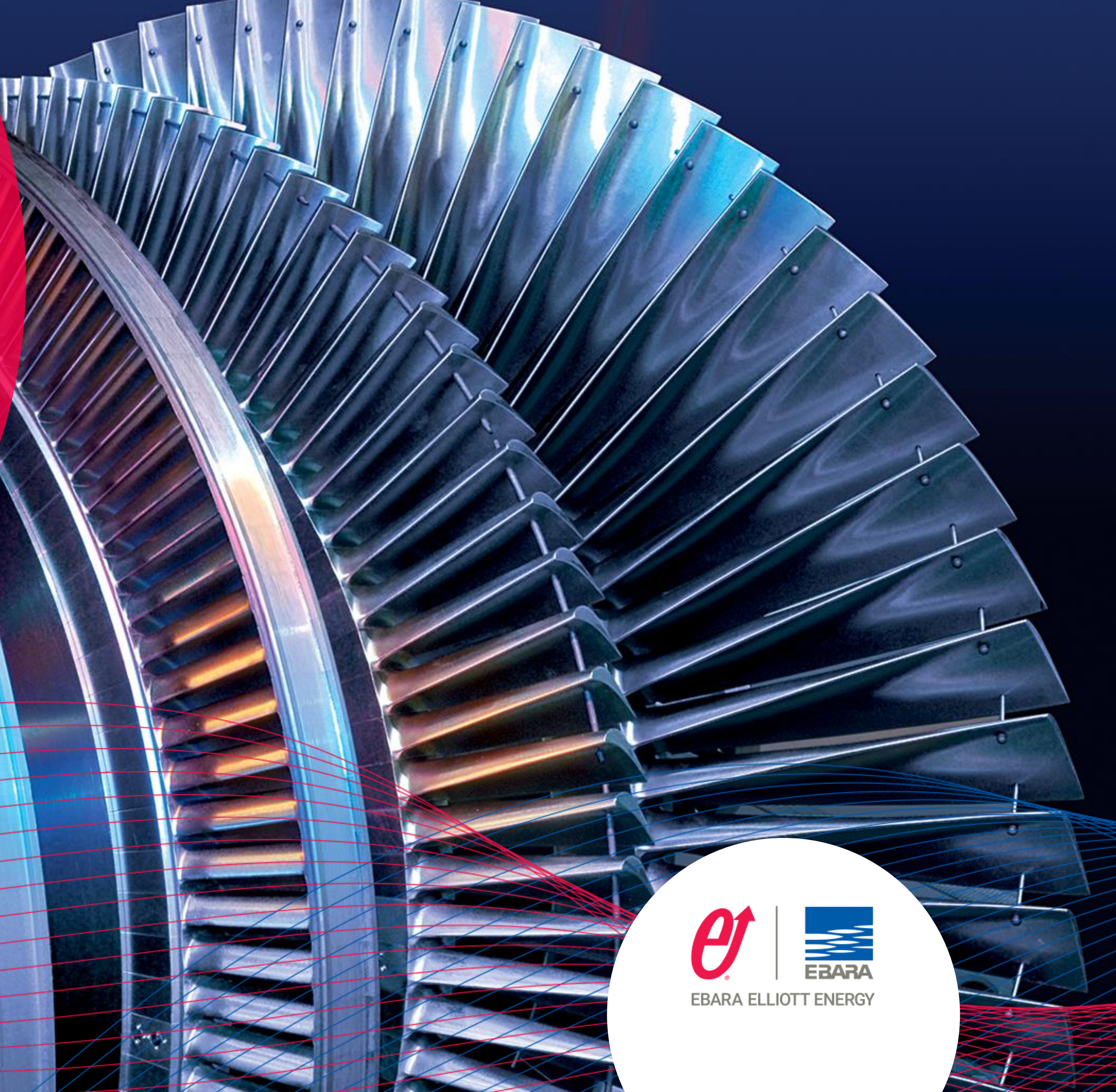
Engineered Solutions

Technical Considerations for Centrifugal Compressor Optimization and Electrification

TNChE 2026
Swaroop Das



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Mission

Provide customer-centric solutions in the quickest and most efficient manner possible. Provide safe working environments that encourage challenge and change. Act and achieve as one team.

Vision

Be the Best Solution Provider in the energy sector by providing premier equipment and service, while actively leading sustainability efforts worldwide.

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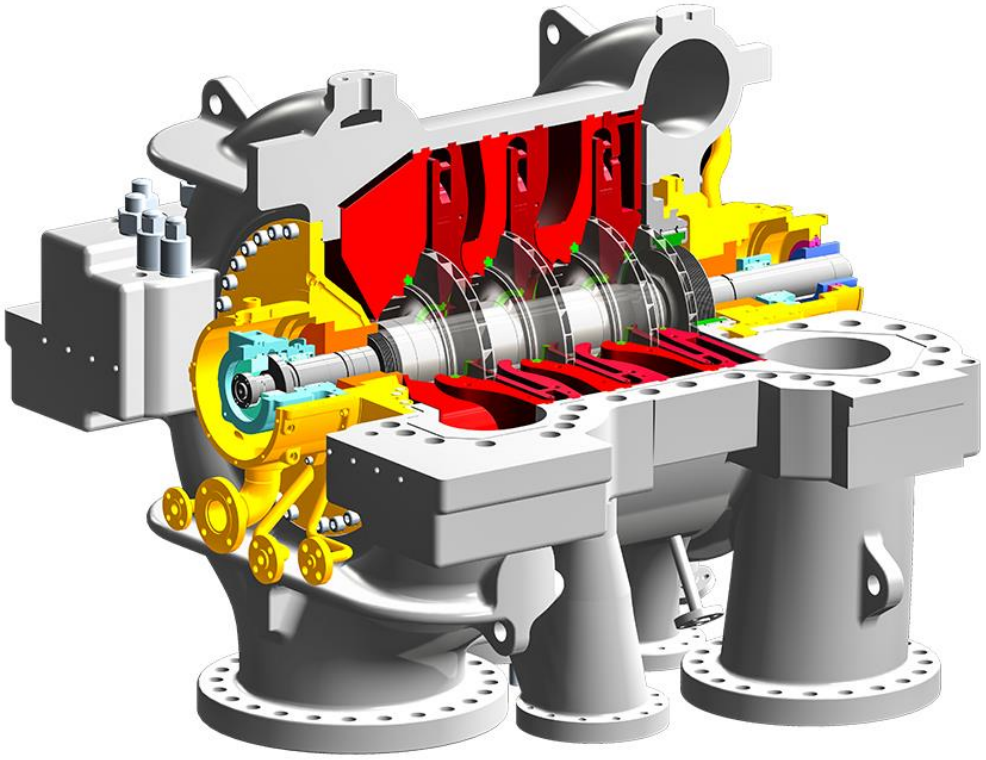
Summary

1. What is a Centrifugal Compressor
2. Concept of re-rating / drop-in
3. Compressor design for electrical motor drives (EMD)
4. Case studies and real world applications
   - Customer A
   - Customer B
   - CAPEX and ROI: Modification vs Re-rate
5. Conclusions: Lessons learnt and best practices

What is a centrifugal compressor and applications?

"Inline centrifugal compressors can be described as a combination of one or more centrifugal compressor stages operating about a common axis. Each stage is comprised of rotating impellers that impart kinetic energy into the gas that is then converted to a rise in static pressure as the gas decelerates."



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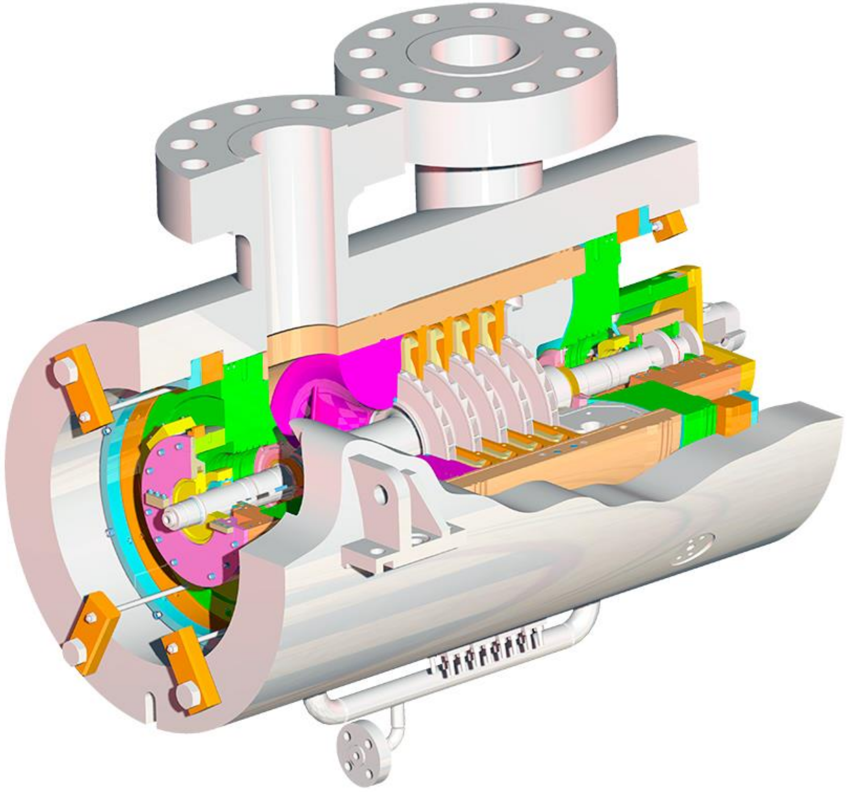
Concept of re-rating

Re-rating a centrifugal compressor requires changing the aero-path. At its core, re-rating involves recalibrating a compressor's design and operational parameters to optimize its performance under new or current working conditions. This means that diaphragms (diffusers) and rotor (impellers and shaft) will be newly supplied with modern aero design.

- Achieve new process parameters or increase efficiency within existing casings
- Minimal changes to foundations, piping and other connections



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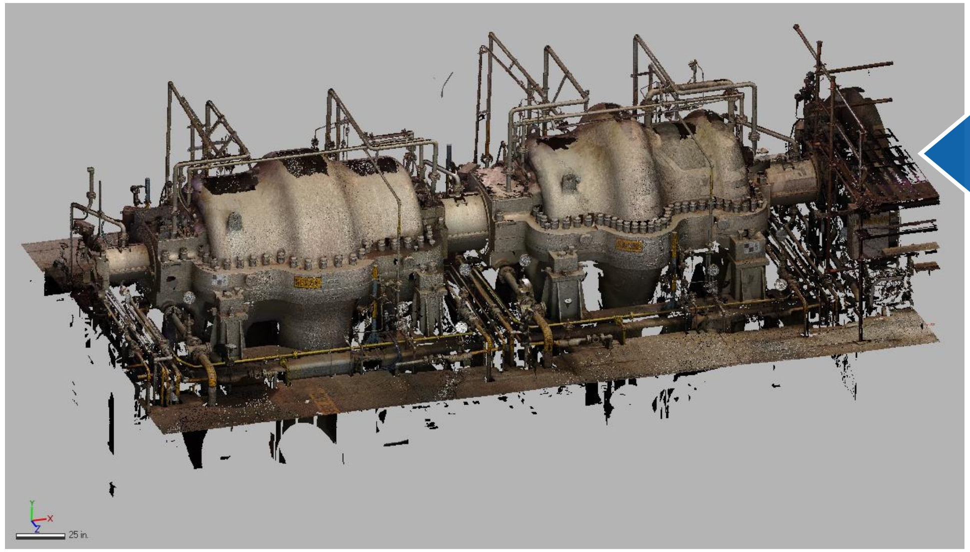
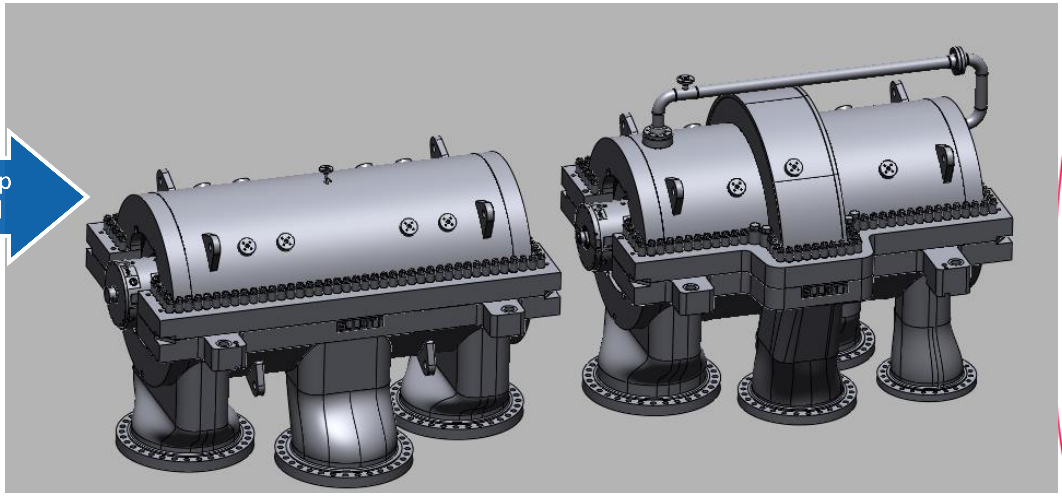
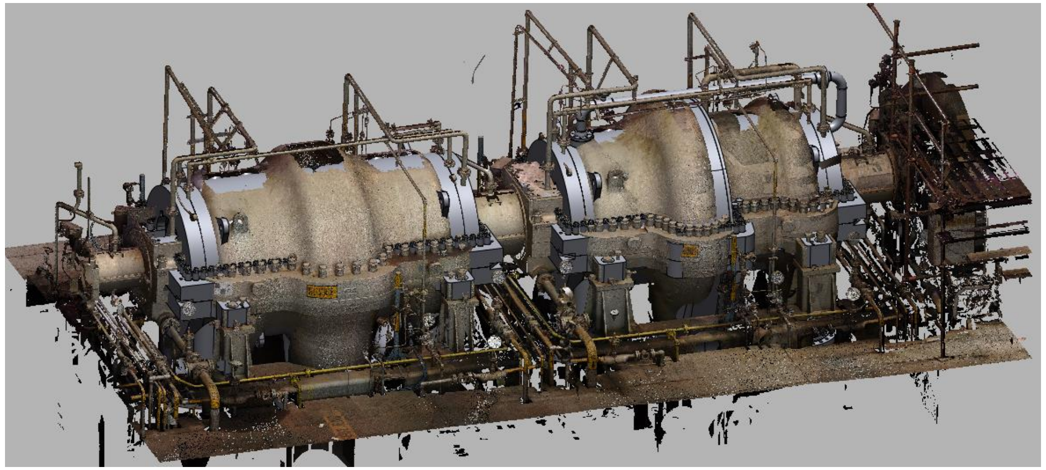
Concept of drop-in replacements



Site Scan

Develop Model





Custom Casing

Overlay casing

- Increase in Capacity of 30%
- Upgrade to Dry Gas Seals & modern aero
- Match process nozzles, auxiliary connections and existing pedestals

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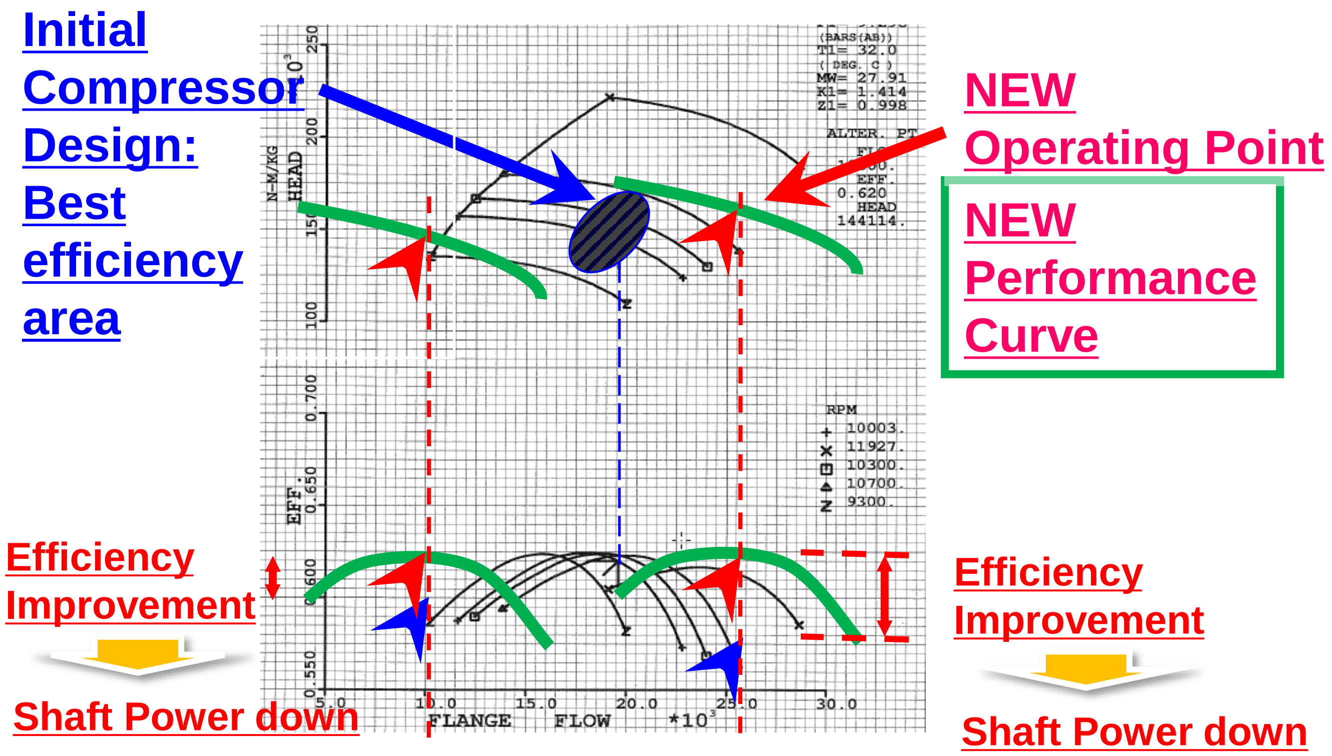
Concept of re-rating

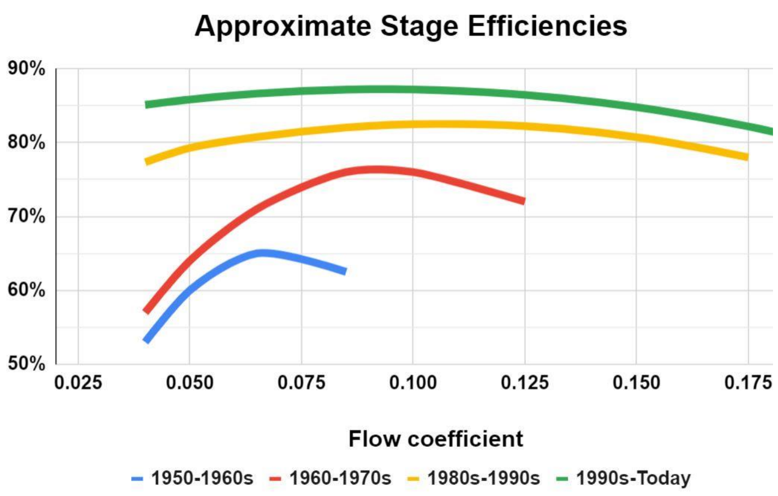
Why re-rating is important: Is the compressor operating at design?

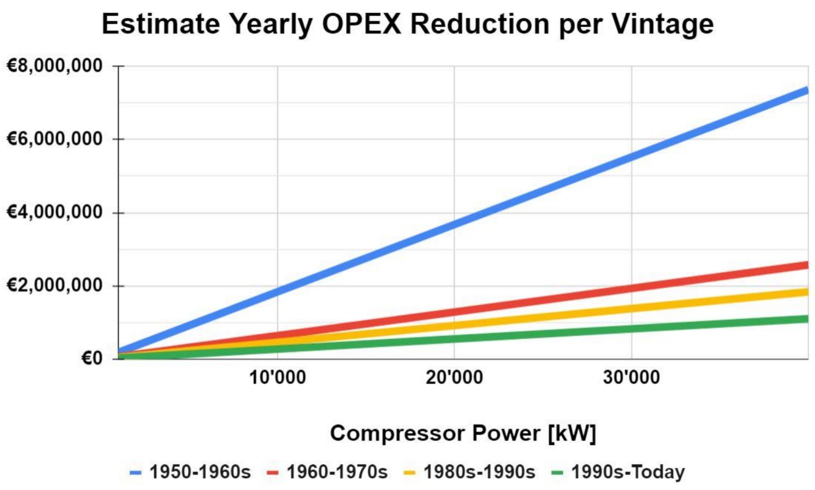


Concept of re-rating

60 €/tonCO2
68 €/MWh
95% availability

POWER AND POTENTIAL POWER SAVINGS (kW)					POTENTIAL TOTAL SAVINGS PER YEAR (€)			
Power (kW)	1950-1960s	1960-1970s	1980s-1990s	1990s-Today	1950-1960s	1960-1970s	1980s-1990s	1990s-Today
1000	200	70	50	30	€ 183.983	€ 64.394	€ 45.996	€ 27.597
3000	600	210	150	90	€ 551.948	€ 193.182	€ 137.987	€ 82.792
5000	1000	350	250	150	€ 919.914	€ 321.970	€ 229.978	€ 137.987
7000	**1400**	490	350	210	**€ 1.287.879**	€ 450.758	€ 321.970	€ 193.182
9000	**1800**	630	450	270	**€ 1.655.845**	€ 579.546	€ 413.961	€ 248.377
11000	**2200**	770	550	330	**€ 2.023.811**	€ 708.334	€ 505.953	€ 303.572
20000	**4000**	**1400**	1000	600	**€ 3.679.656**	**€ 1.287.879**	€ 919.914	€ 551.948
30000	**6000**	**2100**	**1500**	900	**€ 5.519.483**	**€ 1.931.819**	**€ 1.379.871**	€ 827.922
40000	**8000**	**2800**	**2000**	**1200**	**€ 7.359.311**	**€ 2.575.759**	**€ 1.839.828**	**€ 1.103.897**





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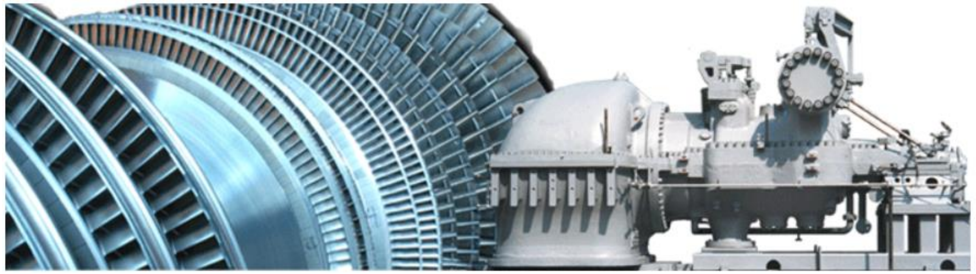
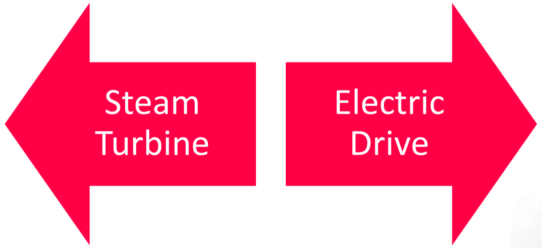
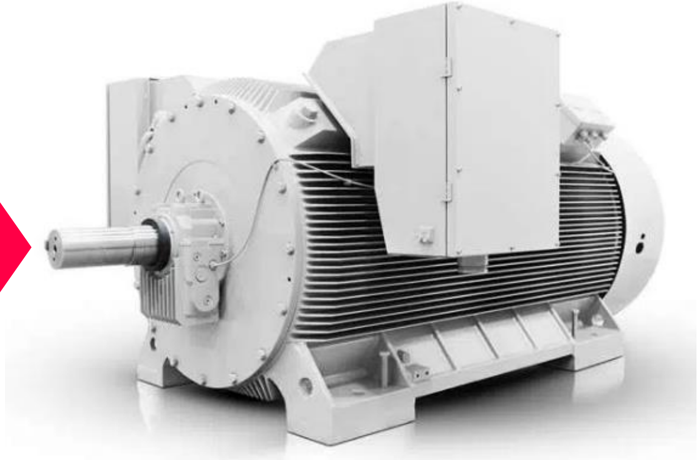
Turbine to Motor Conversion







"Drivers" of change

- Electric motor, drivers – Latest Trends due to clean energy initiatives
- High Steam Cost
- High Carbon Footprint using Steam Turbines
- Potential Lower maintenance interval times and higher efficiency

Considerations

- Impact of Driver Selection on Compressor Design
  - ➢ Shaft End Sizing
  - ➢ Starting torque requirements
  - ➢ Settle-out pressure requirements
  - ➢ Short Circuit faults and Transient torsional requirements
  - ➢ Coast down calculations
- Available Footprint and changes required
- Strings with Gearbox

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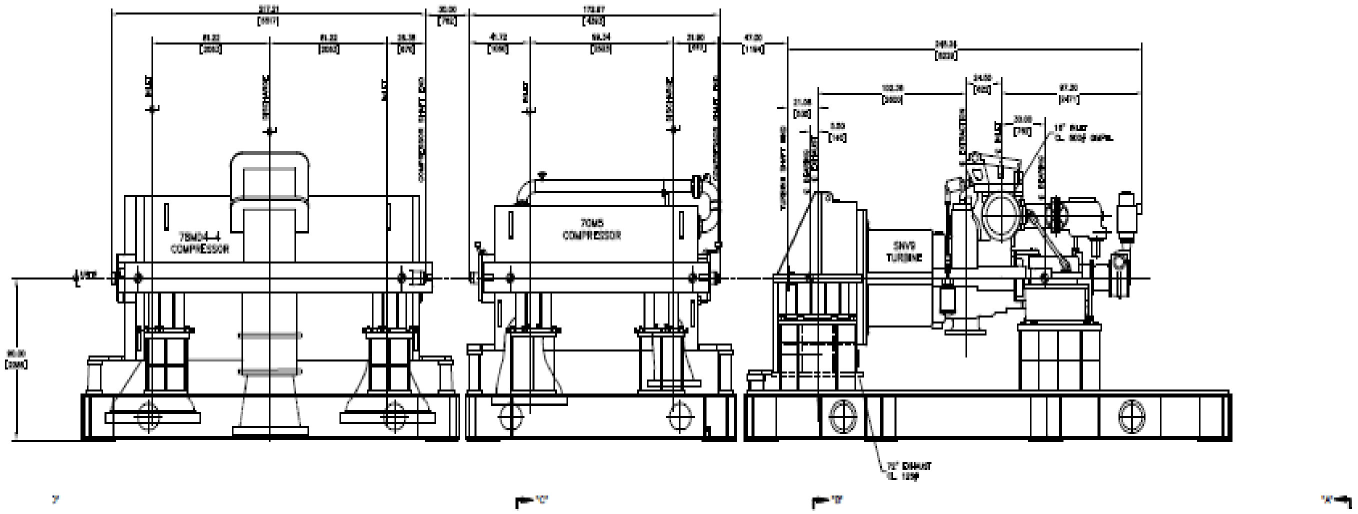
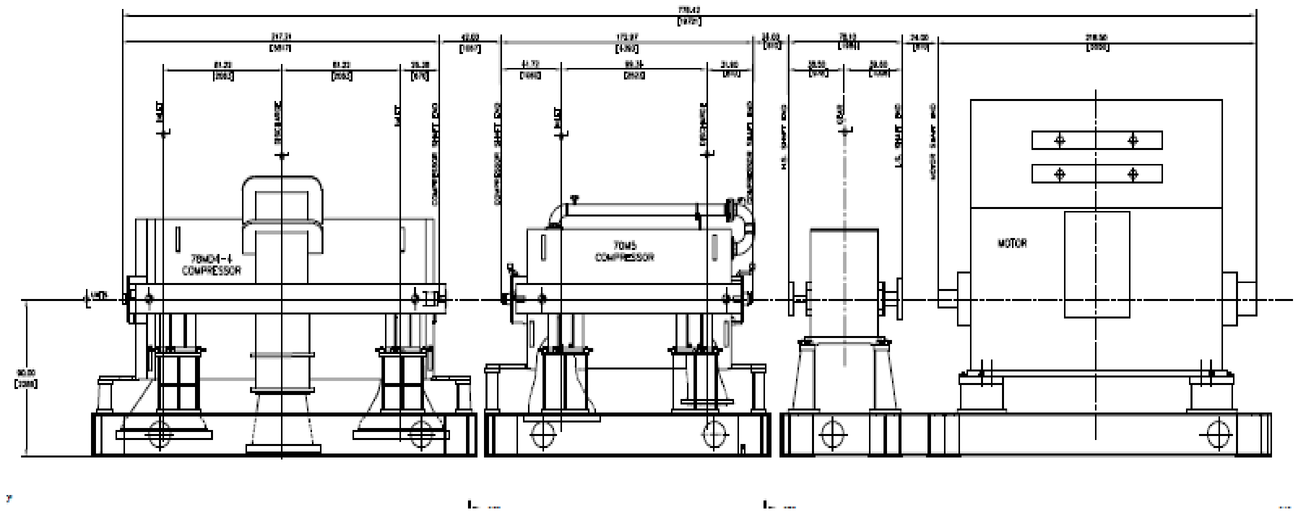
Turbine to Motor Conversion

42 MW Steam turbine driven compressor string dimensions (*steam condenser / generation not shown*):
66.5ft(L) X 14.5ft(W) X 13.5ft(H)
Total String Weight: 710,510 lbs



42 MW electric motor driven compressor string dimensions (*VSD not shown*):
67ft(L) X 14.5ft(W) X 16.9ft(H)
Total String Weight: 753,500 lbs



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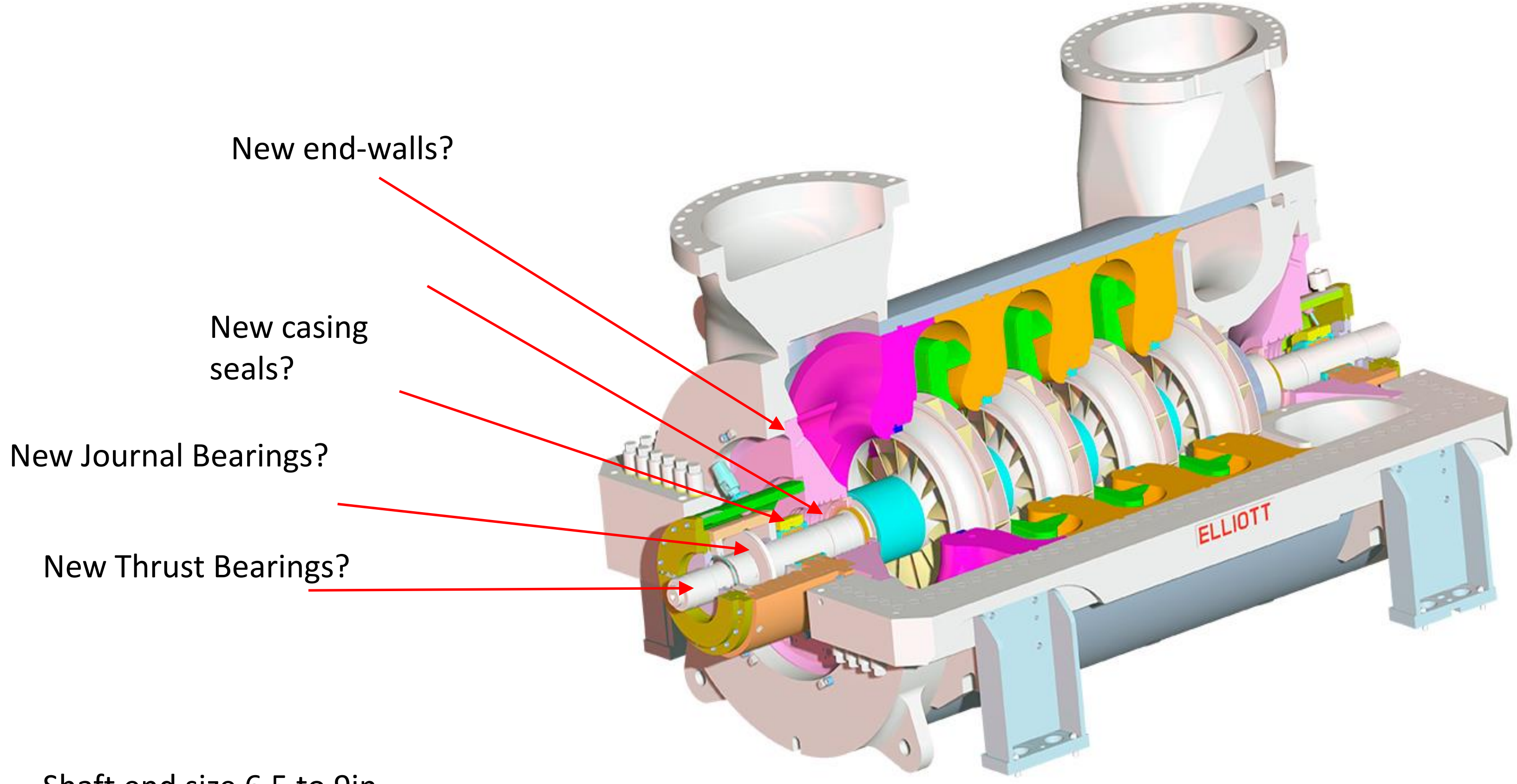
Turbine to Motor Conversion

Shaft End Sizing – How will the new torque affect shaft end size?

- What is the minimum upgrade scope when shaft end size requires increase?
- Can we upgrade parts for increase reliability?
- How does that compare to re-rate?



Shaft end size 6.5 to 9in
New shaft required – requires stacking & unstacking of main rotor and spare rotor

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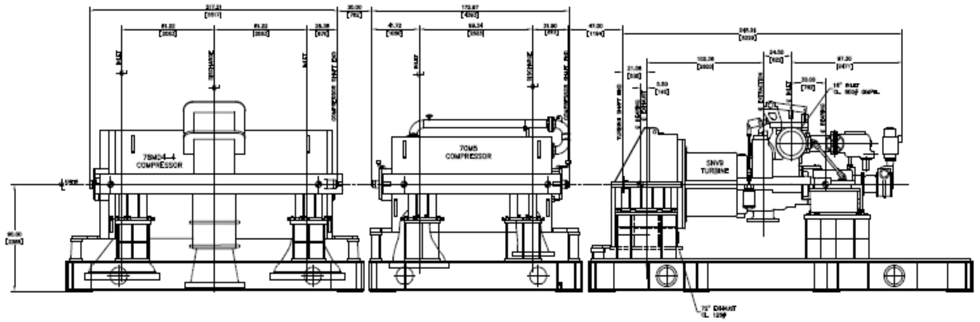
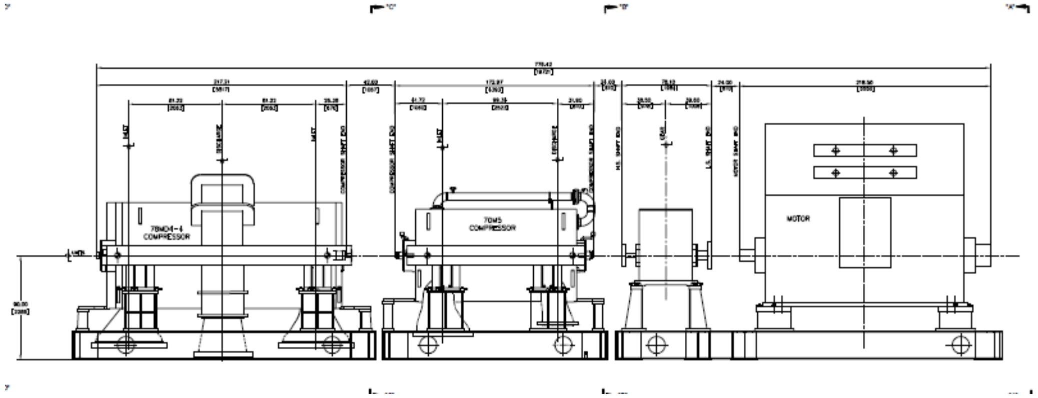
Turbine to Motor Conversion

Shaft End Sizing – How will the new torque affect shaft end size?

- shaft end sizing criteria is based on ANSI/AGMA 6001 standard. This includes consideration of high cycle fatigue for continuous operation and low cycle fatigue for start-up and transient events.
- Short circuit moment
- Significant increase in shaft end sizing for motor drives
- Shaft end size can affects bearing sizes, overhung weight, rotor dynamic analysis.

	Shaft end size (in), Hydraulic fit		
Driver Rating 42MW	**Compressor2**		**Compressor 1**
String Configuration	**Drive**	**Drive Thru**	**Drive**
Steam Turbine+ Compressor2+Compressor1	6.5	5.5	5.5
Synch. Motor w/VFD (LCI) +Gear+Compressor2+Compressor1	9	8.5	8.5
Synch. Motor w/VFD (VSI) +Gear+Compressor2+Compressor1	9	8.5	8.5
Synch. Motor (DOL) Gear+Compressor2+Compressor1	10.5	10.5	10.5





Driver configuration vs. Shaft end sizing

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CAPEX vs OPEX Trade-offs

Configuration	CapEx (Initial Cost)	OpEx: Footprint & Layout	OpEx: Cooling Loads	OpEx: Maintenance
1. Standard Motor + VFD + Gearbox	**Baseline** Standard, off-the-shelf motor and gear components.	**Large** Requires long mechanical skid AND a large, climate-controlled E-house.	**Split** High electrical (VFD HVAC) + Moderate mechanical (Gearbox oil).	**Moderate** Routine gearbox oil changes, standard motor bearings, VFD upkeep.
2. Fixed-Speed Motor + Fluid Coupling / Planetary Gears	**High** Highly specialized, massive mechanical power-split drive.	**Heavy Mechanical** Massive mechanical skid, but minimal electrical room space required.	**Massive Mechanical** Huge oil coolers required to reject 400–700+ kW of thermal fluid slip heat.	**Moderate-High** Complex oil system and fluid coupling maintenance, but extremely long MTBF.
3. High-Speed Motor + VFD (Direct Drive)	**Highest** Engineered-to-order motor, magnetic bearings, and specialized VFD.	**Compact Mechanical** Shortest physical skid, but still requires a large E-house for the VFD.	**Mostly Electrical** High electrical (VFD HVAC), but zero mechanical lube oil cooling needed.	**Lowest** No gearbox, no lube oil console. Only specialized electrical/bearing checks.

CASE STUDIES

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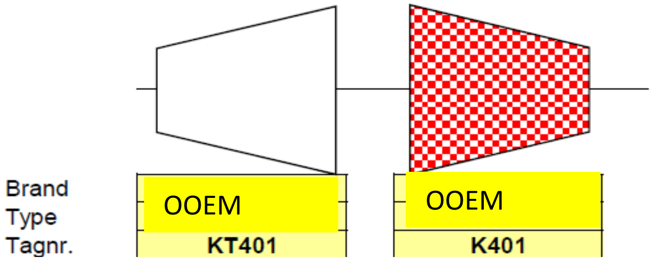
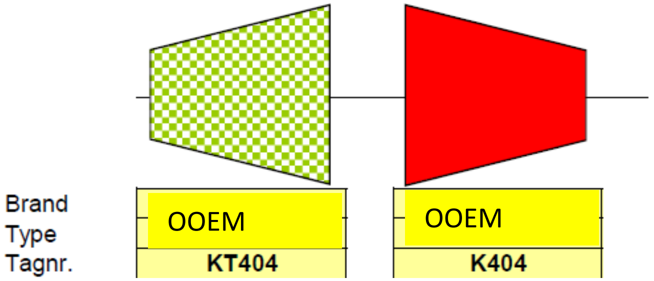
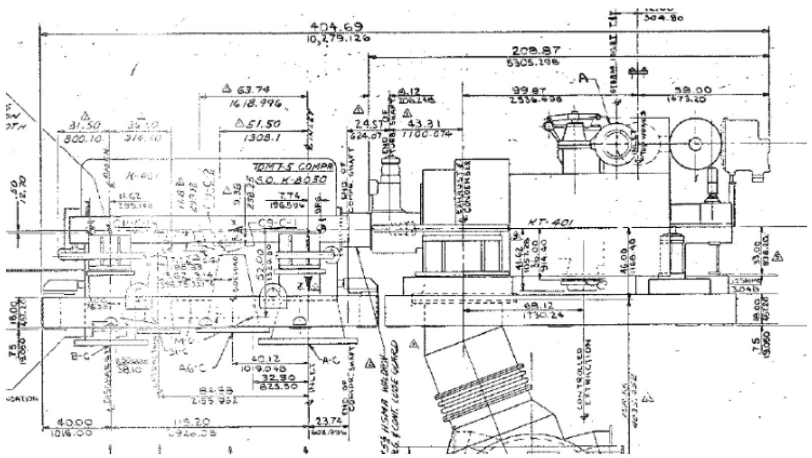
Case Study – Customer A

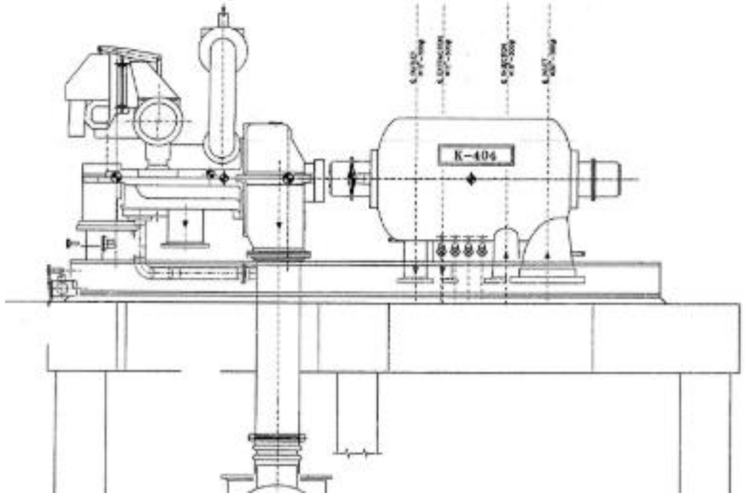
Scope: March 2023 – Electrification study for 3 Compressors to evaluate minimum change requirements and re-rate evaluation.

Jan 2024 – PO to electrify driver of 2 compressors.









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*OOEM – Other OEM

Case Study – Customer A

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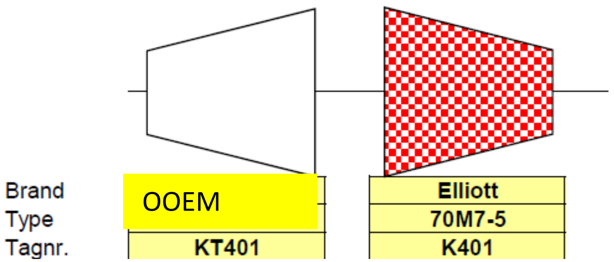
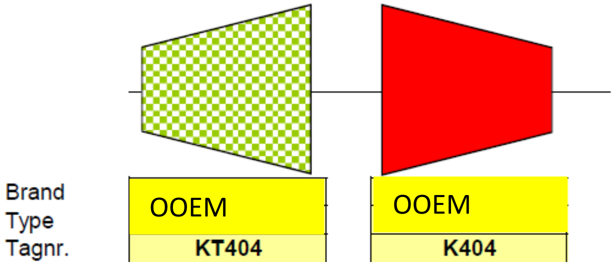




K401	Existing Rotor Performance	Rerated Rotor Performance	Estimated Power Savings	
Speed (rpm)	3707	3742		
Power (kW)	20395	18560	1835	9.0%

Table 1: K401 Rerated Power Summary

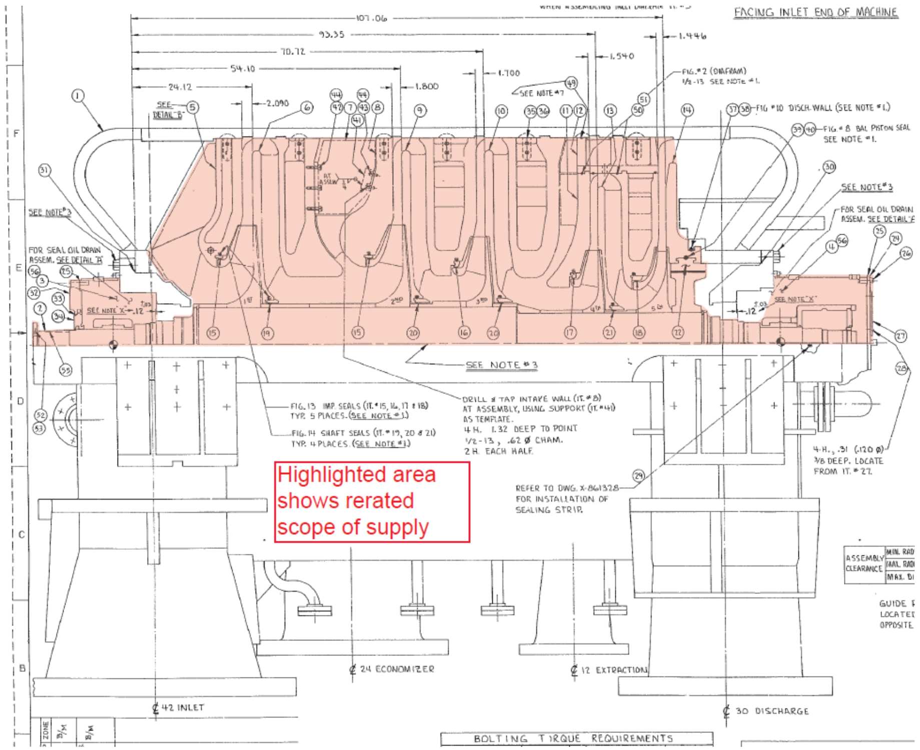
K404	Existing Rotor Performance	Rerated Rotor Performance	Estimated Power Savings	
Speed (rpm)	5214	5298		
Power (kW)	7310	7190	120	1.6%

Table 3: K404 Rerated Power Summary

*OOEM – Other OEM

Case Study – Customer A

Scope: K401 – with re-rate for 1.8MW power saving



- Full gut re-rate
- Spare rotor
- Keep same Thrust bearings
- Keep same end-walls
- Keep casing seals
- New journal bearings
- New coupling/guard
- Spare coupling
- Full Train torsional analysis
- Lube oil modifications.

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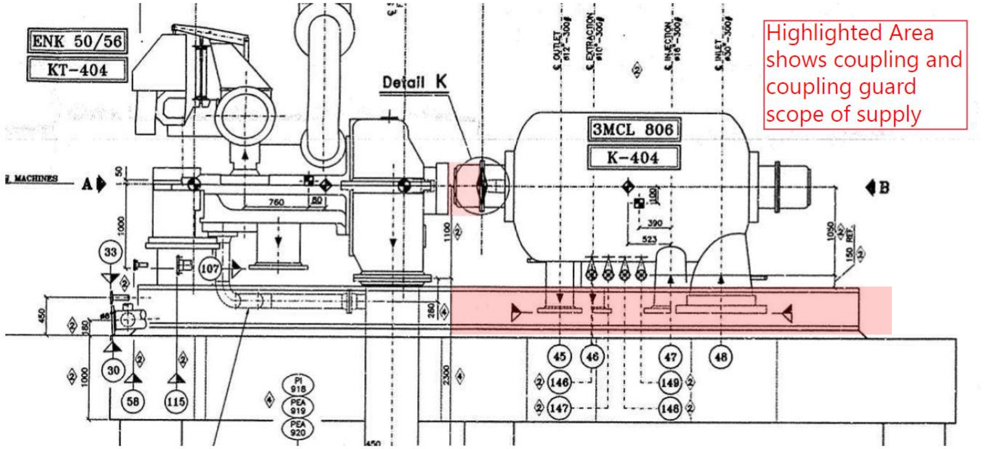
Case Study – Customer A

Scope: K404 – Without re-rate



- New coupling + guard
- Spare coupling
- Full Train torsional analysis
- Lube oil modifications
- Baseplate engineering & modal analysis

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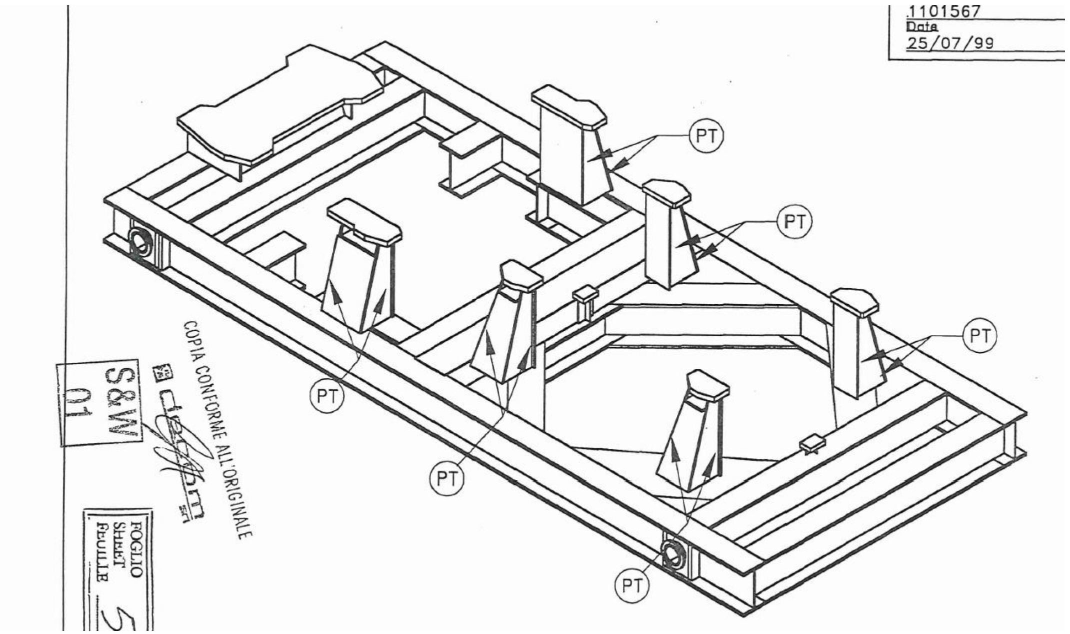
Case Study – Customer A

K404: Baseplate challenges



- No dimensional dwgs
- Reverse Engineer the existing baseplate
- where to cut?
- New motor-Baseplate design
- Location of anchor bolts?
- Rebar of tabletop?

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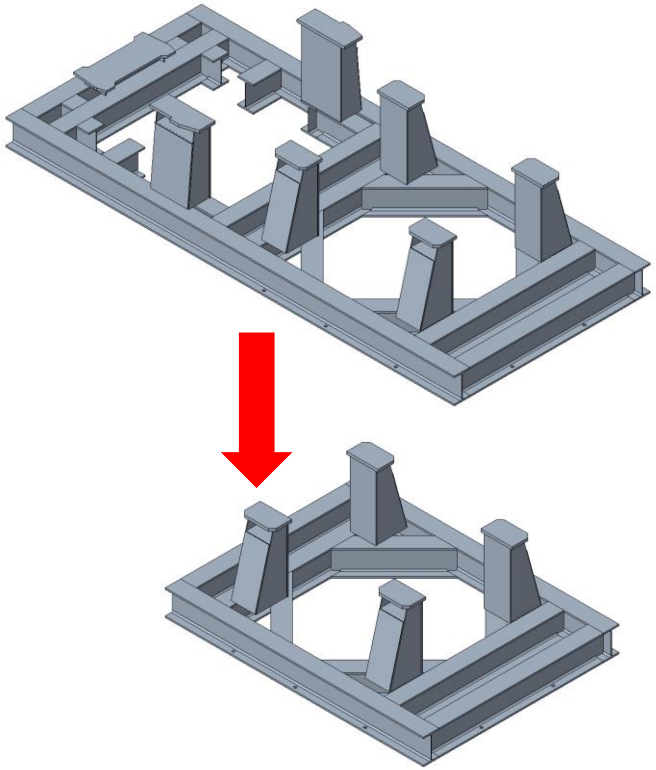
Case Study – Customer A

K404: Baseplate challenges



Objective: The objective is to perform Static structural Analysis, Modal Analysis & Harmonic Analysis on Base Plate Assembly

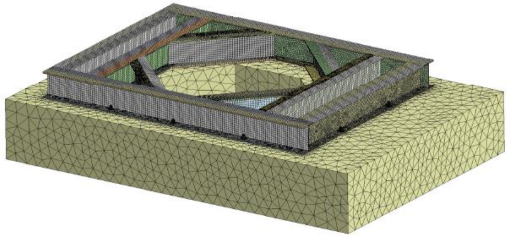
Analysis Approach

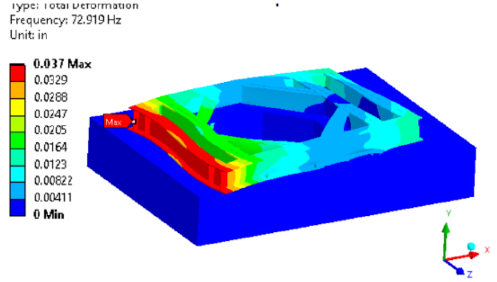
Static Structural Analysis:
Inputs: Compressor Assembly weight
→ O/P
- Stresses
- Deformation

Modal Analysis :
Inputs: Geometry, materials & operating speed
→ O/P
- Natural Frequencies
- Mode Shapes

Force Response Analysis :
Inputs: Rotor Unbalance Force w.r.t Maximum operating speed
→ O/P
- Harmonic Stress
- Deformation

Fatigue Assessment :
Inputs: Mean Stress & Alternating Stress
→ O/P
- Goodman Plot for Infinite Life



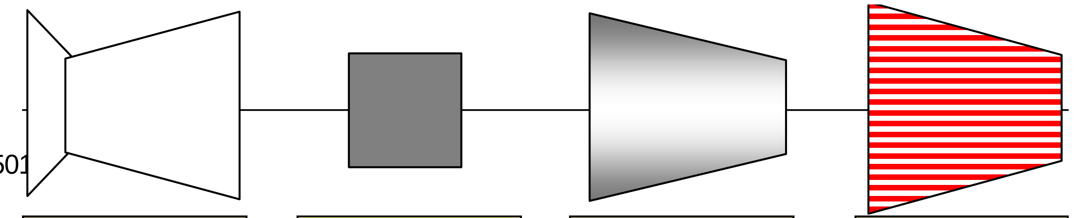


Case Study – Customer B

Scope: October 2023 Electrification study to evaluate minimum change requirements, release compressor startup-curves, Motor Selection and re-rate evaluation.

August 2024 – PO to electrify the compressor

Train 2
Propylene Gas
GBG501-GZ501-GB501-GBT501



Brand	**GE**	**Maag**	**Elliott**	**AEG-Kanis**
Type	**MS5001R**	**GB-50**	**70M7/5**	**G63**
Tagnr.	**GBG501**	**GZ501**	**GB501**	**GBT501**

Compressor	Existing Aero	Re-Rated Aero	Estimated power savings
Power (kW)	19’109	17’777	7%
Speed (rpm)	3’840	~3’840	

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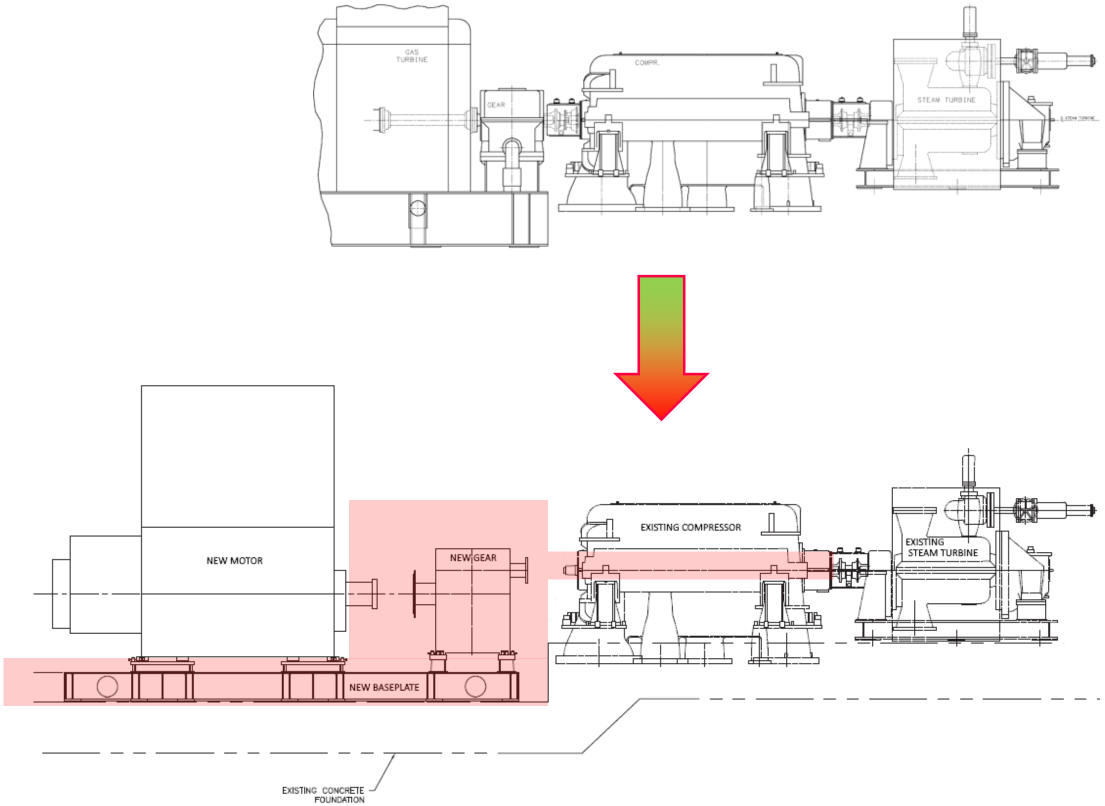
Case Study – Customer B

Scope:

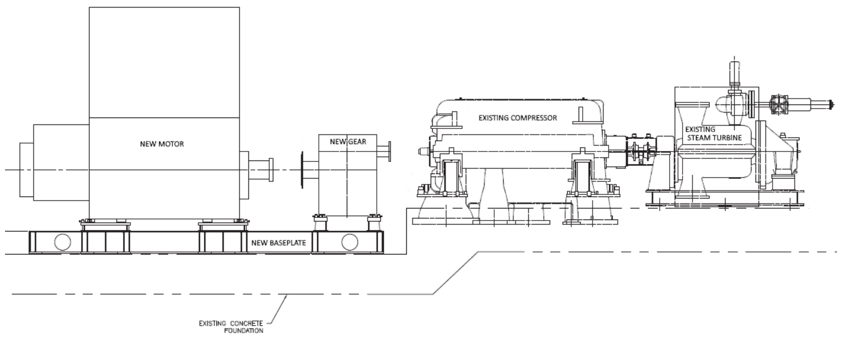
- New Shaft / Thrust Disk
- Rotor Re-shafting services
- Complete Spare rotor
- New end cover/ end seal
- New Journal Bearing assembly
- New GB and GB/Motor Baseplate (and FEA)
- New low speed & high speed couplings and guards
- Full Train torsional analysis
- Lube oil modifications



CAPEX and ROI: Modification vs Re-rate

60 €/tonCO2
68 €/MWh
95% availability

	CAPEX		POWER	ROI
	MODIFICATION	RE-RATE	SAVINGS in kW	
CUSTOMER A	1	2.87	1835	1.5
CUSTOMER B	1	2.95	1332	1.7



Customer B Layout

Customer A: K401 opted for Re-rate
Customer B: Did not opt for Re-rate

ROI/CAPEX excludes offset of purchasing smaller Motor/VFD

ROI/CAPEX would most likely be smaller if it did.

ROI of Customer A and Customer B are very similar but they opted by different approaches. Reasons?

- Complexity of Steam Balance for Customer B?
- Power & CO2 Savings not enough?
- Source of electricity?
- Not enough budget?

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Conclusions: Lessons learnt and best practices

- Engineering studies to identify minimum scope of supply are crucial.
  - Serve as baseline analysis of the feasibility of electrification: Evaluation of scenarios and ensures compatibility.
  - Identify all the necessary minimum scope – avoid overlooking critical aspects
  - Compare minimum scope with extended re-rate scope (CAPEX/OPEX/ROI benefits)
  - Address complexities of electrification of large centrifugal compressors
- Compressor original design point does not match current operating conditions
- **Compressor Re-Rating can bring attractive ROIs and maximizing efficiency and sustainability by furthering reducing CO2 emissions.**
- Ideal Project set up with Compressor OEM or expert having responsibility for Motor / Drive supply.

Thank You

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South East Asia, Australia, India

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