A Suite of Web-Accessible Experiments for teaching Heat Transfer: Pedagogical Aspects

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FAQ on We-Accessible Experiments
Grand Plan for Our Website
Motivating Intellectual Depth Through Use of Web Labs

FAQ on Web-Accessible Experiments in Chemical Engineering

1. **What can be done with web labs?**
   - Experience of taking data from real equipment without being there
   - Anything that can be done with data
     - Analysis
     - Written and oral presentation
   - Team experience under some circumstances
2. **Why not jus use a simulation?**
   - Real equipment usually provides surprises and non-idealities that would not be conceived in constructing a simulation
3. **What can web labs not do?**
   - Provide a hands-on experience
4. **Where do web labs work best ?**
   - In a lab with hands-on experiments: No
   - As an adjunct to a lecture course without a lab component: Yes
     - Projects
     - Expanded homework
     - Class demos
5. **How can web labs provide a pedagogically rich experience?**
   - Visualize complex phenomena on line
   - Motivate intellectual depth

Grand Plan for heatex.mit.edu

Server

Service Units

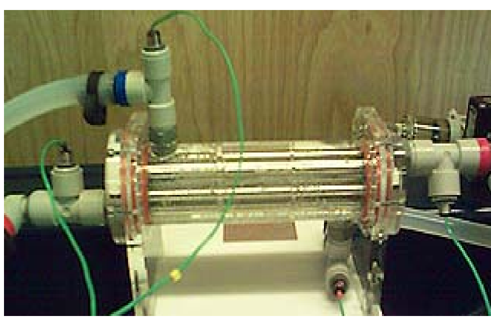
HT30XC

HT10XC

Heat Exchangers

Extended Plate HT37

Shell &Tube HT31



Tubular HT36

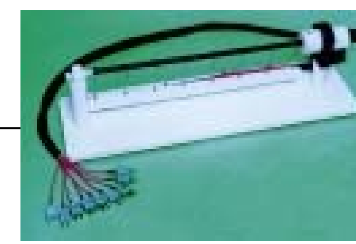
Radiation/Convection

Radiation Errors in Temperature Measurement HT16

Convection and Radiation HT14

Conduction

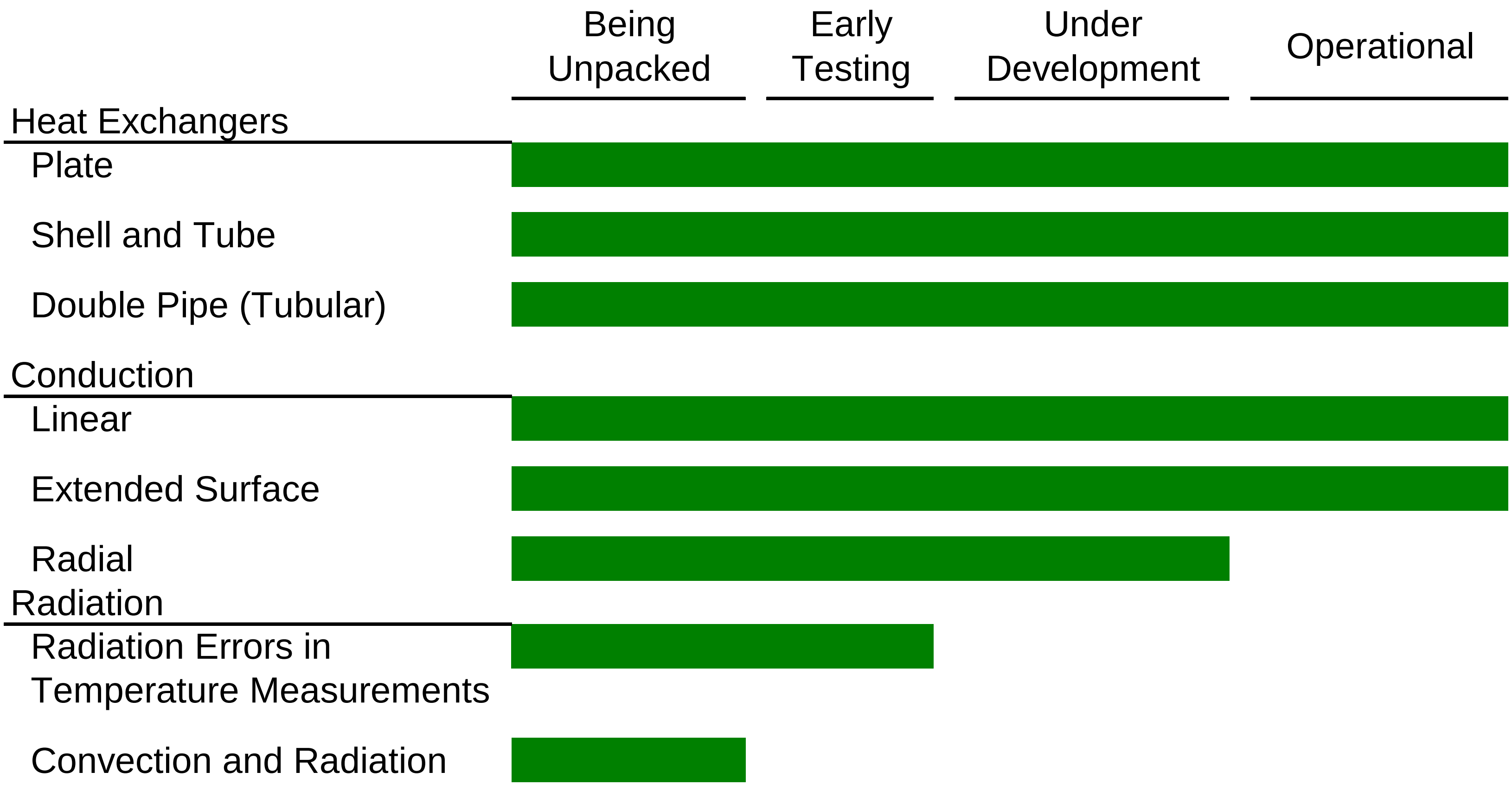
Linear HT11



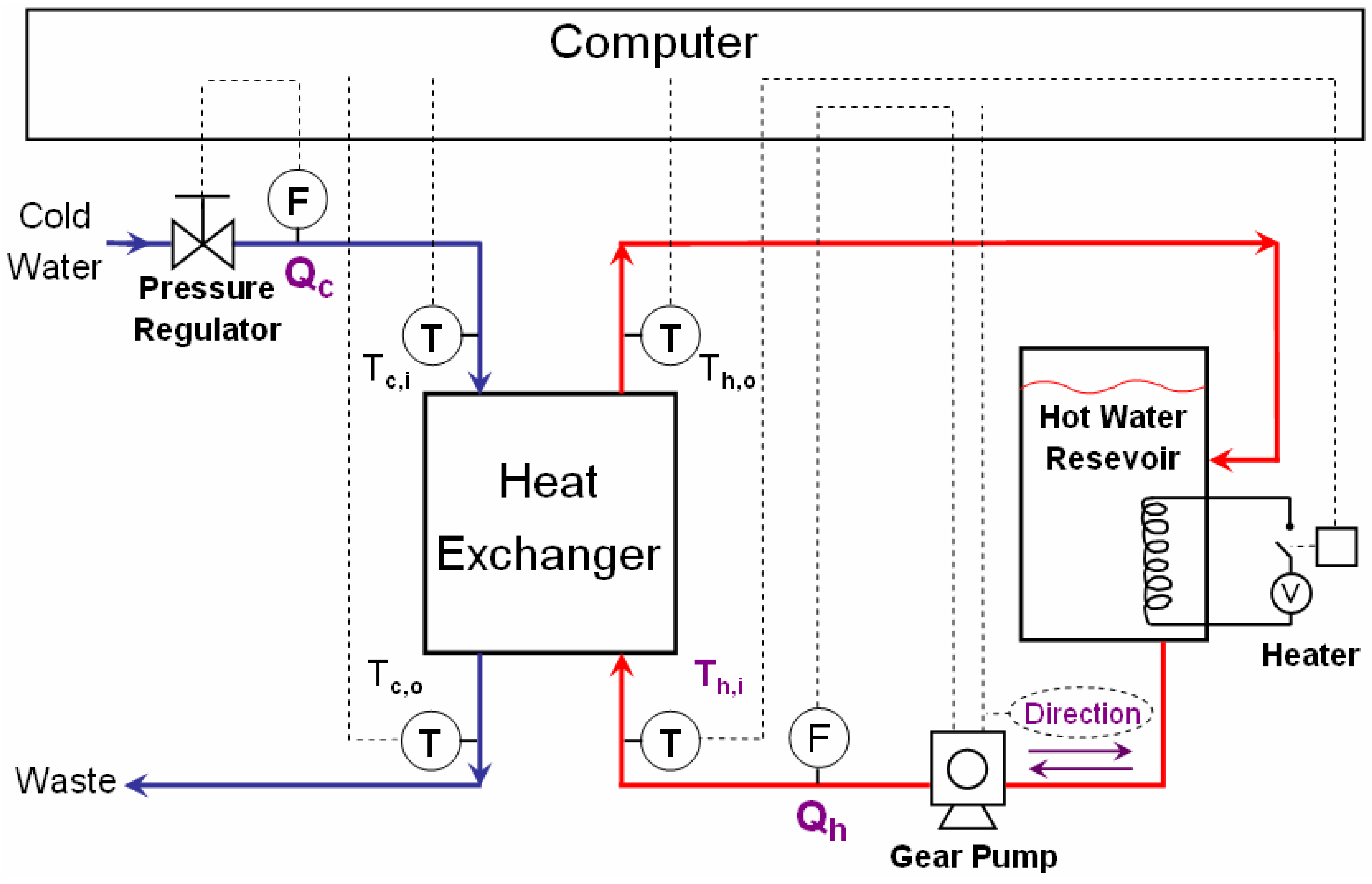
Extended Surface HT15

Radial HT12

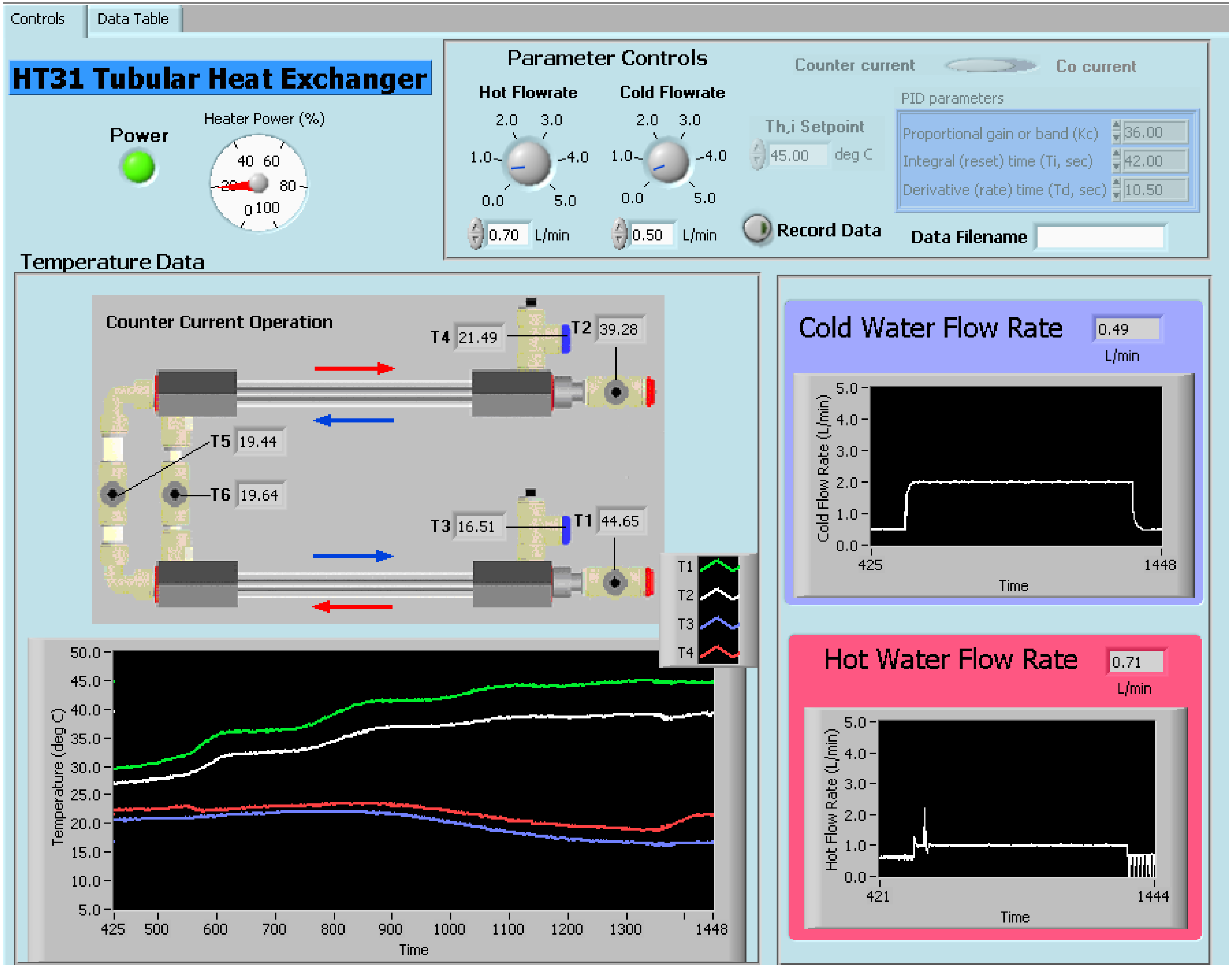
Status of Grand Plan



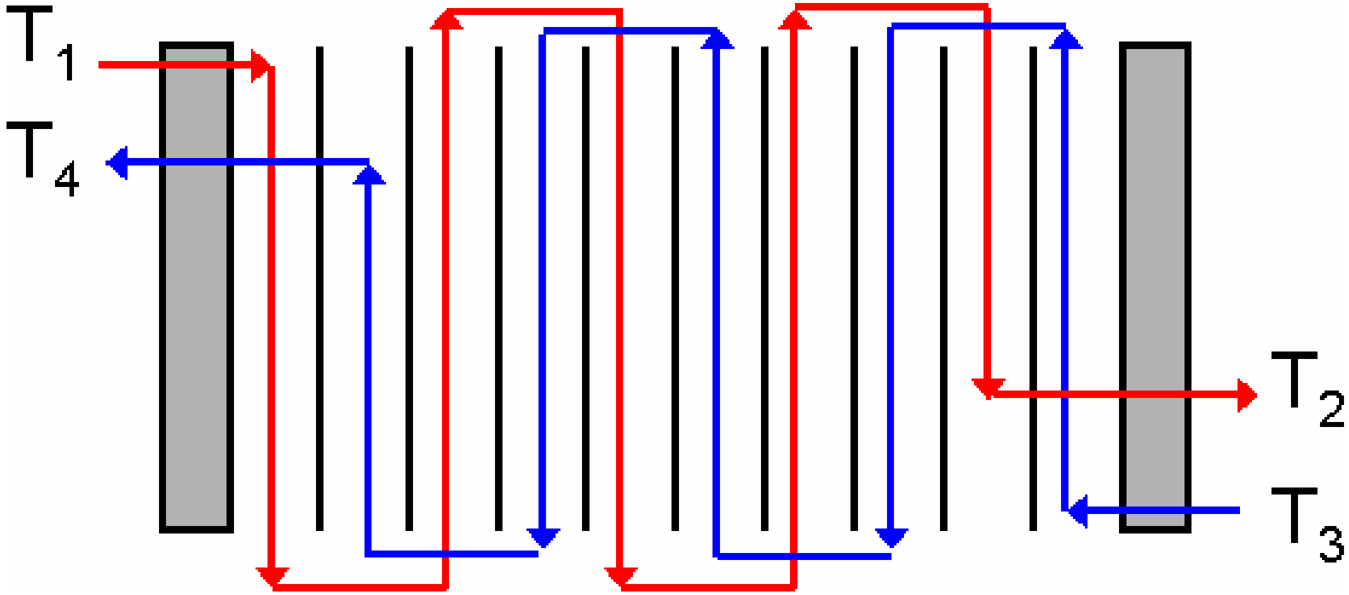
I-Lab Heat Exchanger Schematic Diagram



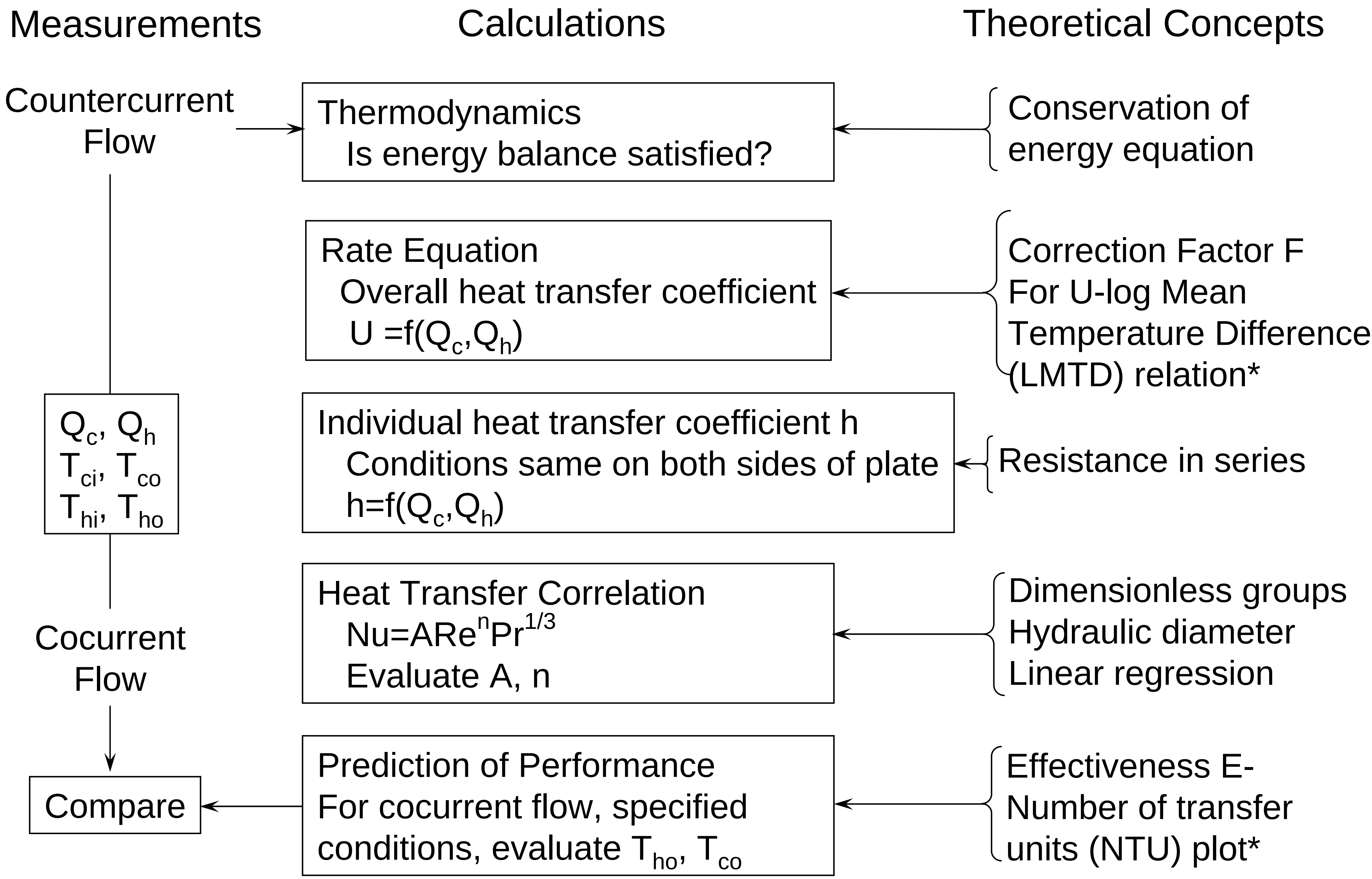
LabVIEW Interface-Heat Exchanger



Schematic of Flat Plate Heat Exchanger in Countercurrent Operation



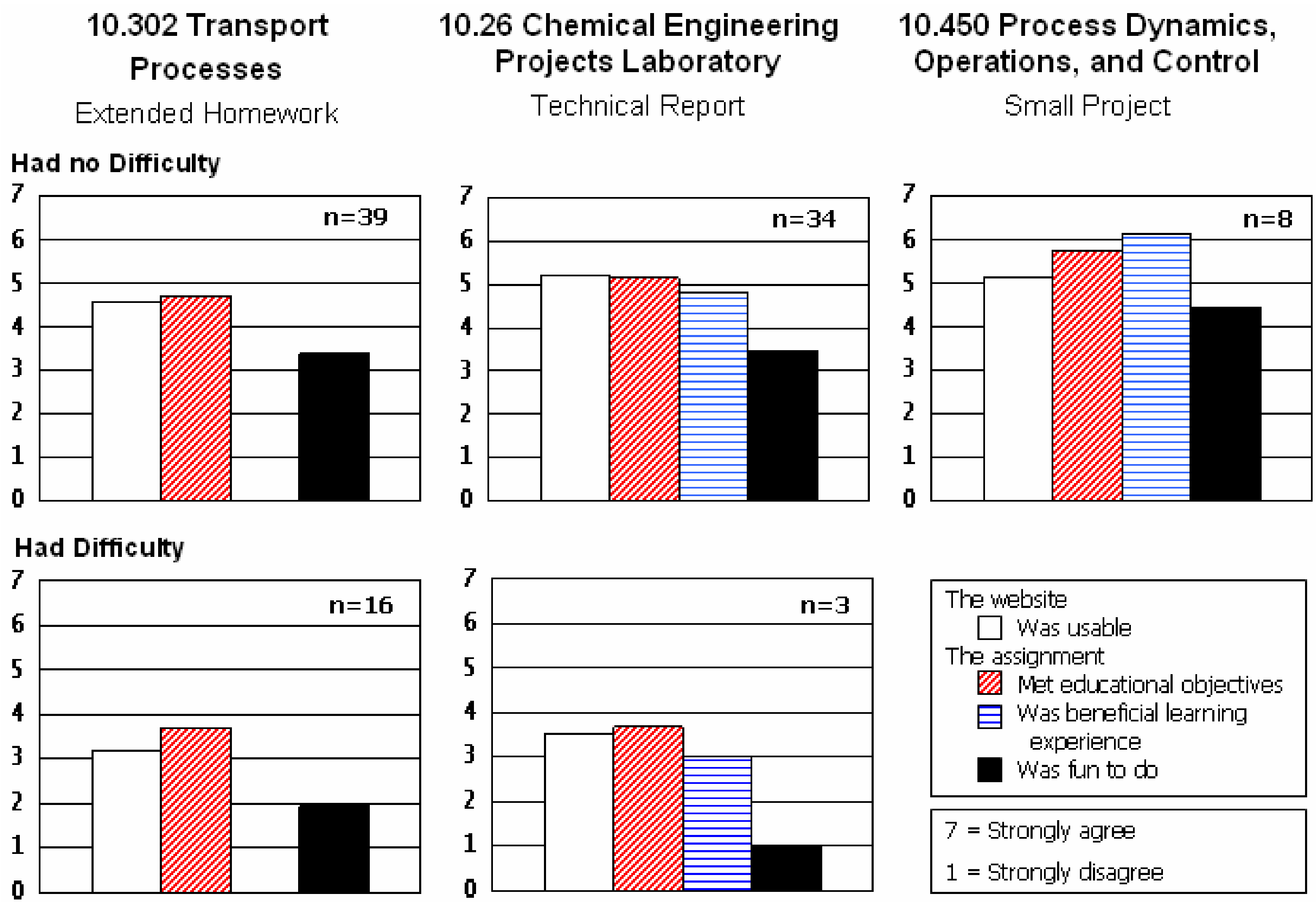
A Comprehensive Evaluation of Heat Exchanger Performance



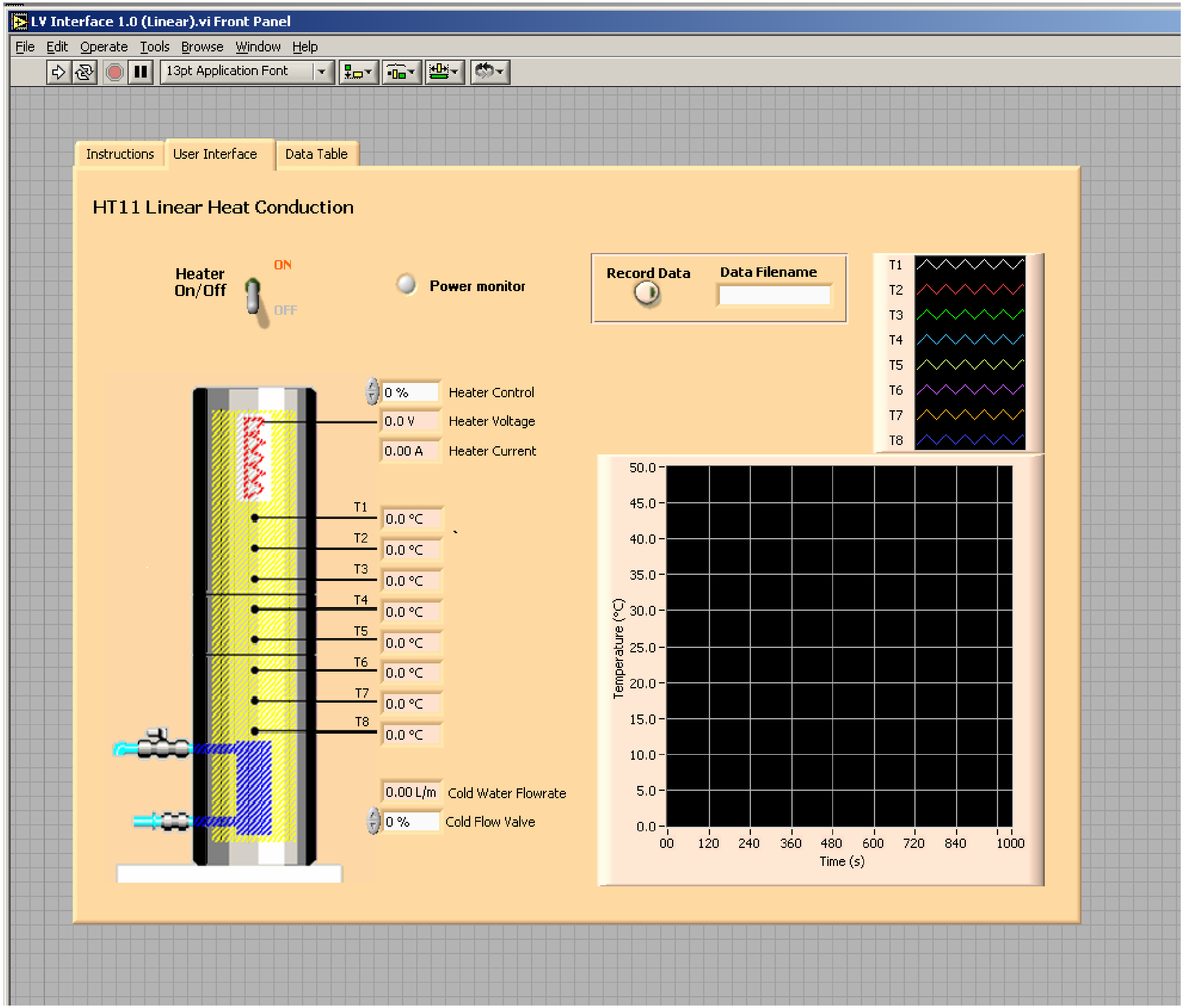
* Required development of theoretical solution

Student Assessment Of I-Lab Heat Exchanger

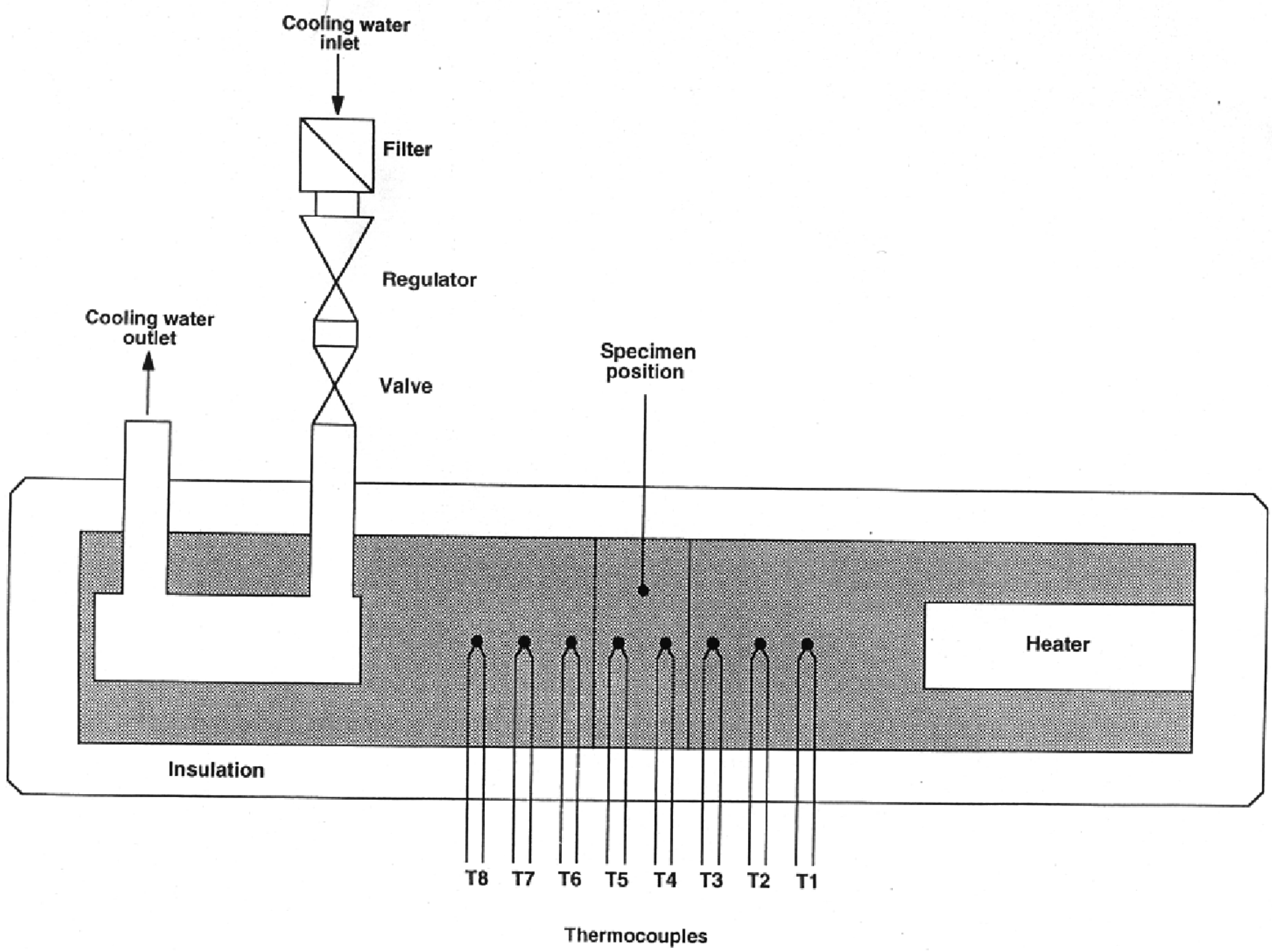
Part 1: Comparison Of Evaluations In Different Classes



LabVIEW Interface-Linear Conduction



Linear Conduction Apparatus



Linear Conduction: Spicing it up with Transient Conduction

Measurements

Steady state
T = f(x)
Brass and stainless steel midsections

Transient
T = f(x,t)
Brass midsection

Calculations

Linearity of data
Overall resistance
Contact resistance
Calculated thermal conductivity

T = f(x) vary t
T = f(t) vary x
Time required to reach steady state
Comparison of theoretical models
Range of validity
Comparison f prediction and data*

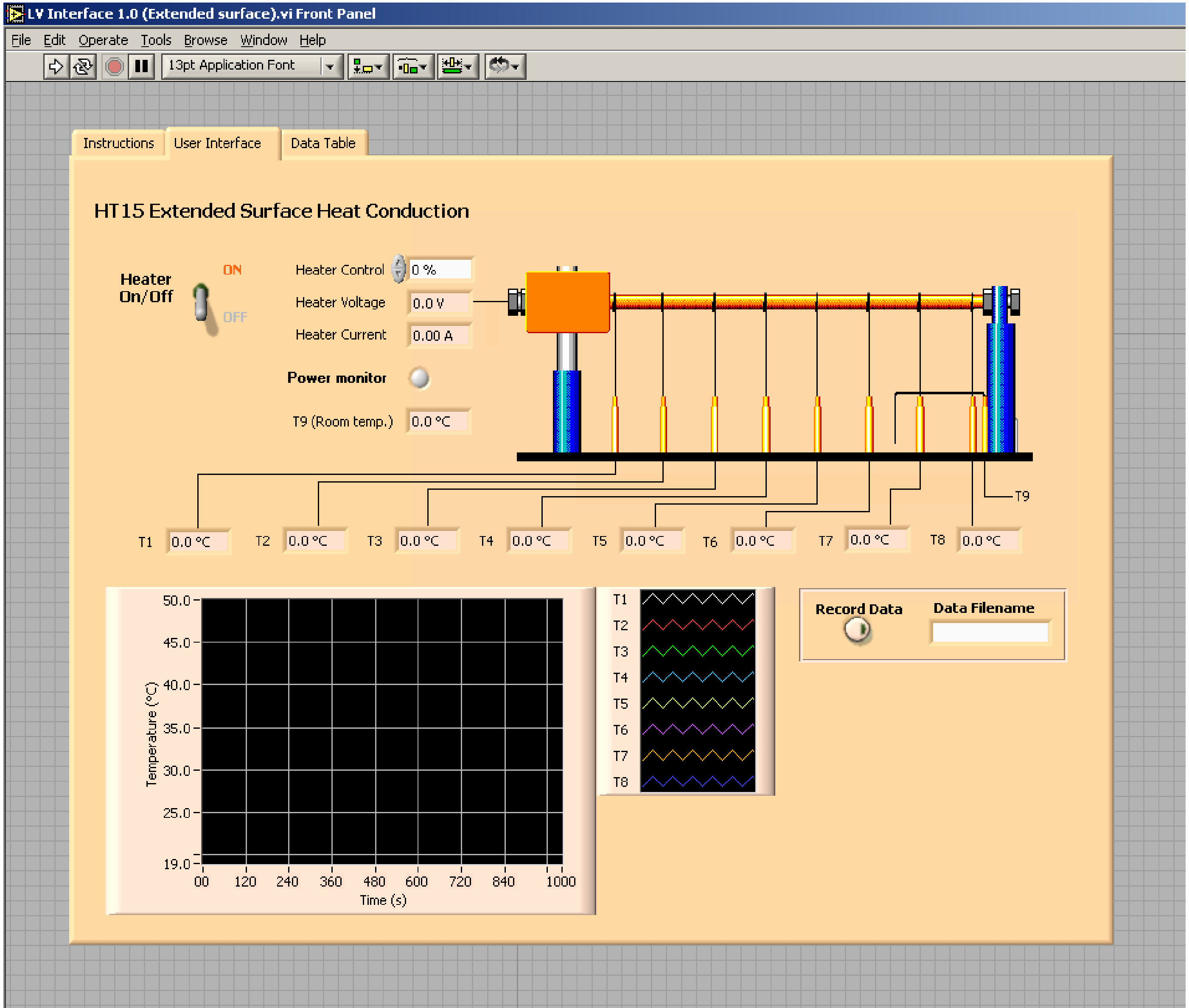
Theoretical Concepts

Steady state theory
Fourier's Law
Thermal resistance
Resistances in series

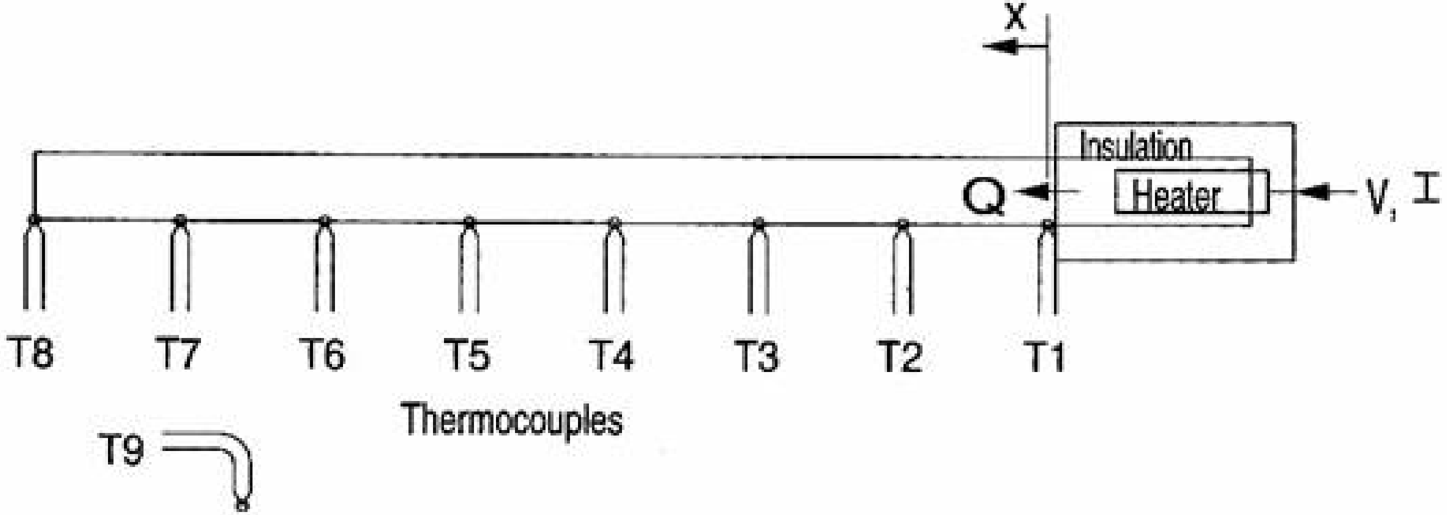
Transient conduction with constant flux BC at heater
- Full series solution
- Semi-infinite medium

* Effective length beyond outer thermocouples required adjustment

LabVIEW Interface-Extended Surface Heat Conduction



Extended Surface Heat Transfer Apparatus



Extended Surface Heat Transfer: A Detective Story

Measurements	Calculations	Theoretical Concepts
Steady State Rod thermocouples $T = f(x)$ Housing surface Non contact thermometer	Fit data to theory Determine h Bi consistent with assumptions? q_f = heat transfer rate into base of fin q_g = energy generation rate by heater $q_g = q_f$ q_c = rate of heat loss from housing to surroundings $q_g = q_f + q_c$	Steady state “fin” solution Steady state macroscopic energy balance
Transient Rod thermocouples $T = f(x,t)$	Explore theoretical prediction $T = f(x)$, vary t $T = f(t)$, vary x Effect of number of terms Compare model predictions Compare data and predictions Prediction is much faster! Is $q_f = f(t)$ 1. $q_f(t)$ = heat loss to surroundings from rod + rate of change of energy in rod 2. $q_f(t)$ from gradient at x=0 (Fourier’s Law) q(t) increases with time because of initially large leakage into housing	Transient solution Full series Semi-infinte rod Unsteady state Microscopic energy balances

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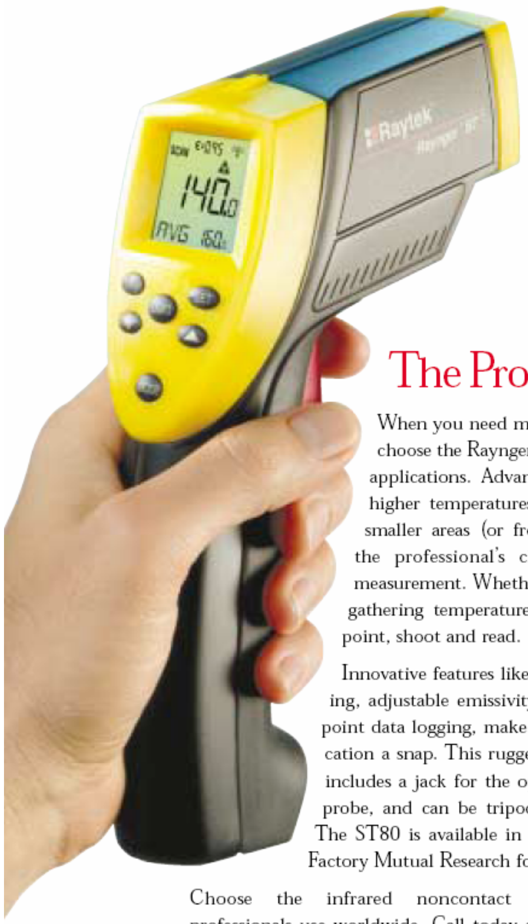

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Extended Surface Heat Transfer: A Detective Story

Measurements

Steady State
Rod thermocouples
  T = f(x)
Housing surface
  Non contact thermometer

→

Calculations

Fit data to theory
  Determine h
  Bi consistent with assumptions?
q_f = heat transfer rate into base of fin
q_g = energy generation rate by heater
$q_g = q_f$
q_c = rate of heat loss from housing to surroundings
$q_g = q_f + q_c$

←

Theoretical Concepts

Steady state "fin" solution
Steady state macroscopic energy balance

Transient
Rod thermocouples
  T = f(x,t)

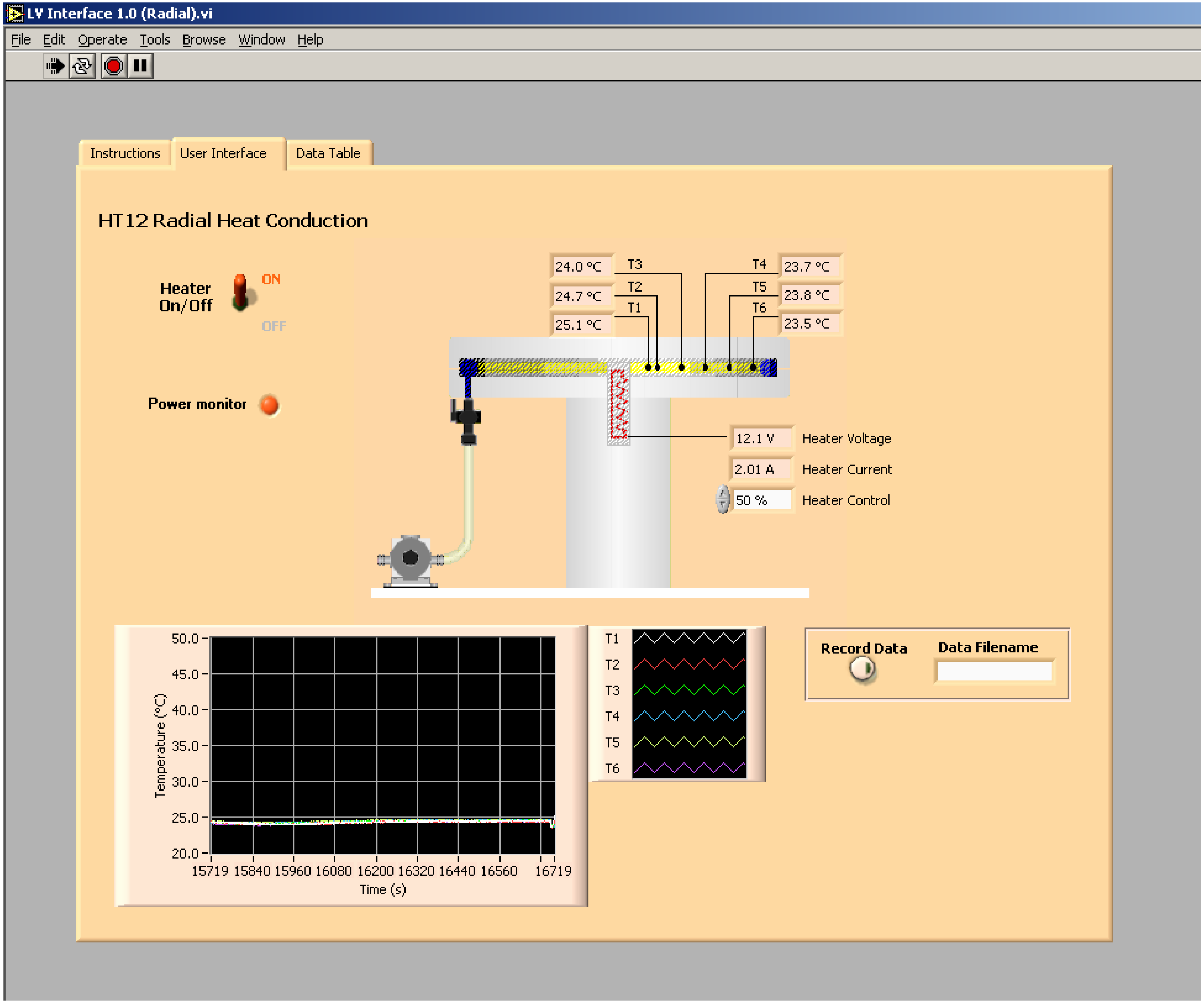
→

Explore theoretical prediction
  T = f(x), vary t   T = f(t), vary x
Effect of number of terms
Compare model predictions
Compare data and predictions
  Prediction is much faster!
Is q_f=f(t)
1. $q_f(t)$ = heat loss to surroundings from rod + rate of change of energy in rod
2. $q_f(t)$ from gradient at x=0 (Fourier's Law)
   q(t) increases with time because of initially large leakage into housing

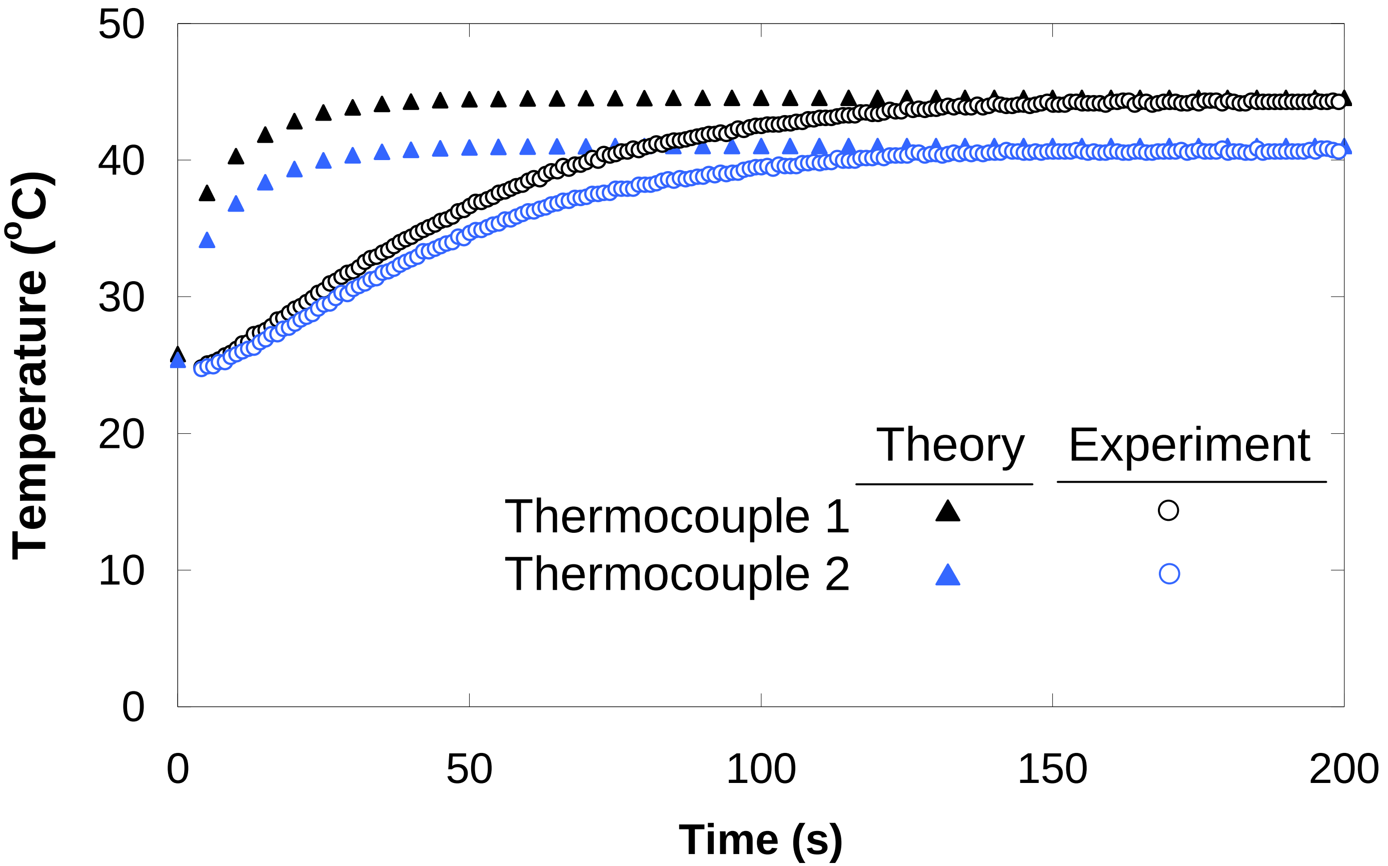
←

Transient solution
  Full series
  Semi-infinte rod
Unsteady state
Microscopic
energy balances

LabVIEW Interface-Radial Heat Conduction



Transient Radial Conduction
A New Detective Story Begins



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