



TOTAL

# TEAM<sup>®</sup> Industrial Services

Accident 19th November 2013 – Lessons Learned

## Accident description & “Lessons Learned”

**Subject:  
Accident  
19th November 2013**

**Total Refinery Antwerp, Belgium**

**Date:  
April 1, 2014**

On November 19, 2013 a steam explosion occurred at the Total Refinery Antwerp in Belgium causing the death of two TEAM technicians. The technicians were working on a leaking 16” bonnet-valve body flange connection when the stud bolt (20 x 1 ½” ASTM A193 B7) securing the bonnet, suddenly failed causing the bonnet-motor assembly to separate from the valve body with great force. The sudden release of the boiler water resulted in the steam explosion.

The product was Boiler water, pressure 70 bar (1015 psi), temperature 290°C (554F). The valve was 16”, # 900 gate valve with a ring type joint (octagonal RTJ) bonnet – body assembly. The valve was in open position.

At the time of the incident, the technicians were performing a re-injection into a leak sealing clamp installed around the joint in March 2011. Almost immediately after the start of their work the accident happened.



*Identical bonnet – motor configuration*



*Identical bonnet – body clamp around adjacent valve*



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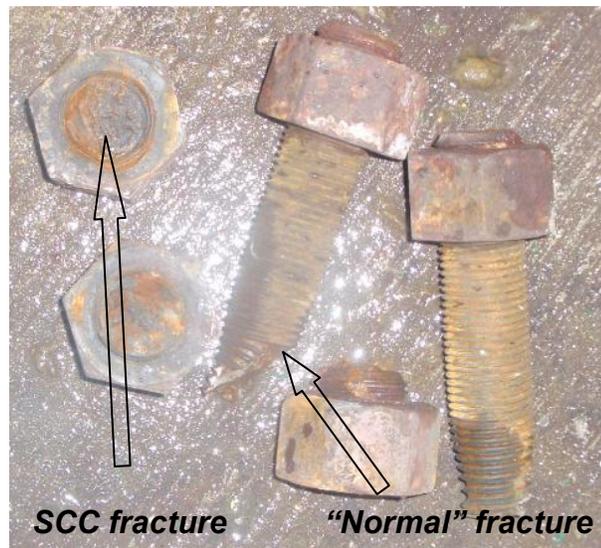
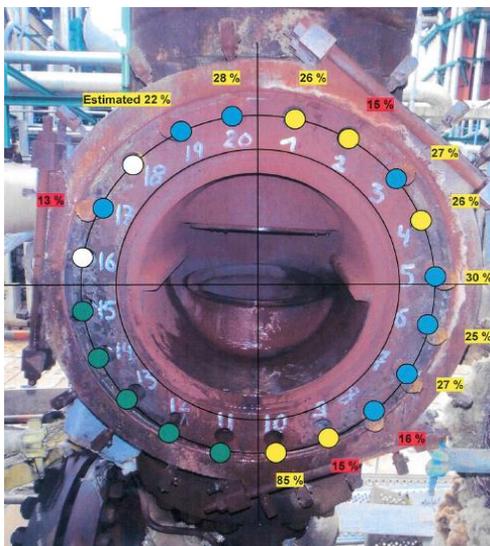
*Valve after bonnet separated*



*Separated bonnet*

### **Cause leading the bonnet to separate from the valve body**

The cause of the bonnet separation was the sudden failure of the stud bolts securing the bonnet. 14 Out of the 20 stud bolts were severely degraded due to (caustic) Stress Corrosion Cracking (SCC) (see also page 5). After examination, the stud bolts showed degradation percentages between 70% and 87%. 6 Stud bolts (no. 11 thru 16) had no signs of SCC and showed “normal” fracture. The bolt failure occurred during the re-injection process through one injection port (between studno.1 & no.2).



**From the investigation the following scenario was developed leading to the failure of the stud bolts.**

1. The valve has an original design or construction flaw. The diameter of the RTJ groove in the bonnet is 5 mm. too small (acceptable ASME tolerance is 0,13 mm). Because of this design or construction flaw, the standard RTJ ring does not fit in the groove as required. This flaw was not known.



*RTJ ring in an exact copy of the bonnet flange. On the right photo the RTJ ring is out of the groove. On the left photo the ring is in the groove.*

2. This design- or construction flaw resulted in a non-parallel bonnet – body flange connection (with standard assembly of the bonnet and stud bolt stress ( $310 \text{ N/mm}^2$ )). In order to create parallel flanges, several stud bolts have to be tightened with stresses close to the minimum yield. Laser measurements established that the original bonnet flange has taken on the shape of an umbrella. This is another indicator of the high forces in the stud bolts.
3. After the 2009 turnaround, there were fluctuations in the quality of the boiler water. Because of this fluctuation, several leaks occurred in the system requiring the installation of several clamps. These boiler water quality fluctuations explain the cause of the leaks but alone are not a cause of the accident.
4. In March 2011, the leak sealing clamp was installed around the bonnet – body joint creating a leak free joint. It was not known at this time that several of the stud bolts in the joint had stresses close to the minimum yield (approx.  $600 \text{ N/mm}^2$  bij  $300^\circ\text{C}$ ). See also point 2 above.

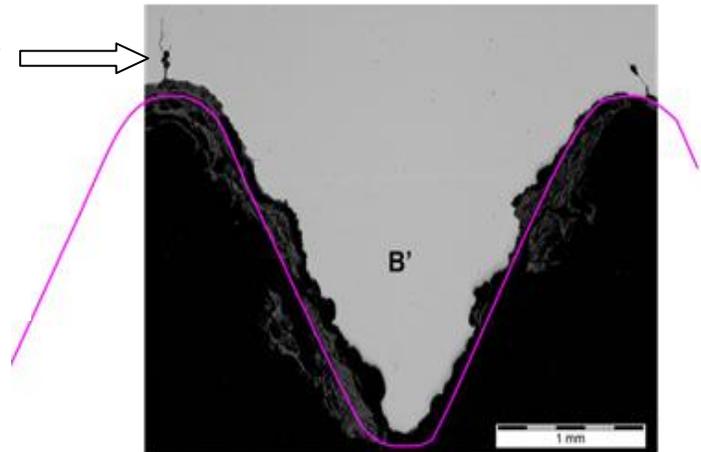
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5. After installation of the clamp, the line was out of service for 5 months between April and November 2011 and again in 2012 for about 6 weeks. Once during this period a visible leak occurred and 1 re-injection was performed. The valve remained under pressure, but at low temperatures (dead end). In this cold condition, a minor leak re-occurred inside the flange – clamp assembly creating a wet corrosive environment in which several stud bolts were subjected to general corrosion. Because of this corrosion, the pressure layer (rolled stud bolts) on the outside of the thread that creates resistance against SCC corroded away.

Possibly there were also initial micro cracks present due to galling (hardness of nut and stud bolt are almost the same) when the bolts were tightened.

SCC crack at bottom of the screw thread →

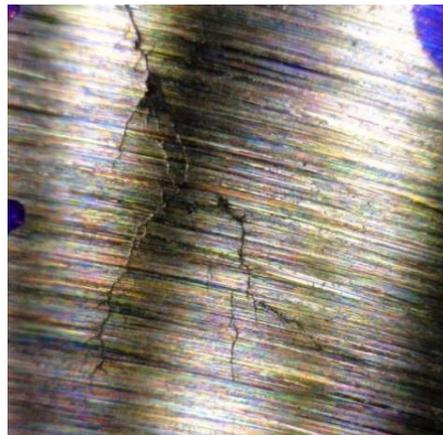
General corrosion affected screw thread of the stud bolts. Light grey is the stud bolt. Purple line is the shape of thread acc. to the standard.



6. After the line came back into service at the end of 2011 the connection leaked several times and injections were performed. During this period an accelerated SCC process started affecting the stud bolts. The boiler water that has leaked evaporates leaving a corrosive residue behind on the degraded stud bolts..



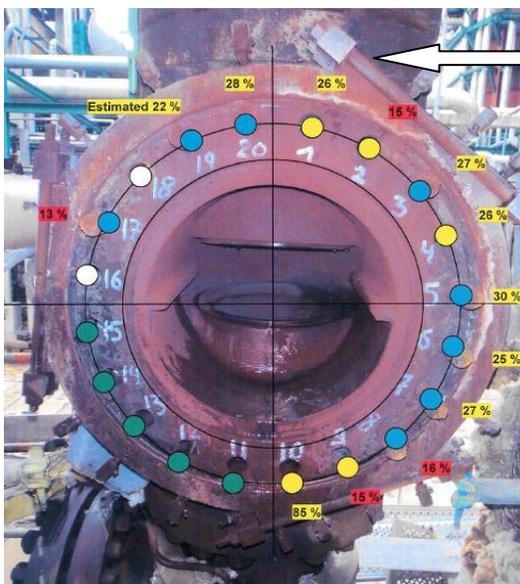
Stud bolt with “old” SCC crack and rest fracture



SCC crack under a microscope

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7. On 19th November 2013, the technicians are performing a re-injection on the bonnet – valve body connection with the severely degraded stud bolts. The additional stress on the severely degraded stud bolts occurring during the re-injection process is enough to let one (or more) stud bolts fail. The Fracture of one (or more) bolt results creates an increase in stress on the weakened surrounding bolts, leading to overload and fracture, resulting in a chain reaction and separation of the bonnet from the valve body causing the explosion.



*Location of the re-injection at the position of the weakened stud bolts. The missing injection valve was found connected to the injection pump hose.*

### What is Stress Corrosion Cracking?

A crack inducing form of corrosion under the **simultaneous** influence of a corrosive product and (high) tensile stresses. Without the tensile stresses, the metal would not or would hardly be affected by the corrosive product. Also, without the corrosive product, much higher stresses would be necessary to let the material fail.

### Causes of the caustic SCC

- Corrosive product (caustic/electrolyte → boiler water)
- Susceptible material (general corrosion affected B7 stud bolts)
- High tensile stresses (tightening of the stud bolts close to the yield to create parallel flanges).
- Temperature > 60-70 °C (process temperature is 290 °C)

**Remark;** De degraded stud bolts all broke at the flange – nut face, which is the location of the highest stresses.

### **Additional research of identical flange – clamp connections.**

- All flange stud bolts (>200 pcs) from the other flange – clamp connections in the unit were inspected (NDE). None of these stud bolts showed any signs of general corrosion or stress corrosion. All of these joints were within the same system and had identical process conditions.
- All clamps were installed in approximately the same period. All clamps had multiple re-injections.
- Same sealants were used for all re-injections.
- This section of the system had not been out of service/ been cold.

### **Clamp was not designed to take the extra axial load due to failure of the stud bolts.**

A strong back device to take the extra axial load on the flange bolts was not a standard design for boiler water at high pressure for Total or TEAM. This was determined on a case by case basis based upon the outcome of the flange bolt calculations. These calculations are based upon (1) stud bolts being in good condition and (2) an evenly spread load.

### **Summary**

- Due to a design- or construction flaw, the RTJ ring does not fit in the groove of the bonnet correctly. In order to create a parallel flange connection, the stud bolts are heavily tightened, resulting in high stress in the stud bolts.
- Fluctuations in the quality of the boiler water caused leaks resulting in the installation of several leak sealing clamps.
- As a result of 5 months out of service (cold condition) the stud bolts have been affected by general corrosion making them susceptible to SCC.
- When the line was placed back in service, all ingredients (high stress, caustic environment, susceptible material and high enough temperature (> 70°C / 158°F) were present for a rapid degradation by SCC.
- During the re-injection process additional forces occurred on the weakened bolts causing them to fail.
- There was no strong back device foreseen.

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## Lessons learned

- Visual inspection is not conclusive regarding the condition of stud bolts or other relevant parts.
- SCC can progress very fast. Stud bolts that are in good condition can, under the right circumstances, degrade rapidly due to SCC.
- In case of a re-injection, as part of the risk evaluation, the condition of the stud bolts should be evaluated. The additional forces on stud bolts due to (re) injections do not cause a problem when the stud bolts are in good condition and have a normal stress. Attention is required when the condition of the stud bolts and stress is unknown. Additional attention is also required when there are re-occurring leaks. When boiler water evaporates, caustic residue can stay behind on the stud bolts.
- Extra attention is required when there are white deposits visible on bolts and /or flanges.

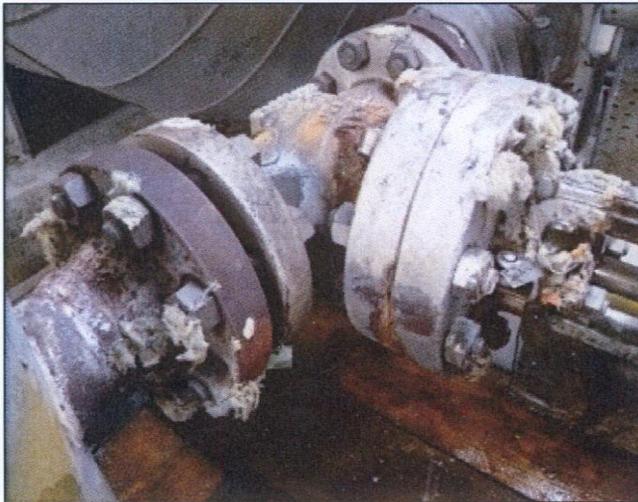


FIG 1



- SCC needs (high) tensile stresses **AND** a corrosive product. Additional attention is therefore required when working on systems containing corrosive products like, but not limited to;
  - Boiler water
  - Boiler feed water
  - Caustic

## Lessons Learned (Cont.)

- Regarding stud bolts stresses;  
History of a (leaking) joint must be recorded and special attention paid. The history must capture what has been done with the bolts and the joint assembly. Un-controlled tightening of the bolts (often the first repair attempt when a joint is leaking) should be avoided. The use of manual or hydraulic torque wrenches is highly recommended when tightening the bolts.
- Extra attention should be paid for possible combinations of conducive factors like stress environment, corrosive environment, installation operating outside normal operating conditions, the systems temporary taken out of service, additional stresses due to activities, etc.
- Different standards allow different calculation stresses. This results in a different outcome in identical situations. Therefore in high risk environments with many unknowns, no matter the result of the calculations, strong backs should be considered.
- In most cases, on-line leak sealing does not rectify the cause of the leak (erosion, corrosion, fatigue, defective material, etc...). Therefore leak sealing clamps and enclosures must be considered to be a temporary repair method and do not replace general maintenance or permanent repairs. It is recommended that, when there is a safe opportunity (for example a scheduled turn around) clamps and enclosures are replaced by a permanent repair.

## Additional attention points (not directly related to the accident).

- Risk of Hydrogen Embrittlement should be considered. Products that require attention are, but not limited to;
  - *Hydrogen Fluoride (HF)*
  - *Hydrogen Sulfide (H<sub>2</sub>S)*
- Some greases that are used for lubrication of stud bolts are known for their potential to cause SCC. Example is Molybdeen Sulfides containing grease.
- There is only limited information sharing between industries when near misses or accidents occur. The more we share our knowledge about these incidents, the less accidents will occur benefitting everybody.