SkoFlo Subsea Back Pressure Regulator Valve

SkoFlo Subsea Back Pressure Regulators (BPRs) are anti-siphoning devices that create back pressure in chemical injection lines to prevent uncontrolled delivery of chemicals into production wells. They are typically installed on subsea chemical injection lines before the injection point into production flow lines. The subsea BPR prevents fluids from draining into injection points in a non-regulated condition when chemical hydrostatic head exceeds injection pressure and the well becomes sub-ambient. Subsea BPRs regulate inlet pressure when the well pressure falls below the factory set point of the device.

It achieves this regulation with a simple debris tolerant mechanical device that does not need power or communication to the SCM. Subsea BPRs can be installed in any orientation on subsea trees and manifolds via a standard SkoFlo docking can and receptacle. Additionally, the small form factor enables installation on logic caps (LCs), umbilical porches, long term covers (LTCs) and SFL cobra heads logic caps in any orientation. Subsea BPR is a self-regulating device activated only when required or needed.

For new fields where well pressure is anticipated to go sub-ambient, Subsea BPRs should be installed for future remediation. The device will remain static until the well pressure drops below the reference pressure in the BPR. For remediation of existing fields where sub-ambient conditions exist, BPRs can be installed subsea without interfacing to the Subsea Control Module.

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Product Datasheet Low Flow Subsea BPR

Pressure Set Point Accuracy

Flow Range	2 to 1200 gpd (0.31 to 189 liters/hr)
Pressure Set Point Accuracy	Target set point pressure accuracy is ± 100 psi The accuracy band includes changes in well pressure from 0 psi to the set point pressure, full flow range of the device and thermal & hysteresis effects. Factory Set point pressure can be set between 2000 to 6000psi at 500psi increments (39F operating temperature)*. When well pressure is above set point pressure, regulator is effectively a fixed orifice with Cv listed below
Failure Mode	Loss of pressure regulation, will not block flow
Cv (well pressure > factory set point pressure)	~0.17 (at maximum flow rate with minimum pressure drop)

Design Ratings**

Design Standards	API 17F (ISO 13628-6), API 17H (ISO 13628-8), ASME B31.3, ASME BPVC Section VIIII
Design Life	25 years at 10% full scale with up to 6000psi pressure drop
Working Pressure Rating	10,000 psig (690 barg) (contact factory for pressures between 10ksi and 15ksi)
Water Depth Rating	10,000 ft (3048 m)
Viscosity	0.5 to 100 cP (contact factory for above 100cP viscosity)
Operating Temperature (Valve)	39°F to 104°F (4°C to 40 °C) – Set pressure is set at 39F*
Debris tolerance	SAE AS4059 Class 12B-F
Mechanical Interfaces	UO8 Couplers, 3/8" AE MP (Mounted in a Docking Canister or MQC/Logic CAP Plate)

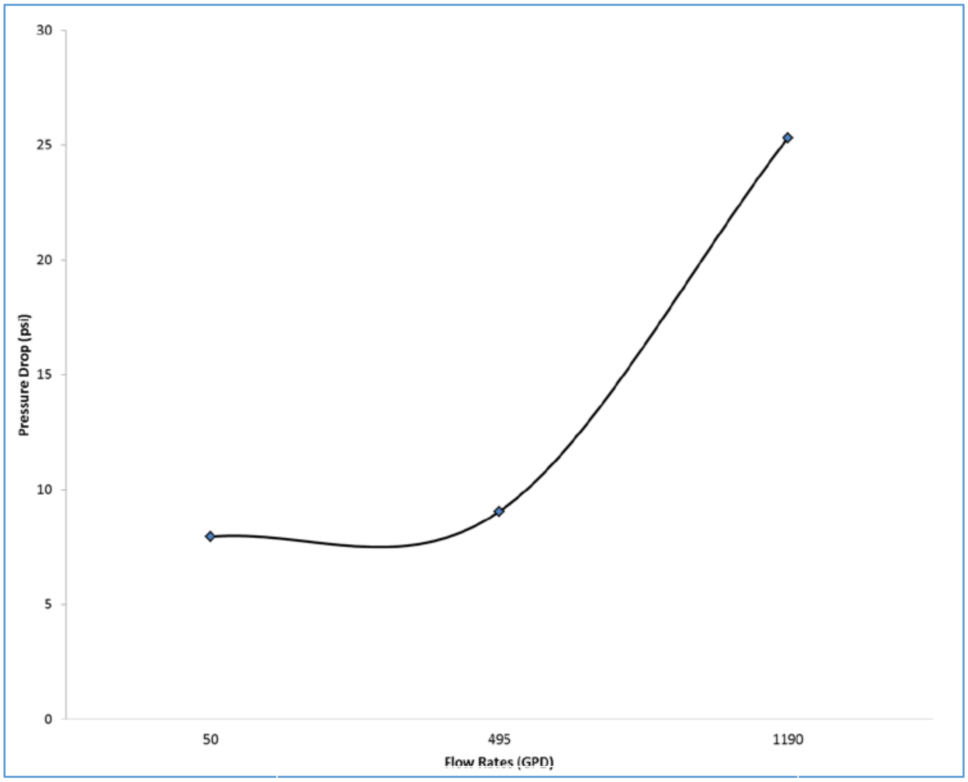
Materials (chemically wetted)

Valve Body	Nitronic 50HS
Metallic components	Nitronic 50, 50HS/ 316/316L SS, Inconel 625/718/X750 Elgiloy, Monel K500, Hastelloy C276, Gold, Inconel 725, Carbide
Non-metallic components	Chemraz 510, PEEK, PTFE
Valve Trim	Ceramic and Carbide
Seals, chemical to sea water	Gold plated Inconel 718 C-Ring

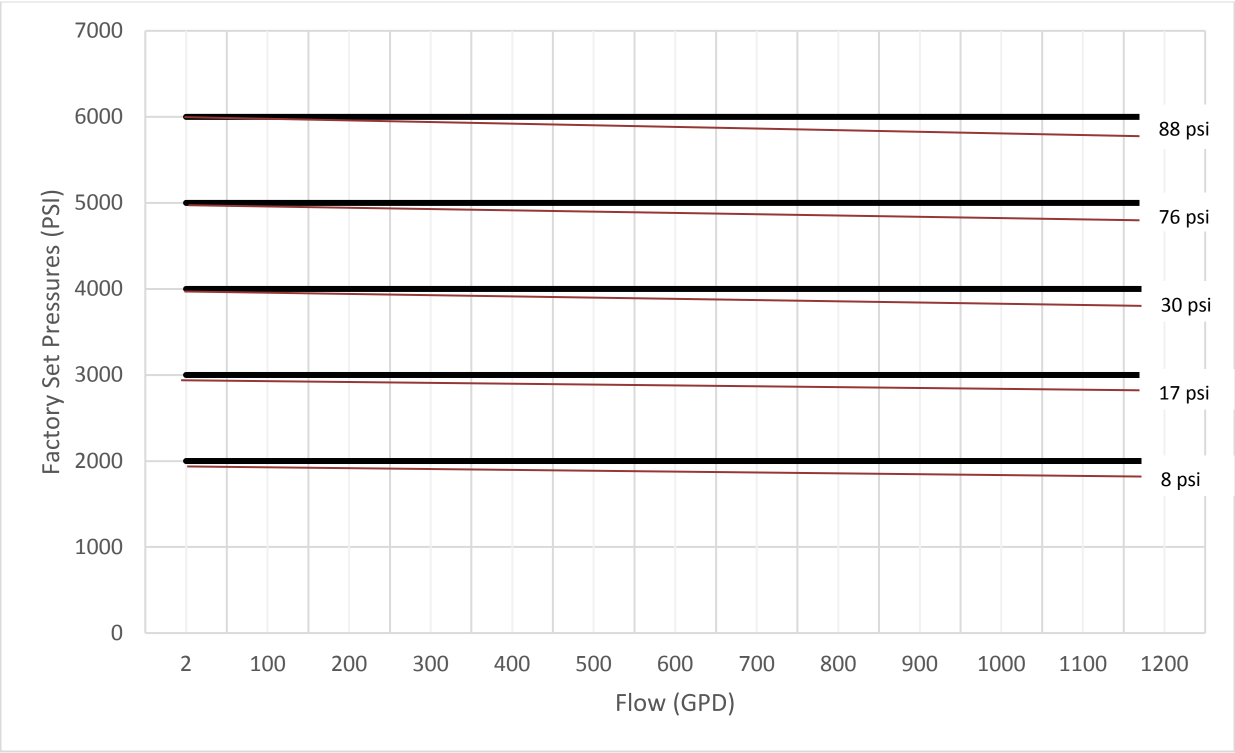
Optional Pressure Sensor for Diagnostic Purposes

Electrical Connector	4-Pin, Teledyne ODI or Siemens Tronic
Electrical Conn Location	Stab or ROV-mate mount with docking canister; contact factory for multi-quick coupling (MQC) plate mount
Voltage	24 ± 4VDC
Power Consumption	2 watts typical
Inrush Current	11A @ 25ms
Temperature Rating for Pressure Sensor	Operating: -20°F to +250°F (-28°C to 121°C) Calibrated: 0°F to 160°F (-18°C to 70°C) Storage: -18°C to 70°C (0°F to +158°F)
Pressure Transducer	Sensor accuracy ±0.05% of full-scale (20,000psi)
Communications Protocol	CANbus (SIIS Rev2 Compliant for Level 2 device) or ModBus

* Contact Factory for a different operating temperature
**Check valve provided on the outlet



Pressure Drop (psi) vs Flow Rates (GPD)



Performance characteristic of the Subsea BPR Set Pressure based on increase in flow

*Set point accuracy pressure = ±100psi

** Graph not sensitive to viscosities

Questions you may have

What was the design/development problem? What needed improvement or correction?

The following problems and challenges led to the design and development of the Subsea Back Pressure Regulator (BPR):

A. Fluid siphoning results in uncontrolled delivery of chemicals
SkoFlo collaborated with Anadarko Petroleum to solve a pressing issue with chemical fluid siphoning at Lucius field in the Gulf of Mexico. Fluid siphoning typically occurs in subsea wells over 2,000 feet water depth which have become sub-ambient.

Unconstrained delivery of corrosion inhibitors cause production lines to fail due to corrosion.

Plugging and possible line abandonment occur due to improper delivery of wax, hydrate, or asphaltene inhibitors.

Chemical over-dosage to address fluid siphoning increases operational cost for additional chemicals and increases overboard treated water emissions.

Subsea BPR eliminates uncontrolled chemical injection caused by fluid siphoning.

B. Due to increased pressure drop in deep wells and deep waters with low formation pressures, downhole check valves may not work within operating range.
A Subsea BPR reduces the pressure drop across the downhole check valve and allows it to work within operating range.

C. Boiling in downhole chemical injection lines
For some wells, a Subsea BPR in combination with downhole check valves suppresses boiling in downhole chemical injection lines.

D. Hose collapse due to fluid siphoning
For application of subsea hoses during temporary operations in deep water, Subsea BPR prevents hose collapse due to fluid siphoning.

E. Flow delivery lapse in longer injection lines that are not in siphoning mode
For an injection line length of two miles and flows below 20 gpd, the flow rate delivery will lapse for approximately 24 minutes due to a well pressure rise of 1000psi. As the line length is increased and/or the flow rate is decreased, the time delay will increase. A Subsea BPR reduces or eliminates flow delivery lapse for long injection lines that are not in siphoning mode.

Describe the design and development solution to the problem.

The goal of eliminating the problems listed in the previous section led to the design and development of the Subsea Back Pressure Regulator (BPR), the device is shown below in Figure 1.1.

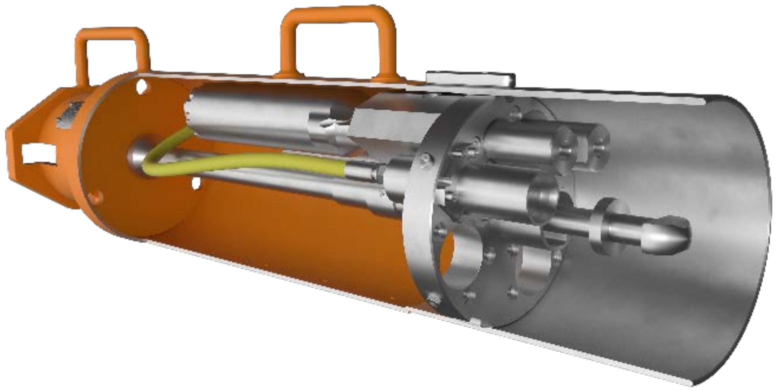


Figure 1.1 SkoFlo Subsea BPR shown in ROV Retrievable Docking Canister

Subsea BPR is a simple and robust anti-siphoning device that creates back pressure in chemical injection umbilical lines to prevent uncontrolled delivery of chemicals into production wells. The BPR is a purely mechanical device which requires no electrical power. An optional pressure sensor is offered for diagnostic purposes upon request.

Subsea BPR devices are typically installed on subsea chemical injection lines before the injection point into production flow lines. See figure 1.2 for typical field architecture and Figure 1.3 for a P&ID of the BPR internals. In the first stage back pressure is controlled by a gas charge reference pressure that activates a valve trim using no electrical power. A second stage within the device minimizes cavitation and maximizes debris tolerance. See figures 1.5 and 1.6 for more detail on the first and second stage processes. Figure 1.4 is a simplified graphic of typical field architecture to the Subsea BPR inlet, with a graphical P&ID overlay in the foreground.

Cavitation is reduced or eliminated by separating pressure drops across two stages. Utilizing two stages allows for larger fluid paths resulting in a higher debris tolerance than in a single stage. This results in longer device life and lower design and operating pressures of topside chemical injection systems.

Please see http://www.skoflo.com/BPR for the animation.

Please see http://www.skoflo.com/subsea-back-pressure-regulators.cfm for a brief demonstration with animation.

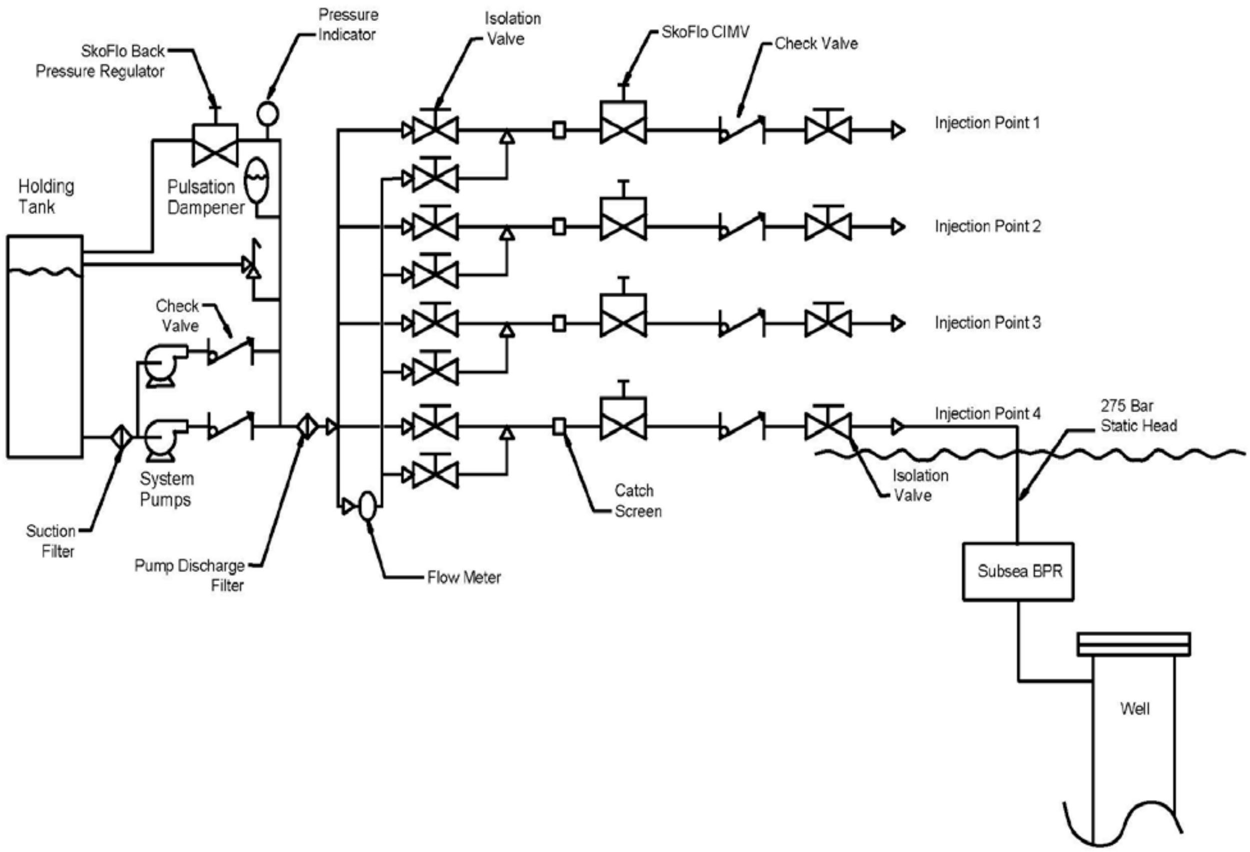


Figure 1.2 – Chemical Injection System Field Architecture

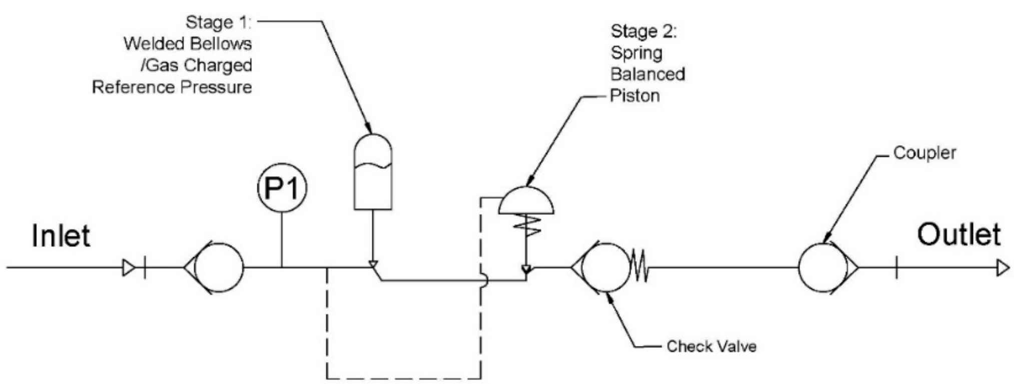


Figure 1.3 Subsea BPR P&ID

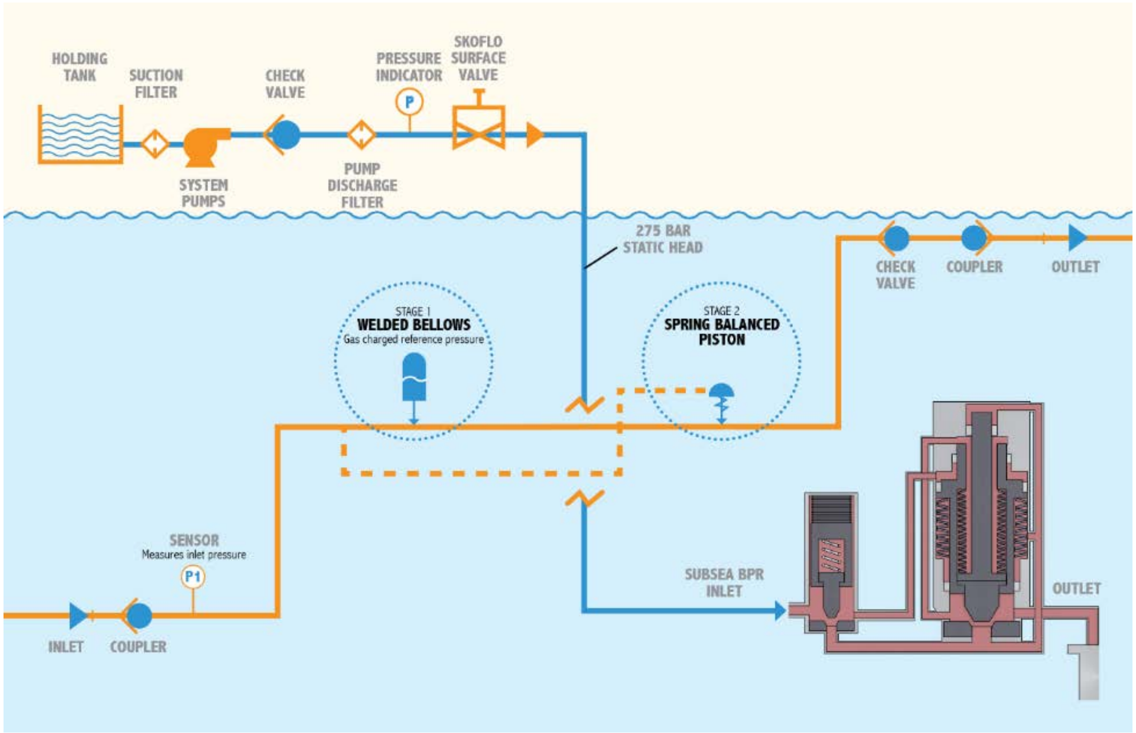


Figure 1.4 Subsea BPR P&ID (orange) and Chemical Injection Field Architecture Graphic

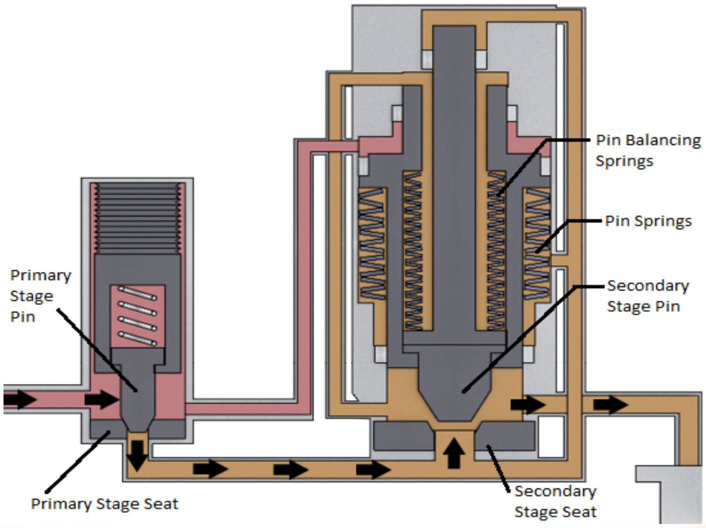


Figure 1.5: First Stage – A gas charge reference pressure activates a valve trim allowing the device to only regulate when the injection pressure falls below a set reference pressure. Otherwise, the device remains in the idle stage, which is simply a fixed orifice.

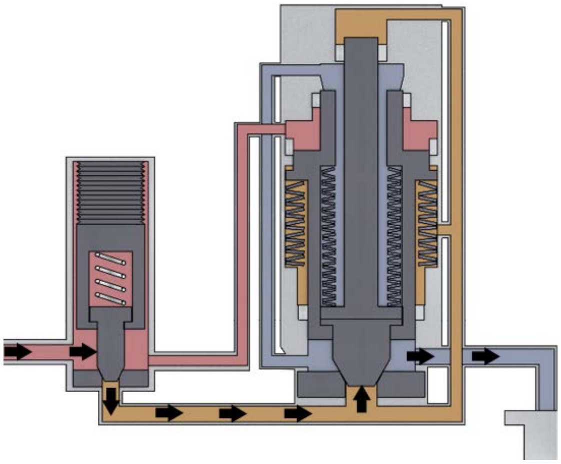


Figure 1.6: Second Stage minimizes cavitation and maximizes debris tolerance

Describe the specific innovation in mechanical engineering.

Previous to the development of the Subsea BPR there was no existing solution to the problems listed in Section 7. The device is capable of dissipating pressure drops over 6,000 psi without erosion or cavitation over a 1200:1 range of flow with a 25-year design life in a harsh subsea environment.

The novelty of the Subsea BPR is that it does not require any external power or control connections. Utilizing a gas charged reference pressure, the device only operates to regulate back pressure when the well pressure falls below a factory set point. Otherwise, the device remains in the idle stage, which is simply a fixed orifice.

Pressure drops are optimized over two separate stages, which allow higher pressure drops to be accommodated to reduce or eliminate cavitation. Additionally, utilizing two stages allows for larger fluid paths; resulting in a high debris tolerance.

This patented innovation will create demand for an entire new class of Subsea products.

What benefits to the manufacturer were realized through this design?

Through the development of the Subsea BPR the manufacturer is able to offer a chemical injection solution to fluid siphoning that did not previously exist on the market. The Subsea BPR in combination with chemical injection metering valves and/or chemical injection pumps allows the manufacturer to offer a more complete chemical injection solution.

- Manufacturer easily customizes the Subsea BPR to suit the user's needs
- Ability to package the Subsea BPR into compact spaces in any orientation without a need to interface with the device.
    - Fits into standard SkoFlo Subsea docking canister
    - Requires no electrical power or communication with the Subsea Control Module
    - Gas charged bellows reduces product size and weight
- Assembly, qualification, and testing are reduced because the device is purely mechanical and requires no power or communications.

Development of the Subsea BPR led engineering, manufacturing, and R&D to more creative solutions with subsea chemical injection challenges.

What benefits to the user were realized through this design?

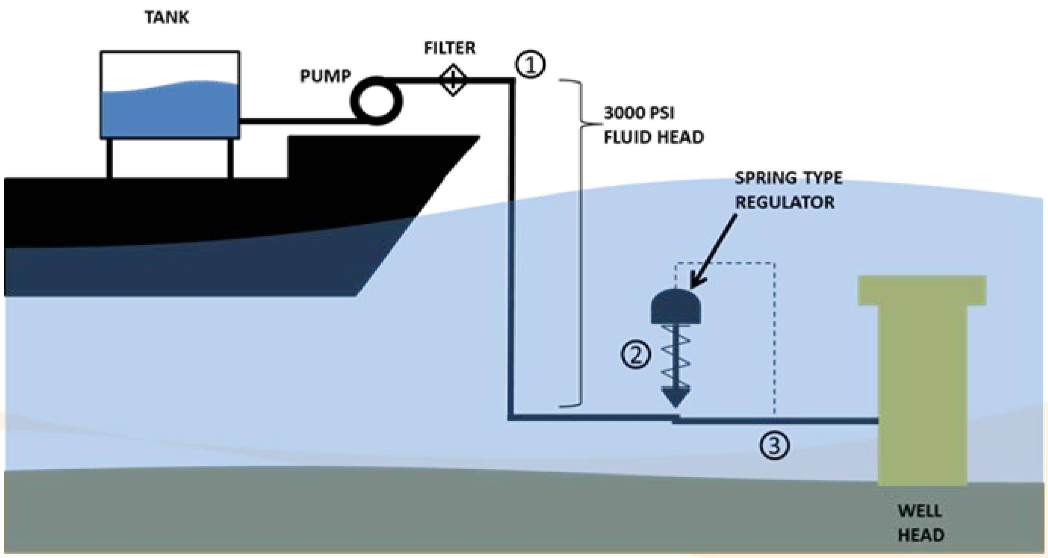
Subsea Back Pressure Regulators (BPR) are used for new or existing oil and gas fields. For brownfields, they are used for wells which have reduced pressures to prolong the life of the field. For greenfields, Subsea BPRs typically start service without regulating pressure and are activated when a well eventually goes sub-ambient.

- This technology enhances and extends the life of a subsea oil or gas well by arresting uncontrolled chemical delivery caused by fluid siphoning. This extends the ability to protect lines for a much longer period of time.
  - Allows corrosion inhibitors to be effectively dispensed; allowing better chemical performance and decreasing the risk of production fluids leaking to the environment
  - Reduces the risk of plugging and line abandonment when injecting hydrate, wax, and asphaltene inhibitors
  - Minimizing chemical over-dosage to address fluid siphoning reduces overboard treated water emissions
  - Allows faster and more frequent pressure testing of chemical injection lines
  - Tolerant to surges in flow several times the full-scale rating to accommodate for transients caused by subsea shut off valves and subsea docking actions.
- Requires no electrical power or communication with a subsea control module
  - Increases reliability
  - Lower installation and operating costs
  - Compatibility with existing fields
- Product is activated at any time within its 25-year design life using a Nitrogen Gas Charge in the first stage.
- No dynamic seals to seawater. All static seals are metal seals.
- Small form factor enables installation on logic caps or umbilical porches in any orientation.
- High level of debris tolerance - Endurance tested at 5,000psi drop to zero outlet pressure with fluids at debris levels multitudes greater than SAE 4059 Class 12 and at twice the rated full-scale flow validating that it requires no subsea filtration.
- When used in combination with downhole check valves in deep wells and deep waters with low formation pressure, the Subsea BPR reduces the drop across the downhole check valve. Reduced pressure drop allows the downhole check valve to work within the operating range.
- This device, in combination with downhole check valves, suppresses boiling in downhole chemical injection lines.
- For application of subsea hoses during temporary operations in deep water, this device prevents hose collapse due to fluid siphoning.
- SkoFlo BPR has option of built in check valve in case reverse pressure conditions over 1,000psi are expected.
- Reduce or eliminate flow delivery lapse for long injection lines that are not in siphoning mode.
  - For example, an injection line longer than two miles with flow below 20 gallons per day, delivery will lapse for approximately 24 minutes due to a well pressure rise of 1000psi.

- Benefits of using SkoFlo's Passive Gas Charge Regulator Design vs Active Spring Type design assuming no Friction Losses

Active Spring Type Regulator with Constant 3500psi drop (No Atmospheric Reference)			
Location	**Start up (psi)**	**Mid Life (psi)**	**End of life (psi)**
Deck (1)	8,500	3,500	500
Sub Sea (2)	11,500	6,500	3,500
Well Head (3)	8,000	3,000	0
Drop Across Back Pressure Regulator	3,500	3,500	3,500

Passive Gas Charge Regulator Charged to 3500psi (SkoFlo)			
Location	**Start up (psi)**	**Mid Life (psi)**	**End of life (psi)**
Deck (1)	5,000	500	500
Sub Sea (2)	8,000	3,500	3,500
Well Head (3)	8,000	3,000	0
Drop Across Back Pressure Regulator	0	500	3,500



Chemical Injection

A New Way to Combat Chemical Siphoning in Low Pressure Wells

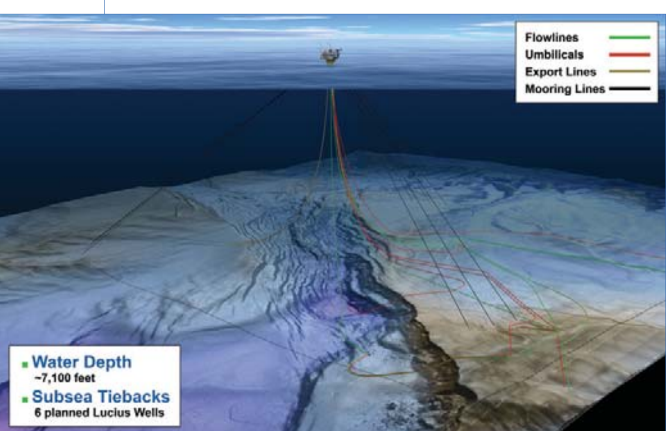
Translucent image of the anti-siphoning device

Subsea oil and gas wells are commonly fed one to three different chemicals from pumps and storage tanks located on production platforms. Miles of high pressure injection line tubing transport chemicals to inject either before or after the subsea choke.

These chemicals are used to inhibit corrosion, scale, ashphaltene, foam, and hydrates that will corrode or block production flow lines carrying crude and natural gas from the well to surface. Adding to the substantial investment of the chemical distribution system, chemical costs to treat produced oil subsea can be significantly high.

As well pressure declines for deep water applications, fluid head in the injection line can greatly exceed well pressure causing chemical to siphon uncontrollably into the well. Most chemicals are designed for continuous rather than batch injection. Erratic batch injection will occur by default when fluid is siphoned leading to sub-optimal chemical treatment.

Chemical feed line design is either distributed or direct systems. Distributed systems share a feed line that branches out to individual wells to save on the cost of the injection lines and allow lower cost of future expansion.



Lucius Platform supplying six subsea wells Image:Anadarko

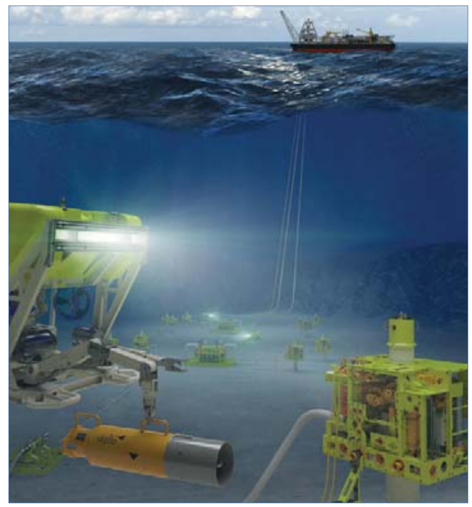
For distributed systems, Chemical Injection metering Valves (CIMVs) are located at the well which measure and control the rate of the chemical into the well. CIMVs prevent fluid siphoning in distributed systems by restricting flow at the well location.

Chemical lines are typically dedicated to individual chemicals to avoid reacting with each other. Direct systems run from the platform to the well and are more common for step out distances less than five miles.

A direct system feeding ten wells with three different chemicals will have over thirty chemical lines including spares leaving the platform.

A need, therefore, exists to prevent fluid siphoning in direct systems in deep water for wells where the well pressure has declined below the fluid head of chemical line feeding it. In February of 2012 Anadarko sponsored SkoFlo Industries to develop a device to combat fluid siphoning for the Lucius field in the Gulf of Mexico.

This oil producing field in 7100 feet of sea water is equipped with a gas lift system which injects gas into the well to lighten the fluid column when the well pressure falls below sea water head. Gas lift causes chemical lines to exceed the well pressure resulting in chemical siphoning.



ROV-deployed system in a subsea scenario

Anadarko did not wish to use a CIMV for this application. CIMVs require power, communication lines, and software interfacing, making them difficult and expensive to deploy after the tree has been installed. CIMVs are typically designed for up to 3000 psi of continuous pressure drop with sufficient pressure on the outlet of the CIMV to prevent cavitation of throttling points. This dramatically shortens the life of the CIMV.

With a fluid head of chemicals above 3500 psi for the Lucius field and the well pressure projected to be as low as 500 psi, a more robust cavitation resistant solution was required.

A back pressure regulator (BPR) used to provide a constant pressure drop in excess of the fluid column was proposed. The final solution consisting of a hermetically sealed gas charged reference pressure activating a throttling valve trim without power or communication fit Anadarko's needs.

Refinement was needed to allow pressure drops in excess of 3000psi inlet and less than 500 psi outlet for future projects subjecting the device to extreme cavitation conditions. The solution was a second throttling stage that engages before the drop across the first stage exceeds damaging levels. Other design considerations were:

- To pass debris levels exceeding SAE 4059 class 12 while throttling.
- To be small enough to deploy in docking hardware provided by SkoFlo or on Multi Quick Coupling (MQC) plate systems for deployment after tree installation.

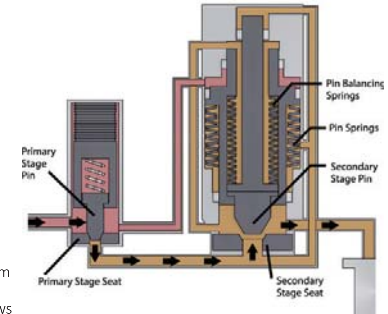
A simplified cross section of this device, referred to as a subsea BPR, is presented below showing a first stage activated by the inlet pressure dropping below the gas charge pressure which in-turn allows the stem to move towards the seat creating a throttling action. The next figure shows the second stage enacting before the first stage experiences excessive pressure drop.

The device was qualified in 2014 then eighteen devices were deployed in December 2014 with some wells already experiencing a 2,500 psi drop across the subsea BPRs.

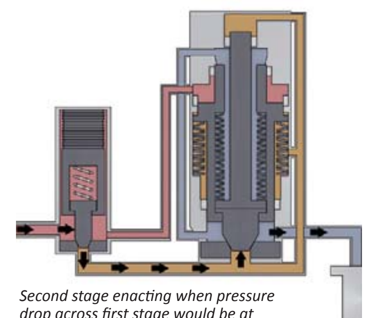
Although the subsea BPRs do not require power or communication, a pressure sensor was added to the inlet of the device to monitor the effectiveness of the device and diagnose potential line plugging feeding it. All devices to date have worked as specified.

Additional applications are:

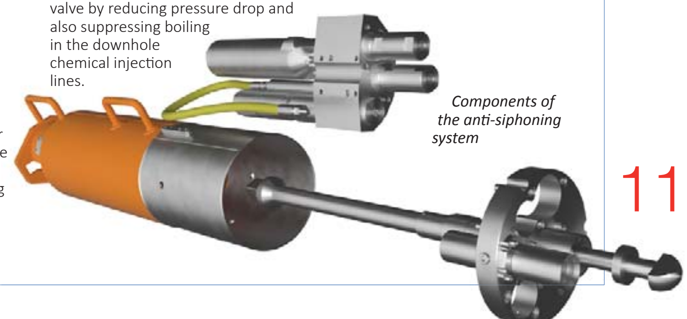
- To eliminate uncontrolled chemical injection and preventing hose collapse caused by fluid siphoning.
- To protect the downhole check valve by reducing pressure drop and also suppressing boiling in the downhole chemical injection lines.



Gas charged first stage enacting when inlet pressure falls below gas charge



Second stage enacting when pressure drop across first stage would be at risk of cavitation damage



Components of the anti-siphoning system

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