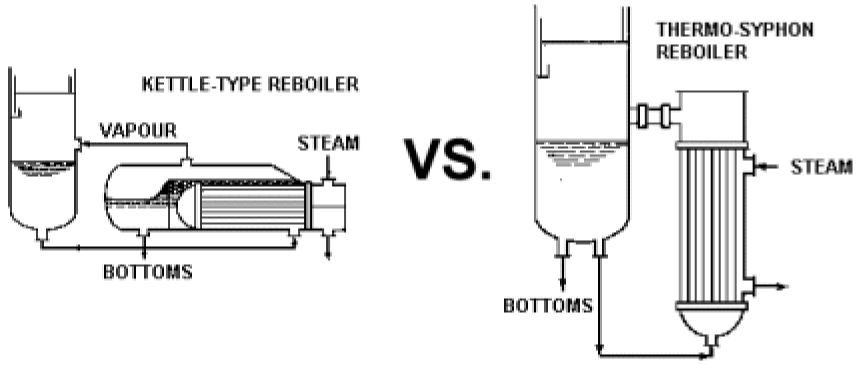
Reboilers: Kettle versus Thermosiphon Designs

"I would like some guidance on the relative benefits of kettle vs. vertical thermosiphon reboilers in NGL (DeC3 and DeC4) service. Specifically we are looking at a turndown of 4:1 and some are concerned that a thermosiphon would not turndown well. I am unconviced as the drive mechanism is based on relative densities and would therefore (I think) be independent of flow through the exchanger. Alternatively does anyone forsee turndown issues with a kettle?"



Read the replies to this message:

Welcome. And thanks for bringing up a subject that is one of my favorites. Reboilers and I have had a robust romance through the years, although I haven't designed or built one in the last 15 years. I started out operating and later designing and building kettles. In my later years I had the opportunity to really get into thermosyphons - some big, some exotic. They all worked. The kettles always worked best – especially with increasing production rate demands and varying plant production (turn-downs). However, it has always been the thermosyphons who presented the challenge and the mystery. But once I got the thermosyphons up and running regularly and steadied the production rate, it was goodbye to reboiler problems and hello to boredom. The Thermos just kept on trucking – night and day – with consistency.

I love the Thermos because of their simplicity, small footprint, and cleanliness during service. But like a good-looking woman, they can be temperamental if process conditions start to vary or change. The kettles have always been the mules of the distillation train: they take a lot of abuse, but can be trash collectors if the process is a dirty or contaminated one. Cleaning out the shellside of a kettle is not my idea of having fun. I can only address vertical thermosyphons and not the horizontal variety, since I've never designed or operated the latter.

I personally would not try to turndown a thermosyphon by more than 2:1. In fact, I wouldn't like to have to design for any turndown on a thermo. I've seen them doing some funny and strange things in the field. If there is going to have to be a turndown involved in the basic plant design, then I would opt for a kettle. I know that except for trash and dirt on the process side of the internal weir, I can make the kettle do just about everything I design for with ease and simple controls. But, as you would suspect, there are the ever-present tradeoffs:

1) Bigger footprint; more space and volume required;
2) Inherently married to a U-tube design; requires clean steam;
3) Larger structural steel requirements for support and tube bundle maintenance;
4) Larger shell, more capital cost.

The relative densities driving the thermosyphon are the difference in bubble formation as the colder liquid enters the bottom tube sheet and starts to vaporize as it travels up the vertical tubes. The trick is to control the bottoms flowrate through the thermosyphon and the vaporization rate.

I've found that stable operation of the thermosyphon depends on a balance between the 2-phase friction plus acceleration losses in the process flow loop and the net static head developed by the liquid in the column. Sudden changes in column bottoms level, composition or steam pressure can upset this balance causing flow oscillations which result in poor column control, low heat transfer rates, and, possible, mechanical vibrations. Since the driving force for flow is low, thermosyphon operation is difficult for viscous fluids. This should not be your problem in de-

Propanizer or de-Butanizer service.

Pool-boiling is an inherent characteristic of a kettle unit and by common sense we know that together with the larger capital expense we have inherited a natural heat and thermal capacitance that withstands process variations and accepts large process rate turndowns (or –ups). That is the principal reasons for going with a kettle when one knows that turndowns are inevitable.

Thanks Art,

I was hoping that I could solicit a reply from you.

Someone else indicated that at turndown the 2 phase flow regime through the reboiler will change due to lower velocities as well as different Gas-to-Liquid ratio. So, along with your excellent reply, I now can see that turndown could cause a problem.
I am supprised that this is not more widely reported in literature. I looked in all the standard texts (Perry, GPSA, Campbells, Kern) and even Kister's Distillation book. Literature seems to suggest that thermos (particularly vertical) are the workhorse in pressure service and with the exception of greater skirt height are prefered. Whereas kettles are given a relatively negative review (Low heat Transfer , increased fouling, larger and expensive - all more of less related to the pool boiling environment).
Why not more glowing reviews of kettles ?

Why does something as important as turndown get overlooked as a selection criteria in all the literature ??
Especially as valve trays are well known to have turndowns of 4:1 (presummably because there is a demand for this) why would this not be as important in the reboiler attached to the column ?

Am I reading the wrong books?

Thankyou Art for offering your experience, often the books are not enough.

As is usually the case after discussing Unit Operations, I often resort to my favorite controls guy, Greg Shinskey, for confirmation on my ideas. In the case of reboilers, I refer you to Greg's famous book, "Distillation Control" (McGraw-Hill, 2nd Ed.; p.102):

"The high velocities encountered within the vertical thermosyphon reboilers are attained with as little as 5 wt% vaporization. This is an important consideration since circulation then depends on that concentration of volatile components – otherwise vaporization will be lost. Columns containing substantial concentrations of only slightly volatile components may exhibit unstable operation for this reason.

"This problem can be more severe in horizontal thermosyphon reboilers where the percent vaporization is higher. Trapping the liquid from the first tray then becomes essential for this type of reboiler to function.

"Note that the liquid circuit between the column base and the thermosyphon reboiler forms a "U" tube". Liquid contained in a U tube has a capability of resonant oscillation like a pendulum. Its period is derived in Reference 5 as:

t = 2 p (L/2g)^1/2 = 0.78 (L)^1/2

where,
t = natural period, sec
L = total length of U tube, ft
g = acceleration of gravity, 32.2. ft/sec2

"The length of the U tube in most columns is about 15 ft, giving a 3-sec period. In absence of friction, oscillation, once begun, would continue indefinitely. However, bubble formation in the thermosyphon reboiler produces enough random disturbances or noise to induce oscillation at the resonant period. Buckley (6) describes unstable reboiler operation having a period of 3 to 4 sec coincident with high heat-flux rates. A restriction in the liquid line can correct this problem by providing damping."

Once again Greg Shinskey points to a practical problem and gives description and resolution. I thought this is a good example that you're not reading the wrong books; you're not reading all the available books, unfortunately. I would strongly recommend you read Shinskey's various book publications. They are full of practical information and problem-solving in an easy-to-read and down-to-earth manner - just like the above example.

Most chemical engineering textbook authors are not coming in through the same front door as Greg Shinskey is. He not only has the brains and know-how departments dominated, he also has the hands-on, daily experience plus the ability to communicate at a down-to-earth level. This is a rare talent in the present engineering field. I've found that together with their vast knowledge of engineering lore, equations, and theory, most educators have a complete lack of familiarity with process hardware and the practical manner of installing, operating, and controlling its operation. This is unfortunate, but true in most cases. Besides that effect, you also have the present situation where investments in the chemical processing industry are no longer being made "for the long haul" – i.e., with the expectation that incremental growth and production increases are to be expected. Today's investment is made for today's fixed and known rate. If you want to reduce it or increase it, it's another completely different ball game. Therefore, turndowns in production rate are not looked upon as good nor are they to be tolerated. Consequently, the process design today is much "tighter" and less flexible than it was in my time (1960s –'80s). Today you are concentrating on the minimum amount of capital with the minimum amount of labor and maintenance to operate. A thermosyphon addresses those needs much better than a kettle and book writers seem to go along with this philosophy, without pointing out the trade-offs.

You are correct, in my opinion, of suspecting that there is a definite place in heat transfer for the obese, ugly, and tough kettle design (inspite of what others may say or write). This is true not only of the reboiler application but also of its refrigeration evaporator application. It has inherent characteristics that have proved to endure and still be very competitive in some operations.

You are very observant and astute in noting that books (and publications) are not enough to carry you through your job. Thank God! That means that as practical thinking humans we don't stand a chance of being replaced by robots. I also believe that it is not the University or the "books" that make you an efficient and experienced engineer. It is your perseverance in self-improvement, your resourcefulness, and your ingenuity that does that.

Happy heat transferring.

I want to add two major things to this thread:

1) I welcome the valued and respected contribution of Walter Driedger to this Forum. His opinions and thoughts on process control are items that should be of avid interest to all engineers in the process industry. One visit to his web site will not only impress you with his practical knowledge, but will convince you that reading, studying, and retaining what he writes on process control will earn you rich rewards in your engineering career;

2) I apologize for not previously mentioning Walt's rich mine of control information found in his website; I personally rank Walt up there with Greg Shinskey as one of the foremost communicators of process key learnings. His practical approach and explanations do much to remove the many unknowns that lurk in the control arena. I have previously said this more than once in the past, but I'll repeat it again: Any young engineer out there would be wise to go to Walt's website and not only download all the available free technical information he has there, but also read and thoroughly digest the very important key and experienced learnings he offers in his papers. To fail to do so is the waste of a great opportunity to get a jump on controlling processes in a safe and practical manner.

Walt: Thank you, once again, for your valued visit. I only hope that it won't be the last time we here can enjoy and profit from your valued experience and knowledge. I look forward to the next time you visit.

Art Montemayor

You might find something useful in "Controlling Steam Heaters" and "Controlling Shell and Tube Heat Exchagers" found at my web site www.driedger.ca.