SkoFlo Subsea BPR Frequently Asked Questions

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.

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Describe the design and development solution to the problem.

The goal of eliminating the problems listed in Section 7 led to the design and development of the Subsea Back Pressure Regulator (BPR), the device is shown below in Figure 2.1.

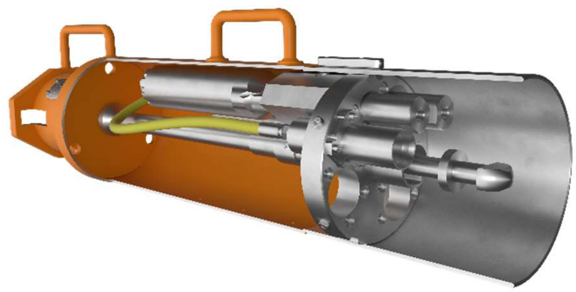

Figure 2.1 SkoFlo Subsea BPR shown in ROV Retrievable Docking Canister

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 2.2 for typical field architecture and Figure 2.3 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 2.5 and 2.6 for more detail on the first and second stage processes. Figure 2.4 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.

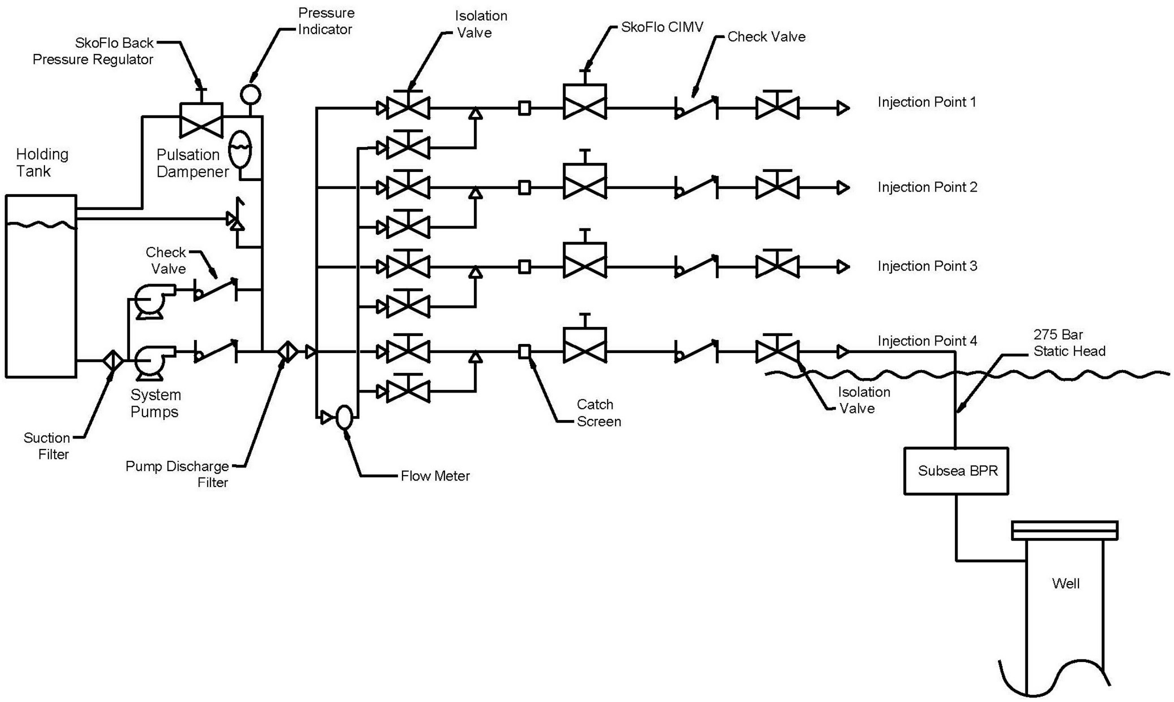

Figure 2.2 – Chemical Injection System Field Architecture

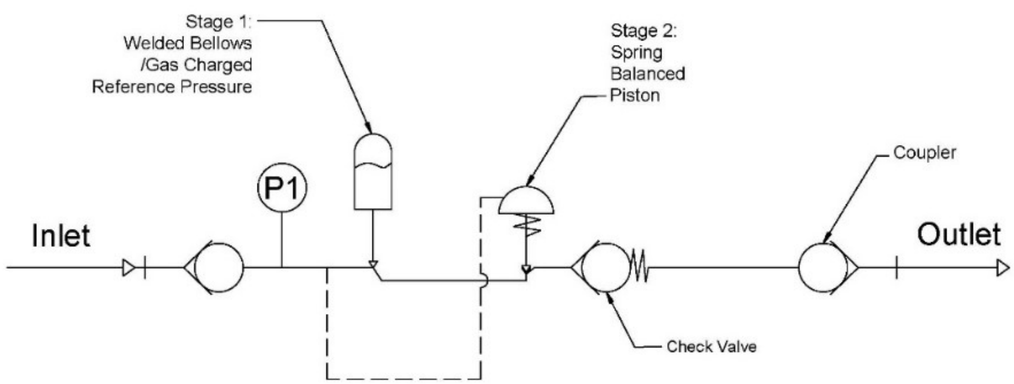

Figure 2.3 Subsea BPR P&ID

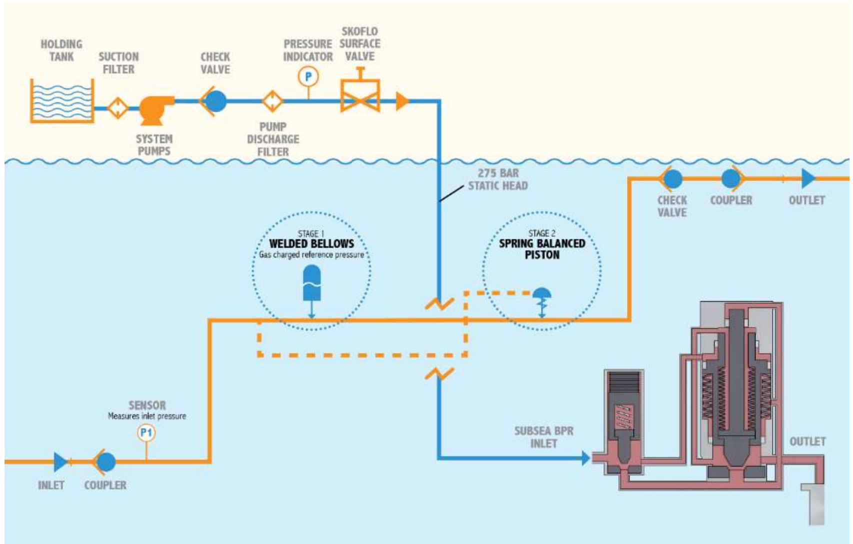

Figure 2.4 Subsea BPR P&ID (orange) and Chemical Injection Field Architecture Graphic

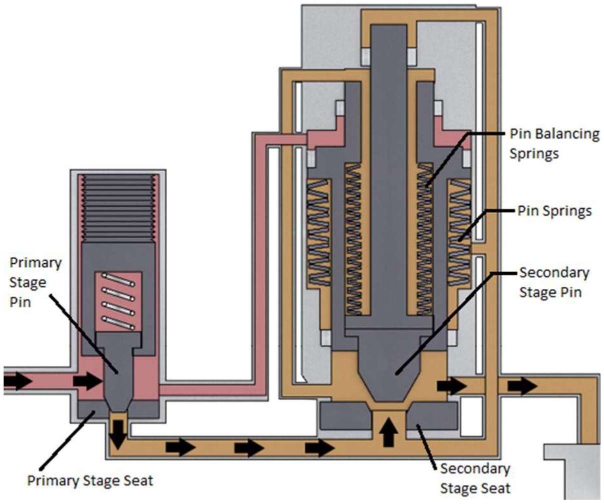

Figure 2.5: First Stage – A gas charge reference pressure activates a valve trim allowing the device to only regulate when the injection pressure falls below a set reference pressure. Otherwise, the device remains in the idle stage, which is simply a fixed orifice.

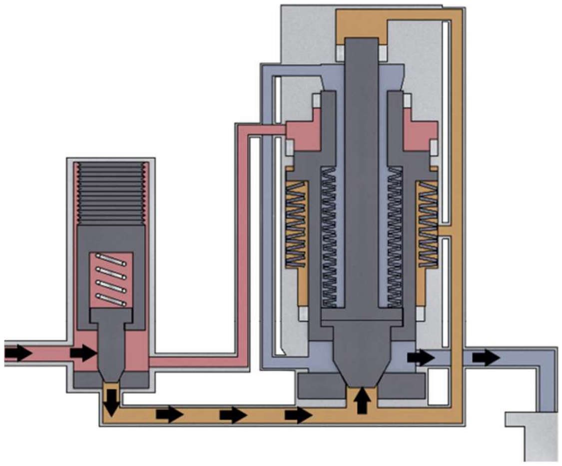

Figure 2.6: Second Stage minimizes cavitation and maximizes debris tolerance

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.

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
- 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
- Small form factor enables installation on logic caps or umbilical porches
- High level of debris tolerance
- 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.
- 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.