Treat LPGs with Amines

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ABSTRACT

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INTRODUCTION

In recent years, there has been increasing interest in sweetening liquefied petroleum gases (LPGs) with amines. However, limited data and design information are available in the literature. This article reviews the fundamental aspects of LPG amine treaters and includes guidelines, design considerations and alternatives for static mixers, jet eductor mixers and columns with structured packing, random packing and sieve trays. All of these current design methods are compared based on plant operating data.

Guidelines are given for sweetening LPGs with amines including amine type, concentration, filtration, temperature, loading, circulation rate and water-wash systems. Also covered is the contacting method used in the absorber. Any of the commonly available amines such as monoethanolamine (MEA), diethanolamine (DEA), diglycolamine (DGA), methyl diethanolamine (MDEA) and MDEA-based solvents usually perform satisfactorily. Design criteria for distributors and LPG disperser plates, amine filtration and LPG settlers and coalescers are important. The contacting method is also important and includes jet eductor mixers, static mixers, and columns with sieve trays, random packing and structured packing.

In removing CO_2, one ideal stage is frequently sufficient to meet product requirements, while two ideal stages are usually required to meet the copper strip test for H_2S. Static mixers appear to perform reliably with 98% to 99% approach to an ideal stage. For columns, structured or random packing appears to perform better than sieve trays. More than one ideal stage can be achieved by using multiple mixing-separation stages or by using countercurrent columns.

Background

LPGs are continually becoming more important as sales products for gas producers. Economically, these liquids

are more valuable as feedstocks and liquid fuels than as a part of the heating value of natural gas. However, LPGs are often contaminated with acidic compounds such as H_2S, CO_2, COS, CS_2 and mercaptans.

H_2S is sufficiently corrosive at concentrations over 2.0 ppm to cause LPG to fail a copper strip test. H_2S in LPG can result in the formation of free sulfur or mercaptans when used as feedstock. Mercaptans impart strong odors to an LPG as well as its combustion products if they are present in any significant quantity. COS and CS_2, although not overly corrosive in LPGs, hydrolyze slowly to H_2S in the presence of free water, sometimes causing an LPG which initially met the copper strip test to fail after storage.[1] Significant quantities of CO_2 can also cause problems by raising the LPG's vapor pressure and lowering its heating value.

Acid gas contaminants must be removed before selling or using an LPG. When quantities are small, a simple caustic wash is both effective and economical. However, as the quantity of contaminants rises, the caustic supply and disposal costs render this approach impractical. Two other common alternatives are available: molecular sieves and amine treating. Molecular sieves have the advantage of drying the product as it is being sweetened, but require a large capital investment and incur high operating costs during regeneration.

Amine treating is an attractive alternative, especially when an amine gas treater is already onsite. In such cases, the liquid treater can often be operated using a slipstream of amine from the main unit. Over the years, early methods of designing amine treaters have been refined substantially, as reported by Holmes, et al.,[2] and Fleming, et al.[3] These methods continue to be refined with time and experience.

DESIGN CONSIDERATIONS

Amine-based LPG and gas-treating processes are similar since both involve contacting a low-density hydrocarbon phase (liquid or gas) with a heavier, immiscible liquid phase (aqueous alkanolamine solution). CO_2, H_2S and COS in the hydrocarbon phase are transferred to the aqueous phase where they react with amine. Rich amine is removed from the contactor, regenerated and recycled. In gas-treating units, the gas is usually (but not always) the continuous phase because of the large volumes of gas involved and limited gas-flow capabilities of flooded columns. In LPG treaters, however, the volumetric hydrocarbon phase flowrate is relatively low, although usually larger than that of the amine, and designs with either liquid as the continuous phase can be considered.
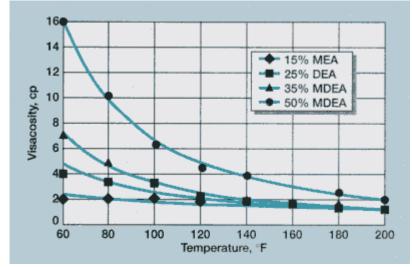
Since regenerators for liquid-liquid treating (referred to as liquid treating) are designed and operated the same way as regenerators for gas-liquid treating (referred to as gas treating), the process design considerations discussed here are limited to those associated with the distributors, filters, settlers and coalescers, water-wash systems and absorbers. These considerations include the amine type, temperature, pressure, loading, concentration, circulation rate and the contacting method used in the absorber.

Amine type.

Any of the commonly used ethanolamines including MEA, DEA, DGA, MDEA and MDEA-based solvents usually perform satisfactorily for liquid treating. Since the contact time for the two liquid phases is relatively long (often up to 30 minutes when the phase separation step is included), more than adequate time is available for the relatively slow reaction between CO_2 and the amines such as MDEA. Thus, the liquid contact time or "residence time," which for gas treating is relatively short and of great importance, is not a consideration for liquid treating.

LPG treater operating temperatures and pressures.

These must be maintained within narrow limits to keep the hydrocarbon in its liquid state, minimize hydrocarbon and amine entrainment, and optimize amine-hydrocarbon separation. Veldman recommends that the lean amine temperature be controlled so that the viscosity is around 2 centipoise at the amine/LPG interface to assure effective phase separation.[4] Fig. 1 shows the relationship between amine solution temperature and viscosity for several amines. Operating temperatures must be greater than about 100^oF for effective separation. DuPart and Marchant reported a similar problem where on extremely cold days excessive amine entrainment in the LPG

product occurs.[5] In this case, improved control of the amine and LPG inlet temperatures reduced amine losses.

Figure 1. Viscosities of aqueous ethanolamine solutions.

As previously noted, operating conditions must be below the LPG bubble point throughout the treating system to ensure that the hydrocarbon remains in a liquid state. The designer must carefully evaluate the entire LPG treating system pressure profile to ensure that an adequate safety margin is maintained. Maximum and minimum LPG and amine operating temperatures should be considered in making this evaluation. It may be desirable to provide temperature control to ensure that neither the amine nor the LPG are too hot or cold. Typical design margins between the LPG bubble point pressure and the LPG treater operating pressure are often 100 psi or greater. The minimum LPG treating system operating pressure is generally 50 psi or more above the LPG bubble point pressure.
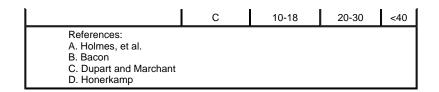
Amine solution flowrates and compositions.

Calculating the minimum required amine flowrate, the maximum product purity attainable, and the relationship between amine flowrate and number of theoretical trays requires accurate liquid-liquid equilibrium data. As previously discussed, this data can be estimated by the approximate method of Honerkamp[6] or the more precise method of Holmes, et al.[2], and TSWEET[7].

The maximum LPG purity possible is that which would be in equilibrium with the lean amine solution. Since equilibrium can only be approached in practical equipment, it is necessary to regenerate the amine to acid gas concentrations below the levels that would be in equilibrium with the desired LPG product purity. For the case of CO_2 removal from LPG with MEA, Honerkamp recommends that the lean amine be regenerated to less than 0.1 mole CO_2/mole amine.[6]

The theoretical minimum amine flowrate occurs when rich amine leaving the contactor is in equilibrium with the entering LPG. However, to provide an adequate driving force for mass transfer over the entire contactor, it is necessary to use an actual flowrate greater than the minimum. Result: the rich solution loading is always below the equilibrium value. Typical recommended rich solution loading values for MEA, DEA and DGA are in Table 1.

Table 1. Recommended solution conditions for LPG treating with alkanolamines.				
	Reference	MEA	DEA	DGA
Rich solution loading, mol acid gas/mol amine	A	0.3-0.4	0.35-0.65	-
	B	<0.4	-	-
	D	<0.5 (CO2)	-	-
Amine Concentration, wt%	A	5-20	25-35	5-70
	B	<18	-	-

		C	10-18	20-30	<40

References:
A. Holmes, et al.
B. Bacon
C. Dupart and Marchant
D. Honerkamp

These rich amine-loading recommendations should be used with caution because the minimum amine circulation requirement is usually determined by the approach to equilibrium at the contactor bottom. The calculation methods outlined by Honerkamp and Holmes, et al., can be used to calculate a flowrate corresponding to the desired approach to equilibrium. A 60% to 70% approach to equilibrium at the contactor bottom usually results in a conservative design. Table 1 also lists the amine concentrations recommended by different investigators.

Treated LPG water wash to remove entrained and soluble amine.

LPG amine treaters can be a source of substantial amine losses.[8-10] Veldman states that amine losses due to amine entrainment and solubility for well-designed and operated LPG treaters amount to about 0.02 lb of amine per barrel of LPG treated.[4] A common method of reducing amine losses is the use of a water-wash system as shown in Fig. 2. Washing the LPG with a dilute amine-water solution reduces the dissolved amine.
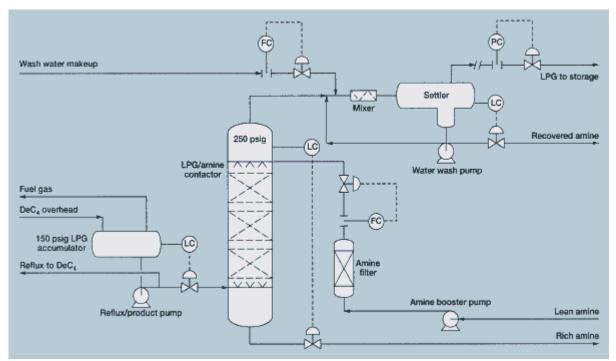

Figure 2. Typical LPG amine treating system with gravity settler and LPG water wash.

Stewart and Lanning review design criteria for LPG water-wash systems.[8-10] For a gravity settler as in Fig. 2, they recommend LPG and wash-water residence times of 15 and 20 minutes, respectively. They also recommend that the water makeup rate should be set so that the wash-water purge to the amine system contains about 3 wt% amine. While solubility data such as that of Veldman can be used to estimate amine solubility losses in the LPG, it is probably best to base the design on 0.02 lb of amine per barrel of feed (about 100 ppmw) as this figure includes amine entrainment. Poorly designed systems with high superficial velocities or with inadequate LPG residence times in the LPG amine contactor can have amine losses as high as 500 ppmw.[4] While there is considerable variation, typical practice is to set the volumetric ratio of wash water to LPG at 1:4, although Stewart and Lanning report one case where the wash water was 6% to 7% of the LPG volumetric flow. See Table 2 for details.

Table 2. Water-wash system operating conditions for recovering MDEA from liquid ethane.		
	Test 1	Test 2

Ethane rate, bpsd	22,000	27,000
Water-wash rate, gpm	44	44
Water-wash amine content, wt %	0.3	0.4
Water-wash makeup, gpm	3.5	3.5
Water-wash rate, % C2 flow	7	6
Source: Stewart and Lanning		

Contacting method.

The contactor designs that have been studied to date include:

Jet eductor mixer.

This type of mixer simply draws one fluid into the other in turbulent flow. The resulting mixture is then charged to a separation drum where contact continues as LPG rises to the top and amine sinks to the bottom. Such units have a theoretical maximum efficiency equivalent to one ideal stage. However, due to less-than-ideal mixing, the jet eductor usually achieves less than one ideal stage. Holmes, et al., has reported data for three cases using jet eductor mixers. For these cases, all the jet eductors performed with efficiencies nearly 98% to 99% of one ideal stage. However, efficiencies as low as 70% have been observed.

If higher acid gas removal efficiencies are required with jet eductor mixers, then a series of two mixer-separator steps must be used with fresh amine solution being fed to the last mixer, if not to both mixers. In some cases, rich solution from the second stage may be fed to the first stage to achieve additional loading of the amine. No additional performance data for jet eductor mixers were available for the present work.

Static mixer.

A second alternative is to use a static mixer to enhance the turbulence and dispersion of LPG into the amine phase. Although this technique still has a maximum theoretical efficiency of one ideal stage, a well-designed static mixer can frequently achieve 98% to 99% or greater efficiency. Given a reasonable amine flowrate, one ideal stage is often sufficient to meet the required specification, especially for CO_2. Fleming, et al., recommend settling times of 20 to 80 minutes unless specially designed coalescers are used.

Columns.

In most column contactors, amine flows downward while the LPG flows upward. Dispersion can be achieved either by sieve plates or by random or structured packing. In columns, complex flow paths are used for contacting instead of velocity turbulence. In addition, since the flows are countercurrent rather than cocurrent, multiple ideal stages can be achieved in a single contactor.

Sieve plates give uniform dispersion. The LPG droplet size is a simple function of the hole size and LPG flowrate. However, this control of dispersion places a lower limit on droplet size – as the holes in the plate become smaller, the LPG has greater difficulty in overcoming surface tension and forcing its way upward through the plate. An additional problem associated with trays: because the droplets are free rising rather than bound to a surface, they are not as well mixed as if they are working their way up through a packed column. Also, they have a greater probability of entraining amine and carrying it back up the column. This implies that the efficiency of any given plate will be relatively low. At least 10 trays are usually required to achieve the equivalent of one ideal stage. Honerkamp, Fleming, et al., and DuPart and Marchant report that sieve trays are less efficient than random packing for LPG treating.

Poured or random packing is less expensive to install than trays. In addition, efficiency is usually higher with packing because the complex meanders in the packing act to continuously stir and break up LPG droplets working their way up through the column. However, the random orientation of poured packing creates the possibility of channeling.

When channeling occurs, easy upward paths may collect virtually all of the LPG, holding it out of contact with descending amine. The only way to limit channeling and ensure good contact is to build the contactor in several

sections with a redistributor between each section. A general rule of thumb is that approximately 8 ft. of random packing is the equivalent of one ideal stage, and a single section of packing rarely exceeds the performance of a single ideal stage.[2] Other disadvantages associated with random packing are poor response to varying hydrocarbon flows[6] and aggravated amine carryover caused by widely varying flowrates. Recycle loops may be used to correct this problem and maintain constant LPG flow as described by McClure and Morrow.

Structured packing is an alternative that retains the advantages of poured packing and sieve trays without the disadvantages previously discussed. Because the individual cells are constructed in an ordered manner, the possibility of channeling is eliminated. In addition, because the flow path is much more complex than that of a sieve tray, good mixing and droplet stirring is also achieved. Structured packing is provided as a single unit, while multiple beds are required for random packing.

By providing the packing as a single unit, the required packing height and contactor height can be reduced or more theoretical stages can be achieved for a given vessel height. Structured packing also has a significantly higher capacity than random packing. Although it is claimed that structured packing is more resistant to plugging than random packing, structured packing is more difficult to clean, and full flow filtration of the lean amine is recommended. Overall, structured packing may achieve results that far exceed that of either sieve plates or random packing.

Design criteria for LPG settlers and coalescers.

Honerkamp recommends using an LPG coalescer or settler downstream of the LPG/amine contactor to remove entrained amine from the LPG. A settler is a horizontal vessel that uses gravity to separate two liquid phases. Baffles to prevent channeling are sometimes provided. A coalescer is a vessel that contains elements such as wire mesh pads that agglomerate small liquid droplets into larger droplets which can then be easily separated by gravity.[11] A coalescer is smaller than a settler and costs less; however, the elements can plug if the liquid is dirty. Performance and size of a coalescer depend on the design of the coalescing elements, which are usually proprietary items.

Although it is difficult to provide generalized guidelines for sizing coalescers, elements used for LPG/amine applications must be resistant to caustic attack, and should be made of stainless steel, polyester or polypropylene. Fiberglass is not suitable, as amine degrades it. Also, the coalescing element's performance cannot depend on a hydrophilic coating since surface-active amine contaminants will "disarm" the treated surface and reduce its coalescing efficiency.[11]

While coalescers cost less, gravity settlers have the advantage of simplicity and operating reliability. Settlers are usually designed on the basis of residence time. Honerkamp reports that a settler downstream of a single stage eductor was designed for a 80 minute hydrocarbon retention time with a hydrocarbon-amine interfacial area of 2,500 gal/day-ft^2 (0.58 ft^2/gpm) used to set the settler dimensions. According to Honerkamp, separators downstream of contactors using either random packing or sieve trays can be smaller than those following mixers or eductors because the degree of agitation is less. Stewart and Lanning recommend LPG residence times of 15 minutes for a gravity settler downstream of a packed bed LPG treater.

Amine filtration for LPG treaters.

Fig. 2 includes an optional amine filter on the lean amine to the LPG/amine contactor. Even though many LPG treaters do not have dedicated mechanical or activated carbon filtration, their use should be considered. Bacon recommends a full flow mechanical and activated carbon lean amine filter for LPG treaters.[12] Russell reports particulate plugging of the random packing beds used in LPG treaters and recommends full flow amine filtration to minimize plugging.[13] DuPart and Marchant also recommend both full flow mechanical and activated carbon filtration of the amine flowing to LPG treaters.[5] Failure to remove impurities can reduce the LPG treating system's capacity.

Criteria used to set the LPG contactor diameter.

It is common practice to base the LPG/amine contactor diameter on the superficial velocity of the two liquid phases combined. There is considerable variation in design superficial velocity recommendations. Perry[1,14]

recommends sizing LPG contactors based on 15 gpm/ft^2. DuPart and Marchant support Perry's recommendation, which is based on gas plant liquids. Russell suggests a superficial velocity of 12 gpm/ft^2, while Changela and Root[15] and Veldman[4] recommend 10 gpm/ft^2. The GPSA Engineering Data Book[16] recommends 20 gpm/ft^2.

A design superficial velocity of 15 gpm/ft^2 is probably appropriate for most gas plant liquids because there is a greater difference between the density of the LPG and amine phases, the amine and LPG are usually relatively clean, and hydrocarbon liquid production typically declines with time. In a refinery application, 10 gpm/ft^2 would seem to be the proper choice because refinery capacity usually increases through a progressive series of revamps, the amine is often contaminated with particulates and surface active compounds, and the LPG usually has a higher gravity than gas plant liquids. In any case, design of a new LPG treater should be based on a design superficial velocity of 15 gpm/ft^2 or less.

The flooding correlation of Crawford and Wilke should be used with caution when evaluating LPG treaters. Strigle suggests that LPG treater design be based on 12% of the flooding velocity given by Crawford and Wilke since flooding in LPG treaters can occur at 20% of the flooding velocity predicted by that correlation.[17]

LPG and amine distributors and LPG disperser plates.

If amine is the continuous phase, LPG must be evenly dispersed at the bottom of each random packing bed. Usually, this is accomplished with a ladder-type LPG distributor beneath the bottom bed and a separate disperser/support plate beneath each bed of packing. The LPG ladder distributor holes should be pointed upward to minimize LPG entrainment in the rich amine.[18]

The disperser/support plate is designed so that LPG pools below the plate and flows up into the random packing through orifices in the plate. Amine, which is the continuous phase, flows through downcomers in the disperser/support plate. The number of downcomers required is determined by the amine flowrate.[5,17] See Fig. 3 for details. Although separate devices can be used for packing support and LPG dispersion, Strigle and DuPart and Marchant recommend a combined disperser/support plate since the support plate commonly used for random packing can adversely affect LPG dispersion. DuPart and Marchant review the merits of different disperser-packing support arrangements.
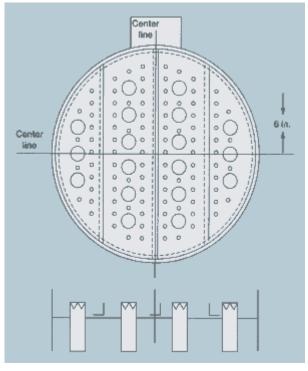

Figure 3. Disperser/support plate for packed columns.[17]

According to Honerkamp, the design of the hydrocarbon disperser/support plates between packed beds is critical. Excessive LPG velocity through the plate orifices can produce emulsions, while insufficient velocity causes poor LPG distribution. DuPart and Marchant, Tse and Santos, and Strigle review LPG and amine distributor and LPG redistributor design criteria.

According to Tse and Santos, LPG velocities in the ladder-type distributor and in the disperser/support plate orifices should be less than 1.25 ft/sec.[18] Russell recommends that the number and size of the orifices be based on a velocity of 1.0 ft/sec.[13] Disperser/support plate LPG orifice design velocities should be in the range of 1.0 to 1.25 ft/sec.[13,17] Russell also states that operating at jet velocities below 0.5 ft/sec can lead to LPG entrainment in the rich amine. Orifice velocities above 1.25 ft/sec can lead to emulsion formation and amine carryover in the LPG.[1,13,14] Orifice diameters should be 0.19 to 0.25 in.[17] Larger orifices produce irregular, non-uniform droplets, reducing mass transfer. Smaller orifices can lead to emulsion formation.[5]

The amine distributor is usually a ladder-type consisting of a series of parallel tubes fed by a central pipe. Orifices in the parallel tubes are pointed down into the top packed bed and are sized assuming the amine velocity does not exceed 170 ft/min.[5,17]

Method of analysis.

A process simulation program called TSWEET was used to assist in the guidelines analysis. It is an advanced process simulation program that models gas and/or liquid treating with amines, sulfur recovery, tail gas cleanup units and sour water strippers. The program's sweetening capabilities have been described in the literature.[19-26]

FINDINGS

Three case studies are presented to expand the pool of operating data beyond that reported by Honerkamp, Holmes, et al., and Fleming, et al. These cases are used along with the previous data to analyze the design considerations for sweetening LPGs with amines.

Case 1: Static mixer contactor.

Table 3. LPG feed composition and conditions for Case 1.	
Parameter	**Value**
Flow, gpm	240
Temperature, °F	110
Pressure, psia	900
Ethane, mol%	85.0
Propane, mol%	14.4
CO_2, mol%	0.6

In this case, a static mixer was used to treat an LPG stream containing 85% ethane and 0.6% CO_2. The static mixer was 4-in. diameter and 24-in. long with six mixing elements as depicted in Fig. 4. The feed LPG as shown in Table 3 was treated with 27 gpm of 80 wt% DGA. Unit operating data are shown in Table 4 with simulation results for one ideal stage using 100% and 98% efficiency.

Table 4. Comparison of operating data for static mixer with simulation results for Case 1.			
	Data	**Simulation**	**Simulation**
Number of ideal stages	-	1	1
Stage efficiency, %	-	100	98
Amine	DGA	DGA	DGA
Amine wt%	30	30	30

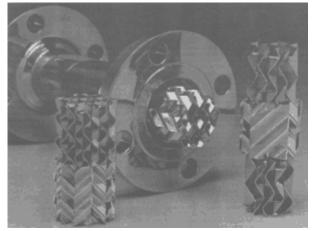| Amine flow, gpm	85	85	85
Amine rich loading, mol/mol	-	0.21	0.21
CO2 in, vol%	0.6	0.6	0.6
CO2 out, ppm	100	15.4	99.8

Figure 4. Example of a static mixer.

As can be seen from Table 4, the static mixer achieved an efficiency of 98% of one ideal stage for Case 1. This 98% efficiency compares favorably with 98.7% obtained by Fleming, et al., with a static mixer and is significantly higher than the 93% reported by Holmes, et al., using a static mixer with five reversing elements. The high amine to LPG flowrate was likely a contributing factor in the high efficiency obtained by Fleming, et al. The lower efficiency obtained by Holmes, et al., may be due to the reversing design of the mixing elements and to somewhat higher amine loading. In general, removal efficiencies on the order of 98 to 99% of one ideal stage should be achievable as supported by the data. If the mixers are not well-designed or if low amine to LPG flowrates are used, efficiencies in the lower 90s may be realized.

Case 2: Sieve tray column.

Table 5. LPG feed composition and conditions for Case 2.	
Parameter	**Value**
Flow, gpm	700
Temperature, $^\circ$F	60
Pressure, psia	800
Methane, mol%	1.78
Ethane, mol%	80.05
Propane, mol%	17.36
i-Butane, mol%	0.17
n-Butane, mol%	0.03
CO_2, mol%	0.61

A column containing 20 sieve trays was used to treat a 700-gpm LPG stream as shown in Table 5. The LPG contained 80% ethane and 0.61% CO_2 and was treated with 85 gpm of 35 wt% MDEA. The column was 90-in. in diameter. The operating data as reported in Table 6 show that this unit was just meeting the required CO_2 specification of less than 750 ppm CO_2. As shown in Table 6, this level of performance corresponds to roughly 90% of one ideal stage, which is rather poor for 20 sieve trays. As reported in Case 5 from Holmes, et al., a 10-sieve-tray column achieved a CO_2 removal efficiency of 99% of one ideal stage. As previously mentioned, column design, including the tray geometry, can have a major impact on performance. The performance of these two columns suggests that insufficient performance data exist to accurately design sieve tray columns for liquid-liquid treating. The 20-tray column also experienced extensive carryover of amine into the LPG.

Table 6. Comparison of operating data for 20 sieve tray column with simulation results for Case 2.			
	Data	**Simulation**	**Simulation**
Number of ideal stages	-	1	1
Stage efficiency, %	-	100	90
Amine	MDEA	MDEA	MDEA
Amine wt%	35	35	35
Amine flow, gpm	85	85	85
Amine rich loading, mol/mol	-	0.205	0.206
CO2 in, vol%	0.61	0.61	0.61
CO2 out, ppm	750	151	749
LPG flow, gpm	700	700	700

Case 3: Structured packing column.

To eliminate amine carryover and increase CO_2 removal capacity, trays in the column for Case 2 were replaced with 20 ft of structured packing. A graphic representation of the structured packing is shown in Fig. 5. After adding structured packing, the column was able to process 2.5 times as much LPG with no carryover or excess CO_2 in the sweet LPG. The operating data with the structured packing are shown in Table 7 with the simulation results. These results show that 20 ft of structured packing at the increased LPG flowrate of 1,750 gpm behave as one ideal stage with a 97.5% efficiency.

Table 7. Comparison of operating data for structured packing column with simulation results for Case 3.			
	Data	**Simulation**	**Simulation**
Number of ideal stages	-	1	1
Stage efficiency, %	-	100	97.5
Amine	MDEA	MDEA	MDEA
Amine wt%	35	35	35
Amine flow, gpm	210	210	210
Amine rich loading, mol/mol	-	0.203	0.203
CO2 in, vol%	0.61	0.61	0.61
CO2 out, ppm	<300	148	298
LPG flow, gpm	1750	1750	1750

Comparison of contacting methods.

Based on the data and work of Honerkamp, Holmes, et al., Fleming, et al., and our work, the amine-LPG contacting methods are summarized and compared in Table 8. When using mixers, if more than one ideal stage is required for the separation, multiple mixing and separation stages must be used. Settling times on the order of 20 to 30 minutes or specially designed coalescers are required to prevent excess entrainment. Since column operations are countercurrent, more than one ideal stage can be realized by using the proper number of trays or packing height. In conventional random packed columns, redistributors should be used about every 8 ft. of packing. In most columns, no additional settling tanks are required to prevent excessive entrainment.

Table 8. Contacting methods for sweetening LPG -- devices and efficiencies	
Contacting Method	**Removal Efficiency**
Jet eductor mixer	70-99% of one ideal stage
Static mixer	98-99% of one ideal stage
Sieve trays	10-20 trays per ideal stage
Random packing	8 ft with redistributor per ideal stage
Structured packing	20 ft per ideal stage*
*Based on one unit with high throughputs.	

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