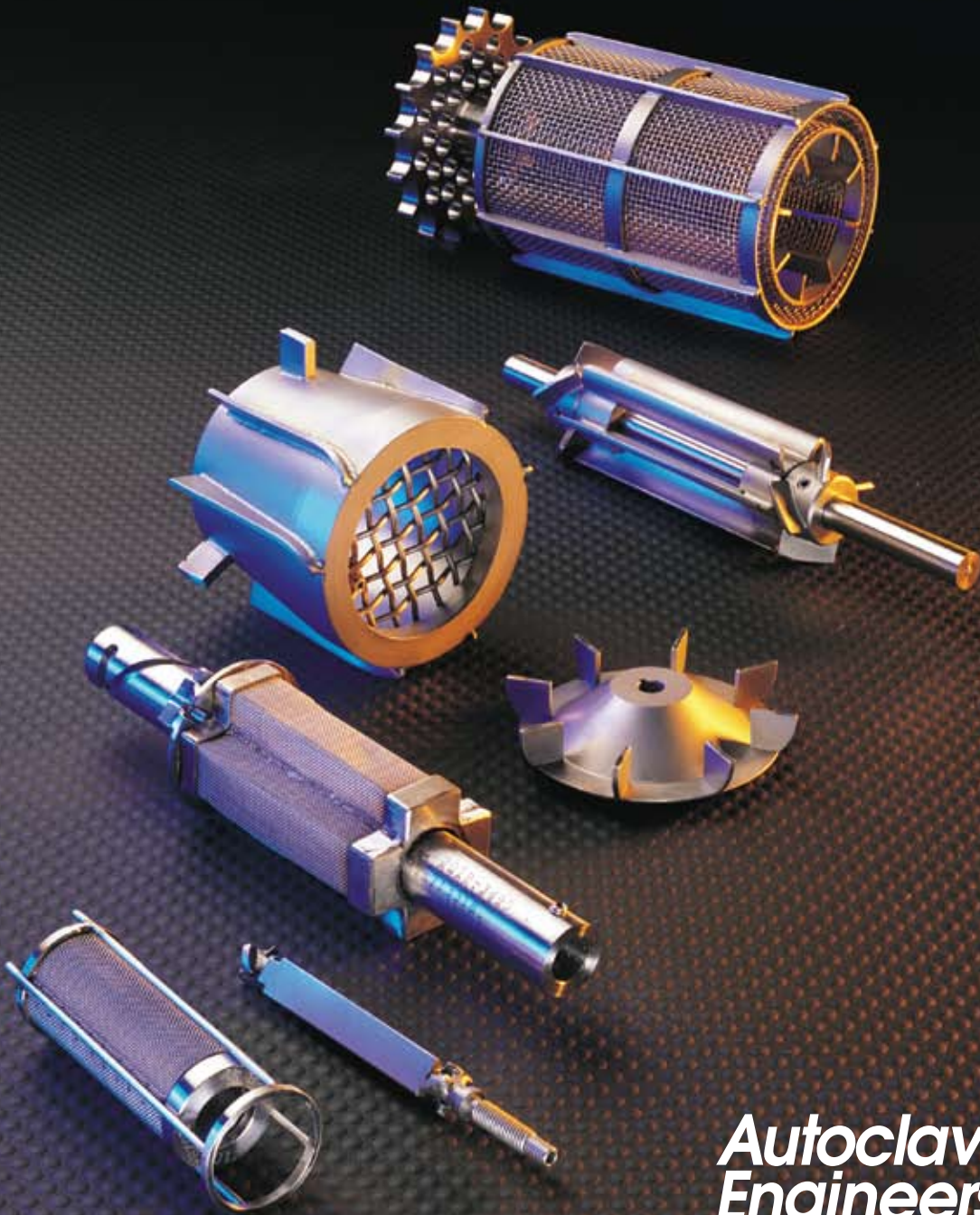


# Autoclave Engineers Catalytic Reactor Selection Guide



**Autoclave  
Engineers**   
Division of Snap-tite, Inc.

Catalytic Reactors



*The World Leading Provider of High Pressure Equipment for Research and Industry since 1945!*

# Catalytic Reactors

## Selection Guide

### At a Glance

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- **Fixed Bed (Tube) Reactors** - Laboratory Reaction Systems
- **High Pressure Stirred Laboratory (Batch) Reactors - CSTR** - Continuous Stirred Tank Reactors
- **Berty** Stationary Catalyst Basket
- **Berty** “Micro” Stationary Catalyst Basket
- **Robinson-Mahoney** Stationary Catalyst Basket
- **Robinson-Mahoney** “Micro” Stationary Catalyst Basket
- **Mahoney-Robinson** Spinning Catalyst Basket
- **Carberry** Spinning Catalyst Basket
- **Harshaw** Stationary and Falling Catalyst Basket
- **Caldwell** Stationary Catalyst Basket
- **BTRS** Benchtop Reactor Systems
- **BTRS-900** Tube Reactor
- **Multi-Train BTRS**

Autoclave Engineers offers a full range of catalyst research apparatus.

**SIZES** - Miniature to Pilot

**PRESSURES** - Vacuum to many thousand psi (several hundred bar)

**TEMPERATURES** - Sub-ambient to 650°F (343°C) is “standard” and higher and lower temperature designs are offered for specific applications. See the following pages for more information. Custom temperature and pressure ratings are available upon request.

**MATERIALS** - Stainless steel and assorted high temperature, corrosion resistant alloys.

**DESIGNS** - An assortment for both supported and unsupported catalyst research, continuous flow and several circulating flow designs for simulating diverse processes.

**CONTROL SYSTEMS** - Manual, through all levels of automation, including integrated systems with full computerized batch automation, data acquisition and fail-safe process controls.

**OPTIONS** - As specified. (Special instrumentation, plated / polished catalyst supports, regulatory certifications, explosion-proof drive, special material handling and sampling etc.)

Autoclave Engineers has developed an extensive library of proven, successful equipment designs for catalyst research. It is not practical to list them all. Feel free to contact Autoclave Engineers with your requirements.



Division of Snap-tite, Inc.

## General Information

# Application Selection Guide

## Reactors



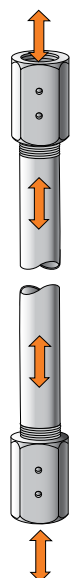
	Page	Reactants			Typical Reactions						
		Liquid/Solids	Gas or Vapor/Liquids	Gas/Liquid/Solids	Hydrogenation	Liquefaction	Oxidation	Hydrotreating	Catalyst Testing	Hydrocarbon Petroleum Studies	Hydro Liquefaction
Fix Bed Reactors	2	X	X	X	X		X	X	X		
CSTR-Continuous Stirred Tank Reactors	3	X		X	X	X	X	X	X		
Berty Stationary Catalyst Basket	4		X		X		X		X		
Berty "Micro" Stationary Catalyst Basket	5		X		X		X				
Robinson-Mahoney Stationary Catalyst Basket	6	X		X		X		X	X		
Robinson-Mahoney "Micro" Stationary Catalyst Basket	7	X		X		X		X	X		
Mahoney-Robinson Spinning Catalyst Basket	8			X	X	X			X	X	X
Carberry Spinning Catalyst Basket	9	X	X	X	X	X	X	X	X		
Hawshaw Stationary and Falling Catalyst Basket	10			X	X		X		X		
Caldwell Stationary Catalyst Basket	11		X		X		X		X		

## Need Help Getting Started?

Selecting the right tool when faced with many choices can be overwhelming. The following series of questions may help in getting focused on the characteristics that differentiate the designs.

- Are the kinetics of the reaction relatively fast or is the process you are trying to simulate a continuous flow process? If either are true, consider tube (fixed bed) reactor based systems like BTRS-Jr.<sup>®</sup> or BTRS 900 (See bulletin "BTRS-1" and Bulletin "RS-BTRS-Jr.").
- Can a fluid be the dominant component of the mixture (perhaps a process solvent) and is unsupported catalyst a viable possibility? If yes, consider a High Pressure Laboratory (Batch) Reactor. (See the stirred reactor selection guide bulletin "SR-SG").
- Is fluid the dominant component and are you using supported catalysts? If yes, select the Robinson-Mahoney stationary catalyst basket design as the preferred tool for most applications. Some researchers suggest that centrifugal separation of components may limit the usefulness of the Mahoney-Robinson spinning basket design to reactions with miscible or soluble components.
- Do you need sequential reactions where first the solid catalyst interacts with the gaseous reactants followed without interruption by a reaction where the solid catalyst is immersed in a liquid phase? If yes, consider the Harshaw "Falling Basket" design.
- Is your reaction a Solid-Gas reaction where the reaction kinetics are relatively slow? There are three designs to consider, Berty, Carberry and Caldwell.
  - Consider the Berty if it is important to reproduce or closely correlate with the collected experimental work completed in Berty equipment. The Berty reactor is offered in various sizes. Select large diameter designs for applications with high pressure drop across the catalyst bed or very low gas density. The larger the diameter of the circulating blower the higher the pressure (head) for a given gas velocity and therefore the greater the circulation flow.
  - Consider the Caldwell if your gas density is so low that generating circulating pressure despite low gas density is your principle consideration.
  - Consider the Carberry if you are interested in single tool that is versatile enough for nearly any gas and/or liquid reaction with a supported catalyst. The Carberry has been chosen to see a range of effects when there is a willingness to correlate Carberry based results with other equipment.
- Need help? Contact Autoclave Engineers and ask for guidance.

## Fixed Bed (Tube) Reactor



**Description:** The tubular reactor is packed with solid catalyst particles. The straight-through flow of gasses and/or liquids is suitable for chemical reactions with rapid kinetics. The reactor can be configured for both upward and downward flow as required by the process.

**Reactants:** Liquid/Solids, Gas/Solids, Gas/Liquid/Solids, Vapor/Solids.

**Typical Reactions:** Hydrogenation, oxidation, hydro-treating, catalyst testing.

**Free Volume:** 0.60 in.<sup>3</sup> (10 cm<sup>3</sup>) and up.

**Common Customizations:** Special materials, specific pressure and temperature rating, furnace assembly, "trickle feed" connection.

**Standard Material:** 316 Stainless Steel

**Maximum Allowable Working Pressure/Temperature Combinations.**

**Examples for the Standard Material**

Pressure Rating	Temperature for the Tabulated Pressure Rating
60,000 psig (4,137 Bar)	100°F (38°C)
48,450 psig (3,340 Bar)	800°F (427°C)

See BTRS-1 Bulletin and RS-BTRTS-Jr<sup>®</sup> Bulletin for Bench Top Reaction Systems ordering information.

See Bulletin PV-CC for information on ordering a tube reactor as a stand alone part.

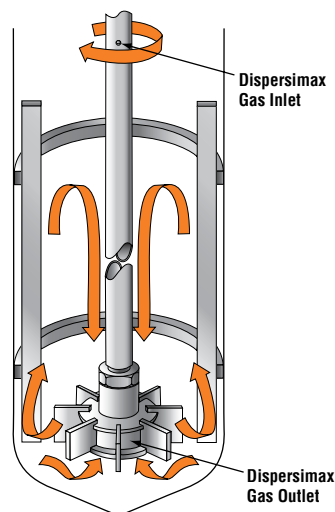
**NOTES:**

Product information can be downloaded after registering your name on the Autoclave Engineers web site:

<http://www.autoclaveengineers.com> to reach the main page of Autoclave Engineers reactor products. Request assembly drawings of the product(s) of interest to get more technical detail.

See the "Ordering Guide" of this bulletin to find drawing numbers and contact your local Sales Representative or Autoclave Engineers directly to obtain assembly drawings.

# High Pressure Stirred Laboratory (Batch) Reactors



**Description:** The stirred (batch) reactor is used to create a slurry using powdered catalyst or in homogeneous catalyst research. Agitation creates isothermal conditions and allows the researcher to select the reaction time. Select the Dispersimax impeller for circulating the head space gas into the liquid phase. Other impeller shapes are offered to simulate other processes.

**Reactants:** Liquid/Solids, Gas/Liquid/Solids, Vapor/Liquid/Solids.

**Typical Reactions:** Liquefaction, isomerization, polymerization, hydrogenation, oxidation, hydro-treating, catalyst testing.

**Standard Material:** 316 Stainless Steel and HASTELLOY® C-276

**Standard Reactor Volume:** 1.83 in.<sup>3</sup> (30 cm<sup>3</sup>) to 244 in.<sup>3</sup> (4,000 cm<sup>3</sup>).

**Common Customizations:** Special materials, windows (video camera view ports and/or spectroscopic windows), non-standard capacity, non-standard vessel diameter and length, MagneDrive® with higher torque rating, welded heat transfer jacket for high pressure/temperature heat transfer fluid system, complete intrinsically safe barrier and control system, ASME code stamp (or CE mark for Pressure Equipment Directive), special vessel lift mechanism.

**Standard Agitator Speed:** 1,000 to 3,300 RPM.

## Maximum Allowable Working Pressure/Temperature Combinations

**Examples for the Standard Closure Design** (Using Gasket With Highest Temperature Rating)

Name of Design	Pressure Rating	Temperature Rating
Multi-Clave™ 10X	725 psig (50 Bar)	392°F (200°C)
ZipperClave®	2,200 psig (151 Bar)	450°F (232°C)
EZE-Seal™	3,300 psig (227 Bar)	850°F (454°C)
Bolted Closure	5,500 psig (379 Bar)	650°F (343°C)
Transparent Reactor Vessel	150 psig (10.3 Bar)	300°F (149°C)

See the Stirred Reactor Selection Guide, Multi-Clave™ 10X, ZipperClave®, EZE-Seal™, Bolted Closure and Transparent Reactor Vessel Bulletins and Ordering Guides.

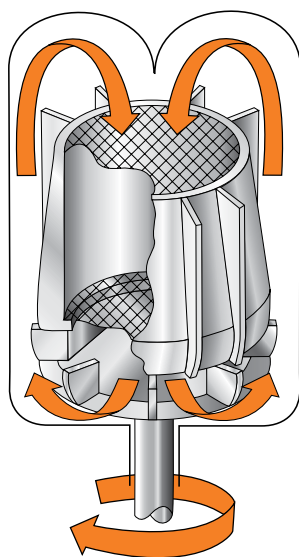
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## Berty Stationary Basket Catalyst Testing Reactor



**Description:** This internal recycle reactor is designed with a fixed, circular, screened catalyst bed and a bottom mounted vane type blower. Fluid circulation is directed upward along the vessel wall and deflected downward through the catalyst bed. Large diameter designs are used in applications with high pressure drop across the catalyst bed or that have very low gas density. The predictable gas/vapor circulation of the Berty design has made it the most widely used gas phase catalyst research tool.

**Reactants:** Gas/Solids, Gas/Liquid/Solids, Liquid/Solids, Vapors/Solids.

**Typical Reactions:** Hydrocarbon oxidation, ethylene hydrogenation, catalyst testing.

**Basket Screen:** 4 x 4 mesh, 0.062" (1.5 mm) wire and a nominal opening size of 0.187" (4.75 mm)

	3" (76.2 mm) Inside Diameter (Standard)	3" (76.2 mm) Inside Diameter (Hi-Temp)	5" (127 mm) Inside Diameter
<b>Basket Volume</b> (5" design includes internal spacers for three volumes)	6.1 in. <sup>3</sup> (100 cm <sup>3</sup> )	6.1 in. <sup>3</sup> (100 cm <sup>3</sup> )	9.8 in. <sup>3</sup> (160 cm <sup>3</sup> ) 18.4 in. <sup>3</sup> (303 cm <sup>3</sup> ) 31.2 in. <sup>3</sup> (511 cm <sup>3</sup> )
<b>Free Volume</b>	17 in. <sup>3</sup> (280 cm <sup>3</sup> )	17 in. <sup>3</sup> (280 cm <sup>3</sup> )	88.5 in. <sup>3</sup> (1,450 cm <sup>3</sup> )
<b>Max Allowable Working Pressure</b>	5,800 psig (400 Bar)	2,450 psig (169 Bar)	3,700 psig (255 Bar)
<b>Temperature</b>	650° F (343°C)	1,200° F (649°C)	650°F (343°C)
<b>Maximum Blower Speed</b>	2,500 RPM	2,500 RPM	2,500 RPM (Gas Service) 1,500 RPM (Liquid service with special impeller for liquids) 500 RPM (Liquid service using standard gas impeller)
<b>Catalog Number Prefix</b>	BC0010...	BM0010...	BC0043...

**Common Customizations:** Special wire mesh size, special materials, specific pressure/temperature rating, ASTM code stamp (or CE mark for Pressure Equipment Directive) special internal spacers for custom basket volumes.

**Standard Material:** 316 Stainless Steel

### NOTES:

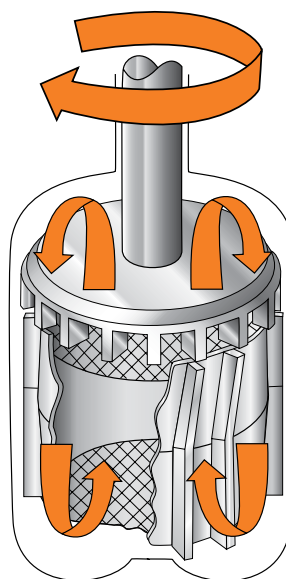
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See page 13 for the Ordering Guide

# Berty "Micro" Stationary Basket Catalyst Testing Reactors



**Description:** This internal recycle reactor is designed with a fixed, circular, screened catalyst bed and a top mounted vane type blower. Fluid circulation is directed downward along the vessel wall and deflected upward through the catalyst bed.

**Reactants:** Gas/Solids, Vapor/Solids.

**Typical Reactions:** Oxidation, hydrogenation, catalyst testing.

**Basket Screen:** 50 x 50 mesh, 0.009" (0.23 mm) wire and a nominal opening size of 0.011" (0.28 mm).

**Inside Diameter:** 1 in. (25.4 mm).

**Basket Volume:** 0.22 in.<sup>3</sup> (3.6 cm<sup>3</sup>).

**Free Volume:** 0.94 in.<sup>3</sup> (15.4 cm<sup>3</sup>).

**Maximum Allowable Working Pressure:** 5,000 psig (345 Bar)

**Maximum Blower Speed:** 5,000 RPM

Version	Standard	High Temperature
Temperature	650°F (343°C)	1,000°F (538°C)
Catalog Number Prefix	CRB2HC...	CRBHT...

**Common Customizations:** Special wire mesh size, special materials, specific pressure/temperature ratings, ASTM code stamp (or CE mark for Pressure Equipment Directive)

**Standard Material:** HASTELLOY® C-276

**NOTES:**

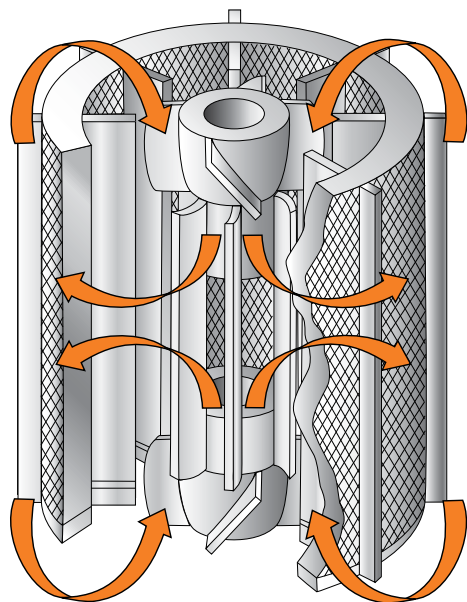
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See page 14 for the Ordering Guide

## Robinson-Mahoney Stationary Catalyst Basket Reactor



**Description:** The fixed annular catalyst basket has baffles inside and outside to control vortices. The rotating shaft is equipped with two impellers that draw fluid into the center of the annulus at the top and bottom and outward through the catalyst bed. The gradient-free design and long duration circulation capability for multiple phases has made the Robinson-Mahoney the most widely used design for supported, heterogeneous catalyst research with liquids.

**Reactants:** Liquid/Solids, Gas/Liquid/Solids, Vapor/Liquid/Solids.

**Typical Reactions:** Liquefaction, hydro-treating, catalyst testing.

**Basket Screen:** 14 x 14 mesh, 0.020" (0.51 mm) wire and a nominal opening size of 0.051" (1.3 mm).

	1.8" (45.7mm) Inside Diameter	3" (76.2 mm) Inside Diameter
<b>Basket Volume</b>	3.0 in. <sup>3</sup> (49 cm <sup>3</sup> )	8 in. <sup>3</sup> (131 cm <sup>3</sup> )
<b>Free Volume</b>	16 in. <sup>3</sup> (262 cm <sup>3</sup> )	63.5 in. <sup>3</sup> (1,040 cm <sup>3</sup> )
<b>Maximum Allowable Working Pressure</b>	5,400 psig (372 Bar)	5,800 psig (400 Bar)
<b>Temperature</b>	650°F (343°C)	650°F (343°C)
<b>Maximum Agitator Speed</b>	1,000 RPM	1,000 RPM
<b>Catalog Number Prefix</b>	BC0005...	BC0012...

**Common Customization:** Conversion kits to switch an EZE-Seal™ or Bolted closure batch reactor into a Robinson-Mahoney catalytic reactor, special wire mesh size, special materials, specific pressure/temperature ratings, ASTM code stamp (or CE mark for Pressure Equipment Directive)

**Standard Material:** 316 Stainless Steel

See page 13 for the Ordering Guide

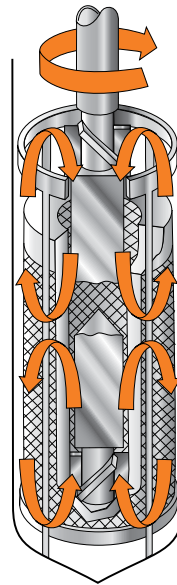
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See the "Ordering Guide" of this bulletin to find drawing numbers and contact your local Sales Representative or Autoclave Engineers directly to obtain assembly drawings.

# Robinson-Mahoney "Micro" Stationary Catalyst Basket Reactor



**Description:** The fixed annular catalyst basket has baffles inside and outside to control vortices. The rotating shaft is equipped with two impellers that draw fluid into the center of the annulus at the top and bottom and outward through the catalyst bed. The gradient-free design and a long duration circulation capability for multiple phases has made the Robinson-Mahoney the most widely used design for supported catalyst research with liquids.

**Reactants:** Liquid/Solids, Gas/Liquid/Solids, Vapor/Liquid/Solids

**Typical Reactions:** Liquefaction, hydro-treating, catalyst testing

**Basket Screen:** 50 x 50 mesh, 0.009" (0.23 mm) wire and a nominal opening size of 0.011" (0.28 mm)

**Inside Diameter:** 1" (25.4 mm).

**Basket Volume:** 0.436 in.<sup>3</sup> (7.15 cm<sup>3</sup>)

**Free Volume:** 3.05 in.<sup>3</sup> (50 cm<sup>3</sup>)

**Maximum Allowable Working Pressure:** 5,000 psig (345 Bar)

**Temperature:** 650°F (343°C)

**Maximum Agitator Speed:** 5,000 RPM

Version	Standard	High Temperature
Temperature	650°F (343°C)	1,000°F (538°C)
Catalog Number Prefix	CRA5HC...	CRAHT...

**Common Customization:** Special wire mesh size, special materials, specific pressure/temperature ratings, ASTM code stamp (or CE mark for Pressure Equipment Directive)

**Standard Material:** HASTELLOY® C-276

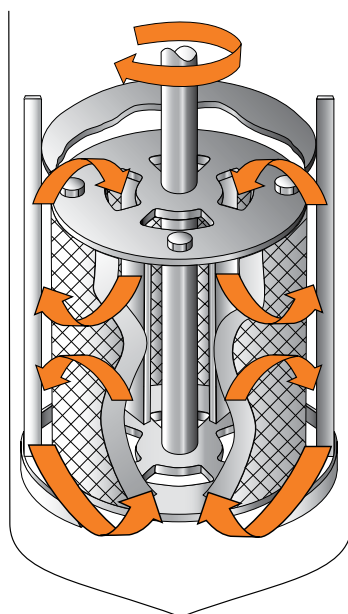
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See the "Ordering Guide" of this bulletin to find drawing numbers and contact your local Sales Representative or Autoclave Engineers directly to obtain assembly drawings.

See Bulletin CR-Micro and page 14 for the Ordering Guide

## **Mahoney-Robinson Spinning Catalyst Basket Reactor**



**Description:** The annular catalyst basket is rotated on a shaft to move the catalyst through the reactants. Baffles inside the basket and fixed baffles outside the basket direct reactant flow.

**Reactants:** Gas/Liquid/Solids, Vapor/Liquid/Solids.

**Typical Reactions:** Hydrocarbon petroleum studies, hydro-liquefaction, catalyst testing.

**Basket Screen:** 14 x 14 mesh, 0.020" (0.51 mm) wire and a nominal opening size of 0.051" (1.3 mm).

**Basket Volume:** 2.2 in.<sup>3</sup> (35 cm<sup>3</sup>).

**Free Volume:** 30 in.<sup>3</sup> (500 cm<sup>3</sup>).

**Maximum Allowable Working Pressure:** 5,500 psig (379 Bar).

**Temperature:** 650°F (343°C).

**Maximum Rotation Speed:** 1,500 RPM. The catalyst and fluid loads may unbalance or overstress the bearings. A typical rotation speed range is 100 to 1,500 RPM.

**Common Customization:** Special wire mesh size, special materials, specific pressure/temperature ratings, ASTM code stamp (or CE mark for Pressure Equipment Directive)

**Standard Material:** 316 Stainless Steel

Contact your Sales or Customer Service Representative for Ordering Information

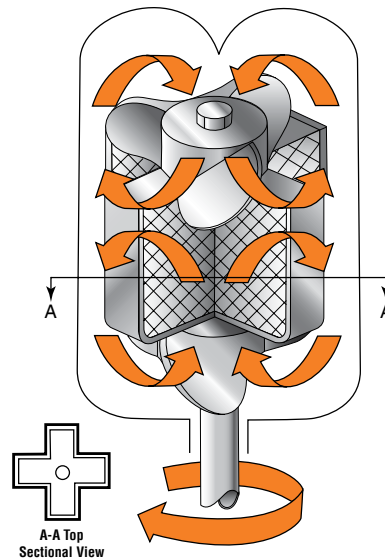
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# Carberry Spinning Catalyst Basket Reactor



**Description:** The catalyst basket has a “cruciform” cross-section. The test catalyst is placed in the cruciform basket and rotated on a shaft. Each arm of the cruciform acts as a differential reactor sweeping through the fluid reactants at high speed. Propellers are mounted above and below the cruciform to direct fluid flow.

**Reactants:** Liquid/Solids, Gas/Solids, Vapor/Solids, Gas/Liquid/Solids, Vapor/Liquid/Solids.

**Typical Reactions:** Liquefaction, hydrogenation, hydro-treating, oxidation, catalyst testing.

**Basket Screen:** 14 x 14 mesh, 0.020” (0.51 mm) wire and a nominal opening size of 0.051” (1.3 mm).

	3” (76.2 mm) Inside Diameter (Standard)	3” (76.2 mm) Inside Diameter (Hi-Temp)	5” (127 mm) Inside Diameter
<b>Basket Volume</b>	2.5 in. <sup>3</sup> (41 cm <sup>3</sup> )	6.1 in. <sup>3</sup> (100 cm <sup>3</sup> )	6.3 in. <sup>3</sup> (103 cm <sup>3</sup> )
<b>Free Volume</b>	18 in. <sup>3</sup> (295 cm <sup>3</sup> )	17 in. <sup>3</sup> (280 cm <sup>3</sup> )	88 in. <sup>3</sup> (1,442 cm <sup>3</sup> )
<b>Max. Allowable Working Pressure</b>	5,800 psig (400 Bar)	2,450 psig (169 Bar)	3,700 psig (255 Bar)
<b>Temperature</b>	650°F (343°C)	1,200°F (649°C)	650°F (343°C)
<b>Maximum Impeller/Basket Speed</b>	2,500 RPM (gas) 1,000 RPM (liquid)	2,500 RPM (gas) 1,000 RPM (liquid)	2,500 RPM (gas) 1,000 RPM (liquid)
<b>Catalog Number Prefix</b>	BC0006...	BC0006...	BC0012...

**Common Customizations:** Conversion kit to switch from a Robinson-Mahoney catalytic reactor to a Carberry reactor, special wire mesh size, special material, specific pressure/temperature ratings, ASTM code stamp (or CE mark for Pressure Equipment Directive)

**Standard Material:** 316 Stainless Steel

See page 13 for the Ordering Guide

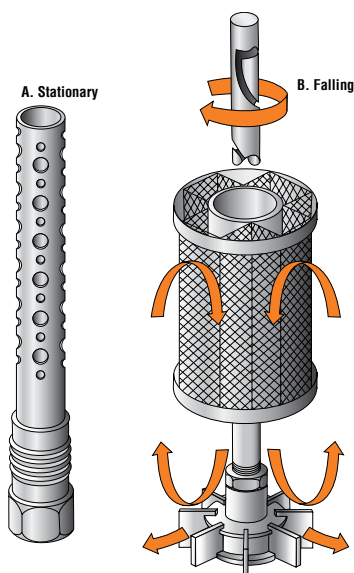
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## Harshaw Stationary and Falling Catalyst Basket Reactor



### Description:

- A.** The catalyst basket is a perforated tube that is installed in the bottom of a reactor. The basket can be easily filled with supported (formed) catalysts and changed between batch runs.
- B.** The catalyst basket has a cruciform shape (similar to the Carberry). The catalyst basket is held in a catch near the top of the grooved agitator shaft in the gas/vapor phase during the initial part of the experiment. The basket releases when the shaft is stopped and momentarily reversed. This allows the catalyst basket to travel down the groove to the bottom position for the liquid phase of the experiment.

**Reactants:** Gas/Vapor/Liquid/Solids.

**Typical Reactions:** Hydrogenation, oxidation, catalyst testing.

	A. Stationary	B. Falling
<b>Basket Screen</b>	Perforated with 0.062" (1.5 mm) and 0.120" (3.0 mm) diameter holes	50x50 mesh, 0.009" (0.23 mm)
<b>Screen Opening</b>	-	0.011" (0.28 mm)
<b>Basket Volume</b>	0.7" in. <sup>3</sup> (17 cm <sup>3</sup> )	2.6" in. <sup>3</sup> (42.6 cm <sup>3</sup> )
<b>Free Volume</b>	60.4" in. <sup>3</sup> (990 cm <sup>3</sup> )	60.4" in. <sup>3</sup> (990 cm <sup>3</sup> )

**Maximum Allowable Working Pressure:** 5,500 psig (379 Bar).

**Temperature:** 650°F (343°C).

**Maximum Rotation Speed:** Variable with the stage of the process and other considerations. 2,500 RPM is the maximum recommended if a) the basket is in the top position (in the gas phase) and b) the catalyst weight distribution is uniform. 1,000 RPM is the maximum recommended if a) the basket is in the lower position (in the liquid phase) and b) the catalyst weight distribution is uniform. Actual rotational speeds may need to be reduced further if catalyst weight distribution is not uniform.

**Common Customizations:** Conversion kits to convert an EZE-Seal™ or Bolted closure batch reactor into a Harshaw Falling Basket Reactor, special wire mesh size, special materials, specific pressure/temperature ratings, ASTM code stamp (or CE mark for Pressure Equipment Directive)

**Standard Material:** 316 Stainless Steel

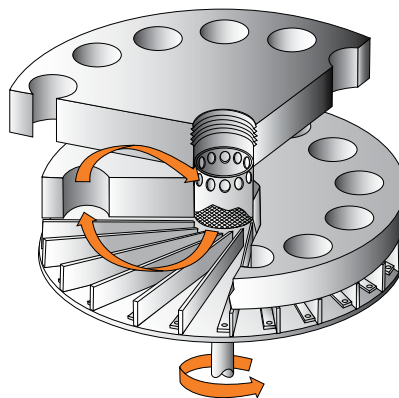
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Contact your Sales or Customer Service Representative for Ordering Information

## Caldwell Stationary Catalyst Basket Reactor



**Description:** The rotating, large diameter, low height impeller blades creates significant circulation gas pressure, even in applications when the gas density is low. The flow is redirected to a centrally located catalyst basket. Tests show the Caldwell design has higher mass transfer coefficients compared to other designs.

**Reactants:** Gas/Solids

**Typical Reactions:** Hydrogenation, oxidation, catalyst testing.

**Basket Screen:** 50 x 50 mesh, 0.009" (0.23 mm) wire and a nominal opening size of 0.011" (0.28 mm).

**Basket Volume:** 0.65 in.<sup>3</sup> (10.7 cm<sup>3</sup>)

**Free Volume:** 54.0 in.<sup>3</sup> (885 cm<sup>3</sup>)

**Maximum Allowable Working Pressure:** 800 psig (55 Bar)

**Temperature:** 950°F (510°C)

**Maximum Blower Speed:** 2,500 RPM

**Standard Material:** 316 Stainless Steel

**Common Customizations:** Metal plating to deactivate the internal metal surfaces of the reactor, special wire mesh size, special materials, specific pressure/temperature ratings, ASTM code stamp (or CE mark for Pressure Equipment Directive)

### NOTES:

Product information can be downloaded after registering your name on the Autoclave Engineers web site:

<http://www.autoclaveengineers.com> to reach the main page of Autoclave Engineers reactor products. Request assembly drawings of the product(s) of interest to get more technical detail.

See the "Ordering Guide" of this bulletin to find drawing numbers and contact your local Sales Representative or Autoclave Engineers directly to obtain assembly drawings.

See Technical Bulletin CR-Cald and page 13 for Ordering Information

# Performance Comparison Chart

## Autoclave Engineers Standard Catalytic Reactors Sizes and Capabilities

Designation	Maximum Allowable Working Pressure/Temperature (see note 1)	Maximum Agitation Speed	Free Volume	Maximum Basket Volume	Screen Size	Screen Operating	Catalog Page
Fixed Bed Reactor	60,000 psig (4,137 bar) @ 100°F (38°C) 48,450 psig (3,340 bar) @ 800°F (427°C)	N/A	10-300 cm <sup>3</sup>	N/A	N/A	N/A	2
High Pressure Laboratory (Batch) Reactor	5,500 psig (379 bar) @ 650°F (343°C) 3,300 psig (227 bar) @ 850°F (454°C)	1,000-3,000 RPM	50-4,000 cm <sup>3</sup>	N/A	N/A	N/A	3
Berty 3" I.D. Standard	5,800 psig (400 bar) @ 650°F (343°C)	2,500 RPM	280 cm <sup>3</sup>	100 cm <sup>3</sup>	4x4 mesh 0.062" (1.5 mm) wire	0.187" (4.75 mm)	4
Berty 3" I.D. Hi-Temp	2,450 psig (169 bar) @ 1,200°F (649°C)	2,500 RPM	280 cm <sup>3</sup>	100 cm <sup>3</sup>	4x4 mesh 0.062" (1.5 mm) wire	0.187" (4.75 mm)	4
Berty 5" I.D. Standard	3,700 psig (255 bar) @ 650°F (343°C)	500-2,500 RPM (see note 2)	1,450 cm <sup>3</sup>	511 cm <sup>3</sup>	4x4 mesh 0.062" (1.5 mm) wire	0.187" (4.75 mm)	4
Berty "Micro" 1" I.D. Standard	5,000 psig (345 bar) @ 650°F (343°C)	5,000 RPM	15.4 cm <sup>3</sup>	3.6 cm <sup>3</sup>	50x50 mesh 0.009" (0.23 mm) wire	0.011" (0.28 mm)	5
Berty "Micro" 1" I.D. Hi-Temp	5,000 psig (345 bar) @ 1,000°F (538°C)	5,000 RPM	15.4 cm <sup>3</sup>	3.6 cm <sup>3</sup>	50x50 mesh 0.009" (0.23 mm) wire	0.011" (0.28 mm)	5
Robinson-Mahoney 300 cm <sup>3</sup>	5,400 psig (372 bar) @ 650°F (343°C)	1,000 RPM	262 cm <sup>3</sup>	49 cm <sup>3</sup>	14x14 mesh 0.020" (0.51 mm) wire	0.051" (1.3 mm)	6
Robinson-Mahoney 1 Liter	5,400 psig (372 bar) @ 650°F (343°C)	1,000 RPM	1,000 cm <sup>3</sup>	131 cm <sup>3</sup>	14x14 mesh 0.020" (0.51 mm) wire	0.051" (1.3 mm)	6
Robinson-Mahoney "Micro" 50 cm <sup>3</sup>	5,000 psig (345 bar) @ 650°F (343°C)	5,000 RPM	50 cm <sup>3</sup>	7-15 cm <sup>3</sup>	50x50 mesh 0.009" (0.23 mm) wire	0.011" (0.28 mm)	7
Mahoney-Robinson Spinning	5,500 psig (379 bar) @ 650°F (343°C)	1,500 RPM (see note 3)	500 cm <sup>3</sup>	35 cm <sup>3</sup>	14x14 mesh 0.020" (0.51 mm) wire	0.051" (1.3 mm)	8
Carberry 3" I.D. Standard	5,800 psig (400 bar) @ 650°F (343°C)	2,500 RPM (see note 4)	295 cm <sup>3</sup>	41 cm <sup>3</sup>	14x14 mesh 0.020" (0.51 mm) wire	0.051" (1.3 mm)	9
Carberry 3" I.D. Hi-Temp	2,450 psig (169 bar) @ 1,200°F (649°C)	2,500 RPM (see note 4)	295 cm <sup>3</sup>	41 cm <sup>3</sup>	14x14 mesh 0.020" (0.51 mm) wire	0.051" (1.3 mm)	9
Carberry 5" I.D.	3,700 psig (255 bar) @ 650°F (343°C)	2,500 RPM (see note 4)	1,442 cm <sup>3</sup>	103 cm <sup>3</sup>	14x14 mesh 0.020" (0.51 mm) wire	0.051" (1.3 mm)	9
Harshaw Stationary 1 Liter	5,500 psig (379 bar) @ 650°F (343°C)	N/A	990 cm <sup>3</sup>	17 cm <sup>3</sup>	N/A	0.062" & 0.12" (1.5 & 30 mm)	10
Harshaw Falling 1 Liter	5,500 psig (379 bar) @ 650°F (343°C)	1,000-2,500 RPM (see note 5)	990 cm <sup>3</sup>	42.6 cm <sup>3</sup>	50x50 mesh 0.009" (0.23 mm) wire	0.011" (0.28 mm)	10
Caldwell 8" I.D.	800 psig (55 bar) @ 950°F (510°C)	2,500 RPM	885 cm <sup>3</sup>	10.7 cm <sup>3</sup>	50x50 mesh 0.009" (0.23 mm) wire	0.011" (0.28 mm)	11

### Notes:

- 1.) The pressure and pressure ratings tabulated above are the standard listing. Autoclave Engineers will provide pressure ratings for unlisted temperatures upon request. Autoclave Engineers will quote custom pressure and temperature ratings upon request if the standard designs are unsuitable.
- 2.) The recommended maximum varies with a) impellers used, b) whether the reactants are gas/vapor or liquid and c) the catalyst weight distribution. See the assembly drawing for detailed information.
- 3.) The tabulated rotation speed is the "ideal" maximum. The catalyst and fluid loads may unbalance or overstress the bearings. A typical rotation speed range is 100 to 1,500 RPM.
- 4.) The tabulated rotation speed is the "ideal" maximum for gas service. The maximum for liquid service is 1,000 RPM. The catalyst and fluid loads may unbalance or overstress the bearings. A typical rotation speed range is between 100 RPM and the maximum.
- 5.) The maximum rotational speed varies with the stage of the process and other considerations.

2,500 RPM is the maximum recommended if:

- a) the basket is in the top position (in the gas phase) and
- b) the catalyst weight distribution is uniform.

1,000 RPM is the maximum recommended if:

- a) the basket is in the lower position (in the liquid phase) and
- b) the catalyst weight distribution is uniform.

Actual rotational speeds may need to be reduced further if catalyst weight distribution is not uniform.

# Catalytic Reactor Ordering Guide

The following reactor assemblies INCLUDE motor, thermocouples and electrically heated 1,300°F (704°C) maximum furnace (for the voltage specified in the table). Be advised, speed controls, tachometer, motor controls, tachometer display, furnace controls and the display for the thermocouple are purchased as separate items. See the “Instrumentation” section of the Autoclave Engineers Catalog for process instruments and controls. The specifications and descriptions found in this Catalytic Reactor Selection Guide supersede the specification information found in the drawings referenced in the tables below.

Catalog Number	Description SS = ANSI 316 Stainless Steel HC = Hastelloy® C-276	Motor	Power Source	Temp. Rating	Furnace Watts	Furnace Current Draw (ampere)	Typical Furnace Power Supply Rating (ampere) See Note 1	Note	General Arrange. Drawing Number	Reactor Subassembly Drawing Number	Weight lb.
BC0006SS06AJ16D	Carberry Reactor 3" SS	DC	120V	650°F (343°C)	3,000	25	31.3		40-9297	40-9092	175
BC0010SS06AJ16D	Berty Reactor 3" SS	DC	120V	650°F (343°C)	3,000	25	31.3		40-9297	40-9092	175
BC0006SS06AJ26D	Carberry Reactor 3" SS	DC	220V	650°F (343°C)	3,000	13.6	17		40-9297	40-9092	175
BC0010SS06AJ26D	Berty Reactor 3" SS	DC	220V	650°F (343°C)	3,000	13.6	17		40-9297	40-9092	175
BC0012SS04AK16D	Carberry Reactor 5" SS	DC	120V	650°F (343°C)	3,000	25	31.3		40-9294	40-9404	300
BC0043SS04AK16D	Berty Reactor 5" SS	DC	120V	650°F (343°C)	3,000	25	31.3		40-9294	40-9404	300
BC0012SS04AK26D	Carberry Reactor 5" SS	DC	220V	650°F (343°C)	3,000	13.6	17		401A-8833	401A-8830	300
BC0043SS04AK26D	Berty Reactor 5" SS	DC	220V	650°F (343°C)	3,000	13.6	17		201C-0941	201C-0942	300
BM0006SS04AJ16D	Carberry Reactor 3" SS	DC	120V	1,200°F (649°C)	3,000	25	31.3	2	40A-0114	40A-0107	175
BM0010SS04AJ16D	Berty Reactor 3" SS	DC	120V	1,200°F (649°C)	3,000	25	31.3	2	40A-0114	40A-0107	175
BM0006SS04AJ26D	Carberry Reactor 3" SS	DC	220V	1,200°F (649°C)	3,000	13.6	17	2	40A-0114	40A-0107	175
BM0010SS04AJ26D	Berty Reactor 3" SS	DC	220V	1,200°F (649°C)	3,000	13.6	17	2	40A-0114	40A-0107	175
BC0005SS05AH16D	Robinson Reactor 300cm <sup>3</sup> SS	DC	120V	650°F (343°C)	1,200	10	12.5	3	N/A	40A-2701	175
BC0005SS05AH26D	Robinson Reactor 300cm <sup>3</sup> SS	DC	220V	650°F (343°C)	1,200	5.5	6.8	3	N/A	40A-2701	175
BC0012SS06AG16D	Robinson Reactor 1 Liter SS	DC	120V	650°F (343°C)	1,700	14.2	17.7	3	N/A	40A-2445	275
BC0012SS06AG26D	Robinson Reactor 1 Liter SS	DC	220V	650°F (343°C)	1,700	7.7	9.7	3	N/A	40A-2445	275
BC0012SS06AG26A	Robinson Reactor 1 Liter SS	AIR	220V	650°F (343°C)	1,700	7.7	9.7	3	N/A	40A-2445	260
BC0039SS01AJ16D	Caldwell Reactor 8" SS	DC	120/220V	950°F (510°C)	4,300	19.5	24.4	4	40A-7814	40A-7813	430
BC0039SS01AJ26D	Caldwell Reactor 8" SS	DC	220V	950°F (510°C)	4,300	19.5	22.4		40A-7814	40A-7813	430

## NOTES:

- 1) Power supply rating is calculated based on NEC (National Electrical Code) requirements for branch circuit overload protection of 125% of load. Verify that your power supply circuit is in conformance with local codes.
- 2) Reactor is equipped with bolts suitable for pressurized use when operating temperatures exceed 1,000°F/538°C.
- 3) See "Conversion Kit" section for kits to convert stirred reactors into Robinson-Mahoney catalytic reactors.
- 4) The motor is wired for 120V service and the furnace is 220V only.

Product information can be downloaded after registering your name on the Autoclave Engineers web site: <http://www.autoclaveengineers.com> to reach the main page of Autoclave Engineers reactor products. Request assembly drawings of the product(s) of interest to get more technical detail.

See the "Ordering Guide" of this bulletin to find drawing numbers and contact your local Sales Representative or Autoclave Engineers directly to obtain assembly drawings.

## Berty/Carberry Reactor

Conversion Kit 3" Berty to 3" Carberry P/N US1075  
 Conversion Kit 3" Carberry to 3" Berty P/N US2004  
 Conversion Kit 5" Berty to 5" Carberry P/N 3100-6959

Closure	Material	Volume	FROM	TO	Part Number
EZE-Seal™	SS Note 1	300 cm <sup>3</sup>	EZ030...	Robinson-Mahoney Stationary Basket	401A-8808
EZE-Seal™	SS Note 1	1,000 cm <sup>3</sup>	EZ100...	Robinson-Mahoney Stationary Basket	401A-9100
EZE-Seal™	HC Note 1	300 cm <sup>3</sup>	EZ030...	Robinson-Mahoney Stationary Basket	402A-8808
EZE-Seal™	HC Note 1	1,000 cm <sup>3</sup>	EZ100...	Robinson-Mahoney Stationary Basket	402A-9100

### Common Customizations:

Conversion kits to convert Bolted Closure Reactors to Robinson-Mahoney Catalytic Reactors

- NOTES:**
- 1) Stainless Steel alloy ANSI 316
  - 2) Nickel alloy HASTELLOY® C-276
  - 3) Contact the factory for other conversion kits
  - 4) Contact the factory for OLD (Pre-1999) conversion kits

The following reactor assemblies INCLUDE motor, thermocouples and 700 Watt, electrically heated 1,400°F (760°C) maximum furnace (for the voltage specified in the table). Be advised, motor controls, tachometer display, furnace controls and the display for the thermocouple are purchased as separate items. See the "Instrumentation" section of the Autoclave Engineers Catalog for process instruments and controls. The specifications and descriptions found in this Catalytic Reactor Selection Guide supersede the specification information found in the drawings referenced in the tables below.

Catalog Number	Description SS = ANSI 316 Stainless Steel HC = Hastelloy® C-276	Motor	Power Source	Temperature Rating	General Arrangement Drawing Number	Reactor Subassembly Drawing Number	Weight lb.
CR0005HC05ZH16A	Microclave 50cc HC	Air	120V	650°F (343°C)	40A-2139	40A-2138	47
CR0005HC05ZH16D	Microclave 50cc HC	DC	120V	650°F (343°C)	40A-2140	40A-2138	62
CRHT05HC05ZH16D	Microclave 50cc HC	DC	120V	1000°F (536°C)	40A-7719	40A-7718	62
CR0005HC05ZH26A	Microclave 50cc HC	Air	240V	650°F (343°C)	40A-2139	40A-2138	47
CR0005HC05ZH26D	Microclave 50cc HC	DC	240V	650°F (343°C)	40A-2140	40A-2138	62
CRHT05HC05ZH26D	Microclave 50cc HC	DC	240V	1000°F (536°C)	40A-7719	40A-7718	62
CRA5HC05ZH16A	Micro Robinson 50cc HC	Air	120V	650°F (343°C)	40A-3159	40A-3158	47
CRA5HC05ZH16D	Micro Robinson 50cc HC	DC	120V	650°F (343°C)	40A-3160	40A-3158	62
CRAHT5HC05ZH16D	Micro Robinson 50cc HC	DC	120V	1000°F (536°C)	TBD	TBD	62
CRA5HC05ZH26A	Micro Robinson 50cc HC	Air	240V	650°F (343°C)	40A-3159	40A-3158	47
CRA5HC05ZH26D	Micro Robinson 50cc HC	DC	240V	650°F (343°C)	40A-3160	40A-3158	62
CRAHT5HC05ZH26D	Micro Robinson 50cc HC	DC	240V	1000°F (536°C)	TBD	TBD	62
CRB2HC05ZH16A	Micro Berty Reactor 12cc HC	Air	120V	650°F (343°C)	40A-3174	40A-3173	47
CRB2HC05ZH16D	Micro Berty Reactor 12cc HC	DC	120V	650°F (343°C)	40A-3175	40A-3173	62
CRBHT2HC05ZH16D	Micro Berty Reactor 12cc HC	DC	120V	1000°F (536°C)	40A-7791	40A-6525	62
CRB2HC05ZH26A	Micro Berty Reactor 12cc HC	Air	240V	650°F (343°C)	40A-3174	40A-3173	47
CRB2HC05ZH26D	Micro Berty Reactor 12cc HC	DC	240V	650°F (343°C)	40A-3175	40A-3173	62
CRBHT2HC05ZH26D	Micro Berty Reactor 12cc HC	DC	240V	1000°F (536°C)	40A-7791	40A-6525	62

**NOTE:** The circulating pressure generated by the impellers in the "Micro Series" reactors is low. Autoclave Engineers makes no claims about the ability to scale-up or correlate "Micro Series" catalytic reactors with any other process equipment.

## Catalytic Reactor Accessories

## Catalytic Conversion Kits for NEW (Post 1999) Stirred Reactors

(see notes)

## Catalytic Reactor Ordering Guide

### NOTES:

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<http://www.autoclaveengineers.com> to reach the main page of Autoclave Engineers reactor products. Request assembly drawings of the product(s) of interest to get more technical detail.

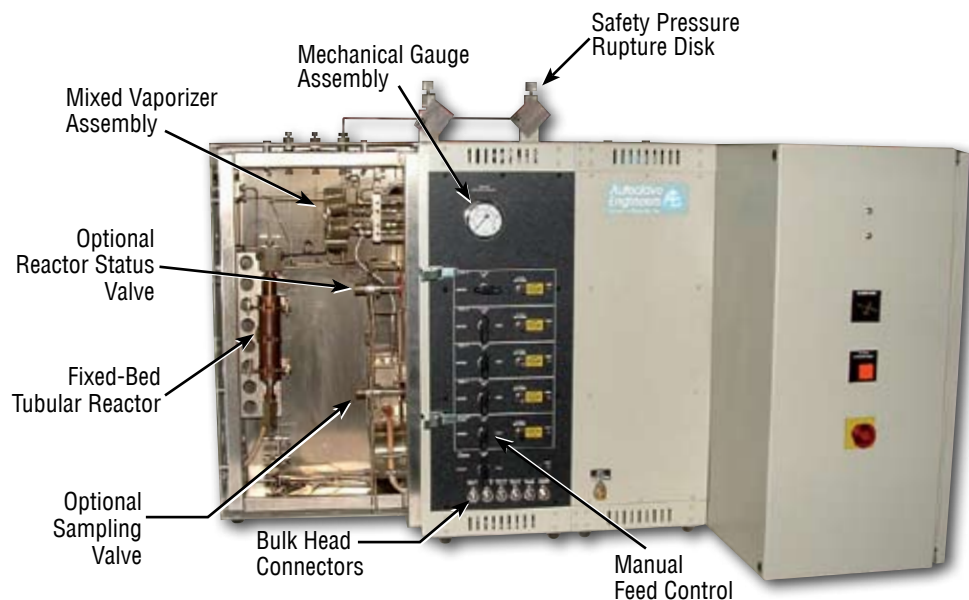
See the "Ordering Guide" of this bulletin to find drawing numbers and contact your local Sales Representative or Autoclave Engineers directly to obtain assembly drawings.

**BTRS-Jr<sup>®</sup>-PC**  
**BTRS-Jr<sup>®</sup>**  
**Micro Scale**  
**Bench-Top**  
**Reaction Systems**

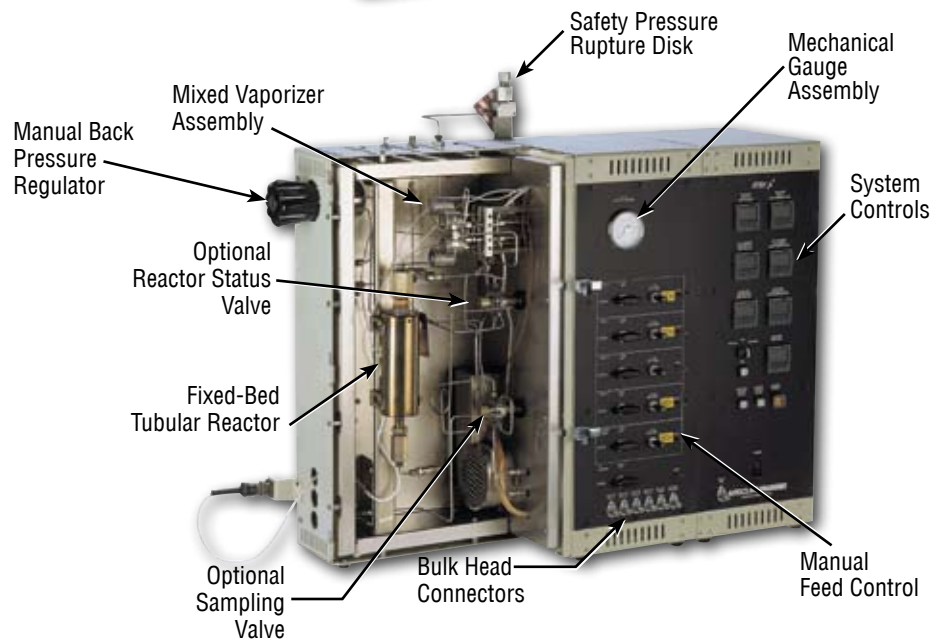
The BTRS are complete, integrated, oven based systems for vapor phase catalyst evaluation. The systems include feed preparation, a fixed bed tubular and product handling. The BTRS-Jr.<sup>®</sup> has manual controls and the BTRS-900 has automated controls. Both units are offered with a variety of options and accessories and operating pressures up to 2,900 psi (200 bar) at 1,202°F (650°C).

The BTRS-Jr<sup>®</sup>-PC is a complete reaction system for vapor phase catalyst evaluation and continuous flow process analysis. The unit is comprised of three major sections, the feed section, the heated process sections, and the control module with supervisory computer system. The majority of the process components are housed within an oven enclosure that is maintained at an isothermal temperature. Request bulletin BTRS-Jr-PC (06-1136SE-1208) for more information.

**BTRS-Jr<sup>®</sup>-PC**



## **BTRS-Jr<sup>®</sup>**



## **BTRS-900 Tube Reactor**

The BTRS-900 is a oven-based, fixed bed reactor system for laboratory scale simulation of continuous flow reactor systems & processes which is equipped with Supervisory Control and Data Acquisition Software (SCADA) for automatic control. The BTRS-900 is a tubular reactor systems with high capacity, dual train capability and equipped with independent temperature controls for key controls & instruments. The pilot scale research system allows scientific studies of flow-through reactor systems



## **Multi-Train BTRS Fischer-Tropsch Reaction System**

**GENERAL DESCRIPTION** - Combinational catalyst screening and evaluation for the Fischer-Tropsch process, petrochemical, hydrocarbon and other specific chemical reactions through our fixed bed and stirred reaction systems.

**FISCHER-TROPSCH: WHAT IS THE PROCESS** - Fischer-Tropsch process and the advances in the technologies and research into the hydrocarbon induced products, coal to liquids, gas to diesel (GTL) and other products such as waxes, solvents and other chemical products. This is not the focus and the future direction.

**FISCHER-TROPSCH: SPECIFIC REACTIONS** - Fischer-Tropsch process is basically the catalyst conversion of synthesis gas which is a mixture of hydrogen and carbon monoxide yielding long chained hydrocarbon molecules. As mentioned, coal to liquids, gas to diesel (GTL) and other products such as waxes, solvents and other chemical products. Autoclave Engineers is now leading the way for research in this process.

**WHY FISCHER-TROPSCH PROJECTS AND INVESTMENTS?** - With soaring oil prices, coal and gas to liquids technologies are becoming more attractive as an alternative route to liquid fuels, Extensive research efforts are underway to realize the full potential of this reaction. Autoclave Engineers expertise facilitates this with our reaction systems approach and engineering support.

**OPTIONS AVAILABLE** - Feed tanks, pumps, wet test meters, mass flow controllers, knock-out pots and GLS.



## Acknowledgements

We acknowledge the accomplishments and contributions of the following authors whose designs and experience have greatly contributed to the enhancement of Chemical Reaction Engineering worldwide:

- Dr. J.M. Berty
- Dr. L. Caldwell
- Dr. J.J. Carberry
- Dr. W.R. Alcorn
- Dr. J.A. Mahoney
- Mr. T.J. Sullivan
- Dr. K.K. Robinson

**Autoclave Engineers** makes *Customized* tools for research.

**Automated Reactor Systems:** Automating inputs and controls is a proven method to eliminate experimental process variation. Automatic data logging can reduce man-hours needed for long-duration experiments.

**In Situ Analytical Instrumentation:** Autoclave Engineers will install any commercially available sensor probe in the reactor vessel (that is rated for the appropriate pressure and temperature) to provide data under actual reaction conditions.

**High Throughput Catalyst Screening (Combinatorial Methodology Applied to Catalysts):** Multiple, automated reactor systems, operating in parallel, can accelerate experimental material development by concurrent sample preparation/evaluation of multiple candidates.

**Sample Handling/Evacuation/Separation/Condensation/Filtering/Purification/Scrubbers/Incinerators/Special Cleaning/Purging Features:** Select commercially available process control elements you need to control chemical interference in the experiment. Autoclave Engineers will integrate the process equipment into complete system to eliminate the source of the interference by process control.

**Safety Systems:** Sensors, controls and interlocks can be designed to minimize the risks of equipment damage and personal injury as well as permit unattended operation.

**Other:** Autoclave Engineers has solved many high pressure/high temperature process problems since 1945. It is likely that a variation of your problem has been solved at least once in those years. Autoclave Engineers invites direct inquiries about special equipment needs.

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06-0047BE-0409

### ! WARNING !

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