Bulletin 5400

Parr Instrument Company

Tubular Reactor Systems

5400

Designing and Building Quality Pressure Apparatus for 125 Years

Series Number:

5400

Type:
Bench Top or Floor Stand

Vessel Sizes, mL:
5 mL - 1000 mL

Standard Pressure MAWP Rating, psi (bar):
3000 (207)
5000 (345)

Maximum Operating Temperature, °C:
350 or 550

Series 5400 Continuous Flow Tubular Reactor Systems

Model 5403 with a 1" inside dia. x 24" length, 3-zone split tube furnace with gas feed system, cooling condenser, gas/liquid separator vessel and automated back pressure regulator.

Tubular reactors are used in continuous flow mode with reagents flowing in and products flowing out. They can be the simplest of all reactor designs. Tubular reactors are often referred to by a variety of names:

- Plug flow reactors
- Pipe reactors
- Packed-bed reactors
- Fixed-bed reactors
- Trickle-bed reactors
- Bubble-column reactors
- Ebullating-bed reactors

Single-phase flow in a tubular reactor can be upward or downward. Two-phase flow can be co-current up-flow, counter-current (liquid down, gas up) or, most commonly, co-current down-flow.

Tubular reactors are used in a variety of industries, including:

- Petroleum
- Petrochemical
- Polymer
- Pharmaceutical
- Waste Treatment
- Specialty Chemical
- Alternative Energy

Tubular reactors are used in a variety of applications, including:

- Carbonylation
- Dehydrogenation
- Hydrogenation
- Hydrocracking
- Hydroformulation
- Oxidative decomposition
- Partial oxidation
- Polymerization
- Reforming
- Fischer-Tropsch Synthesis
- Ammonia Synthesis

Tubular reactors may be empty for homogenous reactions or packed with catalyst or other solid particles for heterogeneous reactions. Packed reactors require upper and lower supports to hold particles in place. Upstream packing often includes inert material to serve as a pre-heat section. Pre-heating can also be done with the Parr internal spiral preheater which keeps incoming reagents close to the heated wall during entry.

It is often desirable to size a tubular reactor to be large enough to fit 8 to 10 catalyst particles across the diameter or annular gap and at least 5 reactor diameters in length.

Tubular reactor systems are highly customizable and can be made to various lengths and diameters and engineered for various pressures, temperatures and materials of construction.

Tubular reactors can have a single wall and be heated with an external electric furnace or they can be jacketed for heating or cooling with a circulating heat transfer fluid. External furnaces are typically rigid, split-tube heaters. Insulation is provided at each end, to minimize heat loss and prevent the end closures from being heated. The heater length is normally divided into one or three separate heating zones, although it can be split into more zones if required.

We can furnish either a fixed internal thermocouple in each zone or a single moveable thermocouple

Open 3-zone Split Tube Furnace with 1" I.D. Tubular Reactor.

in a center line thermowell that can be used to measure the temperature at points along the catalyst bed. External thermocouples are typically provided for control of each zone of the heater, as can be seen in the "Open 3-Zone Split Tube Furnace" photo above.

Gas Feed Systems

Various gas feeds can be set up and operated from a gas distribution rack. In order to deliver a steady flow of gas to a reactor, it is necessary to provide gas at a constant pressure to an electronic Mass Flow Controller. This instrument will compare the actual flow rate delivered to the set point chosen by the user, and automatically adjust an integral control valve to assure a constant flow. Care must be taken to size these controllers for the specific gas, flow rate range and maximum pressure of operation. A mass flow controller needs a power supply and read-out device, as well as a means of introducing the desired set point.

When ordering mass flow controllers, you will need to specify:

1. Type of gas to be metered (e.g. N_2, H_2, CH_4, etc.)
2. Maximum operating pressure of the gas (14, 100, 200, or 300 bar)
3. Maximum flow rate in standard cc's per minute (sccm)
4. Pressure for calibration of the instrument

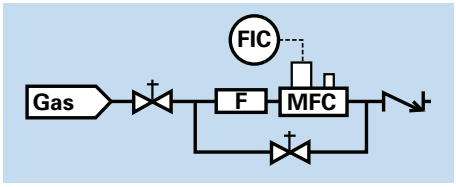
Mass flow controllers are available for use to 100 bar or to 300 bar. Considerable savings can be obtained if the mass flow controller is to be used only to 100 bar.

Series 5400 Tubular Reactor System Specifications

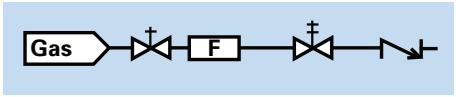
Shaded bar indicates specifications that change within series.

Model Number	5401	5402	5403	5404
Sizes	3/8 in.	1/2 in.	1.0 in.	1.5 in.
O.D. / I.D. (in.)	0.38 / 0.28	0.50 / 0.37	1.50 / 0.99	1.88 / 1.44
O.D. / I.D. (mm)	9.5 / 7.0	13 / 9.5	38 / 25	48 / 36
Heated Length (in.)	6, 12, 24		12, 24, 36	
Maximum Pressure, psi (bar)	3000 (207, 200 for CE orders)		5000 (345)	3000 (207, 200 for CE orders)
Maximum Temperature	550 °C		550 °C	350 °C
Support Spools	No		Optional	
Spiral Pre-Heat	No		Optional	
No. Ports in Top Head	1		4	
No. Ports in Bottom Head	1		4	
Internal Thermocouple	Optional (Moveable or multi-point fixed)			

The schematic at right depicts the installation of a mass flow controller for the introduction of gas to a continuous-flow reaction system. Such installations are enhanced with the addition of a by-pass valve for rapid filling or flushing.



A purge line can also be added. It is typically used for feeding nitrogen or helium to remove air before operation or to remove reactive gases before opening the reactor at the end of a run. The purge line includes a shut-off valve, filter, metering valve, and a reverse-flow check valve.



Shut-off valves can be automated when using a 4871 Control system or 4880 Touchscreen Controller for series 5420 Tubular Reactors. (See page 8).

Liquid Metering Pumps

High pressure piston pumps are most often used to inject liquids into a pressurized reactor operating in continuous-flow mode. For low flow rates, HPLC pumps, many of which are rated for 150-400 bar, are excellent choices.

Typical flow rates for pumps of this type include 0.01-4.0 mL/minute, 0.1-20 mL/minute, and 1.0-40 mL/minute. Pumps are available to accommodate manual flow rate control from their digital faceplate or computer-control from a 4871 Process Controller.

Chemical feed pumps are our recommendation for continuous feeding of liquids when the desired flow rate is greater than 6 liters per hour. Parr can assist with the feed pump selection. We will need to know the type of liquid; the minimum, typical, and maximum desired feed rate; the maximum operating pressure; and any special operating considerations such as explosion proof operation or corrosion possibilities.

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Series Number:
5400

Series 5400 Continuous Flow Tubular Reactor Systems

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Up-flow 5403 Tubular Reactor System with 300 mL heated volume, one purge line, one gas feed, two liquid feeds, product cooling condenser, and automated 2-phase back pressure regulator. An automated liquid sampler captures representative samples at user-programmable intervals.

Cooling Condensers

Cooling condensers are available to cool the reaction products. An adaptation of our standard condensers provide an excellent design.

Back Pressure Regulators

The reactor pressure is maintained by a Back Pressure Regulator (BPR) installed downstream of the reactor. This style of regulator will release products only when the reactor pressure exceeds a preset value by the operator.

When a BPR is used in conjunction with mass flow controllers, the user can maintain a constant flow of gas through a reactor held at elevated constant pressure. This provides for the highest degree of control and reproducibility in a continuous-flow reactor system.

An alternate BPR is also available to permit pressure let-down of a two-phase stream from the reactor. This BPR requires that the operator provide a source of nitrogen or air at a pressure slightly above the desired operating pressure. With this style of BPR, the high-pressure gas/liquid separator can be replaced with a low-pressure liquid product receiver.

Gas/Liquid Separators

Tubular reactors operating in continuous-flow mode with both gas and liquid products will typically require a Gas/Liquid Separator. The separator is placed downstream of the reactor, often separated from the reactor by a cooling condenser. In the separator vessel, liquids are condensed and collected in the bottom of the vessel. Gases and non-condensed vapors are allowed to leave the top of the vessel and pass to the back pressure regulator. It is important to operate the standard BPR with a single fluid phase to prevent oscillation of the reactor pressure.

The Gas/Liquid Separator can be sized large enough to act as a liquid product receiver that is drained periodically. Many of the non-stirred pressure vessels made by Parr are ideally suited for use as Gas/Liquid Separators. Vessels of 300, 600, 1000, or 2000 mL are commonly chosen. Upon request, the bottom of the separator can be tapered and/or automatic liquid drain capability can be added to facilitate draining.

Exploded view of tubular reactor showing reactor vessel, thermocouple, internal spiral channel, spools, split rings, and drop bands.

This continuous flow stirred reactor system is on a cart with our Modular Frame System. This modular frame allows for easy access and flexibility in hook-ups, accessories, and flow, including an interchangeable tubular reactor.

Solids Hopper

Solids hoppers are available which are designed for addition of bulk solids such as catalysts or reactants (i.e. biomass) to a reactor at temperature and pressure. In many applications semi-batch addition of bulk solids into a hot fluid bed, stirred, or other reactor is desired. Parr offers several sizes, including 0.4 L and 1.3 L solids hopper vessels for semi-batch addition of solids at temperature and pressure.

Continuous Bulk-Solids Feeder

Parr's new laboratory-scale automated solids-feed module is designed to continuously deliver free-flowing non-cohesive bulk solids into specially customized Parr continuous stirred, tubular, or fluidized bed reactors.

Control and Data Acquisition Systems

There are three options for control of Parr continuous reactor systems:

Model 4871 Process Logic Controller (PC controlled) enables data logging of process data, programmable safety interlocks, programmable automation, and remote operation (via PC). Automatable features offered include automated pressure control (with ramping capability), automated liquid draining, automated setting of reactant flow rates, automated shutoff valves, and automated sampling. Pre-programmed profiles enable highly reproducible automated test runs. Other features available with the 4871 Process Controller include external vaporization/preheating, differential pressure measurement, physical E-stop button, and analog or digital communication with instruments such as gas monitors and ventilation flow monitors.

Model 4880 3-zone Tubular Touchscreen Controller is also available for use with 5420 series configurable entry level tubular reactor systems with automated shutoff valves, safety interlocks, and data logging. This controller mounts on the reactor flow stand, is not upgradeable, and is designed for use with up to four gas feeds and two liquid feeds.(see pages 8-9)

Model 4848 Reactor Controller (Local Control System) is also available, but limited to control of a single reactor heated zone and monitoring of pressure and temperature. It is not able to control or interlock reactant feeds or interlock more than one heated zone.

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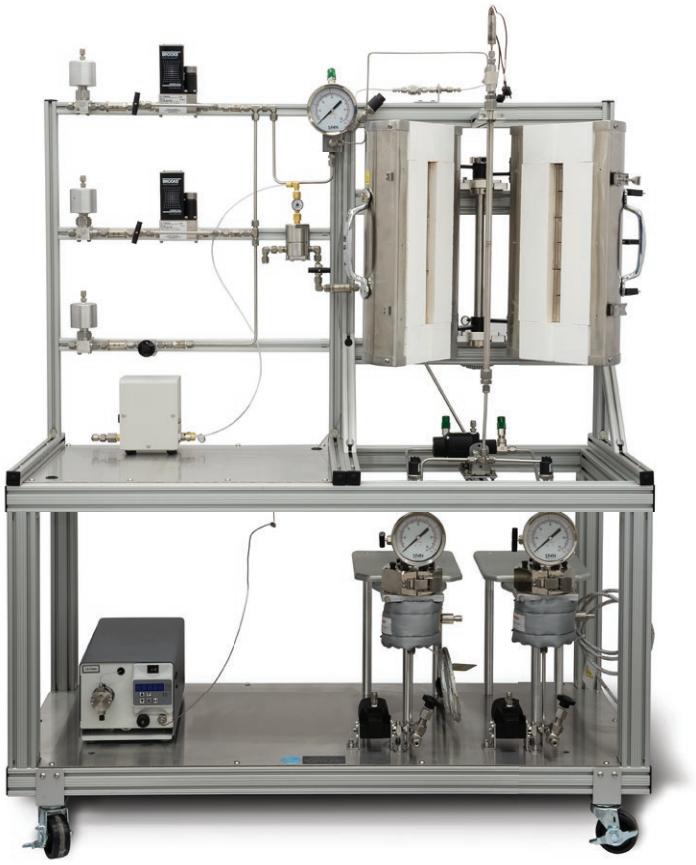

Down-flow 5402 Tubular Reactor System with 20 mL volume, automated shutoff valves to safely shutdown in case of alarm/interlock, two gas feeds, one purge line, one liquid feed, and automated back pressure regulator. Automatically alternates between high pressure liquid collection and draining, with one of two heated gas/liquid separators collecting while the other drains.

Series Number:
5400

Series 5400 Continuous Flow Tubular Reactor Systems

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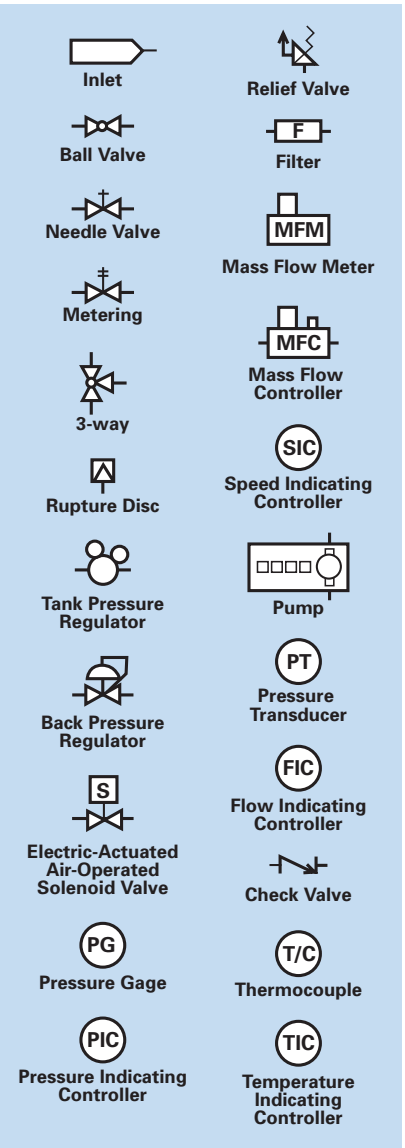
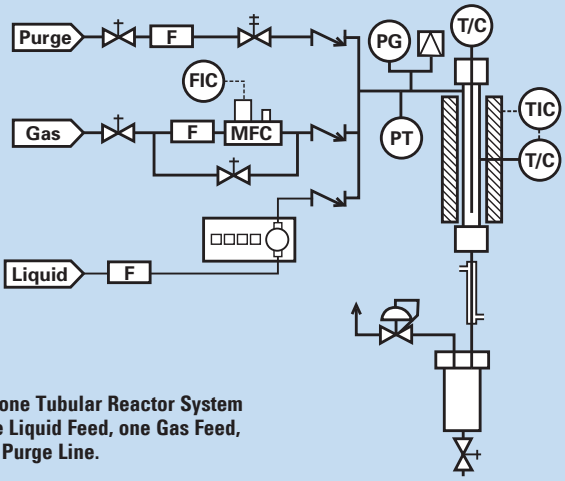
On this page are schematic representations of typical tubular reactor systems, along with a symbols chart to facilitate understanding. We have provided an ordering number for each of these examples.

Key to Symbols

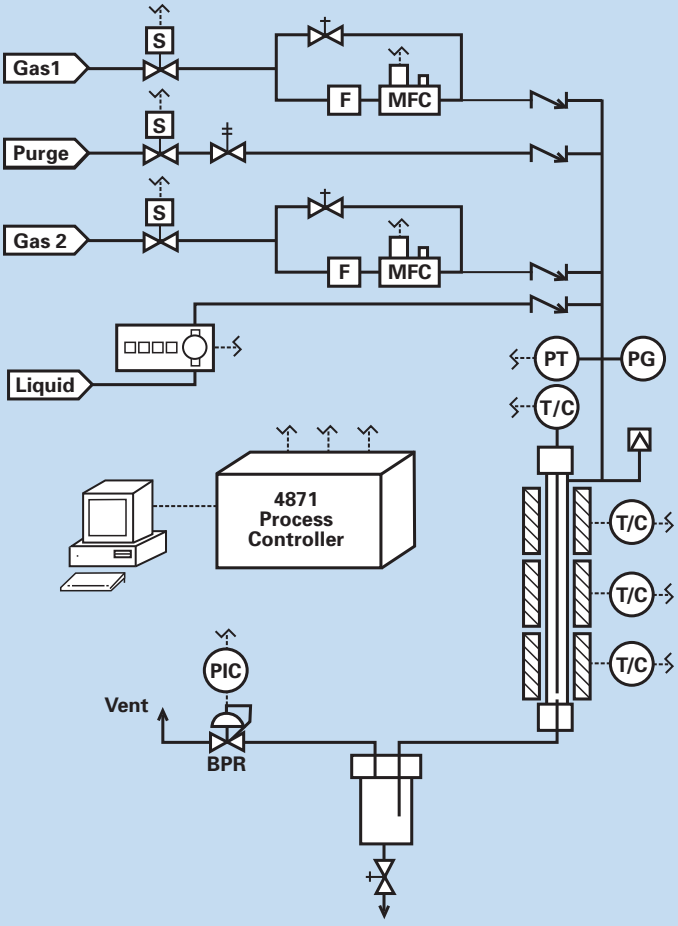


Order No. for this system would be:
5402B-SS-115-ST1(6)-1500-LCS-GF(1)-PL-LF(1)-ITW-CCD-GLS(300)-MPC



Single-zone Tubular Reactor System with one Liquid Feed, one Gas Feed, and one Purge Line.

Order No. for this system would be:
5403F-SS-230-ST3(24)-3000-PCC-GF(2)-PL-LF(1)-ISP-CSS-ITW-GLS(600)-APC-ASV(3)



Series 5400 Ordering Guide

A composite identification number to be used when ordering a 5400 Series Reactor can be developed by combining individual symbols from the separate sections below.

A Base Model	
Model No.	**Size (O.D. / I.D.)**
5401	3/8 in. (0.38" / 0.28")
5402	1/2 in. (0.50" / 0.37")
5403	1.0 in. (1.5" / 0.99")
5404	1.5 in. (1.88" / 1.44")
-F	Floor Stand mounting
-B	Bench Top mounting (≤12" heated length only)

B Materials of Construction	
-SS	T316 Stainless Steel
-A230	Alloy 230
-MO	Alloy 400
-IN	Alloy 600
-800HT	Alloy 800HT
-HC	Alloy C-276
-CS	Alloy 20
-T12	Titanium Grade 2
-T14	Titanium Grade 4

C Electrical Supply	
-230	230 VAC
-115	115 VAC

D Heater Options	
-ST1(#)	Split Tube, 1-zone
-ST3(#)	Split Tube, 3-zone
-FM(#)	Flexible Mantle
-WJ(#)	Welded Jacket
Add suffix for heated length in inches.	
-(6)	6 inches (5401/5402 only)
-(12)	12 inches
-(24)	24 inches
-(36)	36 inches (5403/5404 only)

E Maximum System Pressure	
-200	200 psi / 13.8 bar
-1500	1500 psi / 103 bar
-3000	3000 psi / 207 bar, 200 bar for CE/UKCA
-4500	4500 psi / 310 bar

F Control	
-PCC	PC-based Process Control (Model 4871 for enhanced control options with programming, automatic feed, & interlock)
-LCS	Local Control System (Model 4838)

G Feed	
-GF(#)	Gas Feed (Add required number of feeds)
-PL	Purge Gas Feed Line
-LF(#)	Liquid Feed (Add required number of feeds)

H Product Handling	
-CCD	Cooling Condenser
-GLS(#)	Gas/Liquid Separator (Add Required Volume, mL: 300, 600, 1000, or 2000)

I Pressure Control	
-MPC	Manual Pressure Control
-APC	Automated Pressure Control (Available only with 4871 Process Control)
-ALD	Automated Liquid Drain

J Custom Options (List All Desired)	
-ISP	Internal Pre-heat Spiral (5403/5404 only)
-CSS	Catalyst Support Spools
-CLT	Catalyst Loading Toolkit including: packing rod, corkscrew tool, thermocouple centering tool, and funnel.
-ITW	Internal Thermowell, with Movable T/C
-IZT	Internal, 3-PT, Fixed T/C
-SPH	Separator Heater

K Certifications	
-No Symbol	No Certification Required
-ASME	ASME Certification
-PED	PED Certification
-P	Parr Certification

The system above has three 250 mL tubular reactors operating in parallel and controlled by a 4871 Process Controller with operator interface on a single PC. This system has weighed and/or heated feed tanks and a two-stage pressure let down.

Series Number:

5420

Continuous Flow Tubular Reactor with Touchscreen Control

Type:
Floor Stand

Vessel Sizes, mL:
5 mL - 1000 mL

Standard Pressure
MAWP Rating, psi (bar):
3000 (207, 200 bar for CE)
5000 (345)

Maximum Operating
Temperature, °C,
at High Pressure (HP)
350 or 550

Parr's new Continuous Flow Tubular Reactor with Touchscreen Control was designed with researchers in mind. It offers a compact footprint, easy set-up, and integrated touchscreen control with alarm interlocks, all at a budget-friendly price. Whether for production, research, or teaching unit operations, this system has an impressive collection of capabilities.

Features include:

- Capacity for use of traditional or non-traditional solid catalysts
- Reactor ID's from 0.25" to 1.5" (7 to 38 mm), with lengths of 12" (300 mm), 24" (600 mm), or 36" (900 mm)
- Pressure ratings to 5000 psi (345 bar)
- Temperature ratings to 550 °C
- Gas and Liquid Feeds, Pressure control, Condenser, and Gas/Liquid Separator
- Touchscreen with PID temperature control, gas and liquid feed control, and full data logging with integrated alarm interlocks
- Fully assembled and ready to operate out of the box.

Series 5420 Ordering Guide

A composite identification number to be used when ordering a 5420 Series Reactor can be developed by combining individual symbols from the separate sections below.

A Base Model	
Model No.	**Size (O.D. / I.D.)**
5421	3/8 in. (0.38" / 0.28")
5422	1/2 in. (0.50" / 0.37")
5423	1.0 in. (1.5" / 0.99")
5424	1.5 in. (1.88" / 1.44")

B Materials of Construction	
-SS	T316 Stainless Steel
-A230	Alloy 230
-MO	Alloy 400
-IN	Alloy 600
-800HT	Alloy 800 HT
-HC	Alloy C-276
-CS	Alloy 20
-TI2	Titanium Grade 2
-TI4	Titanium Grade 4

C Electrical Supply	
-230	230 VAC

D Heater Options	
-ST3(#)	Split Tube, 3-zone
Add suffix(#) for heated length in inches.	
-(12)	12 inches
-(24)	24 inches
-(36)	36 inches (5423/5424 only)

E Maximum System Pressure	
-200	200 psi / 13.8 bar
-1500	1500 psi / 103 bar
-3000	3000 psi / 207 bar, 200 bar for CE
-4500	4500 psi / 310 bar

F Feed	
-GF(#)	Number of Gas Feeds (1, 2, 3, or 4)
-LF(#)	Number of Liquid Feed (1 or 2)

G Product Handling	
-CCD	Cooling Condenser
-GLS(#)	Gas/Liquid Separator (300, 600, 1000, 2000 mL)

H Custom Options (List All Desired)	
-ISP	Internal Pre-heat Spiral (5423/5424 only)
-CSS	Catalyst Support Spools
-CLT	Catalyst Loading Toolkit including: packing rod, corkscrew tool, thermocouple centering tool, and funnel.

I Certifications	
-No Symbol	No Certification Required
-ASME	ASME Certification
-PED	PED Certification
-P	Parr Certification

Exploded view of tubular reactor showing reactor vessel, thermocouple, internal spiral channel, spools, split rings, and drop bands.

Series Number:

5410

Fluidized Bed Reactors

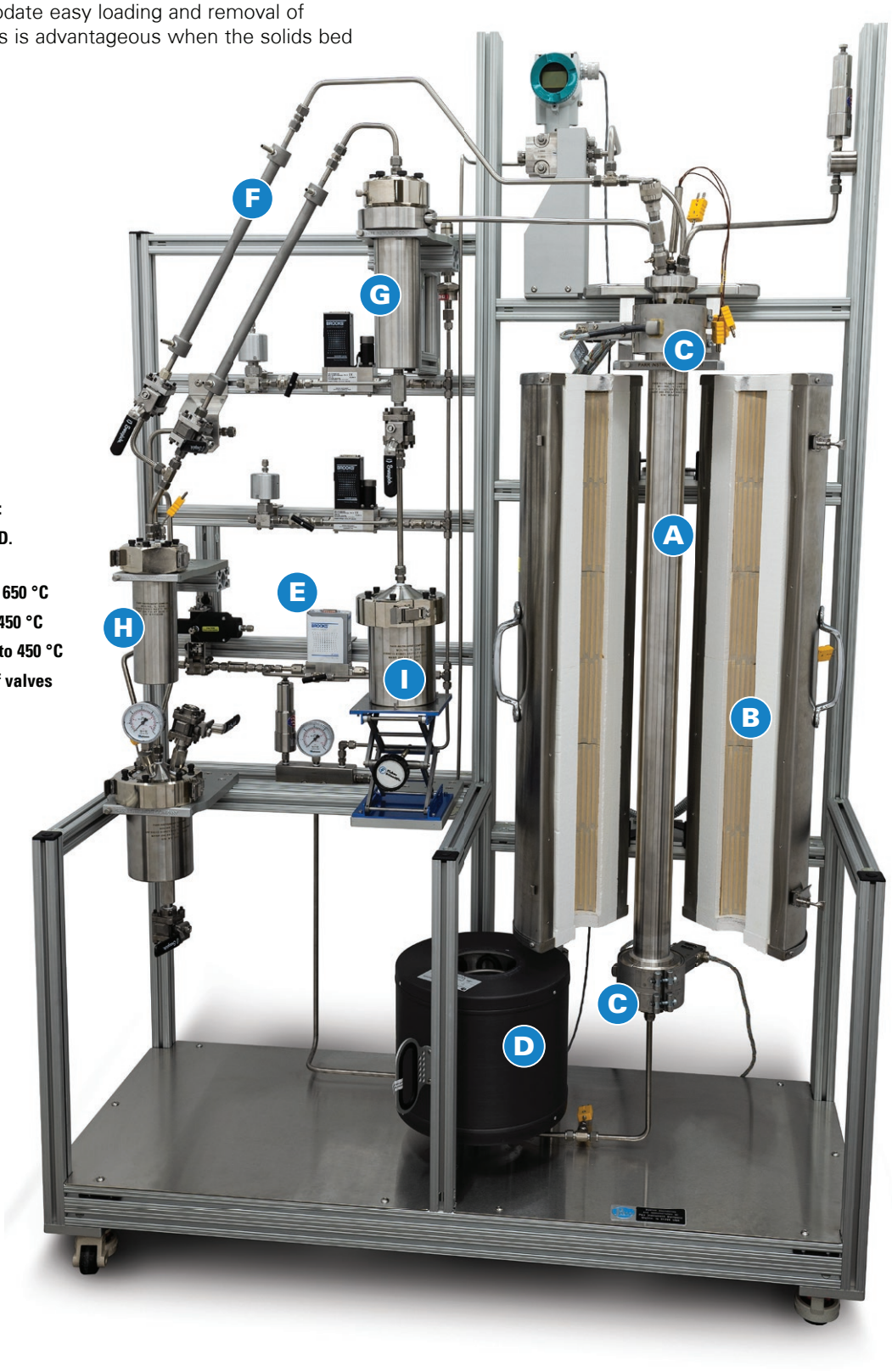
Type:
Floor Stand

Vessel Geometry:
1" ID, 36" length, with 2.5" ID, 2" length disengagement zone or custom

Standard Pressure MAWP Rating, psi (bar):
Up to 3000 (207) based on temperature

Maximum Operating Temperature, °C:
350, 600, or >600

Fluidized Bed Reactors are used extensively in the chemical process industries. The distinguishing feature of a fluidized bed reactor is that the bed of solid particles or catalyst is fluidized by an up flow of gas. This reactor can be designed to accommodate easy loading and removal of catalyst. This is advantageous when the solids bed must be removed and replaced frequently or when a product is a bulk solid. A high conversion with a large throughput is possible with this style of reactor. Such reactors can be configured to provide excellent heat transfer and gas/particle contact.



This Fluidized Bed Reactor System features:

A. **Fluidized Bed Reactor with 2" (50 mm) I.D. and 36" (900 mm) length**
B. **3-Zone Ceramic Heater for heating up to 650 °C**
C. **Band heaters to heat the closures up to 450 °C**
D. **Gas inlet preheater to preheat gases up to 450 °C**
E. **Three gas feeds with automated shut-off valves**
F. **Cooling condenser**
G. **Cyclone separator**
H. **High pressure solids filter**
I. **Solids collection vessel**

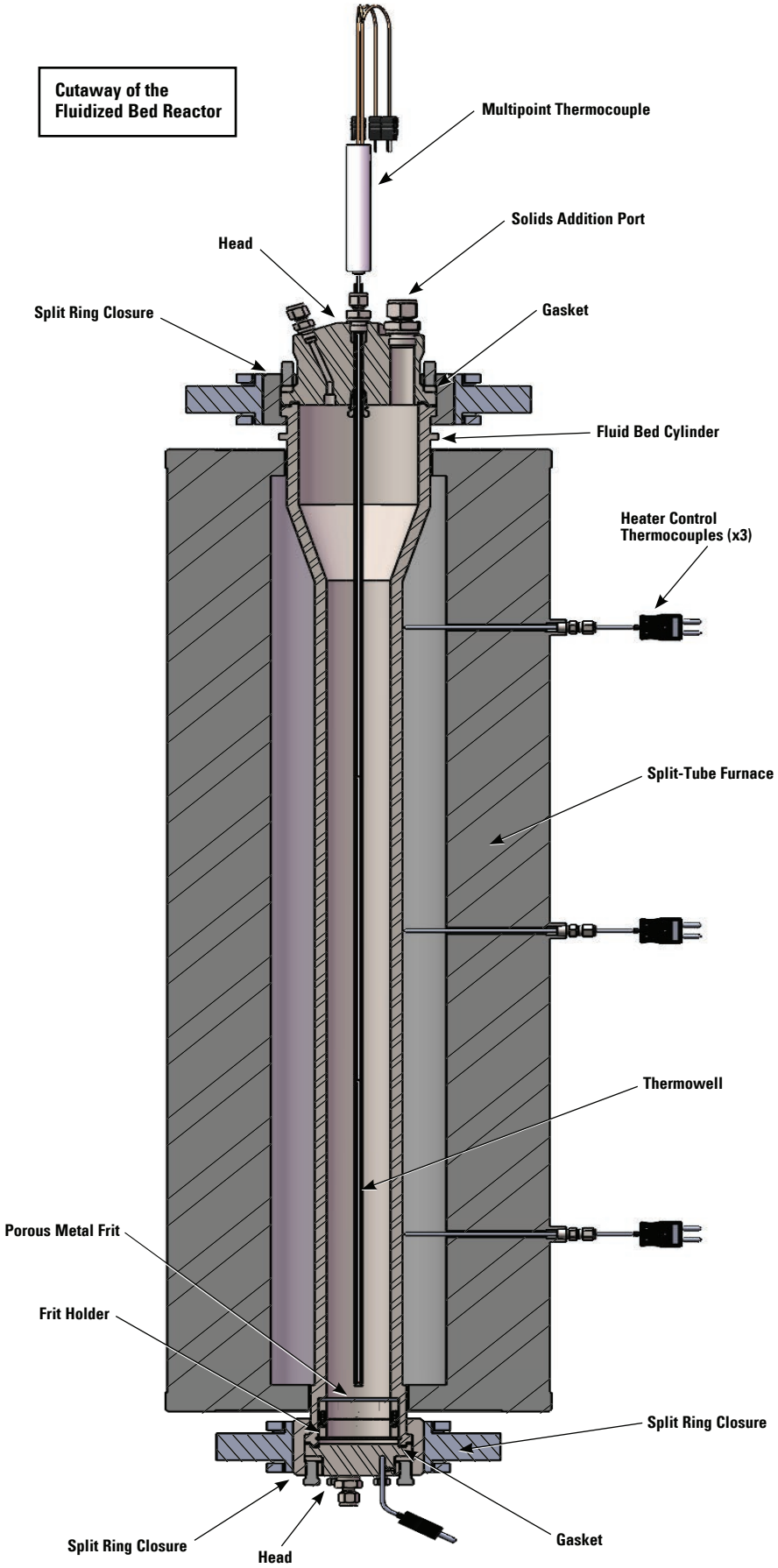
The system is controlled by a Model 4871 Process Controller (not shown).

Fluidized beds have been significantly utilized in chemical processes in which parameters such as diffusion or heat transfer are the major design parameters. Compared to a packed bed, a fluidized bed can enable better control of temperature, elimination of hot spots in the bed, uniform catalyst distribution and longer life of the catalyst. They are also used where a reactant or product is a bulk solid.

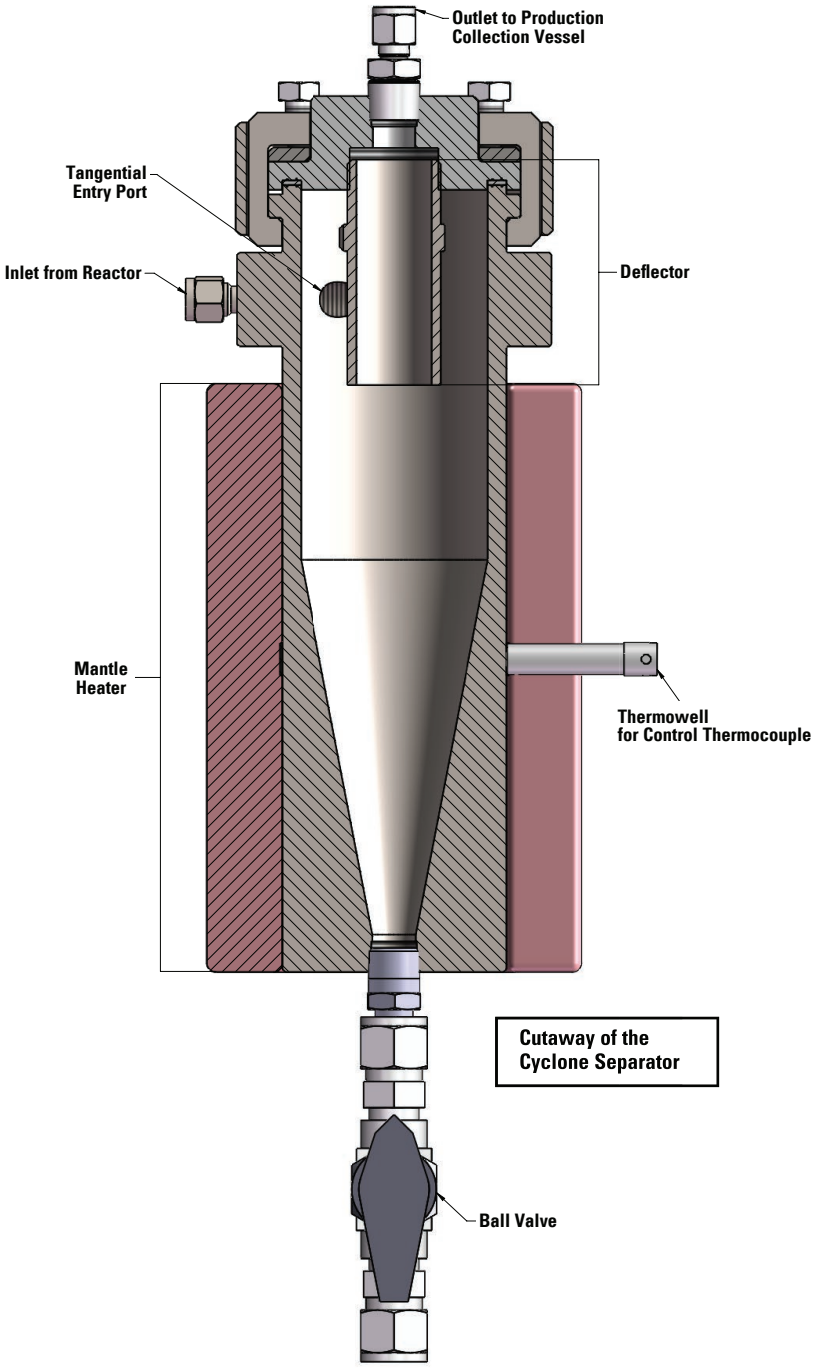
Nearly all significant commercial applications of fluidized bed technology concern gas-solid systems. Applications for fluidized bed reactors include but are not limited to gas-solid reactions, Fischer-Tropsch synthesis, and catalytic cracking of hydrocarbons and related high molecular weight petroleum fractions. Gasification in a fluidized bed can be utilized to convert coal, biomass, and other waste materials into synthesis gas.

The reactor system pictured on the previous page includes the following key components:

- A gas handling and mixing sub-system used to blend, regulate, and pre-heat the flow of reactant gas to the bottom of the reactor.
- The lower portion of the fluidized bed reactor incorporates an easily removable porous metal gas diffusion plate and the top of the reactor widens to form a freeboard or disengagement zone for the fluidized solids.
- A moveable thermocouple in a thermowell is provided for monitoring the internal reactor temperature distribution.
- Internal baffling can optionally be installed.
- A differential pressure transducer capable of measuring pressure drop across or within the bed.
- A heated cyclone separator and high temperature filter is provided immediately downstream of the reactor to capture bulk solids.
- The reaction gases are cooled by a condenser and collected in a product receiver.
- The system pressure can be maintained by an optional automated, dome-loaded, back pressure regulator.
- All system functions and parameters are monitored and maintained by a Parr 4871 Process Controller (not shown).



Fluidized, continued



Ordering Guide

A Base Model	
Model No.	
5410	2" I.D. w/3.75" I.D. Disengagement Zone

B Materials of Construction	
-SS	T316 Stainless Steel
-HC	Alloy 276
-HT	High Temperature Alloy to be determined

See Materials of Construction on page 10 for available alloys

C Electrical Supply	
-115	115 VAC
-230	230 VAC

D Maximum Temperature	
-350	350 °C
-600	600 °C
->600	> 600 °C

E Cylinder Length	
-(36)	36-inches
-(xx)	Other

F Maximum System Pressure	
-200	200 psi / 14 bar
-500	500 psi / 34 bar
-1500	1500 psi / 103 bar
-3000	3000 psi / 207 bar, 200 bar for CE

G Control	
-PCC	PC-based Process Control (4871-style)
-LCS	Local Control System (4838-style)

H Custom Options (List all desired)	
-GF(#)	Number of Gas Feeds (1-3 or TBD)
-PL	Purge Gas Feed Line
-LF(#)	Number of Liquid Feeds (1-3 or TBD)
-ITW	Internal Thermowell, with Moveable T/C
-IZT	Internal, 3-PT, Fixed T/C
-CCD	Cooling Condenser
-GLS(#)	Gas/Liquid Separator (300, 600, 1000, 2000 mL)
-CYC	Cyclone Separator
-SPH	Separator Heater
-MPC	Manual Pressure Control
-APC*	Automated Pressure Control
-ASV(#)*	Automated Shut-off Valves (1-12)
-BSF*	Continuous Bulk Solids Feeder

*Available only with 4871 Process Control (PCC)

I Certifications	
-No Symbol	No Certification Required
-ASME	ASME Certification
-PED	PED Certification
-P	Parr Certification

Please note that all options and combinations are not compatible with all models.

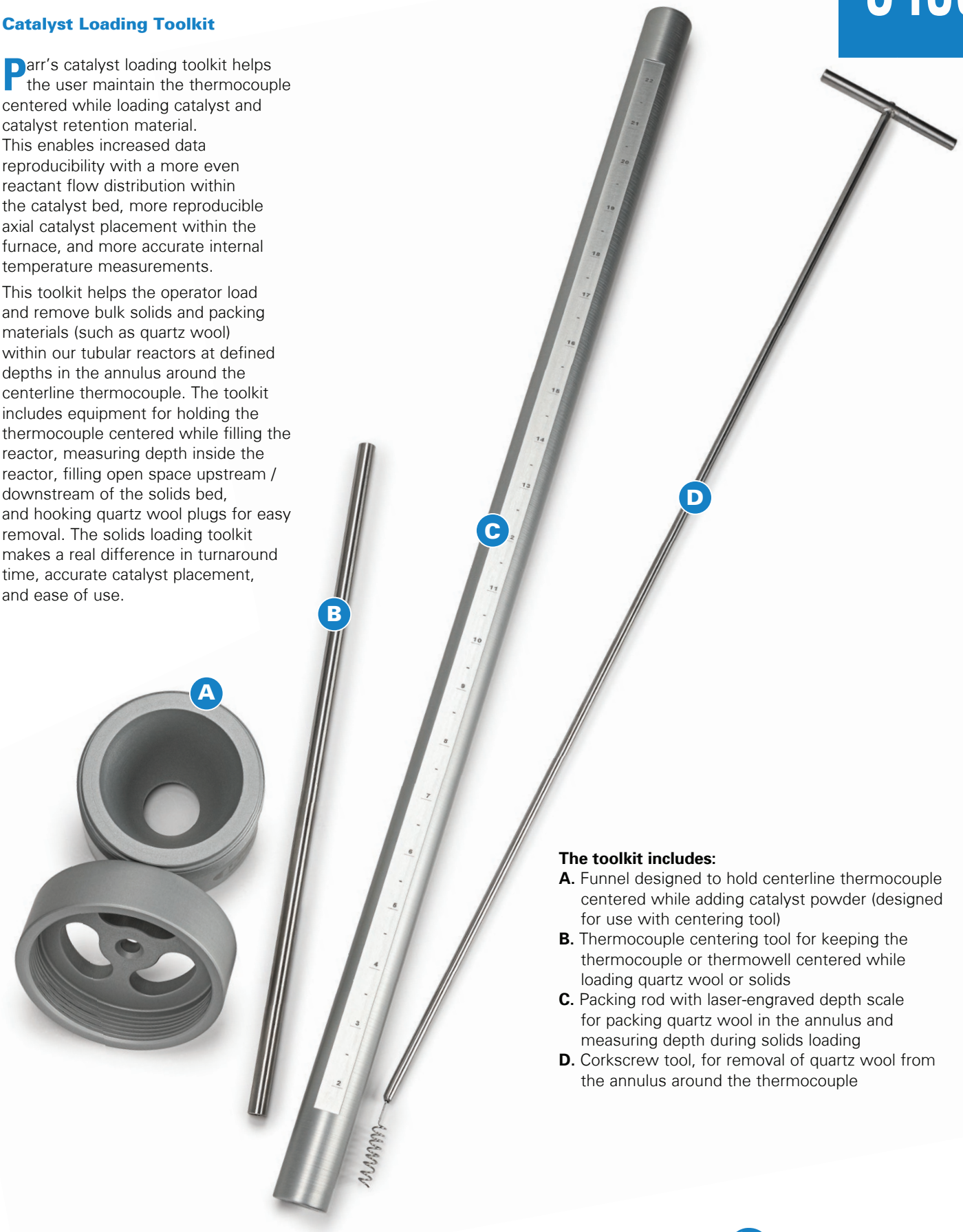
Series Number:
5400

Accessories

Catalyst Loading Toolkit

Parr's catalyst loading toolkit helps the user maintain the thermocouple centered while loading catalyst and catalyst retention material. This enables increased data reproducibility with a more even reactant flow distribution within the catalyst bed, more reproducible axial catalyst placement within the furnace, and more accurate internal temperature measurements.

This toolkit helps the operator load and remove bulk solids and packing materials (such as quartz wool) within our tubular reactors at defined depths in the annulus around the centerline thermocouple. The toolkit includes equipment for holding the thermocouple centered while filling the reactor, measuring depth inside the reactor, filling open space upstream / downstream of the solids bed, and hooking quartz wool plugs for easy removal. The solids loading toolkit makes a real difference in turnaround time, accurate catalyst placement, and ease of use.



The toolkit includes:

A. Funnel designed to hold centerline thermocouple centered while adding catalyst powder (designed for use with centering tool)

B. Thermocouple centering tool for keeping the thermocouple or thermowell centered while loading quartz wool or solids

C. Packing rod with laser-engraved depth scale for packing quartz wool in the annulus and measuring depth during solids loading

D. Corkscrew tool, for removal of quartz wool from the annulus around the thermocouple

Accessories, continued

Continuous Bulk-Solids Feeder

Continuous feeding of bulk solids materials is a technically challenging task, and solids feed equipment is difficult to source, especially for high pressure processes and for the minimal feed rates often required for laboratory and small pilot scale work.

Parr's new laboratory-scale automated solids-feed module is designed to continuously deliver free-flowing non-cohesive bulk solids into specially customized Parr continuous stirred, tubular, or fluidized bed reactors. Designed for a maximum particle size of 2 mm (or 4 mm for larger systems), the automated bulk solids feed system includes a rechargeable solids hopper, hopper isolation valves, and variable speed auger motor. Feed rates are measured on a volumetric basis as calculated from the auger rotation speed.

Bulk-solids material of many types and sizes can be loaded under high pressure using the Parr Bulk-Solids Feeder.

Accessories Ordering Guide

Accessories	
Part No.	
-CLT	Catalyst Loading Toolkit including: packing rod, corkscrew tool, multiple spool pieces, thermocouple centering tool, and funnel.
-BSF	Continuous Bulk Solids Feeder
-ISP	Internal Pre-heat Spiral (5403/5404/5423/5424 only)
-CSS	Catalyst Support Spools (5403/5404 only)

Internal Pre-heat Spiral

Internal spiral channels keep incoming reagents close to the heated wall during entry.

Catalyst Support Spools

Catalyst Support Spools can be added to the reactor to vary the length to diameter ratio.

The Parr Limited Warranty

Parr Instrument Company (Parr) combustion bombs, calorimeters, reactors, pressure vessels and associated products are designed and manufactured only for use by or under the direct supervision of trained professionals in accordance with specifications and instructions for use supplied with the products. For that reason, Parr sells only to professional users or distributors to such users. Parr produces precision equipment and associated products which are **not intended for general commercial use.**

EXCLUSIVE WARRANTY

To the extent allowed by law, the express and limited warranties herein are the sole warranties. **Any implied warranties are expressly excluded,** including but not limited to implied warranties of merchantability or fitness for a particular purpose.

WARRANTY CONDITIONS:

1. **Non-assignable.** The warranties herein extend only to the original purchaser-user and to the distributors to such users. These warranties or any action or claims based thereon are **not assignable or transferable.**
2. **Use of product.** The warranties herein are applicable and enforceable only when the Parr product:
   a. Is installed and operated in strict accordance with the written instructions for its use provided by Parr.
   b. Is being used in a lawful manner.
   c. Has not been modified by any entity other than Parr Instrument Company.
   d. Has been stored or maintained in accordance with written instructions provided by Parr, or if none were provided, has been stored and maintained in a professionally reasonable manner.
3. **The user's responsibility.** Parr engineers and sales personnel will gladly discuss available equipment and material options with prospective users, but the final responsibility for selecting a reactor, pressure vessel or combustion bomb which has the capacity, pressure rating, chemical compatibility, corrosion resistance and design features required to perform safely and to the user's satisfaction in any particular application or test must rest entirely with the user – not with Parr. It is also the user's responsibility to install the equipment in a safe operating environment and to train all operating personnel in appropriate safety, operational and maintenance procedures.
4. **Warranty period.** Unless otherwise provided in writing by Parr, the warranties herein are applicable for a period of one year from date of delivery of the product to the original purchaser/user. Note, however, that there is no guarantee of a service life of one year after delivery.
5. **Notification.** To enforce any express warranty created herein, the purchaser/user must notify Parr in writing within thirty (30) days of the date any defect is detected. Upon request of Parr, the part or product involved must be returned to Parr in the manner specified by Parr for analysis and non-destructive testing.

EXPRESS WARRANTIES

Subject to the above Conditions, Parr expressly warrants that its products:

1. Are as described in the applicable Parr sales literature, or as specified in Parr shipping documents.
2. Will function as described in corresponding Parr sales bulletins or, for specially engineered assemblies, as stated in the sales proposal and purchase agreement.
3. Will remain free from defects in materials and workmanship for the Warranty Period.

LIMITATIONS ON THE PARR WARRANTY

As to the original purchaser/user and to the distributors to such users, Parr limits its liability for claims other than personal injury as follows:

1. **Replacement or repair.** With respect to express warranties herein, Parr's only obligation is to replace or repair any parts, assemblies or products not conforming to the warranties provided herein.
2. **Disclaimer of consequential damages.** In no event shall Parr be liable for consequential commercial damages, including but not limited to: damages for loss of use, damages for lost profits, and damages for resulting harm to property other than the Parr product and its component parts.

INDEMNITY AND HOLD HARMLESS

Original purchaser-user agrees to indemnify and hold Parr harmless for any personal injuries to original purchaser-user, its employees and all third parties where said injuries arise from misuse of Parr products or use not in accordance with specifications and instructions for use supplied with the Parr products.

Parr Instrument Company

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