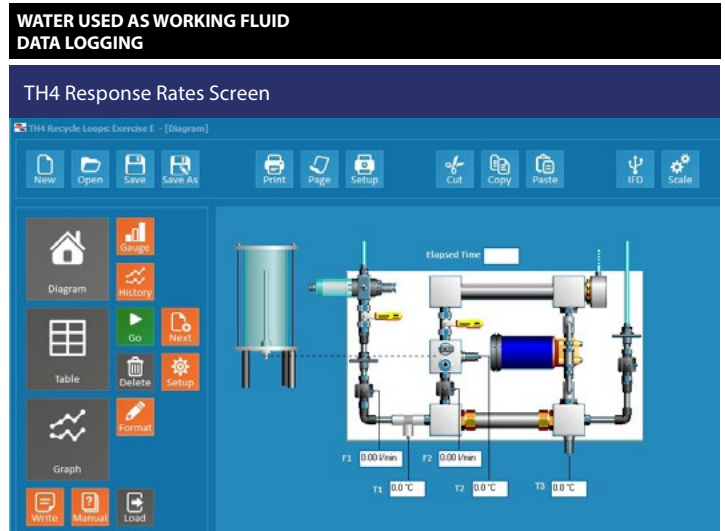


Recycle is a simple phenomenon, which occurs in many aspects of everyday life, but is also a concept that can lead to confusion in engineering applications when combined with other principles such as mass / energy balances and the use of the steady flow energy equation.

The Armfield Recycle Loops apparatus has been designed to demonstrate clearly, both visually and experimentally, what a recycle loop is and to enable mass and energy balances to be performed under steady state and unsteady state conditions. The application modelled is typical of a heating arrangement in the chemical, food or pharmaceutical industries whereby the temperature of a product is raised or lowered offline by recirculating some of the product through a heat exchanger.

The practical training exercises are appropriate to heat transfer and thermodynamics courses and the training of technicians and engineers in those disciplines.



**Key features**

- ▶ The small-scale of the loop ensures that responses can be fully evaluated in a normal laboratory session
- ▶ Water is used as the working fluid for safety and ease of use
- ▶ All electrical sensors can be logged using a PC (not supplied)
- ▶ Optional teaching software is available for data logging

**Experimental content**

- ▶ Demonstrate the effect of recycle on the total mass flow rate of a system
- ▶ Vary the flow through a recycle loop, while observing the inlet and outlet flow rates of the whole system
- ▶ Investigate the steady state heat balance equation applied to a recycle loop
- ▶ Vary the flow rate through a recycle loop, whilst heating the recycle fluid and observing the temperatures of the inlet, outlet and recycle loop flow
- ▶ Investigate the unsteady heat balance applied to a recycle loop
- ▶ Investigate the steady flow energy equation applied to a recycle loop
- ▶ Calculate the heat transfer rate at a range of recycle rates, using the steady flow energy equation
- ▶ Investigate the effect of parameter changes on response rates
- ▶ Vary parameters such as heater power and recycle loop volume and investigate any subsequent change in system response

## Description

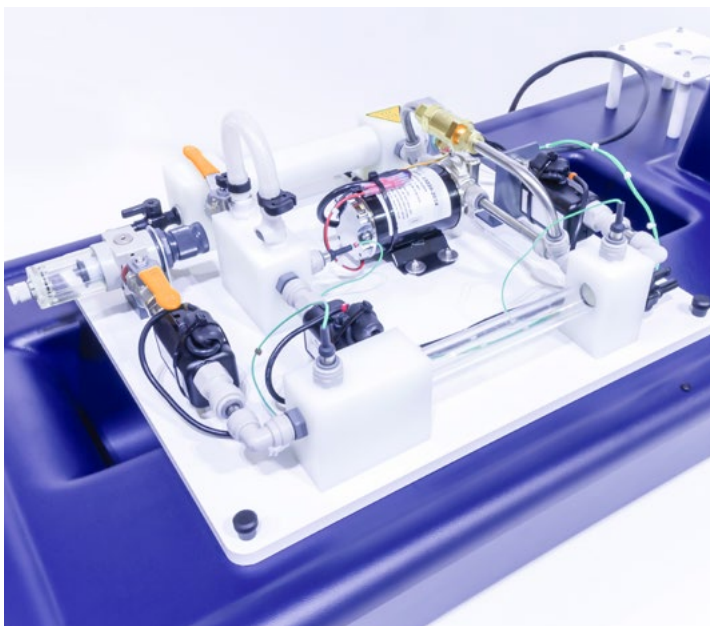
A bench top unit designed to introduce students to the characteristics of a recycle loop and the typical responses under steady state and unsteady state conditions.

The apparatus consists of a through pipe conveying water from a cold water supply to a suitable drain with a loop of pipework connected between the supply and drain connections. This recycle loop incorporates a circulating pump and a heater to raise the temperature of the water in the loop. The heater can be switched on or off to generate step changes when investigating the transient responses of the recycle loop.

A pair of self-sealing fittings enables a short length of pipe or a reservoir to be connected in series with the recycle loop to change the volume of the loop and demonstrate the effect of residence time. The arrangement also permits different lengths of flexible tubing to be connected in series with the loop if it is required to create further changes in residence time.

Water temperatures at the inlet, outlet and within the recycle loop are measured using K-type thermocouples. Water flow rates at the corresponding locations are measured using miniature turbine type flow sensors. Flow sensors are included at the outlet as well as the inlet to show that these two flow rates are always equal (a simple principle that is often confusing when water is flowing through the recycle loop).

All power supplies, signal conditioning circuitry etc. are contained inside the moulded ABS support and integral console with appropriate current protection devices and an RCD for operator protection. Readings from the sensors are displayed on a digital meter with selector switch and all corresponding signals are routed to an I/O port for connection to a PC using an optional interface device included with educational software package.



## Detailed experimental capabilities

Teaching exercises will enable students to become familiar with the following topics:

Understanding the meaning of recycle.

### Steady state mass balances:

- ▶ Demonstrating that whatever the recycle rate, the inlet flow rate always equals the outlet flow rate

### Steady state heat balances:

- ▶ With the heater switched on and at fixed input water flow rate the outlet temperature is independent of the recycle rate
- ▶ With the heater switched on the temperature rise between inlet and outlet can be used to determine the combined heat input of the heater and pump at different input water flow rates

### Unsteady state heat balances:

- ▶ Determining the response when the heater is switched on at different through flow rates
- ▶ Determining the response when the heater is switched off at different through flow rates
- ▶ Determining the effect of a step change in the input flow
- ▶ Determining the effect of recycle with no through flow

### Use of the steady flow energy equation:

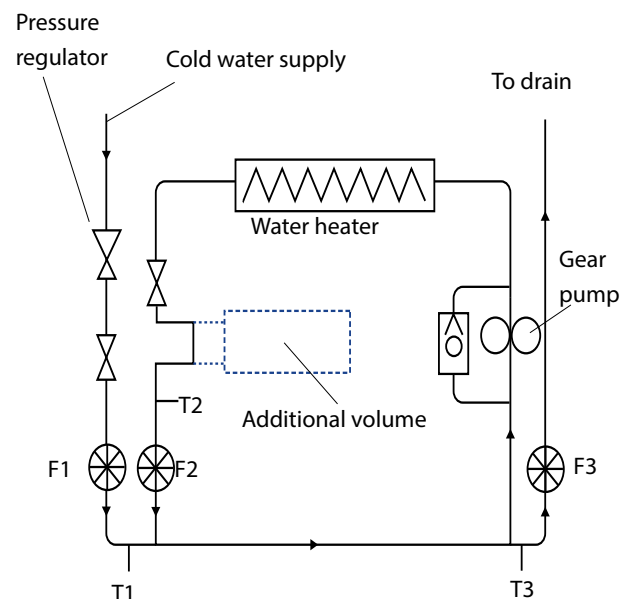
- ▶ For the overall system
- ▶ For the mixing process

### Effects on response rates to parameter changes:

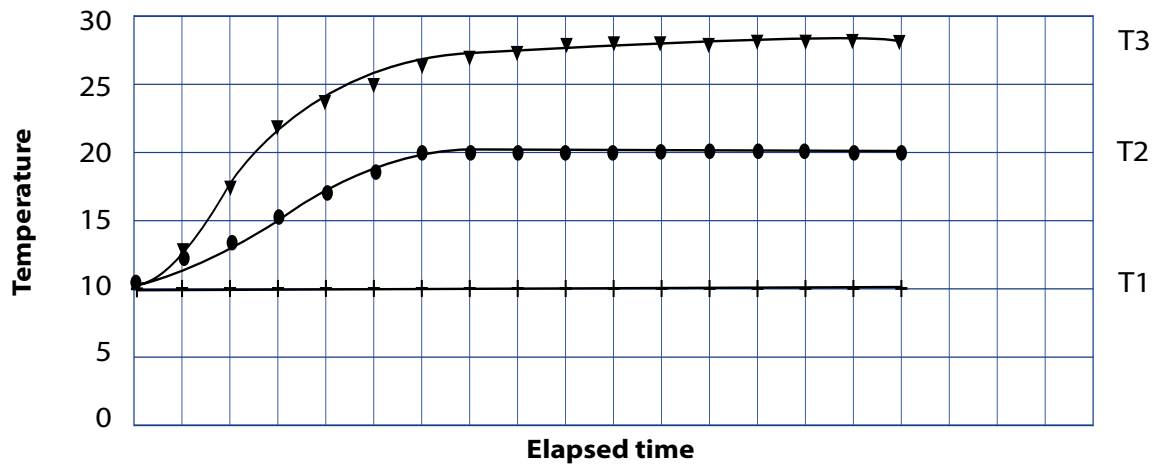
- ▶ In heater power
- ▶ In through flow
- ▶ In recycle flow
- ▶ In loop volume

### Comparison of test results with simulations:

- ▶ Using analytical methods
- ▶ Using finite difference simulations



TH4: Schematic diagram of the loop



TH4: Typical response when the heater in the recycle loop is switched on

### Requirements



### Scale



#### Electrical supply: Single phase

- ▶ TH4-A: 220-240V/1ph/50Hz, 13A
- ▶ TH4-B: 120V/1ph/60Hz, 13A
- ▶ TH4-G: 220-240V/1ph/60Hz, 13A

Mains cold water supply 3 l/min, 2 bar

Drain connection for hot water at 3 l/min maximum



### The TH range for the study of Thermodynamics

- TH1: Temperature Measurement and Calibration
- TH2: Pressure Measurement and Calibration
- TH3: Saturation Pressure
- TH4: Recycle Loops
- TH5: Expansion Processes of a Perfect Gas
- TH6: Film & Dropwise Condensation Demonstration Unit

### Overall dimensions

#### Saturation pressure apparatus

Length	1.00m
Width	0.50m
Height	0.40m

#### Packed and crated shipping specifications

Volume	0.32m <sup>3</sup>
Gross weight	30Kg

### Ordering specification

- ▶ A bench top unit comprising a vacuum formed ABS plastic plinth with integral electrical console on to which is mounted a through pipe with a recycle loop, which incorporates a circulating pump and heater
- ▶ A pressure regulator with filter at the inlet to the apparatus minimises the effect of fluctuations in the cold water supply pressure. Water in the recycle loop is heated by a 2kW electric heater with over temperature protection. Flow in the loop can be varied from 0 (no recycle) to 3 l/min. The through flow of water can be varied from 0 - 1.5 l/min
- ▶ Temperatures at the entry to the system, at the exit from the system and inside the recycle loop are measured using K-type thermocouples. Flow rates at corresponding locations are measured using turbine type flow sensors. A reservoir with self-sealing fittings enables the volume of the loop to be changed
- ▶ All electrical circuits are protected by appropriate protection devices
- ▶ The console incorporates a digital meter with selector switch, which displays the temperatures and flow rates measured. Corresponding signals are routed to an I/O port for connection to a PC
- ▶ An optional interface device and educational software package is available
- ▶ A comprehensive instruction manual is included with a range of fully detailed laboratory teaching exercises

### Optional accessories

#### TH-DTA-ALITE:

Educational software for TH1-TH5 on a USB key complete with data logger (a PC running Windows 7 or later, with a USB port is required)

### Ordering codes

- TH4-A
- TH4-B
- TH4-G

Armfield standard warranty applies with this product

## Knowledge base

- > 28 years expertise in research & development technology
- > 50 years providing engaging engineering teaching equipment

Benefit from our experience, just call or email to discuss your laboratory needs, latest project or application.

An ISO 9001:2015 Company



armfield.co.uk

## Aftercare

Installation  
Commissioning  
Training  
Service and maintenance  
Support: [armfieldassist.com](http://armfieldassist.com)