*VOC-emission of bolted flanges and valves in accordance with government regulations*

# How to *avoid* emissions?

R-H. KLAER, R. HAHN, H. KOCKELMANN, C. BRAMSIEPE, G. SCHEMBECKER, H. SCHMIDT-TRAUB

Environmental regulation and protection increasingly focus on diffuse emissions of harmful gases. Process plants generate substantial diffuse emissions through their flanges and valves. Because of their huge number, it is impossible to test each source of emissions individually. Therefore regulators are allowing testing for prototype technical release.

In Germany, the regulations for the leak tightness of bolted flange joints are laid down by the German "Bundes-Immissionsschutzgesetz" (Federal Immission Control Law). Further details are defined in the „Technische Anleitung Luft" (TA-Luft – Technical Instructions on Air Quality). Especially TA-Luft 5.2.6 describes measures for the handling of volatile organic compounds (VOCs), while the leakage of flange joints has to be determined in accordance with "VDI Richtlinie 2440" (VDI Guideline). This regulation also defines the standards to be met by high-grade gaskets. It states that prototype testing can be carried out by measuring the helium emission and that such measurements may be independent of actual operating conditions. "VDI-Richtlinie 2200" allows a second test method which is based on pressure increase and has to be carried out under real process conditions.

Chemical companies in Germany have committed themselves to using gaskets that have been tested in accordance with one of theses methods. The companies have developed a qualified workflow to assure compliance with the "Bundes-Immissionsschutzgesetz". In a first design step the operating conditions (i.e. pressure, temperature, medium and its corrosive activity) are specified. Based on these data as well as comprehensively documented operational experience, the flange system, which consists of a pair of flanges, a gasket and screws, is specified. Evidence of the sufficient tightness of a flange joint is established according to the European rules EN 1591 and 13555. This process draws on the characteristic mechanical data of gaskets, which for example has been documented in a database developed and maintained by the University of Applied Science in Münster (www.gasketdata.org). Furthermore, the conditions for the assembly of flanges are determined, including the required torque for the screws and

R.-H. Klaer, Bayer Technology Services GmbH, Leverkusen/Germany;
R. Hahn, H. Kockelmann, Material Testing Institute (MPA), University of Stuttgart/Germany;
C. Bramsiepe, G. Schembecker, H. Schmidt-Traub, Plant and Process Design, TU Dortmund

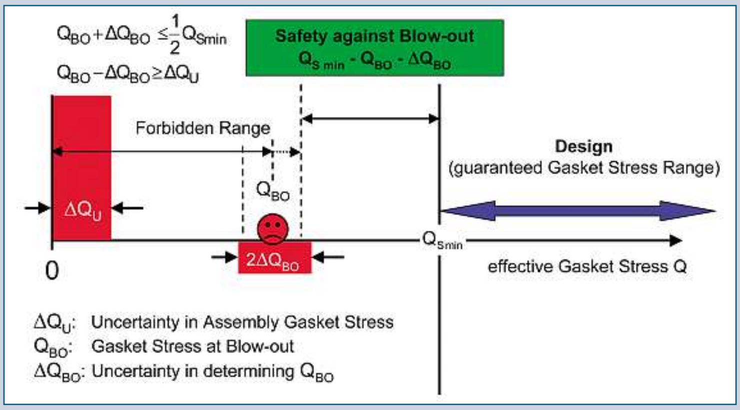


*Fig. 1: Principle of Blow-out Safety*

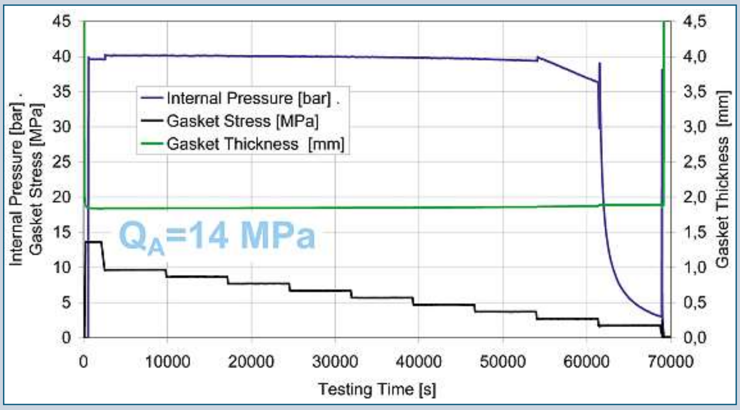


*Fig. 2: Test procedure with stepwise unloading: gasket stress, internal pressure and gasket thickness as a function of time*

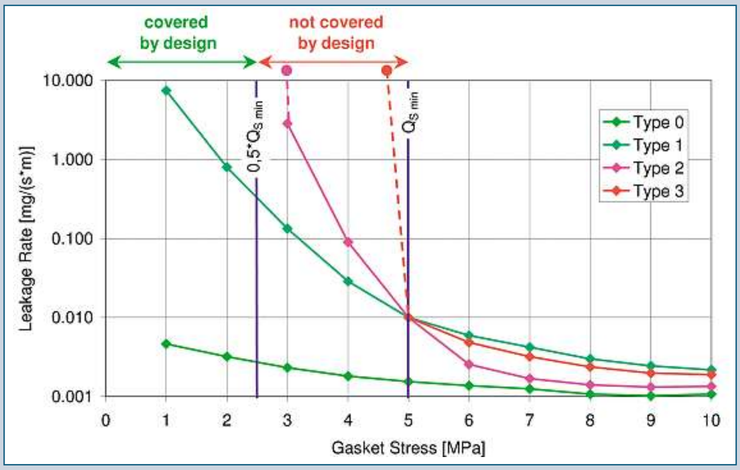


*Fig. 3: Classification of blow-out behavior (schematic)*

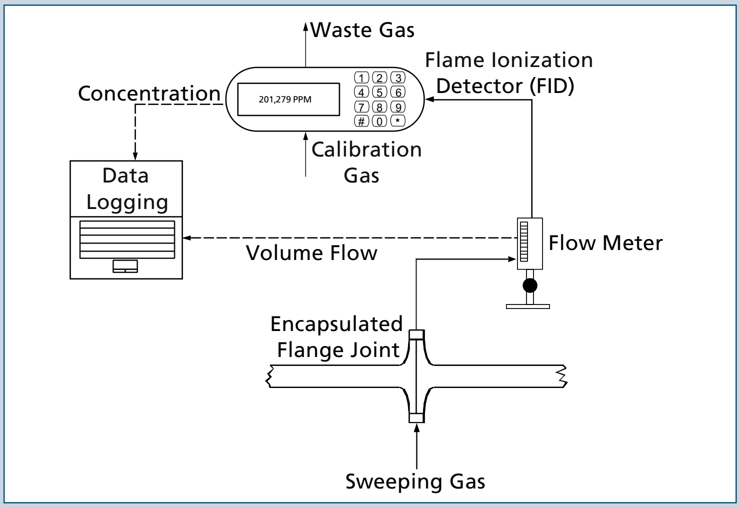


*Fig. 4: Schematic drawing of the sweeping gas method*

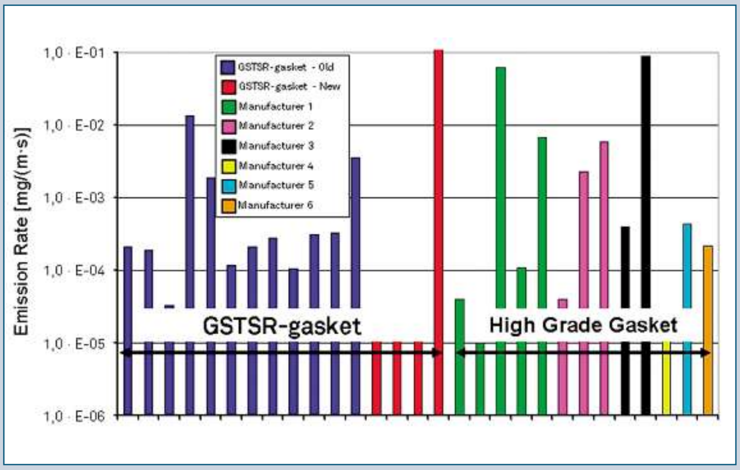


*Fig. 5: Emission rates of Graphite Sealing sheet with Tanged stainless Steel*

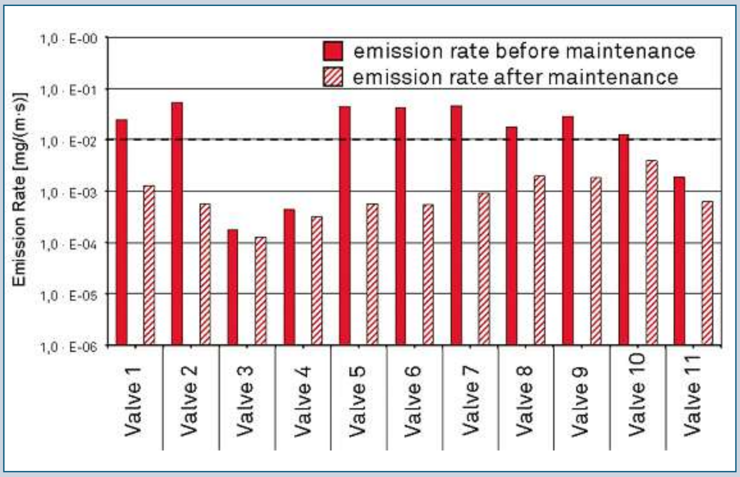


*Fig. 6: Emission rates of valves before and after maintenance*

leakage testing during the erection phase. The required stability of the flange connection is verified, based on EN and DIN standards as well as AD specifications.

## Blow-out safety in the spotlight

In addition to the tightness and stability of flanges, their blow-out safety has to be adduced. While currently no worldwide standards or guidelines exist for establishing the blow-out safety of bolted flange connections, a growing number of government safety organizations require gaskets which cannot be blown out.

The blow-out of a bolted flange connection is defined in two ways: either the gasket or parts of it are blown out of the sealing faces at a certain gasket stress or huge leakage occurs, implying a tightness level two orders of magnitude less than the required tightness class. A gasket is considered blow-out safe if the gasket surface pressure is considered to be at a sufficient and quantifiable level below $Q_{S\ min\ (L)}$ (minimum gasket stress for tightness class L) on blowing-out. From today's point of view sufficient safety from blow-out is achieved if blow-out takes place at a gasket stress of $\leq 0{,}5 \cdot Q_{S\ min\ (L)}$ (see Fig. 1).

## The experimental test procedure

The experimental test procedure is as follows (Fig. 2). After application of assembly gasket stress $Q_A$, internal pressure is applied and the system is heated up to testing temperature. Unloading from this stress level takes place in steps of 1 MPa until a minimum gasket stress of 1 MPa is reached or a blow-out of the gasket occurs (gasket stress $Q_{BO}$). During this procedure the pressure is always kept constant. The respective leakage rate is determined from the pressure drop during the hold times. The leakage rate as a function of gasket stress, determined from the measured pressure drop (Fig. 2) shows a steep increase in the leakage rate after reducing the gasket stress to values below $Q_{S\ min\ (0,01)}$. Many tests were performed on dif-

ferent gasket types, mainly on PTFE-based gaskets, but also graphite sheet gaskets. Four different behavior types were observed with regard to the potential for blow-outs (Fig. 3). According to the definition of safety from blow-out discussed above for behavior types 0 and 1, the design provides blow-out safety. In the case of behavior types 2 and 3 the assembly gasket stress $Q_A$ has to be raised above $Q_{min\ (L)}$ in order to meet the prerequisite of $Q_{BO} \leq 0{,}5 \cdot Q_A$.
In addition to adequate design calculations, the blow-out safety proof requires only a simple blow-out test with stepwise unloading to classify a gasket in terms of blow-out behavior. The procedures described so far are used to design flange joints that fulfill the governmental regulations for environmental protection. They also provide an indication of the extent of diffuse emissions that is likely to occur during operations.

## Real-time measurements of emissions

The tightness of flanges has also been investigated by Hummelt et al. To determine the emission rate of a single flange joint he used the sweeping gas method which is illustrated by the schematic drawing in Fig. 4. The flange joint is encapsulated and the cavity between the gasket and the encapsulation is rinsed with a sweeping gas. The total VOC mass flow is detected by a flame ionization detector. In case of lab experiments, ambient air can be used as sweeping gas but in an operating plant environmental impacts that could affect the measurement must be eliminated, therefore usually synthetic air or nitrogen has to be utilized.
Hummelt developed correlations for gas-filled pipes based on lab experiments. Only limited material data is required to predict diffuse emissions as a function of pressure, medium and gasket stress. But real-time measurements in operating plants show that precise lab experiments do not cover all boundary conditions encountered during plant operation. Of particular importance are external forces like bending moments and vibration as well as mechanical tolerances. Recent measurements also indicate that the diffusion of liquids und gases through gaskets is governed by quite different driving forces so that their emission rates do not correlate.

## Reducing emissions in old plants

These findings are very important for reducing emissions in old plants. Government regulations include transitional arrangement for the environmental upgrade of old plants. They require plant owners to replace old gaskets with new high-quality gaskets within a certain time frame. To determine the impact of this regulation on the environment, emissions of flanges as well as valves have been measured in plants operated by several companies. Fig. 5 shows the emission rates of old GSTSR-gaskets (Graphite Sealing sheet with Tanged stainless Steel Reinforcement) as well as new GSTSR-gaskets and high-grade gaskets that have replaced old gaskets. It illustrates the fact that the replacement of GSTSR-gaskets with new high-grade gaskets does not necessarily decrease emissions. Since modern gaskets are thinner and contain very small amounts of soft material, they cannot compensate roughness and unevenness of the raised face of old flanges and inclinations between the flange faces. For this reason they may not materially reduce emissions compared with older gaskets.
Fig. 6 illustrates the emission from the packing glands of valves in operational plants. The emissions were measured before and after tightening the glands. A comparison of this data clearly shows that in case of valves continuous maintenance can lead to much lower emissions than the replacement of old valves with modern ones. ■