Parr Instrument Company

Tubular Reactor Systems

Designing and Building Quality Pressure Apparatus for Over 100 Years

5400
Tubular reactors are always used in a continuous flow mode with reagents flowing in and products being removed. They can be the simplest of all reactor designs. Tubular reactors are often referred to by a variety of names:

- Pipe reactors
- Packed-bed reactors
- Trickle-bed reactors
- Bubble-column reactors
- Ebulating-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 can have a single wall and be heated with an external furnace or they can be jacketed for heating or cooling with a circulating heat transfer fluid. External furnaces can be rigid, split-tube heaters or be flexible mantle heaters. Tubular reactors are used in a variety of industries:

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

Tubular reactors are used in a variety of applications:

- Carbonylation
- Dehydrogenation
- Hydrogenation
- Hydrocracking
- Hydroformulation
- Oxidative decomposition
- Partial oxidation
- Polymerization
- Reforming

Tubular reactors may be empty for homogenous reactions or packed with catalyst particles for heterogeneous reactions. Packed reactors require upper and lower supports to hold particles in place. Uppermost packing is often of inert material to serve as a pre-heat section. Pre-heating can also be done with an internal spiral channel to keep incoming reagents close to the heated wall during entry, as shown above.

It is often desirable to size a tubular reactor to be large enough to fit 8 to 10 catalyst particles across the diameter and be at least 40-50 particle diameters long. The length to diameter ratio can be varied to study the effect of catalyst loading by equipping the reactor with “spools” to change this ratio.

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

We provide a split-tube furnace for heating these vessels. Insulation is provided at each end so that the end caps are not heated to the same temperature as the core of the reactor. The heater length is normally divided into one, two, or three separate heating zones, although it can be split into as many zones as required.
When ordering mass flow controllers, you will need to specify:
1. Type of gas to be metered (e.g. N2, H2, CH4)
2. Maximum operating pressure of the gas (100 or 300 bar)
3. Maximum flow rate range in standard cc's per minute (sccm)
4. Pressure for calibration of the instrument

Mass flow controllers are available for use to 1500 psi and to 4500 psi. Considerable savings can be obtained if the mass flow controller is to be used only to 1500 psi.

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

Shut-off valves can be automated when using a 4871 Control system.
Series 5400 Continuous Flow Tubular Reactors

Liquid Metering Pumps
High pressure piston pumps are most often used to inject liquids into a pressurized reactor operating in a continuous-flow mode. For low flow rates, HPLC pumps, many of which are rated for 5000 psig, are excellent choices. Typical flow rates for pumps of this type range up to 10 or 40 mL per minute. Pumps are available to accommodate manual 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 2 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 corrosion possibilities.

Back Pressure Regulators
In addition to supplying gases to a reaction through electronic mass flow controllers, the reactor is kept at a constant pressure by installing a Back Pressure Regulator (BPR) downstream of the reactor. This style of regulator will release products only when the reactor pressure exceeds a preset value.

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

Cooling Condensers
It is often desired to cool the products of the reaction prior to handling them. Cooling condensers are available for this purpose. An adaptation of our standard condensers provides an excellent design.
Gas/Liquid Separators

Tubular reactors operating in continuous-flow mode with both gas and liquid products will also require a Gas/Liquid Separator for smooth operation. 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 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 can be manually 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.

Control and Data Acquisition Systems

A variety of solutions exist to meet the needs of system operators. System accessories such as heaters, mass flow controllers, and pumps can be obtained with individual control packages to create a manual, Distributed Control System (DCS) based on our 4838 and 4848 Controllers.

As the number of channels to be controlled increases, economics and convenience will often dictate that the distributed system of individual controllers should be replaced with the computer-based Model 4871 Process Controller (PCC).
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**

- **Inlet**
- **Ball Valve**
- **Needle Valve**
- **Metering**
- **3-way**
- **Rupture Disc**
- **Tank Pressure Regulator**
- **Back Pressure Regulator**
- **Electric-Actuated Air-Operated Solenoid Valve**
- **Pressure Gage**
- **Pressure Indicating Controller**
- **Mass Flow Meter**
- **Mass Flow Controller**
- **Flow Indicating Controller**
- **Speed Indicating Controller**
- **Temperature Indicating Controller**
- **Pressure Regulator**
- **T/C**
- **PT**
- **TIC**
- **PIC**
- **F**
- **S**
- **G**
- **B**
- **M**
- **FIC**
- **PIC**
- **MFC**
- **SIC**
- **P**
- **CCD**
- **GF**
- **GLS**
- **PCC**
- **APC**
- **ASV**

**Order No. for this system would be:**

**5402B-SS-115-ST1(6)-1500-DCS-GF(1)-PL-LF(1)-ITW-CCD-GLS(300)-MPC**

**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)**

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

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Size (O.D. / I.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5401</td>
<td>3/8 in. (0.38&quot; / 0.28&quot;)</td>
</tr>
<tr>
<td>5402</td>
<td>1/2 in. (0.50&quot; / 0.37&quot;)</td>
</tr>
<tr>
<td>5403</td>
<td>1.0 in. (1.9&quot; / 1.0&quot;)</td>
</tr>
<tr>
<td>5404</td>
<td>1.5 in. (2.0&quot; / 1.5&quot;)</td>
</tr>
</tbody>
</table>

Add suffix F for Floor Stand mounting  
Add suffix B for Bench Top mounting

### B. Materials of Construction

- **-SS** T316 Stainless Steel  
- **-HC** Alloy 276  
- **-TI** Titanium  
- **-IN** Alloy 600  
- **-MO** Alloy 400

### C. Electrical Supply

- **-115** 115 VA, 50/60Hz  
- **-230** 230 VAC, 50/60Hz

### D. Heater Options

- **-ST1(#)** Split Tube, 1-Zone  
- **-ST3(#)** Split Tube, 3-Zone  
- **-FM(#)** Flexible Mantle  
- **-WJ(#)** Welded Jacket

Add suffix (6), (12), (24), (36) for heated length (in.)

### E. Maximum Operating Pressure

- **-1500** 1500 psi / 100 bar  
- **-3000** 3000 psi / 200 bar  
- **-4500** 4500 psi / 300 bar

### F. Controller

- **-PCC** PC-based Process Control (4871-style)  
- **-DCS** Distributed Control System (4838-style)

### G. Custom Options

- **-GF(#)** Number of Gas Feeds  
- **-PL** Purge Gas Feed Line  
- **-LF(#)** Number of Liquid Feeds  
- **-ISP** Internal Pre-heat Spiral (5403/5404 only)  
- **-CSS** Catalyst Support Spools (5403/5404 only)  
- **-ITW** Internal Thermowell, with Movable T/C  
- **-IZT** Internal, Zoned, Fixed T/Cs  
- **-CCD** Cooling Condenser  
- **-GLS(#)** Gas/Liquid Separator (300, 600, 1000, 2000 mL)  
- **-SPH** Separator Heater  
- **-MPC** Manual Pressure Control  
- **-APC** Automated Pressure Control  
- **-ASV(#)** Automated Shut-off Valves (1-12)

*Available only with 4871 Process Control (PCC)

### H. Certifications

- **-No Symbol** No Certification Required  
- **-PARR** Parr Certification  
- **-ASME** ASME Certification  
- **-PED** PED Certification  
- **-C** China
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.