AMMO LASER Leak Detection System

Why it is the most reliable leak detection system

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A properly functioning and above all a reliable Leak Detection System is essential for the safe operation of a urea plant because the High Pressure Urea equipment is highly vulnerable for incidents: High pressures, high temperatures and the corrosive circumstances plus the toxic health risks of an ammonia leak requires high demands on the integrity of these items.

The UreaKnowHow.com Incident Database contains already thirty serious incidents in high pressure urea equipment items, where a not proper working leak detection system was involved. Six of these incidents occurred during the last two years (2018 and 2019).

Note: A serious incident is defined when the integrity of the carbon steel pressure bearing wall is threatened, and could lead to a rupture of the vessel.

In seven of the thirty identified incidents the carbon steel pressure vessel wall ruptured, which can be expected when corrosive ammonium carbamate comes into contact with the carbon steel pressure bearing wall. Such a rupture is caused by weakening the heavy carbon steel wall of the vessel under an internal pressure of some 140 bar-200 bar (2030 psig – 2900 psig). Upon that event, amongst others, a large quantity of toxic ammonia will be released.

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The UreaKnowHow.com risk register of a typical high pressure urea reactor with a 316L Urea Grade austenite stainless steel liner shows that some 70% of the identified safety risks can be prevented by having a proper and reliable leak detection system.

In order to avoid any risk that the mechanical integrity of the carbon steel pressure bearing wall is endangered, one needs to assure that any leak through the liner is detected immediately when such a leak starts.

Without in time detection of a liner leak, the failure mode of high pressure urea equipment has proven to be a catastrophic failure.

Be aware that in case of a leak through the liner, the carbon steel pressure bearing wall underneath will be exposed to the extremely corrosive ammonium carbamate. History has shown that ammonium carbamate can corrode carbon steels at very high rates (up to 1,000 mm [40”] per year).

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In case of a liner leak and as long as the pressure behind the loose liner is low, liquid and very corrosive ammonium carbamate will dissociate into gaseous ammonia and carbon dioxide and the corrosion rates to the carbon steel will be rather low.
But in a clogging situation the pressure in the gap between the liner and carbon steel pressure vessel wall will increase and the liquid ammonium carbamate will no longer dissociate and will corrode the carbon steel wall at very high rates.

In most sections in the high pressure urea equipment the process medium will contain urea; this urea will easily crystallize when the temperature is too low or will polymerize when the temperature is too high. Clogging risks are then most significant.
Note that tracing and insulation are prevention measures which only help temporarily.

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Clogging is by far the most serious risk to enable high corrosion rates. A state of the art leak detection system should safeguard first and for all warn before clogging occurs.

Key words to avoid the aforementioned situations are early detection and high reliability

This is the reason that passive leak detection systems, where one waits for the leak to show up at the analyzer are unsafe and not acceptable anymore today. This has been proven through trial and error in numerous incidents, for example Urea Incident 18-005 (FIORDA Urea Case #5)

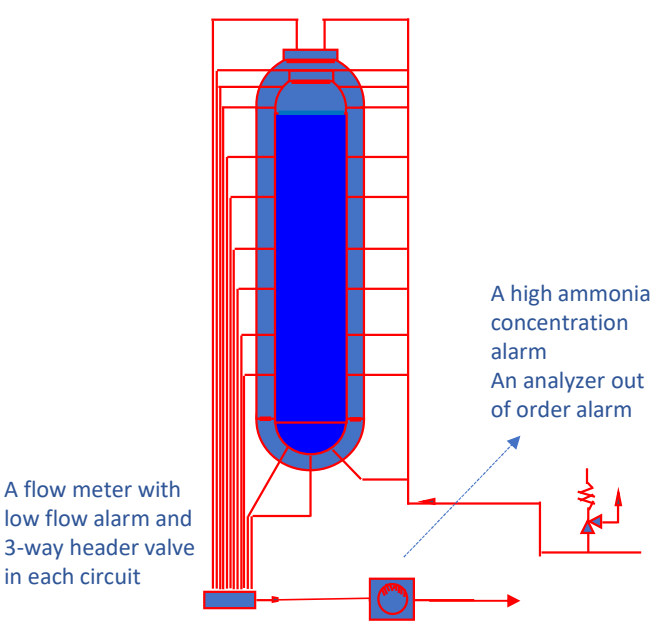
The next question is:

What are the requirements for a state of the art active and reliable leak detection system ?

Note: Find further the Risk Register of active leak detection systems including the lessons learned from related incidents

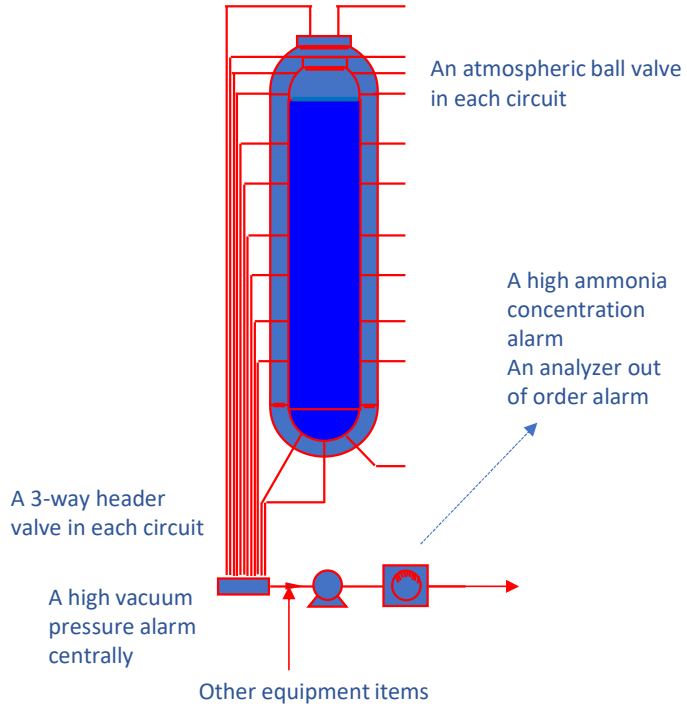
2. Active Leak Detection Systems: Pressurized versus Vacuum type

Active Pressurized System
circulate an inert gas via a network of passageways behind the loose liner



Note: Each equipment item should have a dedicated system

Active Vacuum System
pull vacuum behind the loose liner



2. Active Leak Detection Systems: Pressurized versus Vacuum type

Note that there are various kind of pressurized leak detection systems and there are various kind of vacuum systems.

In this Risk Register we assume an active Pressurized System, where one circulate an inert gas via a network of passageways behind the loose liner and where each leak detection circuit has a flow meter with a low flow alarm in DCS. Plus each high-pressure equipment item has its dedicated ammonia analyser to avoid the risk that a broken tube between the high-pressure equipment and the analyser will go undetected.

And in this Risk Register we assume an active Vacuum Systemin which the vacuum pump is always running and the vacuum pressure is a result of the capacity of the vacuum pump and the numerous small leakages through all tubing connections (typically vacuum pressure is in the range of 0.20-0.30 barabs). This means there is always an airflow through the leak detection tubing helping a fast and reliable leak detection even from long distances.

3a. Risk Register Design and Installation Phase

Initiating event	Preventive system	Failure mode
No stainless steel sleeve in leak detection hole in a layered wall which is welded to inner core layer leading to a risk of carbamate entering between the carbon steel layers	- Remove plugs from vent holes - Do not flush with steam or condensate - Install a state of the art leak detection system	- Corrosion of carbon steel pressure bearing wall - Loss of integrity and rupture
No measurement due to one or more leak detection holes not connected to leak detection system (Urea Incident 98-003)	- Complete check of system during commissioning and after every turnaround - Validation with manufacturing drawings that every leak detection hole is connected - Document properly every check!	- Lack of information from the leak detection system - No possible detection of a leak in the liner

3b. Risk Register High Pressure

Initiating event	Preventive system	Failure mode
Too High Pressure behind the liner when synthesis pressure is too low (*only valid for a pressurized system*)	- Install safety valve with a set pressure of max 0.5 barg - Install a shut down trip when the synthesis pressure is below for example 10 barg	- Liner bulging and rupture
No measurement due to shut down trip when synthesis pressure is too low to avoid risk of liner bulging (*only valid for a pressurized system*)	- Apply a vacuum system. Note that during these phases the liner sees most stresses and a leak detection system is important	- Lack of information from the leak detection system - No possible leak detection

3c. Risk Register No Flow during normal operation — Part 1 of 3

Initiating event	Preventive system	Failure mode
No Flow to analyzer due to a closed valve or clogging situation	- Pressurized system: Install flowmeters with low flow alarm with a defined test frequency. As an alternative regular checking of the flowmeters - Vacuum system: Install pressure meter with high pressure alarm upstream the reactor with a defined test frequency. As an alternative regular checking of open circuits by opening atmospheric ball valves and confirming vacuum pressure increase (AMMO LASER Leak Detection System includes dust caps to avoid the risk of any ingress of foreign material) - Apply sufficient large tubing internal diameter - Apply 3-way valves to assure an pressure-less open connection to outside and a passive leak detection system (fail safe design)	- Lack of information from the leak detection system - No leak detection

3c. Risk Register No Flow during normal operation Part 2 of 3

Initiating event	Preventive system	Failure mode
No Flow to analyzer due to a disconnected tubing	- *Pressurized system*: Install a flowmeter with low flow alarm with a defined test frequency as close as possible to the equipment header. Note this measure only helps when the disconnected tubing is upstream the flowmeter. In case one analyzer is combined for more equipment items, a risk remains of disconnected tubing between the equipment headers and the analyzer. Thus one needs to install a dedicated analyzer for each equipment item. - *Vacuum system*: Install pressure meter with high pressure alarm centrally close to analyzer with a defined test frequency. This will help to detect a disconnected tubing in the complete system, even for more equipment items. Note that in this case the vacuum pressure will increase while the ammonia content remains low, so operator can immediately recognize the problem	- Lack of information from the leak detection system - No leak detection

3c. Risk Register No Flow during normal operation — Part 3 of 3

Initiating event	Preventive system	Failure mode
No flow to analyzer due to no inert gas injection (*pressurized system*)	- Install flowmeter with low flow alarm with a defined test frequency	
No flow to analyzer due to loss of vacuum pressure (*vacuum system*)	- Install pressure meter with high pressure alarm upstream the reactor with a defined test frequency. As an alternative regular checking of open circuits by opening atmospheric ball valves (AMMO LASER Leak Detection System includes sufficient large internal diameter of the tubing and dust caps to avoid ingress of foreign material) - AMMO LASER Leak Detection System includes a vacuum pump with sufficient capacity and reliability plus an installed spare vacuum pump	- Lack of information from the leak detection system - No leak detection

3d. Risk Register No Flow during small liner leak

Initiating event	Preventive system	Failure mode
No Flow to analyzer due to a clogging situation during a small liner leak situation. Note: Small means that leaking flow rate is not restricted by flowmeter in a pressurized system	- Install a reliable and accurate ammonia analyzer including high concentration alarm with a defined test frequency (AMMO LASER Ammonia Analyzer) to assure a timely reaction - Install tubing with sufficient large internal diameter - Trace and insulate tubing. Note that tracing and insulating help only temporary. - In a vacuum system one can open the atmospheric ball valve of leaking circuit to dilute the leak and avoid clogging	- Lack of information from the leak detection system - No leak detection

3e. Risk Register No Flow during large liner leak

Initiating event	Preventive system	Failure mode

No Flow to analyzer due to a clogging situation during larger liner leak situation (for example cracks resulting from fatigue (Urea Incidents 79-001 and 03-002), strain induced intergranular corrosion, design and fabrication failures).
Note: Large means that leaking flow rate is restricted by the flowmeter in a pressurized system
	- Install a reliable and accurate ammonia analyzer including high concentration alarm with a defined test frequency (AMMO LASER Ammonia Analyzer) to assure a timely reaction
	- Install tubing with sufficient large internal diameter
	- Trace and insulate tubing.
	  - Urea Incident 19-006 (FIORDA Urea Case #4) has shown that in a *pressurized system* a large leaking flow rate can be restricted by the flow meter and backflow is possible. Hence all tubing needs to be traced and insulated.
	  - In a vacuum system only the tubing between the equipment and the header needs to be traced and insulated and there is no restriction present for the leaking flow.
	  - Note that tracing and insulating help only temporary
	- In a vacuum system one can open the atmospheric ball valve of leaking circuit to dilute the leak and avoid clogging
	- AMMO LASER Leak Detection System includes also a liquid detection
		- Lack of information from the leak detection system
		- No leak detection

3f. Risk Register (Too) Late Detection during liner leak

Initiating event	Preventive system	Failure mode
(Too) Late Detection of a liner leak due to: - No grooves present (for example tray clips, fatigue at sleeved nozzles, condensation corrosion, strain induced stress corrosion cracking) - One of the grooves are clogged (*only valid for a pressurized system*)	- Install a vacuum system as it monitors the complete liner surface	- Lack of information from the leak detection system - No leak detection

3g. Risk Register No Flow related to earlier leaks and design issues Part 1 of 2

Initiating event	Preventive system	Failure mode
No Flow to analyzer due to clogged grooves caused by solids from an earlier leak (*only valid for a pressurized system*)	- Flush with steam or condensate (Not recommended due to risk of (bi-)carbonate (or other contaminants) Stress Corrosion Cracking in carbon steel behind liner. Note that without water there cannot be any corrosion (Urea incident 04-001). - Apply a vacuum system connected to both leak detection holes	- Lack of information from the leak detection system - No leak detection
No Flow to analyzer due to clogged grooves caused by corrosion of carbon steel caused by an earlier leak (*only valid for a pressurized system*)	- Apply a vacuum system connected to both leak detection holes	
No Flow to analyzer due to only one leak detection hole present (*only valid for a pressurized system*)	- Apply a vacuum system connected to both leak detection holes	

3g. Risk Register No Flow related to earlier leaks and design issues — Part 2 of 2

Initiating event	Preventive system	Failure mode
No Flow to analyzer due to wrong design and/or bad machining of grooves (*only valid for a pressurized system*)	- Apply a vacuum system connected to both leak detection holes	- Lack of information from the leak detection system - No leak detection
No Flow to analyzer due to no grooves present (*only valid for a pressurized system*)	- Apply a vacuum system connected to both leak detection holes	

3h. Risk Register False Indication

Initiating event	Preventive system	Failure mode
False Indication due to the presence of ammonia in atmosphere (*only valid for vacuum system*)	- Use a reliable and accurate analyzer (AMMO LASER ammonia analyzer). Note that continuously the background level of ammonia in the atmosphere will be visible indicating the analyzer is working. In case of an ammonia cloud in the atmosphere, a limited part of the tubing connections will suck in this ammonia and temporary the average ammonia content will increase somewhat but never up to the alarm level, which is at a much higher concentration.	- Lack of information from the leak detection system - No reliable detection

3i. Risk Register No or false analysis ammonia analyzer

Initiating event	Preventive system	Failure of mode
No analysis due to analyzer out of order	- Install a DCS alarm in case analyzer is out of order (AMMO LASER ammonia analyzer) - Or install a redundant analyzer with a deviation alarm and perform regular tests on analyzer	- Lack of information from the leak detection system - No leak detection
No analysis due to analyzer not properly connected	- Install a DCS alarm in case analyzer is not connected (AMMO LASER ammonia analyzer) - Or install a redundant analyzer with a deviation alarm and perform regular tests on analyzer	
False analysis due to a not properly calibrated analyzer	- Use a self-calibrating analyzer (AMMO LASER ammonia analyzer) - Or install a redundant analyzer with a deviation alarm and perform regular tests on analyzer	

4. Conclusions Part 1 of 4

A pressurized leak detection system has the following shortcomings:

1. It only monitors directly in the neighborhoods of the grooves (fixed liner welds)
2. It introduces risks of liner bulging and rupture
3. It does not function properly during start up and shut down (when the synthesis pressure is low); then the liner sees most stresses (heating up, cooling down). In these situations a leak detection system is very important
4. It can restrict the leaking flow and does build up pressure and introduce risks for back flow
5. It is not able to dilute the leak and hence does not minimize the risk of clogging
6. It does not function properly in case the grooves are clogged caused by solids from an earlier leak (one will need to flush with steam or condensate introducing stress corrosion crack risks in the carbon steel behind the liner)
7. It does not function properly in case the grooves are clogged caused by corrosion of carbon steel caused by an earlier leak
8. It does not function properly in case only one leak detection hole is present in a liner compartment

4. Conclusions Part 2 of 4

A pressurized leak detection system has the following shortcomings:

9. It does not function properly in case of bad design and/or machining of the grooves
10. It does not function properly in case of no grooves behind the liner are present
11. Tracing and insulation of all parts of the leak detection tubing is mandatory
12. It requires a dedicated ammonia analyzer for each equipment item
13. Maintenance, recalibration or renewal of the detecting agent is required

4. Conclusions Part 3 of 4

The AMMO LASER Leak Detection System is the most reliable system because:

1. It monitors directly the complete liner area
2. It continuously monitors the vacuum pressure and ammonia content
3. There are no risks for liner bulging and rupture
4. It works also during start-up and shut-down conditions of the HP equipment
5. It does not restrict the leaking flow and does not build up pressure or introduce risks for back flow
6. It dilutes the leak and hence minimize the risk of clogging
7. It functions also in case the grooves are clogged caused by solids from an earlier leak (no need to flush with steam or condensate)
8. It functions also in case the grooves are clogged caused by corrosion of carbon steel caused by an earlier leak
9. It enables leak detection also in case only one leak detection hole is present in a liner compartment

4. Conclusions Part 4 of 4

The AMMO LASER Leak Detection System is the most reliable system because:

10. It enables leak detection in case of bad design and/or machining of grooves
11. It enables leak detection in case of no grooves present
12. The AMMO LASER ammonia analyzer is the most accurate and reliable ammonia analyzer as it provides a DCS alarm in case out of order and/or not properly connected, is ammonia specific and is self-calibrating
13. It is able to distinguish false indication from an ammonia cloud in the atmosphere from a real liner leak. And thus warns the operator also for other upset conditions in the plant.
14. It requires tracing and insulation of only a part of the leak detection tubing
15. It can combine one ammonia analyzer for multiple equipment items (even more urea lines) as distances are much less critical.

5. Additional Features AMMO LASER Leak Detection System

16. Gives the ammonia leak rate and calculates leak size
17. Includes a continuous detection for the presence of any liquid
18. Allows safe and simple introduction of leak detection tracer for pinpointing the leak
19. Can be combined with up to seven other NH3 emission sources continuous monitoring leading to lower ammonia consumption costs
20. No inert gas supply is required and only a low power requirement
21. Already several successful references since 2017
22. A **Guaranteed Pay Back Time** resulting from shorter shut down periods as one can find the leak faster, knows the leak size and is able to assure no damage to carbon steel pressure bearing wall
23. Plus a **Guaranteed Pay Back Time** resulting from lower NH3 consumption figures
24. SAIPEM, as owner and licensor of the Snamprogetti™ Urea Technology, approves the AMMO LASER Leak Detection System for application in all its plants

SAIPEM

AMMO LASER Leak Detection System

#1 Safety Measure with a Guaranteed Pay Back Time