

## Catastrophic water contamination of a Marine based Ammonia Refrigeration system

My first visit to the plant room was something extraordinarily special, the noise was like a microwave full of spoons. It was so abrasive it forced me to wear ear plugs beneath my grade five + hearing protection, If I had of heard the compressors running anywhere else, I would be diving at the emergency stop but knowing that there was no redundancy and almost four million New Zealand dollars' worth of Skip Jack Tuna on board, I slowly backed out of the plant room like I had mistakenly walked into a gang headquarters with the wrong colours. Immediately I requested some jars for oil sampling, after noticing layers of separation and 'chunks' of what I could only presume were crystals in the oil separator sight glass of Compressor number 3.



To my amazement, a strange pink ooze was sampled from compressor three, Number one was thin and cloudy and number two was thick and black. It was clear to say that these compressors would not spin for much longer. I had experienced water contamination many times before but this was unreal. Having just landed in American Samoa less than an hour earlier I was still trying to get acclimatise to the place, let alone the heat of the situation I was in.



My last visit to Pago Pago was almost 10 years earlier, not a lot had changed except that a recent tsunami had demolished a few buildings, but to be honest if you ever have the luck of visiting this special place, you wouldn't know if Godzilla & Mothra had smashed the place to pieces in the middle of the night.

Stunning Pago Pago hooks inside the mouth of a volcano and is home to most of the Pacific's deep sea Tuna fleet. It's a bustling vibrant village nestled amongst a beautiful landscape and beneath the picturesque and appropriately named 'Mount Lava'.

My company had been contacted a couple of days before by a fishing company in distress and from first reports they had been struggling to maintain temperatures. There was also a suspicion of water ingress.

From the lubricant samples I examined. I swiftly advised the Captain to make plans to transfer the product before they lost it all due to fatal compressor failure. At this point in time it was not even an option to change oil, as there was none.

I then went to work to make the best of a dire situation... The system consisted of three Sabroe 128 compressors running in a single stage economised configuration. They were running a primary sea water, secondary circuit fresh water oil coolers as well as HLI liquid injection via Danfoss TEAT valves. The static evaporators were fed by both hand regulation and what they called Automatics (thermal expansion valves) the network of Ammonia pipework had been installed to provide as much redundancy as possible.



Therefore, there were cross overs and three of everything with the exception of the discharge header. Having worked on many Purse Seine vessels previously I knew my way around fishing vessel, however to save time I asked the 2<sup>nd</sup> engineer for a drawing. This was the only drawing until it was updated to a more conventional Process & Instrument Drawing in 2011

The drawing which is now framed on my book shelf looked as though it had been put together by the crew an hour after they had consumed a bowl of peyote each. Once I had stopped giggling, I gazed around the Machinery control room (MCR) which was centrally positioned looking out above the main engine and axillary generators. In the corner of my eye I noticed an Ammonia water sampling beaker.

I proceeded to sample Ammonia from the LP accumulator number two. After draining approximately 20 litres of what could only be described as diarrhoea flavoured ice cream. 50 ml of Ammonia was drawn, a final result of 30 ml of highly contaminated Ammonium hydroxide ( $\text{NH}_4+\text{OH}$ ). This system contained a serious amount of water along with a bunch of other nasties. This had no doubt confirmed the water ingress.



There was no easy way to explain the situation to the vessel manager apart from the system was in a tragic state. Admittedly I used some more descriptively blunt language at the time after the technical terminology was lost in translation.

As Ammonia forms a compound with water there is no way to dry it without distillation. Danfoss invested in a great deal of research to manufacture a specialised drier core with no real results. This is due to the vapour pressure of water being beneath the corresponding refrigerant evaporating temperature provides no way to move the water from the low pressure accumulator.

The work that needed to be completed to revive the system would be highly difficult in Pago Pago due to both staffing engineers as well as sourcing and transporting equipment. All this aside the vessel required three more days' operation before it was allocated an unloading berth across the bay.

I did not believe that the compressors would last the night judging by the violent cacophony of spoon noise. However, myself and the rag tag bunch of assistants began to make improvements to prolong the inevitable.



On inspection of the UNISAB controllers I had identified that the oil pressure cut outs had all been re-calibrated to bypass oil failure. I changed the filters one by one and found each severely blocked with the same ice cream as previously mentioned.

That being said the compressors were still trucking on which is a testament to Danish engineering. Compressor two current draw was noticeably lower than that of the other two. I identified that the capacity slide was seized. We shut her down and firstly inspected the suction strainer. Astonishingly we removed multiple salt crystals the size of a Softballs. Unfortunately, I was unable to take an image as I was under the pump and covered in ice-cream, needless to say I don't think I will see this again.

We removed the capacity slide and it was in deed stuck. We polished it up the best we could and got her running under full load.

By this stage I had been working for almost 26 hours so it was time to call it a day.

On arrival to the vessel the following morning, I found one compressor had destroyed itself and by 10 am a second had failed indefinitely. Finally, aware that I wasn't just being a sensationalist the company managed to organise the offload of their product that afternoon.



**Soiled Oil filter**



The following few days I began making plans and procedures for the purification of the system in which they still insisted took place in Pago Pago. This was going to be impossible to resource so I returned home. As the Ammonia was beyond saving, 3500 kg of now contaminated Ammonia / Ammonium hydroxide mix was released to atmosphere at sea. Something I wish I was able to witness but at the same time did not want to be associated with.

In the following weeks we received a large wooden box full to the hilt of corroded and highly damaged compressor parts in which we were asked to overhaul.



Between three of us it took over a week to clean before we could even begin assessing the damage.

The compressors were no longer available from the manufacturer so we made one machine out of three compressors and sourced the other two from abroad.

Myself and another technician returned a few weeks later to re-commission the system, to our surprise nothing had been completed as per my detailed instructions since my last visit. So we were forced to start from scratch as well as make do with what we could on the island. The system was empty and nothing had been done to purify it in any shape or form. There was a dead line of twelve days so we made some plans in haste.

There are no published Ammonia contamination case studies available which is one of my drivers to write this informative and hopefully entertaining document, we really had little choice but to experiment, having past successful purification experience with fishing vessels, I had cleaned the systems rightfully or wrongfully with evaporative solvents, not having this luxury we had to manufacture a make shift purification system.



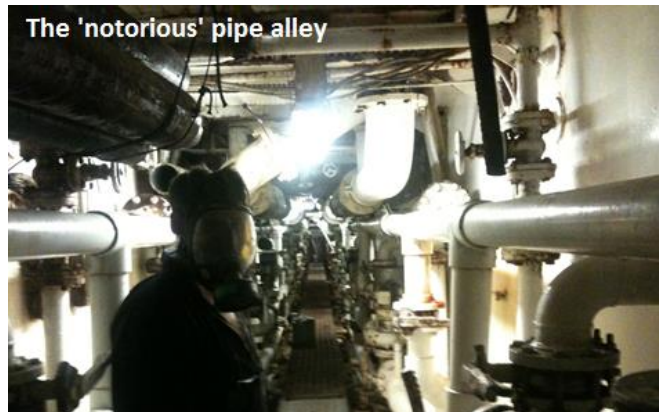
There was nothing that would even possibly resemble what I pictured in my mind available in Pago Pago, so using the curtains from the crew's accommodation held across the top of a 200L drum with rope to act as a solids filter.

The low side of the system consisted of nineteen fish wells, all supplied by manually regulated dry expansion static coils. Each Fish well had dual circuit and valve stations mounted within a Pipe alley or the appropriately named two story 60m x 2m alley of "death" situated below the water line.

We broke each line and had tee pieces and ball valves installed so that we could safely circulate the cleaning medium as well as drain the circuits as low as possible given that they were still situated a number of meters below this.

We quite ingeniously circulated each well with degreaser that was stocked on board to wash the engine room floor. With a few curtain changes, all the sludge and solids were removed. We then flushed each circuit with fresh water until it was running clear. If I was to come across this situation I would use the same procedure except for the curtains. Evaporative solvents are carcinogenic and respiratory irritants.

By this stage the ship was not the most pleasant place to be, the Air conditioning and Provisions was of course supplied by the main plant which was going to be in disrepair for an untold length of time. The crew with nowhere else to reside and on a minimum daily allowance, and with now having no curtains to hide from the sun were getting rather hot, bored and consequently, drunk and agitated. In one instance the chef received a stab wound to the stomach by one of the crew, from the translation I received it was for repeatedly serving potatoes for lunch.



The 'notorious' pipe alley



Quality of welding



Inside fish well

Apart from the now wounded Chef, we were the only ones working and for two hairy chested descendants from temperate climates, we were going through episodes of depression and anger ourselves. I remember at one stage being in the MCR and measuring the ambient temperature at 51°C.

I was approached by someone asking when the system was going to be operational, with just the expression of rage he walked away without a reply on my behalf. Luckily we managed to be in a perfect emotional cycle, where when one of us was down ready to quit or throwing things in a rampage when the Teflon tape tangled, the other was right there to pull each other through.

We eventually managed to find solace by pouring iced water on our heads and after going through four to five t-shirts a day we eventually ended up wearing shorts and rags on our head. Luckily no pictures exist.

The next step was to remove as much water as possible, ideally dry nitrogen would have been more suitable however we pressurized the circuits and pipework using the ships two stage compressed air system to nine bar. Using the ball valves we proceeded to rapidly vent each low point until minimal water vapour was present and when I mean minimal I mean it was still mighty wet but it was the best we were going to get. Having no vacuum pump or dry nitrogen, the ships fire pump and wet deck bilge venturi was the next best thing. Although we were not going to be reaching the triple point and removing a large degree of moisture, it was 45°C and we were able to reach a -80kpa vacuum at best so there was going to be some evaporation of moisture occurring.

Whilst the rest of the system was evacuating we took the opportunity to remove the Coalescors, noticeably there was a few issues.



The system was very dilapidated and dangerous, there were no Ammonia detection systems and the ventilation may as well have been an elephant swinging a banana leaf with its trunk. I decided to walk away again at this stage and leave the duty of care & system re-commissioning to the newly appointed chief engineer. Of course this did not go down too well with the ships management but we are lucky to have had the H&S act of 1992 to defend our rights to a safe workplace.



Again I left a step by step procedure with the vessel. This primarily consisted of regular oil changes and Ammonia purification as many times as possible until it was clear. The vessel was lucky enough to have an intermediate pressure plate heat exchanger which was dedicated to the Accommodation air conditioning system. We decided to utilise this as the purifier.

A purifying cycle was simply completed by isolating the liquid Ammonia supply and allowing to pump out the then draining off any contaminants.



The crew were instructed on the procedure & off they steamed into the sunset.

I received the first report on the 10/06/2010

4 Litres were removed 3 times a day for the first 3 days. Then 3 litres twice per day for the following two then to 1.5 twice a day until the 20<sup>th</sup> of the month in which it had reduced to 500ml. This continued until the 11/11/ 2010 until only <100 ml was being rectified from the PHE. Totalling approximately 200L

As expected the vessel continued to destroy the obsolete compressors. Maintaining a spare on rotation, I think from memory there was ten or so rebuilds that year so needless to say we become quite proficient at both removing them & overhauling.

The ship was luckily enough to fish most of the season, band-aiding the foreseeable issues as the came about. Un-surprising, the schedule of intrusive maintenance which was put forth was not followed once they had the ability to operate. Something not uncommon in our New Zealand based production facilities.

The vessel eventually returned to Port for some much needed special attention. The first thing I noticed on arrival was the Oil pressure safeties were bypassed yet again!





It was decided that the ship must be turned around in six weeks. As the bandages were removed on all assets, one by one, the more 'gangrene' was discovered and this "quick" repair visit turned into a full retrofit lasting the better half of a year involving hundreds of contractors. This project was truly massive!

Apart from all the corrosion repairs, purification was the at top of the priority list. The most challenging task, was working in such close proximity to the public being Auckland Viaduct. Looking back now with my accumulated Health & Safety experience, in hindsight our company should have engaged an independent consultant. Needless to say we made sure that all Ammonia transfers were completed with the wind direction in our favour & safe work method statements & Risk assessments were completed regularly. It ended up taking weeks to finally ventilate the Ammonia to a point where we could open the system beyond the point of no return.

Every asset was overhauled on-board so we were constantly waiting & working around other contractors. Something I was used to having completed five other retrofits but frustrating all the same. We were able to make a good hit on the engine room early on which is what I found the most interesting The sludge! I have never experienced so much. It was un imaginable & eventually became laughable. All low points were drained and every valve and component were overhauled.



Extra filters were fitted to the compressors and eventually the liquid line was provided with an ancillary commissioning filter. Every filter was additionally fitted with magnets for removal of any ferrous material.

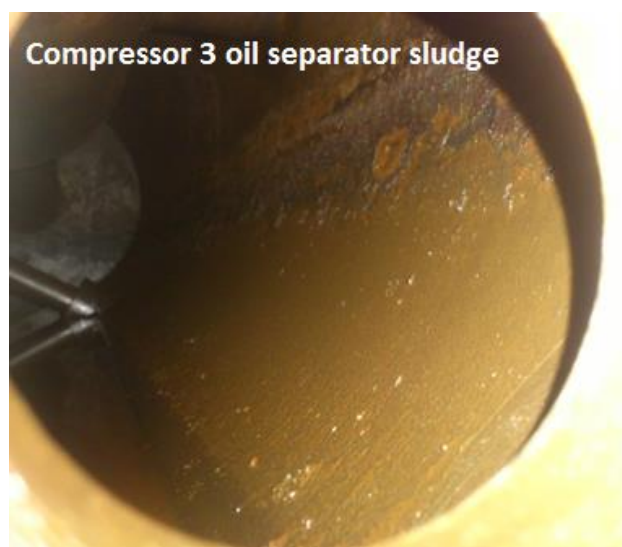
The Oil separators were probably the most challenging, the images do not provide the scale of the contamination with enough justice, the thick layer on the wall of the vessel reasssembled that of a septic tank. Not only were we tasked with inventively cleaning them we were only able to access them through a 2" port.



I commenced the experimentation firstly with solvents with very little success, without agitation, it was hopeless. I tried to mop it as best as possible with a rag on a stick, envisioning that Friends episode where Ross massages a big sweaty guy in a similar fashion.

I manufactured a purification set using a pneumatic pump and a 10-micron filter and had a second attempt, there was an improvement but nothing to rave about. I took a sample to a chemical engineer who suggested Sulphatic acid. This next level approach worked a treat! A little too well, the sludge was gone, but it was causing oxidation on everything above the tideline, fearful of causing further damage I used oil for the remainder of Compressor three with the aid of removing any contaminants as well as providing the wall of the vessel some much needed lubrication.

I successfully utilised sodium hypochlorite degreaser on Compressor two, this performed well and since it was not volatile or so corrosive it was much more user friendly.





Compressor one, I thought it would be worth the opportunity to trial just the oil, mainly to prove a chief engineer wrong.

After 96,000m<sup>3</sup> of Dry nitrogen & endless serious of leak repairs. We commenced evacuation, the best we were able to achieve & maintain with a newly imposed deadline was an 8,000-micron vacuum. In the Marine industry refrigeration is always the first on & last to leave. Although apprehensive the charging of 3,000 kg of Ammonia went without a hitch. So we were ready to fire her up.

Compressor three was started first as sacrificial anode. It was in the worst condition & after less than an hour clocked the oil filter differential on the very expensive Sabroe filter was clogged. We immediately performed an oil change and changed filters as well switched over to the washable Mycom filter

oil & filter log

DATE.	Comp 1.	Comp 2.	Comp 3.	ACRP.
1/10/12.	SAB 6 hrs.	SAB filter 1hr.	GOL. 2hrs.	200ml.
↓	GOL 8 hrs.	GOL. 1 hrs.	SAB filter 1 hrs	3 L.
↓	SAB 8 hrs.	SAB 4 hrs.	SAB 4 hrs.	4 L.
↓	MYC 8 hrs.	SAB. 11 hrs.	GOL 6 hrs.	6 L.
	SAB 13 hrs.	MYC 89 hrs	SAB 11 hrs.	1 L
	SAB 22 hrs.	GOL 89 hrs	MYC 16 hrs.	2 L
	MYC 38 hrs		GOL 16 hrs.	< 1 L.
	MYC 105 hrs		GOL 19 hrs.	2 L.
	GOL 105 hrs		SAB. 22 hrs	
	MYC 162 hrs		MYC. 98 hrs	

As you can see from the oil filter log, the degreaser/ oil purification was a good solution. Compressor three eventually improved to be the best method of cleaning but required further oil changes to get to that point. Compressor one continued to require oil & filter changes until it improved.

At around 100 hours we removed all the commissioning filters, which were all pretty badly soiled. The liquid line was inspected a further 100 hours later however produced no visual contaminants. This fact alone is why when I commission a land based system & find excessive foreign material I tend to question the quality & care of the installation. If a filthy catastrophically failed system can be cleaned with degreaser & stripped back to bare bones & produce these results, there is no viable reason to have any level of contaminants in a new installation.



During the retrofit we installed an oil rectifier in common circuit with each of the three accumulators. This system was DX, but on occasion when run by a Muppet it would flood back heavily. So where we were to remove waste oil & water we flooded back in a controlled manor.

We also removed Ammonium Hydroxide from the dedicated Ammonia Oil Rectifier Purifier (AORP) totalling nineteen litres until hand over to the vessel engineers.

The is really about all I need to harp on about this, I could carry on with more tales but it would be less about contamination & more about the mad life of deep sea fishing. The crucial elements are all there;

- Don't put water in a refrigeration system.
- Listen to your service provider's instructions.
- You don't have to buy a special branded purifier if you have spare evaporators.
- If the oil is that dirty you have to change the oil filter twice...Change the oil.
- Degreaser works as an excellent cleaner (Confirm suitability & no ammonia present)
- Ensure you have a stringent asset management system to avoid this all occurring.

I was luckily enough to be invited to train the new chief engineer on how to operate the system. Which was brilliant I have always wanted to see a Purse Seine vessel in full swing. The system was mostly all manually controlled therefore, on pull down of 100 ton of tuna was jagged we were ritualistically adjusting hand expansion valves & monitoring the system up to 22 hours a day. These days the system has been fitted with Electronic expansion valves which worked brilliantly at first but since little maintenance has been performed it has suffered further contamination numerous times. It is however still fishing to this day with the same compressors clattering away.





I have been wanting to get this story out of my head for some time and admittedly not being a literary or engineering genius it has taken a bit of effort. But if this can give someone a bit of insight to what can go wrong what to do as well as make a few people laugh it is worth every penny so to speak.

This project was truly massive, something no one could of predicted. It's absolutely imperative that I acknowledge the boys, they were nothing short of amazing for all of their dedication & effort. The repeated shift work and late nights away from loved ones & remaining motivated & positively supportive every step of the way in one of the most hazardous & harshest workplaces around.

This little story is dedicated to; Dave Wilson, Imre Ujfalusi, Matthew Watson, Brendon Murray, Mitch Young. Boomba, Fillip Skoljarev, Jack Burgess, Tim Clubb & Ralph Mc Torres.

Special thanks; if you ever read this, a thousand apologies to my beautiful daughter Novah for not being there for you during this job. I will never work this hard on a smelly fishing boat ever again I swear.

This work provided me with some unforgettable memories & learning curves. Meeting interesting characters' witnessing stunning sunsets, being out on the ocean without land in sight, dolphins in the morning, wrestling sharks where they shouldn't be, helicopter rides, eating the freshest Albacore & being paid for the experience all the way

If anyone ever needs any assistance on this subject I would be happy to provide you answers from my experience in greater detail. please feel free to drop me a line [paddy@ammonia.co.nz](mailto:paddy@ammonia.co.nz)

Thanks for reading ☺

