Integrated approach – The way to successful fugitive emissions reduction

Reducing emissions from pipelines and pressure equipment through the proper selection and installation of sealing systems, periodic emissions inspection as well as corrective actions.

By Maria Libionka & Jan Kasprzyk, SPETECH

For more than five decades, air-quality regulations have been progressively developed worldwide. In the European Union, the introduction of the Industrial Emissions Directive IED 2010/75/EU significantly increased requirements concerning atmospheric emissions. These requirements directly affect the design, manufacture, assembly and operation of pressure equipment.

Flange connections, static gaskets and industrial valves are among the potential sources of fugitive emissions. Incorrect gasket selection, inadequate assembly parameters or improper flange or stuffing box surface condition may result in leakage, product losses, personnel exposure and regulatory non-compliance. Effective emission control therefore requires a systematic approach covering the entire equipment lifecycle - namely: design, manufacturing, assembly, operation, maintenance and modernisation.

1. Design

The design stage has the most significant influence on the future tightness and reliability of flange connections and armature. According to EN 1591-1, the required leakage level should be defined during the design process, taking into account mechanical integrity, sealing performance, and operating conditions. The design should specify the flange configuration, flange and bolting materials, gasket type and material, required assembly forces, as well as the type, pressure rating, materials, and sealing arrangement of the armature. For valves and other pressure equipment, both external tightness to the environment and, where applicable, internal tightness between the pressure-retaining and flow-controlling components should be considered.

The EN 1591-1 calculation model considers, among other factors, internal pressure, hydrostatic end force, gasket seating load, friction, and external forces and moments. This enables the designer to assess the integrity and sealing performance of flange connections, including those used to connect valves and other items of armature to the piping system. The design of armature should also consider loads resulting from thermal expansion, vibration, installation, pipe misalignment, and operation, as these can affect the valve body, sealing elements, flange connections, and bolting. Proper selection and specification of the armature are therefore essential to ensure reliable operation and maintain the required tightness throughout the service life.

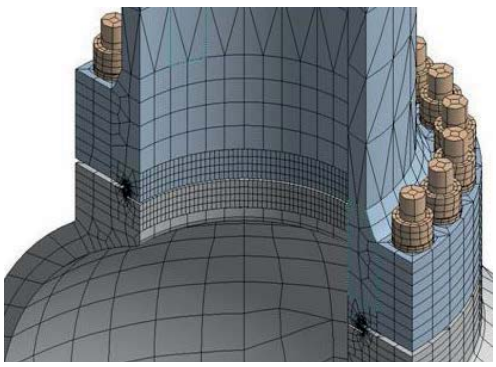


Figure 1 FEM analysis of main flange connection

Gasket and sealing system selection should be based not only on cost and availability but primarily on leakage requirements, pressure and temperature conditions, chemical compatibility, durability, assembly requirements, and maintenance conditions. For armature, the selection of sealing elements should additionally reflect the valve design, operating frequency, medium characteristics, and manufacturer's requirements for installation and maintenance. The complete sealing system should be treated as an integral part of the pressure equipment, including the armature body, stem and bonnet seals where applicable, flanges, bolting, gaskets, and associated sealing elements. Any change to the approved gasket, sealing arrangement, or armature configuration may affect the assumed tightness and should therefore be subject to appropriate technical assessment.

2. Manufacturing

Correct design alone does not guarantee the required sealing performance. Manufacturing quality has a direct impact on fugitive emissions, both for flange connections and valves. Critical factors include the dimensional and geometric accuracy of flange connections, particularly flange flatness and surface roughness. For valves, the dimensional accuracy, alignment, surface finish and condition of bodies, bonnets, stems, seats and sealing surfaces are equally important and should be controlled within the specified manufacturing tolerances.

Gaskets and valve sealing components must comply with the specified design and technical requirements. They should be dimensionally correct, undamaged, clean, dry and supplied with appropriate quality documentation. For valves, this applies in particular to packing, gaskets, soft and metal seats, bellows and other sealing components. Materials, manufacturing processes and relevant inspection records should be properly controlled and traceable. The condition and conformity of bolting are equally important for flange connections.

Valves should be manufactured, inspected and tested in accordance with the applicable valve product and testing standards, including, where relevant, EN 12516, EN 12266-1/-2 and EN ISO 15848-1/-2.



Figure 2 Anti-explosive tests chamber

Product-specific valve standards should also be applied as specified by the project or purchase requirements. EN ISO 15848-1 provides requirements for type testing and classification of industrial valves with respect to fugitive emissions, while EN ISO 15848-2 covers production acceptance testing. The specified leakage class, test temperature, number of mechanical cycles and test medium should therefore be clearly defined.
Valve pressure and leakage testing should be performed in accordance with the applicable standards and specified acceptance criteria. Shell and seat tests verify pressure integrity and shut-off performance, but do not by themselves demonstrate fugitive-emission performance. Where low-emission service is required, dedicated fugitive-emission testing should be specified. Where appropriate, more sensitive gas-tightness methods, including helium leak testing, may be used to identify leakage paths, subject to the applicable test procedure and acceptance criteria.

3. Site assembly

Personnel competence is another critical factor - assembly and supervising personnel must be capable of identifying defects in flange facings, gaskets, bolting and valve sealing components and must follow defined procedures. Training and qualification of flange assemblers and supervisory personnel in accordance with EN 1591-4 are essential elements of low-emission flange assembly. Manufacturing records should provide traceability of materials, inspections, pressure and seat tests and, where applicable, fugitive-emission test results and certificates of conformity.
During installation, all components affecting sealing performance should be verified before final assembly. This includes removal of transport protection, cleaning of flange facings, inspection of flange geometry and confirmation that gaskets and bolting comply with the design documentation.
The equipment should be supplied with an assembly procedure defining the tightening method, tightening sequence and required bolt torque or preload. Depending on the application, controlled tightening may be performed using torque wrenches or hydraulic tensioning equipment.
Properly trained and qualified personnel are essential to ensure that the low-emission performance specified during design is maintained during assembly.

4. Operation and LDAR

During operation, fugitive emission control requires periodic inspection, leak detection and timely corrective action.
The increasingly common LDAR (Leak Detection and Repair) approach provides a systematic framework consisting of:

1. Identification of potential emission sources;
2. Quantitative leak measurement;
3. Corrective action;
4. Documentation and reporting.



Figure 3 LDAR at the instalation

Such programmes are particularly relevant to the chemical, refinery, gas and mining industries. Systematic leak detection allows emissions and product losses to be identified at an early stage and supports compliance with applicable emission requirements.
The growing regulatory focus on methane emissions further demonstrates the importance of systematic inspection and repair of potentially leaking flange connections.

5. Maintenance and modernisation

Maintenance activities typically involve the dismantling and reassembly of numerous flange connections. New gaskets should be used during reassembly, and bolting should be replaced where required.
Before reassembly, flange facings must be inspected for damage, wear, corrosion and other conditions that could compromise sealing performance. Mechanical damage caused during gasket removal is a common source of subsequent leakage.



Figure 4 Maintenance inspection

Where flange facings do not meet the required condition, they should be repaired by appropriate machining, including in-situ machining, or replaced if necessary.
Maintenance shutdowns also provide an opportunity to improve sealing performance through the application of higher-tightness gasket technologies, material upgrades, standardisation of gasket types and adaptation of sealing systems to updated regulatory requirements.

Conclusion

Fugitive emission reduction in pressure equipment requires a lifecycle approach covering design, manufacturing, assembly, operation and maintenance. At the design stage, particular attention should be given to flanged connections, gaskets, bolting and industrial valves. Methods such as EN 1591-1 support the assessment of flange behaviour and sealing performance, while low-emission valve designs and appropriate stem, body and bonnet sealing systems help minimise leakage.
Effective emission control also depends on manufacturing quality, controlled assembly, qualified personnel and proper installation procedures. During operation, LDAR (Leak Detection and Repair) programmes enable systematic identification, measurement and repair of leaks from flanges, valves, valve stem seals and other potential emission sources. Achieving low fugitive emissions therefore requires an integrated approach combining low-emission design, appropriate sealing technology, controlled assembly and systematic LDAR monitoring, inspection and maintenance. ■

About the authors



Jan Kasprzyk is the founder and a long-standing member of the Management Board of SPETECH®. Throughout his professional career, he has held various positions, including Technical Director, Research and Development Director, and Quality Management Representative. He has also served two terms as Chairman of the Flange Gasket Division of the European Sealing Association (ESA).



Maria Libionka works as engineer at SPETECH Sp. z o.o. for four years. She is also a participant in the ESA Young Engineers Initiative.