



E9207 aircooler leak learnings

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E9207 aircooler leak

- Root Cause Analysis
- HCU ACHE data and Bukom experience
- Inspection Guidelines
- Discipline Asset Strategy- MMI on ACHE

Root Cause Analysis



E9207 aircooler overview



Fig. 12: Tube fins
Almost fins were slightly deformed at top side.

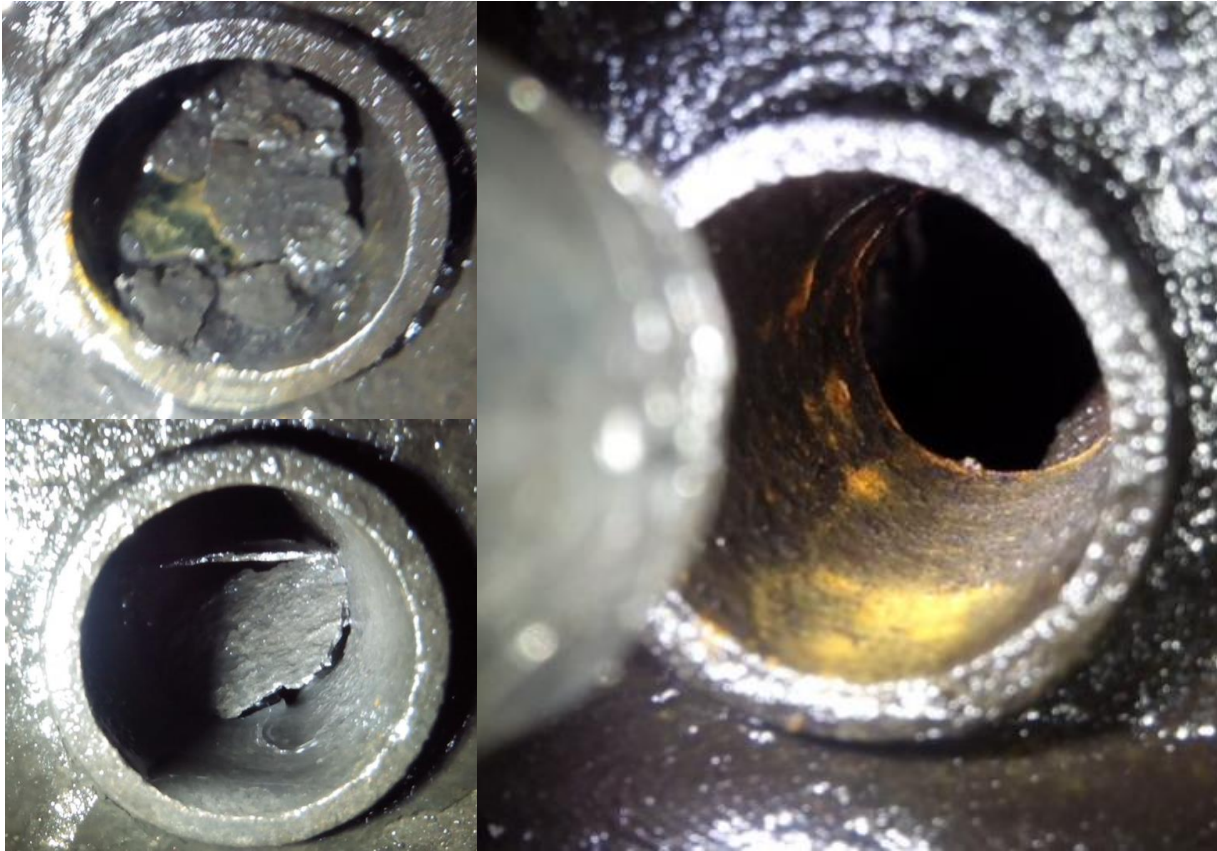
- Top row finned tube bowing
- Suspected there since 2008
- Damaged finned tubes will be hotter causing more tubes expansion



- Service: Mild Vacuum Column MCR (Kerosene)
- Temperatures, Inlet: 150-180degC / Outlet: 50-150degC
- Pressure: 3.5 barg

E9207 tubes condition

- Tubes internal found with internal deposits and scales
- Observed one tube completely sheared off



E9207 aircooler first look

1st Row



2nd Row



3rd Row



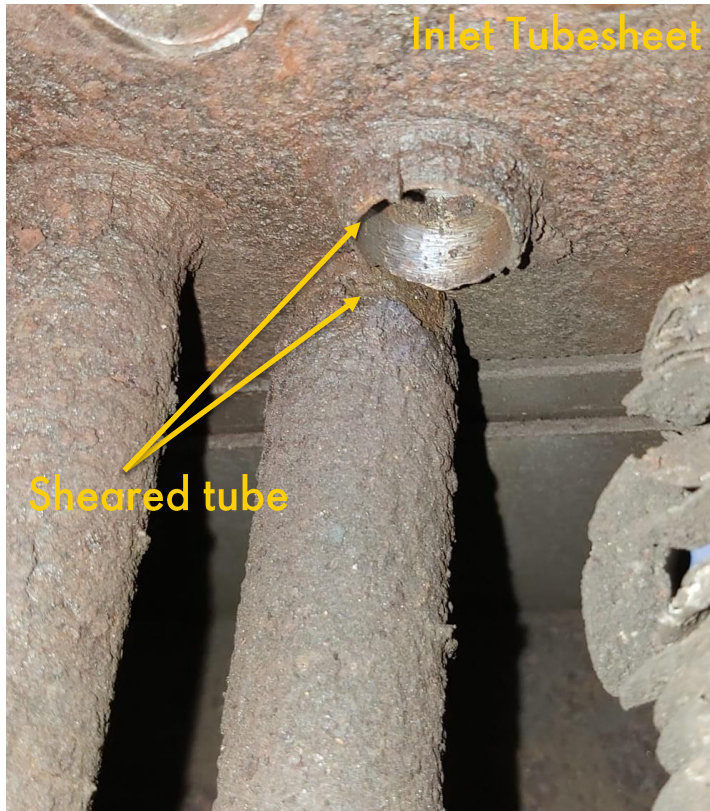
4th Row



5th Row



E9207 Leaked Tube



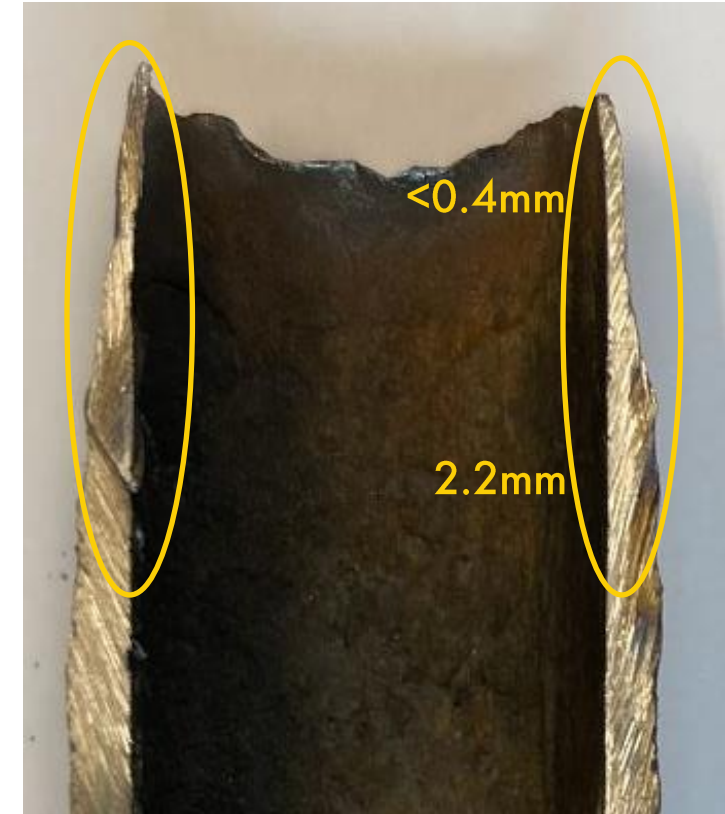
1. As found tube



2. Tube profile at sheared end (near tubesheet)



3. Tube profile away from sheared end



4. Thickness loss from OD

- Leaking tube was found completely sheared at inlet tubesheet.
- Severe localized external corrosion was observed on the tube OD adjacent to inlet tubesheet. Internal corrosion was negligible.
- Remaining tube thickness adjacent to sheared face was $<0.4\text{mm}$ as compared to 2.2mm away from sheared face.

E9207 Leaked Tube



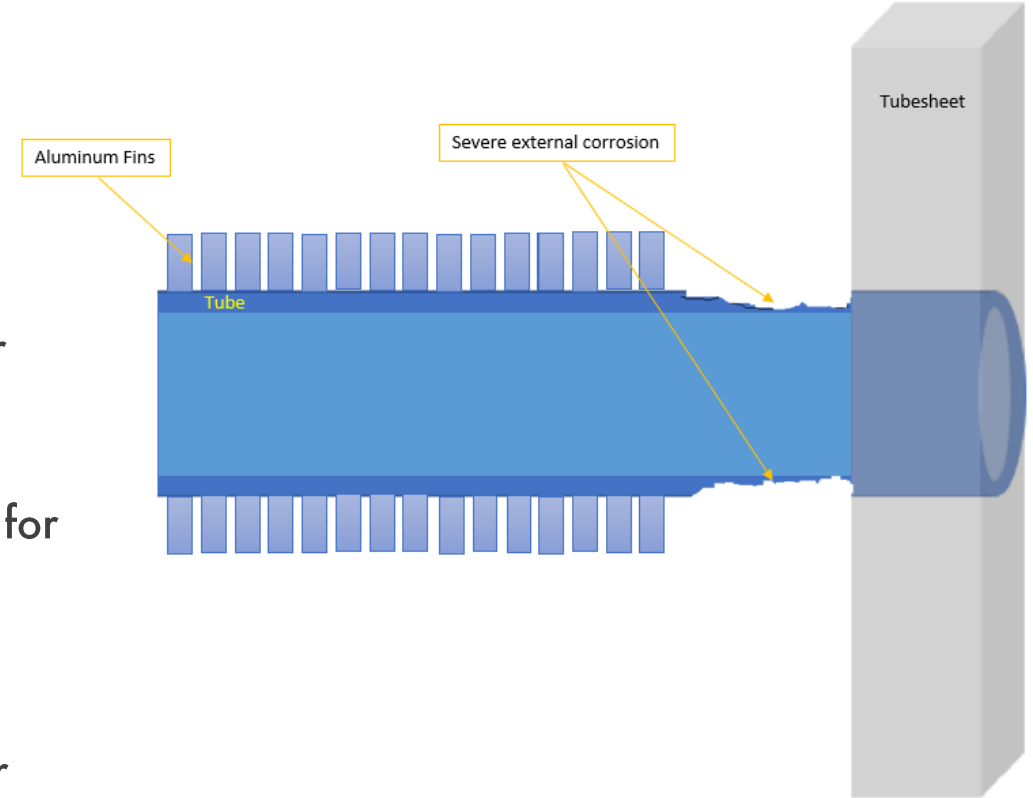
5. Thickness away from sheared face



6. Thickness adjacent to sheared face

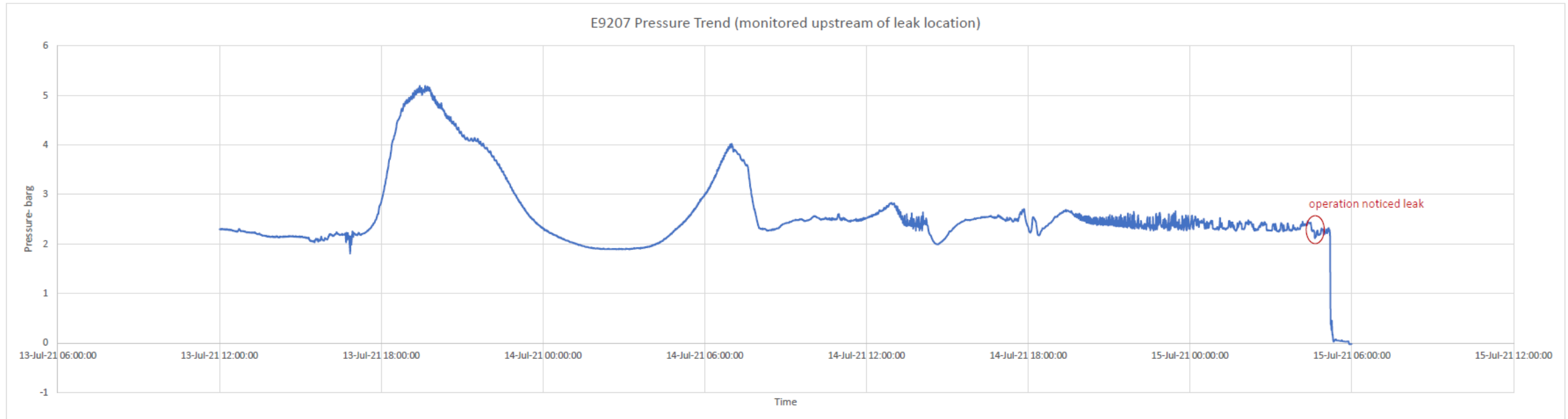
Corrosion Mechanism

- External Atmospheric Corrosion over long term
- Long Term Corrosion Rate, 2.2mm lost in 38 years = 0.06mm/year
- Corrosion rate looks reasonable in terms of atmospheric corrosion for marine environment
- External aluminium fins also acts as a sacrificial galvanic couple for carbon steel tube hence prevents corrosion at finned section
- Therefore, tube ends are more prone to external atmospheric corrosion



Leak

- Pinhole must have been appeared first before the complete rupture/shearing of the tube
- Corrosion scales might have prevented any noticeable leak
- Leak through the pinhole during start-up might have loosened the corrosion scales resulting in overstressing of already thinned down tube which finally sheared under internal pressure and deadweight

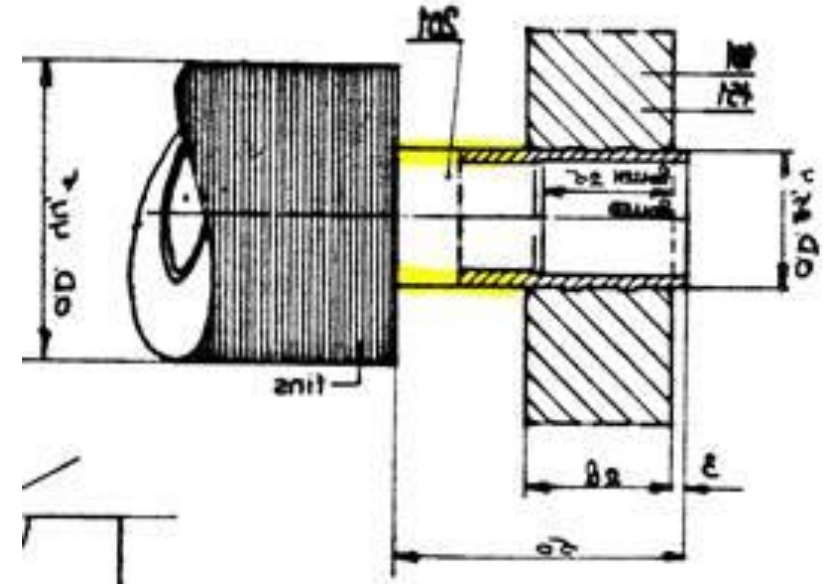


Inspection

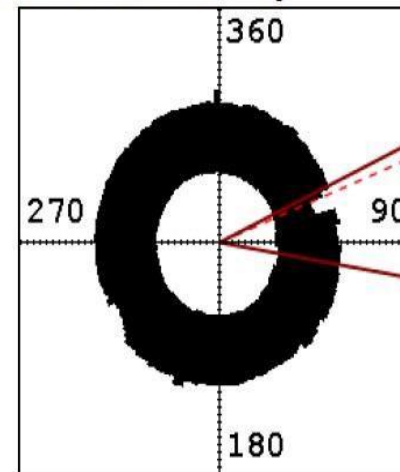
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Inspection

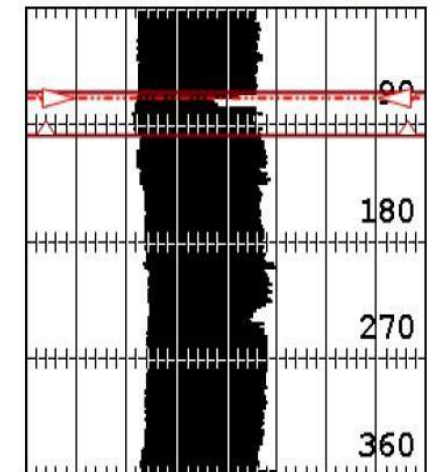
- Tubes that are enclosed in fins cannot be inspected from exterior. Best methods for inspecting tubes are IRIS (internal rotary inspection system)
- This technique requires UHPJ and thoroughly cleaned before any method is effective
- In the current inspection technique, the bare finned section becomes a dead zone with ECT and IRIS.
- External visual inspection of the bare finned section would require access from the top and bottom of the ACHE without obstruction (for instance, the radiator louvers in the case of E9207)



Comments: External Pitting



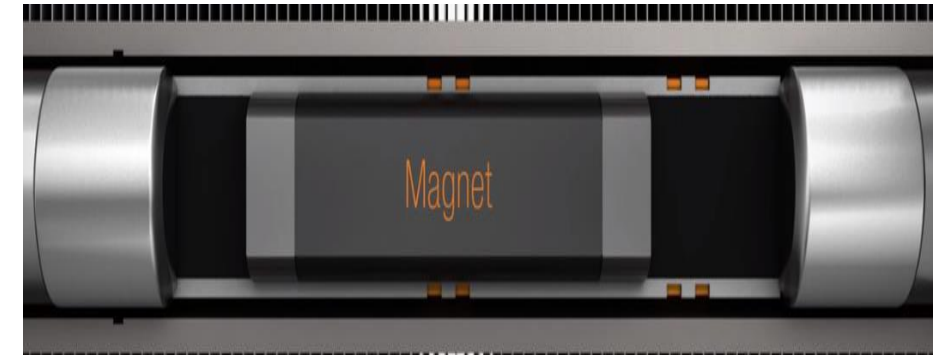
Row: BB Tube: 12



Inspection



- New technique specially designed for such external corrosion mechanism (not tested in Bukom but trials were successful in Upstream)
- A custom probe head was designed wherein both the MFL and PSEC technique could be performed in one single pass.
- The probe is sensitive to both ID & OD defects and further its unique design enables the detection of corrosion that usually happens in the unfinned section of the tubes in a fin fan cooler tube bundle. The unfinned section is usually around 20 to 30mm long and just after the tube sheet.
- MFL + PSEC (Magnetic Flux Leakage + partial saturated eddy current)
- From the trial it is recommended to carry out 100% screening in all tubes using MFL+PSEC probe and followed by checks with IRIS

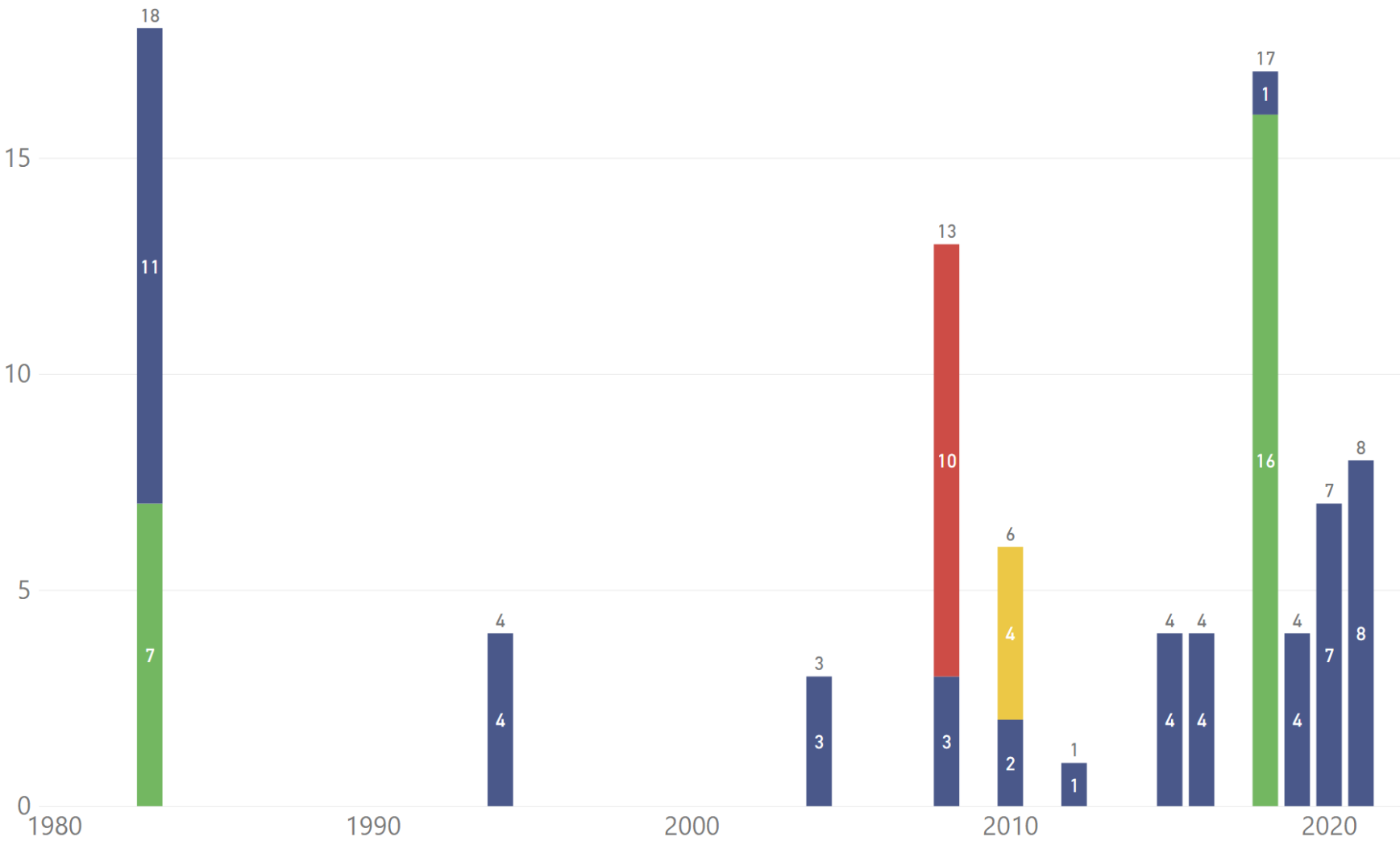


HCU ACHE data and Bukom experience

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HCU ACHE data

Tube material ● Alloy 825 ● CS ● Duplex SS ● SS 316L

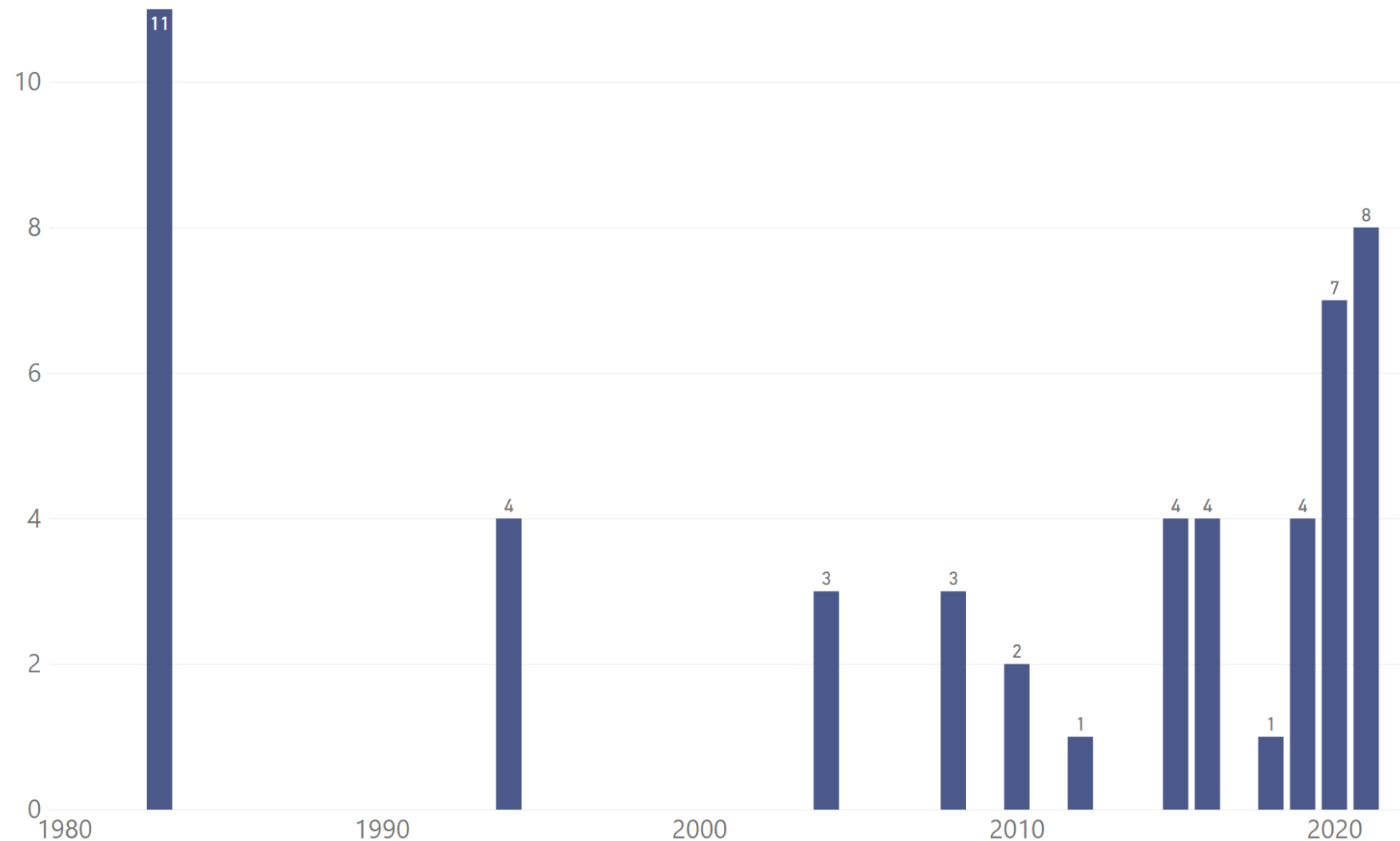


Tube installed date	Alloy 825	CS	Duplex SS	SS 316L	Total
1983	7	11			18
2018	16	1			17
2008		3		10	13
2021		8			8
2020		7			7
2010		2	4		6
1994		4			4
2015		4			4
2016		4			4
2019		4			4
2004		3			3
2012		1			1
Total	23	52	4	10	89

- Alloy 825: E9412 absorber feed gas coolers series and E7902 stripper overhead
- Duplex SS: E6251A/B lean solvent and E6253A/B acid gas condenser
- SS316L: E9416- 1 to 10 lean Sulfinol cooler

HCU ACHE data- CS tubes

Tube material • CS



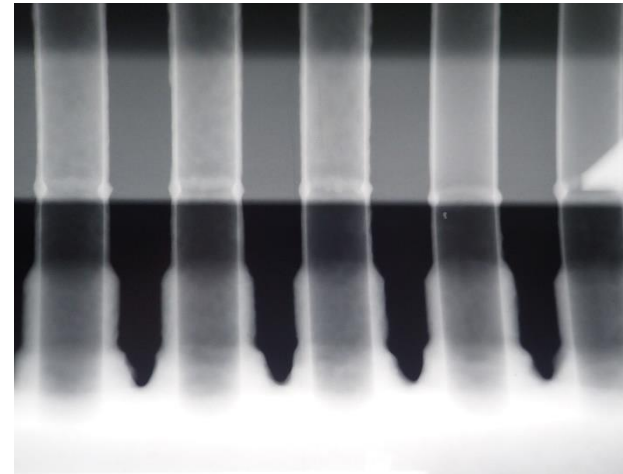
- 15 ACHE with >20 years life
- 8 ACHE between 10 to 20 years life
- 29 ACHE with <10 years life

HCU ACHE data- CS tubes- 24

Equipment ID	Description	Unit	Tube installed date
E9004-1 (PBU)	E9004-1, TOP CIRCULATING REFLUX COOLER	S901-HCU-9000	1983
E9004-2 (PBU)	E9004-2, TOP CIRCULATING REFLUX COOLER	S901-HCU-9000	1983
E9006A (PBU)	E9006A, DISTILLATE COOLER	S901-HCU-9000	1983
E9010-1 (PBU)	E9010-1, TEMPERED WATER COOLER	S901-HCU-9000	1983
E9010-2 (PBU)	E9010-2, TEMPERED WATER COOLER	S901-HCU-9000	1983
E9010-4 (PBU)	E9010-4, TEMPERED WATER COOLER	S901-HCU-9000	1983
E9206-1 (PBU)	E9206-1, MILD VACUUM TOP C/R COOLER	S901-HCU-9200	1983
E9206-2 (PBU)	E9206-2, MILD VACUUM TOP C/R COOLER	S901-HCU-9200	1983
E9220 (PBU)	E9220, MILD VACUUM TOP C/R COOLER	S901-HCU-9200	1983
E9603 (PBU)	E9603, HDT STRIPPER O/H CONDENSER	S901-HCU-9600	1983
E9701 (PBU)	E9701, L.P. CONDENSATE COOLER	S901-HCU-9700	1983
E9208-1 (PBU)	E9208-1, KERO COOLER	S901-HCU-9200	1994
E9208-2 (PBU)	E9208-2, KERO COOLER	S901-HCU-9200	1994
E9223-1 (PBU)	E9223-1, GAS OIL COOLER	S901-HCU-9200	1994
E9223-2 (PBU)	E9223-2, GAS OIL COOLER	S901-HCU-9200	1994
E9211A (PBU)	E9211A, HYDROWAX AIR COOLER	S901-HCU-9200	2004
E9211B (PBU)	E9211B, HYDROWAX AIR COOLER	S901-HCU-9200	2004
E9211C (PBU)	E9211C, HYDROWAX AIR COOLER	S901-HCU-9200	2004
E9114 (PBU)	E9114, FRESH GAS COMP 1ST STG INTERCOOLR	S901-HCU-9100	2008
E9115 (PBU)	E9115, FRESH GAS COMP 2ND STG INTERCOOLR	S901-HCU-9100	2008
E9117 (PBU)	E9117, FRESH GAS COMP 3RD STG INTERCOOLR	S901-HCU-9100	2008
E7903-1 (PBU)	E7903-1, STRIPPED WATER R D COOLER	S901-HCU-7900	2010
E7903-2 (PBU)	E7903-2, STRIPPED WATER R D COOLER	S901-HCU-7900	2010
E9704 (PBU)	E9704, STEAM CONDENSATE COOLER	S901-HCU-9700	2012

Bukom experience

- CD5 2016 TA E8530-2 leaked due to external corrosion at bare section
 - As part of the investigation, 14 ACHE were identified for a thorough close visual inspection from the cowl and 11 were identified with corrosion and planned for replacement in next TA. Out of which, 3 were identified for hydrotest to ensure they last till the next TA.
- PLAT4 2021 E9904 paper thinned tubes at the unfinned section in 2021.
 - ACHE isolated and planned for re-tubing



Operating Experience (Ursa HAL-1062)

- Ursa Platform, Gulf of Mexico (Marine Environment).
- HAL-1062 (2nd Stage Discharge Cooler for Field Gas Compressor-2).
- Tube **rupture** on November 25, 2020.
- Tubes: 0.625" OD x 0.083" wall (A-179 with L-footed Fins).
- Exposed tube ends coated with a **Phenolic coating**.
- MAWP = 2200 psig, $t_{\min} = 0.049$ inches (**Available CA = 0.034 inches**).
- Gas inlet temperature ~305 °F, **intermittent service**.
- ACHE installed new in 1999.
- Tube thickness at the rupture site was ~0.015 inches. (0.375mm)
- Corrosion Rate = $(0.083 - 0.015)/21 = 3.2$ mpy.
- Corrosion rate calculation assumes the coating failed immediately after the ACHE was placed in service.
- Localized external corrosion at a few tubes in the bottom row.
- Tube rows 1, 2, and 3 with significantly less wall loss.



Discipline Asset Strategy- MMI

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Discipline Asset Strategy- Mechanical

Heat Exchanger Bad Actor list/ Site LOPC List

- To study the individual PU Heat Exchanger Bad Actor List to understand the cause of leak
- To implement any modification/ work scope required in TA (i.e. flange face machining, gasket modification, bolt material modification)

Inspection –Scoping

Scheduled Inspection

Heat Exchanger:

1. Heat exchanger tube bundle with last inspection date >15 years ago to plan for tube testing with minimum 50% coverage
2. Heat exchanger tube contingency plan 15% tubes of the heat exchanger tube metallurgy
3. Aircooler heat exchanger scope for (CS and low alloy tubes) :
 - ACHE < 10 years must be external visual inspected focused on the bare finned tubes segment from the accessible location
 - ACHE > 10 years must be subjected to close visual inspection including the bottom rows of tubes AND/OR subjected to tube testing technique capable of detecting tube external corrosion next to header(PSEC + MFL?) 100 %
 - ACHE >20 years must be going for retubing (This is to minimise discovery during TA)