TRICKY LIQUID DISTRIBUTORS

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Prepared for Presentation

at the

Kister Distillation Symposium 2017

Topical Conference

at the

2017 Spring Meeting and 13th Global Congress on Process Safety

of the

American Institute of Chemical Engineers

San Antonio, Texas

March 26 – 30, 2017

Introduction

The design criteria of liquid distributor are well established for packed columns. However, liquid distributor selections and design are still challenging even for reputable vendors. Overlooking the basics often result in costly operational problems.

Case Study #1: Fire in Ammonia Absorber Column

An intermediate petrochemical product is manufactured using ammonia as the main feedstock. Unconverted ammonia is removed from the gaseous product by sulfuric acid absorption in the absorber column. Ammonia absorber column is a two stage absorber equipped with two beds of structured packing with high quality channel trough type distributors and two cooled pumparound circuits. Sulfuric acid is injected automatically to both sections, controlling pH in the pumparound loops.

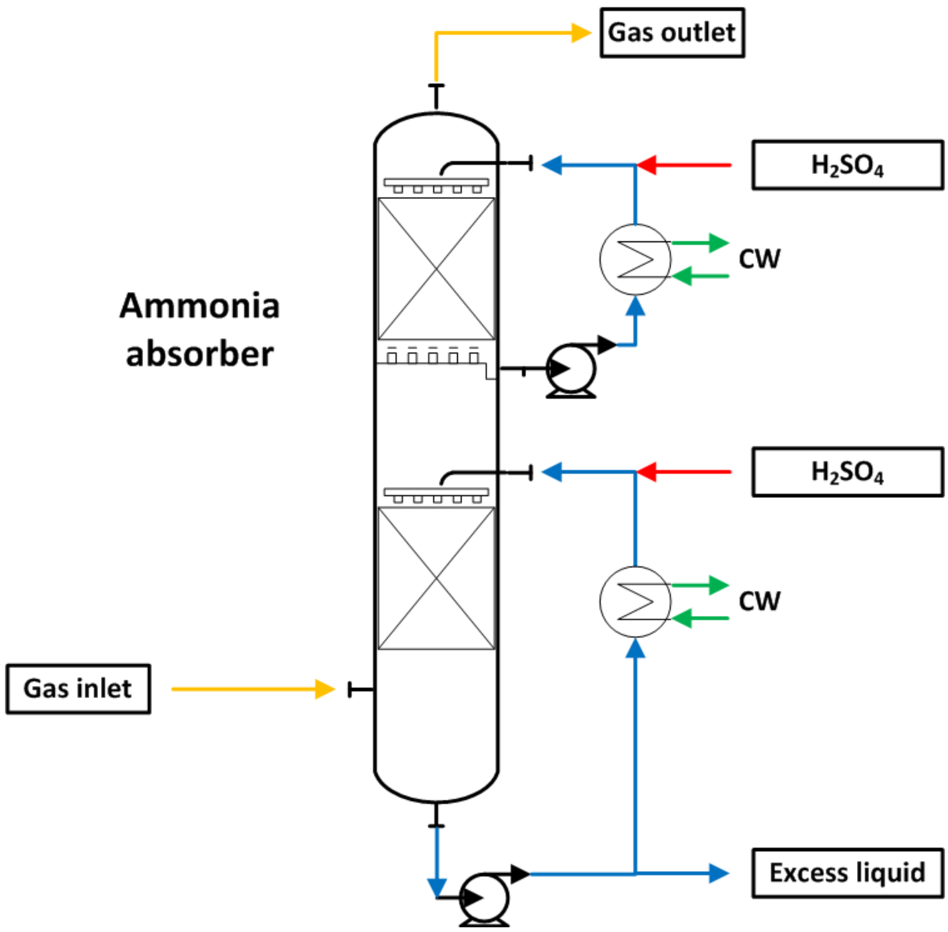

Figure 1: Ammonia absorber

Problem Description

Shortly after the shutdown for cleaning, the absorber column performance deteriorated. Sulfuric acid consumption in the bottom loop dropped, while the acid consumption rose in the top loop. In order to prevent ammonia break-through, operators manually increased acid dosing to the bottom loop and started the investigation to identify the root cause.

Column behavior indicated a problem with bottom section absorption efficiency. Tower internals vendor was consulted but the company excluded such problem could be caused by the new tower internals (namely liquid distributor). Other potential causes were investigated as well:

- sulfuric acid quality (low concentration)
- wrong control system readings (pH probes, acid consumption measurements)

Various troubleshooting actions were performed by the client, including cross-check of lab analyses for various streams, pH probes replacement and acid material balances; however, no abnormality was identified. The client ultimately decided to call in an independent troubleshooter to identify the root cause and to develop possible solutions.

Problem analysis

Field survey and observation indicated liquid distributor as a probable cause with possible plugging, damage and/or tower upset that may have tilted the liquid distributor. As no improvement was expected unless the liquid distributor problem was resolved, a short shutdown was planned for column inspection and repair of the liquid distributor.

When the absorber column was opened we discovered:

- bottom section liquid distributor plugged and tilted (as expected)
- massive damage of bottom section structured packing (a surprise)

To make matters even worse, after removal of damaged packing, it was found that the column shell was deformed in the bottom section. When thermal insulation was removed it was clear that the damage was caused by internal fire in the bottom structured packing bed, a consequence of pyrophoric compounds self-ignition during the shutdown operations.

What started as a small shutdown became as major one with serious safety issues.

Finding the Root Cause

Investigation revealed the following disastrous chain of events:

- Plugged distributor, leading to lower bottom section efficiency.
- Operators' wrong interpretation of column performance and subsequently overdosing of sulfuric acid.
- Packing damaged by high acid concentration.
- By "design", distributor was not properly secured. As a cost saving protocol, the vendor by default omitted the packing hold-down grid in the design. The liquid distributor was simply supported by the structured packing underneath it. For this particular case, liquid distribution quality deteriorated once the distributor shifted/tilted due to dissolved packing underneath it. Out of level liquid distributor led to localized dry spots across the packed bed causing further deterioration in column performance.
- Pyrophoric compounds accumulated in dry packing bed.
- Fire during shutdown.

Cause(s) of Distributor Plugging

Absorber column has been revamped some years back with structured packing and new high quality channel trough type distributors. Original column design had random packing and ladder type distributors. Revamped absorber column worked well for several years.

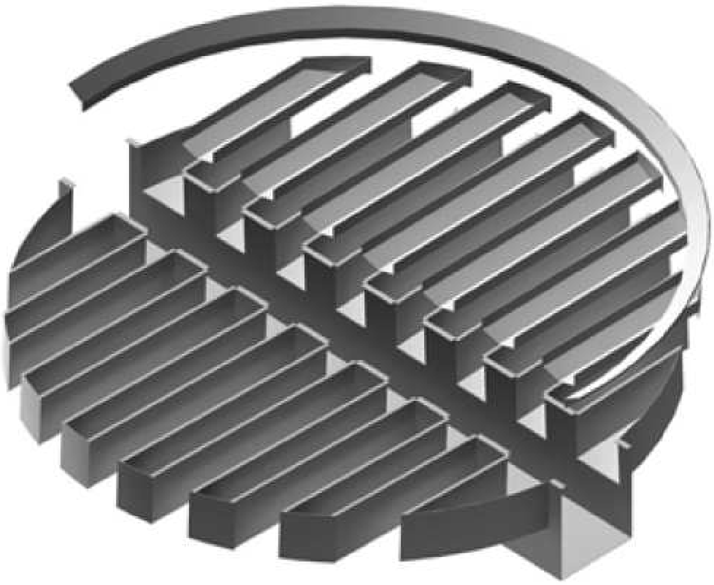

Figure 2: Typical channel through type distributor

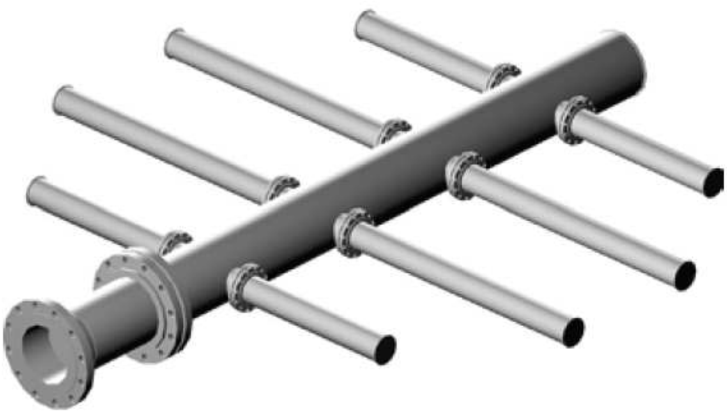

Figure 3: Typical ladder type distributor

Problem started shortly after the shutdown for cleaning. During the shutdown, pumparound coolers were cleaned; column packing and distributors were washed but piping was not washed nor flushed. It was postulated that liquid distributor was plugged by scale deposits released from piping and column shell walls after unit startup.

Rust and scale deposits formation is commonly seen and reported in column operations. This specific problem and design criteria were discussed with the tower internals vendor before the revamp took place. For unknown reasons, a distributor prone to plugging was selected but no preventive measures were applied (no filter requested). The design approach made plugging problem practically inevitable.

Previously, operators had never encountered distributor plugging because of different distributor type: ladder distributor did not suffer from plugging as its open construction allowed the packing underneath to be wetted or washed. The replacement with a "new and better" channel type distributor, though may be an optimum choice from process point of view but ignoring possible plugging, resulted in a serious problem.

Cause of Fire

The shutdown time schedule was very tight so the absorber column was blown with air before all the packing was properly cooled. Pyrophoric compounds formation was underestimated; this column has never experienced problems associated with pyrophoric material.

The overlooked moment was the wrong distributor selection that had led to fouled and dry packed bed. As long as the distributor was fine, packed bed below was always wetted and pyrophoric compounds did not form. The column could also be water washed and cooled properly before opening of tower manhole. Plugged liquid distributor allowed for pyrophoric compounds formation and prohibited proper water washing during shutdown.

Modifications

- Column shell was repaired in the vessel manufacturer's shop.
- New tower internals were provided on an emergency basis. Channel type distributor was replaced with a proven ladder type.
- Pressure transmitter was installed at distributor inlet piping as an indicator of distributor plugging.
- No filter was installed based on previous successful experience with ladder type distributor.

Results

Unit was successfully put into operation after a three weeks repair period. Absorber column is operating well since then.

Morals learned from the Case Study

1) Newer is not always better. High distribution quality does not always mean the best performance in real sense. When selecting packed tower internals, particularly liquid distributor, it is important to understand the application and the operational philosophy.
2) The case study demonstrated the importance of communication with clients, not only during design stage but also when clients consult for advice on shutdown procedures.
3) Special procedures and precautions shall be implemented for columns cleaning where pyrophoric components may form, especially if water washing efficiency is compromised by the damaged distributor.

Case Study #2: Atmospheric column vibrations

Atmospheric distillation of crude oil is a core process of any oil refineries. The technology is well known for many decades and equipment design had been standardized, apparently leaving no room for surprises.

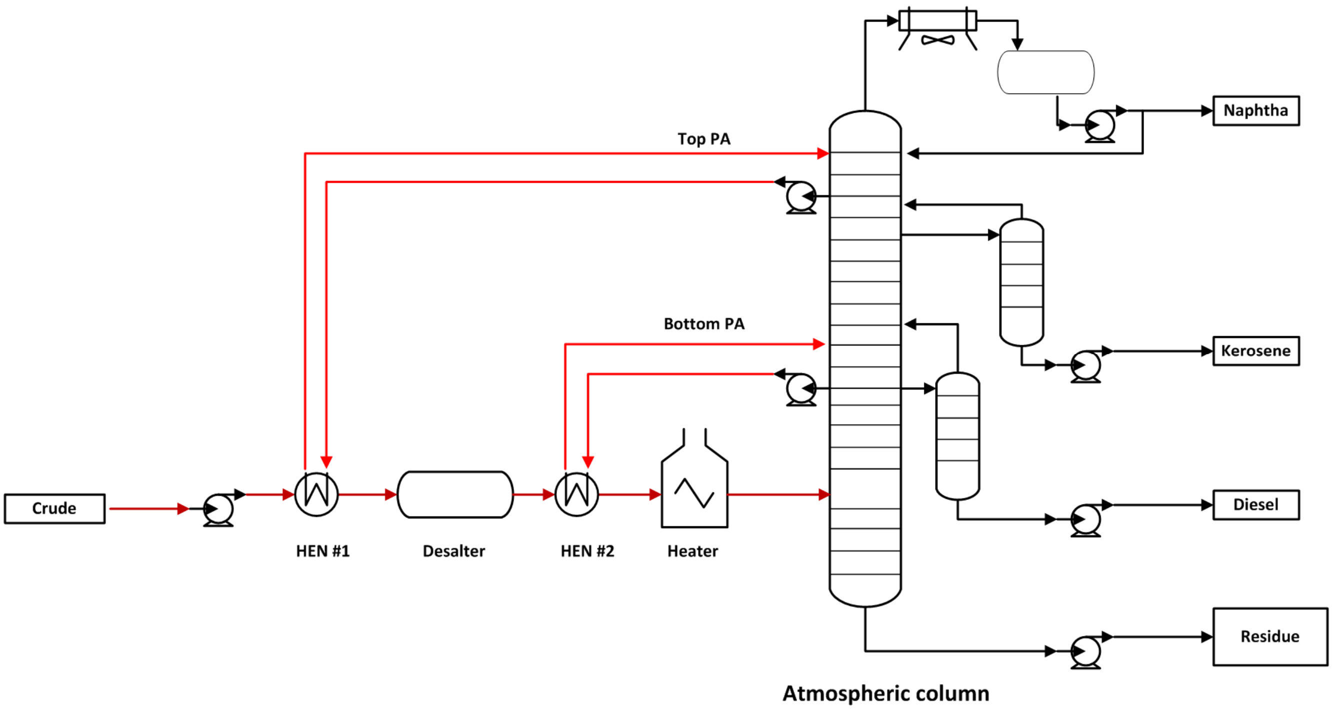

Figure 4: Crude oil distillation unit

Problem description

After the startup of a grass-root atmospheric distillation unit, a main fractionator column could not be operated at design conditions. When feed heater outlet temperature was gradually increased to design value, column vibration was observed because of frequent hydraulic shocks in pumparound section, and risk of flange gasket pop-out (what happened at the first startup). Hydraulic shocks could only be prevented at the expense of downgrading valuable diesel fraction to atmospheric resids (AR) by keeping heater outlet temperature lower than designed value.

Hydraulic shocks were most audible in column pumparound section thus a pumparound return distributor was suspected as a possible root cause. Tower internals supplier strictly rejected this hypothesis, and refused to visit the plant site claiming that “this behavior is not possible”. Based on vendor statement, other potential causes were investigated:

- pumparound pumps cavitation
- vibration of heat exchangers and air coolers in the pumparound loops
- vibration / cavitation of check-valve at pumparound return nozzle
- liquid flashing at pumparound return nozzle / distributor

All the above possibilities were thoroughly investigated but both observation and calculations ruled out these possibilities. An independent troubleshooting effort was in pursuit to help resolve the problems.

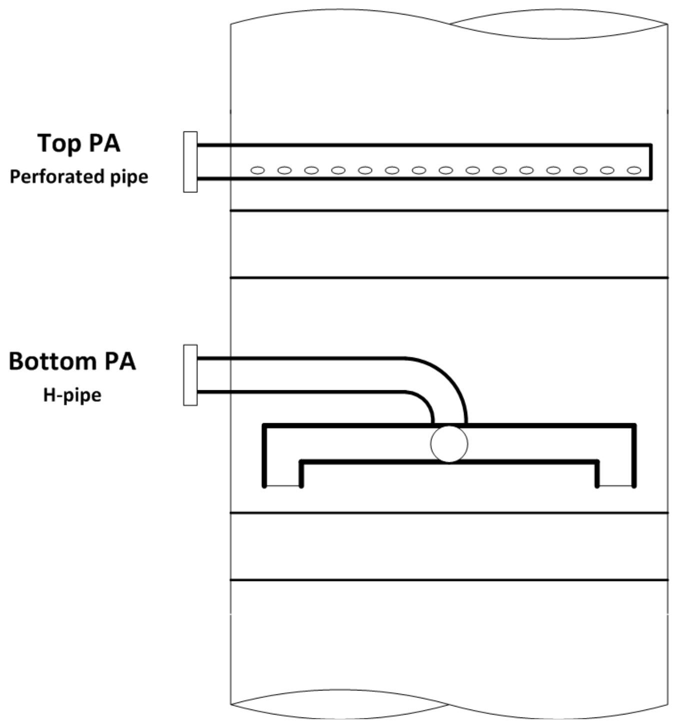

Figure 5: Pumparound inlet pipes before modification

Problem Analysis

Atmospheric column was started up in the following sequence:

- While crude oil is circulated through the unit, fired heater is lit on and atmospheric column feed is heated to its boiling point and above.
- Vapors from the column flash zone were condensed in the overhead system and all liquid is returned back as total top reflux.
- When collector trays are filled with liquid from the top reflux, top (TPA) and bottom (BPA) pumparound pumps are switched on. At the first moment liquid in the pumparound loops is subcooled.
- Column is slowly heated up and normal operating conditions are established.

The list below was gathered via interview sessions with plant operators:

- Operator did not observe column vibration when the column is operated only with top reflux.
- Hydraulic shocks started only when pumparound pumps are switched on (liquid is cold).
- Hydraulic shocks can be prevented only if P/A return temperature is kept high. *High P/A return temperature has limited pumparound cooling duty and consequently the feed heater outlet temperature. Maintaining a lower fired heater outlet temperature has resulted in loss of diesel to AR.*
- If P/A return temperature drops below a certain limit, hydraulic shocks started again.
- It was difficult to switch from top reflux to pumparound reflux.
- Attempts to keep P/A return temperature as high as possible has resulted in longer column startup and stabilization, up to12 hours.

Hydraulic shocks are usually induced by unsteady two phase flow, either by liquid flashing or vapor condensation. Based on field observations, high P/A return temperature prevented shocks while low temperature induces shocks thus liquid flashing at P/A return nozzle was excluded from the list. No matter how strange it sounded, the real cause of the problem is an instant vapor condensation on cold liquid surface inside of the P/A return distributor.

Based on field observations and troubleshooters' experiences, following sequence for hydraulic shocks was established:

Hydraulic shock (water hammer) mechanism:

- Hot vapor from column enters the distributor pipe and condenses on cold liquid surface.
- Instant vapor condensation created local vacuum (draft) inside the P/A return pipe, causing more vapor to be sucked into the pipe.
- High velocity vapor flow reversed the liquid flow direction, forming a slug inside of the pipe.
- The resultant slug flowed in the opposite direction against the main liquid stream. Hydraulic shock resulted when the slug struck the main liquid stream.
- Once the liquid exited the pipe the vicious cycle repeated itself.

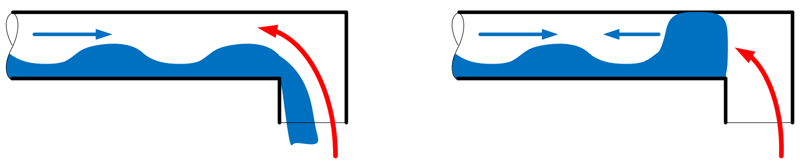

Figure 6: Vapor backflow causing water hammer

Modifications

Column internals modifications were performed during a short shutdown. Both top and bottom pumparound return distributors were equipped with hydraulic seals to prevent vapor backflow.

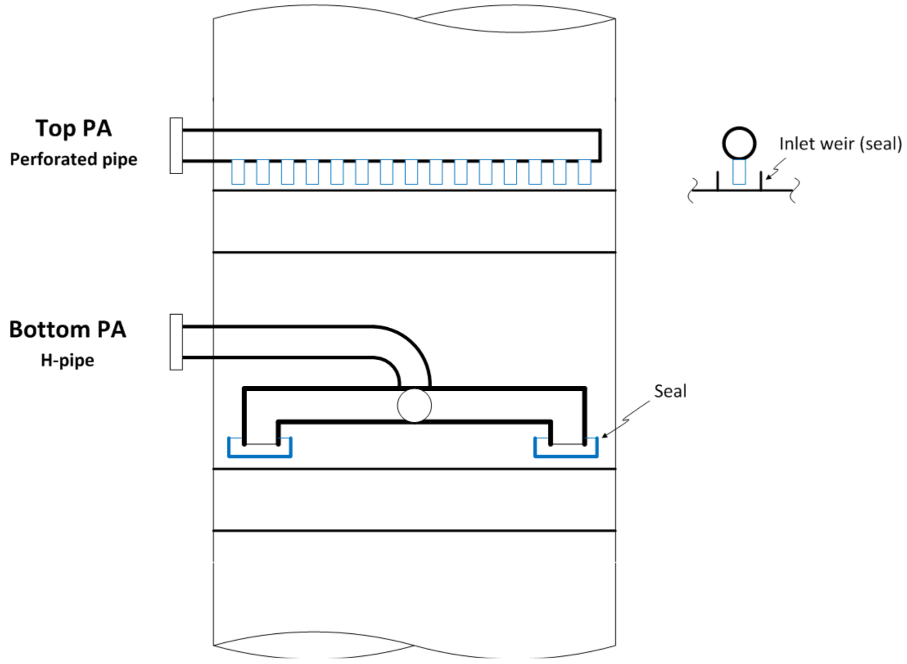

Figure 7: Pumparound inlet pipes after modification

Results

Crude oil distillation unit was successfully started after the modifications and reached design capacity and product quality without any sign of hydraulic shocks. Atmospheric column startup took only one hour, instead of 12 hours as previously experienced.

Morals Learned From the Case Study

1) Successful troubleshooting always starts from plant survey.
2) Overlooking the basics in column internal design often resulted in costly operational problems.