HTRI® The Exchanger

Issue 1 ● 2011

Stopping Time

The new MVU gives us
a look inside the exchanger

Join us at one of our member meetings in 2011!

HTRI member meetings begin in September. The corporate reports and technical presentations, along with multiple training sessions, provide opportunities for you to learn more about using HTRI methods and technology. Visit www.HTRI.net for more details about these and other events in 2011 or to register. *Early registrants receive reduced pricing on session fees.*

Annual Meeting of Stockholders and North American Meeting
September 19 – 23, 2011
The Ritz-Carlton
Amelia Island, Florida, USA

- Lessons Learned in Engineering Services Seminar
- ***X****fh* Workshop
- Advanced ***X****ace* Workshop
- ***X****phe* Workshop

Asian Meeting
October 4 – 7, 2011
The Ritz-Carlton
Seoul, Korea

- Lessons Learned in Engineering Services Seminar
- Advanced ***X****ist* Workshop
- Vibration Analysis Workshop

European Meeting
October 10 – 14, 2011
Steigenberger Kurhaus Hotel
The Hague, The Netherlands

- Lessons Learned in Engineering Services Seminar
- HTRI ***X****changer Suite* Essentials Workshop
- Kettle Reboilers Short Course
- ***X****vib* Workshop

Asian Meeting
October 25 – 28, 2011
Crowne Plaza Beijing
Beijing, China

- HTRI ***X****changer Suite* Essentials Workshop
- ***X****phe* Workshop
- Vibration Analysis Workshop
- Condensers Workshop

Asian Meeting
November 7 – 10, 2011
Pan Pacific Yokohama Bay Hotel Tokyu
Yokohama, Japan

- Condensers Workshop
- ***X****ist* Workshop

Asian Meeting
November 14 – 17, 2011
Goodwood Park Hotel
Singapore

- ***X****ist* Workshop
- Advanced ***X****ist* Workshop
- Reboilers Workshop

Asian Meeting
December 12 – 16, 2011
The Taj Mahal Hotel
New Delhi, India

- Designing for Success: Shell-and-Tube Heat Exchangers Seminar
- Lessons Learned in Engineering Services Seminar
- Advanced ***X****ace* Workshop
- Vibration Analysis Workshop
- Advanced ***X****ist* Workshop

In this issue...

Notice
The articles and opinions in this newsletter are for general information only and are not intended to provide specific advice.

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HTRI recycles

Rhetoric to Action

Claudette D. Beyer
President &
Chief Executive Officer

As we end our 49th year in business, our fiscal year accomplishments once again assure our position as the leading global provider of best-in-class process heat transfer technology, products, and services.

In April 2011, we completed Phase One of our corporate headquarters move from College Station to the Business Park of Navasota, Texas, USA. These new facilities are located about 14 miles south of College Station on over 25 acres of land that we own, where our Research & Technology Center (RTC) was completed in 2007. These capital asset investments are important to the long-term viability of HTRI. Most of the engineering staff and those with closely related responsibilities moved into a new office building which is located next to a Conference Center with classroom-style space for nearly 80 persons and an adjacent dining area. The new conference facility offers advanced audiovisual technology that will facilitate expansion of training offerings. Part of the former office annex adjacent to the RTC also will be converted to a laboratory for training purposes. Within the next few years, we expect to sell our current headquarters and construct a second office building to consolidate our corporate headquarters in the Business Park.

In May, we held the first event in the new Conference Center. Our entire global team—including sales managers and representatives—attended Directions 2011, an annual meeting that focuses on our corporate status, review of policies and procedures, assessment of progress, as well as sharing of best practices. Attendees also participated in training; Marco Satyro, Chief Executive Officer of Virtual Materials Group Inc. (VMG), updated staff on the VMGThermo physical properties package that is integrated with ***X**changer Suite*.

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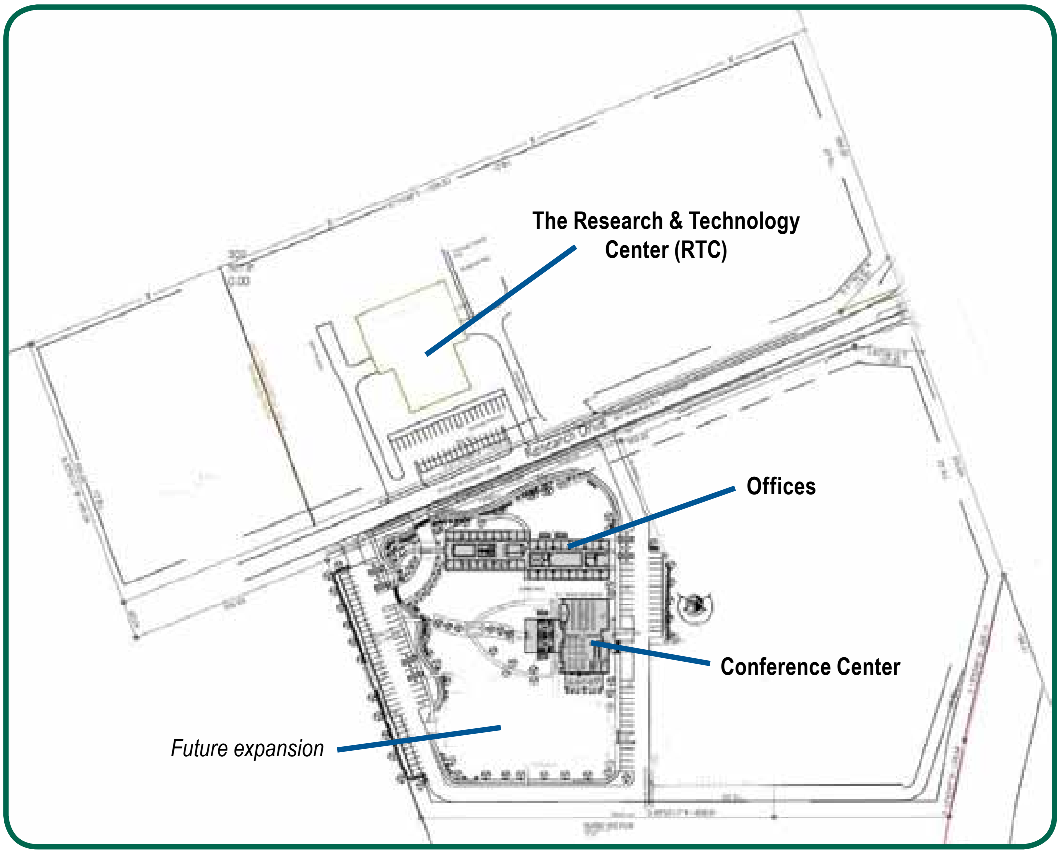

Above, the HTRI campus at the Business Park in Navasota, Texas.

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Discussions about current operations provided insights for improvements and for planning for the future. Deliberations during Directions 2011 led to decisions—moving us from rhetoric to action.

Deliberations during Directions 2011 led to decisions—moving us from rhetoric to action.

We continue to capitalize on the myriad benefits of the Honeywell alliance, as well as to collaborate with numerous companies and academic institutions. Leveraging these opportunities contributes to our success, and provides ever-increasing value to over 650 companies and nearly 500 of their registered subsidiaries that comprise the current membership of the HTRI consortium. We proudly note that our growth has continued unabated throughout the difficult worldwide economic challenges.

Interior views of the Conference Center.

In September our annual round of member meetings begins—starting with the Annual Meeting of Stockholders and North American Meeting at Amelia Island, Florida, USA, and ending calendar year 2011 with a December meeting in New Delhi, India. Additional member meetings and training events will be held in the first half of 2012. Please check our website (www.HTRI.net) under Upcoming Events for the meeting and training location that works best for you.

In the meantime, take advantage of our free webinars, offer your expertise to a Task Force, and participate in your local Communication Committee (CC). If there is not a CC in your area, we will help you get started! Contact your local representative or write to us at CC@HTRI.net. The CC minutes and staff responses are posted online, offering an informative, useful glimpse into our technology. I strongly encourage you to make time to read these insightful documents.

The newly constructed Conference Center at the Business Park in Navasota, Texas.

On August 1, 2011, we begin our 50th year of operations. Whether you work in a company that has been a member for many years or one that joined last year, we applaud your use of our technology and your participation in the activities of the consortium. We look forward to hearing from you via Task Forces and Communication Committees, having dialogue with you online via your technical inquiries as well as webinar participation, and seeing you at our worldwide meetings and training events.

Staff are meeting important milestones across departments throughout our company. We are taking advantage of individual expertise while cross-functional teams learn from one another and utilize ever-evolving technology.

Our focus is on the continuous creation of value for all member companies and the end users of our technology. We remain committed to strengthening the power of the consortium.

Claudette Beyer

Research at the RTC


J. W. "Bill" Clepper
Chief Operating Officer

Work at the Research & Technology Center (RTC) continues to provide new opportunities for developing methods and correlations that benefit our members and contract customers. The following table highlights the status of Technical Operating Plan projects and the operation of test units at the RTC. Descriptions of the projects in the Technical Operating Plans for FY 2011 and FY 2012 are available in the Member Center – Governance on www.HTRI.net.

Test or Support Unit	Completed	In Progress/Planned	Comments
High Temperature Fouling Unit (HTFU)	• Crude oil fouling tests with carbon steel test sections • Development of predictive models for desalted crude 18 • Characterization of the crude oil and deposit as related to the dominant fouling mechanism	• Fouling tests with stainless steel test sections • Analysis and testing of mitigation strategies	Using a number of crude oils, we will generate fouling maps that relate the fouling propensity of the operating conditions and chemistry to the crude oil.
Low Pressure Condensation Unit (LPCU)	Data collection for condensation of three pure fluids (steam, n-heptane, and n-octane) at test pressures ranging from 0.41 to 31 kPa (3.1 to 230 Torr) and with condensation flow regime varying from mist flow to gravity-controlled flow	• Data collection of condensation of pure fluid with noncondensable gas • Additional tests for condensation of mixtures with and without noncondensable gas	With these new data, we will be able to evaluate and improve our existing heat transfer and pressure drop methods for condensation at vacuum conditions.
Multipurpose Boiling Unit (MBU)	Single-phase, onset of nucleate boiling (ONB), flow boiling, and adiabatic two-phase flow tests using five fluids for two plain tube bundles (one staggered and one inline)	• Installation of an inline low-finned tube bundle • Single-phase and flow boiling tests using five fluids	Visualization through windows on the test shell enhances determination of bubble formation and growth, as well as two-phase flow patterns for cross flow. For the first time, we have collected ONB data using mixtures.
Multipurpose Condensation Unit (MCU)	Data collection for inclined tubeside downflow and upflow (reflux) condensation (60-degree apex angle) and flooding	Data collection for inclined tubeside downflow and reflux condensation (30-degree angle from horizontal)	Data from reflux and downflow tests (heat transfer and pressure drop) will be analyzed. We are procuring elliptical tubes for testing in FY 2012.
Multipurpose Visualization Unit (MVU)	Data collection for a variety of air/water flow rates using a no-tubes-in-window (NTIW) bundle with perpendicular-cut baffles	Data collection for a single segmental bundle with perpendicular-cut baffles	Initial tests show that phase separation is a concern for perpendicular-cut baffles.
Prototype Test Unit (PTU)	• Upflow heating and cooling tests of 748 fpm (19 fpi) and 1063 fpm (27 fpi) inline low-finned tube bundles for mixed convection study • Cooling tests on helical baffled subcooler using single-phase, liquid pentane, and liquid paraxylene, between1588 kg/hr (3500 lb/hr) to 8709 kg/hr (19200 lb/hr)	• Upflow heating and cooling tests of a plain inline tube bundle for mixed convection study • Helical baffled subcooler testing by cooling propylene glycol and heating pentane vapor	Crossflow heat transfer data will allow us to verify forced convection predictions and account for effects of natural convection. Helical baffled exchanger performance with respect to pressure drop and heat transfer will validate CFD to help develop accurate methods in ***X****ist* software.
Tubeside Single-Phase Unit (TSPU)	• Plain tube single-phase laminar heating and cooling tests with propylene glycol and polybutene for two tube lengths • Twisted tape single-phase laminar, transition, and turbulent liquid heating tests with propylene glycol and p-xylene	• Testing with final tube length and test fluid for twisted tape study • Tubeside testing of single-phase non-Newtonian fluids	Plain tube tests verify the intube temperature pinch phenomenon for mixed convection flows in horizontal tubes. These data are being used to improve our laminar tubeside methodology.

Visualizing air/water flow in a shell-and-tube heat exchanger

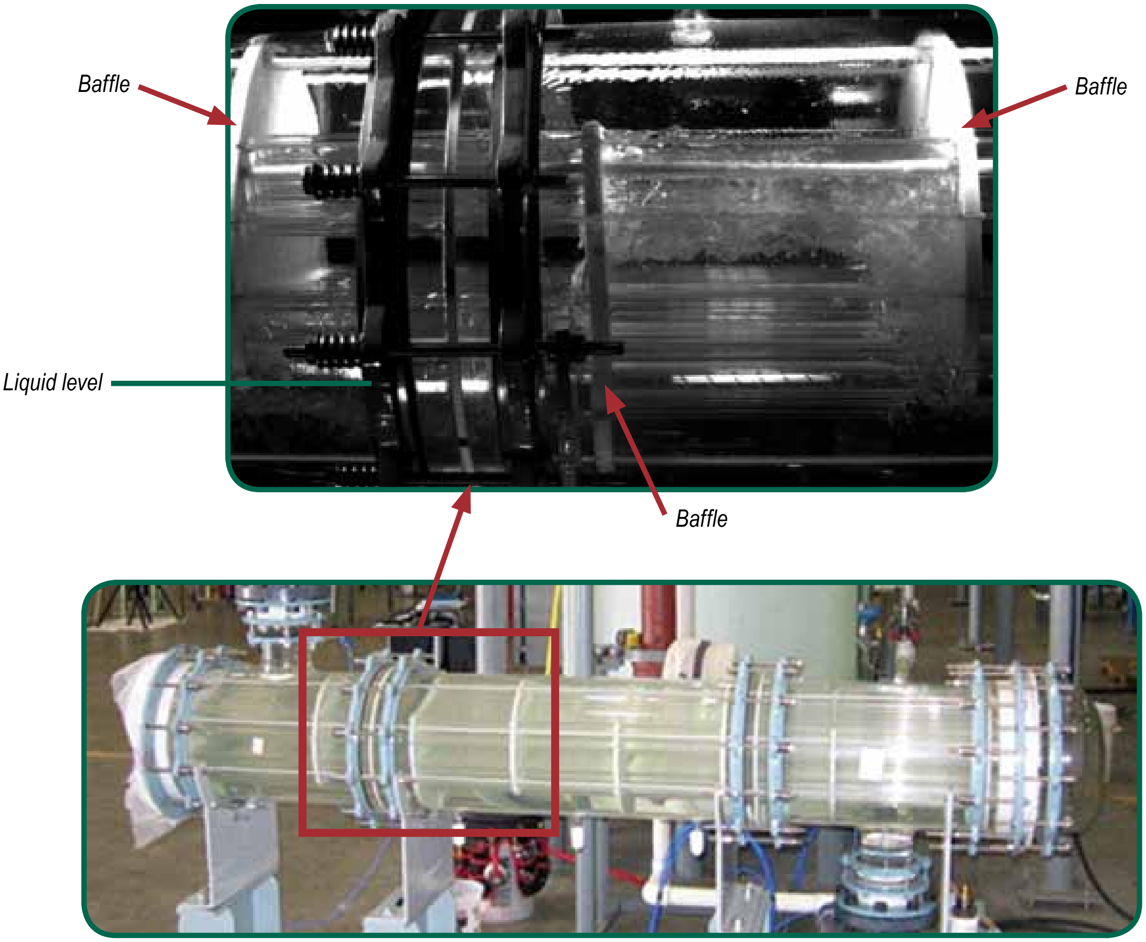
Rose C. Craft
Engineer, Research

Accurate prediction of two-phase heat transfer and pressure drop requires a thorough understanding of the flow patterns, flow distribution, and phase separation. Because there are few flow visualization studies on the shellside of a shell-and-tube heat exchanger, flow regime maps based on tubeside data are used for shellside flow. However, these tubeside flow regimes do not describe the more complicated shellside flow accurately.

HTRI recently built a Multipurpose Visualization Unit (MVU) consisting of a transparent shell-and-tube heat exchanger (TSTX). We designed the TSTX so that we can visualize flow on the shell side, on the tube side, and in the headers. Our studies will also include varying baffle spacings and orientations, with tubes or no tubes in windows. The Pyrex construction of both the shell and the tubes allow us to test no-phase-change air/water mixtures. In the future, metal tubes can replace the Pyrex tubes, and we can study phase-change two-phase flow.

As pictured below, the TSTX is set up as a no-tube-in-window bundle with perpendicular-cut baffles. An air/water mixture enters the shell at the bottom of the exchanger and exits at the top. Taken with a high-speed camera, videos of shellside air/water flow confirm the phase separation and flow patterns which occur. A severe amount of separation greatly affects the performance of the exchanger. Being able to predict when this separation will occur gives us the opportunity not only to design more efficient exchangers but also to better troubleshoot exchangers already in operation.

HTRI plans to use these videos to improve our flow regime map and develop criteria for phase separation. This information is invaluable for accurately predicting the performance of an exchanger.



The MVU and TSTX allow us to capture high-speed video of flow; these videos provide the information needed for us to accurately define flow regimes. A still image from one such video appears above the MVU photo.

Rapid prototyping for new processes

Thomas G. Lestina
Vice President,
Engineering Services

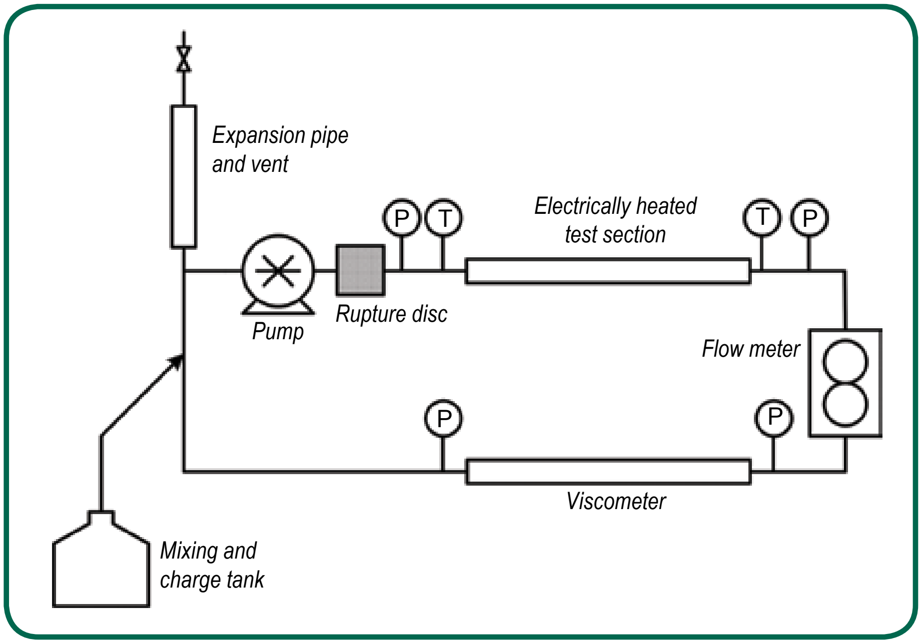
After we start consulting with a customer interested in a new process, we often recommend the building of a rig to test the heat transfer and pressure drop. Commercial simulators simply cannot provide sufficient confidence for processes with highly complex flows, non-ideal mixtures, slurries, or non-Newtonian or high fouling fluids.

A prototype process flow loop provides a wealth of data to ensure that heat exchanger designs will perform as predicted. Data which can be validated are

- apparent viscosities for the process fluid necessary to develop traditional heat transfer and pressure drop correlations
- specific heat of the process fluid to ensure heat exchanger duties can be predicted
- heat transfer correlations for design
- friction factor correlations
- fouling potential of the process fluid
- performance characteristics of heat exchanger geometries

The key to success is designing and building a flow test rig quickly. To design smartly, we use targeted CFD simulations of proposed designs to increase the probability of success and thus prevent costly rework. A test rig can be completed within three months, although long lead-time components are usually a critical path. Once a rig is completed, results of each test can be immediately directed to improve design criteria for heat transfer equipment in the new process.

If you are designing a new process, HTRI may be able to help you develop design criteria for heat transfer equipment as well as design and build a process test rig. Contact us at Contracts@HTRI.net to find out how.



Recent prototype process test rig for viscous fouling slurry

How critical is critical pressure?

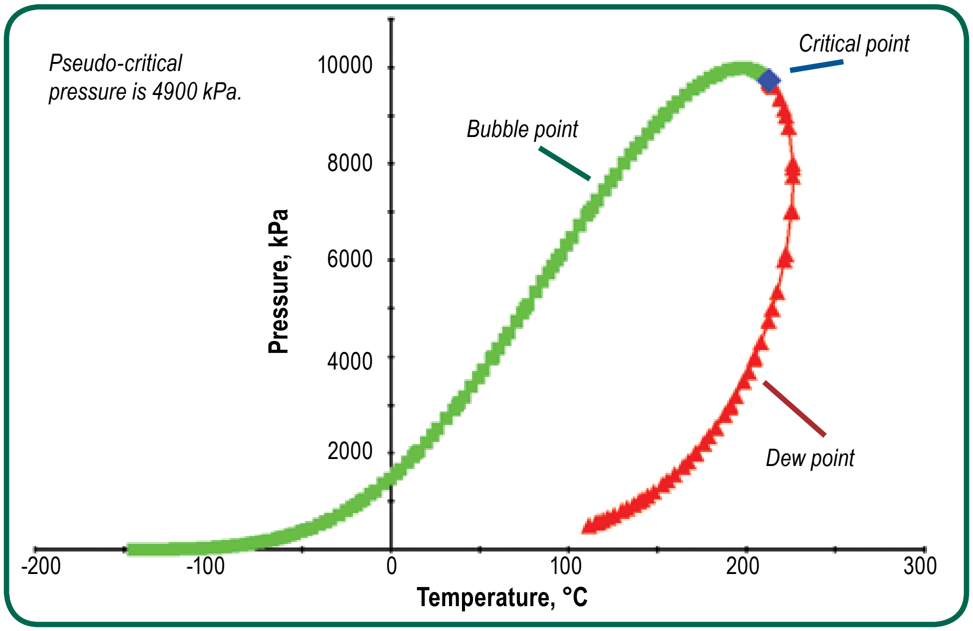
Andrew J. Mountford
Project Engineer,
Engineering Services

Engineering practice has long demonstrated that boiling characteristics of a fluid can be correlated with the reduced pressure, which is the operating pressure divided by critical pressure. Many literature methods for calculating the critical heat flux for film boiling are based only on reduced pressure.

Originally conceived for single-component fluids, these reduced pressure-based methods are attractive because they require only the operating and critical pressures to estimate heat transfer without other fluid properties. Extending this approach to accommodate multicomponent fluids means that the true mixture critical pressure must be accurate.

But arriving at such a determination is no easy feat—deriving the true critical pressure (from the critical pressures of the constituent components) depends on the mixing rules and the equation of state used.

Faced with this difficulty, many users resort to pseudo-critical pressure, which is generally obtained by taking the mole fraction average of the pure component critical pressures. However, HTRI does not recommend this approach because it can lead to *significant* inaccuracies, as evidenced by the mixture of ethane-benzene shown in the figure below.



Phase envelope diagram for 50:50 ethane-benzene mixture, showing calculated bubble points in green, calculated dew points in red, and the critical point in blue

Due to the challenges of calculating the true critical pressure and the consequences of inaccurate calculations, it is no wonder that HTRI intends to move away from reduced property-based methods altogether in favor of the physical property-based alternatives. In the meantime, we suggest a workaround: estimate the true critical pressure by increasing the operating pressure of a mixture until the dew and bubble points are identical. This approach is reported to provide satisfactory results provided that the proper fluid property model is selected.

Stay tuned to our website for a new TechTip on this subject.

The future of kettles

Thomas G. Lestina
Vice President,
Engineering Services

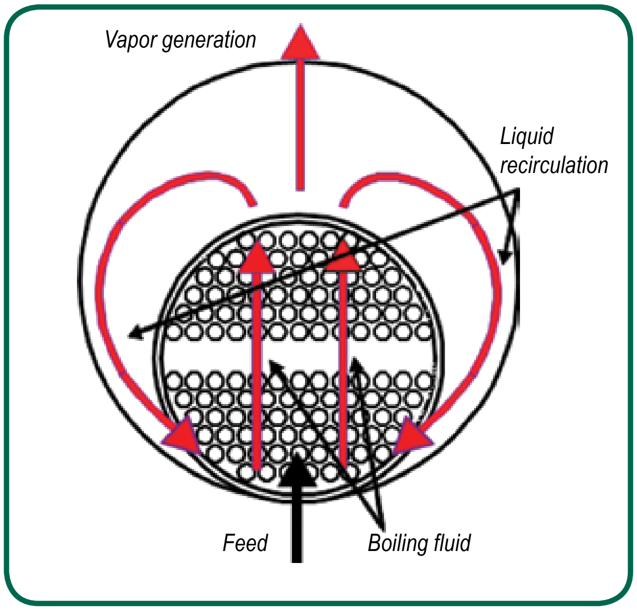
Based on the problems reported to us through our technical support and contract services, kettle reboilers and vaporizers can be an operating headache. Commonly reported problems include bundle dryout, low heat flux due to buildup of heavy components, and excessive entrainment.

Over the last several years, HTRI has increased our research into kettles to improve our understanding and the operating guidelines we provide our members. This research has taught us that the thermal hydraulics of kettle operation are far from simple:

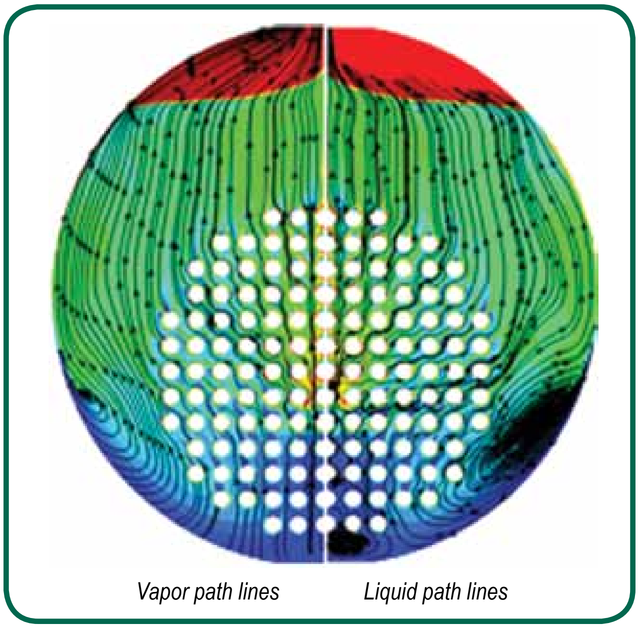
- the circulating two-phase flow patterns have 3D complexity—the flow varies not only from the bottom to the top of the bundle but also along the bundle length
- the “dome” of froth on top of the bundle and the entrainment distribution are difficult to predict from first principles
- the build-up and distribution of heavy components are challenging to predict

While we are confident that our continuing research will deliver improved thermal performance simulation methods to troubleshoot operating kettles and design new applications, we also observe a trend in industry to consider alternatives to kettles. For pure component vaporization, flooded evaporators, multipass horizontal tubeside evaporators, plate-frame and plate-fin geometries can be selected. For reboilers, horizontal shellside reboilers can be used. For traditional kettle applications such as amine reboilers, plate-frame applications are possible. These alternative geometries facilitate more precise thermal designs because the flow distribution patterns can be better predicted.

Kettle designs will not disappear anytime soon, but be sure to consider alternatives.

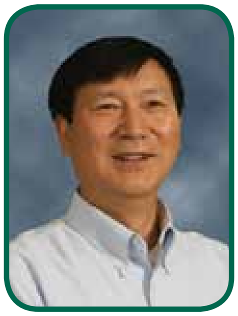


X*ist kettle circulation model*



CFD analysis of vapor and liquid circulation in a kettle

HTRI conducts experiments on condensation in vacuum



Zhihua "Frank" Yang
Manager, Research

Vacuum condensers have applications in the process and power industries. The complex, thermal hydraulic behavior of vacuum condensation and the lack of research data have limited the development of an accurate method for the design and rating of vacuum condensers. Many unresolved issues include the following:

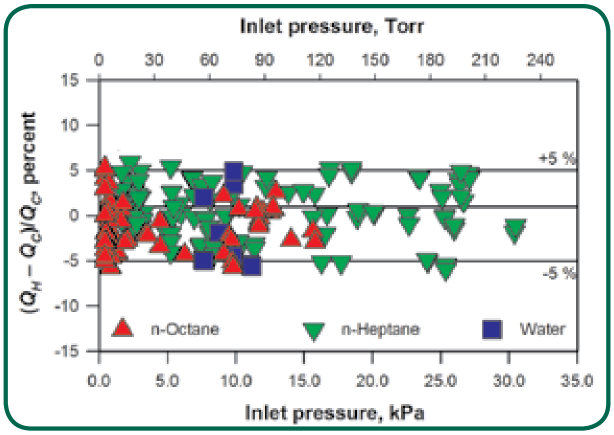
- Pressure drop (especially frictional versus momentum)
- Heat and mass transfer at high vapor shear
- Influence of noncondensable gases
- Vapor-liquid equilibrium
- Fluid physical properties
- Heat transfer of subcooled condensate

Very little research has been reported on vacuum condensation, especially under high vacuum conditions ($P < 6.9$ kPa or 52 Torr). A *torr* is approximately equal to one mmHg but is precisely 1/760 of an atmosphere.

Responding to HTRI users who need design guidance for condensers operating in these conditions, HTRI embarked on a multiyear research project in 2009. We designed the Low Pressure Condensation Unit (LPCU), shown at right, at the Research & Technology Center in Navasota, Texas, and completed its construction in 2010. The main flow loops of the LPCU include

The LPCU

- condensation
- cooling (primary refrigerant loop and second closed loop)
- noncondensable gas



Measured heat balance vs. inlet test pressure

The design pressure in the condensation loop ranges from 0.27 kPa (2 torr) to atmospheric pressure.

HTRI completed our first experiments on intube downflow condensation of pure components on the LPCU in 2011. Using three fluids, we collected data over a pressure range from 0.41 to 31.0 kPa (3.1 – 230.0 Torr). The graph at left presents the heat balance versus the inlet test pressure on the measured experimental data. The results show that the measured heat balance falls within ±6 percent for all data cases.

The experimental data from this ongoing research program will allow us to improve our heat transfer and pressure drop methods for condensation in high vacuum. At this time, we plan additional experiments to help us develop methods for

- tubeside condensation in the presence of noncondensable gases
- tubeside condensation of mixtures
- shellside condensation

More details are available to HTRI members in a recent publication, *Q 15-2: Vacuum Condensation: Experimental Capability and Initial Intube Data*, posted to the Member Center of our website at www.HTRI.net.

Customizing reports in *Xchanger Suite*

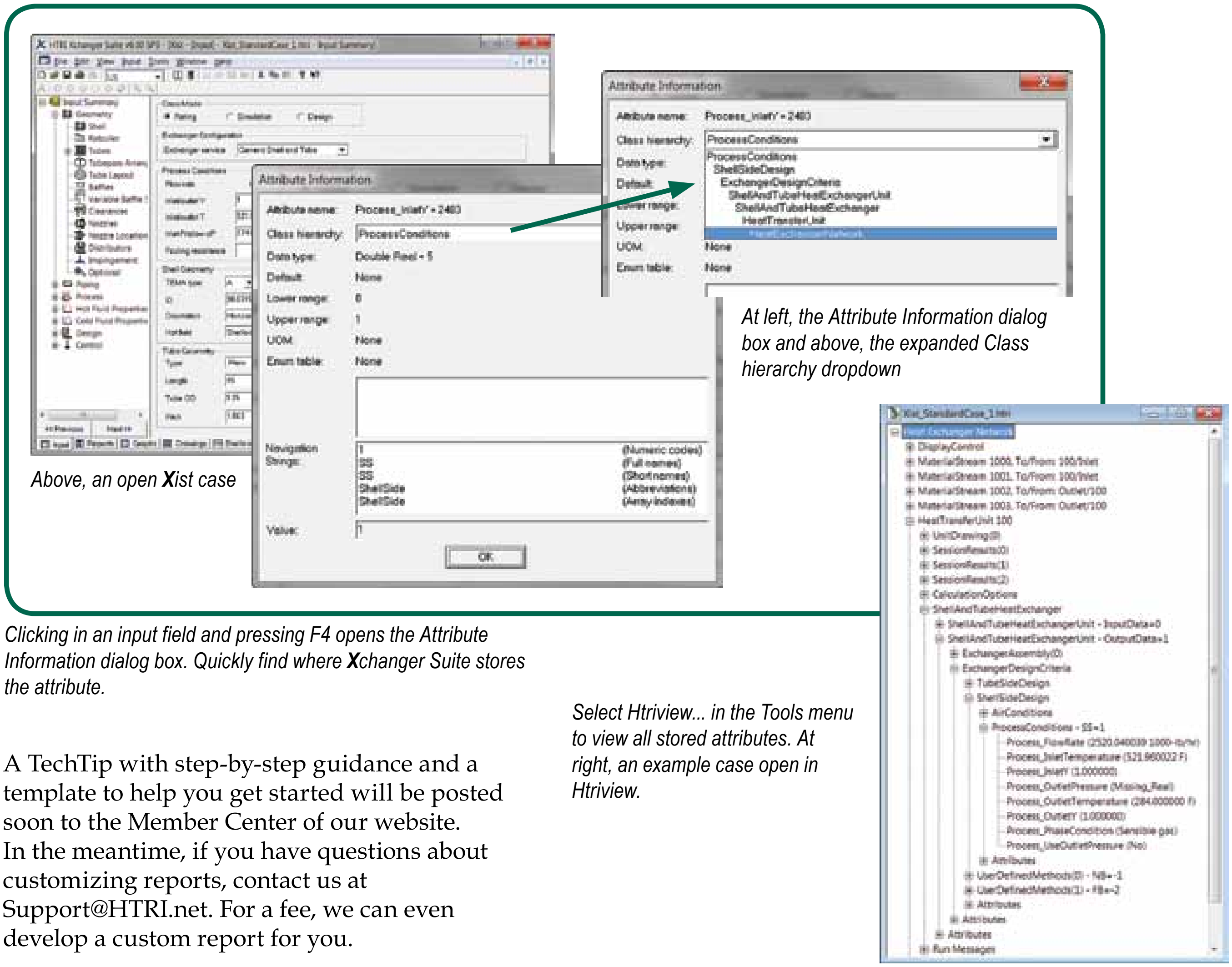
Lauren V. Moran
Engineer,
Engineering Services

Many of our members may not realize that they can generate a customized output report in Microsoft® Excel®. Through the automation server (*Xchanger Suite* COM interface), users can pull the required information from an *.htri file in Version 6 into Excel for modification. In Version 7 (not yet released), reports will use an Excel-based format to allow actual customization of existing output reports.

An Excel file is the most common format for custom reports. A spreadsheet is used to load output data from an *Xchanger Suite* run and extract these data into a custom data sheet. Sample Excel worksheets are included in the *Xchanger Suite* installation to demonstrate the use of Visual Basic to interface with Excel and the automation server. These files are called "XaceDemo.xls", "XistDemo.xls", and "XpheDemo.xls".

The most common questions about report customization that we receive in Technical Support involve attributes, navigation strings, and their location. In *Xchanger Suite*, click in an input field and press the F4 button (F9 for Version 7) to activate the Attribute Information dialog box, which displays the attribute name and the navigation string.

The Class hierarchy shows the location (in reverse order) where the attribute is stored. Htriview…, available in the Tools menu, shows all the stored attributes.



Above, an open *Xist* case

At left, the Attribute Information dialog box and above, the expanded Class hierarchy dropdown

Attribute name: Process_InletY - 2460
Class hierarchy: ProcessConditions
Data type: Double Real - 5
Default: None
Lower range: 0
Upper range: 1
UOM: None
Enum table: None

Navigation Strings:

```
1                (Numeric codes)
SS               (Full names)
SS               (Short names)
ShellSide        (Abbreviations)
ShellSide        (Array indexes)
```

Value: 1

```
ProcessConditions
 ShellSideDesign
  ExchangerDesignCriteria
   ShellAndTubeHeatExchangerUnit
    ShellAndTubeHeatExchanger
     HeatTransferUnit
      HeatExchangerNetwork
```

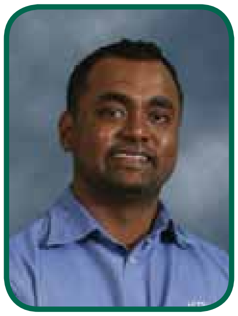
Clicking in an input field and pressing F4 opens the Attribute Information dialog box. Quickly find where ***X**changer Suite* stores the attribute.

Select Htriview... in the Tools menu to view all stored attributes. At right, an example case open in Htriview.

```
Heat Exchanger Network
  DisplayControl
  MaterialStream 1000, To/From: 100/Inlet
  MaterialStream 1001, To/From: 100/Inlet
  MaterialStream 1002, To/From: Outlet/100
  MaterialStream 1003, To/From: Outlet/100
  HeatTransferUnit 100
    UnitDrawing(0)
    SessionResults(0)
    SessionResults(1)
    SessionResults(2)
    CalculationOptions
    ShellAndTubeHeatExchanger
      ShellAndTubeHeatExchangerUnit - InputData=0
      ShellAndTubeHeatExchangerUnit - OutputData=1
        ExchangerAssembly(0)
        ExchangerDesignCriteria
          TubeSideDesign
          ShellSideDesign
            AirConditions
            ProcessConditions - SS=1
              Process_FlowRate (2520.040039 1000-lb/hr)
              Process_InletTemperature (521.960022 F)
              Process_InletY (1.000000)
              Process_OutletPressure (Missing_Real)
              Process_OutletTemperature (284.000000 F)
              Process_OutletY (1.000000)
              Process_PhaseCondition (Sensible gas)
              Process_UseOutletPressure (No)
            Attributes
          UserDefinedMethods(0) - NB=-1
          UserDefinedMethods(1) - FB=-2
          Attributes
        Attributes
      Attributes
  Run Messages
```

A TechTip with step-by-step guidance and a template to help you get started will be posted soon to the Member Center of our website.
In the meantime, if you have questions about customizing reports, contact us at Support@HTRI.net. For a fee, we can even develop a custom report for you.

Understanding the fundamentals of crude oil fouling

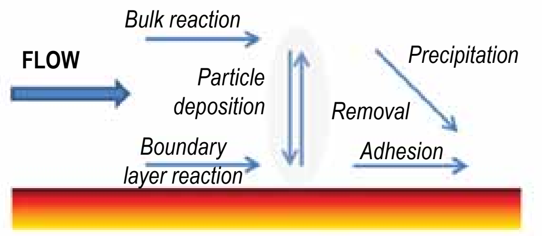


Cecil A. Coutinho
Engineer, Research

The formation of deposits on the heat transfer surfaces is one of the most severe problems in the design and operation of heat exchangers. In most industrial applications, fouling causes inefficient heat transfer, which increases fuel consumption, emission of greenhouse gases, and the development of toxic deposits. While several types of fouling processes (coking, corrosion, asphaltene decomposition, crystallization) can occur simultaneously, insight into the chemical properties of the fluid can provide engineers the ability to predict the performance degradation of units and plan accordingly.

The primary objectives of the HTRI crude oil fouling research program include

- identifying and quantifying key variables affecting crude oil fouling
- examining fouling deposit characteristics
- determining the effect of the crude oil chemistry on fouling behavior
- developing appropriate and relevant mitigation strategies



Multistep fouling mechanism

By examining the ways that fouling changes the crude oil composition, analyzing the deposits, and identifying characteristic fouling rate behavior, we can determine the dominant fouling mechanism, which enables us to develop targeted mitigation techniques. The diagram above demonstrates the complexity of the crude oil fouling processes. Identifying the dominant fouling mechanism requires consideration of mass transfer, heat transfer, and fluid mechanics, before chemical and/or physical mitigation approaches can be developed.

At least partial understanding of the mechanisms of the deposition process, the structure of the deposits, and the factors which govern adhesion to the heat transfer surfaces is necessary to develop and implement methods to reduce fouling. At HTRI, we aim to isolate and evaluate the various fouling mechanisms that are typically seen in crude, and develop mitigation strategies that address and reduce its development. With an in-house fouling rig (the High Temperature Fouling Unit), we also conduct proprietary fouling tests at conditions of temperature, shear, and pressure that mimic refinery conditions. More information is available to our members in technical articles and reports posted to the Member Center of our website, www.HTRI.net.

Puzzler—Phase-Change Regimes

Solution on page 20

Unscramble the letters on the left to make words related to phase-change regimes. Then use the circled letters from those words to form the answer on the right.

RTGYAVI	☐☐☐○☐☐○
ALNRMAI	○☐☐○☐☐☐
ELNUTUBRT	☐☐○☐☐☐○☐☐
SEAHR	○☐○☐○
LEODOCUBS	☐☐☐☐☐☐○○☐
VCVEICENOT	☐☐☐☐☐☐○☐☐○
TUNACEEL	☐○☐☐☐☐○☐
HUAREEPSEDT	○☐○☐○☐☐☐☐☐☐

Why Johnny enjoyed his work in vacuum distillation:

○○○○ ○○○○○○
○○○○○○○○

HTRI designs a new fouling test unit

James T. Schaefer, Jr.
Project Engineer,
Engineering Services

HTRI Engineering Services and Research personnel have teamed up to design a new fouling test unit, which will not only allow us to meet the increasing demand for proprietary contracts but also expand our crude oil fouling research.

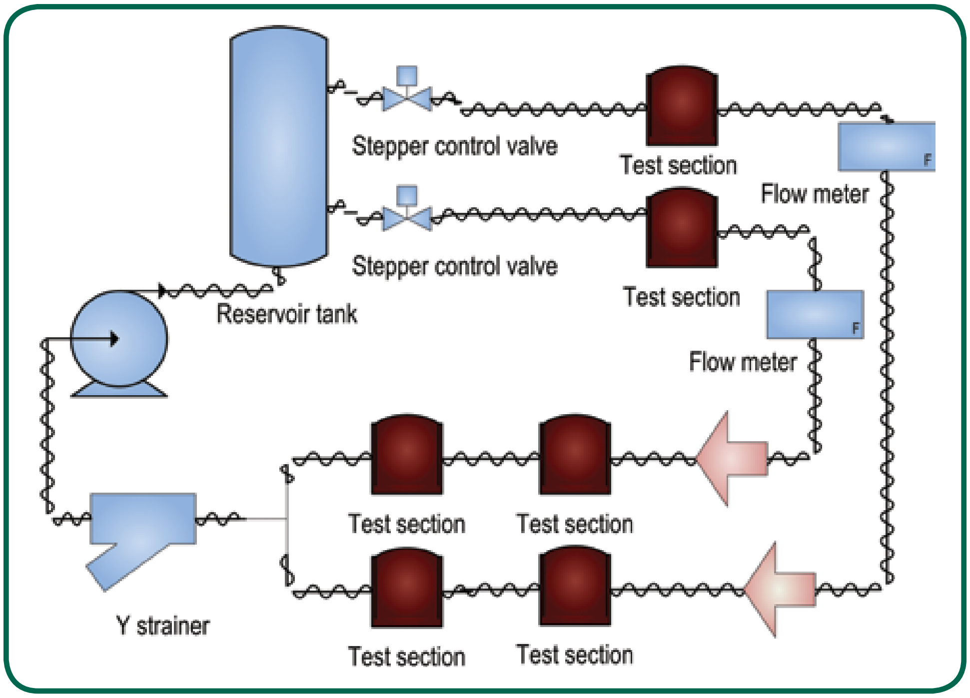
Similar in concept to the existing High Temperature Fouling Unit (HTFU), the new unit heats a charge of crude oil in circular test sections to controlled wall temperature and shear stress conditions. With this unit, we can test most refinery product and by-product streams. Other design parameters for the new rig include the following:

- Design pressure: 6895 kPag (1000 psig)
- Design temperatures: 343 °C (650 °F) bulk, 468 °C (875 °F) wall
- Test fluid charge volume: 49.2 L (13 gal)
- Test section ID: 6.4 mm (0.252 in.)
- Test section velocities: less than 3.2 m/s (10.6 ft/s)

A key feature of the new fouling unit is the capability to test two different shear stresses, each at three different temperatures simultaneously, as shown in the Process and Instrumentation Diagram (P&ID) below. This capability can reduce the amount of time required to complete a test matrix or group of test points for proprietary contracts.

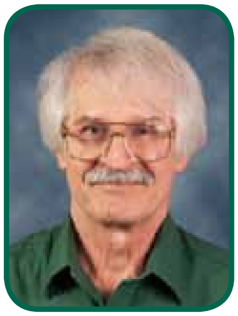
We plan to duplicate the components that work well in the current HTFU (i.e., the canned motor slurry pump, intube test section, electrical furnace heaters, and coriolis mass flow meters) while we improve others (adding stepper motor flow control valves, removing the bypass line around the test section, and decreasing contact with the nitrogen blanket) where we can. We are now reviewing the design and may start building the rig in 2012.

If you are interested in evaluating the fouling propensity of a new crude or crude blend, contact Contracts@HTRI.net.



Basics in tube layout

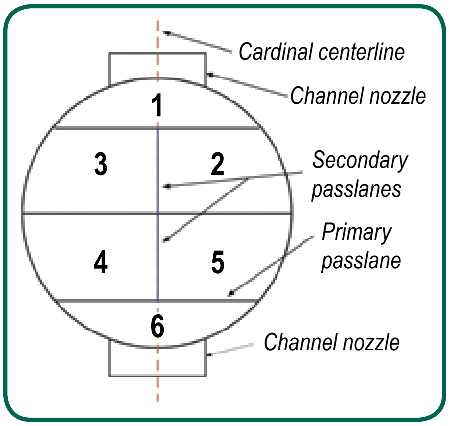
Specifying an H-banded layout



Richard L. Shilling
Sr. Engineering Consultant

HTRI is rewriting our tube layout program for *Xist* 7, providing new layout options. This article introduces a few of the new types that will be available.

H-type tube layouts provide for effective tubecounts with approximately equal numbers of tubes per pass when six or more tubepasses are needed. The figure below shows the most common H-type layout, the H-type 3 layout. This geometry features a single tubepass at the top and bottom of the bundle and only two secondary pass partitions on the cardinal centerline. This type is limited to even tubepasses and may not allow for a maximum tubecount.



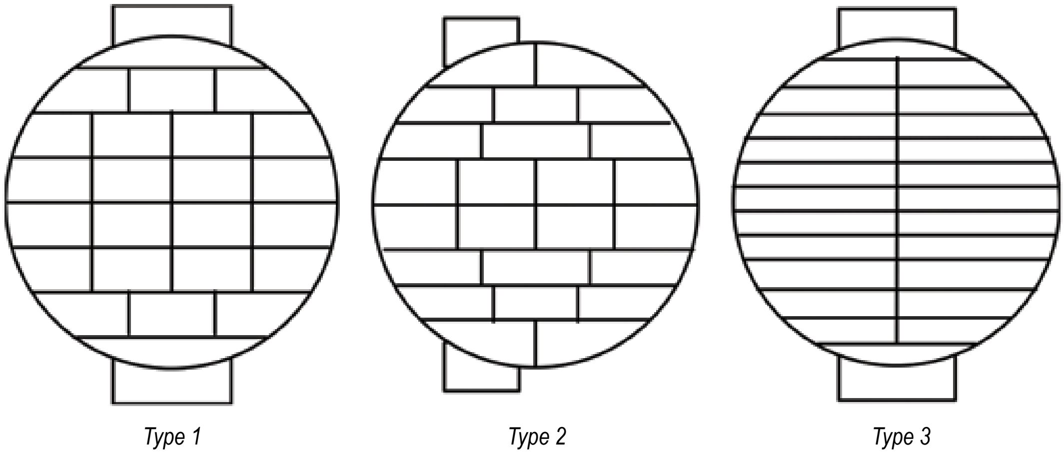
Typical H-type layout for a design with six tubepasses

Xist 6 is capable only of H-type 3 layouts. *Xist* 7 adds type 1 and type 2 H-type layouts:

- H-type 1 layout: This layout has only one tubepass at the top and bottom of the bundle. Between primary passlanes, more than two tubepasses are possible so that some secondary passlanes may be placed off the cardinal centerline.
- H-type 2 layout: Two tubepasses are located above and below the top and bottom primary passlanes. As with H-type 1 layouts, more than two tubepasses may be set between primary passlanes.

When tube layouts were drawn by hand, type 1 and type 2 layouts were more common than type 3 layouts for more than eight tubepasses. The H-type 1 and 2 layouts were developed around the principle that a more "square" pass area requires less passlane perimeter, leaving more area available for tubes. In addition, type 1 and 2 layouts can accommodate both even and odd tubepasses.

For fewer than ten tubepasses, the differentiation between layout types often disappears. A six-pass H-type 1 layout is identical to a six-pass H-type 3 layout, and a six-pass H-type 2 layout is identical to a six-pass quadrant layout. The



H-type layouts with 24 tubepasses (channel nozzles shown)

H-type 1 and 2 layouts are intended for more than six tubepasses.

To illustrate the advantages of H-type 1 and 2 layouts, consider 24 tubepasses in a shell of 1829 mm (72 in.) in inside diameter, with tubes of 19 mm (¾ in.) in outside diameter on a 24-mm (15/16-in.) triangular pitch. Tubecounts for different layouts are shown in the table at right.

Layout Type	Effective Tube Count	% Increase in Area over Ribbon
Ribbon	4006	0.0
Quadrant	4550	13.6
H-type 1	4730	18.1
H-type 2	4724	17.9
H-type 3	4550	13.6

The increase in area is obvious. For smaller shells with the same number of tubepasses, the percent increase in area from an H-type 3 layout to an H-type 1 or type 2 layout is even greater.

AIChE students tour the RTC

In March 2011, HTRI was visited by students representing several universities participating in the AIChE Regional Student Conference held at Texas A&M University (TAMU), College Station, Texas. HTRI staff provided a tour of our Research & Technology Center and answered questions related to heat transfer, how we conduct our experimental programs, and how the membership helps guide our efforts. We would like to thank TAMU students Scott Hailey and Phillip Schneider, as well as Dr. John Baldwin for their interest and assistance in coordinating the site visit.

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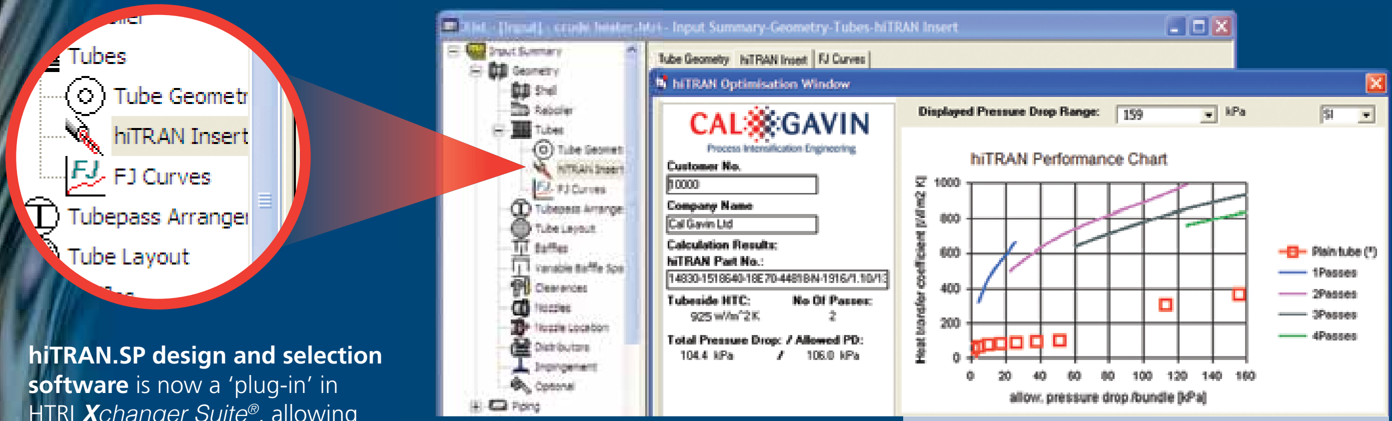

Customer No.
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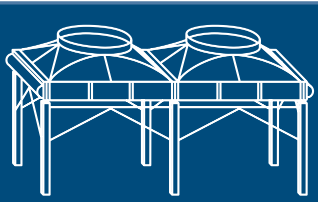
Company Name
Cal Gavin Ltd
Calculation Results:
hiTRAN Part No.:
14830-1518640-18E70-4481BN-1916/1.10/13
Tubeside HTC: 925 W/m^2 K
No Of Passes: 2
Total Pressure Drop: / Allowed PD: 104.4 kPa / 106.0 kPa
Displayed Pressure Drop Range: 159 kPa SI

Heat transfer / Pressure drop / Pass arrangement

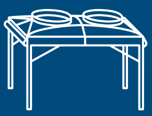
hiTRAN
Matrix Elements remove the boundary layer allowing heat transfer increase of up to 20 times

hiTRAN.SP design and selection software is now a 'plug-in' in HTRI ***X****changer Suite*®, allowing engineers to optimise the design of shell & tube and crossflow heat exchangers equipped with **hiTRAN** Matrix Elements.

Comparison design with and without hiTRAN



▲ Plain Bore Finned Tube

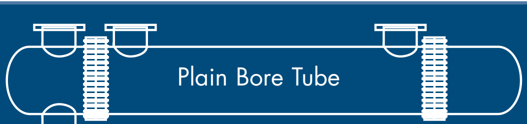


▲ hiTRAN System

Improved Design for an Aircooled lube oil cooler installed on a gas turbine driven compressor: Heat load 373kW

Design Comparison	Plain Bore Finned Tube	hiTRAN System
Number of rows x tubes/row	6 x 46	3 x 30
Tube length, mm	7925	3350
Number of tube passes	6	1
Heat transfer rate, W/m^{2}K	3.29	20.95
Oil pressure drop, kPa	71	71
Finned surface, m^2	3058	563
Total fan power, kW	11.8	5.0
Plot dimensions, m	2.74 x 8.54	2.05 x 3.96
Weight, kg	8500	2200

≈ Only $^1/_3$ of the plot area needed
≈ Same duty at same pressure loss
≈ Less than $^1/_2$ the fan power
≈ Allows lower noise level to be met
≈ Lowest cost option



Improved design for a shell and tube exchanger, cooling heavy cycle gas oil in a fluid catalytic cracking unit of an oil refinery.

Design Comparison	Plain Bore Tube	hiTRAN System
Shell diameter	1524	689
Number of tubes	1828	371
Tube length, mm	6096	6096
Number of tube passes	8	1
Effective surface area, m^2	874	179
Heat transfer rate, W/m^{2}K	40	182
Tubeside pressure drop, kPa	70	70

≈ Only $^1/_4$ of the effective area needed
≈ Same duty at same pressure loss
≈ Lighter, simpler construction
≈ Further economy possible with low-fin tube
≈ Lowest cost option

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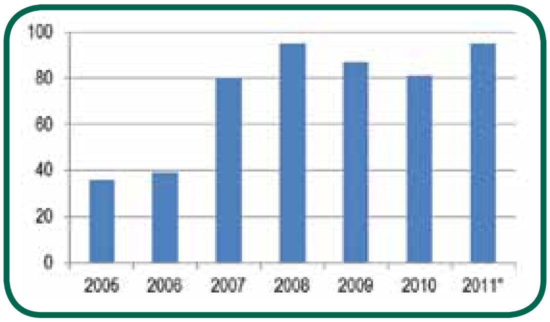
Membership growth picks up again

After record growth in Fiscal Year 2008 was followed by a slight slowdown as the economy took a downturn during the last few years, HTRI is again recruiting new members at a very good pace. With two months left in the current fiscal year, we have already recruited 95 new members, matching the largest number of new members achieved in any previous year. The chart below shows the number of new members recruited since 2005. We are working hard to exceed the 100 mark this year and make it the best year ever.



*New HTRI members (*through May 2011)*

Although the success of the Sales team depends primarily on the quality of our research and software products, it is important for us to develop, communicate, and implement a good sales strategy. Since 2006, we have held Sales meetings every 12 to 18 months, bringing together all worldwide sales staff and sales representatives in one location. These meetings also provide sales representatives the opportunity to interact with HTRI staff and learn about our latest developments. Our most recent Sales meeting was held in May 2011 at our new facilities in Navasota, Texas.

We recently completed our first HTRI Latin American Meeting in Mexico. We conducted most presentations and two of the three workshops in Spanish. Each session was well received by the 30 or so participants that attended.

We have many other opportunities to meet with members and prospects during the rest of 2011. A summary follows for each of our regions. Additional details are available in the Upcoming Events section of the HTRI website.

Asia-Pacific

- HTRI Asian Meetings (Seoul, Korea; Beijing, China; Yokohama, Japan)
- INCHEM TOKYO 2011

EMEA

- MIOGE 2011 (Moscow, Russia)
- WTT Expo (Karlsruhe, Germany)
- HTRI European Meeting (The Hague, The Netherlands)

India

HTRI Asian Meeting (New Delhi, India)

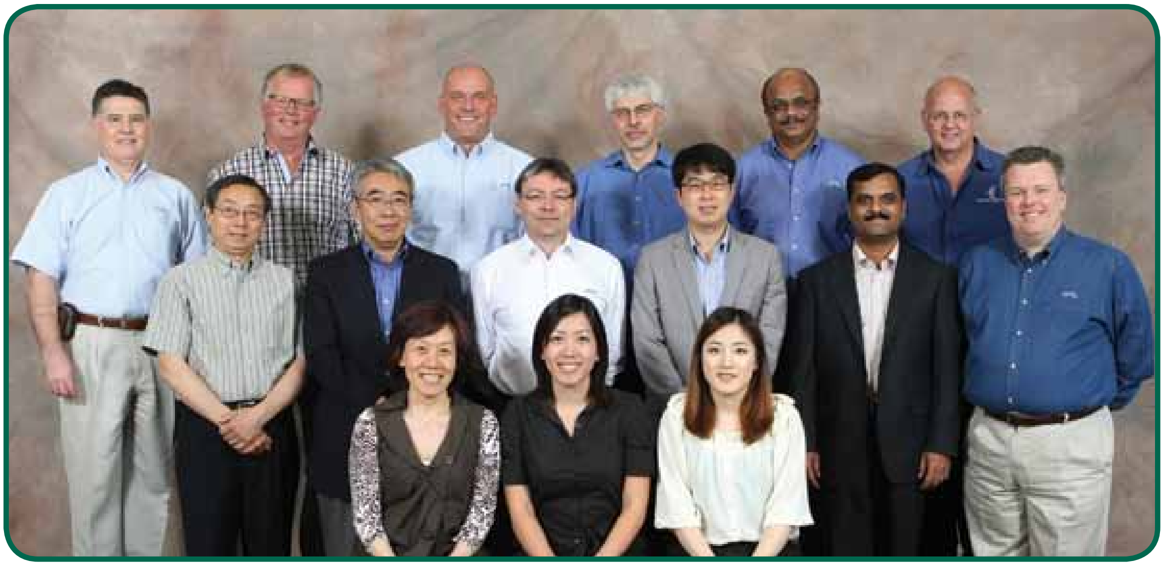
Southeast Asia

HTRI Asian Meeting (Singapore)

USA/Canada

- ChemInnovations 2011 (Houston, Texas, USA)
- HTRI Annual Meeting of Stockholders and North American Meeting (Amelia Island, Florida, USA)
- 2011 AIChE Process Technology Conference (Galveston, Texas, USA)

Fernando J. Aguirre
Vice President, Sales &
Business Development



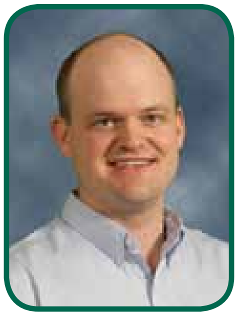
HTRI Sales Team and Representatives

Top row (left to right):
Fernando J. Aguirre, Bert Boxma (The Netherlands), Hans U. Zettler (EMEA), Andrea Bordoni (Italy), Rajan Desai (India), Christo van den Heever (South Africa)

Middle row (left to right):
Baozuo Sun (China), Hirohisa Uozu (Asia-Pacific), Sergei Demenok (Russia), Alex Kim (Korea), Yuvaraj Munirathinam (Middle East), Greg Starks (USA/ Canada)

Bottom row (left to right):
Fang Zhao (China), LiAnne Choong (Southeast Asia), Sunny Lee (Korea)

Seeing clearly through mixed convection in heat exchangers



J. Brandon Dooley
Engineer, Research

Christy M. Laird
Engineer, Research

Designing and rating shell-and-tube heat exchangers for mixed convection conditions can, for some of us at least, induce strong feelings of disorientation and confusion, much like trying to decipher a distant object obscured by a mirage. Ironically, understanding a little more about some of the physical phenomena that give rise to mirages can offer greater clarity into the inner workings of mixed convection in process heat transfer equipment.

Natural convection occurs as a result of buoyancy-driven circulation caused by local temperature-induced density gradients in a fluid. As a fluid is heated, the warmer, less dense fluid rises and simultaneously is replaced by cooler, denser fluid.

In the most common type of mirage, air near the ground is heated and rises to form an unstable, inverted stratum with the cooler air above. This phenomenon, coupled with the fact that the refractive index of air varies with density, ultimately produces the well-known optical illusions observed in a mirage.

When natural convection occurs in heat exchanger tubes or tube bundles, the warmer fluid generally rises and stratifies in the upper regions of the exchanger. When present with forced convection, natural convection can significantly affect heat transfer.

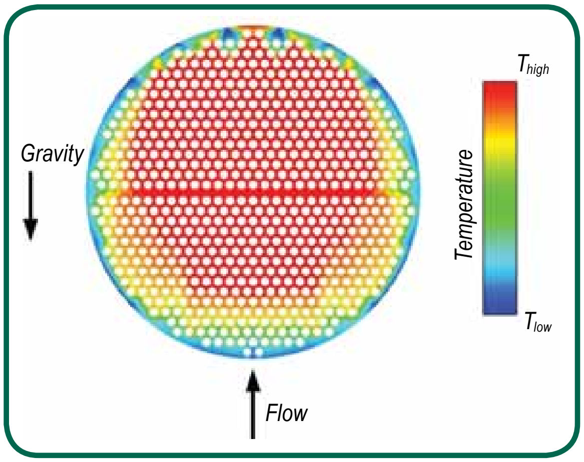


Figure 1. In-plane temperature contours for laminar shellside vertical crossflow with mixed convection

Do you see the lake in the picture? The "water" is actually an image of the sky above produced by an inferior mirage (the most common type), photographed by Mila Zinkova on April 4, 2007, in the Mojave Desert near Primm, Nevada.

We can more precisely quantify the extent of natural convection in a thermal-fluid system by comparing two classic dimensionless quantities:

1. the Grashof number, Gr, which is the ratio of buoyant and viscous forces in a fluid

2. the Reynolds number, Re, which is the ratio of inertial and viscous forces in a fluid

Scaling analysis shows us that if $Gr \gg Re^2$, the buoyant forces in the fluid are much larger than the inertial forces, and consequently, heat transfer occurs primarily through natural convection. On the other hand, if $Re^2 \gg Gr$, inertial forces dominate, and forced convection is the controlling heat transfer mechanism.

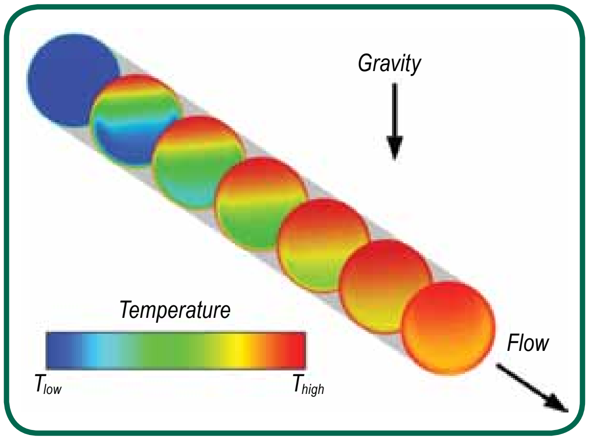


Figure 2. Intube temperature contours for horizontal laminar tubeside flow with mixed convection

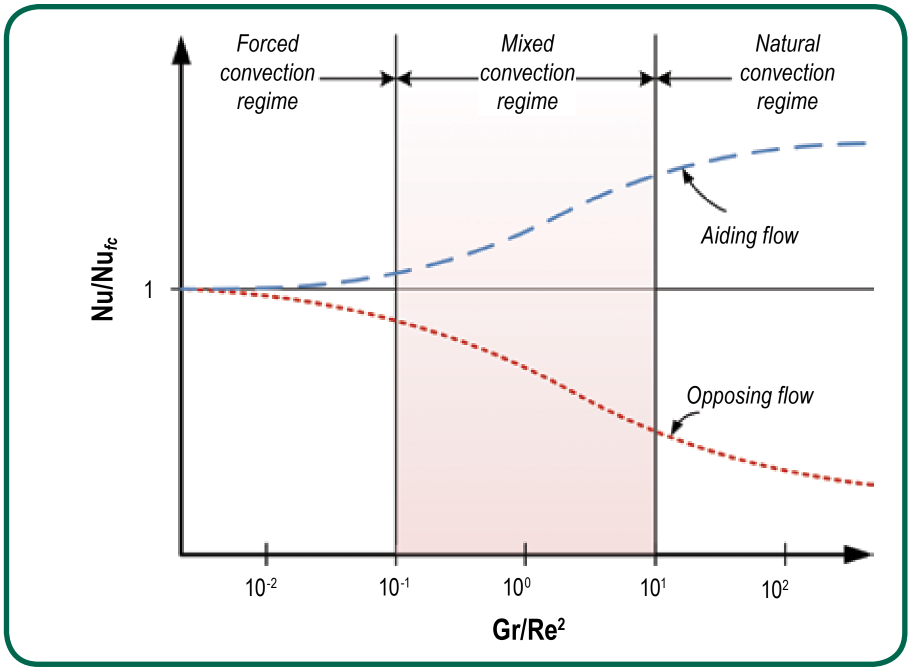


Figure 3. Representative example of Nusselt number versus Gr/Re^2 for laminar heat transfer convection regimes with aiding and opposing flow

When Gr and Re^2 are of the same order of magnitude, however, both forced and natural convection mechanisms contribute comparably to heat transfer in what is otherwise known as mixed convection.

While many process heat exchangers are designed with forced convection heat transfer in mind, mixed convection can become an important consideration in some instances. For example, in an exchanger design that requires a supplementary rating for turndown conditions, mixed convection can significantly impact the accuracy of heat transfer predictions, particularly in the laminar flow regime. Much of the uncertainty associated with mixed convection stems from the by-products of thermal stratification and flow maldistribution, as illustrated by the CFD-generated temperature contours plots shown in Figures 1 and 2 for shellside and tubeside flows, respectively.

For cases such as those depicted in Figures 1 and 2, traditional laminar forced convection correlations will underpredict heat transfer because of the aiding effect provided by natural convection in these flow configurations. While we consider such aiding flows to be conservative from a design perspective, the thermal engineer must still use caution when working with mixed convection because heat transfer can be impaired when fluid buoyancy opposes the primary flow. The implications of aiding and opposing flow on heat transfer are illustrated by the variation of the Nusselt number (relative to that of pure forced convection) with Gr/Re^2 shown in Figure 3.

The situation becomes even more complicated when we consider flows in the transition and turbulent regimes. The buoyancy-driven circulations associated with mixed convection generally render laminar flows more susceptible to undergoing early transitions to turbulence. And in the turbulent flow regime, the effects of the aiding and opposing flow configurations can be opposite of those associated with laminar flow. For example, aiding flow in the turbulent regime can actually impair heat transfer due to the local suppression of turbulent kinetic energy (a phenomenon known as laminarization).

HTRI continues to work toward greater understanding of mixed convection phenomena in both shellside and tubeside flows. Our research enables us to improve the accuracy and fidelity of our physical heat transfer models and, in turn, helps our members to see more clearly through the mirage of complexities that mixed convection can cause.

HTRI welcomes new staff and announces promotions

We recently added new staff to our team.

- David B. Gibbons, Senior Project Engineer, Engineering Applications
- Julie A. Goss, Coordinator, Marketing
- Garrett G. Makovicka, Desktop Support Specialist
- Jason D. Chambless, Applications Developer
- R. Wade Gilbert, Research Technician
- Christina A. Chasse, Administrative Assistant
- Kendra B. Cocek, Administrative Assistant

Congratulations are extended to recently promoted staff and those who assumed new roles.

- Hans U. Zettler, Director of Sales, EMEA
- LiDong Huang, Manager, Research
- Zhihua "Frank" Yang, Manager, Research
- Amy J. Pilkington, Coordinator, Administrative Support; Senior Administrative Assistant, Office of the President

Solution to Puzzler *on page 12*

Scrambles:
GRAVITY
LAMINAR
TURBULENT
SHEAR
SUBCOOLED
CONVECTIVE
NUCLEATE
SUPERHEATED

Answer:
Why Johnny enjoyed his work in vacuum distillation—
VERY LITTLE PRESSURE

Recent presentations and publications

R. R. Desai and P. KrishnaMurthy, Product-life-cycle evaluation of heat exchanger performances for plant's process thermal engineering needs using HTRI *Xchanger Suite* modules and pinch analysis using HEXTRAN, presented at Institute of Technology, Nirma University, Ahmedabad, India, June 30, 2011.

L. Huang and K. J. Farrell, Bouyancy effect on forced convection in vertical tubes at high Reynolds numbers, *J. Thermal Science and Engineering Applications* **2**(4), 041003-1 – 041003-6 (2010).

T. G. Lestina, Selecting a heat exchanger shell, *Chem. Eng. Progress* **107**(6), 34 – 38 (2011).

J. M. Nesta and C. A. Coutinho, Update on designing for high-fouling liquids, *Hydrocarbon Processing* **90**(5), 83 – 86 (2011).

V. Sathyamurthi and J. T. Schaefer, The importance of research, *Process Heating* **18**(5), 15 – 17 (2011).

R. L. Shilling and F. J. Aguirre, Improved methodology for specifying margins in heat exchanger design, in *Proc. Seventh International Starch Technology Conference*, University of Illinois, Urbana, Illinois, USA, June 5 – 8, 2011.

R. L. Shilling, M. P. Rudy, and T. M. Rudy, Risk-based design margin selection for heat exchangers, *Heat Transfer Engineering* **32**(3-4), 307 – 313 (2011).

Technical publications issued

November 2010 – July 2011

Reports

CS-15	Shellside reflux condensation methods
CT-25	Condensation heat transfer in micro-finned tubes: Review of literature methods
CT-26	Flooding in inclined tubes

Q

***Q* 15-1**	Flow boiling with limited vaporization
***Q* 15-2**	Vacuum condensation: Experimental capability and initial intube data

The Member Center on the HTRI website provides access in the Technical Documentation section to reports and to ***Q*** articles. Access requires the installation of HTRI e-Library and an Internet connection.

Your access to information in the Member Center is based on your membership category. If you would like to upgrade your membership to gain access to material not currently available to you, please contact Membership@HTRI.net.

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November 2010 – May 2011

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HTRI ***X**changer Suite* 6.0
Service Pack 3

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***X**jpe* ***X**phe* ***X**spe* ***X**tlo*
***X**vib*

HTRI ***X**changer Suite Educational*

HTRI e-Library 2.0

Software distributed by HTRI

EHT 2.2

RCSWin..............................05.03.2011

Honeywell UniSim®
Heat Exchangers........................ R400
UniSim CFE, UniSim FPH, UniSim FWH, UniSim PFE, UniSim PHE, UniSim PPL, UniSim STE

To order HTRI software updates, e-mail **Orders@HTRI.net**

upcoming events

Research Update: Shellside Reflux Condensation
August 18, 2011
Webinar

TechTip: Modeling Horizontal Thermosiphon Oil Coolers
September 8, 2011
Webinar

ChemInnovations 2011
September 13 – 15, 2011
George R. Brown Convention Center
Houston, Texas, USA

WTT Expo
September 27 – 29, 2011
Karlsruhe Trade Fair Center
Karlsruhe, Germany

Research Update: Condensation Inside Micro-finned Tubes
October 6, 2011
Webinar

For more details, see Upcoming Events at www.HTRI.net