तेल उद्योग सुरक्षा निदेशालय
Oil Industry Safety Directorate
ISO 9001:2015 certified

सुरक्षा संवाद
Suraksha Samwad

An opportunity to learn from mistakes....

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Sh. Ravi K
Retired Executive Director, BPCL

RAVI K, retired as Executive Director from a Maharatna Public sector Oil Company in India, has thirty-six Years' experience in Project Management, HR, Refining, and renewables technologies including Plant operation & maintenance with a leading and superannuated as Executive Director.

Currently Advisor for, Detect Technologies Pvt. Ltd, a start-up company in Chennai that promotes patented Hardware and intelligent software solutions for Turnaround and Project monitoring of Process plants and cross-country pipelines including assessment of Health and condition of Process units.

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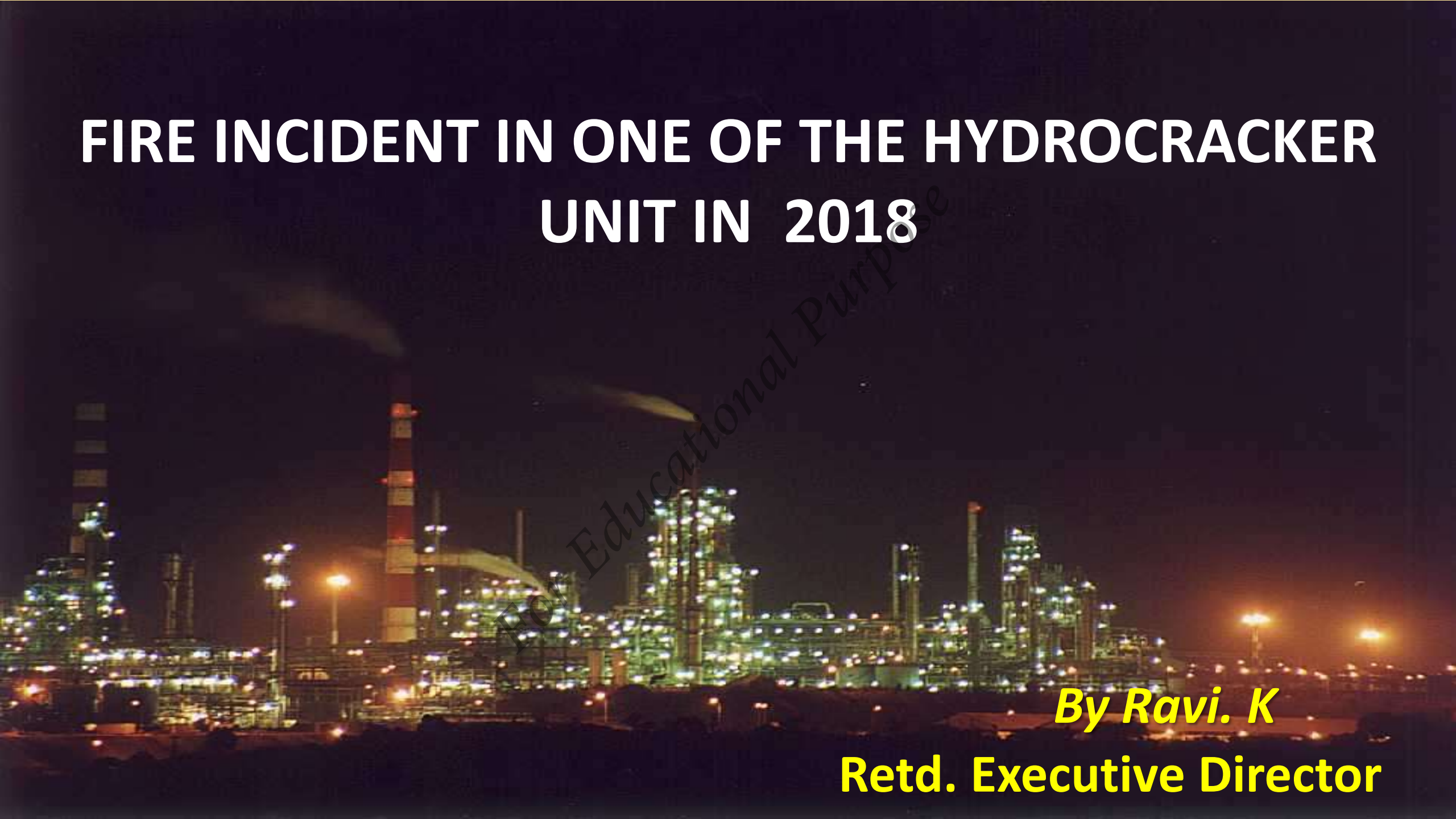
FIRE INCIDENT IN ONE OF THE HYDROCRACKER UNIT IN 2018



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By Ravi. K

Retd. Executive Director

AGENDA

- Brief description of Incident
- Preliminary Investigation findings
- Preliminary recommendations
- Detailed Investigation findings
- Recommendations
- Learnings
- Failure animated scenario

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BRIEF DESCRIPTION OF INCIDENT

A hissing sound was heard at 1442 Hrs. and simultaneously in the control room Hydrogen followed by H2S alarm sounded indicating a leak. Immediately the panel officer triggered the dump valve operation to depressurize the system and initiate a safe shutdown of the unit.

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BRIEF DESCRIPTION OF INCIDENT

Matter of seconds, the leak aggravated with a sudden release of hydrogen and hydrocarbon mixture at high volume rates when the system pressure was 160 Kg/Cm2. This vapour cloud got ignited and probably could have triggered shock wave through the earth and also through the sound waves which could have travelled to a radius of about 2-3 Km creating resonance vibration to glass panes etc. in the surrounding area.

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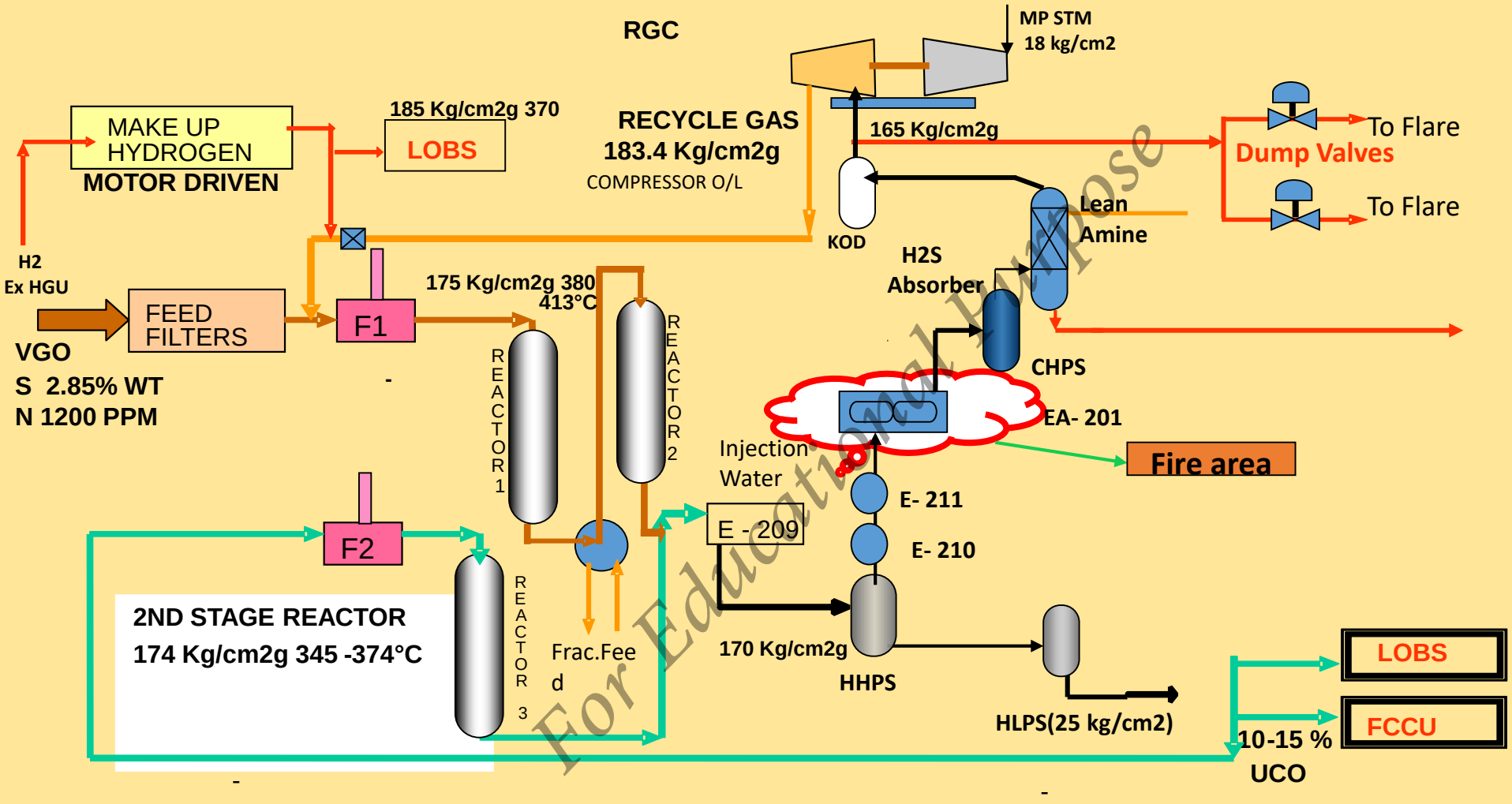
SIMPLIFIED PROCESS FLOW SCHEME



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The purpose of the Air Fin Cooler is for cooling the Hot High Pressure Separator (HHPS) outlet gases from around 145 to 60 Deg C to maximize recovery of hydrocarbon liquid from the vapour stream.

PRELIMINARY INVESTIGATION FINDINGS

- The following methodology was adopted for the investigation.
  1. Process data analysis pertaining to operation of Hydrocracker Unit
  2. Interview of personnel
  3. Inspection History of Reactor Air Fin Cooler involved
- All Process parameters of the unit (pressure, temperature, level and flow) were found normal and well within the design limits.
- Operating crew responded quickly to minimise the impact of the incident in terms of adhering to all standard operating procedures (SOP)

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PRELIMINARY INVESTIGATION FINDINGS

- Response of the firefighting crew including Mutual Aid Response Group members was excellent both in terms of availability of firefighting equipment and availability of adequate quantity and pressure of fire water and trained personnel.
- There were no fatalities. Injured personnel were immediately taken to Occupational Health Centre (OHC) for treatment, and few of them were sent to nearby hospital for further treatment.
- Primary cause of the incident was Vapour cloud fire due to weld failure of the bottom plate joint of Air Fin Cooler.

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Normally in such cases the ignition could happen due to

1. Reverse Joule Thompson effect (RJT)
2. Electrostatic Charge generation
3. Hot surface ignition
4. External Sources

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- JT is a phenomenon by which gases cool on coming thru’ a small narrow opening. However H2 gas exhibits reverse JT effect as it heats up when releasing thru’ small opening. This compounded by the friction will accelerate heating process.
- Mixture of H2 with Air when it comes along with flammable hydrocarbon can have a potential for Electrostatic ignition when during lightning, Thunderstorms etc.
- Hot surface ignition is another possibility where the leaking gases comes in contact with a hot surface.
- External sources where any spark from hot work in nearby area.

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- As there were no equipment operating at an external temperature above 200 deg.C, in the area where the vapour cloud could have traversed, the hot surface ignition possibility gets ruled out.
- Also there was no lightning / Thunderstorm at that time.
- There was also no hot work electric spark to trigger the fire.
- It was then concluded that the ignition of emitted explosive mixture containing hydrogen and hydrocarbon could be predominantly due to **RJT effect.**

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Post the Incident and cooling operations, the team inspected the Air Fin Cooler area and found that the weld seam of AFC 132-EA- 201 C had opened up at the bottom weld joint of the header box to the tube sheet (Photograph shown below):

SIDE VIEW

BOTTOM VIEW

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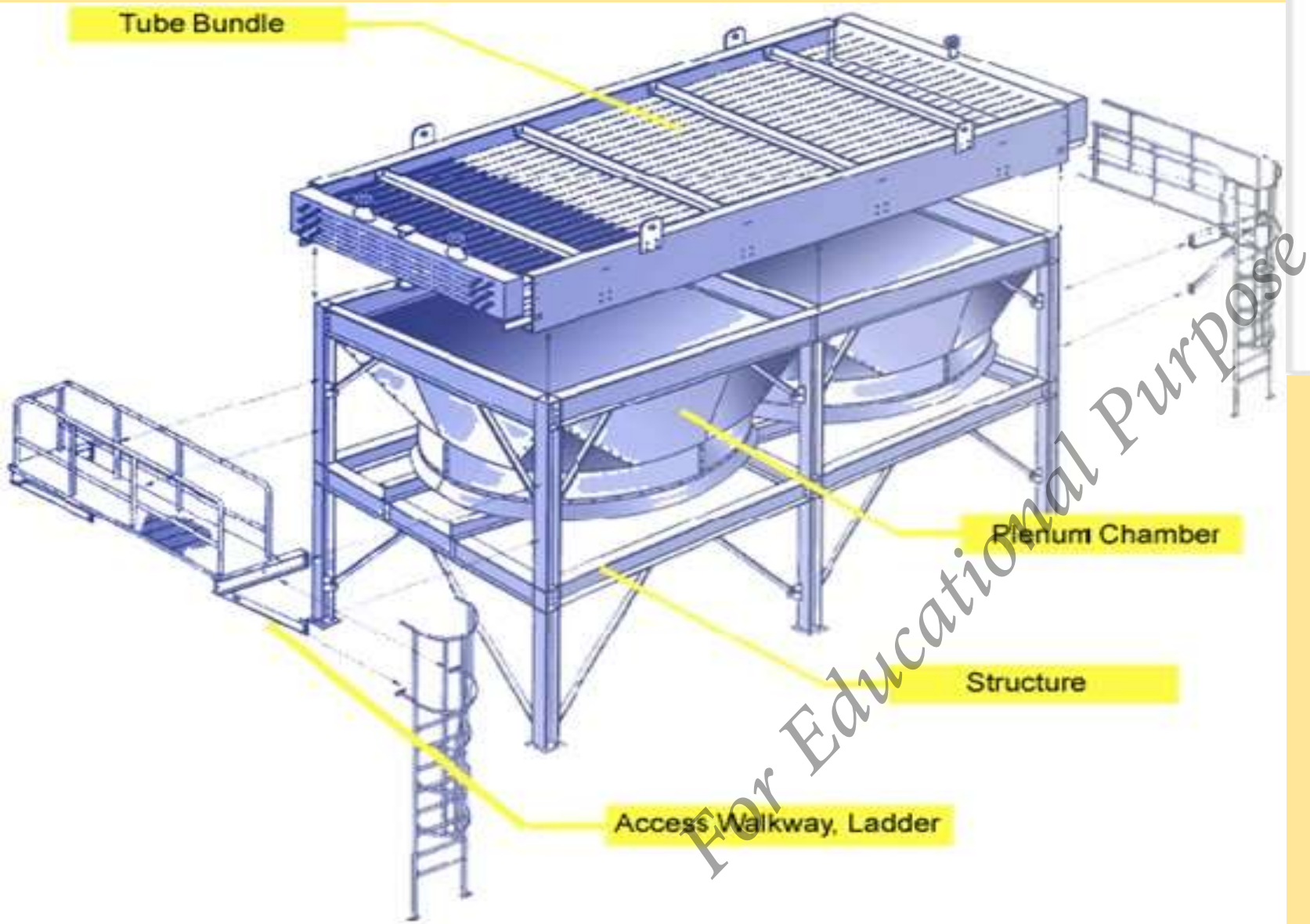

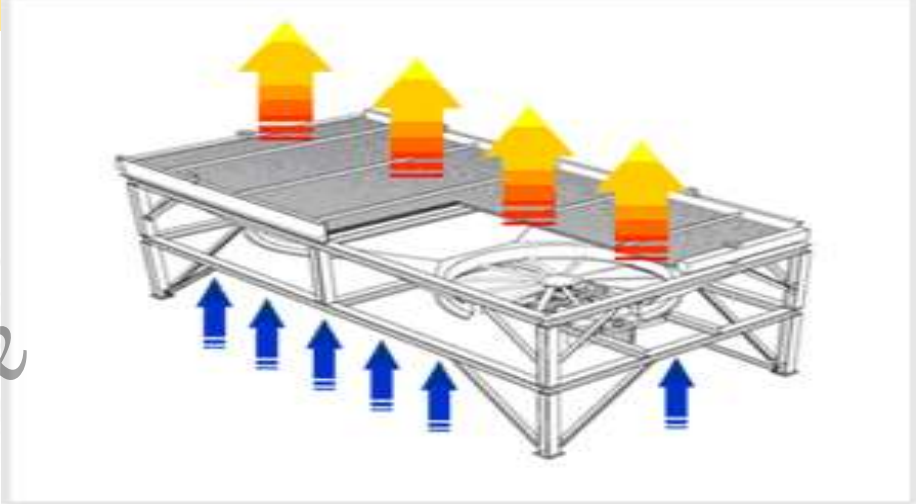

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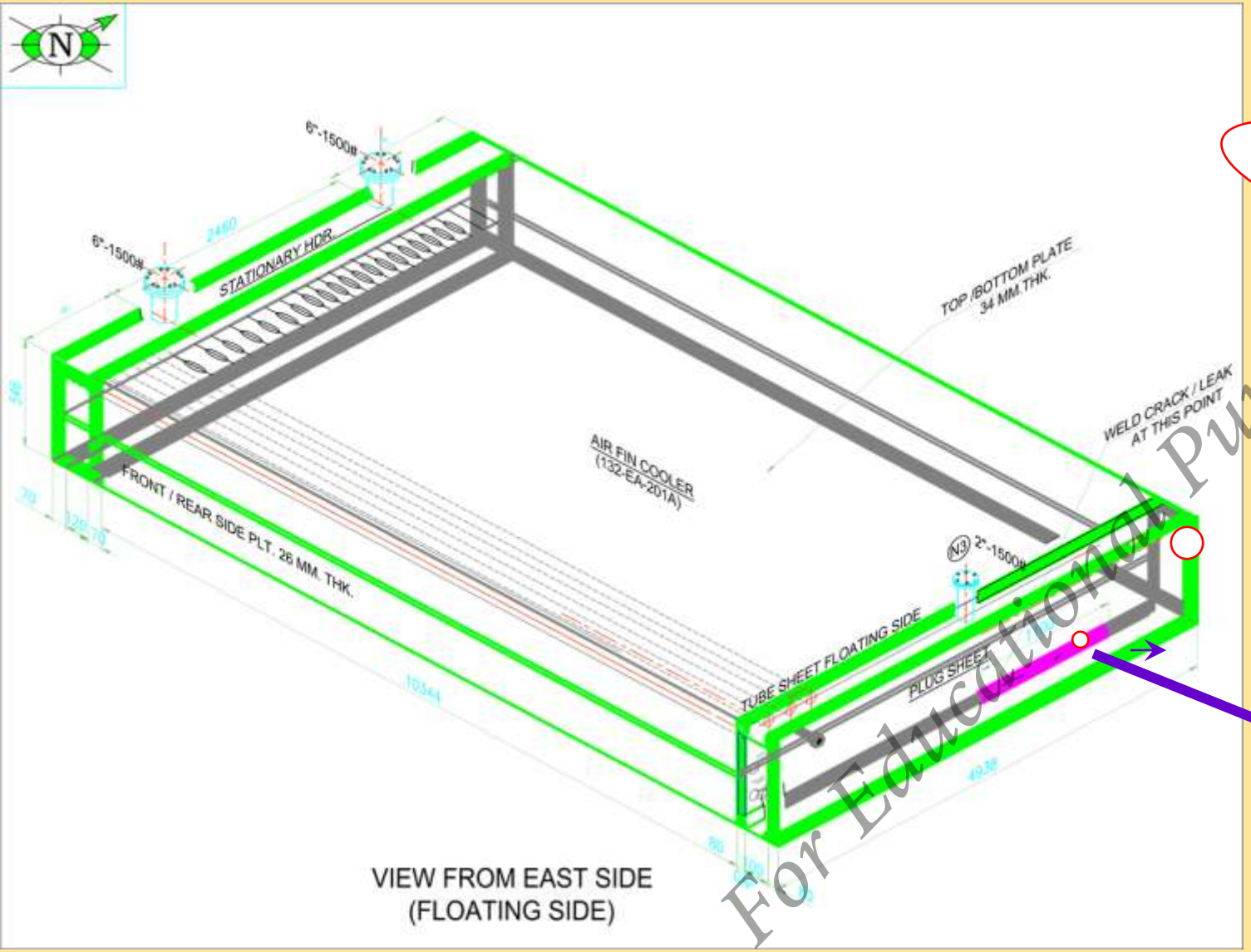
GENERAL ARRANGEMENT OF AN AIRFIN COOLER



WELD CRACK at the bottom part of Header box plate joint

- **Weld leak section**
- **Approx. length 1095mm**

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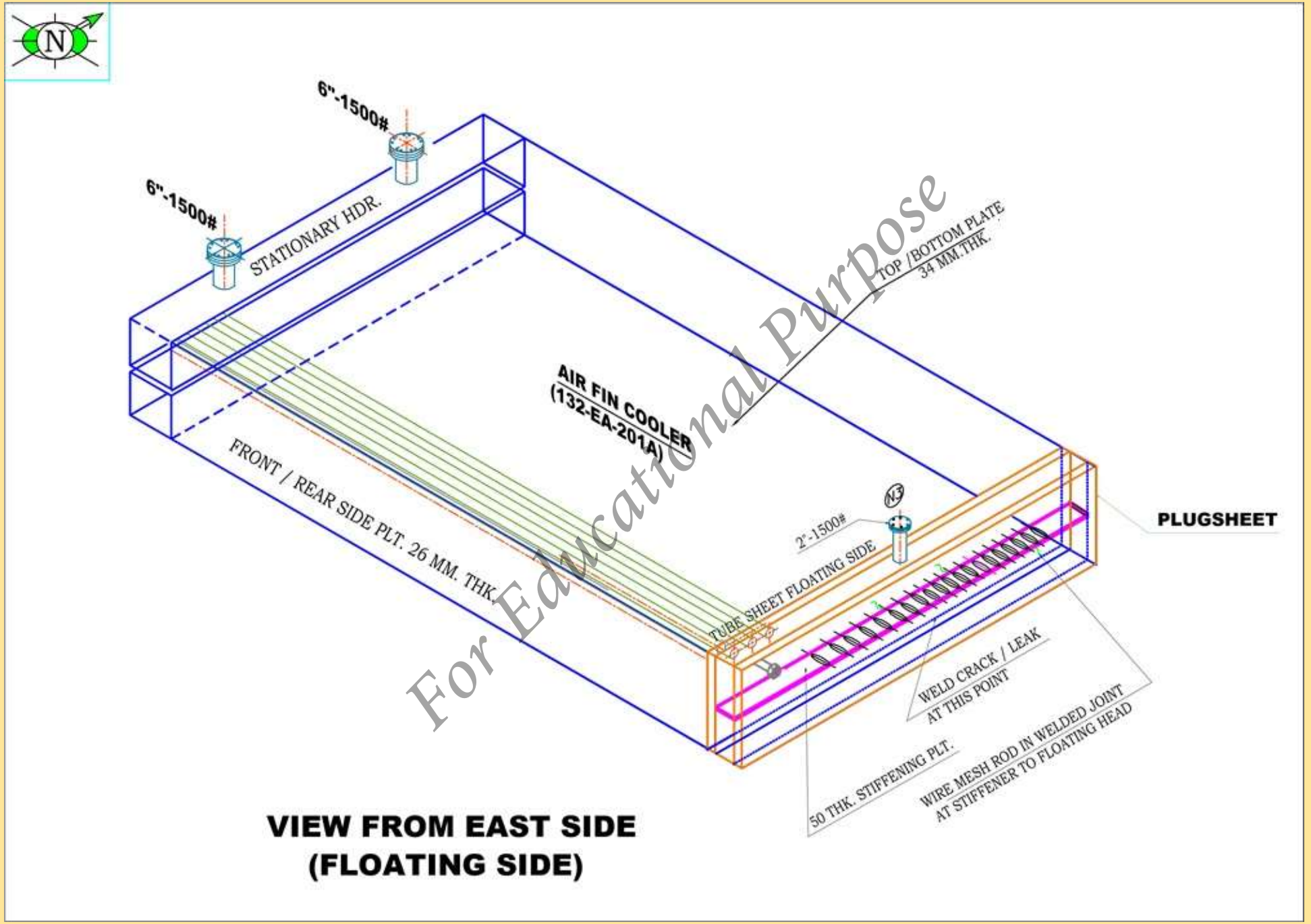
TOP VIEW OF AIR FIN COOLER HIGHLIGHTING FAILURE



VIEW FROM EAST SIDE
(FLOATING SIDE)

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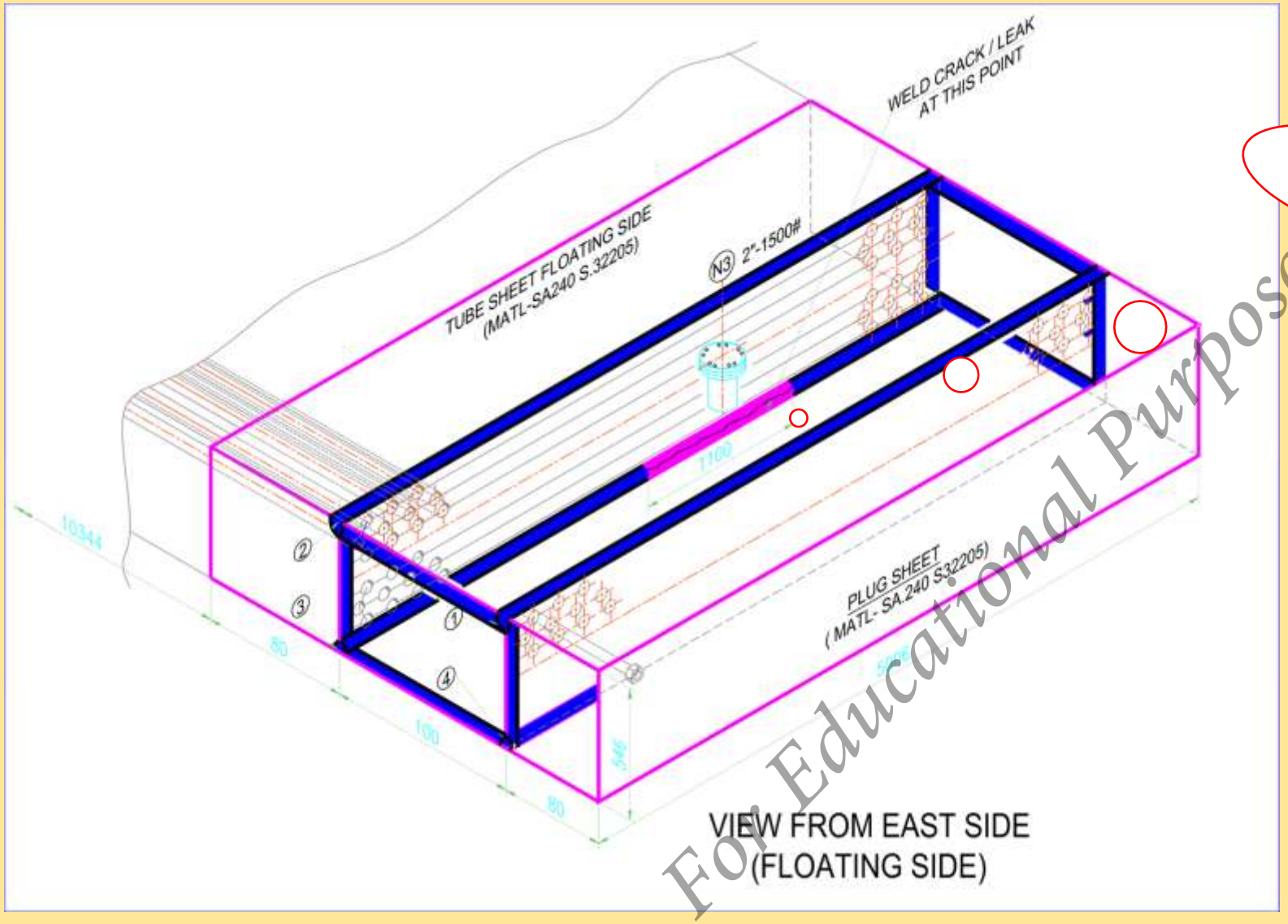

WELD CRACK at the bottom part of Header box plate joint

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VIEW FROM FLOATING HEAD WHERE FAILURE OCCURED

Reactor Effluent Air Fin Coolers (132 E 201A/B/C/D) of HCU of material Duplex Stainless steel, were manufactured and supplied by M/s. GEI Hamon Industries Ltd., in 2004 and Inspection was by Third Party Inspection agency during manufacturing and testing of this equipment. Subsequently this equipment was commissioned in 2005.

Comprehensive inspection of all the four air fin coolers, was carried out in all the scheduled turnarounds (including the last one in April 2017) and all the air fin coolers were found to be in healthy condition during the last comprehensive inspection in April, 2017.

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Preliminary recommendations:

- A detailed metallurgical failure analysis of the cracked weld may be carried out with the help of a competent agency to understand root cause of the failure which will enable to finalize the final recommendation.

- “Fit for Service” study to be carried out by an external competent agency of the Reactor Effluent Air Fin Coolers and other affected equipment in the unit to ascertain equipment health.

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DETAILED INVESTIGATION FINDINGS

- Primary cause of the incident was due to weld failure of the bottom plate joint of Air Fin Cooler.

- Based on metallurgical failure analysis of the cracked weld the following are concluded:-
  - The failure of the REC resulted in to sulfide stress corrosion cracking originating from highly stressed regions of poorly executed attachment welds of stiffener plate, followed by consequential over loading failure from the faulty weld configuration having notch between tube sheet and bottom plate, containing embedded carbon steel rod/wires due to poor fabrication quality .
  - Basically the AFCs are designed to work in H2 and Sulphide atmosphere and hence the welding of the Duplex Stainless steels are supposed to done with high precision by qualified welders with approved welding procedure.
  - However the analysis has clearly brought out that the welding was not done to the required quality even at the root level. Moreover at some weld locations there were carbon steel rods and wires put as filling along with the welds.
  - The stiffener seems to have failed first due to improper welding. As a consequence of stiffener plate weld failure, the weld between bottom plate and tube sheet having stress concentration at the root in form of embedded carbon steel rod and wires as well as deviation from original design geometry had triggered in higher stress and made it susceptible to Stress Corrosion cracking and resulted in to header box failure.

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CUT SECTIONS OF THE PORTIONS WHERE FAILURE OCCURED

Recommendations

- Extreme caution to be exercised during the selection of fabricator by approving their quality assurance system, quality control system and past proven track-record of fabricating same materials of similar design.
- Carrying out design check to ensure adequate inspectability of the design during the fabrication phase.
- The design should take into account the threshold stress values for sulfide stress corrosion cracking and fatigue analysis.
- Incorporating appropriate inspection tool to assure the quality of inaccessible welds. Use of advanced NDT methods such as crawler mounted digital radiography, crawler mounted ultrasonic testing or automated pulsed array ultrasonic testing tools should be considered for this purpose.

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LEARNINGS

What happened during initial fabrication of AFC?

The stiffener plate located inside the floating header box was supposed to have a full penetration weld joint with tube sheet and plug sheet as per approved drawing. But the metallurgical analysis revealed that, this joint was not welded properly with gaps found in the root and at some there was no welding at root.

Also carbon steel wires and pieces of carbon steel rod was also found in the root weld.

How to ensure TPI performance?

TPI shall ensure that all the fabrication aspects including weld joints are addressed in the Quality Assurance plan (QAP).

QAP shall have hold points at each critical stage.

Inspection shall be carried out by competent and experienced person who also has design engineering knowledge.

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LEARNINGS

Why it could not be found in periodic inspection?

The stiffener plate joint welding inside the header box is inaccessible for any inspection during normal turnaround Inspection.

How to ensure that such incidences are avoided in future?

Deploy advanced Non Destructive Testing (NDT) technique like Phased Array Ultrasonic testing (PAUT) for weld scanning at manufacturing stage to ensure sound welds.

Strict adherence to approved QAP.

Ultrasonic scanning and also using PAUT technique to inspect of all accessible weld joints of header boxes.

Internal visual inspection / Boroscope inspection by opening 100% header plugs.

100% tube inspection using advance NDT like Internal Rotary Inspection System (IRIS) during M&I.

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