Stirred Reactors and Pressure Vessels

Designing
and Building
Quality
Pressure
Apparatus
for Over
100 Years

Chapter 3

10

This pdf is chapter three of our Catalog 4500.
Please refer to all five chapters to make the proper equipment choice for your needs.

Optional Fittings

Optional Fittings 3

Heaters

Parr has designed standard electrical heaters for all of the reactors in our product line. Different types of heaters are used for individual reactors to best meet the operational needs, heating load, and expected operating temperatures. The standard heater type and power rating for each reactor model is listed in the reactor specification tables. The standard designs will typically be one of the following:

Clamp-On Band Heater.

These are normally used for very small reactors where maximum watt densities and heat transfer are required due to the limited surface area available on the vessel.

Rigid Heating Mantles.

These are quartz fabric mantles housed in aluminum shells. They are used on moderate sized reactors in designs where the heater can be moved on or off the vessel. They are light weight and easy to handle, but they are not used to support the weight of the vessel and they are generally limited to operating temperatures of 350 °C or less.

Calrod-Type Sheathed Element Heaters.

These are rugged heaters with Calrod-type elements held within a metal shell. They are used for medium to large reactors for operating temperatures to 350 °C. In some cases the heater shell itself forms a part of the reactor support. An advantage of Calrod heaters is that the heating elements are easily replaceable.

Ceramic Heaters.

These are special purpose heaters with an electric element embedded in a shaped ceramic body which is held within an insulated metal housing. They are used for reactors designed for temperatures to 600 °C and for large multi-zone heaters.

Optional and Custom Heaters.

Parr offers a variety of heater designs which can be substituted for the standard heater normally furnished with each reactor. Most of these can also be used with Parr non-stirred pressure vessels as well. The principal features and recommended applications for these heaters are described below.

Flexible Heating Mantles.

These can be furnished for many different applications. These are similar to the rigid type described above except they are not held in an aluminum housing. They have a flexible fabric outer case for electrical and thermal insulation. This type of mantle is particularly useful for heating vessels with irregular shapes, such as those with windows in the cylinder wall, since they are flexible and can be split and laced onto a vessel around any external protrusion. As with rigid mantles, they will produce temperatures up to 350 °C, but they are limited to watt densities of 10 watts per square inch. This type of heater can be made to cover any of the vessels offered by Parr, and they are sometimes preferred when only moderate temperatures are required. Since they are constructed of cloth, an electrical ground wire cannot be provided.

Note: These heaters are not CE approved

Aluminum Block Heaters.

These are available on special order for nearly all Parr reactors and pressure vessels. For the 5 gallon and 10 liter vessels they are made by casting a Calrod-type heating element into an aluminum jacket which is designed and machined to fit the outside contours of the vessel to be heated. The heater is cast in two halves which are bolted together and clamped onto the vessel. A cooling coil is cast into the block and used either for cooling with cold water or heating with steam or other liquid. For vessels of 2 gallons or less the heaters are machined from solid blocks of aluminum and heater wells are machined into the walls of the block. Cooling channels can also be machined into the walls of these heaters

Aluminum block heaters have three distinct features which recommend them for many applications:

1. **Since the heating elements are sealed** within these housings, explosive vapors cannot reach them and the heater can be considered explosion proof, provided it is equipped with explosion proof wiring and a safety cut-out to ensure that the heater will not exceed a specified temperature limit allowed for the explosive atmosphere.
2. **With heat spread uniformly** throughout the aluminum block, uniform heating is applied to all surfaces of the vessel, comparable to the rapid response obtained with a steam or hot oil jacket, but without requiring costly steam generators, oil baths, circulating pumps and other accessory equipment.
3. **Since there is a cooling coil** in the aluminum block, this style heater can also provide external cooling for controlling an exothermic reaction without the internal clutter and cleaning problems associated with internal cooling coils. Eliminating an internal coil also permits the use of spiral, anchor or other stirrers which cannot be used with an internal coil.

Circulation Jackets.

A jacket can be welded to the outer wall of most Parr pressure vessels to provide a means for heating or cooling the vessel with a hot or cold liquids or steam. This type of heating is ideal for users who want to duplicate plant operating conditions, using a jacketed reactor comparable to jacketed equipment used in their plant. Since there are no electrical components in a jacket, and since the maximum temperature can be controlled by controlling the temperature of the heating medium, a jacketed vessel will be accepted as explosion proof and suitable for use in hazardous atmospheres.

Rapid and uniform heating can be attained with a jacketed vessel since the heating medium is in direct contact with the vessel. And by controlling the temperature of the heating medium, temperature overshoots can be avoided when working with sensitive materials. Standard jackets are designed for operating pressures up to 100 psig (7 bar) within the jacket. Higher pressure jackets can be provided if required.

Aluminum Block Heater with Cooling Channel and Heat Shield for 1000 mL Vessel.

Cylinder, 2000 mL with Welded Circulating Jacket.

Stirrer Motors and Drives

Torque vs. Stirring Speed

The standard, open-type, variable speed motor installed on each Parr reactor will produce stirring speeds from zero to between 600 and 800 rpm with a torque adequate to drive the installed impellers in average viscosity mixtures. Higher horsepower motors and special stirrers can be provided for higher viscosities, and drive pulleys can be changed to produce higher stirring speeds, but several basic rules must be considered when changing any of these components.

The highest torque from any motor is obtained at lower stirring speeds. Increasing the stirring speed reduces the torque in inverse proportion to the speed. For operations involving high viscosity mixtures, the motor size, the type of impeller and the stirring speed must be matched to provide an effective mixing system.

As a general rule, the magnetic coupling installed on each Parr reactor will have a torque rating considerably higher than the torque obtainable from any of the motors offered for use with that apparatus, thus the magnetic drive should be able to handle any of the optional motor/stirrer combinations.

Explosion Proof Motors

Explosion proof motors designed for Class I, Groups C and D and Class II, Groups F and G with variable speed control can be furnished for any Parr reactor.

Air Motors

Air-driven motors can be installed on most reactors. The horsepower rating, torque, and available speed are all dependent upon the pressure and available volume of the driving air source. Maximum torques are delivered at relatively slow speeds and maximum horsepower is delivered at high speed.

Geared, Direct Drive Motors

A geared, direct drive motor can be installed on most fixed head floor stand reactors. This is an attractive arrangement for handling heavy stirring loads.

Any 1/4 hp or larger, variable-speed standard or explosion-proof motor can be used. Gear box drives are available with ratios of 3:1, 5:1 and 10:1. The 1800 rpm maximum speed will be reduced in an amount determined by the reduction ratio of the gear box, and the associated torque values from the table will be increased in the same ratio.

Stirrer Drive Motors

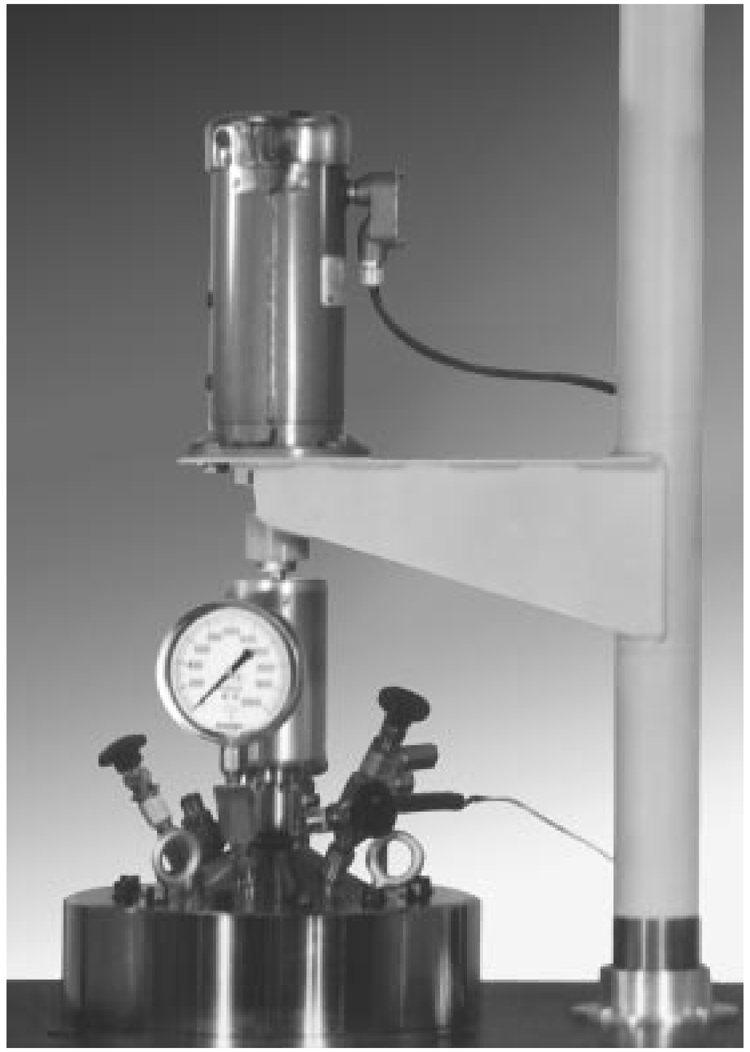
				Standard Pulley		Optional Pulley	
Motor Designation	*HP Rating*	*Explosion Proof*	*Variable Speed*	*Max Speed RPM*	*Max Torque in-lb*	*Max Speed RPM*	*Max Torque in-lb*
-VS.12	1/8	No	Yes	700	11	1800	4
-XP.25	1/4	Yes	Yes	700	22	1800	9
-AM.25	1/4	Yes	Yes	1000	10	2500	15
-VS.25	1/4	No	Yes	700	22	1800	9
-VS.50	1/2	No	Yes	700	45	1800	18
-XP.50	1/2	Yes	Yes	700	45	1800	18
-AM.50	1/2	Yes	Yes	1000	40	2500	30
-VS.75	3/4	No	Yes	700	68	1800	27
-XP.75	3/4	Yes	Yes	700	68	1800	27

Note: Some motor combinations may deliver more torque than a specific magnetic drive can transmit. Check for match.

VS = variable speed, XP = explosion proof, AM = air motor

1 in-lb = 0.11 Nm

1 hp = 0.75 Kw



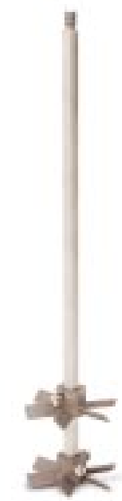
5 Gallon Reactor with Direct Drive, Variable Speed Motor

Geared Drive Motor with Cover Removed

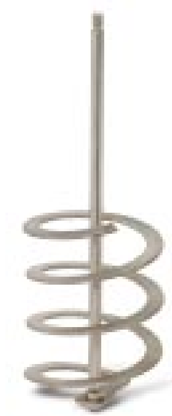
Gear Box Torques

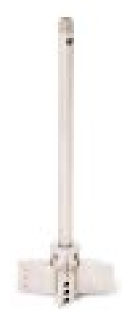
	3:1 Gear Box		5:1 Gear Box		10:1 Gear Box	
Motor HP Rating	*Max Speed RPM*	*Max Torque in-lb*	*Max Speed RPM*	*Max Torque in-lb*	*Max Speed RPM*	*Max Torque in-lb*
1/4	600	27	360	45	180	90
1/2	600	54	360	90	180	180
3/4	600	81	360	135	Not Recommended	

Stirrer Options


Turbine Type Impeller


Anchor Stirrer


Spiral Agitator


Gas Entrainment Impeller


Paddle Type Impeller


Anchor Type Impeller with Wiper Blades

Turbine Type Impellers

Parr reactors are usually equipped with turbine type impellers which produce an excellent mixing action over the range of stirring speeds at which these reactors typically operate. These impellers are made in four-blade and six-blade styles, with the smaller four-blade impellers used only on Micro and Mini Reactors. These impellers, for reactors with 300 mL volume or greater, may be positioned anywhere on the stirring shaft, with one impeller usually located near the bottom of the vessel to keep solids up in suspension and a second impeller positioned near the base of the vortex to pull reactant gases down into the liquid phase. These impellers generally provide excellent mixing for systems with effective viscosities up to approximately 25,000 centipoise with a 16 in-lb magnetic drive or up to 50,000 cP with 60 in-lb magnetic drive.

Anchor Stirrers

Anchor stirrers are available in several configurations for use with moderate to high viscosity materials. This type of stirrer usually works best in vessels with an inside depth to diameter ratio of 1.5 to 1 or less. They are intended to operate at relatively slow speeds and generally require a heavy duty drive system capable of generating and delivering sufficient torque to the agitator. Footless magnetic drives work well with anchor or spiral stirrers. Three basic types are offered:

1. A U-shaped, flat bar anchor.
2. A flat blade, paddle type anchor.
3. A two-arm or three-arm, self centering anchor with PTFE wiper blades.

   All of these designs may not be appropriate or available for each reactor size. Please contact the Parr Technical Service Department for assistance in selecting an anchor stirrer suitable for the intended operating volume and viscosities.

Spiral Stirrers

Spiral stirrers can be installed in any 1 liter, 2 liter or 1 gallon reactor to produce a positive down thrust or upward thrust action when working with viscous polymers or other high viscosity mixtures. They work best in floor stand reactors with adjustable speed, heavy duty drive systems. Either left-hand (down thrust) or right hand (upward thrust) spirals are available. The down thrust spiral is generally preferred for heavy suspensions.

Gas Entrainment

Gas Entrainment Impellers

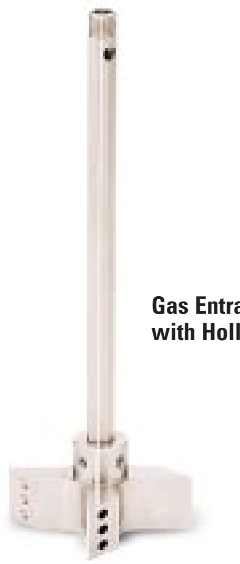
Parr offers a new series of gas entrainment impellers for users who want to obtain maximum gas dispersion into a liquid system. This is obtained with a unique impeller attached to a hollow stirring shaft through which gases are continuously recirculated from the head space above the liquid thru the impeller into the liquid phase. As with all impellers, the speed of the stirrer creates a vacuum at the tip of the impeller. Gas enters openings near the top of the shaft and is pulled through dispersion ports located at the tips of the impellers. In the Parr system with dispersion ports located at the very tips of the impellers, the higher the stirring speed — the higher the vacuum — and the higher the driving force for this very effective gas dispersion system.

These impellers are offered as a complete package which includes the impeller, the hollow shaft with coupling, and any required foot bearings and brackets for the intended reaction. The baffles are a separate option which must be ordered individually.

Since these gas entrainment impellers operate best in the 1000 - 1200 rpm range, users will want to ensure that their stirrer drive system is set up to deliver these operating speeds, alternate pulleys and belts are available to convert existing reactor systems.

Baffles

Because it is the relative speed of the tip of the impeller to the liquid phase that governs the mass transfer, baffles, which impede the rotation of the liquid with the impeller, can greatly enhance the operation of these gas entrainment impellers. While some natural baffling is provided by the internal thermowell, dip tube and cooling coils, the removable baffles listed in the table are recommended for use with these gas entrainment impellers. These baffles may also be beneficial with the more traditional turbine type impellers for certain applications.


Gas Entrainment Impeller with Hollow Shaft


Removeable Baffle Set


Gas Entrainment Impeller

Gas Entrainment Impellers & Baffle Sets*

Reactor Series No.	*Volume mL*	*Impeller Part No.*	*Baffle Set Part No.*
4560	300	A2042HC	A2043HC
4560	450	A2042HC2	A2043HC2
4560	600	A2042HC3	A2043HC3
4520/30	1000	A2044HC	A2045HC
4522/32	2000	A2044HC2	A2045HC2
4540	600	A2046HC	A2045HC
4540	1200	A2046HC2	A2045HC2
4550	3750	A2048HC	A2049HC
4550	7500	A2048HC2	A2049HC2
4555	18750	A2110HC	A2111HC
4570	1000	A2050HC	A2045HC
4570	1800	A2050HC2	A2045HC2
4575	500	A2052HC	A2043HC2
4580	3750	A2054HC	A2055HC
4580	5600	A2054HC2	A2049HC2

* Please specify magnetic drive size and style.

Catalyst Baskets

Catalyst baskets can be provided for holding a supported catalyst so that it will not be destroyed or changed by the stirring action of the impeller. These can be installed in reactors with volumes ranging from 300 to 2000 mL. Two interchangeable styles are available. Special heads, internal cooling coils, thermowells and dip tubes are required to provide clear space in the vessel for these baskets.

Catalyst Basket Dynamic Design

Catalyst Basket Static Design

Catalyst Basket Static Design with Uniflow Stirrer

The Static Design

In the static design the mesh basket holding the catalyst remains stationary while impellers on the stirring shaft and baffles outside of the basket direct the flow of reactants over the surface of the contained catalyst. A unique gas entrainment impeller provides a uniform flow of both gas and liquid over the fixed catalyst bed held within the annular basket. The Parr design for these baskets includes a rigid bottom support which permits high speed stirring without excessive vibration. Cooling coils, internal temperature measurements and liquid and gas sampling operations can be continued as usual without interference from the installed catalyst basket.

The Dynamic Design

In the dynamic design the catalyst is held in an annular shaped, mesh basket which is attached to the stirrer drive in place of the stirring shaft. The rotating basket then serves as an impeller for stirring the reactants. Fixed baffles and coaxial impellers ensure good circulation over the surface of the contained catalyst. The dynamic baskets are available for reactors with volumes of 1000, 1800 and 2000 mL. Dynamic baskets must be installed in reactors equipped with at least 1/4 hp motors to ensure that sufficient stirrer torque and speeds are available for proper operation. Dynamic baskets are interchangeable with static baskets in 1 liter and larger vessels.

Catalyst Basket Assemblies

Reactor	Volume	Style	Catalyst Volume CC	Basket Catalog No.
4561*	300	Static	40	A2026HC
4562*	450	Static	40	A2026HC2
4563*	600	Static	40	A2026HC3
4566*	300	Static	40	A2026HC4
4567*	450	Static	40	A2026HC5
4568*	600	Static	40	A2026HC6
4520/30*	1000	Static	150	A2037HC
4520/30*	1000	Dynamic	150	A2038HC
4520/30*	2000	Static	150	A2037HC2
4520/30*	2000	Dynamic	150	A2038HC2
4540*	600	Static	40	A2310HC
4546*	1200	Static	40	A2310HC2
4570	1000	Static	150	A2039HC
4570	1000	Dynamic	150	A2040HC
4570*	1800	Static	150	A2039HC2
4570*	1800	Dynamic	150	A2040HC2
4570	500	Static	40	A2041HC

* May require special inlet tube and thermowell.

Condensers

Parr offers two styles of condensers for attachment to the head of a stirred reactor or pressure vessel. These can be made in various sizes to match the size of the reactor.

Straight Reflux Condenser

Reflux Take-Off Condenser

Condenser with Receiver on 1 Gallon Reactor

Straight Reflux Condenser

The reflux condenser consists of a length of tubing connected directly to the head of a vessel and equipped with a water cooling jacket. Condensed vapors are returned directly to the vessel and any noncondensable gases can be released through a needle valve at the top of the condenser. A spiral wound inner packing in the condenser ensures maximum effectiveness in a rather short length.

Reflux/Take-Off Condensers

The reflux/take-off condenser consists of a water jacketed tube, the same as described above, assembled with a receiving vessel attached to the lower end of the condenser. Any vapor, such as water from a polymerization reaction, can be condensed and collected in the receiver, from which it can be withdrawn through a bottom valve. Any noncondensable gases can be released through a needle valve at the top of the condenser. If condensate collection is not required, the receiver can be removed and the condenser can be mounted directly above the reactor for direct reflux into the vessel.

Modifications

Many users opt to install a ball valve at the head of the reactor below the condenser to use as a shut-off to the condenser. Alternate quick connect fittings are available as well as a variety of volumes for the collection vessels.

For reactors with volumes of 1000 mL and greater, the heads are modified with larger connection ports to accommodate the condenser.

Condensers

Reactor	Style	Note	Inner Tube Diameter	Standard Receiver mL	Part No.
4560 / 4590	Reflux/Take-off	Mod. Gage Opening 1/4" NPT	1/4"	150	A2011HC
4560 / 4590	Reflux	Mod. Gage Opening 1/4" NPT	1/4"		A2012HC
4560 / 4590	Reflux/Take-off	Mod. Cool Coil Opening 1/4" NPT	1/4"	150	A2013HC
4560 / 4590	Reflux	Mod. Cool Coil Opening 1/4" NPT	1/4"		A2014HC
4520 / 4530 / 4550	Reflux/Take-off	3/8" NPT	3/8"	300	A2001HC
4520 / 4530 / 4550	Reflux	3/8" NPT	3/8"		A2002HC
4530HD	Reflux/Take-Off	3/8" NPT	3/8"	300	A2003HC
4530HD	Reflux	3/8" NPT	3/8"		A2004HC
4540 / 4570 / 4580	Reflux/Take-off	3/8" NPT	3/8"	300	A2016HC
4540 / 4570 / 4580	Reflux	3/8" NPT	3/8"		A2017HC
4555 / 4556	Reflux/Take-off	1/2" NPT	3/4"	1000	A2018HC
4555 / 4556	Reflux	1/2" NPT	3/4"		A2019HC

Safety Rupture Discs

All pressure vessels must be equipped with a primary pressure relief device and in virtually all cases this is a rupture disc.

The standard rupture disc used on Parr vessels is a pre-bulged metal disc designed to fail in tension at the rated pressure. We have chosen Alloy 600 for our standard discs for two reasons. First, its burst pressure is not significantly effected by the operating temperature so the burst pressure will remain within 8% of the room temperature rating over its entire operating temperature range. Secondly, Alloy 600 has good chemical resistance to a broad range of materials. In many cases we can add a thin gold foil to the inside face of the disc for added corrosion protection. Discs made of Alloy C-276, Tantalum and other materials are available on special order.

If conventional rupture discs are repeatedly stressed with pressures approaching their design burst pressure, they will yield and eventually fail at pressures below their design pressure. **To avoid this, prebulged discs should not be subjected to pressures beyond approximately 70% of their rating in normal operations.**

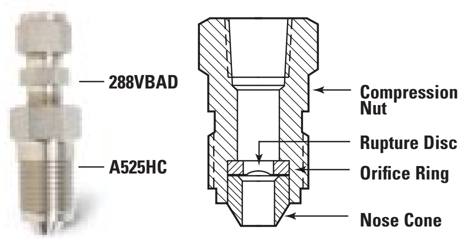
All design codes require that the maximum rating of a relief device installed on a pressure vessel must not permit the operating pressure to rise more than 110% of the vessels maximum allowable working pressure, MAWP.

For users who need to operate up to the MAWP, rupture discs based upon a different operating principal are available. These discs are scored so that they break in shear as opposed to tension. Discs of this design can be used routinely up to 90% of their rated burst pressure. Scored discs are, unfortunately, significantly more expensive than the conventional discs.

All Parr reactors and pressure vessels in small sizes up to and including 2 liters use 1/2 inch diameter rupture discs in assemblies having a 1/4 inch diameter orifice. One gallon and larger vessels use a 15/16 inch diameter rupture disc in assemblies having a 1/2 inch diameter orifice.

Users are invited to contact the Parr Technical Support Staff with any requirements for special rupture discs. Rupture discs for Parr equipment must be matched to the range of the pressure gage, and must carry a rating higher than the intended maximum working pressure.

In general, the 1000 psi disc shown for the 1/4 inch orifice and the 600 psi disc shown for the 1/2 inch orifice are the minimum burst pressures available without going to more temperature sensitive and less corrosion resistant materials of construction. When gages with ranges below this value are installed on a reactor, Parr will install a spring-loaded relief valve to protect the gage in addition to the rupture disc which is the fail-safe device for the vessel.



A525HC Safety Head Assembly

Rupture Discs for 1/4" Orifice

Burst Rating psig	*Inconel Disc*	*Gold-Faced Inconel Disc*	*Scored Inconel Disc*
1000	526HCPD	581HCPD	
2000	526HCPF	581HCPF	526HCP21YD
3000	526HCPG	581HCPG	526HCP35YD
4000	526HCP40CT	581HCP40CT	
5000	526HCPH	581HCPH	526HCB347YD
8000	526HCPJ	581HCPJ	
12000	526HCPL	581HCPL	

Rupture Discs for 1/2" Orifice

Burst Rating psig	*Inconel Disc*	*Scored Inconel Disc*
1000	708HCP10CT	
1500	708HCP16CT	
2000	708HCP20CT	1608HCP23*
3000	708HCP30CT	1608HCP33*
3000	1415HCP30CT	
4500	1415HCP45CT	

*requires special holder

Pressure Relief Valves

Spring-loaded relief valves should be viewed as supplements and not substitutes for a safety rupture disc which is the primary means protecting the vessel and the operator in case of accidental over-pressure. Spring loaded relief valves can be added to a reactor or vessel to:

- **Relieve** pressures near the maximum operating pressure.
- **Reseal** once excess pressure has been relieved.
- **Protect** low pressure components at pressures below available rupture disc ranges.

The relief valves listed below can be installed on any Parr vessel. These relief valves are stainless steel and have FKM O-rings. Other valves and O-ring materials are available on special order.


A175VB Relief Valve

Relief Valves

Part No.	Relief Pressure Range psi	Discharge Connection
A140VB2PA	50-150	1/4" NPT (M)
A140VB2PB	150-350	1/4" NPT (M)
A140VB2PC	350-600	1/4" NPT (M)
A175VB	750-1500	1/4" NPTF
A175VB2	1500-2250	1/4" NPTF
A175VB3	2250-3000	1/4" NPTF
A175VB4	3000-4000	1/4" NPTF

Note: When ordering any of the above relief valves, the user may specify a desired set pressure.

Pressure Gages


593HCPF Gage
3-1/2" Dia.


56HCPF Gage
4-1/2" Dia.

Gages for Parr pressure vessels can be furnished with either 3-1/2 inch or 4-1/2 inch dials in any of the ranges shown in the table below. All have stainless steel Bourdon tubes and 1/4 inch NPT male connections.

Alloy 400 gages are available on special order. Accuracy is .5% of full scale for the 4-1/2 inch size and 1 percent for the 3-1/2 inch gages. All are calibrated in both pounds per square inch (psi) and bars. Gages in Pascal units are available on special order. Compound gages which show vacuum to 30 inches of Mercury and positive pressures to 300 psi/20 bar are also available.

When ordering a special gage, specify the gage diameter, the desired range and scale units.

The gage on a pressure vessel should be 150 percent of the maximum operating pressure. This allows the gage to operate in the most accurate pressure range and prevents the gage from being stressed repeatedly to its full range, which will effect the calibration.

Pressure Gages

Pressure psi	*Range bar*	*4-1/2" Dia. Gage No.*	*3-1/2" Dia. Gage No.*
0-100	0-14	56HCPA	593HCP1AD
0-200	0-28	56HCPB	593HCP2AD
0-600	0-40	56HCPC	593HCP6AD
0-1000	0-70	56HCPD	593HCPD
0-2000	0-140	56HCPF	593HCPF
0-3000	0-210	56HCG	593HCPG
0-4000	0-280	NA	593HCP40AD
0-5000	0-350	56HCPH	593HC50AD
0-7500	0-517	56HCP75AD	NA
0-10000	0-700	56HCPK	NA
30" Hg Vac/300 psi		56HCP3YB	593HCP3YB

Gas Measurement Systems/Gas Dosing

Parr offers a variety of accessories for its line of pressure reaction vessels to enable the investigator to accurately determine the amount of gas consumed in a reaction conducted at elevated pressures and temperatures. There are essentially two methods used to measure the amount of gas delivered to a reaction vessel. These are:

1. **The measurement** of the pressure drop in an auxiliary supply vessel of known volume.
2. **The measurement and integration** of the flow rates using an electronic mass flow meter.

Each of these methods has its advantages and limitations as discussed below.

Intermediate Supply Tanks.

Certainly the simplest method to measure the amount of gas consumed in a reaction is to feed the gas from a vessel of known volume and to measure the pressure drop in this vessel during the course of the reaction. The trick in this method is to select a supply vessel with a volume matched to the amount of gas that will be consumed in the reaction. It needs to be large enough to contain enough gas to complete the reaction and small enough that the pressure drop will be significant and measurable. This basic technique can be applied in a number of ways.

1. **The supply tank can be connected directly** to the reaction vessel. This is the simplest and least expensive. The principal limitation of this approach is that the reaction pressure will fall as gas is consumed and the reaction will not be conducted at a constant pressure.
2. **The supply tank can be fitted with a constant pressure regulator.** The regulator must be selected to match the planned operating pressure. This regulator will deliver gas to the reaction vessel at constant pressure overcoming the limitation described in (1) above.
3. **Initial and final pressures in the supply tank** can be measured with analog gages, or continuous pressure readings can be made and recorded using pressure transducers. While the transducers add cost, they also add increased resolution and the opportunity to follow the rate of the pressure drop and hence the rate of reaction.
4. **Enhanced precision can be achieved** by measuring the temperature in the supply tank and applying corrections as appropriate.

Parr has put together a series of high pressure burettes in comlete packages for direct connection to our reactors. The basic ones are listed on page 88.

These burettes can also be equipped with digital pressure transducers, internal thermocouples and data acquisition and reduction support. Please contact our customer support group for information on these possibilities.

Mass Flow Meters.

At first glance, an electronic flow meter connected to recording electronics would seem to be the easiest way to measure the amount of gas delivered to a reaction and in many cases it is. The trick in this method is to select a flow meter with a pressure and a measurement range appropriate to the reaction. Some additional considerations are:

- Mass flow meters tend to have an accuracy of 1% of the full-scale flow rate. Since the meter must be sized to record the maximum expected flow rate, the accuracy is poor when the reaction is nearly completed and the flow rate is lower. Some systems overcome this by placing two meters in parallel and shifting over to the lower flow rate meter once the initial surge is over.
- Meters are calibrated for a specific gas. If the user will work with only one gas, e.g. hydrogen, this is not a significant restriction.
- Electronic flow meters are relatively fragile and must be protected with filters to ensure reliable service.

Mass Flow Controllers

add an automated control valve to the mass flow meter to provide gas flows that are proportional to an electronic set point. Although normally used to provide a constant flow rate to reactors operated in a continuous-flow mode, a unique application in batch reactions is to allow the set point to be dictated by the error signal from the reactor pressure transducer. As gas is consumed, the pressure drop signal can be configured to increase inlet flow. This signal can be sent to multiple control-lers, enabling the make-up gas to be a mixture with an operator-specified ratio. This technique is often used in the study of co-polymers and ter-polymers.

4351 Gas Dosing System

The Parr 4351 Gas Dosing System has been developed to take advantage of the attractive features of the auxiliary supply vessel concept and to overcome the limitations normally encountered with them. The system uses a small intermediate reservoir equipped with a set of valves to automatically refill the reservoir as needed. The reservoir is equipped with a precision pressure transducer for continuously measuring the pressure in the reservoir as well as an internal thermocouple to enable full compensation for temperature changes in reservoir.

This system works in conjunction with a PC. All of the signal conditioning modules, input and output controls, recording and reporting software are included with the 4351 package. The software provided enables the user to set the refill criteria for the automatic reservoir. It logs and accumulates the flow and applies not only the temperature corrections but also the compressibility factors for the gas being used. The instrument has been designed to determine total flow as opposed to instant flow rates. The flow rates and hence reaction rates, can be derived from the logged data.

The principal advantages of the 4351 Gas Dosing System are:

4351 Gas Dosing System with PC.

4351 Technical Specifications

Maximum supply pressure	200 bar
Maximum practicable delivery pressure	180 bar
Reservoir Volume	150 mL
Minimum recommended pressure difference	10 bar
Maximum recommended pressure difference	180 bar
Accuracy of one gas pulse	+ / - 2%
Maximum practical flow rate	1 gas pulse / minute

Fill Pressure 160 bar									
Delivery Pressure/bar	20	40	60	80	100	110	120	130	140
Gas delivered per pulse/mmoles	780	660	540	420	300	240	180	120	60

Fill Pressure 110 bar									
Delivery Pressure/bar	10	20	30	40	50	60	70	80	90
Gas delivered per pulse/mmoles	540	480	420	360	300	240	180	120	60

1000 mmoles = 22.4 liters @ STP

Wide Dynamic Range - The system can record gas consumption with a precision of one millimole of gas. The maximum value is limited only by the size of the main gas supply. Bypass lines to fill the vessel initially are not required.

Improved Accuracy - The accuracy of the instrument is not affected by the flow rate of the gas being monitored.

Automatic Control - The reservoir is filled, emptied and refilled under computer control. There are no manual manipulations of the control valves required.

Multiple Gas Capability - The user can convert from one reactant gas to another by simply entering the correct compressibility factor for the gas being used.

Improved Safety - With automatic refill and unlimited volume capability, the system can eliminate the need to bring large amounts of hazardous gasses into the laboratory. The controller has been designed in two packages. The reservoir with the valves and the electronic controls. This makes it possible for electronics to be mounted remotely from any hazardous areas.

High Pressure Gas Burettes

Parr offers a series of high pressure burettes intended to introduce gas (commonly hydrogen) to a reactor at a constant pressure. The burettes consist of a high pressure reservoir equipped with an inlet valve, a pressure gage and a relief valve. A constant pressure regulator with a check valve, a connecting hose and a support stand are included with each pipette.

The amount of gas consumed in a reaction can be determined by knowing the volume of the high pressure reservoir and observing the pressure drop in the reservoir during a reaction.

Parr high pressure burettes can be furnished in various sizes as shown in the adjoining table, each with a regulator to deliver gas to the reactor over the designated pressure range. The moles of gas shown in the table represent the amount of hydrogen that will be held in the burette at the maximum pressure. The deliverable volume will be a function of the difference in pressure between the pipette and the reactor. The size of the burette should be selected as large enough to provide sufficient gas to complete the reaction while still maintaining sufficient pressure in the burette to force gas into the reactor.

Reservoirs with larger volumes are available as are regulators with different delivery ranges. Modifications can be made to these basic systems to add an internal thermocouple to the reservoir and/or a pressure transducer for digital readout and/or recording.

A2283HC High Pressure Gas Burette

Burette			*Delivery Pressure Range**		
*Volume mL**	*Maximum Pressure psi*	*Total H2 Volume Moles*	*0-1800 psi*	*0-1200 psi*	*0-700 psi*
150	1800	0.8	A2280HC	A2280HC2	A2280HC3
300	1800	1.5	A2281HC	A2281HC2	A2281HC3
500	1800	2.6	A2282HC	A2282HC2	A2282HC3
1000	1800	5.1	A2283HC	A2283HC2	A2283HC3
2250	1800	11.5	A2284HC	A2284HC2	A2284HC3
500	5000	7.1	A2285HC	A2285HC2	A2285HC3

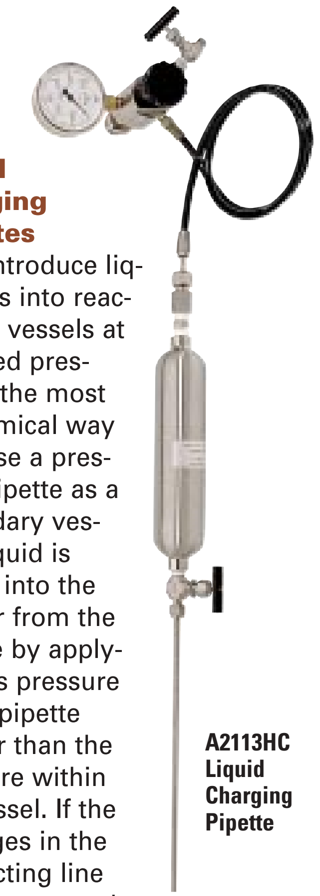
Liquid Charging Systems

Liquid Metering Pumps

Liquid metering pumps are the more appropriate way to introduce liquids into a reactor or vessel at elevated pressures on a continuous basis as opposed to the batch process for which the liquid filling pipettes are commonly used. A wide variety of pumps are available to meet various pressure, flow, and control requirements. The pumps listed here cover some of the more common pressure and flow requirements associated with Parr reactors and pressure vessels. The pumps described under these catalog numbers include an inlet filter, a reverse-flow check valve and the outlet tubing to the reactor. Special pumps can be furnished to meet requirements outside the range of these pumps.

Part No.	*Flow Rate mL/min*	*Pressure Max psi*	*Wetted Material*	*Remote Control 0-10 VDC*
A2286HC	0.01-10	2500	PEEK	No
A2287HC	0.01-10	5000	Stainless	No
A2288HC	0.04-40	1500	Stainless	No
A2289HC	0.01-10	5000	Stainless	Yes
A2290HC	0.04-40	1500	Stainless	Yes
A2291HC	1.0-80	5000	Stainless	No

Liquid Charging Pipettes



A2113HC Liquid Charging Pipette

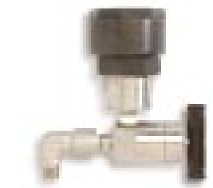
To introduce liquids into reactors or vessels at elevated pressures, the most economical way is to use a pressure pipette as a secondary vessel. Liquid is forced into the reactor from the pipette by applying gas pressure to the pipette greater than the pressure within the vessel. If the passages in the connecting line are large enough, slurries or catalyst suspensions can also be charged into the reactor in this manner.

The pipettes listed below offer a choice of volumes and are rated for pressures to 1800 psi. They include a nitrogen filling connection for attachment to a nitrogen tank. More elaborate pipette systems can be assembled to special order to include additional fittings, such as a pressure gage for the pipette, a pressure relief valve or a large opening ball valve. Special pipettes can also be furnished for higher pressures to 5000 psi.

Part No.	*Pipette Volume mL*	*Pressure Rating psi*
A2113HC3	50	1800
A2113HC4	150	1800
A2113HC	300	1800
A2113HC2	1000	1800

Solids Charging Systems

One of the modifications most frequently requested is a port or other means to feed liquids, solids, or slurries into the vessel without removing the head. This can be done in various ways.



Solids Charging Auger

Ball Valve Solids Charging Ports

A ball valve with a 3/8 inch diameter opening can be installed on any one liter or larger vessel and used in conjunction with a high pressure pipette for injecting slurries under pressure. These are opened or closed with a quarter turn of the handle. Larger diameter valves are available for 1 gallon and larger vessels. These ball valves will withstand the full pressure developed in a reactor at moderate temperatures, but their pressure rating falls off rapidly at temperatures above 100 °C.

Part No.	*Nominal Size*	*Orifice diameter*
A143VB	1/4" NPT (F)	0.250"
A132VB	3/8" NPT (F)	0.375"
396VBAD	1/2" NPT (F)	0.406"

A143VB Ball Valve

Capped Openings

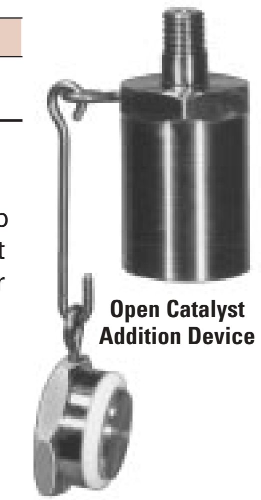
A capped opening in the head of a reactor can serve as a convenient solids charging port, offering the largest possible diameter and a significantly shorter passage than a ball valve. A male connector with a cap is usually used to close the opening. These will have a reliable metal to metal seal and the ability to withstand the full temperature and pressure for which the vessel is rated. Tubing can be connected to the fitting, but this type of connector is normally used only where solids or slurries will be added at atmospheric pressure.

Reactor	*Available Fitting Sizes*
Mini	1/4" NPT (F)
1 & 2 Liter	3/8" NPT (F)
Gallon & up	1/2" NPT (F)

Closed Catalyst Addition Device

Catalyst Addition Devices

Parr has developed a unique device for adding small amounts of solids (or liquids) from a sealed container held within a reactor. It is of particular interest to users performing kinetic studies of catalytic reactions. This device consists of a small cylindrical chamber with a cap that is sealed to the body with an O-ring. It attaches to the underside of the vessel head with a 1/8"NPT connection. To discharge the contents of the holder, gas pressure is applied through a valve installed on the top of the head. When the applied pressure is greater than the pressure within the reactor, the cap is forced open and the catalyst or other contents of the holder will be released into the reactor. This device works best in the taller, 450 mL and 600 mL Mini Reactors, and in the 1 liter and larger Parr Reactors.



Open Catalyst Addition Device

Complete Reactor	*Mounting Size*	*Assembly No.*	*Thread*
Mini	6 cc	A550HC3	1/8" NPT
One Liter	8 cc	A550HC	1/8" NPT
Larger	20 cc	A550HC2	1/8" NPT

Cooling Coils

Serpentine Cooling Coil 1000 mL

Spiral Cooling Coil 1000 mL

Internal cooling coils are available for all but the smallest Parr reactors. These coils provide an extremely effective means of removing heat from the vessel to control an exothermic reaction or for cooling the reactor at the end of a test. Since heat is transferred through the relatively thin wall of the coil instead of the thick wall of the vessel, cooling rates are generally much faster than heating rates; particularly at temperatures above 80 °C. Water is normally used as the cooling medium although compressed air can be used for modest cooling loads. Cooling coils are offered in three standard configurations:

Single Loop - Single loop coils consist of a vertical run of tubing formed into a "hairpin" shape. These are normally installed on small reactors where there is minimum space available.

Serpentine Coils - Serpentine coils consist of six to eight vertical runs of tubing uniformly spaced around the circumference of the vessel. These coils provide reasonable surface area, minimum interference with stirring patterns, a reasonable amount of baffling, and ease of cleaning and maintenance.

Spiral Coils - Spiral coils consist of multiple loops wound just inside the inside diameter of the vessel. They are normally available only for the 4 and 6 inch ID vessels although other sizes have been built on special order. They do maximize the cooling area available, but sometimes at the expense of uniform stirring and ease of cleaning.

The individual reactor specifications will dictate the style of coil or coils available for each reactor. On some reactors the coils are included as standard while on some reactors they are optional.

Cooling coils are available in the same choice of materials as the reactor bodies themselves. All cooling coils are removable. Plugs are available to close the openings in the head and in most cases these openings can be converted to alternate inlets/outlets if cooling is not required.

Glass Liners 2000 and 1000 mL Sizes

PTFE Liners 2000 and 1000 mL Sizes

Liners

Removable, open top, cylindrical liners made either of borosilicate glass or PTFE can be furnished to fit any Parr reactor and most of the general purpose vessels. These liners slide into the cylinder and require no additional fittings, but they cannot be used in a reactor equipped with a spiral cooling coil. Although they will not keep corrosive vapors from reaching the surfaces of the cylinder and head, they make it much easier to add and remove liquid reactants, and they give some protection to the cylinder when working with corrosive solutions. It must be noted, however, that adding a PTFE liner will slow the heat transfer rate into and out of the vessel, and it may be necessary to adjust the temperature control method to prevent overheating.

Liners

Fits ID, in.	Cylinder Size, mL	Glass Liner Part No.	PTFE Liner Part No.
1.3	50	1431HC	1431HCHA
1.3	100	1431HC2	1431HC2HA
1.5	75	2920HC	NA
2-1/2	250	762HC10	NA
2-1/2	500	762HC2	NA
2-1/2	300	762HC	762HC4HA
2-1/2	450	762HC2	762HC5HA
2-1/2	600	762HC3	762HC6HA
2	100	762HC7	762HC7HA
2-1/2	160	762HC8	762HC8HA
3-1/4	600	2312HC	2312HC3
3-1/4	1200	2312HC2	2312HC4
3-3/4	1000	1441HC	1441HCHA
3-3/4	1800	1442HC	1442HCHA
4	1000	398HC	398HCHA
4	2000	399HC	399HAHA
6	1 Gal.	894HC	894HC4HA
6	2 Gal.	894HC2	894HC5HA

Bottom Drain Valves

Bottom drain valves can be added to most Parr reactors. These valves are particularly useful for those working with polymers or other material that must be discharged from the reactor while they are still hot and before they can solidify. These valves are also quite useful for the 1 gallon and larger vessels which are too large to conveniently lift from the heater for product recovery. At the other end of the spectrum, bottom valves are rarely installed on the micro and mini reactors with their small volumes and light vessel weights.

The standard bottom drain valve is a rising stem, process sampling valve. In the closed position the stem of the valve is flush with the inside bottom of the vessel so that there is no dead space between the bottom of the vessel and the shut off point of the valve. In the fully open position the stem is retracted completely to open a clear passage from the vessel.

When the valve is reclosed, any material in this passage will be pushed back into the reactor by the rising stem. Valves with 3/8 inch diameter clear passage are recommended for vessels with volumes from 1000 mL to 2 gallons. A 1/4 inch valve is available for 600 mL and smaller vessels. High pressure and larger diameter valves are available where required.

These valves will withstand the full operating pressures and temperatures of the vessels in which they are installed. They are available in nearly all of the current Parr materials of construction. Air actuated valves are available for larger reactors. Users can also specify that a reactor ordered with a bottom valve shall have a tapered bottom so that it will drain easily through the valve opening.

Not all Parr reactors will accept a bottom drain valve. Since the valve extends approximately 8 inches below the bottom of the vessel, the entire vessel must be raised by this amount to accommodate the valve. This makes some models too tall for convenient bench top operation. The specification tables for each model will identify those reactors in which a bottom drain can be readily installed, and those which will not accept a bottom drain, or those which will require custom modification of the heater and support stand to accommodate a bottom valve.

A465VB Bottom Drain Valve

Needle Valves and Ball Valves

Needle valves and ball valves can also be installed as bottom outlet valves. Needle valves are generally used on the smaller reactors. While ball valves can be used for large discharge passages, they are generally limited in their operating temperature/pressure capabilities and they leave a fairly large dead space between the bottom of the vessel and the seat of the valve.

Bottom Drain Valves

Part No.	Opening Diameter-Inch	Outlet Connection	Max. Pressure psi	Max. Temp. °C
A485VB	0.25	1/4 NPT (F)	3000	225
A465VB	0.38	3/8 NPT (F)	2000	350
A177VB	0.31	3/8 NPT (F)	5000	500
A285VB	0.38	1/2 NPT (F)	1900	265
A296VB	0.69	1" NPT (F)	1900	265

Valves and Fittings

Parr stocks and can install a wide variety of valves and fittings for use with these reactor and pressure vessels.

These include:

- Needle Valves with NPT or tube connection.
- Regulating Valves with NPT or tube connection.
- Ball Valves with NPT or tube connection.
- High Pressure Valves
- Severe Service Valves
- Remote Operating Valves
- Tube Connectors
- Pipe Connectors
- Plugs
- Union Coupling Adapters

Please contact our customer service department for details.

Manual Control Valves for Compressed Gas Tanks

Tank valves with couplings to fit standard compressed gas cylinders are available in stainless steel for corrosive gases and in nickel plated brass for non-corrosive gases. The brass valves have a 2-1/2 inch dia. pressure gage which shows the tank pressure. Both styles have a 1/4 inch NPT female outlet which will accept any pressure hose or gas tube assembly. These valves do not regulate the delivery pressure of the gas. Pressure regulators are available on special order.

T303 Stainless Steel Valves-No Gage

Fits CGA Tank Valve No.	Outlet No.	Typical Usage
A120VBPN	510	Propane, butane, ethylene oxide
A120VBPP	660	Chlorine, sulfur dioxide, nitric oxide

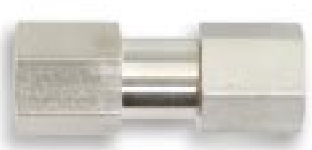
Nickel-Plated Brass Valves with Cylinder Pressure Gage

Fits CGA Tank Valve No.	Outlet No.	Typical Usage
A120VBPQ	320	carbon dioxide, methyl bromide
A120VBPR	350	hydrogen, carbon monoxide, ethylene
A120VBPS	540	oxygen
A120VBPT	580	nitrogen, argon, helium
A120VBPU	590	air

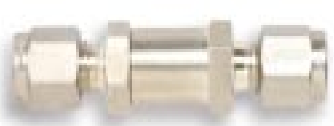
Note: Can be furnished with DIN/BSP connections on special order

Safety Check Valves

Whenever gases or liquids are introduced into a vessel under pressure, the supply pressure must be greater than the pressure in the vessel to prevent reverse flow back into the supply system. Protection against reverse flow can be obtained by installing a check valve in the supply line. With a check valve in the line, the valve will snap shut if the supply pressure is too low, or if the pressure in the vessel should rise above the supply pressure. This protection is particularly important on stirred reactors where gas enters through a dip tube. With liquids in the vessel, any back pressure will force liquid back into the gas tank or into the gas supply system.



363VB Check Valve



364VB Check Valve

Poppet Check Valves

Part No.	Material	Connections
363VBAD	Stainless	1/4" NPT Female
364VBAD	Stainless	1/4" Tube

Parr stocks the poppet check valves listed above for incorporation into the user's supply lines. These valves have a 10 psi normal cracking pressure and are rated for 3000 psi maximum working pressures. Check valves with other specifications can be furnished on special order.

Thermocouples

Parr offers a variety of thermocouples for use in these reactors and pressure vessels. The "standard" thermocouple is a Type J (iron-constantan) which is well suited to the operating temperature range of these vessels. Other materials as well as platinum resistance (RTD) elements are available as special orders. These thermocouples are sealed in 1/8 inch diameter stainless steel sheaths and have a standard plug connection at the end of the probe.

These thermocouple assemblies can either be sealed directly into the head of the vessel using a male connector with an 1/8 NPT thread or inserted into a protective well. Thermowells are used on larger vessels to protect the thermocouple from physical damage and on all vessels of a corrosion resistant alloy other than stainless steel.

Dual element thermocouples with two separate thermocouples in a single sheath and spring loaded thermocouples designed to be installed through the heater to the outside wall of the vessel are also available.

Thermocouples should be approximately four inches longer than the depth of the vessel so that a smooth bend can be made at the top to clear other head fittings.

The A470E2 extension wire is used to connect from the thermocouple to the control or readout device. The standard length is six feet, but longer lengths are available.

Type J Thermocouples with 1/8" Diameter

Part Number	Stem Length	Sheath Material
A472E	7.5"	T316 Stainless Steel
A472E2	9.5"	T316 Stainless Steel
A472E3	11.5"	T316 Stainless Steel
A472E6	15.5"	T316 Stainless Steel
A475E5	21.5"	T316 Stainless Steel
A472E4	5.5"	T316 Stainless Steel
A472E8	2.5"	T316 Stainless Steel

Most of the above listed thermocouples are also available as Type K (Chromel-Alumel).

Pressure Hose

Three different pressure hose assemblies are available for high pressure gas connections to both stirred and non-stirred vessels. The standard hose is a 6 foot length with a male"A" socket connector on one side and a 1/8 inch NPT(M) nipple with a 1/4 inch NPT(M) bushing on the other end. The "A" socket side of the hose attaches to couplings installed on the inlet valve of all stirred reactors as well as to a side port of the gage block assembly for the non-stirred vessels. The choice of either 1/8 inch NPT of 1/4 inch NPT on the opposite end of the hose allows for attachment to most gas tank valves, pressure regulators or other gas supply sources.

The A495HC Hose Assembly is made of nylon. It is rated for 2500 psi and is very flexible and easy to use with dry, non-corrosive gasses (nitrogen, hydrogen and oxygen). Care must be taken to ensure that the nylon hose does not come in direct contact with any hot surfaces on the vessel or heater. One of these hoses is included with each complete Parr Series 4500, 5100, and 5500 Stirred Pressure Reaction Apparatus.

The A490HC Hose Assembly is a braided, stainless steel hose with a PTFE lining, rated for 2500 psi. It is reasonably flexible and recommended for use with corrosive gases and liquids, and for applications requiring additional abrasion resistance, but it is not intended for high temperature liquids or gases.

The A506HC Assembly is a 6 foot length of 1/8 inch OD stainless steel tubing, rated for 7500 psi. This small diameter tubing is "bendable", but it is not as flexible as the other hoses. It is recommended for corrosive gases, high temperature transfers and other high pressure applications. Special versions of this assembly can be made of other corrosion resistant materials. Larger tubing can be used, but it is rigid rather than flexible.

Special hoses with different lengths or end fittings can be assembled for special orders.

A495HC Pressure Hose

A490HC Pressure Hose

A506HC Hose Assembly

Pressure Hose

A495HC	Pressure hose assembly, 6-ft, reinforced Nylon
A495HC5	Pressure hose assembly, 6-ft, reinforced Nylon, with non-return valve
A495HC7	Pressure hose assembly, 10-ft, reinforced Nylon
A490HC	Pressure hose assembly, 6-ft, PTFE-lined, braided stainless steel
A490HC5	Pressure hose assembly, 6-ft, PTFE-lined, braided stainless steel, with non-return valve
A506HC	Gas tube assembly, 6-ft, 1/8" OD, T316SS

Explosion Proof Apparatus

All Parr reactors are normally equipped with open type, variable speed motors, electric heaters and controllers intended for use in non-hazardous environments. These standard units can be used in most laboratories without undue hazard, but there will be situations where the installed equipment must be considered explosion proof. Parr offers various optional stirrer drives and heating systems to meet these strict requirements.

Model 4524 Reactor, 2000 mL, Fixed Head Style with Aluminum Block Heater

USA and Canadian Codes

Designing electrical equipment to be operated in a hazardous location is a complex subject, governed by extensive national electrical codes and supplemented by local regulations which require that all electrical equipment installed in a governed location must be approved for use with the specific gas, vapor or dust that will be present in that location. USA and Canadian electrical codes classify hazardous locations according to the nature and concentration of specific hazardous or flammable materials. These are divided into three classes:

Class I - Flammable liquids, gases or vapors.
Class II - Combustible or electrically conductive dusts.
Class III - Easily ignitable fibers or flying particles.

There are two divisions within each of these classes.

Division 1 - Where the flammable material exists in the atmosphere under normal operating conditions.
Division 2 - Where the hazardous material is confined within a closed system from which it may be released only under abnormal conditions, such as a leak in the system.

Class I locations are further subdivided into four Groups, A, B, C and D which identify specific explosive gases and vapors. Explosive dusts and fibers in Class II are subdivided into Groups E, F and G. Most hazardous applications for Parr apparatus will occur in atmospheres identified by Class I, Group A for acetylene, Group B for hydrogen and Groups C and D for most other combustible gases and vapors. Class II, Group F covers coal dust. Most other combustible dusts, such as flour and grain, are in Group G. Minimum ignition temperatures and energy levels are established for specific materials in each group.

The European Community, International Electromechanical Commission (IEC) has corresponding classifications for hazardous locations. Parr will work with all users to provide equipment compatible with their own local codes.

The components in Parr reactor systems which may be considered hazardous, and the steps that can be taken to reduce or eliminate the hazards they represent, are described below.

Explosion Proof Motors

Because of sparking from brush contacts, electric motors clearly represent the principal explosion hazard introduced by a stirred reactor. Electric motors approved for Class I, Groups C and D, and Class II, Groups F and G atmospheres are readily available in most sizes and voltages. These sealed motors are suitable for most hazardous applications, and they are sometimes used with hydrogen, but they are not approved for Class B atmospheres. To meet Class B requirements, a motor must be purged by building up a positive pressure of air within the motor to prevent explosive gases or vapors from reaching electrical ignition sources. This requires a special, air purged motor which can be provided when required.

An alternate method of dealing with the explosion hazard is to use an air driven motor. These are powered by compressed air and offer a convenient and satisfactory drive system for use in flammable atmospheres, including hydrogen. They are available in sizes suitable for all Parr reactors.

Explosion Proof Heaters

The easiest way to provide an explosion proof heater is to use a steam or hot oil jacket and ensure that the highest temperature that can be reached in the jacket is well below the minimum ignition temperature for the specific hazardous atmosphere in which it will be installed. An aluminum block heater can be considered explosion proof if it has explosion proof wiring, and if it is operated with an auxiliary controller that will hold the surface temperature below a safe maximum. Electric heaters purged with clean air can also be considered explosion proof, but it is doubtful that seals can be maintained in a purged heater to provide true protection over a long period of time.

Please see page 76 for additional information on heater selection.

Explosion Proof Wiring

In an explosion proof system, all electric wiring with significant voltage or current carrying capability must be routed in approved sealed conduit or in specially sealed flexible cables. All terminations and switches must be contained in approved boxes or housings. The user must provide all local wiring and connections to a power supply, and must ensure that the installation meets all requirements of the local electrical code.

Certain sensors, such as thermocouples, pressure transducers and tachometer pickups carry such low electric loads that they are a potential ignition source only in the event of a most unusual failure. In many installations these low hazard components are not seen as a problem. They can, however, be protected with isolation barriers which will make them intrinsically safe even in an unusual failure. These energy limiting electronic barriers can be provided where required.

Explosion Proof Controllers

The most commonly used method for dealing with the ignition hazard introduced by a temperature or process controller is simply to locate the controller outside of the hazardous atmosphere. Another choice is to install the controller in a cabinet which can be purged with clean air within the hazardous location.

Air Motor

Special Systems

Parr can furnish systems approved for use in hazardous locations up through Class I, Division 1, Group B in which specific hazardous gases will be present. Each of these formally approved systems must be designed and built on a custom basis, with all current carrying wiring and fittings installed in accordance with the requirements discussed above.

Windows

Windows can be installed in Parr stirred reactors and pressure vessels for visual observations, light transmission and other purposes. They usually are installed in pairs so that light can be introduced through one window while the other is used for viewing. Our standard material for these windows is quartz. Sapphire is also available for small diameter windows. Alternative window materials are available for specific transmission requirements. They can be mounted in several different ways.

Screw-in Windows

The simplest window is a screw-in type with a 5/8 inch diameter viewing area. The element in these windows is sealed in a fitting which screws into the vessel using a standard 1/2 inch NPT male pipe thread. Obviously, the vessel wall must be thick enough to provide full engagement for this thread. PTFE gaskets and O-ring seals restrict the maximum operating temperature to 225 or 275 °C, depending upon the O-ring material. Pressure ratings range from 2000 to 5000 psi, depending upon the window material and its thickness. Although these windows are rather small for straight optical viewing, they work well for small video systems and for laser and other analytical beams. A limitation of this design is that there is a dead space approximately 1.25 inches long between the inner face of the window and the inside wall of the vessel.

Integral Windows

Parr has developed designs for installing windows in the wall of the vessel so that the inside face of the window is very close to the inside wall of the vessel. This eliminates the large dead space associated with screw-in windows. These windows are offered in the two styles described below. The maximum size of the window will depend on the size of the cylinder in which it will be installed.

Circular Windows with a .62 inch diameter viewing area are the standard. Circular windows are available in a variety of materials including sapphire for very high pressures. This type of window is generally used for visual, photographic or optical sensor observations.

Oblong Windows with a viewing area 3.50" long and .62" wide are the standard size and can be installed on vessels of 100 mL and larger. These windows are commonly used for visual observations in both the vapor and liquid phases and for observing the liquid level in the vessel. Multiple windows can be stacked on larger vessels.

Windows in both the round and oblong styles can be furnished in larger sizes upon request. The windows we have rated above as standard are maintained in our inventory for readily available replacements.

All reactors and pressure vessels equipped with windows require custom designed heaters and supports. Flexible heating mantles and attached circulating jackets are the most commonly used heaters for window vessels.

Windows are sealed into these vessels with O-rings. For this reason, vessels equipped with windows are restricted to operating temperatures of 225 or 275 °C depending upon the O-ring material selected.

Insulated Electrical

A variety of insulated electrical leads can be installed in any Parr reactor or pressure vessel for electrical measurements or to supply power to an internal heater or other devices. Three different gland designs are available. These screw into a vessel and will have pressure and temperature ratings to match those of the vessel in which they will be used.

Transducer Glands

Transducer glands are used for applications requiring a number of small insulated wires in a single gland. Wire sizes from 14 to 24 gage are used to carry small currents and voltages in the millivolt range. A unique feature of this design is that multiple wires (up to 16) can be individually insulated through a single gland.

100 mL Vessel Based On 2430HC3 Cylinder, with Two Quartz Windows

Electrode Glands

Applications requiring a single electrical conductor with current carrying capacities from 20 to 100 amperes and voltage ratings to 2000 volts can be handled with an electrode gland. These glands have a single conductor (or electrode) in sizes from 0.093 to 0.312 inches in diameter, with the ends of the conductor threaded so that internal and external lead wires can easily be attached.

Power Leads

Power leads can be provided with either single or multiple flexible wires in sizes from 14 to 18 gage. Current ratings range from 5 to 20 amperes at up to 600 volts. Either PTFE or ceramic insulation is available. Ceramic glands can be used to the full temperature rating of any Parr vessel. Pressure ratings will vary from 1000 to 10000 psi, depending upon the design of the gland, its size and the type of insulation used.

Miscellaneous Sensors

Parr has installed a number of different sensors in its various reactors and pressure vessels, including both single point and continuous liquid level sensors, pH electrodes and dissolved oxygen electrodes. Each of these installations must be carefully developed in consultation with the user, the electrode or probe supplier and the Parr Engineering Department. Glass electrodes with O-ring seals will carry rather severe temperature and pressure restrictions. There are also space restrictions which generally dictate that accessories of this type can only be installed in 1000 mL or larger vessels.

Temperature Limits

There are a number of factors that determine the maximum temperature rating of a pressure vessel. For most applications it is the gasket material. Vessels with O-ring seals are limited to 225 °C unless exotic materials are used to extend this temperature to 275 °C. Parr's design for contained PTFE gaskets extends the operating temperature range to 350 °C. Flexible Graphite (FG) material essentially removes the gasket as the limiting factor. Maximum temperature limits for the metals used in these vessels are established by ASME code and other standards. Most metals have maximum temperature limits between 400 and 800 °C. The allowable strength for these metals falls off rapidly as they reach maximum operating temperature. Finally, the difficulties encountered with screw threads and other closure components operating at high temperatures establish a practical temperature limit for externally heated vessels. We have found 600 °C to be a reasonable limit.

Internally Heated Vessels

Exposed Heaters. Another approach has proven useful in extending the maximum temperature limit. In this design the heater or furnace is placed inside the pressure vessel. The heater is surrounded by a layer of insulation. This creates a hot zone in the center of the vessel and prevents the walls from exceeding their allowable limit. Properly designed, temperatures as high as 1200 °C can be achieved in the core of the vessel while the walls remain below 250 °C. This system is very energy efficient. Internal heaters can be less powerful than external heaters. Internally heated vessels are equipped with insulated electrical feed throughs to power the heater and multiple thermocouples to monitor and control the temperatures in the hot zone and the vessel inner wall.

The reactions or studies carried out in internally heated vessels must be limited to those which will not destroy the exposed internal heaters and insulation. These are normally gas-solid reactions or controlled atmosphere heat treatment studies. The heating elements are normally ceramic. Some users have developed induction style heaters and insulators and have extended their investigations to above 2500 °C.

Although internal heaters can be installed in almost any non-stirred Parr pressure vessel the 1.8 liter, Model 4683 High Pressure/High Temperature vessel is an excellent starting point. It can accommodate a cylindrical, insulated heater 1.75 inch diameter by 8 inch deep, capable of producing and sustaining internal temperatures to 1200 °C.

Protected Heaters. Internally heated vessels have also been manufactured with cartridge type heating elements inserted in specially designed "thermowells". These wells protect the heater from the reactants and expand the applications that can be studied. Cartridge type heaters have a maximum temperature of 850 °C.

Spare Parts Kits

Each stirred reactor is furnished with a set of spare parts and fittings including a 6 foot gas supply hose, head gaskets, rupture discs, and a set of replacement parts for the stirrer drive.

A reserve supply kit of spare parts can be ordered from the list below to provide sufficient parts and tools to handle most normal replacements and emergency repairs during the first year of heavy usage. These kits include replacement gaskets, O-rings, rupture discs drive belts and seals. These kits are a convenient package of the small perishable items required for normal maintenance of the reactor.

When ordering any kit for an existing reactor please specify the preferred gasket/seal material, the range of the rupture disc, material of the reactor and the length of the drive belt.

Spare Parts Kits For Reactors

Part No.	Reactor Series
4509M	4521, 22 w/mag drive in 1370HC Series Heads
4539M	4531, 32 w/mag drive in 1370HC Series Heads
4539MA	4531/32 w/HD mag drive/755HC Head
4549MA	4544-47 Bench Top
4549MB	4544A-47A, 4544C-46C Floor Stand
4559M	4551, 52 with magnetic drive
4569M	Series 4560 w/magnetic drive
4579B	Series 4570 HP/HT Reactor
4579D	Series 4575-76 HP/HT Reactor
4589B	Series 4580 HP/HT Reactor
4599	Series 4590 Micro Reactor
4559PCM	Series 4555 Reactor
5109M	Series 5100 Glass Reactor
5119M	Series 5110 Glass Reactor

External Valves and Fittings

Materials of Construction

In the standard configuration, the valves, gage, magnetic drive and other external parts on Parr reactors are furnished in stainless steel, even when a different material is specified for the cylinder, head and internal wetted parts. The external stainless components are typically only exposed to the vapor of the reactants and are at much lower temperature than the cylinder and internal fittings. These conditions allow stainless steel external fittings to perform satisfactorily in most cases. If external parts made of a material other than stainless steel are required for safety or other reasons, Parr can accommodate this in most cases. Any request for external parts made of a specific material must be stated clearly when ordering.

Valves

Most reactor valves are available in Alloy 400 as well as stainless steel at a reasonable cost premium. Valves made of Alloy C-276 are also available, but generally only on special designs and at a considerable cost premium. Soft materials such as titanium and zirconium generally make poor performing valves.

Gages

Pressure gages are available in Alloy 400 and stainless steel. Other materials of construction are not available. The standard method for protecting the gage in a corrosive environment is to install a diaphragm gage protector. These have a flexible diaphragm which isolates the gage from the reactants and a sealed hydraulic connection for pressure transfer to the gage. These assembles are too large to install on all but the largest Parr reactors.

As an alternative, Parr has designed an oil filled piston isolator gage protector to isolate the gage (and transducer, if required) on small reactors and pressure vessels where space is limited. These isolators can be furnished in any of the current Parr materials of construction.

Pressure Transducers

Pressure transducers are only available in stainless steel and Alloy C-276. Parr provides a mounting adapter with a water cooling jacket on pressure transducers to protect them from excessive temperatures. These can be augmented with piston style isolators similar to gage protectors when corrosion resistance is required. When a gage and a pressure transducer are installed, a single isolator can protect both.

Magnetic Drives

Magnetic drives can be furnished in all of the current Parr materials of construction except nickel, which is magnetic.

Rupture Discs

The standard material of construction for rupture discs is Alloy 600. A gold facing is available for the smaller discs used on vessels up through 2 liters in volume. Alloy C-276, Tantalum and other premium materials are available on special order.

Laboratory Reaction Systems

Parr Instrument Company is pleased to work with customers in the design and assembly of complete laboratory or pilot plant reactor systems, offering a full spectrum of reactor designs, ranging from simple, Stirred Tank Reactors for batch operation to Continuous Flow Stirred Tank and Tubular Systems. Parr can furnish either the essential components for assembly by the user, or a completely assembled turnkey system. Parr's experience in this field has ranged from table-top micro systems to small operating pilot plants, each with a reactor (or reactors) designed to meet the user's particular requirements. Our experience in systems includes:

Continuous Flow Stirred Tank Reactor Systems

This mode of operation requires that reactants be introduced and products removed on a continuous basis. Generally, this must be done with the reactor at elevated temperatures and pressures. Reactors used for these applications must be modified to provide sufficient inlets and outlets for the reactants and products as well as designs for maintaining continuous operating levels and pressures under flow conditions.

Continuous Flow Tubular Reactor Systems

Instead of a stirred tank reactor these systems use a tubular vessel generally packed with a fixed bed of catalyst. Reactant liquids and gasses are fed to the reactor at a controlled rate through pre-heaters and mixing systems. Products are collected from the discharge of the reactors and are cooled and separated for recovery.

Reactor Ancillary Systems

Both stirred tank and tubular flow reactors will require feed and recovery systems when operated in a continuous flow mode. Subsystems and components developed for incorporation into these systems include:

Gas Feed Systems

These systems commonly include one or more of the following components:

Intermediate Reservoirs. These gas supply tanks can be sized to the expected consumption of the reaction so that the pressure drop in this reservoir can be measured to determine total consumption by the reaction. If the pressure is measured continuously, the rate of pressure drop can be converted to reaction rates.

Constant Pressure Gas Regulators. These regulators, sometimes called forward pressure regulators, will deliver gas to a reaction to maintain a constant pressure within the reactor. They are a simple and effective means for controlling the pressure in systems where it is desirable to feed a non-flowing reactor over time.

Electronic Mass Flow Meters. These meters will measure the flow rates of gases into a reactor. They are very valuable for systems with integrated computer control.

Electronic Mass Flow Controllers. These are electronic flow meters with an added flow control valve which delivers the flow at a constant rate which can be set by the user.

Back Pressure Regulators. These regulators are generally installed on the gas discharge line of a reactor to maintain the desired pressure within the reactor by regulating the flow of exit gases. They can be set either manually, or by gas pressure, or electronically, as required. These back pressure regulators are commonly used with mass flow controllers to ensure that the flow of gas passing through a reactor has been held at a constant pressure.

Laboratory Reaction Systems

Liquid Feed Systems

There are two commonly used liquid feed systems:

Pressure Pipette Assemblies. These generally consist of a small pressure vessel from which liquid feed material can be forced into a reactor. The vessel is pressurized with nitrogen (or other gas) to a pressure greater than that in the reactor, and the liquid is fed into the reactor through an appropriate control valve. This arrangement is usually selected for systems in which liquid is introduced as a batch rather than continuously. A liquid level indicator or sight glass can be added to provide some degree of measurement and control.

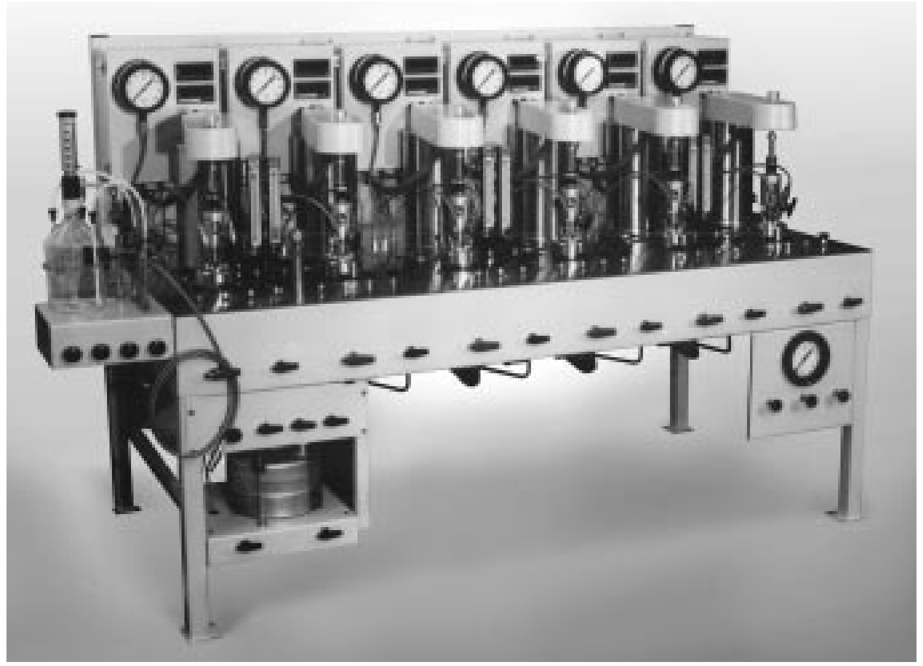
Liquid Feed Pumps. A variety of liquid feed pumps are available, but the most commonly used ones for Parr reactors are those designed for high pressure liquid chromatography. These small pumps have available flow rates and operating pressure ranges well suited to Parr reactor systems. Chemical feed pumps are also available for larger systems. Most pump models are available for remote or manual control.

Product Handling Systems

The following components are commonly employed to deal with the hot, high pressure product streams leaving a reactor.

Cooling Condensers. These can be used in various ways: to separate and return condensable solvents to the reactor from the exhaust stream; to take off condensable liquids; to cool exhaust gases before they reach a back pressure regulator; or to cool a liquid product. Many different sizes and configurations are available.

Gas/Liquid Separators. These are generally recovery vessels which receive a mixed flow of gasses and liquids and separate them for appropriate recovery or venting. Often they are equipped with coolers and/or reflux condensers.



A Six-Unit Multiple Pressure Reactor

Liquid Level Control Systems. At high pressures and temperatures in small systems, liquid levels are most practically controlled by stand pipes or discharge level controls rather than by electronic controls. While some electronic controls are available, they are not always small enough or sensitive to the small level changes experienced in bench scale and small pilot plant systems. Pressure and/or temperature ratings may also be inadequate for a particular installation.

Control and Data Acquisition Systems

Multiple Modular Control Systems. Simple reactor systems can be controlled with individual controllers for each of the variables in the system, such as: separate temperature zones, operating pressure, flow rates, stirrer speed, etc. Analog outputs can be included for data output and can be connected to the Parr Model 4846 Data Acquisition System.

Integrated Computer Control Systems. The Parr Series 4870 Process Controller is an example of an integrated computer control system which can control the process as well as the individual components of the system. It uses a PC for the user interface terminal, data logging and archiving system.

System Integration and Mounting

Integrated Support Stands. Support structures for the reaction vessel and its various subsystems can be designed and fabricated to provide systems which are ready to install in the user's spaces. The Parr Instrument Company technical staff is available to assist in the design, selection and integration of components for custom reactor systems.

600 mL Stirred Vessel with four Windows, Bottom Split-Ring Closure, and Clamp-on Cooling Block

Custom Built Catalyst Preparation System

Laboratory Reaction Systems

Custom Turn-Key System with 4870 Process Controller, Custom Power and Valve Controllers, Automated Valving/Interlock/Cooling Systems

12-Station Reactor System, with Custom Vessels, Heaters, Mag Drives, Tilt, Drive, Stands, Fittings

16-Station Reactor System, with Sixteen 300 mL Mini Reactors, with Footless Magnetic Stirrers, Two 4870 Process Controllers, and Sixteen 4875 Power Controllers

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