ASIA TURBOMACHINERY & PUMP SYMPOSIUM
SINGAPORE | 22 – 25 FEBRUARY 2016
MARINA BAY SANDS

TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

TEXAS A&M UNIVERSITY

ExxonMobil

HITACHI
Inspire the Next

Polytropic Efficiency Improvements and Sustenance on Centrifugal Compressor: Corrosion Erosion and Impact of Fouling

	Author	Organization
1	Tan Chek Zin	ExxonMobil, Singapore
2	Ng Wei Sing	
3	Arni R. Tharakaram	
4	Satoshi Koguchi	Hitachi Japan

Presenter

	Author	Position	Working Experience	Organization
1	Tan Chek Zin	Machinery Engineer	7-years supporting maintenance & technical in the refinery.	ExxonMobil Singapore
2	Ng Wei Sing	Machinery Engineer	7-years supporting maintenance & technical in the refinery.	
3	Arni R. Tharakaram	Lead Machinery Engineer	15-years supporting maintenance & technical issue regard rotating equipment.	
4	Satoshi Koguchi	Compressor Designer	12-years working experience in Hitachi supporting design department.	Hitachi Japan

Abstract

This paper presents a case study on the rapid deterioration of compressor polytropic efficiency relating to systemic fouling and corrosion issues. Due to such issues, compressor service life was reduced from 10 years to only a few years. All compressor overhauls were driven by compressor polytropic efficiency drop hovering between 10 to 22%.

Elemental analysis of samples collected from the internal of compressor confirmed the presence of possible fouling /corrosion. The aluminum labyrinth was the first to suffer, followed by trailing face of the impeller. Deep grooving damage was evident for 1st, 2nd and 3rd inter-stage labyrinths that were fully filled with black particles.

Extensive improvement studies were conducted to manage system corrosion and liquid ingress in order to improve compressor reliability and polytropic efficiency sustenance.

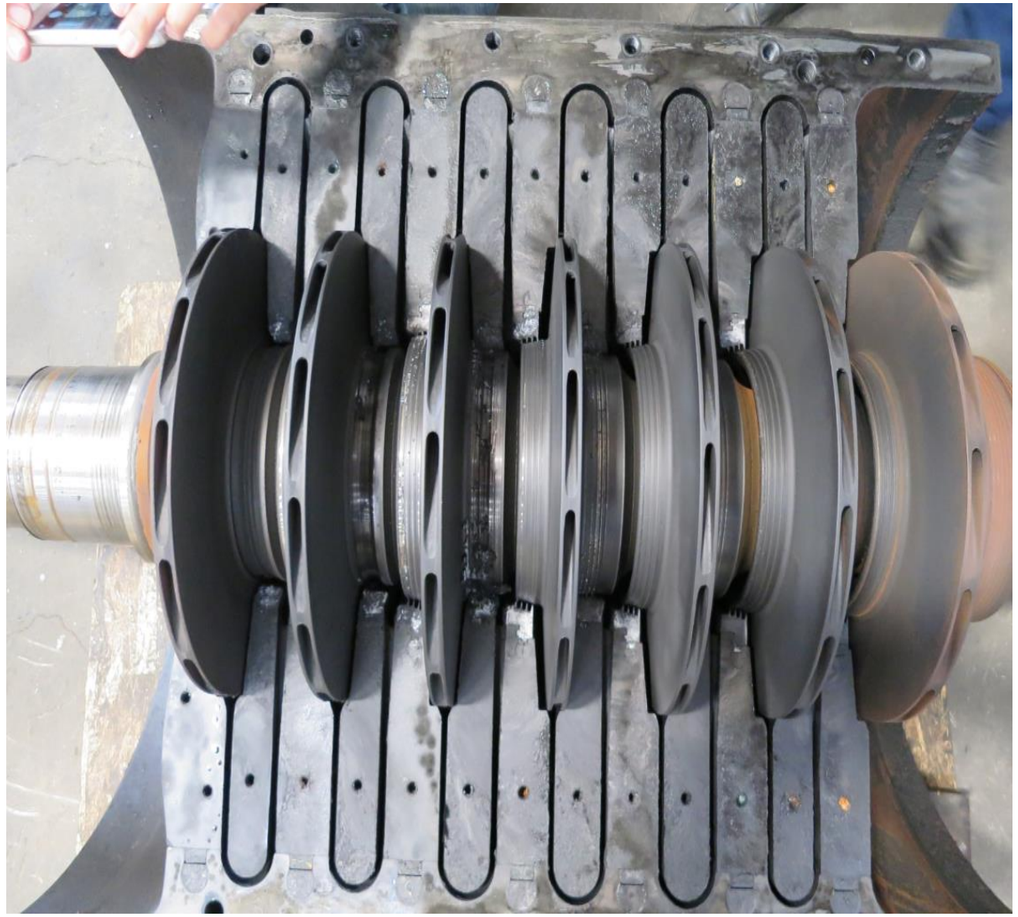
Problem Statement

- Frequent polytropic efficiency drop due to fouling/erosion/corrosion inside compressor
- Unable to achieve design/rated polytropic efficiency after 2nd overhaul
- Compressor service life getting shorter (from 10 years to a few years)
- Compressor overhauls were driven by compressor polytropic efficiency drop hovering between 10 to 22%
- Radial vibration was increasing when polytropic efficiency drop by 22%

How to Tackle/Resolve the Problem

- Observation for past compressor overhauls
- Elemental Analysis on the fouling/particle inside compressor / system
- Unit Creep Up vs Compressor Overhaul Frequency
- Surface grinding on inner casing and diaphragm
- Improvement on system / piping modification
- Improvement on compressor design / modification (under evaluation)

Machine Details

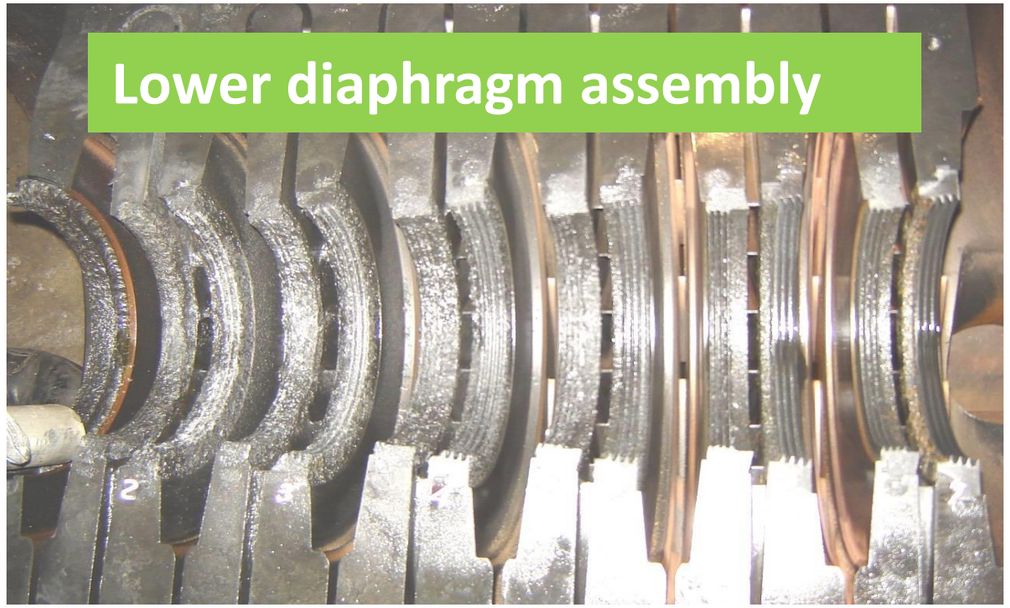


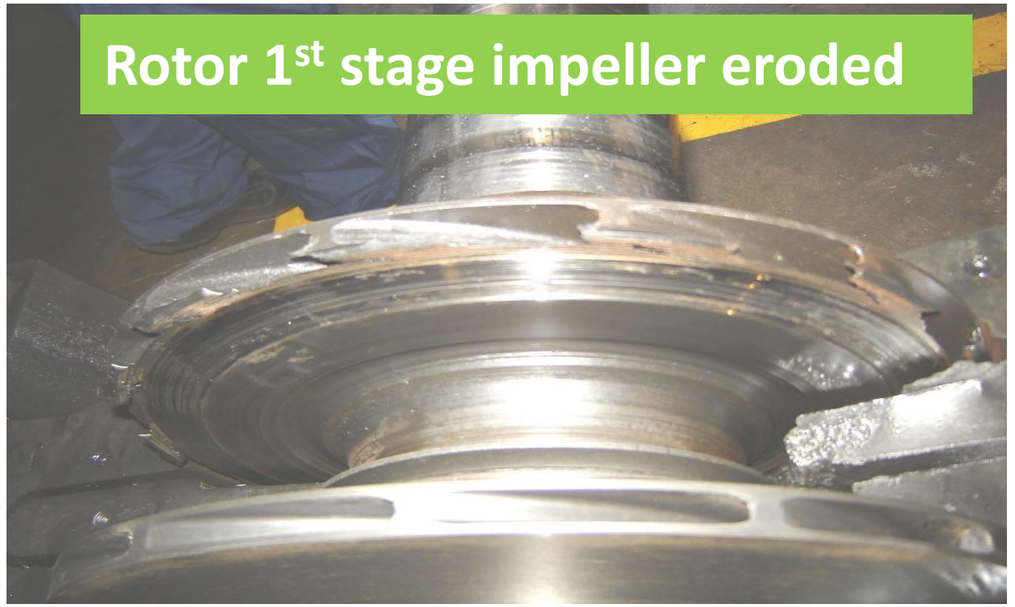
- Hydrogen service
- 7-stages compressor
- Steam Turbine driven (1.25MW)
- 7,000 rpm to 12,968 rpm
- Suction Pressure = 15,000 KPaG
- Discharge Pressure = 19,000 KPaG
- Oil Film Seal
- Aluminum labyrinth
- Buffer Gas (H_2) from Make-Up Compressors (lubricated reciprocating) compressor)

Impeller Diameter	340
Type	Enclosed
Material	13% Cr SS (AISI 414)

First Overhaul Observation

- Compressor efficiency downtrend detected
- Heavy deposit of black muddy scales in the compressor diaphragm
- Severe erosion in 1st stage rear impeller shroud
- Severe erosion of impeller labyrinths from 1st stage to 3rd stage
- Pitting marks found in the compressor 1st and 2nd stage impeller
- 3rd to 7th stage impellers found in good condition





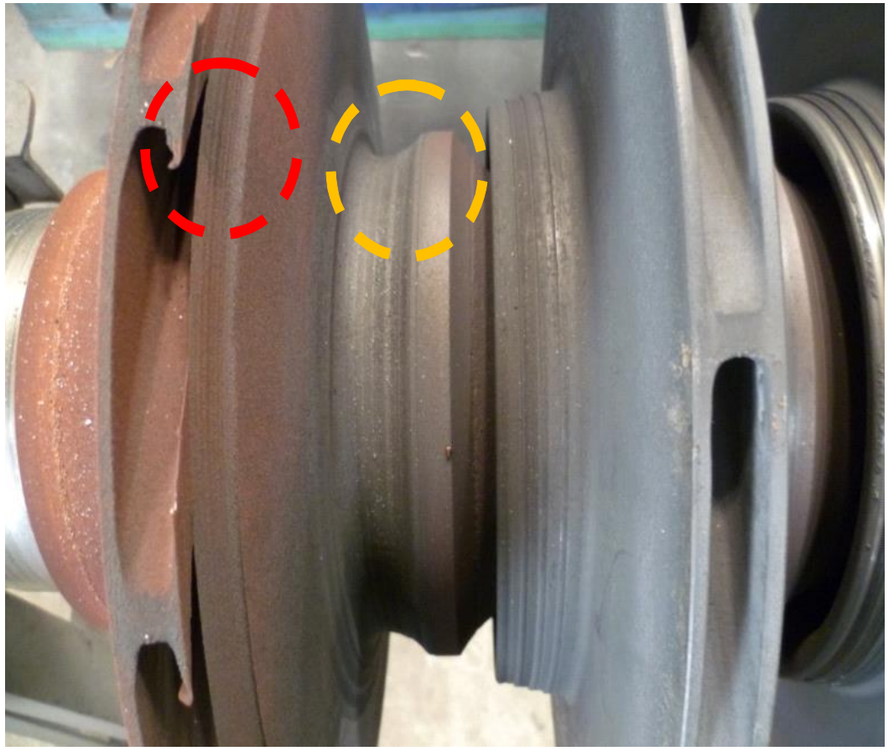
Second Overhaul Observation

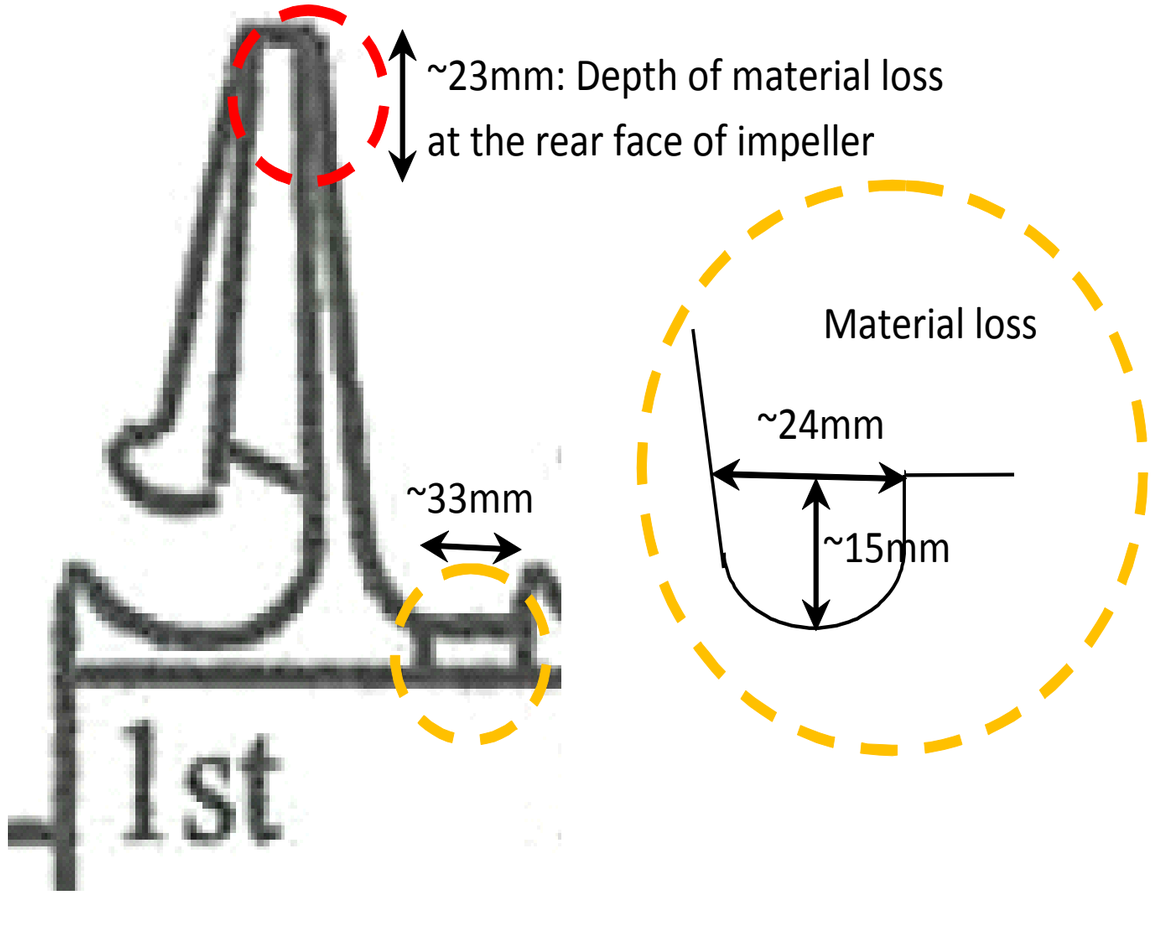
- Compressor efficiency downtrend detected
- Radial vibration was increasing prior to overhaul
- Severe erosion in 1st stage rear impeller shroud
- 2nd & 3rd stage rear impeller observed rubbed
- Severe erosion for all impeller labyrinths
- Pitting marks found in the compressor 1st to 6th stage impeller. (1st to 6th stage impeller replaced)

1st Stage Impeller damages

Impeller labyrinth corroded

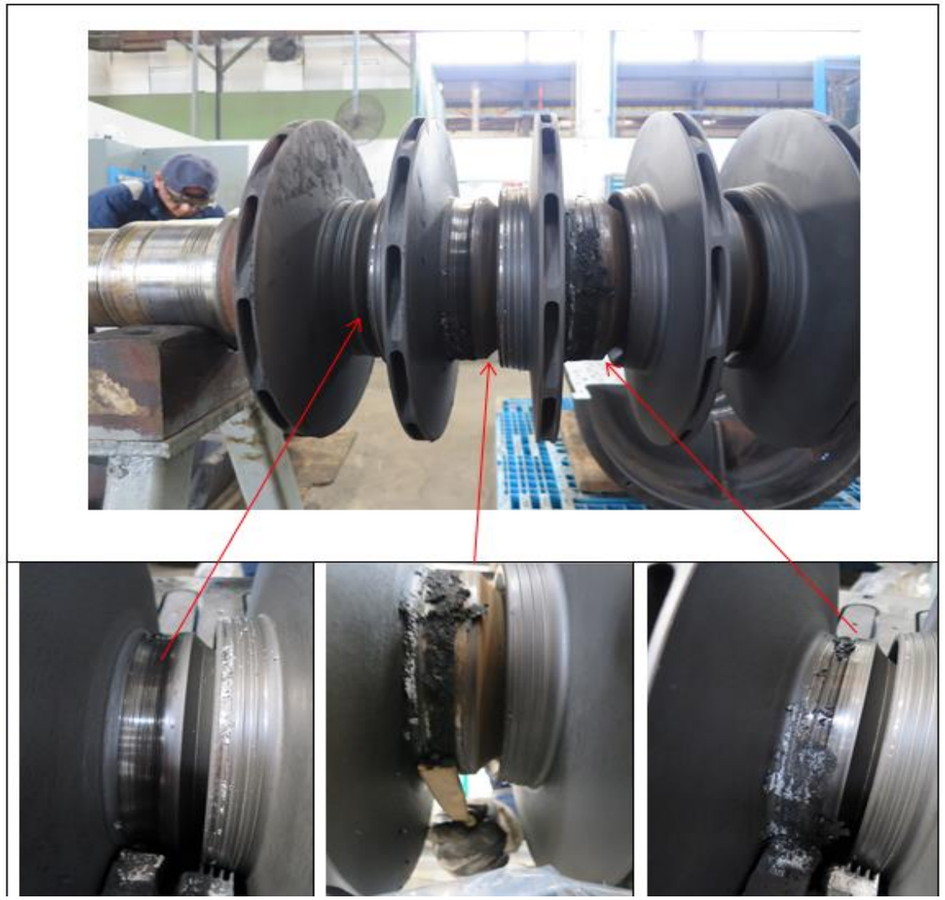
Second Overhaul Observation





Third Overhaul Observation

- Deep grooving mark and severe material loss observed on 1st, 2nd and 3rd inter stage labyrinth.
- Severe erosion on all impeller labyrinths.



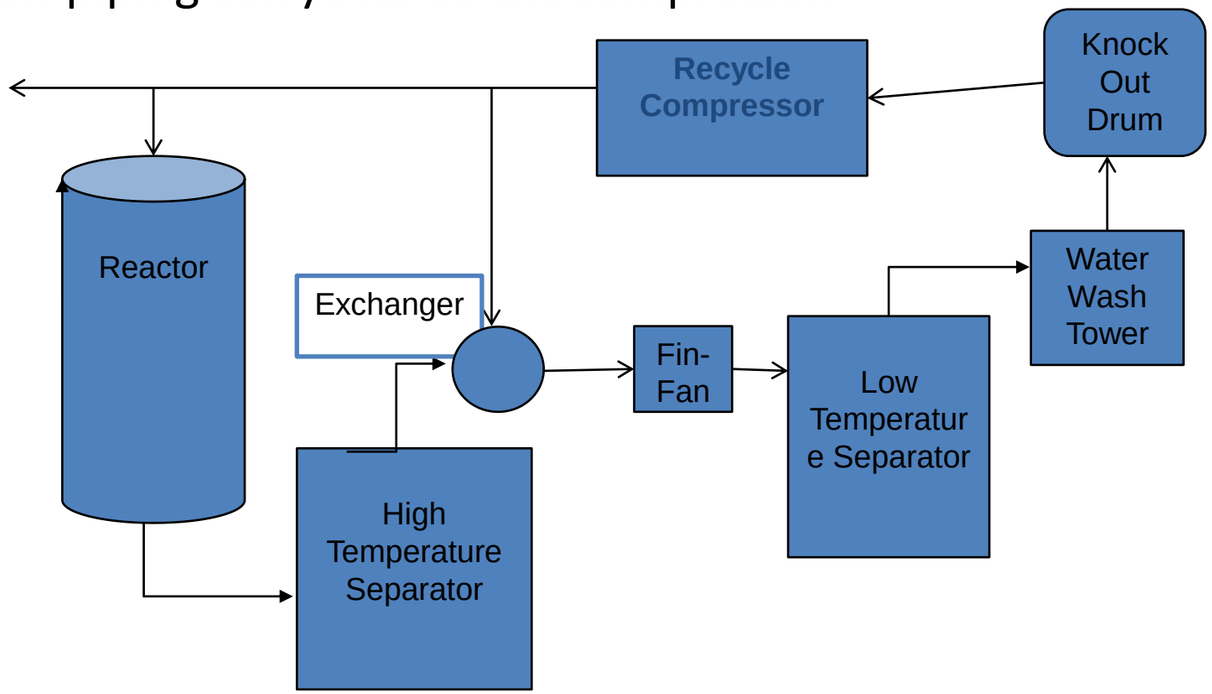
Elemental Analysis

- Sulfur (S), Nitrogen (N) and Chloride (Cl) elements were tested on the samples taken from compressor rotor and labyrinth, indicates ammonium salts (NH_3HS and NH_4HCl) presence.
- Presence of ammonium salts was largely due to ineffective washing of the salts in the water wash tower.
- Liquid distributor orifices were heavily fouled with solid fouling, causing water to overflow vapor risers during operation, causing mal-distribution and loss of packing efficiency.

Water condensation in compressor suction piping carryover to the compressor.

Impact of ammonium salts :-

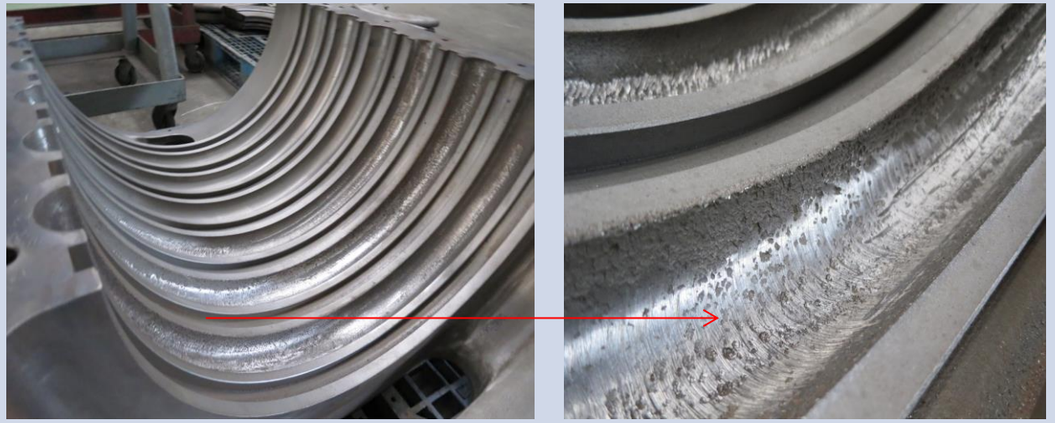
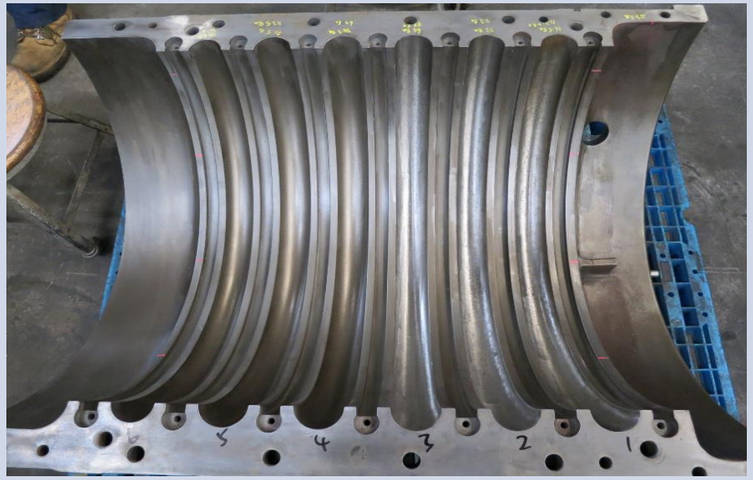
- Severe erosion on labyrinth
- Corrosion and erosion on impeller



Unit Creep Up vs Compressor Overhaul Frequency

- Unit output increased without compressor major design upgrade/modification.
- Due to unit output increase, higher S, N, Cl loading likely speeded up erosion/corrosion rate in the compressor internal.
- Compressor service life was reduced from 10 years to a few years.
- All compressor overhauls were driven by poly efficiency drop.

Surface grinding during 3rd OH to achieve Design Poly Eff.

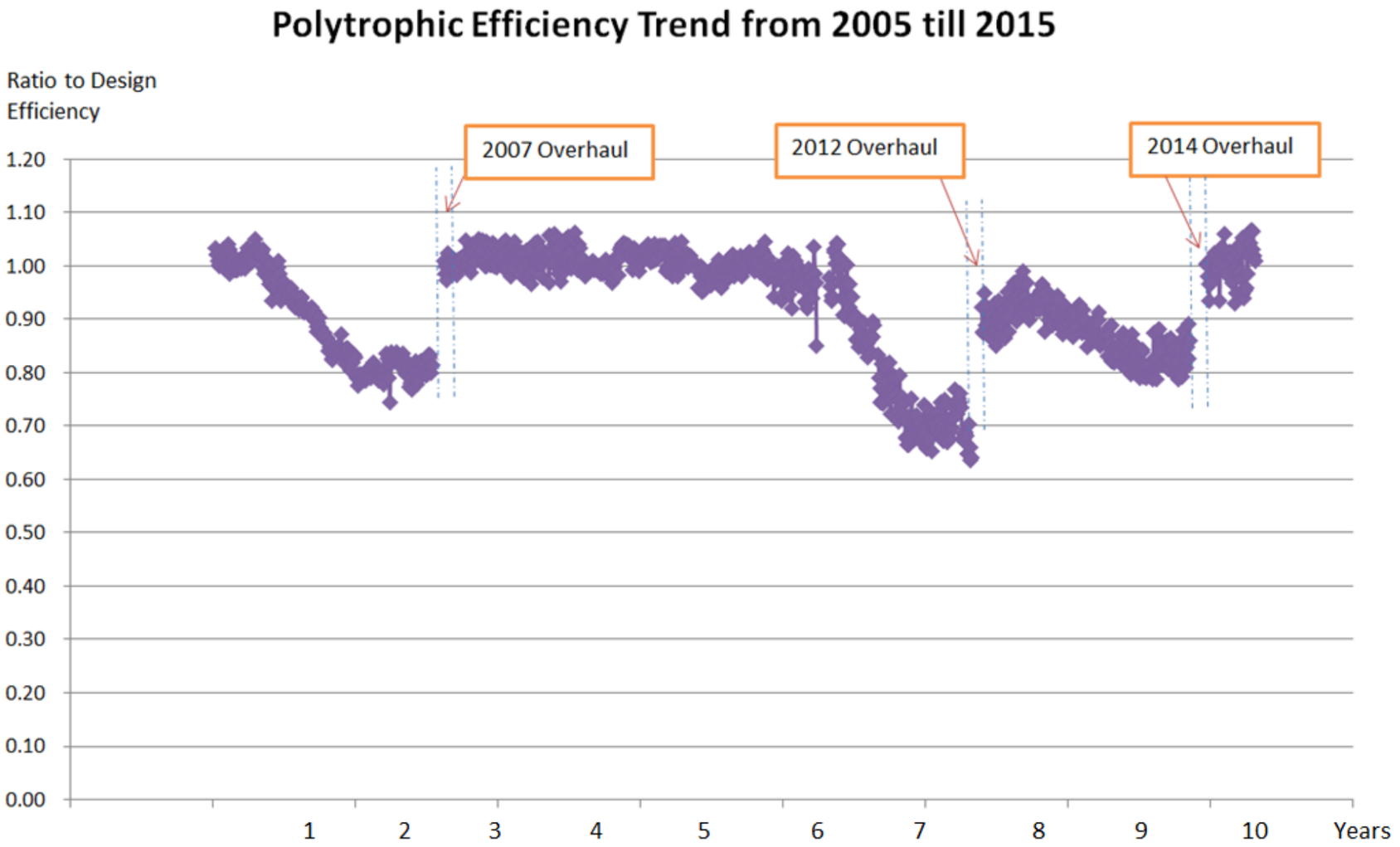
	Before Surface Grinding	After Surface Grinding
Inner Casing		
Diaphragm		

Improvement on Piping & System

1. To maintain compressor suction temperature by insulating suction piping (from Knock-Out-Drum to compressor suction flange) to prevent water condensation
2. Suction line from knock-out-drum to compressor suction flange was chemically cleaned
3. Water wash tower liquid modifications
4. Chloride mitigation project on High Temperature Separator overhead circuit for removing ammonium salts.
5. Knock-out-Drum modifications for better liquid knock-out. Installation of slotted pipe distributor, 2 layers of Crinkle Wire Mesh and horizontal perforated plate

Sustaining Compressor Polytropic Efficiency

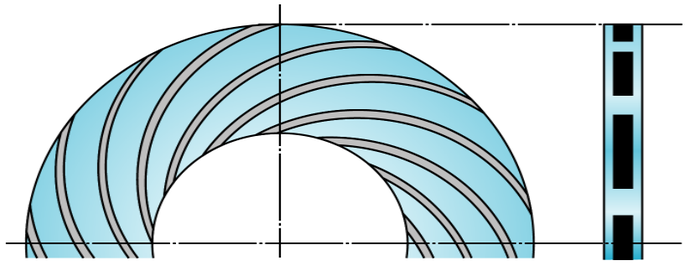
After 3rd overhaul, compressor able to achieve design poly efficiency



Compressor Design Upgrade / Modification

To increase design poly efficiency

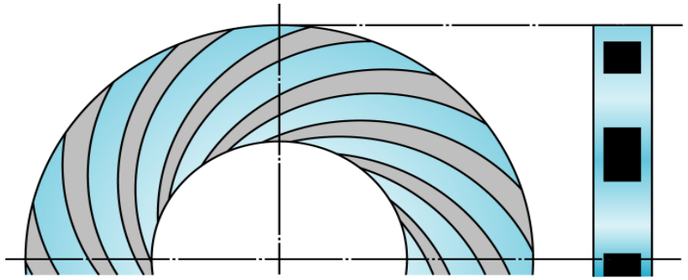
- Wedge Type impeller : Efficient impeller for low flow coefficient (Φ1=0.008)



CONVENTIONAL TYPE IMPELLER

Narrow

(High friction loss)

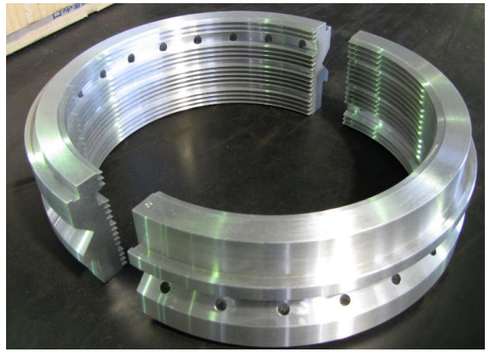


WEDGE TYPE IMPELLER

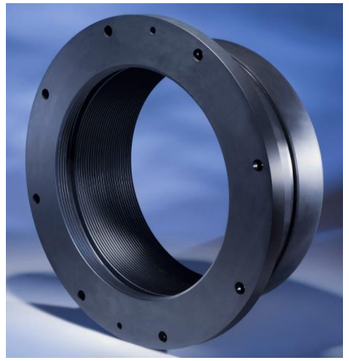
Wide

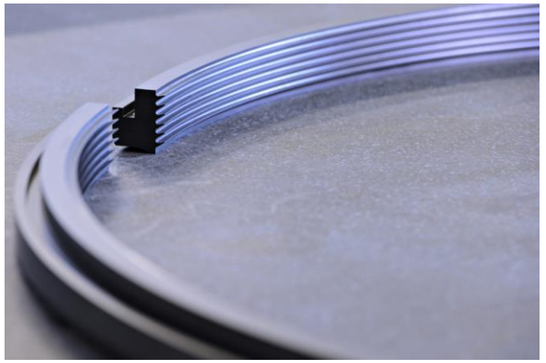
(Low friction loss)

- PEEK labyrinth : reduce leakage with very narrow gap



Aluminum labyrinth





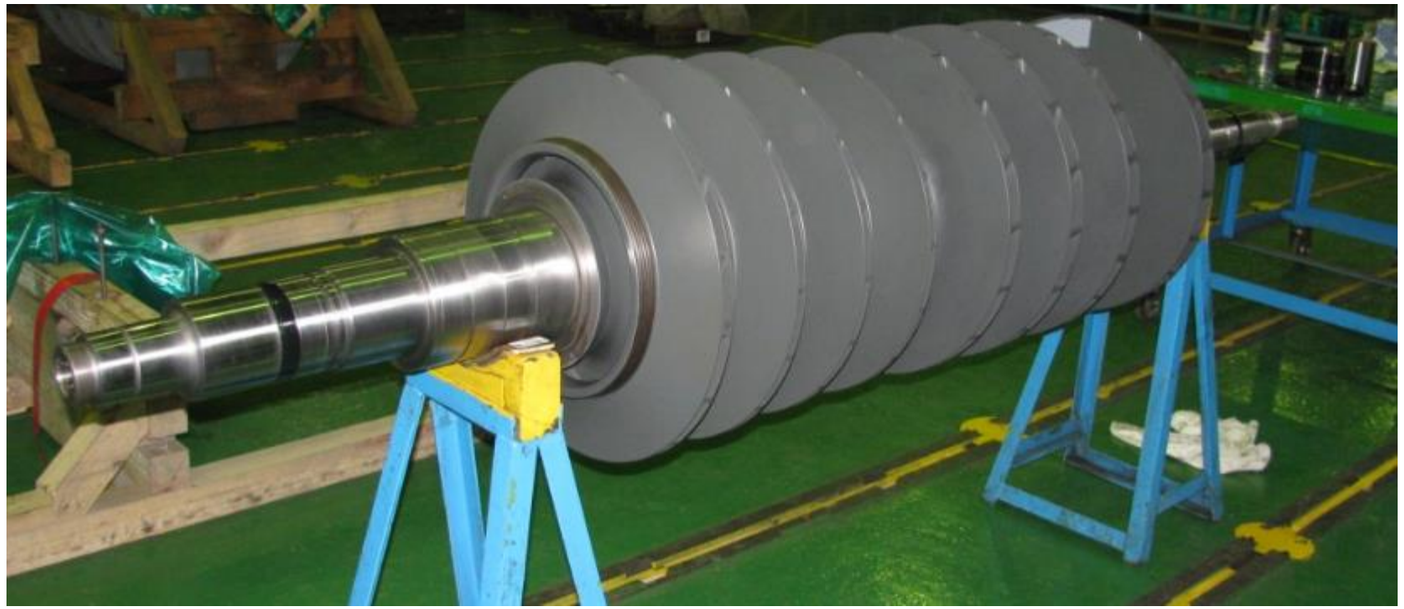
PEEK labyrinth

(Pictures courtesy of Greene, Tweed)

Compressor Design Upgrade / Modification

To maintain design poly efficiency

- Rotor coating to keep smooth surface and prevent corrosion



Sample picture of coated rotor

- PEEK Labyrinth

  Since PEEK material are resistance to corrosive agent, labyrinth will keep their shape even under corrosive atmosphere, which maintain smaller leakage.

What We Have Learnt?

- Systematic study of deposits should be considered for plant creep conditions, if there has been history of Polytropic efficiency drop.
- Ammonium salt & other fouling can build up in labyrinth & impeller of centrifugal compressor, resulting erosion/corrosion of compressor component, capacity reduction and high vibration
- Surface smoothness of diaphragm and inner casing will affect flow and poly efficiency. This is proven by surface grinding during 3rd overhaul to achieve design poly efficiency
- Improvement on piping & system is possible to reduce fouling and to sustain compressor poly efficiency