fluitec
mixing + reaction solutions

25 Jahre Fluitec
25 Years Fluitec

In-line Reaction Technology

Modular reaction systems from milli to maxi

It was back in 1993 when Fluitec launched its first static mixer in the market. Today, Fluitec is a reliable partner for high quality products whose know-how spans a wide range of mixing, heat transfer and reaction applications in the chemical, petrochemical, pharmaceutical, environment and food industries.

View of the production shop – apparatus weighing up to 3.5 tons is manufactured in-house

The Fluitec management:
Daniel Altenburger (Managing Director), Silvano Andreoli (Manager Production), Alain Georg (Manager R&D), Tobias Vögeli (Manager Sales)

The Fluitec team

Contents

Contiplant – continuous reaction technology

The modular design of the Contiplant system is based on Fluitec's continuous mixer / heat exchangers. It allows the process for a target product to be developed quickly and reliably on a laboratory scale and scaled up safely to production level.

Thanks to this modularity, it is now an easy matter to test the conversion from batch to continuous reaction processes and assess the economic impact using a Fluitec Contiplant system. In many cases, significant business potential can be identified based on the higher concentrations, better temperature control or other process intensification measures.This potential can then be leveraged consistently when moving from the laboratory to the pilot plant due to the excellent heat transfer rate of the Fluitec Contiplant modules.

This universal modularity results in a shorter and more straightforward design phase.

The Fluitec Contiplant system

In addition to standardised Contiplant reactors in various sizes, dosing systems developed in-house and PLCs with process visualisation round off the Fluitec Contiplant system.

PLC with process visualisation

Dosing systems

Contiplant reactor with sensors and actuators

Structure of a complete Fluitec Contiplant system

The CONTIPLANT reactor modules

For the Fluitec engineers who developed the Contiplant in-line reactor series, modularity, flexibility and ease of handling were top priorities alongside efficient apparatus technology.

The result is a system in which reactors of different diameters and lengths, and with different internal elements, can be combined with one another. Since the connections are identical on every reactor, the individual modules are fully compatible – the reactor type and diameter are irrelevant. The number of reactors can also be varied without any problems.

Building in-line reactors that meet the most diverse needs has never been simpler. Fast reactions with high exothermicity, for example, can now be combined in the same set-up as residence time reactors.

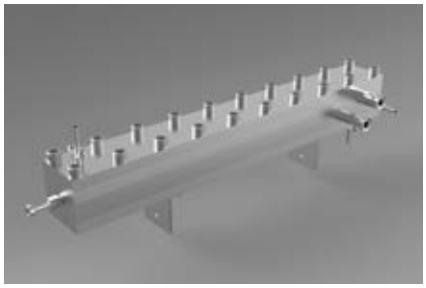
Contiplant reactor series

Fluitec has in-line reactors for various applications in its portfolio. To enable us to provide a complete range of solutions – from reactors with a low throughput and small tube diameter to production-scale systems – we developed three series which are scalable in both directions.

Fluitec also manufactures individual components beyond the standardised Contiplant series. Components with a throughput of up to 20'000 kg/h have been implemented in the past.

contiplantLAB by fluitec

Small diameters and low throughputs

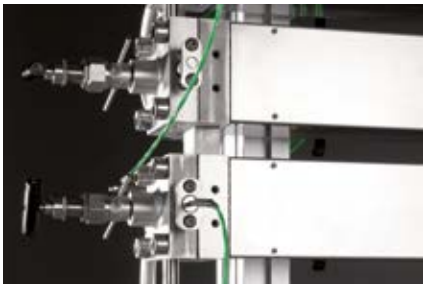


Used for

- Basic research
- Low throughputs < 2 kg/h
- Strongly exothermic reactions

contiplantPILOT by fluitec

Modular pilot plants



Used for

- Studies in preparation for safe scale-up
- Throughputs from 1 to 20 kg/h
- Small pilot and production plants

contiplantMODULE by fluitec

Modular production-scale reactors

Used for

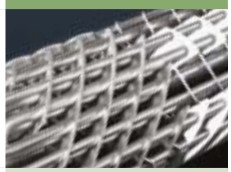
- Small production plants
- Throughputs from 20 to 2000 kg/h
- Scale-up from a ContiplantPILOT System

Fluitec in-line reactors with plug flow characteristics

At the heart of every CONTIPLANT reactor are its internal elements. Static mixers and mixer bundles have plug flow characteristics and mix continuously in the radial direction all along the reaction section. A homogeneous product is guaranteed at all times in both turbulent and laminar flow. Static mixers enable 3 to 15 times better heat transfer on the inside with laminar flow compared to the empty tube, depending on the geometry. This results in a large heat-exchanging area and precise temperature control. If very high heat removal rates are specified, XR technology and Fluitec mixer / heat exchangers are the solution of choice. In this case, the heat-exchanging area is enlarged by internal cooling tubes and the uniform flow in the static mixer ensures high, constant heat transfer.

Residence time distribution

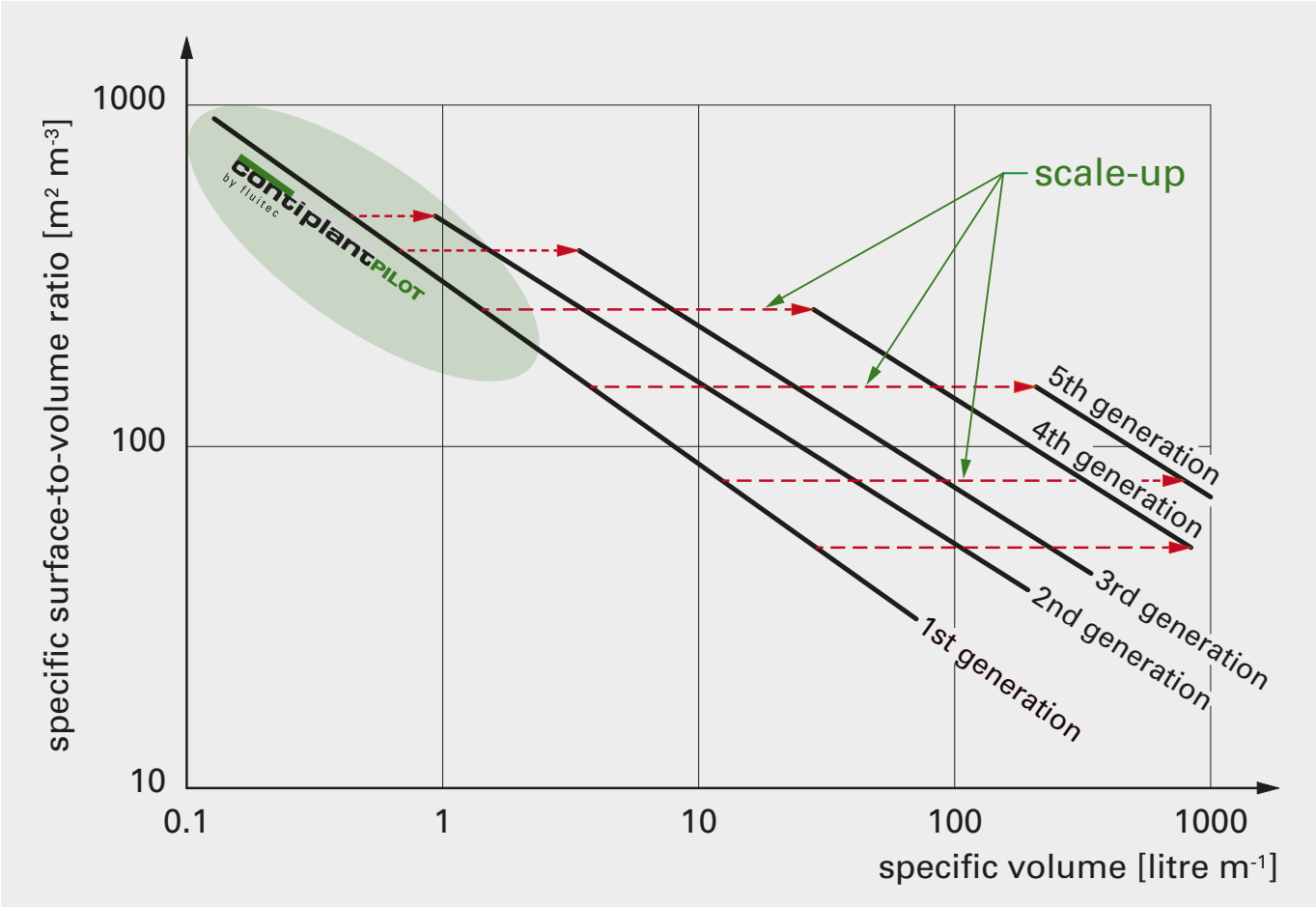
Owing to their very good residence time distribution, static Fluitec mixer / heat exchangers approximate an ideal tube reactor. When static mixers are used, a uniform velocity profile is created over the entire cross-sectional area, even with laminar flow (plug flow profile). In contrast to an empty tube, static mixers enable a narrow residence time distribution to be achieved in the reactor. Bodenstein numbers Bo = 100 to 400 are the norm.

Geometry	CSE-XC/6	CSE-X/4	CSE-X/8	CSE-W	XR technology
					
Installation type	Static mixer	Static mixer	Static mixer	Static mixer	Mixer / heat exchanger
Mixing efficiency	Very good	Good	Very good	Poor	Good
Residence time distribution	Very high Bo numbers	High Bo numbers	High Bo numbers	Low Bo numbers	High Bo numbers
Pressure drop	Low	Medium	High	Low	High
Heat transfer	Good	Good	Good	Medium	Very good
Price	Low	Low	Medium	Low	High
Typical applications	• Pilot, production • Mixing • Homogenising • Small quantities of heat	• Lab, pilot, production • Residence time sections • Homogenising • Small quantities of heat	• Lab, pilot, production • Mixing • Homogenising • Residence time sections • Medium quantities of heat	• Lab, pilot • Residence time sections • Homogenising • Small quantities of heat	• Pilot, production • Mixing • Homogenising • Large quantities of heat • Fast reactions

Scale-up

One of the outstanding features of the Contiplant system is its scalability. The use of Fluitec mixer / heat exchangers (CSE-XR technology) enables safe scale-up in terms of heat transfer, mixing efficiency and residence time distribution. The Fluitec scale-up concept is based firstly on apparatus with a constant surface-to-volume ratio and secondly on mixing elements which assure the specific mixing efficiency – and hence also the required heat transfer at the heat exchanger tube – with larger apparatus. Simply increasing the surface area by adding more heat exchanger tubes only partially produces the desired effect, which is why the structure of the mixing elements also has to be adapted if the diameter is increased. Different generations are defined for describing the combination of suitable mixer geometries, diameters and heat exchanger tubes.

A production-scale residence time section is built



The Fluitec scale-up concept

Reactor Concepts

Fluitec introduced safety classes for continuous processes because standards and regulations for assessing continuous reactions are virtually non-existent.

Fluitec safety classes 1 to 5, with four characteristic temperatures, are one possible way to assess continuous reactions. The assessment is based on Stoessel's division into criticality classes, which has been adapted for continuous processes.

The safety classification is determined by the following characteristic temperatures:

- T_p = Process temperature range
- $T_m = T_0 + \Delta T_{ad}$ = Maximum temperature attainable under adiabatic conditions
- TS = Maximum allowable temperature of the pressure equipment; temperature at response pressure of the bursting discs or the safety valve
- T_{ONSET} = Onset temperature of the decomposition reaction

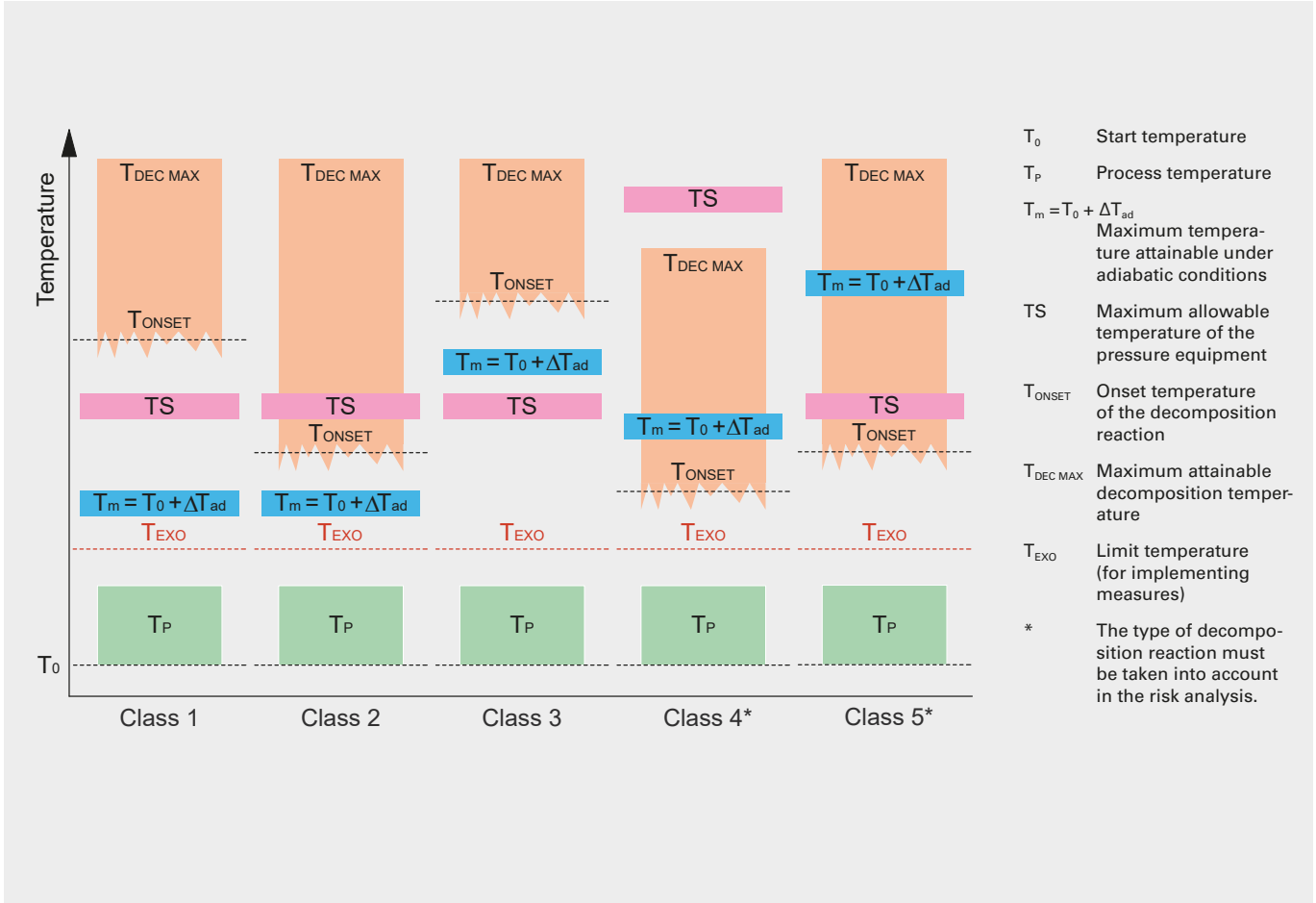
Amongst other things, these temperatures are obtained by means of differential scanning calorimetry (DSC) measurements.

The process is assigned to one of the five safety classes based on a purely thermal assessment in accordance with the safety class diagram. Class 1 and 2 reactions are considered to be safe, in other words no additional measures are required. Fluitec recommends installing a safety purge system (SPS) for class 3 or higher reactions. The safety purge system (SIS with SIL) empties the reactor in a very short time. The safety purge is automatically tripped if T_{EXO} (maximum tolerable limit temperature) is reached.

Processes assigned to safety classes 4 and 5 are particularly critical because T_m is greater than T_{ONSET}. In the absence of additional measures, therefore, a thermal runaway scenario will trigger a decomposition reaction.

Class 4 and 5 processes must consequently be diluted, either with solvent or using a plug flow recycle reactor (PFRR), so that T_m is reduced to a value below T_{ONSET} and the safety classification of the reactions changes to class 1 or 2.

Provided no secondary reactions occur with the product, our advice is to give preference to PFRR mode over dilution with solvent on environmental grounds.



Safety classes for continuous processes based on F. Stoessel (2008), Thermal safety of chemical processes, Wiley-VCH, Weinheim

Plug flow reactor (PFR)

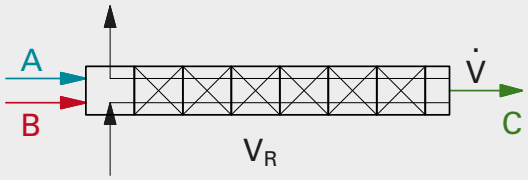
Static Fluitec mixer / heat exchangers are used as ideal, continuous reactors.

The reactor space of an ideal tube reactor is formed by a tube which tends to have a very large length L in relation to its diameter. It is assumed that no mixing occurs in the flow direction and that the reaction mixture has a constant composition over the entire cross-sectional area at all points in the tube, hence the name plug flow reactor (PFR).

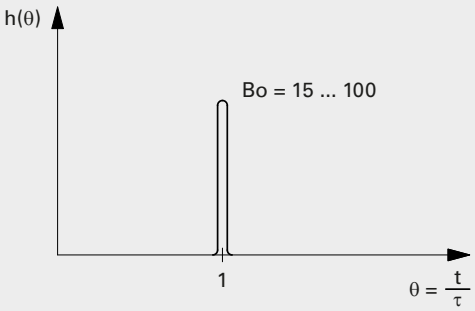
Taking account of the void volume ε_m, static Fluitec mixer / heat exchangers approximate an ideal tube reactor owing to their very good residence time distribution. This is particularly true in the case of highly viscous fluids. The proven, idealised plug flow reactor model is optimally suited for homogeneous chemical reactions in continuous operation due to the low back-mixing of the reaction mass in Fluitec mixer / heat exchangers.

ContiplantPILOT PFR

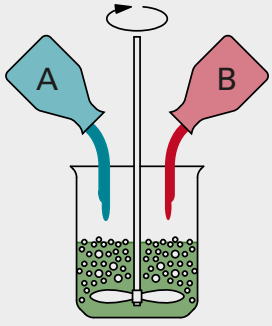
Reactor arrangement



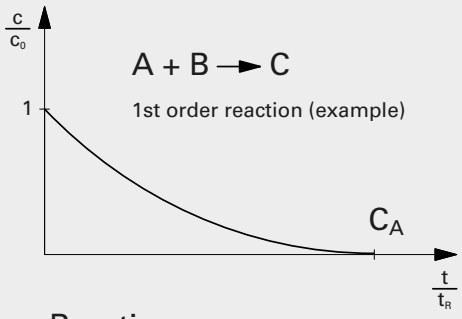
Continuous tube reactor PFR



Residence time distribution with impulse marking



Batch



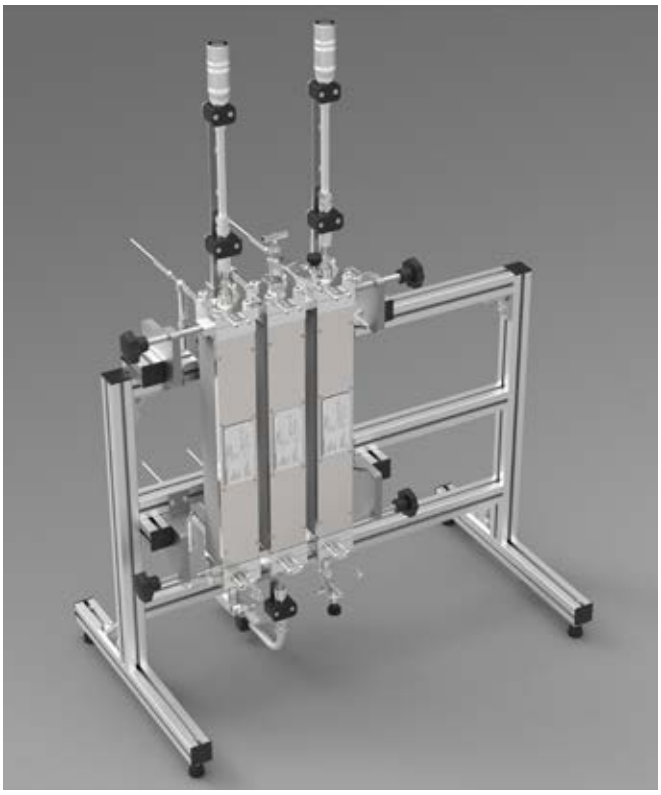
Reaction course

Schematic of a plug flow reactor (PFR)

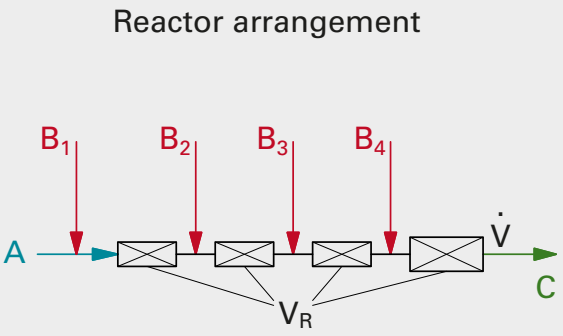
Continuous cascade reactor CCR

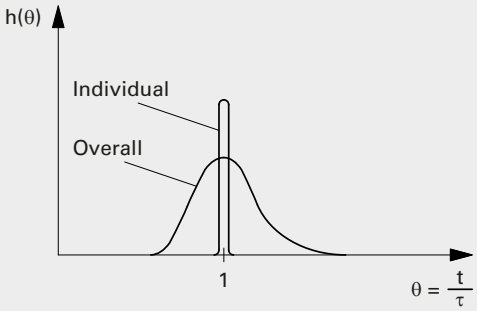
The continuous cascade reactor is a special type of plug flow reactor. One or more reactants are only partially added at the start of the reaction section and are instead divided up and supplied at several different points along that section (cascaded).

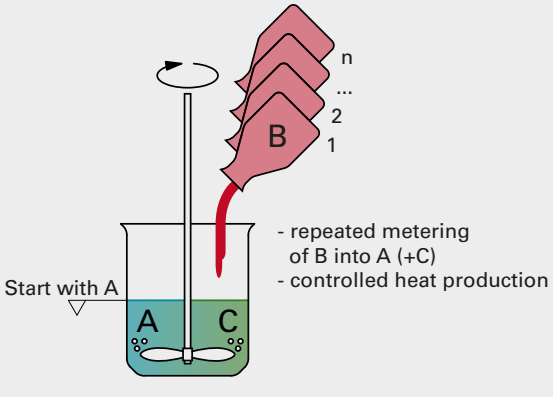
The cascade design can have an influence both on the reaction in general and on heat build-up / conversion in particular. Cascade reactors place higher demands on the control and regulating devices and especially on the dosing technology. A continuous cascade reactor is therefore more complex to operate than a plug flow reactor.

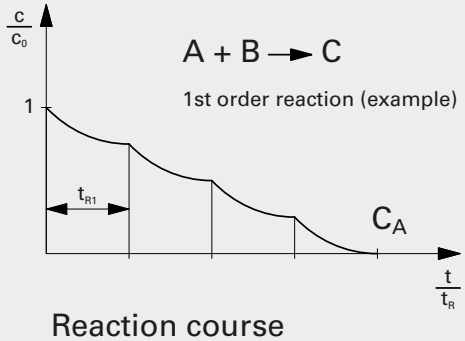


Example of a continuous cascade reactor (CCR)







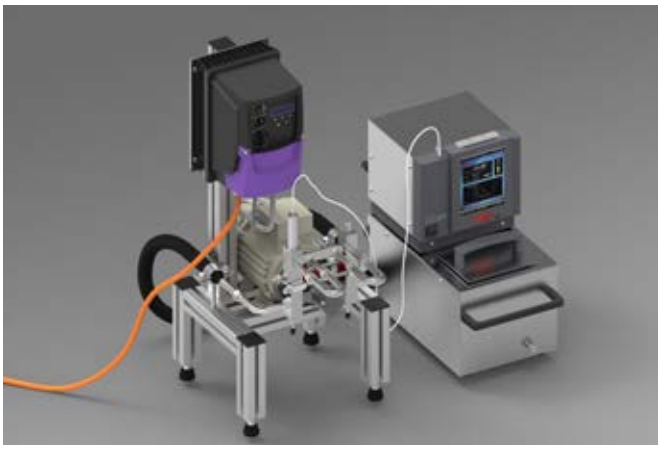


Schematic of the cascade reaction

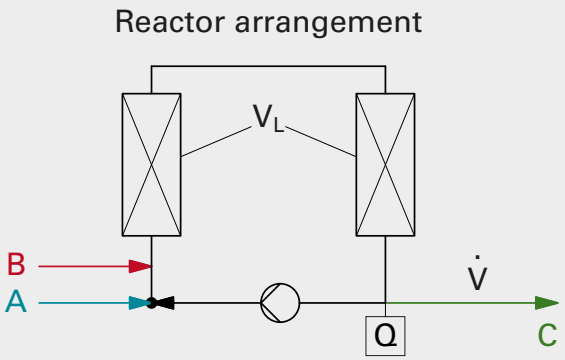
Recycle reactor (RR)

A continuous recycle reactor is a reactor where part of the reaction mixture at the outlet is returned to the inlet via an external loop and added to the inlet stream again. The reactor is equipped with at least one static mixer / heat exchanger with plug flow characteristics. This reactor type is also commonly known as a loop reactor.

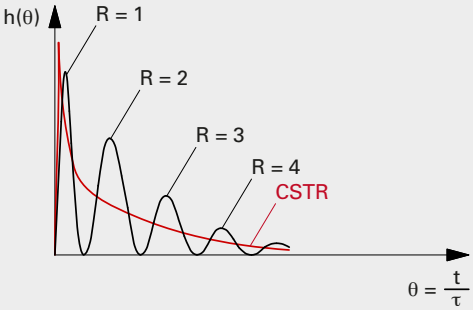
Recycling of materials and heat is a widespread approach in chemical reaction technology when designing production processes. In Fluitec loop reactors, a pump which also monitors the flow is used to control recycling. The aim of recycling is generally to mix the starting materials or the reaction mixture in a controlled way and / or control the temperature. Fluitec loop reactors are normally combined with mixer / heat exchangers. Thanks to the excellent plug flow characteristics in the reactor loop, mathematical calculation methods based on simple model concepts enable better prediction and control of the reactors. Laboratory-scale loop reactors are moreover ideal for reaction characterisation.
Fluitec loop reactors are specially designed so that the complete reactor system has plug flow characteristics in the loop from the inlets (A, B) to the outlet (C). The recycle ratio is generally between 20 and 50.



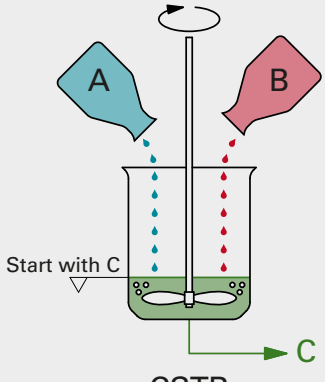
ContiplantLAB loop reactor



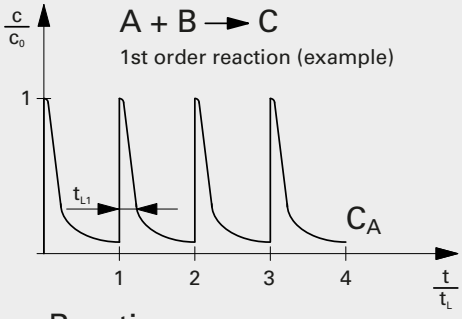
Continuous recycle reactor RR



Residence time distribution with impulse marking



CSTR



Reaction course

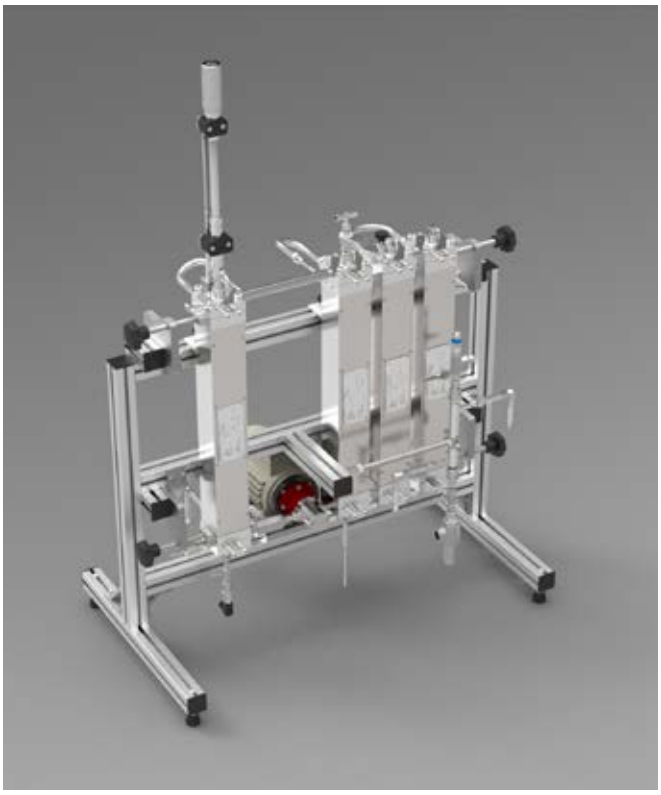
Schematic of a recycle or loop reactor (RR)

Plug flow recycle reactor (PFRR)

The Fluitec PFRR was specifically designed for continuous reaction processes combining a very high conversion rate with reliable control of exothermic reactions. A plug flow reactor is installed at the outlet of the recycle (loop) reactor (RR) in order to maximise the conversion. The recycle rate in the recycle reactor is reduced such that sufficient heat removal is still guaranteed owing to the dilution of the product. A recycle ratio between 2 and 10 is generally selected.

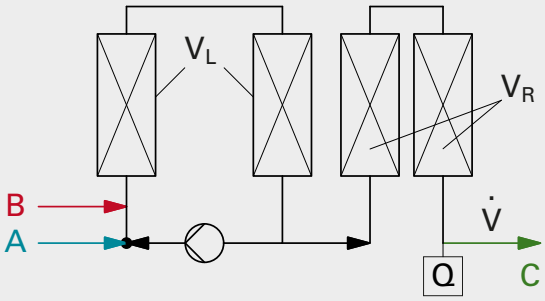
The ContiplantLAB and ContiplantPILOT sizes of the Fluitec PFRR are ideal for reaction characterisation.

In many applications, the plug flow reactor at the outlet of the recycle reactor corresponds to a residence time section.

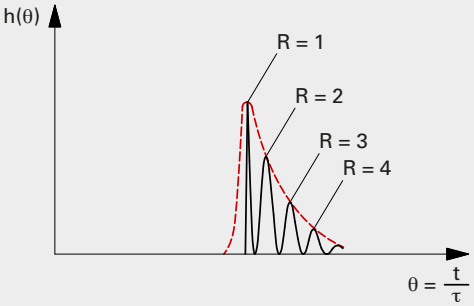


ContiplantPILOT PFRR

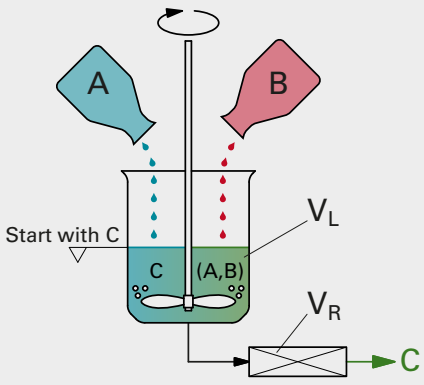
Reactor arrangement



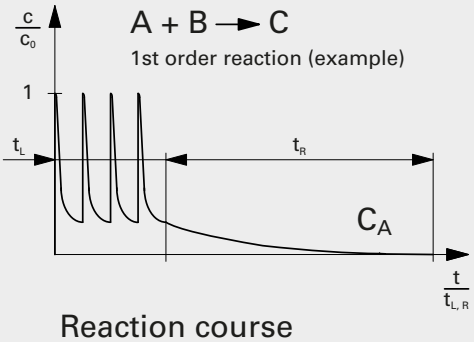
Continuous recycle reactor + residence time



Residence time distribution with impulse marking



CSTR + residence time reactor

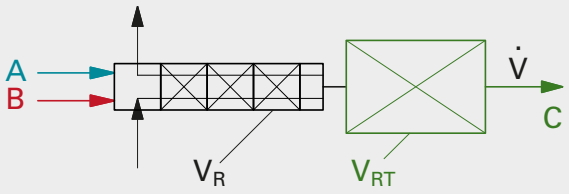


Reaction course

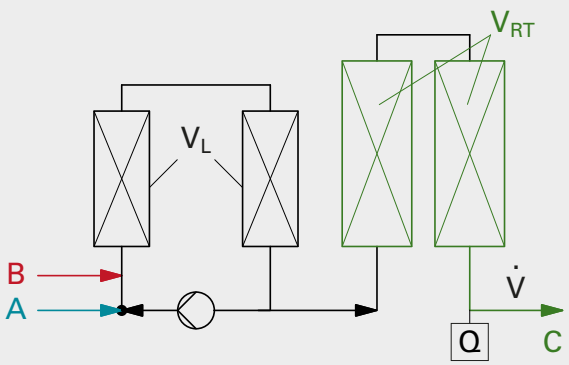
Schematic of a plug flow recycle reactor (PFRR)

Residence time section

In many reactions, conversion rates > 80% tend to be achieved within a few seconds or minutes. However, in continuous reaction systems additional residence time sections are installed downstream to enable nearly maximum conversion > 99%.
These downstream residence time sections consist of long pipes, ideally with CSE-X static mixers or CSE-XR mixer / heat exchangers attached in order to facilitate complete conversion. If designed correctly, static mixers also have plug flow characteristics in laminar flow conditions. As a result of this, residence time reactors with Fluitec CSE-X mixers or CSE-XR mixer / heat exchangers can have a flow velocity of no more than 1 to 5 mm/s – equivalent to a reactor length of between 1.5 and 3 m for a residence time of 30 minutes, for example. Thanks to these special process properties, Fluitec CSE-X mixers and CSE-XR mixer / heat exchangers are ideal for carrying out chemical reactions.



Continuous residence time reactor

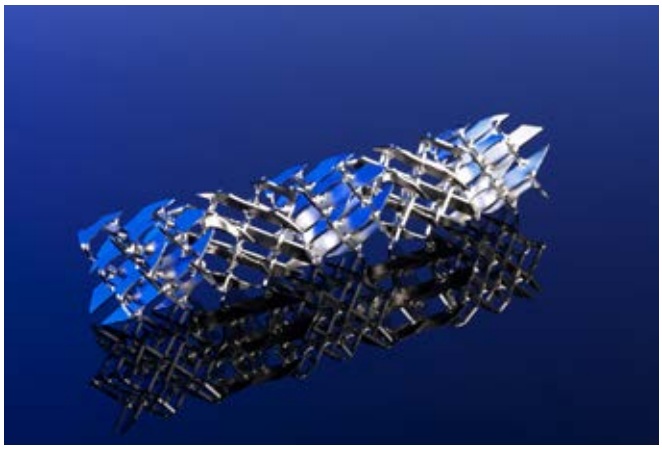


Continuous recycle reactor + residence time

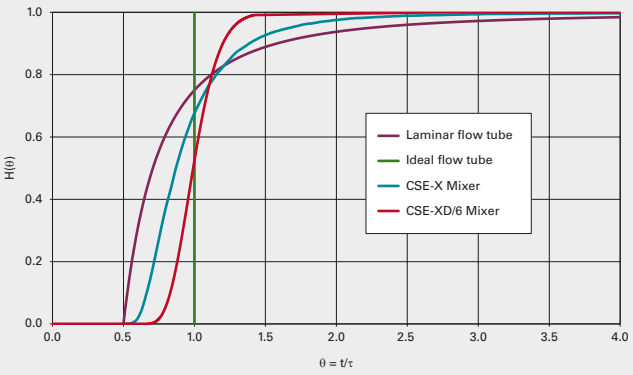
Schematic of a residence time reactor

The new CSE-XD/6 residence time mixer

The novel CSE-XD/6 mixer was developed as a next-generation static mixer with a narrower residence time distribution. This new mixer geometry systematically eliminates critical wall areas with low flow rates. A significantly improved residence time distribution is consequently achieved compared to the traditional CSE-X mixer geometry.



The CSE-XD/6 mixer geometry developed for residence time sections



Cumulative residence time curve

ContiplantPILOT residence time reactor with axial multipoint temperature measurement and a heating and cooling unit

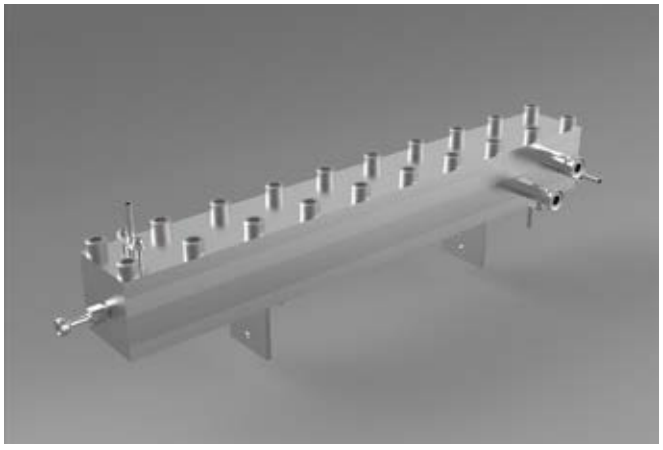
ContiplantLAB Reactor Series

The ContiplantLAB reactor series was developed for small tube diameters and low throughputs. Particular attention was paid to easy dismantling. On a conventional tube reactor with a double shell tube and static mixers mounted in the inner tube, the mixing elements are often difficult to remove and install. The smaller the tube diameter, the more complicated removal and installation becomes. The ContiplantLAB half-shell reactor is split lengthwise for this reason. The long side of the housing can be disassembled to enable quick and easy access to the mixing elements. Since ContiplantLAB housings are stackable, the reactor system can be flexibly expanded.

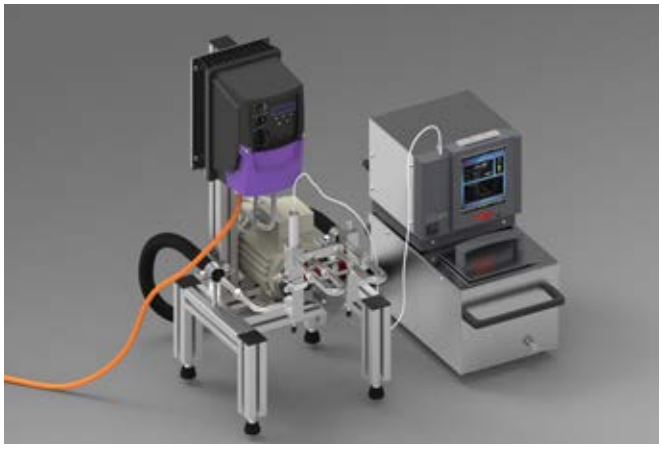
Thanks to their unrivalled ease of dismantling, ContiplantLAB reactors can also be used for basic tests on reactions during which deposits are formed.

Sizes	Di = 4.6 to 16 mm
Housing materials	1.4404 / 1.4571 Hastelloy Other materials on request
Max. allowable pressure	60 bar at 300°C The allowable temperature range is dependent on the O-ring type. The maximum temperature range is from -46°C to +300°C. It is not possible to cover the complete range with just one O-ring

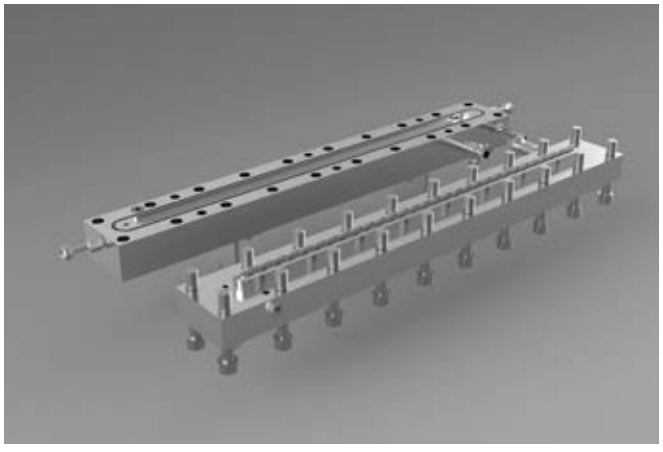
Reactors in the ContiplantLAB series can be combined directly with ContiplantPILOT reactors. Many of the sensors and actuators in the ContiplantPILOT series can also be used for the ContiplantLAB series. For more information, please refer to the section on ContiplantPILOT.



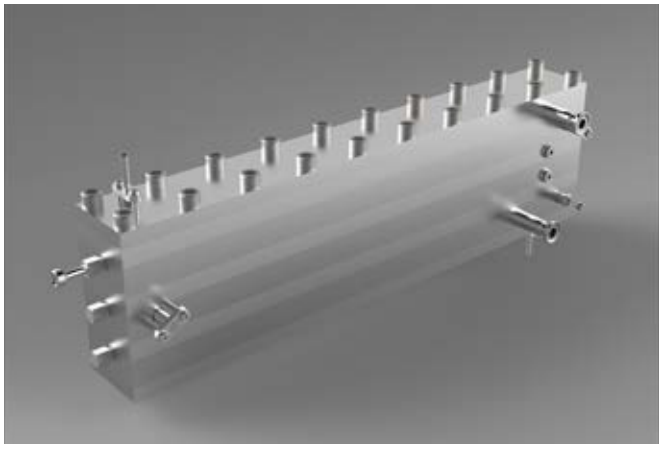
ContiplantLAB half-shell reactor



ContiplantLAB loop reactor



Open ContiplantLAB half-shell reactor



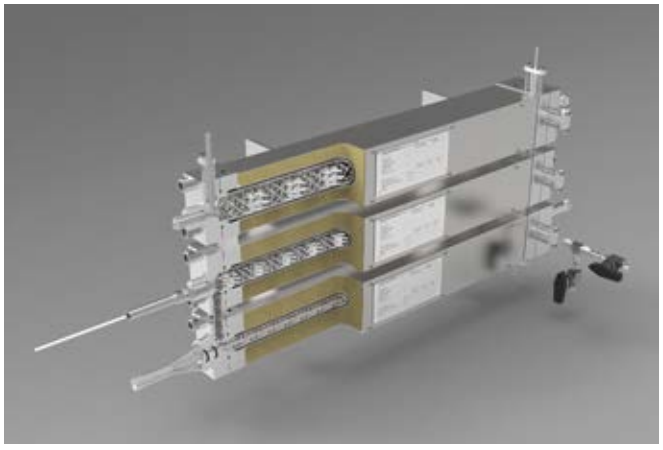
Stacked ContiplantLAB reactor

ContiplantPILOT Reactor Series

The highly modular ContiplantPILOT reactor series provides the greatest possible support for process design. ContiplantPILOT reactors are available with many different diameters, lengths and mixing elements.

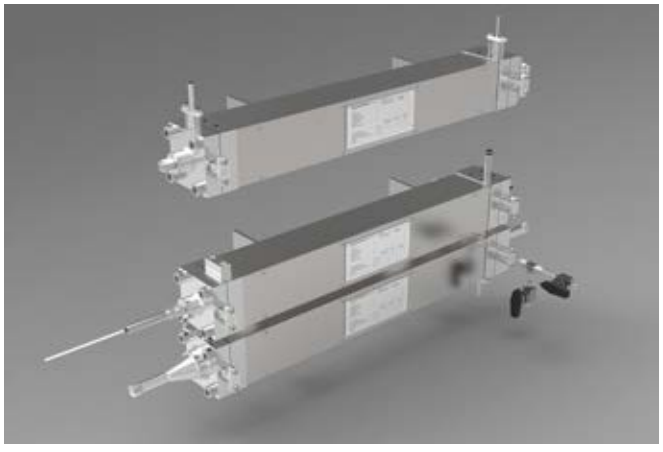
Amongst other things, the Fluitec ContiplantPILOT system is suited for polymerisations, esterifications, acetylations and neutralisations.

Sizes	Di = 12.4 to 36 mm (DN10 to DN32)
Rated pressure	PN100 (PN160 and PN320 on request)
Housing materials	1.4404 / 1.4571 Hastelloy Tantalum Glass
Max. allowable pressure	60 bar at 300°C The allowable temperature range is dependent on the O-ring type. The maximum temperature range is from -46°C to +300°C. It is not possible to cover the complete range with just one O-ring
Special versions	Versions with other gasket shapes (e.g. spiral wound) as an option



Combination of different tube diameters

ContiplantPILOT reactor in a vertical arrangement



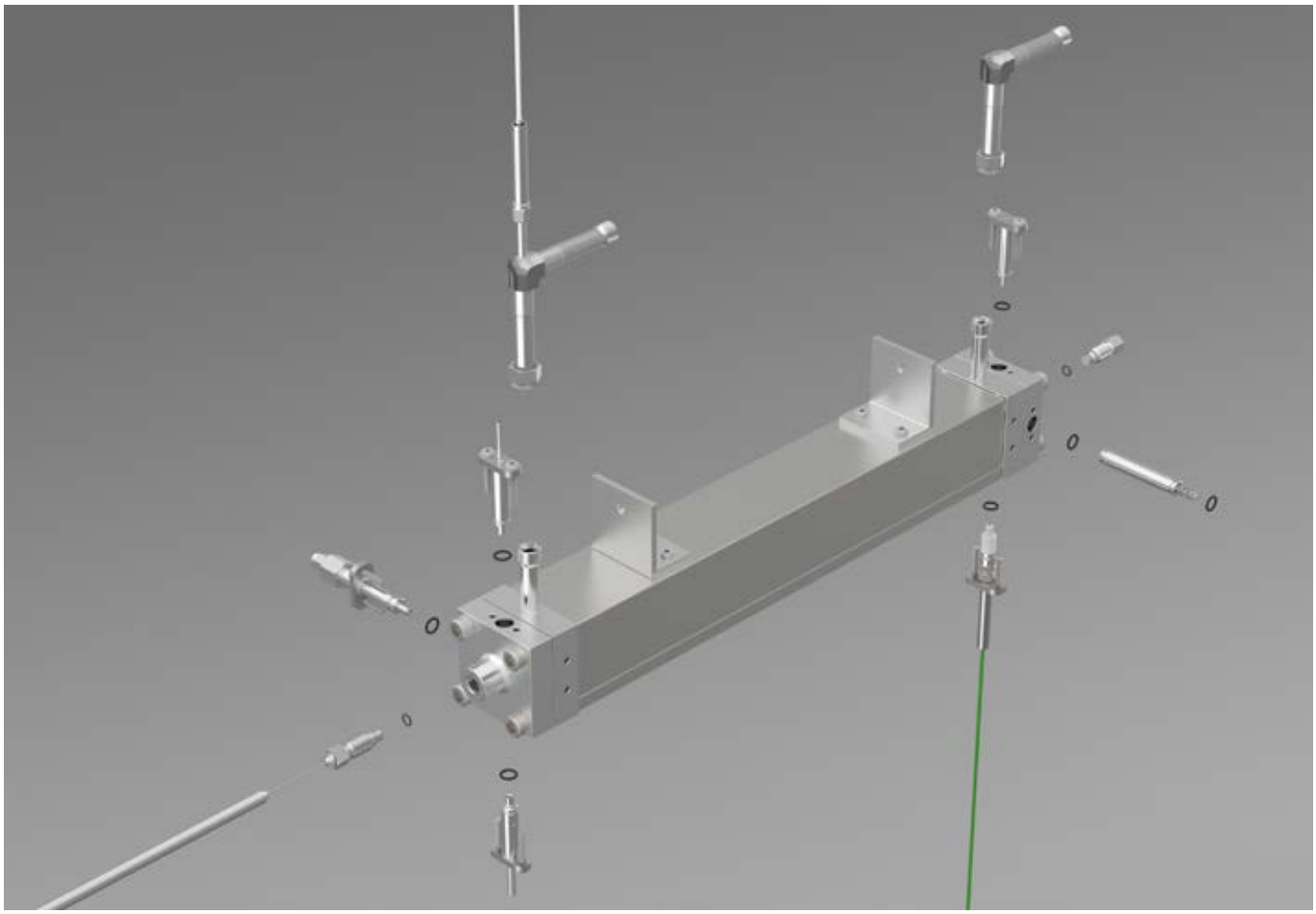
The individual modules can be stacked and are easy to combine and replace

ContiplantPILOT for low temperature applications with special, high performance insulation

ContiplantPILOT and periphery

Optimised peripherals are essential for continuous reaction processes in the laboratory or in a pilot plant in order to guarantee perfect control and monitoring of the reaction. The Contiplant series includes sensors, actuators and other peripherals specially developed for this purpose, which have no detrimental effects on the residence time range, heat transfer or mixing efficiency.

Amongst other things, the Fluitec portfolio contains the special high-speed premixer cooler Helix-Torpedo, injection valves, dosing points, rinsable sampling valves, various temperature sensors such as the axial multipoint temperature sensor for process monitoring, pressure sensors with no dead spots, bursting discs, etc. Dosing systems developed in-house and PLCs with process visualisation round off the Fluitec Contiplant system.



This exploded drawing shows the ContiplantPILOT reactor with its numerous measuring points (4 possibilities per flange). Two 1/2" 20 UNF threads and six 12 H9 system holes are provided.

Gaskets

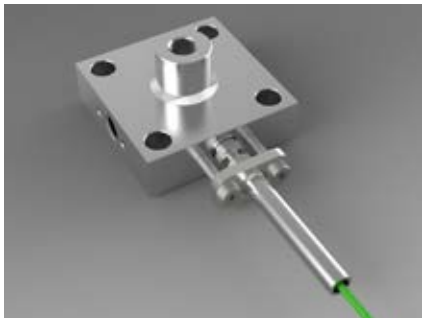
O-rings are normally used as gaskets for the Contiplant-LAB and ContiplantPILOT series. We offer the same delivery options for both the ContiplantLAB and the ContiplantPILOT system.The following standard O-rings can be supplied for this apparatus.

Other materials are available on request.

Compound	Viton	FFPM-250	FFPM-250-LT	FFPM-300	FFPM-300-FDA
$T_{min.}$	-10°C (-15°C)	-15°C	-40°C (-46°C)	-15°C	-15°C
$T_{max.}$	200°C	250°C	250°C	300°C (325°C)	300°C (310°C)
Colour	Black	Black	Black	Black	White
Chemical resistance	+	+++	+++	++++	++++
Price	Low	Medium	High	High	High

Components for lateral connection to ø12 H9 system hoes (examples)

Injection valve



Fluitec temperature sensor K1

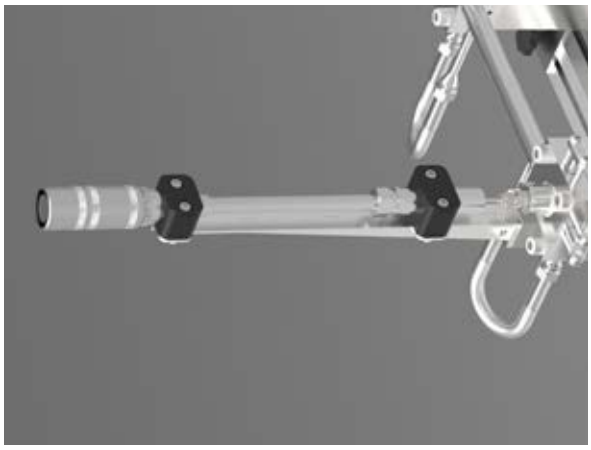
Injection nozzle ø 1.59 x 0.53

Injection nozzle ø 6 x 2.0

Relief valve, type 12h9-R3A-6MM

Fluitec blind plug, type 12h9

Components for front connection to 1/2" 20 UNF threads (examples)



Axial temperature sensor with 10 measuring points

Fluitec temperature sensor Pt100

Vent valve

Blind plug

Fluitec bursting screw

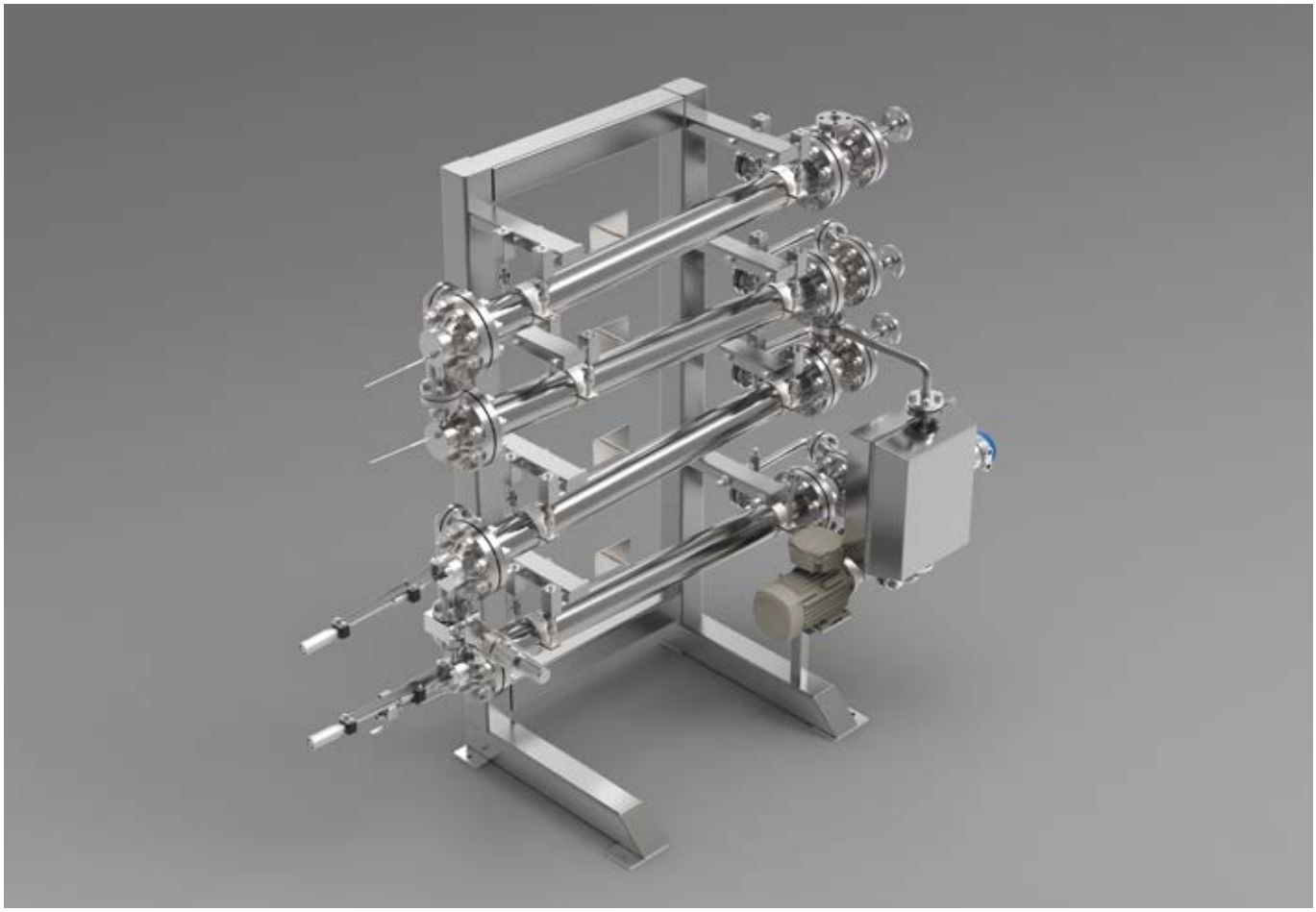
Pressure transmitter

ContiplantMODULE Reactor Series

Thanks to the Fluitec scale-up system and the use of scalable reactors in the ContiplantLAB and ContiplantPILOT series, processes can nowadays be scaled up safely to production level.

The reactors in the ContiplantMODULE series have a standard size but many degrees of freedom, to enable them to be matched as closely as possible to each customer's application.

Fluitec PFR in sterile design



Fluitec 20 l PFRR reactor, ContiplantMODULE

Heating/Cooling Systems for Contiplant www.fluitec.ch

Fluitec temperature control systems convince with unique thermodynamic properties and functionality to meet even the highest requirements. These systems offer highly precise and reproducible heating and cooling results, very short heating and cooling times and a wide temperature range from -20°C to +300°C. Each system is equipped with a booster pump for optimal heat transfer, enabling up to 4 reactors to be operated in parallel or 3 reactors in series. This robust pump ensures maximum circulation efficiency at a defined flow rate. Provided the system is operated with the correct thermal oil, flow meters can be dispensed with.

Components for Contiplant heating and cooling systems (examples)

Fluitec temperature control system, type 65-300

Fluitec temperature control system, type 20-250

Fluitec temperature sensor Pt100-HTM-M16x1

Fluitec 3-way manifold

HTM 90° connecting pipe

HTM 180° connecting pipe

Large Reactor Systems

PFR reactor with 1000 kg h^{-1} and 20 min residence time

The standardised ContiplantMODULE series is suitable for any throughput up to approximately 500 kg h^{-1}. Larger reactors and reaction systems with a maximum throughput of 10'000 kg h^{-1} can also be supplied based on the Fluitec scale-up system. These systems are specially designed and built for each individual application.

Reaction system scaled up to 4000 kg h^{-1}

Inquiry data sheet In-line Reaction Technology

fluitec mixing+reaction solutions

Contact:

Company:		Phone:	
Name:		Fax:	
Street:		E-Mail:	
ZIP/Town:		Country:	

Inquiry:

Project / Inquiry-Nr:	
Inquiry requested until:	
Only budget quotation:	☐ Yes ☐ No

Reaction Data:

	Unit:	Educt	Additive 1	Additive 2	Product
Name fluid:	[-]				
Flow minimal:	[kg h^{-1}]				
Flow normal:	[kg h^{-1}]				
Flow maximal:	[kg h^{-1}]				
Density:	[kg m^{-3}]				
Viscosity:	[mPas]				
Specific heat capacity:	[J kg^{-1}K^{-1}]				
Thermal conductivity:	[W m^{-1}K^{-1}]				
Temperature at the beginning:	[°C]				

Reaction control: ☐ Polytropic ☐ Adiabatic ☐ Isothermic ☐

Order of reaction: ☐ 1. order ☐ 2. order ☐

	Unit:	Heating/cooling stream
Name fluid:	[-]	
Flow:	[kg h^{-1}]	
Temperature:	[°C]	
Density:	[kg m^{-3}]	
Viscosity:	[mPas]	
Specific heat capacity:	[J kg^{-1}K^{-1}]	
Thermal conductivity:	[W m^{-1}K^{-1}]	

	Unit:	Substrate
Molaric weight:	[g mol^{-1}]	
Enthalpie of substrate:	[J mol^{-1}]	
Molaric flow rate:	[mol h^{-1}]	
Desired turn-over:	[%]	
Desired residence time:	[s]	
Start temperature:	[°C]	
Adiabatic temperature rise:	[°C]	
Allowed tolerance of temperature:	[°C]	±
Temperature after reaction:	[°C]	

Mechanical Data:

Design: ☐ Contiplant ☐ Production line ☐

Material: ☐ 316 Ti / 316 L ☐ Tantal ☐ Hastelloy C22 ☐

Reactor: Max. allowed pressure: bar Max. allowed temperature: °C

Heating jacket: Max. allowed pressure: bar Max. allowed temperature: °C

Description of the reaction and remarks:

Other Fluitec Products

Static Mixing

Solutions for static mixing

Mixing / Heat Exchange

Unique mixer / heat exchanger combinations

Systems

DeNOx systems, mixing and dosing systems

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mixing + reaction solutions

www.fluitec.ch

For more information, please visit our website

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