Static and experimental assessment of insulating flanges

Flanges are a tried and proven fastening method for high-pressure pipelines which as such requires no explanation. Insulating flanges represent a special case. In addition to the electrical demands, they entail high mechanical loads on the insulating material, because the forces from the pipeline system have to be transmitted locally by a material whose strength properties are significantly lower than those of steel, which is the material otherwise used. These stresses become significant where high tensile and bending loads may occur in the pipeline system in addition to the internal pressure loads. This is particularly so in the case of high-pressure gas installations. The following details how insulating flanges are rated for such cases, and how their correct technical design can be verified by measurement in the course of acceptance testing.

THE INSULATING FLANGE AS A STANDARD COMPONENT

A typical insulating flange along with components details is depicted in ***Figure 1*** and ***Figure 2***. The metallic materials and their properties are defined to an adequate degree of precision by standards, and are available on the market with the necessary certification.

Insulating materials are specified in DIN EN 60893, and compliance of their electrical properties is guaranteed by the manufacturers. However, the materials are not produced in compliance with the standards for pressure vessels or pressurised pipelines, and certainly not for the carrying of environmentally hazardous substances.

So the most suitable insulating material must be selected depending on the expected operating conditions. The material must then be subjected to additional testing of mechanical strength, gas-tightness, and resistance to the medium being transported.

This means the characteristic data of the specific insulating material must be tested and specified in each individual case. As the insulating materials have much lower strength characteristics than the metallic materials, and are thermosets, higher safety factors must also be applied in the design and calculation process.

Above certain pressure loads or external mechanical force limits, it is essential that the insulating material is adequately armoured. When using metal seals, this metallic armouring – as shown in figure 1 – is necessary because of the metal seals. In addition to providing gas-tightness, this creates a mechanical binding force between the insulating flange component and the flange faces which causes the internal pressure forces acting on the insulating flange to be discharged into the flange faces.

The installations subjected to mandatory monitoring, where components as a minimum require an acceptance test certificate type .1 or type 3.2, reliable and permanent marking (such as by branding iron) with details of the manufacturer, factory serial number, DN and DP is of course essential. This marking is vital for quality verification of the materials used.

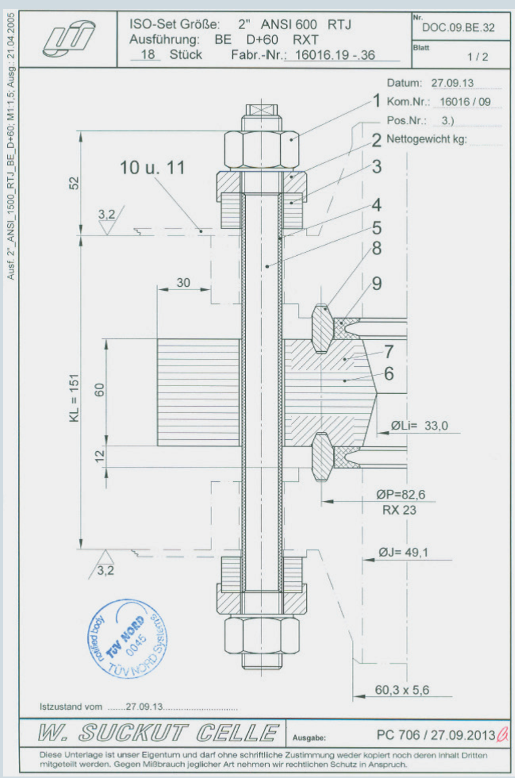

Figure 1: *Schematic diagram of insulating set*

ISO-Set Größe: 2" ANSI 600 RTJ
Ausführung: BE D+60 RXT
18 Stück Fabr.-Nr.: 16016.19 - .36
Nr. DOC.09.BE.32
Blatt 2 / 2

Datum: 27.09.13 Kom.Nr.: 16016/09 Pos.Nr.: 3.) Nettogewicht kg:

Pos.	Stück	Benennung	Werkstoff	Normblatt	EN 10204 Nachweis	Bemerk.
1	16	Muttern, 5/8" UNC	ASTM A194 verzinkt	ANSI B18.2.2 2H	3.1	LE 2H
2	16	Stahl-U-Scheiben	Stahl verzinkt	09.ET.33	-	-
3	16	ISO-U-Scheiben	PF CC 203	DIN EN 60893	-	-
4	8	Bolzenisolierung	GFK 2mm	-	-	
5	8	Schraubenbolzen, 5/8" UNC	ASTM A193 B7, verzinkt	09.ET.78	3.2	Bley B7
6	1	ISO-Flansch D+60 J = 49,1Ø Li = 33,0Ø	HGW PF CC	DIN EN 60893 CH *)	3.1	HIPPE
7	2	Armierungsringe für R 23	C-Stahl P355 QH1	CH 712221	3.1	BGH
8	2	Dichtringe RX 23	soft iron D - 4	API Std. 6A CH 07111915	3.1	Ke
9	2	Füllringe für RX 23	PTFE	ET	-	-
10.0	2	Kabellaschen Ausführung: A	1.4541	ET.45	-	-
10.1	2	Zahnscheiben A 23	A 2	DIN 6797	-	-
11.0	1	EX-Funkenstrecke mit Kabel 2x2m lg., Muttern u. Schr. VA	Fabr.: DEHN Type: ExFS 100 KU	PTB ZELM		ATEX E 099 EXAM

*) 6 Stück CH 2150550-24 Fabr.-Nr.: 16016.19; .21; .23; .24; .26; .32
7 Stück CH 2150546-24 Fabr.-Nr.: 16016.20; .25; .28; .31; .33; .34; .35
1 Stück CH 2150542-31 Fabr.-Nr.: 16016.30

Fertigteilabnahme :
Nach: DIN 2470 T.2 TRFL DGRL 97/23/EG
Durch: TÜV Nord Hamburg APZ : nach EN 10204 - 3.2
Kennzeichen : 2" 600 RX 23 T Fabr.-Nr. 16016.19 - .36
Betriebsdruck bar : 101 Prüfdruck bar : 152
Schraubenanzugsmoment bei Prüfdruck: M ≥ 100 Nm
Istzustand vom ..27.09.13

notified body TÜV NORD 0045 TÜV NORD Systems

W. SUCKUT CELLE Ausgabe: PC 706 / 27.09.2013

Diese Unterlage ist unser Eigentum und darf ohne schriftliche Zustimmung weder kopiert noch deren Inhalt Dritten mitgeteilt werden. Gegen Mißbrauch jeglicher Art nehmen wir rechtlichen Schutz in Anspruch.

Figure 2: *Insulating set parts list*

Figure 3: *Test sample with blind flanges*

Figure 4: *Test sample with dished ends*

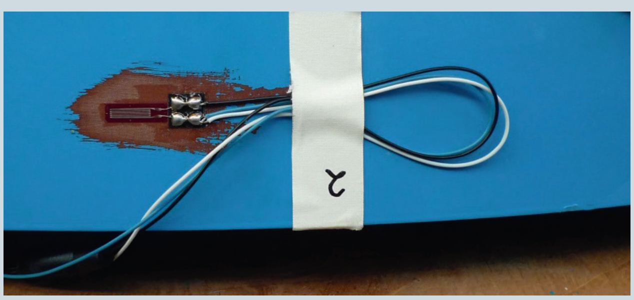

Figure 5: *Strain gauge on insulation*

Another precondition for trouble-free functioning of insulating sets is insulation of the bolts. The dimensions of the bolts must conform to the flange standard, providing pressure-tight insulation over the necessary length so that occurring bearing stresses do not cause short-circuits. Reliable electrical isolation of the bolt head and nut from the contact surface must also be ensured. In this context it must be considered that the insulating material is the weakest link in terms of bolt strength. It is therefore necessary to utilise the available contact surface on the flange face to the maximum for the diameter of the ISO standard washers. To maintain the permissible area contact pressure, the bearing force of the nut must be distributed uniformly across the available area based on custom fabrication of steel washers.

The materials available today make it easy to produce ISO-compliant sets for line diameters of 44" and pressures of 100 bar. Operating pressures of up to 500 bar can be absorbed with the aid of custom designs. Flanges offer the advantage over insulating couplings that their electrical and mechanical properties can be verified at any time. Insulating flanges are only suitable for underground installation in custom fabrication variants, though, as insulating components normally have no place in such installations, because then a residual line section with no cathodic corrosion protection is in the ground.

SYSTEM CALCULATION

DIN EN 1591 provides a comprehensive standardisation framework for the calculation of flange joints. It does, however, follow the trend of recent standards in setting out a very extensive system of formulae which must incorporate characteristic values and input parameters which do not necessarily logically derive from the known constraints and parameters of the case being calculated. Manual application of the calculation methods is not possible, and should only be entrusted to engineers with relevant experience. One alternative, advisable in specific cases characterised by high loads or unusual dimensions, is to apply an FEM calculation incorporating all components with their characteristic value data. However, in view of the relative softness of the insulating materials compared to steel, those calculations must be carried out in physically and geometrically non-linear mode, and it is not possible to apply the law of superposition. This means the calculation must be made separately for each combination of pressure, tensile forces and bending moments. In view of the effort involved in this, it is most practical to restrict the calculation to a small number of parameter combinations and to verify the results by monitoring based on measurement during acceptance testing.

EXPERIMENTAL VERIFICATION OF CALCULATIONS

Iso-sets supplied for high-pressure gas systems require an acceptance test certificate (see above). The acceptance test pressure is 1.5 times the design pressure (DP) of the pipeline. This testing verifies the leak-tightness of the

system and the electrical insulation. The steel components used are blind flanges or flanges with dished ends (***Figure 3*** and ***Figure 4***).
The calculation of the Iso-set can be very easily verified using strain gauges. As shown in ***Figure 5***, the strain gauges are mounted in the circumferential direction of the insulating material and the build-up of circumferential tensions is determined depending on the applied pressure stages. No temperature compensation is required owing to the short duration of the test.
Experimentation in the course of several acceptance tests has found circumferential tensions of a magnitude up to 5 N/mm^2. These are negligible values which affirm the calculation result indicating that the internal pressure forces acting on the insulating material are transmitted onto the steel flange by means of the binding force between the flange/seal/armouring, and thus there is no significant static load on the insulating material in the form of a ring load-bearing structure.
The 100 bar (10 N/mm^2) internal pressure acting directly on the insulating material likewise poses no problem, as insulating materials to DIN EN 60893 have compressive strengths of more than 100 N/mm^2 and hence provide substantial safety in this context.
In a special case, the manufacturer Suckut was contracted to supply insulating flanges in 2", 16" and 24" sizes subject to 100 bar pressure and also potentially to high additional tensile and bending forces from the overall system. In consultation with the test body, it was stipulated that each of the flanges being supplied would be subjected to a pressure test at 240 bar – i. e. a multiple of the subsequent operating pressure – in order to simulate the additional forces. A test of such a kind represents a realistic load for testing of the flanges and insulating bolts. The insulating material is subjected to a very high radial tension which is inconceivable in subsequent operation. Consequently, it made sense to monitor this special testing likewise by strain gauges. This also produced tension values not exceeding the aforementioned 5 N/mm^2, and again in this case the force fit was fully assured by way of the seal and the armouring of the insulating material. All components were accepted by the customer.

OUTLOOK

The results presented affirm the empirical findings that flanges and insulating flanges represent a safe static connection and that they are also capable of withstanding very high additional loads. It is unsatisfactory, however, that little empirical knowledge has been gathered with regard to the forces actually occurring in complex systems. System planners' calculations generally consider only a small number of parameters, without recording the actual loads resulting from the combination of random load cases.
It is therefore desirable that characteristic systems should be monitored over a protracted period of time with regard to the forces acting on the ISO flanges, in order to identify an order of magnitude of the real load cases. Such an approach is made all the easier because monitoring by strain gauge provides a very simple, highly robust and cost-effective measurement method.

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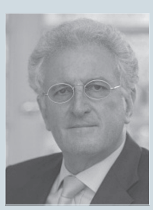
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