


	<b>Steam reformer – Eddy Current Report</b> <b>Reliability Analysis</b>	<b>Report: RPT-002</b> <b>Revision: 0</b> <b>Date: April 6<sup>th</sup>, 2025</b> <b>By: O.Olatte</b>
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0	Initial Issue	OO	OO	OO	06/04/2025
Revision	Description	By	Checked	Approved	Date

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## 1. Introduction

This report details a reliability analysis to the reformer status based on Eddy current inspection results report to the catalyst tubes installed in the Reformer US-01-103-R-0100, located at VertGTL plant in Lake Charles, LA. As an additional antecedent, is considered a report based on a LOTIS inspection report from 2004, issued by LENA (Linde) in 2013 as preparation to the reformer inspection and works made in 2014.

The EC inspection was performed in 2014 after ten (10) years of service and results show that it is reasonable to conclude that the tubes are in the third stage of creep with some tubes presenting evident creep damage, other incipient damage and others no indication of evident damage. On the other and, the LOTIS report was performed in 2004 and also reports creep damage in the form of tubes bulging. It can be said that both reports are congruent on the results presented.

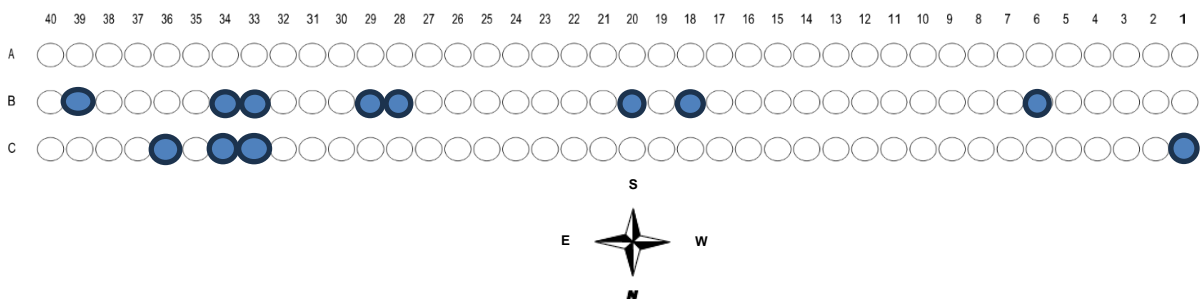
It is relevant for the purposes of this analysis to point out that tubes where creep damage was not detected by the EC inspection technique are not free of creep damage and are only in early stages of the failure mechanism not detectable by EC.

The scope of this report covers only the results of the Eddy current inspection performed and Linde report. No process or maintenance information was available for analysis. Some conclusions and recommendations are proposed for future operation.

## 2. Information Reviewed

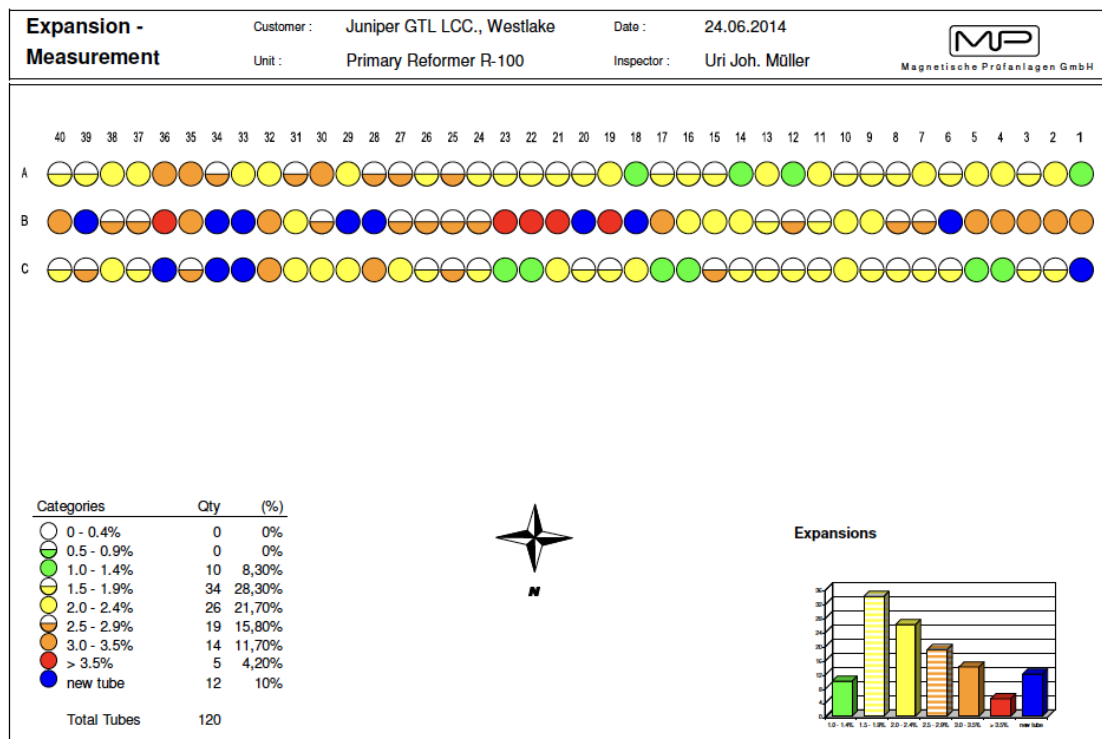
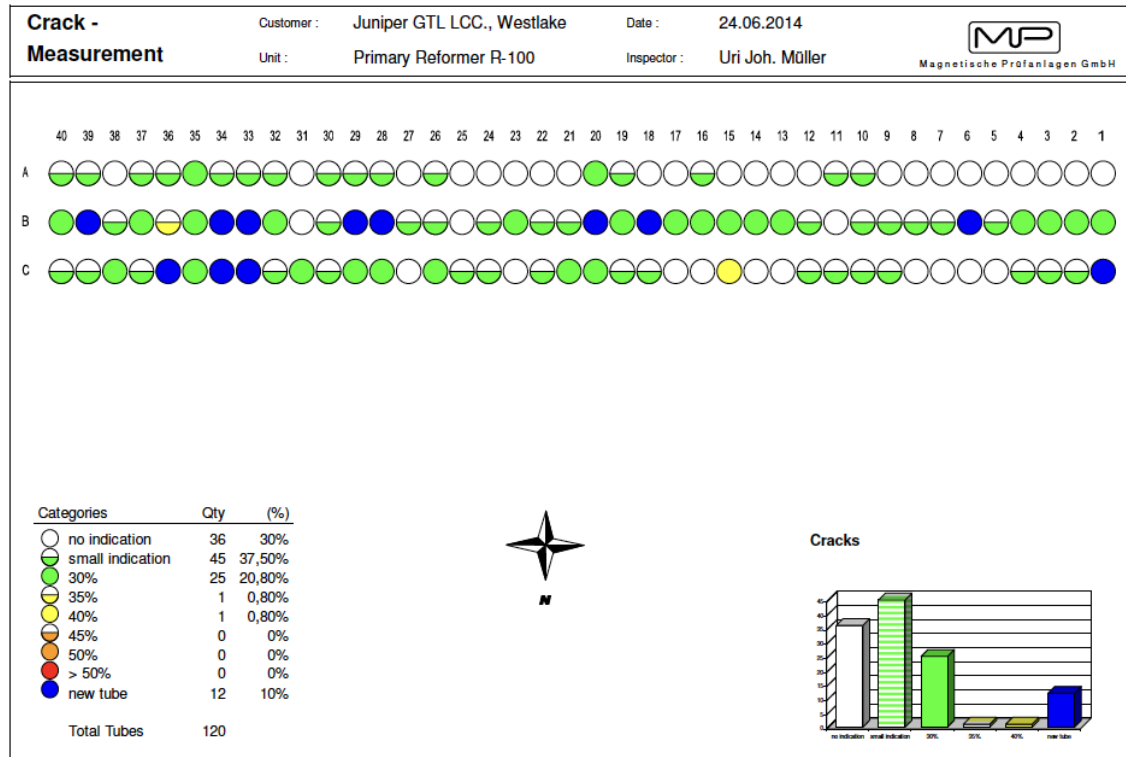
### General

- The EC results report was issued on: June 26<sup>th</sup>, 2014 (during the refurbishment construction).
- Number of tubes inspected: 120 Catalyst Reformer Tubes.
- Shape of furnace: 3 rows, 40 tubes each.
- Tube material: Pyrotherm G25/35Nb (POSE - MARRE).
- Tube dimensions:
  - O.D.: 5.59" (Ø 142 <sup>+1.5</sup> mm)
  - MSW: 0.607" (15.45 mm)
  - I.D.: 4.3125" (Ø 109.5 <sub>-1</sub> mm)
- Age of the Tubes: Installed in 1994 approx. **10 years** of operation until 2005. It is assumed that between 2005 and 2014 tubes saw no service.
- Furnace has been in operation and served for a PRAXAIR HYCO plant from 1994/1995 until September 2005.
- Tubes replaced in late 2004:
  - Row-A: None
  - Row-B: #6, #18, #20, #28, #29, #33, #34 and #39
  - Row-C: #1, #33, #34 and #36

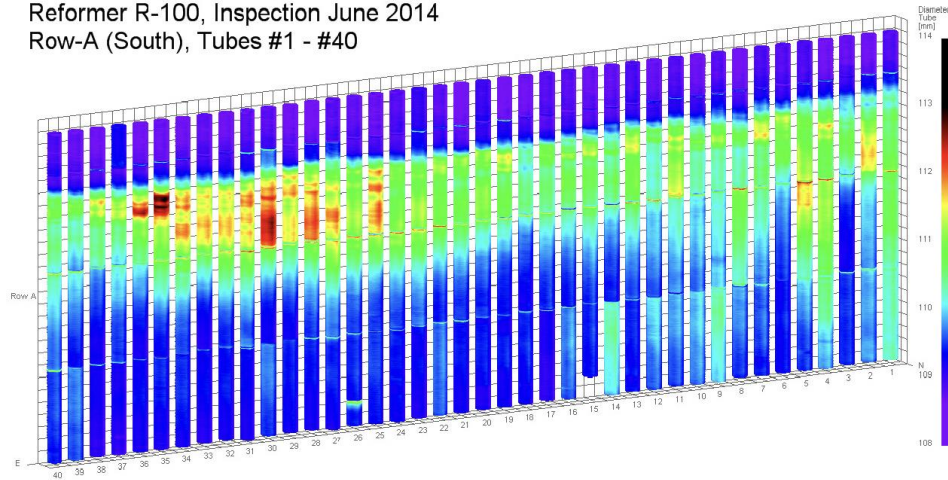


- The inspection system contained an eddy current defect detection system, *penetrating the complete tube wall*, and a simultaneous measurement of the *outside tube diameter* with a dual laser device.
- All 120 reformer tubes of the Reformer R-100 were also inspected with an *ID measuring device*.

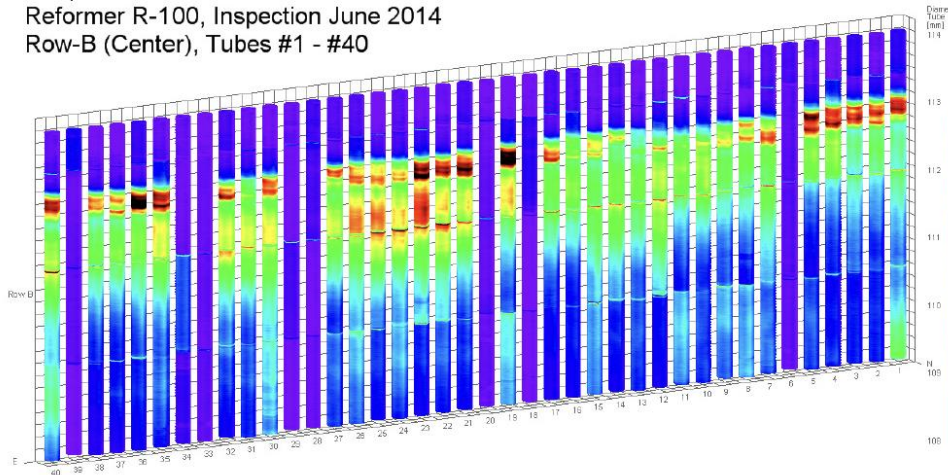
## Inspection Results



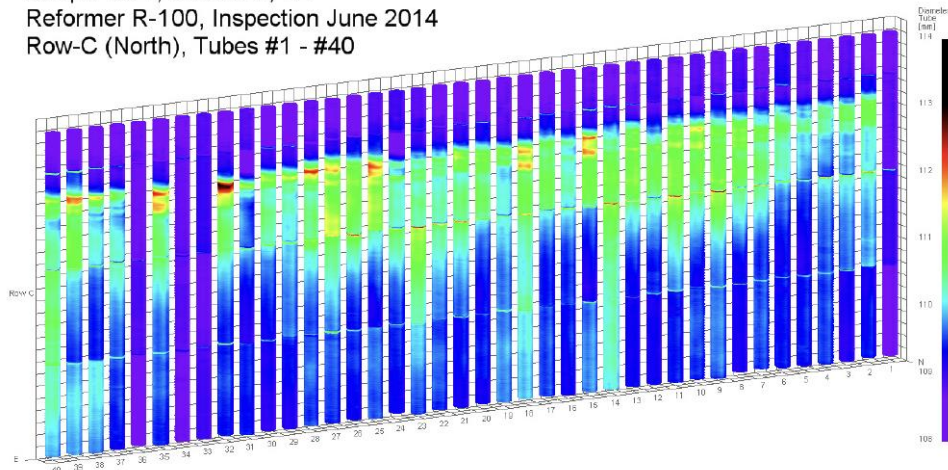
Juniper GTL, Westlake, LA  
Reformer R-100, Inspection June 2014  
Row-A (South), Tubes #1 - #40



Juniper GTL, Westlake, LA  
Reformer R-100, Inspection June 2014  
Row-B (Center), Tubes #1 - #40



Juniper GTL, Westlake, LA  
Reformer R-100, Inspection June 2014  
Row-C (North), Tubes #1 - #40

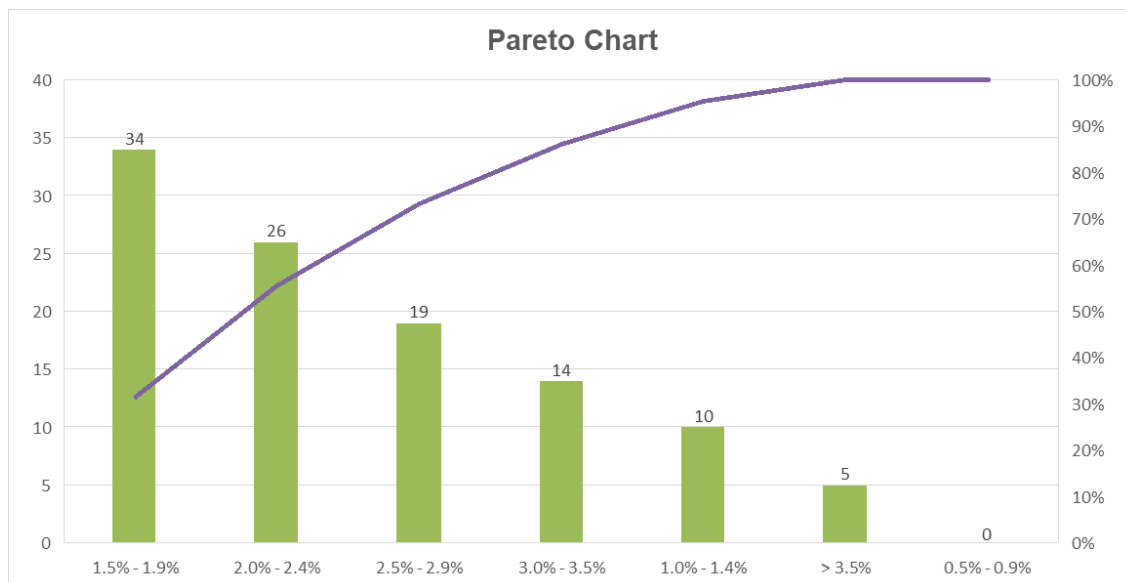


### 3. Reliability Analysis

#### 3.1 Data Analysis

Additional to the information provided on the EC inspection report, the following may be deducted from the results of the inspection:

<b>Tubes with SMALL indications:</b>	<b>45</b>
<b>Tubes with 30% of thickness damaged:</b>	<b>25</b>
<b>Tubes with 35% of thickness damaged:</b>	<b>1</b>
<b>Tubes with 40% of thickness damaged:</b>	<b>1</b>
<b>Tubes with 45% of thickness damaged:</b>	<b>0</b>
<b>Tubes with 50% of thickness damaged:</b>	<b>0</b>
<b>Tubes with more than 50% of thickness damaged:</b>	<b>0</b>
<b>72 out of 120 tubes present damage</b>	<b>60.0%</b>
<b>Max damage registered is 40% of the thickness</b>	
<b>37.5%</b>	<b>Show small damage detectable by Eddy Current</b>

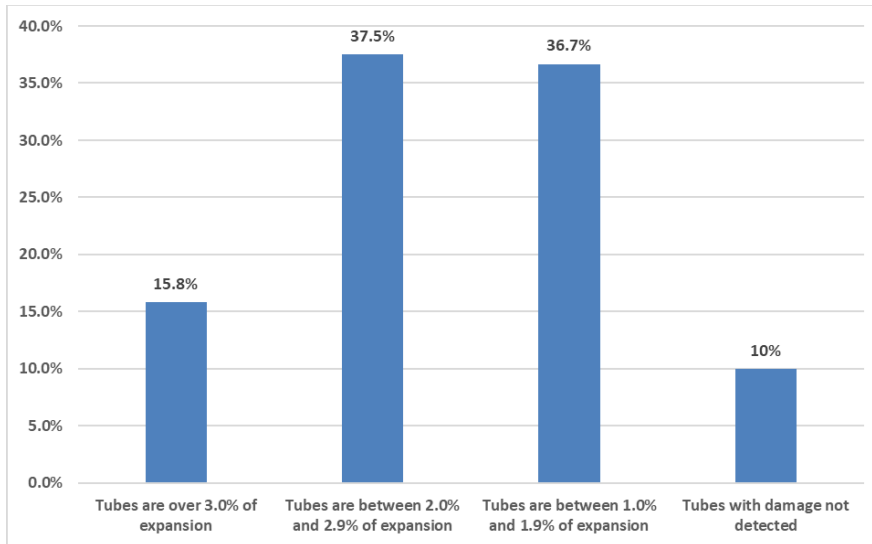


<b>15.8%</b>	<b>Tubes are over 3.0% of expansion</b>
<b>37.5%</b>	<b>Tubes are between 2.0% and 2.9% of expansion</b>
<b>36.7%</b>	<b>Tubes are between 1.0% and 1.9% of expansion</b>
<b>10%</b>	<b>Tubes with damage not detected</b>



Maximum expansion detected	4.40%	B	36		
Tubes with max expansion	1				
Minimum expansion detected	1.20%	A	18	C	4
Tubes with min expansion	2				

It can be observed that the great part of the tubes today are in the range between 1.0% y 2.9% with a distribution quite normal. See figure below.



This reveals that there is a great number of tubes that are progressing to 3% and above expansion. It can be seen that the tubes over 3% tend to be greater than those with no damage detected, insinuating a growing tendency of these tubes. This transition depends on temperature, time and transients in service. This applies despite the number of tubes removed and replaced.

As presented on the Pareto chart, the tubes 3% or above in diameter expansion have to be replaced to avoid an unexpected and expensive reformer shutdown.

### 3.2 Conclusion of the Eddy Current Report - 25th of June 2014

#### Summary


Typical hydrogen reformer catalyst tubes suffer the most heat at the bottom of the tube.

All 120 tubes in the R-0100 hydrogen reformer do not show any sign of crack signals or major expansion values at the bottom of the tube.

Significant tube expansion values were found in the upper section of the firebox caused through issues with the burners. It is suspected that the flames were almost touching the tubes through false circulation or bad flame patterns.

SGE Energia / Juniper GTL scheduled already to replace all the burners in this furnace.

It is recommended to replace the worst tubes with an eddy current crack signal of more than 30% and/or an expansion of more than 3.5%. This consideration would require replacing six tubes, namely tubes **B19 (#59) – 3.9% expansion, B21 (#61) – 3.5% expansion, B22 (#62) – 3% expansion, B23 (#63) – 3.8%, B36 (#76) – 4.4% expansion and C15 (#95) – 2.70% expansion.**

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As a follow up of implemented measures, it was suggested to execute a subsequent inspection (only OD and EC) of this furnace after a rather short time period of no more then **1-2 years operation**.

**Tubes new at the time of the inspection (LOTIS results): 12; Tubes recommended for replacement as per EC results: 6**

New Tubes (LOTIS)	B-6	B-18	B-20	B-28	B-29	B-33	B-34	B-39	C-1	C-33	C-34	C-36
Tubes to Replace (Eddy Current)	B-19	B-21	B-22	B-23	B-36	C-15						

New situation should all these replacements were executed:

Maximum expansion detected	3.50%	B	35		
Tubes with max expansion	2				
Minimum expansion detected	1.20%	A	18	C	4
Tubes with min expansion	2				

Crack signal of 40% wall damage on the tube #15 in row C (#95).

Significant eddy current crack indication with a 35% wall damage signal has been recorded on tube #36 in row B (#76).

25 tubes in this furnace do have a crack indication in the range of 30%.

A total of 45 tubes in the R-100 reformer showed minor indications, which were categorized in the data sheet as “Small Indication”.

**These registered small indications are still so small in size compared to the calibration standard, that they are not categorized yet.**

All of the above mentioned eddy current crack signals between “Small Indication” and 40% wall damage are found on the upper tube section at a distance of approx. 1.4m from the ceiling. None of the tubes do show any crack signal in the lower tube section towards the manifold.

### 3.3 Linde Report

Title: TECHNICAL SUMMARY FOR R-100 CATALYST TUBE REVIEW

Date: July 23<sup>rd</sup>, 2013

Author: H.Le

#### Antecedents

- The reformer was built and installed by LENA in 1994.
- In 2004, Praxair contacted Quest TrucTec to inspect the reformer tubes of R-100 Hydrogen Reformer.
- Tubes replaced implementing the recommendation from Quest TrucTec and the reformer operated until Praxair shutdown the entire unit in 2005. The reformer never restarted.

#### Inspection Results (Notes are from O.Olatte)

Outside of LOTIS examination, no other non-destructive test was done on the coils.



During the inspection, numerous tubes were found which contained **creep strain greater 3%**.

- 31 of the 120 tubes inspected (**25.8%**) contained inner diameter of **>3.0%** creep expansion
- 51 of the 120 tubes inspected (**42.5%**) contained inner diameter between **2.0% - 2.9%** creep expansion
- 38 of the 120 tubes inspected (**31.6%**) contained inner diameter between 1.0% - 1.9% creep expansion

**Note: 68.3% with a major compromise due to creep damage.**

Praxair replaced 12 tubes that have maximum percent growth in the tube inner diameter range from 3.3 % to 5.6% with the 12 existing spares. The replaced tubes were: 45, 46, 60, 68, 69, 73, 74, 81, 112, and 114.

**Note:** Using the Eddy current tubes designation these tubes replaced are: B-5, B-6, B-20, B-28, B-29, B-33, B-34, C-1, C-32 (C-33?) and C-34. USTT detected this tubes as new tubes in the 2014 inspection.

LENA recommendation was to replace all tubes with the maximum % growth in the tube inner diameter over **3%**. The (20) tubes need to be replaced: 35, 36, 41, 42, 43, 47, 48, 57, 59, 61, 62, 63, 67, 72, 76, 77, 80, 113, 115, and 116.

**Note:** Using the Eddy current tubes designation these tubes replaced are: A-35, A-36, B-1, B-2, B-7, B-8, B-17, **B-19, B-21, B-22**, B-27, B-32, **B-36**, B-37, B-40, C-33, C-35 and C-36. Tube in bold coincide with Eddy current report recommendation for tubes replacement. Apparently since these tubes are again found during the EC inspection, it can be assumed that the LENA recommendation was partially followed or ignored.

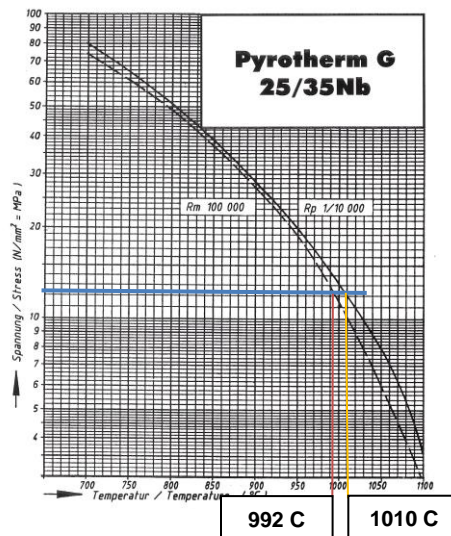
Per API 530, catalysts tubes are designed to last for total life cycle of 100,000 hours, or approximately 11 years of continuous service. Given the design conditions and design thickness, pressure part calculation is done and determined expected life for catalysts tubes is **135,000 hours**.

Per calculation, the catalysts tubes have **4 years of remaining life**. However, LENA suggests **preparing for coil replacement within the next 4 years of operation** reason is the impacts on the catalysts tubes are unknown during operation period after the Quest inspection and prior to shut down in 2005 because of **insufficient data from operation**. Plus, **statistically half of the original tubes will likely become unserviceable within 4 more years of operation given same operation condition**.

Creep stress rupture: 10.24 MPa.

Temperature: 871C (Fluid), 971C (design)

**Note:** USTT identify tubes as Pyrotherm G25/35Nb (POSE - MARRE)

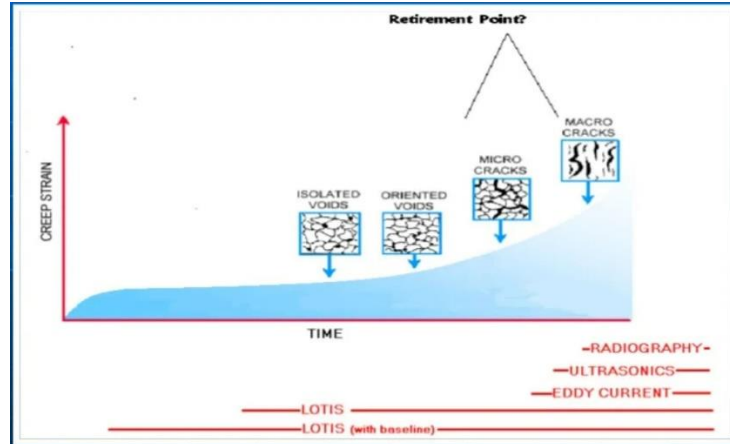


**Note:** at the design stress the Pose Maree material fits the 100,000 hrs (min) and plus rupture life. At the design pressure the allowable temperature for 100,000 hrs is about 992 C. Design temperature is 971C. The service life designed of 135,000 is credible.


The problem detected here is not one about design is a malfunction of the arch burners system. Causes have to be investigated in order to find a solution.

## 4. Discussion and Recommendations

- 4.1 It is apparent that the reformer operated until 2005 when tubes had already 10 years of service. In 2004 an inspection with LOTIS was done to the tubes and the report on results was commented by Linde.
- 4.2 Apparently the reformer did not operated since 2005 and in 2014 works were executed again including a Eddy Current inspection to the tubes.
- 4.3 From both reports it is possible to conclude that tubes with higher diametral expansion were removed and replaced with new tubes.
- 4.4 The information gathered from both inspections lead to the conclusion that the upper section of the tubes is facing end of life or third creep stage.
- 4.5 It is relevant to point out that the Eddy Current respond, obviously, to the sensitivity of the technology, hence, a tube showing no defects, not necessarily is free of creep damage. This may be the case of row A tubes which present a number of tubes with “no defects”. The following figure presents the sensitivity comparison between some NDE technologies in the creep damage detection of creep damage.



- 4.6 It is clear that the arch burners functioning and / or operation need a thorough revision as it is clear that the damage seen to the date is related to flame impingement. This issue needs to be addressed looking to a prolonged tubes operation. This may involve a change in design or replacement of the burners.
- 4.7 From both USTT and Linde report it can be concluded that 18 tubes (15%) have been replaced since 2004.
- 4.8 Though the design seems to be adequated considering Metalteck or Pose Maree tubes, it is apparent that the progression of the damage and the inspection results point to the fact the tubes already reached the third stage of creep damage at the top section. This makes difficult to predict future performance of the tubes left inside the radiant section after the two inspection executed in 2004 and 2014. This is based mostly on the exponential growth nature of the third stage of creep which is very dependent on operation and transients the reformer is submitted to.

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- 4.9 In order to ensure a more reliable operation considering the tubes condition after start up, it is key to ensure the arch burners are inspected and repaired / redesigned prior to service. Also a revamping of the reformer should be planned and executed.
- 4.10 In paralell, if no replacement or revamp is performed, a set of new tubes should be kept on site ready for replace failed tubes. The number should be at least 20 tubes to cover all possible failures that occur to tubes with diameter expansion over 3%.
- 4.11 Operation conditions should also be evaluated in order to avoid damaging the tubes in service due, for example, to overheating incidents or transients due to trips.