

Surge Analysis for Water Injection Systems in the Offshore Oil & Gas Industry

Surge Pressure

Surge pressure, also known as “Water Hammer”, is an important design consideration for water injection systems in the Offshore Oil and Gas Industry. When designing a Subsea water injection system, the following challenges are frequently encountered:

- **High operating pressures** are required to inject large volumes of water into hydrocarbon reservoirs. High operating pressures mean high surge pressures, and significant costs are incurred to design a system capable of withstanding a high maximum allowable surge pressure.
- **High fluid velocities** are often encountered as operators try to squeeze the maximum performance from their systems, or when an existing system has been expanded considerably beyond its original scope. Higher surge pressures are generated when incompressible fluids at high velocities are suddenly halted.
- **Long Pipelines**, which can be several kilometres in length, are often deployed to connect offshore platforms/FPSOs to Subsea water injection equipment. When fluid is halted (e.g. by sudden valve closure) pressure energy is transferred to the pipe wall and a pressure wave is sent, at the speed of sound, from one end of the pipeline to the other.

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Ajmal Zia, Flow Assurance
Engineer within the Offshore
Oil & Gas Industry



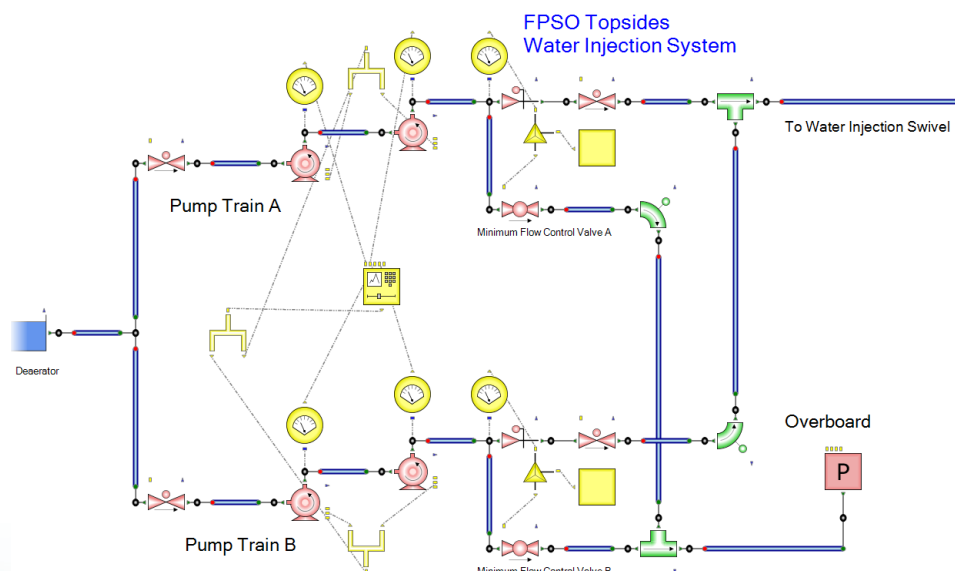
The time it takes for the pressure wave to reach the opposite end of a pipeline is increased with the length of the pipeline; additional fluid flows into the pipeline during this time and must be compressed resulting in increased surge pressure.

- **Subsea Pipelines & Equipment** are difficult to protect against pressure surges. Protective equipment such as bursting discs or surge tanks, which are often employed on Onshore/Topsides facilities, are impractical to install underwater. Extending valve closure times or staggering the valve closure sequence are the most practical options to mitigate surge pressure Subsea.
- **Rapid valve closure times** tend to be utilised for emergency shutdown valves to ensure a facility will reach safe conditions in a quick and efficient manner. Rapid valve closure increases surge pressure because fluid is halted more quickly.

Identifying Surge Cases

Surge analysis on water injection systems is performed to determine the maximum pressure surges that can occur as a result of transient events such as rapid valve closure during pipeline operation, or pump trip and restart operations.

The first step in any surge analysis is to identify credible cases where surge can arise. For example, closure of a single valve in a complex water injection network is unlikely to be an issue; however, closure of all wells while water injection pumps continue to operate (e.g. due to malfunction of a facility's shutdown system) is potentially a serious concern.



Flowmaster screenshot of a Topsides water injection system

The Role of Flowmaster

After the surge cases have been identified, the next step is to build an accurate simulation model using Flowmaster. Both the Topsides and Subsea systems need to be considered to ensure confidence in any results obtained.

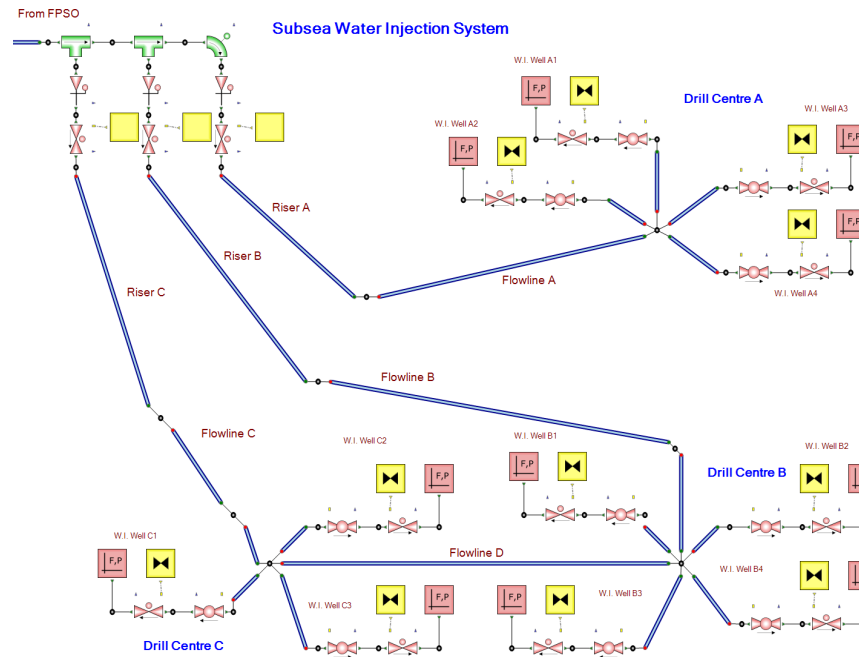
Water injection models usually commence at the deaerator, which, due to the very brief nature of the transient events can be considered to be a constant-head flow source. The water injection pumps and any major fittings are modelled downstream of the deaerator. It is critical that control systems (e.g. minimum flow controllers), safety devices (e.g. Topsides bursting discs) and shutdown systems are included as they can have a significant impact on the results.

For the Subsea system all the pipelines and wells are included. The model usually ends downstream of the injection trees, or immediately upstream of the reservoir. Choke valves are modelled to control the flow rate to each well and the injection wing or master valves are slammed shut to create a surge event. Subsea risers, pipelines and jumpers should be modelled using the elastic pipes option to improve simulation accuracy.

When surge analysis is carried out at an early stage in the design of a water injection facility Flowmaster can be used to predict the maximum surge pressure and this can be used to select system design pressure. For surge analysis on an existing system Flowmaster can be used to investigate measures to mitigate surge (e.g. extending valve closure time) to ensure that the system's maximum allowable surge pressure is not breached. It is important that surge cases considered are realistic otherwise considerable expense may arise due to an overly-conservative design pressure on a new facility, or due to unnecessary modifications to an existing facility.

The advantages of using Flowmaster for surge analysis include:

- The fully elastic behavior of pipelines is accounted for.
- Small time steps can be used to accurately simulate fast-transients.
- Simulation times for large models, with many components and nodes, are relatively fast.
- Complex control systems can be utilized including P&ID controllers and advanced scripts (e.g. to trip water injection pumps upon detection of high discharge pressure).



Flowmaster screenshot of a Subsea water injection system

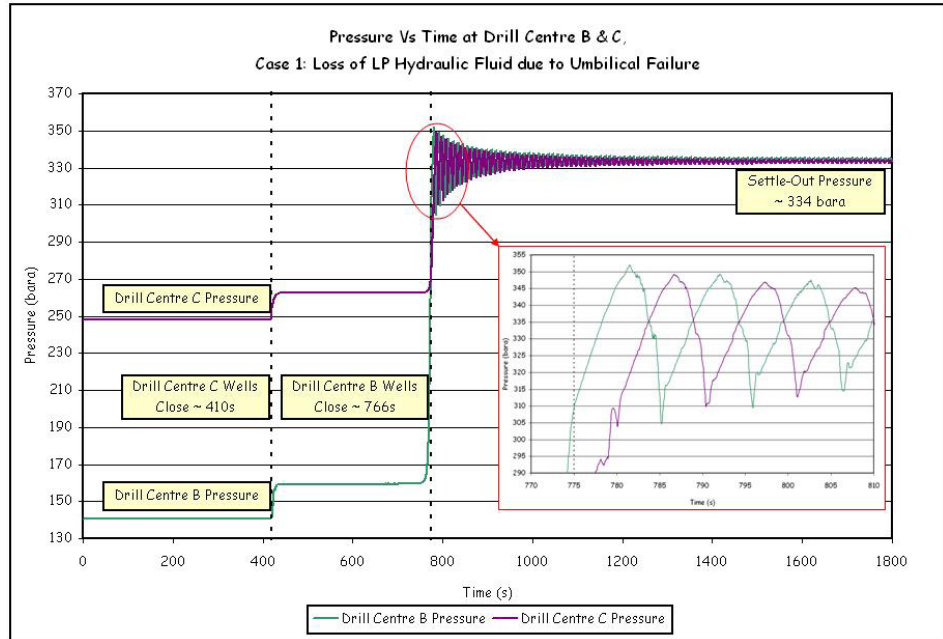
Ajmal Zia, Flow Assurance Consultant within the Offshore Oil and Gas industry explains how Flowmaster has been used for surge analysis of water injection systems, ranging from conceptual studies to detailed design.

“We recently conducted surge analysis for a Client involving the tie-in of a new drill centre to an existing system. The design pressure of the existing water injection system had to be adhered to, but significant changes to the control system were possible because a new MCS (Master Control Station) was being installed to service the new drill centre.” explains Ajmal Zia.

Example Surge Analysis Project

The first step was to assemble the relevant discipline engineers and operators to discuss the potential surge cases. The following cases were identified:

- Loss of LP (Low-Pressure) hydraulic fluid due to umbilical failure resulting in closure of all wells at 2 drill centres.
- Subsea electrical power failure resulting in closure of all wells at the new drill centre.
- Malfunction of MCS resulting in shutdown of all Subsea wells while Topsides pumps continue to operate.
- Operator error resulting in mistaken valve closure.



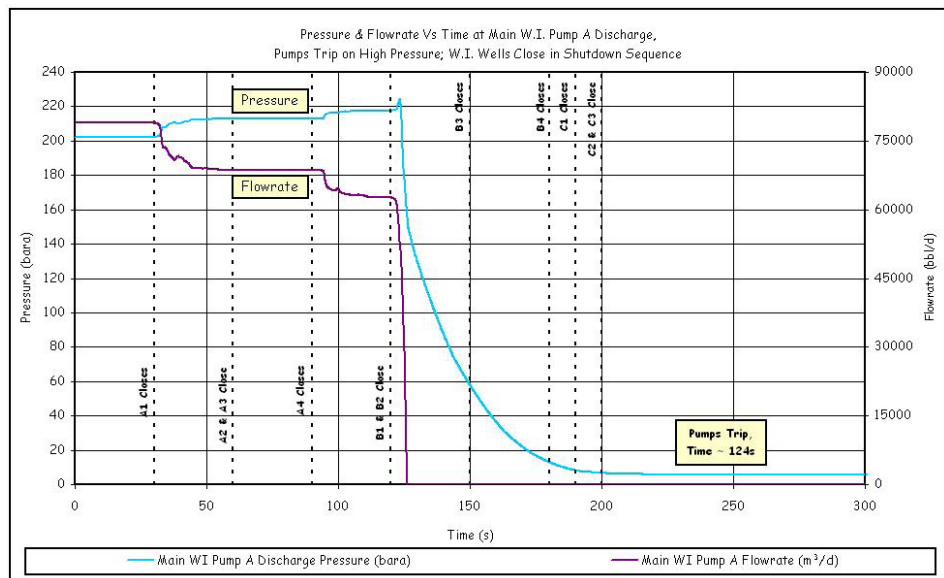
Pressure Vs Time for Umbilical Failure Case

Results

Next, using Flowmaster, each case was simulated in detail and it was determined that the maximum allowable surge pressure could be breached in each case.

The following mitigating measures were proposed for each case:

- Trip Topsides water injection pumps upon detection of loss of LP hydraulic lines. This required the installation of new pressure transmitters external to the HPU (Hydraulic Power Unit).
- Trip Topsides water injection pumps upon detection of loss of Subsea electrical power.
- Program the MCS to stagger the closure of wells in the event of a shutdown.
- Implement new control system logic to prevent simultaneous closure of wells by operator error. Each additional well is prevented from closing until the previous well closure sequence is completed.



Discharge Pressure & Flowrate Vs Time for Emergency Shutdown Case

Conclusion

In all cases, the mitigating measures either eliminated surge pressure entirely, or reduced it within acceptable limits.

“Flowmaster was an indispensable tool on this project. The simulations made it possible to quantify the severity of each surge case and to assess the effectiveness of each solution.” concludes Ajmal Zia, Flow Assurance Engineer within the Offshore Oil & Gas industry.