European Sealing Association e.V.

Tightness in gasketed flanged unions

PART III: New Standards for Calculation and Testing. The European Standards

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6.3.– European Union. EN Standards

In April 2001 the new EN-1591-1 standard was approved, within the framework of Directive 97/23/CE PED covering everything related to pressure equipment. Its title: "*Flanges and their joints – Design rules for gasketed circular flange connections – Part 1: Calculation method*". These rules are the basis for Annex G of EN 13445-3, as an alternative to the Chapter 11 (Flanges) method of the same standard. In 2009 a new version of EN 1591-1 was approved. We thus reach the new European standardization system. The new method is due to Working Group WG 10 of TC 74 Technical Committee in CEN. Its theoretical precedent is a calculation method, TGL 32903/13, used in the former German Democratic Republic. Although born in asbestos times, it accounted for leakage levels and was not purely academic, but proven by actual application. In addition to the basic variables of traditional methods:

- fluid pressure
- material strength values of flange, fastener and gaskets
- gasket compression parameters (related now to tightness values),
- fastener loads

it accounts for these new ones:

- possible scatter in fastener stresses due to tightening methods
- changes in gasket stress due to deformation of all connection components
- influence of the piping or shells welded to the flanges
- external axial forces or bending moments
- temperature differentials between fasteners and flanges.

The calculation is based on the elastic analysis of the stress/strain relations in each and every part of the flanged connection, corrected by the eventual plastic behaviour of the gasket material. The first determination is the minimum load required in the fasteners at the initial tightening to ensure that the residual stress on the gasket does not fall below the minimum required by the gasket material in any successive specified loading condition. The gasket parameters are obtained by the EN 13555 tests. The initial loading is determined by iteration, since it depends on the effective gasket width, which in turn depends on the initial fastener load.
Secondly comes the calculation of the internal forces derived from the value selected for the initial fastener load, for all loading conditions (assembly, hydrostatic test and operation), checking their respective acceptability.
EN13555 was not ready at the time of the EN 1591 publication, which came instead with a temporary standard, ENV 1591-2, "*Flanges and their joints. Design rules for gasketed circular flange connections. Gasket parameters*", which gave values based on very limited experimental basis (BRITE EuRam nº BE 5191, "*Asbestos-free gasket materials for flanged unions*", *1993 to 1996*). Furthermore, Article 1 gave a warning advice to obtain the gasket parameters from the manufacturer in order to use the EN 1591-1 calculation method.
However CEN TC 74 had formed another working group, WG 8, with the mandate to establish the gasket parameters needed by TC 74. This group produced a number of dimensional standards for flanges,

These are the main parameters' symbols and definitions:

Parameter	Definition
Q_{smax}	maximum gasket surface pressure that may be imposed on the gasket at the indicated temperatures without collapse or compressive failure of the gasket
$Q_{min(L)}$	minimum gasket surface pressure on assembly required at ambient temperature in order to seat the gasket into the flange facing roughness and close the internal leakage channels so that the tightness class is to the required level *L* for the internal test pressure
$Q_{smin(L)}$	minimum gasket surface pressure required under the service pressure conditions, (i.e.) after off loading and at the service temperature, so that the required tightness class *L* is maintained for the internal test pressure
P_{QR}	a factor to allow for the effect on the imposed load of the relaxation of the gasket between the completion of bolt up and after long term experience of the service temperature
E_G	the unloading moduli determined from the thickness recovery of the gasket between the initial compression surface pressure and unloading to a third of this initial surface pressure

The Standard specifies three tightness classes, as in DIN 28090-1:

Tightness classes	$L_{1,0}$	$L_{0,1}$	$L_{0,01}$
Specific leak rates [mg s- 1 m- 1]	≤ 1,0	≤ 0,1	≤ 0,01

fasteners and gaskets (EN 1514 and EN 12560 series), and a quality assurance standard for these gaskets, EN 14772, with test methods such as DIN 28090-2 kept in place. But their main work, approved by CEN in October 2004 was EN 13555 *"Flanges and their joints – Gasket Parameters and Test Procedures relevant to the Design Rules for gasketed circular flange connections"*.

These leak rates refer not to those expected in service conditions but to those obtained in the EN 13555 helium tests and are expressed in milligrams of helium per second and per unit length of the gasket perimeter[1]. Work is going on in the search for correlations between these test leak rates and those to be expected with real industrial fluids.

The above parameters are determined through compression, relaxation, leakage and creep tests, very similar to those of ROTT and DIN 28090-1. Fig. 1 (Annex B of EN 13555) gives the idea of the main equipment required.

To obtain $Q_{min(L)}$ and $Q_{smin(L)}$, repeated compression and relaxation cycles are made, measuring the leakage rate at different surface gasket pressures, with a 40 bar internal helium pressure. The compression phase simulates the surface pressure on the gasket on assembly while the relaxation phase simulates service conditions after partial off-loading of the gasket when service pressure is applied. Fig. 2 (Figure 4 of EN 13555) illustrates the resulting data; in ordinates the leak rate flows and in abscissae the effective surface pressure on the gasket. The line formed by the measured points during compression represents the assembly conditions and it is used therefore to determine the $Q_{min(L)}$ values, the solid rectangles marking the intersections with the ordinate value for each tightness class. Service conditions are represented by the broken unloading lines. As before, the $Q_{smin(L)}$ values for each tightness class are given by the intersections (hollow rectangles) with the corresponding ordinates value lines.

7.– Present situation

The calculation and testing methods of EN 1591-1 and EN 13555 are making progress in Europe. Amendment A1 to EN 1591-1 was published in 2009. The test methods in particular have advanced independently of their demand for calculation purposes. This is due to two main reasons: a) there is a clear need to find reference tests for the new gasket materials, which cannot be properly characterized by the typical properties specifications developed in the asbestos times; b) the availability of state-of-the-art testing equipment adopted by the main gasket manufacturers worldwide. The first revision of EN 13555 is now taking place by CEN TC 74.

Adoption of the EN 1591-1 calculation advances unequally across Europe, depending on country and industrial sector[2]. In Germany the TA-Luft regulations, VDI 2200 and 2290 for flanged unions and the VDI 2440 for oil refineries require the use of EN 1591-1 with the EN 13555 and DIN 28090-3 parameters. The KTA-211 Standard for the German nuclear industry requires also EN 1591-1. In other European countries, EN 13445 leaves open the option between its Chapter 11 and its Annex G. The use of EN 1591 will grow as more calculation software becomes available and the PED Directive is enforced. EN 13445 was drafted when the application of EN 1591 was rather theoretical due to the absence of reliable gasket parameters. The situation now is very different, as shown by the commendable initiative of Prof. Dr. -Ing. Alexander Riedl, Fachhochschule Münster, and his team, who have set up an on-line gasket database where gasket manufacturers can publish their EN 13555 materials parameters obtained from tests audited by the academic institution. The new EN 1591-2:2008 gives the reader two on-line references on gasket parameters: Fachhochschule Münster's and the European Sealing Association's.

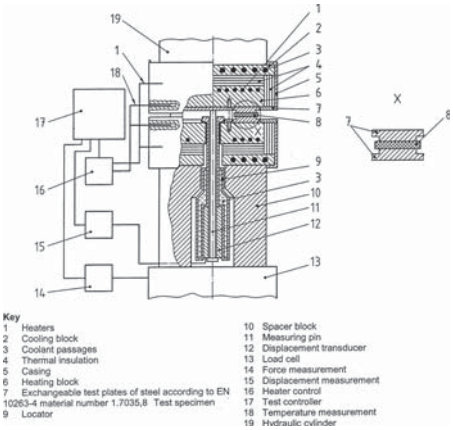

Figure 1. Test rig schematic for compression, compression creep and creep relaxation tests.

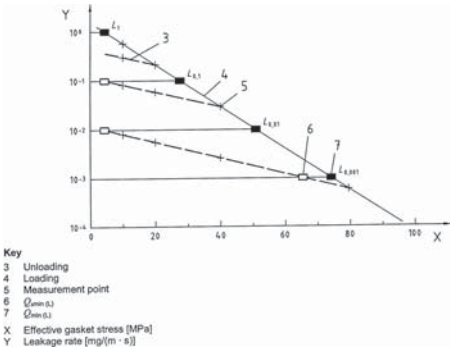

Figure 2. Leakage rate as a function of gasket stress (for an internal pressure of 40 bar in this case).

8.– Conclusion and perspectives

Quality gasket manufacturers are presently capable of supplying the materials required by EN 1591 and EN 13555. Future developments will bring new materials and approaches. Emissions control and safety require rigorous training and certification schemes for personnel involved in the installation and maintenance of fluid handling sealing systems. In Europe a number of initiatives have been taken in this connection. The future Standard, now Draft prEN 1591- 4 (October 2011) *"Flanges and their joints. Design rules for gasketed circular flange connections. Part 4: Qualification of personnel competency in the assembly of bolted joints fitted to equipment subject to the Pressure Equipment Directive"* will deeply influence industrial sealing practice.

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[1] As a reference, quite outside this present field, but nevertheless worth noting, we can point to the value which the General Electric laboratories have considered a zero leak level: < 10^{-8} Nml/s (~ 17x 10^{-10} mg/s) helium.

[2] Because of lack of space we do not enter into the CEN/TS 1591-3 and prCEN/TS 1591-5, still in development, on metal to metal contact and full face gaskets resp.