PREVENTING FLANGE FIRES

Flanged joints will leak and cause fires, despite proper design, fabrication, and installation: some of the whys, and what to do.

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Nearly every company has been faced at some time or another with the situation where a flanged joint, operating at temperature, has leaked, and if it contains a flammable fluid, has caught fire. This occurs despite the fact that the joint has been designed correctly to an existing code, and has been correctly fabricated and erected. This presentation attempts to exxplain why this may occur and to suggest some remedial measures which can be taken to correct the situation.

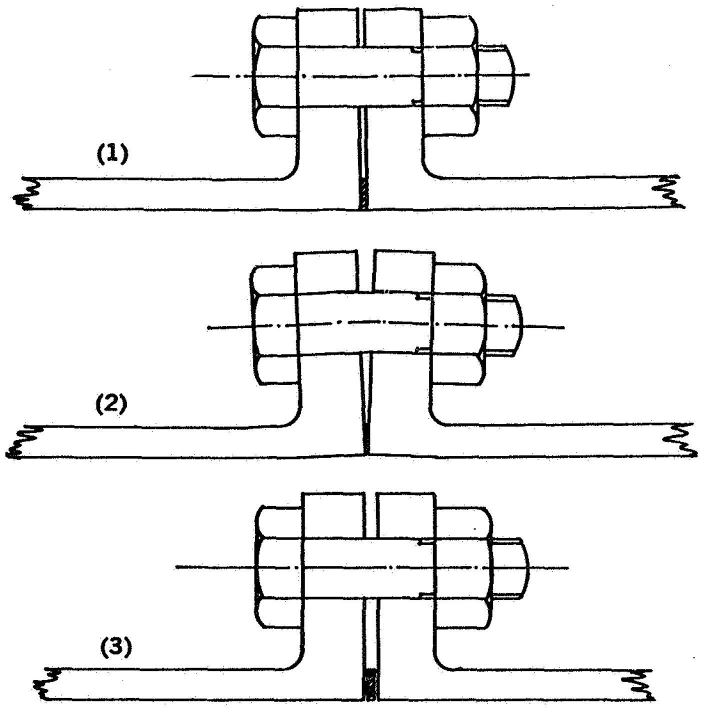
The fault may be basically in that many engineers place too much reliance on the material given in design codes. This is not to say that the codes are incorrect, but that in many instances it is impossible to give a simple formula which can cover the many variables which are encountered in design. Flange design is a case in point: it seems a logical way of joining two pipes, but the stress analysis of the system is extremely complex, particularly when one takes account of the number of variables in geometry and design conditions which can exist. A private company reference (1) conducts a constructive criticism of the strengths and weaknesses of the British and American design codes with respect to flange design. The references under Literature cited comprise *inter alia,* the various codes and the basic methods used therein for flange design. In all the codes mentioned, i.e. ASME Section VIII, B.S.10, B.S.1500, and B.S.1515, no account is taken of temperature transience. On the one hand, this may be looked upon as a major omission, but conversely temperature transience is difficult to define in absolute terms to allow the simple solution that one would hope to find in a design code.

Temperature transience effects

The effect of temperature transience may be appreciated by considering Figures 1-3. In Figure 1 is shown a flanged joint, pressure being retained by a gasket between the ends of the pipe. Now consider the effect of introducing a hot fluid into the pipe: the inner wall heats up and a temperature gradient is established across the pipe wall. Within the bulk of the pipe this results in a longitudinal tensile stress on the outside wall and a compressive stress at the inner wall. The end of the pipe, i.e. at the joint, is discontinuous and this results in a rotation of the pipe ends and flanges as shown in Figure 2. This will result in:

a. an increase in the strain of the bolts, and therefore the loading.
b. a deflection of the flanges.
c. an increase of load on the gasket.

Supposing there to be no mechanical failure, the joint is not likely to leak at this point in time. This possibility arises when the whole joint assembly reaches a steady operating temperature. During the transient period, the bolts and/or flanges may have yielded, and the gasket may have been overcompressed. The preload on the joint would therefore be reduced, and this may be sufficient to cause a leak, Figure 3.



Figures 1-3. A normal gasketed joint (1) will be deflected when hot fluid puts stress in pipe (2) and if bolts or flanges have yielded can result in a reduced preload and leakage (3).

Self-tightening joint can leak

Yet another possibility of leakage is shown by Figures 4 and 5. Figure 4 shows a lens ring joint: this joint is frequently described as being "self-tightening" due to the internal pressure in the pipe. A little investigation of this claim will quite probably show that the "tightening" loads in the joint ring may not be able to overcome the friction loads on the faces, and the joint falls far short of its "self-tightening" appellation. If such a joint is operating in hot service and the temperature is suddenly reduced, the joint ring, being of small mass and with but a small heat path to the more massive flanges, can suffer considerable radial strain relative to the flanges to the extent that a leak is occasioned as in Figure 5. Where this is likely to happen, the addition of an insulating pad between the joint ring and the pipe bore as shown in Figure 6 can be remarkably effective.

The joint shown in Figure 7 will withstand thermal transience very well. It will be seen that the flanges are more massive than might be expected from normal design formulae. This produces a rigid assembly which is more likely to reduce flange rotation. The bolt moment arm is reduced thereby reducing the bolt extension. In addition the bolts are long so that they can accept considerable extension without yielding. This type of design has given good results, and the extra capital cost for the long bolts and heavy flanges is a small price to pay for a satisfactory joint.

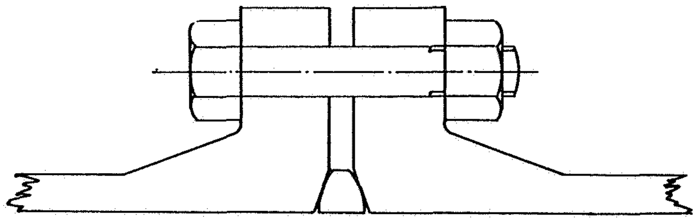


Figure 4. A lens ring joint of the self-tightening type due to internal pressure.

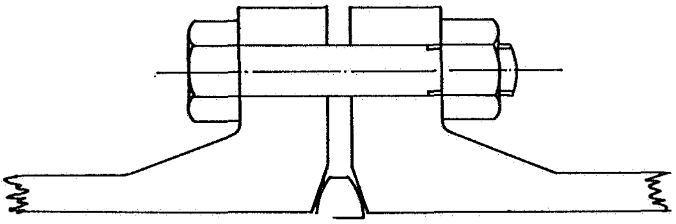


Figure 5. If temperature is suddenly reduced, joint ring can suffer radial strain and leak.

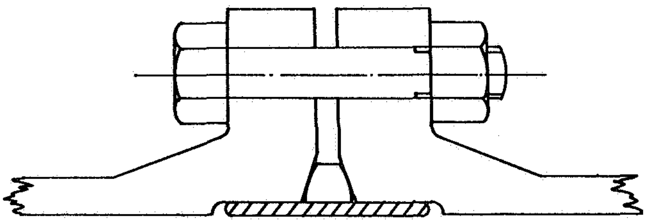


Figure 6. Addition of insulating pad between joint ring and pipe bore is remarkably effective.

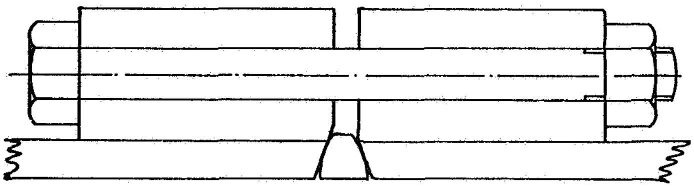


Figure 7. More massive flanges of this joint will withstand thermal transience.

How to retrieve a situation

However, this is being wise before the event. What can one do to retrieve a situation which is already in trouble? Obviously, changing the flanges is a major undertaking. A frequently applied solution is that shown in Figure 8; here long bolts are used with individual sleeves. The flanges will behave as before, but the longer bolts and the sleeves allow considerably more flange movement before the bolts yield and protect the flanges and gasket from excessive load.

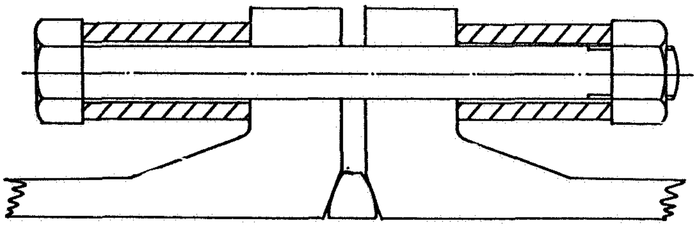


Figure 8. Longer bolts and sleeves allow considerably more flange movement.

Another design is shown in Figure 9, where the necessary flexibility is achieved through the use of Belleville washers; care should be taken to ensure that temperatures are not suficiently high to cause a loss in the temper of the washers.

Another aspect which merits study is the gasket itself: this should possess sufficient resilience in order to recover from overcompression. This property varies with the type of gasket; the metal-augmented gasket, known variously by the trade names, "Metaflex", "Flexatallic", *inter alia,* is very good in this respect, particularly when used with a solid metallic annulus to protect it against gross overcompression. Solid metallic gaskets are also variable in their flexibility: the gasket used in the Grayloc joint, Figure 10 has obviously been carefully thought out. A very shallow angle is used so that the gasket can be considered pressure-energized; it is deformed radially inwards on closing the joint so providing initial sealing, whilst a central annulus gripped between the flanges prevents it from being yielded by overtightening. The variant shown in (a) depends on fine feather edges for a seal which has a practical

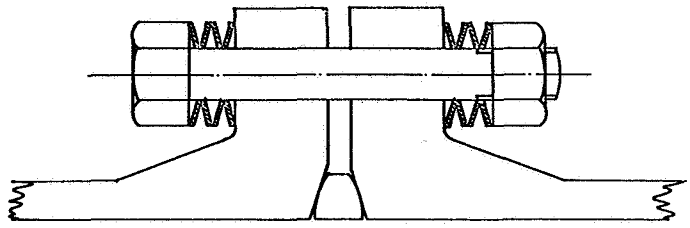


Figure 9. Necessary flexibility can be achieved through Belleville washers.

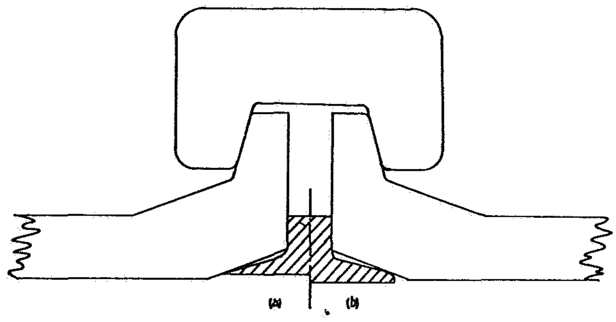


Figure 10. Gasket used in the Grayloc joint has obviously been carefully thought out.

drawback in that they are easily damaged and quickly corroded if conditions are adverse. The variant shown in (b) is a more robust design. The other details of the design, i.e. the use of a clamp ring, are not novel but have many practical advantages over the usual bolted flange, particularly that of rigidity.

No general substitute yet

Having commenced this presentation with the implication that the flange joint is not the simple and logical method of joining two pipes that it is generally thought to be, it must be confessed that there is not to the author's knowledge any viable general substitute at this time. However the joint shown in Figure 11 is worthy of note. This is a Swedish design and has been used for connecting together the two halves of an atomic reactor. At first sight it appears complicated, but apart from a considerable amount of machining at an angle, the system is remarkably simple. The bolt loads are referred back to the vessel or pipe wall (albeit at an angle!), the flanges are relatively small, and it will be noted that the outer members A are not large rings, but a series of small identical blocks. Like many ingenious designs, its merits can only be appreciated after some study by the reader.

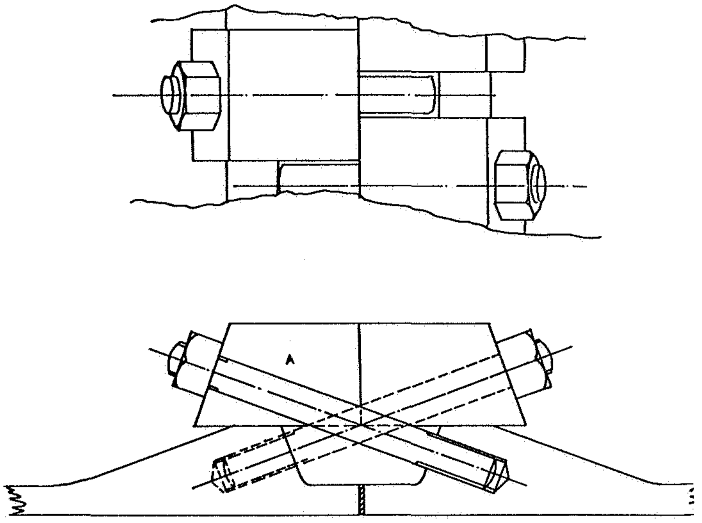


Figure 11. A Swedish design for connecting the two halves of an atomic reactor.

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