# Amine Basic Practices Guidelines

The following is a compendium of basic operating guidelines for  $H_2S/CO_2$  amine systems. It was compiled by process experts from several major oil and gas processing companies and independent consultants. It is based on their collective experiences relating to operating guidelines for  $H_2S/CO_2$  amine systems. The intent is to help the industry better understand and operate their amine plants with the goals of improved environmental compliance, improved reliability, reduced operating costs, and improved sulfur plant operation.

In putting this document together, a number of assumptions were made. Some of the key assumptions, particularly in the "action" section, include:

- Plant equipment functions as designed and is correctly designed.
- All instrument readings (flows, temperatures, and pressures) are correct; "repair instruments" is not included as a listed action.
- Amine quality is within established limits.

We have described how to operate a generic amine unit that we believe to be typical of those in the industry. The reader may have to adjust the information presented here where his operation or amine unit is atypical.

In preparing these practices we have used one set of terminology, recognizing that other terminology is used in the industry. Examples include:

Regenerator – stripper, reactifier, tower, still, still tower Absorber – treater, contactor, scrubber

# <u>Disclaimer</u>

It should be noted there is no operational guarantee implied with the data or procedures presented in this manual. They are intended to be used as guidelines against which to measure or evaluate specific amine unit operations.

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#### 1. FEED GAS PRETREATMENT

For gas feeds, commonly applied apparatus includes knockout drums, filter-separators or a water wash drum or column.

The Inlet Knockout Drum functions to catch entrained hydrocarbon liquids and occasional slugs. It is difficult to size the apparatus for slug protection and the need is determined by an analysis of the upstream system considering the tendency of the source to carryover. A pump may be added if significant carryover is expected.

A Filter-Separator is frequently used to remove liquids and solids from gas streams. What about adding aerosol coalescing separation??

A water wash drum is a trayed column recommended for gas streams from an FCC, Coker, or Vacuum Unit that may contain cyanides, acids ammonia or particulates. A circulating water stream removes these contaminants. Liquid is bled to the sour water system. Sour water stripper feed is commonly used as make-up because the ammonia is a good buffer and this minimizes refinery sour water.

The goal of any of these alternatives is to prevent the introduction of hydrocarbons, acids or other contaminants into the contactor to help prevent foaming, corrosion, and other upsets.

	Filter Se	parator	Pressure	Drop
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•	• Normal Range:		< 2 psi
•	Ins	trument:	Differential pressure gages (field) Differential pressure transmitter/recorder/alarm (board)
•	Sta	tus Check:	Field, once/shift (round); board, at alarm or upset
•	De	viation:	< 0.1 psi reading
		Cause:	Torn elements, open bypass
		Consequence:	Hydrocarbon contamination leading to foaming Filter material carried into amine equipment
		Action:	Confirm board and field instruments in agreement. Close bypass. Replace elements.
•	De	viation:	Continual rise
		Cause:	Particle accumulation, high liquid loadings
		Consequence:	Reduced throughput, HC contamination leading to foaming
		Action:	Drain liquid boot more frequently (manual drain). Check level instruments (auto drain). Check for separation efficiency in upstream equipment. Clean or replace dirty element.

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### 1. FEED GAS PRETREATMENT - cont

•	Deviation:	Sudden increases
	□ Cause:	Upstream upset, level control failure (high) on upstream equipment, liquid/solid fouling
	□ Consequence:	Blind-off leading to relief or compressor problems HC contamination of amine leading to foaming, reduced throughput
	□ Action:	Control upset in upstream unit. Drain liquid buildup. Clean or replace dirty element.

# Liquid Levels

•	Normal Range:	Level in gage glass (field), 50% +/- 25% (board or field level instrument)
•	Instrument:	Gage glass, d/p cell, float, or other level sensor / transmitter / readout / alarm
•	Status Check:	Field start once/shift (round)

- Status Check: Field, start once/shift (round) Board, at alarm or upset
- Deviation: No level ever shows
  - Cause: Bypassing, manual drain valve leaks, torn element
  - Consequence: Hydrocarbon contamination of amine leading to foaming, gas release to unprotected vessels or atmosphere
    - Action: Close bypass Check valves for leaks Replace element
- Deviation: Gradual level increase
   Cause: Infrequent manual draining, faulty level control/control valve, higher than normal liquid influx
   Consequence: Hydrocarbon contamination of amine leading to foaming
   Action: Control upstream upsets Increase manual drain frequency
  - Increase manual drain frequency Check level control valve

# 1. FEED GAS PRETREATMENT - cont

# Water Wash Drum Circulation Rate

•	No	rmal Range:	5 - 10 gpm/sq.ft.
•	Ins	trument:	Flow controller
•	Sta	tus Check:	On alarm at sign of upset
•	De	viation:	Low
		Cause:	Pump failure, loss of suction, control failure
		Consequence:	Breakthrough of contaminants to amine contactor (cyanides, acids, ammonia, particulates, organics)
		Action:	Check pump, restart or start spare, check tower level

# Water Wash Drum Level

•	• Normal Range:		Design normal liquid level +/- 5%
•	Ins	trumentation:	Level gauge, high and low level alarms
•	Sta	tus Check:	Every round and at alarm
•	De	viation:	Low
		Cause:	Water carryover, loss of makeup water
		Consequence:	Loss of circulating water
		Action:	Check downstream KO pot for water, check source of makeup water and restore
•	De	viation:	High
		Cause:	Excess makeup water, hydrocarbon carryover
		Consequence:	Loss of treating
		Action:	Check upstream source for problems, increase purge rate

An overhead knockout drum may be installed to pick up amine carryover. This requirement is a function of contactor design and the perceived likelihood of entrainment of foaming. If foaming is expected, a water spray to collapse the foam may be appropriate.

# Level

•	Nor	rmal Range:	Empty to just visible
•	• Instrument:		Level gauge (sight glass) High level alarm in critical service Automatic level control valve in "wet" service
•	• Status check:		Level to be visually checked on every round and vessel drained as needed. If alarm is provided, in response to it
•	Dev	viation:	High
		Cause:	Upset in upstream equipment
		Consequence:	If not stopped, liquid will carry over and contaminate downstream processes
		Action:	Drain liquid - hydrocarbon to a slops system Amine to the amine system Check operation of upstream equipment

With liquid hydrocarbon contactors, carryover of amine is a common occurrence. A simple knockout drum may be acceptable if the expectation is that the only significant carryover of amine will be as slugs, but a coalescer-separator is generally recommended to recover chronically entrained droplets. Recovery is further maximized by the upstream injection of recycle water which is typically limited to 5 wt-% amine.

# Level

•	No	rmal Range:	Visible interface
•	Inst	trument:	Level gauge (sight glass) High level alarm in critical service Automatic level control valve in "wet" service
•	• Status Check:		Level to be visually checked on every round and vessel drained as needed. If alarm is provided, in response to it
•	Dev	viation:	High
		Cause:	Upset in upstream contactor
		Consequence:	If not stopped, liquid will carry over and contaminate downstream processes
		Action:	Drain liquid to the amine system Check operation of upstream equipment
•	Dev	viation:	Low
		Cause:	Drain valve open or passing
		Consequence:	If not stopped, hydrocarbon will carry under and contaminate the regenerator
		Action:	Check drain valve

#### 4. GAS ABSORBER

The Gas Absorber (or Contactor) is a typical counter flow gas-liquid contactor equipped with trays or with random or structured packing, typically containing about 20 trays or equivalent. Adequate separation space is required at the top and mist pads are frequently used.

Common industry practice is to maintain lean amine temperatures  $10-15^{\circ}F$  hotter than the raw gas feed to the absorber, to avoid foaming due to HC condensation where the gas is saturated. However, if the gas is not saturated or any heavy (C<sub>6</sub>+) HCs are not surface active, condensation may not be an issue and it may be preferable to minimize the lean amine temperature (to  $80^{\circ}F$ ) in order to maximize fuel gas cleanup.

Design pressures of the contactor and associated KO pots normally match the gas source design pressure so that the contactor does not require overpressure relief capacity for full gas flow at blocked discharge. Tower material is steel; trays are typically 304, 316 or 410SS. Stress relieving (post weld heat treatment) is preferred for all amine vessels, and is an absolute necessity for MEA systems.

#### **Differential Pressure**

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		Action:	Add antifoam (discriminately), reduce gas and/or lic check relative gas/amine temperatures to determine HC condensation, check feed gas for entrained HC's	uid rates, likelihood of
		Consequence:	Poor efficiency, liquid carryover, general plant upse	t
		Cause:	Foaming, flooding	
•	De	eviation:	Sudden increase, erratic action	
		Action:	Cleanout, identify root cause (e.g. corrosion, contam	nination)
		Consequence:	Flooding, poor efficiency, off-spec treated gas, capa	city limit
		Cause:	Possible fouling	
•	De	eviation:	Gradual increase	
		Action:	Mechanical repair	
		Consequence:	Poor efficiency, off-spec treated gas	
		Cause:	Possible tray damage	
•	De	eviation:	Consistently low	
•	Sta	atus check:	At alarm or sign of upset	
•	• Instrument:		Continuous recorder w/alarm. <i>Note:</i> By locating th cell tap at roughly the same elevation as the top sigh connection, it doubles as an independent high-level	e lower d/p t glass alarm.
•	• Normal Range:		0.1 - 0.2 psi/tray	

# Feed Gas Flow Rate

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		Action:	Adjust conditions determining rate	
		Consequence:	Increased utility consumption	
		Cause:	Change in controller status or supply pressure	
•	De	eviation:	High	
		Action:	Adjust conditions determining rate	
		Consequence:	Potential reduction in acid gas recovery	
		Cause:	Change in controller status or supply pressure	
•	De	eviation:	Low	
•	Sta	atus check:	At alarm or sign of upset	
•	Ins	strument:	Controller w/alarm	
<u>An</u> •	nino No	e Flow Rate	As necessary to achieve on-spec treated gas within loading targets	n rich amine
		Action:	Increase amine flow	
		Consequence:	Increased amine demand, possible jet flooding	
		Cause:	Upstream process change	
•	De	eviation:	High	
		Action:	Reduce amine flow, supplement feed gas with rec if warranted	ycle or clean gas
		Consequence:	Reduced amine demand, potential reduction in ma due to weeping	ass transfer
		Cause:	Upstream process change	
•	De	eviation:	Low	
•	Status check:		At sign of upset or change in process conditions	
•	Instrument:		Continuous recorder	
•	Normal range:		Site specific	

# Feed Gas Temperature

•	Normal range:	80-120°F
•	Instrument:	Indicator
•	Status check:	Once/round or at sign of upset
•	Deviation:	Low
	□ Cause:	Change in upstream process and/or ambient conditions
	• Consequence:	Reduced acid gas recovery in extreme cases
	□ Action:	Increase temperature of feed gas and/or amine
•	Deviation:	High
	□ Cause:	Change in upstream process and/or ambient conditions
	• Consequence:	Potentially reduced acid gas recovery
	□ Action:	Decrease feed gas temperature, or increase amine flow rate to improve heat balance

# Lean Amine Temperature

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	□ Action:	Increase lean amine cooling
	□ Consequence:	Potentially reduced acid gas removal due to poor equilibrium at high absorber temperatures Excessive moisture in treated gas, with potential downstream condensation and resultant corrosion/fouling
	□ Cause:	Change in upstream process and/or ambient conditions
•	Deviation:	High
	□ Action:	Reduce lean amine cooling or supply heat
	• Consequence:	Potentially reduced acid gas removal from high viscosity or low rate of reaction
	□ Cause:	Change in upstream process and/or ambient condition
•	Deviation:	Low
•	Status check:	Once/round or at sign of upset
•	Instrument:	Indicator
•	Normal range:	90-130°F

# Lean Amine / Feed Gas Temperature Differential

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	□ Action:	Increase amine circulation rate	
	• Consequence:	Reduced acid gas removal, corrosion	
	□ Cause:	Undercirculation	
•	Deviation:	High	
	□ Action:	Reduce amine circulation rate	
	• Consequence:	Excessive utility consumption	
	□ Cause:	Overcirculation	
•	Deviation:	Low	
•	Status Check:	Site-specific, ranging from once/shift to weekly	
•	Hazard:	Potential H <sub>2</sub> S release	
	□ Caution:	Samples exposed to air or allowed to weather may accurate results. Relative $H_2S$ loss is significantly increased by hig pressures, LPG entrainment and excessive (> 0.5)	y not yield h contactor mole loadings.
•	Analysis:	Spot lab sample	
•	Normal range:	Maximum within target (see Appendix for typical loadings), contingent on satisfactory gas cleanup	rich amine
Ri	ch Amine Loading		
	□ Action:	Increase lean amine temperature	
	□ Consequence:	Condensation of HCs, potentially resulting in foar emulsification	ming and/or
	□ Cause:	Change in upstream process and/or ambient condi	itions
•	Deviation:	Low	
•	Status check:	Once/round or at sign of upset	
•	Instrument:	Indicators on individual streams	
•	Normal range:	Lean amine at least 10°F hotter than feed gas, who saturated	ere gas is HC-

# H2S in Treated Gas

•	Normal range:	10-50 ppm
•	Instrument:	Optional online analyzer
•	Analysis:	Length-of-stain tube
•	Status check:	Once/round or at sign of upset
•	Deviation:	High
	□ Cause:	One or more of following: flooding, foaming, inadequate stripping, amine rate, temperature or quality
	□ Consequence:	Contractual/environmental non-compliance
	□ Action:	Adjust process conditions as warranted

#### 5. LPG CONTACTOR

The LPG Contactor (Absorber) is similar in most respects to the gas contactor with regard to materials, configuration, and design pressure considerations. These essential differences must be kept in mind:

- 1. There is a liquid-liquid interface to deal with; it is recommended that amine be the continuous phase, with the interface above the packing or trays.
- 2. The flow of the discontinuous phase is from bottom to top and trays must be designed accordingly.
- 3. The operating pressure/bubble point temperature relationship must be considered and it may be necessary for amine temperature to be below liquid hydrocarbon temperature to assure that localized vaporization of hydrocarbon does not occur.

#### Hydrocarbon Flow

•	No	rmal Range:	<ul><li>Hydrocarbon flow direction is upward through the contactor.</li><li>The rate is dependent on upstream devices such as level control or flow control from storage.</li><li>Flow rate can vary from design rate down to 20-30% depending on refinery requirements.</li></ul>
•	Inst	trument:	Minimum recommended is flow rate indication. Recording instrumentation should be considered and provides indication of instability and upset conditions.
•	Sta	tus check:	Once/shift or upon upset or alarm
•	Dev	viation:	High
		Cause:	Upstream flow rate changes
		Consequence:	Process upset Sour product Emulsion formation at interface Amine carryover to downstream process
		Action:	Find cause of problem, add antifoam
•	Dev	viation:	Low
		Cause:	Upstream flow rate changes
		Consequence:	None
		Action:	Lower lean amine rate

# **Amine Flow Rate**

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		Action:	Adjust cooling to get amine to proper temperature	e
		Consequence:	Sour product, amine carryover	
		Cause:	Improper amine cooling, upstream HC processing	g problems
•	De	viation:	High	
•	Sta	tus check:	Once/shift or on indication of problems	
•	Ins	trument:	Recommended lean amine temperature, hydrocar temperature and rich amine temperature.	bon feed
<u>T</u> e	No	e <mark>rature</mark> rmal Range:	Temperature is a function of the hydrocarbon tem is normally the major flow component. Some heat of reaction occurs and contributes to the the system. Bubble point of the hydrocarbon must be conside Normal temperature ranges from 100°F to 130°F. Higher temperatures tend to break emulsions and control but hinder absorption and create bubble p	aperature since it ne temperature of red. assist interface oint problems.
		Action:	Adjust amine flow to design rates	
		Consequence:	Loss of interface control, improper phase separat	ion, amine losses
		Cause:	Improper set point	
•	De	viation:	High	
		Action:	Adjust amine flow to design rates	
		Consequence:	Sour product	
		Cause:	Improper set point	
•	De	viation:	Low	
•	Sta	tus check:	Once/shift or on alarm and indication of problem	S
•	Ins	trument:	Minimum recommended is flow rate indication. Recording instrumentation should be considered.	
•	No	rmal Range:	Amine flow rate should be adjusted at design flow loadings. Rates may be varied to match hydrocarbon loads Normally, flows are relatively low and may rema regard to economic considerations.	v rate and rich if required. in fixed without

# 5. LPG CONTACTOR - cont

• [	Deviation:		Low
	ב	Cause:	Improper amine cooling, upstream HC processing problems
	ב	Consequence:	Loss of interface control due to emulsions, loss of amine, sour produc
		Action:	Bypass cooler to heat up amine
Pres	ssu	<u>re</u>	
• 1	• Normal Range:		The minimum pressure is a function of the liquid hydrocarbon composition to be treated and the temperatures anticipated in the contactor. Operation near bubble point conditions must be avoided. Recommended is RVP of the hydrocarbon plus 50 psi unless the operating temperature causes the vapor pressure at conditions to be much higher.
• 1	[nst	rument:	Normal control is by a backpressure control system on the contactor overhead system. As a minimum, pressure indication on hydrocarbon overhead Recorder recommended
• 5	Stat	tus check:	Once/shift or on upset
• [	Dev	viation:	Surges
	ב	Cause:	Hydrocarbon or amine control problem, feed composition change
	ב	Consequence:	Loss of interface control, sour product, loss of amine, hydrocarbon flow may stop, hydrocarbon undercarry or amine losses
		Action:	Look for upstream hydrocarbon or amine control problems. Consider level controllers resetting flow controllers.
• I	Dev	viation:	Low
	ב	Cause:	Improper set point
C	ב	Consequence:	Loss of interface control, partial vaporization of hydrocarbon, amine carryover
	ב	Action:	Raise set point to recommended minimum Raise pressure set point or lower temperature

#### 6. FLASH DRUM

The Rich Amine Flash Drum provides for the venting of flashed light hydrocarbons and separation of liquid hydrocarbons ranging from LPG to gas oil. It is recommended that the flash drum be operated at a pressure of 15 psig or less, although pressures as high as 90 psig .are not uncommon. At low pressure, a rich amine pump is required.

Flash gas at less than fuel gas header pressure can be disposed of to the vapor recovery system, flare, incinerator or heater firebox – usually subject to amine scrubbing, as  $H_2S$  levels are typically on the order of several %.

Level instrument design must consider the potential for accumulation of liquid HC layers of varying densities.

Stilling wells are required for liquid feed to avoid continual turbulent mixing of liquid hydrocarbon with amine. Materials are as for the Gas and LPG Contactors.

#### Pressure

•	No	rmal operating range:	<ul> <li>(1) High pressure (no rich amine pump): 45-65 psig</li> <li>(2) Low pressure (with rich amine pump): 0-25 psig</li> </ul>
•	Ins	trumentation:	Pressure controller
•	Sta	tus Check:	If amine foaming is observed
•	De	viation:	High
		Cause:	Excessive hydrocarbon in rich amine
		Consequence:	Regenerator foaming, SRU upset or fouling
		Action:	Correct absorber operation, clean up amine, add antifoam, skim hydrocarbon from flash drum
•	De	viation:	Low
		Cause:	System venting to atmosphere or relief system
		Consequence:	May not get into the regenerator
		Action:	Find leak
•	De	viation:	Negative pressure
		Cause:	Relief stack draft causing a vacuum on the system
		Consequence:	Air may be drawn into flash drum and contaminate the amine or cause an explosive mixture
		Action:	Adjust relief system pressure to hold positive pressure on drum

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#### 6. FLASH DRUM - cont

#### Flash Gas Rate

Instrumentation:

- Normal operating range: Depends on absorber pressure and feed composition •
- Flow indicator and/or pressure controller Status Check: At alarm or sign of upset
  - Deviation: High Cause: Hydrocarbon carryover from absorber Consequence: Foaming and reduced acid gas absorption (possible violation), foaming in regenerator (SRU upset) Action: Correct absorber operation, clean up amine, add antifoam, skim

hydrocarbon from flash drum

#### **Hydrocarbon Level**

- Normal operating range: 0-5% level above amine
- Instrumentation: Sight glass
- Status Check: Once per round or regenerator foaming problems
- Deviation: High Cause: Insufficient skimming
  - Consequence: Amine foaming, SRU upset
  - Action: Increase skim rate, check gas and liquid absorber operation for hydrocarbon carryunder

### **Amine Level**

- Normal operating range: 40-75% when flash drum is system's surge capacity
- Instrumentation: Level recorder, low and high level alarms
- At or changing level Status Check:
- Deviation: High Cause: Water leaking into system, absorbers returning amine inventory, absorber level problem, imbalance in amine flows Consequence: Amine carryover into gas system, diluting amine strength
  - Action: Remove some amine from plant. Check amine strength.

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# 6. FLASH DRUM - cont

•	Deviation:		Low
		Cause:	Dehydrating amine system, absorber upset and holding up or losing amine, foaming in absorbers or regenerators, or system losses.
		Consequence:	Flash gas or liquid hydrocarbon carryover in rich amine to regenerator due to low residence time for gas or liquid hydrocarbon separation (SRU upset)
		Action:	Add amine or condensate to plant, find leak or loss

The Rich Amine Pump(s), required for low pressure flash drum operation may be to API or ANSI specifications, but must consider the following:

- 1. Mechanical seals are required of a quality to contain rich amine, a potentially toxic fluid.
- 2. Pump cases and seals must be designed for the relieving conditions of the flash drum, plus pump differential pressure.

Pump materials include steel or stainless steel case and chrome or chrome-nickel stainless intervals.

#### 8. LEAN/RICH EXCHANGERS

The Lean-Rich Exchanger is a heat conservation device, exchanging Regenerator bottoms at reboiler temperature against rich amine feed to the Regenerator, at about ambient temperature, to preheat the feed. Both shell-and-tube and plate-and-frame exchangers have been used. For shell-and-tube units, 18-8 stainless tubes are recommended with stress relieved steel for the shell, tube sheets, and channels.

As with all equipment, design pressures must consider actual maximum system pressure. If the Rich Amine Flash Drum relief valve provides rich side protection, the rich side pressure can be designed for Flash Drum design pressure plus Lean Amine Pump differential. Lean side design depends on location but should at least match Regenerator design pressure.

#### **<u>Rich Outlet Temperature</u>**

•	• Normal Range:		Will vary with system design and current operation, a 10 degree change from "normal" value should be investigated
•	Ins	strument:	Control-board mounted on final rich amine, temperature, local temperature indicators
•	Sta	tus Check:	Once per round Heat transfer coefficients calculated monthly
•	De	viation:	High rich amine temperature
		Cause:	Low fuel rate
		Consequence:	Flashing and corrosion in exchangers and regenerator inlet piping
		Action:	Check amine flows, possibly bypass hot lean amine flows
•	De	viation:	Low
		Cause:	Exchanger fouling
		Consequence:	Poor stripping in regenerator and/or increased reboiler steam demand
		Action:	Check all temperatures for poor performance (fouling), clean exchangers
<u>Pr</u>	essu	ire	
•	• Normal Range:		Design, typical 5-10 psig
•	• Instrument:		Local pressure gauges
•	• Status Check:		Recorded as part of heat transfer monitoring or at capacity limitation

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#### 8. LEAN/RICH EXCHANGERS - cont

 Deviation: High
 Cause: Fouling, equipment failure
 Consequence: Reduced circulation Reduced heat transfer High lean amine temperature and low regenerator feed preheat
 Action: Locate the point of high pressure drop

#### 9. REGENERATOR

The Regenerator is usually a trayed tower, although packed towers are occasionally used. Trays of 410SS or 18-8SS are used successfully. The tower shell is of steel (516-60 or 516-70) and is stress relieved. The feed nozzle is usually of 18-8SS or is lined with an 18-8 SS sleeve. Feed is below a rectifying section and above the stripping section. Not all of this is true in the gas patch.

Capacity in the bottom may be provided for surge (common in tail gas treater systems) or surge may be external (preferred in primary systems).

Design pressure is based on system protection requirements and potential over pressure sources.

#### **<u>Reflux Drum Pressure</u>**

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		Action:	Reduce feed Reduce reboiler duty Drain hydrocarbons from flash drum Raise reflux temperature Steam out liquid gas product Drain hydrocarbon liquid from reflux drum Shutdown and clean overhead line	
		Consequence:	Relief, unit shutdown, reduced heat input, increa loadings, decreased throughput, downstream un or upset accelerate amine degradation	ased lean it shutdown
		Cause:	Downstream unit problems, blocked outlet line, pressure controller, flooded vessel, excessive rel duty, hydrocarbon contamination	failed boiler
•	De	viation:	High or rising pressure	
		Action:	Determine cause for loss of feed or heating med reflux purge and clean water makeup to control Minimize velocities by optimizing steam consum	ium, install corrosion. nption
		Consequence:	Upset of or shutdown of downstream sulfur unit to atmosphere, unit shutdown	, release
		Cause:	Failed pressure controller, loss of reboiler heat s loss of feed, loss of containment	ource,
•	De	viation:	Low or decreasing pressure	
•	Sta	tus Check:	Field, once/shift(round); board, at alarm or upse	t
•	Ins	trument:	Pressure gage (field), transmitter/recorder alarm	(board)
•	No	rmal Range:	5-15 psig	

# Top Pressure For Conventional Condenser/Drum Overhead Systems

Noi	rmal Range:	5-15 psig (set primarily by downstream sulfur unit)
Instrument:		Gage (field), transmitter/recorder/alarm (board)
• Status Check:		Field, once/shift(round); board, at alarm or upset
Dev	viation:	High or Rising Pressure
	Cause:	Condenser fouled and plugged on the process side, condenser fouled on the cooling media side, loss of cooling media
	Consequence:	Upset of downstream sulfur unit, foaming and excessive entrainment, relief, unit shutdown, acceleration of amine degradation, increased lean loadings, reduced throughput
	Action:	Reduce feed Reduce reboiler duty Drain hydrocarbons from flash drum Steam overhead line Drain hydrocarbons from reflux drum Shutdown and clean overhead line
ch A	<u>mine Feed Rate</u>	
Noi	rmal Range:	System dependent
Inst	rument:	Field, local flow indicator/ controller; board, meter/ transmitter/recorder/alarm (prefer to have flow control reset by upstream drum level)
Stat	tus Check:	Field, once/shift(round); board, at alarm or upset
Dev	viation:	Sudden loss of flow
	Cause:	Loss of flash drum or contactor levels, flow control failure, plugging from corrosion products or salts, high regenerator pressure
	Consequence:	Loss of throughput, loss of treating capability, SRU upset
	Action:	Check rich flash drum level control. Check contactor level control and flows. Check rich amine feed circuit for plugging in valves, orifices filters, or exchangers. Remove heat stable salt anions and sodium Remove degradation products (reclaim), check for hydrocarbons to regenerator.
	Nor Inst Stat Dev Ch A Nor Inst Stat Dev	Normal Range: Instrument: Status Check: Instrument: Check: Instrument: Cause: C

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•	De	viation:	Gradual decline in flow
		Cause:	Declining rich amine flash drum level resetting flow, plugging from corrosion products or salts, leaks or open drains
		Consequence:	Loss of throughput, loss of treating capability
		Action:	<ul><li>Balance flows in and out of system. Check for contactor foaming or upset.</li><li>Check for maintenance activity (filter changes, equipment draining).</li><li>Balance reflux purges and makeup water rates.</li></ul>

# Acid Gas Product Rate

•	Nor	rmal Range:	System dependent
•	Inst	trument:	Field, local flow indicator; board, meter/transmitter/ recorder alarm (should coordinate into downstream sulfur unit control scheme)
•	Stat	tus Check:	Field, once/shift(round); board, at alarm or upset
•	Dev	viation:	Sudden loss of flow
		Cause:	Loss of feed, loss of reboiler heat input, downstream unit shutdown, plugged overhead line, pressure controller failure, loss of containment, tower internals malfunction
		Consequence:	Loss of throughput, loss of treating capability, relief, unit shutdown
		Action:	Restore feed. Restore reboiler heating media. Steam out or otherwise heat overhead line; raise reflux or pumparound return temperature.
•	Dev	viation:	Sudden increase in flow
		Cause:	Hydrocarbon intrusion into regenerator, foaming, tower internals malfunction
		Consequence:	Amine carryover, upset/shutdown of downstream sulfur unit
		Action:	Skim rich amine flash/reflux drums for hydrocarbon Change carbon filter
Le	Lean Loading		
•	Noi	rmal Range:	Amine and acid gas dependent. Lean loadings vary from 0.002 to 0.1 mol acid gas/mol amine
•	Inst	trument:	Laboratory test

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•	Sta	tus Check:	Laboratory, once/day to once/week. Special consideration: In $H_2S$ -containing systems, residual $H_2S$ tends to oxidize to thiosulfate when exposed to air. Caution must be taken in sampling and sample handling.
•	De	viation:	Lean loading exceeds spec/treated gases and liquids fail to meet spec.
		Cause:	Insufficient reboiler heat input caused by: insufficient heating media supply, over-circulation, fouled lean/rich exchangers, fouled reboiler, loss of regenerator level Leaking lean/rich exchangers when rich amine exceeds lean amine pressure Caustic contamination
		Consequence:	Off-spec products, excessive corrosion
		Action:	Increase reboiler heat input. Decrease circulation. Increase amine strength. Remove heat stable salt anions and sodium. Clean fouled exchangers. Check sodium level.

# **Bottom Level**

•	No	rmal Range:	Field, in sight glass; board 50% +/- 25%
•	Ins	trument:	Field, gage glass, Level-Trol or d/p cell with local indicator Board, d/p cell or float/transmitter/recorder/alarm
•	Sta	tus Check:	Field, once/shift; board, at alarm or upset
•	De	viation:	Sudden loss of level
		Cause:	Control failure, loss of feed, rapid pressure-up, foaming
		Consequence:	Bottoms pump failure, loss of circulation causing off-spec products, lean circulation pump failure/shutdown, loss of reboiler heat input
		Action:	Check controller. Check for loss of feed. Check for signs of hydrocarbon incursion. Skim flash drum and reflux drums for hydrocarbons. Change carbon filter

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# **Tower Pressure Drop**

•	Noi	rmal Range:	0.05-0.2 psi/tray	
•	Inst	trument:	d/p gage (field), d/p cell/transmitter/recorder/alarm	
•	Stat	tus Check:	Field, once/shift(round); board, at alarm or upset	
•	Dev	viation:	Little or no pressure drop	
		Cause:	Loss of feed, loss of reboiler heating media, tray blowout, tower internals malfunction	
		Consequence:	High lean loadings leading to off-spec products, unit shutdown downstream sulfur unit shutdown	
		Action:	Determine reason for loss of feed Determine reason for loss of heating media	
•	Dev	viation:	Occasional sudden rise then returning to normal	
		Cause:	Foaming, hydrocarbon intrusion from flash drum, hydrocarbon refluxed to tower, reboiler heat input fluctuations, tower internals malfunction	
		Consequence:	Amine and/or hydrocarbon carryover into downstream sulfur unit high lean loadings leading to off-spec products, tray blowout	t,
		Action:	Determine composition of reflux, if high in amine stop purge of reflux to stop amine loss, if high in hydrocarbon increase purge. Test feed and bottoms for foaming tendency, add antifoam until pressure drop is normal. Monitor carbon filter, change if necessary. Skim rich amine flash drum and reflux drum for hydrocarbon. Ensure proper levels are maintained in rich flash and reflux drum check level instruments Check reboiler heating medium control for fluctuating pressure, temperature, or flow. Reduce feed rate. Reduce heat input	,
•	Dev	viation:	Gradual buildup or sudden permanent buildup	
		Cause:	Buildup of corrosion products causing tray plugging, damage. Excessive corrosion rates caused by high ammonia/amine concentrations in reflux, insufficient heat input leading to excessive lean loadings, under-circulation leading to excessive rich loadings, high heat stable salt anion content. Excessive particle accumulation caused by poor filtration, increased filter pore size to control filter replacement cost, filter placement, accumulation of particles in rich amine flash drum	
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Consequence:	Reduced throughput, high lean loadings leading to off-spec products, increased energy consumption, reduced circulation leading to higher rich loadings, higher corrosion rates, increased filtration costs and increased plugging
Action:	Discontinue antifoam additions and change carbon filters to prevent antifoam buildup and foaming episodes Remove heat stable salt anions and sodium Remove amine degradation products (reclaimer) Shutdown and chemical or water wash tower Reduce filter pore size. Clean rich amine flash drum bottom Add additional filtration upstream of regenerator Keep lean loadings minimal, keep rich loadings at or below recommended levels

# <u>Top Temperature For Conventional Condenser/Drum Overhead Systems Or Pumparound</u> <u>Type System Pumparound Draw Temperature</u>

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		Action:	Reduce reboiler duty. Re-establish condenser/pumparound cooler cooling media. Reduce circulation.
		Consequence:	Overtax overhead system leading to excess water loss and poor downstream sulfur unit feed, increase amine in reflux water by entrainment and/or vaporization, increase corrosion rates throughout regenerator, accelerate amine degradation, excess energy costs.
		Cause:	Too high heat input, loss of reflux or pumparound cooling media, too low loadings
•	De	viation:	High
		Action:	Raise reboiler heat input. Raise reflux or pumparound return temperatures. Raise condenser cooling media temperature
		Consequence:	Increased lean loadings leading to off-spec products
		Cause:	Insufficient heat input, too cold reflux or pumparound return temperatures, reflux level or pumparound flow control valve failure, excessive rich loadings, tower internals malfunction
•	De	viation:	Low
•	Sta	tus Check:	Field, once/shift(round); board, at alarm or upset
•	Instrument:		Field, temperature gage; board, thermocouple/transmitter/recorder/ala
•	No	ormal Range:	190-230°F

# **10. REGENERATOR OH CONDENSER**

The Overhead Condenser may be either shell-and-tube or an aerial cooler. A single pass exchanger with water on the tube side is usually selected for shell-and-tube.

Tube materials have frequently been dictated by water quality, but usual steel construction is preferred.

Amine side design pressure should match the Regenerator and the Condenser is typically protected by the Regenerator safety valve.

#### 11. REFLUX DRUM

The Reflux Drum collects condensate from the Overhead Condenser and allows acid gas to separate and flow to the SRU. The Reflux Drum is carbon steel, and does not require stress relieving. It is designed for pressure such that it can be protected by the Regenerator safety relief valve. It is sized to provide for vapor-liquid separation and for 5 minutes of Reflux Pump capacity holdup.

### Acid Gas Product/Reflux Temperature

•	Normal Range:	90-130° F
•	Instrument:	Field, temperature gage; board thermocouple/ transmitter/recorder/alarm
•	Status Check:	Field, once/shift(round); board, at alarm or upset
•	Deviation:	Temperature reads below 90°F
	□ Cause:	Too much cooling media, too cold cooling media, insufficient heat input, reflux level control problem, pumparound temperature control problem
	□ Consequence:	Plugged overhead line with hydrates or NH <sub>3</sub> .
	• Action:	Confirm instrument readings Cut cooling media rate or raise its temperature Raise reboiler heat input

The Reflux Pump is a small ANSI or API pump. Materials are steel with 400 or 300 series stainless steel impeller and internals or 300 series stainless steel case and internals. Casing pressure is designed for Regenerator pressure plus pump differential. Mechanical seals must contain hazardous materials.

## **Reflux Rate**

•	No	rmal range:	Dependent on tower heat balance. Reflux ratio varies from 1 to 3 moles of reflux water to mole acid gas product.
•	Ins	trument:	Reflux rate controlled by reflux drum level in a conventional system. Controllers can be field or board mounted.
•	Sta	tus Check:	Field, once/shift(round); board, at alarm or upset
•	De	viation:	Loss of reflux
		Cause:	Control failure, loss of feed, loss of reboiler heating media, leaks, plugging, loss of cooling media, fouled or plugged overhead exchanger, pump failure
		Consequence:	Increased amine strength leading to heat/mass transfer problems or pumping problems, loss of levels reducing circulation and throughput, excessive water to downstream sulfur unit, upset of air to acid gas ratio in Claus unit
		Action:	Check controller, insure correct valve trim and metallurgy Determine if feed lost, correct upstream unit Determine if heating media lost, correct supply problem Determine if cooling media lost or restricted
•	De	viation:	Reflux ratio too low
		Cause:	Controller problems, insufficient reboiler heat input, plugging, pump problems
		Consequence:	High lean loadings leading to off-spec product, liquid carryover to downstream sulfur units.
		Action:	Check/repair controller Raise reboiler heat input Clear plugging in reflux system

# Pumparound Rate (Special/Option)

•	No	rmal Range:	Dependent on tower heat balance. Flowrate is normally reset by tower overhead temperature. Flowrate is also dependent on draw temperature. Internal reflux ratios similar to the external reflux ratio for conventional overhead systems are maintained.
•	Instrument:		Flow Control reset by tower top temperature, draw tray level indicator/controller, makeup water and purge water controls board or field mounted, low/high level/flow/ temperature alarms
•	Sta	tus Check:	Field, once/shift(round); board, at alarm or upset
•	De	viation:	Decline or loss of pumparound flow
		Cause:	Loss or decline in heat input, increase in rich loadings, loss of cooling media, leaking draw tray, insufficient makeup water, too large purge rates, coolant side of exchanger fouled
		Consequence:	Excess water to downstream sulfur unit, increase in pressure which raises temperatures which accelerates corrosion, erratic amine strengths
		Action:	Increase heat input to reboiler Increase lean circulation Restore cooling media flow Compute water balance and adjust purge/makeup Clean pumparound cooler
•	De	viation:	Increase in pumparound flow
		Cause:	Improper water balance, too low tower top temperature setting, condenser leak
		Consequence:	Erratic amine strengths, plugged overhead lines
		Action:	Compute water balance and adjust purge/makeup rates Raise tower top temperature Analyze chloride level of amine, shutdown and repair condenser.

# **12. REFLUX PUMP – cont**

# Ammonia Buildup

•	No	rmal Range:	0-1.0 wt%
•	An	alytical Method:	Ion chromatography (IC), conductometric titration
•	Sta	tus Check:	Once/week to Once/month depending on system
•	De	viation:	Ammonia exceeds 1.0 wt-%
		Cause:	Low or no purge, water wash systems upstream of contactors not operating or saturated, high ammonia levels in unwashed gases
		Consequence:	Accelerated overhead system corrosion, reflux of H <sub>2</sub> S back to the stripping section of the regenerator, high lean loadings leading to off-spec product, overhead line plugging, excessive ammonia to SRU not designed for ammonia destruction
		Action:	Purge reflux/pumparound

#### **13. LEAN AMINE PUMP**

Lean Amine Pumps are usually downstream of the Lean-Rich Exchanger to keep NPSH requirements low. In some systems, these are high pressure pumps; in others they are lower pressure and supply booster pumps at individual Absorbers. Accordingly, pumps may be ANSI or API and must consider:

- 1. Mechanical seals.
- 2. Pressure protection level that defines casing rating.

Pump materials include steel or stainless steel case and chrome or chrome-nickel stainless internals.

The Lean Amine Cooler may be a shell-and-tube exchanger, an aerial cooler or a combination, usually designed as a single pass with amine on the tube side. The recommended material in contact with the amine solution is steel. Temperature considerations as mentioned for the contactors may dictate lean amine cooler design or it may be dictated by coolant conditions. In general, cooler amine (down to 80°F) assures better performance. Welded elements in contact with the amine must be stress relieved for MEA service; stress relieving should be considered for all amines.

Some refiners have used plate-and-frame exchangers if pressures are not excessive.

#### **Outlet Temperature**

•	Noi	rmal Range:	90-130°F (minimum 10°F hotter than sour fuel gas)
•	Instrument:		Local temperature gauges, control board mounted on final lean amine temperature
•	• Status Check:		Lean amine temperature checked once per round or at alarm or upset. All other temperatures are checked weekly Heat transfer coefficients should be calculated monthly
•	Dev	viation:	High
		Cause:	Cooler bypass open, exchanger fouling, loss of cooling water
		Consequence:	Reduced H <sub>2</sub> S removal efficiency in downstream contactors. Hydrocarbon vaporization in liquid/liquid contactors
		Action:	Close cooler bypass, calculate heat transfer coefficients and clean exchangers, check cooling water supply, rapid loss of cooling may be an indication of mechanical problems.
•	Dev	viation:	Low
		Cause:	Cooler bypass closed, loss of heat to regenerator
		Consequence:	Condensation of hydrocarbons in absorbers
		Action:	Open cooler bypass Check regenerator bottoms temperature for deviation

# 14. LEAN AMINE COOLERS - cont

# **Pressure**

•	No	rmal Range:	Design, 5-10 psig typical
•	Instrument:		Local pressure gauges
•	• Status Check:		Recorded as part of heat transfer monitoring, or at capacity limitation
•	De	viation:	High
		Cause:	Fouling, equipment failure
		Consequence:	Reduced circulation or high lean amine temperature leading to off-spec product, reduced heat transfer
		Action:	Locate the point of high pressure drop

#### **15. REBOILER**

The Regenerator Reboiler may be:

- a. Once through kettle.
- b. Once through horizontal shell-and-tube.
- c. Once through vertical shell-and-tube.
- d. Conventional kettle.
- e. Horizontal thermosiphon.
- f. Vertical thermosiphon

For a, b, d, and e, steam is on the tube side. For c and f, amine is on the tube side. Tubes are usually of 316 SS although steel tubes are used successfully in some units. Steel shells must be stress relieved. Design pressure on the amine side must at least match the Regenerator; steam side design is fixed by the steam system.

Steam is normally used as heat medium; there are alternatives, but tube wall temperature must be kept below some maximum for each amine.

#### **<u>Reboiler Temperatures (In/Out)</u>**

•	No	rmal Range:	230-260° F (dependent upon tower pressure, heat stable salt content, tray loadings, amine type and concentration)
•	Instrument:		Field, temperature gages; board, thermocouple/transmitter/ recorder/alarm
•	Sta	tus Check:	Field, once/(round), board, at alarm or upset
•	De	viation:	Low
		Cause:	Loss of reboiler heating media, fouling of reboiler or lean/rich exchangers due to excessive corrosion rates, failure of reflux/ pumparound control leading to overcooling, loss of containment
		Consequence:	High lean loadings leading to off-spec product, emission of toxic gases to atmosphere
		Action:	Confirm initial and final state and flows of heating media and calculate duty to exchanger. Compute tower heat balance. Compute required heat requirement and compare to available heat. Compute reboiler and lean/rich exchanger heat transfer coefficients to determine fouling. Clean exchangers if fouled. Isolate leak. Remove heat stable salts and anions. Remove amine degradation products (reclaim)

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# 15. REBOILER - cont

•	Deviation:		High
		Cause:	Tower overhead or acid gas product line plugged or pressure control problem, too hot heating media, too high heat input, hydrocarbon incursion causing higher pressures, high heat stable salt anion and sodium content, improper circulation of amine through reboiler, improper design of reboiler, high amine degradation product levels
		Consequence:	Increased corrosion rates leading to filter plugging and equipment fouling and plugging, corrosion damage leading to reboiler failure, decreased throughput, acceleration of amine degradation
		Action:	Clear overhead line pressure restrictions Confirm temperature and pressure of heating media, adjust as needed Skim rich flash drum/reflux drum for hydrocarbons Decrease reboiler heat input Remove heat stable salt anions and sodium Remove amine degradation products (reclaim) Evaluate heat transfer equipment for coefficient and hydraulics. Clean reboiler and/or lean/rich exchangers

# **<u>Reboiler Heat Input</u>**

•	Normal Range:	540-1350 BTU/gal amine solution (0.65-1.5 lb stm/gal amine, 50 psig stm). Dependent on amine type, strength, rich loading, lean loading requirements, stripping trays available, ratio of $H_2S$ to $CO_2$ in rich, ammonia and amine concentration in the reflux, and overhead pressure
•	Instrument:	Flow controller with indicator/recorder, heat to feed ratio controller, field or board mounted, alarm
•	Status Check:	Field, once/shift; board, at alarm or upset
•	Deviation:	Loss of heating media flow
	□ Cause:	Controller failure, loss of supply, condensate system bottleneck
	• Consequences:	Loss of treating capability, off-spec product
	□ Action:	Restore supply of heating media Lower condensate system pressure

#### **16. AMINE FILTER**

An amine filter is always required. It may be full flow or slip stream, on the lean or the rich side of the system and may be cartridge, bag, precoat, sand, etc. Most systems apply lean slipstream cartridge or bag filters. A 25% slipstream is the recommended minimum. 20 micron is a reasonable maximum and 5 micron a reasonable minimum for filter element porosity.

In some systems, rich amine filtration is recommended, and special care must be taken to assure that elements can be removed safely.

Filter cases are of steel, stress relieved as for other steel elements, and designed to match the pressure of the absorbers or lean amine pump discharge conditions.

#### **Pressure Drop**

•	No	rmal Range:	Design start of run up to design change pressure drop
•	Ins	trument:	d/p gauge and/or pressure gauges
•	Sta	tus Check:	Once per round
•	De	viation:	Low
		Cause:	Low flow, failure of filter media or internals
		Consequence:	Contaminant buildup in the amine will lead to foaming, poor $H_2S$ removal and corrosion. Filter media can migrate to other parts of the unit causing pressure drop and poor performance.
		Action:	Check piping for filter line-up Block-in filter and inspect media and internals (exact response filter media dependent)
•	De	viation:	High
		Cause:	Buildup of contaminants on filter media or failure of filter media
		Consequence:	Reduced filtration rate, leading to foaming and fouling
		Action:	Change filter media, look for root cause of corrosion

# **16.** AMINE FILTER – cont

# Amine Appearance

•	Normal Range:	Clear (Pencil can be read across a pint jar)
•	Analysis:	Visual inspection
•	Status Check:	Once per shift
•	Deviation:	Fail visual test (cloudy, particulate)
	□ Cause:	Reduced rate to particulate filter Contamination of amine (dirty fuel gas) Corrosion Filter media spent, bypassed or damaged
	• Consequence:	Foaming Equipment fouling Equipment failure (corrosion)
	□ Action:	Check filter pressure drop, change if high, inspect if low Check filter outlet sample, if dirty charge media Verify/increase rate to filter Check amine at each contactor Test amine for corrosivity

# Length Of Run

•	Normal Range:		Site specific
•	Inst	trument:	Log of filter changes
•	Sta	tus Check:	When an unusual pattern develops
•	Dev	viation:	Short period between changes
		Cause:	Increased contamination or corrosion, or process upset
		Consequence:	Increased costs
		Action:	Check absorbers for unstable operation Check flash drum for excessive hydrocarbons Test amine for corrosivity Test amine for contaminants

# **16.** AMINE FILTER – cont

# Flow Rate

,

•	Noi	mal:	Design rate
•	Inst	rument:	Flow controller
•	Stat	tus Check:	Monitor each round
•	Dev	viation:	Low
		Cause:	High filter pressure drop Filter bypassed
		Consequence:	Contaminated amine
		Action:	Verify filter line-up Change filter at high d/p

The Amine Carbon Treater is optional and may be rich or lean, slipstream of full flow. In general, it must be immediately downstream of the lean Amine Filter, or a dedicated filter, to be sure it does not become clogged with particulates. A 10-20% slipstream is usually sufficient.

Steel construction with appropriate stress relieving is satisfactory. The Amine Carbon Treater will remove entrained hydrocarbons, but not dissolved acids or salts. It will, in general, enhance amine quality and system performance.

### **Pressure Drop**

•	No	rmal Range:	Design start of run up to design change delta pressure
•	Ins	trumentation:	Delta pressure gauge and/or pressure gauges
•	Sta	tus Check:	This is monitored each day
•	• Deviation:		Pressure drop low
		Cause:	Filter is being bypassed Failure of internals
		Consequence:	Contaminant buildup in the amine will lead to foaming Poor H <sub>2</sub> S removal and corrosion Carbon filter media can migrate to other parts of the unit causing pressure drop and poor performance
		Action:	Check piping for filter line-up Block-in filter and inspect media and internals
•	De	viation:	High
		Cause:	Buildup of contaminants on carbon
		Consequence:	Pressure drop will back out flow resulting in less treating
		Action:	Block in and change carbon
		Note:	Pressure drop is not a good indicator of spent carbon; other testing may indicate end of useful life prior to pressure drop.

#### **17. CARBON TREATER - cont**

#### **Filter Outlet Amine Condition**

•	No	rmal Range:	Outlet sample less foaming tendency than inlet sample
•	An	alysis:	Visual check, foam test
•	Sta	tus Check:	Visually checked each shift, foam test weekly (simple hand shake of the sample will give some indication)
•	Dev	viation:	Fail visual foam test
		Action:	Run a formal foam test
•	Dev	viation:	Failure of foam test
		Cause:	Amine contamination, particularly organic Excess antifoam Carbon bed is exhausted Reduced rate to carbon filters
		Consequence:	Foaming in regenerator and contactors Fouling of equipment
		Action:	Foam test carbon bed in and out Fail replace carbon Pass verify/increase rate to carbon filter Check antifoam addition rate high - reduce Check contactors for hydrocarbon source Check rich amine flash drum Check particulate filter delta p
Ca	rbo	n Usage	
•	No	rmal:	Site specific

- Instrument: Record of carbon addition
- Status Check: When an unusual pattern develops
- Deviation: Increased consumption
  - Cause: Increased contamination
  - Action: Check contactors, flash drums Test amine for contaminants

# **17. CARBON TREATER - cont**

# Flow Rate

•	Norr	mal:	Design rate
•	Instr	rument:	Local flow meter
•	Statu	is Check:	Monitored each round
•	Devi	iation:	Low
		Cause:	High filter pressure drop, filter bypassed
		Consequence:	Contaminated amine
		Action:	Verify filter line-up Change carbon at high pressure drop

Recommended following the carbon treater, the Carbon Treater After Filter is a relatively course particulate filter to stop any carbon particles which break through; or, in particularly, to prevent spread of carbon throughout the unit on failure of the carbon support structure.

Materials and design pressure are as for other filters.

#### **19. AMINE SURGE TANK**

In primary amine systems, an Amine Surge Tank is required. It is usually an API tank with fuel gas or nitrogen blanket. It may also be a pressure vessel. The tank may need steam coils or circulation means to assure that the solution viscosity does not increase in cold weather.

Great care must be taken in venting such tanks; usually a vent to an incinerator or heater firebox is acceptable.

#### **Level – Routine Gauging**

•	Normal Range:	20-80%
•	Instrumentation:	Field level indicator
•	Status Check:	Once per day or following transfer
•	Deviation:	Loss of level
	□ Cause:	High amine losses
	• Consequence:	Increased operating cost
	□ Action:	Check for leaks, carryover from contactor or regenerator overhead
•	Deviation:	Gain of level
	□ Cause:	Possible amine dilution due to water leak
	□ Consequence:	Possible tank overflow
	• Action:	Check amine strength – if low, look for water cooler leak or excessive water makeup.

# **19. AMINE SURGE TANK - cont**

# **Blanketing – Pressure**

•	Normal Range:	1-2 inches of water	
•	Instrumentation:	Split-range pressure controller on inert gas makeup with flow indicator	
•	Status Check:	Operator check of setting	
•	Deviation:	High	
	□ Cause:	Set point adjustment incorrect or malfunctioning controller, light hydrocarbons in lean amine	
	• Consequence:	High usage of inert gas, foaming, SRU upset	
	□ Action:	Adjust set point or check pressure controller, check for hydrocarbon carryover from flash drum or absorber	
•	Deviation:	Low	
	□ Cause:	Set point adjustment incorrect or malfunctioning controller	
	□ Consequence	Air contamination of amine, causing increased generation of heat stable salts and degradation of amine	
	• Action:	Adjust set point or check pressure controller	

On primary amines (MEA, DGA) a Reclaimer is recommended to remove heat stable salts (HSS) and degradation products. It is usually a kettle with 316 SS tubes and provision for easy addition of caustic or soda ash.

Reclaimers frequently contain spargers to pass steam directly through the residue sludge to assist in reacting caustic or soda ash. Steel shells must be stress relieved. Steam supply must be hot enough to vaporize the amine and is usually in the 150-250 psig range.

#### FEED RATE

•	Normal range:	As necessary to maintain level (1-3% of Regenator feed)
•	Instrument:	Optional indicator/recorder
•	Status check:	Once/round or at sign of upset
•	Deviation:	Low
	□ Cause:	Low demand due to low vaporization rate caused by fouling or high process temperature
	• Consequence:	Low reclaiming rate
	□ Action:	Clean reclaimer or dilute amine
•	Deviation:	High
	□ Cause:	Instrument malfunction resulting in liquid carryover
	• Consequence:	Low temperature, inadequate reclaiming
	□ Action:	Adjust conditions as necessary to maintain proper level
W	'ater Rate	
•	Normal range:	As necessary to maintain desired temperature
•	Instrument:	Controller
•	Status check:	Once/round or at sign of upset
•	Deviation:	Low
	□ Cause:	Controller malfunction
	• Consequence:	High temperature (due to over concentration of amine)
	□ Action:	Adjust rate

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# 20. DGA RECLAIMER - cont

•	De	eviation:	High
		Cause:	Controller malfunction
		Consequence:	Low temperature (due to dilution)
		Action:	Adjust rate
<u>St</u>	eam	n Rate	
•	No	ormal range:	Site specific
•	Ins	strument:	Continuous recorder
•	Sta	atus check:	Once/round or at sign of upset
•	De	eviation:	Low
		Cause:	Reduced heat transfer rate due to fouling or high process temperature
		Consequence:	Low reclaiming rate
		Action:	Clean reclaimer or dilute amine
•	De	eviation:	High
		Cause:	Low process temperature due to dilute amine
		Consequence:	Low reclaiming rate
		Action:	Increase amine concentration by dehydration
Te	emp	<u>erature</u>	
•	No	ormal range:	360-380°F
•	Ins	strument:	Continuous recorder/controller
•	De	eviation:	Low
		Cause:	Low amine concentration
		Consequence:	Low reclaiming rate
		Action:	Increase steam rate
•	De	eviation:	High
		Cause:	High amine concentration
		Consequence:	Low heat transfer rate, low reclaiming rate, degradation
		Action:	Dilute the inventory by adding condensate to the reclaimer

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# 20. DGA RECLAIMER - cont

# Level

•	Normal range:	40-60%
•	Instrument:	DGA flow controller
•	Status check:	Once/shift or at sign of upset
•	Deviation:	Low
	□ Cause:	Instrument malfunction
	• Consequence:	Low reclaiming rate
	□ Action:	Adjust feed rate
•	Deviation:	High
	□ Cause:	Instrument malfunction
	• Consequence:	Potential liquid carryover with salt entrainment
	□ Action:	Reduce feed rate

# **NaOH Addition**

•	Normal range:	Stoichiometric equivalent of heat stable salts
•	Analysis:	Spot lab sample
•	Status check:	Weekly
•	Deviation:	Below normal
	• Consequence:	Potential corrosion, incomplete amine recovery
	□ Action:	Adjust addition rate as appropriate
•	Deviation:	Above normal
	• Consequence:	Potential caustic embrittlement
	□ Action:	Adjust addition rate as appropriate

Reclaimers are installed in MEA units to permit cleaning up amine contaminated with heat stable salts. They work by converting the amine salts to sodium salts, and boiling the amine away from the resulting salt solution. A batch consists of the following steps: filling the reclaimer with amine, adding caustic or soda ash, adding steam to the bundle to boil off the water and volatile MEA, while making up with lean MEA to hold levels. This continues until the temperature of the slowly concentrating salt solution in the reclaimer nears the thermal degradation temperature of the MEA. Sometimes live steam is injected into the reclaimer at the end of the run to strip out any remaining MEA. The sludge in the reclaimer is dumped and the cycle can be repeated.

# Steam Rate

•	No	rmal Range:	Varies with size and design of unit. Set to provide reasonable boil up rate, without excessive bumping or carryover to regenerator.
•	Inst	trument:	Flow controller, usually local
•	Sta	tus Check:	Once per shift.
•	Dev	viation:	Low
		Cause:	Improper setting, or controller malfunction.
		Consequence:	Low boil up, extended reclaiming run.
		Action:	Increase steam flow until bumping or violent boiling is heard, then reduce slightly.
•	Dev	viation:	High
		Cause:	Improper setting, or controller malfunction.
		Consequence:	Bumping, carryover of salts into regenerator, inability to clean up MEA.
		Action:	Decrease steam flow until bumping or violent boiling is no longer heard

### Feed Rate

•	Normal Range:	Controlled to maintain level in reclaimer.
•	Instrument:	Displacer level controller, gauge glass on reclaimer.
•	Status Check:	Once per shift

# 21. AMINE RECLAIMER - cont

•	Deviation:		High level
		Cause:	Improper set point or controller malfunction.
		Consequence:	Carryover of salts into regenerator, inability to clean up MEA.
		Action:	Re-adjust level.
•	De	viation:	Low level
		Cause:	Improper set point or controller malfunction.
		Consequence:	Exposed tubes may cause thermal degradation of amine on hot tube surface.
		Action:	Re-adjust level.
Te	emp	<u>erature</u>	
•	No	ormal Range:	260-300°F, slowly increasing during run as salt concentration in reclaimer increases; end of run is when 300°F temperature is reached
•	Ins	strument:	Local indicator, many have recorder.
•	Status Check:		Every four hours.
•	De	viation:	Low temperature
		Cause:	Inadequate steam flow or pressure (below about 35 psig) or excessive amine flow. If temperature fails to increase during the run it may indicate
			carryover of salts to the regenerator.
		Consequence:	carryover of salts to the regenerator. Slow or no reclaiming, poor amine quality.
		Consequence: Action:	carryover of salts to the regenerator. Slow or no reclaiming, poor amine quality. Increase steam rate or pressure. Inspect/replace demister and check level to reduce carryover. Reducing steam rate may help reduce carryover.
•	De	Consequence: Action:	carryover of salts to the regenerator. Slow or no reclaiming, poor amine quality. Increase steam rate or pressure. Inspect/replace demister and check level to reduce carryover. Reducing steam rate may help reduce carryover. High temperature
•	De	Consequence: Action: wiation: Cause:	<ul> <li>carryover of salts to the regenerator.</li> <li>Slow or no reclaiming, poor amine quality.</li> <li>Increase steam rate or pressure.</li> <li>Inspect/replace demister and check level to reduce carryover.</li> <li>Reducing steam rate may help reduce carryover.</li> <li>High temperature</li> <li>High steam pressure (above about 90 psig) or salt concentration in reclaimer too high.</li> </ul>
•	De	Consequence: Action: wiation: Cause: Consequence:	<ul> <li>carryover of salts to the regenerator.</li> <li>Slow or no reclaiming, poor amine quality.</li> <li>Increase steam rate or pressure.</li> <li>Inspect/replace demister and check level to reduce carryover.</li> <li>Reducing steam rate may help reduce carryover.</li> <li>High temperature</li> <li>High steam pressure (above about 90 psig) or salt concentration in reclaimer too high.</li> <li>Thermal degradation of MEA, possible corrosion.</li> </ul>

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Acid gasses bearing excessive amounts of ammonia require special consideration to prevent line blockage and associated sulfur plant problems. Water wash systems to remove ammonia prior to feeding sulfur plant is common for these conditions. Ammonia is removed with water purged from this unit and routed to the sour water stripper.

#### **Circulating Water Rate**

•	Normal Range:	5-10 GPM/ft <sup>2</sup>
•	Instrumentation:	Flow controller with low flow alarm
•	Status Check:	At alarm
•	Deviation:	Low
	□ Cause:	Possible plugging in scrubber
	□ Consequence:	Inadequate NH <sub>3</sub> removal – SRU upset
	□ Action:	Cleanout

### **NH3 Concentration Of Water**

•	No	ormal Range:	0-1 wt% $NH_3$ (high liquid velocities in your system may require lower $NH_3$ concentration in order to keep corrosion rates down)
•	Instrumentation:		Sample and lab analysis
•	Deviation:		High
		Cause:	Too low water makeup rate
		Consequence:	Inadequate NH <sub>3</sub> removal resulting in SRU fouling, NH <sub>4</sub> HS corrosion
		Action:	Increase makeup rate
•	De	viation:	Low
		Cause:	Too high water makeup rate
		Consequence:	High operating cost
		Action:	Decrease makeup rate

# 22. NH3 SCRUBBER – cont

# **Temperature**

•	Normal Range:	80-120°F
•	Instrumentation:	Temperature controller on circulating water cooler, temperature indicator
•	Status Check:	Once per round or at alarm
•	Deviation:	High
	• Cause:	Increased NH <sub>3</sub> to scrubber or not enough cooling
	• Consequence:	Increased $NH_3$ to SRU (plugging), increased water to SRU (lower efficiency)
	□ Action:	Increase water makeup or coolant rate
•	Deviation:	Low
	□ Cause:	Too much cooling
	• Consequence:	Possible plugging of acid gas line from hydrate, due to low ambient temperatures and long runs of acid gas lines
	□ Action:	Decrease water makeup rate or cut back coolant rate

#### **Amine Condition**

Condition and proper care of the solvent is as important to successful operations as equipment maintenance and performance. Amine should be near color free and void of particulate matter.

#### Amine Strength, Active Amine

•	No	ormal Range:	Dependent on amine type, acid gases removed, selectivity requirements, treating requirements, and corrosion control parameters	
•	• Analysis Method:		Acid titration using pH meter or color indicator, automatic acid titration with potentiometric or conductometric readout (Caution: amines containing high amounts of sodium or organic acid anions will interfere with pH and color indicator titrations. Organic acid anions will titrate similarly to amines because they behave as weak bases at the endpoint of the amine titrations.)	
•	Sta	atus Check:	Once/shift to once/week depending on water balance, heat stable salt anion accumulation, sodium accumulation, or upset	
•	De	eviation:	Low	
		Cause:	Dilution from excess make-up water, upset or routine losses, accumulation of heat stable salt anions, leaks, laboratory error	
		Consequence:	Loss of capacity, reduced throughput, waste water emissions violations, cost to replace lost inventory, corrosion rate acceleration	
		Action:	Run duplicate to verify lab work Check system water balance and make-up requirements, adjust water makeup Check for hydrocarbon incursion. Change carbon filter if sample shows hydrocarbon layer or if cloudy. Skim rich flash drum/reflux drum for hydrocarbons. Ensure proper temperature for lean amine to each contactor. Check for foaming in individual contactors and regenerators and add antifoam only as needed. Remove heat stable salt anions.	

# Amine Condition – cont

•	Deviation:		High
		Cause:	Lack of make-up water, over addition, laboratory error, high organic acid anion content
		Consequence:	Loss of levels/level alarms, declining flow to regenerator, reduction of heat and mass transfer capabilities, pumping problems, freeze up, high reboiler temperatures and amine decomposition
		Action:	Run duplicate sample to verify lab work, use conductometric titration method. Check system water balance and make-up requirements, adjust water make-up. Adjust addition procedures

# **Amine Strength, Inactive Amine**

•	No	rmal Range:	<ul><li>0-10 % of the active amine concentration.</li><li>(Caution: This guideline is only correct if no sodium is present.)</li></ul>
•	Ana	alysis Method:	Base titration using pH or color indicator, automatic titration using potentiometric or conductometric method (Caution: errors in the titration will occur as the lean loading of the sample increases)
•	Sta	tus Check:	Once/week to once/shift depending on heat stable salt anion accumulation
•	Dev	viation:	Inactive amine exceeds 10 % of total amine concentration
		Cause:	Insufficient heat input into regenerator causing high lean loadings, heat stable salt anion accumulation caused by contaminants in streams being treated
		Consequence:	Corrosion rate acceleration, plugging, additional filter costs, exchanger fouling, loss of capacity, aggravation of foaming, equipment failure, loss of containment, unit shutdown
		Action:	Water wash streams to be treated. Remove heat stable salt anions ("reclaim").
			Purge contaminated amine and makeup with fresh.

### Amine Condition - cont

#### Amine Quality, Heat Stable Salt Anions

•	Normal Range:		0-0.8 wt % of solution
•	Analysis Method:		Ion Chromatography
•	Status Check:		Once/two weeks to once/month dependent on accumulation
•	Deviation:		Heat stable salt anions exceed 0.8 wt%
		Cause:	Contaminants in treated streams (e.g. O <sub>2</sub> , SO <sub>2</sub> , HCN, HCl, formic acid, acetic acid, oxalic acid), contaminants in the make-up water (e.g. chlorides, phosphates, sulfates, nitrates)
		Consequence:	See inactive amine strength high deviation section
		Action:	Water wash streams to be treated Remove heat stable salt anions Reclaim Purge contaminated amine and make up with fresh

# Amine Quality, Metals Including Sodium

•	Normal Range:	Sodium 0-0.2 wt-%, all others below 100 ppm (except in metal passivation additive systems). Dissolved iron above 25 ppmw may be indicative of excessive corrosion.
•	Analytical Method:	Sodium, Ion Selective Electrode(ISE), Inductively Coupled Plasma (ICP), Atomic Absorption(AA), Ion Chromatography (IC); Iron and others, ICP, IC
•	Status Check:	Once/two weeks to once/quarter dependent on accumulation of heat stable salt anions and metal contamination

•	Deviation:		Iron exceeds 25 ppmw	
		Cause:	Corrosion rate acceleration caused by high temperature, high velocity, high heat stable salt anion content, and high $H_2S$ and/or CO <sub>2</sub> concentrations	
		Consequence:	See Inactive amine strength high deviation section	
		Action:	Lower lean loadings by increasing reboiler heat input Reduce rich loadings by increasing circulation or amine strength Lower reboiler input to reduce velocity in reboiler piping and in overhead system Lower circulation to decrease rich amine velocities Purge ammonia from the regenerator reflux Remove heat stable salt anions and sodium Reduce pressure to lower regenerator temperatures Reduce lean amine temperatures to reduce corrosion in contactor bottoms Reclaim Purge contaminated amine and make up with fresh	
•	De	viation:	Charge equivalents of metals exceeds charge equivalents of heat stable salt anions	
		Cause:	Over-neutralization during caustic or soda ash addition	
		Consequence:	High lean loadings leading to off-spec products, corrosion rate acceleration	
		Action:	Remove heat stable salt anions and sodium	

### **Amine Quality, Chlorides**

- Normal Range: 0-1000 ppmw
- Analytical Methods: Ion chromatography (Caution: some IC anion methods will not distinguish formates from chlorides), silver nitrate titration (inaccurate due to silver-amine complexes)
- Monitoring Frequency: Once/two weeks to once/month dependent on accumulation

•	Deviation:		Chloride level exceeds 1000 ppmw	
		Cause:	HCl from reformer hydrogen or crude gases, cooling water leak, poor quality make-up water	
		Consequence:	Chloride stress cracking, pitting on reboiler tubes	
		Action:	Remove heat stable salt anions	

#### Amine Quality, Suspended Solids

•	Nor	rmal Range:	0-100 ppmw, solution clear water-white to yellow to green
•	Analysis Method:		Visual inspection, filtration, weight of filtered solids
•	Status Check:		Visual check once/shift or day
•	Deviation:		Solution is green or green with black particles, is turbid, particles settle out after standing for long periods of time, solution is white to yellow with large black particles
		Cause:	Break-up of carbon in carbon filter entering amine corrosion
		Consequence:	Plugging, reduced throughput, foaming
		Action:	Use correct carbon filter loading procedures. Use harder carbon. Change particle filters, go to smaller filter pore size Reduce corrosion rates by reducing acid gas concentrations, temperatures, heat stable salt anions, and velocities

#### Amine Quality, DEA Formamide

- Normal Range: Unknown
- Analytical Methods: NMR, IR, GC-Mass Spec
- Status Check: Not established
- Deviation: None known

The formamide comes from reaction of formate heat stable salt anions and the DEA. The only way known to break up the formamide is a catalytic process developed by Mobil Oil. The formate can be removed by heat stable salt anion removal techniques. The formation of the formamide takes up amine capacity by reacting the amine.

#### **Caustic Neutralization**

"Neutralization" with caustic has long been practiced as an economical means of displacing bound amine from heat stable salts. In addition, there was once a widely-held belief that it reduced corrosion by elevating the pH and suppressing ionization. However, contradictory corrosion studies within the past 10 years have resulted in controversy.

ConocoPhillips and MPR Services asserted that corrosivity of the HSS anions is not reduced by caustic, and in fact is sometimes made worse. Union Carbide and Dow Chemical, on the other hand, continued to maintain that corrosivity is generally reduced by neutralization, and Carbide went so far as to market an alternative to caustic called DHM. The views of both camps are typified by the following articles (among others):

- "Why Caustic Addition is Bad for Amine Systems", Mecum/Veatch/Cummings (MPR Services), Hydrocarbon Processing, Oct-97.
- "Remove Heat Stable Salts for Better Amine Plant Performance", Cummings/Mecum (MPR Services), Hydrocarbon Processing, Aug-98.
- "Neutralization Technology to Reduce Corrosion from Heat Stable Amine Salts," Liu/ Dean/Bosen (Union Carbide), NACE International, Corrosion/95, Mar 26-31, 1995.
- "Effect of Heat Stable Salts on MDEA Solution Corrosivity", Rooney/Bacon/DuPart (Dow Chemical), Hydrocarbon Processing, Mar-96.

In addition, unpublished studies suggest that caustic can effectively increase HSS levels by fixing the acid anions to the point of inhibiting their tendency to otherwise be regenerated in the regenerator.

The consensus of the ABPG is that caustic should not be added.

Water must be added to the amine system to replace that lost as vapor in the treated and acid gas streams, and via the reflux  $NH_3$  purge and miscellaneous physical losses. Makeup is usually accomplished by periodic manual adjustment basis inventory, with determination of free amine strength at sufficient frequency to ensure operation within established limits.

Makeup water should be condensate-quality. Service, and even boiler feed, water should be avoided due to dissolved solids and treatment chemicals that can accumulate in the system to cause corrosion, fouling and foaming. In the absence of a convenient source of condensate or demineralized water, steam can be injected into the regenerator.

#### Foaming

Minor foaming can adversely impact absorption and/or stripping efficiency, without obvious tower instability. More severe episodes can result in tray flooding. Typical symptoms of the latter are:

- Low/erratic tower levels and bottoms rates
- Erratic offgas rates
- Liquid carryover
- Increased/erratic tower pressure differential

Foaming is commonly attributed to HCs. Technically, however, only surfactant HC components – aromatics and soaps, in particular – cause foaming.

Surfactants may also cause HC emulsions, which are readily evidenced by a hazy or milky appearance. Regenerator foaming is often caused by such HC buildup in the reflux. In the event of tower instability, purging reflux is the first corrective action to try.

Ideally, surfactant buildup is avoided by carbon filtration, resin filtration or D-Foam, Inc. flotation. If occasional antifoam addition has been found necessary, **usage should be minimized for two reasons:** 

- Antifoam is itself a surfactant, and excessive dosages can actually promote foaming.
- Antifoam is adsorbed by carbon, thus reducing the carbon's capacity to adsorb the organics typically responsible for foaming.

Silicone antifoam is not advised, as it tends to foul equipment.

Excessive iron sulfide particles are also associated with foaming. Technically, they do not cause foam, but they stabilize it.

Unless refinery contactor feed gas is effectively water washed, it will likely contain minor levels of NH<sub>3</sub> which will be absorbed in the amine by virtue of its water solubility. It will be stripped out in the regenerator, but then reabsorbed in the reflux.

 $H_2S$  re-absorption in the reflux will increase in proportion to the NH<sub>3</sub> buildup until levels are so high as to become corrosive. Also, as the NH<sub>3</sub> and H<sub>2</sub>S concentration of the reflux approaches saturation, NH<sub>3</sub> will start leaking through to the SRU, potentially fouling the header with solid ammonium hydrosulfide (NH<sub>4</sub>HS). Often, the first indication is plugged instrument taps.

Excessive NH<sub>3</sub> buildup also increases reboiler steam demand to a predictable degree.

Common industry practice is to periodically measure the NH<sub>3</sub> content of the reflux and purge as necessary to maintain ~ 1 wt-%. Alternatively, it is easier to routinely monitor the H<sub>2</sub>S, where 2 wt-% would be the corresponding target (neglecting CO<sub>2</sub>). Initially, relative CO<sub>2</sub>/H<sub>2</sub>S levels should be determined to ensure that CO<sub>2</sub> corrosion is being adequately mitigated.