SA FIRE PROTECTION

OVERCOMING DELUGE SYTEM RELIABILITY CHALLENGES WITH THE DOUBLE CHAMBER DELUGE VALVE MODEL VDD

Overcoming Deluge System Reliability Challenges with the Double Chamber Deluge Valve model VDD

1 A MATTER OF INTERPRETATION

This review will concentrate on the role of the deluge valves, also known to Reliability Engineers as **final elements**. Those valves play a fundamental role in the success of the mitigation effect as their availability is key to deliver the water to the sprayers and therefore to protected targets. Some of the most advanced series of international standards for addressing the subject of reliability in fire protection are the NORSOK S-001[1] and the OLF 070[2] which provides the guidelines for the qualification of safety functions in deluge systems.

Among the significant technical contributions that those standards have provided to fire protection engineers, it is worth noticing that they finally have clarified a big misinterpretation that was obsessing the fire industry. It is in fact now clear to fire protection engineers that a deluge valve **is a final element** as the fire water is fully dependent by its availability to open on demand. This clarification has finally resolved the argument within the fire engineering community of Oil & Gas when it became necessary to document the reliability of a deluge valve as requested by S-001 itself.

The wrong interpretation considers the solenoid valve as the final element when instead it is just a component of the deluge valve control trim. Moreover, some have compounded the theory by proposing the installation of parallel solenoid valves acting on a single deluge valve meets the aim of increasing the reliability of the deluge system. Clearly this is all wrong!

The right interpretation is in fact addressed by OLF 070 which clarifies that the deluge valve shall perform its reliability as a whole and hence as a common aggregate of the deluge valve, its control trim and its pilot solenoid valve. The OLF 070 clarifies the definition of what final elements are which is the actual valve that controls the opening/closing of water and not its pilot solenoid valves which is of course an important part of the deluge system but again is only a part of it.
Furthermore, "The **fire water system shall be operable at all times including periods of maintenance** and shall ensure adequate supply of water for firefighting. **The system shall be designed** and calibrated **such that deluge nozzles will receive water not later than 30 seconds after a confirmed fire signal has been given.** For the fire water system, the fail-safe principles shall apply…"[3]

[1] NORSOK S-001 (2000) Norwegian Technology Standards Institution
[2] OLF 070 (2004) 070 - Norwegian Oil and Gas Application of IEC 61508 and IEC 61511 in the Norwegian Petroleum Industry

The availability of deluge valves at all times can be achieved with redundancies of either the activation control trim and the flow control chamber. The Double Chamber Deluge Valve model VDD (also simply known as the VDD), in fact has been designed to incorporate all these characteristics and comply exactly with the requirement of S001 granting **continuous operability even during maintenance. The VDD and its control trim is also designed to respond to failures in no time and therefore grant water flowing to nozzle instantaneously.**

In light of the above the double chamber deluge valves took the attention of the technical community for the design of fire protection systems for critical hazards. The VDD, is a system on its own which is comprised of two separate control trims (hydraulically bridged to form a unique actuation), which are capable to propagate the command to any of the two parallel membrane type chambers. The resulting deluge package is capable to perform with a very high level of reliability to the point that it has been validated by BV for integration in safety functions within Fire & Gas systems up to SIL 3. In addition to that the valve is equipped with an isolation system which allows for the impairment of a portion of the valve in order to allow for routine inspection, maintenance and/or repairs meanwhile the other portion of the valves remains operational and therefore grants continuous fire protection to the process equipment. This in compliance with NORSOK S001 Par. 10.7 which requires to the deluge packages to be available at all times.

[3] NORSOK S-001: Par. 10.7 *Active Fire Protection* (2000) Norwegian Technology Standards Institution

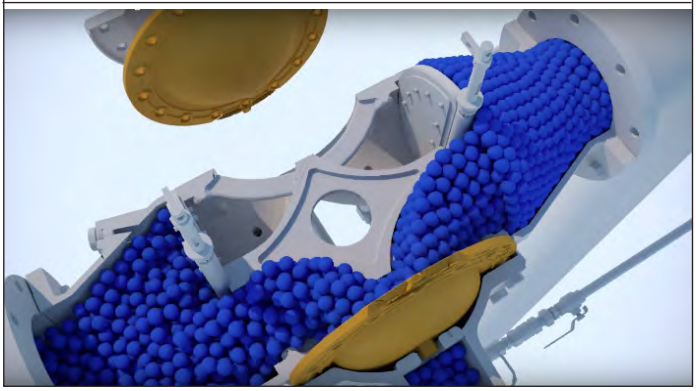
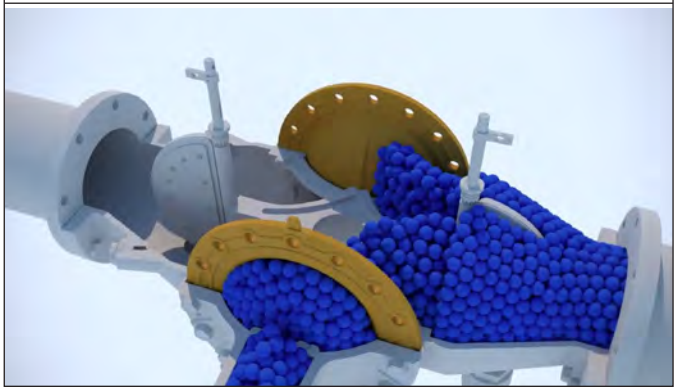
2 WHAT REGULATORS STATE REGARDING DELUGE SYSTEMS

According to OLF 070, the aim of the deluge system is to deliver a certain amount of water where need. As such, operators are encouraged to consider the function of the entire deluge system not simply some of its components:

Release of firewater / Deluge; (fire water **demand signal** processed in **Fire & Gas logic**, start of **fire pump**, and opening of **deluge-valve**)	SIL 2	The SIL requirement applies to the sub-function needed for opening of one deluge valve, given confirmed fire or gas, i.e.: - the fire water demand signal processed in the fire pump logic - start of fire pumps - Opening of one deluge-valve (given confirmed fire) **The function is considered successful when a certain amount of water (l/min) flows through the deluge valve.**

Table 7.1, section 7.6 of 070 – Norwegian Oil and Gas Application of IEC61508 and IEC 61511 in the Norwegian Petroleum Industry (2004).

In addition, NORSOK S-001[4] highlights that "*the fire water system shall be operable at all times including periods of maintenance and shall ensure adequate supply of water for firefighting*". The use of the term "*at all times*" emphasises the importance of availability but also it could be argued that it is deliberately used as a reliability demand. In point 10.7.4 it is noted "*Deluge valves shall be provided with manual bypass including flow restriction to match flow through the valve*". Furthermore, the bypass line shall be taken from another section of the ring main ensuring fire water supply at all times, including maintenance situations. Thus, the Deluge is intended to automatically release a certain amount of water upon confirmed gas detection for explosion mitigation at all times, irrespective of maintenance activities. Despite this, the industry has focused on highly reliable detectors and logic solvers while overlooking the importance of the reliability of the final elements (such as deluge valves), being able to complete the loop in order to achieve explosion mitigation.

ONE CHAMBER OPERATIONAL, ONE CHAMBER UNDER INSPECTION NFPA 25	BOTH CHAMBERS OPERATIONAL
	

[4] NORSOK S-001 (2008) Norwegian Technology Standards Institution

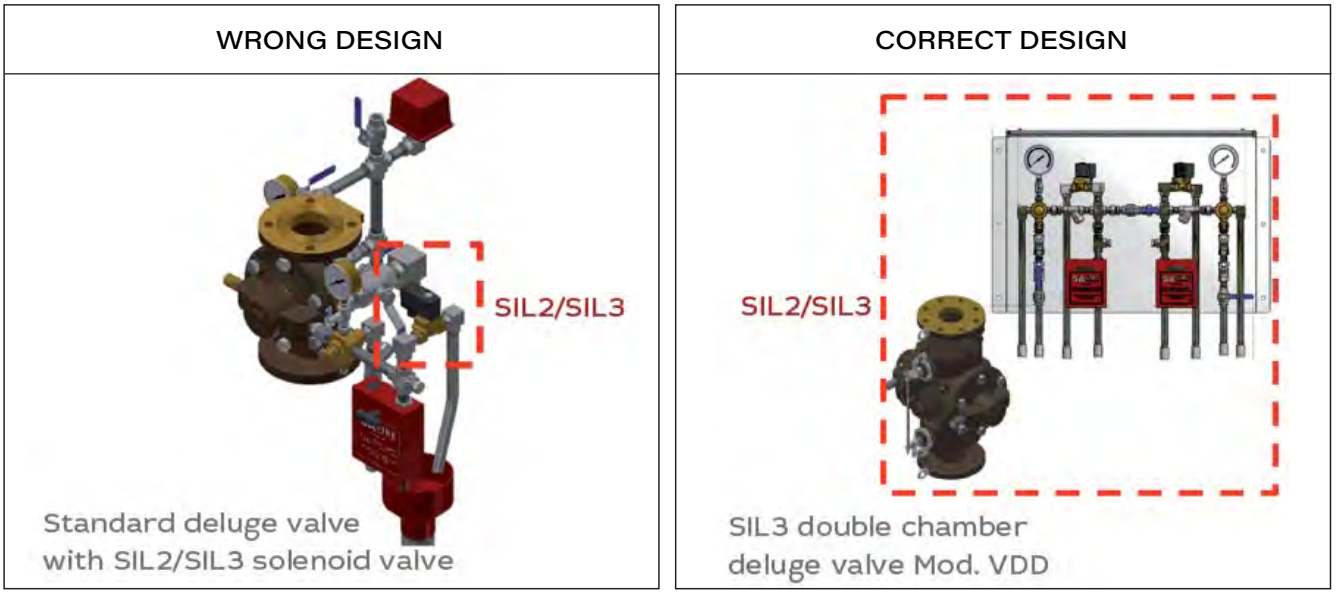
3 WORKING PRACTICE

Analysis demonstrates that the unavailability of the fire water system is highly reliant on the reliability of the deluge valves; in addition, "*the deluge valves constitute 95.5 % of the total unavailability*"[5], therefore the deluge valve has a critical function in the system. It is also shown that "*by designing fire areas that depend on one deluge valve instead of two decreases the system unavailability to about 50 % of the original unavailability*"[5]. It is important that the fire water system is available on demand at all times.

Table A.16 PFD results for deluge Component	Voting	PFD per component	System PFD	System PSF
F&G logic + I/O	1oo1	4.4×10^{-3}	4.4×10^{-3}	$5\ 10^{-5}$
Fire water pump	1oo2	9.4×10^{-4}	5×10^{-5}	-
Fire water diesel engine	1oo2	1.9×10^{-3}	1×10^{-4}	-
Electric generator	1oo2	1.4×10^{-3}	7×10^{-5}	-
Electric motor	1oo2	1×10^{-3}	7×10^{-5}	-
Deluge valve	1oo1	1×10^{-2}	1×10^{-2}	-
Total Function	-	-	**0.015**	**5×10^{-5}**

Table A.16, section 7.6 of 070 – Norwegian Oil and Gas Application of IEC61508 and IEC 61511 in the Norwegian Petroleum Industry (2004).

In respect of the data reached in the above table the overall system would only attain a quantitative SIL 1 level.



[5] Pettersen, M (2009) *Reliability Analysis of Fire Water Systems on Offshore Installations*. Norwegian University of Science & Technology

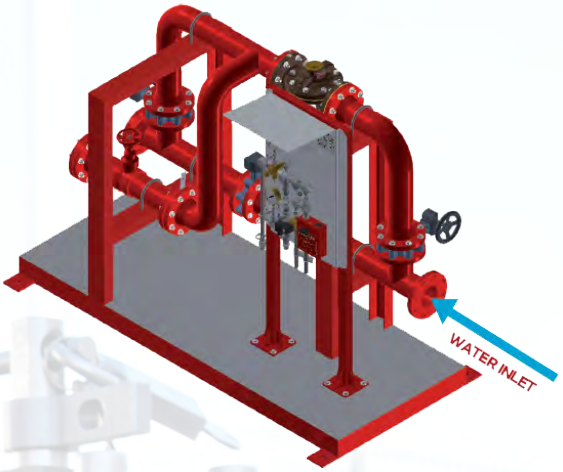
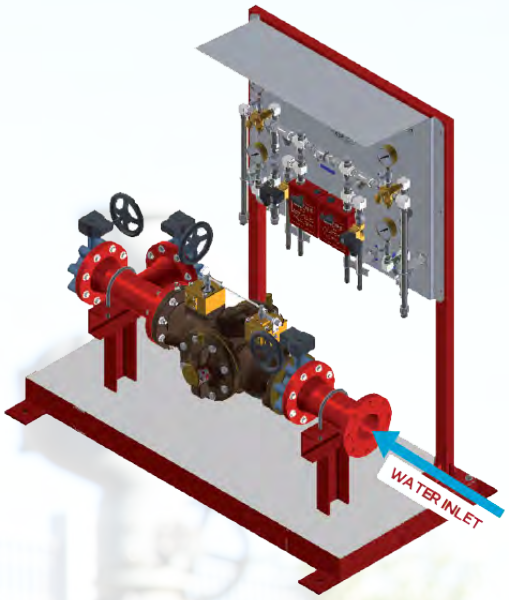
As seen from the above table a SIL 2 function can be achieved by installing a Double Chamber Deluge Valve or with more frequent testing of the standard valve. It is therefore concluded that the SIL 2 requirement is achievable!

4 KEY FEATURES OF THE DOUBLE CHAMBER DELUGE VALVE

The Double Chamber Deluge Valve Model VDD was designed for fire protection systems according to NFPA15, UL 260 and IEC 61508/61511. Furthermore, the VDD was designed to accommodate installations requiring high safety function performance ensuring the requirements mentioned in the "Recommended Guidelines for the application of IEC61508 and IEC61511 in petroleum activities on the Norwegian Shelf" which called for a minimum SIL2 level for the "***Deluge valve including actuator, solenoid and pilot valve***".

The VDD:

Has a fully redundant architecture; - has a built-in emergency bypass line; - comes with a hydraulic bridge between the trims which allows each trim to control both diaphragms: - can overcome double failure in the trim + priming chamber; - is very unlikely to fail on demand: - responds to failure affecting the valve in zero time; - provides continuous fire protection; - according to IEC 61508/61511; - is validated by Bureau Veritas up to SIL 3, is UL listed.

VALVE TYPE	STANDARD DELUGE SKID	DOUBLE CHAMBER MODEL VDD SKID
TYPICAL CONFIGURATION		
WEIGHT	Depends on the specific skid design	Less than the traditional because of the absence of the bypass line. Approx. 40% less depending on the configuration
NEEDED SPACE	Project Specific	Reduced because of built-in bypass line
MAINTENANCE (COST & TIME)	Industry standard	Same as per the traditional deluge valves but possible to be performed without impairing the fire protection system and therefore keep the process running.
DELIVERY TIME	Standard	Standard
TYPE OF MATERIAL YOU CAN SUPPLY	Cast Iron, Cast Steel, Stainless Steel, Super Austenitic Stainless Steel, Duplex, Super Duplex, Hastelloy, Bronze, NAB, or Titanium	Bronze, Nickle Aluminium Bronze, Super Duplex Titanium under development
MIN AND MAX VALVES SIZE	2” (DN50) to 10” (DN250)	3” (DN 80) to 8” (DN200)
PRESSURE MIN / MAX	1,38 bar to 26 bar	1,38 bar to 26 bar
ENGINEERING WORK	No major impact	Simplified skid structure
CERTIFICATION ON THE VALVES AND COMPANY	UL Listed	Validation certificate for SIL 3 Systems UL Listed
OTHER IMPORTANT THINGS		Designed to comply with: OLF 70 & NORSOK S-0001 Certified by Bureau Veritas for SIL 2/3 Deluge Systems Increased availability by providing continuous fire protection even during maintenance or repairs; Immediate response to failures due to hot back up chambers and trims operation.

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