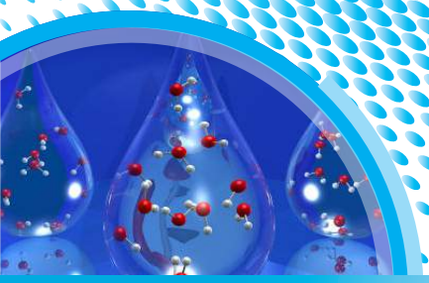
PROCESS & REACTION ENGINEERING

The **SOLTEQ®** Basic Process & Reaction Engineering offers a wide and comprehensive range of product for process and reaction engineering experiments. Our Basic Process equipment includes basic principles and unit operations for process engineering study. Students are able to learn fundamentals, operation and analysis of the unit operations involved. Experiments for basic principles include diffusion coefficients for liquid and gas, vapour-liquid equilibrium, corrosion, mixing, fluidization and falling film study. The unit operation section provides experiments for distillation, liquid-liquid extraction, solid-liquid extraction, gas absorption, evaporation, and drying. The Reaction Engineering equipment allows students to study and analyse reaction kinetics, as well as residence time distribution (RTD) study. Different types of reactors found in industry are represented, i.e. batch reactor, continuous stirred tank reactor (CSTR), plug flow reactor and packed bed reactor. Advanced unit operations such as gas adsorption and pressure swing adsorption (PSA) are also included.



SOLTEQ®

PROCESS & REACTION ENGINEERING

Equipment List

PROCESS ENGINEERING

Corrosion Study Kits (Model : BP 01) SOLDAS SOLCAL

This **Corrosion Study Kits** is designed to demonstrate the science of corrosion in industrial processes.

This unit consists of:

- Eight test cells made of glass with specially machined lids enabling sample to be mounted
- Test specimen pieces of steel, zinc, brass and copper
- Air pump
- pH meter and electrode
- Low voltage supply

Experimental capabilities:

- Effect if pH and DO concentration on corrosion rate
- Study of galvanic action, cathodic protection, electrolytic corrosion and chemical inhibition

Falling Film Absorption Unit (Model : BP 02) SOLDAS SOLCAL EI

This **Falling Film Absorption Unit** is designed for experiments on liquid film controlled gas-liquid absorption process.

This unit consists of:

- Wetted wall column made of glass
- Deoxygenating column filled with glass packings
- Water tank and feed pumps
- Air compressor
- Dissolved oxygen analysers
- Gas and liquid flow meters

Experimental capabilities:

- Calculation of liquid film mass transfer coefficients
- Determination of coefficient values in power law relationship

Liquid Diffusion Coefficient Apparatus (Model : BP 09) SOLDAS SOLCAL EI

This **Liquid Diffusion Coefficient Apparatus** is designed to measure liquid diffusivity in an equimolar counter diffusion process.

This unit consists of:

- Unique diffusion cell with a precise honeycomb
- Diffusion vessel made of clear acrylic
- Conductivity meter
- Magnetic stirrer

Experimental capabilities:

- Measurement of mass transfer rates and diffusion coefficients
- Examine the effect of concentration
- Carry out analysis of an unsteady state mass transfer process

Gaseous Diffusion Coefficient Apparatus (Model : BP 10)

This **Gaseous Diffusion Coefficient Apparatus** is designed to measure molecular diffusivity of gases.

This unit consists of:

- Precision bore glass capillary tube to contain volatile liquid
- Thermostatic bath with transparent sides
- Horizontal glass tube for flow of bulk air
- Air pump
- Travelling microscope mounted on a scale

Experimental capabilities:

- Measurement of mass transfer rates and diffusion coefficients
- Use of Fick's Law to measure diffusion coefficients
- Effect of temperature on mass transfer rates and diffusion coefficients

Vapour Liquid Equilibrium Unit (Model : BP 16) SOLDAS SOLCAL EI

This **Vapour Liquid Equilibrium Unit** is designed to investigate vapour and liquid equilibrium of a binary mixture at pressures up to 10 bar.

This unit consists of:

- Stainless steel evaporator with electrical heater and liquid/vapour sampling ports
- Condenser made of stainless steel coils
- Pressure and temperature sensors for both liquid and vapour phases
- Pressure relief valve

Experimental capabilities:

- Effect of initial composition on boiling temperature and vapour phase composition
- Determination of minimum boiling point of binary mixture
- Effect of addition of salts into mixtures

Fixed and Fluidised Bed Unit (Model : BP 23) SOLDAS SOLCAL EI

This **Fixed and Fluidised Bed Unit** is designed to study the behaviour of flow of fluid through both fixed and fluidised bed of solid particles. Differences in flow behaviour can be visualized clearly.

This unit consists of:

- Columns
- Water supply
- Air supply
- Bed materials

Experimental capabilities:

- Determination of pressure drop through fixed and fluidised bed for both air and water systems
- Verification of the Carman-Kozeny equation
- Observation of the differences between particulate and aggregative fluidisation
- Behaviour of fluidised bed for various types of bed material

Solid-Liquid Extraction Unit (Model : BP 40) SOLDAS SOLCAL EI

This **Solid-Liquid Extraction Unit** is designed to demonstrate the principles of extraction process whereby some components are selectively removed from solid using a suitable solvent.

This unit consists of:

- Extraction vessel
- Evaporator with electric heater
- Packed column
- Solvent condenser
- Product cooler
- Receiver vessel

Experimental capabilities:

- Determination of extraction efficiency
- Effects of solvent flow rate, contact time and solvent feed temperature on extraction efficiency
- Batch and continuous extraction
- Semi-continuous extraction using Soxhlet methods
- Mass balance analysis

Solid-Liquid Extraction Unit (Model : BP 41)

This **Solid Liquid Extraction Unit** is designed for students demonstration on the extraction process whereby components can be selectively extracted from solid mixtures using a suitable solvent.

This unit consists of:

- Rotating Extractor
- 3 sets of solvent delivery system
- Input Hopper

Experimental capabilities:

- Demonstration of continuous multi-stage solid-liquid extraction operation
- Demonstration of open (continuous) and closed (batch) loop percolation extraction
- Comparison of one, two and three stage continuous processes
- Effects of solvent flow rate, processing time and solvent feed temperature on the extraction efficiency
- Process economics
- Mass balance analysis

Gas Absorption Unit (Model : BP 50-80) SOLDAS SOLCAL EI

This **Gas Absorption Unit** is designed to provide students with a hands-on experience on gas absorption by means of liquids (solvent absorption).

This unit consists of:

- Absorption packed column
- Sump tank
- Feed pump
- Instrumentations for measurement of air, liquid and gas flow rates and column pressure drop

Experimental capabilities:

- Absorption of CO_2 from air-CO_2 mixtures using sodium hydroxide solution
- Determination of CO_2 saturation point in NaOH solution and time to reach saturation
- Effect of CO_2 compositions, air and liquid flow rates on absorption efficiency
- Hydrodynamics of a packed column
- Determination of loading and flooding points of the column

Gas Absorption-Desorption Unit (Model : BP 51-80) SOLDAS SOLCAL EI

This **Absorption-Desorption Unit** is designed to provide students with a hands-on experience on gas absorption and desorption.

This unit consists of:

- Absorption and desorption columns
- Sump tanks
- Circulation pumps
- Condenser
- Heat exchanger

Experimental capabilities:

- Absorption of CO_2 from air-CO_2 gas mixture using water
- Desorption of CO_2 from the solution into air
- Determination of CO_2 saturation point in water and time to reach saturation
- Effect of CO_2 compositions, air and water flow rate on efficiency
- Effect of liquid temperature and air flow rate on desorption efficiency
- Hydrodynamics study of a packed column
- Determination of loading and flooding points of the column

Liquid-Liquid Extraction Unit (With Solvent Recovery) (Model : BP 60) SOLDAS SOLCAL EI

This **Liquid-Liquid Extraction Unit** is designed to demonstrate the principles and operation of liquid-liquid extraction and solvent recovery processes. The mobile unit consists of an extraction system and a solvent recovery system.

This unit consists of:

- Extraction and distillation columns
- Feed and solvent tanks
- Extract and raffinate tanks
- Reboiler
- Distillate tank
- Feed metering pumps
- Condenser

Experimental capabilities:

- Mass balance study
- Effect of feed flow rates on extraction efficiency
- Hydrodynamics of liquid-liquid systems
- Effect of solvent to feed ratio on extraction efficiency
- Effect of organic and aqueous phase as continuous phase

Liquid-Liquid Extraction Unit (Without Solvent Recovery) (Model : BP 61) SOLDAS SOLCAL EI

This **Liquid-Liquid Extraction Unit** is designed for demonstration of liquid-liquid extraction.

This unit consists of:

- Extraction column
- Feed and solvent tanks
- Extract and raffinate tanks
- Feed metering pumps

Experimental capabilities:

- Operation of a liquid-liquid extraction
- Effect of feed flow rates on extraction efficiency
- Effect of solvent to feed ratio on extraction efficiency
- Effect of organic and aqueous phase as continuous phase
- Determination of number of theoretical plates

Rotating Disc Liquid-Liquid Extraction Unit
(Without Solvent Recovery)
(Model : BP 63) SOLDAS SOLCAL EI

This **Rotating Disc Liquid-Liquid Extraction Unit** is designed for demonstration of liquid-liquid extraction with rotating disc.

This unit consists of:
- Extraction column
- Rotating disc
- Feed and solvent tanks
- Feed pumps
- Extract and raffinate tanks

Experimental capabilities:
- Operation of a liquid-liquid extraction
- Effect of feed flow rates on extraction efficiency
- Effect of solvent to feed ratio on extraction efficiency
- Effect of disc rotation speed on extraction efficiency

Double Effect Evaporator
(Model : BP 70) SOLDAS SOLCAL EI

This **Double Effect Evaporator** is designed to provide students with practical knowledge of evaporation process. Operations of single or double effect climbing film evaporator will be demostrated.

This unit consists of:
- Evaporator columns
- Vertical tube with heating jacket
- Cyclone separator
- Distillate cooler
- Concentrate and distillate receiver

Experimental capabilities:
- Operation of a single or double effect climbing film evaporator
- Effect of parallel, forward or backward feed sequence
- Effect of feed flow rate, evaporator temperature and pressure on evaporation rate and concentration levels
- Determination of capacity, sensible and evaporative heat loads of evaporator
- Mass and energy balance calculations

Continuous Distillation Column Unit (Model : BP 80-50) SOLDAS SOLCAL EI

This **Continuous Distillation Column Unit** is designed to demonstrate the principles and operation of continuous distillation. Students will be able to compare performance between tray column and packed column.

This unit consists of:

- Bubble cap tray and packed columns
- Feed and distillate vessels
- Feed pump
- Reboiler
- Reflux divider
- Phase separator

Experimental capabilities:

- Operation of batch and continuous distillation
- Effect of reflux ratio, feed flow rate, temperature, composition and feed position on product purity
- Effect of column loading on column efficiency
- Determination of number of theoretical plates using the Mc-Cabe-Thiele diagram
- Azeotropic distillation

Solids Handling Study Equipment (Model : BP 102)

This **Solids Handling Study Equipment** is designed to demonstrate the characteristics and behaviour of solid particles.

This unit consists of:

- Sieve shaker with six sieves
- Cylindrical hopper made of clear PVC
- Horizontal cylinder made of clear PVC
- Transparent V-cone mixing vessel
- Stainless steel ball mill charged with grinding material
- Glass cyclone and digital balance

Experimental capabilities:

- Particle size distribution, sieving techniques, hopper discharge, bulk density, angle of repose, solids mixing and ball mill comminution
- Study of cyclone operation for air pollution control

Catalytic Packed Bed Reactor (Model : BP 105)

This **Catalytic Packed Bed Reactor** is designed for demonstration of catalytic chemical reaction in tubular reactors.

This unit consists of:

- Two feed tanks
- Chemical reactor
- Stainless steel product tank tank – with sight glass
- Circulating hot bath
- Process control console

Experimental capabilities:

- Tubular flow reaction demonstration
- Determination of catalyst effect
- Investigation of catalyst modulus
- Reaction process equation
- Temperature effects on reaction kinetics
- Mass and energy balances
- Reaction rate determination
- Determination of mean residence time

Tray Drier (Model : BP 772) SOLDAS SOLCAL EI

This **Tray Drier** is designed to demonstrate industrial drying process.

This unit consists of:

- Axial flow fan with variable fan speed
- Electrical heaters with variable power input and protected against over temperature
- Drying chamber with transparent door
- Rack of trays suspended from the arm of a digital balance
- Instrumentations to measure air flow rate, humidity and temperature

Experimental capabilities:

- Use of psychrometric charts for mass and energy balances
- Demonstration of drying rate curve
- Effect of temperature and air velocity on drying rate

Liquid Mixing Equipment (Model : FM 103) SOLDAS SOLCAL EI

This **Liquid Mixing Equipment** is designed for laboratory experiments on solid-liquid and liquid-liquid mixing.

This unit consists of:

- Cylindrical mixing vessel made of Perspex
- Mixer motor with variable speed control
- Range of impellers such as a propeller, turbine and various flat blade paddles

Experimental capabilities:

- Visualisation of mixing and flow patterns
- Power and speed characteristics of different impellers
- Mixing of solid/liquid suspensions or immiscible liquids
- Study on mixer speed and torque limits

Spray Dryer (Model : FD 20)

This **Spray Dryer** is designed for demonstration of rapid spray drying processes involving aqueous emulsions, solutions, suspensions and colloids. Spray dryers are generally used in the food industry to process fish extracts, heat sensitive materials, milk and egg products, cereals, plant and vegetable extracts, etc.

This unit consists of:

- Atomizing mode: Two-fluid airflow spray nozzle
- Drying glass chamber
- Glass cyclone separator
- Exhaust fan

Experimental capabilities:

- Processing aqueous emulsions, solutions, suspensions and colloids
- Downward co-current operation (a fine jet of the liquid is brought into contact with a hot air stream)
- Incorporates manual jet de-blocking device

REACTION ENGINEERING

Liquid Phase Stirred Tank Reactor (Model : BP 100) SOLDAS SOLCAL EI

This **Liquid Phase Stirred Tank Reactor** is designed to demonstrate the behaviour of a stirred tank reactor.

This unit consists of:

- Reactor – CSTR made of glass
- Stirrer system – variable speed, digital display
- Cartridge heater type, 1kW with temperature controller
- Internal cooling coil
- Condenser
- Feed tanks and pumps for each reactant
- Product or waste tank
- Flow and temperature measurement
- Conductivity meter

Experimental capabilities:

- Batch or continuous saponification reaction of ethyl acetate and sodium hydroxide
- Effects of residence time and reaction temperature on reaction rate

Tubular Flow Reactor (Model : BP 101) SOLDAS SOLCAL EI

This **Tubular Flow Reactor** is designed to demonstrate the behaviour of a plug flow reactor.

This unit consists of:

- Reactor – "Plug flow reactor" made of stainless steel coil
- Water jacket made of glass
- Stirrer system – variable speed, digital display
- Cartridge heater type, 2kW with temperature controller
- Cooling coil
- Feed tanks and pumps
- Product or waste tank
- Flow and temperature measurement
- Conductivity meter

Experimental capabilities:

- Continuous saponification reaction of ethyl acetate and sodium hydroxide
- Effects of residence time and reaction temperature and on reaction rate constant
- RTD studies

CSTR in Series (Model : BP 107) SOLDAS SOLCAL EI

This **CSTR in Series** is designed to demonstrate the dynamic behaviour of reaction in series

This unit consists of:

- Three CSTR in series made of glass
- Stirrer system – variable speed, digital display for each reactor
- Sump tanks and pumps
- Dead time coil
- Product or waste tank
- Flow meters
- Conductivity meters

Experimental capabilities:

- RTD studies on three CSTR in series
- Effects of step input and pulse change
- Non-ideal reactor behaviour using dead time coil

Batch Reactor (Model : BP 109) SOLDAS SOLCAL EI

This **Batch Reactor** is designed to demonstrate the behaviour of a batch reactor

This unit consists of:

- Reactor – made of glass, vacuum jacketed
- Stirrer system – variable speed, digital display
- Cartridge heater type, 1kW with temperature controller
- Feed tanks and pumps for each reactant
- Product or waste tank
- Water bath with 4kW heater and temperature controller
- Flow and temperature
- Conductivity meter

Experimental capabilities:

- Batch saponification reaction of ethyl acetate and sodium hydroxide
- Determination of reaction rate constant
- Effect of temperature on reaction rate constant
- Determination of activation energy

RTD Studies in Packed Bed Reactor (Model : BP 112) SOLDAS SOLCAL EI

This **RTD Studies in Packed Bed Reactor** is designed to demonstrate principles of RTD in a packed bed reactor.

This unit consists of:

- Packed bed reactor – glass column (DN100 x 1.5m) filled with Raschig rings
- Sump tanks and feed pumps
- Waste tank
- Flow meters for liquid and gas
- Conductivity meters

Experimental capabilities:

- Step change and pulse input responses
- Effect of flow rate on pulse input
- Co-current and counter-current modes

Crystallisation Unit (Model : BP 123)

This **Crystallisation Unit** is designed to demonstrate basic principles of crystallization and operations of a crystallizer

This unit consists of:

- Feed and product vessels
- Crystallization pump and vessel
- Heat exchanger
- Distillate condenser
- Heating/Cooling systems
- Condensate vessel

Experimental capabilities:

- Demonstration of crystallization processes using evaporation, surface cooling, vacuum cooling (optional) and reaction methods
- Study of solubility curves and phase diagrams for crystallization
- Observation of formation of crystals, nucleation and crystal growth
- Effects of circulation and feed flow rates on crystallization rates
- Effects of temperature, reaction and pressure (optional) on crystallization rates

Reactor Service Unit + 3 Reactors (Model : BP 150) SOLDAS SOLCAL EI

This **Reactor Service Unit + 3 Reactors** is designed to demonstrate the behaviour of different types of reactors using a common service unit with interchangeable reactors.

This unit consists of:

- Continuous stirred tank reactor
- Plug flow reactor
- Batch reactor
- Feed tanks and pumps
- Waste tank

Experimental capabilities:

- Saponification reaction between NaOH and Et(Ac)
- Effect of temperature on reaction kinetics
- Effect of residence time on extent of conversion
- Studies on reaction rate constant
- Calculation of activation energy using the Arrhenius equation
- RTD studies using step change and pulse input

Benchtop CSTR in Series (Model : BP 151) SOLDAS SOLCAL EI

This **Benchtop CSTR in Series** is designed to introduce students to the dynamic behaviour of reactors in series.

This unit consists of:

- Reactors – three reactors made of borosilicate glass, capacity 1 L each
- Stirrer system – variable speed motor with speed controller and indicator, stainless steel impeller
- Sump tanks
- Dead-time coil
- Conductivity meters
- Flow meters

Experimental capabilities:

- Mass balance analysis
- Dynamic behaviour of CSTR in series
- Effect of step change and pulse input
- Non-ideal reactor behaviour using dead-time coil

Gas Adsorption Unit (Model : BP 200) SOLDAS SOLCAL EI

This **Gas Adsorption Unit** is designed to demonstrate the working principles of gas phase adsorption.

This unit consists of:

- Evaporator
- Adsorption columns
- Adsorbent – molecular sieve
- Heating sleeves with insulation
- Drying columns
- Thermostat
- Vacuum pump

Experimental capabilities:

- Adsorption process for removal of hydrocarbon (n-hexane or cyclo-hexane) from carrier gas stream
- Adsorption process for removal of n-hexane from hydrocarbon mixture
- Plot of breakthrough curves
- Effect of carrier gas flow rate on the separation process
- Column regeneration

Pressure Swing Adsorption Column System (Model : BP 202-A) SOLDAS SOLCAL EI

This **Pressure Swing Adsorption Column System** is designed to demonstrate the fundamental and working principles of pressure swing adsorption. Air separation is used as an example.

This unit consists of:

- Adsorption columns
- Adsorbents – zeolite and activated carbon, molecular sieve
- Heating sleeves with insulation
- Vacuum pump
- Temperature, pressure and flow measurements
- Oxygen concentration measurement

Experimental capabilities:

- Operation of pressure swing adsorption process
- Determination of adsorption bed capacity
- Determination of saturation limit
- Determination of adsorption isotherm equilibrium and profile characteristic
- Effect of pressure and flow rate
- Comparison of different adsorbent material and properties
- Mass transfer study

Short Path Distillation System (Model : BP 217) SOLDAS SOLCAL EI

This **Short Path Distillation System** is designed for demonstration of separation process for thermal sensitive products. The short residence time and low evaporation temperature process is a great advantage for many high-molecular-weight organic compounds particularly in the fields of chemistry, pharmaceutical and food industry.

This unit consists of:

- Short path evaporator made of borosilicate glass comes with heating jacket and stirrer dirve
- Feed funnel
- Products and condensate vessels
- Graduated cylinder
- Vacuum system
- Heating and cooling circulation systems

Experimental capabilities:

- Determination of thermal separation efficiency
- Effects of evaporator temperature, stirrer speed, mixture ratio and feed flow rate on separation efficiency
- Mass balance analysis

Fixed Bed Adsorption Reactor (Model : BP 208) SOLDAS SOLCAL EI

This **Fixed Bed Adsorption Reactor** is designed to demonstrate the principles of adsorption of CO_2 from a binary gas mixture onto the surface of a solid adsorbent (activated carbon). The process takes place in a fixed bed column.

This unit consists of:

- packed fixed bed adsorption column
- hot water circulation system
- infrared detector

Experimental capabilities:

- Adsorption and desorption processes under various operating conditions
- Breakthrough curves
- Quasi-isothermal regime at low concentrations and pressures
- Solute movement theory which describes the adsorption and desorption processes
- Understand the formation of compressive and dispersive fronts in adsorption processes
- Adsorption equilibrium isotherm of CO_2

Reactor Basic Unit (CSTR) (Model : BP 400) SOLDAS SOLCAL EI

This **Reactor Basic Unit (CSTR)** is designed to introduce students to the behaviour of a CSTR reactor.

This unit consists of:

- Reactor comes with stirrer system and internal cartridge heater
- Feed tanks and feed pumps
- Measurements for flow and conductivity
- Temperature control

Experimental capabilities:

- Chemical kinetic studies
- Effect of residence time, temperature and mixing
- Batch or continuous operations

Reactor Basic Unit (Batch) (Model : BP 409) SOLDAS SOLCAL EI

This **Reactor Basic Unit** is designed to introduce students to the behaviour of a batch reaction.

This unit consists of:

- Batch reactor comes with stirrer system
- Feed tanks and feed pumps
- Hot water bath
- Measurements for flow and conductivity
- Temperature control

Experimental capabilities:

- Chemical kinetic studies
- Effect of temperature on reaction rate constant
- Determination of activation energy