AFT Impulse™ Study Reveals Flaws in Injection System Emergency Protection Methods

CASE STUDY

Ground Injection
Oil & Gas Industry

Wood PLC
Calgary, Canada
Platinum Pipe Award Winner: Operational Benefits and Sustainability

Wood PLC was tasked to assess the water injection system of an offshore production platform expansion. The injection system is comprised of a low-pressure section fed by two booster pumps, and a high-pressure section driven by two 1000 hp injection pumps that feed to the wellhead. All four pumps have check valves and automated minimum-flow control valves or auto-recirculation valves for no-flow deadhead protection. The system as modeled can be found in Figure 1. The system was flagged as an area of concern due to the long flowlines and high operating pressure of the injection system (more than 10,000 psi / 690 bar).

Chris Bibby was tasked with performing a transient analysis in AFT Impulse for pump start-up, controlled shutdown, emergency shutdown, and valve failure scenarios to determine if pressures or forces exceeded acceptable limits. Through testing, the controlled start-up and shutdown cases were controlled easily by the injection pump VFDs to avoid a drastic transient response.

> "The protection system began to open well after the flow reversal and check valve slam already occurred."

The emergency shutdown (ESD) case considered the uncontrolled trip of pumps and simultaneous closure of the discharge shutdown valve. Due to the high pressure added across the injection pump, significant reverse flow occurs as the pumps trip, resulting in check valve slam at the system's four check valves. The check valve slam causes a low-pressure transient and cavitation in the low-pressure section of the system. The slam event and subsequent cavitation collapse resulted in unacceptable forces well above piping and pump nozzle guidelines. An axial non-slam check valve was able to mitigate these effects and eliminate the transient cavitation, reducing forces to acceptable levels.

The valve failure scenario closes off the discharge to the wellhead with the pumps running. In theory, automated minimum-flow control valves would redirect flow overboard and avoid pump deadhead due to the slowly closing valve. As found in Figure 2, the sequence of events revealed the intended protection opened after reverse flow, check valve slam, and more severe forces resulted.

While replacing the check valves mitigated the slam event for the ESD scenario, forces remained unacceptable for the valve failure. The owner installed limit switches in the valves to indicate to the pumps if the valve failed, initiating a controlled shutdown. Further, Bibby considered the response of a worst case limit switch failure, generating transient forces to export to Ansys for a dynamic stress and load analysis. Ultimately, even a double failure of limit switches had low risk of contamination or catastrophic failure.

Bibby cited many of AFT's visualization tools to understand the cause-and-effect of transient events and thereby strategies for mitigation. Visualization tools made communicating the results to owners and providing supporting evidence for suggestions clear across their many analysis cases. Bibby could model the control logic and response of the system with AFT's Event Manager and the implications of vapor formation and collapse on pressure following the check valve slam. AFT Impulse was instrumental in mitigating these failure risks and ensuring protective measures didn't exacerbate an emergency.

Wood is a global leader in consulting and engineering across energy and the built environment, helping to unlock solutions to some of the world's most critical challenges. They provide consulting, projects and operations solutions in more than 60 countries, employing around 40,000 people.

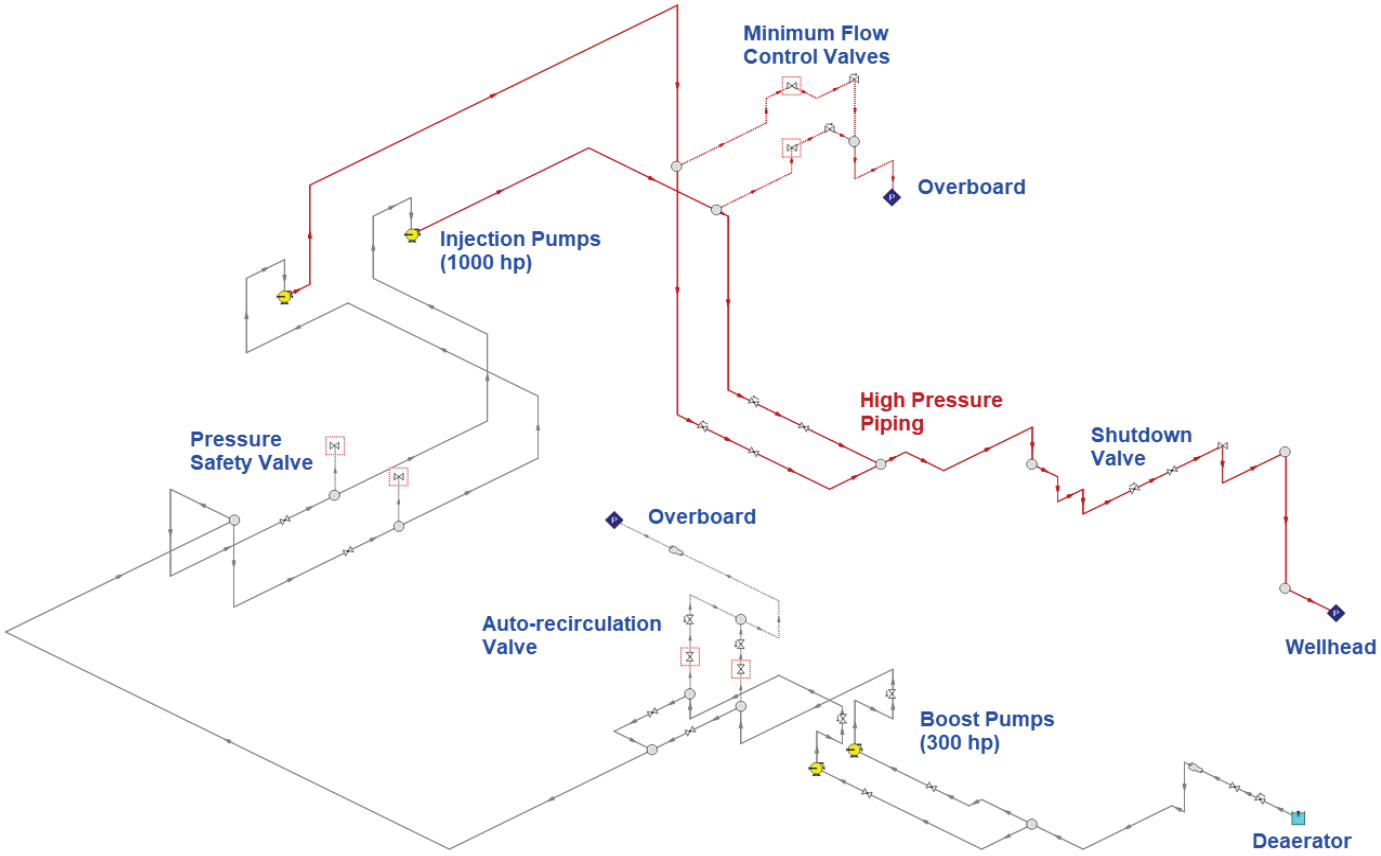

Figure 1: Workspace view of the injection system highlighting the supply, pumps, protection systems, and wellhead discharge.

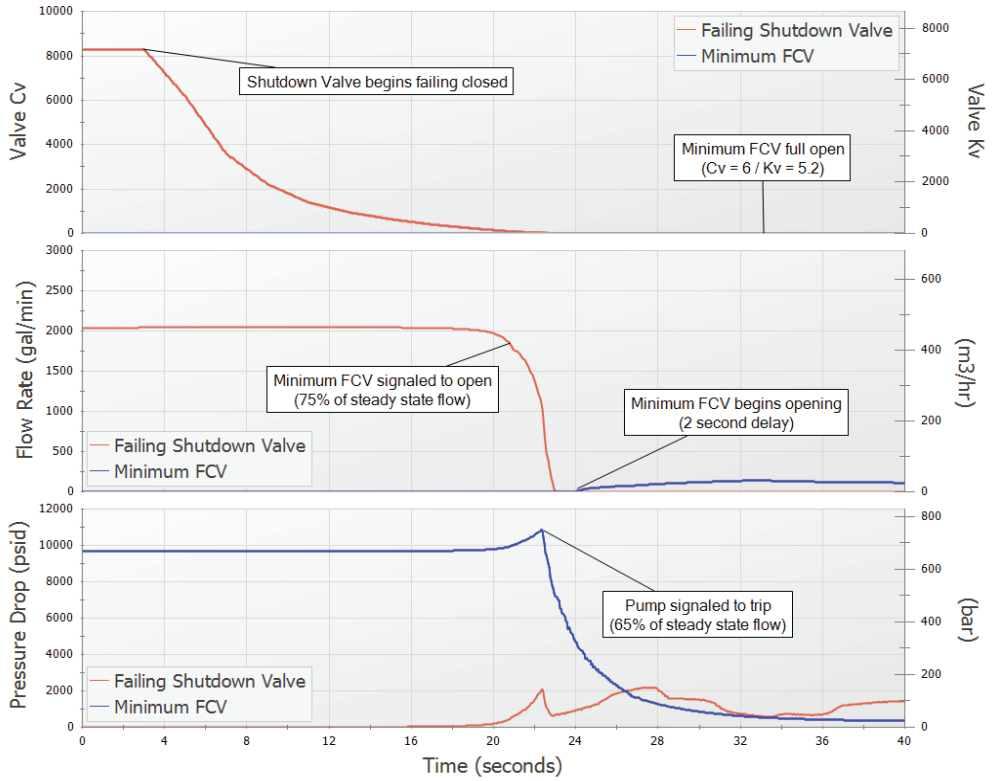

Figure 2: Transient graph showing the temporal relationship between the failing valve reducing flow, the trip of the pump to avoid deadhead, and the late opening of the minimum flow control valve