

HOT BOLTING AND THE MORSAFE™ CLAMP

Thomas Lamb¹, Ian Thompson²

¹ Hydratight Limited, Aberdeen, United Kingdom

² Hydratight Limited, Morpeth, United Kingdom

1. Introduction

ASME PCC-2 [1] defines Hot Bolting as ‘the sequential removal and replacement of bolts on flanged joints while under reduced operating pressure’.

Hot Bolting is historically used predominantly for pre-shutdown activities which include removing, cleaning, lubricating and reinstalling existing bolts. This process is intended to remove uncertainty and make the shutdown more predictable, effective and assured.

With a growing number of aging assets across the world corrosion is becoming a greater issue. An increasing focus on the integrity of pressure boundary bolted flange joints, has resulted in operators being more proactive in the replacement of corroded/degraded fasteners. Whilst it would be desirable to perform this task during a maintenance shutdown period, this is not always possible and operators are increasingly engaging in bolt replacement activities whilst the process remains online (live).

Hot Bolting can also be employed to upgrade the material specification or grade of bolts, whether due to insufficient mechanical strength or incompatibility with joint component materials. Furthermore, non-destructive inspection routines may also reveal fasteners having metallurgical defects (e.g. stress corrosion cracking). The location of such defect may not be visible to the naked eye or could be obscured by its location (i.e. masked by the flange or the gasket). Figure 1 shows a typical joint having fasteners with a material not compatible with the flange.



Fig. 1: Galvanic Corrosion Effect on Joint Components with incompatible materials requiring Hot Bolting to upgrade bolts

The key advantage of Hot Bolting on a ‘live’ line is eliminating the need for breaking containment. This typically means the operation can be performed with no or limited disruption to production. It also means that the need for leak testing and return to service requirements are all eliminated.

By way of example, a campaign in 2019 which covered 142, predominantly four bolt flanges, managed to reduce a planned shutdown campaign from 14 days to 3 days. Table 1 shows more examples of estimated savings based on successful Hot Bolting campaigns.

UK Asset	Number Of Flanges Hot Bolted	Estimated saving in production (days)	Estimated Cost Savings (\$M)
Platform A	1000 +	21	42
Onshore Gas Site A	10	1	0.255
Platform B	42	2	4
Platform C	150 +	4	8
Platform D	200 +	5	10
Platform E	63	3	15
Onshore Gas Site B	4	2	0.26

Table 1: Estimated savings from Hot Bolting Scopes

However, with this reward comes greater risk. Hot Bolting may expose personnel to hazards associated with release of contained mediums under pressure and/or temperature, flammable and/or toxic substances, stored energy, etc.

To highlight the high level of danger involved in operations involving pressure boundary bolted flange joints, reference can be made to an explosion at the Sodegaura Refinery, in Japan in 1992 where loose bolts were reported to cause a section of the channel cover to develop a leak which subsequently exploded. There were 17 casualties of which over half were fatalities. Whilst a design flaw was identified as the root cause, this incident demonstrates the dangers involved when working with live plant. Similarly, the fatality caused by an HS2 release during a hot bolting scope in Wyoming in 2001 reinforces these dangers. There is also a well-publicized incident offshore in the Gulf

of Mexico in late 2009 where a hot bolting exercise ended in a fire on the asset again highlighting the dangers involved in this practice.

While competence in joint assembly and tightening practices have improved in recent years, this does not necessarily make technicians competent for working with 'live' plant or processes. In a study conducted on the Norwegian Continental Shelf [2] it was shown that 55% of hydrocarbon leaks were attributed to human intervention with a follow up study also showing around 20% of leaks occurring at the planning stage. This reinforces the need for specialist, trained and competence assessed personnel to perform specialist tasks throughout each step of any Hot Bolting campaign where the risk of loss of containment are seriously increased.

These dangers can be increased further by utilising inexperienced site personnel or contractors to perform critical or hazardous operations and it is worth observing, that some operators have limited or no recognition of best practice relating to Hot Bolting activities. This leads to an attempt to document their intent through creation of their own in-house specific documents. Such documents are typically drafted based on company philosophies, process applications or on site/user experiences. As such there can be little harmonisation between customers and/or sites and Hot Bolting Procedures end up being inconsistent and lack comprehensive instruction.

2. The MorSafe™ Clamp

In cases where pressure boundary bolted flanges have less than eight fasteners, it is important to consider the impact of removing a single stud. At its simplest level, removing a single stud has the potential of reducing the clamping load on the gasket contact surface. However, the situation is not that simple. For example, removing a single fastener in a four-bolt flange effectively leaves 180° of the gasket contact surface unsupported. If you consider the rules in ASME VIII [3] relating to the spacing between active adjacent studs, the removal of a single stud on a four-bolt flange would more than likely to compromise the spacing limits.

In this scenario it is necessary to employ a restraining device on the four-bolt flange and this is where the MorSafe™ clamp, the only Hot Bolting Clamp on the market designed specifically for this purpose (i.e. does not utilise accessories intended for another function), comes into its own.

The MorSafe™ clamp was designed and patented in 2014 and fully considers the need for controlled device

fasteners and reduces/eliminates the associated load transfer to the gasket. The MorSafe™ Clamp has been the cornerstone of Hydratight's Hot Bolting Service and the benchmark for Hot Bolting innovation ever since. The MorSafe™ Clamp's unique, patented feature is a pair of backstops per bolt, each half the diameter of the corresponding parent fastener. These backstops are activated before the final clamp load is applied ensuring any load is passed directly through the clamp bolt as shown in figure 3. This ensures the Hot Bolting Clamp can match the existing flange configuration while safely applying the required load to ensure flange separation is not possible during fastener change out.

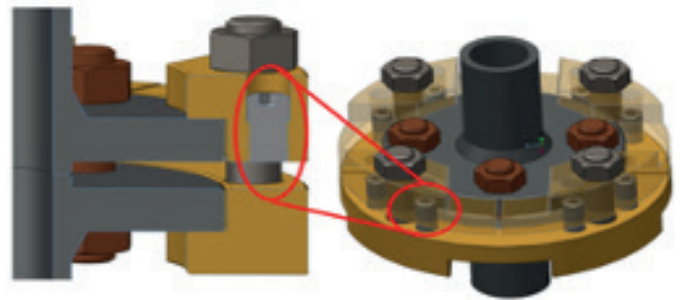


Fig. 2: Diagram of MorSafe™ Hot Bolting Clamp highlighting backstops

The MorSafe™ Clamp's modular design also allows it to be adapted to suit any geometry or application and the added integrity this device offers makes this option attractive for flanges where conventional Hot Bolting (i.e. without an additional restraint device) might have been previously considered. Concerns such as stress corrosion cracking or serious corrosion/severe mediums may drive technical authorities to utilize the safer option the MorSafe™ clamp offers.

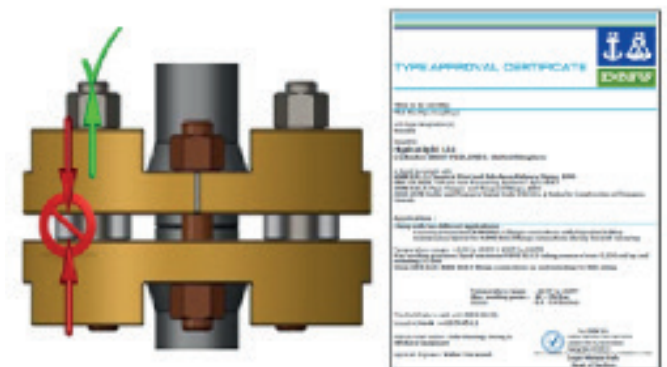


Fig. 3: MorSafe™ Hot Bolting Clamp highlighting key feature and DNV certificate.

The clamp can also be designed as a reinforcement solution which will mitigate integrity issues associated with deteriorated fasteners. Providing the material specifications can be aligned, a design for 'life-of-asset' could be achievable, thus offering long or short term integrity assurance at a time where maintenance on aging assets comes with increasing costs.

In 2015 Hydratight gained DNV type approval for the MorSafe™ Clamp (renewed in 2019) and it has been used in over 4000 applications in the field ranging from ½" to 30" flanges including a variety of bespoke configurations either as long-term integrity assurance installations or Hot Bolting campaigns. Over the last 5 years the MorSafe™ Clamp has had significant success in the North Sea with several operators prohibiting live fastener replacement on four bolt flanges without the MorSafe™ Clamp

3. The other option

Historically, where an additional restraint device was required, a G or C clamp would be utilised in an attempt to prevent flange separation during bolt change out. Where such devices are employed there is a belief that these clamps have a similar capability to the MorSafe™ Hot Bolting Clamp and hence they make any Hot Bolting operation safer. However, without careful consideration, to the use and control of such devices, the activity can be made more dangerous. Where there are such oversights, break in containment, sudden releases, blow-outs, explosions, etc. are likely and the severity of such incidents can be catastrophic to personnel, plant, the environments and communities.

Furthermore, the G-Clamp's suitability to withstand the forces associated with flanged joints on 'live' lines may also be questionable. In an attempt to secure G-Clamps to the flanged connection their fasteners are typically tightened based on operator feel and/or experience. Such practices are at best uncontrolled and more likely inaccurate. Uncontrolled tightening practices can lead to fasteners being under or over loaded. Whilst the former can render the G-Clamp useless in support of the pressure boundary bolted flange joint should the parent fastener fail catastrophically during Hot Bolting, the latter is very likely to lead to load transfer to the gasket and hence give rise to change in gasket contact stress, thus increasing the potential for leakage and/or catastrophic events. The ability to maintain a consistent load is also dubious as the G-clamp will 'flex' due to the flange separation forces experienced during the hot bolting process as shown in diagram in figure 4.



Fig. 4. Forces applied to G-Clamp during hot bolting operations

One further consideration when using G-Clamps; during the Hot Bolting process it may be necessary to use force and/or accessories to remove the parent flange fastener(s). If these clamps are not secured it is possible for them to be dislodged accidentally. When such a condition exists the parent flange may be left in a dangerous condition.

It is therefore imperative that Hot Bolting should not be undertaken without a thorough review of the equipment and processes to be used to ensure the safety of the site. Although Hot Bolting can reduce plant downtime, these are potentially hazardous activities and therefore extreme caution shall be exercised in their planning and execution. In considering potential applications for Hot Bolting, any potential benefits from such activities shall be carefully weighed against the risks and captured in a purpose designed Hot Bolting Risk Assessment.

4. Best Practice

ASME PCC-2 [1] and EEMUA Information Sheet 17 [4] offer the best guidance in regard to Hot Bolting and outline some of the basic criteria that requires consideration for any successful operation. Both documents are viewed as mandatory reading as part of any planning process and Hydratight has developed a robust suite of Hot Bolting procedures and processes, aligned with these documents, that fully consider all the relevant factors associated with working on live plant. A corresponding Hot Bolting Risk Assessment has also been developed which analyses all relevant aspects of any specific joint.

There are multiple issues which can influence the ongoing integrity of the pressure boundary flanged joint, for example, stud and/or nut condition, gasket type and/or condition, bolt load (induced or remaining). It is also necessary to pay attention to the operating envelope parameters such as pressure, contained medium, other joint components, etc. before any field work can

commence. The importance of assessing these elements is critical for the overall success of the operation and as the Risk Assessment is usually based on technician experience it is of vital importance to utilize experienced personnel from specialist service contractors when planning and executing these tasks.

After considering all these factors, using a restraint clamp will likely increase the safety of this task and could mitigate against potential, unexpected and catastrophic events, during these scopes. In this scenario, the suitability and effectiveness of such Hot Bolting Clamps should be assessed as well. In cases where a Risk Assessment, development of Hot Bolting Procedure or planning of a work scope are being undertaken, thorough consideration shall be given to the likes (but not limited to) of:

- a. Observable versus hidden defect of parent flange fasteners.
- b. Constrained versus unconstrained gaskets and their blow-out potential.
- c. Interaction of flange and fastener (e.g. through bolts versus tapped hole flanges).
- d. Leak history of the joint.
- e. Medium being contained (e.g. hazard potential or criticality of service).
- f. Operating parameters (e.g. pressure and temperature).
- g. Personnel competence.

Irrespective of the technique employed for Hot Bolting, the importance of record-keeping cannot be understated, and all assets should have a joint integrity management system to co-ordinate workflows. Having knowledge of the joint history will offer assurance in determining previous tightening practices, leak history, replacement target loads, etc. which can be captured and stored within Hydratight's iDMS asset management system to further improve the thoroughness of any operation. Most importantly it is vital to have a safety-focus mind set and maintain awareness of the dangers associated with the process, environment and task through planning and execution. The most effective way of ensuring the safe completion of a Hot Bolting scope of work is to employ specialist contractors with purpose-designed equipment and an extensive successful track record of prior engagements for removing bolts. For this, Hydratight has the experience, competency, history, record keeping capabilities and most significantly the MorSafe™ Clamp to ensure the safest, most efficient hot bolting operations can be carried out.

REFERENCES

- [1] ASME PCC-2, Repair of Pressure Equipment and Piping, 2015
- [2] Vinnem, J. E., Seljelid, J., Haugen, S., and Husebø, T., Analysis of Hydrocarbon Leaks on Offshore Installations, 2007
- [3] ASME VIII, Boiler and Pressure Vessel Code Division 1 and Division 2, 2017
- [4] EEMUA Information Sheet 17, Guidance Procedure for the Removal and Replacement of Flange Joint Bolt-ing on Live Piping and Equipment, 2005