Education and Culture
Leonardo da Vinci

Sustainability in commercial laundering processes

Module 5
Usage of energy in laundries

Chapter 4

Heating energy and heat exchangers

Content

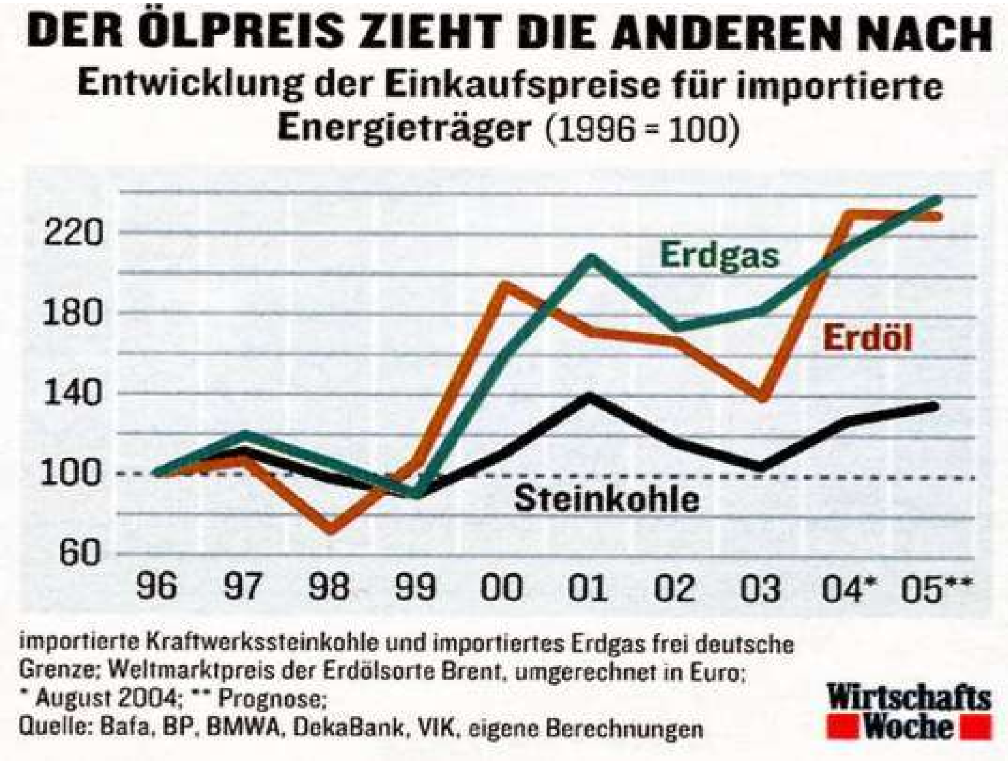
- Basics of heat recovery in wash processes
- The 4 basic laws of thermodynamics
- Optimizing the heat exchange (type of flow, temperature differences, mass flow etc.)
- Different designs of heat exchangers
- Example: Kannegiesser corrugated pipe heat exchanger
- Summary of advantages

Learning targets

After finishing the module you will

- have a basic knowledge about heat exchangers in wash processes.
- know the 4 basic laws of thermodynamics.
- understand the influence of the type of flow (i.e. countercurrent/concurrent, laminar/turbulent) on the efficiency of heat exchangers.
- be able to deduce from the theoretical basics practical recommondations for optimizing heat exchangers.
- know different designs of heat exchangers and their fitness for use as waste water heat exchangers in laundries.
- know the advantages of using heat exchangers in wash processes.

German magazine "Wirtschaftswoche" from August 26, 2004:



Natural gas

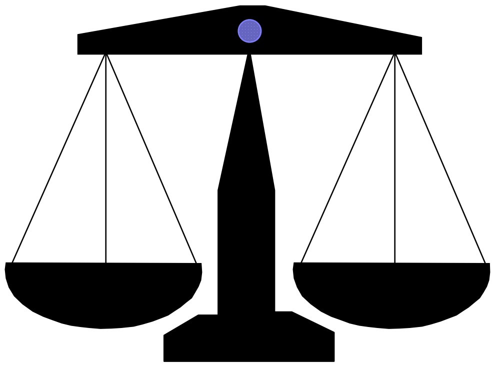
Crude oil

Hard coal

The costs for energy have increased by more than 100 % since 1999!

What does Heat Recovery mean?

Energy which is normally lost in the process is recovered by heat exchanger for reuse in the process.



Calculation basis: $Q_{in} = Q_{out}$

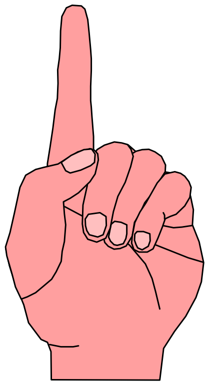
How does heat recovery work with Batch Washers?

Very simple!

Before going to drain, the hot bath passes the heat exchanger for cooldown and in turn for heating up of counterflowing fresh water.

How much energy for washing can be recovered?

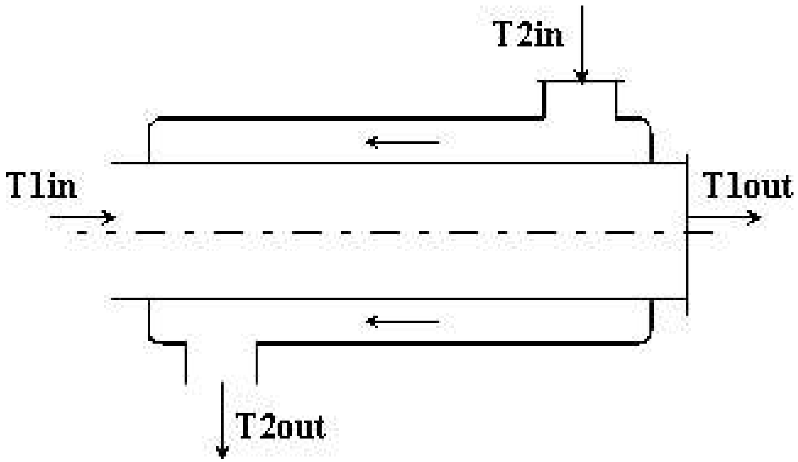
Theoretically > 50 %



- In general, only 40 to 45 % of the wash bath is recovered, otherwise pre-wash temperature would exceed 40 °C.
- Acceptable pre-wash temperatures over 40 °C allow higher volumes of wash bath recycling.

How is heat recovery calculated?

Temperature difference of each side, multiplied by the flow volume and the specific energy capacity = KWh output.



T1in:	waste water inlet
T1out:	waste water outlet
T2in:	fresh water inlet
T2out:	fresh water outlet

$$\Delta T = T_{in} - T_{out}$$

$$\dot{Q} = \Delta T * c * \dot{m}$$

$$\dot{Q}_{FW} = \dot{Q}_{waste\ water}$$

$$Savings = \dot{Q} \times {}^{€}\!/_{kWh}$$

The basic laws of thermodynamic

- "Zeroth" law of thermodynamics
  If system A is in thermal equilibrium with system B, and system B is in thermal equilibrium with system C, then system A is in thermal equilibrium with system C.

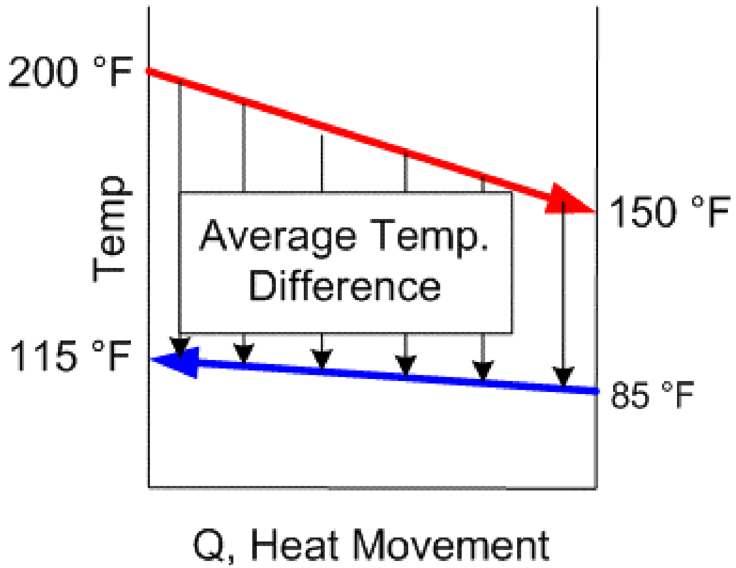
- First law of thermodynamics
  Energy can neither be created nor destroyed; it can only change forms.

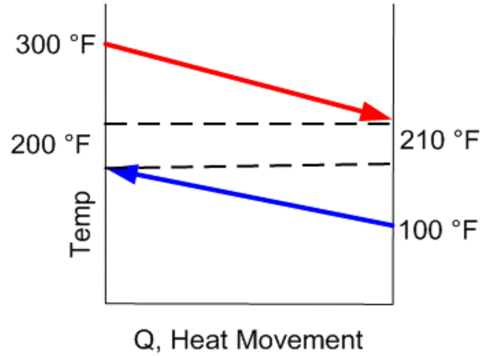
- Second law of thermodynamics
  Two bodies which are at different temperatures exchange heat in such a manner that heat flows naturally from the hotter to the colder body.

- Third law of thermodynamics
  A temperature of absolute zero (0 K) is unattainable.

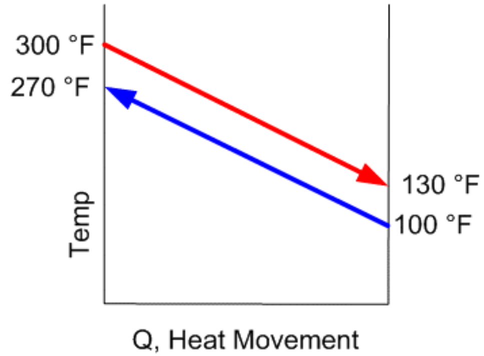
Second Law of Thermodynamics

Heat can only move from a higher to a lower temperature fluid:





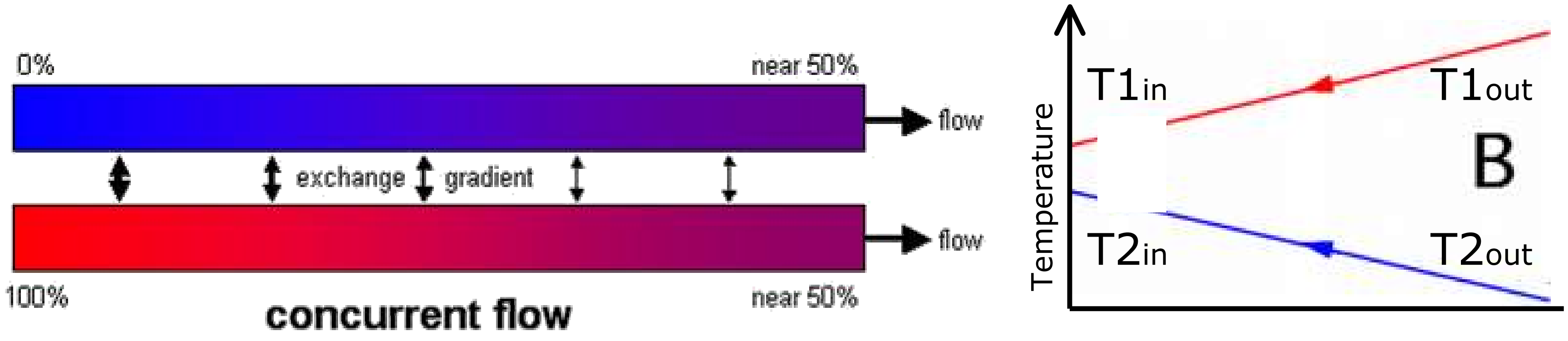
Concurrent flow

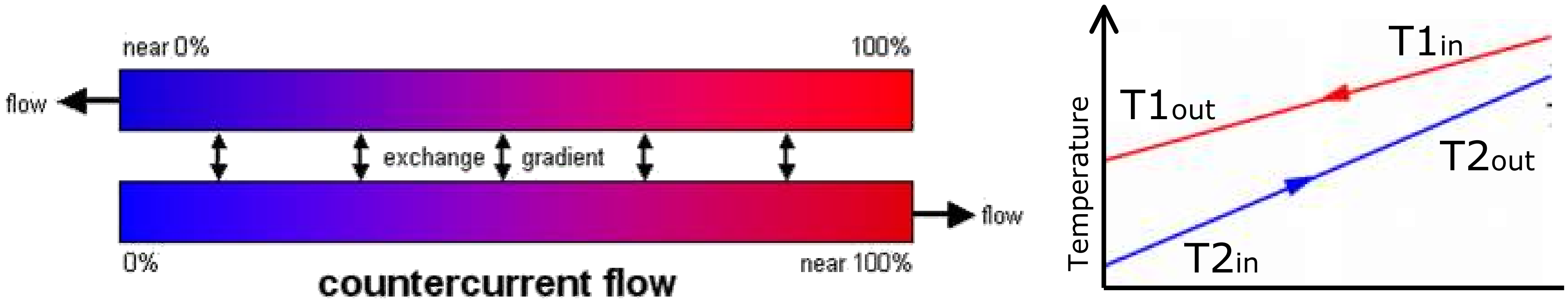


Countercurrent flow

Source: www.cheresources.com

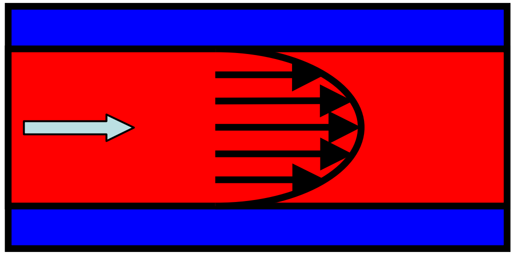
Concurrent and countercurrent flow in heat exchangers



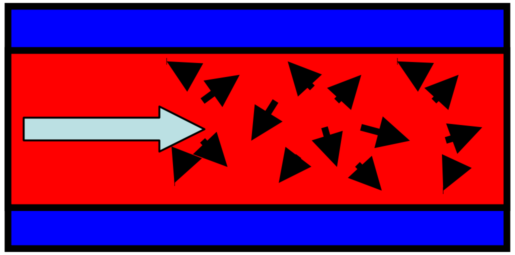


(with $T1_{in}$ = 100% and $T2_{in}$ = 0%)

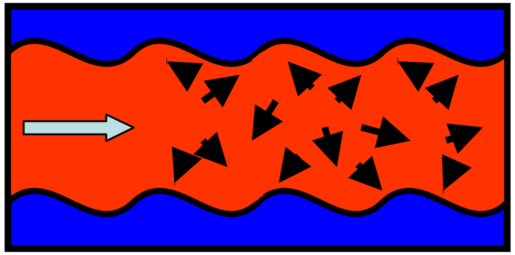
Laminar and turbulent flow in heat exchangers



Laminar flow



Turbulent flow
due to increased speed



Turbulent flow
due to surface design

- The flow caracteristics depend on the **flow speed**, on the **length of the flow** and on the **viscosity of the liquid** ("Reynolds number")
- **Laminar flow leads to a poor heat exchange**
- However: In heat exchangers, the flow speed and length are limited due to the pressure losses
- Therefore, turbulences are increased by the heat exchanger design

Optimizing the heat recovery

$T1_{in}$:	waste water inlet	$T2_{in}$:	fresh water inlet
$T1_{out}$:	waste water outlet	$T2_{out}$:	fresh water outlet
$\Delta T1$:	$T1_{in} - T1_{out}$	$\Delta T2$:	$T2_{out} - T2_{in}$

Ideal heat recovery: $T2_{out} = T1_{in}$

This is only possible in a theoretical situation with **counter-current flow**, with **no losses to the surrounding** and with **infinite time**.

In this ideal situation, if all energy has been transfered from the waste water to the fresh water, then **$T1_{out}$ must equal $T2_{in}$**!

⇨ Precondition for optimizing a heat exchanger: **$\Delta T1 = \Delta T2$**

What does this mean in practice?

- $\dot{Q} = \Delta T \times c \times \dot{m}$
- $\dot{Q}_{\text{fresh water}} = \dot{Q}_{\text{waste water}}$ (first law of thermodynamics)
- $\Delta T_{\text{fresh water}} = \Delta T_{\text{waste water}}$ (as seen before)
- $c_{\text{fresh water}} = c_{\text{waste water}}$ (heat capacity of water = 4.186 kJ/kgxK)

- Therefore: $\dot{m}_{\text{fresh water}} = \dot{m}_{\text{waste water}}$

⇨ **Equal temperature differences** for both liquids are archieved with **equal mass flows** in both directions

Example

Kannegiesser Corrugated Pipe Heat Exchanger

Measuring in a laundry:

Ingoing bath: 54.1 °C

Outgoing bath: 36 °C

Outgoing fresh water: 38.5 °C

Ingoing fresh water: 21.4 °C

Summary of the basics

For optimizing the heat exchanger, make sure that

- the flow directions are connected in **countercurrent** direction
- there are **turbulences** in the liquids
- a **big surface** for the heat transfer is available
- the **mass flow** and the **temperatur differences** in both directions **are the same**
- **as much time as possible** is available for the heat exchange (i.e. for a tunnel washer, throttle the rinse flow to almost the total cycle time)

Types of heat exchangers

Shell and Tube
Heat Exchanger

Corrugated Pipe
Heat Exchanger

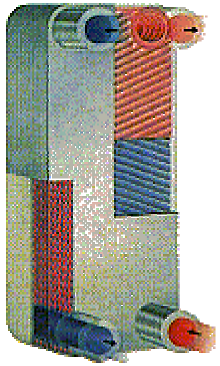
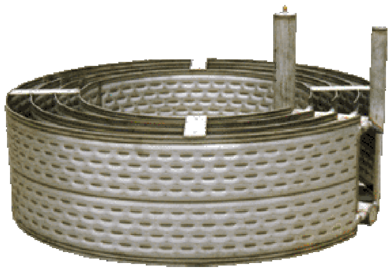


Plate Heat Exchanger



Panel Heat Exchanger

Rotating Discs
Heat Exchanger

Shell and Tube Heat Exchanger

- Cold medium flows through the jacket space (baffle plates).
- Hot medium flows through the tubular path (single or multiple coil).

↑ Proven technology
↑ Satisfactory efficiency
↑ Satisfactory price-performance ratio
↑ Insensitive to water hammer blows
↓ Not suitable with soiled medium

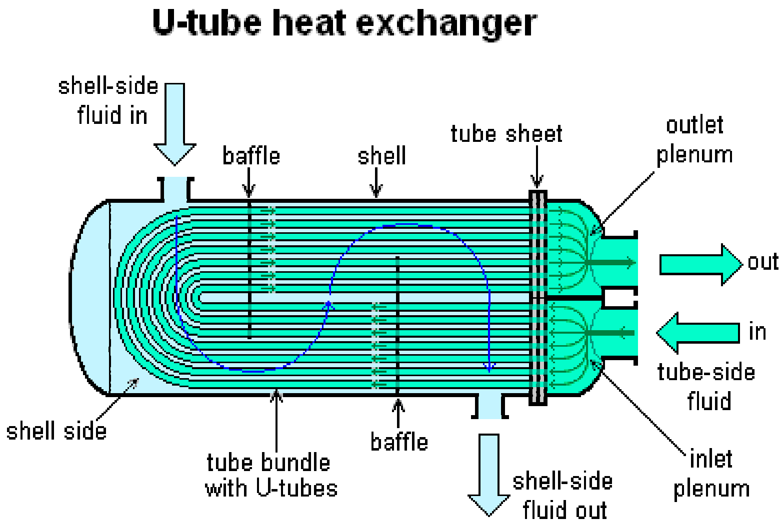
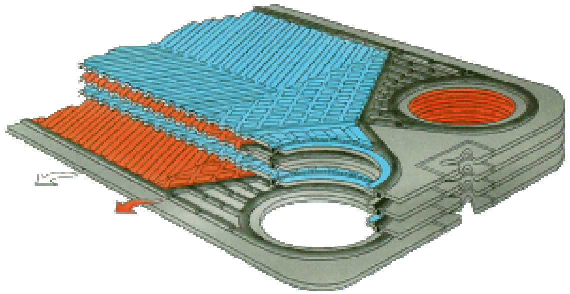


Plate Heat Exchanger

- Assembly of profiled plates with pass-through openings.
- Flow channels resulting from 180° staggered arrangement of plates.

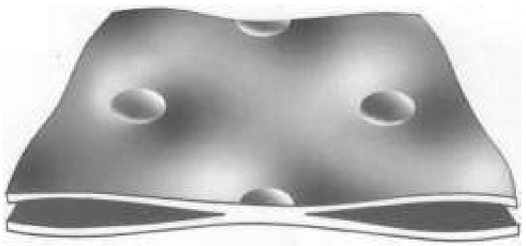
↑ Optimum transfer efficiency on small foot print
↑ Good price-performance ratio
↑ Good efficiency
↑ Very flexible and expandable
↓ Not suitable with soiled medium

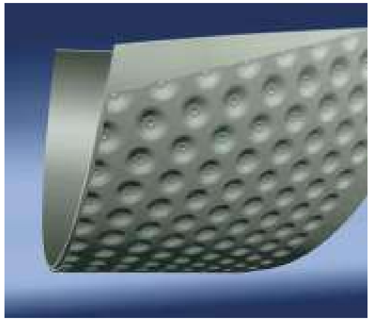


Panel Heat Exchanger

- Heat transfer by means of thermo sandwich plates.
- Sandwich means two plates of identical gauge spot-welded together.

↑ Flexible styling
↑ Compact design
↑ Very high efficiency
↑ Low maintenance





Application in Laundries

- Stand-alone unit for waste water cooling and fresh water heating
- Placed beside the washer
- No connection to the washer control
- Also: Heating band for ironers

Rotating Discs Heat Exchanger

- Fresh water is pressed through the inner pipe and pushed by rotation to the surrounding discs.
- Soiled water counterflows the discs.

↑ Large exchange surface
↑ Selfcleaning rotor
↑ High efficiency
↑ Compact design
↑ Suitable with soiled water

Application in Laundries

- Offered by chemical suppliers (OEM)
- Stand-alone unit for waste water cooling and fresh water heating
- No connection to the washer control

Corrugated Pipe Heat Exchanger

- Pipe-in-pipe system especially adapted for application in laundries.
- Soiled water moves through a corrugated centre pipe.
- Fresh water counterflows through a likewise corrugated outer pipe.

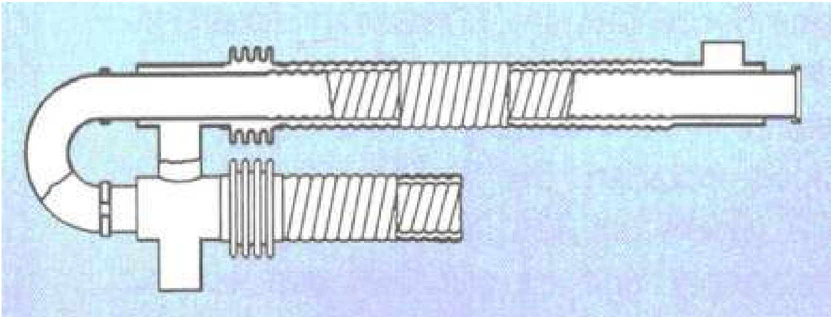
- ↑ Simple components
- ↑ Maintenance-free, wear-resistant
- ↑ High efficiency
- ↑ No mix of material
- ↑ Insensitive to water hammer blows
- ↑ Suitable for soiled water
- ↑ Horizontal and vertical application
- ↑ Connected with washer control

The corrugation of both pipes has two main reasons:

1. Enlargement of surface ⇨ increase of efficiency
2. Creation of turbulences ⇨ increase of efficiency, always clean pipes

Kannegiesser Heat Exchanger Package

Corrugated Pipe Heat Exchanger



- Inner tube up to Ø 114 mm (4“)
- Outer tube up to Ø 154 mm (6“)
- Volume flows up to 40 m^3/h
- Operating pressure 6 to 40 bar
- Compact design

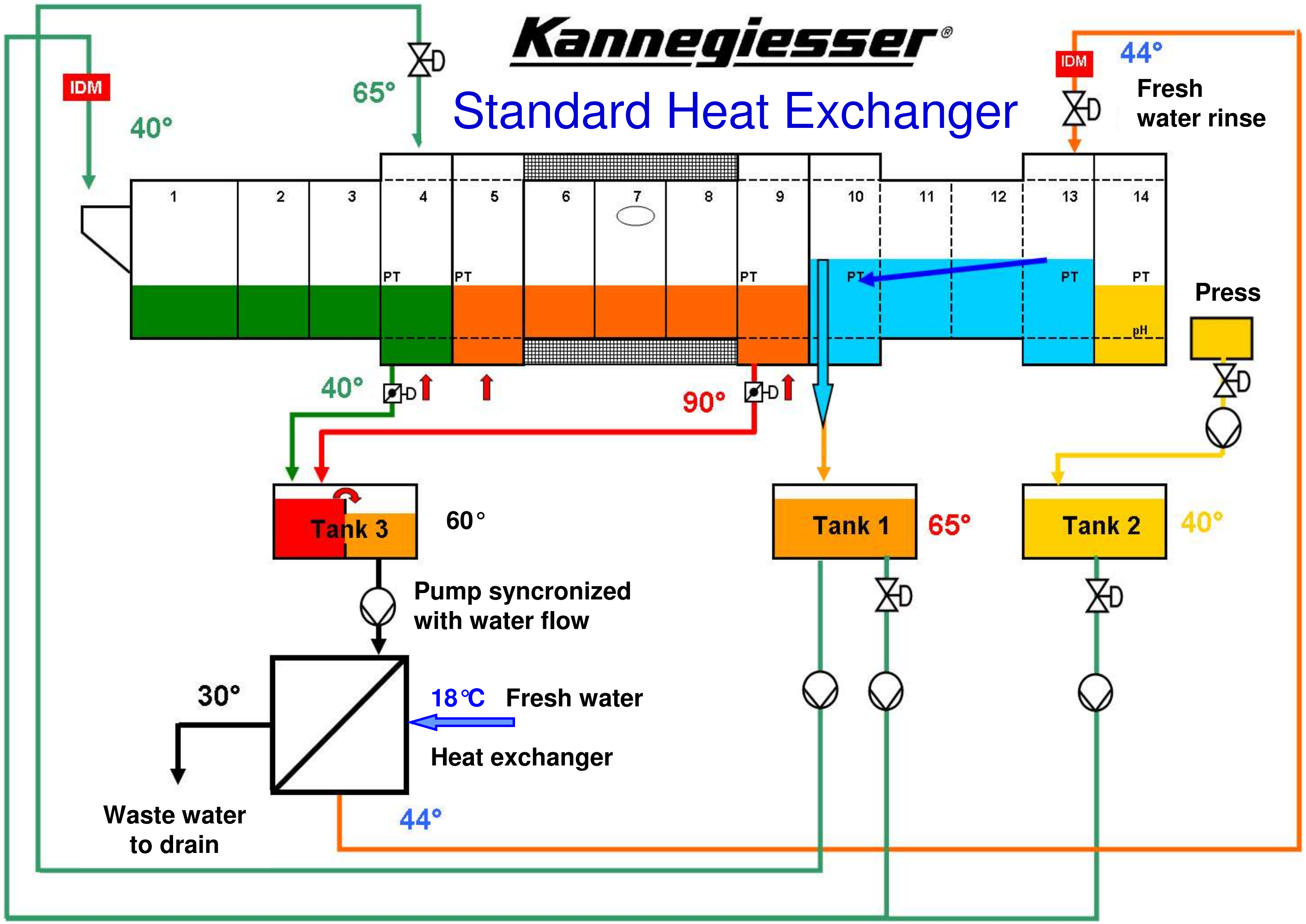
No problems with sludge or pressure variations!

Kannegiesser Heat Exchanger Package

Corrugated Pipe Heat Exchanger

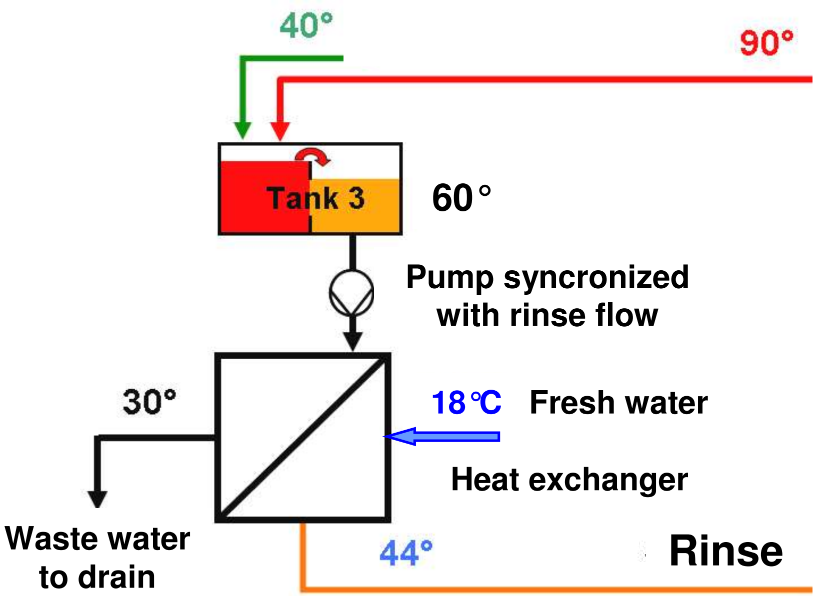
	
Standard Heat Exchanger	Heat Exchanger with Controlled Flow Temperature

Standard Heat Exchanger



Kannegiesser Heat Exchanger Package

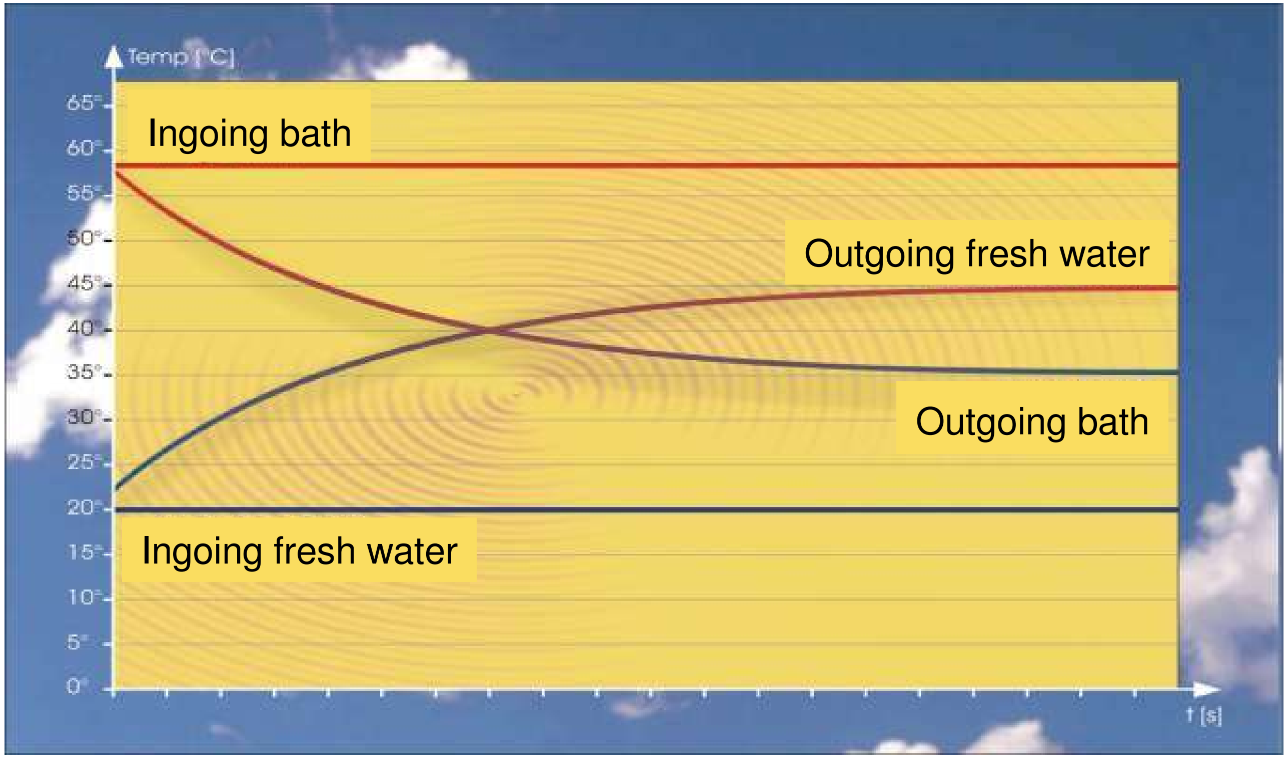
Corrugated Pipe Heat Exchanger



- Drain of waste water into separate reservoir tank.
- Frequency-controlled pumping of exactly identical waste water amounts through the heat exchanger, which equal the fresh water quantities counter-flowing the batch washer rinse zone.

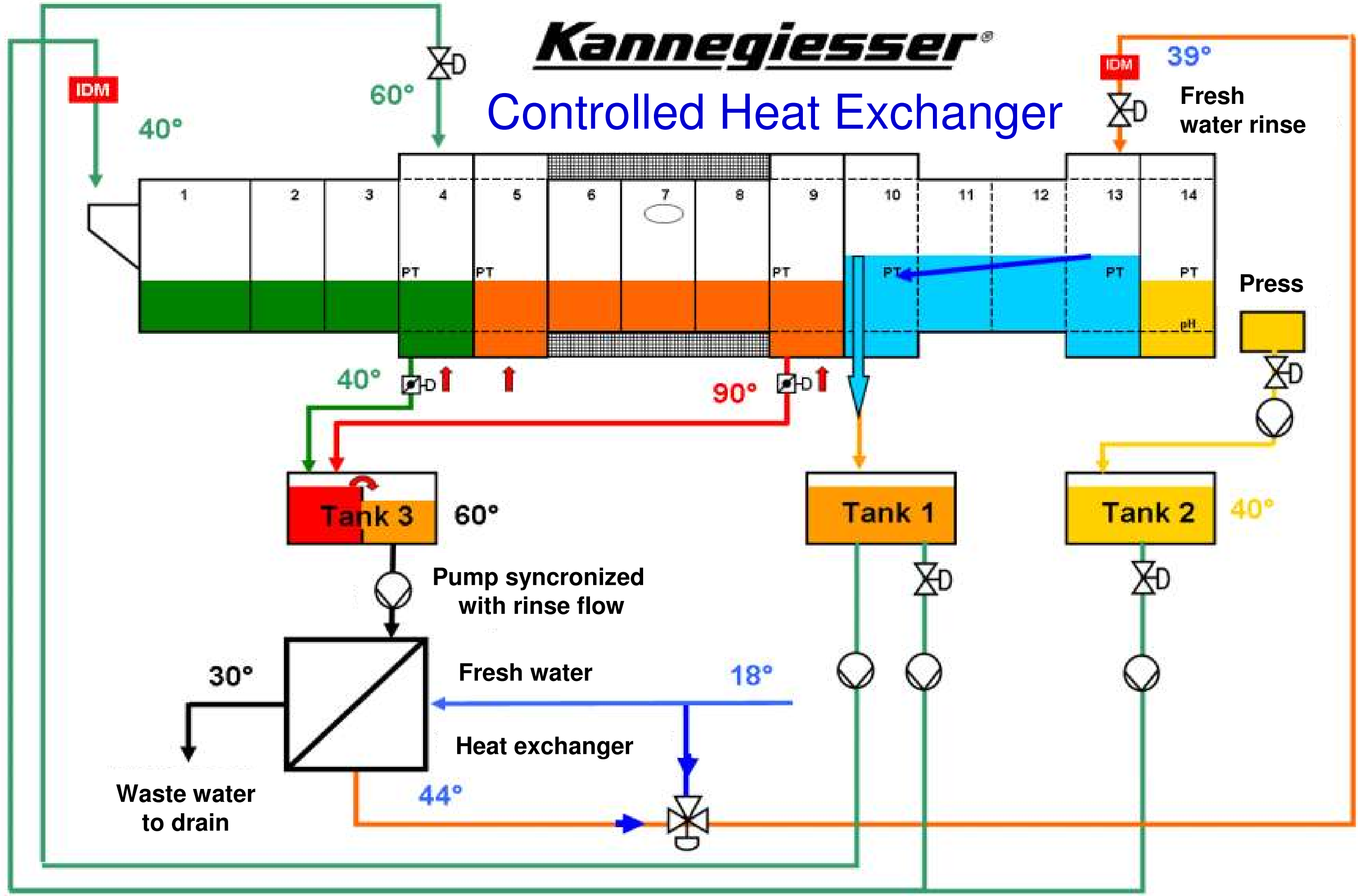
Kannegiesser Heat Exchanger Package

Corrugated Pipe Heat Exchanger



High efficiency due to counterflow

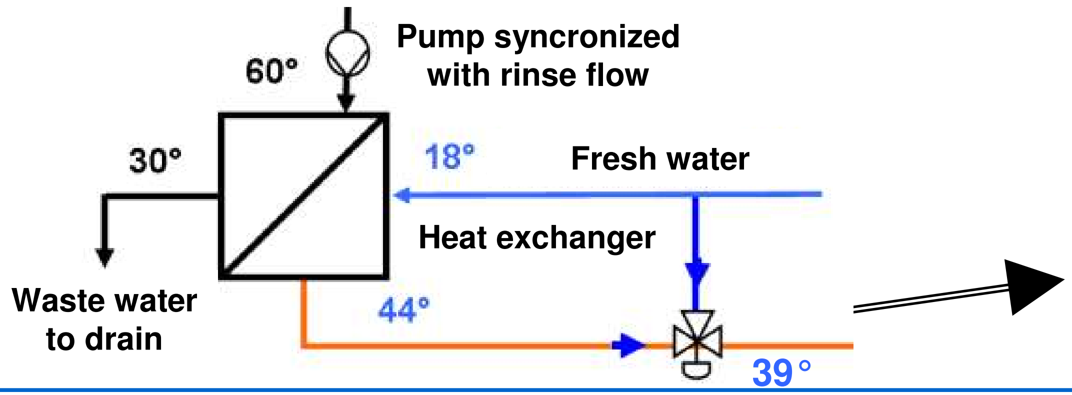
Controlled Heat Exchanger



Kannegiesser Heat Exchanger Package

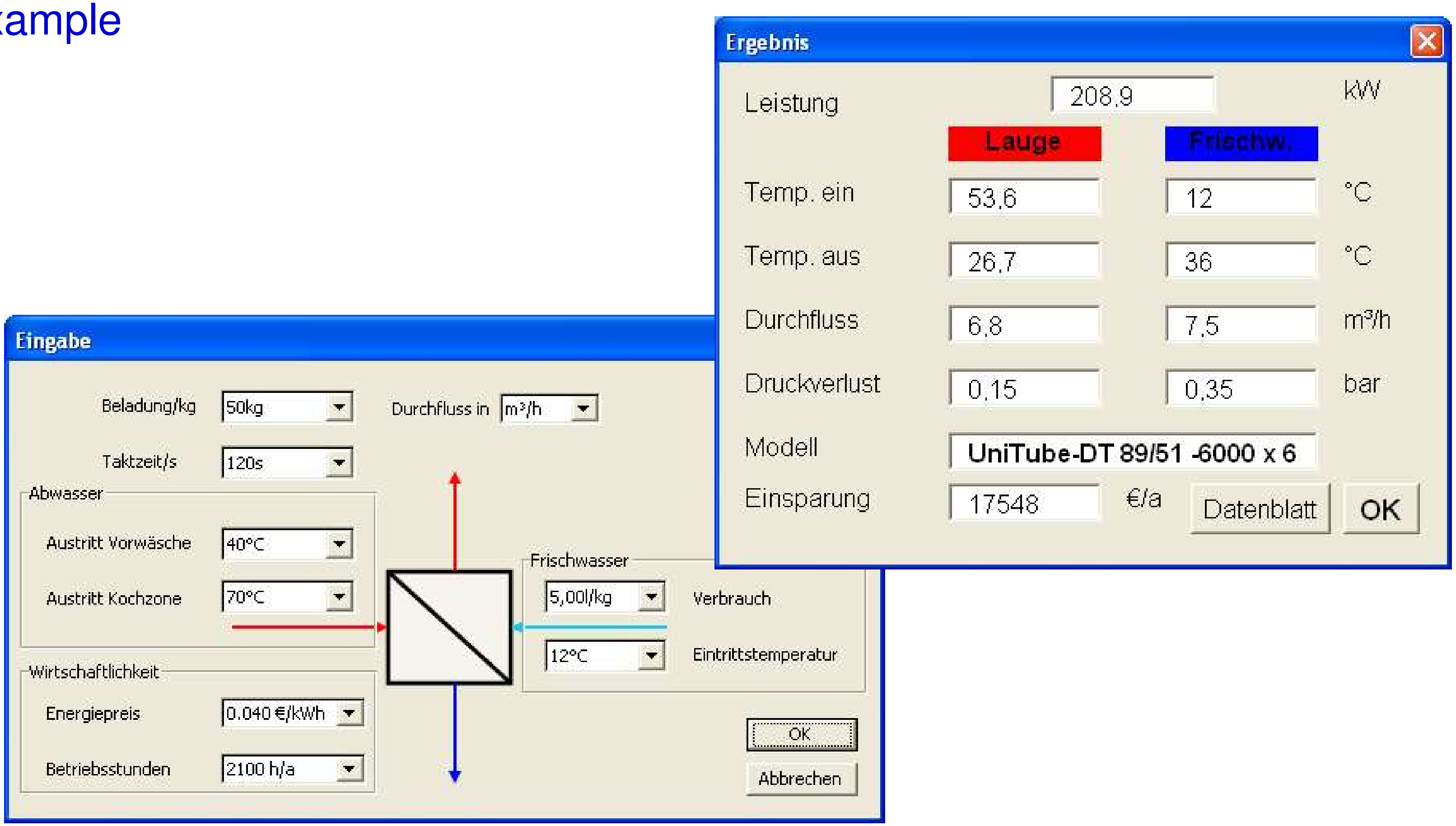
Heat Exchanger with Controlled Rinse Flow Temperature

- Selection of defined rinse flow temperatures for each wash programme.
- Based on the heat exchanger outlet temperature the control of the mixing valve calculates the required fresh water amount to reach the programmed rinse flow temperature.



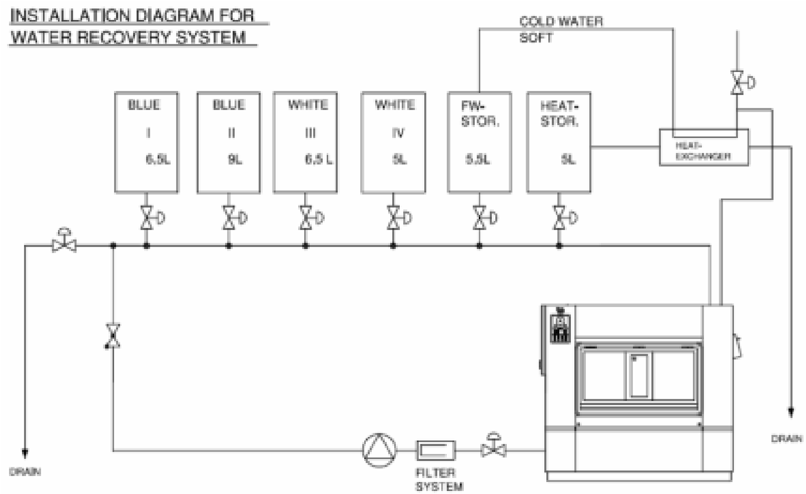
Kannegiesser Heat Exchanger Package

Example



Kannegiesser Heat Exchanger Package

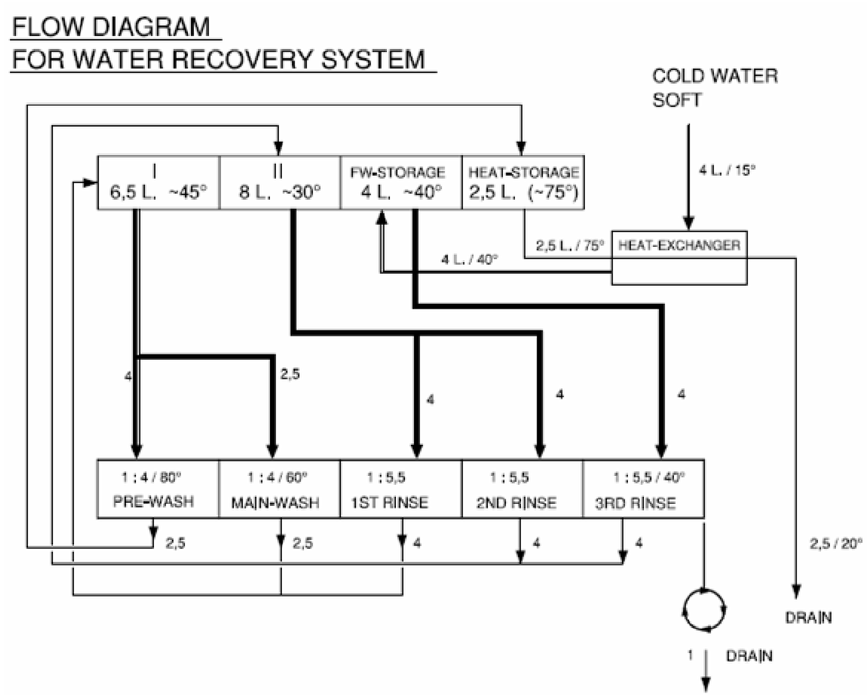
FAVORIT 2700 Low Consumption Technology



Kannegiesser Heat Exchanger Package

FAVORIT 2700 Low Consumption Technology

- Capacity 300 kg/h
- Water recovery system utilising energy from the waste water
- Reducing waste water temperatures and pH-values according to german rule ATV-A 115
- Reduction of fresh water consumption up to 80 % (4,0 - 8,0 ltr/kg)
- Reduction of steam consumption up to 60 % with integrated heat exchanger



Kannegiesser Heat Exchanger Package

Summary

ADVANTAGES: Heat Recovery Systems in general

- Lower drain water temperatures, compliance with public rules
- Higher rinse temperature lead to better rinse effect through swelling of fibres
- Higher water extraction, lower residual moisture, shorter drying times
- Savings through lower energy consumption in the finishing process

Kannegiesser Heat Exchanger Package

Summary

ADVANTAGES: Kannegiesser Corrugated Pipe Heat Exchanger

- High efficiency
- Simple components, no material mix
- Maintenance-free, wear-resistant
- Insensitive to water hammer blows and sludging
- Horizontal and vertical application
- Connected with washer control

Kannegiesser Heat Exchanger Package

Summary

ADVANTAGES: Controlled Rinse Flow Temperature

- Individual setting of rinse temperature for each wash programme
- No hazard of excessive extraction temperatures (mixed fibres)
- Tank temperature control of the extraction unit
- No fresh water consumption in compartment 1 caused by excessive pre-wash temperatures