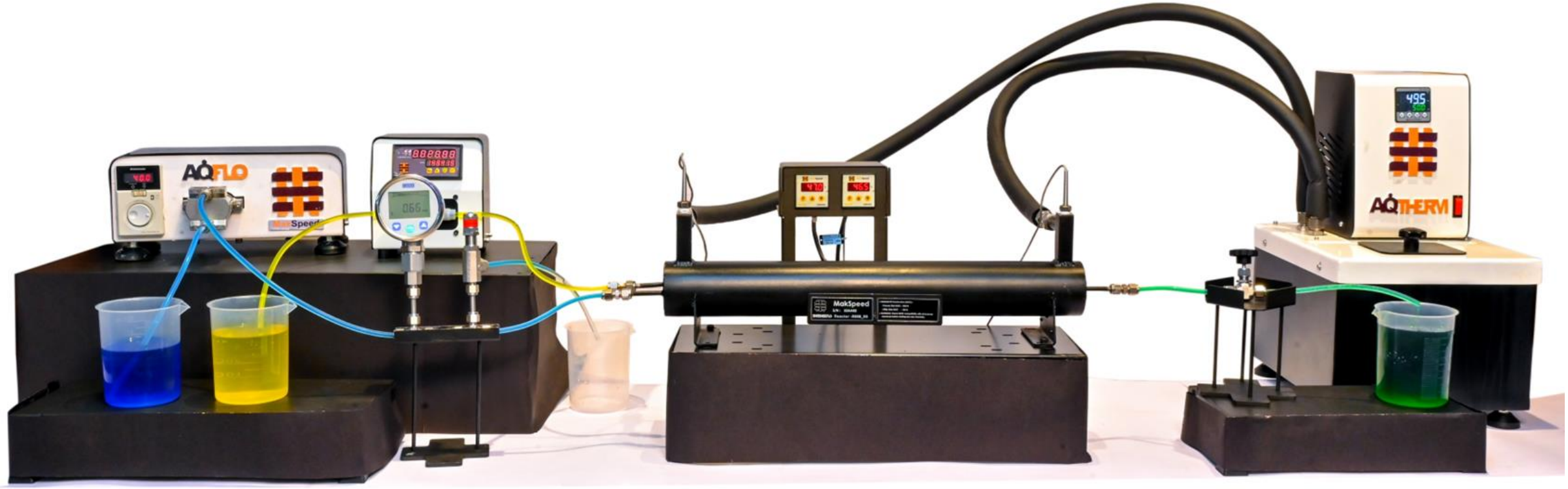
MakSpeed

Flow Chemistry
Advanced Solutions for Net Zero Pathways

ChemPharma Summit, 21st June 2024

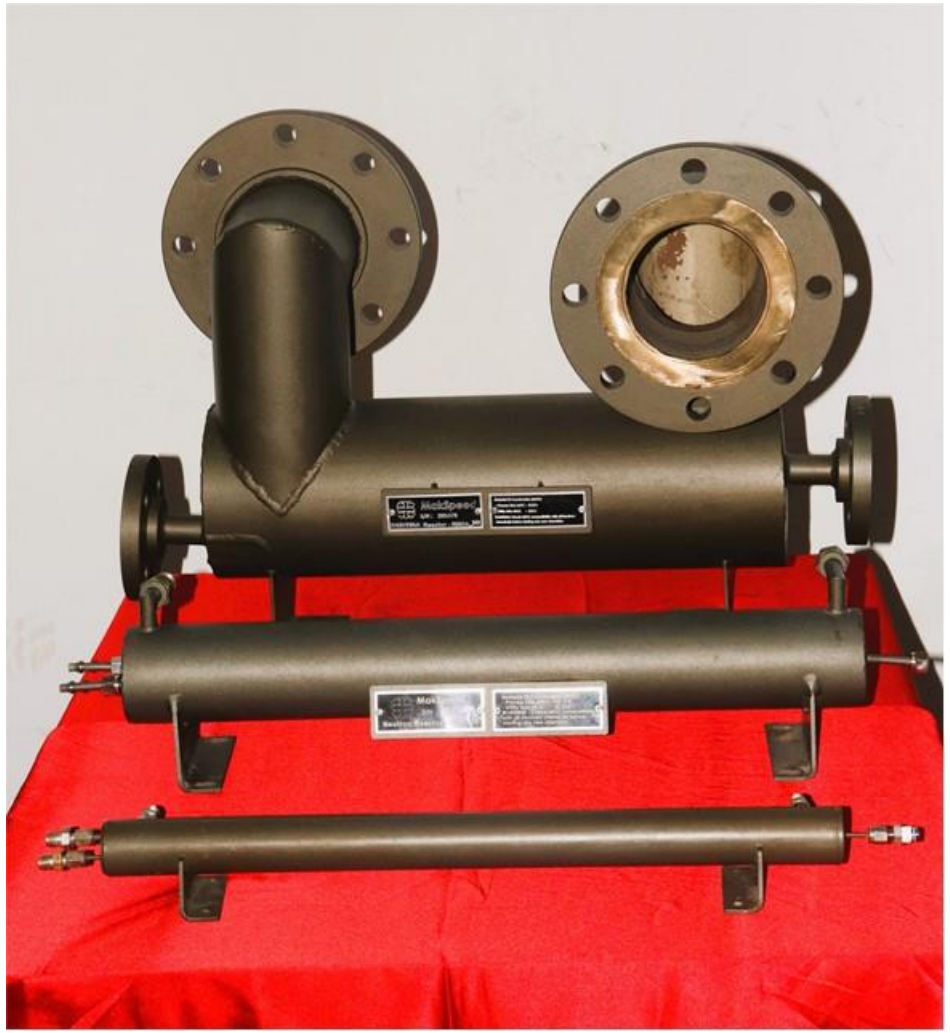
Simple definition of flow Chemistry

- Reactants are continuously pumped thorough a reactor which provides Residence time, Mixing, and Correct (Isothermal) Temperature such that desired product is received in the outlet.



Inherent Capabilities of Flow Chemistry System

- Enhanced Mixing and Heat Transfer capabilities : Process Intensification
- Same level of performance at Lab, Pilot and Production Scale : Seamless scalable solution
- Operated in Continuous Mode



Advantages of Flow Chemistry

- Due to design aspects
  - Process Intensification (Improved Mass & Heat Transfer)
  - Scalable Solution
  - Multipurpose solution
- Due to Operation aspects
  - Steady state continuous operation
  - QbD

➢ Material efficiency – Waste reduction

➢ Energy efficiency

Application of Flow Chemistry

- Converting Existing Batch Process to Continuous
- Development of New processes as ‘Continuous’

➢ Current Focus of Industry is ‘Batch to Continuous’

Conceptual Methodology to Convert Batch to Continuous

Step1: Evaluation of batch process to assess potential of process to convert from batch to continuous

Step 2: POC study using Lab scale 10 ml reactor

Step3: Optimization using Pilot scale 100 ml reactor

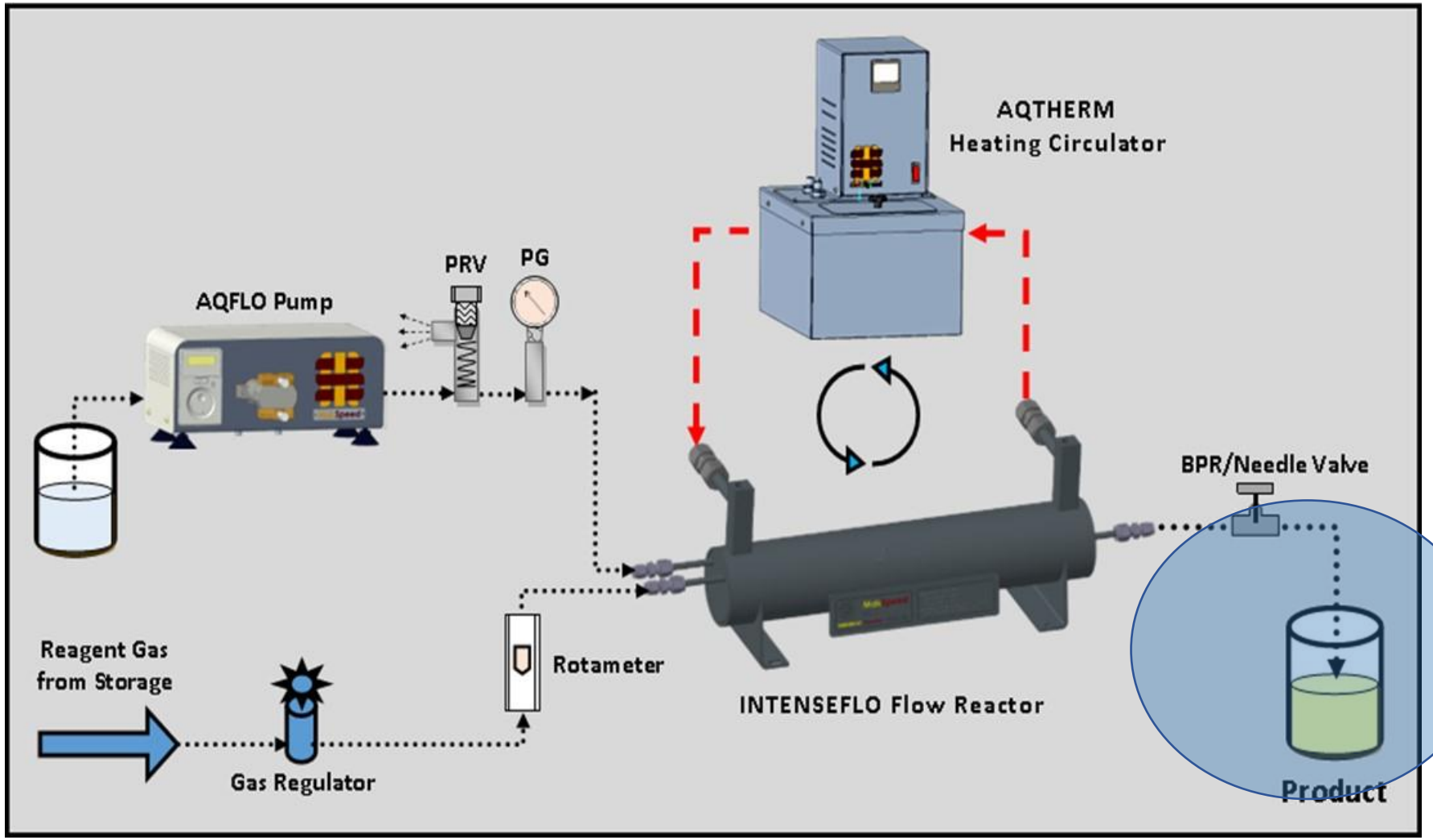
Step4: Production reactor to be designed based results of optimization

Case Study: Semi-Batch Chlorination

- Typical 2 to 3 kL GL reactor
- Initial addition of SM and solvent
- Cool it to -5 to -10 degC
- Start adding chlorine slowly to ensure temperature remains in limits
- Wait for couple of hours after addition is complete
- Follow up with separation steps

Batch Reactor

Set-up for Continuous Chlorination



With safe Gas disposal system!!

Chlorination: Comparison of Batch and Flow

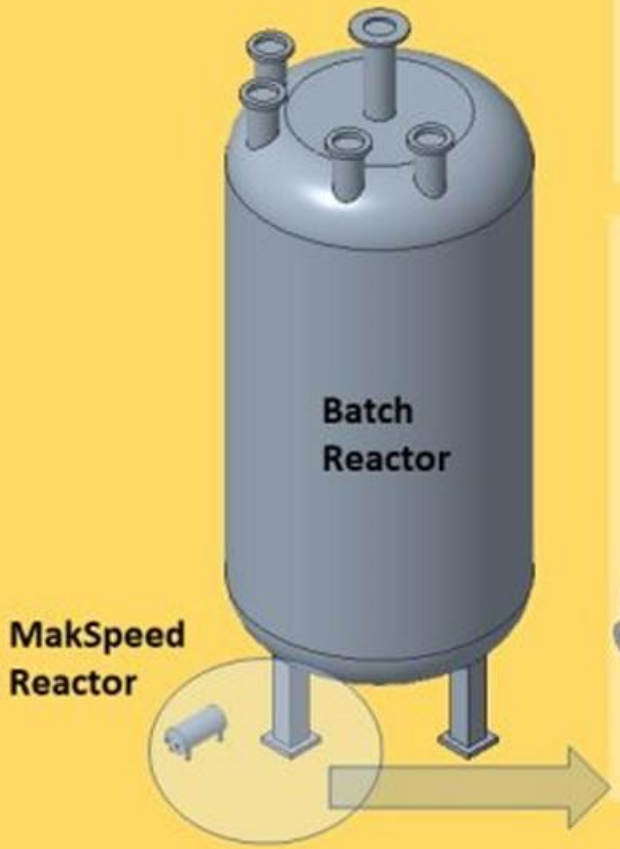
Details	Conventional Process	Continuous Process
Operation	Semi-Batch	Continuous
Temperature	-20 °C to -10 °C	Ambient (30 °C)
Solvent	80%	40%
Conversion	90%	99%
By-product	10-12%	9-11%
Residence time	16 hrs	~1 min

Batch Vs Continuous: Decreased Foot Print/ Increased Safety

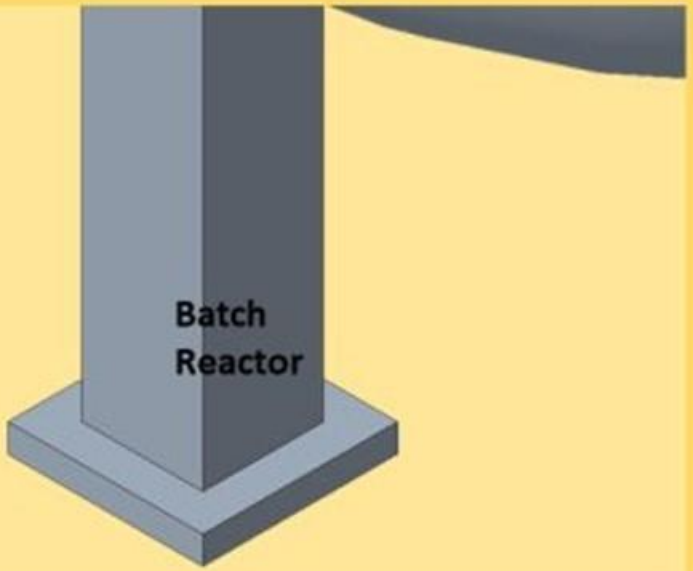
Size Comparison of Batch vs MakSpeed Flow Reactor for same production

Batch Volume	3 KL
Solvent	80%
Reaction time	16 hrs
Per day throughput	800 kg

Flow Reactor Volume	1.5 L
Residence time	1 min
Solvent used	40%
Operation per day	16 hr
Product throughput	864 Kg



Enlarged View



Lab Set- for Continuous Nitration Process Development

Nitration: Process Optimization

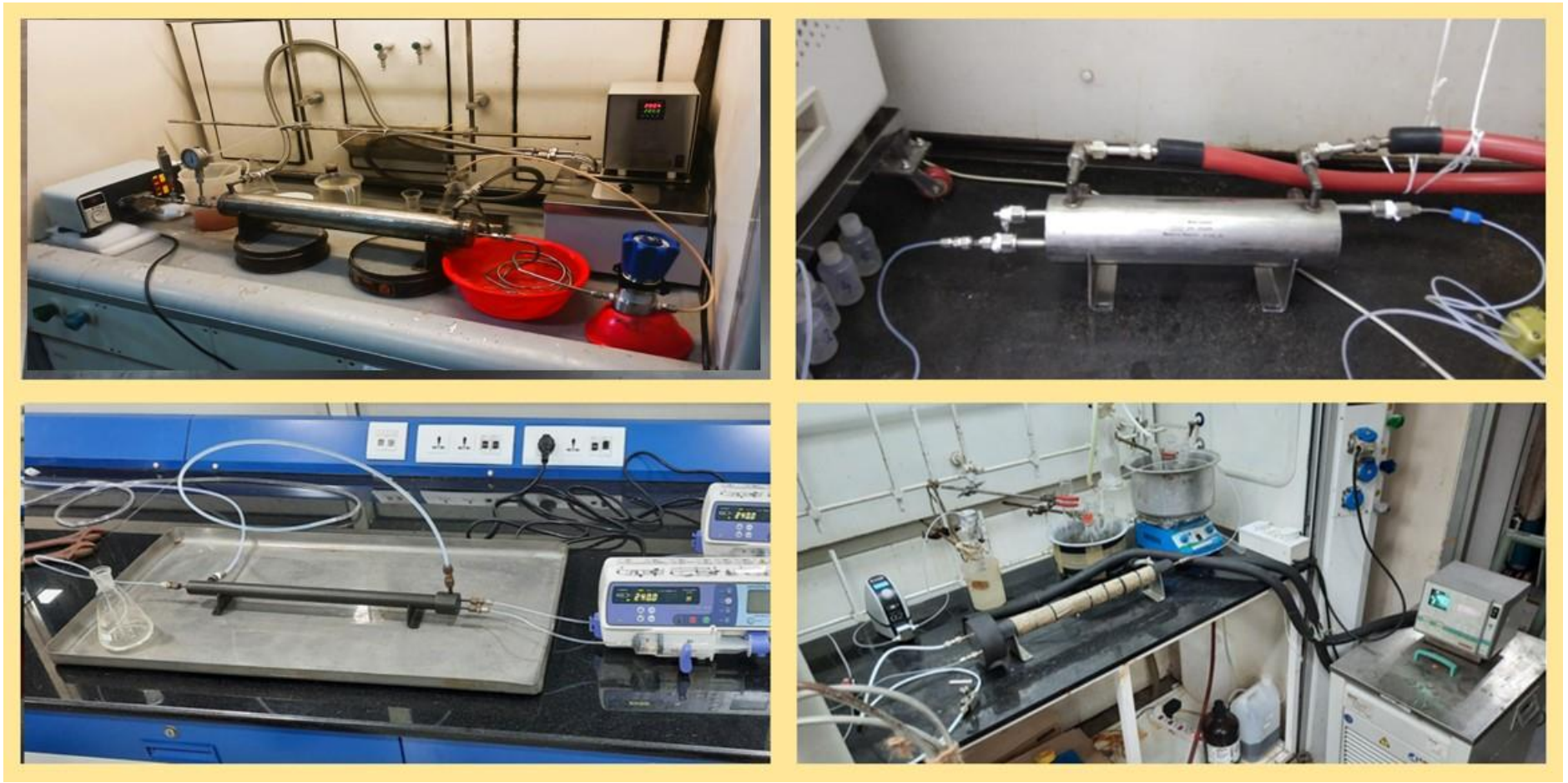
Feed-A (ml/min)	Feed-B (ml/min)	Residence Time (sec)	Temperature (°C)	Molar Ratio	Product (%)	Impurity (%)	
31	29	10	Low	High	High	Low	Impact of Residence Time
10.3	9.7	30	Low	High	Low	Low	
37.6	22.4	10	Medium	Low	Low	Low	Impact of Mole Ratio at Medium Temperature
34	26	10	Medium	Medium	High	Low	
31	29		Medium	High	High	Low	
37.6	22.4	10	High	Low	High	High	Impact of Mole Ratio at High Temperature
34	26	10	High	Medium	High	Medium	
31	29	10	High	High	High	Medium	
68	52	5	Medium	Medium	High	Low	Impact of Residence Time
45.3	34.7	7.5	Medium	Medium	High	Low	
118.9	81.1	3	Low++	Medium ++	High	Low	First Pass Optimum
71.4	48.6	5	Low++	Medium ++	High	Low	
35.7	24.3	10	Low++	Medium ++	High	Low	

Production Reactors: 500 ml to 50 Litres

Throughput capacity up to 5 tons/day

Applications of Flow Chemistry by MakSpeed

- We have successfully performed **Chlorination** (using Chlorine Gas), **Nitration** (using Concentrated HNO3+ H2SO4), **Epoxidation/oxidation** (using H2O2), **Isomerization** and **Esterification** chemistries.. And may more..



Thank You!

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