Distillation Absorption 2010
A. B. de Haan, H. Kooijman and A. Górak (Editors)

DESIGN-TROUBLESHOOTING OF AN ABSORPTION COLUMN – IMPORTANCE OF DETAILS

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Abstract
An absorption column was suffering from operational problems due to the interaction of gas and liquid in the column bottoms at the total draw-off (chimney) tray. In the bottom of the column one downcomer was discharging liquid directly into the bottoms compartment, which functions as the suction drum for a circulation pump. This caused cavitation of the pump. This problem was solved by installing a "roof" blocking the direct flow of liquid from the downcomer to the pump suction compartment breaking the momentum of the discharged liquid. The liquid and gas interact vigorously in the confined space between the risers of the chimney tray. This interaction causes leakage of the liquid through the risers. This problem was mitigated by reducing the liquid flow. Both problems show that details in the design of Shell calming section multi-downcomer trays are importantfor proper operation.

Keywords: Absorption Column, Chimney Tray, Leakage, Cavitation, Riser

1. Process Description

In the absorption column shown in Figure 1 a gas stream containing small amounts of sour gases is contacted with caustic to remove them. The contacting devices are Shell calming section multi-downcomer sieve trays. The gas is first contacted with the weak (lower) caustic cycle and then with the strong (upper) caustic cycle. The strong caustic make-up is dosed to the strong caustic cycle. Strong caustic overflows to the weak caustic cycle through an overflow pipe. On top of the strong caustic section is a wash water section to remove entrained caustic for the protection subsequent process equipment. The three sections are separated by total draw-off (chimney) trays. The bottom part of the column consists of two chambers. The small one is the suction vessel for the weak caustic circulation pump. The large one allows for the phase separation of caustic and condensed gasoline. The weak caustic is withdrawn from the bottom of the large chamber and the gasoline can occasionally be removed by a skim line.

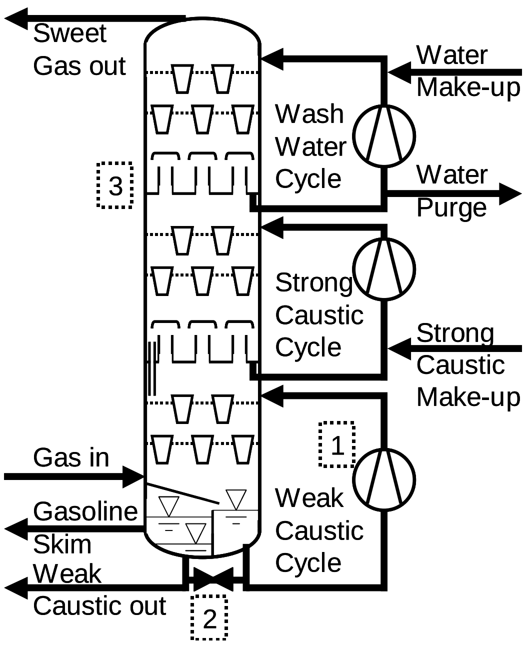

Figure 1. Sketch of the absorption column

2. History of this absorption column

The old column had to be replaced due to severe corrosion damage. The new column was supposed to be an improvement, because more advanced design features, summarized in Table 1, were used to give additional gas handling capacity with the same column diameter as the old column (see figures 2, 3, and 4).

Table 1. Comparison of the design features of old and new column

Old Column	New Column
Spare gas capacity 28%	Spare gas capacity 50%
Sieve trays with conventional downcomers	Sieve trays with calming sections (multiple downcomers)
Chimney trays with one riser	Chimney trays with six risers
Extended downcomers guide liquid to chimney trays and column bottoms	Multiple downcomers allow the liquid to splash everywhere

3. Problems with this absorption column

For the description of the problems we refer to the numbers in Figure 1. The caustic circulation pump (1) could not be supplied with liquid from the small side chamber as the pump failed to deliver head due to cavitation. Therefore, the pump had to be supplied via the valve (2) from the large settling chamber. This made the gasoline separation from the caustic solution in the large settling chamber by gravity impossible. The gasoline had to be removed by other, objectionable means from the process.
Contrary to the design intent the total draw-off tray separating wash water section and strong caustic section (3) was allowing water to pass into the caustic section below. The water diluted the caustic, which caused an increased consumption.
These problems did not occur with the old column.

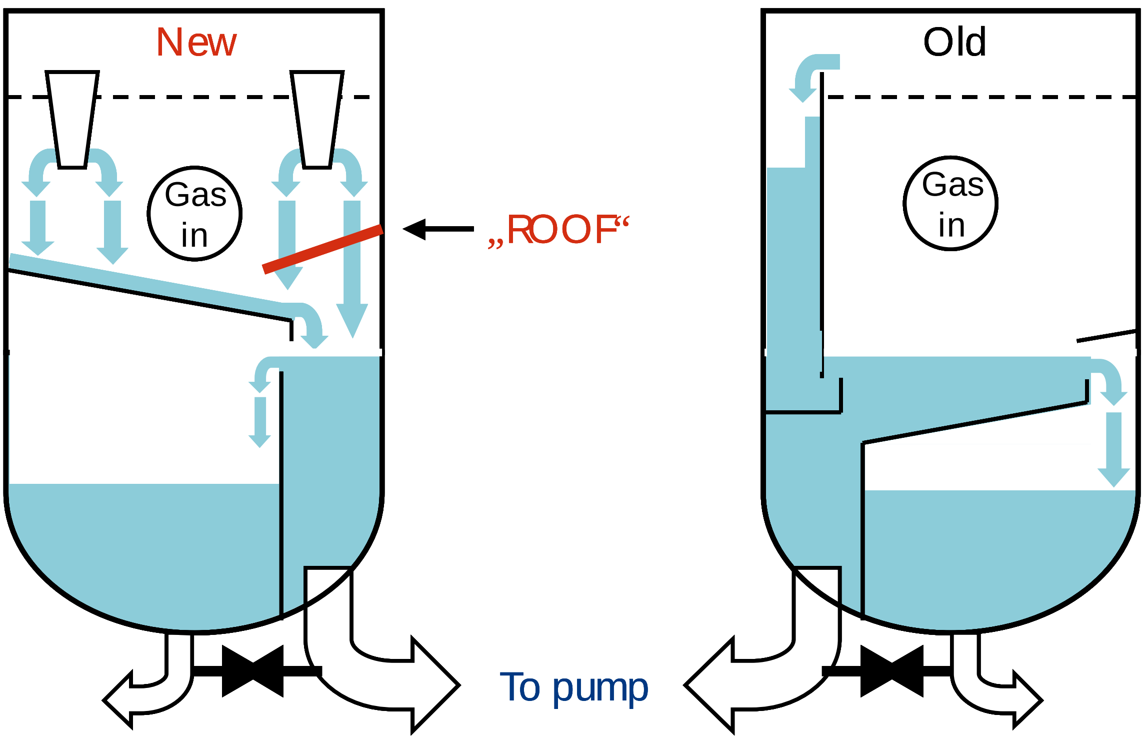

Figure 2. Liquid flow in bottom part of new and old column

3.1 Solution of problem: Cavitation of the weak caustic circulation pump
One downcomer was discharging its liquid directly from about 2 m height into the small chamber. This "waterfall" entrained so much gas, that the small bottom chamber failed to sufficiently separate gas and liquid. A "roof" above the small bottom chamber was installed. This broke the momentum of the "waterfall". After this modification the weak caustic circulation pump could be operated as per original design intent without cavitating. The liquid flow in the bottoms part of the old and new column and the location of the new "roof" are shown in Figure 2.

3.2 Detailed description of problem: Leaking chimney tray
During a plant shutdown the draw-off tray was visually inspected and a leak test of the draw-off tray confirmed its tightness. With no gas flow but with water circulation only, the total draw-off tray did not lose level (see also data in Table 2). With gas flow the total draw-off tray lost level. Water was diluting the caustic solution below the total draw-off tray. The leak rates of the draw-off tray during operation were determined by the following small experiment (refer to Figure 1):

1. Close the valve for the water purge
2. Close the valve for the water make-up
3. Wait an appropriate time (30 min to 6 h) and watch the water level on the draw-off tray drop
4. Calculate the reduction in water volume on the draw-off tray by multiplying the difference in level (level at start of experiment – level at end of experiment) with the free cross-sectional area
5. Divide the water volume from step 4 by the time difference (time at start of experiment – timel at end of experiment) to obtain the leak rate

The flow of gas and liquid through the chimney tray of new and old column is depicted in Figure 3. Figure 3 clearly shows how the liquid was flowing through the extended downcomers in the old column and did not intermingle with the upflowing gas. In the new column the liquid flows through the narrow space between two risers (chimneys). Gas and liquid intermingle. Figure 4 shows a top view of the Chimney tray and the downcomers above. The critical areas, where a downcomer discharges liquid right between the risers are marked in Figure 4.

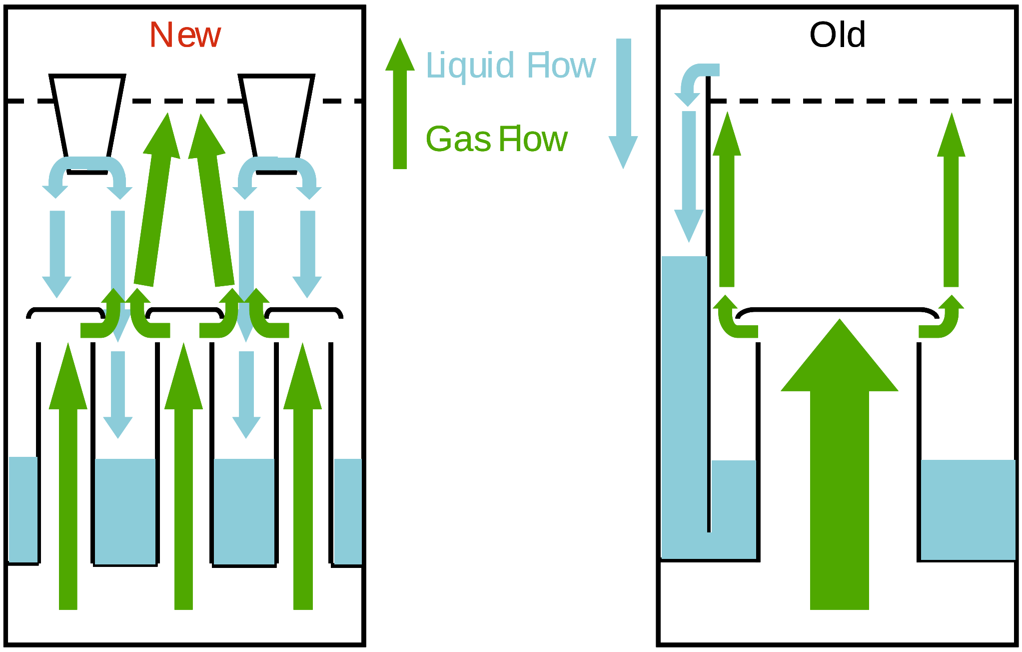

Figure 3. Liquid and gas flow on the chimney tray of new and old column

The typical gas and liquid rates at the riser exit and at the downcomer exit are shown in Figure 5. Leak rates, i. e. the flow of water leaking through the chimney tray divided by the wash water circulation flow (see Figure 1) are shown for different gas and liquid loadings in Table 2.

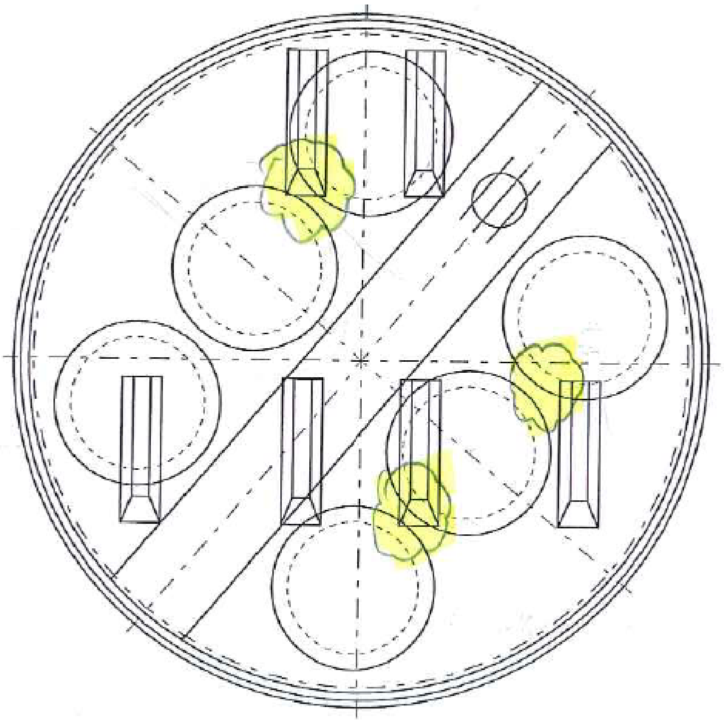

Figure 4. Top view of chimney tray, overlay with downcomers, critical areas are marked

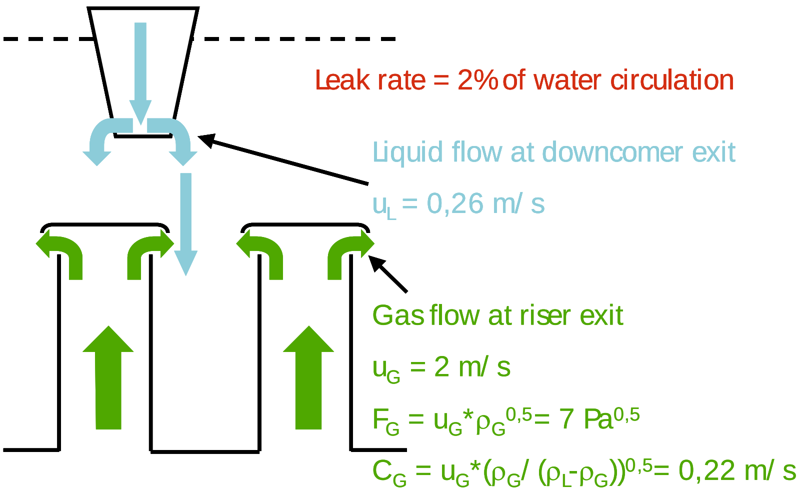

Figure 5. Sketch and data for gas and liquid flow on the chimney tray

Table 2. Leak rates as function of gas and liquid flow

u_G	F_G	C_G	u_L	Leakage
m/s	$Pa^{0,5}$	m/s	m/s	%
1,8	6,1	0,20	0,27	2,0
1,7	5,9	0,19	0,27	1,9
1,4	4,8	0,16	0,20	0,6
0,0	0,0	0,00	0,27	0,1

Table 3. Key dimensions

Key Dimension	Value	Unit
Inner diameter of the column	2564	mm
Number of Risers	6	-
Fractional area (all risers)/(total cross sectional area)	22.8	%
Riser height	1350	mm
Distance from riser top to tangent line of cap	125	mm
Distance between adjacent risers	670	mm
Diameter of riser	508	mm
Diameter of cap	620	mm
Distance between downcomer outlet and cap	220	mm
Number of Downcomers	6	-
Height of downcomer opening	15	mm
Width of downcomer opening	450	mm

Table 2 and Figure 5 are to be considered together. The results in Table 2 indicate that:

1. The leak rate increases if the gas flow increases.
2. The leak rate increases if the liquid flow increases.

The interpretation is that gas and liquid interact in the narrow space between two risers and that this interaction leads to the leakage of liquid through the chimneys. An increase in the flow of either phase (gas or liquid) increases the leak rate.

3.3 Solution of problem: Leaking chimney tray

The problem can be mitigated operationally by minimizing the liquid flow or gas flow. The gas flow is related to the plant throughput. That means, a reduction of the gas flow would curtail the plants capacity. However, the liquid flow is only limited by the possibility of unsealing the downcomers. Therefore, the liquid flow can be reduced. As shown in Table 2 this has a significant effect on the leak rate. This solution was implemented. Ultimately, this problem should be solved by improving the design of this chimney tray. The new design should eliminate the detrimental interaction of gas and liquid to an extent sufficient to reduce the leak rate through the risers to almost nil. Three possible design changes are outlined in the following.

1. Install riser caps, that overlap the riser. This means forcing the gas to flow down first through the annulus between riser and overlapping riser cap. This also means that the liquid will have to flow upward to leak through the riser. See Figure 6 for a graphical representation of this solution.
2. Install a collector trough on top of the risers, to collect the liquid from the downcomers and conduct it away from the confined space between the risers. This solution uses a similar rationale as the solution for the problem with the cavitating pump as described in section 3.1. See Figure 7 for a graphical sketch of this solution.
3. Remove the tray with the multiple downcomers above the chimneys and replace it with a tray with an extended conventional downcomer. This would in fact mean to go back to the design of the old column as shown in Figure 3. This would also reduce the gas handling capacity of the column (see Table 1).

None of these three alternatives was implemented yet. A comparison of these three possible alternatives is shown in Table 4. The collector trough seems to be the most favorable solution.

4. Conclusions

Column internals other than separation trays occasionally do not get the due attention of the process and equipment designer. Poorly designed bottom compartments and total draw-off trays can be very detrimental to safe and economical column operation. Design details of Shell calming section multi-downcomer trays are as important as for normal trays to ensure proper operation.

There are in principle two regions in a column: The mass transfer region, where intimate contact of the phases is necessary, and the phase separation region, where the two phases are supposed to disengage and to go separate ways. Tray designers must avoid intermingling of the phases in the phase separation regions where possible.

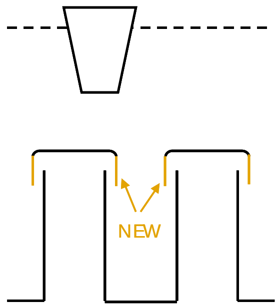

Figure 6. Sketch and data for gas and liquid flow on the chimney tray

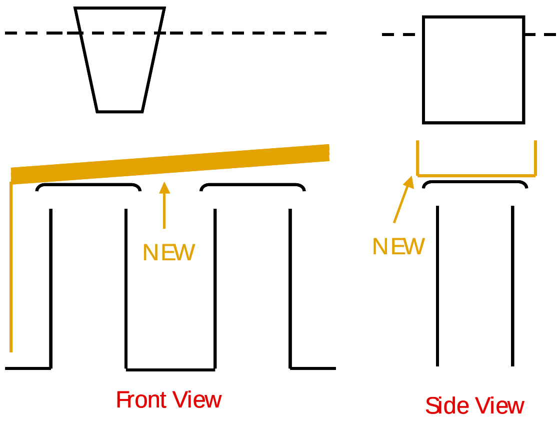

Figure 7. Sketch and data for gas and liquid flow on the chimney tray

Table 4. Comparison of the three design solutions

Solution	Advantages	Disadvantages
1. Overlapping riser caps	Easy installation with minimum amount of additional material	Not enough space between the risers - gas will be accelerated in the annulus between riser and overlapping riser cap, causing pressure drop, and impingement of the accelerated gas onto the liquid surface, potentially causing cavitation of the ciculating pump.
2. Collector trough	Proven technology Relatively easy installation	Makes the distribution of the liquid uneven across the area.
3. Extended conventional downcomer	Proven technology	Most difficult installation of all three options. Hot work at the column wall necessary (supports for the extended downcomer). Reduces vapor handling capacity of the column by reverting back to conventional tray and downcomer design.