Incident Summary #II-1213103-2021 (#22551) (FINAL)

SUPPORTING INFORMATION	Incident Date		June 21, 2021
	Location		Abbotsford
	Regulated industry sector		Boilers, PV & refrigeration - Refrigeration system
	Impact – Injury	Qty injuries	2
		Injury description	One individual received first and second-degree chemical burns on their head, ear, neck, and upper chest from contact with ammonia. A second individual received first and second-degree chemical burns on their forearm and bicep of their left arm from contact with ammonia.
		Injury rating	Moderate
	Damage	Damage description	Approximately 6.7 lbs of ammonia leaked from the refrigeration system into the mechanical room of the facility
		Damage rating	Minor
	Incident rating		Moderate
	Incident overview		An industrial food processing facility, which uses ammonia in a refrigeration system to cool large coolers, chillers, and freezers, had an ammonia leak at an auto-purger in the mechanical room. While attempting to isolate the equipment and stop the leak, an employee of the facility was exposed to ammonia and received chemical burns. A technician working for a refrigeration contractor arrived later and was also exposed to ammonia and received chemical burns.
INVESTIGATION CONCLUSIONS	Site, system and components		The facility incorporates an industrial refrigeration system using ammonia as the refrigerant. The system has a refrigeration capacity of 918 tons and a total refrigerant charge of approximately 15,000 lbs of ammonia. The facility has sensors to monitor for ammonia leaks, alarms which indicate when ammonia has been detected and exhaust fans to ventilate ammonia from the space. Ammonia in a refrigeration system exists in both liquid and a gas form. It is toxic and produces a strong odor. When ammonia contacts moisture it forms ammonium hydroxide which is very caustic. Exposure to ammonia may result in irritation to the eyes, mouth, throat, and lungs, burns to the skin, and in high concentrations can be immediately fatal. The refrigeration system utilizes an auto-purger which is an automatic electronically controlled device for purging non-condensable gas (air) from the refrigerant system, (Image 2). Air is removed from the system to reduce internal pressures and increase operating efficiency. The auto-purger takes momentary samples of gas from multiple points in the refrigeration system, condenses any ammonia vapor in the gas sample back to a liquid, and separates out the air. When enough air accumulates in the auto-purger it is purged out of the device through a water bubbler tube. The air bubbles up through a column of water in the tube which absorbs any residual ammonia before purging it out into the mechanical room. During, and shortly after purging, fresh water is automatically added to the tube to flush any ammonia laden water out through an open overflow tube to a floor drain (Image 1).

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	The auto-purger uses a time delay relay for the solenoid which purges gas to the water bubbler tube. When the air has been purged from the unit, an internal float will raise, opening an electronic circuit ending the purge. In normal operation, the relay will close the purge gas solenoid valve if the purge exceeds one hour of continuous gas release. The time delay relay resets after the purge is completed, starting a new 1 hour time delay during the next purge. In the event of a system malfunction, the relay will deenergize the solenoid preventing excessive amounts of gas from being released, which may include ammonia. During start-up of the auto-purger or during conditions of high gas removal, the relay can be manually switched from "normal" operation to "continuous bubbling" by use of a toggle switch on the relay, (Image 6). When the relay is switched to "Start Up Only or Continuous Bubbling" it will not shut off the purge gas solenoid after 1 hour, allowing it to remain on continuously. The manufacturer of the auto-purger suggests detailed maintenance on a routine basis to ensure safe operation of the equipment. They state that even with maintenance performed through the lifecycle of the appliance, the auto-purger should be replaced after 15 to 20 years of service. The facility has a documented Ammonia Exposure Control and Response Program (ECRP), and a standard operating procedure (SOP), for investigating ammonia leaks within the facility. These documents allow authorized workers trained in the procedure to investigate leaks. The workers require personal ammonia detectors and full-face respirators. Only teams of two authorized workers may investigate a leak and can only enter an area if the levels of ammonia are less than 250 parts per million(ppm). If at any time the levels exceed 250 ppm, the workers should evacuate the area and wait for assistance from the refrigeration contractor. Concentrations of 300 ppm and up are considered immediately dangerous to life and health (IDLH). The facility typically used the same refrigeration contracting firm to conduct equipment maintenance and repairs. Employees of this contracting firm were required to follow safety procedures stipulated by both the employer (contractor), and the facility (customer). The refrigeration contractor's corporate safety policy states that appropriate body protection such as coveralls, must be worn to ensure a worker's skin is protected from a harmful substance that may injure the skin on contact, or may adversely affect a worker's health if it is absorbed through the skin. Employees of the contractor are required to read and sign off on the acknowledgement of the Safety Policy.
Failure scenario(s)	The auto-purger had been operating in the facility for over 30 years. It was not included in a preventative maintenance schedule, and no documented maintenance had been recently performed on the auto-purger by the facility employees, or the facilities refrigeration contractor. The unit had been experiencing failures which allowed ammonia to escape into the mechanical room, three times previously in the 4 months leading up to the incident. Recommendations for a major overhaul or replacement of the auto-purger had been made twice prior to the incident, on April 1st and June 19th, 2021. The facility had not developed plans or taken any actions to address the overhaul or replacements needed. The unit had recently been tested, adjusted, and put back into operation three times by the refrigeration contractor prior to the incident.

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	Two days before the incident, while following up on a previous ammonia release, the contractor found, and drained oil from the auto-purgers condenser. The contractor again recommended a preventative maintenance and oil drain service, and also recommended planning and budgeting for a major overhaul or replacement. On the day of the incident the auto-purger began venting ammonia into the mechanical room again, and an employee supervising the system evacuated the facility and called the refrigeration contractor. The contractor was unable to attend the scene for over an hour and the employee attempted to isolate the auto-purger and turn it off to stop the leak. The valve for the water supply line to the auto-purger was closed and fresh water did not enter the bubbler to purge out the ammonia saturated water to the drain. The top cap for the bubbler had been removed and the bubbler tube was open on the top, (Image 4). The knob for the control switch was missing from the auto-purger, (Image 5) and the control switch was the only switch in the vicinity of the auto-purger that would disconnect power to the unit to turn it off. The employee entered the room alone, as they were the only authorized person on shift at the time. They isolated two valves but did not turn the unit off because they did not know how. While observing the pressure gauge on the top of the unit after the valves were closed, ammonia saturated water spayed out of the top of the bubbler tube, burning the employee on their head, neck, and upper chest. The refrigeration technician arrived later and entered the mechanical room wearing a short-sleeved t-shirt and having exposed skin on their arms. The technician opened the water valve to flush the ammonia saturated water out of the bubbler, and when water flowed into the bubbler it reacted with the ammonia and splashed up, burning the technician on the exposed skin of their arm.
Facts and evidence	**Statements** **Injured employee (4th class Power engineer)** • When the ammonia alarms went off, they evacuated the facility and contacted the refrigeration contractor. • They saw the auto-purger shaking and ammonia vapor leaking from the top of the bubbler tube and from the drainpipe at the floor. No water was draining out of the drainpipe, just ammonia vapor. • The technician stated on the phone that they were coming from far away and would not be able to attend for 1.5 to 2 hours. • The employee felt obligated to try to stop the leak because they did not want the entire staff from the plant who had been evacuated to be waiting outside for hours until the contractor could arrive and fix the problem. • They asked the technician on the phone what they could do to stop the leak and the technician stated that they could isolate the auto-purger from the refrigeration system and turn the unit off. • The employee was qualified and trained to isolate and shut off the auto-purger. • Being unaware of how to turn the unit off, they left it on and proceeded to close the inlet valves to the auto-purger while leaving the suction valve open. • The cap was which was supposed to be in place was not installed on the top of the water bubbler tube, and after closing the valve, the liquid in the bubbler tube sprayed out the top, covering the employee.

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- They received burns on their head because they could not wear a hard hat while wearing a full-face respirator.
- Their regular duties include isolating and draining oil from some components in the refrigeration system but not the auto-purger. Maintenance and repair of the auto-purger is only done by the refrigeration contractor.
- They were unfamiliar with the equipment and unknowledgeable about the valve configurations and required maintenance.
- Ammonia concentrations in the compressor room had reached 450 ppm as indicated on their personal monitor while they were in there attempting to isolate the auto-purger. They did not evacuate the area when the concentrations exceeded 250 ppm as is required in the facilities standard operating procedure (SOP) for investigating ammonia leaks.

Conclusions:
The employee was qualified and trained to investigate leaks, operate refrigeration valves, and turn off the refrigeration equipment, yet was not knowledgeable of how to turn off and isolate the auto-purger. The facility only had one authorized person on shift at the time of the incident. The actions of the employee did not adhere to the facilities' SOPs for safe investigation of ammonia leaks, which resulted in injury.

Injured refrigeration contractor technician

- They received a call of an ammonia leak and plant evacuation and spoke with the power engineer (Injured employee) on site. The employee asked what they could do to help stop the leak, the technician told them they could shut the liquid and hot gas valves and switch the unit off. The employee said they did not know the location of these valves, so they told the employee to not touch any valves and wait until he arrived.
- The technician arrived on site after the employee was injured and the fire department was on scene. The monitors indicated the ammonia levels in the mechanical room were 160ppm.They entered the room and found the high-pressure liquid and foul gas valves in the closed position and the auto-purger was still powered on. The water supply valve to the auto-purger was closed and was not adding water to the bubbler to purge the ammonia.
- They energized the water supply solenoid and reached over the bubbler, and manually opened the water supply valve. When water entered the bubbler, the liquid in the bubbler tube sprayed up through the top, which did not have the cap installed. They were wearing a short-sleeved t-shirt and had exposed arms, which allowed the ammonia to contact their skin and cause burns.
- They have been working in the refrigeration trade for 15 years and had seen other auto-purgers venting ammonia instead of non-condensable (air). The failure of an auto-purger resulting in an ammonia release was not an isolated event in industry and is a possible hazard in all ammonia refrigeration systems, incorporating similar auto-purgers.

Conclusions:
The technicians' statements indicate the water supply valve to the auto-purger was in the closed position, which prevented mitigation of the ammonia exposure hazards associated with the failure. As a result of the technicians neglecting to wear the appropriate personnel protective equipment while investigating the ammonia leak, the technicians were injured in the course of their duties.

Senior plant engineer

- The auto-purger had been in operation at the facility for more than 30 years.

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- Monitoring and documentation of the volumes of oil removed and added to the system had previously been done but had not been done by employees in the recent past.
- Employees do not conduct maintenance or repairs of the auto-purger, including oil draining. This work is only done by the refrigeration contractor.
- After the first recommendation to have the auto-purger overhauled was presented in April, it was discussed between the senior engineer, plant manager, and refrigeration contractor. The discussion included the estimated costs associated with overhaul versus replacement, and whether they wanted to overhaul it or wait and replace the unit later. No plans were created, or actions taken to overhaul or replace the unit between the conversation and the incident.

Conclusions:
The Senior Plant Engineer's statements indicate the auto-purger is aged and routine scheduled maintenance had not recently been conducted on it. Recommendations to repair or replace the equipment was not actioned by the facility management which failed to prevent the incident.

Refrigeration contracting company managers

- Oil was found and drained from the auto-purger heat exchanger the week prior, by a technician who responded to a previous occurrence of the auto-purger passing ammonia.
- There were indicators that there may have been a maintenance issue or, a component that was allowing more oil than usual into the system.
- Oil can accumulate in an auto-purger reducing the efficiency of the internal condenser heat exchanger, which then does not provide enough cooling to condense the ammonia. This ammonia vapor can accumulate, and be treated and released, as non-condensable (air) by the auto-purger.
- They have seen on multiple occasions similar failures of other auto-purgers venting ammonia instead of non-condensable. It has typically occurred on older units and has been found to be from excessive oil accumulation in the heat exchangers.

Conclusions:
The contractor statements indicate that the auto-purger failure scenario at this facility is a known industry issue, and actions required to prevent this failure are also known. The contractor recognized the leading indicators of a potential failure, and actions could have been taken to repair or replace the equipment at this facility, before failure.

Facilities previous refrigeration contractor

- The previous refrigeration contractor had made recommendations for repairs or maintenance to the senior plant engineer, who would seek approvals from facility management, and issue work orders for approved jobs.
- The facility worked on a tight budget and many of their recommendations were not approved by management, often stating that they did not have the money in their budget for preventative repairs.

Conclusions:
The contractors' statements indicate that recommendations for the refrigeration system had to be approved through the facility management, and many recommendations were not approved citing financial reasons. This may have

contributed to the auto-purger operating in a state of disrepair, which contributed to the incident.

Facility safety specialist

- Facility management had received the refrigeration contractor's recommendation for auto-purger overhaul or replacement 11 weeks prior to the date of this incident
- Follow-up on the refrigeration contractor's recommendation to have the auto-purger overhauled was not planned or actioned by the facility. The recommendation occurred during a period when the Plant Manger had resigned, and an interim Vice President had been managing the operations of the facility. The facility employee assumed that this may have affected planning and actions, from the contractor's recommendation.
- When considering recommendations from a contractor regarding equipment operation, repair, and replacement. Factors include facility spending limits, and the approval for expense process (AFE), for requesting funding over facility spending limits.
- The AFE process over $10,000 typically requires executive approval, which has been seen to take as long as 18 months from submission.
- The facilities budget did not have an item line for scheduled replacement of refrigeration equipment at the facility.
- The refrigeration contractor performed a safety audit of the refrigeration system in 2020. The safety audit included current conditions, and risk levels associated with failures. The auto-purger was included in the site assessment and was not perceived as a risk.

Conclusions:
Recommendations for overhaul or replacement of the auto-purger had not been acted on by the facility management. The decisions to act on the recommendation may have been affected by the absence of the Plant Manager, who duties were being managed by an interim Vice President at the time. The approval for expense process may have delayed requested repairs and maintenance, which increased the risk of a hazardous failure of the auto-purger. The facility did not budget for scheduled proactive replacement of the auto-purger at the end of its lifecycle and work was done reactively when the auto-purger was run to failure. The contractor failed to include predicted risk of the auto-purger failure in the safety audit report.

Documents

Manufactures technical brief

The manufacturer of the auto-purger released a technical brief in 2005. The brief included the following suggested maintenance and lifecycle information, that was not in the original installation and operation manuals:

- Maintenance including cleaning the water bubbler, inspecting and cleaning metering orifices, testing the 30# check valve, pumping down the auto-purger, and removing accumulated oil should be done routinely, which may be monthly, quarterly, or other. (None of this required maintenance had been conducted on the auto-purger in the recent past)
- Annually, the auto-purgers should have their solenoid valves and strainers serviced, check valves replaced as necessary, be leak tested and be verified for proper operation.

- Electronical components in the unit have an expected maximum life of 7-10 years.
- Even with maintenance being performed, the auto-purger should be replaced after 15 to 20 years of service. (The unit at the facility had been in service for over 30 years)

Auto-purger installation and operation manual

The manufacturer installation and operation manual for the auto-purger contains a troubleshooting section, identifying 9 possible causes for the auto-purger to pass ammonia instead of non-condensables to the atmosphere. These reasons are:

1. The foul gas line is not open
2. The purge gas solenoid valve is leaking
3. There is oil in the purger
4. The relief check valve is leaking or stuck open
5. The vent solenoid valve is leaking or stuck open
6. The liquid level control valve is not operational
7. The foul gas solenoid valve is not open
8. A purge point or purge point solenoid is not connected
9. The float switch is not properly installed

Conclusions**:**
The auto-purger has several failure modes that may allow ammonia to be released. Oil was found in the purger, during previous troubleshooting by the refrigeration contractor, for a previous ammonia release from the auto-purger in April.
The refrigeration contractor and facility did not have copies of and were unaware of the manufacturers technical brief identifying suggested maintenance, and lifecycle range of the auto-purger. It is the responsibility of the facility owner to follow equipment manufacturers recommendations for repair and replacement of process equipment. The owner did not follow the equipment manufacturer recommendations and those of qualified refrigeration contractors, to complete necessary repairs or replace the equipment, to prevent a hazardous incident, such as an ammonia release.

Facility site safety audit report

A site safety audit was performed by the refrigeration contractor in 2020, and the report issued in early 2021. The purpose of the audit report is to inform key stakeholders on the condition of the refrigeration plant components, as well as the potential safety risks associated with their failures. The report included recommended timelines for individual component replacements, and high-level budget estimates for capital planning. The audit report failed to recognize the auto-purgers condition, or any hazards associated with its failure.

Training

The injured facility employee received training for awareness of the facilities ammonia exposure control plan (ECP) in 2017, and again in 2019. These plans and procedures include requirements to only investigate ammonia leaks in teams of two authorized workers and to immediately evacuate the area if ammonia concentrations ever exceed 250 ppm. The employee was qualified and authorized to investigate the leak but did so alone as they were the only authorized person scheduled to work on shift at the time of the leak. The employee remained in the room after the ammonia

concentrations exceeded 250 ppm and were observed by the employee as being over 400 ppm and up to 450 ppm. An authorized employee investigating an ammonia leak alone, and remaining in an area exceeding 250 ppm, is contrary to the facilities standard operating procedures.

The refrigeration technician received training on the contractor's health and safety policies and ammonia emergency response procedure in 2018, which include the following requirement: "*Appropriate body protection such as coveralls must be worn to ensure a worker's skin is protected from a harmful substance that may injure the skin on contact or may adversely affect a worker's health if it is absorbed through the skin*" This would include exposure to ammonia. The worker entered the compressor room wearing a short-sleeved t-shirt. The skin of their exposed arms received burns when they were exposed to ammonia.

Site observation

Site and equipment examinations were conducted after the incident. The examination of the as found site, and equipment, found the following:

- The water line shut off valve was in the off position. This would not allow fresh water to flush out the ammonia saturated water from the water bubbler tube.
- The auto-purger was set to continuous bubbling operation. This would not shut off the purge solenoid after 1 hour, allowing continuous leaking of ammonia.
- The auto-purger control knob was missing from the front of the appliance, and only a small, scribed line on the switch shaft, indicated the switches position. The control knob has 18 different set positions, including off, auto, and 16 different positions for manual purge point operation.
- No other electrical disconnect switches were in the vicinity of the unit that would turn the appliance off.
- The top cap for the water bubbler tube was removed and found sitting on the top of the auto-purger cabinet, which allowed the water/ammonia mixture to splash out injuring workers.
- A large amount of scale was found in the bottom of water bubbler and on the outside of drain tube, indicating the bubbler has not been descaled in sometime.

Equipment testing

The auto-purger was tested in place then removed for disassembly and examination. The testing and examination found the following:

- The manual switch that was missing the knob could not be rotated by hand and required a pair of pliers to rotate. It was not evident how to turn the auto-purger off and required tools to do so.
- The check valve on the high-pressure liquid line had a damaged seal that had broken apart upon disassembly, indicating it had not been replaced during routine maintenance in some time, and was possibly not functioning correctly, (Image 8).
- The relief check valve was saturated in oil, and when the valve was disassembled, the oil seal was found to be deformed. This deformation

indicates the seal was not functioning correctly, resulting in high levels of oil accumulating inside the unit, possibly inhibiting the condensing action of the heat exchanger, allowing ammonia vapor to pass through as non-condensables. (Image 9)

- The metering valve taper was worn and had a flat side narrowing considerably, indicating the unit had been in service for an extended amount of time, and the component had not been replaced as a result of routine maintenance or repair. (Image 7).
- A large amount of scale was found in the bottom of water bubbler and on the outside of drain tube, indicating the bubbler has not been descaled in sometime.

Summary

The auto-purger had exceeded the manufactures specified life expectancy by over ten years. There were no records of maintenance or repairs performed on the auto-purger, and the auto-purger was found in a state of disrepair that preceded the date of failure. The auto-purger had not been included in any routine preventative maintenance schedules and there was no budget or schedule for its replacement. The auto-purger was being operated to failure by the facility, and maintenance and repair would only be conducted by the refrigeration contractor upon request of the facility employees.

Evidence suggests excessive oil had been accumulating throughout the refrigeration system. It is likely that oil accumulation in the auto-purger had contributed to it venting ammonia into the mechanical room February 18th, April 1st, and June 16th, 2021, prior to the incident. No actions or plans were taken or developed to overhaul or replace the unit following the first recommendation to do so by the contractor on April 1st, 2021, or the second recommendation on June 19th, 2021.

The day of the incident the water supply to the auto-purger was in the incorrect closed position, which did not allow fresh water to flush ammonia out of the bubbler. The cap that should be installed on the top of the bubbler tube had been removed, so the ammonia saturated water in the tube was able to spray out the top, and onto the workers. The delay relay was set to “continuous bubbling”, so the unit did not stop purging ammonia into the bubbler after one hour.

When the alarm sounded the employee investigated the leak alone because they were the only scheduled authorized worker on shift at the time. The employee did not evacuate the area in the compressor room when the concentrations exceeded 250 ppm. They did not know or had been instructed on how to turn the unit off to stop the purging. The knob for the control switch was missing and there was no other disconnect switch in the vicinity of the unit. The employee received burns on the top of their head because they couldn’t wear a hardhat when wearing their full-face respirator. The refrigeration technician received burns on their arm because they were not wearing long sleeved protective clothing, and had bare skin exposed on their arms.

Management personnel at the facility were made of aware of ammonia leak hazards associated with the auto-purger. They were responsible to take actions to prevent or mitigate equipment failure and failed to do so.

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Causes and contributing factors	The cause of the incident was very likely due to the auto-purger being operated for 30 years, well past its maximum expected lifecycle of 20 years, and routine inspection and maintenance of the auto-purger was not performed at the facility. A contributing factor to this incident was the auto-purger being continually put back into operation without proper identification and repair of the underlying problem. Failure of the employees to follow the ammonia exposure control plan, ammonia emergency response procedure, and health and safety policies, likely contributed to the injuries sustained.

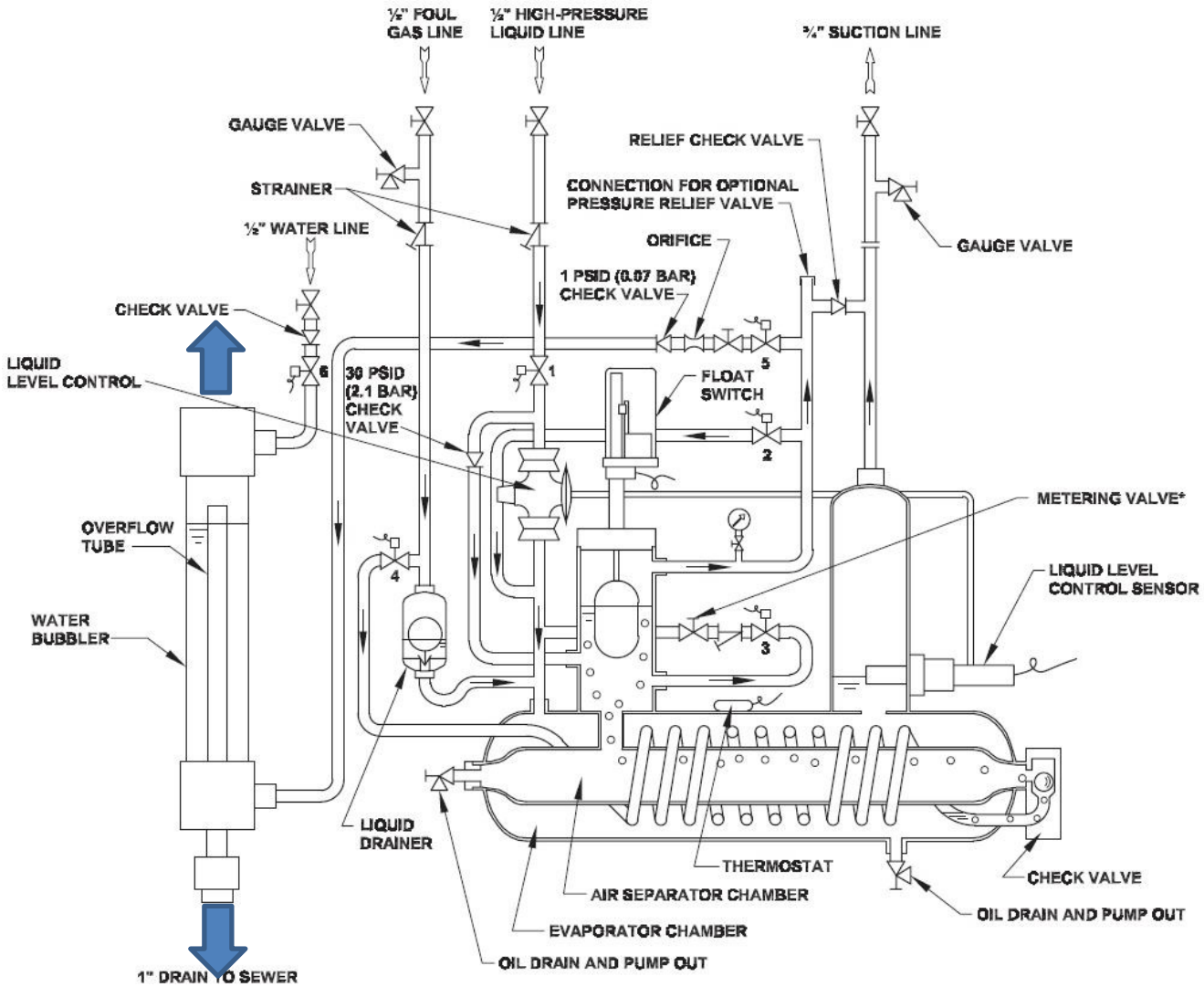

Image 1 – Diagram from auto-purger installation and operation manual showing auto-purger function. Blue arrows indicate locations of ammonia release. *(Manufacturer's installation and operating instructions)*

Image 2 – Auto purger installation in mechanical room.

Image 3 – Blue arrow indicating water bubbler tube. Yellow arrow indicating location the water bubbler tube cap should be installed.

Image 4 – Blue arrow indicating water bubbler tube cap in its found location after the incident.

Image 5 – Auto-purger control switch with missing knob. The end of the switch shaft has a slight scribed line indicating the switches set location. It is horizontal indicating it is in the “Off” location. When tested the shaft could not be turned by hand and required tools to rotate.

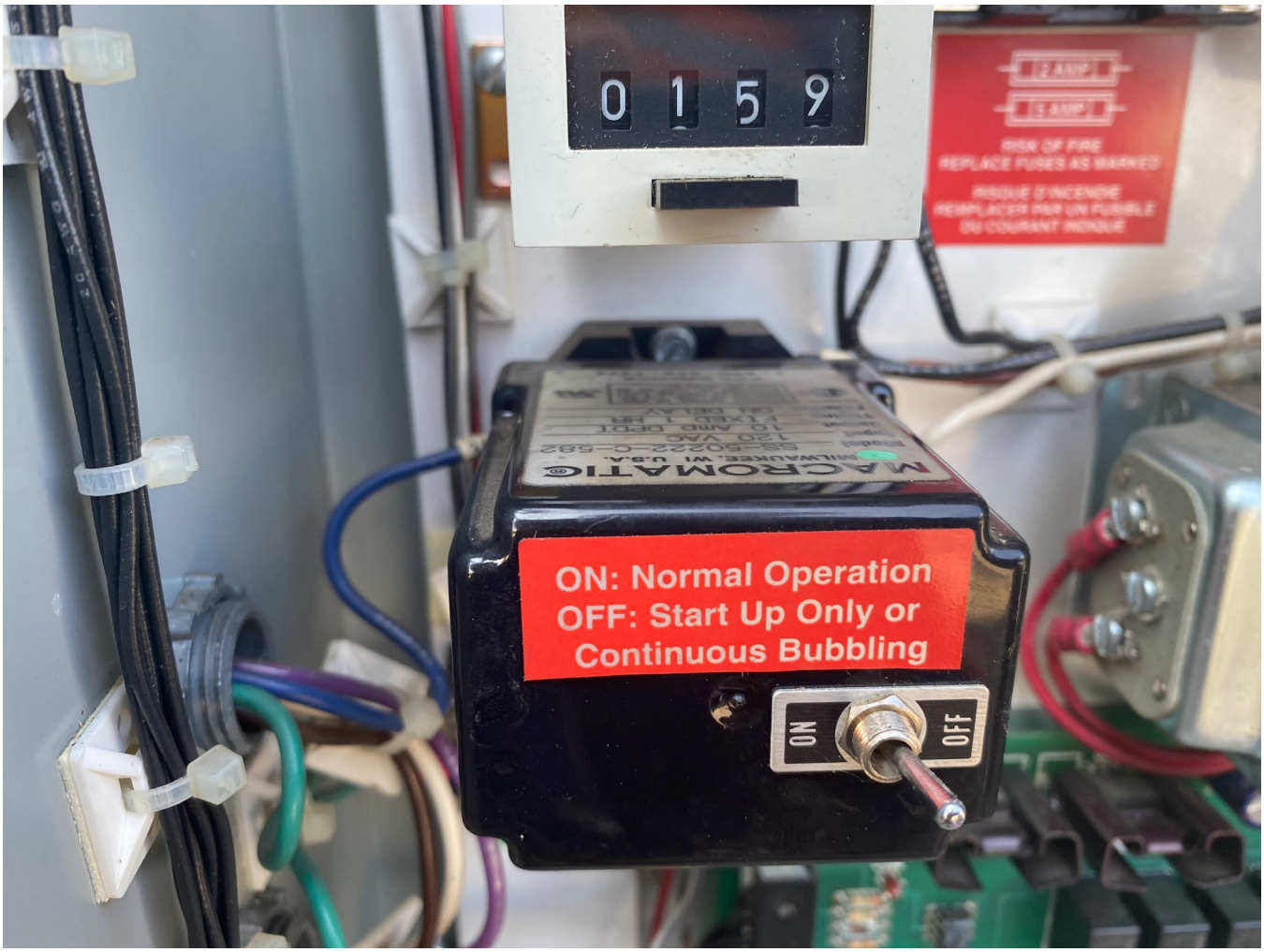

Image 6 – Auto purger time delay relay switch as found in the “Off” setting for startup or continuous bubbling. In this position the auto-purger would not shut the purge solenoid if it purged for longer than 60 minutes. If set to normal operation the purge solenoid would have deactivated after 60 minutes possibly reducing the amount of ammonia released.

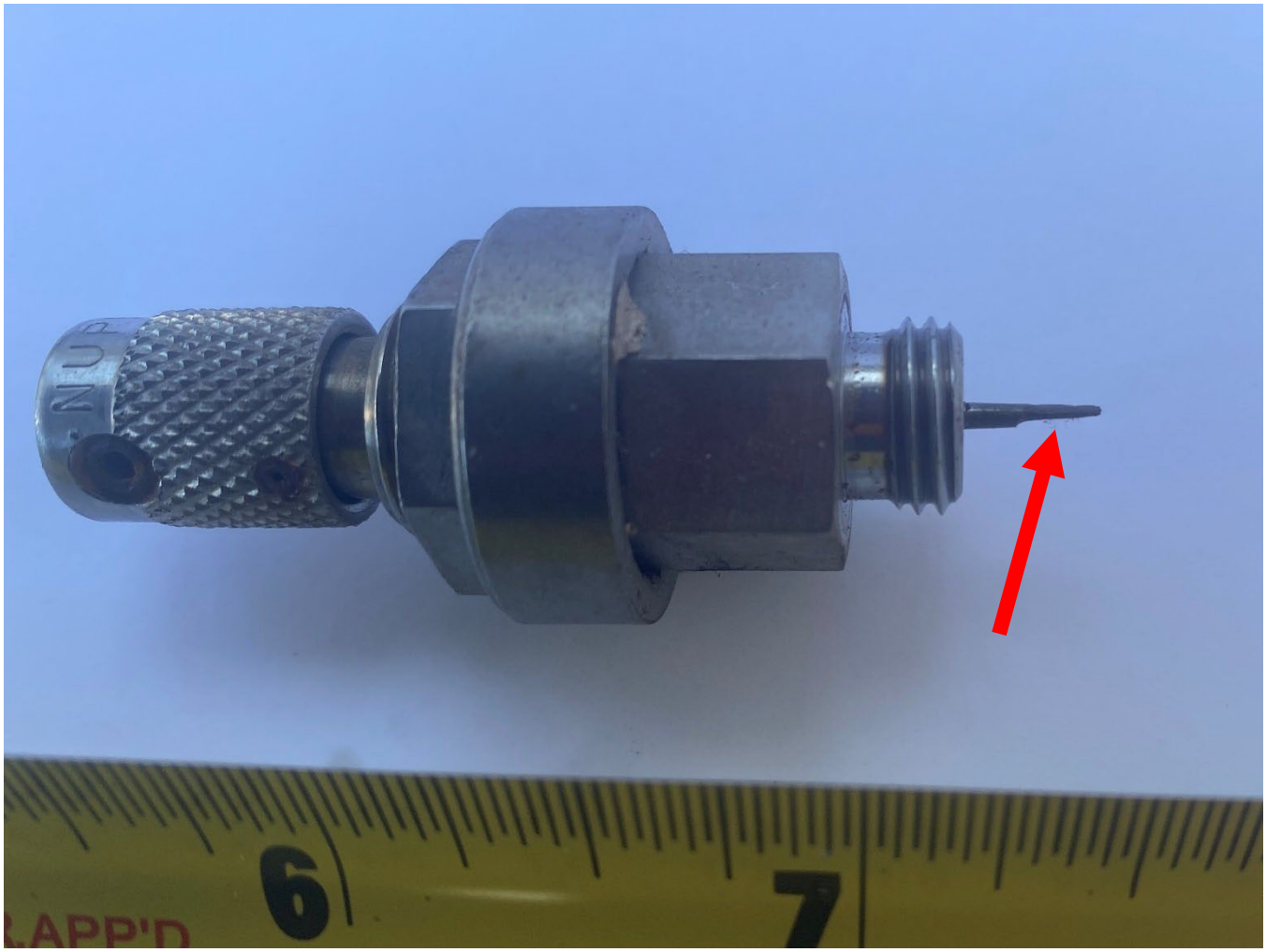

Image 7 – The auto-purger metering needle valve. Red arrow showing worn taper indicating extended time in service.

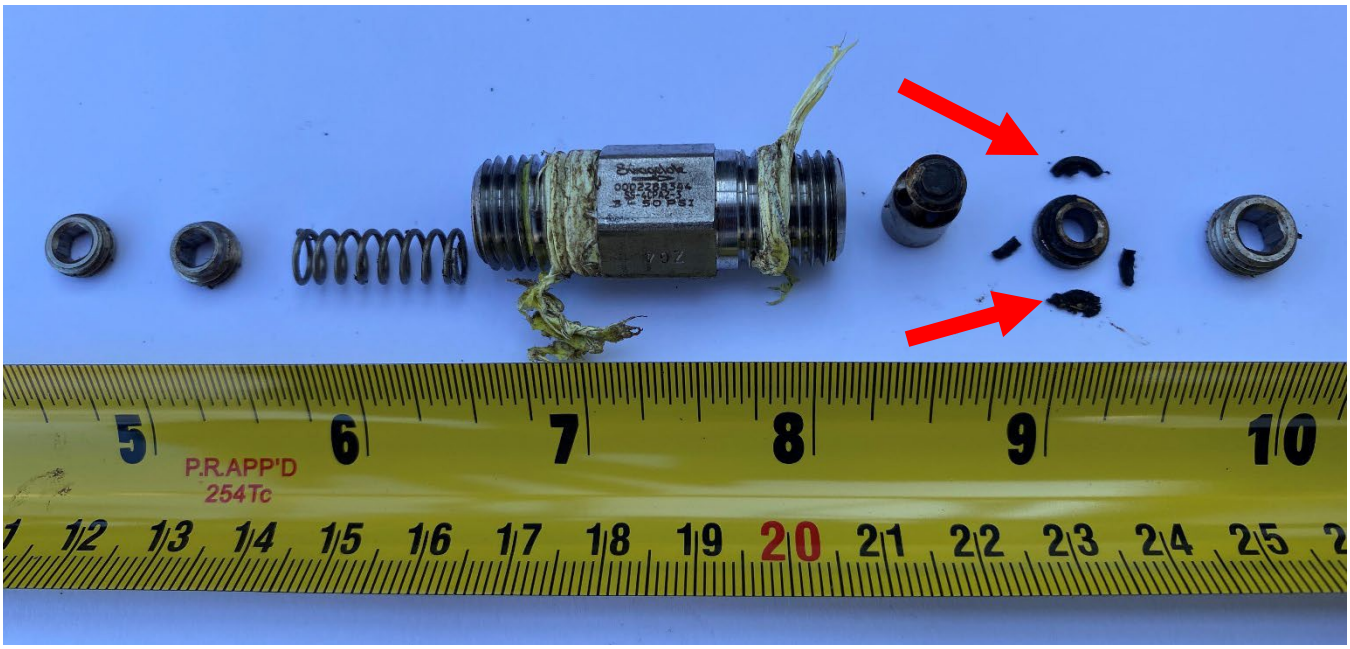

Image 8 – The auto-purger check valve showing damaged valve seal.

Image 9 – The auto-purger relief check valve showing oil saturation of the internal components.