GRCTHINK

PTES Turbomachinery

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High Temperature Compressors Exist

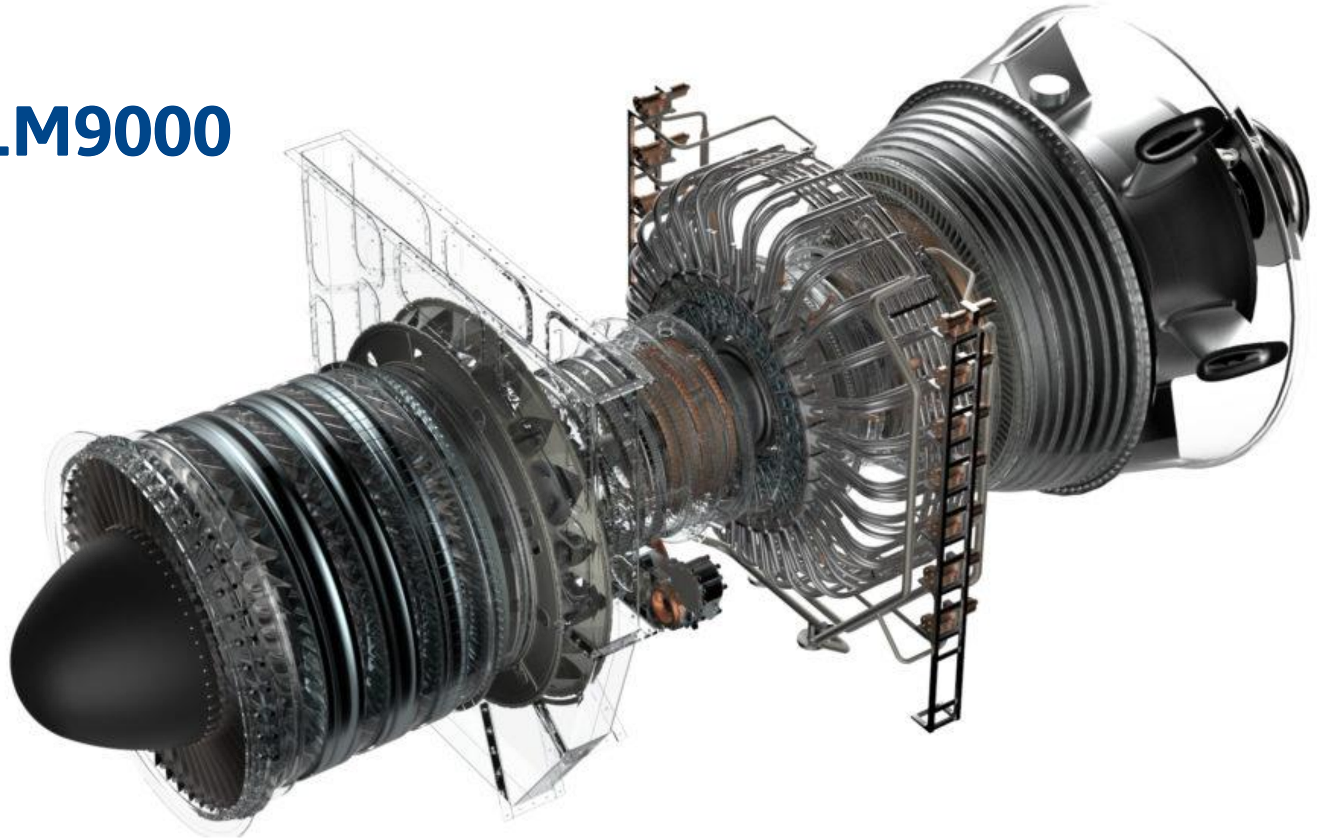
Turbomachinery Design and Cost

- Can a 100MW 550°C compressor be developed in two years, below $500/kW (not nickel), above 85% isentropic efficiency?
  - What are the relative challenges of ideal gas vs CO2 fluids?
  - What subcomponent development is needed? Dry gas seals, bearings, etc
  - What other performance metrics should be set and tested?

→ **Yes,**

Using existing aircraft engine technology

LM9000



Aeroderivative based on GE90-115B

Performance Assessment

https://www.ge.com/content/dam/gepower-pgdp/global/en_US/documents/product/gas-power-systems-product-catalog-2019.pdf

LM9000				
Compressor				
PR	Effy	Flow	Texit	Power
[-]	[-]	[kg/s]	[C]	[MW]
33.5	0.85	182.8	600.2	107.5
Storage Heat Exchanger				
Tout	DP/P	Qin		COP
[C]	[%]	[MW]		[-]
300.0	3	55.1		1.15
Turbine				
PR	Effy	Flow	Texit	Power
[-]	[-]	[kg/s]	[C]	[MW]
32.5	0.9	182.8	-25.0	59.7

LM9000 compressor meets PTES goals

- Texit = 600C
- Net power 48 MW per machine (2x for 100 MW)

LM9000 for PTES Development Needs

Compressor Exit Diffuser and Volute

- Collect hot air and move to PTES heat exchanger

New low-temperature power turbine

- 300C Turbine Inlet Temp
- Uncooled, stainless steel
- Based on Steam Turbine technology to minimize NRE and product cost

Casing, Bearings, and Sumps for Modified Design

Gearbox to couple Synchronous Drive Motor

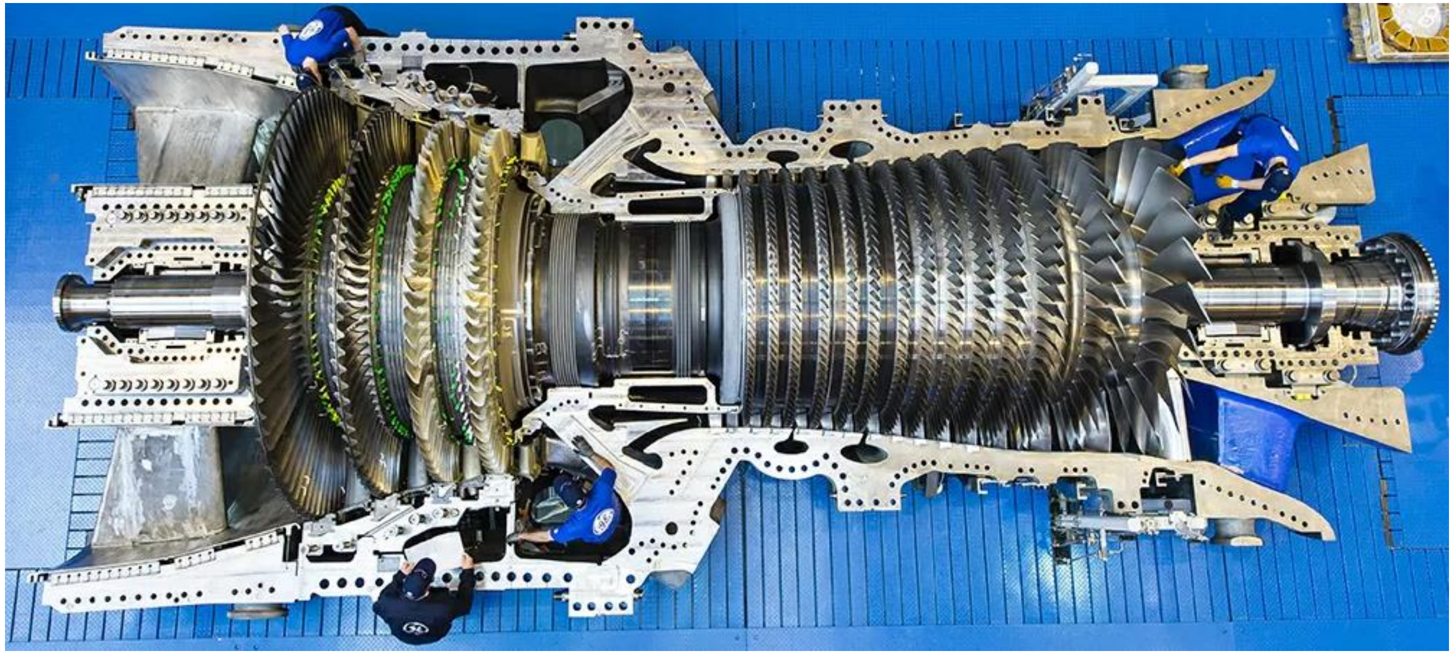
- 3600/1800 RPM motor for 60 Hz applications
- Drive both high speed core and low speed booster
- Integrate turbine with HS or LS shaft (TBD)

Do we need a turbine?

Yes –

- COP < 1 without a turbine
- Resistive heat lower CAPEX and higher efficiency than throttle

Scaling Up – 7HA.02



7HA.02				
Compressor				
PR	Effy	Flow	Texit	Power
[-]	[-]	[kg/s]	[C]	[MW]
23.1	0.85	730	507.1	360.9
Storage Heat Exchanger				
Tout	DP/P	Qin		COP
[C]	[%]	[MW]		[-]
300.0	0.03	151.9		1.10
Turbine				
PR	Effy	Flow	Texit	Power
[-]	[-]	[kg/s]	[C]	[MW]
22.4	0.9	730	-3.6	222.6

500 C Compressor Discharge

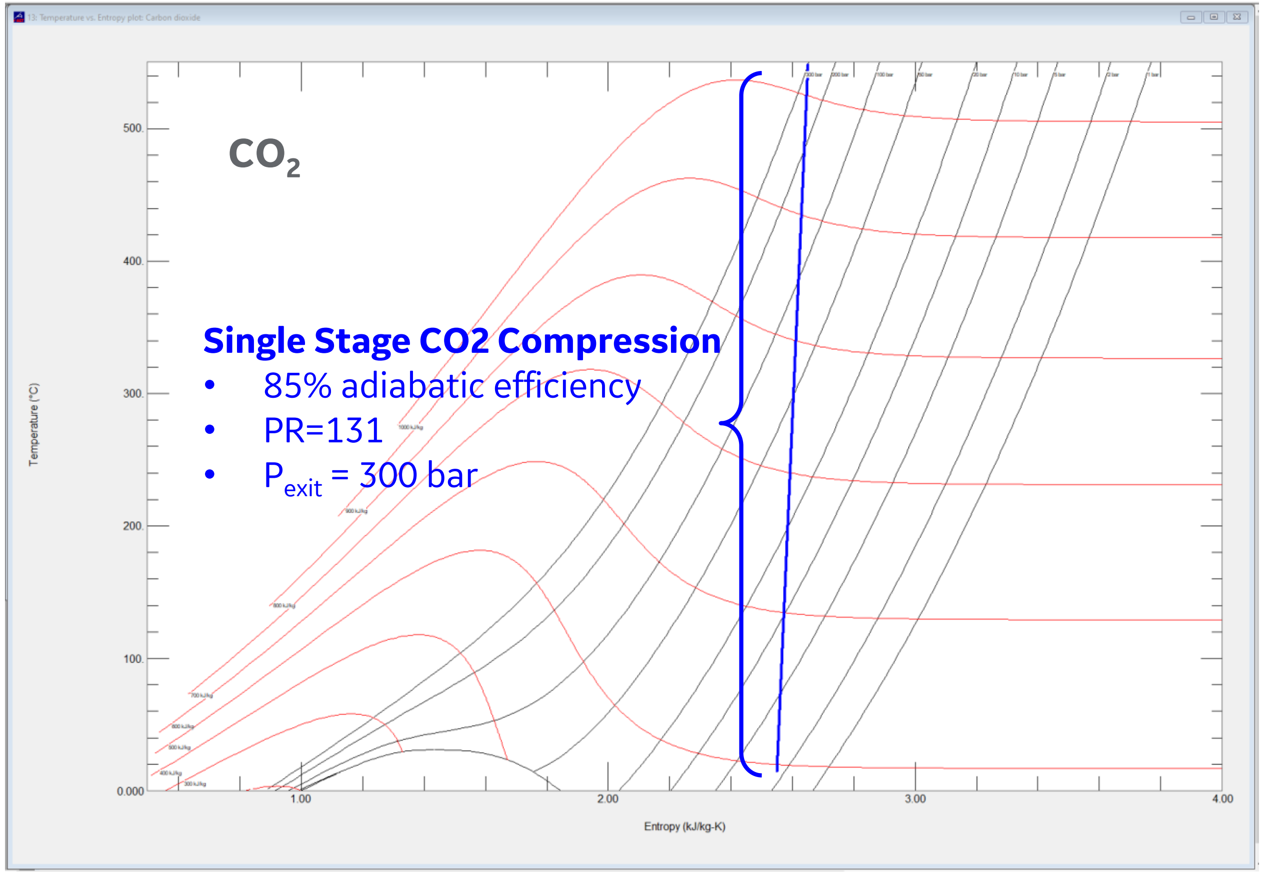
138 MW Net Input @ 3600 RPM

- No gearbox required

COP = 1.1 → 150 MW Heat Input

Simple Single Shaft Architecture

Working Fluid



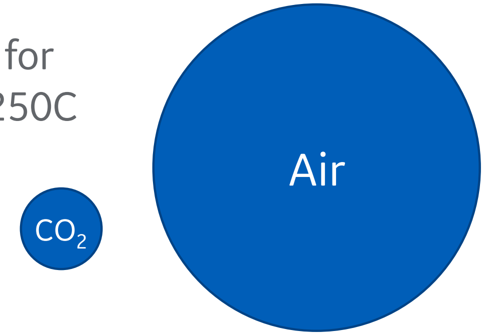
CO_2 Based Heat Pump

- Requires PR=131 to achieve 550C
- 300 bar exit pressure
  - High density – 183 kg/m^3
- Only minor real gas effects
- Closed cycle requires low T HX

Air Based Heat Pump

- Requires PR=31 to achieve 550C
- 31 bar exit pressure
  - Low density – 12.7 kg/m^3
- Open cycle – no low T HX

Relative pipe Size for
100 MW$_{th}$ @ ΔT=250C



Conclusions

High Discharge Temperature Air Compressors Currently Used in Aircraft Engines

- High PR for Cycle Efficiency without Bottoming Cycle
- Largest engines are still < 100 MW scale
- Repurposed aeroderivative shortest path to PTES application @ 550C
- Requires development of custom gearbox, turbine, and bearings

Heavy Duty Gas Turbines Provide Scale

- Lower PR, optimized for combined cycle
- Compressor discharge up to 500C in HA.02
- Simple single 3600 RPM shaft
- 140 MW in a single machine
- Requires development of a custom turbine and bearings.

CO_2 Requires High PR to Achieve 550C

- PR > 100 or staged system
- High discharge pressure results in small (but thick) pipes