



Prevention solution for corrosion issues in CO₂ removal units in ammonia plants

Case Study Report

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1. INTRODUCTION

A release of Benfield Solution (Hot Potassium Carbonate) and Syngas from the level bridle of the CO2 Absorber in the Ammonia plant resulted in a plant shutdown and subsequently a fire. The fire was safely brought under control. There were no personnel injuries, and damage was limited to the level bridle and the immediate vicinity of the bridle. Restorative work, including demolition, material procurement, fabrication, NDE and insulation took seven days.

2. BACKGROUND

The CO2 removal system includes the absorption column, desorber column and associated pumps and exchangers. Lean Benfield solution composition contains approximately 29% potassium carbonate, 3% Activator (LRS10) and 0.7% vanadium pentoxide.

The bridle is made up of two nozzles attached to the tower (B1 & B2), four nipples attached to two separate level glasses (LG1, LG2, LG3 and LG4) and two further nipples attached to a level transmitter LT, all of which provides the level of Benfield solution within the absorption tower – Figure 1. The normal level during operation is as indicated in Fig. 1 (marked “L.L”) and operating data for the level bridle pipe is given in Table 1.

The failure occurred in the form of a sudden, total loss of containment with no previously identified leaks in the area. A section of the bridle was found to have peeled off. The failure took place directly in line with nozzle B1, approximately 1ft 3 inches below it. Upon inspection, immediately after the incident, vertical grooves emanating from the nozzle downwards were noted. There appears to have been some corrosive actions due to condensation of the Benfield vapour at nozzle B1 which continuously ran down the sides of the bridle wall. The appearance of the transverse part of the fracture surface is shown in Figure 4.

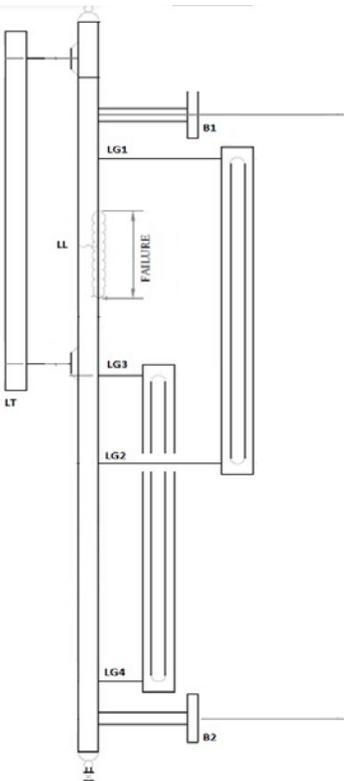
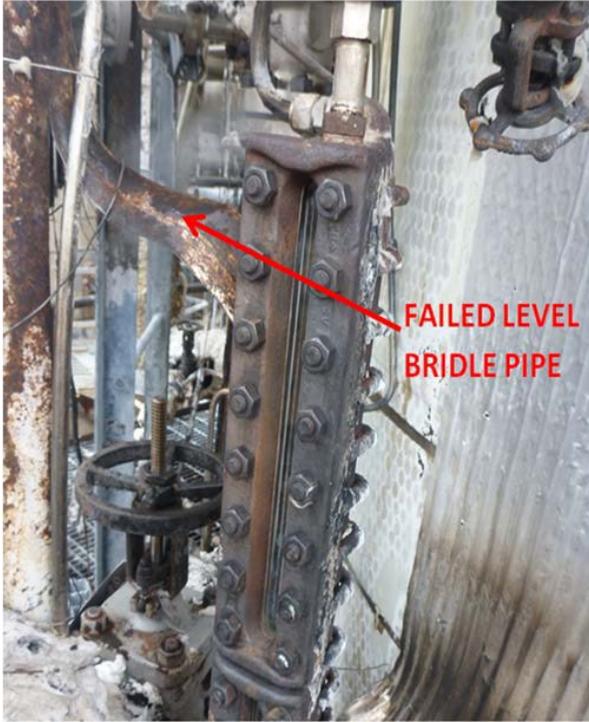


Figure 1. Level Bridle Arrangement



Figure 2. Failed level bridle



Parameter	Value
Diameter"	3"
Schedule	40
Nominal Thickness	5.5mm
Operating Temperature	240°F (116°C)
Operating Pressure	400psig (27.6 bar)
Material	SMLS API 5L (carbon steel)

Table 1. Design Data for LT Level bridle pipe

Figure 3. Failed level bridle



Figure 4. Traverse part of fracture surface

3. CONCLUSION

- The tube ruptured due to ductile overload in the result of localised thinning from internal surface corrosion.
- The source of corrosive liquid appears to be condensation of Benfield vapours at nozzle B1, which had continuously run down the bridle wall. The depth of the corrosion grooves tapered off as the general Benfield liquid level was reached.
- The appearance of the rupture indicated that the tube initially ruptured along two deep longitudinal corrosion grooves.
- The very narrow fracture surfaces on the longitudinal parts of the rupture showed that the bridle had suffered from severe local wall metal loss. The bridle wall thickness was less than 0.5 mm along parts of the deeper corrosion grooves. This thickness was below minimum required thickness to withstand the internal pressure of 400 psig (~28 bar) [3] and suggested that the rupture was initiated due to this reason (mechanical overload).
- The failure was not due to CO₂ Stress Corrosion Cracking as initially thought.

4. LESSONS LEARNED

- Designing/operating/maintaining an efficient tracing system including nozzles that would reduce or prevent CO₂ condensate corrosion remains a challenge. If this phenomenon was identified during original design or plant operation, the decision to upgrade this level bridle in stainless steel would have been taken.
- Plant startup procedure in transient conditions or during passivation process was not detailed enough to include these types of bridles and also with such a complex design, it might not even be practical.
- From the Risk Based Management Inspection program (RBMI), analysis at a loop/cluster level to a detailed inspection scope must be down to a component level and in this case, the level bridle should have been treated as a specific component. In this way, the bridle would have had defined degradation mechanisms. For this loop “Rich Benfield”, the damage mechanisms were erosion/corrosion, CUI and CO₂ SCC.
- Ultrasonic Testing measurements would have been the primary Non-Destructive Examination method for erosion/ corrosion.
- CUI was part of the general inspection scope for small diameter connections to pressure equipment, however UT measurements were not done for the bridle.

5. RECOMMENDATIONS

- Upgrade bridle chamber assembly at the next turnaround to stainless steel material, this way avoiding the complexity of not knowing if passivation takes place or not.
- In the corrosion study reviews, chambers and attachments to pressure equipment such as this should be classified as separate component for a better definition of the potential damage mechanisms according to the corrosion loop. As such it should also have its own detailed inspection plans.
- Review the passivation procedure for potential ‘dead leg’ areas in corrosive systems.
- Improve the process of draft inspection plan (outcome of RBMI) to the detailed equipment inspection plan to ensure nothing is taken for granted or not included.
- Regularly inspect the carbon steel bridle chamber installed until the next turnaround cycle.
- Review papers on condensation corrosion in ‘dead legs’.

- Consider using diaphragm seals for liquid (level) measurement. Level measurement by means of differential pressure measurements is still one of the leading level measurement principles. Diaphragm Seals are used to separate the pressure instrument from the process, to protect the vulnerable measuring element. The use of Diaphragm Seals is recommended when the process medium:
 - i. Is too aggressive, corrosive, toxic and/or highly viscous
 - ii. Has a (extremely) high or low temperature
 - iii. Has crystallization and/or polymerization
 - iv. Requires sanitary or other customized process connections
- With diaphragm seals, the process wetted parts could be equipped with any material, suitable for the process and chemically resistant to the process medium.

Diaphragm Seals are also used for liquid level measurements in pressure retaining tanks instead of 'wet legs' or 'dead legs'. Dead legs or wet leg are generally made with tubing mounted directly to the transmitter and is filled with process medium. Diaphragm Seals Systems offer installation flexibility and maintenance advantages over wet leg systems. Diaphragm Seals make it easier to maintain the fluid between the tap and the transmitter, especially on the reference or low pressure side. In vacuum systems, a closed seal system, rather than an open wet leg, maintains a constant height for the low side reference. The Diaphragm Seal System does not need to be refilled or drained. They are also not vulnerable to plugging or freezing and they are easier to control than wet leg systems.

(Reference – [Diaphragm Seal Solutions by Badotherm](#)).

6. DEFINITIONS

CUI	Corrosion Under Insulation
NDE	Nondestructive Evaluation
RBMI	Risk Based Management Inspection
SCC	Stress Corrosion Cracking
UT	Ultrasonic Thickness

7. REFERENCES

1. Failure of Level Bridle in Benfield Service, AIChE white paper presented at Ammonia Safety Symposium in 2016
2. http://www.badotherm.com/downloads/Badotherm_diaphragm_seals_introduction_and_basic_principles.pdf (page 14)

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