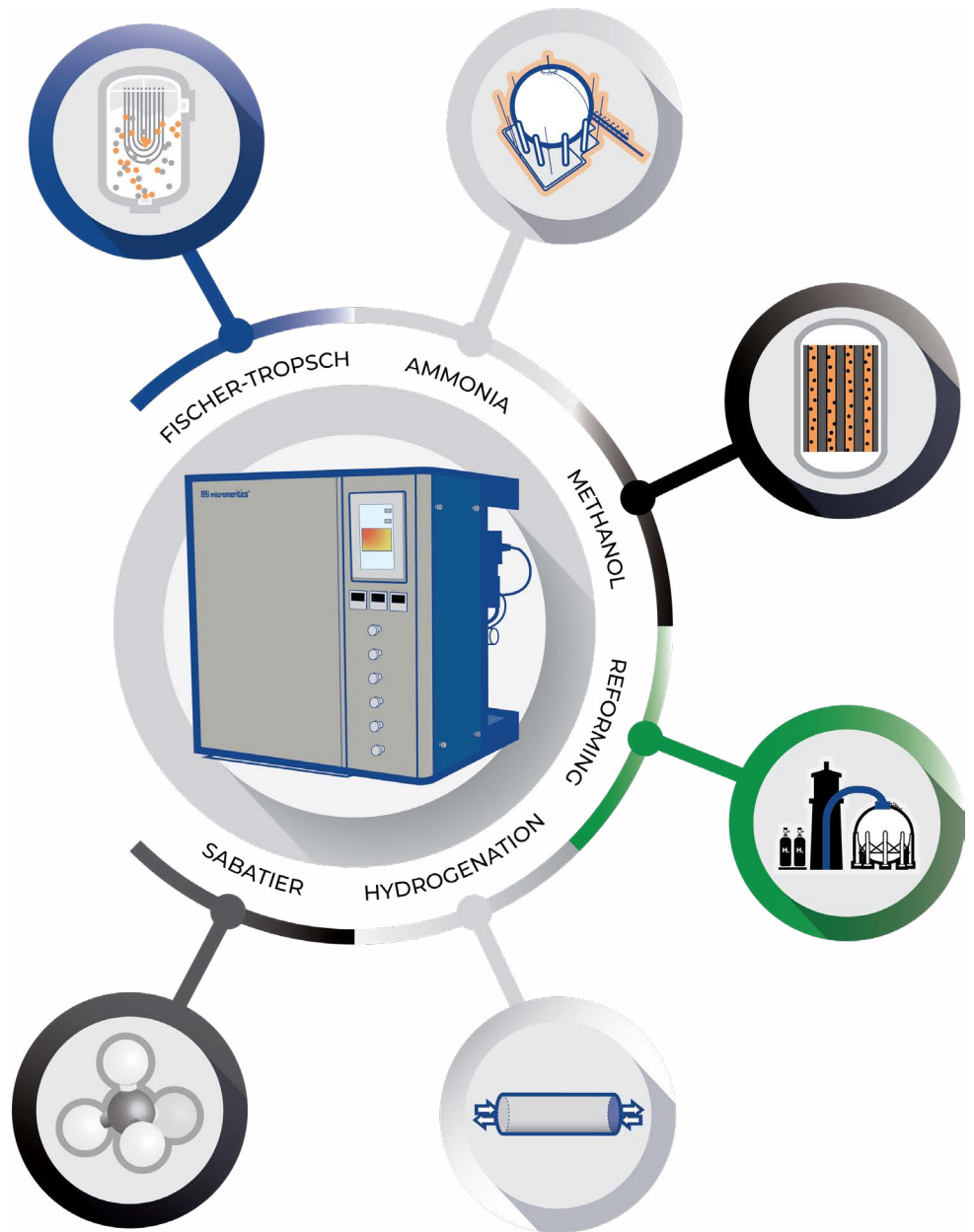


# FLOW REACTOR DESIGNS

SOLUTIONS FOR MAJOR INDUSTRIAL PROCESSES

[micromeritics.com/FR](http://micromeritics.com/FR)





# FISCHER-TROPSCH

CONTINUOUS FLOW REACTOR CONFIGURATION

## Standard Configuration

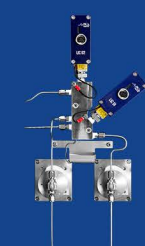
- **L/L/G Separator** to divide the organic and aqueous phases for continuous product analysis.
- **Wax Trap** at reactor outlet to prevent plugging.
- **Heated Lines & Chamber** for stable and reproducible reaction conditions.



Flow Reactor System

## Recommended Options

- **Integrated Liquid & Gas Outlet Measurements** to determine mass balance and reaction yield.
- **Autosampler** to study the liquid product at user-defined intervals.
- **Automated Bypass Valve** allows complete product stream to be analyzed.
- **Analyzer Software Integration** to optimize the kinetics, selectivity, and yield.
- **Independent dual reactor model (FR 200)** available to double throughput.



L/L/G Separator



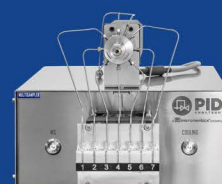
Wax Trap



Heated Lines & Chamber



Integrated Liquid / Gas Outlet Measurements



Autosampler



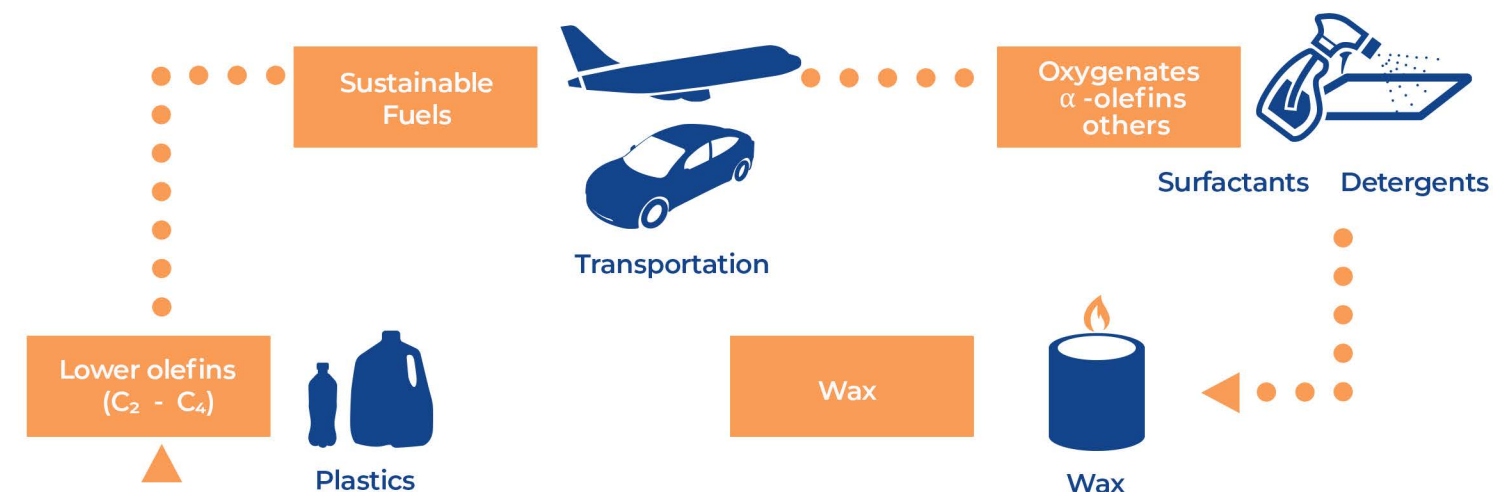
Automated Bypass Valve



Analyzer Software Integration

## FISCHER-TROPSCH SYNTHESIS

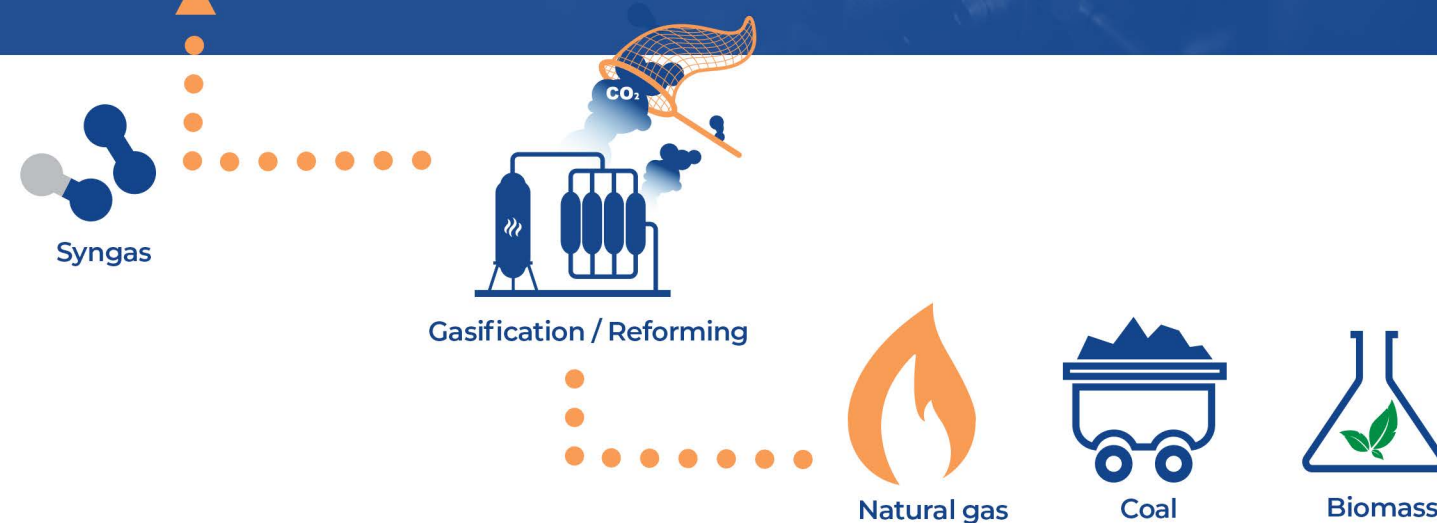
Liquid Hydrocarbons & Wax



Liquid fuels and other chemical products can be produced from syngas via the well-known and catalytic chemical process called **Fischer-Tropsch (FT)** synthesis.



FISCHER-TROPSCH SYNTHESIS







# AMMONIA SYNTHESIS/DECOMPOSITION

FLEXIBLE REACTOR PLATFORM

## Standard Configuration

- **Gas Inlets** for N<sub>2</sub>, H<sub>2</sub>, and inert gas standard.
- **High-Resolution Pressure Control** with patented valve up to 100 (+/- 0.1) bar.
- **Heated Lines & Chamber** to avoid condensation of ammonia.
- **Analyzer Software Integration** to optimize the kinetics, selectivity, and yield.



Flow Reactor (FR-100)

## Recommended Options

- **Safety Gas Sensors** to detect H<sub>2</sub> and NH<sub>3</sub> leaks integrated with safety system.
- **High Pressure Dosing System** to feed liquefied NH<sub>3</sub> gas to study its decomposition to produce H<sub>2</sub>.
- **Materials of Construction** are available to match demanding operating conditions.



Gas Inlets



High-Resolution Pressure Control



High Pressure Dosing System



Heated Lines & Chamber



Analyzer Software Integration



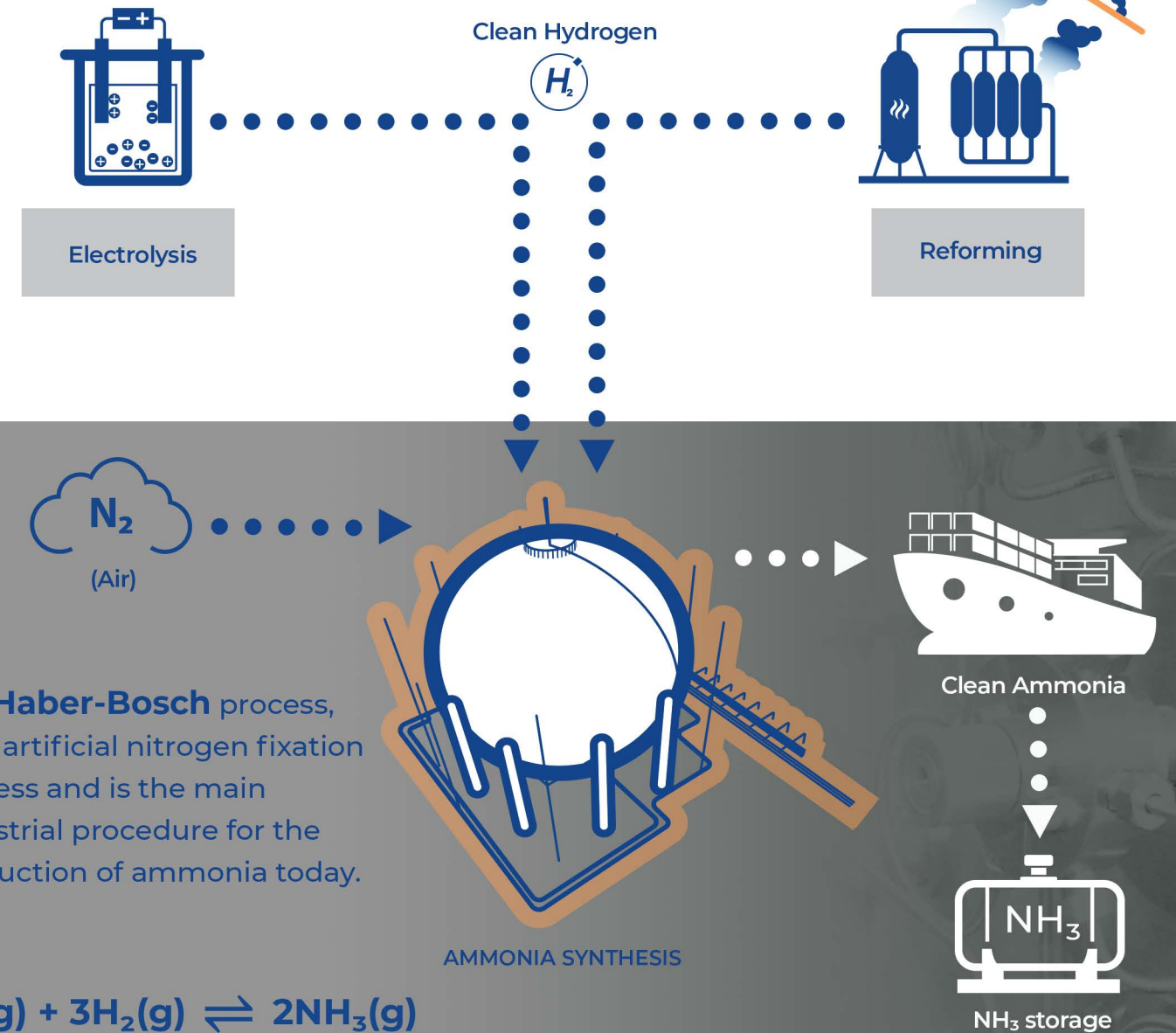
Safety Gas Sensors



Materials of Construction for the Reactor

## AMMONIA

Synthesis / Decomposition



Fertilizer



Marine Fuel



Chemical Precursor



Ammonia Decomposition



Hydrogen



Fuel Cells and other applications



# METHANOL SYNTHESIS (AND HIGHER ALCOHOLS)

ADAPTABLE FLOW REACTOR DESIGNS

## Standard Configuration

- **Gas Inlets** for reactants (CO, CO<sub>2</sub>, & H<sub>2</sub>) and inert gas standard.
- **Patented L/G Separator** with low dead volume for accurate catalyst activity and reaction kinetics studies.
- **High-Resolution Pressure Control** up to 100 (+/- 0.1) bar.



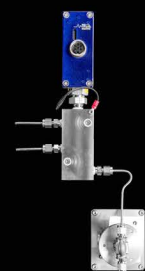
Flow Reactor (FR-100) Interior

## Recommended Options

- **Wax Trap** mandatory for higher alcohol synthesis or when high MW compounds are expected.
- **Safety Gas Sensors** to detect H<sub>2</sub> leaks integrated with safety system.
- **Coriolis Mass Flow Controller** for CO<sub>2</sub> feed between 30-50 bar or **High-Pressure** option for CO<sub>2</sub> dosing up to 200 bar.
- **Materials of Construction** are available to match demanding operating conditions.
- **Integrated Liquid Outlet Measurements** to determine mass balance and yield.



Gas Inlets



L/G Separator



High-Resolution Pressure Control



Wax Trap



Safety Gas Sensors



Coriolis Mass Flow Controller



Materials of Construction for the Reactor



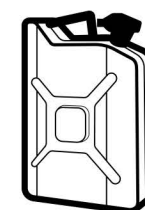
Integrated Liquid Outlet Measurements

## METHANOL SYNTHESIS

And Higher Alcohols



Marine Fuel



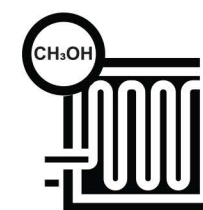
BioDiesel



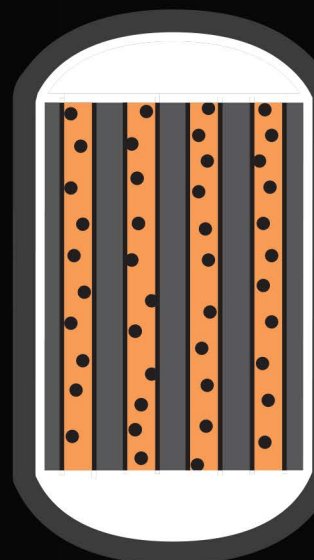
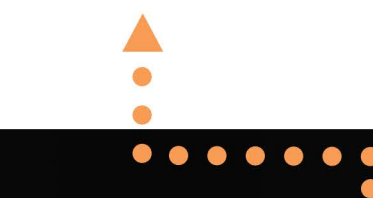
Plastics



Pharmaceutical Products



Fuel Cells



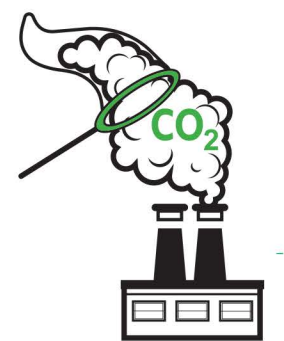
CO<sub>2</sub>  
Carbon Dioxide

H<sub>2</sub>

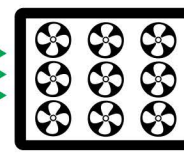
Clean Hydrogen

METHANOL SYNTHESIS

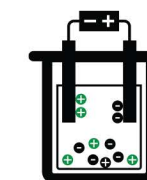
One route to produce methanol is characterized by the addition of carbon dioxide to hydrogen.



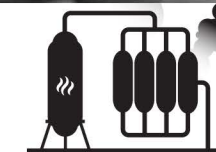
Industrial Carbon Capture



Direct Air Capture



Green Electrolysis



Steam Reforming



Biomass





# STEAM / DRY REFORMING

CONTINUOUS FLOW REACTOR CAPABILITIES

## Standard Configuration

- **Gas Inlets** for reactants (CH<sub>4</sub> & CO) and inert gas standard.
- **Patented L/G Separator** with low dead volume for accurate catalyst activity and reaction kinetics studies.
- **Liquid HPLC Pump** with integrated mass flow meter for precise, stable feed control of water plus a **Liquid Evaporator** to generate steam.
- **Materials of Construction** are available to match demanding operating conditions.



Flow Reactor (FR-200) Interior

## Recommended Options

- **Safety Gas Sensors** to detect H<sub>2</sub> and CO leaks integrated with safety system.
- **Additional Gas Inlets** for CO<sub>2</sub> for dry reforming, air/O<sub>2</sub> for catalyst regeneration, or H<sub>2</sub>.
- **Integrated Gas Outlet Measurements** to determine mass balance and reaction yield.



Integrated Liquid / Gas Outlet Measurements



L/G Separator



Liquid HPLC Pump



Liquid Evaporator



Materials of Construction for the Reactor



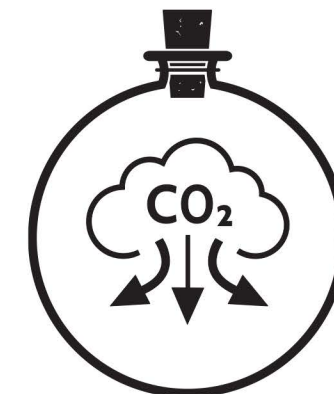
Safety Gas Sensors

## REFORMING

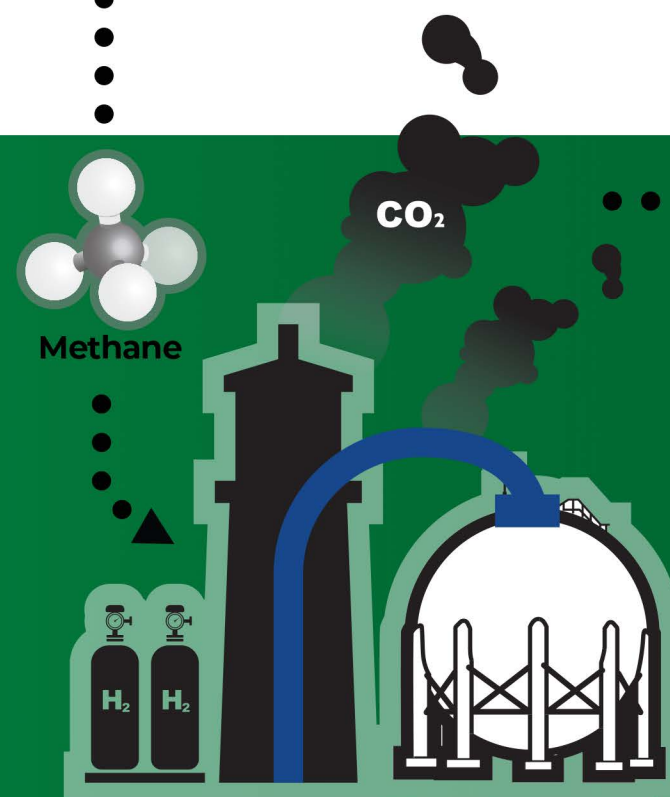
Steam & Dry



Natural Gas



CO<sub>2</sub> Capture



H<sub>2</sub> PRODUCTION

Steam methane reforming (SMR) is a process in which natural gas is heated with steam to produce a mixture of carbon monoxide and hydrogen used in organic synthesis.



Clean Hydrogen



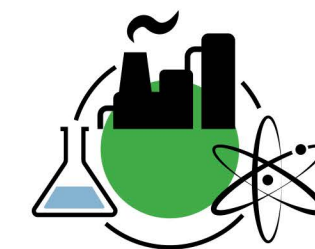
Fuel Cell Electric Vehicle



Sustainable Aviation Fuels



Ammonia / Fertilizer



Chemical Processes



# SABATIER PROCESS

FLOW REACTOR MODULAR CAPABILITIES



## Standard Configuration

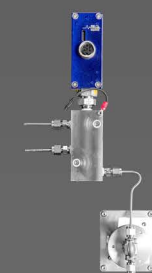
- **Patented L/G Separator** for the efficient separation and recovery of liquid streams (H<sub>2</sub>O).
- **Gas Inlets** for reactants (CO<sub>2</sub> & H<sub>2</sub>) and inert gas standard.
- **High-Resolution Pressure Control** up to 100 (+/- 0.1) bar.



Flow Reactor System

## Recommended Options

- **Safety Gas Sensors** inside the thermostatic chamber to detect H<sub>2</sub> leaks are integrated with safety system.
- **Materials of Construction** are available such as, a Quartz Reactor for ambient pressure and high temperature studies.



L/G Separator



Gas Inlets



High-Resolution Pressure Control



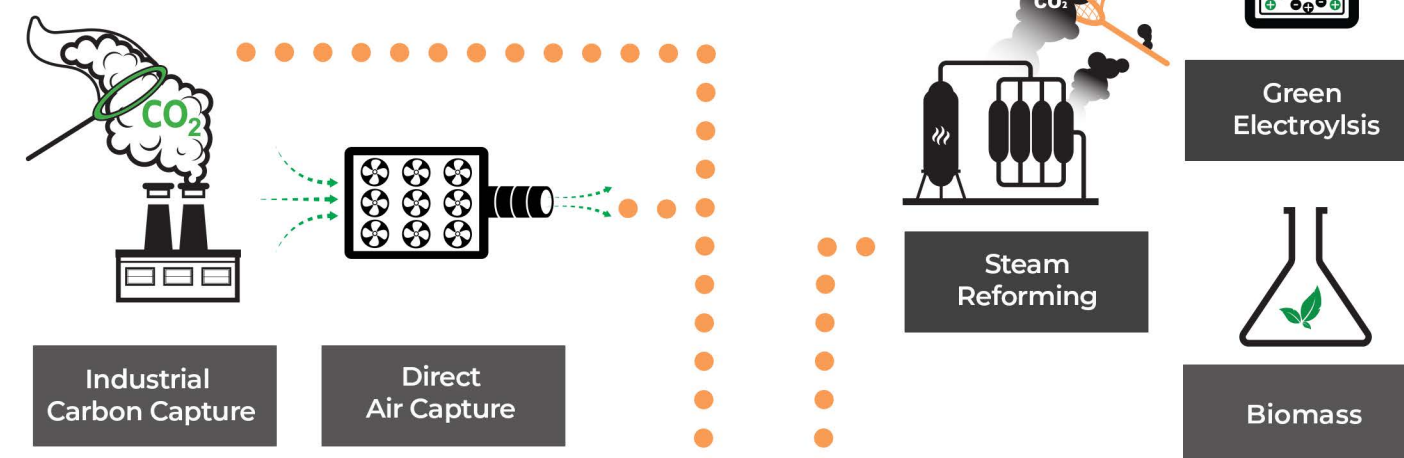
Safety Gas Sensors



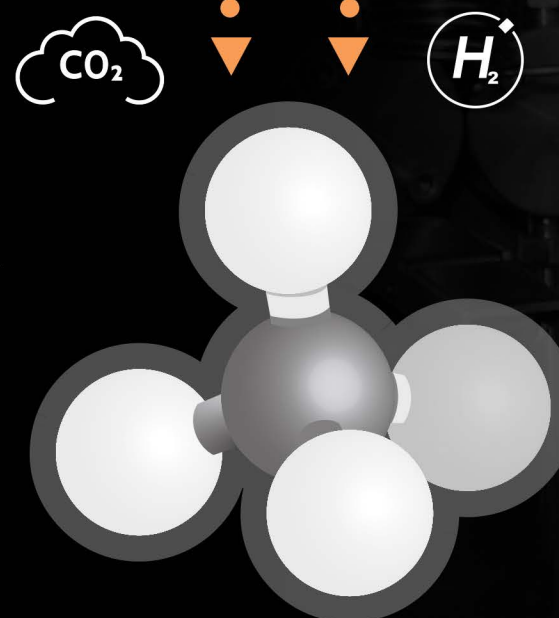
Materials of Construction for the Reactor

## SABATIER PROCESS

Methane Production



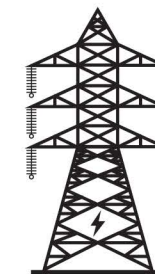
The **Sabatier Process** produces methane and water from a reaction of hydrogen with carbon dioxide at elevated temperatures.



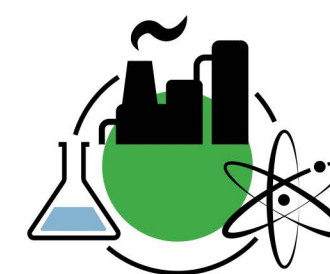
Sabatier Process



Heating



Electricity



Other Industrial Uses



Sustainable Vehicle Fuel



# HYDROGENATION

ADAPTABLE FLOW REACTOR PLATFORM

## Standard Configuration

- **Patented L/G Separator** with low dead volume for accurate catalyst activity and reaction kinetics studies.
- **Liquid HPLC Pump** with integrated mass flow meter for precise, stable feed control & temperature control up to 80°C for heavy hydrocarbons.



L/G Separator



Liquid HPLC Pump



Integrated Liquid / Gas Outlet Measurements



Autosampler



Automated Bypass Valve



Safety Gas Sensors



Liquid Evaporator



Flow Reactor (FR-200)

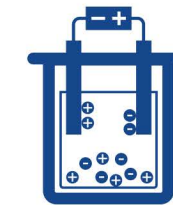
## Recommended Options

- **Integrated Liquid & Gas Outlet Measurements** to determine mass balance and reaction yield.
- **Autosampler** to study the liquid product at user-defined intervals.
- **Automated Bypass Valve** to sample all vapor phase products to understand kinetics.
- **Safety Gas Sensors** to detect  $H_2$  leaks integrated with safety system.
- **Liquid Evaporator** (50-450°C) for researchers who need to vaporize their liquid feed stocks.

## HYDROGENATION & Dehydrogenation



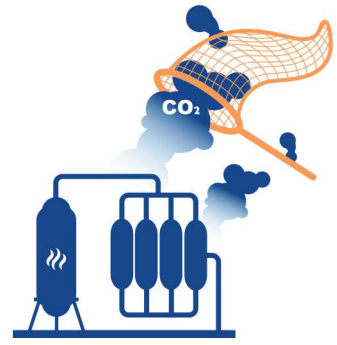
Toluene Feed-Stock



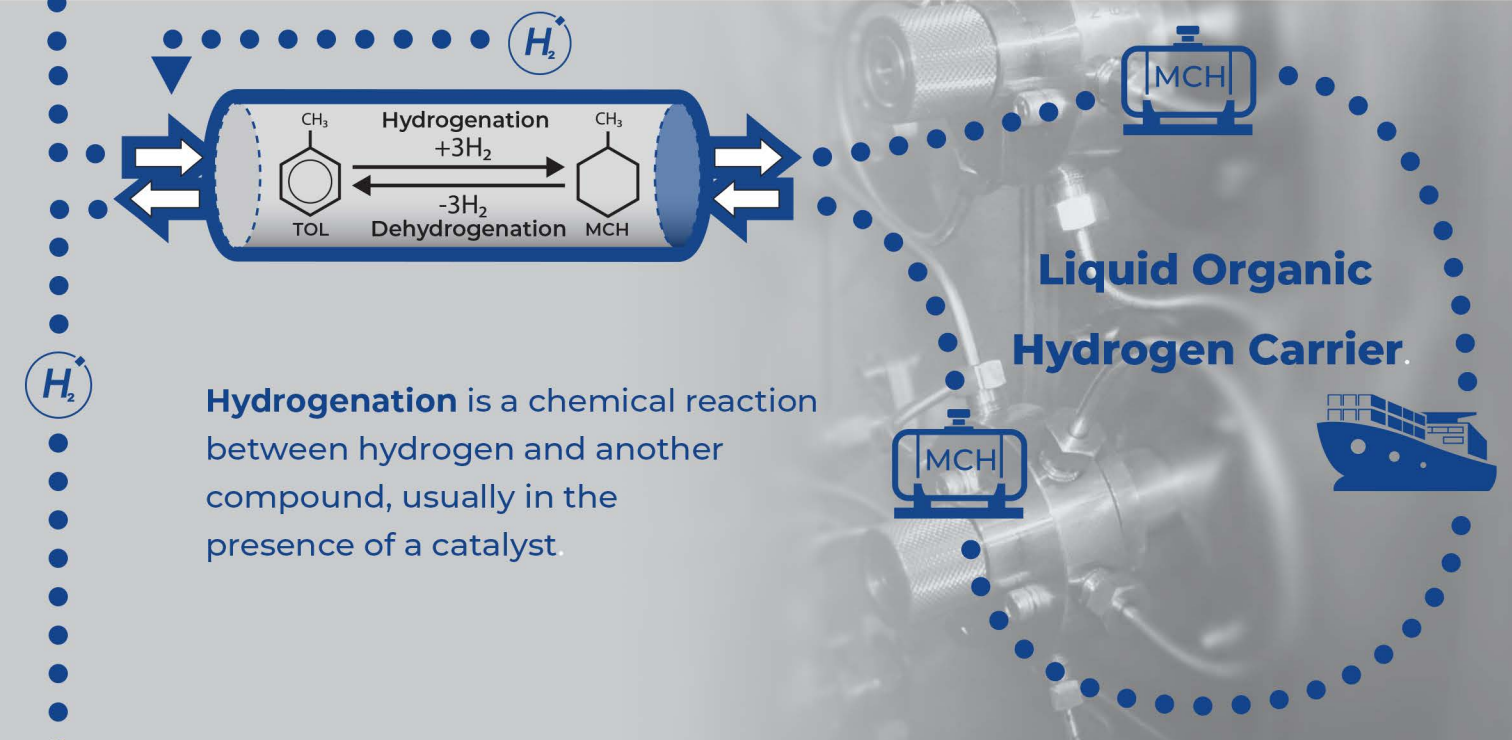
Electrolysis



Biomass



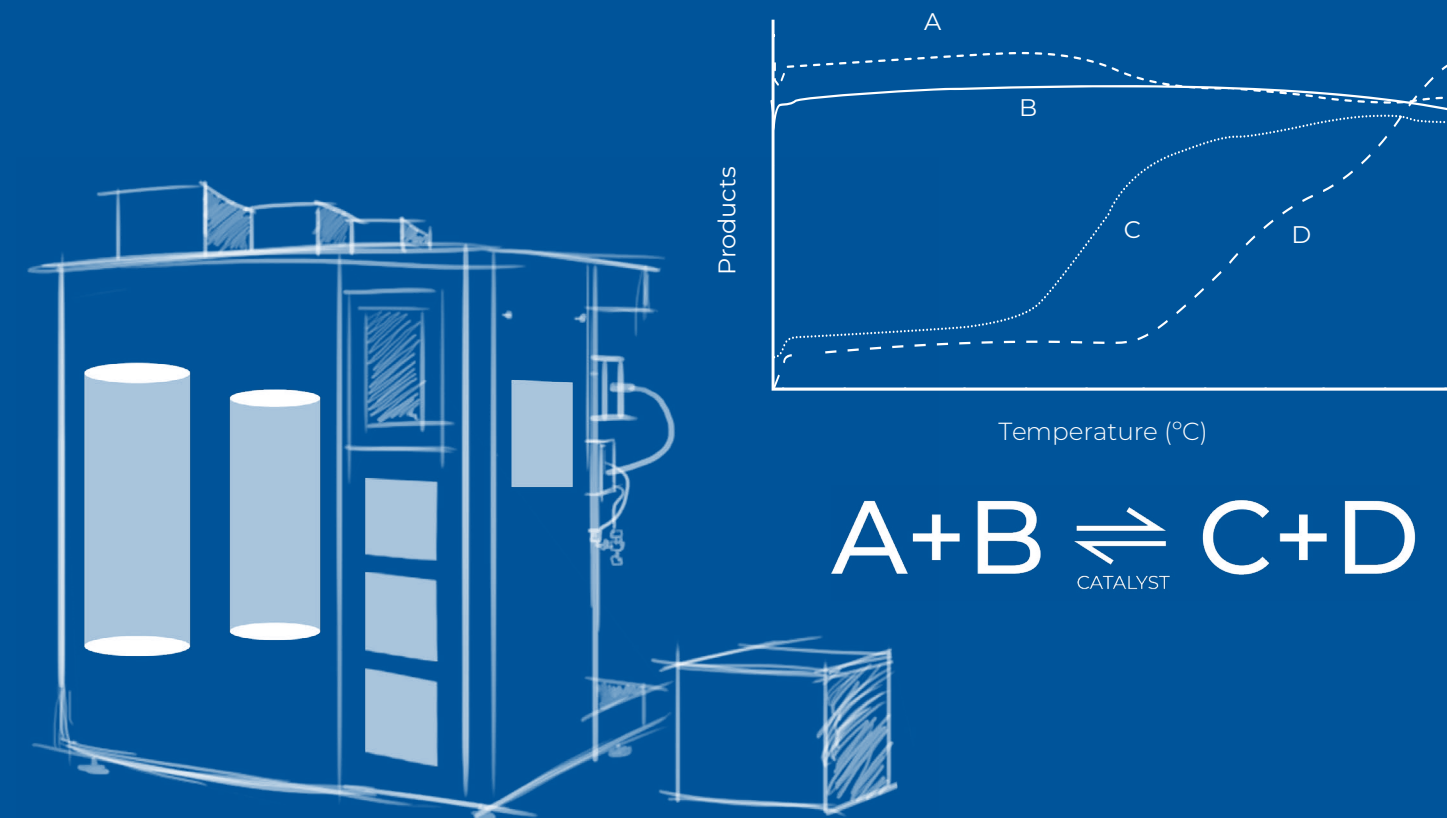
Steam Reforming



# FLEXIBLE REACTOR PLATFORM

## ADAPTABLE TO A WIDE-RANGE OF CHEMICAL REACTIONS

The **FR-series** flow reactor modular capabilities support a wide-range of catalytic chemical reactions. Input streams, reactant flow, operating conditions, and output analysis can be configured to meet your specific needs.



# In-Situ Catalyst Characterization System (ICCS)

## Advanced Characterization Unit for the Flow Reactor

The Micromeritics ICCS offers advanced catalyst characterization for the Flow Reactor to understand the effects of reaction conditions on critical parameters.

- Characterization without the need to remove the catalyst from the reactor.
- Use of TPR, TPD, TPO, as well as Pulse Chemisorption.
- Analysis can be performed both before and after the reaction.
- High pressure capabilities.

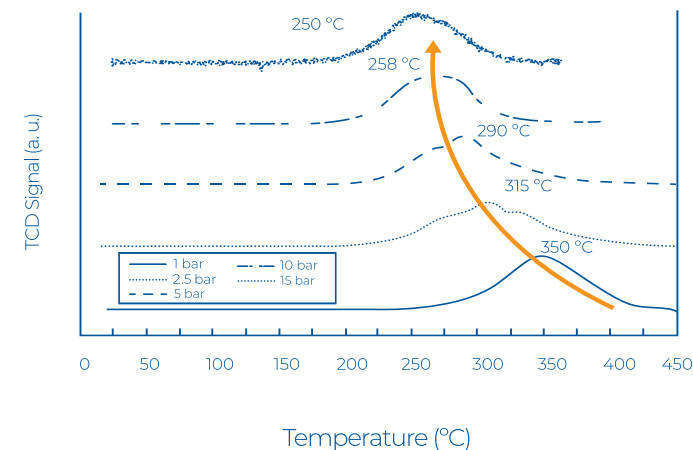
### Benefits of In-Situ catalyst Characterization

- Monitor changes in active sites, oxidative states, metal dispersion, and desorption behavior.
- Determine deactivation mechanism to maximize a catalysts' lifetime.
- Understand changes in performance over extended periods.

ICCS



### PRESSURE IMPACT ON REDUCTION TEMPERATURE



This figure shows the shift on the reduction temperature of a CuO catalyst as function of increasing pressure.



SCAN QR CODE FOR  
MORE INFORMATION



**CONTACT US TODAY!**

[micromeritics.com/worldwide](https://micromeritics.com/worldwide)



**Micromeritics Instrument Corporation**

4356 Communications Drive, Norcross, GA 30093 USA

Tel.: +1 770-662-3636

© 2023 Micromeritics Instrument Corp. All rights reserved. All trademarks are the property of Micromeritics and its subsidiaries unless specified. The DNV logo is the property of Det Norske Veritas. The Intertek ETL logo is the property of Intertek. The IEC IECEE logo is the property of IEC. Specifications, terms and pricing are subject to change. Not all products are available in all countries. Please consult your local sales representative for details.