STRIPBURN
SIMPLE AND EFFICIENT BTEX CONTROL FOR DIRECT FIRED TEG REBOILERS

Ralph Hicks and Dale Gallaher
PetroDesigns, Inc.
Harvey, Louisiana

Allen Logue
Gly-Tech, Inc.
Harvey, Louisiana

ABSTRACT

The "STRIPBURN" process is a simple method which assures 100% combustion of undesirable VOC emissions from glycol units. This process can be adapted to new or existing units and maintains a positive pressure in the still overhead system, minimizing corrosion.

The two main approaches to BTEX control are 1) burn the BTEX components in a flare or as fuel, and 2) inject them into the sales gas stream. Most options use a cooling device on the still column exiting stream to condense the water and VOCs. The "non- condensables" are injected into the reboiler in a separate burner or "mixed" with main fuel via an eductor. This presents two major concerns:

- **The almost atmospheric pressure does not provide adequate mixing of air and VOCs to assure complete combustion**. For natural draft burners there is no mixing when the burner is off and condensation causes a slight vacuum from the condensing vapors, allowing oxygen entrainment and corrosion.
- Other methods are compression or eduction, which increase the pressure and allow disposal to flare or fuel. These add additional capital and operating costs, are more difficult to operate and consume more energy.

In the "STRIPBURN": process, the flash gas and makeup gas are used to strip the glycol, allowing intimate mixing with the VOCs. The still overhead vapors are cooled and the non-condensables are used in the main burner. This assures 100% combustion of the VOCs while maintaining a positive pressure in the still overhead system.

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INTRODUCTION

The basic idea of StripBurn is to use the flash gas from the TEG (Triethylene Glycol) returning from the contact tower plus make-up gas as stripping gas in the reboiler and then as fuel for the reboiler. It provides complete combustion of the BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) components and decreases the fuel cost for gas dehydration. The issues for these designs along with the advantages and limitations of StripBurn systems are covered in this paper. Additionally, some other options for BTEX control will be discussed and compared with StripBurn.

VOC EMISSION CONTROL

BTEX and other VOC (Volatile Organic Components) emissions are an environmental problem for the natural gas industry, since one of the components is carcinogenic and all are normally present in natural gas streams. The most common gas dehydration system uses TEG to adsorb water from the gas. Unfortunately, TEG also adsorbs VOCs which are driven off with the water in the reboiler. Due to the number of glycol dehydration systems in use (over 40,000 in the U. S.) and the estimated amounts of VOCs absorbed by them, many governments have now regulate emissions from glycol dehydration units.

There are two main approaches to BTEX control for natural gas production. The first is to burn the BTEX components in a flare or as fuel and the second is to inject them back into the sales gas stream. There are, of course several variations of each approach. Reference (1) reviews some of the more popular methods.

The most commonly employed options, due to simplicity of operation and cost, use a cooling device on the still column exiting stream to condense the water and VOCs with the "non-condensables" being injected into the reboiler in a separate burner. This presents two major concerns:

- **The almost atmospheric pressure does not provide adequate mixing of air and VOCs to assure complete combustion**. Many assume that the main burner will combust the non-condensables; but, induced draft burners operate intermittently and the non-condensables are simply emitted out the stack instead of the flare or vent system during the non-operating periods,

- During the periods of minimal inflow to the reboiler while the condenser is operating, a slight vacuum is pulled due to the condensing of vapors since no incoming vapors are available to occupy the space. This allows oxygen entrainment and severe levels of corrosion. Some companies actually build their condensing separators from fiberglass to overcome this problem.

Other methods have been deployed to combat the above described problems, such as compression or eduction, which increase the pressure and allow disposal to flare or fuel. These add additional capital and operating costs, as well as being more difficult to operate and consuming more energy.

A better method has been developed, which we call the "STRIPBURN": process. This simple method is to cool the still overhead vapors and use a mixture of non-condensable vapors and makeup gas as fuel in the main burner (see Figure 1). This assures 100% combustion of the VOCs while maintaining a positive pressure in the still overhead system. The main burner can be either natural or forced draft while the fuel gas can be injected into a sparger pipe or an external stripper column, depending on the dewpoint depression requirements. Note that a natural draft burner imposes 3 to 5 psi back pressure on the reboiler in order to provide sufficient pressure for efficient operation of the burner, while the forced draft system imposes only a few ounces.

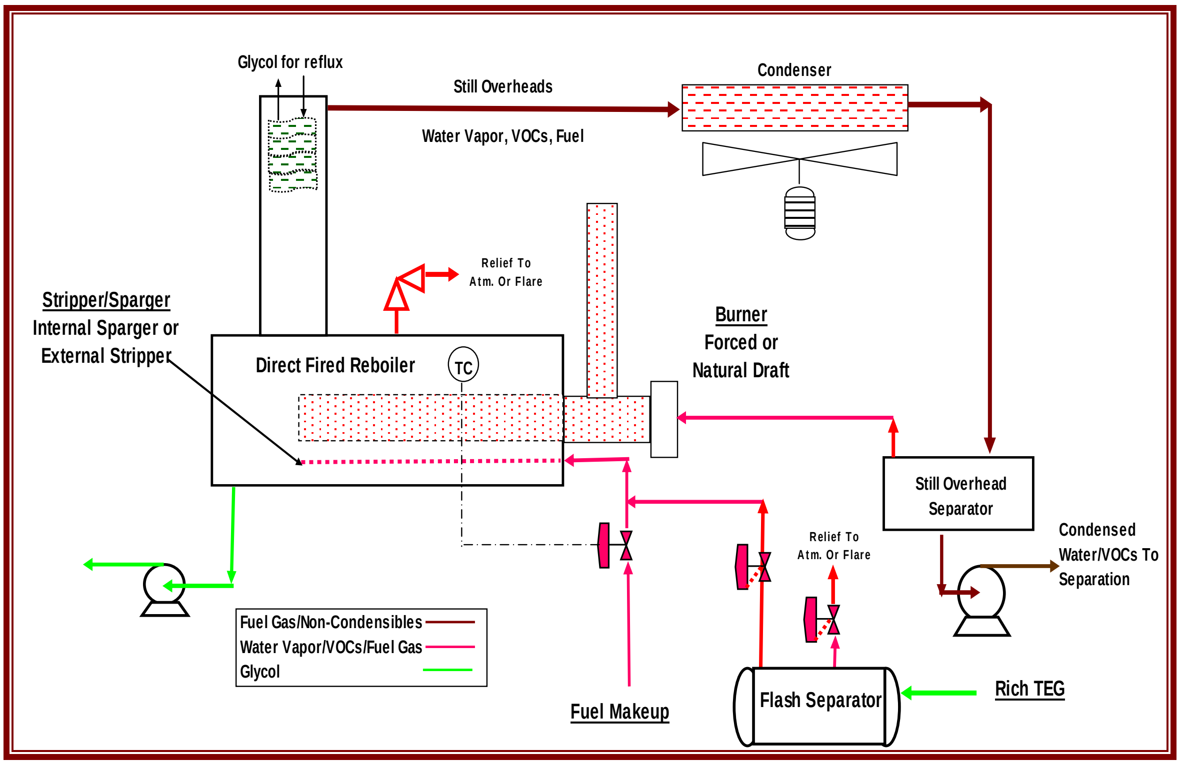


Figure 1 – Simplified Flow Schematic

Many of the competing control systems require frequent sampling to assure that the required percentage of the VOC vapors are indeed being kept from release into the atmosphere. Due to intimate mixing of the VOCs with the primary fuel gas, complete combustion is assured so sampling of the vapors from the still column will likely not be required in most states. This system also reduces the amount of VOCs in the condensed water, due to a reduced partial pressure of the gas.

MIXING GASES

A predecessor of PetroDesigns conceived the basic concept of mixing the fuel gas with the stripping gas, with or without the flash gas, condensing the liquids and burning the remainder in a forced draft burner. The forced draft burner was deemed necessary as opposed to a natural draft burner, since it requires only inches of pressure for operation, has a very large turndown ratio, including the air/fuel ratio necessary for varying BTU contents. At the time, many possible locations had no power and the clients were averse to the use of forced draft burners, since natural draft burners were so prevalent.

Since that time, forced draft burners are now better accepted due to 1) the use of electronic controls such as PLC systems; 2) recommendations by the EPA and other emission control authorities for the use of electric motor driven glycol pumps instead of gas powered; and 3) more concern for NOX controls on burners.

Working on a joint project, PetroDesigns and Gly-Tech Services, Inc., a specialist in glycol unit maintenance and operations, realized that both options, natural draft and forced draft, had their own applications – natural draft for systems with need for little turndown and the forced draft where turndown is advantageous.

GAS BALANCE – FUEL GAS/FLASH GAS/STRIPPING GAS

The following will review the process logic associated with the "system", covering the flash gas and fuel gas uses along with the need and necessary quantities of stripping gas. An updated version of **PC GLYCOL,** called "VBA Glycol," was used for most of the process and mechanical calculations. This program and various versions have been in use for glycol unit design and operations studies for over 20 years. Users have been Shell, ExxonMobil and many other oil companies and along with glycol unit manufacturers. It has been found to be an excellent predictor of actual process performance of glycol units[2,3] .

The need to efficiently burn all of the hydrocarbons in the still column overhead stream places a number of constraints on the design. However, these constraints can be easily met and the result is an economically efficient system with near zero BTEX emissions.

The fuel consists of the flash from the glycol returning from the contactor plus make-up from an outside source if the flash is not adequate to meet the fuel or stripping gas requirements. If the flash gas or the stripping gas volumes exceed the fuel requirement, an auxiliary burner would be required to burn the excess gas or, preferably, alternative control methods considered. It is, therefore desirable to design the system so that the fuel/stripping gas requirements exceed the flash gas rate. As will be shown, this can be done for the majority of the cases.

Fuel Gas

Most of the fuel gas requirements for a given system are dependent on the amount of water being removed, the TEG circulation rate needed to remove the water and accomplish the desired outlet water content, and the size of the glycol/glycol exchangers. The entrained VOCs are a very small factor in the overall load. Figure 2 shows the heat envelope to be used to calculate the reboiler duty.

$$\text{Reboiler Duty} = \text{Heat Out} - \text{Heat In} \tag{1}$$

where

Heat Out = Lean Glycol Out + Condenser Duty +Condensed Water/VOCs

Heat In = Rich Glycol In + Fuel Gas In

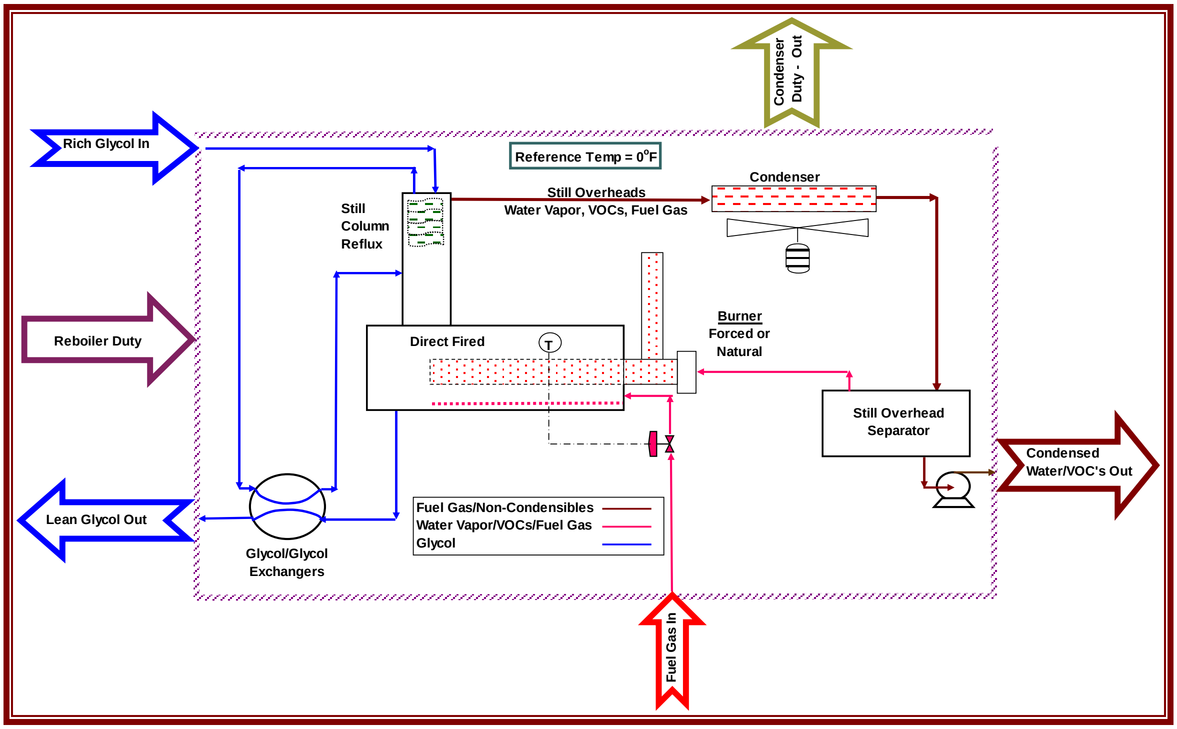


Figure 2 – Simplified Flow and Gas Uses - Pressurized Reconcentration System

For glycol units, a common design rating is the number of gallons of glycol circulated per pound of water removed (herein referred to as gal/lb). Much of the literature recommends an outdated value of 3 gal/lb, a value commonly used in the 60's and 70's. With 1) the advent of structured packing allowing smaller towers and more contacts without inordinately large vessels, and 2) a better understanding of the equilibrium data for the TEG/natural gas/H2O system, ratios as low as 0.50 gal/lb are successfully being employed.

Figure 3 plots the fuel requirements for the range 0.5-3.0 gal/lb and for 50, 75, and 100°F glycol/glycol exchanger approach temperatures.

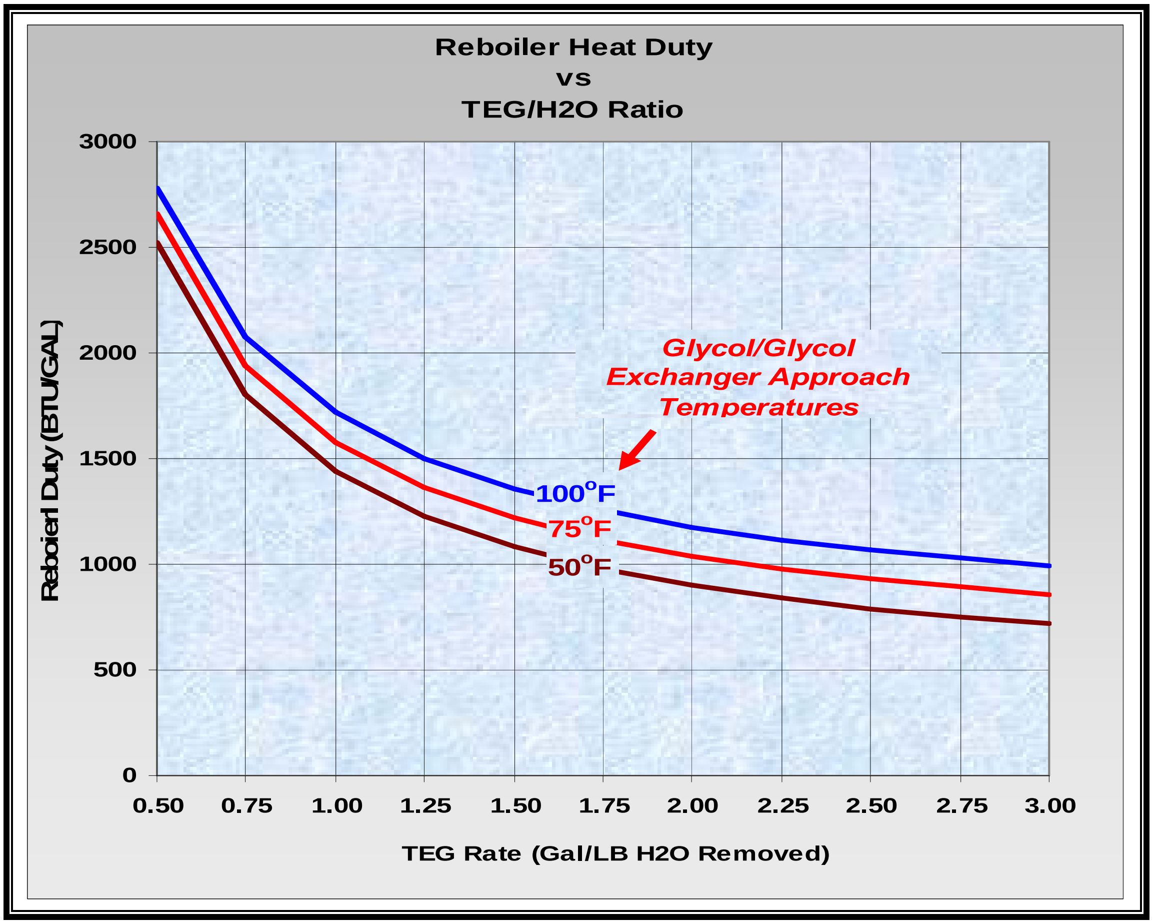


Figure 3 - Reboiler Duty vs. Ratio - TEG/Water Removed Ratio

The values are not precise since the heat transfer coefficient (U value) for the glycol/glycol exchangers will vary with the flow rate. This does not present a substantial variation, however, and as can be seen from Figure 3. The variation as a per cent of the total lessens as the TEG rate approaches 0.50 gal/lb.

Flash Gas

The most interesting feature from Figure 3 is the rapid increase in the BTU/gal requirement at the lower gal/lb circulation rates. This assists greatly in cases wherein it is desirous to burn the associated flash gas that returns with the glycol. This entrained gas is primarily methane due to its being the prime constituent in the gas stream, but it also contains the VOCs and the heavier hydrocarbons. Since the rate of entrainment (or solution gas) is a function of the gas analysis, as well as the contactor operating pressure and temperature, the actual values will vary from project to project. Figure 4 shows the flash gas for two different compositions – pure methane and a typical 0.70 SG gas with VOC components included.

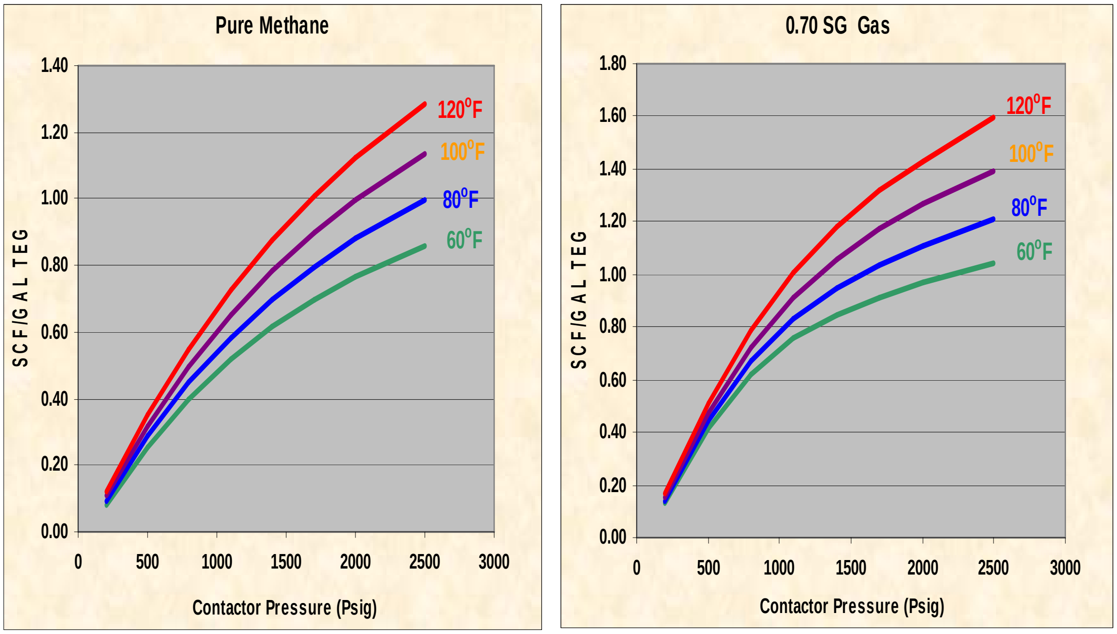


Figure 4-A *Figure 4-B*

Figure 4 – Flash Gas – Two Compositions vs. Pressure at various Contactor Temperature

Hysys Version 3.1 was used to compute the flash gases in Figure 3 and Figure 4. This analysis showed an interesting phenomenon for the absorption of the light hydrocarbons (methane, ethane and propane) in the TEG. As one would expect, the absorption increased as the pressure increased; but, unexpectedly, the **absorption also increased as the temperature increased**. Further investigation showed this to indeed be the case (private communications, Hyprotech [4] and internet search – Bryans Research [5]).

To show the difference in composition and variation with temperature, Figure 5 was prepared for three different pressures (500, 800, and 1400). This shows the increase with temperature as well as the expected greater amount of absorption for the heavier (richer) gas.

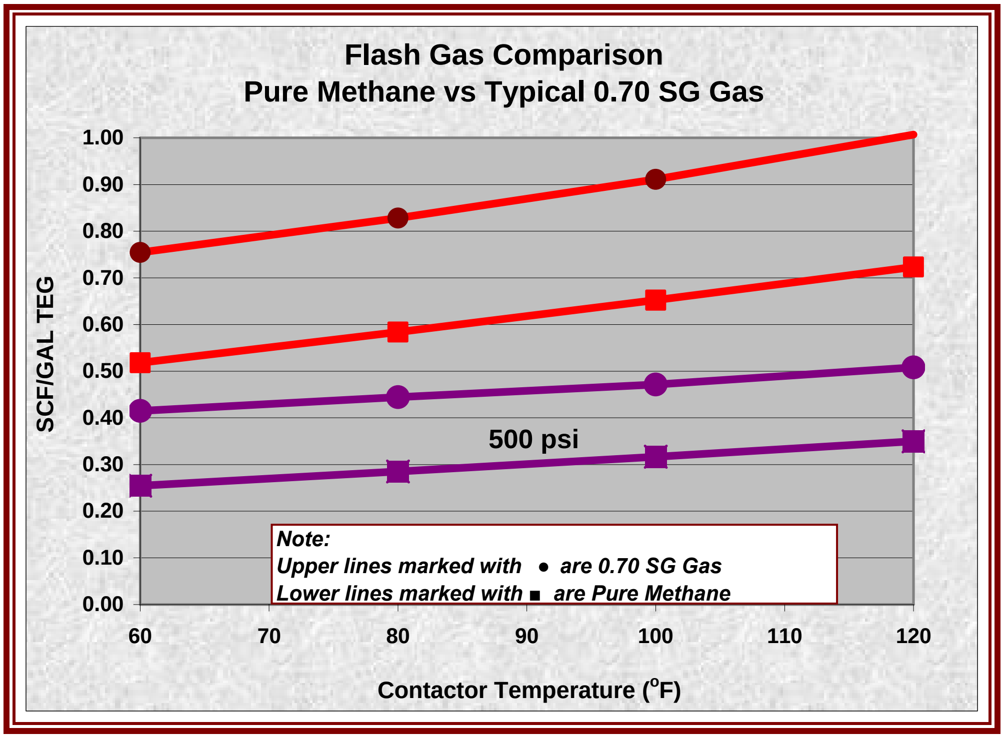


Figure 5 - Flash Gas - Two Compositions vs. Pressure and Temperature

The above flash gas assumes standard positive displacement pumps and does not include gas associated with gas powered pumps such as Kimray. In most cases, the use of gas powered pumps will result in more return gas than is required by the reboiler. Although the "STRIPBURN" process could combust much of the gas, there will still be some vapors to flare. **As noted in the STAR report[6], when compression is unavailable, motor driven pumps are recommended.**

Comparison – Fuel/Flash Ratio

The concept of the "STRIPBURN" process is to burn all the vapors from the returning glycol, including the flash gas. To do this, obviously the flash gas must be less that the fuel gas.

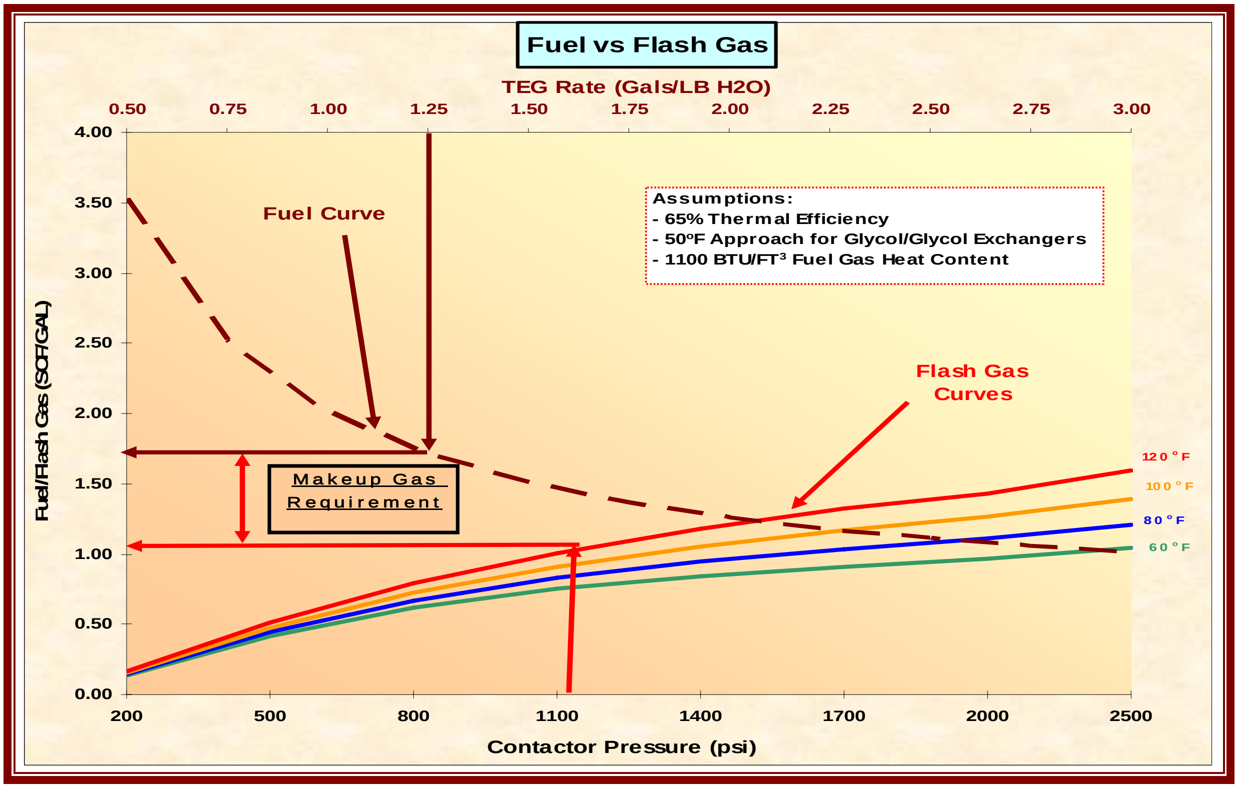


Figure 6 - Fuel/Flash Relationship

Figure 6 shows the fuel and flash gas for a typical system where the theoretical contacts in the contactor and the lean TEG concentration require a lean glycol circulation rate of 1.25 gals/lb. For this case, about 0.70 SCF/GAL gas is required to "make up" the difference in the required fuel gas and the returning flash gas. The make-up gas and the flash gas will both be used for stripping gas, thereby allowing for a lower glycol circulation rate.

Stripping Gas

A common method for rating the difficulty of a dehydration requirement is the required dewpoint depression. Figure 7-A shows the dewpoint vs. water content for 500, 1000, and 1500 psi while Figure 7-B indicates the equivalent dewpoint depression for a 120^{o}F contact temperature.

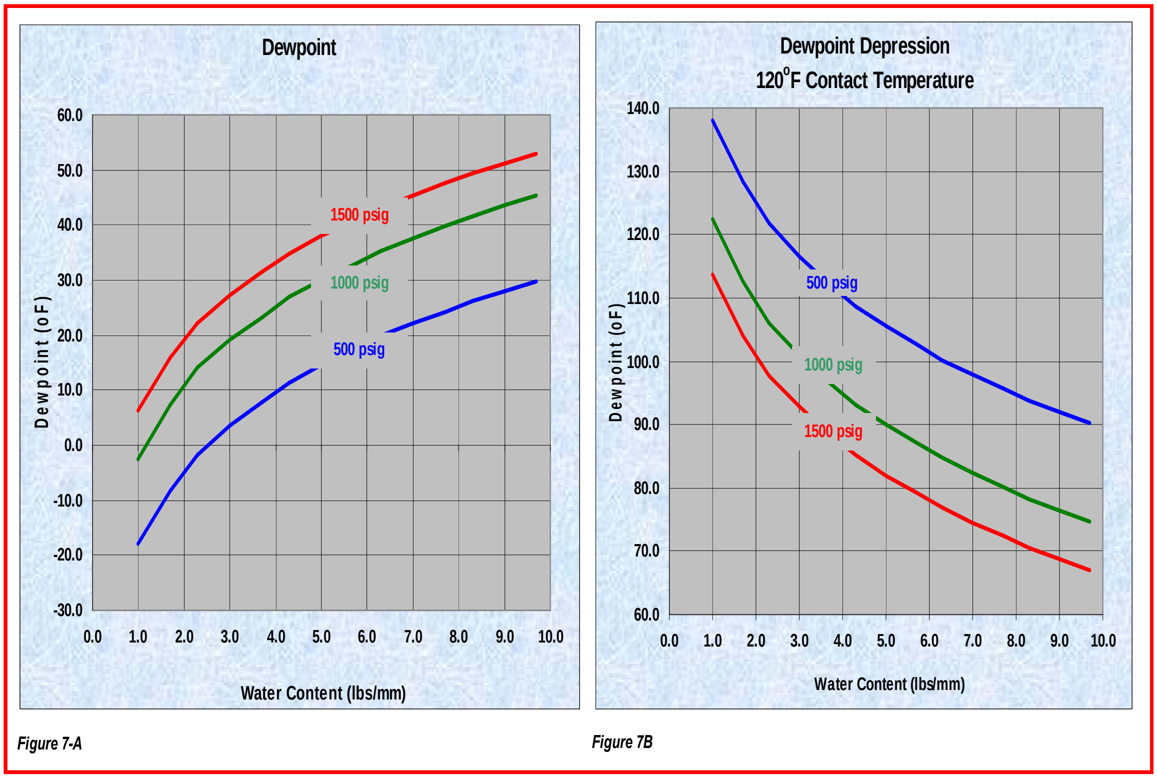


Figure 7 - Dewpoint & Dewpoint Depression

The need for stripping gas is determined by the gas operating conditions (temperature, pressure, water content in and out), number of theoretical contacts (height of packing or number trays), TEG rate, and the lean TEG concentration. Figure 8 shows a typical the dewpoint depression vs. the lean TEG circulation rate for various lean TEG concentrations.

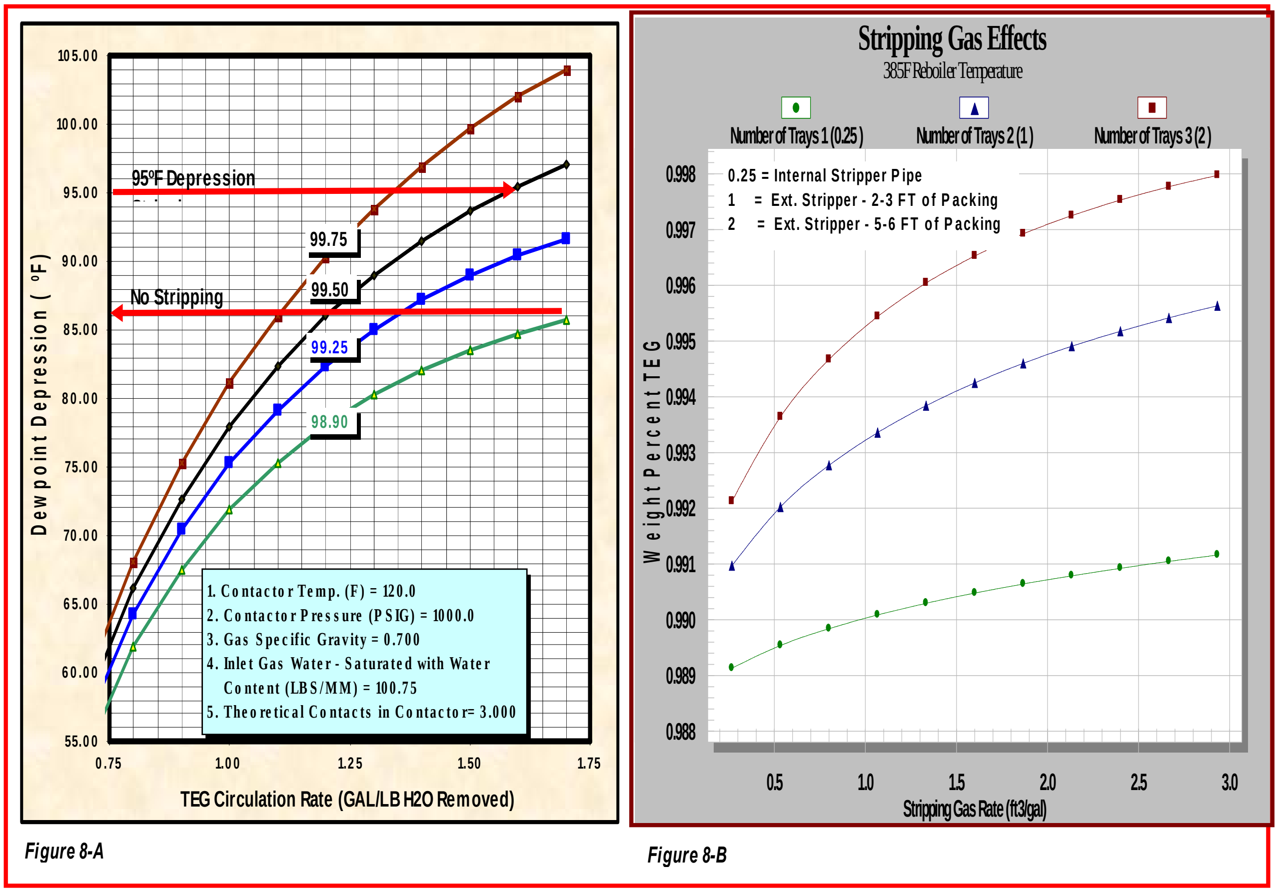


Figure 8 - Dewpoint Depression vs. TEG Rate and Concentration

Since reboiler temperatures of 390°F result in about 98.9% lean TEG, the case in Figure 8-A shows that stripping gas will be required for depressions above 90°F. Using stripping gas curves such as shown in Figure 8-B, the lean TEG requirement can be determined. For example, should the dewpoint depression requirement be 100°F, a lean TEG concentration of 99.5% will be required. To achieve this concentration and maintain a stripping rate less than the total fuel requirement will require a counter-current stripper with slightly more than 1.0 theoretical contacts.

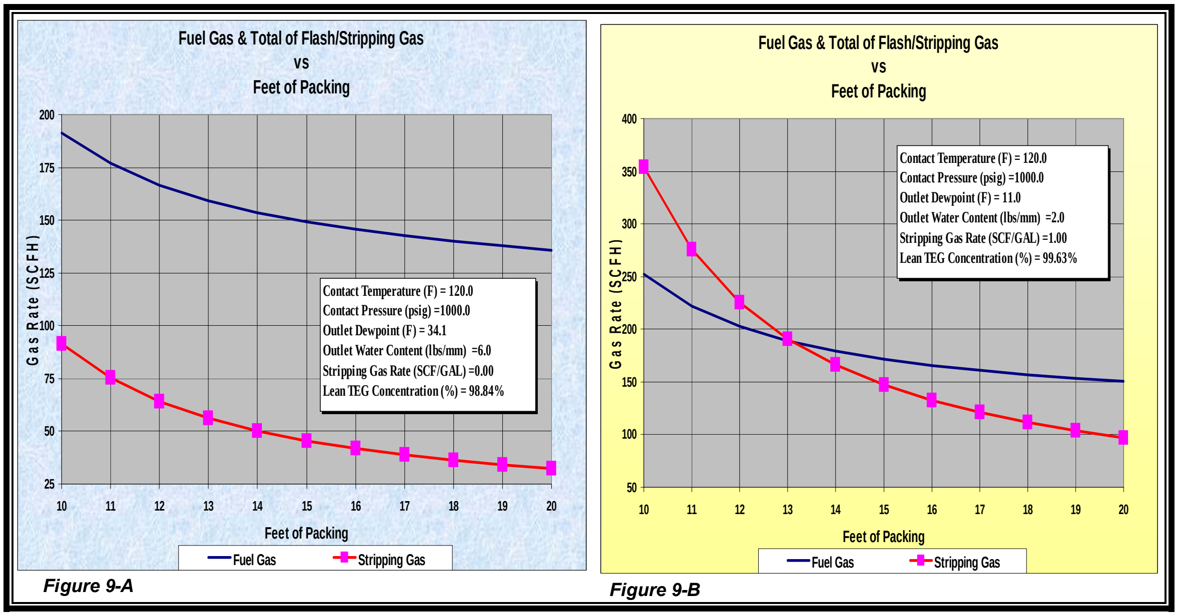


Figure 9-A

Figure 9-B

Figure 9 - Effect of Contactor Packing Height

The number of contacts in the contactor also can determine the relationship of the flash and stripping gas to the fuel gas. **Error! Reference source not found.** shows this effect – 9-A showing a less stringent dewpoint depression requirement for which the fuel gas is always greater. Figure 9-B indicates that a minimum of 13’ of packing is required to reduce the stripping gas rate to a value less than the fuel gas rate.

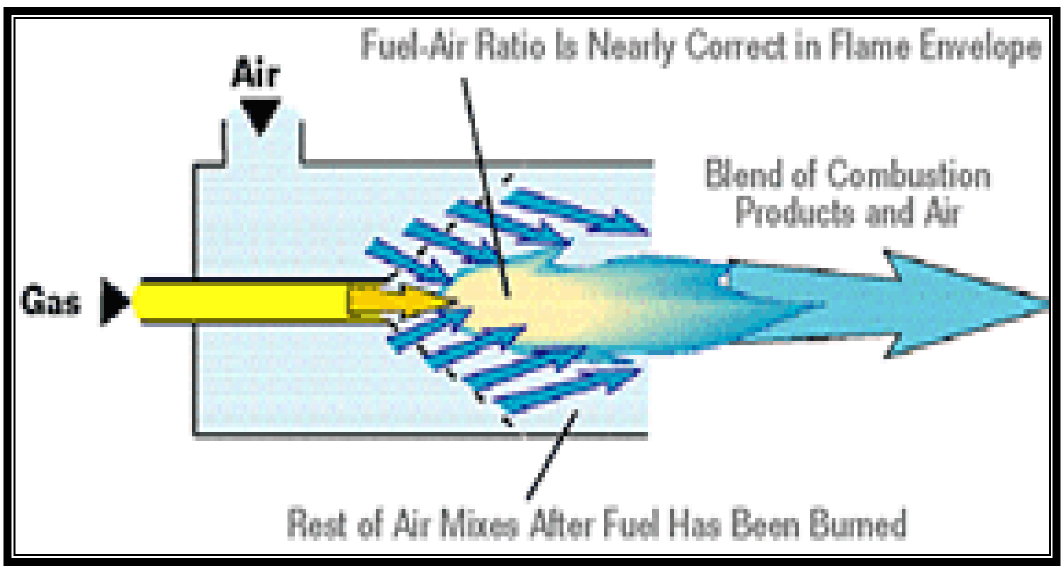
Adding more packing in the contactor and/or stripper, thereby increasing the theoretical contacts in either or both, reduces the cases where the flash gas is greater than the required fuel gas. When this does occur, such as for very high dewpoint depression requirements, other options should be considered, e.g., use of the pressurized reconcentration system or compression of the excess overhead vapors – either at flash pressure or reboiler pressure.

BURNERS/CONTROL

The key to the "STRIPBURN" system is the burners, in that they must burn continuously and must assure combustion of the VOCs. The two type burners used in oil and gas field processing are natural draft and forced draft. The following reviews the design features and recommends cases in which each is to be properly applied.

Natural Draft

Natural draft burners are the most common, since the capital cost is low, the fuel efficiency adequate and no power is required. The device is relatively simple with the burner draft pulling in enough air to allow for combustion of the fuel gas which is introduced through a mixing device (Figure 10). The key to the efficiency is to assure that the air/gas ratio stays within the flammability limits while combustion is occurring, the stoichiometric value being about 10 part air to 1 part fuel gas. Since the draft is primarily dependent on the heat in the burner stack, the air rate does not vary drastically so the turndown is limited. Excess air rates of 10-20% are also required to assure complete combustion, thereby reducing the overall efficiency to 60-70%.



http://www.process-heating.com/CDA/ArticleInformation/Energy_Notes_Item/0,3271,96664,00.html

Figure 10 - Natural Draft Burner

For units where the glycol rate and water removal will be somewhat constant, the natural draft burner will perform well. The reboiler pressure needs to be higher, though, to allow for adequate pressure drop and velocity through the burner nozzle (orifice) to allow for proper mixing of the air and fuel. For a properly designed burner, this pressure can be as low as 3 psi with 5 psi being preferred. In the "STRIP/BURN" system, all fuel gas is being used as stripping gas and offsets the increase in the lean glycol concentration. Figure 11 shows that a typical reboiler operating at 5 psig with an internal stripping coil and 1.75 SCF/GAL fuel/stripping gas will produce lean TEG of 99.25%. This is considerably better than the 98.6^{+}% concentration achieved at atmospheric pressure with no stripping gas.

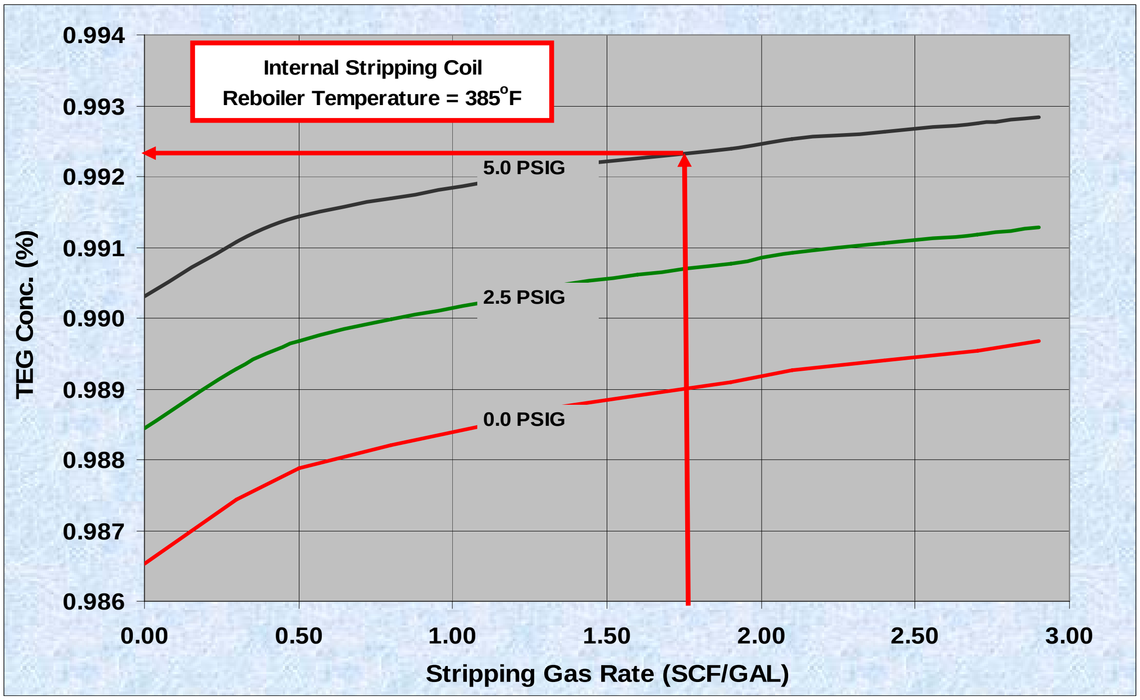
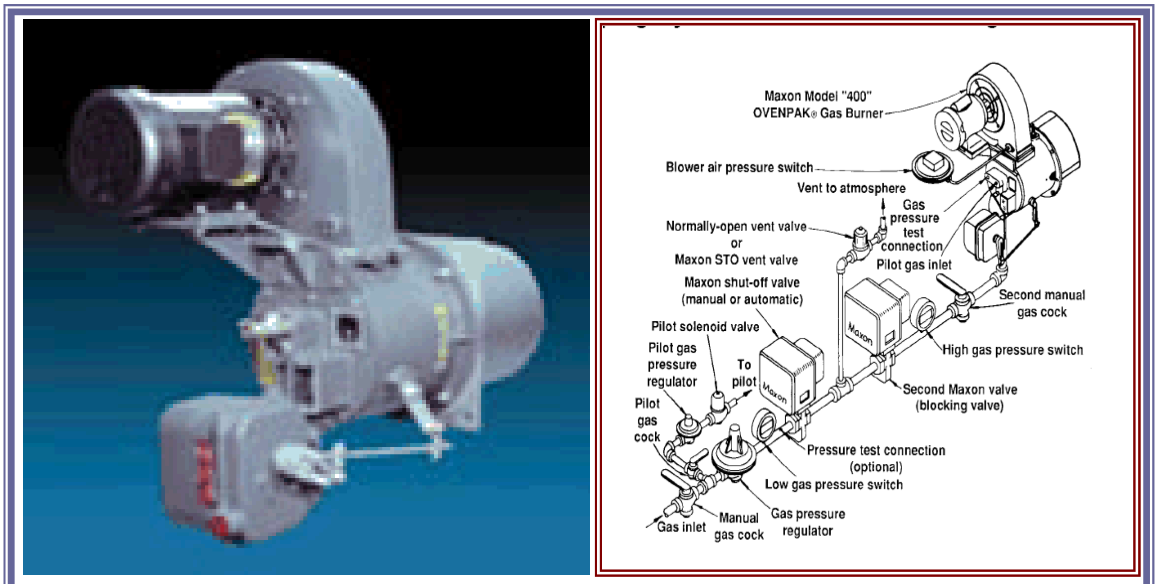


Figure 11 - Lean TEG Concentration vs. Stripping Gas and Reboiler Pressure

Forced Draft

Forced draft burners have blowers/fans that produce 2-6 inch of air pressure to induce high air velocity, creating a lot of turbulence in the firebox with more uniform heating. This increased air pressure allows the reduction of excess air to the 5-10% range and allows burner efficiencies of 75%. They also are quieter, reduce NOX emissions and have a much better turndown ratio (40:1 or greater).



Courtesy of Maxon Corporation (www.maxoncorp.com)

Figure 12 - Typical Forced Draft Burner

There are many manufacturers of forced draft burners, many offering complete package solutions (Figure 12). Although they appear complex, the current solid state control systems make them simple to operate while increasing the reliability.

Recommended Control Schemes

The methods recommended for controlling the burners is fairly simple. The natural draft burners are slightly more complex (see Figure 13) due to the lower turndown capability. The flash gas is allowed to always go to the burner with the temperature controller allowing makeup gas as required. A manual globe valve is suggested for cases in which the flash gas may be inadequate to maintain minimum fire.

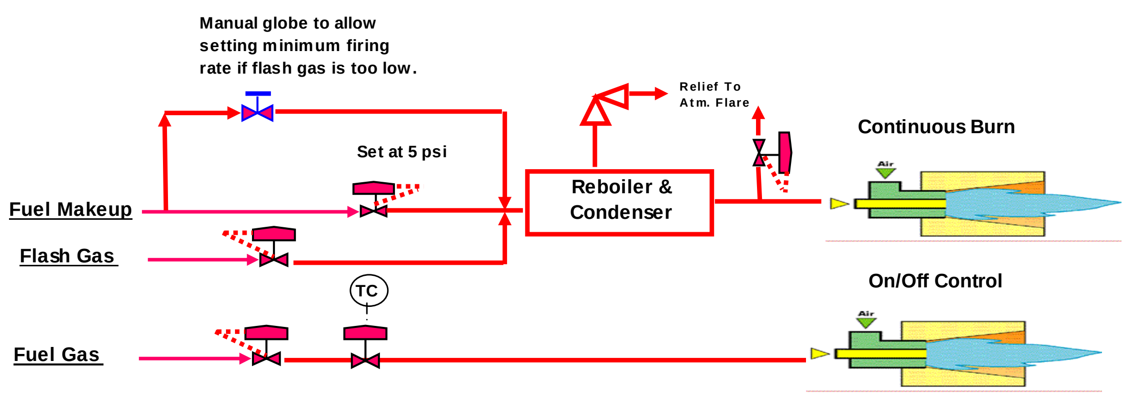


Figure 13 - Control System – Natural Draft Burner

To provide increased flexibility, a separate on/off burner is recommended with the control being from the reboiler temperature controller. This burner can be a "standard design' for a 10-12 psi fuel gas pressure.

The forced draft burner is designed to continually burn whatever gas is being sent to it at a constant air/fuel ratio. This ratio can easily be set to assure adequate combustion even if the fuel is very rich (Figure 14).

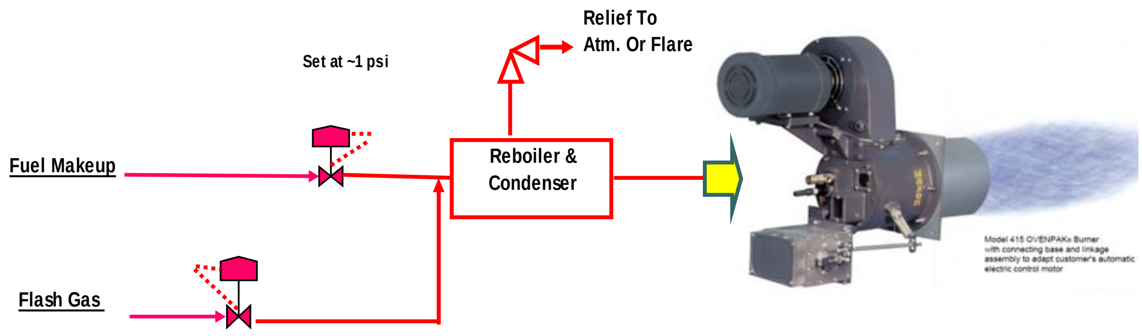


Figure 14 - Control System - Forced Draft Burner

EXPERIENCE

Exxon Mobil - St. Regis Gas Plant

In April, 2004, a precursor to the natural draft “StripBurn” system was introduced to ExxonMobil as a means to eliminate glycol reboiler still column vent emissions at their St. Regis Gas Plant in Jay, Florida. The existing system had used Nitrogen for stripping with the still column vent emissions being piped to a forced draft aerial cooler for condensation of water vapor and VOCs. The non-condensable hydrocarbons and N_2 were vented to atmosphere, but a change in the air permit required the elimination of the hydrocarbon vent.

To eliminate emissions, natural gas was used in the countercurrent stripping column in place of the N_2 and the “non-condensables” after the cooler were routed to a specially sized low-pressure burner assembly and used as primary fuel. The burner assembly was sized to fit in the existing burner flame arrestor housing. The stripping gas rate was set to provide a continuous burn in the new burner while the glycol circulation rate was set slightly higher than process requirements for dew point depression. This arrangement insured heat duty requirements were slightly in excess of the new burner. The existing burner, operating in the normal fashion, cycled on and off as required. The system operated reliably from start-up until the present time.

Kinder Morgan - Fandango Gas Plant

In August, 2004, Gly-Tech was contacted by Kinder Morgan’s Fandango Gas Plant just north of Zapata, Texas. Kinder Morgan indicated that during hotter summer months the inlet gas temperature to their glycol contactor often exceeded 140^{o}F, requiring a glycol purity of 99.75% or greater to meet dewpoint requirements. The unit was already equipped with a condenser and sump for liquids collection and an external countercurrent-stripping column was added.

The “StripBurn” system was employed to recover the stripping gas so enough packing height was provided in the stripper to allow the desired TEG concentration to be met with <2 scf/gal gas – a rate that requires a slight amount of supplemental fuel gas. To burn the gas in a natural draft burner, the reboiler was reinforced to allow for operation at 3-4 psi. The existing natural draft burner was replaced with one designed for the low pressure while a supplemental fuel gas line with flow being controlled by the existing temperature controller was added. The unit operated as expected and is still in service.

Duke Energy – Moss Bluff

Duke Energy showed interest in the natural draft "StripBurn" system in early 2005 as part of an overall upgrade of their Moss Bluff Facility outside of Liberty, Texas. The 100% vapor recovery aspect solved an air quality issue while the use of the recovered off gas as the primary fuel source for the glycol reboiler promised a quick return on investment. In December 2005, a VOC condenser unit was installed and modifications were made to upgrade the reboiler and surge tank operating pressures to about 4 psi. A newly installed flame arrestor, housing two low-pressure burners, was installed. The flash gas from the glycol-condensate-gas separator was piped to a fuel gas scrubber with additional dehydrated gas being added as required. The flash gas is supplemented by dehydrated gas and is used both as fuel for the primary burner and as stripping gas. The stripping gas, along with the non-condensable hydrocarbons from the Still Pure Unit, fuels the off gas burner. The system is in service at this time.

ADVANTAGES

The use of the "STRIPBURN" glycol reconcentration system offers many advantages such as:

- All vapors released from the glycol are completely combusted. 100% combustion is assured as contrasted to the method of injecting the VOCs into the stack.
- Less fuel consumption since glycol rates can be lower due to the use of stripping gas and the complete combustion of the "non-condensables."
- The larger than normal amount of gas being mixed with the VOCs results in less VOCs in the condensed water vapor from the overheads since the vapor-liquid equilibrium is shifted in such a way as to minimize the condensation of the VOCs. Thus, the disposal water will contain significantly lower quantities of undesirable components.
- No environmental testing of the facility for atmospheric discharge of VOCs should be required since no VOCs will be released to the atmosphere as is oftentimes the case with conventional technology.

In summary, pressure operation of glycol reboilers is a proven concept that offers many advantages as compared to other VOC or acid gas control schemes. This is now another tool that can be applied by process engineers in these environmental control situations.

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