Continuous Flow Reactors
Packed Bed Tubular Reactors
CSTR

Flow Chemistry Specialist™
from Lab to Production Scale
About AMAR

Serving Industry Since 1974

ISO, CE, PED, ASME U/U2, UL, CSA, Ex-Proof, ATEX certified

Largest manufacturer & exporter of flow reactors / autoclaves in India

Inline with government's MAKE IN INDIA campaign

Exports to over 50 countries worldwide

40 distributors worldwide for local support

Manufacturing on CNC/VMC & automated machines

Unmatched quality & safety standards

Custom built turnkey solutions with all accessories

Metal microreactors in technical collaboration with NCL  Pg. 1-6
AMaR-1 Micromixer - 1 ml  Pg. 2
AMaR-2 Microreactor - 12 - 2 ltr  Pg. 3
AMaR-3-3D flow reactor - 12 - 5 ltr  Pg. 4
AMaR-4/4P pinch coil tubular reactor - 100 ml - 150 ltr  Pg. 5-6
AMaR-5 mesh flow reactor - 100 ml - 1 ltr  Pg. 6
Photochemical flow reactor - AMaR-PFR - 12 - 200 ml  Pg. 7
Static mixer AMaR-SM - 12 - 200 ml  Pg. 7
Multipurpose HPHT tubular reactor - AMaR-MFR - 1 - 50 ml  Pg. 8
AMaR range of micro / flow reactors & accessories  Pg. 9
Glass microreactor of LTF-Germany  Pg. 10-11

Fixed bed tubular reactors  Pg. 12-16
CSTR  Pg. 17
Malshe’s interchangeable vapor phase reactor  Pg. 17
Optional accessories  Pg. 18-21

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 Micro-mixer and Reactors (In technical collaboration with CSIR-NCL)

Salient features

• Available in integrated multilayer & tubular metal construction for mixing, reaction & heat transfer
• Microchannels with modular system to connect multiple reactors in series or parallel
• Reactors from 1 µl to 150 ltr
• Pressures up to 350 bar & temperatures up to 500°C
• Flow rates up to 4000 LPH per unit
• MOC: SS316, Hastelloy, Inconel, Monel, Titanium, Tantalum lined, PTFE, PEEK etc.
• Suitable for various liquid-liquid, gas-liquid homogeneous - multiphase reactions, gas, solid & liquid catalytic reactions
• Lab to plant scale turnkey solutions with pumps, utilities, pressure & flow control, safety device & controls in SCADA

Transform your process development capabilities using AMaR series continuous flow reactors

Key design attributes

The devices developed under AMaR series are designed to offer excellent mixing and heat transfer for carrying out fast and exothermic reactions. The design is based on extensive experiments as well as years of research on flow and transport processes carried out at CSIR-National Chemical Laboratory, Pune. The geometry is selected in a manner that while they offer high heat transfer area per unit reactor volume, they also allow flow of dilute suspension of nano-catalysts. The channels / tubes may also be packed with catalyst for catalytic reactions.

Advantages of AMaR continuous flow reactors over batch reactors:

• Better mixing & very high heat transfer area per unit volume
• Faster reactions & better selectivity
• Higher yield & low pressure drop
• High safety & ideal for exothermic reactions
• Reduced waste and faster transfer of process from laboratory to pilot / commercial scale manufacturing
• Easily scaleable
• Very small foot print

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 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, nitrification of aromatic substrate, acylation, formylation, methylation, synthesis of nanomaterials, knevenagel condensation, meerwein arylation, glycosylation hydrolysis, alklylation, sulfonation, sulfoxidation, synthesis of deuterated solvents, acetylation, oximation, cyclization, liquid-liquid extraction etc.
  - G-L-S and L-S catalytic reactions: esterification, hydrogenation etc.
• Extraction and separation of Co from Ni using AMaR-3

List of publications using AMaR reactor:

• Selectivity engineering of the diazotization reaction in a continuous flow reactor, DOI: 10.1039/CSRE00056D, Citation: React. Chem. Eng., 2016, 1, 387-396.
• Continuous flow nitration of o-Xylene: Effect of nitrating agent and feasibility of tubular reactors for scale-up DOI:10.1021/acs.oprd.5b00064, Organic Process Research Development.
**AMaR-1: Micromixer** *(Patented)*

**Application**
Mixing of miscible liquids or immiscible liquids or gases creating dispersion of immiscible fluids or gases in liquids and carrying out very fast, exothermic & homogeneous reactions. Some of the tested applications include nitrations, halogenations, sulfoxidation, sulfonation, esterification, diazotization, condensation reactions, halogenations, reduction, oxidation, etc.

**Flow pattern**

**Design**
Design: It comprises of broad converging diverging channel (with width to depth ratio between 5 to 20) with flow past triangular objects to avoid formation of dead zones. This helps to use maximum of the space and is scalable.

<table>
<thead>
<tr>
<th>Technical specifications</th>
<th>Standard</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMaR-1</td>
<td>AMaR-1J</td>
<td></td>
</tr>
<tr>
<td>Volume (ml)</td>
<td>1 ml microreactor + 5/10 ml residence coil</td>
<td>----</td>
</tr>
<tr>
<td>Flow rate (ltr/hr)</td>
<td>3.6 (for 1 sec. residence time)</td>
<td>----</td>
</tr>
<tr>
<td>Design pressure (bar)</td>
<td>50</td>
<td>----</td>
</tr>
<tr>
<td>Design temperature (°C)</td>
<td>-50 to 200 (with FKM-Viton ‘O’ ring)</td>
<td>-50 to 250 (with FFKM-Kalrez ‘O’ ring)</td>
</tr>
<tr>
<td>Material of construction (MOC)</td>
<td>SS 316</td>
<td>Hastelloy C 276, Inconel, Monel, Titanium, Tantalum lined, Carbon filled PTFE, PEEK</td>
</tr>
<tr>
<td>Heat transfer area (m²/m³)</td>
<td>&gt; 2000</td>
<td>----</td>
</tr>
<tr>
<td>Dimensions (mm)</td>
<td>115 W x 58 D x 14 H</td>
<td>142 dia x 203 ht</td>
</tr>
<tr>
<td>End connections</td>
<td>3 nos. inlet &amp; 1 no. outlet</td>
<td>----</td>
</tr>
<tr>
<td>Heating/ Cooling</td>
<td>by dipping in thermostat</td>
<td>SS304 jacket</td>
</tr>
</tbody>
</table>

**Model no. for enquiry**

<table>
<thead>
<tr>
<th>Model</th>
<th>Materials code*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMaR-1</td>
<td>Hastelloy C-HC6</td>
</tr>
<tr>
<td></td>
<td>Inconel-INC</td>
</tr>
<tr>
<td></td>
<td>Monel-MN4</td>
</tr>
<tr>
<td></td>
<td>Titanium-Ti2</td>
</tr>
<tr>
<td></td>
<td>Tantalum lined</td>
</tr>
<tr>
<td></td>
<td>PTFE-CFT</td>
</tr>
<tr>
<td></td>
<td>PEEK-PEK</td>
</tr>
</tbody>
</table>

*If other than SS316

**Flow chemistry starter set - metal microreactors**
It consists of AMaR-1, AMaR-3 (1 ml), 5 ml residence time coil, 2 pumps, heating cooling circulator/peltier cooler with optional back pressure regulator. It is ideal for educational institutes and R&D to get introduced to flow chemistry with proof of concept & lab trials.
**AMaR-2: Microreactor** *(Patented)*

**Application**
Mixing of miscible liquids or immiscible liquids or gases creating dispersion of immiscible fluids or gases in liquids and carrying out very fast, exothermic & homogeneous reactions. Some of the tested applications include nitrations, halogenations, sulfoxidation, sulfonation, esterification, diazotization, condensation reactions, halogenations, reduction, oxidation etc.

**Design**
It comprises of broad channel (with width to depth ratio between 5 to 20) with flow past triangular objects to avoid formation of dead zones. This helps to use maximum of the space and is scalable. Openable reactor plates enable easy cleaning especially for reactions involving solid formation.

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**Technical specifications**

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume</strong></td>
<td>1) 12 ml per plate</td>
<td>Upto 120 ml for 10 plates in series or parallel</td>
</tr>
<tr>
<td></td>
<td>2) 50 ml per plate</td>
<td>Upto 500 ml for 10 plates in series or parallel</td>
</tr>
<tr>
<td></td>
<td>3) 200 ml per plate</td>
<td>Upto 2000 ml for 10 plates in series or parallel</td>
</tr>
<tr>
<td><strong>Flow rate (ltr/hr)</strong></td>
<td>0.144 to 24 (for single plate)</td>
<td>1.44 to 240 (for 10 plates in parallel)</td>
</tr>
<tr>
<td><strong>Design pressure (bar)</strong></td>
<td>20</td>
<td>--</td>
</tr>
<tr>
<td><strong>Design temperature (°C)</strong></td>
<td>-50 to 200 (with FKM-Viton ‘O’ ring)</td>
<td>-50 to 250 (with FFKM-Kalrez ‘O’ ring)</td>
</tr>
<tr>
<td><strong>Material of construction (MOC)</strong></td>
<td>SS316</td>
<td>Hastelloy C276, Inconel, Monel, Titanium, Tantalum Lined, Carbon filled PTFE, PEEK</td>
</tr>
<tr>
<td><strong>Heat transfer area (m²/m³)</strong></td>
<td>&gt; 2000</td>
<td>--</td>
</tr>
<tr>
<td><strong>End connections</strong></td>
<td>3 nos Inlet &amp; 1 No outlet</td>
<td>Intermittent liquid addition or sampling</td>
</tr>
<tr>
<td><strong>Heating/Cooling</strong></td>
<td>Circulating thermic fluid through external SS304 jacket on both the sides</td>
<td>--</td>
</tr>
</tbody>
</table>

*Assuming 5 sec. residence time

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**Performance Characteristics**

**RTD for AMaR-1 / AMaR-1J / AMaR-2**

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**Model no. for enquiry**

<table>
<thead>
<tr>
<th>AMaR-2</th>
<th>Volume per plate</th>
<th>No. of plates*</th>
<th>Material**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
<td>2 - 10</td>
<td>Hastelloy C-HC6</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
<td>Inconel-INC</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td></td>
<td>Monel-MN4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Titanium-TI2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tantalum lined-TNL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PTFE-CFT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PEEK-PEK</td>
</tr>
</tbody>
</table>

*If more than 1
**If other than SS316
AMaR-3: Pilot scale 3D flow reactor (Patented)

**Application**
Mixing of miscible liquids or immiscible liquids or gases creating dispersion of immiscible fluids or gases in liquids and carrying out very fast, exothermic, homogeneous, heterogeneous & catalytic hydrogenation reactions. Some of the tested applications include diazotization, nitrations, oxidation with different oxidizing agents, sulfoxidation, hydrogenation, sulfonation, etc. The reactor has been used in many industries for a wide range of reactions under various conditions from cryogenic to High temperature & High Pressure Reactions.

**Design**
It consists of a sequence of symmetric 3D converging units with or without obstructions. This is scalable and gives high throughput.

AMaR-3 A: Asymmetric AMaR-3 (Patented)

**Application**
Mixing of miscible liquids or immiscible liquids or gases creating dispersion of immiscible fluids or gases in liquids and carrying out very fast, exothermic, homogeneous, heterogeneous & catalytic hydrogenation reactions.

**Other technical specifications:** Same as AMaR-3

**Design**
Design: It consists of a sequence of asymmetric 3D converging units with or without obstructions. This is scalable and gives high throughput.

<table>
<thead>
<tr>
<th>Technical specifications</th>
<th>Standard</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (ml)</td>
<td>1, 12, 50, 200, 1000</td>
<td>2 - 5 ltr with different cone volumes</td>
</tr>
<tr>
<td>Flow rate (ltr/hr)*</td>
<td>0.06 to 120</td>
<td>360</td>
</tr>
<tr>
<td>Design pressure (bar)</td>
<td>100</td>
<td>200/350</td>
</tr>
<tr>
<td>Design temperature (°C)</td>
<td>-50 to 250</td>
<td>350</td>
</tr>
<tr>
<td>Material of construction (MOC)</td>
<td>SS 316</td>
<td>Hastelloy C276, Inconel, Monel, Titanium</td>
</tr>
<tr>
<td>Heat transfer Area (m²/m³)</td>
<td>1000</td>
<td>200 to 1000</td>
</tr>
<tr>
<td>End connections</td>
<td>2 nos. inlet with Y mixture, 1 no. outlet, pressure gauge, rupture disc</td>
<td>Intermittent addition or sampling ports, safety relief valve, thermocouple</td>
</tr>
<tr>
<td>Heating/ Cooling</td>
<td>SS304 jacket</td>
<td>---</td>
</tr>
</tbody>
</table>

*Assuming 5 sec. residence time

**Model no. for enquiry**

<table>
<thead>
<tr>
<th>AMaR-3 Volume in ml</th>
<th>Material*</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Hastelloy C-HC6</td>
</tr>
<tr>
<td>50</td>
<td>Inconel-INC</td>
</tr>
<tr>
<td>200</td>
<td>Monel-MN4</td>
</tr>
<tr>
<td>1000</td>
<td>Titanium-Ti2</td>
</tr>
<tr>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td></td>
</tr>
</tbody>
</table>

*If other than SS316

**Residence time distribution (RTD)**

![RTD graph for AMaR-3 volumes 30, 50, and 200 ml]
AMaR-4, AMaR-4P (Patent filed): Production scale tubular flow reactor / mixer / heat exchanger

**Application**

Mixing of miscible liquids or immiscible liquids or gases creating dispersion of immiscible fluids or gases in liquids and carrying out very fast, exothermic & homogeneous reactions. The mass transfer will take place entirely depending upon the flow regime. This flow reactor has been fabricated and designed for various flow capacities for the industry. Standard as well as tailor made for each chemistry. AMaR-4P offers excellent mixing with no compromise on heat transfer rates. It can be used as a static mixer for homogeneous reaction for fluids of lower viscosity. It can also be used as heat exchanger.

**Design**

It consist of a sequence of coils made from pinched tube (AMaR-4P) or normal tubes (AMaR-4) of various sizes. This is a scalable and high throughput flow reactor. The heat transfer area is high and the numbering up approach has been used for conducting the reactions. The reactor gives better mixing with several sampling ports measurement locations and flexibility to operate in parts.

**Flow pattern AMaR-4**

<table>
<thead>
<tr>
<th>Technical specifications</th>
<th>Standard</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>100 ml, 200 ml, 500 ml, 1 ltr, 2 ltr, 5 ltr, 10 ltr</td>
<td>Customizable upto 150 ltr</td>
</tr>
<tr>
<td>Flow rates (ltr/hr)</td>
<td>0.6 to 600</td>
<td>upto 4000</td>
</tr>
<tr>
<td>Design pressure (bar)</td>
<td>100</td>
<td>upto 350</td>
</tr>
<tr>
<td>Design temperature (°C)</td>
<td>-50 to 250</td>
<td>350</td>
</tr>
<tr>
<td>Material of construction (MOC)</td>
<td>SS 316</td>
<td>Hastelloy C 276, Inconel, Monel, Titanium</td>
</tr>
<tr>
<td>Heat transfer area (m²/m³)</td>
<td>600 to 1850</td>
<td>----</td>
</tr>
<tr>
<td>Heating/ Cooling</td>
<td>Circulating thermic fluid through external MS</td>
<td>SS304 jacket</td>
</tr>
</tbody>
</table>

**Model no. for enquiry**

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Volume</th>
<th>Material*</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMaR-4</td>
<td>100 ml</td>
<td>Hastelloy C-HC6</td>
</tr>
<tr>
<td>AMaR-4P</td>
<td>200 ml</td>
<td>Inconel-INC</td>
</tr>
<tr>
<td></td>
<td>500 ml</td>
<td>Monel-MN4</td>
</tr>
<tr>
<td></td>
<td>1 ltr</td>
<td>Titanium-Ti2</td>
</tr>
<tr>
<td></td>
<td>5 ltr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 ltr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

*If other than SS316

**AMaR-4 with charging vessels, pumps & control panel**

**AMaR-4P 12 ltr. being used for neutralization 4 tonnes per day throughput**

**2 ltr AMaR-4P being used for acetylation at 100 lph**

CSIR-NCL will help you customize AMaR-4 reactors specific to your reaction needs

Design and IP of this reactor design and different variations are owned by CSIR-NCL, Pune
Residence time distribution (RTD)

Effect of angle between successive pinches on mixing in pinched tube flow reactor for a range of flow rates. Images are taken at the 5th pinch point from the inlet. (left column \( \theta = 30° \), (middle column) \( \theta = 45° \), (right column) \( \theta = 90° \).

AMaR-5: Mesh flow reactor

**Features**
- Suitable for miscible & immiscible liquid liquid reactions like aromatic liquid nitration, slurry reactions etc.
- It increases the mass transfer area significantly

**Technical specifications:**

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (ml)</td>
<td>100, 200, 500, 1000</td>
<td>100</td>
</tr>
<tr>
<td>Design Pressure (bar)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Design Temperature (°C)</td>
<td>-50 to 250</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>SS 316</td>
<td>Hastelloy C</td>
</tr>
<tr>
<td>End connections</td>
<td>2 inlets &amp; 1 outlet</td>
<td></td>
</tr>
<tr>
<td>Heating/Cooling</td>
<td>SS304 jacket</td>
<td></td>
</tr>
</tbody>
</table>

Amr in collaboration with NCL is in continuous process of improving the existing reactors, designing and developing new reactors for the benefit of process industry, hence all the specification are subject to change without prior notice.

**Model no. for enquiry**

<table>
<thead>
<tr>
<th>AMaR-5</th>
<th>Volume in ml</th>
<th>Material*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>Hastelloy C-HC6</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>500</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>*If other than SS316</td>
</tr>
</tbody>
</table>

**Industry applications**

The reactors like AMaR-4 are in successful operation in the industry for pilot and commercial scale production. Our clients have used them for producing fine and specialty chemicals involving immiscible phases for very exothermic reactions (-40 kJ/mol<\( \Delta H < -210 \) kJ/mol) followed by their continuous quenching, extraction and work-up to the tube of 200 kg/day to 1800 kg/day. The pinched tube reactors are also used for carrying out pilot scale reactions, L-L extraction, G-L absorption, etc. These systems can be given any form to fit in the available space. AMaR3 reactor has been successfully tested for G-L-S catalytic hydrogenation. The design of AMaR2 helps to reduce the axial dispersion significantly and also eliminates dead zones in the reactor. This has helped for successfully replicating the lab scale results at pilot scale with no deviation in selectivity. All of these are scalable designs and we encourage our clients to use more number of similar reactors rather than using less number of large volume reactors. With our existing capabilities of designing fixed bed reactors we can even connect these flow reactors with fixed bed systems to facilitate multistep synthesis at various scales.
Photochemical Flow Reactor - AMaR-PFR

Amar Equipments Pvt. Ltd. are the largest manufacturer of Metal Flow Reactors in India. With knowledge of more than 4 yrs in the field of Flow Chemistry and based on research and development of various reactions; we at Amar, have combined the advantages of continuous flow processing with the added benefits of ultraviolet light to enable photochemical reactions and a consistent distribution of UV light to ensure

- Higher productivity for photochemical reactions.
- Better performance.
- Homogenous absorption of light through the depth of the reaction channel.
- Higher yields.

One of the key issues of scaling-up organic photochemistry in an immersion-well (batch) reactor is that light penetration to the surrounding solution is limited by the high absorption of the substrate and falls off rapidly with distance from the lamp. Essentially the reaction solution nearest the lamp screens the bulk of the reaction solution from UV. This effect is also amplified if the reaction solution is concentrated. When the scale of the reaction is increased with the same lamp it becomes increasingly more difficult to drive the reaction to completion. Attempts to do so often result in over-irradiation of the product and formation of side products and photopolymers.

This is where flow photochemistry becomes a very attractive proposition, as in principle it can overcome all the key problems of batch photochemistry.

Features
- UV transparent Chemically inert tubes
- Reactor volume 12, 50, 200, 1000 & 2000 ml
- Flow rate upto 240 ltr/hr
- Pressure upto 35 bar & 175 °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

Static Mixer- AMaR-SM

Technical specifications

<table>
<thead>
<tr>
<th>Volume</th>
<th>Standard</th>
<th>Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume in ml</td>
<td>12 ml, 50 ml, 200 ml</td>
<td>----</td>
</tr>
<tr>
<td>Design pressure (bar)</td>
<td>100 bar for metal &amp; 20 bar for PTFE</td>
<td>upto 350</td>
</tr>
<tr>
<td>Design temperature (°C)</td>
<td>-50 to 250 for metal &amp; -50 to 150 for PTFE</td>
<td>-50 to 350</td>
</tr>
<tr>
<td>Material of construction (MOC)</td>
<td>SS 316</td>
<td>Hastelloy C</td>
</tr>
</tbody>
</table>

Application

- Photo chlorination
- Production of Vitamin D
- Photo alkylation
- Artemisinin production (anti malarial drug)
- Production of E-caprolactame

Model no. for enquiry

<table>
<thead>
<tr>
<th>AMaR-SM</th>
<th>Volume in ml</th>
<th>Material*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
<td>Hastelloy C-HC6</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>
| *If other than SS316

Application

- High viscosity mixing
- High-low viscosity mixing
- Gas mixing in turbulent regimes
- Dispersion of immiscible liquids
- Low viscosity material in short length
- Mix reacting material in short length
- Blending of aqueous solutions
- Mixing of miscible fluids
- Mixing of acids, juices, oils etc.
- Improvement in chemical reactions involving gases such as vinyl chloride, ethylene dichloride, maleic anhydride etc.
HPHT Multipurpose Flow Reactor-AMaR-MFR

Features
- Homogeneous and Heterogeneous reactions in same setup using interchangeable tubular attachments
- Pressures upto 350 bar
- Temperatures upto 500°C
- With gas flow controller & liquid metering pump
- Very compact, versatile & Economical

For Homogeneous Reactions
- PTFE, SS 316 or Hastelloy C helical tubular reactor from 1ml to 50 ml volume to fit in same furnace

Application
- Alkylation
- Heterocycle synthesis
- Supercritical reaction etc.

For Heterogeneous Reactions
- SS316 or Hastelloy C vertical catalyst holding tube from 0.5ml to 20 ml volume to fit in same furnace

Application
- Hydrogenation
- Oxidation
- Carboxylation etc
## Summary of AMaR range of micro / flow reactors & accessories

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Item</th>
<th>Volumes per plate/reactor</th>
<th>Flow rate range (ltr/hr)</th>
<th>Max. design pressure (bar)</th>
<th>Max. design temperature (°C)</th>
<th>Material of construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AMaR-1 Micromixer</td>
<td>1 ml</td>
<td>0.06 - 3.6</td>
<td>50</td>
<td>-50 to 250</td>
<td>SS316, Hastelloy C, Inconel, Monel, Titanium, PTFE, PEEK</td>
</tr>
<tr>
<td>2</td>
<td>AMaR-2 Micro-reactor</td>
<td>12 ml – 200 ml</td>
<td>0.72 – 24</td>
<td>20</td>
<td>-50 to 250</td>
<td>SS316, Hastelloy C, Inconel, Monel, Titanium, PTFE, PEEK</td>
</tr>
<tr>
<td>3</td>
<td>AMaR-3 (3D flow reactor)</td>
<td>1 ml - 5 ltr</td>
<td>0.06 - 360</td>
<td>350</td>
<td>-50 to 350</td>
<td>SS316, Hastelloy C, Inconel, Monel, Titanium, PTFE, PEEK</td>
</tr>
<tr>
<td>4</td>
<td>AMaR-4 /4P (Pinch Tube Flow Reactor)</td>
<td>100 ml – 150 ltr</td>
<td>6 - 4000</td>
<td>350</td>
<td>-50 to 350</td>
<td>SS316, Hastelloy C, Inconel, Monel, Titanium, PTFE, PEEK</td>
</tr>
<tr>
<td>5</td>
<td>AMaR-5 Mesh Reactors</td>
<td>100 ml - 1 ltr</td>
<td>6 - 360</td>
<td>100</td>
<td>-50 to 350</td>
<td>SS316, Hastelloy C</td>
</tr>
<tr>
<td>6</td>
<td>AMaR-PFR (Photochemical flow Reactor)</td>
<td>12 ml -200 ml</td>
<td>0.72 - 144</td>
<td>20</td>
<td>-50 to 150</td>
<td>UV transparent polymer tube</td>
</tr>
<tr>
<td>7</td>
<td>AMaR-SM (Static Mixer)</td>
<td>12 ml -200 ml</td>
<td>0.72 - 144</td>
<td>20</td>
<td>-50 to 250</td>
<td>SS316, Hastelloy C</td>
</tr>
<tr>
<td>8</td>
<td>AMaR-MFR (Multipurpose Tubular / Flow Reactor)</td>
<td>1 ml -50 ml</td>
<td>0.06 - 90</td>
<td>350</td>
<td>500</td>
<td>SS316, Hastelloy C, PTFE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Electrode – Fe, Cu, graphite, Ti, Ni, etc.</td>
</tr>
<tr>
<td>9</td>
<td>AMaR-EFR (Electrolysis Flow Reactor)</td>
<td>0.04 ml – 4 ml</td>
<td>0.002-14.4</td>
<td>20</td>
<td>200</td>
<td>SS316, Hastelloy C</td>
</tr>
<tr>
<td>10</td>
<td>AMaR – PDR (PDMS Flow Reactor)</td>
<td>0.01 ml – 4 ml</td>
<td>0.0006 - 14.4</td>
<td>20</td>
<td>60</td>
<td>PDMS</td>
</tr>
<tr>
<td>11</td>
<td>AMaR – LLS (Liquid liquid separator)</td>
<td>0.4ml – 30 ml</td>
<td>0.024-12</td>
<td>20</td>
<td>200</td>
<td>SS316, Hastelloy C, with PTFE membrane</td>
</tr>
<tr>
<td>12</td>
<td>AMaR-BPR (Back Pressure Regulator)</td>
<td>—</td>
<td>0 - 60</td>
<td>20</td>
<td>200</td>
<td>SS316, Hastelloy C, with PTFE membrane</td>
</tr>
<tr>
<td>13</td>
<td>LTF, Germany Mr. Lab</td>
<td>1 ml</td>
<td>0.06 - 3.6</td>
<td>5</td>
<td>200</td>
<td>Borosilicate / Quartz glass / Quartz glass</td>
</tr>
<tr>
<td></td>
<td>Mr. XXL</td>
<td>8 ml</td>
<td>0.48 - 50</td>
<td>15</td>
<td>200</td>
<td>Borosilicate / Quartz glass / Quartz glass</td>
</tr>
<tr>
<td>14</td>
<td>Fixed, Fluidized, Trickle Bed Reactor</td>
<td>5 ml – 50 ltr</td>
<td>Gas 0.6 - 6000</td>
<td>350</td>
<td>1000</td>
<td>SS316, Hastelloy C, Inconel</td>
</tr>
<tr>
<td>15</td>
<td>CSTR</td>
<td>25 ml -2000 ltr</td>
<td>0 – 2000</td>
<td>350</td>
<td>500</td>
<td>SS316, Hastelloy C, Inconel, Glass</td>
</tr>
</tbody>
</table>
Glass Micro Reactors from LTF-Germany

- Available in integrated multilayer glass construction for mixing, reaction & heat transfer
- Micro channel with modular system to connect multiple reactors in series or parallel
- Pressures up to 100 bar & temperatures up to 400°C
- Flow rates up to 30 LPH
- Up to 500 ml internal volume
- Channel size: 5 µm - 15 mm
- Suitable for various liquid-liquid, gas-liquid homogeneous & multi phase reactions
- Microreactors from glass, quartz, silicon and glass-silicon compounds
- Useful in photochemical & UV induced reactions

Flow Chemistry Starter Set

- Easy to use for professional education and laboratory synthesis
- Plug and play
- 4 Mr. Lab reactors
- 2 Single syringe pumps
- Frame work with tube and fittings
- Instruction for 13 reactions as below

Optional: XXL-S-02 reactor, continuous syringe pumps, heating cooling circulator

List of some of the MRT reactions done on LTF starter set

(The starter set has manual with details of how to carry all the reactions below)
- Iodine clock reaction (Landolts reaction)
- Hydrolysis of acetic acid chloride (acetyl chloride)
- Alkaline hydrolysis of 4-nitrophenyl acetate
- Esterification of 4-nitrophenol to 4-nitrophenyl acetate
- Hippuric acid from glycine and benzoyl
- Aldol condensation of acetone and benzaldehyde to dibenzalacetone (1, 5-diphenyl-1, 4-pentadiene-3-one)
- Condensation of 1,3-diphenyl-2-propanone with benzil to tetrabenzyliclohexadienone
- Addition of phenyl magnesium bromide to fluorenene
- Bromine addition to styrene to 1,2-dibromo-1-phenylethane
- Oxidation of 2, 2-dimethyl-1, 3-propanediol to 2, 2- dimethylmalonic acid
- Bromination of anisole to 4-bromotoluene
- Nitration of phenol to 2-nitrophenol and 4-nitrophenol
- Photodissociation of p-methoxybenzyl alcohol to p-methoxy benzaldehyde in a microreactor with riboflavin tetraacetate as a catalyst

Common reactors for common reactions

The series MR Lab was developed to integrate standard lab syntheses from batch process to continuous process using standard lab equipments such as temperature vessels, heaters or cooling agents.

The connecting via the front face saves the system space without creating any dead volume. The chip is connected via 1/4” UNF 28 fittings for 1/8” pipes.

A supporting frame is designed to simplify the dipping process of chips in vessel.

Mr. Lab

- Pressure tested @15 bar (218 psi)
- No dead volume
- Easy to use & space saving

Mr. Lab

- Easy to use flow chemistry starter set
- Plug and play
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A supporting frame is designed to simplify the dipping process of chips in vessel.
Mr. XXL

- From batch to continuous process
- Integrated layers for mixing / reaction / heat transfer
- Pressure tested @15 bar (218 psi)
- Connecting via 1/4" UNF 28 fittings and ¼" swagelok
- Easy to use & space saving
- Dimension: 150 mm * 150 mm * 14mm

**Heating cooling layer**
Design pressure: 6 bar
Flow rate of water by 6 bar: 3-4 l/min

**Mr. XXL ST 1**
- Inlet A1, A2 and A3
- Mixer of micromixer type ST
- Delay time extension channel with installed equipment type ST, volume 8 ml
- Product: P1

**Reaction stretch:**
Design pressure: 15 bar
Flow rate of water by 6 bar: 50 ml/min

**Mr. XXL ST 2**
- Delay time extension channel with mixing fixture, volume 8 ml
- Product: P1

**Reaction stretch:**
Design pressure: 15 bar
Flow rate of water by 6 bar: 50 ml/min

**Mr. XXL ST 4**
- Prewarm of A1 and A2
- Additional connectors (A3/P1, A4/P2), elective product outlet (measure outlet) or additional inlet.
- Delay time extension channel, volume: 5 ml
- Product: P3

**Reaction stretch:**
Design pressure: 15 bar
Flow rate of water by 6 bar: 70 ml/min

**Mr. Pilot**
- Microreactor/mixer from borosilicate glass
- Mixer + Residence time for mixture-intensive substances
- Dimension: 250 x 100 x 6.4 mm
- Volume: 1 ml to 16 ml
- Inclusive connection profile 1/4”-28 UNF

**Example of Applications**
The following reactions are done with ST type mixer or combination of ST type and jet mixer( emulsifier) if 2 phase reaction was carried out.

- Synthesis of semiconducting polymers for OLED applications
- Synthesis of azo dye via azo coupling
- Synthesis of hydroxymethylfurfural (HMF) and furandicarbonacid (FDCA) out of renewable resources
- Synthesis and work up of nitrate ester
- Catalyzed oxidation for synthesis of functional aldehyde
- Synthesis and conversion of diazomethane
- Photochlorination, bromination, alkylation etc.
Fixed Bed Tubular Catalytic Reactor System

Multi-phase reactor systems are widely used in fine chemicals, oil and gas, petrochemical refineries, pharmaceutical, pesticides and in research centers. With the evolving needs of the industry for enhanced productivity and lower cost of production; Amar offers these reactor systems in continuous manner for various applications with system integration and automation which maximizes the efficiency and accuracy of research and production operations.

Salient Features

- Reactor volumes from 5cc to 100 ltrs. Higher volumes optional.
- Designed up to 350 bar & 1000 °C. Higher ratings optional.
- Various MOCs such as SS316, Inconel, Hastelloy etc.
- Explosion proof plants for highly explosive reactions/hazardous area.
- Table top or skid mounted plants.
- Either a standard or customisable unit can be offered for gas liquid feed combinations, product outlets, series or parallel reactors, multi zone heating furnaces etc. with integrated controls, high level of safety, automation and SCADA software.
- Fixed, fluidized, trickle bed designs offered.

Applications & system

Catalyst testing, oxidation, reforming, hydrogenation, dehydrogenation, liquefaction, fischer Tropsch process, hydro-cracking, carboxylation, catalyst screening, fluid catalytic cracking (FCC), microreactor system, syngas reactor system, pyrolysis reactor system, packed bed reactor system, vapor rig system, biomass gasification system, hydroprocessing catalyst testing system, catalyst reduction unit, multi-purpose reactor unit, vapor phase reaction system etc.

2 reactors with flexibility to connect in parallel & series
Reactor volume: ~30 ml
Pressure: 100 Bar.
Temperature: 800 °C.
Materials: SS316 & inconel

10L capacity fixed bed catalytic reactor, used to manufacture MIBK (methyl-isobutyl ketone) on a pilot scale. 2 reactors can be connected in series or parallel. Design conditions: 25 bar & 200°C.
Hydrodesulfurization and some vapor phase reaction
Reactor volume: 10, 20 & 50 ml
Pressure: 100 bar
Temperature: 800 °C
Material: Inconel

Bench scale system for monolith reactions
Reactor volume: 40 ml
Pressure: 10 bar
Temperature: 1000 °C
Material: Quartz

Reactor volume: 50 ml
Pressure: 100 bar
Temperature: 600 °C
Material: SS316
Pilot Scale Tubular Reactor for Continuous Biojet Fuel production

Bio vegetable oil (V.O.) and diesel are used as feed materials. Hydro-treating process, isomerization process, followed by cracking reaction process is used to continuously produce Biojet Fuel.

Applications

• Reactor 1 & 2 Volume: 314 ml
• Design Pressure: 120 Bar
• Design Temperature: 500 °C
• Material: SS 316

System Specifications

• System consists of two numbers of catalytic tubular reactors operating in series
• Charging vessels, weighing balance, liquid pumps, gas flow controller, pre heaters, reactor with multi zone furnace, multi port stream selector valves, automated back pressure regulators, exhaust gas flow meter etc. are some of the accessories fitted with the system
• N2 purge panels have been provided for Feeding section, intermediate product section and for final product section to make system explosion proof
• Fully automated PLC based control with remote monitoring and SCADA software
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.

**Description**
- System consists of six numbers of catalytic tubular reactors operating in parallel. With individual gas MFC and mixed gas stream MFC, automatic back pressure regulator and optional liquid feed pump
- Oven to heat the outlet lines of all the reactor tubes to avoid condensation
- Electrically actuated stream selector valve to send the selected stream to 2 position valve which will be used to send fixed quantity of sample to Gas Chromatograph
- Highly sophisticated and fully automated PLC /DCS with SCADA software with suitable safety alarms, interlocks & temperature safety switch (TSS)
### Table Top Reactor System (TTRS)

The table top reactor system is very compact & complete semi or fully automated system for vapor phase catalyst evaluation and continuous flow process analysis. The reactor and feed lines are mounted within an isothermal oven.

#### System Specifications:
- Reactor volume: 5-50 ml
- System pressure: Upto 200 bar
- Temperature rating (reactor): Upto 650 °C
- Temperature rating (oven): Upto 200 °C

#### Description:

**Feeding section:**
- Feed streams are provided for 4 reactants (2 liquids, 2 gases), the purge gas and the GC carrier gas.
- Feed lines includes bulk head union connectors, inline filters, metering valve, 3-way ball valve and check valve.

**Reactor section inside oven:**
- **Preheater & vaporizer:** This section includes 2 coils for preheating gases and 2 coils for vaporizing liquids.
- **Reactor:** volume available from 5 – 50 ml.
- **Reactor status valve:** The optional multiport reactor status valve can permit reactor bypass.
- **Sample valve:** Sampling valve can be provided for transfer of sample of product to GC unit.
- **Back pressure regulator:** Manually operated (standard) with optional automatic control.

**Product collection section:**
- **Gas liquid separator:** Volumes upto 250 ml will be placed after reactor and before back pressure regulator.
- **Heated transfer line:** It connects the sample valve to the gas chromatograph unit (supplied by client).

#### Malshe's Interchangeable Vapor Phase Reactor

(Patent pending)
- Gas recycling through stationary or rotating catalyst basket
- Reactor volumes 100 ml - 100 ltr
- Multiphase reactor
- Material: 316, Hastelloy, etc.
- Pressures upto 200 bar & temperature upto 500°C
- Upto 3000 RPM
- Supplied with condenser, gas liquid separator & optionally liquid metering pump & gas flow controller
- The same reactor setup can be used for liquid phase & vapour phase reaction with minimum changes of internal components giving it a great flexibility & cost economy.
CSTR - Continuous Stirred Tank Reactor System

**Salient Features**

- Product is developed / produced on continuous basis for better productivity
- Stirred tank reactors of 25 ml to 2000 ltr net filling volume
- Available in different materials like SS-316 / 316L, Hastelloy C, Monel, Inconel, Nickel, Titanium, Tantalum, Zirconium etc.
- Pressures upto 350 bar & temperatures upto 500°C
- Single or multiple reactors connected in series
- Multiple inlets & outlets for addition & transfer / removal of gases & liquids
- Ex-proof / CE / PED / ASME / U stamp certified system on request
- 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

High pressure CSTR for hydrogenation

CSTR for hydro-cracking of heavy hydrocarbon oils
Optional Accessories

Optional accessories are offered to increase the versatility of the equipment, to add value & feature to the standard product & to provide complete range of instrument/equipment required for a particular application. Most of the optional accessories are common for all flow reactors unless specified. The standard optional accessories can be enquired by simply mentioning their code & required specifications.

Complete mounting of all the accessories shall be done on reactor skid.
All the indicators/controllers are mounted on a common SS panel.

Gas Pressure Regulator (FPR)
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 Teflon PTFE high pressure hose pipe (4m long) with non return valve.

**Optional:**
1) Regulators upto 350 bar, automated regulator
2) Regulator for other gases like NH₃, CO₂ etc. & MOC of Hastelloy C

Gas Booster (GB)
Gas boosters are useful when the cylinder pressures are much lower than the reactor rated pressures. In such case the booster takes gas at lower pressure from cylinder & compresses the same to deliver at higher pressures. They are generally pneumatically operated. The booster systems are supplied with air filter regulator, pressure relief valves, inlet-outlet pressure gauges, valves & flexible hose pipe.

**Optional:**
• Boosters upto 700 bar pressure

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. User has to specify the maximum flow rate range, pressure & gas for ordering MFM/MFC.

**Optional:**
1) Ex-proof MFM / MFC can be offered on request.
2) MFM/MFC upto 300 bar pressure

Coriolis Gas - Liquid Mass Flow Meter/Controller (CFM/CFC)
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.

**Optional:**
• Ex-proof CFM/CFC can be offered on request

Digital Pressure Indicator (DPI)
It consists of SS316 pressure sensor (transmitter) & digital pressure indicator/ controller (mounted on common control panel) with pressure alarm & optionally heater cut off for safety. Digital pressure indicator has pressure reading in bar & psi, where as controller reads any one of the units. The pressure sensor has temperature limitation upto 100°C & hence the same is provided with water cooling jacket.

**Optional:**
1) Intrinsically safe pressure sensor.
2) Pressure sensors with Hastelloy C / Inconel wetted parts can be offered on request.
Optional Accessories

Liquid Metering Pump System (LMP)
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. The system comes with a metering pump, flow indicator, controller, liquid sump, pressure gauge, strainer & high pressure hose.
Pressure safety valve, flow totalizer can be offered on request. Types of pumps offered are:

a) 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, PTFE

b) High pressure more accurate HPLC type low flow metering pumps for high pressures upto 350 bar & flow range from 0.01 upto 100ml/min.
These pumps can be used along with precision weighing scales to measure the total liquid charged at any point of time. Materials: SS316, option: Hastelloy C, Titanium

c) High pressure syringe, PTFE diaphragm, gear, peristaltic pumps can be offered for pumping corrosive chemicals at low / high pressures for specific application & flow rate condition.
In line flow meters can be connected to measure & control the flow of the liquids.

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

Open Bath Heating Circulator (HB)
It is used to heat jacketed reactor from ambient to 150°C by circulating thermic fluid inside the jacket. It consist of bath, pump, level switch, heater & internal cooling coil for cooling from high temperature to ambient temperature using chilled water or brine solution.
It is suitable for reactors up to 5 liter volume
Optional: Ex-proof heating bath

Closed Loop Heating Circulator (CLH)
It is used to heat jacketed reactor from ambient to 350°C by circulating thermic fluid. It consist of a closed pressure withstandng tank, magnetically coupled pump, heater, level indicator & internal cooling coil for cooling from high temperature to ambient temperature using chilled water or brine solution.
Suitable for reactors up to 100 ltr volume
Optional: Ex-proof circulator

Low temperature open bath circulator (CB)
It is used to cool or control reactor temperature to -50°C by circulating thermic fluid cooled to up to -75°C inside the jacket or internal coil. It consists of a bath, pump, compressor, condenser & level switch.
Suitable for reactors up to 100 ltr volume

Heating Cooling open bath circulator (HCB)
It is used to heat, cool & control reactor temperature by circulating thermic fluid in the autoclave jacket. It consists of a bath, pump, heater, compressor, condenser & level switch.
Temperature range: -25°C to 175°C.
Suitable for reactors up to 5 ltr volume

Closed loop heating cooling circulator (CLS)
It is used to heat, cool & control reactor temperature by circulating thermic fluid in the autoclave jacket. It consists of a bath, pump, heater, compressor, condenser & level switch.
Temperature range: -35°C to 200°C / -80°C to 180°C.
Suitable for reactors up to 1000 ltr volume.

Flow Control Valves (FOV / FCV)
These valves can be connected at jacket inlet for controlling flow of steam/ hot oil/ water for temperature control from PID or at the inlet or outlet of the autoclaves for control of pressure.
Two options are available:
• (FOV) On/off pneumatic ball valve actuated by 230V output from panel to solenoid valve inline of air supply
• (FCV) Pneumatic proportionate flow control valves with I to P convertor (for accurate temperature / pressure control).
Optional Accessories

Condenser (CN)
It is a SS-316 tube in tube out, helical coil in a vessel rated for 100 bar & 500°C for condensing the vent vapours from the system. It can be offered in different materials, higher pressure & different surface areas. The condensate can be collected separately in a receiver.

Optional: 
1. Pressures upto 350 bar
2. Different materials
3. Corrugated tubes heat exchangers for better efficiency / compact size.

Gas Liquid Separator (GLS)
It is SS-316 pot connected at the outlet of the condenser to separate gas & liquid. It is offered in different volumes & materials on request. It can be optionally provided with level indication & control.

Receiver Pot (RP)
SS-316 receiver pot can be connected at the outlet of the gas liquid separator to collect the condensate separately. It is also provided with a port to apply vacuum & offered in 250 ml, 500 ml, 1 ltr, 2 ltr & 5 ltr volumes. Higher volumes & other materials can be offered on special request. It can be optionally provided with level indication.

Back Pressure Regulator (BPR)
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 or through a hose to safe area. The pressure can be set initially on the gauge, by manually varying the knob until the gas comes out. Once the set pressure is exceeded the excess pressure is released until the reactor pressure becomes equal to or below the set pressure. The pressure release is slow & gradual & the set pressure can be varied at any point.

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

Pressure Safety Valve (PSV) & Safety Rupture Disc (RD)
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 (SCD)
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.

Optional: Wireless data communication from PC to panel or mobile alerts can be supplied on request.

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

**Level Control**
Level sensor mounted on GLS or receiver pot for continuous sampling with minimum pressure drop

**Liquid-Liquid Separator**
This unit is used to separate slug flow of two immiscible liquids used in biphasic reaction or two phases of an extraction flow. MOC: ETFE, PFA and PTFE, pressure 300 psi.

**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

**Sample / Status / Stream Selector Valve**
These valves have unique variety of connecting slots and ports arrangements. It allows multiple planes of ports, facilitating unique multiposition configurations useful for stream selection, column selection or trapping. Can be configured for use at temperatures up to 350°C or pressures up to 10,000 psi.

**Oven / Furnace**
This can be used for various applications commonly where condensation is major issue during process. The complete assembly can be placed inside oven to avoid condensation or to maintain particular temperature throughout the process. Temperature rating: 200°C for oven & 500°C for furnace.

**In Situ FTIR Spectroscopy (IR)**
In situ high temperature, high pressure infrared (IR) probe is offered for real time chemical reaction monitoring. It provides specific information about reaction initiation, conversion, intermediates & end point. Suitable for 1 ltr to 100 ltr reactors upto 100 bar & 200°C.

**Control Panel**
Compact SS-304 (for corrosion resistance & longer life) control panel with microprocessor based accurate 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. Heater, cooling/ solenoid valve/ pump/ sensors etc. utilities are connected to panel by simple plug & socket arrangement. The panel is very easy to open & all internal components are plug socket type, making replacement easy. Digital pressure indicator/ controller, flow indicator, flow totaliser, heater temperature cascade controller, level, pH etc. indicators are provided additionally on same common control panel depending on the optional accessories selected.

**Optional:**
a) Digital temperature indicator in flameproof enclosure mounted on trolley & non FLP SS panel mounted remotely in safe area.
b) Complete ex-proof - flame proof (FLP) Group IIa/IIb or IIC, ATEX zone 1, class 1 div. 2 certified control panels mounted on trolley
   **Note:** FLP panels should be opted only if the heater & motors are FLP and area is totally ex-proof as FLP panels are too bulky & inconvenient for operation & maintenance.
c) Touch screen panel with SCADA software for single or multiple autoclaves.
d) PLC based control panel with touch panel HMI or remote SCADA software & PC control.
e) Panels with Rs 485 port for remote PC communication through SCADA software with local display.
f) CE, UL / CSA marked control panels can be supplied on request.