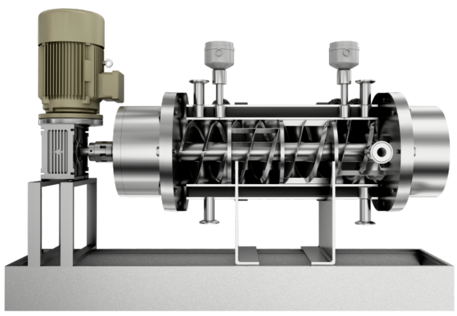
FLOW REACTOR

HYDRODYNAMIC FLOW REACTOR (HFR)

THIN FILM REACTOR (TFR)

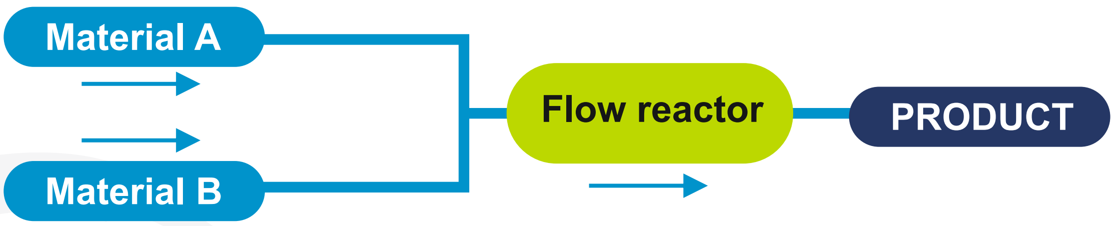
PLUG FLOW REACTOR (PFR)



FLOW REACTORS employ continuous flow technology to execute chemical reactions continuously. Reagents are continuously added to a flow reactor vessel inlet whilst product is constantly collected at the reactor outlet, to create a continuously flowing stream of reactants and outputs.

A continuous flow reactor embodies the principles of flow chemistry. Flow reactors are designed to operate at a continuous steady state, which means the internal stream, temperature, reagent feed and flow rates are all constant, to produce an unceasing flow of chemical reactant material which generates a continuous product output.

The flow reactor administers the integration of two or more reactive compounds, which are then mixed and flowed through a highly controlled stream to generate a continuous reaction.



Flow reactions take place in tubular system, whether it be a capillary or micro-structured device made from a non-reactive material. Coiled tubing is commonly added within the design to aid both mixing and heat transfer. Temperature control is then maximized by adding heat or coolant transfer fluid.

While the core principle behind all flow reactors remains the same—santered on a continuous flow mechanism—the choice among various types depends entirely on the specific application.

Here is a comparative overview of the Hydrodynamic Flow Reactor (HF Reactor), Plug Flow Reactor, and Thin Film Reactor, outlining their operation principles and suitable applications.

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FLOW REACTOR

Hydrodynamic Flow Reactor (HF Reactor)

DESIGN

A tubular reactor periodically “pinched” (narrowed) at intervals along its length, either straight or coiled.

OPERATION

Pinched segments create alternating zones of high and low shear, converging/diverging flow, and internal changes in flow direction. This enhances mixing and heat transfer drastically.

ADVANTAGES

Excellent for exothermic, multiphase, or rapid mixing reactions without the need for static mixers; scalable and economical for continuous operations; improves mass transfer and residence time distribution.

APPLICATIONS

Used in chemical synthesis, extraction, and multiphase reactions were enhanced inline mixing and heat transfer are critical.

Plug Flow Reactor (PFR)

DESIGN

A long, straight tubular reactor (sometimes coiled), with reactants flowing in one direction with little back-mixing.

OPERATION

The fluid elements (“plugs”) move along the reactor with a uniform velocity, maintaining their identity; concentration and temperature gradients exist along the reactor's length, but no mixing in axial direction.

ADVANTAGES

High conversion per unit volume; suitable for fast single-phase reactions.

APPLICATIONS

Widely used for gas-phase or liquid-phase chemical production, polymerization, and reactions requiring clear separation of reaction zones.

Thin Film Reactor

DESIGN

Consists of a flat or rotating surface on which reactants spread into a thin film, often aided by mechanical movement or centrifugal force.

OPERATION

The thin film maximizes surface area for heat and mass transfer, and provides extremely rapid mixing due to low film thickness.

ADVANTAGES

Efficient for highly viscous or heat-sensitive materials; allows easy control over film thickness and residence time; excellent for fast reactions.

APPLICATIONS

Used in polymerization, vacuum distillation, biochemical reactions, and processes were the rapid removal of products or efficient heat management is needed.

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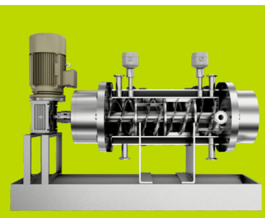
COMPARATIVE OVERVIEW





	HYDRODYNAMIC FLOW REACTOR (HFR)	THIN FILM REACTOR (TFR)	PLUG FLOW REACTOR (PFR)
Flow Regime	Segmented, alternating high/low shear zones; partial plug flow	Very thin laminar film, continuous renewal	Ideal plug flow (no axial mixing)
Mixing	Enhanced at pinch points; good overall mixing	Extremely high due to surface renewal	Minimal axial mixing; radial mixing only
Mass Transfer	High; enhanced by shear and surface renewal; supports multiphase	Excellent, especially at surface	Moderate; depends on tube diameter and flow type
Residence Time Distribution	Narrower than CSTR but broader than ideal PFR; closer to plug flow but with some dispersion	Very narrow, determined by film thickness and flow rate	Dirac delta function for ideal case; very narrow
Pressure Drop	Moderate to high due to repeated constrictions	Low; depends on film characteristics	Relatively low unless high velocity or very long tubes
Heat Transfer	Improved by alternating constriction and mixing zones	Excellent, due to high surface-area-to-volume ratio	Good, especially in small-diameter tubes
Best For	Rapid mixing, exothermic/multiphase, extraction, high mass transfer	Heat-sensitive, viscous, rapid or surface-driven reactions	Fast, single-phase reactions, polymerization, large-scale chemical synthesis

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FLOW REACTOR

Key Distinctions

	ADVANTAGES	LIMITATIONS
Pinched Tube Reactor	Enhances mixing and mass transfer for exothermic or multiphase reactions without auxiliary mixers.	Higher pressure drops and some dispersion compared to ideal plug flow; complex construction.
Plug Flow Reactor	Provides predictable conversion and selectivity with narrow residence time; scalable, efficient for uniform reactions.	Limited radial mixing; less effective for mixing-limited or multiphase reactions; can form hot/cold spots.
Thin Film Reactor	Maximizes surface for heat/mass transfer; ideal for viscous or sensitive materials.	Limited to processes that can be conducted in thin films; not suited for large bulk volume.

Application Summary

Hydrodynamic Flow Reactor (HF Reactor):

Heterogeneous extractions, two-phase and fast exothermic reactions, high mass transfer scenarios.

Plug Flow Reactor:

Bulk chemicals, polymerization, continuous gas/liquid-phase synthesis where minimal mixing suffices.

Thin Film Reactor:

Polymers, pharmaceuticals, distillation, reactions needing rapid heat removal or low residence time dispersion.

Each reactor design addresses the balance between mixing, mass transfer, and residence time control differently for specific chemical engineering needs.

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