FDO Sanitary Back Pressure Regulator with Active Damping

REGULATOR USE AND STARTUP

WARNING:

Make sure that you have read and understand these directions before using, installing, or maintaining the Equilibar pressure regulator. Take steps to ensure this instruction manual reaches the operator of this regulator and stays with the regulator throughout its lifetime. Use, installation, operation, and maintenance of all pressurized products including this regulator must be performed by personnel who are properly trained and qualified through experience or specific training.

Failure to properly observe the instructions contained in this document may result in, but is not limited to:

- Serious personal injury or death
- Unconstrained release of the pressurized media
- Permanent damage to the pressure regulator and/or permanent damage to connected equipment

Fig. 1

BACKGROUND

The Equilibar® FDO Series valves are precision back pressure regulators (BPRs) for sanitary applications. The integrated active damper model is designed to dampen downstream pulsations. These BPRs control the fluid pressure at the inlet port by allowing excess flow to vent from the system through the regulator's outlet port. The flow direction is from inlet to outlet. The Equilibar BPR is pilot operated. The pressure setpoint is determined by the pressure applied to the *pilot* or *reference* port on the dome of the regulator (see **Fig. 1)**. The BPR will control the pressure at its inlet port in a precise 1 to 1 relationship with the setpoint pressure applied to the pilot port. This *pilot pressure* may be applied with a mechanical knob adjusted regulator or with an electronic pressure regulator (electro-pneumatic regulator).

Refer to **Fig.1**. The Equilibar BPR uses a flexible membrane diaphragm to both sense the pressure and to provide a direct seal against the orifices in the regulator body. The pilot pressure is applied to the top side of the diaphragm. The Inlet port pressure is sensed on the other side of the diaphragm. When the pilot pressure is higher than the Inlet pressure, the diaphragm is pushed firmly against the orifices to form a seal and the regulator is effectively closed. When the inlet pressure builds and just equals the pilot pressure, the closing forces are removed from the diaphragm and media can begin to pass from the Inlet to the outlet port. When sufficient media has passed through the regulator, the Inlet pressure will be reduced slightly, and the diaphragm is allowed to seal against the orifices again. In steady-state, equilibrium is achieved and the diaphragm modulates into a position where just enough flow is allowed out of the regulator in order to maintain a steady pressure at the inlet port.

How the FDO with active damping model works:

In applications where pulsation damping is important, we offer this FDO sanitary BPR model with active damping. The FDO Active Damping (AD) system is in the bottom cap and uses a continuous flow of pressurized gas supply to maintain a pressurized *lower* diaphragm for optimized damping. Supply gas pressure feeding the active damper should be slightly greater the downstream pressure. **(Fig. 2).** This unique technology will create an equilibrium with the downstream system pressure, even as the system pressure changes over time. For instance, if the downstream pressure of the process increases by 20 psi over the course of the "run", the Active Damping system will self-adjust to provide continuous optimal damping without user interaction. This configuration requires a modified bottom cap and reduces downstream pulsation an average of 50%. **Note:** At steady state conditions, the AD solution typically consumes 200 ml/min of air.

Example Setup: An active damping FDO can be used downstream of a delivery pump feeding the chromatography column. (See **Fig. 3**). The BPR modulates flow to maintain pressure upstream of the FDO. This BPR model will also actively dampen pulsations in the downstream media going to the chromatography process.

Equilibar has trained engineers who can work with you to suggest a regulator design and wetted materials for your specific application. These suggestions are recommendations only and are dependent on complete and accurate information from the end user about the application. It is the ultimate responsibility of the user to determine the compatibility of the media with the materials of construction of the back pressure regulator and with the pilot gas in use.

The diaphragm installed in the back pressure regulator is a careful balance between the pressure, temperature, media compatibility, and flow rate considerations. Often performance in one area may be sacrificed in order to obtain acceptable performance in another. Many diaphragm types cannot achieve tight shutoff and must have some minimum system flow always present. If the system flow rate to the BPR is less than the minimum flow rate required by the installed diaphragm, then the system pressure will fall below the target setpoint pressure. Equilibar sales engineers will work with you to provide guidance for low flow performance of your application.

2 SET-POINT OPTIONS

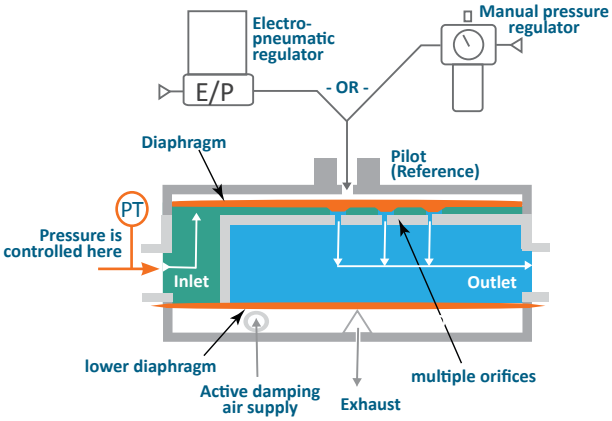


Fig. 2 Equilibar® FDO back pressure regulator with active damping

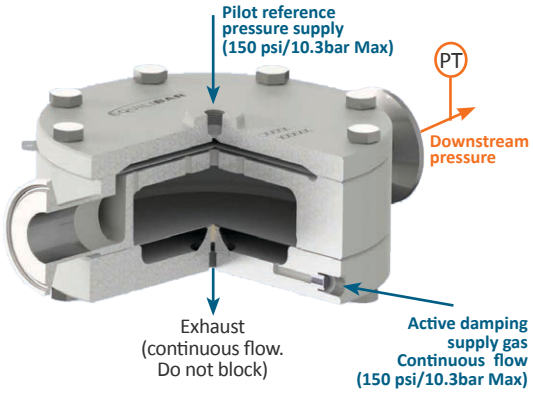
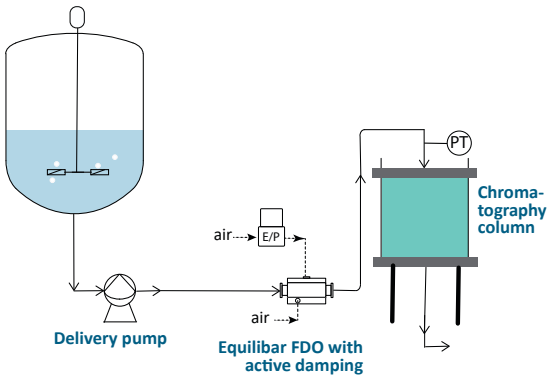


Fig. 3 Chromatography column feed pulsation control



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READ BEFORE INSTALLING

1. Inspect the Equilibar BPR upon receipt. Verify that the part number on the product label matches what you ordered.
2. Verify that the rating on the Equilibar BPR label for maximum allowable working pressure (MAWP) and maximum allowable working temperature (MAWT) will not be exceeded when the BPR is used in your process.
3. Call or e-mail Equilibar if you have any questions, concerns, or need a new copy of these instructions. Be sure to include the full part number and serial number of the BPR you are inquiring about. (01-828.650.6590, info@equilibar.com)
4. Take precautions to prevent injury to personnel in the event of a diaphragm failure or external leak. Sensitive fluid controls such as an Equilibar BPR can experience internal or external leaks. See standard terms and conditions for important limitations of liability notes.
5. Diaphragms may fail in the open or closed position. Proper safety precautions should be taken for either failure mode
6. The Equilibar BPR is not a "Safety Accessory" as defined by the Pressure Equipment Directive 2014/68/EU. Be sure to install appropriate over pressure protection devices such as safety relief valves or rupture discs to protect the system and the BPR from exceeding the maximum allowable working pressures. These safety devices must meet applicable law, codes, regulations, and standards for your jurisdiction
7. Every Equilibar regulator is individually hand tested at the factory for operation and external leakage. Leak testing is typically performed at 1.5X the MAWP.
8. Equilibar regulators are cleaned internally and externally at the factory using aqueous based cleaners in an ultrasonic cleaner and manual wipe down with denatured alcohol.
9. The Equilibar factory applies Krytox™ FDA, NSF H1 Food Grade Lubricant to bolt thread connections that are not wetted by the process fluid.
10. Inlet ports are stamped with an "I"; Outlet ports are stamped with an "O".
11. The inlet "I" port is connected to the point in the system where it is desirable to maintain or control the pressure. The best pressure control will be seen if the plumbing to the BPR inlet port is as short and as large as practical to minimize the amount of pressure drop in the plumbing.
12. Install a strainer or filter (100 micron/100mesh or better upstream of the Equilibar BPR to prevent plugging of the orifices. Consider the effect the pressure drop in the filter will have on the system pressure control.
13. System media will be vented out the BPR outlet "O" port.
14. Provide adequate exhaust line capacity to prevent pressure build-up on the BPR outlet port. Short or oversized exhaust lines are recommended.

NOTE ABOUT PILOT PRESSURE

- The pilot regulator can be manual or electronic. It controls the inlet setpoint pressure.
- The pilot pressure supply gas should be a filtered, inert, compressible gas compatible with the process media flowing through the BPR.
- The controlled process inlet pressure is a near exact 1:1 relationship to the pilot pressure. Set the pilot pressure to the desired process pressure, not to exceed 150psi/10.3bar.

NOTE ABOUT ACTIVE DAMPING PRESSURE

- The AD supply pressure should be filtered, inert, compressible gas compatible with the media flowing through the BPR.
- AD dampens downstream pulsations but does not control downstream pressure. Downstream pressure is typically lower than the controlled inlet pressure.
- AD supply pressure should always be greater than the nominal downstream pressure. Equilibar recommends a starting point of approx. 50psi/3.5bar greater than the downstream system pressure, with a maximum of 150psi/10.3bar.

INSTALLING - STEP BY STEP

Follow these steps carefully to avoid injury or equipment damage

1. Equilibar BPRs, pilot pressure regulators and AD pressure supply regulators arrive ready to use.
2. Install the pilot regulator following the instructions included with the order. Check the performance of the pilot regulator before attaching it to the reference port of the Equilibar BPR. For best stability when using an electronic pilot regulator, the tubing between the outlet of the electronic regulator and the dome of the BPR requires a minimum volume of 2 in³/ 35cc.
3. Set the AD pressure supply line at approx. 50psi/3.5bar greater than the average downstream system pressure, not to exceed the maximum of 150psi/10.3bar.
4. The Equilibar BPR will control in any orientation and may be mounted in any plane. However, for ***maximum drainability*** performance, install the FDO vertically with the inlet down, such that fluid flows upward through the valve during normal operation. See figure C on page 4.
5. Install the BPR ensuring the inlet "I" and outlet "O" are installed in the proper direction of flow. Pressure is controlled at the inlet "I" port.
6. Connect the pilot regulator outlet line to the reference port of the BPR. Adjust the pilot pressure to the desired process setpoint.
7. The BPR is designed to have reference pressure applied even when there is no pressurized media at the inlet "I" port.
8. Equilibar performs an initial *'setting'* of the diaphragm at the factory. This is done by applying the customer standard operating pressure to the reference port of the Equilibar BPR. This 'setting of the diaphragm' can help the diaphragm perform at lower flow rates. New FDO valves come with diaphragms already set. We recommend performing an initial *setting* when a new diaphragm is installed during maintenance.
9. Attach the AD pressure supply line to the active damping supply port in the side of the bottom cap.
10. **NOTE:** During normal operation, only start the flow of process fluid after the reference pressure and AD supply pressure have both been applied. Applying process fluid pressure without energizing the Active Damping system can result in irreparable lower diaphragm damage, resulting in poor performance of the AD system.
11. Cleanability has been evaluated using riboflavin at 5 ft/ sec. Cleaning results will vary by media and process design. Customer is responsible for verifying the efficacy of their process cleaning. To optimize cleaning, the pilot pressure ***must be disengaged*** during the cleaning process to allow full CIP flow through the valve. However, the AD supply pressure ***must remain engaged*** during CIP to avoid diaphragm damage.
12. Exercise caution when reducing the pilot pressure to prepare for CIP. The BPR will attempt to reduce its inlet pressure at the same rate that the pilot pressure is being reduced. This can result in extremely rapid release of process media through the outlet port of the regulator. Reduce the pilot pressure as slowly as practical.
13. After CIP/SIP step, ensure process line remains pressurized for optimal drainability.
14. When preparing for maintenance or shutting the system down, turn the process fluid off before removing pilot pressure supply to the reference port.

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MAINTENANCE NOTES

- Maintain strainer or filter upstream of device to avoid debris getting trapped in the orifices
- It is expected that diaphragms will need to be replaced on a regular basis, the timing of which is dependent on the application.
- Spare diaphragms and repair parts are available for purchase from Equilibar.
- It is recommended to order repair parts prior to performing maintenance. Contact Equilibar to order for your specific model. Please have the part number available to ensure proper spare parts are ordered.
- Visit our maintenance website for videos or contact us for more information at equilibar.com/contact.

PREPARING FOR MAINTENANCE OR TROUBLESHOOTING

- When preparing for maintenance or shutting the system down, turn the process fluid off ***before removing pilot pressure supply*** to the pilot/reference port. This step will prevent a sudden release of system media pressure through the BPR.
- Release the pilot pressure and remove the pilot/reference port piping to clear the BPR for maintenance. Also depressurize and remove the AD pressure supply piping. Equilibar BPR's can be serviced 'in-line' and need not be removed from the system piping.
- Loosen the bolts in the BPR and disassemble wearing proper protective equipment. See exploded view and instructions on page 4 for more details.
- Inspect diaphragms and active damping orifice and mount for integrity to determine if they need to be replaced or cleaned.
- Clean all stainless steel surfaces to remove any residual process fluids or particulates.
- Reassemble with new or clean parts following the instructions on page 4. Bolts threaded into the BPR body should have a small amount of lubricant to prevent thread galling. Thread galling is usually permanent and causes the regulator to be scrapped. The Equilibar factory applies Krytox™ FDA, NSF H1 Food Grade Lubricant to bolt thread connections that are not wetted by the process fluid.
- After reassembling, follow step by step installation instructions on page 2.

TROUBLESHOOTING

PROBLEM	POSSIBLE SOLUTIONS
Maximum flow is reduced	Clean out internal orifices
Will not maintain back pressure at low flow rates	1. Inspect the regulator for debris or diaphragm damage which prevents the diaphragm from sealing against the orifice in the regulator body 2. "Set" the diaphragm as described in STEP BY STEP instructions on p.2 3. Contact Equilibar Applications Engineer to review low flow specifications
External leak around diaphragm	1. Check for loose screws. If they have loosened, tighten to torque values listed. 2. Check for misaligned flanges, PD Insert or diaphragms 3. Check for scratched sealing surfaces 4. Check diaphragms for damage. Replace as necessary
Chatter on the downstream tubing	1. Increase exhaust piping size 2. Contact factory for additional assistance
Air in process exhaust	Check for ruptured diaphragm
Fluid out of the reference port	Check for ruptured diaphragm
Pulse damping effectiveness faded or lost	1. Ensure proper system startup (See Installing #10 on p.2) 2. Inspect diaphragm for permanent deformation and replace if necessary. 3. Inspect AD orifice insert for clogging 4. Inspect AD orifice mount for correct orientation. See Figure in "assembly instructions" on p. 4

RATED PRESSURE NOTE

Equilibar regulator bodies have a *shell pressure rating* based on the body and bolt strength using principles of the ASME B31.3 and confirmed using hydrostatic testing. These shell pressure ratings are the maximum rating for each design as listed in the technical brochures. For example, FDO6 is listed as having a maximum pressure rating of 150 psig (10bar) standard.

Equilibar configures individual regulators to the specific customer application which may involve fitting the valve with a thinner diaphragm to meet precision or low-flow requirements. The diaphragm selection, operating temperature, chemical composition or other factors may cause pressure derating. Therefore, the MAWP printed on an Equilibar BPR label reflects that of the selected diaphragm and application conditions but will not exceed the shell pressure rating of the body design.

The maximum pressure rating for the shell is always based on the body and bolt strength and is not printed on the product label. Customers may contact Equilibar engineers if they desire to increase unit MAWP by upgrading diaphragm thickness.

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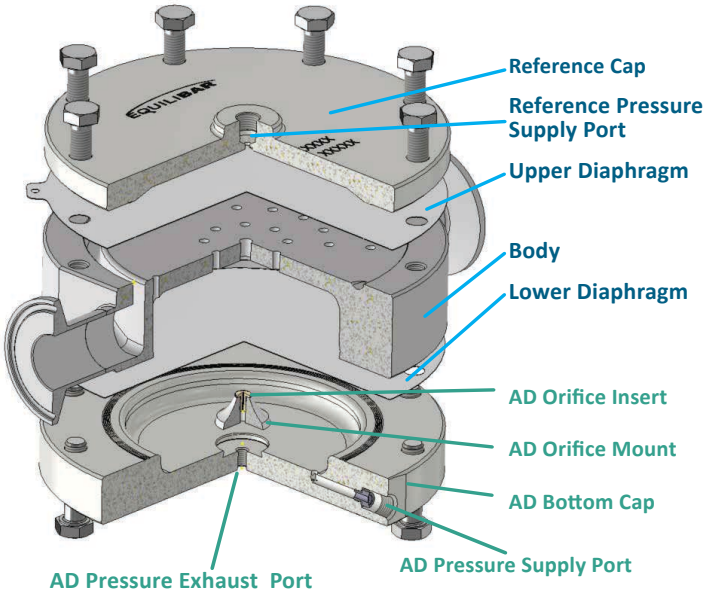
ASSEMBLY INSTRUCTIONS

Using the exploded view at right may help follow the assembly instructions.



1. Start with the bottom cap and body upside down.
2. Insert bottom bolts into bottom cap, then invert and set bottom cap on a flat surface, resting it on the bolt heads. Place the active damping (AD) orifice insert and orifice mount in the bottom cap recess. (See exploded view for details).
3. Lay bottom diaphragm on top of the AD Insert and bottom cap, aligning the holes with the bolts.
4. If diaphragm thickness varies, install the thicker one on the bottom during this step.
5. Holding diaphragm in place, invert bottom cap and place onto the bottom of the body, aligning bolts with holes. Hand tighten bottom cap bolts in an alternating pattern as shown in Figure B.
6. Flip entire assembly over so the top of the body is now accessible. Lay the top diaphragm on the top of the body, aligning bolt holes. This will be the thinner diaphragm if you have diaphragms of varying thickness.
7. Carefully place reference cap on diaphragm and body, aligning bolt holes.
8. Insert and hand tighten reference cap bolts in a star pattern as shown in Figure B.
9. Tighten bolts using the recommended torque procedure below to a torque value listed in the table below for the proper FDO size.

FDO Size	Final Torque
FDO 2, 3, 4	29 - 34 in-lb (3.3 - 3.8 Nm)
FDO 6 - 24	120 ± 5 in-lb (13.6 ± 0.5 Nm)

Note: ***Torque bolts slowly with hand tools using the star pattern shown in Figure B to ensure uniform tightening. Motorized or pneumatic torque wrenches are not advised.***

a. Starting with the top bolts on the reference cap, torque bolts to a very low torque (~5 in-lb / 0.6 Nm) using a star pattern as shown in Figure B.

b. Torque top bolts further to a moderate torque (~40 in-lb / 4.5 Nm) for large sizes and ~15 in-lb / 1.7 Nm for small sizes) using the star pattern shown.

c. Give the top bolts a final torque to the desired torque from the table.

d. Repeat torque instructions a-c for the bottom bolts.

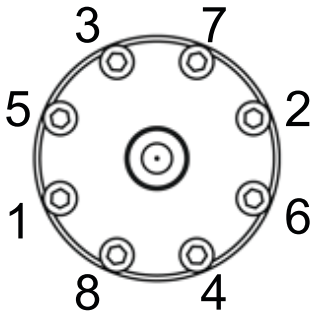


Figure B: Sample Bolt Torque Pattern

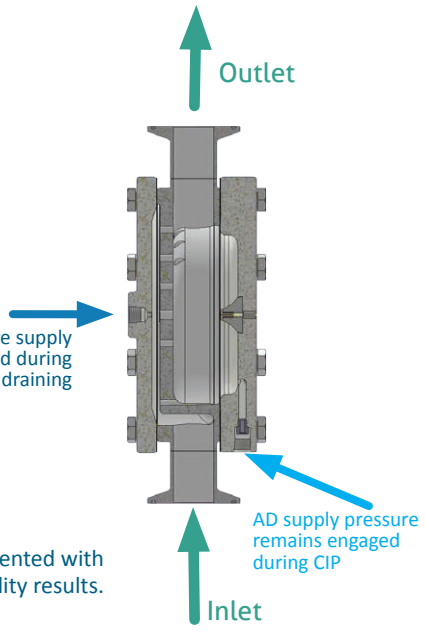


Figure C: FDO sanitary valve oriented with inlet down for optimal drainability results.

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SYSTEM HAZARD ANALYSIS

Both normal operation as well as possible failure modes and foreseeable misuse must be accounted for in the design of the system which interacts with and connects to the Equilibar back pressure regulator (BPR). It is the responsibility of the end user to account for these hazards. **Please read all of the following safety and hazard precautions before installing or operating any equipment.**

a. The BPR is not certified as or marketed as a pressure vessel safety relief valve. The BPR is a precision pressure control valve. Guarding against overpressure must be achieved with devices designed and marketed as such.

b. Sensitive diaphragms and external seals can leak. It is the responsibility of the end user to use this product in a way that prevents injury to personnel should leakage occur. See Standard Terms and Conditions for important Limitation of Liability notes.

c. If the internal diaphragm ruptures or leaks, the gas or fluid on the pilot port can be introduced into the process fluid. Make sure that the fluids are compatible and not hazardous when mixed.

d. If the internal diaphragm ruptures or leaks, process fluid can enter the pilot port plumbing. Precautionary measures to consider are described below and on our website at www.equilibar.com/equilibar-safety-information/

   i. Make sure that the process fluids and the pilot are compatible and not hazardous when mixed. Most auxiliary pressure regulators used to provide pilot pressure to the BPR are of the self-relieving design. Guard against the process fluid relieving out the pilot regulator if the BPR diaphragm fails. One method to accomplish this is to set the pilot pressure into a static volume chamber that is sealed with an ON/OFF valve after the pressure is set to the desired value. Another method is to feed the pilot pressure from the pilot regulator through a check valve to the BPR. In order to reduce the pilot pressure a bleed from the pilot port to a safe location must be employed. In many cases this bleed can be made to the output of the BPR.

   ii. If an electronic pressure regulator is used then special consideration must be made. In addition to reviewing the prospect of having the process media coming in contact with and venting out of the electronic pressure regulator, the possibility of ignition of the media by the electronic pressure regulator must be examined. It is the user's responsibility to determine if a hazardous area classification exists and to make sure that the electronic pressure regulator employed meets or exceeds the requirements of intrinsic safety for that area.

e. If the internal diaphragm ruptures or leaks the result is often that the BPR will fail into a closed position. This results in a blocked pipe with no path for the fluid to escape through the BPR. Over pressurization of the upstream can occur. Steps must be taken to ensure that the upstream piping is made sufficiently strong to withstand this or is guarded by an overpressure relief device.

f. Make sure the process pressure to be controlled is connected to the BPR "I" Inlet port. Process fluid flow is from "I" Inlet to the "O" Outlet. If the BPR is connected in reverse it will still operate but it will give poor control and can result in excess pressures.

g. Observe the maximum temperature and pressure ratings on the BPR label. Take steps to insure these values cannot be exceeded. Where necessary to protect equipment, a suitable type of safety overpressure relief valve must be connected in parallel to the BPR. The overpressure relief valve must be rated to prevent the pressure or temperature from exceeding the BPR maximums as listed on the BPR label. In some installations a rupture disc may be substituted for the safety relief valve.

h. If the discharge piping on the BPR "O" Outlet port becomes blocked, the BPR will open and fill the discharge piping to the same pressure as the maximum pressure in the system. The discharge piping must be rated to contain this pressure or have a safety relief valve to limit this pressure at or below the safe pressure of the discharge piping.

i. Do not use the BPR as a structural member. All piping and plumbing connections to the BPR should be adequately supported. The BPR series is available with a mounting bracket to facilitate the installation.

j. Enriched oxygen media (>21%) should not be used in the BPR unless Equilibar has specifically worked with you to provide a product rated and labeled for enriched oxygen. Standard products are not oxygen cleaned. Particle impact, adiabatic compression, and diaphragm motion can all cause ignition in an enriched oxygen media. This kindling chain can cause the entire BPR to oxidize extremely rapidly resulting in high temperatures, discharge of flames and molten metal, and unrestrained escape of process fluid.

k. The metal cap and body of the BPR are excellent conductors of heat.

   i. Assume the external temperature of the BPR will rise or fall to match the temperature of the process media flowing through it. In addition to thermal hazards posed to humans by directly touching the BPR exterior, it is the duty of the end user to verify that the temperatures of the process media do not exceed the ignition temperatures of any combustible gases or dust (or mixture) that may be present local to the BPR.

   ii. Assume the internal temperature of the BPR will rise or fall to match the temperature of the ambient environment. Ensure that the process media flowing through the BPR cannot be damaged or ignited by the maximum and minimum ambient environment temperatures. Low ambient temperatures can cause the media within the regulator to freeze. Expansion cooling in certain gases can also cause freezing. Freezing can block the BPR and cause excess pressures to build on the "I", Inlet, port. Expansion of water due to freezing can damage the regulator. Ice formation from freezing can perforate metallic foil diaphragms.

l. The BPR has been carefully designed by skilled engineers to provide proper safety ratios and adequate pressure regulation. Do not attempt to modify the BPR in any way, including adding or enlarging orifices or ports or replacing machine screws (bolts). Only replace the internal O-rings or diaphragms with Equilibar factory provided repair parts.

m. Never perform maintenance or inspections on a system when pressurized fluids are present. De-pressurize the system before performing this work. De-pressurize inlet pressure before reference otherwise a quick drop in reference pressure can lead to a violent exhaust of the upstream pressure through the regulator.