According to statistics published by the US Environmental Protection Agency (EPA), there are hundreds of tank spills involving hazardous materials every day.

These spills may affect drinking water and, if exposed to an ignition source, there is the potential for an explosion. The cost of such incidents is measured in thousands, millions, or even billions of dollars, and can affect a company’s survival.

While there are other possible causes of tank spills – including leaks, tank ruptures from corrosion, incorrect couplings or tank openings being left open – overfilling is the most prominent problem.

Tank overfill is defined as the point where the product inside a tank rises above the critical level and risks causing a detrimental impact. This can include product overflow or tank damage. Fortunately, overfills are predictable and therefore preventable.

Historical data from the bulk liquid storage industry shows that one overfill occurs for every 3300 filling operations. So, for a group of 100 tanks where each tank is filled three times per month, the rate of overfill is once a year.

The consequences of a tank overfill can include the following:

- Risk to life and health.
- Environmental pollution.
- Property damage.
- Impact on corporate social responsibility.
- Public relations damage.
- Damage to the entire industry (reputation, regulations, fines).
- Legal consequences (including imprisonment).

The benefits of investing in robust overfill prevention go beyond fulfilling regulatory requirements and minimising risk. It also helps to increase profits through improved plant efficiency and reduced labour costs.

An overfill prevention system (OPS) provides a better understanding of what is in the tank, which means operators will be able to conduct faster transfers and utilise the tank more effectively.

Historically, overfill prevention has been synonymous with equipment known as the OPS. These assets have been installed to fulfil incomplete prescriptive regulatory requirements. However, safety has often taken a back seat to operational key performance indicators, with safety procedures becoming ineffective or, in some cases, disregarded. While overfills are typically attributed to

Shawn Statham and Marco Ferrara, Emerson Automation Solutions, explain how triple offset valves provide an effective solution to preventing liquid tank overfilling.
An automated overfill prevention system (AOPS), as defined in API 2350, is designed to prevent petroleum tank overfill and is the first globally recognised overfill prevention standard for the bulk liquid storage industry.

An automated overfill prevention system (AOPS) improves the risk reduction compared to a MOPS. By ensuring that each component is optimised for safety, an AOPS reduces workload for operators.

End users can enhance their safety systems by installing an AOPS, allowing customers to maintain required safety integrity levels (SIL) while reducing overfill risks.

A SIS typically includes a logic solver, sensors, and an automated emergency isolation valve as the final element, with each component contributing to the average probability of failure on demand (PFDavg).

A complete solution for AOPS

Studies by the Offshore and Onshore Reliability Data (OREDA) project reveal PFDavg contributions of 8% from the logic solver, 42% from sensors, and 50% from the final element. Based on this study, it is possible to determine that a significant portion of system reliability depends upon the final element.

The final element, however, faces several challenges as it typically sits static in an open position exposed to the process media, which, depending upon seat design, can lead to stiction and potential valve failure. Valve torque must be assessed over the lifecycle of the application to ensure actuators are sized correctly. Actuators must also be designed to sit static for long periods of time. The brackets and couplings should be designed and manufactured to withstand the extreme forces while maintaining perfect alignment of drive train components to prevent premature failure of the valve and the actuator.

IEC 61508 and 61511 do not address integration of the final element. Combining components into a complete package is typically left to best practices. With multiple brands and manufacturers involved, operators tend to see a wide array of solutions with little standardisation. Operators report reduced reliability, resulting in a high rate of systemic failures and spurious trips. These failures often reduce safety, drain plant resources, and increase operating expenditure.

Working with an original equipment manufacturer (OEM) single solution provider is beneficial to operators as it provides a single point of accountability for the final element in an AOPS system. It also ensures maximum component compatibility, delivering greater reliability throughout the safety lifecycle.

A comprehensive, intelligent solution for the final element will include a valve, actuator, and intelligent controls.

Utilising a digital valve controller allows for continuous condition monitoring, partial stroke testing, and comprehensive diagnostics to ensure the health of the final element.

By ensuring that each component is optimised for safety, and with the particular advantages inherent in using triple offset valves (TOVs), a single-supplier solution can deliver a system that provides even greater safety levels than the sum of its parts.

Manufacturer support is critical throughout the safety lifecycle. Ideally, an OEM will have expertise to assist with development of the safety requirement specifications (SRS), SIL verification, diagnostic coverage, proof testing, site acceptance testing, commissioning, condition monitoring, and end of life planning.
To ensure maximum reliability and availability, final elements should be engineered and designed to meet the required SIL. Designing a reliable final element begins with selecting the best valve for the application. There are several key benefits in using TOVs instead of traditional process valves. Firstly, with an accurate valve, material and actuator selection, systematic failure can be significantly minimised.

Secondly, the asymmetric trim design of the TOV delivers different valve behaviour, depending on the direction of the differential pressure. In the preferred sealing direction of the valve, the pressure keeps the valve closed, allowing safer functioning in emergency shutdowns. In the opposite direction, where the pressure facilitates opening the valve, TOVs improve safety when the function is to provide emergency open, including blowdown/vent operations.

**TOVs: an optimised ESD valve**

Using traditional emergency shutdown (ESD) valves – such as gate, plug, and ball – typically requires a large automation package. In addition, these valves sit static for extended periods of time, becoming vulnerable to stiction, with sealing surfaces continually in contact with the media. Failure to stroke fully and provide bubble-tight shutoff defeats the purpose of installing the ESD valve and is a major concern for end users.

These issues, combined with more stringent health, safety and environmental requirements, mean that tank farm operators are increasingly selecting TOVs for liquid hydrocarbon storage tank protective services.

Originally used as fire-safe shutoff valves for hydrocarbon storage tanks, TOVs have brought value to facilities as they can maintain a leak-proof seal under anticipated fire exposure. When integrated into a system where other components also offer enhanced safety, TOVs can provide a highly effective solution.

Easy to operate, TOVs are often used for the isolation of matrix manifolds and pump areas instead of ball and plug valves. They can also be used as general shut-off/on-off valves to provide the flow logic by selecting one flow path against another, and to connect external equipment to the system.

The popularity of TOVs in tank farm safety systems has increased because of their high reliability. Technical developments – including non-rubbing, metal-to-metal TOVs, which ensure a long mean time between failures (MTBF) – have also helped to reduce lifetime costs of the valve.

TOVs feature optimised seating angles that significantly reduce the risk of jamming compared to traditional gate isolation valves. In addition, their absence of body cavities avoids the risk of leakage and reduced operability, and minimises medium contamination.

Automated TOVs can achieve SIL 3 according to IEC 61508, and are increasingly used to handle functions within emergency systems. They can be selected as emergency valves on storage tank inlets and outlets.
providing rapid isolation of the vessel in response to an emergency signal. TOVs can also be used as emergency valves on storage tank overflow lines, acting as an ESD on the overflow line. This prevents the discharge of excessive product, preventing an overfill event. When used as an ‘emergency open’ process function, these valves recirculate the extra product, fulfilling a key safety function.

The utilisation of TOVs in storage tank safety systems has been driven by the basic design principles applied to emergency valves, and the resulting inherent advantages.

**Advantages of an asymmetric design**

When assessing the SIL rating for a valve, two critical items are the failure rate of the valve to deliver full stroke, and the failure rate of the valve to deliver tight shutoff. Quarter-turn, non-rubbing, torque seated, metal-to-metal TOVs are designed to achieve SIL 3 with a low probability of failure.

Like a globe valve, TOVs use a sealing system made up of a stationary seat and rotating sealing surface, sharing an identical conic section shape. They also provide closing with no rubbing, due to a single, instantaneous contact between sealing elements only when closed position is reached.

Unlike globe valves, TOVs utilise a rotational movement, relying on the cones with an inclined apex to achieve shut-off. This makes a TOV a quarter-turn valve.

TOVs are also bidirectional and capable of a full shut-off, achieved through three offsets:

- The shaft is placed behind the plane of the sealing surface.
- The shaft is placed to one side of the pipe/valve centreline.
- The seat and seal cone centrelines are inclined with respect to the pipe/valve centreline.

The asymmetric design of the valve means that, depending on the flow direction – shaft side or disc side – the valve will tend to close or open. So, when the differential pressure acts on the shaft side, it generates a torque that keeps the valve closed. When the differential pressure acts on the disc side, the valve will tend to open.

This asymmetric design provides a safer valve installation for fail-open/fail-close protective functions. Since they do not have any soft components in their construction, metal-to-metal valves are also firesafe.

**Conclusion**

Effective AOPS solutions are optimised to reduce systematic failures and spurious trips, while ensuring the availability and reliability of critical automated shutdown valves. Special attention must be paid when selecting each individual component to ensure the custom solution being built will meet the user’s specific safety and reliability standards. Working with a single OEM for component selection, manufacturing, assembly, testing, and installation will help ensure the technologies work together in harmony upon delivery.