Incident Summary #II-1087124-2020 (#19499) (FINAL)

SUPPORTING INFORMATION	Incident Date			October 17, 2020
	Location			Peace River Region
	Regulated industry sector			Boilers, PV & refrigeration - Refrigeration system
	Impact	Injury	Qty injuries	0
			Injury description	Not Applicable
			Injury rating	None
		Damage	Damage description	Failure of a pressure vessel releasing Freon into a machinery room.
			Damage rating	Major
	Incident rating			Major
	Incident overview			While staff attempted to start a recreational facility's refrigeration plant for their cooling season, an uncontrolled release of Freon filled a machinery room to an extremely high concentration of 1200 Parts Per Million.
INVESTIGATION CONCLUSIONS	Site, system and components			During the cooling season, this recreational facility maintains its ice at sub-zero temperatures by circulating cooled brine throughout a piping system called the brine cycle. The brine cycle (Image 1) is made up of six main components: brine pump, expansion tank, chiller, Normally Open valve, the brine, and the substance to be cooled. At this facility the brine cycle begins at the brine pump, where brine is drawn from the cooling floor piping and is pushed through the chiller supply pipe. As the brine travels through this supply pipe it passes an expansion tank inlet and then enters the chiller. After the brine is cooled the brine leaves the chiller and flows through the cooling floor piping then past the Normally Open valve inlet and back to the brine pump. Brine is a high concentration solution made of salt (NaCl) and water (H_2O) and is cooled at the chiller by the exchange of thermal energy also known as heat. A chiller (Image 2) is a horizontal pressure vessel that is made up of an outer shell, inner tubes, and inner tube sheets. The inner tubes and inner tube sheets form a barrier between Freon gas and the brine. Freon is the common name for a non-flammable low toxicity refrigerant gas that when introduced as a liquid into the chiller boils taking the heat out of the brine. The cooled brine flows through a 6" supply pipe then through multiple 1" pipes. These 1" pipes travel through a large concrete slab and return to another 6" return pipe (Images 11 & 12). This concrete slab is known as the cooling floor where heat is absorbed from water turning the water to ice. Circulation of the brine begins at the brine pump and this facility utilizes a centrifugal pump to move the brine. A Centrifugal Pump (Images 6, 7, & 10) is a mechanical device designed to move a fluid by means of the transfer of rotational energy from one, or more driven rotors called impellers. During normal operation a centrifugal pump can generate oxygen vapor from the rotation of these impellers. This phenomenon is known as Cavitation. Cavitation (Image 8) occurs when a fluid, such as water, undergoes a rapid change of pressure which leads to the formation of small oxygen-filled bubbles in places where pressure is relatively low.

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	The now warmed brine continues through the brine cycle and passes a Normally Open valve inlet to the expansion tank. The purpose of the Normally Open valve is to allow oxygen vapor to leave the brine cycle in the expansion tank which is open to atmosphere inside the mechanical room. The brine which has now given up any oxygen to atmosphere in the expansion tank now returns from the expansion tank back into the brine cycle at the Normally Open valve where the warmed brine is drawn into the brine pump and pushed into the chiller where the cooling process is repeated.
Failure scenario(s)	• During 2017 construction a centrifugal pump was installed having no potential for head pressure. Head pressure is the height of a liquid column that corresponds to earth's gravity. Higher the column the greater the head of pressure. In addition to no potential for head pressure the piping configuration, changes of pipe size from 6" to 1", and many 180˚ pipe turns upstream of the pump contributed to several points of flow restrictions. Due to the flow restrictions and no potential for head pressure upstream of the centrifugal pump. This pump would have experienced cavitation and would have dispersed oxygen downstream of the centrifugal pump. Since the Normally Open valve was installed upstream of the brine pump and not at the highest point of the brine cycle it could not remove oxygen from the chiller. Therefore oxygen accumulated at the highest point of the brine cycle in the chiller. This trapped oxygen increased the rate of corrosion to the chillers inner tubes and over time corrosion thinned the inner tubes to a point of failure. Allowing Freon to escape the chiller through the purge valve (number 22 Image 1) into the machinery room. • Throughout operation and during the non-cooling season the brine cycle piping leaked brine from the 1" threaded connection at the 6" headers and the 1" pipe clamp connections at the180˚ turns. These leaks likely contributed to causing an imbalance in the brines placing the percentage of salt, water, inhibitor, and pH outside the brines control range. Imbalanced brine also would have increased the rate of corrosion to the chillers inner tubes and tube sheet, and over time corrosion thinned the inner tubes to a point of failure. Allowing Freon to escape the chiller through the purge valve (number 22 Image 1) into the machinery room. •
Facts and evidence	• Calcium chloride percentage was reported to be at 20.5%. One percent below the required control range of 21.5% as reported on the Brine Analysis Report. (Image 9). • Parts Per Million(ppm) of Complex Phosphate Inhibitor (cPO4) was reported to be at 6ppm well below the 20 to 30ppm control range required on the Brine Analysis Report (Image 9). • Evidence that cavitation occurred on the impellors of the centrifugal pump in the form of pitted corrosion (Images 8 & 10). • Normally Open valve (number 11 Image 1) is located at the end of the brine circulation, upstream of the brine pump, and not at the highest point of the brine cycle. • Documented evidence supplied by the refrigeration contractor indicates that brine loss had occurred on a number of occasion. Which may have allowed for oxygen to be introduced into the brine cycle. (Images 6,11, & 12) • Refrigeration contractor confirmed that the inner tubes of the chiller had failed allowing Freon to enter the brine side of the chiller.

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	• Staff reported that when opening the chillers purge valve (number 22 Image 1) to relieve the system of oxygen, Freon escaped into the machinery room.
Causes and contributing factors	It is likely that the imbalanced brine solution, episodes of significate loss of brine, and trapped oxygen led to premature corrosion and thinning of the chillers inner tubes. This allowed Freon to enter the brine side of the chiller. So that when staff opened the chillers purge valve (number 22 Image 1) Freon entered the expansion tank and escaped into the machinery room.

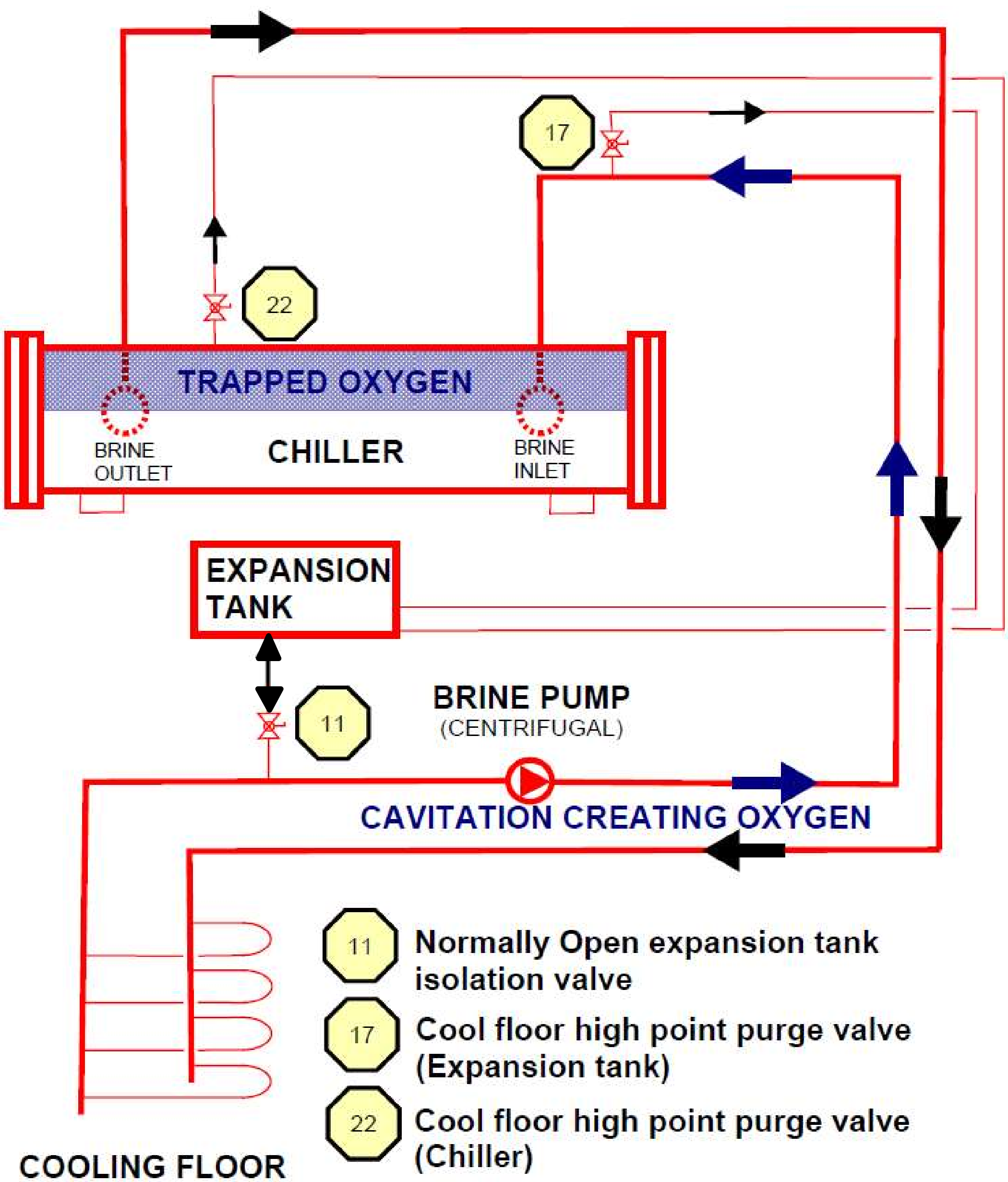

Image 1 **Diagram highlighting brine pump cavitation, trapped oxygen in the Chiller, Normally Open valve, and purge valves.**

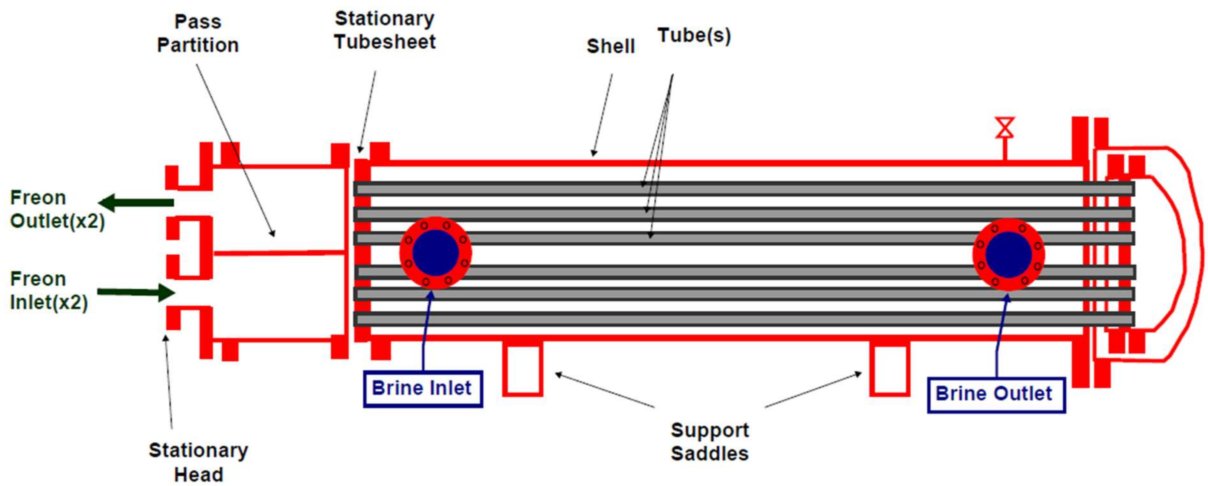

Image 2 **Diagram of existing Chiller.**

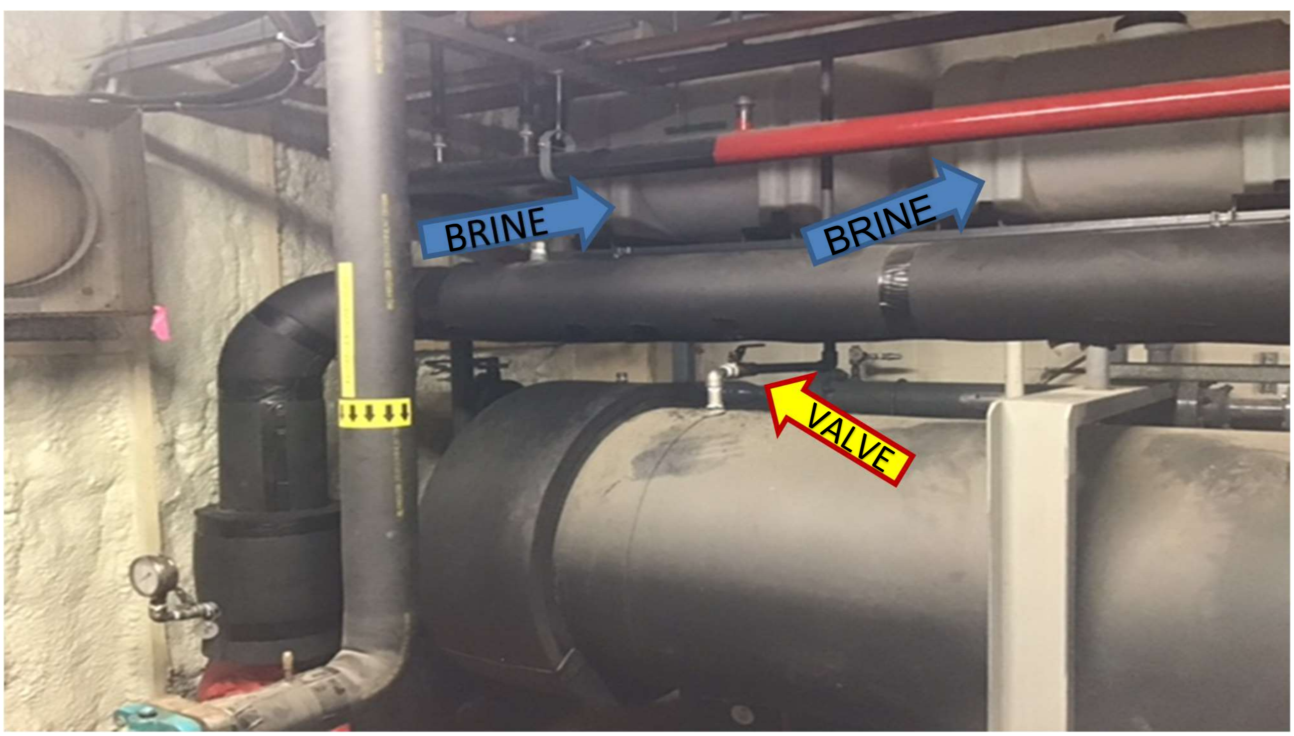

Image 3 **Existing Chiller highlighting location of cool floor high point purge valve item number 22 and brine expansion tanks.**

Image 4 **Item number 22. Cool floor high point purge valve.**

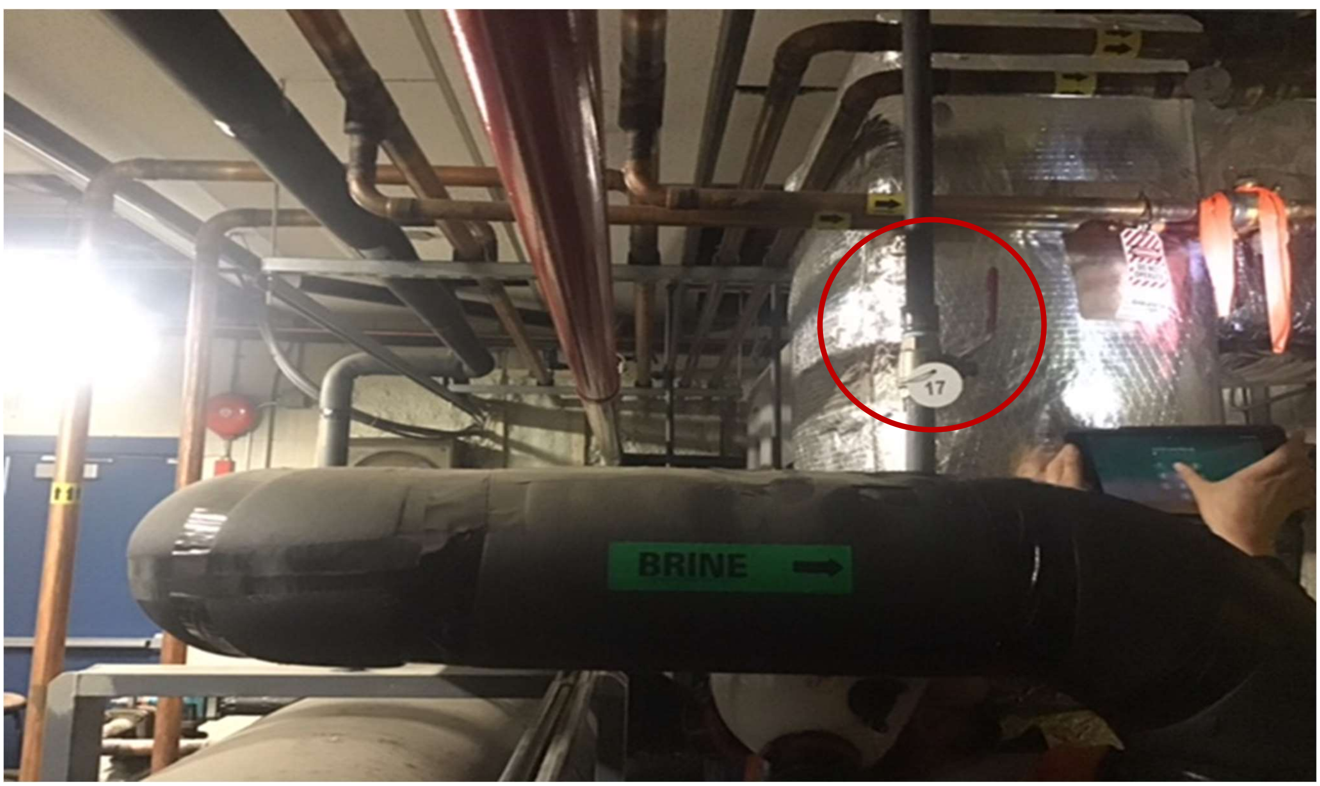

Image 5 **Item number 17. Cool floor high point purge valve.**

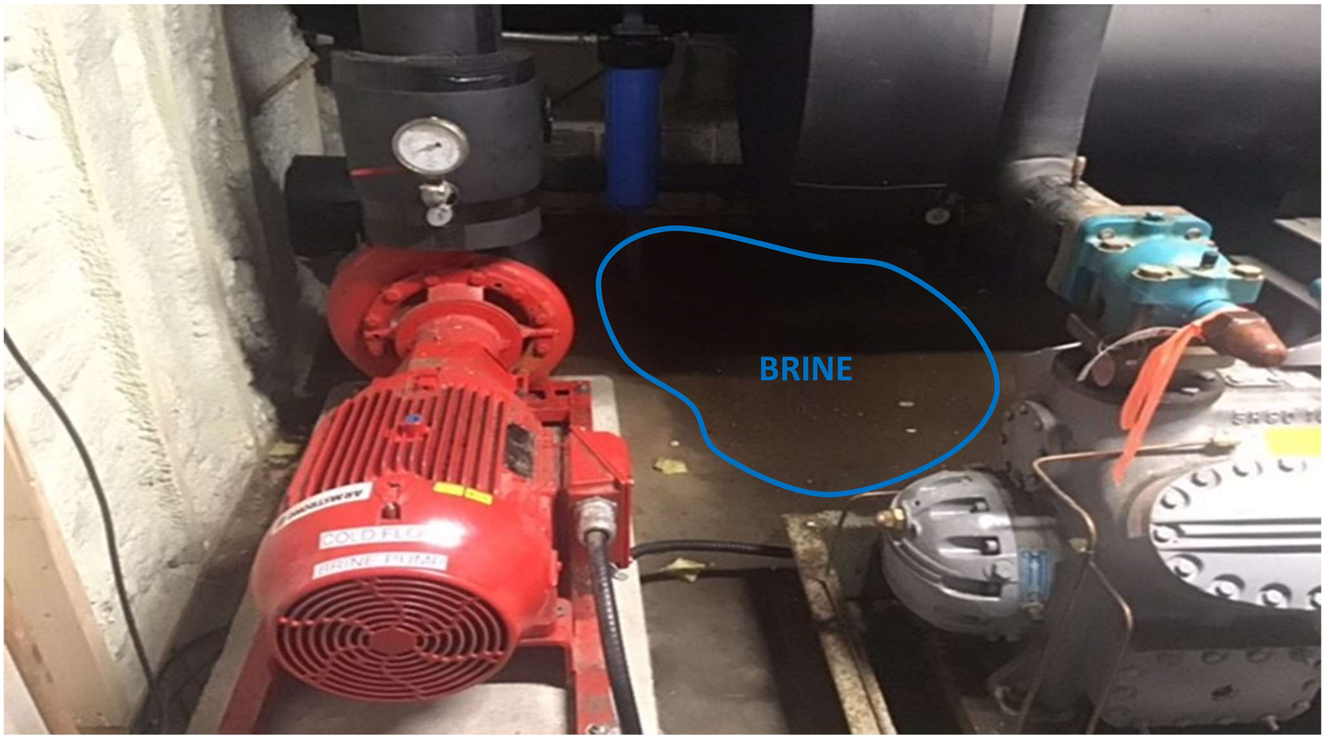

Image 6 **Existing centrifugal pump and pooled brine.**

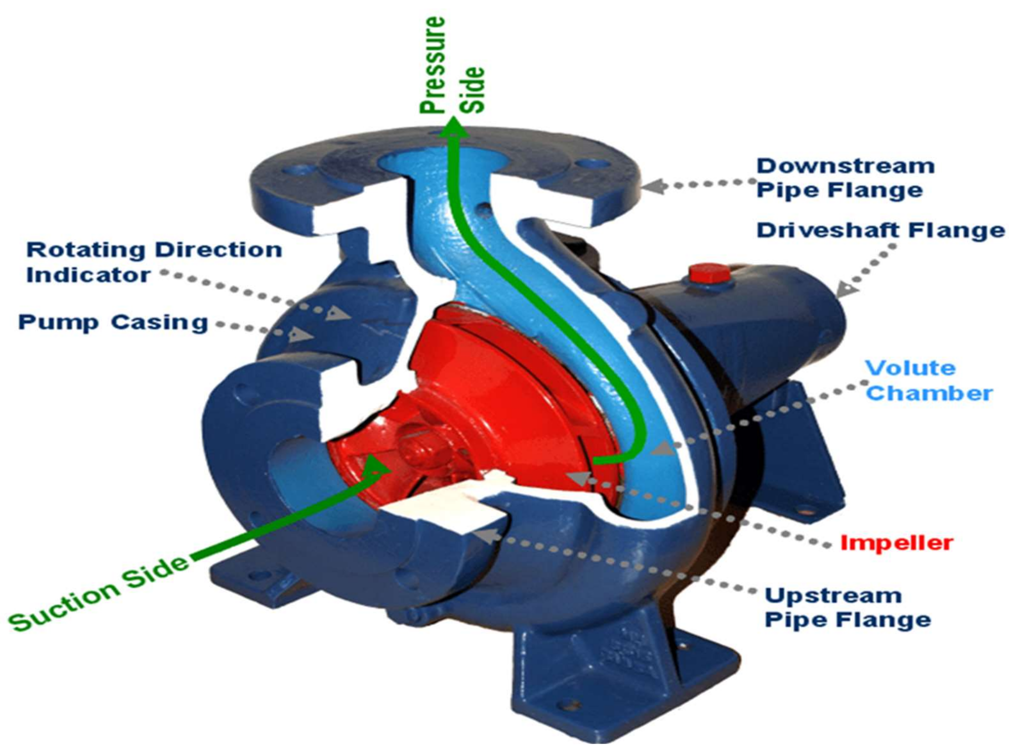

Image 7 **Diagram of Centrifugal Pump Head.**

Centrifugal Pump – Components, Working, Types and Application. *2021, April 20. The Constructor Building ideas.*

https://theconstructor.org/practical-guide/centrifugal-pump-working-types/2917/

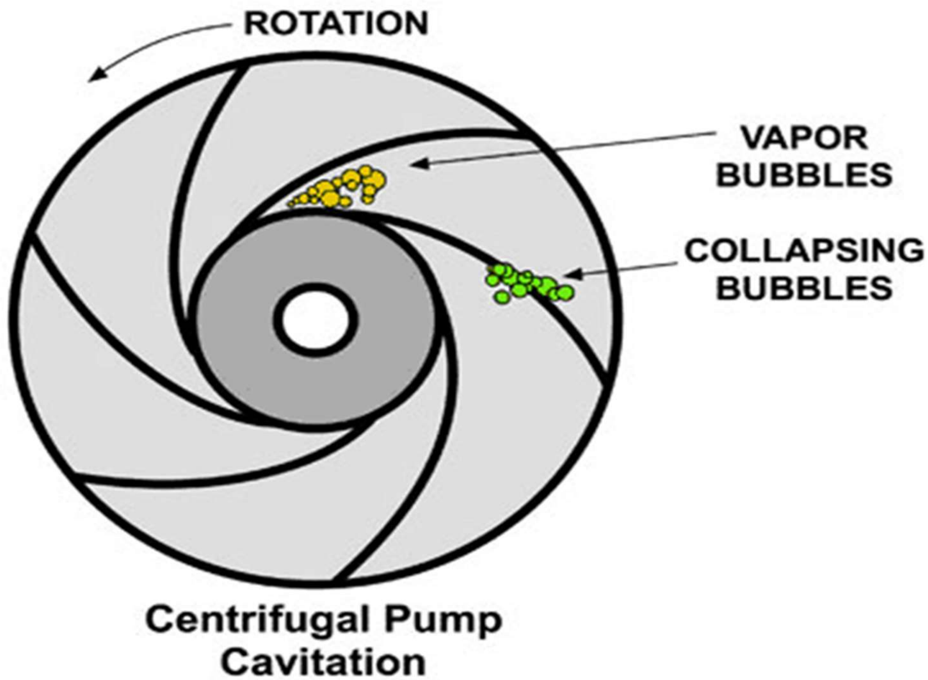

Image 8 **Cavitation Diagram.**

Suction Cavitation. 2021, April 20. Nuclear-power.net.

https://www.nuclear-power.net/nuclear-engineering/fluid-dynamics/centrifugal-pumps/cavitation/

CONSTITUENT	C.F.	Control Range
Sample Date	October 27, 2020	
Appearance	Light Amber/Cloudy	Clean/Clear
Visible Solids	< 30 ppm	< 30 ppm
Specific Gravity	1.19	1.20 Min.
% Calcium Chloride	20.5	21.5% Min
Freezing Point (°C)	-19.00	-5.0 °F or -20.5 °C Min
Visible iron	< 30 ppm	< 30 ppm
Complex Phosphate Inhibitor (cPO_4)	6 ppm	20/30ppm $cP0_4$ at 1.2% Z-5750
pH	9.36	8.50 to 9.50
Dissolved iron	< 10 ppm	< 10 ppm
Ammonia	0 ppm	0 ppm

FINDINGS & RECOMMENDATIONS

Cooling Floor:

pH is good at 9.36.
Visible solids are good at < 30 ppm.
cPO_4 is low at 6 ppm.
Add 10 L of Z-5750 per 1000 L of brine in order to increase cPO_4 concentration to 20/30 ppm.

Image 9 **Brine Analysis Report.**

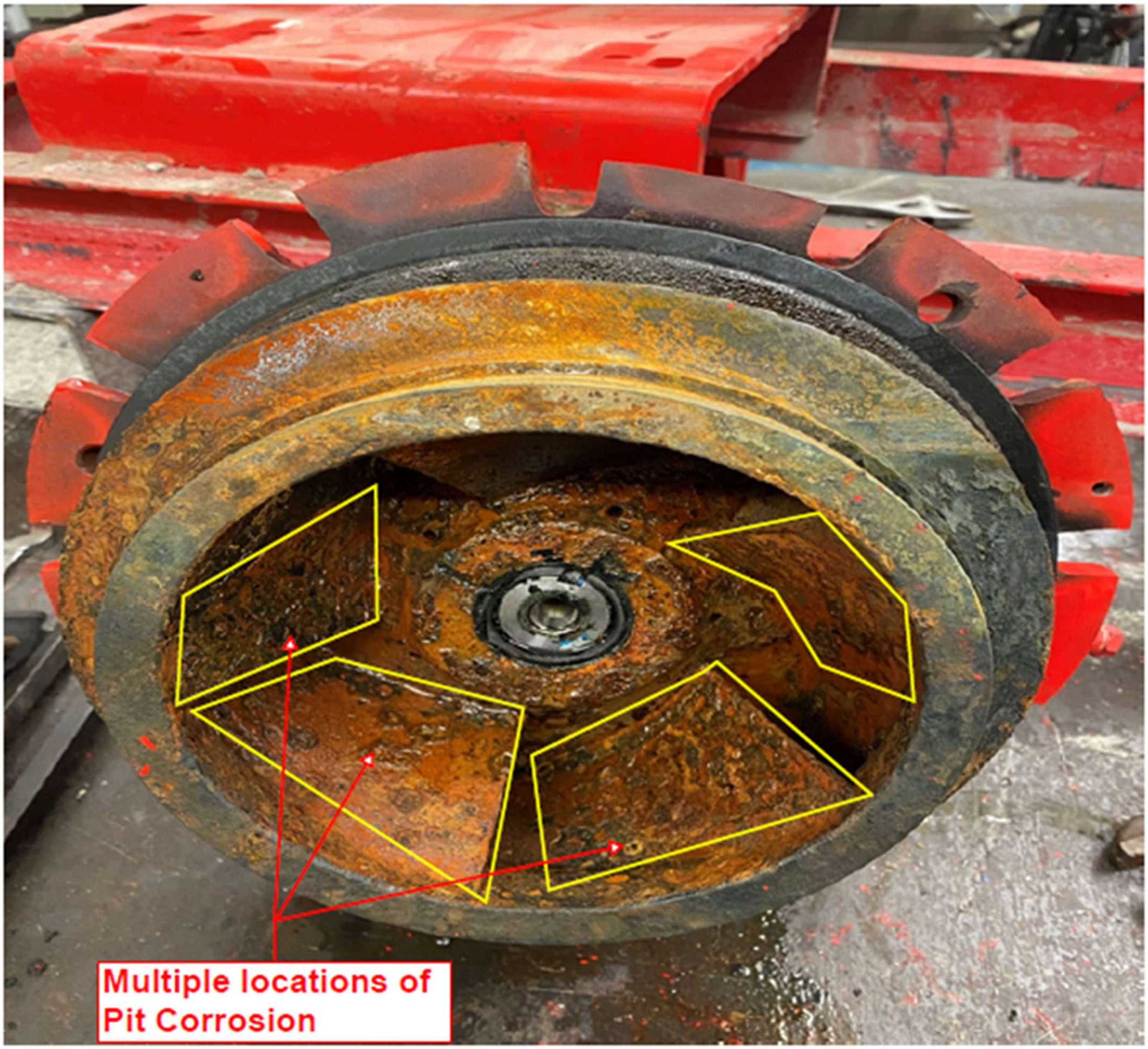

Image 10 **Pitted corrosion on existing brine pump impeller.**

Image 11 **Brine leaks off Brine Cycle at 1” 180˚ turns of ice sheet.**

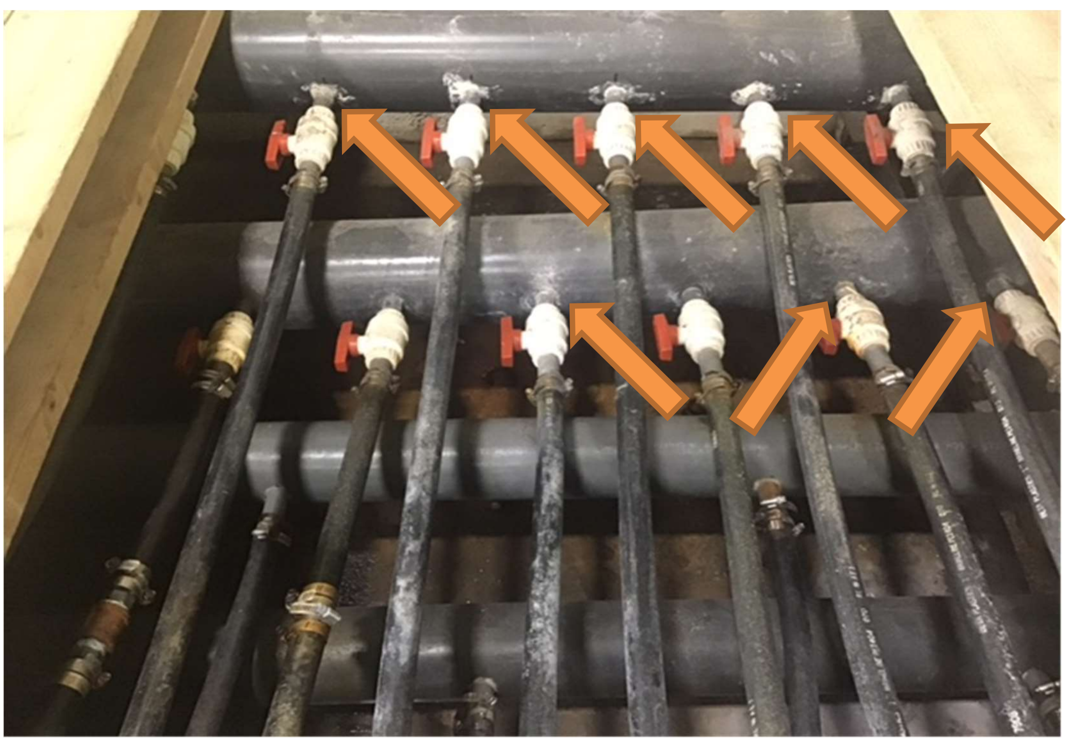

Image 12 **Brine leaks off Brine Cycle at 1” outlets off 6” supply and return piping**