

CONTINUOUS FLOW TECHNOLOGY

About **AMAR**

Serving Industry Since 1974

New 50000 sqft state-of-the-art manufacturing facility

Largest manufacturer of pressure & flow reactors in India

Expertise in custom designing high pressure & flow system

Inline with government's MAKE IN INDIA campaign

Exports to over 50 countries worldwide

Over 6000 successful installations worldwide

More than 2000 delighted customers globally

Manufacturing on CNC/VMC & automated machines

Unmatched quality & safety standards

ISO, CE-PED, ASME U, CSA, UL, Ex-Proof, ATEX certification

Prompt & efficient after sales service

Highly skilled & trained team of more than 200 personnel



OUR PRODUCTS

Pressure Reactor & Systems

Stirred Pressure Autoclaves
Plant Scale Pressure Reactors
Parallel Synthesizer
Eco Catalyst Screening
Glass Autoclaves
Magnetic Drive Couplings / Stirrers
Pressure Vessels
Acid Digestion Bomb
Shaker Hydrogenator
Super Critical Fluid Extraction
HPHT Corrosion Testing
Gas Hydrate Formation System
Agitated Nutsche Filter & Dryer
Heating Cooling Circulators

Flow Reactor & Systems

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SALIENT FEATURES

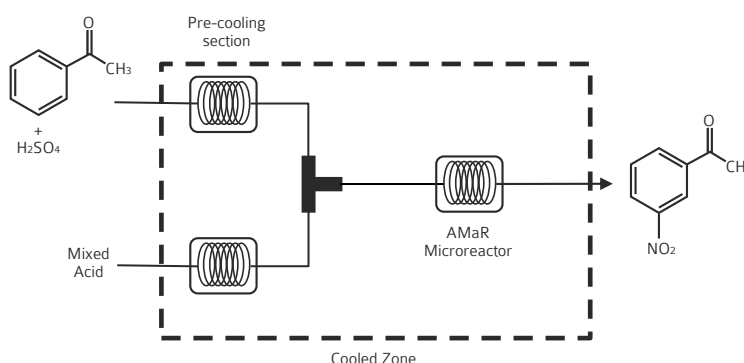
- Available in integrated microchannel & tubular metal construction for continuous flow process
- Reactors from 1 ml to 200 ltr
- 3D printed metal microreactors
- Very high heat and mass transfer coefficient
- Pressures up to 350 bar & temperatures up to 500°C
- SS316, Hastelloy, Inconel, Titanium etc. materials
- Suitable for various liquid-liquid, gas-liquid - multiphase reactions, and reactions involving solids
- Lab to plant scale turnkey solutions with pumps, utilities, pressure & flow control, safety device & controls in SCADA
- Easy scale-up from lab to production
- AMaR series of flow reactors are developed in technical collaboration with NCL, Pune

APPLICATIONS

AMaR series is ideal for carrying out a wide range of chemical reactions in the field of pharmaceuticals, fine and specialty chemicals in a continuous manner.

Suitable solutions for

- Homogeneous reactions: Neutralization, condensation, dehydration etc.
- Multiphase Reactions:
 - Gas-liquid reactions (G-L): oxidation, ozonolysis, halogenation, chlorination, bromination etc.
 - Liquid-liquid reactions (L-L): nitration, diazotization, azo coupling, transfer hydrogenation, sulfoxidation, amination, nitration of aromatic substrate, acylation, formylation, methylation, synthesis of nanomaterials, knoevenagel condensation, meerwein arylation, glycosylation hydrolysis, alkylation, sulfonation, sulfoxidation, synthesis of deuterated solvents, acetylation, oximation, cyclization etc.
 - G-L-S and L-S catalytic reactions: hydrogenation, pyrolysis, gasification, vapour phase reactions, etc.



GUIDELINES ON WHEN TO USE AMaR SERIES OF FLOW REACTORS

- **Inconsistent batch performance** due to high sensitivity towards process variables (temperature, pressure, concentration, time and mixing)
- **Process needs**
 - High heat transfer area
 - Efficient mixing
 - Rapid mass transfer
 - High interfacial area
- **Safety issues in**
 - Storing large inventories of hazardous reactants
 - Handling of hazardous and unstable chemicals
 - Generation of unstable intermediate by-products during the reaction
 - Runaway reactions
- **Process waste related issues**
 - Need for enhancing the selectivity close to theoretical value
 - Avoiding generation of waste that would need treatment
 - Need to avoid or reduce the downstream processing efforts for purification
- **Distributed production**
 - Produce only as per the local requirement/ consumption (location wise production)
 - Produce only as and when needed (avoid inventories)
- **Optimal utilization of facility**
 - A continuous flow manufacturing facility can also be used for production of multiple products with almost same peripherals
 - Space occupancy will be less
 - Achieve same or even better results than conventional batch operation



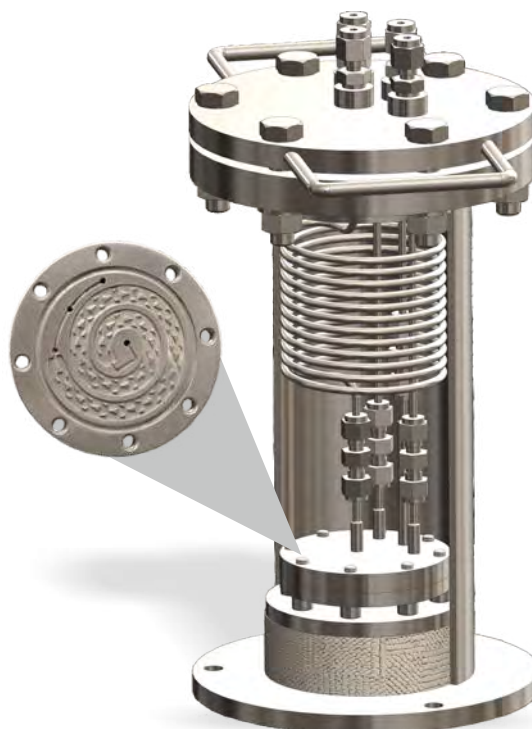
AMaR-1 LAB MICROREACTOR

SALIENT FEATURES

- Screening tool for continuous flow feasibility studies
- Suitable for reaction of miscible, immiscible liquids & gases
- Patented microchannel design
- Extremely effective mixing
- Very high heat transfer area
- Easy to clean - openable design
- Economical
- Ideal for fast & exothermic reactions

TECHNICAL SPECIFICATIONS

Volume	1 ml + 10 ml residence coil
Flow rate (lph)	Upto 40
Design pressure (bar)	50
Design temperature (°C)	-30 to 250 (with FFKM-Kalrez 'O' ring)
Material of construction	SS 316 / Hastelloy C- 276
Heat transfer area (m ² /m ³)	>2000



AMaR-2 MICROREACTOR

SALIENT FEATURES

- Patented microchannel design with alternate reactor & utility plates
- Modular design for easy scale-up from lab to production
- Very high specific surface area for effective heat transfer
- Openable design for ease of maintenance
- Alternate 3D printed fused design for very high heat transfer coefficient

APPLICATIONS

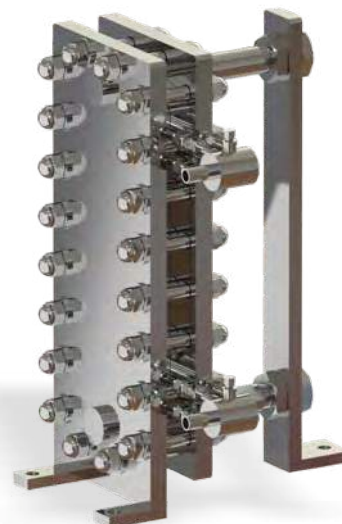
AMaR-2 is suitable for fast and highly exothermic liquid-liquid reactions. Some proven applications include reactions like nitration, halogenations, sulfonation, diazotization, oxidation/reduction, etc.

TECHNICAL SPECIFICATIONS

	Standard	Optional
Volumes	12 ml per plate	Upto 120 ml with 10 plates
	50 ml per plate	Upto 500 ml with 10 plates
	200 ml per plate	Upto 2000 ml with 10 plates
Flow rate (lph)	Upto 720	Upto 7200
Design pressure (bar)	20	50
Design temperature (°C)	-50 to 200	-50 to 350
Material of construction	SS 316	Hastelloy C 276
Heat transfer area (m ² /m ³)	500 - 2500	----



AMaR-2



AMaR-3: CONICAL FLOW REACTOR



SALIENT FEATURES

- Patented conical 3D design offering effective mixing
- High pressure capability as completely fused design
- Suitable for mass transfer limiting reactions
- Modular construction hence easily scalable

APPLICATIONS

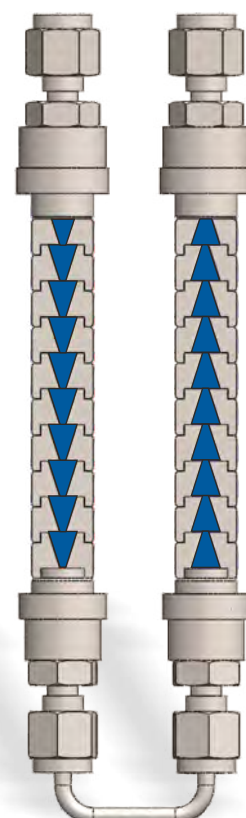
AMaR-3 is suitable for liquid-liquid immiscible reactions & gas-liquid reactions. Some proven applications include fast and exothermic reactions like halogenations, oxidation, condensation reactions, etc.

TECHNICAL SPECIFICATIONS

Volumes	1 ml to 200 ml
Flow rate (lph)	Upto 720
Design pressure (bar)	100
Design temperature (°C)	-50 to 350
Material of construction (MOC)	SS 316 / Hastelloy C 276
Heat transfer area (m ² /m ³)	500 - 2600



3D view of AMaR-3 assembly



Internal flow through candle

AMaR-4P: PINCHED TUBE FLOW REACTOR

SALIENT FEATURES

- Patented pinched-tube design for effective mixing
- Pilot to plant scale flow reactor with different size pinch tubes
- High heat transfer surface area due to pinching
- Metric tons production capacity
- Suitable for mixing of miscible, immiscible liquids & gases
- Most economical reactor in terms of cost / unit volume of reactor
- Effective for continuous L-L extraction

APPLICATIONS

AMaR-4P is a versatile reactor with applications ranging from miscible/immiscible liquid-liquid reactions, gas-liquid reactions, liquid-liquid extraction. They can be used in conjunction with AMaR-2 or AMaR-3 to provide the necessary residence time for desired conversion.

TECHNICAL SPECIFICATIONS

Volumes	100 ml to 200 ltr.
Flow rate (lph)	upto 10000
Design pressure (bar)	50
Design temperature (°C)	-50 to 350
Material of construction (MOC)	SS 316 / Hastelloy C 276
Heat transfer area (m ² /m ³)	200 - 1400





TUBULAR REACTOR & STATIC MIXERS



TECHNICAL SPECIFICATIONS

	Standard	Optional
Volumes	100 ml to 200 ltr.	Customized
Flow rate (lph)	up to 10000	-
Design pressure (bar)	100 bar	Up to 350
Design temperature (°C)	-50 to 350	-50 to 350
Material of construction (MOC)	SS 316	Hastelloy C

APPLICATIONS

- Optional static mixer elements for better mixing.
- Mixing of high viscosity fluids, gas-liquid & slurry applications.
- Dispersion of immiscible liquids.
- Mixing of acids, juices, oils etc.



PHOTO-FLO REACTOR

SALIENT FEATURES

- UV transparent chemically inert tubes
- Reactor volumes 12, 50, 200, 1000 & 2000 ml
- Flow rates up to 240 ltr/hr
- Pressures up to 18 bar & 150 °C temperature
- Efficient, uniform irradiation
- Precise control over exposure time
- For superior selectivity
- Safer operations compared to batch (bulk of solvent is away from lamp)
- Scale independent (capable of producing from few gm to kgs)
- Highly concentrated solution can be irradiated
- Photochemical flow reactor combines the advantages of continuous flow processing with the added benefits of ultraviolet light to enable photochemical reactions and a consistent distribution of UV light.

APPLICATIONS

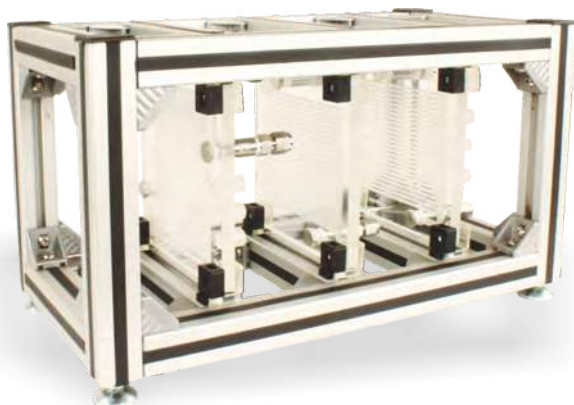
- Photo chlorination
- Production of vitamin D
- Photo alkylation
- Artemisinin production (anti malarial drug)
- Production of ϵ -caprolactame



FLOW REACTOR & SYSTEMS



GLASS MICROREACTOR



- Volume: 0.1 ml to 50 ml.
- Up to 15 bar & 300 °C
- Material: Glass, quartz, silicon, glass-silicon compounds.
- Integrated multilayer glass construction for mixing, reaction & heat transfer.

MULTI-FLO REACTOR



- Cost-effective starter set for proof-of-concept studies.
- Interchangeable reactor modules of AMaR-2, AMaR-3, AMaR-4, AMaR-4P with heating cooling.
- Up to 50 bar & -50°C to 350°C.
- Material: SS316, Hastelloy C.

ELECTROCHEMICAL FLOW REACTOR



- Volume: 5 ml to 3000 ltr.
- Design pressure: Up to 2 bar & 120°C.
- Wetted part: PTFE.
- Graphite, lead, copper, platinum, aluminium, iron, titanium, Mg, SS, Zn, Cu/Ni electrodes.

LIQUID LIQUID SEPARATOR



- Flow rate: Up to 12 lph.
- Design temperature: Up to 120°C.
- Wetted part: PTFE.
- Advanced membrane-based liquid-liquid separation.
- Highly efficient than gravity based separations, even for challenging emulsions.



SOLI-FLO REACTOR

SALIENT FEATURES

- Homogeneous and heterogeneous reactions in same setup using interchangeable tubular attachments
- Pressures upto 350 bar
- Temperatures upto 400°C
- Offered with gas flow controller & liquid metering pump
- Very compact, versatile & economical

FOR HOMOGENEOUS REACTIONS

- PTFE, SS 316 or Hastelloy C helical tubular reactor in 4, 8, 16 ml volume to fit in same furnace

APPLICATIONS

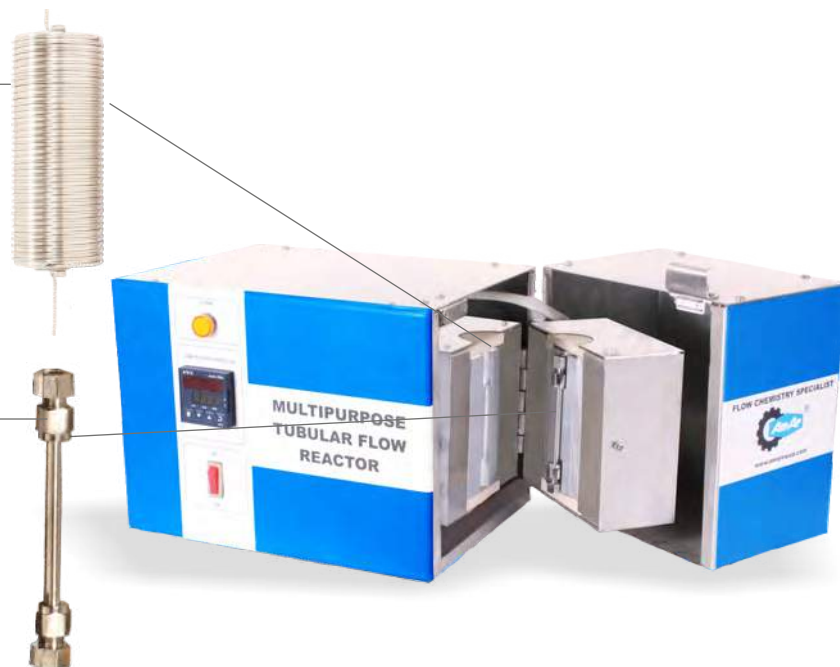
- Alkylation
- Heterocycle synthesis
- Supercritical reaction etc.

FOR HETEROGENEOUS REACTIONS

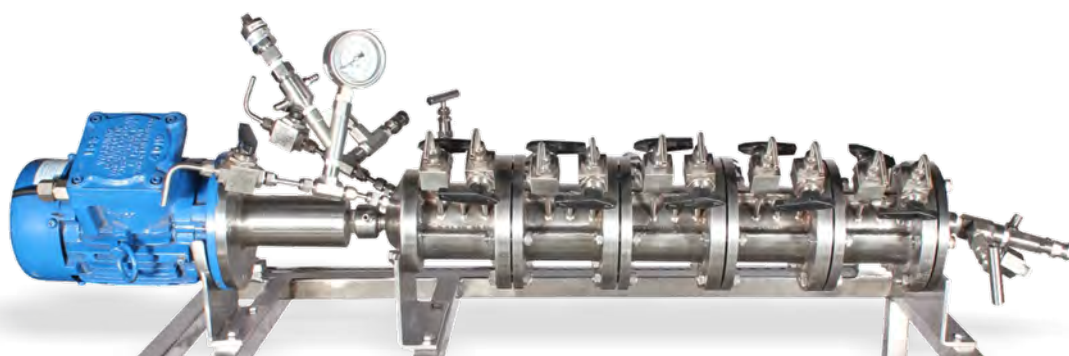
- SS316 or Hastelloy C vertical catalyst holding tube in 1, 2, 4 ml volume to fit in same furnace

APPLICATIONS

- Hydrogenation
- Oxidation
- Carboxylation etc



SLURRY-FLO REACTOR



SALIENT FEATURES

- Multiple jacketed reaction vessels connected in series horizontally with common magnetically coupled agitator
- Offers a cost effective way of having high number of mixed stages
- It can handle clean fluids / immiscible fluids / slurry application or reactions with long reaction times
- Scalable to large volumes
- The operating pressures can be as high as 50 bar
- The reaction times could range from a few seconds to as high as 10 hours

TECHNICAL SPECIFICATIONS

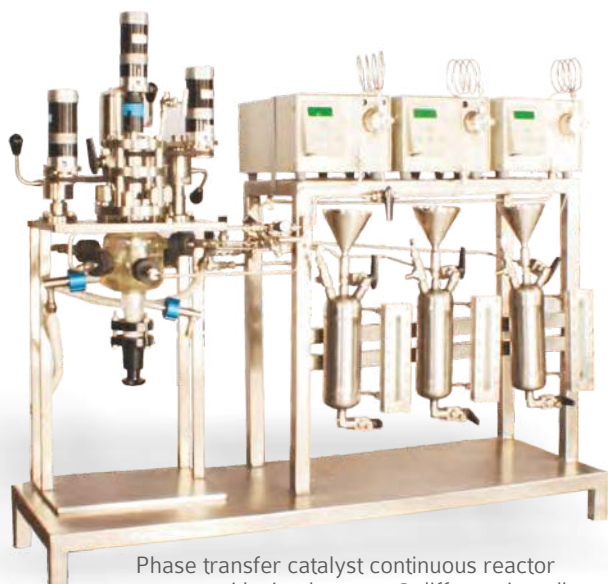
Volumes	250 ml to 5 ltr.
Flow rate (lph)	Upto 300
Design pressure (bar)	50
Design temperature (°C)	-30 to 200
Material of construction (MOC)	SS 316 / Hastelloy C 276
Heat transfer area (m ² /m ³)	60

CONTINUOUS STIRRED TANK REACTOR



SALIENT FEATURES

- Product is developed / produced on continuous basis for better productivity
- Stirred tank reactors of 25 ml to 10000 ltr
- Single or multiple reactors connected in series
- SS-316, Hastelloy C, inconel etc. materials
- Pressures upto 350 bar @ 500°C
- Ex-proof system for hazardous area
- Fully automated PC controlled systems to continuously monitor, record & control various parameters like temperature pressure, motor speed, gas / liquid flow etc.
- Gas mass flow controller, metering pumps, level controller, catalyst filtration system with SCADA software etc. are provided for a typical hydrogenation application.



Phase transfer catalyst continuous reactor system with simultaneous 3 different impeller speeds at 3 different levels



1 ltr, 4 nos. CSTR in series



High pressure CSTR for hydrogenation



CSTR for hydro-cracking of heavy hydrocarbon oils



PACKED BED REACTORS

SALIENT FEATURES

- Fixed, fluidized, trickle bed designs offered.
- Reactor volumes from 10ml to 100 ltrs.
- Designed up to 350 bar & 1000°C.
- SS316, Inconel, Hastelloy C etc.
- Explosion proof plants for hazardous area.
- Tabletop or skid mounted plants.
- Customisable systems for gas liquid feed combinations, series or parallel reactors, multi zone heating furnaces etc. with integrated controls, high level of safety, automation and SCADA software.

APPLICATIONS

- Catalyst screening
- Hydrogenation
- Fischer-tropsch process
- Hydro-cracking
- Vapor phase reaction
- Coal to syngas production
- Pyrolysis reactions
- Biomass gasifications



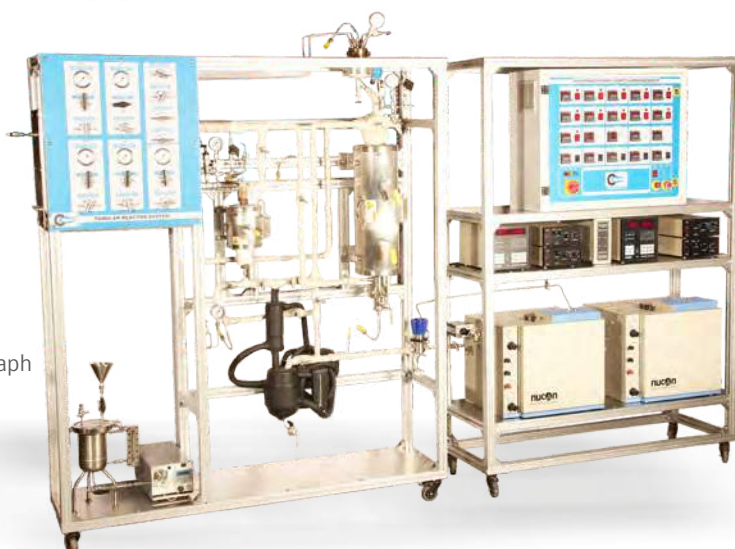
Micro reactor assembly for
Liposome formation
Reactor volume: 100 ml
Pressure: 100 bar
Temperature: 500 °C
Material: Hastelloy C



2 reactors with flexibility to connect
in parallel & series
Reactor volume: ~30 ml
Pressure: 5 bar.
Temperature: 1000 °C.
Materials: Inconel



Table Top
Reactor
System
(TTRS)

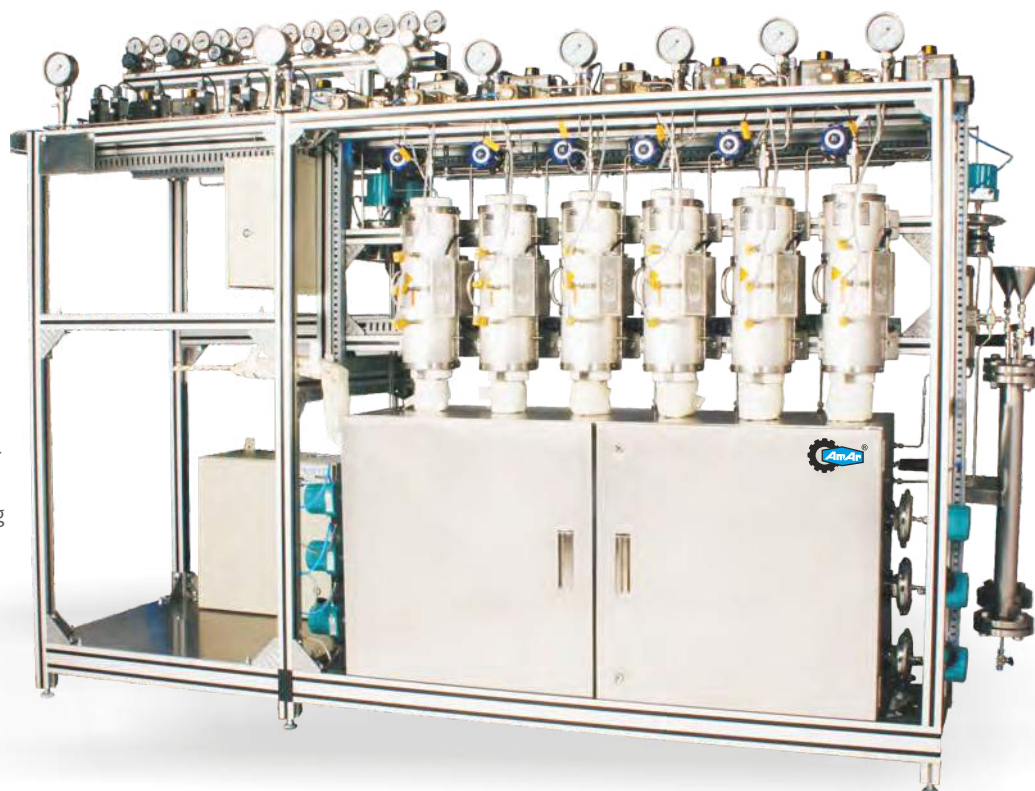


Reactors: 2 nos.
Pressure: 100 bar
Temperature: 700 °C
With gas chromatograph

PACKED BED REACTORS

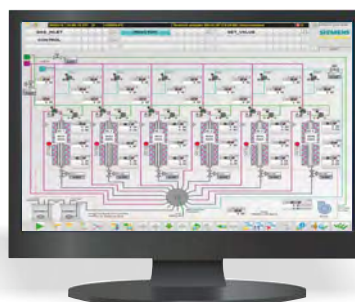


High throughput multi tube reactor system for catalyst screening



SYSTEM SPECIFICATIONS

- Reactor volume: 6 Nos- parallel- 10 to 100 ml. same or of different volumes (optional: upto 16 nos in parallel).
- Design pressure: 100 bar
- Design temperature: 900 °C
- Material: SS 316, Inconel, Hastelloy C, etc.



Pilot scale tubular reactor with purge panels for continuous biojet fuel production

FLUIDIZED BED REACTORS

Pressure: 5 bar
Temperature: 1000 °C
Material: Inconel



Pyrolysis reactor system
Hybrid system of fixed & fluidized bed



Fluidized bed coal to
syngas gasification facility
Pressure: 10 bar
Temperature: 1050 °C
Gasification rate: 60 - 150 kg/h

CUSTOMISED FLOW REACTOR SYSTEMS



50 ml AMaR-2 pilot scale skid



AMaR-4 reactor system



AMaR-2 reactor system



AMaR-4 1500 ml automated pilot skid assembly



1 Ltr AMaR-3 reactor system



SCALED-UP FLOW REACTOR SYSTEMS

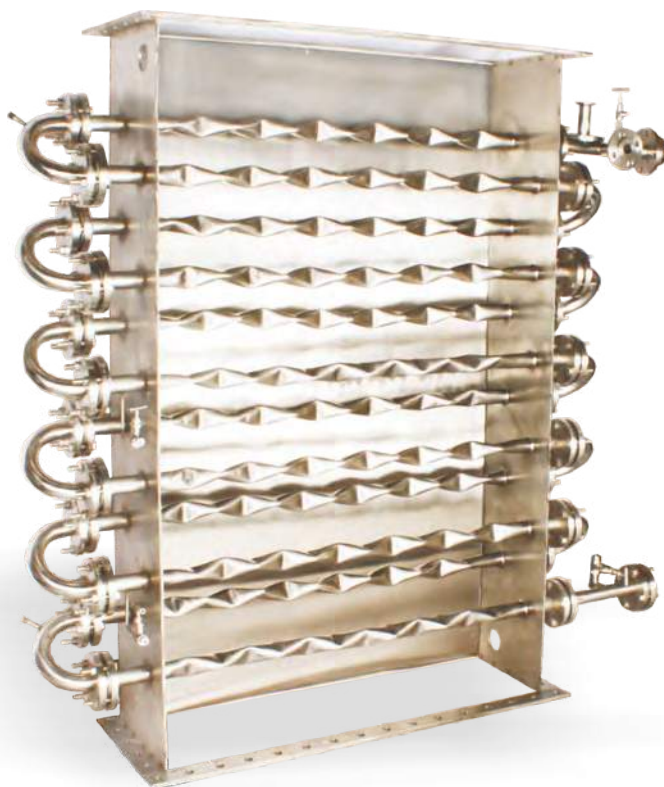
Amar has expertise to design, manufacture & integrate commercial flow reactor systems with pumps, accessories, utilities, automation on a common skid up to 10000 lph. for various applications.



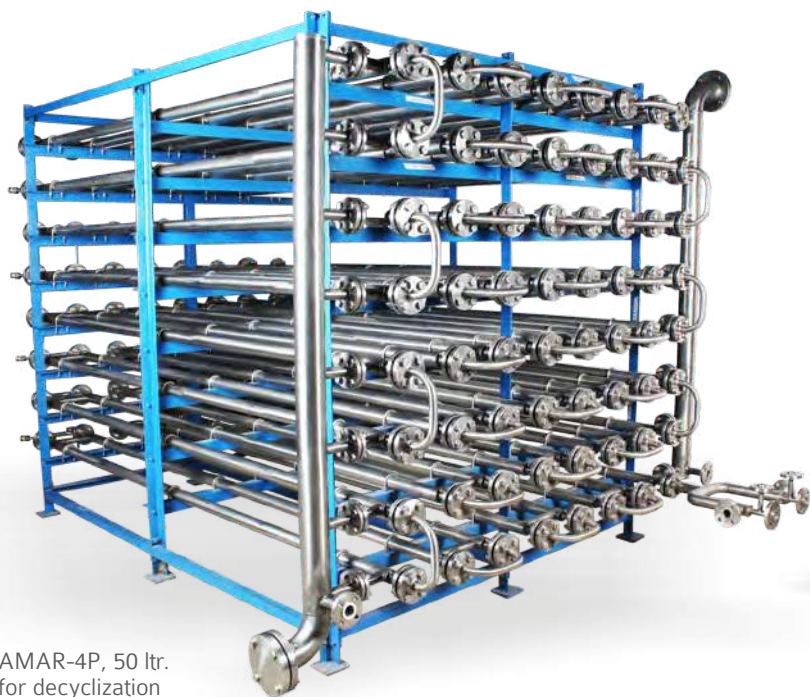
AMAR-4, 2 Ltr
Nitration reaction with
15 lph throughput



AMAR-4, 10Ltr
N-alkylation with
600 lph throughput



AMAR-4P, 12 ltr
Neutralization
4 ton / day throughput



AMAR-4P, 50 ltr.
for decyclization
at 1000 lph



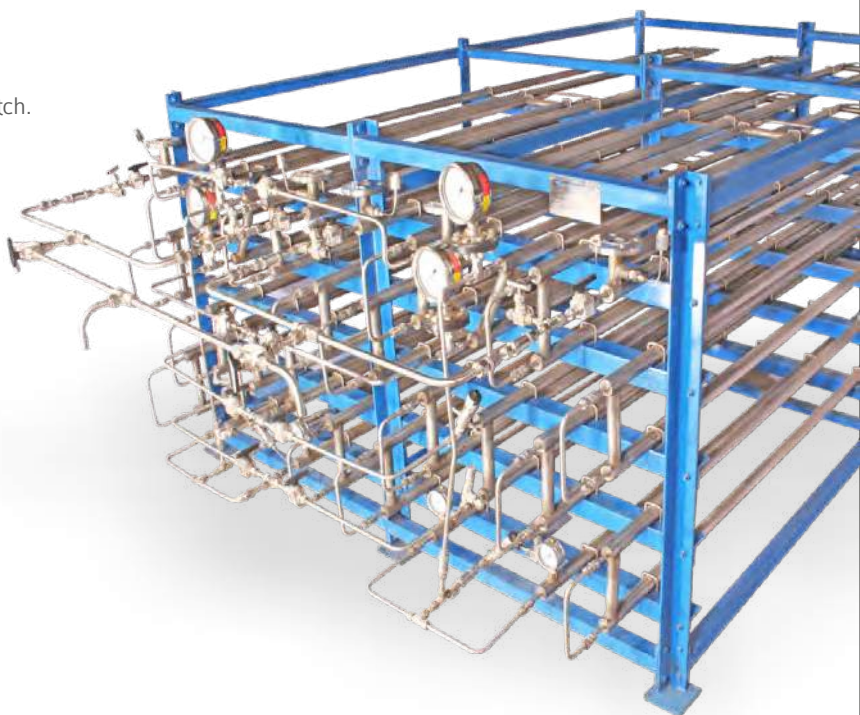
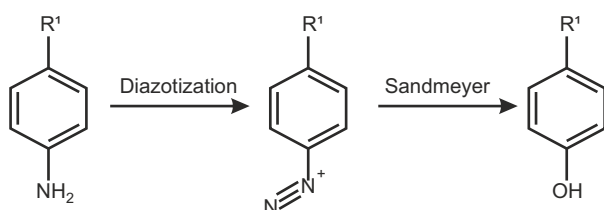
AMAR-4P, 2 ltr
Acetylation at 100 lph

SCALED-UP FLOW REACTOR SYSTEMS



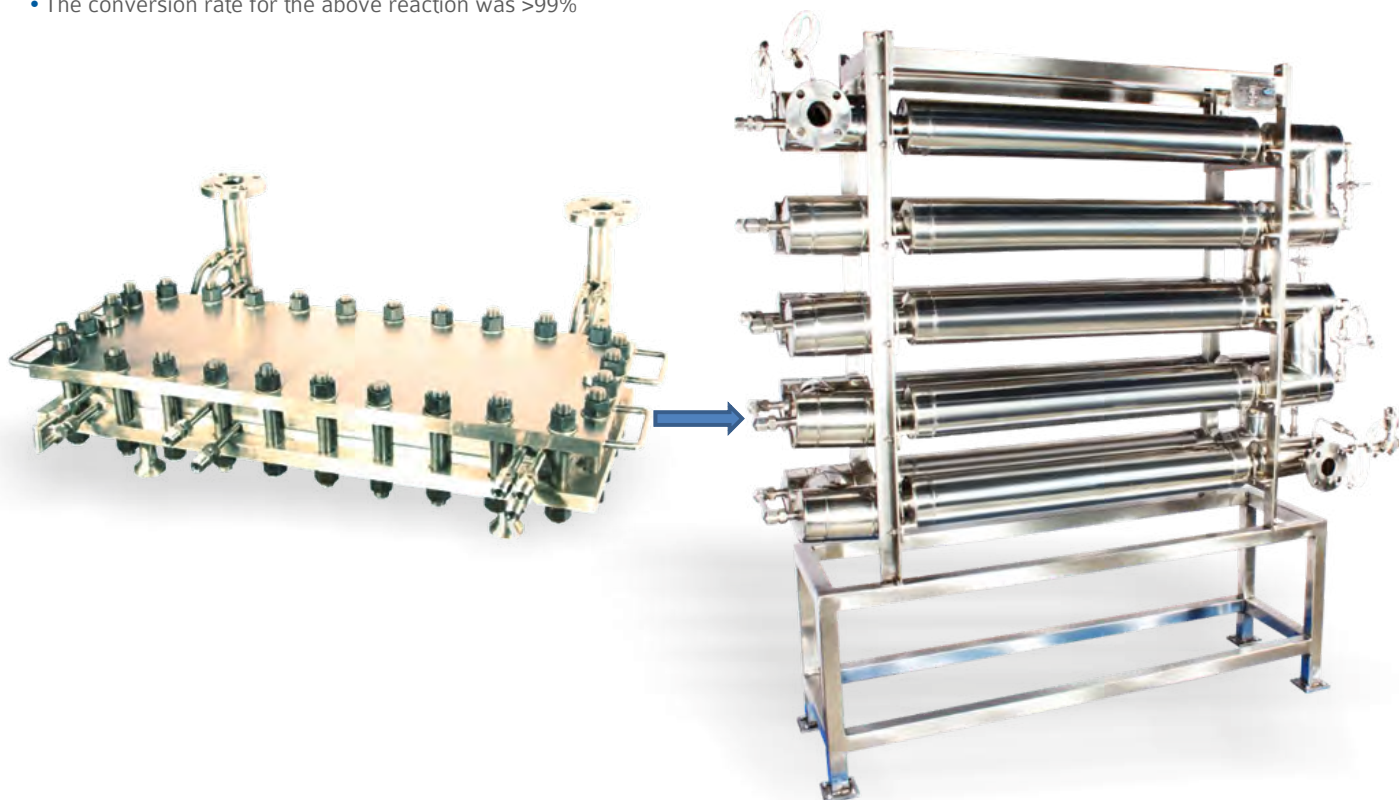
DIAZOTIZATION FOLLOWED BY SANDMEYER REACTION

- The scale-up of the above operation was 50 kg/day.
- The conversion rate for the above reaction was >99%.
- It could handle >40% solid loading in AMaR-4 reactor.
- The selectivity for flow process was 75% against 30% in batch.



NITRATION REACTION

- Process for this nitration reaction was set using lab-scale AMaR micro & tube reactor in series
- Microreactor takes out initial heat of reaction followed by pinched tube reactor for residence time
- Similar residence times and product quality were observed from lab-scale to pilot-scale
- The scale-up of the above operation was successful at 9 ton/day using AMaR flow reactor of 4 ltrs
- The conversion rate for the above reaction was >99%



GAS PRESSURE REGULATOR

To manually charge different gases at desired pressures upto 140 bar / 2000 psi or higher into the reactor from gas cylinder. Nitrogen, Oxygen & Hydrogen can be charged through same regulator (with special adaptor). The regulator is made from SS316 & comes with inlet - outlet pressure gauges & flexible SS braided PTFE high pressure hose pipe (4m long) with check valve.



THERMAL GAS MASS FLOW METER (MFM) / CONTROLLER (MFC)

MFM can be used to measure accurate mass flow rate of gas (in gm/hr or LPH) & totalized quantity of mass / volume (in gms/ltr) charged in the reactor at any point. Mass flow controller (MFC) is used to charge the set flow rate of gas into the reactor at high pressures upto 100 bar. The same MFM / MFC can be used for multiple gases by just entering the conversion factor for different gas densities provided the gases are inert to each other. The MFM/MFC comes with high pressure flexible hose, inlet filter with digital gas flow indicator.



MFC



Flow Indicator & Totaliser

CORIOLIS GAS - LIQUID MASS FLOW METER / CONTROLLER

These are used for higher & accurate gas or liquid flow rate indication or control in cases where thermal mass flow meters are not suitable. A common meter can be used for different gases & liquids for a particular range of flow.



Coriolis Mass Flow Meter



Coriolis Mass Flow Controller

DIGITAL PRESSURE INDICATOR

It consists of SS316 / Hastelloy C pressure sensor (transmitter) & digital pressure indicator/controller (mounted on common control panel) with pressure alarm.



Pressure Sensor

LIQUID METERING PUMP SYSTEM

This system is used to charge liquid at a desired rate from as low as 1 ml/hr to 100 ltr/hr, is under pressurized condition.

- High pressure accurate HPLC type low flow metering pumps for high pressures upto 350 bar & flow range from 0.01 upto 100ml / min. Materials: SS316, option: Hastelloy C, Titanium
- Diaphragm metering pumps for pressures upto 100 bar & minimum flow range of 60-600 ml/hr to maximum 10-100 lit/hr. The flow rates are varied by varying the motor speed with variable frequency drive. Materials: SS316, option: Hastelloy C, Titanium
- Low / high pressure syringe, pumps can be offered for pumping corrosive chemicals.



(a)



(c)



(b)

WEIGHING BALANCE

To measure precise amount / quantities of feed / product consumed or produced during process.



HEATING COOLING CIRCULATORS

- Single fluid closed loop system from -90 °C to 250°C.
- Heating cooling bath circulators from -70°C to 175°C.
- High temperature circulators from ambient to 350°C.
- Chillers up to -15°C.
- Suitable for reactor volume from 10 ml to 3000 ltr.



OPTIONAL ACCESSORIES



FLOW CONTROL VALVES

These valves are used to control flow, pressure or level

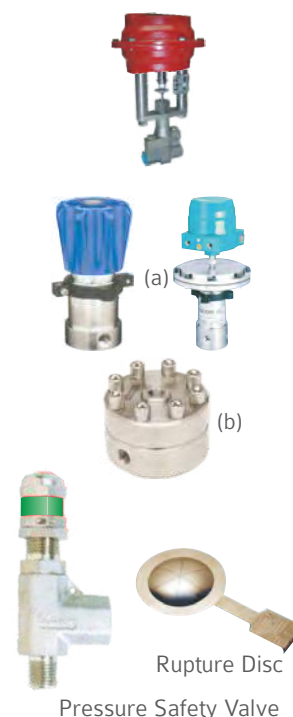
BACK PRESSURE REGULATOR

It is SS 316 regulator mounted on the vent line of the reactor & is used for maintaining constant pressure inside the reactor upto 350 bar. The pressure is maintained by releasing the excess pressure into the atmosphere.

- Optional:**
- a) Electronic actuated digital pneumatic back pressure regulator, (6 bar air supply is set digitally & can be released at preset rate of pressure release required).
 - b) Pneumatically actuated pilot operated back pressure regulator (air / N₂ gas supply for rated pressure is required)
 - c) Electronic control unit & forward regulator with 4 mtr. hose for activating (b) above.
 - d) Materials: Hastelloy C, PTFE etc.

PRESSURE SAFETY VALVE & SAFETY RUPTURE DISC

Safety rupture discs can be provided for pressure ratings of 100 bar & pressure safety valves can be provided for any pressures from 1 to 350 bar with provision to vary release pressure within a certain range. These valves come with PTFE / Viton / Kalrez 'O' rings.



SCADA SOFTWARE FOR REMOTE OPERATION & RECORDING

SCADA is a supervisory control & data acquisition software with all controllers / indicators having RS 485 modbus communication port or PLC & HMI / touch panel, for online display, set point changes & data logging of various parameters like pressure, temperature, liquid / gas flow rate, oil/heater temperature, level, pH, ORP, IR etc. remotely from PC as well as locally from panel. It gives continuous online data logging at predefined (variable) time interval, online graphical representation as well as historical data & graphs on PC for single or multiple autoclaves. RS 485-232 convertor & cable upto 50 m or higher is also supplied.



PURGE CABINET

Cabinet with nitrogen purging for explosion proof zones can be offered by mounting nonexplosion proof instruments & assembly inside the cabinet



WET GAS METER

Wet gas meter is an analog instrument used to measure exhaust gas flow for gas mixer & is available in all flow rate ranges. It can give output for digital flow indication



CONTROL PANEL

Control panel consists of programmable PID temperature controller cum indicator with temperature alarm system (settable), safety alarm & heater trip system for malfunctioning of controller / sensor/ temperature rise beyond set limit. Digital pressure indicator / controller, gas / liquid flow indicator, totaliser, level etc. indicators are provided additionally on same common control panel depending on the optional accessories selected.

Optional:

- a) Touch screen panel with SCADA software.
- b) PLC based control panel with touch panel HMI or remote SCADA software & PC control.
- c) Complete ex-proof - flame proof (FLP) Group IIA / IIB or IIC, ATEX zone 1, class 1 div. 2 certified.





FLOW CHEMISTRY SERVICES

**R&D facility dedicated to flow chemistry
feasibility trials & process development**



Flow chemistry

Process development

Piloting

Custom equipment design

Commercialization support

High pressure chemistry

Custom synthesis



OUR VALUED CLIENTELE





AMAR EQUIPMENT PVT. LTD.

📍 Valson Textile Mills, LBS Road, Bhandup (W), Mumbai - 400078, INDIA.

☎ +91-22- 6225 5000 🏠 www.amarequip.com ✉ flowreactor@amarequip.com