Environmental Projects for the Pulp and Paper Industry in the U.S.A.

Ms. Karra Nichols
Mr. David W. Keyser
A. H. Lundberg Associates, Inc.
P.O. Box 597
Bellevue, WA 98009

SUMMARY

U.S. pulp and paper mills have been actively upgrading their environmental systems in order to comply with new government regulations restricting emissions. These include noncondensible gas collection and incineration systems, as well as foul condensate treatment systems. A. H. Lundberg Associates, Inc. has played a key role in implementing these projects. Innovative techniques and processes for minimizing capital and operating costs have been developed. Such technology includes thermal oxidation of noncondensible gases in the recovery boiler, reduction in the quantity of collected dilute noncondensible gases, and efficient heat recovery in steam stripping systems. Methods for reducing natural gas usage in dedicated incinerators as well as waste heat boilers for heat recovery have also been implemented. The technology applied in U.S. projects can be utilized as well in Chile.

INTRODUCTION

The United States Environmental Protection Agency (EPA) promulgated their MACT I and MACT III Cluster Rule regulations in April of 1998 requiring the reduction of Hazardous Air Pollutants (HAPs) in both air and water emissions. As the leading process system vendor for environmental compliance systems, A. H. Lundberg Associates, Inc. was instrumental in providing innovative methods for the implementation of these processes and the reduction of energy costs associated with their operation. Similar process strategies may be applicable for implementation in Chile.

This paper presents an overview of several of the process systems installed to implement the regulations in a cost effective manner. Included are discussions of evaporator integrated condensate stripping systems, waste heat boilers on direct fired thermal oxidizers, methods for reduction in the volume of dilute gas collection flow, and thermal oxidation of dilute noncondensible gas in recovery boilers.

LOW VOLUME HIGH CONCENTRATION NCG

The MACT I Cluster Rules regulations required collection and disposal of low volume high concentration noncondensible gases (LVHC NCG) for all kraft pulp mills to be completed by April of 2001. LVHC NCG is defined by its concentration as being above the upper explosion limit. It contains TRS (Total Reduced Sulfur) compounds, including hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide, as well as VOC (Volatile Organic Compounds), particularly turpentine and methanol. Sources of LVHC NCG include turpentine recovery vents, blow heat recovery vents, evaporator sources, and continuous digester relief.

Lundberg Associates has been instrumental in the design and supply of LVHC NCG systems for U.S. mills. Various options and designs were provided in order to suit each mill's particular requirements. Potential incineration locations have included Lundberg Associates' direct fired thermal oxidizers with SO_2 scrubbing, recovery boilers, power boilers, lime kilns, and open flares. Each system was individually tailored to collect the required sources and to incinerate the gases to meet government specifications within three years of implementation of the Cluster Rules.

High Volume Low Concentration NCG

The compliance date for U.S. mills to collect and dispose of the high volume low concentration (HVLC NCG) is still more than four years away. However, many mills are actively pursuing their options for HVLC NCG systems in order to avoid a last minute rush to meet compliance. Even prior to implementation of the Cluster Rules, Lundberg Associates has played a key role in the design and supply of HVLC NCG systems to U.S. kraft pulp mills. Extensive experience with NCG systems has improved our knowledge so that we may more effectively collect, condition, and transport the HVLC NCG for incineration. Typical HVLC NCG sources include brown stock washer hoods, brown stock washer filtrate tanks, weak and strong black liquor storage tanks, soap skimming tanks, and knotter hoods. Also, washers, filtrate tanks, and blow tanks in oxygen delignification systems are collected as HVLC NCG sources. The potential incineration locations for HVLC NCG are the same as described above for LVHC NCG. Oftentimes, however, the large volume of HVLC NCG limits the possible incineration locations.

In particular, a direct fired thermal oxidizer (dedicated incinerator) can be designed specifically for the required HVLC NCG flow. Lundberg Associates uses the HVLC NCG as combustion and/or cooling air for the incinerator when LVHC NCG and stripper off gases are also being burned. Not only is the HVLC NCG thoroughly combusted, but an additional fan for ambient air is often no longer required. Using the HVLC NCG as combustion air also reduces the incineration chamber and subsequent equipment sizes.

Thermal Oxidation of Dilute NCG in Recovery Boilers

As the Cluster Rules have required combustion of NCG, U.S. pulp mills have been searching for existing incineration locations to minimize capital costs. Although formerly avoided, the recovery boiler has become a primary choice for HVLC NCG incineration. The recovery boiler offers several locations for disposal of the NCG, including through the tertiary air system or a dedicated burner. A. H. Lundberg Associates has developed a safe and effective method for HVLC NCG incineration in the recovery boiler based on BLRBAC (Black Liquor Recovery Boiler Advisory Committee) recommendations.

Because the gases are to be burned in the recovery boiler, Lundberg Associates' NCG systems incorporate a series of interlocks and gas conditioning features designed to exclude the potential for water to enter the boiler. These are in addition to the safety features and interlocks typically included for NCG incineration systems.

At a recent system installation, the dilute NCG was collected, conditioned, and transported to the existing recovery boiler for injection through a dedicated burner. Since the HVLC NCG flow was relatively small, 2,000 ACFM (3,400 m^3/hr), and LVHC NCG was to be burned as well, a dedicated burner was a logical choice. An independent natural gas fuel train was supplied for the burner to provide a continuous pilot.

Furthermore, the gases were conditioned prior to the burner to prevent moisture from entering the boiler. First, the HVLC NCG was cooled in an indirect contact gas cooler. This vessel not only removes moisture from the gases, but it reduces the gas volume, allowing for smaller line sizes and equipment downstream. Next, the gases were motivated to the boiler with a steam ejector. Although fans are typically used in HVLC NCG applications, a steam ejector was used in this case due to the low gas flow. The HVLC gases were heated to 250ºF (120°C) in a shell and tube steam heater to further reduce the possibility of condensation. Prior to the heater, an entrainment separator was installed to remove any remaining moisture droplets.

Additionally, the piping was arranged so a minimum elevation distance existed between the boiler NCG firing nozzles and the rupture disc located in the respective piping system. The rupture disc serves as a mechanical means of ensuring that a slug of condensate contained in the NCG cannot be pushed into the recovery furnace. By arranging the piping such that the elevation differential between the firing nozzle and the rupture disc is in excess of the rupture disc burst pressure, a minimum safety factor is built into the system.

Similarly, dilute NCG was injected into the recovery boiler at another Lundberg Associates' NCG system installation. The HVLC NCG was collected from the decker hood, a spill collection tank, and a blow tank. Additional sources are to be added in the future. The NCG was sent through a cyclone separator to remove any entrained liquor or fiber, although typically direct contact fiber scrubbers or chevron entrainment separators are preferred for fiber removal. The gases were then cooled in an indirect contact gas cooler, motivated via an HVLC NCG fan, and heated to 150°F (65°C) prior to incineration. Entrainment separators were installed as well to remove excess moisture from the NCG. The gases were injected into the boiler tertiary air windbox through five independent ports. The tertiary air forced draft fan was tied into the HVLC NCG line to the boiler to ensure sufficient gas flow through the nozzles. The HVLC NCG was injected into the recovery boiler in such a manner as to ensure that boiler operation was not affected.

This multiple nozzle configuration was ideal due to the phased approach of installing the HVLC NCG system. Since the mill only wanted to collect three HVLC NCG sources initially and then add additional sources in the future, the multiple boiler nozzles made it possible. The required velocity and pressure drop through the nozzles could be met by using any combination of nozzles. This configuration allowed the collected gas flow to vary while evenly distributing the gases at the tertiary air level.

Other dilute NCG system features that preclude the possibility for carrying moisture into the boiler include low point drains and sloped piping. Low point, entrainment separator, and cooler drains are necessary to effectively remove condensate from the NCG. Also, the NCG lines are sloped in order to facilitate draining and avoid any low points in the piping. Lundberg Associates' HVLC NCG systems are designed with multiple safety features to prevent the possibility of moisture from entering the boiler.

In order to effectively incinerate the dilute noncondensible gases in the recovery boiler, care should be taken to sufficiently condition the gases to be transported without the possibility for condensation or moisture carryover into the boiler.

METHODS FOR REDUCTION IN THE VOLUME OF DILUTE NCG

In dilute noncondensible gas systems, the problem of excessive quantities of NCG requiring collection often arises. The HVLC NCG sources are typically large tanks or hoods that are not well sealed, allowing excess air infiltration. Once these sources are collected into the NCG system, the smallest leak, opening, or hole will bring excess air into the system since the sources are operated under vacuum. Also, the potential for washer hood doors to be left open can add to the quantity of air that must be collected. This requires that downstream equipment and piping be sized for the excess conditions, otherwise inadequate collection occurs. Several methods and techniques have been developed to minimize the HVLC NCG flow, thus producing a more manageable, cost-effective system.

For example, some existing brown stock washer hoods are being replaced with new low-infiltration washer hoods. These limit the amount of air that is drawn into the hood. Another method of minimizing the air intake to brown stock washer hoods is through reconfiguration of the air doctor fans. Typically, air doctor fans draw in ambient air to the washer hood to separate the sheet from the drum. This method brings additional unnecessary air into the system. A. H. Lundberg Associates has overcome this problem by using dirty air for the air doctor fans. At one particular installation, air was recirculated directly from the washer hood to the air doctor fan. This simple configuration did not require extensive modifications. Often, air doctor fans must be replaced with stainless steel units due to the corrosive nature of the recirculated gases. In addition, an entrainment separator is recommended upstream of the fan to prevent moisture from potentially damaging the fan. The entrainment separator and any low point drains can be drained back to the respective washer hood or filtrate tank.

Alternatively, the vent from the brown stock washer hood's respective filtrate tank can also be used to provide air to the air doctor fan. This method, however, generally requires that the filtrate tank be able to withstand slight pressure and vacuum conditions. Pressure vacuum relief devices can be supplied to protect the filtrate tanks. These can be water sealed or mechanical type relief devices. Both of these methods allow the air doctor fans to operate without bringing excess air into the HVLC NCG system.

Similarly to reduce the total HVLC NCG flow, the brown stock washer filtrate tanks can be vented directly to their respective washer hood, rather than collected as a separate HVLC NCG source. This helps minimize the HVLC NCG collection system, because the air is circulated between the washer hood and the filtrate tank. In this instance, the filtrate tank requires some pressure tolerance in order to maintain the NCG flow to the washer hood.

Pressure and vacuum protection on the tanks collected into the HVLC NCG system is another important aspect that contributes to the HVLC NCG flow. If the tank is only rated for atmospheric conditions, it cannot be sealed and collected, as the source will be under vacuum. Aside from modifying the tank structure, the only way to collect the tank is to sweep air into it. This involves installing an air intake on the tank to allow for ambient air infiltration. This is a cost-effective way to collect the NCG from an atmospheric tank without structural modifications. If the air intake is too large, however, collection of the HVLC NCG becomes nearly impossible due to the large ingress of air. Fugitive emissions from the tank can often be seen. This problem can be reduced through the use of a flapper type device located on the air intake. As a very slight vacuum develops in the collected tank, the flapper door will open to allow air to enter and prevent excess vacuum while restricting flow.

Other modifications can be made to ensure pressure and vacuum protection at the sources. A. H. Lundberg Associates has supplied similar flapper door type devices to allow for ambient air infiltration or tank venting on a continuous digester blow tank. These weighted mechanical devices were designed to relieve at either 5” (130 mm) water column pressure or vacuum to protect the tank. The weights on the flapper doors can be modified to vary the relief settings.

Ultimately, any modification that can be made to limit the amount of air infiltration to the HVLC NCG system will help minimize the capital costs. This includes smaller line sizes, smaller equipment downstream, reduced fuel usage for incineration, and a minimal impact at the incineration point.

EVAPORATOR INTEGRATED FOUL CONDENSATE STRIPPING SYSTEMS

A. H. Lundberg Associates has supplied multiple foul condensate steam stripping systems since the mandate of the MACT I requirements to efficiently treat contaminated kraft mill foul condensates, particularly those from the digester and the evaporators. Each system has been designed to meet the specific requirements of the mill, as well as to provide compliance with the MACT I regulations. Several systems have been designed to generate steam for use within the mill, while others are integrated into an existing evaporator system as a primary means of heat recovery. A secondary heat sink can also be implemented using water or black liquor in a trim reflux condenser.

The primary advantage to integrating an evaporator set into the stripping system is the ability to reuse the heat recovered through all the bodies of the evaporator set. Typically, it is desirable to integrate the stripping system reflux condenser with the first effect of the evaporator set. This allows the heat to be passed through to all the remaining effects, improving its economy. Heating liquor or boiler feed water, while efficient, does not produce the same effect through the rest of the evaporator set. The steam economy improves as the stripper integration is introduced sooner in the evaporator set. Figure 1 shows a typical flow diagram for an evaporator integrated steam stripping system.

One Lundberg Associates’ project in particular focused on integrating a new foul condensate stripping system into the existing six-effect evaporator set. The steam stripping system was designed for 500 gpm (31.5 lps) foul condensate. A falling film steam reboiler was included to allow for recovery of the steam condensate used for stripping, as well as to reduce the volume of stripped condensate. The reboiler is a shell and tube vessel with stripped condensate from the bottom of the column recycled on the tubeside to generate steam for stripping. Live steam is made up to the reboiler shellside to heat the stripped condensate. The primary reflux condenser was added to the evaporator set as a parallel first effect. The evaporator integration also included the supply of new first and sixth effect evaporator bodies to operate in parallel with the current arrangement. The existing first and second effects were changed to the new second effect 2AB and 2C bodies, while the third and fourth effects were changed to the new third effect

3A and 3B bodies. The result was a modified nine body six-effect system that can function with or without the stripping system in service.

The design of the evaporator modifications not only allowed for the steam stripping system to be integrated, but for a 25% increase in evaporator capacity as well. The heat from the stripper is recovered as additional evaporation in the new parallel first effect evaporator body. The vapor from the top of the stripping column is partially condensed in the new reflux condenser evaporator body. The heat contained in the overhead vapors is used to concentrate the liquor from 33.9% total solids to 36.2% total solids, with 27,607 lb/hr (12,520 kg/hr) of evaporation. The uncondensed vapor from the falling film reflux condenser is passed on to the trim reflux condenser where water is heated. The overall steam economy is 5.19 lb evaporation per lb steam. This is just slightly lower than the 5.53 steam economy when the evaporator set is run without the stripping system. The small decrease in economy is due to condensate preheat steam requirements in the stripper.

A falling film body was chosen as the new first effect body to be integrated into the stripping system. This technology offered the mill a high degree of turndown and thus, improved their ability to match the digester system's production rates. Another advantage of the falling film reflux condenser/evaporator body is the ability to operate with a very low temperature differential between the reflux vapor and the boiling liquor. The low temperature differential avoids subcooling of the reflux condensate and eliminates the possibility of generating red oil within the reflux loop.

Similarly, another recent project involved the integration of an evaporator body into a new foul condensate stripping system. This evaporator modification was necessary to justify the high design flow rate of 900 gpm (56.8 lps) foul condensate to the stripping system. The primary reflux condenser was integrated into the evaporator system as a parallel first effect. It was designed to evaporate liquor from the 2A effect evaporator body. The new primary reflux condenser/first effect was designed for 54,183 lb/hr (24,573 kg/hr) evaporation, increasing total solids from 38.5 to 42.5%. Liquor from the primary reflux condenser is then concentrated to 49.4% total solids in the first effect and sent to the product flash tank. Sample operating data from this stripping system are shown in Table 1 below.

Table 1: Evaporator Integrated Steam Stripping System - Sample Operating Data

Sample Date and Time	Steam Flow to Stripper (klbs/hr)	Cond. Flow to Stripper (gpm)	Methanol Conc. to Stripper (mg/L)	Methanol Conc. from Stripper (mg/L)	Methanol Removed (lb/day)	Removal Efficiency (%)
Design	85.3	900	2,530	126.5	25,944	95+%
8/27/01 8:00	51.3	475	3,695	73.7	20,609	98.0
8/29/01 8:00	53.8	485	3,834	70.0	21,860	98.2
8/31/01 8:00	55.1	524	4,268	114.0	26,098	97.3
9/10/01 8:00	55.1	501	3,584	66.6	21,098	98.1
9/12/01 8:00	61.1	550	3,417	56.0	22,145	98.4
9/13/01 7:35	60.0	600	3,358	155.5	23,021	95.4
9/13/01 9:00	58.0	600	3,199	149.9	21,918	95.3
9/13/01 10:30	56.0	600	3,297	176.0	22,435	94.7
9/13/01 12:00	54.0	600	3,224	193.1	21,788	94.0
9/13/01 13:30	52.0	600	3,188	306.0	20,717	90.4
9/13/01 15:00	50.0	600	3,313	370.0	21,156	88.8
10/1/01 8:00	59.9	540	3,341	52.4	21,261	98.4
10/3/01 8:00	59.7	524	3,484	60.2	21,512	98.3
10/4/01 8:00	59.5	524	3,087	42.7	19,097	98.6

This method of heat recovery from the stripping system was also beneficial in that it simultaneously increased the capacity of the evaporator set. Other modifications were made to the evaporators to allow for the capacity increase. These upgrades included a new parallel first effect evaporator body and reconditioning of the existing liquor heater. The result was an eight body six-effect system. The steam economy of the system is currently 3.94 lb evaporation per lb steam, including the steam required to operate the stripping system. The steam economy is based upon theoretical steam requirements, and does not include venting or radiation losses.

Furthermore, the reflux condenser in a steam stripping system can be designed to generate clean steam. The stripping system essentially acts as a pressure reducing station when a steam generator is used. Often a reboiler is included with the stripping system to provide feed water to the steam generator. This practice permits the recovery of the sensible heat from the steam condensate and maximizes steam generation. For instance, Lundberg Associates installed a 500 gpm (31.5 lps) steam stripping system to operate with 47,222 lb/hr (21,420 kg/hr) of 60 psig (414 kPa) steam to the reboiler. The falling film reflux condenser/steam generator partially condensed the vapors from the top of the stripping column to produce 39,026 lb/hr (17,702 kg/hr) steam at 30 psig (207 kPa). The uncondensed vapor is passed on to the trim condenser. Table 2 provides sample operating data from this stripping system with steam generation.

Table 2: Steam Stripping System with Steam Generation
Sample Operating Data

Sample Date and Time	Cond. Flow to Stripper (gpm)	Steam Flow to Reboiler (klbs/hr)	Steam Flow from Steam Generator (klbs/hr)	Steam Outlet Pressure from Steam Generator (psig)
Design	500	47.2	39.0	30.0
4/11/01 14:55	521	48.4	45.6	30.0
4/11/01 16:50	517	49.7	48.1	30.1
4/11/01 17:26	521	41.0	35.5	30.1
4/11/01 17:50	521	50.7	45.7	30.1

The steam stripping system can be designed to operate at even higher pressures to produce higher pressure steam. One such project produced 60 psig (414 kPa) steam from the reflux condenser/steam generator with 132 psig (910 kPa) steam to the reboiler. This 600 gpm stripping system produced 58,360 lb/hr (26,472 kg/hr) steam at 60 psig (414 kPa) with 68,710 lb/hr (31,166 kg/hr) steam at 132 psig (910 kPa) to the reboiler. Generating clean steam is a thermally efficient method of recovering the heat from a foul condensate stripping system. The small losses in efficiency are due to the thermal value of the steam and the lost preheating requirements.

Clearly, the integration of a steam stripping system with an evaporator set or for the production of steam is an efficient way to recover and utilize heat.

STRIPPER OFF-GAS AS FUEL FOR DIRECT FIRED THERMAL OXIDIZERS

With the increase in the number of steam stripping systems in the U.S., the methods for handling and incineration of stripper off gas (SOG) have come under focus. As with LVHC and HVLC NCG, the stripper off gases must be properly conditioned and transported for incineration. Stripper off gas, however, must be handled separately from the other types of NCG. SOG can be incinerated in various locations, including boilers, lime kilns, and dedicated incinerators. A dedicated incinerator is often a primary choice for incineration of the SOG due to its ability to be used as fuel.

The cost of operating a dedicated incinerator can be reduced using stripper off-gas (SOG) as fuel. A. H. Lundberg Associates' incinerator burners are designed to use both natural gas (or fuel oil) and stripper off gas for combustion of the NCG. The stripping system is designed to produce SOG at 50 wt% methanol to ensure that there is enough methanol in the SOG to serve as fuel. The fuel value of SOG at 50% methanol is generally sufficient to limit the use of natural gas to the minimum natural gas flow required for low fire conditions. The stripper off gas is piped to both a port on the burner and the incineration chamber. The incinerator can operate with or without the use of stripper off gas as fuel. The incinerator uses natural gas (or other auxiliary fuel) in the event the SOG is not available or ready for use as the primary fuel (i.e. stripper start-up and shutdown conditions).

For instance, one recent dedicated incinerator installation included burning of LVHC NCG, HVLC NCG, and SOG. The normal natural gas flow to the burner is 33 SCFM (56 Nm^3/hr) using SOG as fuel. In the event that SOG is not available, the natural gas requirement increases by more than ten times to 350 SCFM (595 Nm^3/hr). At a similar dedicated incinerator installation, the minimum natural gas flow with SOG as fuel is 40 SCFM (68 Nm^3/hr); without SOG, the required natural gas flow is 500 SCFM (850 Nm^3/hr). The large fuel requirement increase is due to the large quantity of HVLC NCG that must be heated and completely combusted. Clearly, these examples demonstrate the economic benefits of operating the dedicated incinerator with stripper off gas as fuel.

WASTE HEAT BOILERS ON DIRECT FIRED THERMAL OXIDIZERS

With the mandate of the Cluster Rules, pulp mills have been forced to find suitable locations for burning their noncondensible gases. Direct fired thermal oxidizers, or dedicated incinerators, have become a popular method for disposing of these hazardous gases. In order to earn back the cost of these dedicated incineration systems, several installations have included a waste heat boiler to generate clean steam with the hot waste gases. Figure 2 shows a standard dedicated incinerator and waste heat boiler arrangement.

A waste heat boiler is only a worthwhile investment if there is enough heating value in the gases to justify the cost of the boiler. With a small incinerator or relatively low flow waste gas streams, the investment for a waste heat boiler is not justified. However, with large quantities of HVLC NCG or high combustion/cooling air requirements to a dedicated incinerator, the investment of a waste heat boiler becomes warranted.

For example, at one Lundberg Associates' dedicated incinerator installation, a waste heat boiler was supplied to generate 20,200 lb/hr (9,160 kg/hr) steam at 180 psig (1,240 kPa). The dedicated incinerator was designed to handle 3,650 ACFM (6,200 m^3/hr) of LVHC NCG, 1,325 lb/hr (600 kg/hr) of 50 wt% methanol SOG, and 13,500 ACFM (22,935 m^3/hr) of HVLC NCG. Only 40 SCFM (68 Nm^3/hr) of natural gas is required with SOG as auxiliary fuel. With the large HVLC NCG flow that must be heated to 1,600ºF (870°C) for 0.75 seconds in order to meet Cluster Rule requirements, there is sufficient heat available to produce steam.

First, the NCG is combusted in the incineration chamber at the required time and temperature, and then transported to the waste heat boiler via a brick-lined hot gas transition duct. The waste heat boiler is a fire tube type boiler with an integral steam drum. It is constructed of all carbon steel with a refractory lined gas inlet chamber (smoke box). Hot gas from the incinerator is used to evaporate boiler feed water to produce steam. A typical installation includes a blowdown separator as well as the boiler trim. The blowdown separator is provided as a flash chamber for the waste heat boiler's blowdown water. The flash steam from the separator is vented to the atmosphere. The remaining blowdown water is cooled in an aftercooler that is integral with the separator drain connection and then sewered. The cooled gases exit the waste heat boiler at approximately 500ºF (260°C). This temperature must remain high in order to stay above the dew point of SO_3. Only high pressure steam is produced in the waste heat boiler for this same reason. Finally, the gases are further cooled in a direct contact Hastelloy quench before being sent to the SO_2 scrubber.

At another Lundberg Associates' dedicated incinerator installation, a waste heat boiler was included to produce 23,500 lb/hr (10,658 kg/hr) steam at 165 psig (1,138 kPa). The incinerator was designed to combust only LVHC NCG and SOG. Due to the high heat content of these gases, however, a large combustion and cooling air requirement of 12,000 SCFM (20,387 Nm^3/hr) is necessary. This large flow of air must be heated to 1600ºF (870°C) for 0.75 seconds as well, so it is desirable to recover this heat. This is accomplished in the waste heat boiler. By generating clean steam, a waste heat boiler is an ideal way to recover some of the costs of a dedicated incinerator.

CONCLUSION

Overall, Lundberg Associates' expertise in meeting the Cluster Rule requirements in the U.S.A. will be applicable to future environmental projects in Chile. The possibilities range from thermal efficient steam stripping systems to collection and incineration of noncondensible gases. The cost effective solutions outlined above have already been implemented in the recent surge of environmental system upgrades.

Future environmental projects in Chile that focus on condensate treatment or noncondensible gas collection and incineration can utilize the technology implemented over the past several years, as well as in the years to come. This technology includes combustion of dilute NCG in the recovery boiler and the methods for reducing the noncondensible gas source flows. Also, foul condensate steam stripping systems can be integrated into existing evaporator sets to provide improved heat economy. Dedicated incinerators can be operated with stripper off gas as fuel to provide natural gas savings. Additionally, a waste heat boiler can be supplied to recover some of the costs for installing a direct fired thermal oxidizer. Each of these examples promotes cost savings to help overcome the investment required for environmental systems. These techniques can be applied to future Chilean environmental projects.