Amine Treating Plant
General Operation

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Introduction

This is provided for general plant operation information/guidelines.

Safety is of prime importance in any operation. Amine plants are no exception. Amine treating plants have natural gas under pressure, rotating equipment, toxic gases, high voltage, etc.. All operators must be trained in these areas before working with Amine Treating Plants. A safety section is included in this manual, but this does not replace proper training. Always completely assess all situations before progressing.

ASSESS BEFORE YOU PROGRESS
Safety

Assess Before you Progress

A. General

Operators and other employees having access to the plant need to be trained in all safety procedures and accept that safety is everyone’s responsibility, and that it is their duty to report any safety issue or potential safety issues.

Operators and others must be aware of the following:

1. Piping systems contain gas or liquid under pressure. Piping systems that need to be opened for maintenance or repairs must be isolated by block valves and depressurized using vents and/or drains provided in the piping or equipment.

2. Pressure Safety Valves (PSVs), also known as relief valves, need to be checked on a regular basis to ensure their proper operation.

3. Rotating equipment such as fans and pumps are provided with coupling guards. These guards must be kept in place at all times during operation of the equipment.

4. Electrical equipment must be maintained by qualified personnel. Electrical switch gear must be locked out on equipment which is being serviced.

B. Hydrogen Sulfide Gas/ Hazards of Hydrogen Sulfide

Hydrogen sulfide is an extremely toxic gas and can cause immediate death. Operating personnel MUST be trained to work in a hydrogen sulfide environment. Particular emphasis should be given to the problems and situations listed below. Fresh air masks must always be worn when there is a possibility of the presence of toxic concentration of hydrogen sulfide. Typical activities and locations which may permit hydrogen sulfide to escape are:

1. Repair or modifications to equipment or lines containing hydrogen sulfide, such as installing blind flanges, changing orifice plates, acid gas injection equipment and/or PSVs.

2. Sample or purge connections which may be improperly opened. These should have a safeguard such as being plugged or locked when not in use.

3. Water drained from the vent scrubber and reflux accumulator may contain some dissolved hydrogen sulfide which can flash out of solution upon release of pressure.

4. Flare not burning, allowing H₂S to settle in low lying areas. (H₂S is heavier than air)
5. Hydrogen Sulfide is extremely flammable. Its flammability range is much greater than methane.

C. Fire

Care should be taken to keep the flanges and other connections tight to avoid leakage of any process gases.

Adequate ventilation in all areas to prevent gas

No welding should be done in the plant area except with permission of the supervisor and upon issuance of the proper permits. Flammable gases may be present which may be odorless.

Smoking should be restricted to designated areas beyond the perimeter of plant operation.
Amine Plant Operational Overview

The treating facility for each plant varies. However, each plant employs an amine solution for removal of carbon dioxide and of hydrogen sulfide by absorption and chemical reaction.

The feed gas is pretreated through a filter coalescer to remove any entrained solids and/or liquids from the feed stream. The gas proceeds through the contactor column where the acid gases (CO$_2$ and H$_2$S) are removed from the gas stream.

The sweetened gas flows through the Sweet Gas Cooler where it is cooled before going to the Overhead Scrubber. The scrubber removes any liquid that is condensed by the exchanger before the sweet gas is processed downstream.

The lean amine is fed into the top of the contactor and flows countercurrent to the gas down through the trays where contact with the gas takes place. The rich amine is collected in the bottom of the tower. The level is maintained by a level transmitter and control valve which dumps the rich amine into a flash tank.

In the flash tank, hydrocarbon gasses entrained in the amine are flashed off and directed for disposal. If hydrocarbon liquid is present, it rises to the top of the amine solution in the flash tank where it can be removed via an internal collection “box” and then drained to disposal.

From the flash tank, the rich amine goes through a filtration process. A portion of the rich amine is directed through a carbon filter for the adsorption of hydrocarbons and degraded products from the amine. The removal of any remaining solid contaminants then takes place in the particulate filter.

The rich amine continues to the Rich/Lean Exchanger where it is heated. The amine then enters the Amine Still tower and flows down the still through the trays where contact with steam strips the acid gases from the amine. The amine is collected in a draw off pan (chimney tray) under the trays where it is then gravity fed to the horizontal thermosiphon Reboiler, on direct fired reboilers it will flow into the bottom of the reboiler. In the reboiler, the solution is heated until a portion of the solution is vaporized. This liquid/vapor (steam) mixture is piped back to the still column sump below the trays. As the steam travels up through the trays it strips the acid gas components from the amine.

Water in the vapor exiting the top of the still is condensed in the Reflux Condenser and collects in the Reflux Accumulator. The water is returned to the top of the tower using the Still Reflux Pumps, where it is comingled with the still feed liquid (rich amine). Vapor not condensed in the Reflux Condenser consists primarily of water vapor, hydrogen sulfide and carbon dioxide. These acid gases flow through the system back pressure valve and are sent to disposal.

Amine in the still column sump is considered to be regenerated and is called “lean amine”. The lean amine is gravity fed through the Rich/Lean Exchanger to the Booster Pumps.
The lean amine is then further cooled in the Lean Amine Cooler (air-fin) and delivered to the Solution Pumps. This pump increases the amine pressure high enough for it to enter into the top of the Amine Contactor and start the treating process over again.
System Component Operation

1) Inlet Filter Coalescer

a) Purpose

The filter coalescer removes all solids and liquids from the natural gas stream via a series of filtration elements. Solids are trapped in the filter elements, and liquids are collected in the vessel sump.

b) Control

The level glass on the sump allows for visual check of the liquid level in that section of the vessel.

i) The filter coalescer sump should have a high liquid level shutdown that shuts the SDV valve on the inlet gas line.

ii) The vessel is equipped with a differential pressure (dP) gauge to monitor flow restrictions due to contaminant buildup. This should shut down the plant before filter ruptures and allows contaminates pass through.

c) Safety

This vessel is protected by a PSV sized for fire relief.

d) Problems

e)

i) The filters are more likely to clog in the initial start-up phase because of dirt in the pipes and vessels.

ii) The elements must become completely saturated before they will begin stripping liquids. This may take up to 24 hours, depending on the free liquid in the stream.

iii) After the initial clean up, the filters should operate for several months between changes.

iv) Micron size of the elements can affect how quickly the filter clogs.

2) Sweet Gas Cooler

a) Purpose

The Sweet Gas Cooler is an air-cooled exchanger that cools the sweetened gas from the Amine Contactor condensing water vapor out of the gas.

b) Controls

i) The Sweet Gas Cooler should be equipped with variable or 2 speed fans, to allow for a wide range of air flow across the Cooler tubes to compensate for large swings in ambient temperatures from winter to summer.

ii) The Cooler section should also equipped with a pneumatic louver control that allows the Cooler to compensate for temperature swings for day and night.

c) Safety

i) The Cooler fans are equipped with vibration shutdowns in the event that a bearing failure, blade breaks or build up of dirt on the blades renders them out of balance.
d) Problems
   i) Large swings in temperature from day to night may require that the fans’ speeds be stepped up or down.

3) Overhead Scrubber

   a) Purpose
      The scrubber removes any condensed liquids formed in the Sweet Gas Cooler. Liquids collected in the scrubber are level/pressure controlled into the rich amine line prior to the Flash Tank. If this is piped to the drain system, amine carried over from the contactor would be lost.

   b) Control
      i) The level glass allows for visual check of the liquid level.
      ii) The scrubber has a high liquid level shutdown.

   c) Safety
      This vessel should be protected by a PSV sized for fire relief.

   d) Problems
      i) The potential exists for the liquid dump valve to hang open and blow gas into the amine regeneration system. The trim on the dump valve should be sized based on the flash tank relief PSV capacity.
      ii) High liquid levels can result in liquid carryover into downstream equipment.

4) Contactor

   a) Purpose
      The Contactor is where the amine and gas come in contact with one another. The Contactor is built with 20 stainless steel trays. These trays maximize the contact between gas and amine. As the amine travels across each of the trays in a zigzag pattern down the tower, the gas traveling up through the tray valves crosses through the amine. The amine removes the acid gases from the gas stream.

   b) Control
      i) The amine falls to the bottom of the tower where a level is maintained by the level controller and level dump valve.
      ii) The contactor sump has a low liquid level shutdown that shuts the SDV valve in the rich amine line from the contactor to the flash tank. This will stop the amine flow into the flash tank in the event that the level drops below the intended level.
      iii) Maintaining a liquid level in the contactor keeps the high pressure gas from being sent to the flash tank. (Note. The flash tank PSV is sized to handle the amount of gas that can pass through the amine dump valve should it ever hang open.) This should be verified by operation personnel.
      iv) The contactor sump has a high liquid level shutdown that stops the Booster Pumps
and the Circulation Pumps in the event that the level exceeds the intended level.

c) Safety
   i) The contactor has a relief valve sized to protect the contactor based on conditions
given in design. This should be verified by operation personnel.

d) Problems
   i) Ensure that amine is circulating through the tower before starting gas flow through
   the tower. If the trays do not have a liquid level established, the gas velocity through
   the trays will “lift” the amine and carryover into downstream equipment.
   
   ii) Erratic gas flow can cause amine to be swept from the tower into the downstream
   scrubber. Maintain a steady inlet gas flow to prevent this.
   
   iii) Pressuring up the contactor too fast can cause a velocity sweep through the tower that
can damage the valve trays. The correct procedure is to pressure up slowly by
   opening the manual valve slowly when allowing gas to enter the contactor.
   
   iv) Foaming in the tower can decrease contact and treating capacity.

   1) Foam is caused by
      (a) Particulates in the amine
      (b) Heavy hydrocarbons and/or condensation of hydrocarbons in the tower
      (c) Accumulation of degraded amine byproducts

   2) Foaming can be detected in the contactor by watching the output of the level
   controller. When foaming occurs the level in the contactor becomes erratic causing
   the output to swing, at times from closed to wide open. Monitoring the differential
   pressure across the tower is also a good indicator of foaming. If the differential
   pressure increases by more than 25% above the normal baseline, this is an
   indication that foaming is about to occur or is already occurring.

   3) Anti foam can be injected into the feed amine to reduce or eliminate this problem.
   Do not over inject antifoam as it will make the problem worse, a little is “good” a
   lot is “bad”.

   4) Check to see that filters and hydrocarbon skimmers are working properly.

5) Carbon Filter Vessel

   a) Purpose

      This vessel is filled with activated charcoal. The charcoal, or carbon, is there to adsorb
      hydrocarbons and iron sulfides. Also adsorbed in the carbon are some heat stable salts and
      other contaminants. The carbon also acts as a particulate filter, catching the larger of the
      particles.

   b) Controls
      i) If the carbon filter is only filtering a side stream of the amine flow. Operators should
         keep maximum flow through the filter.

      ii) The vessel should be equipped with a dP gauge to monitor flow restrictions due to
          contaminant build up.

   c) Problems
      i) Because the carbon catches solids it will clog up over time. This can be minimized
by keeping the amine clean.

ii) The carbon can be cleaned by running (counter flow) very hot water through the carbon vessel and washing out the adsorbed hydrocarbons and other trace oils, as well as removing some of the solids.

6) **Particulate Filter**

a) **Purpose**

The Particulate Filter is to remove the solids that pass through the carbon filter or carbon itself. On start-up the filters will need monitored closely. After the system is cleaned up, the filter will only have to catch the particulates that are washed from the gas by the amine solution.

b) **Controls**

i) The vessel is equipped with a dP gauge to monitor flow restrictions.

c) **Safety**

This vessel is protected by a PSV sized for thermal relief. Over pressure is protected by the PSVs on the flash tank.

d) **Problems**

i) The filters are more likely to clog in the initial start-up phase because of dirt in the pipes and vessels, as well as carbon fines that escape from the carbon filter vessel.

ii) After the initial clean up the filters should operate for longer periods between changes.

iii) Micron size can affect how quickly the filter clogs. The smaller the micron of the filter, the cleaner the amine will be, but the more often the filters will need to be changed. It is recommended that 20 micron filters be used after the system operation has been established.

7) **Flash Tank**

a) **Purpose**

The rich amine from the contactor is pressure fed through the filters and into the Amine Flash Tank through a throttle type control valve (as opposed to open and shut operations). The amine has a residence time of at least 10 minutes in this vessel. This allows the amine to release the absorbed hydrocarbon molecules. This also allows the heavy hydrocarbons to float to the top where they can be manually removed out of the vessel via a 1” drain line.

b) **Controls**

i) The pressure in the flash tank is controlled by a pressure valve. This controller is set at 60 psig and sends the flash gas to disposal (fuel or flare).

ii) The level in the flash tank is controlled by a level controller.

1. This level is set to maintain the level in the vessel and throttle the dump valve.
2. The level dump valve is located downstream of the rich/lean heat exchanger. This maintains the flash tank pressure through the exchanger to keep gas from flashing as it is heated, causing corrosion.
iii) The flash tank should have a high liquid level shutdown. That shuts the SDV valve in the rich amine line from the contactor to the flash tank. This will stop the amine flow into the flash tank in the event that the level exceeds the intended level.

iv) The flash tank should have a high pressure shutdown that also shuts the SDV valve in the rich amine line from the contactor to the flash tank.

c) Safety
   i) The flash tank is supplied with a relief valve that is sized to relieve the maximum amount of gas that can pass through the contactor dump and or overhead scrubber should the valve fail open. Valve trim size on contactor and overhead scrubber should have the smallest trim possible to reduce risk associated with valve failure.
   
   ii) If the contactor valve is changed, or the size of the trim is change, this relief valve should be resized.
   
   iii) If the operating pressure of the contactor is raised it should be sized for the new operating conditions.

d) Problems
   i) The flash tank is prone to high level shutdowns.
      
      (1) The reasons for this are
      
      (a) Flash tank pressure too low to push liquid out fast enough.
      (b) Problems with the flash tank level control or dump valve.
      (c) Foaming.
      (d) Filters downstream plugged
      (e) Exchanger fouling
   
   ii) Hydrocarbons and compressor oils that build up in the flash tank will need to be manually skimmed off regularly.

8) Rich/Learn Exchanger

a) Purpose
   The purpose of the Rich/Learn Exchanger is to recover heat from the lean amine and preheat the rich amine before putting it into the Still Column. Also, it cools the lean amine out of the Amine Still surge, helping the Booster Pumps run at a cooler temperature. It also reduces the size required for the air-cooled fin fan exchanger. The Rich/Learn Exchanger is a shell and tube exchanger. While not as efficient as the plate frame exchangers, they are less likely to clog and cause maintenance problems.

b) Controls
   i) There are no controls on the exchanger.

c) Safety
   i) The exchanger is protected by the relief valves on vessels before the exchanger.

d) Problems
   i) The problems with exchanger are fouling, or the settling of solids in the tubes that can plug it off. Good filtration will increase the life of the exchanger.
   
   ii) Corrosion/erosion can occur if the amine flashes off gasses when it is heated in the exchanger. Maintaining the highest pressure possible will reduce the risk.
9) Flash Tank Dump Valve

a) Purpose
   The purpose of this valve is to maintain the level of the liquid in the flash tank. Putting it downstream of the Rich/Lean Exchanger tubes also maintains the flash tank pressure in the exchanger, minimizing corrosion. This valve should be located as close to still inlet as possible.

b) Control
   This valve is controlled by the level control on the flash tank.

c) Problems
   The only problem with this valve is that it will operate for days at the same place and stick. It helps to manually cycle the valve every day or so to prevent this from happening.

10) Still Column

a) Purpose
   The Still Column is a traysed vessel with 20 round valve trays. In this vessel, steam from the reboiler strips the acid gas from the rich amine, thus “regenerating” the rich amine into lean amine.

b) Control
   i) The pressure in this vessel is maintained by a pressure control valve located in the Reboiler Accumulator vapor outlet line. It is best to maintain the Still overhead pressure (before the Reboiler Condenser) between 12-14 psig to ensure the best regeneration parameters.
   ii) Since this is essentially a closed loop system, the volume of amine, while fed by the flash tank dump valve, is controlled by the circulation rate of the solution pump.
   iii) The steam load, or quantity of steam going up through the tower is controlled by the Hot Oil flow, or heat input into the reboiler. The steam load is a function of pressure and temperature.

c) Safety
   The Still Column is protected from overpressure by a PSV on the overhead piping. There are no block valves in the line between this vessel and the PSV.

d) Problems
   i) Foaming in the still can be a problem, although it is seen more often in the contactor.
      1) If foaming is suspected, the reflux can be tested for amine concentration. If there is more than 0.5% amine in the reflux this would indicate that some amine is carrying over the top.
      2) A dP meter or gauge can be mounted around the still (a dP meter is not currently installed). An erratic dP would indicate that foaming is taking place. Be sure that the dP change is not caused by fuel pressure changes which cause steam flow rate changes.
      3) Fouling of the trays is also possible if proper filtration is not maintained.
11) Reflux Condenser
   a) Purpose
      To cool the Still Column overhead vapor and condense the water out of the acid gas.
   b) Control
      i) The reflux condenser should be equipped with (2) 2-speed fans or VFD fan, allowing for a wide range of air flow across the Cooler tubes to compensate for large swings in ambient temperatures from winter to summer.
      ii) The Cooler section should also equipped with a pneumatic louver control that allows the Cooler to compensate for temperature swings for day and night.
   c) Safety
      i) The Cooler fans are equipped with vibration shutdowns in the event that a bearing fails, blade breaks or buildup of dirt on the blades renders them out of balance.
      ii) The condenser is protected from over pressure by a back pressure regulator located in the outlet piping of the Reflux Accumulator and by the PSV located upstream of this cooler.
   d) Problems
      i) Large swings in temperature from day to night may require that the fans’ speeds be stepped up or down.
      ii) In cases where the ambient temperature falls below 0°F, the fans can’t be turned off because the reflux condenser will still require air movement.
      iii) Gas buildup in the Cooler can cause the liquid to channel through the cooler and decrease efficiency.
      iv) The problems in the condenser are corrosion and temperature control.
      v) It can be difficult to keep the reflux at the desired temperature on units with the lean amine and reflux condenser in the same structure, because the fan speed is set to cool the lean amine side of the cooler.
      vi) Corrosion can be monitored by having lean amine samples tested regularly, and corrective action taken based on results.
      vii) When plant is goes down the condenser can freeze up. To help prevent and thaw the cooler a side stream of amine, off of the lean amine booster pump, can be piped into the inlet of cooler.

12) Reflux Accumulator
   a) Purpose
      The Reflux Accumulator is where the water and vapor is separated after going through the air-cooled condenser (exchanger).
   b) Control
      i) The level is controlled by a direct acting level controller that opens the valve when the level is above set point to allow the pumps to pressure the reflux into the rich amine line to the top of the still, to help strip rich amine.
ii) Pressure is controlled by the back pressure control valve located in the outlet piping.

iii) The accumulator has a low liquid level shutdown that stops the Reflux pumps in the event that the level falls below the intended level.

c) Safety

i) Vessel is protected from over pressure by the PSV located in the Still Column overhead piping.

d) Problems

i) Foaming in still can cause erratic/high levels in flash.

ii) The problems with the operation of this vessel are related to the liquid level.

iii) The liquid level controller opens the dump valve, sending the Reflux into the Rich Amine Stream.

iv) After operating at the same level for a period of time the level control may not respond to system changes, causing the level to go either high or low. The pump loses prime and then the reflux is not pumped from the vessel. A high level shutdown results.

v) High temperature in this vessel can result if the louver controller on the condenser fails to maintain the temperature set point.

vi) Hydrocarbon buildup can occur if the temperature is operated below the dew point of any contained hydrocarbon’s dew point. These are removed via a skimmer.

vii) Excessive water consumption in the treating unit results if the temperature is operated too high.

13) Reflux Pumps

a) Description

These are normally centrifugal, vertical inline pumps

b) Purpose

Reflux Pumps pressure the reflux water back into the rich amine piping and returns it into the top of the still. Reflux pumps also maintain the level in the reflux accumulator.

c) Controls

i) Reflux is pumped against a level control valve. When the level rises above the set point the valve opens sending reflux into the rich amine piping to the Still Column.

ii) A return line back into the vessel keeps the pump from running against a closed valve, which would cause the pump seal to overheat.

d) Safety

i) Over pressure protection is provided by the pump’s inability to increase the pressure more than 35 psig.

e) Problems

i) Problems with the Reflux Pumps come most often from the level controller and control valve. These components hold the level steady for long periods of time, when a change occurs in the system they fail to react and cause a high level shutdown which will put the panel in alarm shutting off all burners and motors.
ii) Running the pump dry or deadheaded will cause seals to become too hot and fail.

14) Reboiler

a) Thermosiphon

i) Purpose
On plants 200 gpm and above The reboiler is normally a shell and tube thermosiphon that heats the amine solution with hot oil as the heating medium. The temperature of the solution rises to the point that a portion of the water is vaporized into steam. The vapor/liquid mixture is fed via pipe to the bottom of the Still Column. On plants 100 gpm and below the reboilers are direct fired, with amine surge located on the opposite end of the fire tube.

ii) Control
The oil flow rate through the Reboiler is adjusted by a flow control valve after the reboiler. The flow may also be varied/controlled by a temperature sensor in the still overhead line.

iii) Safety
The tube side of the Reboiler is protected from over pressure by a pressure relief valve located on the Still overhead line. The shell side of the Reboiler is protected by a thermal PSV located on the shell side outlet line.

iv) Problems
The Reboiler doesn't present many challenges.

b) Direct fired reboilers

i) On plants 150 gpm and below the reboiler is normally a direct fired reboiler, with the amine surge located on the opposite side of the fire tube.

ii) Controls- Burners are controlled by the overhead temperature. The overhead temperature is set based on the still pressure and amine performance. Amine test should be ran to determine actual performance.

iii) Safety-
Vacuum breaker should be installed if Reboiler is not capable of withstanding absolute vacuum.
Blanket gas should be used to keep vessel at a positive pressure.

iv) Problems
If temperature is too high on reboiler the fire tubes can collapse. High temperature shutdown with two automated valves should be used to ensure shutdown.
15) Booster Pumps

a) Description

These are normally centrifugal, horizontal inline pumps.

The Booster Pump increases the pressure of the lean amine solution to push through the Lean Amine Cooler and supply adequate feed pressure to the Solution Pump. Two pumps should be furnished to provide 100% backup for the pump service.

b) Controls

i) The feed pressure to the pump controls output pressure.

ii) Each pump should be designed to supply 60 psig of boost (head), added to the 8-15 psi of feed pressure will give an outlet pressure of 68 - 75 psig.

iii) Check valves should be supplied on the outlet of each pump to prevent backflow through the non-running pump.

iv) Pump discharge vent valves should be supplied to purge air from pump and piping before start-up and while it is operating.

c) Safety

i) Over pressure is prevented by the inability of the pump to produce more than 60 psi of boost.

ii) Pump suction low pressure switches will shut down the pumps to protect them from cavitation caused by low suction pressure.

iii) Caution should be exercised when working on or around the pumps because the liquid being pumped can be very hot, normally 120°F, but can be much higher.

d) Problems

i) At times priming the pumps can prove to be difficult. Start the pump and run for 30 seconds, then stop and allow solution to stop moving. Then bleed the air from the bleed valve.

ii) Trapped air or gas is hard to remove from the system.

iii) Running the pump with the suction and/or discharge valves closed or when the Solution Pump is not running will cause seals to overheat and leak.

iv) Running both pumps will allow the stronger pump to pump and cause the weaker of the pumps to deadhead and cause seal problems as described in above.

16) Lean Amine Cooler

a) Purpose

The Lean Amine Cooler is an air-cooled exchanger and cools the lean amine from the Booster Pumps going to the Solution Pumps. This location allows the Solution Pumps to operate at cooler temperatures. This also allows operations to set the amine temperature to optimize treating conditions in the Contactor.

b) Control

i) The lean amine cooler should be equipped with 2-speed of VFD fans, allowing for a
wide range of air flow across the Cooler tubes to compensate for large swings in ambient temperatures from winter to summer.

ii) The Cooler section should also be equipped with pneumatic louver control that allows the Cooler to compensate for ambient temperature swings.

c) Safety

i) The Cooler fans are equipped with vibration shutdowns in the event that a bearing fails, blade breaks or buildup of dirt on the blades renders them out of balance.

ii) The cooler should be protected from over pressure by a combination of a system PSV and centrifugal pump maximum head boost.

d) Problems

i) Large swings in temperature from day to night may require that the fans’ speeds be stepped up or down.

ii) Gas buildup in the Cooler can cause the liquid to channel through the cooler and decrease efficiency.

iii) Care needs to be taken to make sure the tubes are full of liquid. This is accomplished by bleeding vapor from the inlet piping.

17) Solution Pumps

a) Description

HPS pumps multi-stage, horizontal, high pressure or positive displacement pumps

b) Purpose

Solution Pumps pressure the lean amine solution into the Contactor through the closed loop circulation system.

c) Control

i) There is a bypass from the discharge header on the pump to the flash tank. This allows the pumps to start without having a high load on them.

d) Safety

i) The pumps have discharge PSVs that protect the pump against a closed valve start.

ii) The PSV also protects the pump from trying to pump against more than rated pressure.

iii) Pump suction low pressure switches will shut down the pumps in the event the suction pressure drops below the switch setting.

iv) Pump discharge high pressure switches will shut down the pumps in the event the discharge pressure climbs above the switch setting.

18) Hot Oil Heater (normally on plants 200 gpm or larger)

a) Description

This is normally a direct fired heat exchanger that maintains the temperature of the oil heating medium circulating through the shell side of the Reboiler.
b) Control
   i) A high stack temperature switch monitors the stack flue gas temperature leaving the heater. This switch will shut down the burners to the Hot Oil Heater if the stack temperature limit is exceeded.
   ii) A high temperature monitor on the oil outlet piping adjusts the amount of fuel gas fed into the burner system. If the upper limit is exceeded it will shut down the burner and the blower.
   iii) The vessel is equipped with a dP switch to monitor flow restrictions due to contaminant buildup.

c) Safety
d) Problems
   i) High stack temperature – Check the system for low flow, or a blocked strainer. This may also indicate a tube leak in the heater.
   ii) Black smoke from stack indicates the burner is too rich in fuel gas. Increase the air flow by opening up the air dampers on the burner housing.
   iii) White smoke form the stack indicates the burner is too lean in fuel gas. Decrease the air flow by closing the air dampers on the burner housing.
19) **Hot Oil Pumps**

a) **Description**

   These are normally centrifugal, horizontal inline pumps.

b) **Purpose**

   The Hot Oil Pump increases the pressure of the oil heating media to push through the Hot Oil Tank and supply adequate feed pressure to the Reboiler. Two pumps should be furnished to provide 100% backup for the pump.

c) **Control**

   i) Check valves should be on the outlet of each pump to prevent backflow through the non-running pump.

d) **Safety**

   i) Pump suction low pressure switches should shut down the pumps to protect them from cavitation caused by low suction pressure.

   ii) Pump discharge high pressure switches should shut down the pumps in the event the discharge pressure climbs above the switch setting.

e) **Problems**

   i) Running the pump with the suction and/or discharge valves closed or when the Solution Pump is not running will cause seals to overheat and leak.

   ii) Running both pumps will allow the stronger pump to pump and could cause the weaker of the pumps to deadhead and cause seal problems as described in above.

20) **Hot Oil Surge Tank** (on plants with hot oil system)

a) **Description**

b) **Purpose**

   The Hot Oil Surge Tank is located downstream of the Reboiler. It provides storage capacity for the heating medium and maintains an adequate amount of oil flowing to the system pumps.

c) **Control**

   i) The level glass allows for visual check of the liquid level

   ii) The surge tank should have a low liquid level shutdown that stops the Hot Oil Pumps in the event that the level falls below the intended level.

d) **Safety**

   i) The Hot Oil Surge Tank should have a low level shutdown which shuts down the Hot Oil Pumps.

   ii) This vessel is protected by a PSV sized for thermal relief.

e) **Problems**

   While not complicated, an understanding of the overall system and how it works will make it easier to operate
**Preparation for Initial Operation**

There are several things which must be accomplished prior to plant start-up. While each plant is different, here is a general list. Each one is extremely important to insure the safety of operating personnel and equipment during start-up, and to assure that the plant can be placed in operation with relatively little difficulty.

1) **General**
   a) Make sure all electrical equipment: Panel, motors, controllers are rated for the area they are in. For example class 1 div 2.
   b) Check to insure that the Solution Pumps have an adequate level of oil in the crank cases.
   c) Have a qualified electrician check the wiring and rotation on each pump and fan motor.
   d) Energize the panel and check the ESD conditions. Test all the unit shutdowns.
   e) Ensure that manual valves in amine piping to and from the amine contactor are closed.

2) **Fill System with Water**
   a) Fill the Still Column sump to top of surge sight glass.
   b) Open the valves to allow the water to gravity feed through the rich/lean exchanger to the Booster Pumps using the Booster Pump bleed valves to allow the air to escape. When water flows steady from the bleed valve, close valve.
   c) Open suction and discharge valves on the Solution Pumps.
   d) Open the bypass valve from the Solution Pump discharge to the Flash Tank.
   e) Turn on a Booster Pump. Pump pressure will push water through the Lean Amine Cooler and Solution Pump into the Flash Tank.
   f) Cycle Solution Pump valves to insure that each pump has time to push all air out of pump.
   g) When the Flash Tank has a level above the middle of sight glass, turn off the Booster Pump.

3) **Pressurize Vessels & Set Pressure Controls**
   Add fuel gas to Flash Tank using start-up valve on vessel. Set Flash Tank pressure at 60 PSIG using the pressure controller.

4) **Flash Tank and Filters**
   a) Open the vent valve and the manual valves on the Carbon Filter. Allow the water to gravity feed into the filter to allow air to escape. When water flows out of the vent valve, close valve.
   b) Open the vent valve and the manual valves on the Particulate Filter. Allow the water to flow into the filter allowing air to escape. When water flows out of the vent valve, close valve.
   c) Open any remaining manual valves to the Flash Tank dump valve, filling the Lean/Rich Exchanger. Adjust the level control on the Flash Tank.
   d) Set the flow control valve at the Carbon Filter to maintain a flow of 100 GPM through the flow meter/element.
   e) Set level to maintain level even with the level control valve
5) Reflux
   a) Open the level fill valve on the Reflux Accumulator.
      i) Allow water to fill vessel to above the level control, open suction valves on reflux
         pumps. Open bleed valves and allow air to escape, priming the pumps.
      ii) Start one pump and set level recycle valve.
   b) Close fill valve and set level.

6) Pumps
   a) Restart the Booster Pump. Check that discharge pressure is 60+ psi.
   b) Check to insure that bypass (from the Solution Pump discharge to the Flash Tank) is still
      open.
   c) Set frequency on VFD to 50 Hertz
   d) Start Solution Pump.
      i) Allow pump to circulate into the flash tank to check level control and to ensure that a
         level is maintained.
   e) Check system for leaks and repair.
   f) Observe system operation to insure that all levels and pressures are maintained.

7) Hot Oil System/Reboiler
   a) Open the vent valve on the Hot Oil Surge Tank.
   b) Fill the tank, making sure the oil level is visible on the level monitor.
   c) Start the Hot Oil Pumps and fill the system piping and Reboiler with oil.
   d) Light the burner and visually check the flame pattern. Set the burner control switch to
      212°F and a high limit of 225°F. Check that the switch turns on and off properly as this
      temperature is maintained. Circulate at this temperature until vapors are no longer visible
      venting the tank.
   e) Increase the temperature setting in 50°F increments until the operating temperature is
      attained, and no vapors are venting. Close the vent valve.
Amine System Cleaning Procedure

This is the procedure recommended by the amine supplier. On new units it may not be necessary to wash the system. If so, skip down to step 3, rinse the unit and start up.

STEP 1: Charge the amine unit with a 5% amine solution. Start the unit using the start-up procedure listed in that section. If the pressure on the contactor is insufficient to allow this circulation rate the level will go out of sight in the Contactor with the level control valve wide open, it may be necessary to reduce the rate or increase contactor pressure. Confirm that there is flow through the Reboiler, and start the hot oil flow to bring the reboiler temperature to 140°F. The solution should be circulated through all bypasses, vessels and exchangers in the amine circuit. Observe the solution color and the pressure drop across the amine filter. It may become necessary to change filters. Start the amine cooler and reflux condenser fans. Increase the reboiler heat input until a level is established in the reflux accumulator. Start the Reflux Pump. Continue circulating for at least four (4) hours. Shut the hot oil flow to the Reboiler off. Drain the solution from the unit as completely as possible using all vessel drains.

STEP 2: Block in the Charcoal Filter and open the bypass. Again, fill the system with steam condensate and repeat the wash as in step 1 above. After circulation has been established, fill the charcoal filter about half full of water and carefully pour in the activated charcoal.

STEP 3: Fill the system with a recommended amine solution, place the unit in operation.
Amine System Startup

Plant Pressurization and Start-up

After the amine system has been cleaned, purge the amine contactor by slowly pressurizing with gas to normal operating pressure and check for leaks then blow down. Repeat pressurization and blow down and then pressurize again. With the contactor at operating pressure and no gas flow, liquid circulation should be established as follows:

i) Open all valves in the discharge piping to the contactor such that the pumps will pump directly to the contactor. Close bypass valve from Solution Pumps to Flash Tank.

ii) With the Solution Pump in operation, a level can soon be established in the bottom of the Contactor.

iii) As soon as a liquid level is established at the midpoint of level indicator, all hand valves in the amine feed line to the flash tank should be opened and the level controller set to maintain this level.

iv) Establish a level in the Flash Tank, and when this level controller is set and amine flow established to the Still, complete amine circulation has been established.

v) Amine filters (carbon and particulate) should now be put in operation. Open the manual valves around the Carbon filter. The small vent valves at the top of the filters should be opened to allow any vapor in the filter to be vented and then close them. Establish amine flow through the particulate filter by opening the discharge valve and closing the filter bypass valves. Verify a 100 GPM flowrate is going through the Carbon Filter.

vi) As the temperature in the reboiler increases, steam is generated. The overhead temperature out of the Still increases as vapors pass by the indicator. These vapors along with the acid gas in them go out the Still overhead line. Water is condensed and flows to the Reflux Accumulator. Vapors from the accumulator will be directed to the vent system.

vii) Now that complete amine circulation is established with amine flow through the filters and the Reboiler and Still at design temperature, gas flow through the Contactor can be initiated.

Charcoal Filter

It is suggested that regular tests be made of the amine solution to determine hydrocarbon content and establish approximate useful life of the activated charcoal.
Still Operations

System pressure is a factor in achieving adequate regeneration of the amine solution. Higher system pressures require higher reboiler temperatures to maintain a proper lean amine concentration. This pressure can be varied within limits to achieve optimum operating conditions. Higher system pressure will aid in condensing reflux and insuring flow from the reboiler through the exchanger. There is an upper pressure limit, however, in which the boiling point of the amine solution is too high to be achieved with the reboiler provided. The lower limit of still pressure will be the pressure at which adequate suction head for the Amine Booster Pumps cannot be maintained and/or it prevents proper stripping of the amine.

Water losses will occur during normal operations, and this water must be replaced on a regular basis. In the absence of an actual test to determine amine strength, it is normally assumed that essentially no amine loss has occurred, and water is added as required to maintain normal operating levels in the surge tank. Provision has been made to add water to the system with a make-up pump. It will be necessary to watch levels while the plant is being charged and when normal levels are restored, water make-up should be stopped.
Restart of a Typical Amine Regeneration Unit

1. Open bypass valve on discharge of Solution Pump.
2. Start amine Booster Pump and Reflux Pump.
4. Start Lean Amine and Reflux Cooler fans.
6. Start Hot Oil flow into the Reboiler.
7. Check control valve on the Flash Tank and Contactor.
8. Check the Amine Contactor skid.
9. Watch overhead temperature until it is at set point (210°F) and that temperature controller has begun controlling the steam flow.
Amine Unit Operational Suggestions

Certain points on amine treating plants can be a source of problems from time to time and trouble often occurs during plant start-up. Among these are:

Solution Pumps

Solution pumps should be inspected carefully while operating, to make sure cavitation is not occurring. High quantities of CO₂ in the lean amine stream can result in cavitation. Large amounts of suspended solids in the amine solution can cause erosion of the solution pumps. Hence, filter operation needs to be monitored on a regular basis.

Still Operation

Inattentive operation may result in high quantities of CO₂ remaining in the lean amine solution during start-up, due to difficulty in obtaining smooth operations. This can result in damage to the reboiler, exchanger, booster pumps, cooler tubes and solution pumps. Careful testing of the lean amine solution during the early period of plant operation can prevent damage to the system. Normally, CO₂, H₂S, and water are present in the overhead, all of which cause corrosion. A small amount of amine in the overhead condensate will provide corrosion inhibition. Too much amine in the stream, however, means that the reflux rate is not high enough and will result in high amine losses. Our recommendation is that the reflux condensate should contain about 0.5 percent amine.

Heat Exchanger Performance

Heat exchanger performance should be checked as soon as possible after start-up. Usual experience is that a great deal of contamination or fouling occurs in the heat exchangers during the initial period. This tends to reduce overall operating efficiency and has, in some cases, resulted in the plant being unable to process the required amount of gas. Operating data on the exchange and heat removal of the exchangers can provide invaluable information for determining fouling rates and factors as the plant becomes older. This data is also valuable if corrosion is suspected in any heat exchange equipment.
Amine Contactor

The amine contactor should be operated so that the temperature of the lean amine to the contactor is always held about 10°F higher than the inlet gas temperature. If this is not done, it is possible, especially with rather wet hydrocarbon streams, to condense hydrocarbons in the rich amine streams. When this occurs, foaming will result. The control valve on the rich amine stream from the contactor is subject to very severe service. Since the pressure is usually sharply reduced at this point, there is always the possibility of the evolution of CO₂ and H₂S. It is well to keep a close watch on the valve, even to the point of using the manual bypass and inspecting the inner valve assemblies.

Solution Loading

There have been several references to allowable loading of amine scrubbing solutions in industry literature. In general, these references have been in terms of volumes of acid gas per volume of solution and have disregarded amine concentrations and pressures on the heat exchangers. These factors are important. The objective of the control of amine solution loading is to prevent evolution of acid gas in the heat exchangers and thus to prevent corrosion. Exceeding allowable loading will result in the presence of bicarbonate or hydrosulfide which is undesirable from a corrosion standpoint.

Solution Stripping

Articles on amine treating largely have failed to mention the influence of proper (or improper) solution stripping or the corrosion experienced. But care to maintain proper stripping of the lean solution can result in worthwhile operating savings. When rich amine solution is introduced into the stripping still, H₂S is stripped first. Carbon dioxide removal is more difficult, and the result of it being left in solution in the lean amine is more critical.

As the lean solution is taken into the exchanger for receiving heat necessary to accomplish stripping, any CO₂ present above 5 to 7 percent volume of amine solution will be subject to being evolved in the exchanger. This causes erosion and corrosion to the exchanger tubes. If much CO₂ is released, severe corrosion will result. The amount of residual CO₂ in the lean amine can also affect the operation of the solution pumps since high residual CO₂ can cause cavitation in these pumps.

In plants operating for the absorption of hydrogen sulfide only, this problem becomes somewhat simpler due to the fact that H₂S is easier to strip from amine solutions as discussed above. In this case, the H₂S residue in the lean amine should be used as the control on the effectiveness of
stripping in the plant. In plants absorbing carbon dioxide only, the stripping problem is more acute. In these plants, it may become necessary to reduce the amine concentration and use higher circulation rates to effect easier stripping of the amine solution.

**Foaming**

Foaming difficulties often occur in gas treating units employing amines. Foaming is a complex phenomenon. Many theories have been advanced to explain all aspects of observed behavior. The mere production of some foam is not the cause of operating difficulty in gas treating columns. Troublesome operation results when the foams generated have too much stability. The effect an additive has on foaming properties of the system often depends upon when it is added. Some materials, when added prior to foam generation, act as foam stabilizers. This is important in the evaluation of foam suppressants in amine gas treating units.

Some foam stabilizers have long hydrocarbon chains which terminate in a polar group that is not sufficiently polar to offer appreciable water solubility on the molecule. Further, concentration, temperature, and salt content affect foam stability as does the presence of finely divided insoluble materials.

Each situation has to be evaluated individually. Simple laboratory studies conclude that foaming contributes to troublesome operations and excessive amine losses. The foaming characteristics of a solution may be determined qualitatively by using a medium or fine fitted-glass dispersion tube to bubble air through a sample of the plant solution in a graduated cylinder. A means of measuring air flow should be provided so that reproducible rates can be used. The following observation should be made.

1. Type of foam formed, i.e., bubble size, apparent consistency.
2. Time required for foam to reach maximum height.
3. Time required for foam to break after air flow is stopped. To evaluate these observations, the same test should be made on equivalent amine solutions made up from fresh unused amine.

In gas treating units, excessive foaming will usually be due to the presence of small amounts of stabilizers. Some known offenders are:

1. Field corrosion inhibitors carried into the units from the field.
2. Plug valve greases which contain soap bases.
3. Naphthenic acids and higher molecular weight organic acid which are present in certain petroleum streams.
4. Suspended solids.
5. Hydrocarbons dispersed in the solution.

To evaluate foam inhibitors, they should be added to a sample prior to running the foam test. This is important since in these units an additive has to function as a foam inhibitor when added prior to foam generation. In regard to foam inhibition, effectiveness is dependent upon the chemical nature of the material causing foaming. This means that each unit has to be evaluated individually and various inhibitors tested.

Some silicones that have been found effective for amines and glycols are: Down Corning Silicone Antifoams and GE Antifoam 60. In certain cases, combinations of these silicones are more effective. Another material that is effective in certain cases is Wyandotte’s Pluronic L-61.

In testing foam inhibitors, attention should be given to ease of dispersion. This may be indicative of how readily they will be lost from the system. Best care for foaming is proper care of the amine. In the case of amine solutions, the first steps in this program are proper and adequate filtration. If use of inhibitors is necessary, they should be evaluated on a laboratory scale by adding the inhibitors before addition to the gas treating units. Remember that foam inhibitors do not solve the basic problem; rather they are a means of control until the causes can be learned and cures started.

In the case of amine solutions used to treat gases containing cyanides and hydrogen sulfide, a complete amine analysis should also be run when heat stable salts are believed to be present. If these materials are present in appreciable concentrations, corrosion can be expected. It will be necessary to dump a portion of solution and make up with fresh amine. Other analyses that may be useful when heat stable salt and/or degradation products are indicated include: cyanide sulfide, mercaptans, ash, iron oxalate, and sulfates.

If foaming is believed to be occurring, a determination of foaming tendency should be made. The concentration of volatile acids should be determined. A significant amount of such acids may be an important factor. To remove such materials, remove a portion of the solution and make up with fresh amine.

Another important factor which can be estimated visually or determined gravimetrically is suspended solids. Filter rates should be such that visual examination of a sample indicates negligible amounts of suspended solids. They may contribute to foaming and corrosion (both erosion and cell type) when deposited on equipment surfaces.
Amine Analysis and Control

Analysis of the amine solution is essential to proper operation of the amine plants. Proper analytical data will make it possible to evaluate the performance of the unit, and to maintain the amine solution in a condition to give good acid gas absorption with a minimum of corrosion problems. Analyses which provide a means of obtaining data for proper operation are:

1. Amine content of the lean solution should be determined by titration. This enables the operator to detect changes in amine concentration. Any sudden changes are indicative of improper operation. Efforts should be made to find the cause of these concentration changes.

2. Carbon dioxide and/or hydrogen sulfide in both rich and lean solutions should be determined once a shift. These analyses will show whether or not the solution is being overloaded and adequately stripped. These are important factors in the prevention of corrosion, particularly the carbon dioxide which is harder to strip.

Many times it is considered impossible to run the above analyses once a shift, despite their importance. During plant start-ups a higher frequency may be desirable. Longer intervals decrease the chances of detecting improper operation. After the plant operating conditions have stabilized, determination of H$_2$S and CO$_2$ in the solution can be made once a week.