

## The Distillation Group Newsletter

### Welcome

Welcome to The Distillation Group newsletter. Feel free to send copies to your colleagues and friends (copyright information is on the last page). This issue includes two case histories of operating problems caused by incorrect level measurement, updated technical information available, DGI services, and high-capacity trays and hanging downcomers.

---



Linked distillation towers in a complex plant configuration

---

### Contents

1	Welcome	5	DGI Services
2	Liquid levels and density	6	Web page update
4	Calendar	6	Question: High-capacity trays and hanging downcomers
4	Call-for-papers		Copyright
5	Publications	10	

---

Liquid Levels and Density

Case histories with DP cell problems

Differential pressure (DP) cells are the most often used level measuring device in the process industries. Differential pressure cells measure the pressure difference between two points and send a differential pressure reading to the plant control system. Typically, DP cells are rated in inches of water equivalent. Standard ranges include 0 to 20, 0 to 50, 0 to 100, 0 to 200, and 0 to 500 inches of water differential pressure.

The control system converts the DP cell reading into a liquid level based on an assumed specific gravity inside the vessel. Levels based on DP cells can err for different reasons. Previous columns have covered many reasons DP cells or sight glasses can give false readings. This column covers some case histories of specific DP cell problems.

Cryogenic unit with two operating modes

The first case involves a cryogenic field extraction unit that had two possible operating modes. The first mode was an ethane rejection mode where ethane was sent overhead. The second mode was an ethane recovery mode where the main tower switched to a demethanizer operation. The overhead product was methane and lighter and the bottoms product was ethane and heavier. The recovered liquid (tower bottoms) was sent to a separate plant that segregated the liquid stream into consumer LPG and petrochemical feeds.

The plant started up in the ethane rejection mode successfully and operated there two years. After downstream facility modifications were made, the plant shifted into the ethane recovery mode. Tower problems occurred immediately. Major problems were intermittent flooding of the tower and inability to effectively control coldbox heat integration.

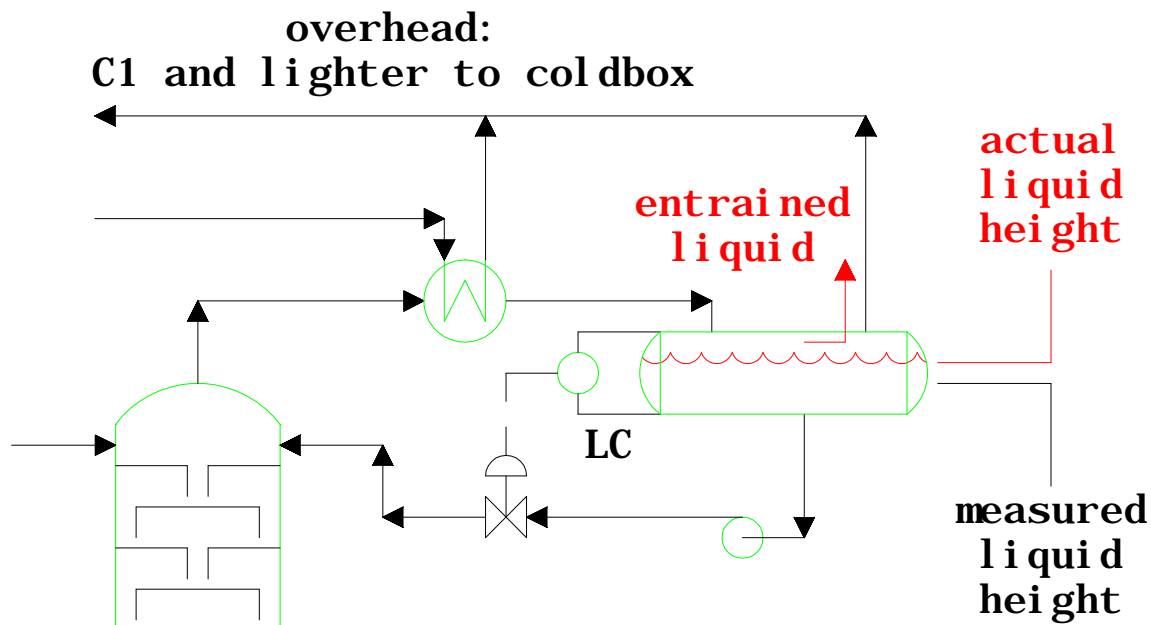


Figure 1  
Effect of improper liquid levels in overhead drum

Field troubleshooting identified the culprit as changed densities in the tower. The ethane recovery mode had lower liquid densities. The lower liquid densities inside the tower caused 'measured' liquid levels to be lower than the actual liquid levels. Normal tower boot liquid level variations caused liquid back-up into the reboiler return line. Normal overhead drum liquid level variations (Figure 1) created liquid entrainment into the overhead vapor going to the heat integration in the coldbox. The problem was especially acute in the overhead drum.

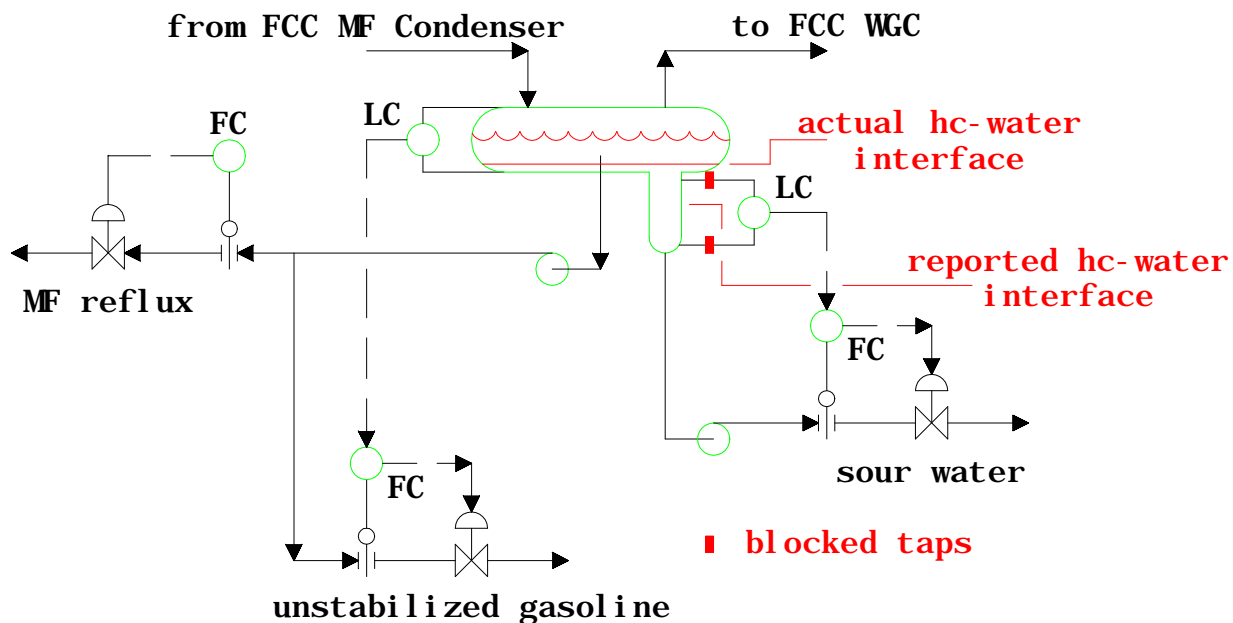
Calibrating the liquid level measurement for the new densities immediately corrected the operating problems.

### Water hold-up causing level problems in overhead reflux drums

Many drums in hydrocarbon systems have water boots and separate water levels controllers. Typical services that have these on overhead drums include atmospheric columns, coker main fractionators, visbreaker atmospheric columns, and fluid catalytic cracker (FCC) main fractionators, among others.

On one FCC main fractionator, a fouled water level measurement resulted in pump cavitation, seal problems, and increased maintenance costs.

Immediately after a turnaround, the FCC started up without problems. However, after several weeks of operation pump seal problems on the reflux pump became common. Field troubleshooting quickly identified that the pump was cavitating. The initial conclusion was that the net positive suction head (NPSH) available was insufficient. This was puzzling because the pump had always worked before. An alternate idea proposed at this point was that the pump was damaged, creating a need for a higher NPSH. One pump of the two parallel pumps in the service was pulled and inspected. No apparent reason for NPSH problems was found with the pump. Design of the piping from the drum was checked. Again, no source of NPSH problems was found.



**Figure 2**  
Blocked water level taps

Over time, the new operation was accepted as normal. However, the situation continued to nag on some of the operators involved. While on site for operator training, the author was asked about this problem and a new troubleshooting effort started. Field data was gathered and compared to operating

data. One suspicious observation was immediately obvious. The water level measured in the drum never seemed to vary. The connections to the water level instrument were blown out and the instrument placed back in service. The measured water level immediately jumped from 54% of range to 100%. The water level was above the upper water level tap. A plug in the line to the water level instrument had blocked the instrument at 54% of range.

Actual water level varied down to nearly zero to up to the internal draw-off pipe to the unstabilized naphtha pump. Two problems were damaging the pump. First, water density is much higher than the naphtha density. The reported naphtha level in the drum was much higher than the actual naphtha level. Calculations showed that under some conditions the flow to the pump could be cut off entirely. At other times water ended up in the pump suction. Sudden water slugs to the pump dramatically increased power load and caused pump damage.

Review of operating records showed that at the same time pump seal failures increased, gas plant operation became less stable. The water in the unstabilized naphtha increased water entrapment in the gas plant absorber-stripper and increased propylene losses. The problems, seemingly unconnected, had the same cause, a single level instrument giving incorrect readings. Supporting evidence came from trends in main fractionator pressure drops. The main fractionator pressure drop had been gradually rising. Water in the main fractionator reflux vaporizes inside the fractionator and deposits solid salts. The salts plug trays and packing, increasing pressure drop.

Unit operation substantially improved with the level instrument back in service correctly.

### Further Reading

The [full text](#) of this article, including all eleven figures, can be found on the DGI website, and is scheduled for *Hydrocarbon Online Tech Tips* in March 2001, or can be obtained by sending a message to our paper server. Send an e-mail to [techrequest@distillationgroup.com](mailto:techrequest@distillationgroup.com) with the number 095 in the subject line to receive a PDF copy of the article.

---

### Calendar

2001-April-1 to 3, NPRA Petrochemical Conference, San Antonio	<a href="http://www.npradc.org">www.npradc.org</a>
2001-April-1 to 6, ACS National Meeting	<a href="http://www.acs.org">www.acs.org</a>
2001-April-22 to 26, AIChE Spring National Meeting, Houston Annual Meeting	<a href="http://www.aiche.org">www.aiche.org</a>
2001-August-26 to 30, ACS National Meeting	<a href="http://www.acs.org">www.acs.org</a>
2001-September-10 to 13, ISA Conference	<a href="http://www.isa.org">www.isa.org</a>

---

### Call-for-Papers

#### 51<sup>st</sup> Canadian Chemical Engineering Conference

Halifax, Nova Scotia

14-17 October 2001

[www.chemeng.ca/halifax2001/welcome\\_e.html](http://www.chemeng.ca/halifax2001/welcome_e.html)

Most of the professional associations are more known for academic participation at their meetings rather than having a high percentage of industry participation. The result is that presentations made at these meetings suffer from rather much theory and not too much practical application value. In a laudable effort to make their meeting emphasis more practical, the Canadian Society for Chemical Engineering is seeking submissions for industry participants to present papers on practical problems and issues. One industry they are actively seeking participation from is the hydrocarbon processing industry. Contact Bill Svrcek at 403-282-3945 (Calgary) or [svrcek@ucalgary.ca](mailto:svrcek@ucalgary.ca) if you are interested in participating.

## Publications

The following articles are the latest publications from DGI:

- 095 Liquid Levels and Density, *Hydrocarbon Online*, scheduled for March 2001.
- 094 Cat Naphtha Sulfur Management: Undercut or Not? *Hydrocarbon Processing*, February 2001: 75-77.
- 093 Retrofitting: How to Have Successful Revamps Instead of Failed Projects, *Hydrocarbon Online*, 19 February, 2001
- 092 Proper Field Technique with Sight Glasses and the Importance of Field Observation, *Hydrocarbon Online*, 7 February, 2001
- 091 Effectively Control Column Pressure, *Chemical Engineering Progress*, January, 2001: 38-48.

Look for the coming articles on:

Manage Fast-Track Retrofits With These Guidelines, *Chemical Engineering*, March 2001.  
Troubleshooting Practice in the Refinery, AIChE Spring Meeting, April 2001.  
Troubleshooting Refinery Vacuum Towers, AIChE Spring Meeting, April 2001.  
Designing and Revamping Crude Processing Sequences, AIChE Spring Meeting, April 2001.  
Conventional Simulators for Advanced Distillation Processes, AIChE Spring Meeting, April 2001.  
Tray Zone Flooding for Valve and Sieve Trays, AIChE Spring Meeting, April 2001.

---

## DGI Services

DGI offers a variety of troubleshooting, revamp, and training services for petroleum refining and petrochemical clients. Our emphasis is on separations equipment and their auxiliaries. This includes distillation, absorption, stripping, extraction towers, control systems, and attached hydraulic loops, exchangers and other equipment.

### ***Troubleshooting***

DGI performs field troubleshooting to identify and solve unit problems. Practical, proven field technique combined with extensive experience quickly identify your problem and find cost-effective solutions.

### ***Revamps***

Effective revamps require teamwork between many different people and organizations. Process and equipment specialists, such as DGI, create the most profitable custom revamps for your plant. DGI's expertise lies in recovery processes. Based on a proven sequence of (1) plant review to identify opportunities, (2) plant performance testing, (3) conceptual process analysis, and (4) revamp specific engineering, DGI delivers revamp designs that maximize profits and minimize investment.

### ***Training***

Engineer and operator training programs customized to meet your site and company needs. Offerings include Advanced Distillation Technology, Distillation Operations, and Crude Unit Operations. Material is organized into groups of modules allowing for customization to fit your needs. Practical points are emphasized with case studies of real unit problems and profits made from improved equipment and operation.

---

## Web Page Updates

The main DGI web page at [www.distillationgroup.com](http://www.distillationgroup.com) has been updated with several new sections. These include a search function and a Q&A section. The features are fully functional. Of course, you can skip directly to these features with the following links:

Search [www.distillationgroup.com/search.htm](http://www.distillationgroup.com/search.htm)

Q&A [www.distillationgroup.com/questions.htm](http://www.distillationgroup.com/questions.htm)

The new Q&A section, titled Questions on Technology, already has eight detailed questions and answers posted. A new question is added approximately every two weeks. All questions have been submitted by different plant operators and designers. Don't hesitate to send in your questions.

---

## Questions and Answers

### *High-capacity trays: what is a hanging downcomer tray?*

*Subject: High-capacity Trays*

*Date: Mon, 5 Mar 2001 16:31:01 +1100*

Andrew,

What is a hanging downcomer tray (can you provide a picture)? How does it increase capacity?

L., Asian Refiner

*Subject: High-capacity Trays*

*Date: Thur, 8 Mar 2001 10:32:00 -0600*

### **Overview**

High-capacity trays can greatly increase distillation tower capacity. However, they should be used with caution. Many plants have had successes, others have had repeated failures. Often, the difference between success and failure is understanding the performance limits and compromises in advance. Effective application of high-capacity trays requires more precise knowledge of operating conditions and flexibility requirements: greater attention to design detail: and careful installation.

### **Normal versus High-Capacity Trays**

A normal tray consists of an active area where mass-transfer takes place, a downcomer to move the liquid from tray-to-tray, and an open area where vapor-liquid disengagement takes place and the vapor moves from tray-to-tray. The tray's ability to mix, then separate vapor and liquid limits the tray capacity. A standard tray has an area under the entering downcomer and over the exiting downcomer where liquid and vapor cannot mix on the tray deck. This 'inactive' area is what high-capacity trays attempt to use.

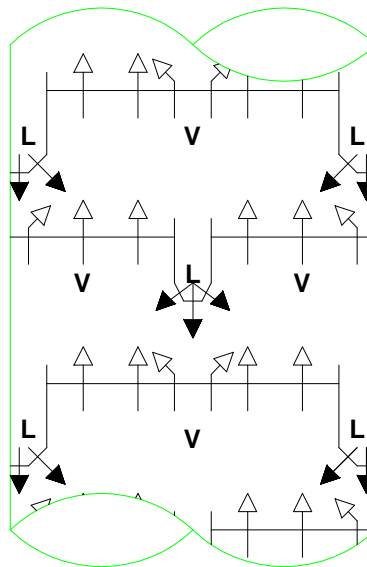
The major type of high-capacity tray that has found wide acceptance are those that convert the area under the downcomer to active area. Figure 1 shows an illustration of a tray with the area under the downcomer converted to active area [1]. Figure 1 is a side view including the flow of vapor and liquid.

The UOP Multiple Downcomer (MD) tray was the first commercially successful tray with active area under the downcomers [2]. The MD-type tray still makes up the majority of high-capacity tray installations. Recently, several variations of trays with increased active [3,4,5,6] area have been aggressively marketed. Increased numbers of tray failures have come along with the aggressive marketing of high-capacity trays [7].

## How High-Capacity Trays Work

First, the area under the downcomer must be made into active area, either with perforated holes or directional valves. Second, something must make sure that the downcomer still works. To work, the downcomer needs to be able to pass liquid from a higher tray to a lower tray.

If vapor rises through the downcomer, liquid is prevented from flowing down. The result is a flooded downcomer, flooding the tower in turn. The solutions to keep vapor out of the downcomer are distance, head, direction and momentum. Distance refers to the distances between the tray active area and the downcomer. Head is the height of liquid in the downcomer and the pressure exerted by the liquid. Direction is the direction of movement of the liquid and the vapor. Momentum is the speed of the moving liquid and vapor. A combination of some, or all, of these is used in high-capacity trays to prevent the downcomer from flooding.



**Figure 1**

Side view of hanging downcomer tray

The distance required between the bottom edge of the downcomer and the tray deck varies for each variant of the high-capacity tray. However, for any given design, a range of useable distances is possible. If the downcomer is too close to the tray deck, the froth from the rising vapor cannot escape sideways. The downcomer outlet area is choked and the tray will flood. If the distance is too great, two things can happen. First, the falling liquid from the downcomer can have enough momentum to go right through the holes in the tray below. Second, the downcomer may be so short that it lacks volume to disengage the froth into vapor and liquid. The downcomer backs up and the tray floods at relatively low liquid rates.

Liquid height, or head, exerts a pressure equal to its height times its density. Vapor is prevented from rising up the downcomer by the liquid head. The liquid head in the downcomer is also set by the pressure drop of the liquid leaving the downcomer. The higher the pressure drop, the higher the liquid level in the downcomer.

In a high-capacity tray, the clearance needed to allow vapor to escape from under the downcomer creates a large downcomer opening. The large downcomer opening does not impose sufficient back pressure to hold a liquid level in the downcomer. A restriction in the downcomer creates sufficient pressure drop on the liquid that a head builds up and vapor cannot bypass.

Direction and momentum can also help to prevent vapor bypassing up the downcomer. In some designs [5,6,8] the vapor rising through the active area under the downcomer is sent through slots angled across the tray instead of through conventional slots.

**Dynamic Seals and What They Mean**

Every variation of high-capacity tray has its own combination of features that are supposed to make the tray work correctly. Nevertheless, one thing that all the commercial high-capacity trays (that convert the downcomer inlet area into active area) have in common is a dynamic seal on the downcomer. This is important. It restricts the flexibility of the tray and makes installation tolerances critical.

What is a dynamic seal? Figure 2 compares a conventional tray with a positive seal, a conventional tray with a dynamic seal, and high-capacity trays with dynamic seals. Figure 2A shows a conventional tray with a positive seal. The bottom edge of the downcomer is below the top edge of the outlet weir. The outlet weir holds a liquid level on the tray and seals the downcomer. At higher liquid rates, the conventional tray may even have its outlet weir chopped off (Figure 2B). This reduces the tray pressure drop (and can increase the tower capacity). However, now the only thing sealing the downcomer is the height of liquid back up in the downcomer. If liquid rates are high, this will work. All high-capacity trays use dynamic seals. Figure 2C shows a high-capacity trays with a dynamic seal.

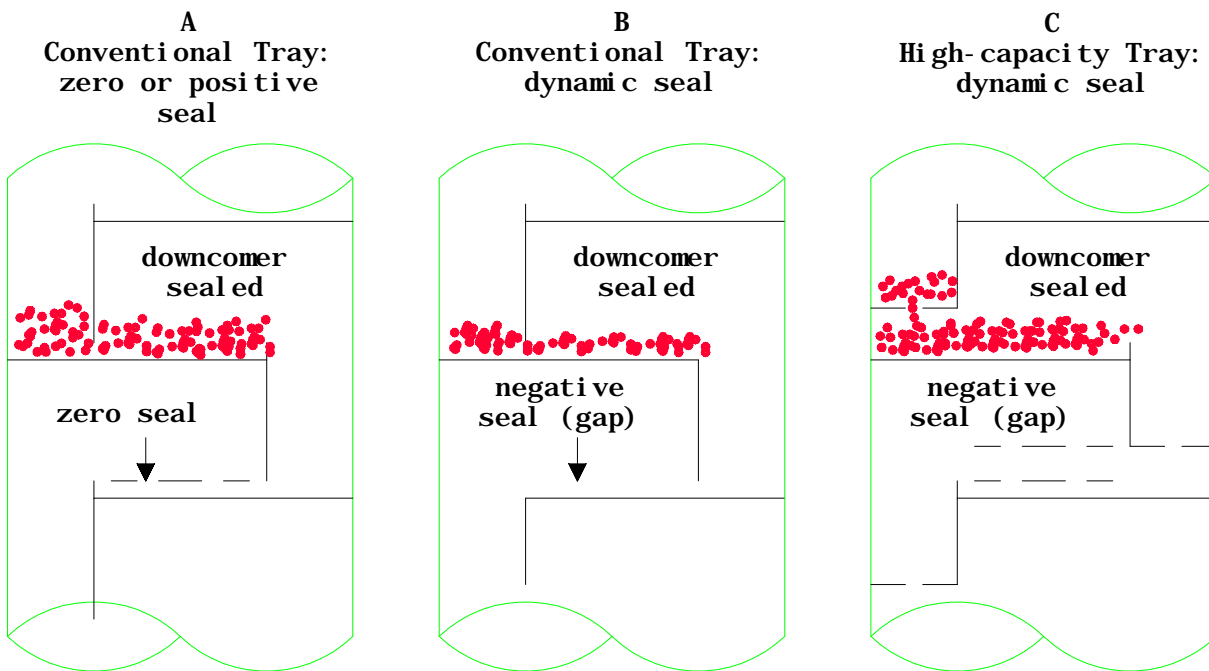


Figure 2  
**Static and dynamic seals**

Why are dynamic seals important? The only thing preventing vapor bypassing up the downcomer and flooding the tower is the height of liquid in the downcomer. A minimum amount of liquid must be kept in the downcomer to prevent vapor from bypassing through the downcomer. This sets the minimum liquid handling rate of any given tray. Filling the downcomer up with froth and backing liquid onto the tray above sets the maximum liquid rate of the tray. The tray can only operate between these two limits. A conventional tray's downcomer (with a positive seal) does not have the same lower operating liquid rate that a high-capacity tray needs. High-capacity trays have less operating flexibility than conventional trays. This issue of minimum liquid to seal the downcomer is always a challenge because it conflicts with the priority objective of maximizing downcomer capacity. Vendors tend to err on the side of high capacity. Turndown is almost always less than predicted.

While the dynamic seal places a limit on tray flexibility from one direction, two other factors restrict the liquid flexibility of high-capacity trays from the other direction. First, the effective height of the downcomer on a high-capacity tray is less than that of a standard tray on the same tray spacing. Second, tray spacing is often changed when using high-capacity trays to increase the number of

distillation stages in the same shell. Nearly all high-capacity trays have shorter effective downcomer heights than conventional trays. Downcomer height gives flexibility to handle liquid rate changes. The shorter downcomer height gives less flexibility.

What happens when the dynamic seal unseals? Two major things can happen. The first is if the downcomer completely unseals. Vapor heads up the downcomer, bypassing the liquid. If the high-capacity tray has a perforated (sieve) active area, liquid now falls through the tray deck. No vapor-liquid mixing occurs. Little fractionation takes place.

Second, if the downcomer partly unseals and the liquid and vapor rates are correct, the entire active area plus the downcomer area can effectively turn into a dual-flow tray. In a dual-flow tray, the vapor rises and the liquid falls through the same hole. A high-capacity tray that unseals and acts like a dual-flow tray will have less capacity than the correctly functioning high-capacity tray. Whether or not dual-tray mode failure occurs depends on the liquid and vapor loads, fluid properties, and tray type and design. Failure modes can switch back and forth between bypassing and dual-flow operation with very small changes in tower loads. This makes troubleshooting high-capacity trays very difficult.

In addition to the downcomer limitations, high-capacity trays often have very high hole areas on the tray deck. High hole areas pass more vapor. They also restrict vapor handling flexibility. Combining downcomer limits with vapor handling limits, high-capacity trays can have very limited flexibility. As a rule, the higher the capacity through a given tower diameter, the less flexibility is available. In fact, extreme designs approach point operation devices. Point operation devices are trays that will only operate at one specific loading point. They have no turndown capability.

### **How Much Can High-Capacity Trays Help You?**

Over-zealous capacity claims have been made for many types of high-capacity trays. This has led to several failures of towers to meet expected capabilities. If too much vapor goes up through inlet area devices under the downcomer, tray efficiency may suffer significantly. For a 'conventional' hanging downcomer high-capacity tray, don't expect capacity increase in a revamp to exceed the percent gain in active area. This assumes a one-to-one changeout, with no efficiency effects, change in tray spacing, or change in number of flow passes.

### **Further Material**

Further reading can be obtained by sending a message to our paper server. Send an e-mail to [techrequest@distillationgroup.com](mailto:techrequest@distillationgroup.com) with the three digit number of the reference wanted in the subject line to receive a PDF copy of the article (remember to include the zero at the front of the number, if noted).

- 077 Should You Switch to High Capacity Trays?; A. Sloley; *Chemical Engineering Progress*, January, 1999: 23-35.
- 076 High-Capacity Distillation; A. Sloley; *Hydrocarbon Processing*, August, 1998: 53-60.
- 073 High Capacity Trays for Realistic Revamps; A. Sloley; Chemical Engineering Exposition and Conference, Houston, 3-4 June, 1998.
- 070 High Capacity Trays - Basic Choices; A. Sloley; Distillation Technology Conference, Orlando, April 2-4, 1998.
- 065 Customized Tower Revamps - Success and Failure; A. Sloley; *Fuel Technology and Management*, January 1998: 48-50.
- 040 Why Towers Do Not Work: Part II; A. Sloley, S. Golden, and E. Hartman; *National Engineer*, Vol. 99, No 9, September 1995: 16-22.
- 038 Why Towers Do Not Work: Part I; A. Sloley, S. Golden, and E. Hartman; *National Engineer*, Vol. 99, No 8, August 1995: 19-34.

### **References**

1. Chuang, K. T.; Everatt, A. E. Gas liquid contacting apparatus. U.S. Patent 4,504,426, 12 March 1985.
2. Bruckert, W. Vapor liquid contacting system and method. U.S. Patent 3,410,540, 12 November 1968.
3. Nye, J. O.; Gangriwala, H. A. Nye trays. Presented at the AIChE Spring National Meeting, 30 March 1992.

4. Sauter, J. R.; Hauser, R. P.; Harris, J. Fractionation trays. U.S. Patent 5,618,473, 8 April 1997.
5. Yeoman, N.; Griffith, V. E.; Hsieh, C.-L. Vapor liquid contact tray and downcomer assembly and method of employing same. U.S. Patent 5,480,595, 2 January 1996.
6. Binkley, M. J.; Thorngren, J. T.; Bonilla, J. A.; Gage, G. W. Downcomer-tray assembly and method. U.S. Patent 4,956,127, 11 September 1990.
7. Sloley, A. W.; Golden, S. W.; Martin, G. R. Why towers do not work. AIChE Spring National Meeting, 19-23 March 1995, Houston.
8. Binkley, M. J. Method of and apparatus for flow promotion. U.S. Patent 5,192,466, 9 March 1993.

Andrew Sloley  
DGI

Go to [www.distillationgroup.com/questions/question008.htm](http://www.distillationgroup.com/questions/question008.htm) to see the full response to the question, including all 11 figures.

---

## Copyright

All material herein is copyright Andrew Sloley, 2000, all rights reserved. This newsletter may be redistributed subject to the following conditions: 1) the newsletter is redistributed in its entirety without modification or editing of any kind, including modification or deletion of this copyright notice: 2) redistribution is free and without charge: 3) redistribution is not part of a collection of material or other work. All other use and redistribution is prohibited without the express written consent of the copyright holder in advance of such redistribution. Posting of the material for access on data retrieval systems is prohibited, except with the express written consent of the copyright holder, whether such systems are available to the general public or not.