Repair of ammonia converter's basket in Abu Qir Fertilizers Company, November 2018

PRESENTED BY:

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Haldor Topsoe, Denmark

Abstract:-

- *In one of the oldest ammonia plants in Egypt owned by Abu Qir Fertilizers Company, this case happened in November 2018 for an ammonia converter basket after 13 years of operation.*
- *After suffering from a power failure shutdown, the ammonia plant could not load its synthesis loop due to an abnormal increase in pressure difference across the ammonia converter. This paper illustrates the failure found in the ammonia converter's basket and the repair procedures done in collaboration with the basket's manufacturer Haldor Topsoe to run the plant again and the failure analysis of the case.*

1. Introduction:

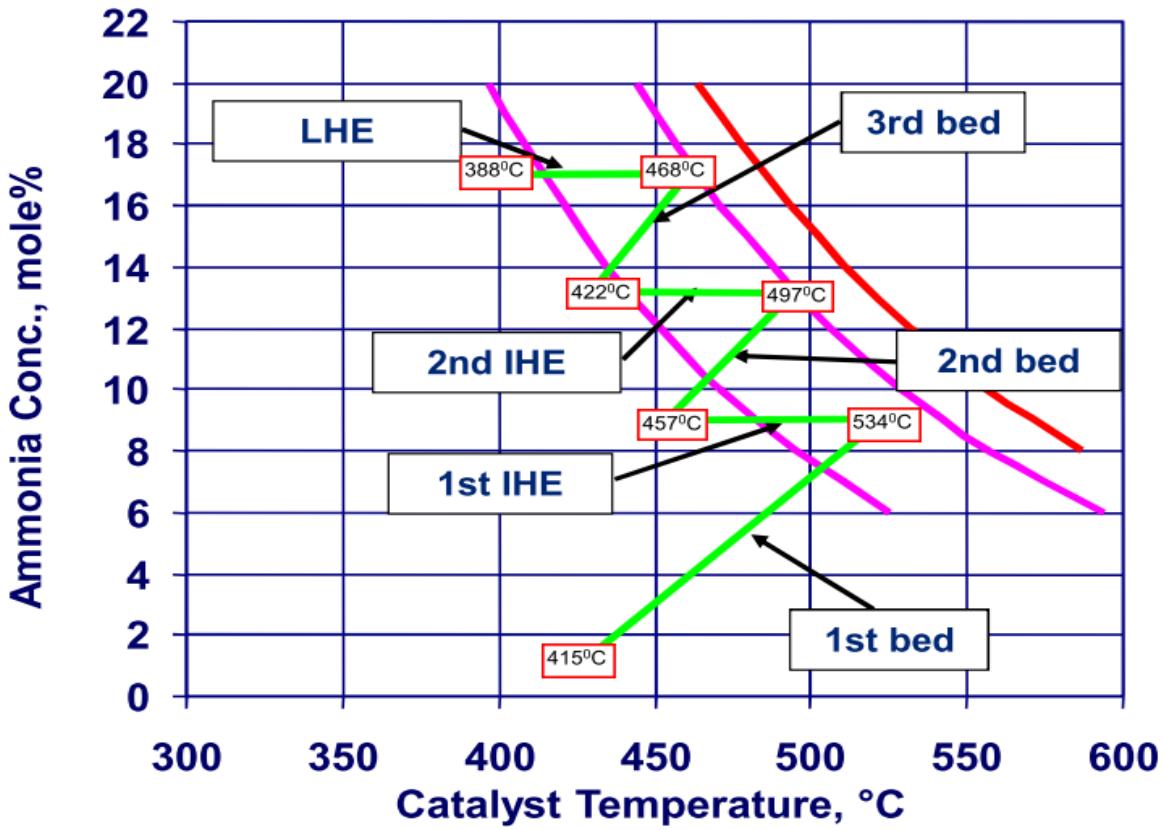
- Abu Qir Fertilizers company is one of the leading fertilizers companies in the middle east consisting of three plants, two ammonia-urea plants and one ammonia-nitric acid-ammonium nitrate.
- Founded in 1976, the first plant which was designed by UHDE was originally operating at synthesis loop pressure of 320 bar and benchmark ammonia production of 1000 MTPD.
- It was revamped in 1986 where the operating pressure was reduced to 280 bar with increased ammonia production of 1100 MTPD and finally revamped again in 2005 when Haldor Topsoe's ammonia converter basket type S300 was installed in the same high pressure shell to reach an operating pressure of 250 bar with an operating temperature of 500 ℃ and same ammonia production.

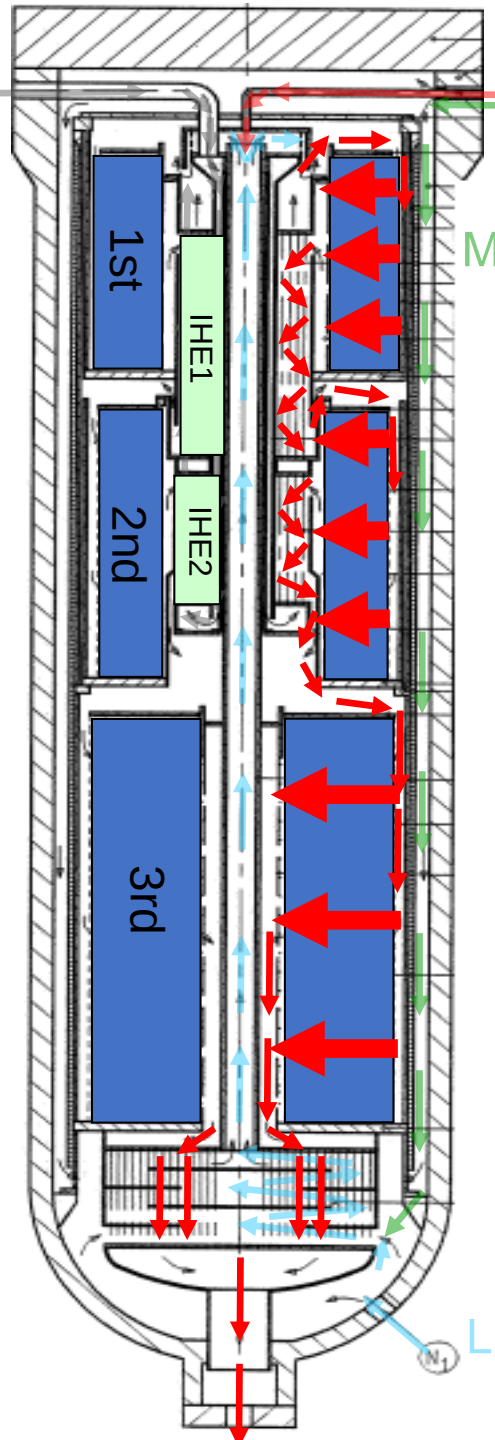
Ammonia converter basket:

- The S-300 converter basket consists of three radial flow catalyst beds with cooling after both the first and second catalyst beds by means of interbed heat exchangers located in the center of the two upper catalyst beds. The lower heat exchanger is at the bottom end of the basket transferring heat between the outlet flow to be cooled and the inlet flow to be pre-heated.

- The pure radial flow combined with interbed heat exchanger enable low pressure drop across the catalyst beds and operation close to equilibrium of the reaction. This ensures better performance and conversion rate and hence gaining higher ammonia production. The reaction temperature in the catalyst beds range between 415^0C and 534^0C.

Ammonia converter basket:





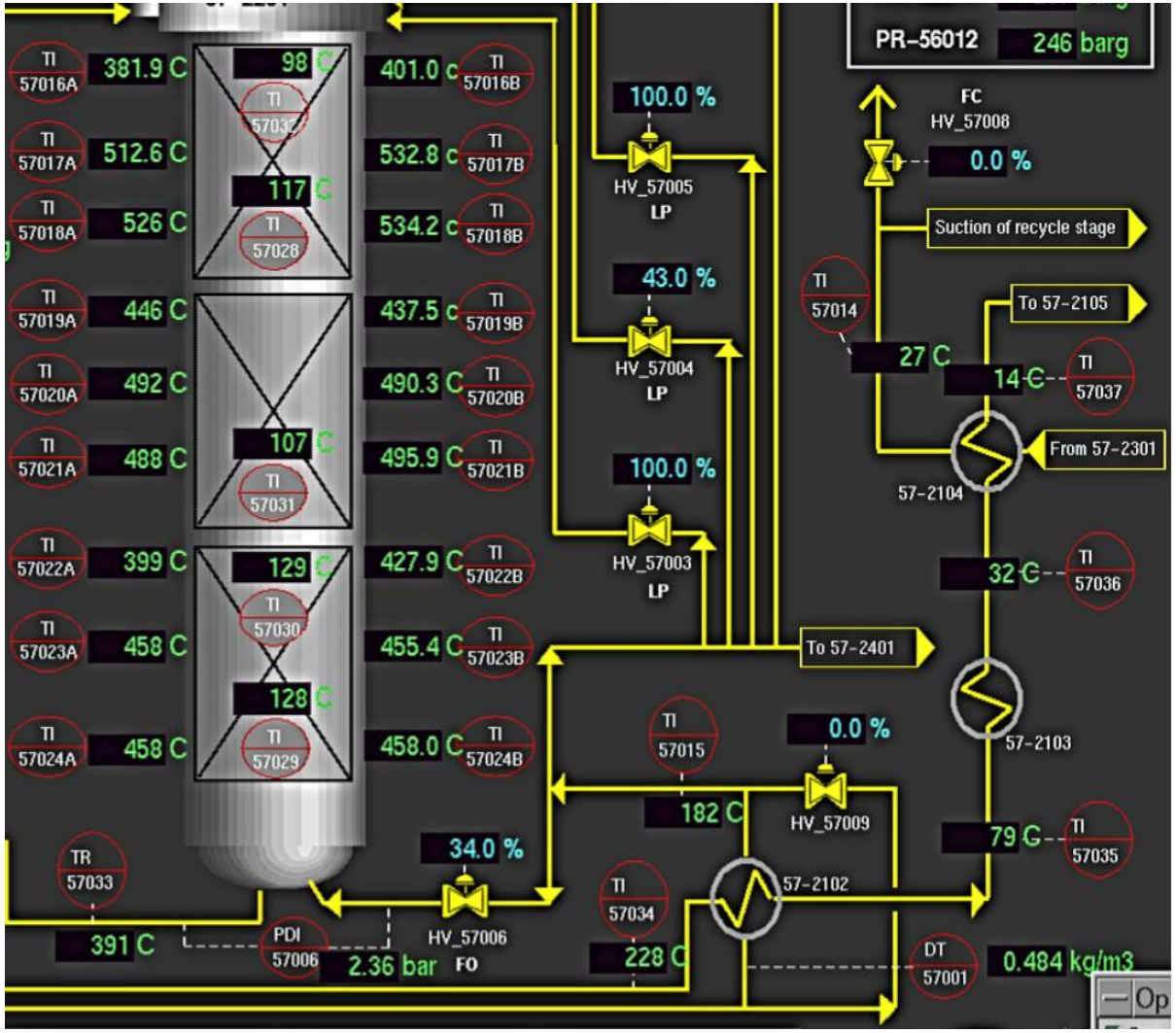
Arab Fertilizer Association
since 1975

Problem description:-

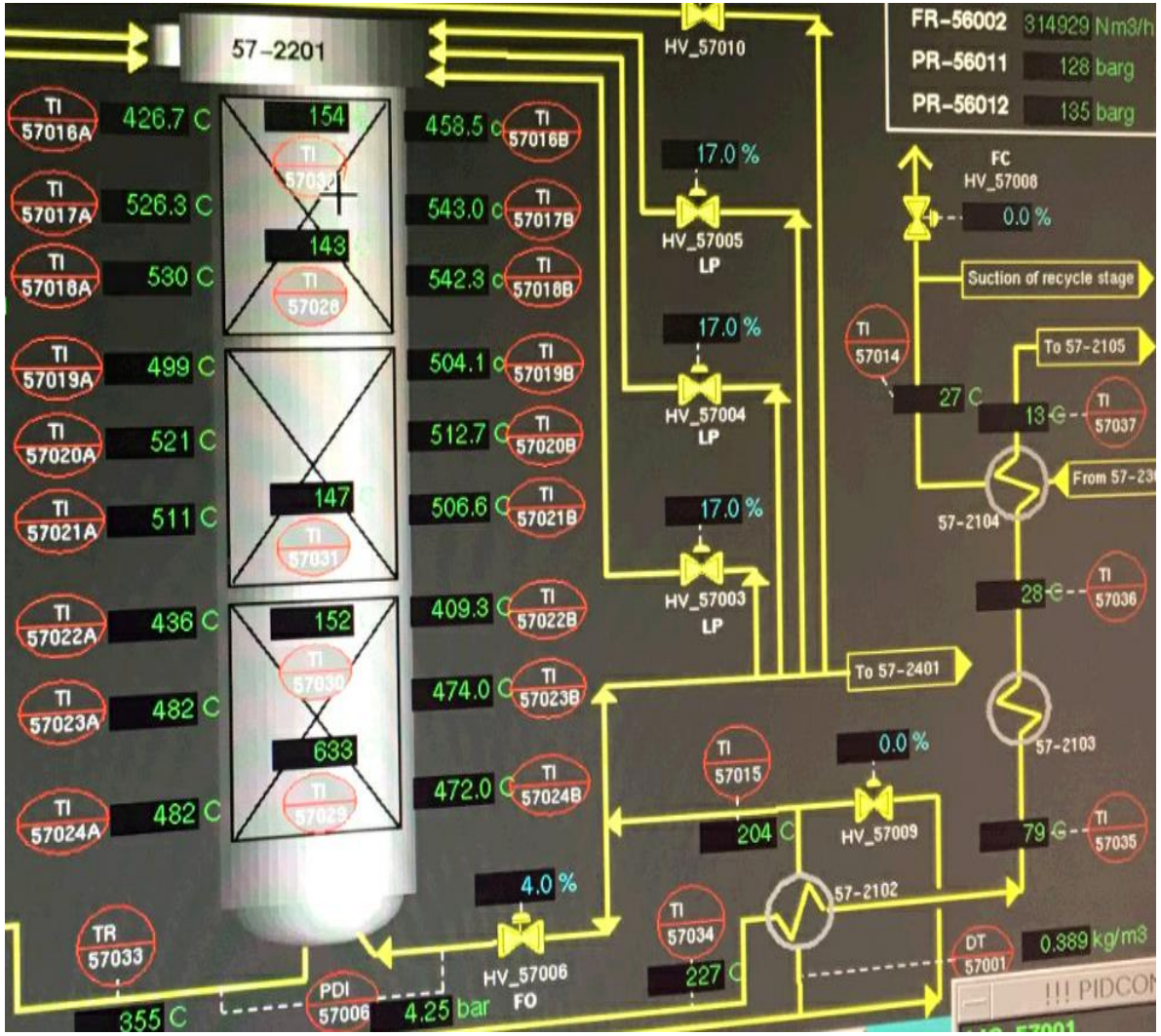
- In November 2018, after 13 years of basket operation, the plant stopped due to a power failure. The synthesis loop was depressurized and the converter was nitrogen blanketed till power failure problem was solved.
- The plant was operated again for one day, then a leakage in boiler feed water preheater was noticed, so it had to be stopped again. Some postponed maintenance activities were carried out in a time frame of one week.
- When starting up the plant again, a significant abnormal pressure difference showed up reaching 10 bars while it normally measures 2.5 bars in full load condition.
- The loop pressure was 120 bar, the anti-surge valves were fully opened so minimum flow was passing through the converter and pressure difference was 4.5 bar, any attempt to load the reactor would lead to increase the pressure difference and then the flow rates to the converter had to be reduced again.

Problem description (cont.):-

Screenshot from DCS Normal Operation



Screenshot from DCS Abnormal condition



Problem description (cont.):-

- The checklist included all loop heat exchangers and separators and even catalyst poisoning with water or nitrogen but all checks were in vain and the converter was stuck in reduction mode.
- All symptoms lead that there was a problem inside the converter, nearly no flow exiting the vessel.
- Abu Qir Fertilizers contacted the basket's manufacturer Haldor Topsoe seeking technical advice.
- After a site visit for data collection, Haldor Topsoe confirmed that the basket had to be checked for mechanical damage.
- After quick preparations, the plant was stopped, cooled down and purged to be ready for internals' inspection.

Maintenance procedures:-

- The high pressure vessel’s top cover was dismantled, it is consisting of four main components: top cover, bottom cover, lens gasket and sealing segments between them.

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Maintenance procedures:-

- The inner connections distributing the gases to the basket’s passages with the expansion joints were found intact. Theses connections were dismantled and removed.

Maintenance procedures:-

- The basket’s cover was dismantled, then the first bed cover was dismantled and the first bed catalyst was unloaded no sintering was noticed.

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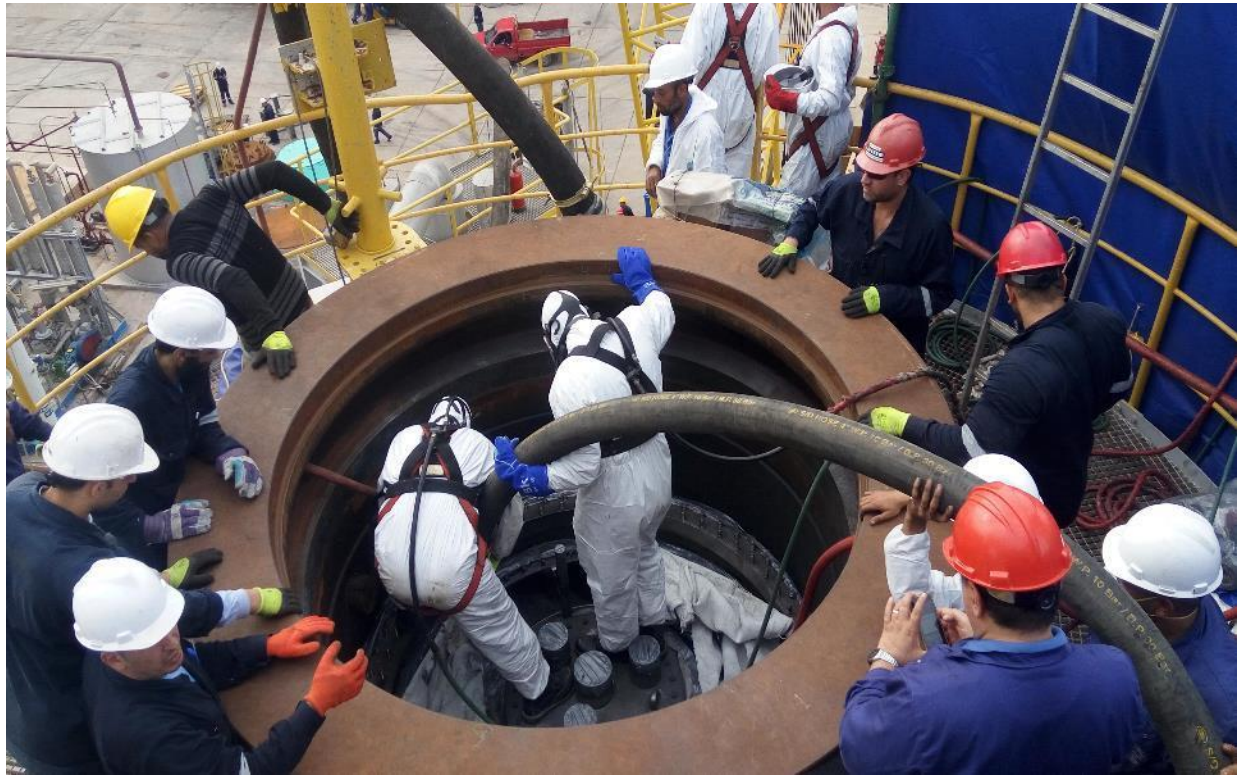
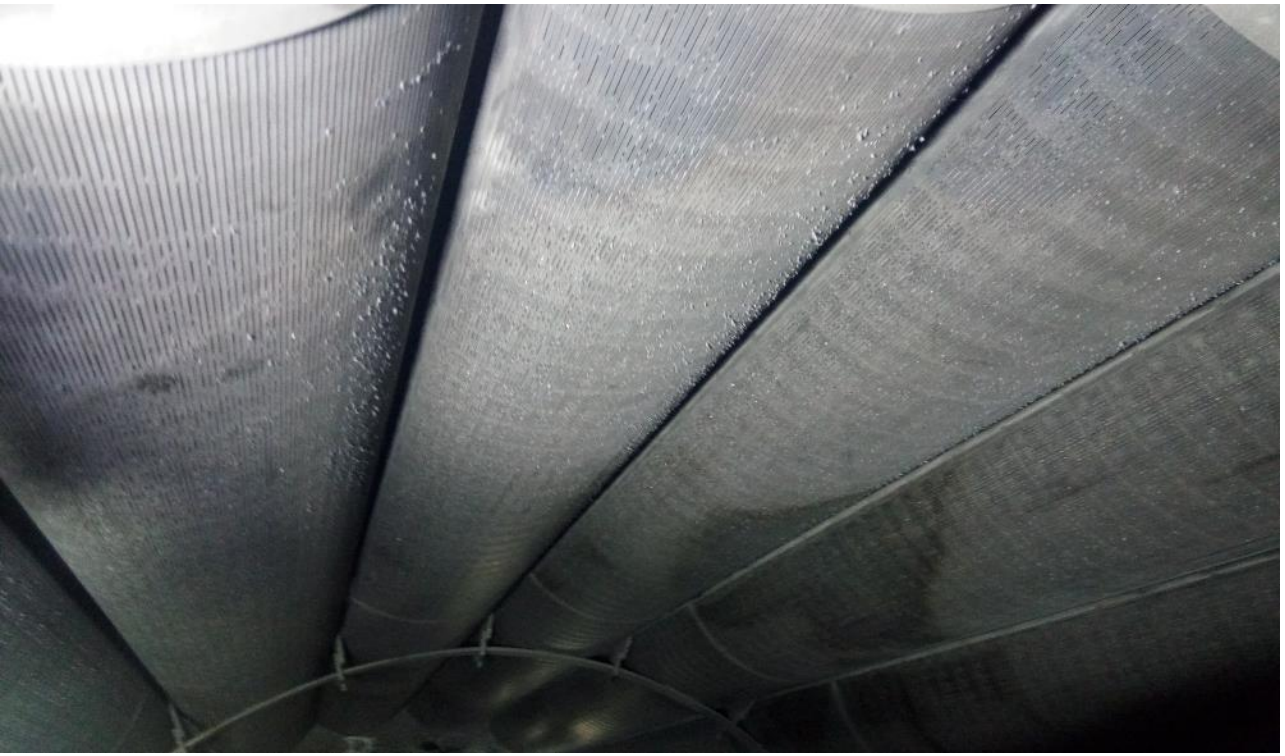


Maintenance procedures:-

- When inspecting the first bed, the center and outer screens were found in good condition and no mechanical failures or ruptures were found.



OUTER SCREEN

CENTER SCREEN

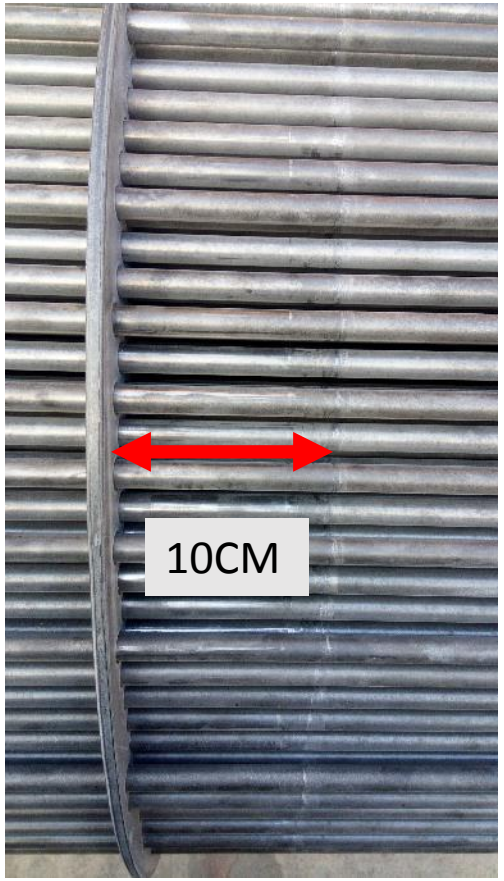
Maintenance procedures:-

- The first bed was removed out of the basket and the upper heat exchanger was dismantled and removed

Maintenance procedures:-

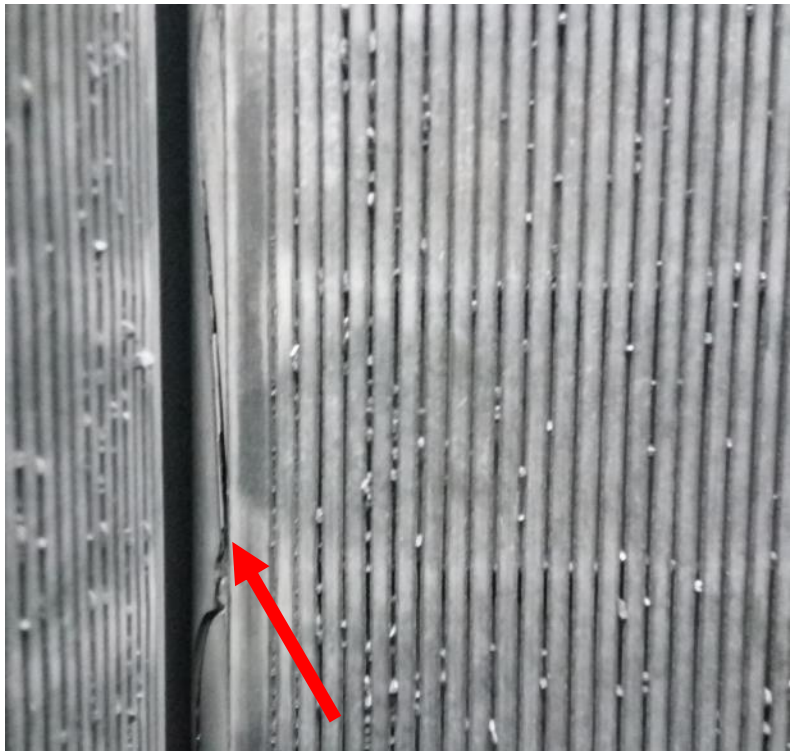
- The intermediate upper heat exchanger was inspected, the baffles were found displaced by 100 mm towards lower direction, all baffles' tie rods were broken and the baffles were stuck at the new position and could not be repositioned.

BAFFLES' ORIGINAL POSITION



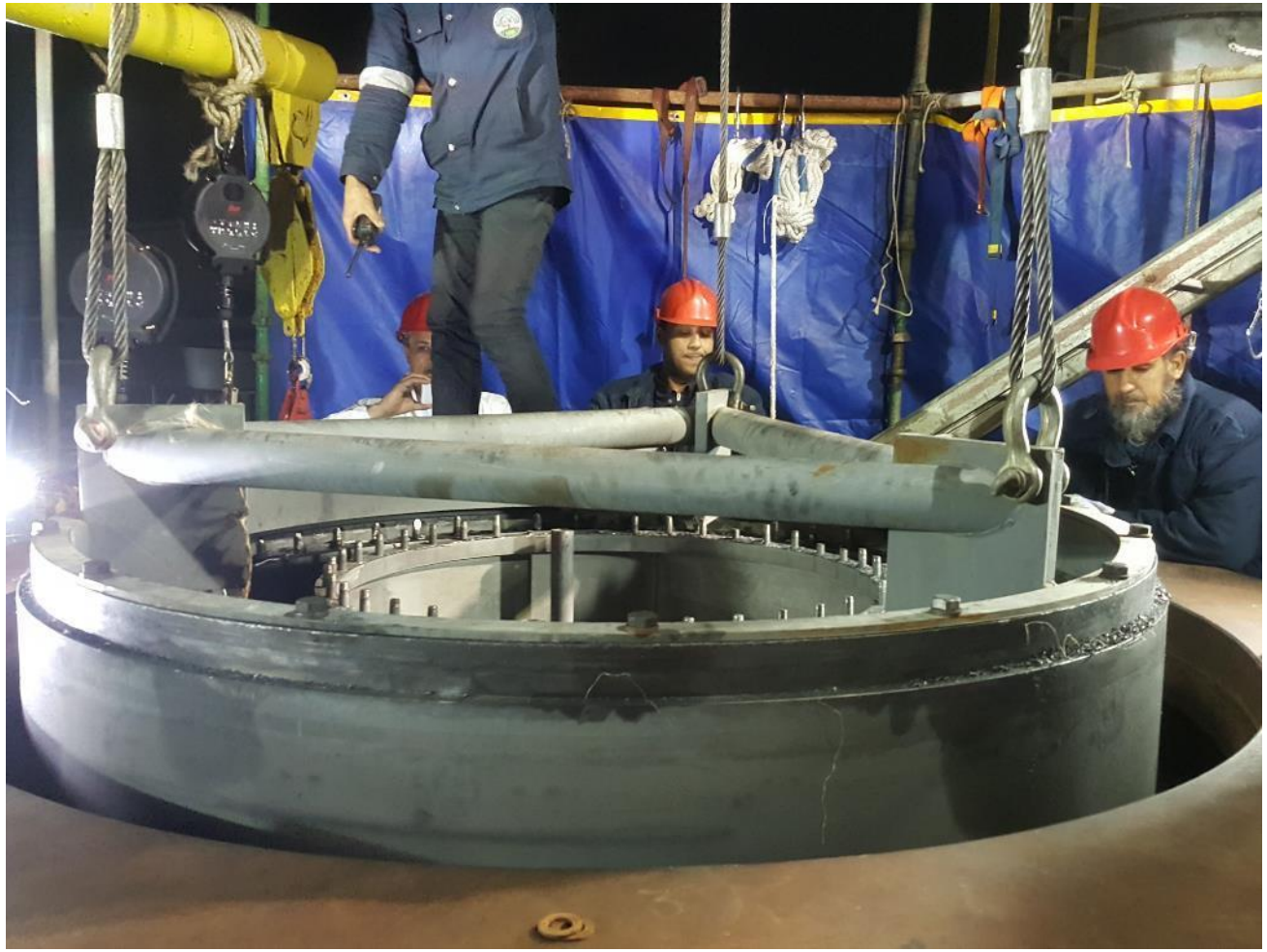
Maintenance procedures:-

- The second bed’s catalyst was unloaded.
- By inspecting, the center screen was found in good condition, some cracks were found in the outer screen due to long time operation at elevated temperatures but no major mechanical failures or rupture were found. Still the main problem cause was not reached.



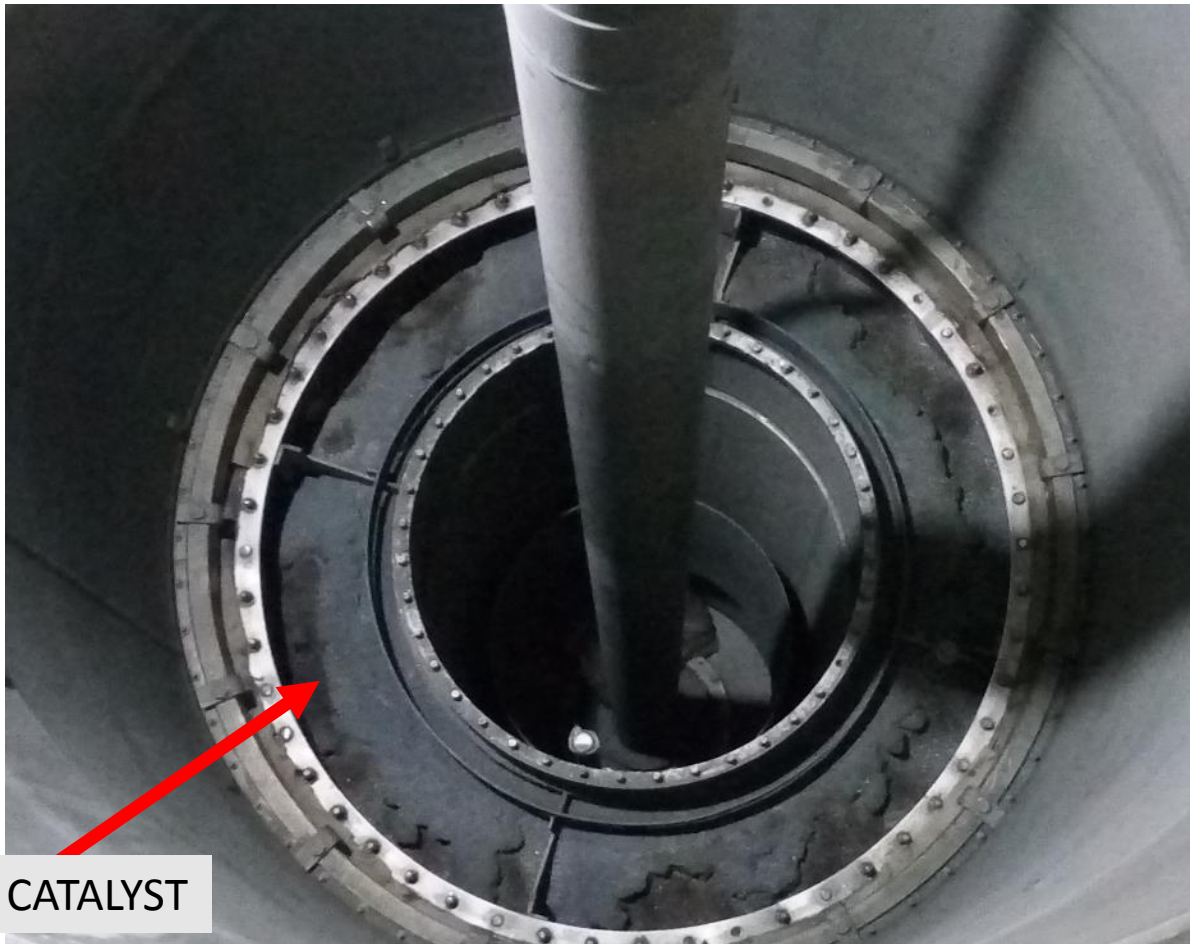
Maintenance procedures:-

- The second bed then was removed using its special lifting device.



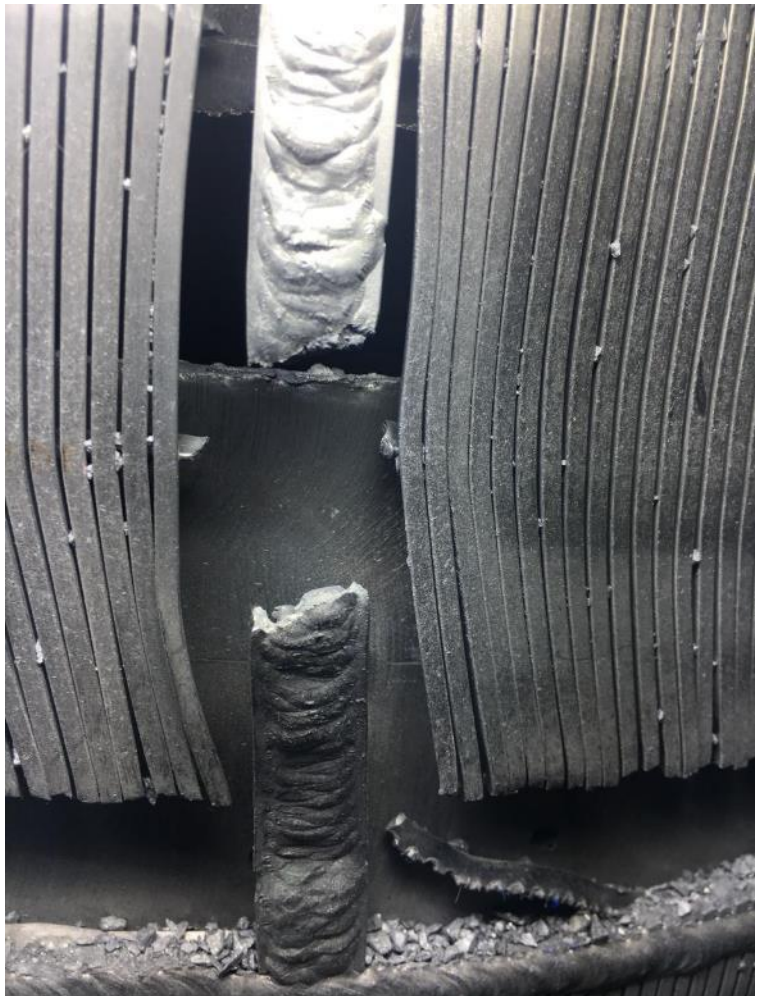
Maintenance procedures:-

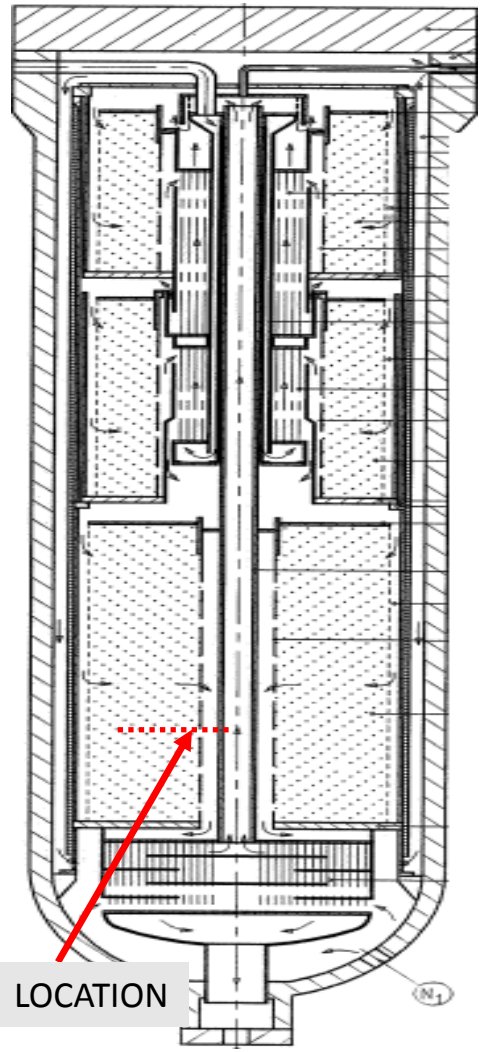
- The third bed top cover was dismantled and the catalyst was unloaded, sintering was more spread in this bed.



Maintenance procedures:-

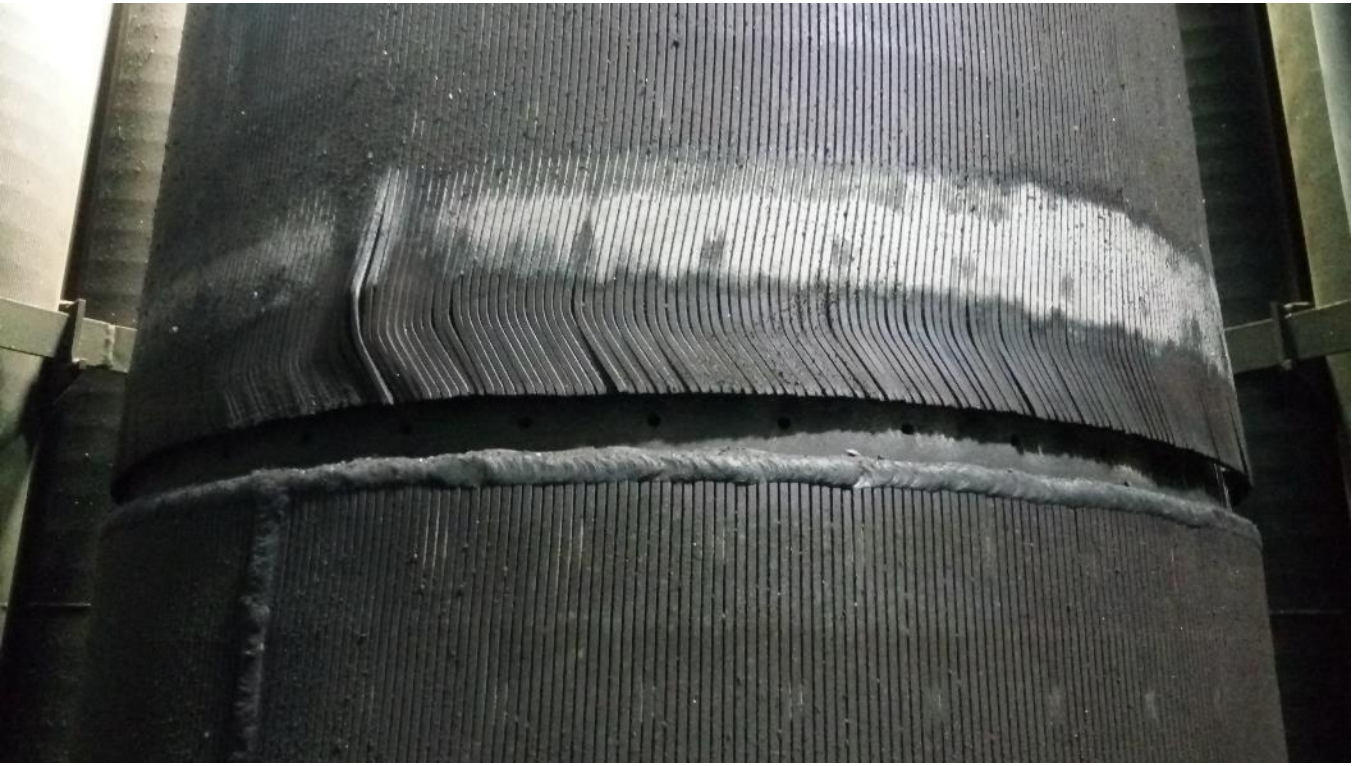
- By inspecting the center screen, a rupture was found at approximately 1.8 meter from bottom.





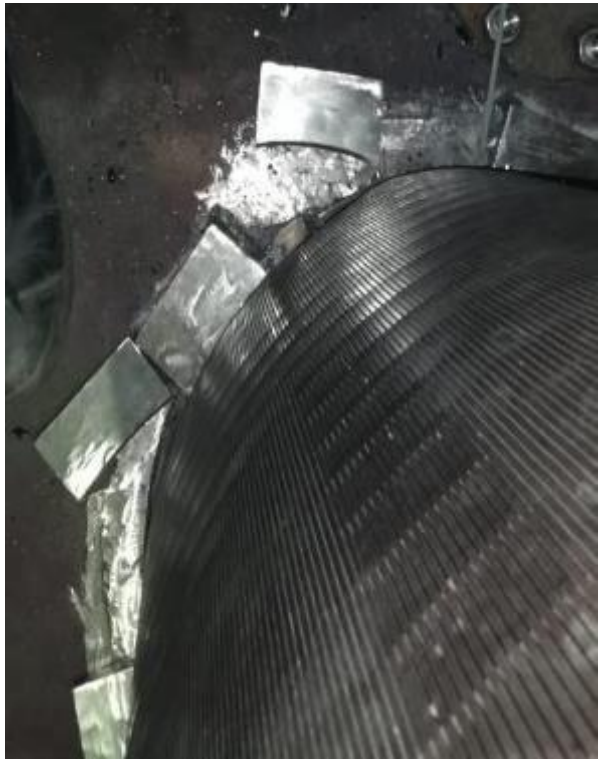
Maintenance procedures:-

- The failure happened in a welding between the center screen's segments, nearly half of the circumference was crack opened of 5 cm.



Maintenance procedures:-

- The locking clips of the center screen were grinded off, the center screen was removed out to allow the repair process.



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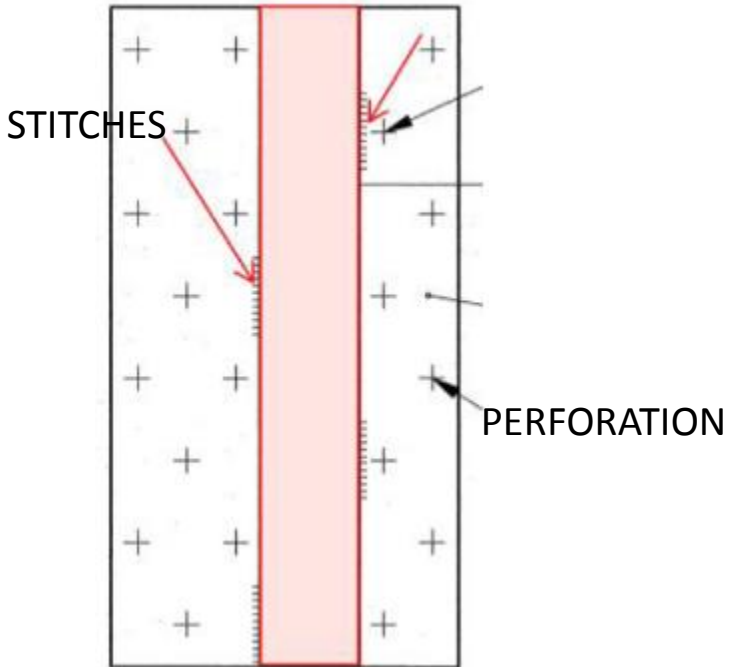
Rupture repair procedures:-

- The center screen consists perforated pipe and screen wire with a clearance of 6 mm between them, with material of construction of Alloy 600.
- The repair procedures sent by Haldor Topsoe contained two main points, first to stitch weld longitudinal reinforcement bars inside the center screen distributed around the circumference with full length to prevent the same rupture to occur again at a different position



Rupture repair procedures:-

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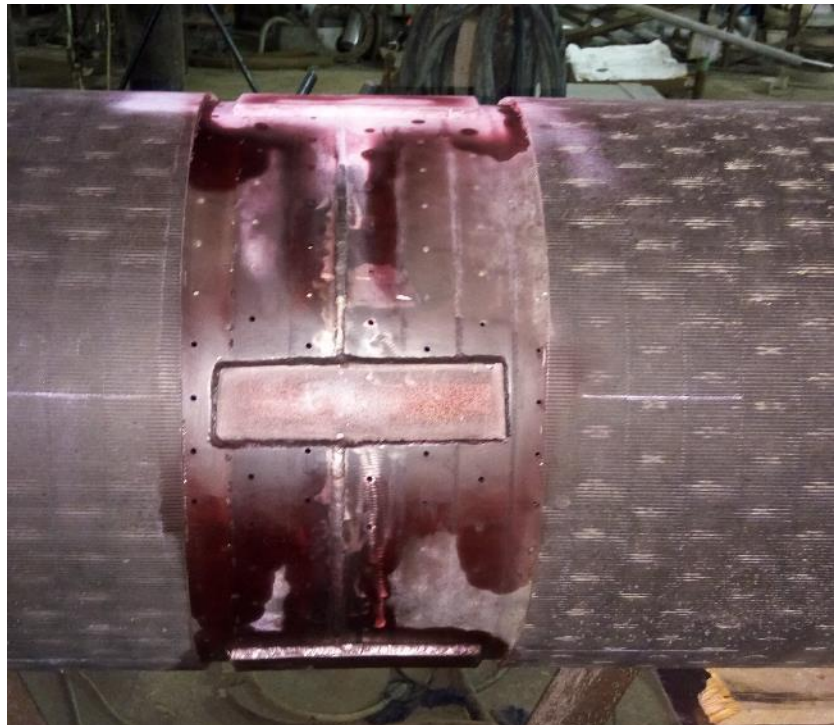
Rupture repair procedures:-

- The second point is to repair the failed area of the center screen.
- The repair at rupture was to cut away a band of 250 mm of damaged screen wire and weld reinforcement bars of the same length filling the clearance and finally welding a ring of 500 mm diameter with proper overlap with intact screen wire to seal and support the failure area.



Rupture repair procedures:-

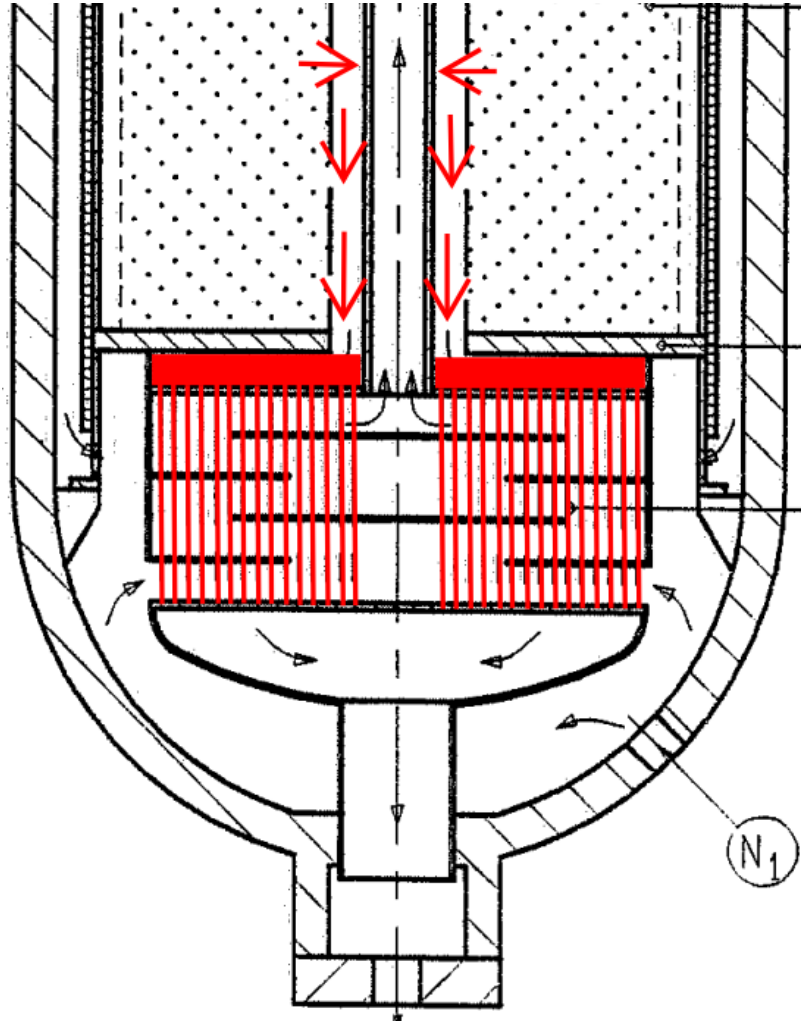
- The difficulty in the repair procedure was the welding position as the welder needed to crawl inside a pipe less than 500 mm diameter and then weld stitches at different positions which needed a special qualifications in technical and physical aspects.

Rupture repair procedures:-

- The patch was tested by PT and then the center screen was ready for assembly.

Maintenance procedures:-

- When the center screen was removed, it was found that catalyst escaped from the center screen rupture and trapped in the chamber between the basket's bottom and the lower heat exchanger's tube sheet.
- The escaped catalyst was sintered and the tube sheet appeared affected and blocked by the migrated catalyst.
- Since there was no access to that heat exchanger below the basket, it was decided to lift up the basket out of the vessel to inspect and clean the tube sheet and also to remove the remaining trapped catalyst.



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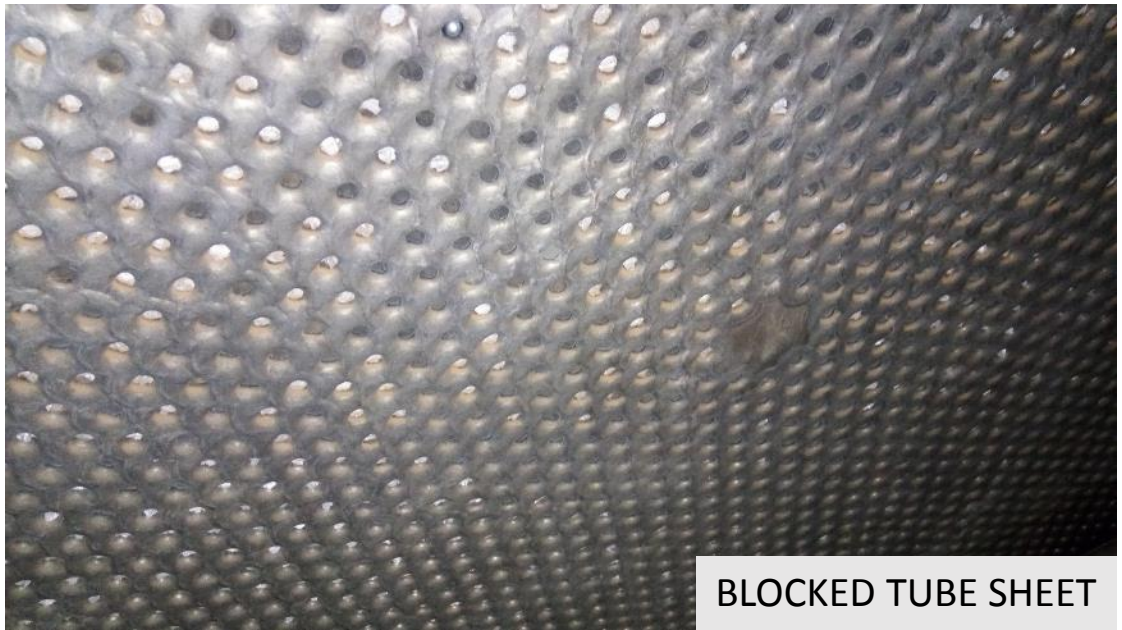
Maintenance procedures:-

- The lower heat exchanger was cut out and inspected.
- All exchanger tubes were filled and plugged with catalyst. The upper tube sheet was damaged and fused on 90% of its area as well as 90% of tube to tube sheet weldings.
- It was also noticed that many tubes were ruptured enabling catalyst to enter the shell side.



BLOCKED TUBE SHEET

CATALYST IN SHELL

Maintenance procedures:-

- Abu Qir had to either purchase a new heat exchanger from Haldor Topsoe's subsuppliers or manufacture a new one in local companies or workshops.
- Haldor Topsoe's subsupplier informed Abu Qir that the typical manufacturing time for a new exchanger would take approximately two months excluding the shipment.
- The local manufacturing choice was the time efficient solution.
- A national company located in Suez had the qualifications needed to manufacture a new equipment.
- A team from Abu Qir fertilizers and Haldor topsoe moved to Suez to carry out the process.
- By working in three shifts and by intense supervision, the manufacturing process consumed only two weeks which is considerably a huge time saving comparing to the alternate option.

Maintenance procedures:-

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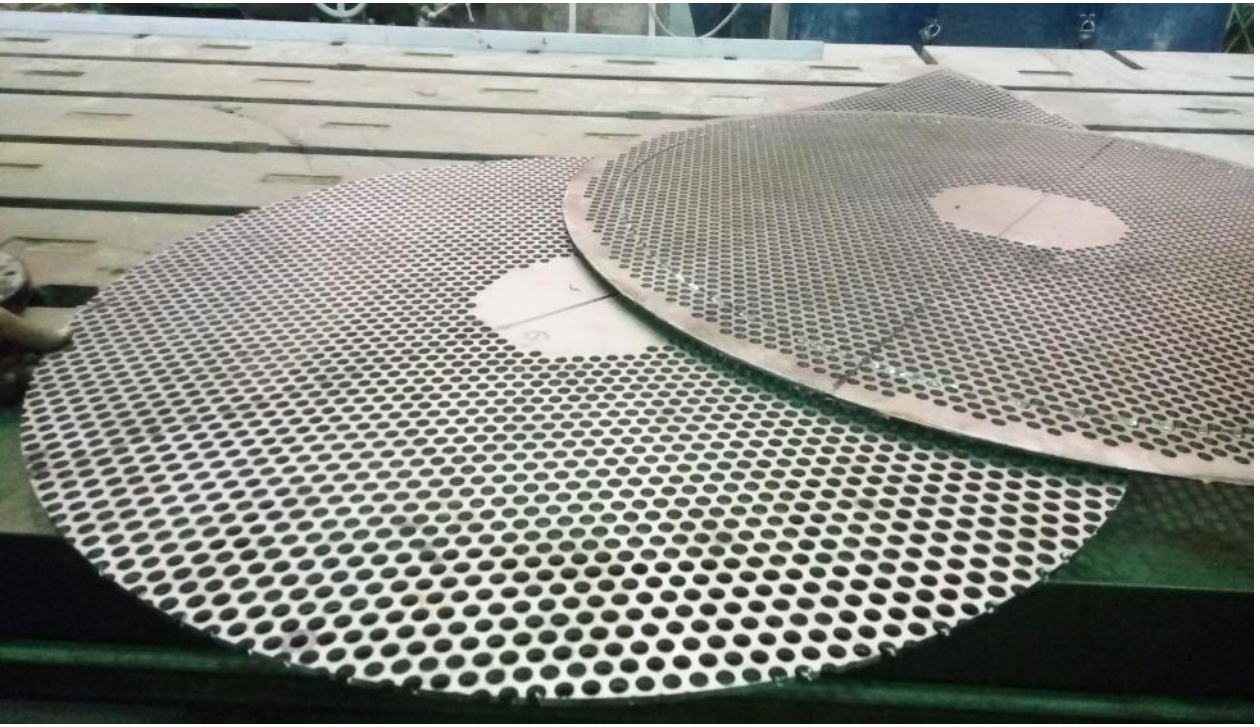

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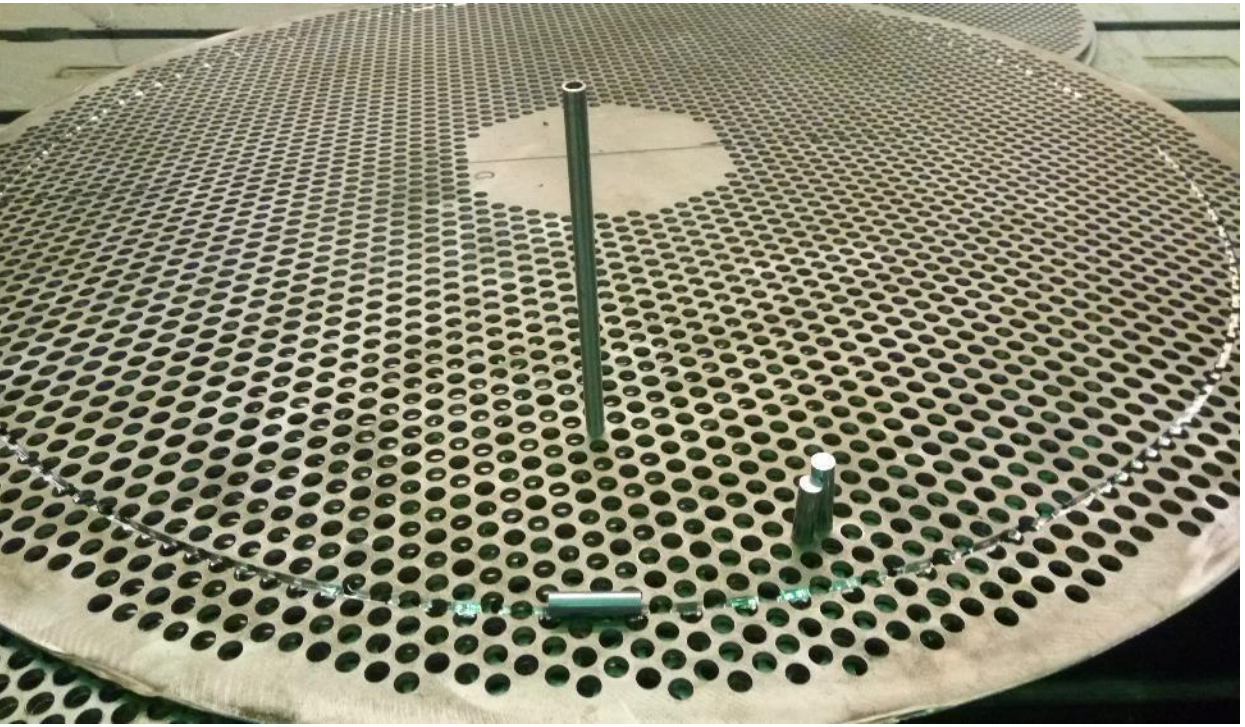

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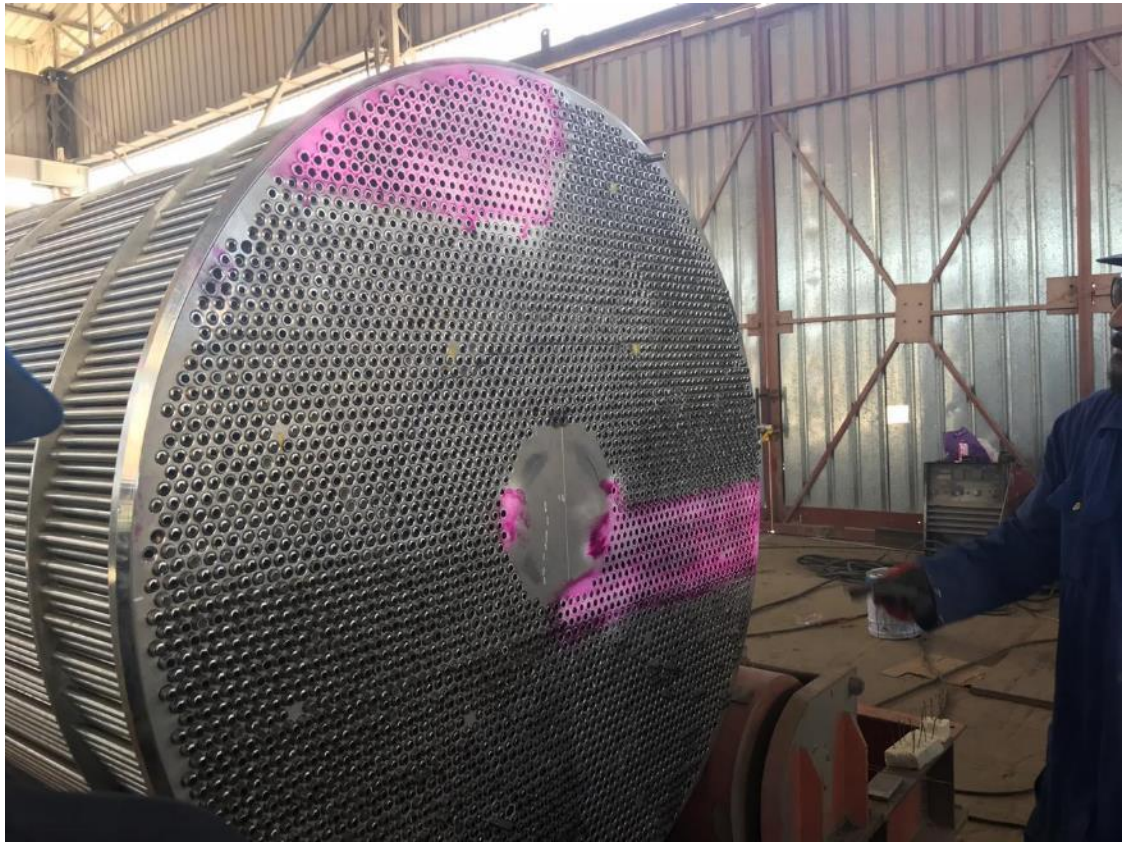

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- The basket was inspected thoroughly, hair cracks were found at bottom end.
- The cracks were grinded off, reinforcements were welded at the bottom of the basket to support it against the catalyst weight above it, all bolts were replaced by new set.

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- A simulation was carried out by Haldor Topsoe and the CFD study concluded that there will be no remarkable effect on the exchanger's performance.

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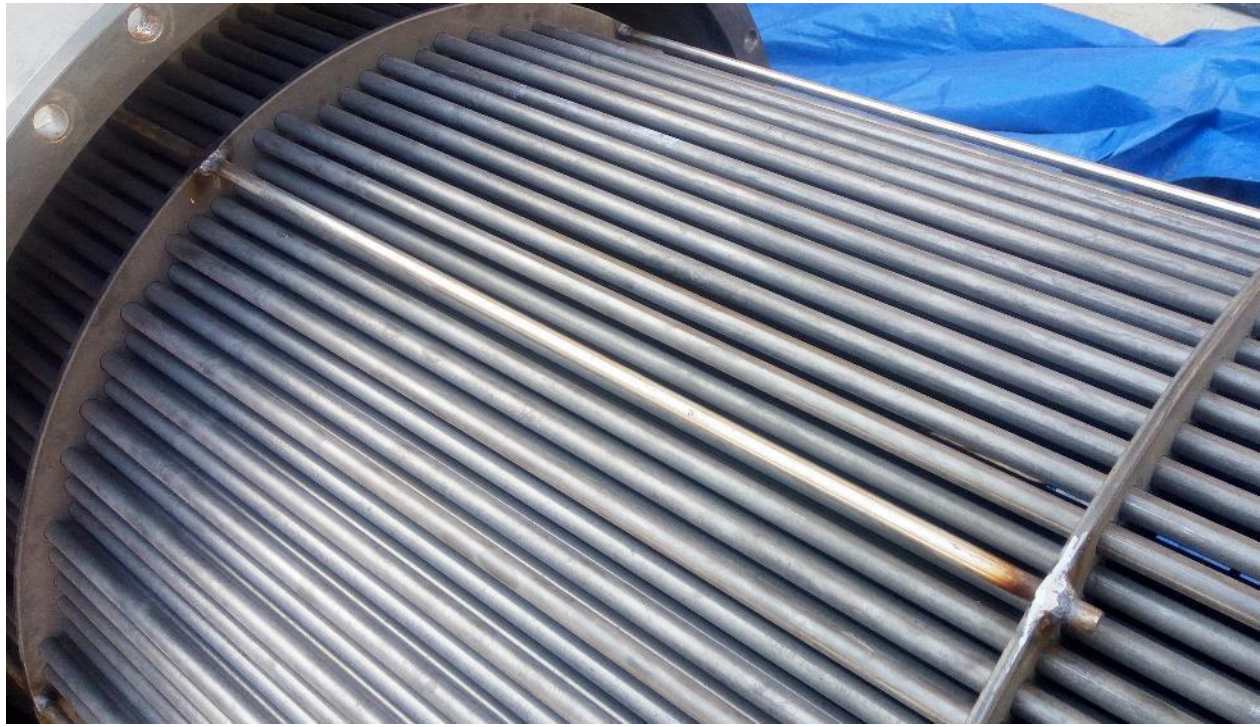
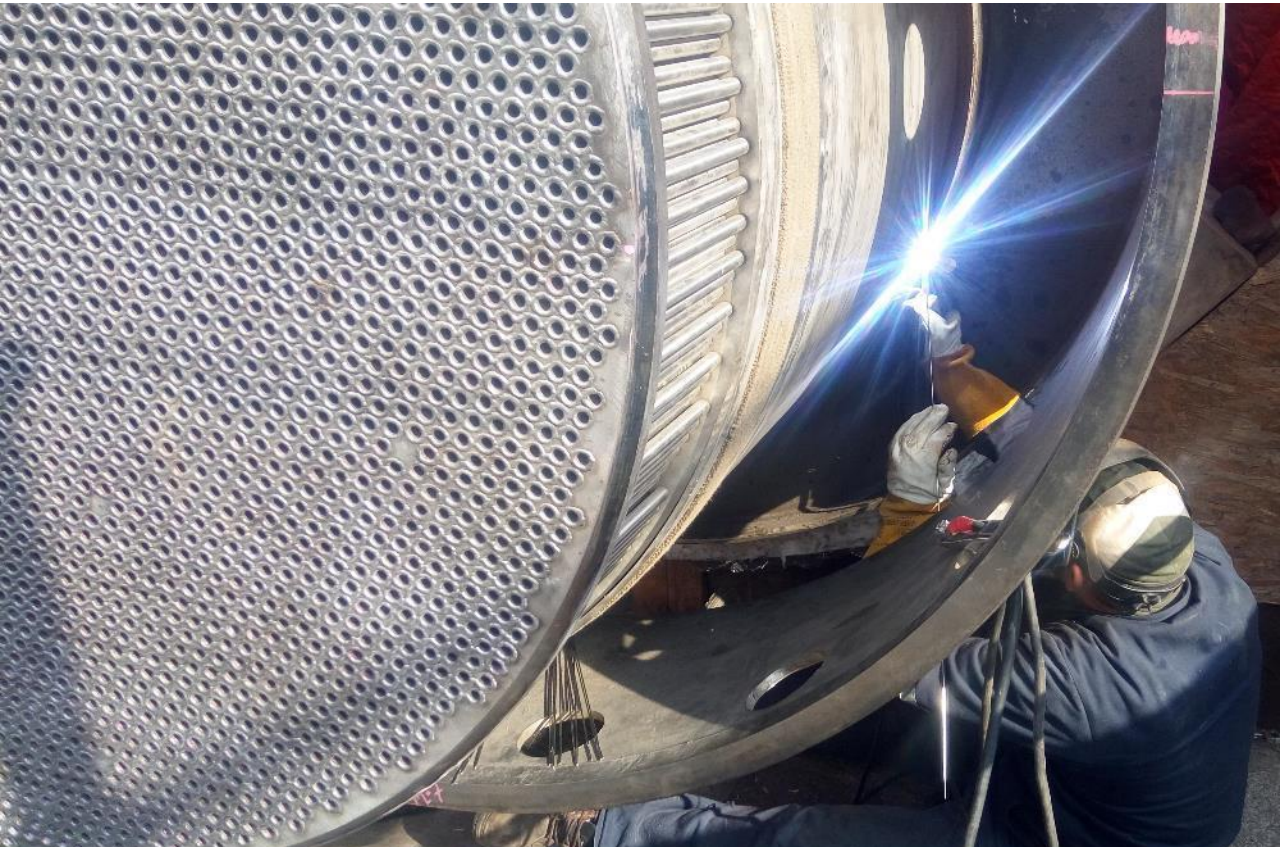


Maintenance procedures:-

- The new heat exchanger was aligned to the bottom of the basket with outmost precision and welded back again and the cut-out windows as well were welded and after PT of the welds, the basket was ready to be installed again inside the high pressure vessel.



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Maintenance procedures:-

- The basket was installed and aligned inside the pressure vessel, the repaired center screen was installed and its locking plates were welded and the third bed’s catalyst loading started.

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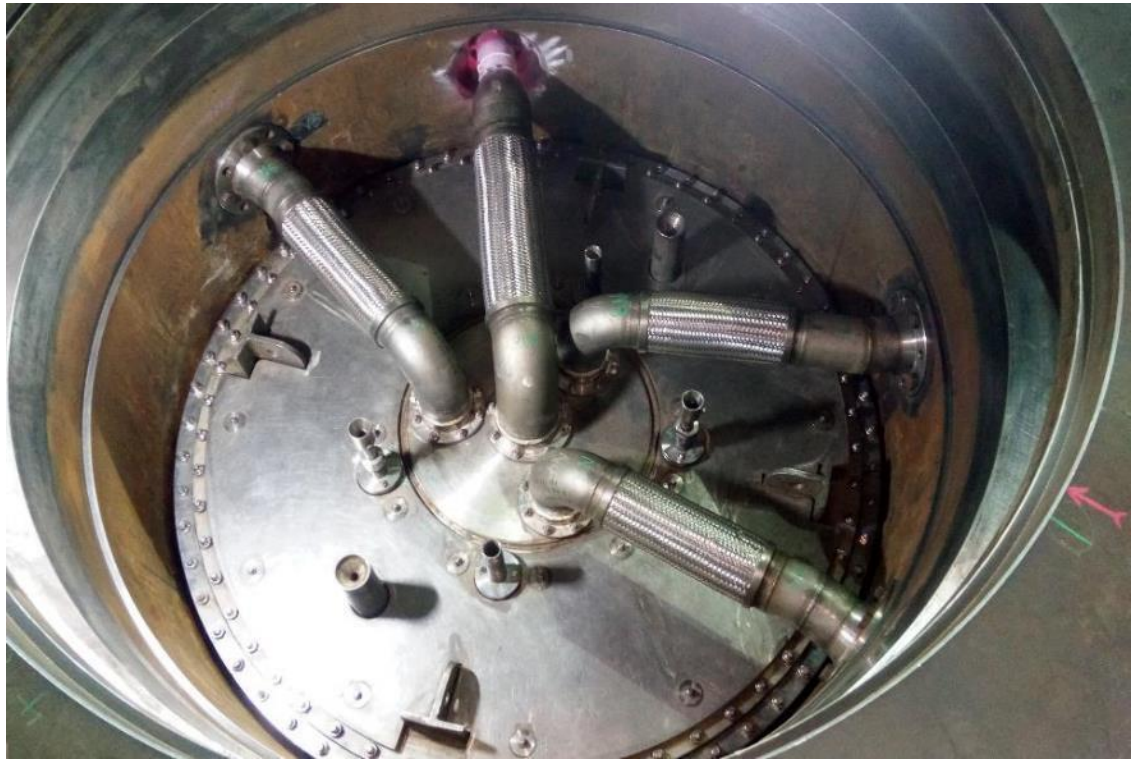
Maintenance procedures:-

- After showerhead loading of the third bed, the third bed cover was reinstalled. The second bed was installed inside the basket, then the second bed catalyst was loaded and the bed cover was reinstalled. The two upper interbed heat exchangers where installed and the first bed was installed inside the basket and it was loaded with catalyst. The first bed cover was reinstalled and the basket's cover was reinstalled.

Maintenance procedures:-

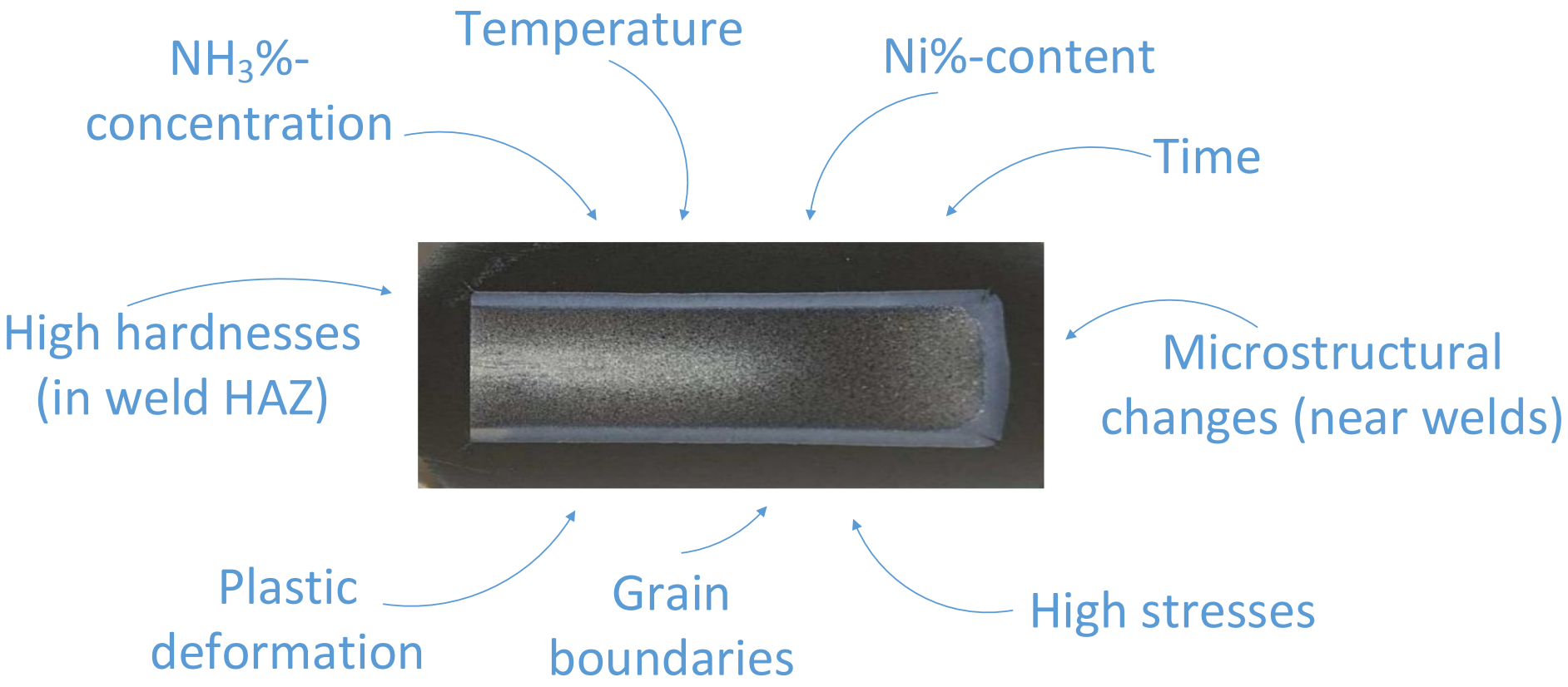
- Subsequently the flexible connections above the basket cover were installed, as tie in between basket and pressure shell. Finally, the converter's high pressure top cover was assembled after that and the reactor was then ready for reduction.
- The repair successfully ended after 32 working days. The plant currently is running at full load without any drawbacks.



Failure analysis:-

The following damage mechanisms are considered applicable for the ammonia converter basket:-

- **Nitriding.**



Failure analysis:-

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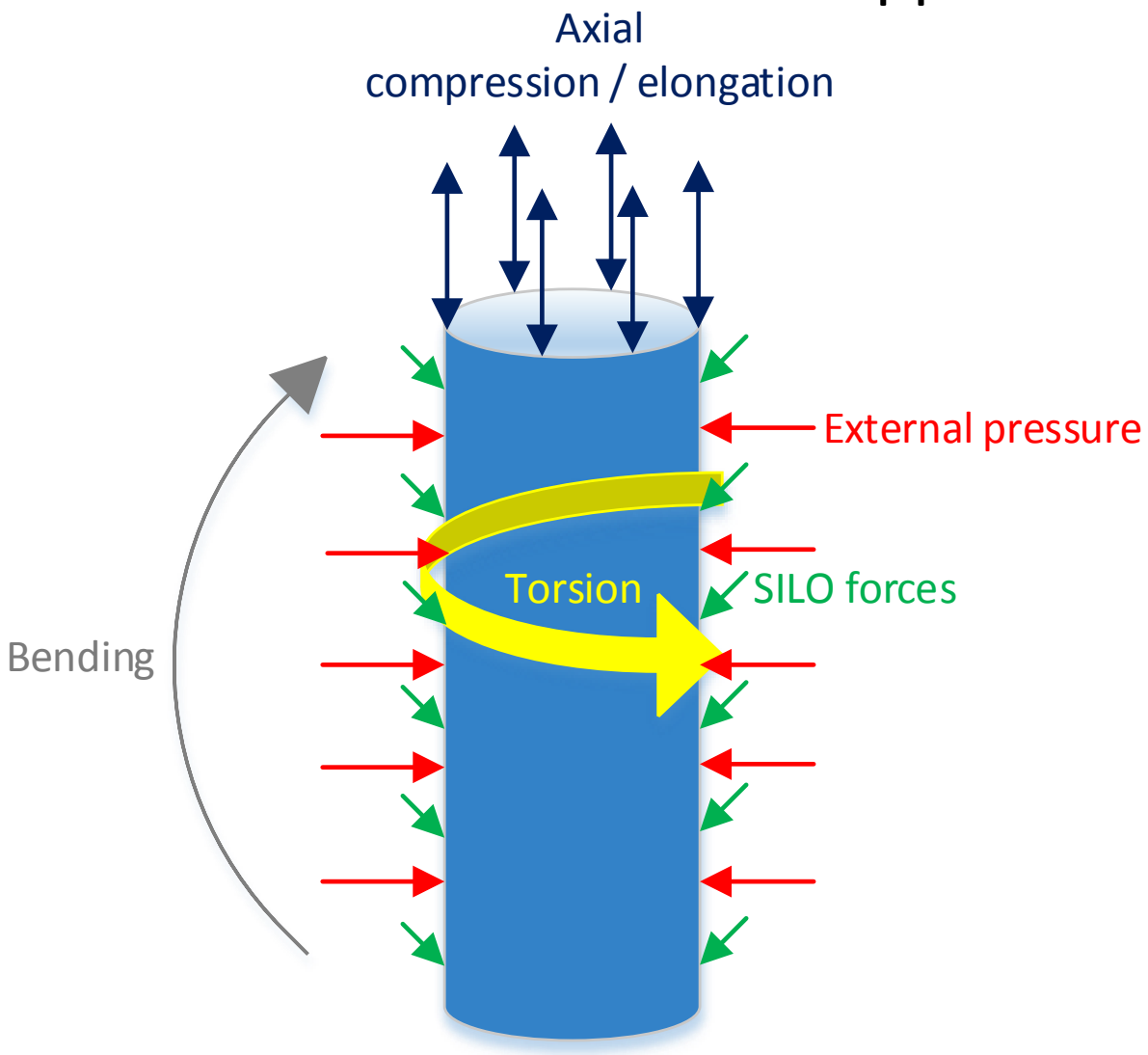
- **Mechanical loads.**



Failure analysis:-

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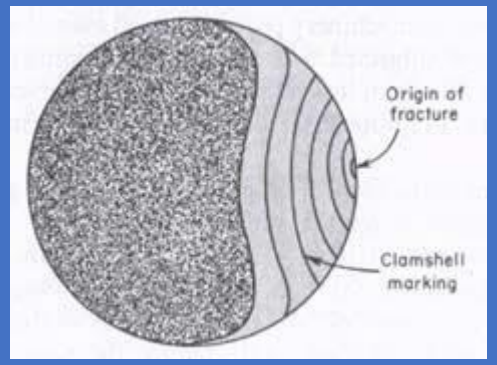
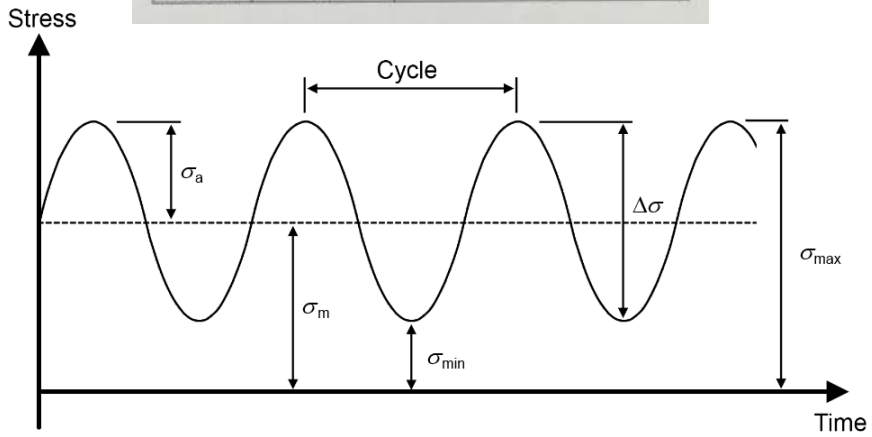
- **Thermal stress and cyclic loads - Fatigue**

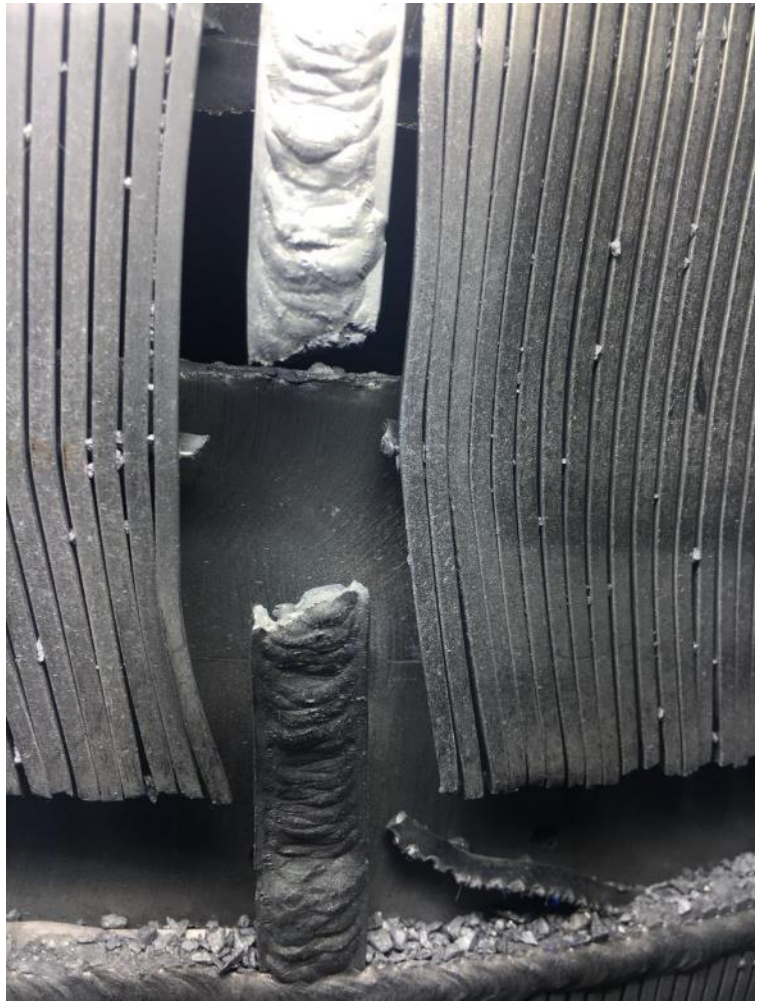
	Scenario	Stress
	Too fast start startup (high temperature gradient)	Increased axial compression on center screen
	Too fast shutdown (high temperature gradient)	Increased axial elongation on center screen
	Uneven temperature distribution due to unsymmetrical activation of catalyst (hot side + cold side)	Increased bending stresses on center screen (“Banana shape”)
	Excessive number of load cycles	Fatigue

Year	Startups	Shutdowns & Trips
2005	5	4
2006	5	5
2007	4	4
2008	3	3
2009	1	1
2010	9	9
2011	5	5
2012	8	8
2013	6	6
2014	8	8
2015	10	10
2016	5	5
2017	3	3
2018	9	10
Total	81	81



Failure analysis:-

- The basket has been subjected to an extensive number of shutdowns and startups. Every time the center screen is exposed to a thermal and mechanical stress. When this stress is applied repeatedly, then small, localized structural damages will occur in the material and the material will progressively weaken due to fatigue. The nominal maximum stress that can cause a rupture on weakened material are much less than the tensile and yield strength of the material. Thereby microscopic cracks will begin to form at the stress concentrators such as near weldings.
- Eventually a crack will reach a critical size, the crack will propagate suddenly, and the structure will fracture.



Conclusion:-

The root cause of the center screen failure is a combination of several factors:

- After long operating period under high pressure and temperature, the center screen material faced nitriding which increased the hardness of the surface making it more prone to surface cracks.
- Due to the extensive number of startups/shutdowns, the center screen have been exposed to many cycles of thermal and mechanical stresses, progressively weakened and fatigued the material.
- The center screen was exposed to a high mechanical load, during the sudden plant stoppage as caused by the power failure.
- The rupture of the fatigued material was caused by a combination of the above factors and ultimately by the power failure that the plant suffered from.

Conclusion (cont.):-

- When trying to re-operate the plant, the catalyst escaped gradually from the gap in center screen of 3rd bed till it was trapped in the chamber between the basket bottom support plate and the heat exchanger tube sheet.
- The failure of the lower heat exchanger is a follower effect of the ruptured center screen. The cause of the damage is the thermal shock from the excessive heat released by the trapped catalyst.
- The trapped catalyst and plugging of the tubes of the lower heat exchanger resulted in the high pressure difference.

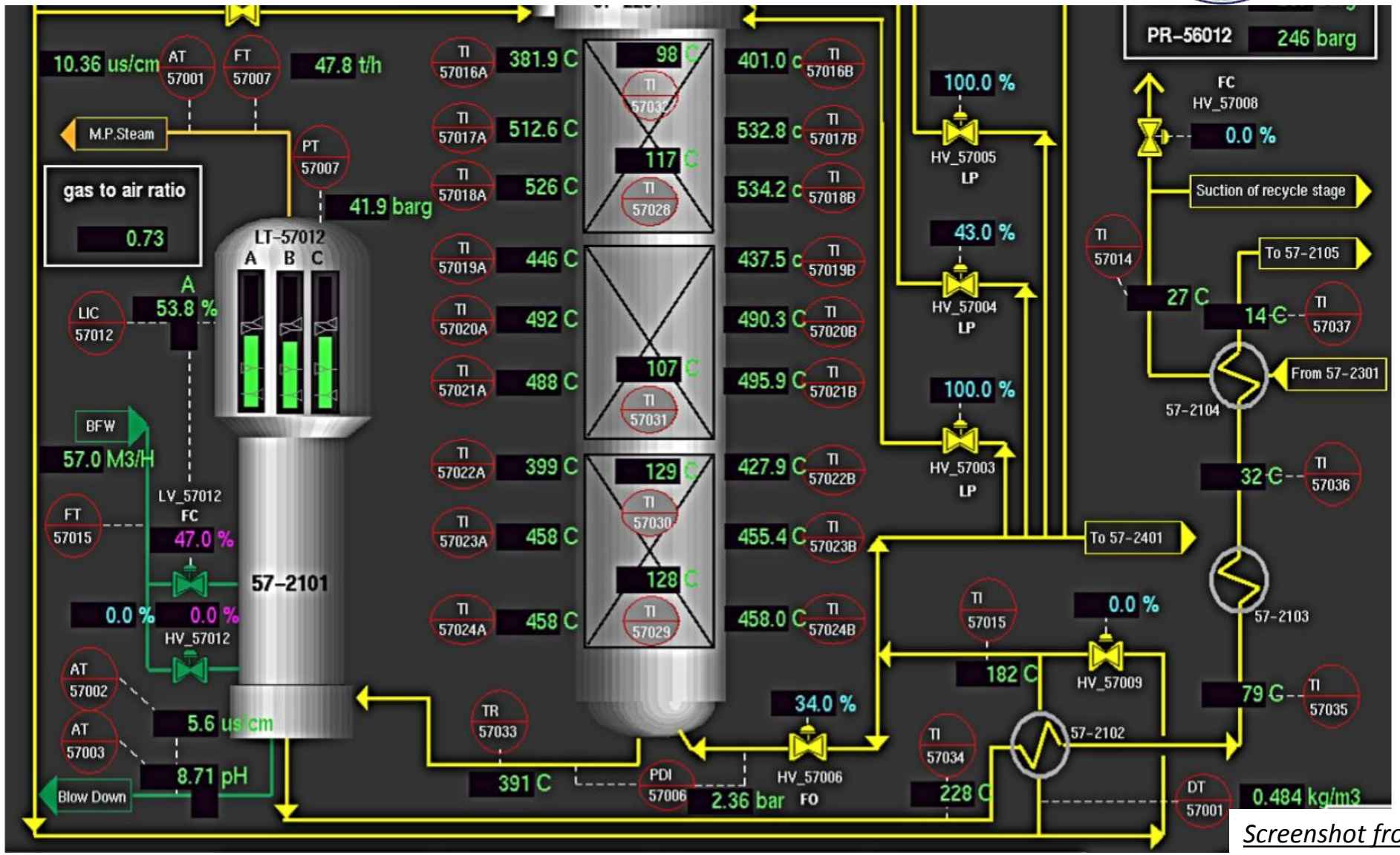
Conclusion (cont.):-

- The failure could potentially have turned into a situation of more than 3 months production stop. But due to a strong team effort between Abu Qir maintenance and Haldor Topsoe the plant was up running again after only 32 days.

THANK YOU.

QUESTIONS?

Problem description (cont.):- JAKOB



Screenshot from DCS at full load.