Case Study

Overview

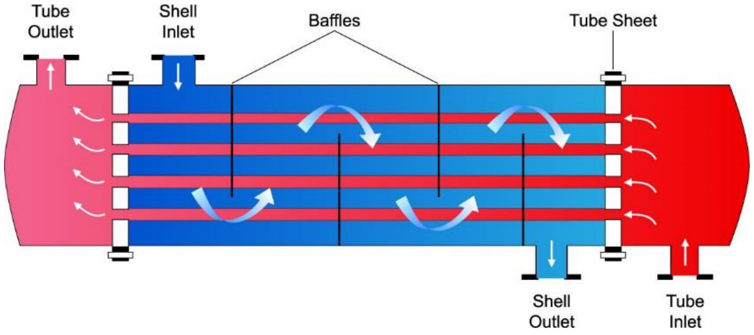
Heat exchangers, evaporators and reactors are integral pieces of equipment within many industrial processes including chemical refining, pharmaceutical production and food processing.

By necessity this equipment is sealed, opaque and in many cases involves fluids that are corrosive, flammable or explosive. These conditions, combined with the limitations of point sensing restrict how performance is measured.

In many cases it is essential to obtain a much clearer picture of performance inside the equipment.

- in order to optimize the process and maximize yield
- to reduced equipment cost
- to ensure proper equipment/process operation under conditions of normal degradation, fouling, scaling

A typical Shell and Tube Heat Exchanger



The Problem - Heat Exchanger Characterization

The Technical University of Braunschweig collaborated with CALGAVIN LTD of Alcester UK to optimize the design of a heat exchanger used in the processing of Hexanol. The goals of this design optimization were to minimize both the size and cost of the heat exchanger as well as to optimize the heat transfer process for maximum yield under all operating conditions.

The Challenge

Measuring inside of heat exchangers with traditional point sensors is difficult and yields inadequate information for an effective design optimization.

- Traditional point sensors introduce a source of ignition that is not compatible with a flammable substance such as Hexanol
- Each data point requires an individual sensor and lead routed to the data acquisition unit
- The size of the lead harness makes the ingress into the heat exchanger challenging. It’s size and weight can impact the process being measured
- The limited number of data points provides insufficient data to fully characterize heat transfer and changes in phase

A Heat Exchanger for Condensing Hexanol

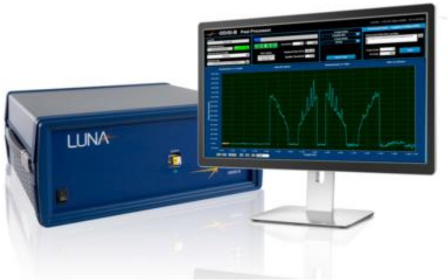
The Solution

High Definition Fiber Optic Sensing System

Luna’s High Definition Distributed Fiber Sensing (HD-FOS) solution uses a single sensor to provide thousands of temperature sensing points **inside** the heat exchanger.

The Interrogator

An ODiSI system with high definition fiber optic sensing (HD-FOS) was used in this test to make a high definition distributed measurement inside the heat exchangers. At right is Luna’s ODiSI system.



The Sensor

The heat exchangers were instrumented with an HD-FOS temperature sensor. These sensors are lightweight, low profile and can easily be installed within challenging environments. The sensors are EMI immune and use no electrical signal (no source of ignition)

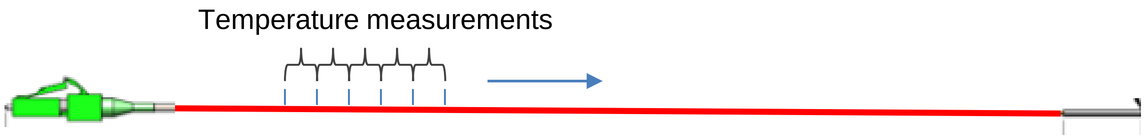
The Switch

An (8) channel optical switch can be used to serially interrogate multiple sensors. Luna offers both an (8) and (36) switch that can convert a single channel interrogator into a multi channel system

A Solution for Characterizing Heat Transfer Inside the Heat Exchanger

A high definition fiber optic sensing system was used to measure temperature inside the heat exchanger and provide a distributed temperature measurement of the Hexanol being condensed by circulating water. The distributed temperature probe was constructed by inserting a high definition fiber optic sensor inside a stainless steel capillary tube. This single low profile sensor could be easily inserted inside the heat exchanger and provide a temperature measurement every millimeter along the length of temperature sensor.

A 1 mm gage length and a 2m fiber sensor can provide up to 2000 distinct temperature measurements



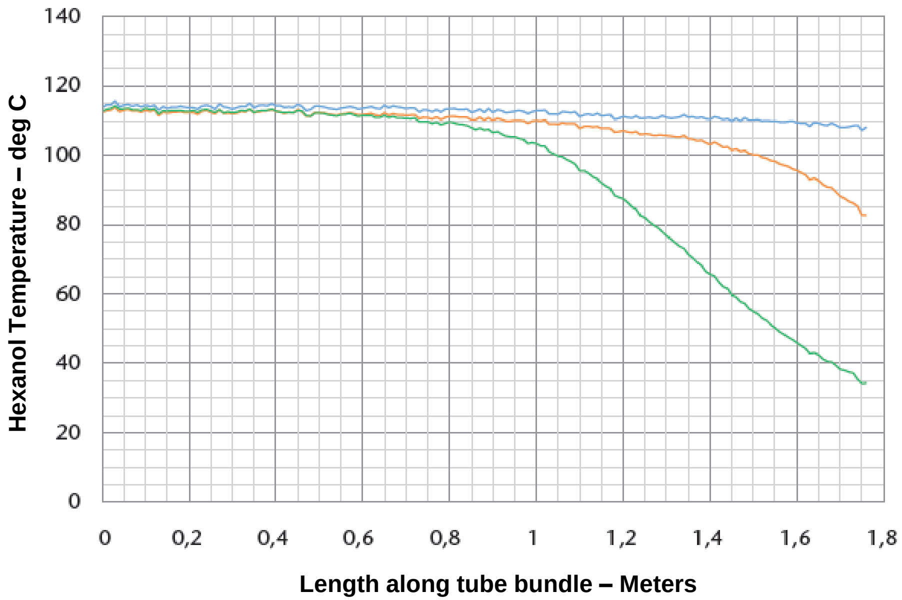
The fiber sensor is inserted inside a stainless steel capillary tube

The Results

As a result of using Luna's ODiSI with high definition fiber optic sensing, changes were made in the design of the cooling tube layout to improve performance at reduced heat exchanger cost. Furthermore, a deeper understanding of the operating envelope under varied operating conditions was obtained.

- A profile of the Hexanol condensing temperature vs. heat exchanger location was recorded at cooling water temperatures of 40 C, 60 C and 80 C.
- At 40 C the Hexanol was fully condensed however it was observed that in some locations within the heat exchanger excess cooling was provided
- At 60 C it was observed that full condensation was delayed deeper into the heat exchanger
- At 80 C condensation of the Hexanol did not occur

The profile of the condensing point of Hexanol. Test conducted with cooling water temperatures of 40C, 60C and 80C
Heat exchanger pressure = 200 mbar



Heat Exchanger Cooling water temperature

- **80 C**
- **60 C**
- **40 C**

Conclusions

- **Unprecedented In-Situ Sensing Capability:** A High Definition Fiber Optic Sensor, with it's flexibility and low profile, was successfully embedded inside a heat exchanger condensing a flammable substance. The sensor was able to provide a complete characterization of the condensation process across the length of the heat exchanger.

- **Optimization of Heat Exchanger Design Reduces Cost:** Heat exchanger design can be optimized to reduce material cost while maintaining the same, or improved, performance. For industrial scale heat exchangers the cost reduction can be substantial.

- **Understand the Performance Envelope Under All Operating Conditions:** In this application the parameters of cooling water temperature and condenser pressure were varied to understand the impact on the condensing process. Additionally, an operating envelope could also be defined that reflects a degradation of the heat exchanger due to fouling and scaling of the cooling tubes.

- **Maximize Process Yield:** In many cases a precise control of 'product' temperature at specific pressures is essential for maximizing yield. A full characterization of these relationships is critical in the pilot plant stage.

Other Applications and Markets

Pharmaceutical

Precise control of heat transfer and phase change processes are critical to ensuring the quality of production in large scale batch processing.

Pilot Plants for Chemical Refining

Fibers introduce no source of ignition and are well suited for hazardous environments. In the pilot production stage the high definition distributed sensing offers insight to optimize the process for maximum yield.

Power Generation

Large heat exchangers are an integral part of power generation plants. The high definition distributed sensing can help heat exchanger OEM's achieve maximum performance at minimal equipment cost under all operating conditions.

LUNA | Thanks To…

- This work was performed by Polytec, of Waldbronn Germany, in conjunction with the Technical University of Braunschweig , and CALGAVIN LTD

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