

# Film Evaporation Technology



# Film Evaporation Technology at Sulzer Chemtech

Sulzer Chemtech, a member of the Sulzer Corporation, with headquarters in Winterthur, Switzerland, is active in the field of process engineering, employing 3'000 persons worldwide. Sulzer Chemtech is represented in all important industrial countries setting standards in the fields of mass transfer and static mixing with its advanced and economical solutions.

Sulzer Chemtech is organized into four business units, one of which is the Process Technology group. This business unit was formed in early 2009 following the acquisition of Kühni, a Swiss company with more than 75 years experience in innovative separation processes. Today, Sulzer Chemtech Process Technology is headquartered in Allschwil (Basel), Switzerland. We provide a unique and wide portfolio of separation and application technologies, amongst which film evaporation technology.

Our film evaporators enable you to produce high-purity substances from heat-sensitive and complex products. The use of vacuum and the short time a product stays in contact with the heated surface are two essential factors to prevent a deterioration of quality through secondary reactions (like polymerization and condensation) and to preserve organoleptic product properties (color, smell, taste), as required in many industries - food, fine chemical and pharmaceutical.

We provide you with a solution and support you in your continuous effort to improve the product purities while increasing the yields at the same time.

We are able to offer you specialized film evaporation technologies, with both static and mechanically agitated film evaporators.

## Typical Applications

Our film evaporators are widely used in the industry as single equipment but also as column reboilers in vacuum and high vacuum rectification and distillation systems. An overview of the typical applications for our film evaporators are:

- Product purification
- Solvent recovery
- Concentration of solutions
- Concentration of slurries
- Degassing
- Stripping and thus reducing of industrial waste streams

## Industries and Products

Our film evaporators are mainly used in the following industries:

- Chemical and fine chemical industry
- Pharmaceutical industry
- Food and beverage industry
- Biotech industry
- Oleochemical industry
- Nutraceutical industry

## Equipment Overview

Our tubular falling film evaporator is specifically suited to process your heat-sensitive products with a low viscosity and a low tendency for fouling. It consists of a tube bundle crowned by a proprietary liquid distribution device that ensures an efficient and uniform distribution of the liquid to all the tubes and a continuous film along the tube length.

Our thin or wiped film evaporator is the ideal apparatus for you, if you need a continuous processing of your heat-sensitive, viscous and fouling products. It consists of a single evaporation tube fitted with a mechanical rotating device that ensures a uniform distribution of the liquid on the heated surface, a constant mixing of the film and minimal fouling of the evaporation surface.

In our short path evaporator, a vertical condenser is placed inside the wiped evaporation chamber which results in a very short distance between the heating and condensing surface. The pressure drop across the system is thus minimized and evaporation in the pressure range well below 1 mbar is feasible.

*Our head offices in Allschwil, Switzerland*



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# Falling Film Evaporator

**Our falling film evaporator facilitates gentle heating at a low pressure drop**

## Design

Our falling film evaporator is the simplest and most commonly used type of film evaporator. The liquid flows as a thin film on the inside of heated vertical tubes, driven by gravity. The resulting vapor normally flows cocurrently with the liquid, in the centre of the tubes.

A full evaporation stage consists of the falling film evaporator itself including the feed distribution system, a separator to separate the vapors from the residual liquid, and a condenser. Additionally, when high evaporation ratios are required, a part of the concentrated liquid is recycled back to the inlet of the evaporator, in order to ensure that sufficient wetting of the tubes is maintained.

We can supply our falling film evaporators in a wide range of standard sizes, as well as individually customized sizes.

The gas-liquid separators are available in a standard range, including various optional design features. The application of this device is not always required, however. For example, when your falling film evaporator is used as a reboiler, the still vessel of a batch plant, or the bottom section of a distillation column can often serve the same purpose.

The essential part of our falling film evaporator is the proprietary liquid distribution system. It allows an even distribution of the liquid feed to all the tubes and ensures a continuous thin film along the entire tube length. Dry zones are thus eliminated and the quality of your products is preserved.

*On-site installation of a large falling film evaporator*



## Advantages

Our falling film evaporation technology is suitable to a wide range of applications with the following advantages:

- High heat transfer coefficients
- Short residence time on the heated tube surface
- Low pressure drop
- Suitable for vacuum operations
- Low temperature difference between process and heating medium
- High evaporation ratios
- Wide operating range
- Low susceptibility to fouling
- Cost effective equipment
- Suitable for application according to GMP guidelines

*Tube inserts of a falling film evaporator*



*Examples of falling film evaporators*



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# Distribution System for Falling Film Evaporators

**Our proprietary distribution system is the essential part of our falling film evaporator**

## Design

Our feed distributor is a two stage system, with a highly accurate performance and a wide operating range.

Your process liquid feed enters the falling film evaporator through the inlet feed pipe and is directed to the top liquid distributor.

From the distributor the liquid then flows to the tube sheet which is equipped with many drip points to ensure the generation of an even and calm static liquid height upstream of the tube inlets.

After this pre-distribution, the liquid is directed tangentially onto the tubes through slits in specially designed tube sleeve inserts. These inserts ensure stable and uniform liquid films. In addition, the liquid will be evenly and well distributed to all the tubes. All this leads to the formation of an excellent liquid film and thus to a smooth and gentle evaporation in our falling film evaporator.

## Sleeves

Each and every tube in our evaporator is equipped with proprietary sleeve inserts. The inserts are installed manually, without the need of any tools. Nor is welding required to secure the sleeves in their position.

The number of so-called reflectors on each sleeve and the corresponding installation angle are carefully designed and adapted to the process conditions to create a tangential flow of liquid into the tubes.

Together with an optimized liquid static head, the sleeves ensure the generation of a uniform liquid film in the tubes and the desired film thickness.

The conceptual design is based on testing results and our extensive experience. The detailed sizing is supported with our in-house developed propriety design tool.

## Features

Some special features of our sleeves are:

- Removable type for easy installation
- Guided plates in slots to generate a tangential liquid entry
- Slots at tube sheet level providing self-draining possibility
- Especially suited for processes with polymerization issues
- Flexible range of operation
- Precision laser-cut manufacturing

Special distribution systems can be designed to meet your specific requirements, such as:

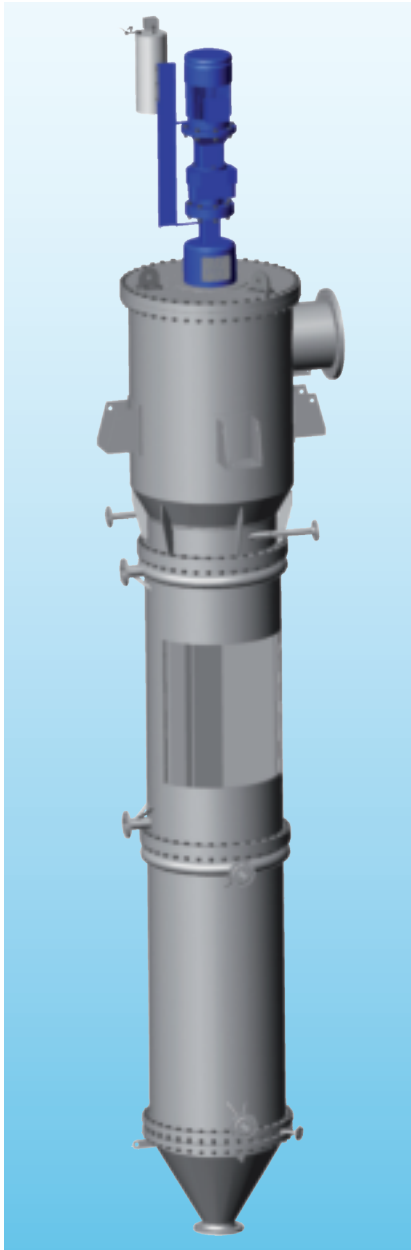
- Distribution of viscous products
- GMP design



*3-D model of a falling film evaporator*

# Wiped Film Evaporator

**Our wiped film evaporator is the ideal apparatus, if you need a continuous processing of your heat-sensitive, viscous and/or fouling products**



*3-D model of a wiped film evaporator*

## Design

Our wiped film evaporator consists - in contrast to a falling film evaporator - of merely one single evaporation tube fitted with a mechanical rotating device, the so-called rotor.

The distributor is welded to the rotor according proprietary design. This ensures your liquid feed is evenly distributed onto the heated surface of the evaporator. It then flows downwards in a spiral motion which is created by the blades of the rotor. Turbulent eddies are formed at the rotor tips, which continuously agitate and remix the liquid film.

The resulting vapor normally rises upwards, countercurrently to the liquid flow. It passes through a gas-liquid separator mounted at the top of the evaporator and is then normally directed to the downstream condenser. The concentrate leaves the unit via the bottom of the evaporator.

The upper part of the rotor incorporates a liquid distributor and a centrifugal separator. To effectively dis-entrain liquid droplets from the vapor flow, rotating baffles mounted on the rotor are complemented by static ones.

## Advantages

Our design offers following advantages:

- High heat flux
- Low residence time
- Low pressure drop allowing operation down to 1 mbar absolute
- Robust design minimizing maintenance costs
- No dead zones and no liquid hold-up
- Easy to clean

*On-site installation of a rotor into a wiped film evaporator*



# Wiped Film Evaporator

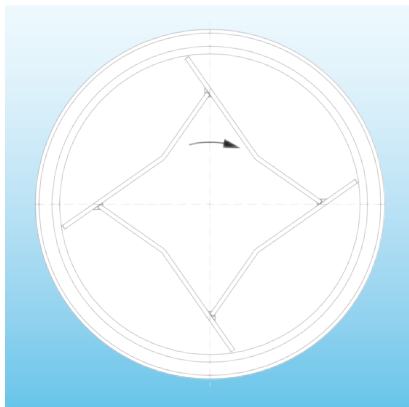
## Rotor Types

Our wiped film evaporators are available with different types of rotors selected on the basis of your application and your additional specific needs.

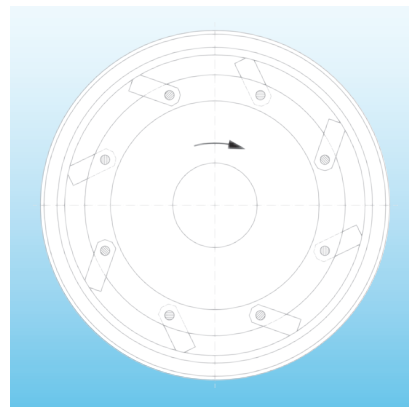
Type L - This rotor has several rigid blades that have a fixed and well-defined clearance from the wall of the shell.

Type P – This rotor has hinged wiper blades, which swing outwards by the centrifugal force and wipe the heated shell surface.

Type R – This rotor has rotating rollers, which create the film and adjust themselves to different film thicknesses.



Baseline principle of our L-type rotor

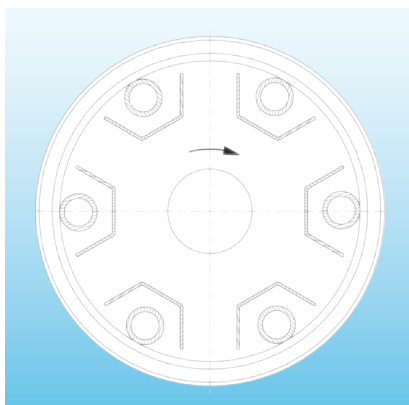


Baseline principle of our P-type rotor

## Glass-Lined Evaporators

We supply our wiped film evaporators made of solid or clad metal alloys, including exotic ones, but also as glass-lined units.

A fundamentally different design is introduced in case glass-lining is a specific requirement. As a consequence the rotor is designed to be self-supporting and does not require a bottom bearing.



Baseline principle of our R-type rotor



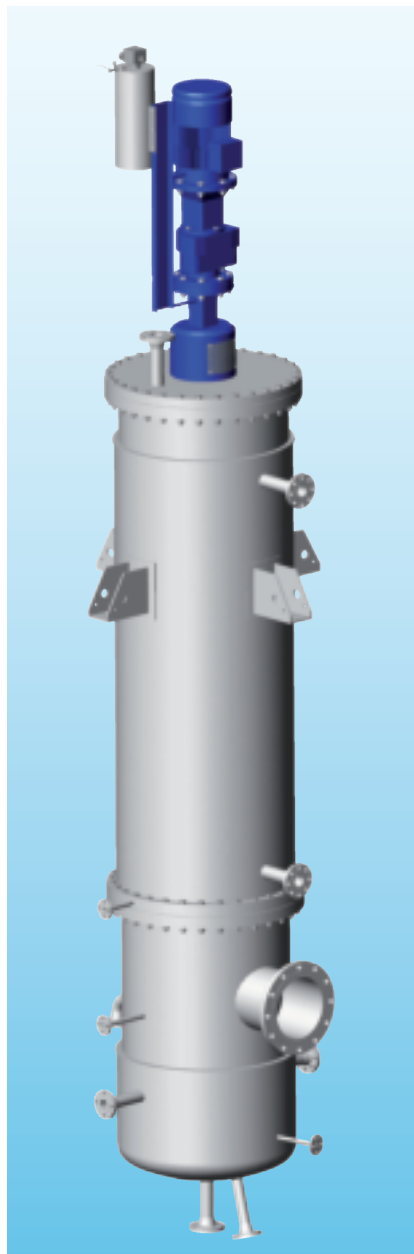
Inside of a glass-lined evaporator

A wiped film evaporator ready for installation on-site



# Short Path Evaporator

**Our short path evaporator is specifically suited to produce high purities and yields for extremely heat-sensitive substances and compounds with a high molecular weight**



3-D model of a short path evaporator

## Design

In our short path evaporator, a vertical condenser is placed inside the wiped evaporation chamber which results in a very short distance between the heating and condensing surfaces.

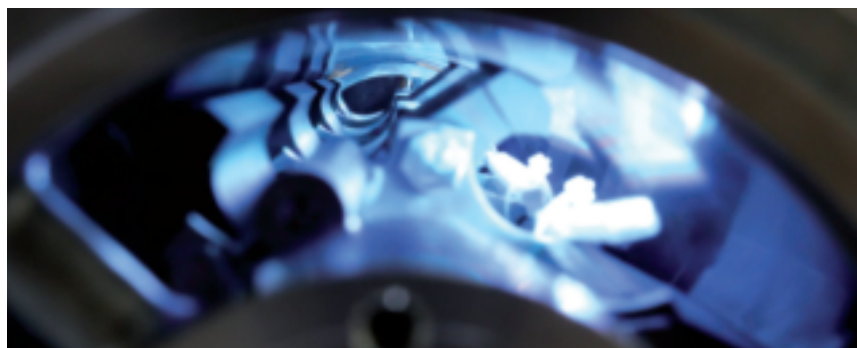
The liquid film is created and maintained mechanically like in our wiped film evaporator. In contrast to the wiped film evaporator, the resulting vapors migrate to the central condenser where they are condensed. The distillate flows down the tubes of the condenser and leaves the evaporator through a bottom nozzle. The concentrate is collected at the bottom of the shell and is taken out via a lateral nozzle.

The pressure drop across the system is thus minimized and evaporation can be performed in the pressure range below 1 mbar, and in special cases even at pressures down to about 0.01 mbar.

## Some Typical Applications

- Evaporation of organic compounds with a high molecular weight (usually over 200 g/mol)
- Purification of fats and derivatives
- Concentration of Active Pharmaceutical Ingredients
- Purification of additives for food products and cosmetics
- Removal of residual monomers after the polymerization reaction
- Purification of edible oils
- Deodorization

Inside view of a short path evaporator

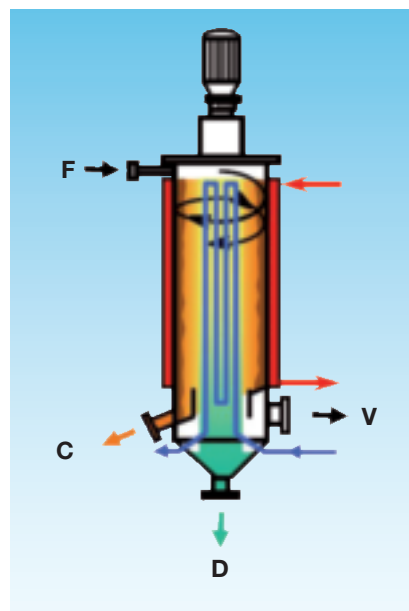


## Advantages

Our short path evaporator offers following advantages:

- Low residence time
- No liquid hold-up
- Very low pressure drop
- Suitable for extremely heat-sensitive products
- Suitable for evaporation of components with very high boiling points

*Basic principle of a short path evaporator (F stands for feed, C concentrate, D distillate and V vacuum)*



# Selection of Equipment

**With the right choice of our film evaporation equipment you optimally produce high-purity substances from your heat-sensitive and complex products**

## Selection of Evaporator Type

A correct selection of the type of evaporator is essential to offer you the most economical solution for your purification or concentration requirement. This solution includes the possibility to combine different types of evaporators in one process.

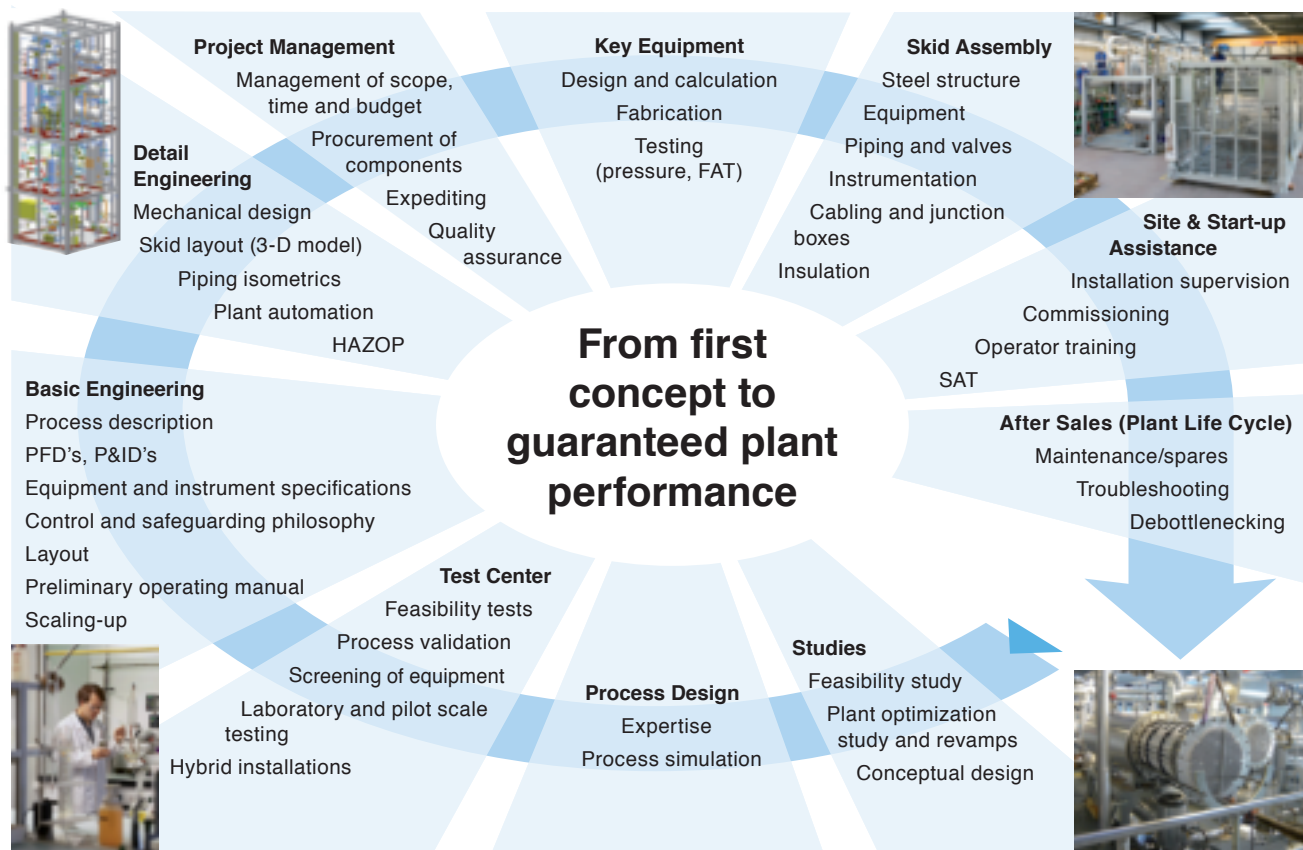
We ensure you the most suitable equipment selection by following:

- Our proven and longstanding experience, as also reflected on our extensive list of references
- Established, safe and reliable scale-up methods for design
- Systematic testing activities at our in-house test facilities, also supporting process scale-up and delivery with process guarantees

Our test facilities support testing with all types of film evaporators, with both pilot and lab scale equipment. Rental equipment is available as well, to facilitate testing at your own premises.

Besides process related criteria, we also take economical criteria into account. When examining economic aspects, we are aware that operational reliability is an important factor for you. Late delivery and commissioning, non-performance and downtime due to equipment failure can lead to loss of production and may involve substantial costs to rectify.

Therefore, in addition to purely technical criteria, the vast experience and reliability of Sulzer Chemtech as technology partner are important attributes. When cooperating with us, you will find a partner with outstanding test facilities and numerous reference applications in any area of film evaporation. Our state-of-the-art equipment and proven scale-up procedures, in combination with our highly skilled employees will provide you a process solution with guaranteed performance.





# Feasibility Study and Trials

Your optimal process solution is guaranteed by our design based on pilot trials in our state-of-the-art test center and our extensive know-how on film evaporation technology

## Optimal Process Solution

In many cases it is not possible to accurately predict film evaporation performance from theory alone, especially when the products are temperature-sensitive or viscous. Tests are therefore carried out to:

- Examine flow and wetting characteristics
- Evaluate and optimize the evaporator type
- Determine optimum achievable concentrations (often on ppm level)

## Test procedure

Tests are set-up based on the first results using a rotary evaporator, on estimates of partial pressures, or on customer's data. After selection of the type of evaporator, the test parameters are established:

- Operating pressure / feed flow
- Recirculation ratio
- Cocurrent/countercurrent
- Stripping gas
- For wiped film evaporators:
  - Wiper geometry
  - Product take-off system

## Lab and Pilot Trials

Laboratory or pilot plant trials are necessary to secure the correct design of the film evaporation equipment. We undertake these to establish optimal operating conditions, and, depending on the evaporator type, the most favorable geometric parameters (size and type of rotor). Successful trials allow us to safely scale-up to an industrial size unit, and to provide you full process guarantees. We are capable of carrying out all testing, including establishing missing physical properties, in our own test center. We have the following evaporation test equipment available:

- Rotary evaporator: 1 l
- Flash evaporator:  $\varnothing$  250 mm
- Falling film evaporators:
  - In glass: 0.12 m<sup>2</sup>
  - In SS316L: 0.4, 0.8, 1.2 m<sup>2</sup>
- Wiped film evaporators:
  - In glass: 0.025, 0.06 m<sup>2</sup>
  - In SS316L: 0.14 m<sup>2</sup>
- Short path evaporators:
  - In glass: 0.04 m<sup>2</sup>
  - In SS316L: 0.14 m<sup>2</sup>

The pilot plants can be operated with temperatures ranging from 20 to 320 °C and pressures from 0.01 to 1'000 mbar (1 Pa to 100'000 Pa). Feed rates are between 0.5 kg/hr and about 200 kg/hr.

Mobile test units are available for tests on your premises. If required, we can provide you assistance and training for such in-house tests.

## Test Center Services

After your feed material has been made available to us, we perform the testing as well as the analyses. The majority of the required analyses, including of chemical compositions and physical properties can be performed in-house.

If desired, samples of the tested end-products can be given back to you for your own research and development activities. We may also support your introduction of a newly developed product into the market. For this purpose samples can be produced in larger quantities.

Sulzer test center in Allschwil, Switzerland



Pilot unit of a thin film evaporator in our test center



# Process Plant Solutions

**We are a high-quality, full service provider, from first concept to guaranteed plant performance**

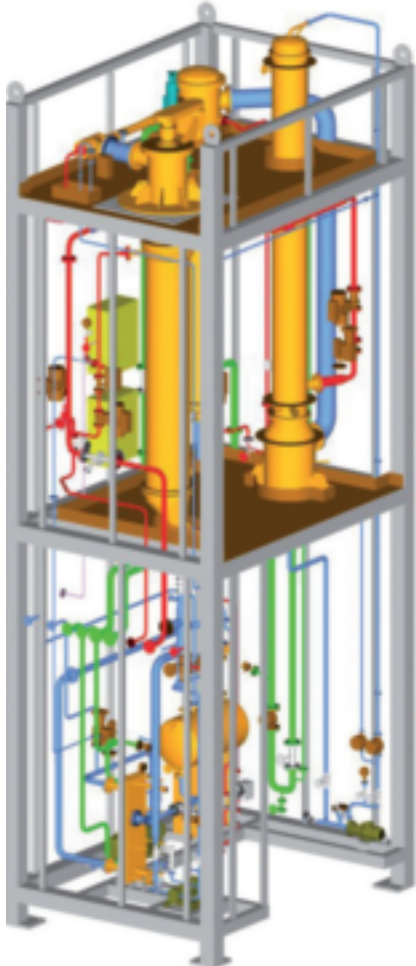
## Studies and Conceptual Designs

We provide specialist process engineering services to support you in your key process developments and decision making. In this area we offer following services:

- Feasibility studies
- Process conceptual designs
- Plant optimization, debottlenecking and revamp studies involving, for example, increase of plant capacity, improvement of product specifications or reduction of operating costs

We develop process solutions for both new and existing plants. While developing concepts we closely cooperate with you.

*3-D model of a two-stage skid-mounted evaporation unit, including a falling film evaporator and a wiped film evaporator*



## Process Guarantees

The most promising process solution is confirmed by lab and pilot plant testing. Testing may have the following purposes:

- Process validation supporting conceptual design work
- Consideration of the effect of unknown or trace components
- Optimization of operating parameters
- Verification of process stability
- Screening of equipment
- Supporting scaling-up

The successful completion of tests enables us to offer you plant solutions with full process guarantees.

## Design and Scale-up

In the field of film evaporation, scaling-up from pilot units to industrial size equipment is an important and critical step. It is not at all straightforward and simple empirical methods will normally fail. Our extensive experience in successful scale-up is supported by our detailed understanding of the fundamental theories of hydrodynamics and mass transfer playing a role in evaporation.

## Project and Quality Management

All of the project activities are performed by our highly qualified and experienced in-house staff. Our project teams work under the guidance of the project manager who has overall responsibility for the project budget, schedule and quality. Our project manager remains in close contact with you throughout the entire project.

In all our activities we employ an efficient Quality Assurance System which is accredited in accordance with the latest standards of ISO9001 for Quality, Safety, Health and Environment.

*Skid-mounted unit with a falling film evaporator as column reboiler*



# Process Plant Solutions

**We are a high-quality, full service provider, from first concept to guaranteed plant performance**

## Manufacturing Service

Every evaporator we supply is manufactured under our complete responsibility in a modern workshop equipped with state-of-the-art manufacturing tools with certified production processes. Column shells are either manufactured in-house, or by approved and qualified sub-suppliers. The latter approach is followed for very large columns, for glass-lined columns, or when special design codes are to be applied.

GMP and CIP are requirements well-known to us. Design, manufacture and certification of many evaporators have been carried out in accordance with these and other standards and design codes, being European, US, or other. The range of construction materials includes stainless steel, special alloys as well as titanium, zirconium and tantalum.

We deliver our evaporation technology as a basic design package with state-of-the-art proprietary equipment. In addition, we have a specific long-term experience in fabrication, installation and start-up of our solutions as skid-mounted units.

## Skid-Mounted Plants

Skids are assembled in our modern, purpose-built workshops in Switzerland or China or at selected, certified sub-contractors depending on the place of delivery.

Maximum skid sizes are 4 x 4,5 x 25 m. Larger plants consist of more than one module.

Advantages of skid-mounted, turn-key plants are:

- Minimal interfaces and clear overall project responsibility
- Short delivery time through an integrated fast track execution
- Low overall investment costs
- Reduced on-site erection and hook-up time and thus minimal site disruption
- Manufacture of the complete plant under workshop conditions ensuring the highest quality
- Completion of the Factory Acceptance Test (FAT) prior to delivery
- Qualification tests prior to plant delivery

## Installation, Commissioning and Start-up

We have a team of highly experienced installation supervisors, who provide erection support services for site-built plants, and for the off-loading and installation of skid-mounted plants. These supervisors liaise closely with your construction manager, safety officer and mechanical contractor, to ensure a safe and trouble-free installation.

Following installation, our process engineers undertake plant commissioning following a structured plan. The commissioning team is usually headed by the process engineer responsible for the plant design. This phase ends with the start-up of the process unit followed by a Site Acceptance Test (SAT). Training of your operators may take place in parallel.

At plant hand-over, you will be provided with final, as-built documentation including operating manuals, final lay-out drawings and certificates. A dedicated after sales group ensures the support for spare parts and services during the whole lifetime of the plant, wherever you are around the globe.

Right from plant start-up you can benefit from your optimal performing plant solution based on our film evaporation technology.



*Two-stage skid-mounted evaporation unit with a falling film evaporator and a wiped film evaporator*

**www.sulzer.com**

Please check for your local contact

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Sulzer Chemtech is represented in all important industrial countries and sets standards in the field of mass transfer and static mixing with its advanced and economical solutions.

The activity program comprises:

- Process components such as fractionation trays, structured and random packings, liquid and gas distributors, gas-liquid separators, and internals for separation columns
- Engineering services for separation and reaction technology such as conceptual process design, feasibilities studies, plant optimizations including process validation in the test center
- Recovery of virtually any solvents used by the pharmaceutical and chemical industry, or difficult separations requiring the combination of special technologies, such as thin film/short-path evaporation, distillation under high vacuum, liquid-liquid extraction, membrane technology or crystallization.
- Complete separation process plants, in particular modular plants (skids)
- Advanced polymerization technology for the production of PLA and EPS
- Tower field services performing tray and packing installation, tower maintenance, welding, and plant turnaround projects
- Mixing and reaction technology with static mixers
- Cartridge-based metering, mixing and dispensing systems, and disposable mixers for reactive multi-component material

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