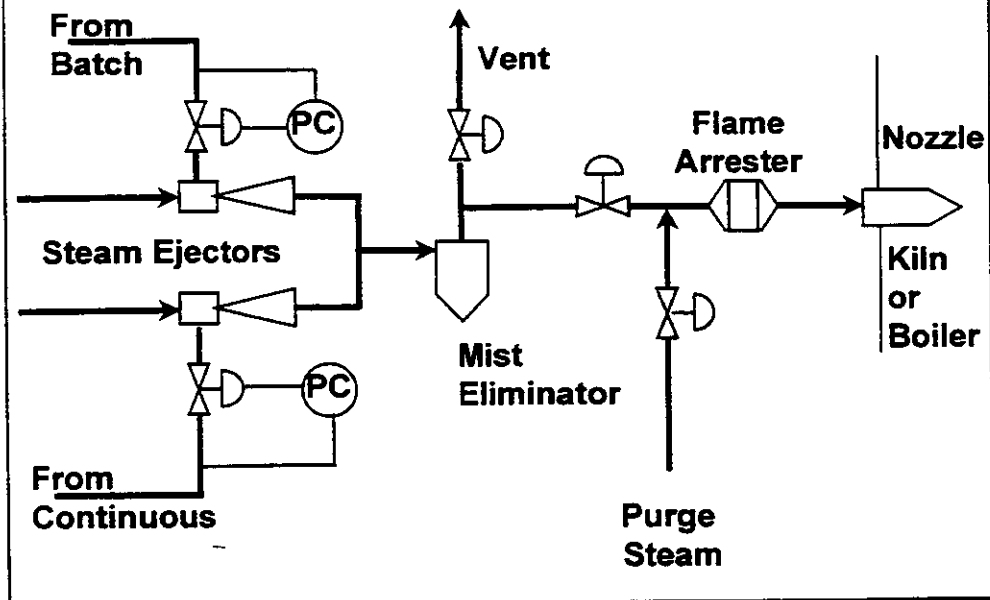
## BLOW GAS COLLECTION



# BATCH DIGESTERS

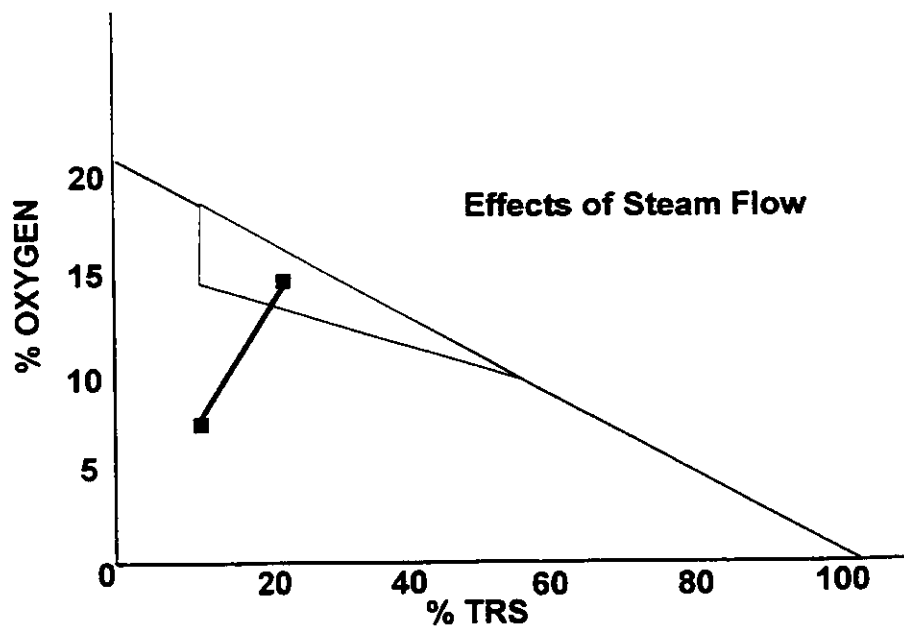
Blow Steam Condensers  
Must Work Properly

## NCG COLLECTION



**CONTINUOUS AND  
BATCH NCG SOURCES  
MUST BE SEPARATED**

**EXPLOSIVE RANGE OF NCG**



## **MURPHY'S LAW**

**If Anything Can Possibly Go  
Wrong, Sooner Or Later,  
It Will Go Wrong**

## **LEVELS OF PROTECTION**

1. Keep Air Out
2. Eliminate Ignition Sources
3. Line Protection
  - Flame Arresters
  - Rupture Discs

## **SCRUBBING NCG**

- **Reduces SO<sub>2</sub> Emissions**
- **Reduces Kiln Rings**
- **Reduces TRS During Venting**

## **SCRUBBING NCG**

- **Alkaline Solution**
- **White Liquor**
- **Specialty Chemical**

## **BURNING NCG**

### **MINIMUM CONDITIONS FOR BURNING NCG**

- **TEMPERATURE 1600°F (870°C)**
- **RESIDENCE TIME 0.75 SEC.**
- **EXCESS OXYGEN 3 - 4 %**



## **EQUIPMENT FOR BURNING NCG**

- Lime Kiln
- Power (Bark) Boiler
- Recovery Boiler
- Incinerator

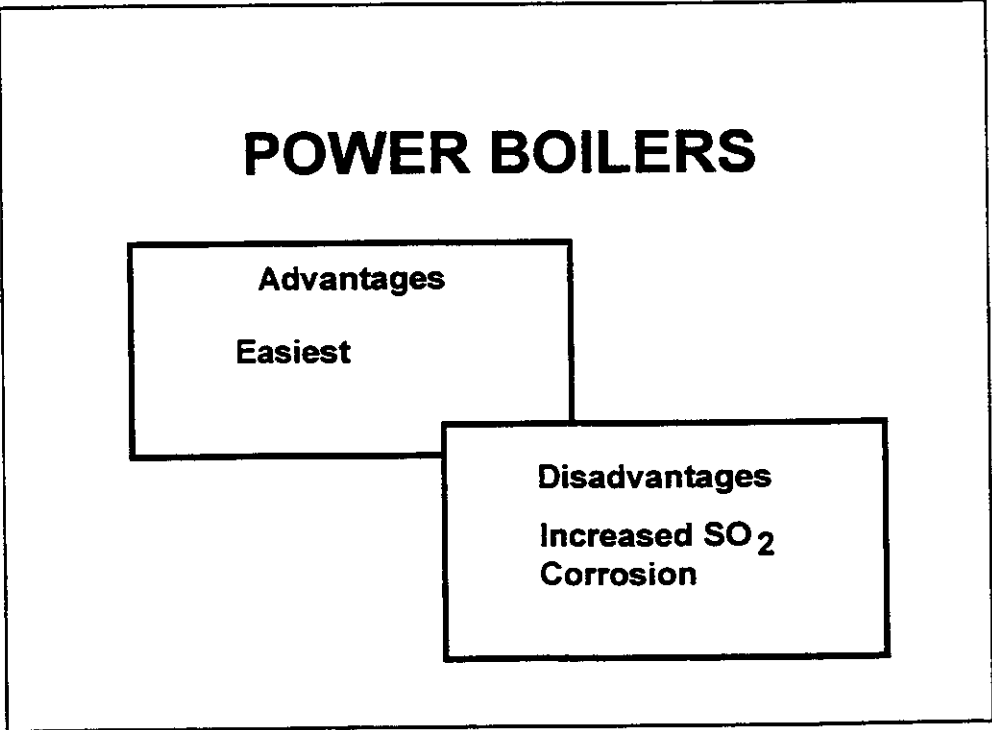
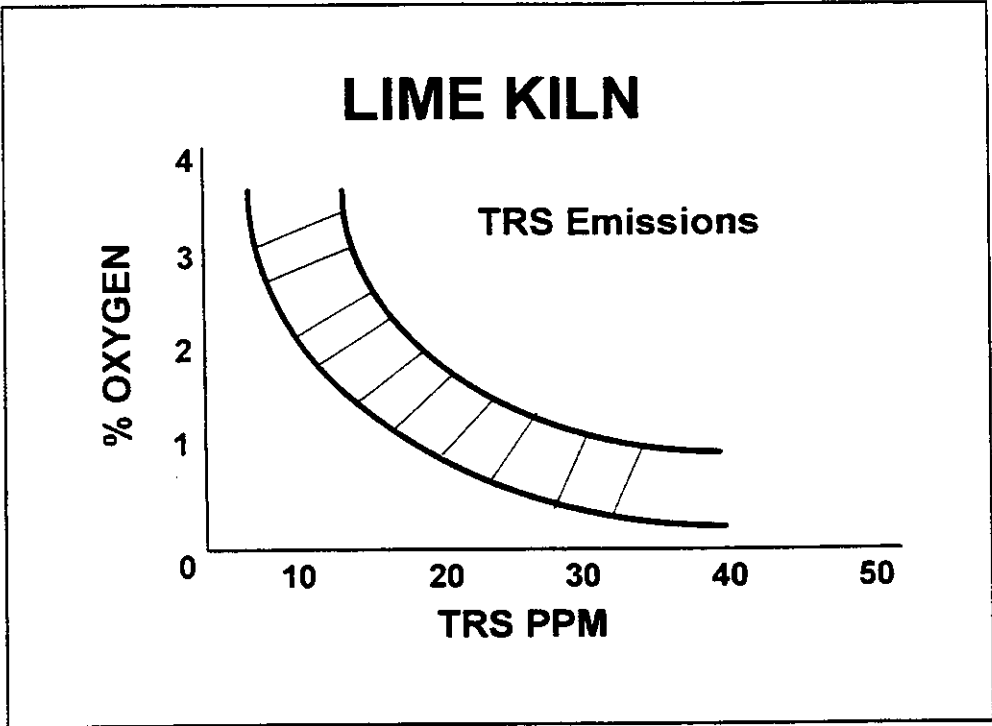
## **LIME KILN**

### **Advantages**

**Traditional  
Recovers SO<sub>2</sub>**

### **Disadvantages**

**Inefficient  
Ring Formation**



## **POWER BOILERS**

**Ash from Coal and  
Bark Absorbs SO<sub>2</sub>**

## **RECOVERY BOILER**

**Advantages  
Theoretically Best  
Recovers Sulfur**

**Disadvantages  
Recovery Operators Do  
Not Like This Idea**

## **INCINERATOR**

**Advantages**  
**Least Risk**

**Disadvantages**  
**Expensive**  
**SO<sub>2</sub> Emission**

## **OTHER CONSIDERATIONS**

- **Bigger is better**
- **Uptime**
- **Distance**
- **Politics**

## **CLUSTER RULE**

- **Requires 99% uptime**
- **Downtime also allowed for “Startup, Shutdown and Malfunction”**
- **All vents must be monitored**

## **CONCLUSION**

**Safe, Reliable, and  
Explosion Free NCG  
Systems are Possible**