The Distillation Group, Inc. Technology in Distillation

Issue 01 2000-12-01

The Distillation Group Newsletter

Gas plant towers with fired reboilers

Welcome

For some time, a newsletter from The Distillation Group, Inc. (DGI) has been promised to the many people that have requested it. Finally, here is the first issue. Following issues will arrive on approximately a quarterly basis.

The major part of the content will come includes technical material in two sections: first, a technical editorial: second, a question and answer forum. Sandwiched between these a short calendar will contain reminders of some industry events. Advertising fluff will be kept to a minimum, usually just a few lines.

The technical editorial material collected for the newsletter started life in a variety of ways: extracts from longer articles: material on papers started but never completely finished: and brief ideas meriting a short discussion are just a few. Nevertheless, in all cases, the technical editorial is complete and can be taken as a stand-alone work.

The question and answer forum format will vary depending on the material. Every week a good question that applies to many units comes in, usually by electronic mail. Rather than just giving a brief answer that does not get to many people, a more complete answer distributed to interested readers is more rewarding for everyone. Don't hesitate to send in your questions as well.

The newsletter format has been kept simple to make it as clean and as easy to read as possible. Electronic distribution can create all sorts of formatting problems. If what you see looks a little odd, don't hesitate to fax a printed copy for format corrections in the next issue.

Hopefully, you will find the contents interesting and useful. Feel free to send copies to your colleagues and friends (copyright information is on the last page).

Contents

PO Box 10105, College Station, TX 77842-0105 USA
info@distillationgroup.com
Phone 979-764-3975
Fax 979-764-1449

Foam and how we get wrong liquid levels

Troubleshooting and control have the same needs, objectives: understanding the process and making it work better.

Automatic control systems have advanced far from their initial applications in the process industries. The conversion from local single-input single-output loops through initial application of advanced methods to current multivariable, adaptive, and neural network applications has increased plant profits. Petroleum refineries, petrochemical plants, gas processors, and other industries all benefited from control system improvements.

However, even our best control systems depend upon the information that comes to them. Control systems are decision systems. Control systems 'decide' to change some process conditions to maintain others at desired targets. Like every decision system, poor information leads to poor decisions. Poor decisions equal poor control. Poor control costs money.

Inaccurate information that fools our control system often fools us as well. When troubleshooting, we often use the same data the control system uses. Our judgment allows us to interpret the data differently, or even ignore it. Interpretation and judgment choices depend upon our knowledge of the process, understanding of fundamentals, and of how equipment works.

Modern control systems contain more than software and computers. They contain hardware to measure the process and transmit the information to the computer. Recent reporting has concentrated on the 'sexy,' new things in computers and software and overlooked the fundamentals of how the hardware works. Design errors, improper installation, and ineffective maintenance of the hardware cause many control problems.

For both troubleshooting equipment and improving unit control, we need to understand the fundamentals of how equipment works, how the process works, and how our measurement of the process works. Understanding the primary measures, how the control system or the troubleshooter interprets the unit readings, is key to solving process problems. It is also the key to designing *and* installing profit making control systems.

Poor level control makes operation unstable and damages equipment

One of the basic facets of stable and effective control is system inventory control. Pressure control regulates vapor inventory. Level control regulates liquid inventory.
A common control configuration with distillation towers has bottom level controlling the bottoms product rate. Normally, this is on cascade control.

Inaccurate liquid indication causes many expensive operating problems. If the level is lower than expected, pump cavitation damage may result. Cavitation damages pump seals. Damaged pump seals leak. Maintenance costs increase. Leaks can lead to fires, massive unit upsets and place personnel in danger.

Poor liquid level control reduces the effectiveness of advanced control systems. Decoupled control systems depend upon using liquid inventory changes to dynamically compensate for control disturbances while minimizing regulatory changes to the system.

High liquid levels damage equipment. Liquid backing into reboiler return lines damages trays. Entering reboiler vapors push the liquid up the tower. Tray damage results. Damaged trays do not work. Product losses result. One common area with damage is stripping trays in an atmospheric crude petroleum distillation tower. In one case, poor level control allowed liquid to back up over the stripping trays in the bottom of the tower. Stripping steam then hammered the liquid against the trays, damaging them. Damaged stripping towers in atmospheric crude towers can drop yields by up to 15 percent on crude.

At a different refinery, startup problems caused a high level in an atmospheric crude tower. The liquid backed over the stripping trays and filled the flash zone over the feed inlet nozzle. Entering feed threw the liquid up the tower and destroyed the stripping trays. During startup, steam was not yet being fed to the unit. Hence, the stripping trays escaped the fate of the wash trays further up the tower.

Damaged wash trays allowed residue to entrain into the atmospheric gas oil (AGO) product. AGO with entrainment poisons downstream catalysts and reduces yield. After nearly a year of operation with dark AGO and millions of dollars in losses, the unit was shut down and repaired.

In other cases, entering vapors may push foam up the tower and flood the trays. Figure 1 shows how the problem affected an amine stripper in a proprietary amine gas-treating unit. The tower floods. Liquid may even end up going out the tower overhead line. This plant lost an overhead accumulator full of liquid at least once and often twice per week. Foam entrainment forced a capacity reduction. Reduced capacity drops production or forces operation at lower product purities. Both problems cost money.

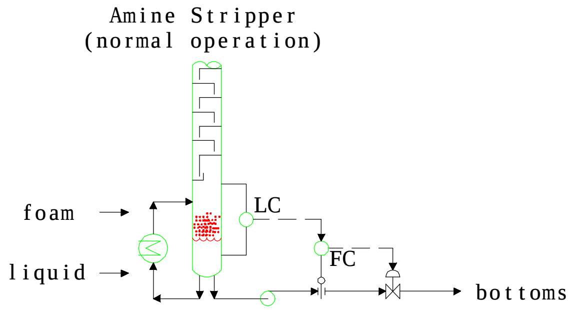

Figure 1
Amine stripper flooding from foaming

How is liquid level measured?

Many different devices measure the vessel level. Choices include displacement floats, buoyancy floats, thermal measurements, thermocouple arrays, radiation methods, sight glasses with optical sensors, and differential pressure cells. Due to the low cost and wide applicability, differential pressure (DP) cells are the most common.

DP cells, sight glasses and liquid level measurement problems

DP cells are very similar to sight glasses. Understanding how sight glasses can fool us explains how the process fools the DP cell. The immediate response on seeing a sight glass is that the sight glass shows the liquid level in the vessel. In reality, the sight glass is a DP cell. The sight glass measures the DP inside the vessel and reports that DP to us in a height of liquid that we see in the sight glass. The DP generated inside the tower is the height of liquid, DH, times the liquid density, DL, or DH*DL. The height shown outside the tower is the DP divided by the density in the sight glass, DS, or DP/DS.

Data from DP cells is interpreted in the same way. Control calculations use an assumed liquid density to determine the liquid level inside the vessel.

Obviously, if the liquid in the sight glass is the same density as the liquid in the vessel, the reading in the sight glass is accurate. Problems begin when the vessel boot density does not equal the sight glass density. Looking back to the foaming absorber in Figure 1 can show the foam level inside the vessel and get Figure 2. The higher liquid density in the sight glass shows a lower liquid level than what the lower density foam creates inside the tower.

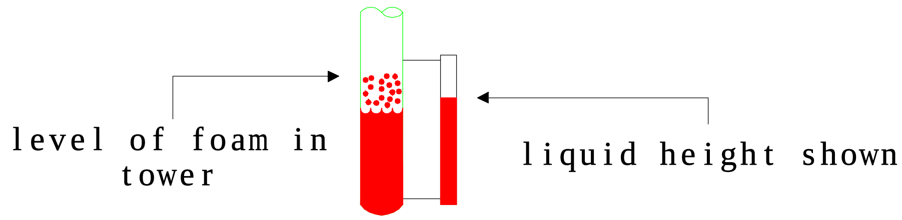

Figure 2
False level reading from foam

Foaming is a major cause of tower problems. Foaming creates inaccurate level measurements. The indicated (or DP cell) liquid level is lower than the actual foam level. The tower floods prematurely: often unexpectedly.

Further Reading

The full text of this article, including all eight figures can be found at Hydrocarbon Online, Tech Tips, http://www.hydrocarbononline.com/content/news/newsindex.asp?bucket=tech+talk or can be obtained by sending a message to our paper server. Send an e-mail to techrequest@distillationgroup.com with the number 089 in the subject line to receive a PDF copy of the article.

Calendar

2001-March-18 to 20, NPRA Annual Meeting, New Orleans
2001-April-22 to 26, AIChE Spring National Meeting, Houston

Publications

Look for the January 2001 *Chemical Engineering Progress* article on distillation pressure control.

Training

Revamps upgrade your facility to meet new challenges and maintain profitability. Training upgrades your personnel for the same challenges. DGI training uses modules customized to cover many different areas for your plant. Modules are combined to create a training program for your facility and audience. Material can range from very specific to general discussion of principles of distillation, operation, and product recovery. DGI training uses an interactive approach for both operator and engineer audiences. Don't go to sleep in front of hundreds of PowerPoint slide during your next training session. Contact us instead and we'll keep you awake while upgrading your skills.

Web Page Updates

The main DGI web page at www.distillationgroup.com is being updated with several new sections. These include a search function and a Q&A section. The features will be fully functional within the next few weeks. Until then, access to the search and Q&A pages requires a direct address to the page in your browser as they are not linked into the site navigation bar yet. You can reach search and Q&A at:
Search www.distillationgroup.com/search.htm
Q&A www.distillationgroup.com/questions.htm

Questions and Answers

Operation of a recirculating reboiler on a naphtha splitter

Subject: Thermosyphon Reboiler
Date: Tue, 28 Nov 2000

I hope you don't mind if I ask you a question. You seem very knowledgeable in the refining industry. I am a Top Operator in the Reforming Division a refinery.

We have a tower that receives a cracked gasoline and takes a cut of light gasoline off the top that we don't want in the reformer. The bottoms go to the reformer platformer. We do this because reforming light ends actually lowers the octane and thus your reformer has to work harder.

On the bottom of this tower we have a thermosyphon reboiler that uses 500 degree F (260 degree C) diesel as its heat medium. I was told that if I raised the level in the tower, I could get more heat transfer to the tower product. We were at max diesel flow on the other side of the reboiler and had a good level in the tower. Is this true?

The tower runs at about 12 pounds and about 300 degrees F (149 degrees C) on the bottom of the tower.

Thank you for taking the time to answer this question.

T., US Gulf Coast Refinery

Subject: Thermosyphon Reboiler
Date: Tue, 28 Nov 2000

T.,

One question, there are three major different reboiler configuration types 1) once through, 2) recirculating with a baffle on the thermosyphon side, and 3) recirculating without a baffle. Your question implies that you have configuration 3. This is the least common configuration in a refinery.

Could you check on what baffle arrangement you have in the bottom of the tower? It does make a difference to the answer. Additionally, there are other, less common configurations as well. It would be helpful also to know the temperature into the reboiler, out of the reboiler, and of the product (if you have them on the control system). This tells a lot about how the reboiler is working.

Subject: RE: Thermosyphon Reboiler
Date: Tue, 28 Nov 2000

Thank you so much.

The reboiler is a U tube exchanger with the hot oil (595 degrees F, 313 degrees C) going into the tube side and out of the tube side at 310 degrees F (154 degrees C). On the tower side, the shell inlet is 295 degrees F (146 degrees C) and the shell outlet is 305 degrees F (152 degrees C). We have a 60 percent level in the tower.

The inlet of the shell side comes from very close to the bottom of the tower and splits at the shell inlet. At the outlet of the shell the split joins back together and enters the tower just below Tray 1. There are 50 trays in the tower and Tray 1 is probably 40 feet from the bottom. There are no baffles in the tower bottom. I am attaching some drawings. I hope they open for you. They are from our data system.
<Tif files attached>

T., US Gulf Coast Refinery

Subject: Thermosyphon Reboiler
Date: Wed, 29 Nov 2000

T.,

Summary

I'll start out with the summary so you can get the results fast, then a detailed background will follow that you can look at in any level of detail you want.

- Your reboiler is pinched on the diesel side. In the best possible circumstances, you could only get another three percent duty from this stream.
- With the elevations you have, raising the sump level will only increase your recirculation rate by a tiny amount, at best. Two-phase flow is a complex problem, and units can go unstable with even small changes. Secondly, a higher level may make foam entrainment from the boot more likely, flooding the tower.
- Increased recirculation rate does not always increase duty in the reboiler. It can go down as well.

The only effective operating changes that get more duty into the exchanger are:

- Increase diesel rate (which you say is at a maximum)
- Decrease tower pressure (probably limited by tower and condenser constraints already).

Systems can always behave unpredictably, however, the risk of operating upset for a small level change is low for this system. Changing the level and looking at the result (is the diesel temperature out of the reboiler lower, this equals more heat into the tower) is straightforward and cheap. If you want, try it. Just don't be surprised if the duty change is impossible to find.

I'd be interested in hearing what happens if you do try the higher liquid level.

Details

The Basic System

What your figures show is a recirculating reboiler without a baffle, exactly as you described. The major reason to use this configuration is that the tower requires a relatively large percentage of the liquid traffic entering the boot be vaporized for tower boilup.

The major question you have is about the affect of higher liquid level in the boot. Will it increase, decrease, or have no affect on the heat you can get into the system?

To answer your question, we'll look at some general characteristics of this type of system as well as specific factors for your system. Figure 1 shows your unit, approximately to scale.

Liquid descends the tower, overflows from tray 1's downcomers and enters the sump. Liquid from the sump goes to the reboiler, partially vaporizes, and returns as a two-phase mixture into the sump. The returning liquid from the reboiler mixes with the liquid that enters the sump from tray 1. The sump liquid going to product and reboiler feed is a mix of the tray 1 liquid and the liquid returned from the reboiler.

The mixed liquid in the sump must have the product composition required. Liquid from tray 1 has a lighter composition that the product. Since the tray 1 liquid mixes with the reboiler return liquid to generate the product, the reboiler return liquid must be heavier than the product composition.

Temperature, pressure, and composition are related. If you fix two of them, the other is fixed as well. Tower operating pressure is fixed by the control system against the need to get the heat out of the overhead condenser and by tower capacity required. Since the mixed sump composition is set by downstream requirements, the temperature required in the sump is now set as well. Since the sump liquid is lighter than the reboiler return liquid, the reboiler return must be hotter than the sump liquid.

Looking at changes in recirculation rate for your system requires looking at two different factors: first, how much can a level change affect recirculation rate: second, how does a change in recirculation rate affect heat transfer and duty in the reboiler.

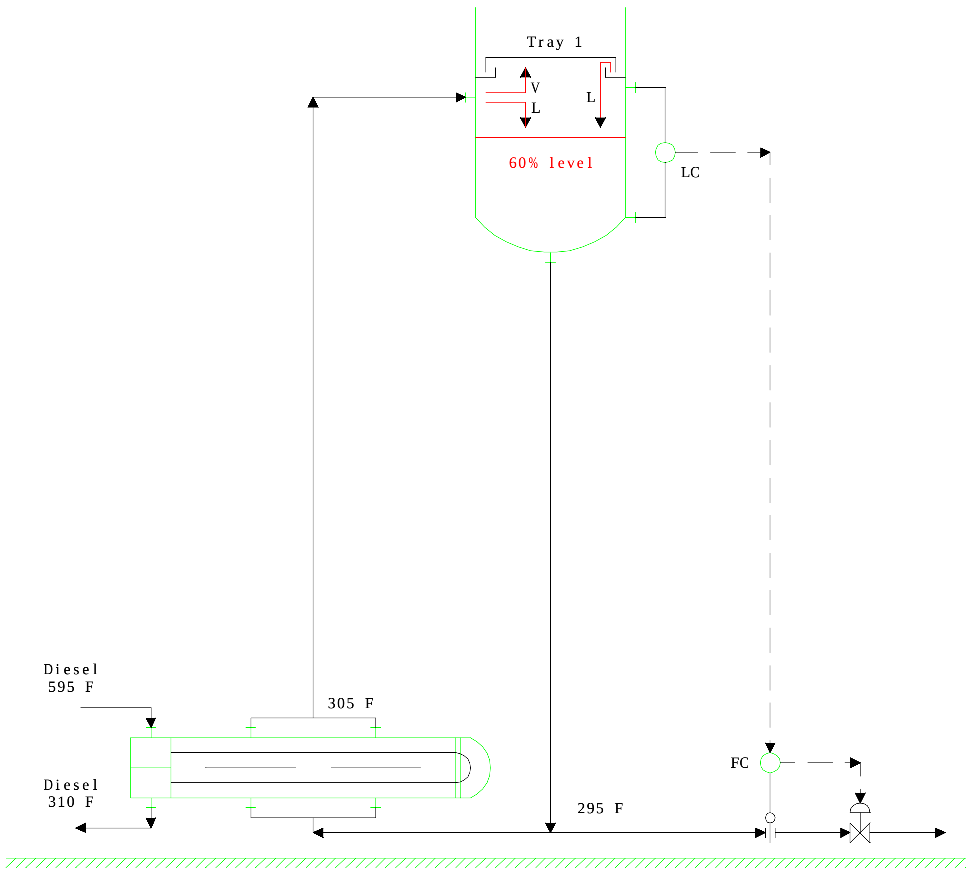

Figure 1
Reboiler system

How Level Changes Recirculation Rate

Recirculation in these systems is driven by the density difference between the outlet line and the inlet line. Figure 2 shows your system with the important heights noted.

The system pressure balances based on the total driving force for flow must equal the total resistance to flow:

$$driving\ force\,in = resist\ force\,against\ flow$$

or

$$H1 * density1 = DP_{pipein} + DP_{pipeout} + DP_{reboiler} + H2 * average\,density2$$

Increasing the height of high-density liquid (level in the boot), increases the driving force for flow. This increases circulation rate. However, increased circulation rate, increases pressure drops as well. For most systems, the pressure drops in the inlet piping and the reboiler are small compared to the driving force in the inlet pipe and the pressure drop plus static head in the outlet pipe.

For your system and the pipe diameters shown, increasing the height within the boot will have only a minor impact on circulation rates. The total height from the liquid level to the exchanger inlet flange is around 33 feet (10 meters). Increasing the height by an extra one or two feet (less than one meter) will have only a minor affect on recirculation rate.

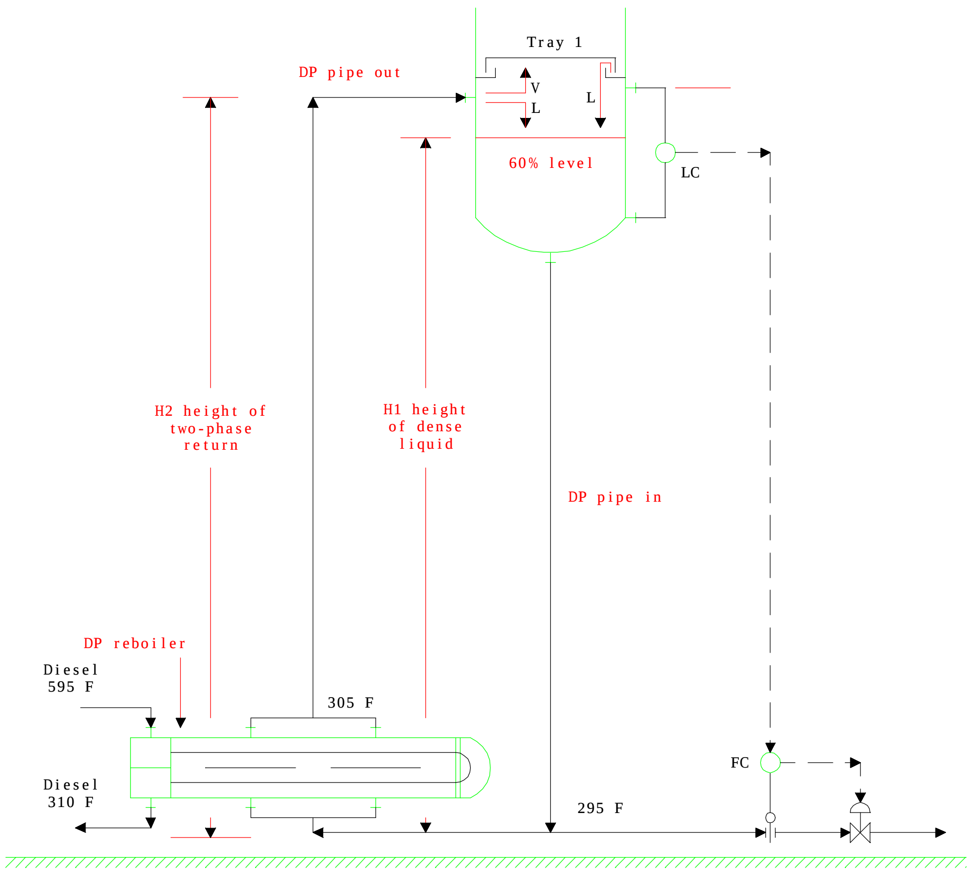

Figure 2
Reboiler system driving forces

How Recirculation Affects Heat Transfer

Heat duty (Q) from an exchanger is defined by its surface area (A), corrected log mean temperature difference (LMTDc), and overall heat transfer coefficient (U).

$$Q = U * A * LMTD_C$$

To get more duty from an exchanger you must increase either U, A, or LMTDc. Obviously, you don't change the exchanger area. This leaves U and LMTDc.

Product composition sets the sump temperature. The sump temperature is the result of mixing colder liquid from tray 1 with hotter liquid from the reboiler. Assuming the composition changes are small, the higher the recirculation rate, the lower the reboiler outlet temperature you need to get the mixed temperature to the product conditions. Increased circulation rate improves the LMTDc.

However, to get more duty into the tower, you must get more duty out of the diesel (hot oil) heat source. Since you state that the diesel flow is fixed, getting more heat out of the diesel requires cooling it more. Currently, the exchanger reboiler is pinched on the diesel outlet. The diesel outlet is only 10 degrees F (5 degrees C) hotter than the inlet of the reboiler feed. The maximum duty that you could ever get out of the diesel would be to get it down to the temperature of the shell inlet. This would only increase the tower duty by (10)/(595-305)=3.4 percent. Even achieving this would require an exchanger with infinite surface area and no internal temperature pinches in the exchanger. Very little benefit is available from increasing the recirculation rate. Given that the exchanger is pinched, changes in U also have only a small impact on exchanger performance.

Normally, we think that increasing the velocity through an exchanger increases U. This is not always true for reboilers. This is a very complex problem that really doesn't merit discussing in detail for your unit, because the pinch on the heat source overrides all the other factors. Results depend upon the flow rate, percent vaporized, two-phase flow regimes, heat flux present, physical properties, and geometry of the system. The **Handbook of Heat Transfer** [1] has a very good discussion of the problem on pages 15.75 to 15.84. The examples shown include a kettle reboiler and a horizontal thermosyphon reboiler just like yours. Careful review of the text shows that heat transfer coefficients can decrease in some circumstances with increasing recirculation. I have observed this behavior in a few units and completely agree that it is real and not just a theoretical problem.

Further Reading

Further reading can be obtained by sending a message to our paper server. Send an e-mail to 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 required).

053 Properly design thermosyphon reboilers: A. Sloley; *Chemical Engineering Progress*, 50(3), 1997 March: 52-64

[1] Rohsenow, W.M., Hartnett, J.P., and Cho, Y.I. **Handbook of Heat Transfer**. The McGraw-Hill Companies, Inc., New York, 1998.

Copyright