



# Experiences of using a Web-based Virtual Shell and Tube Heat Exchanger Experiment by Adult Continuing Learners



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Edwin Link's 'link trainer'  
flight simulator from 1928  
with pneumatic and  
electrical instrumentation

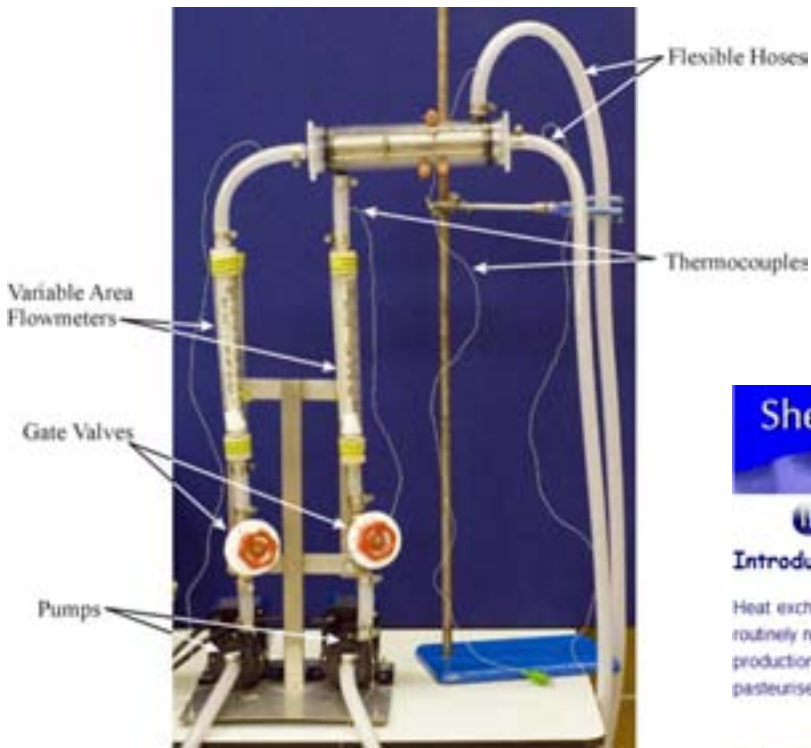
Predates computers...



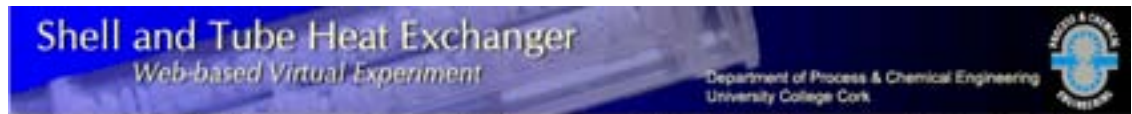


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# Two stage design of the virtual lab experiment



1. The design, construction, operation (data collection) and modelling of a lab scale model Shell & Tube Heat Exchanger (STHE) (Jiříček)



[Introduction](#)

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## Introduction

Heat exchangers are involved in heat transfer, one of the most common industrial transfer processes. In all industries liquid or vapour streams routinely need to be heated and/or cooled, this operation is typically performed by heat exchangers. These heat exchangers may form part of the production process or may be used for heat recovery from waste streams. Heat exchangers can go under many names such as boilers, pasteurisers, air heaters, jacketed vessels, condensers, evaporators and so on.

SHELL AND TUBE heat exchangers are the most common type used in the Chemical and Process Industries and are found throughout all processes from steam generation to refrigeration and at various points in production process.

In this experiment you will become familiar with the operation of a laboratory scale shell and tube heat exchanger. By varying the operating parameters and recording the resulting inlet and outlet temperatures you can determine rates of heat flow for each stream as well as the overall heat transfer coefficients for this particular heat exchanger.

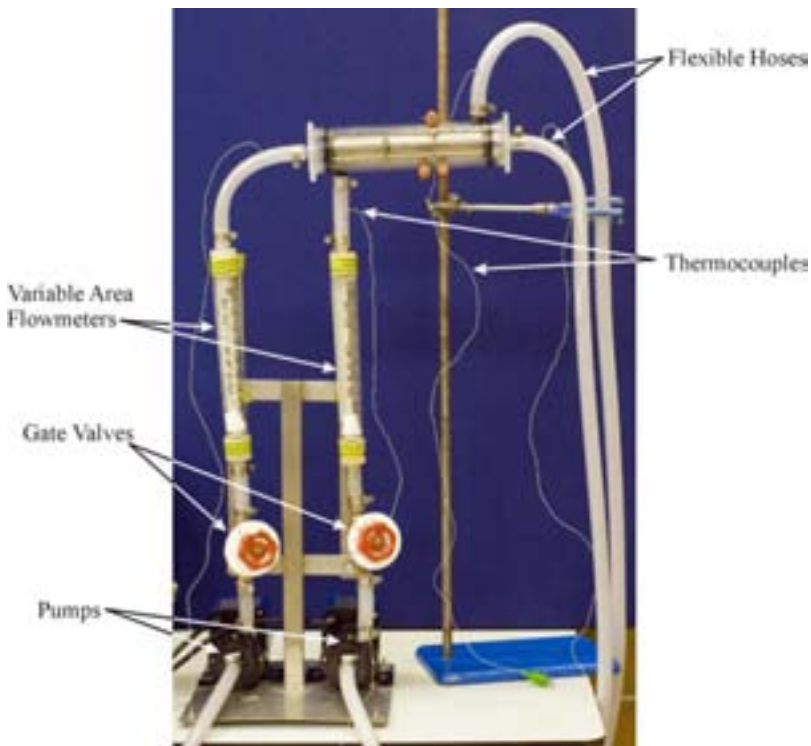


2. The development of an online virtual laboratory software interface (Barrett)



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## Two stage design of the virtual lab experiment



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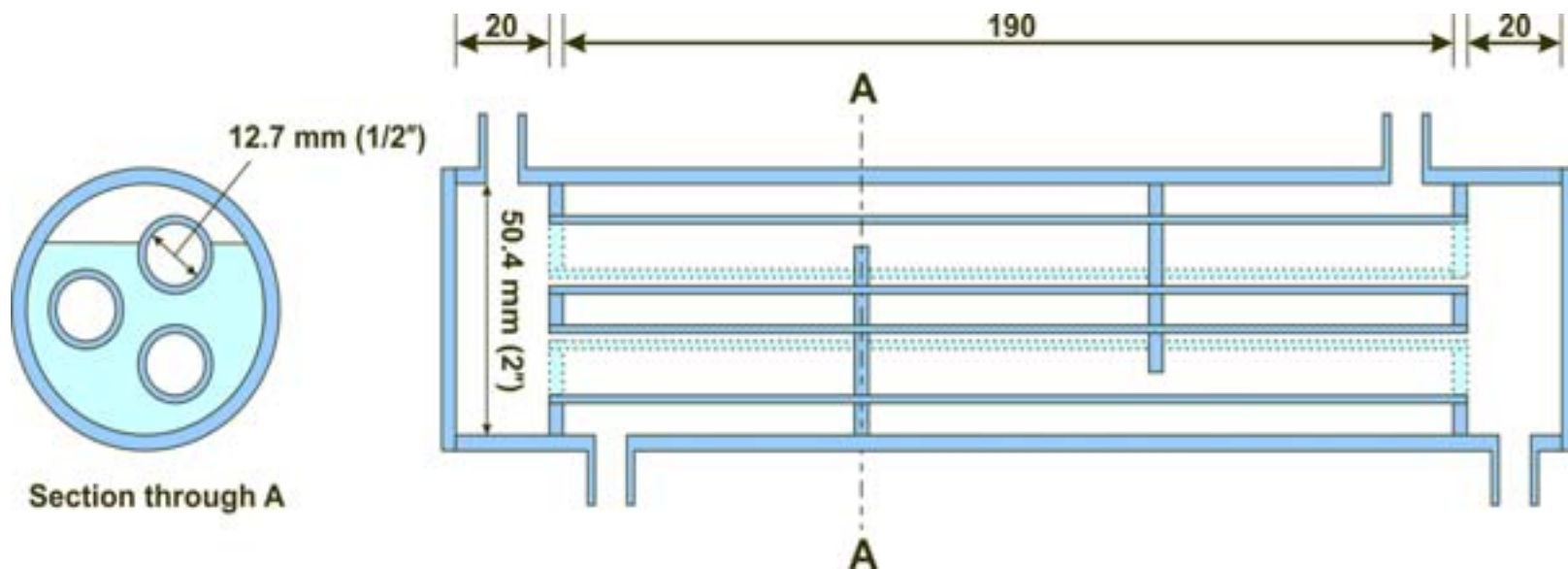


Polycarbonate replica model built to produce a 360° rotatable website image



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## Shell and tube heat exchanger design



**Shell side:** transparent polycarbonate

**Tubes:** stainless steel with helical static mixer elements



## Experimental data collection

- Hot (tube side) inlet from heating bath: @ 35°C, 50°C, 65°C, 80°C
- Cold (shell side): mains water @ 18°C
- Flowrates: 1 kg/min - 5 kg/min
- Co-current and counter current configurations
- Data was collected from 360 successful experiments



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# Online software development

**Shell and Tube H**  
Web-based Virtual

**Shell and Tube Heat Exchanger**  
Web-based Virtual Experiment

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University College Cork

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**Introduction**

**Introduction**      **Apparatus**      **Procedure**      **Experiment**

**Experiment**

Heat exchangers are involved in heat transfer processes. They are routinely used to heat and/or cool process streams. They may be used for pasteurizers, air heaters, jacketed vessels, etc.

T3: 60.85 °C  
T2: 32.75 °C  
T4: 65 °C  
T1: 18 °C

Shell flowrate: 0 kg/min  
Tube flowrate: 3.5 kg/min

Set Inlet Temperature: 65 °C

Flowrates (kg/min)  
Shell: 0  
Tube: 3.5

Temperatures (°C)  
Shell Inlet: 18  
Tube Inlet: 65  
Shell Outlet: 32.75  
Tube Outlet: 60.85

Reset Graph

Start      Record

Datapoint recorded.

Printer friendly Data Sheet

... diameter and 230 mm length which forms the shell. The tubes used in the actual experiment are 10 mm diameter and 230 mm length which forms the shell. The tubes used in the actual experiment are 10 mm diameter and 230 mm length which forms the shell.

**Shell and Tube Heat Exchanger**  
Web-based Virtual Experiment

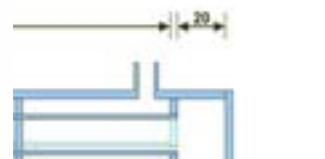
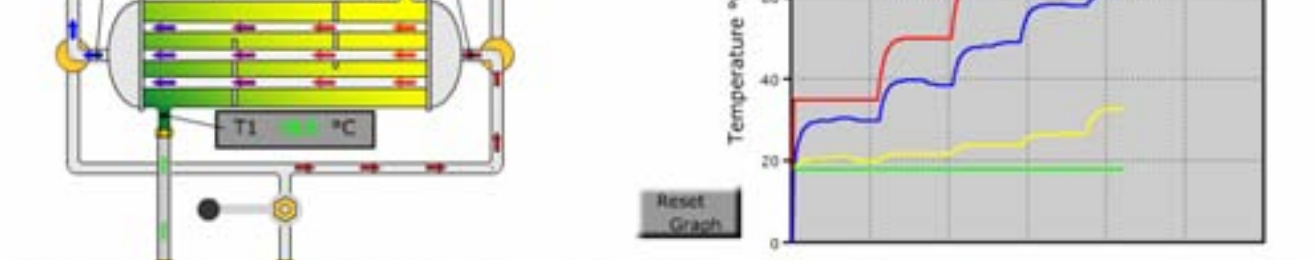
**Introduction**

**Shell and Tube Heat Exchanger**  
Web-based Virtual Experiment

**Introduction**

**Shell and Tube Heat Exchanger**  
Web-based Virtual Experiment

**Introduction**



**Procedure**

**Experiment**

**Experiment**

1. Adjust flow rates to desired value.
2. Click on Start/Reset button to start the experiment.
3. Adjust Temperature to desired value.
4. Select required flow direction (C for counter-current, P for parallel) using the flow selection lever.
5. When steady state conditions are reached, click on Record Button.
6. Repeat using different flow directions.
7. Click on "Print Friendly Data Sheet" to print the data.
8. Calculate heat flow in Watts for each flow direction. Perform a Heat Balance on the heat exchanger.
9. Calculate the overall heat transfer coefficient.

No of Points Recorded: 19

Flow Direction	Flow kg/min		Temperature °C			
	Shell	Tube	Inlet Shell	Inlet Tube	Outlet Shell	Outlet Tube
><	2	1	18	35	20.53	29.86
>>	2	1	18	35	20.65	30.43
>>	3	1	18	35	19.99	29.72
>>	3	1	18	50	21.75	39.66
><	3	1	18	50	21.7	38.37
><	3	1	18	65	23.74	47.9
>>	3	1	18	65	23.65	48.96
>>	3	3.5	18	65	26.31	58.26
><	3	3.5	18	65	26.44	57.91
><	1	3.5	18	65	32.75	60.85

Printed friendly Data Sheet

Flow Direction	Flow kg/min		Temperature °C			
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><	3	1	18	50	21.7	38.37
><	3	1	18	65	23.74	47.9
>>	3	1	18	65	23.65	48.96
>>	3	3.5	18	65	26.31	58.26
><	3	3.5	18	65	26.44	57.91
><	1	3.5	18	65	32.75	60.85



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## Application of online virtual laboratory



- Two year part-time evening **Diploma in Process and Chemical Engineering @ University College Cork**
- Heat Transfer and Applied Thermodynamics Module

- Laboratory complemented students' exposure to STHE design in module
- Virtual and online nature of the laboratory particularly suitable for part-time learners;
  - easily used during night classes (and by a high number of users simultaneously) when real labs and support off limits
  - remote access available online outside of class time
- Students gathered experimental data in class (as with actual experiment), and began to construct spreadsheets from which relevant performance plots could be constructed and conclusions/reflections drawn
- Write up completed by the students remotely out of class as part of their continuous assessment (*experimental procedure: see paper*)





# Inquiry

## Questions on Virtual Laboratory

1. Did participants find the virtual laboratory user-friendly?
  2. How did it aid understanding of the principles of heat exchanger design and operation relative to the lectures?
  3. How did it aid understanding of the principles of heat exchanger design and operation compared with a real laboratory experiment?
  4. Would learners actually prefer the virtual laboratory to a real lab experiment?
- A survey was developed and feedback obtained longitudinally among learners from 2009 to 2012
  - Students also invited to provide qualitative feedback



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## Survey Results

On a scale of 1 to 5 (where **5 is maximum**), please indicate the rating you would propose for each of the following.

With respect to the Heat Exchanger Virtual Lab Experiment, how did you consider the following:	1	2	3	4	5
User friendliness	-	-	-	17	21
Usefulness in gaining a better understanding of heat exchanger design and operation <i>compared with lectures alone</i>	-	-	1	17	20
Usefulness in gaining a better understanding of heat exchanger design and operation <i>compared with a real laboratory experiment</i>	-	1	10	19	8
In this module, to what degree would you prefer the HE VLE to a real lab experiment? (3 equals no preference)	-	5	11	13	9

83% response rate (38/46)



## Qualitative Feedback

Qualitative feedback very supportive of the virtual lab experience:

- *‘Excellent tool. Gives better understanding of heat exchange.’*
- *‘Very good that the program is online and I was able to finish the assignment at home.’*
- *‘Extremely useful in demonstrating the principles of heat exchangers’*
- *‘Being able to complete the experiment online means you can work on it at your own pace and you have access to it when it suits you. A real experiment may also be of benefit but I would choose the online version if I had to choose.’*



## Reflections

While showing impressive support for the online lab, the context (i.e. evening part-time students and associated constraints) should be noted.

The results also appear to reveal a degree of comfort among contemporary (adult) learners with using computers as simulators.

## In Conclusion

This project has demonstrated that a well designed virtual laboratory experiment, when used in the right context, can offer significant benefits as a learning tool, even compared with real experiments.



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