12 Megawatt Cascaded Humidified Advanced Turbine (CHAT) Plant General Overview

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Abstract

In the bulk of the power market, distributed energy technologies will find it difficult to compete with the nearly 60-percent-efficient combined-cycle plants as the design of choice for a power generator, at least in the near or medium term. It should be expected that the cost of electricity ($/kWh) produced by a small capacity, and therefore less efficient and more expensive, distributed generation (DG) plant would be higher at the place where power is generated compared to that produced by large power plants. DG plants are helped in this competition with large central-station plants by various charges associated with the delivery of power from those plants, such as a capacity charge ($/kW) for the power availability, transmission losses, and distribution fees. Also, sometimes DG economics are justified by the deferral of construction of transmission lines.

Therefore, for the success of the DG, which has many operational and institutional merits, it is very important to develop small capacity combustion turbines with efficiency approaching that of large utility plants. The latest initiative by DOE, denoted as FMGT – flexible mid-size gas turbines- is targeting efficiencies of 45 percent with potential increase to 47 percent.

This presentation shows the latest developments on a 12-MW Cascaded Humidified Advanced Turbine (CHAT) plant with an estimated efficiency of 45 to 46 percent, based on proven turbomachinery components provided by Rolls Royce Allison and Dresser–Rand. This two-shaft combustion turbine (CT) with intercooling, reheat, humidification, and recuperation is ready for the demonstration project.

This presentation also shows thermal cycles, plant performance and operations, and results of construction costs estimates and it identifies major equipment suppliers. Special attention will be paid to economics of the CHAT plant in the DG application with comparison to other available options.

12 MW CHAT Plant
General Overview
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General Information on CHAT Technology

- U.S. Patent #5,347,806 and #5,386,688
- Inventor: Dr. M. Nakhamkin
- Title Co-Holders:
  - Cascaded Advanced Turbine, L.P. (CAT,L.P.) - with exclusive rights to license, commercialize, use, sell, manufacture, and operate the CAT/CHAT plants.
  - Electric Power Research Institute,(EPRI) -with rights to participate in the technology technical advancements.

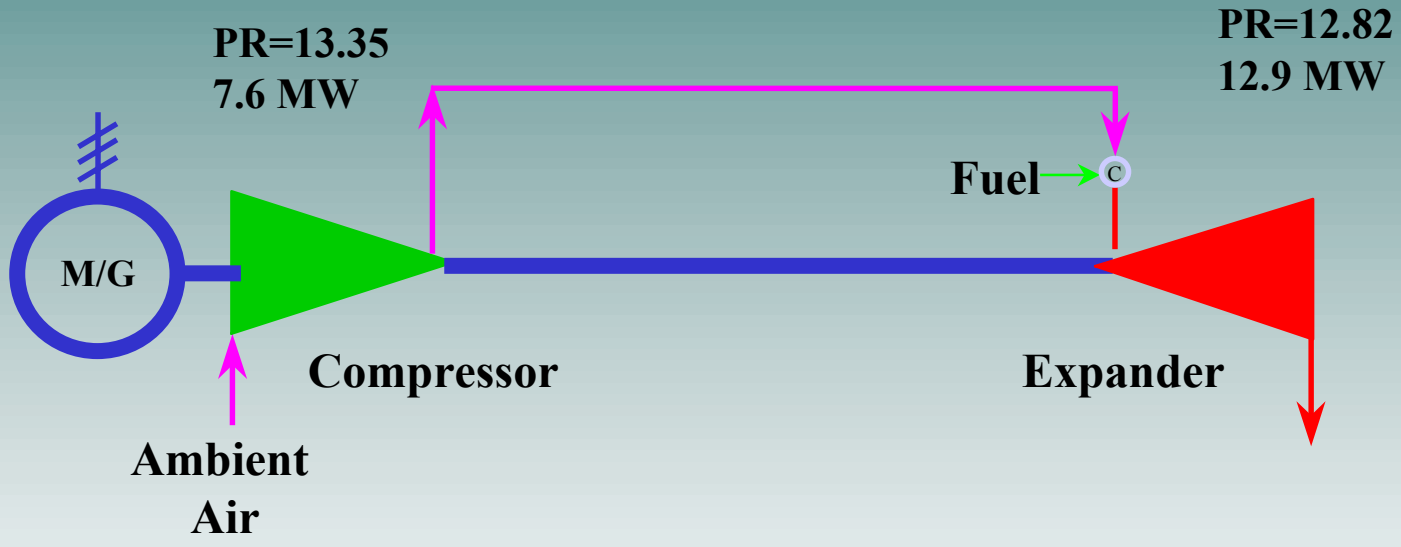
What is CHAT?

- *C*ascaded *H*umidified *A*dvanced *T*urbine
- CHAT is a sophisticated thermal cycle with reheat, intercooling, recuperation, and humidification
- Near-Term Consideration: It is the most pragmatic approach for the sophisticated thermal cycle development based on integration of current technology combustion turbine and industrial turbomachinery components including external intercoolers, reheat combustors, recuperator and saturator. CHAT has combined cycle efficiency and simple cycle operating flexibility and specific costs ($/kW)
- Prospectives: Presents a bridge for future combustion turbine advancements with potential performances (efficiencies and emissions) beyond those achievable for combined cycle plants.

What is CHAT?

- *C*ascaded *H*umidified *A*dvanced *T*urbine
- Multi-phase development program targeting near term and long term applications
- Eliminates the need for extensive and expensive development
- High probability for a success

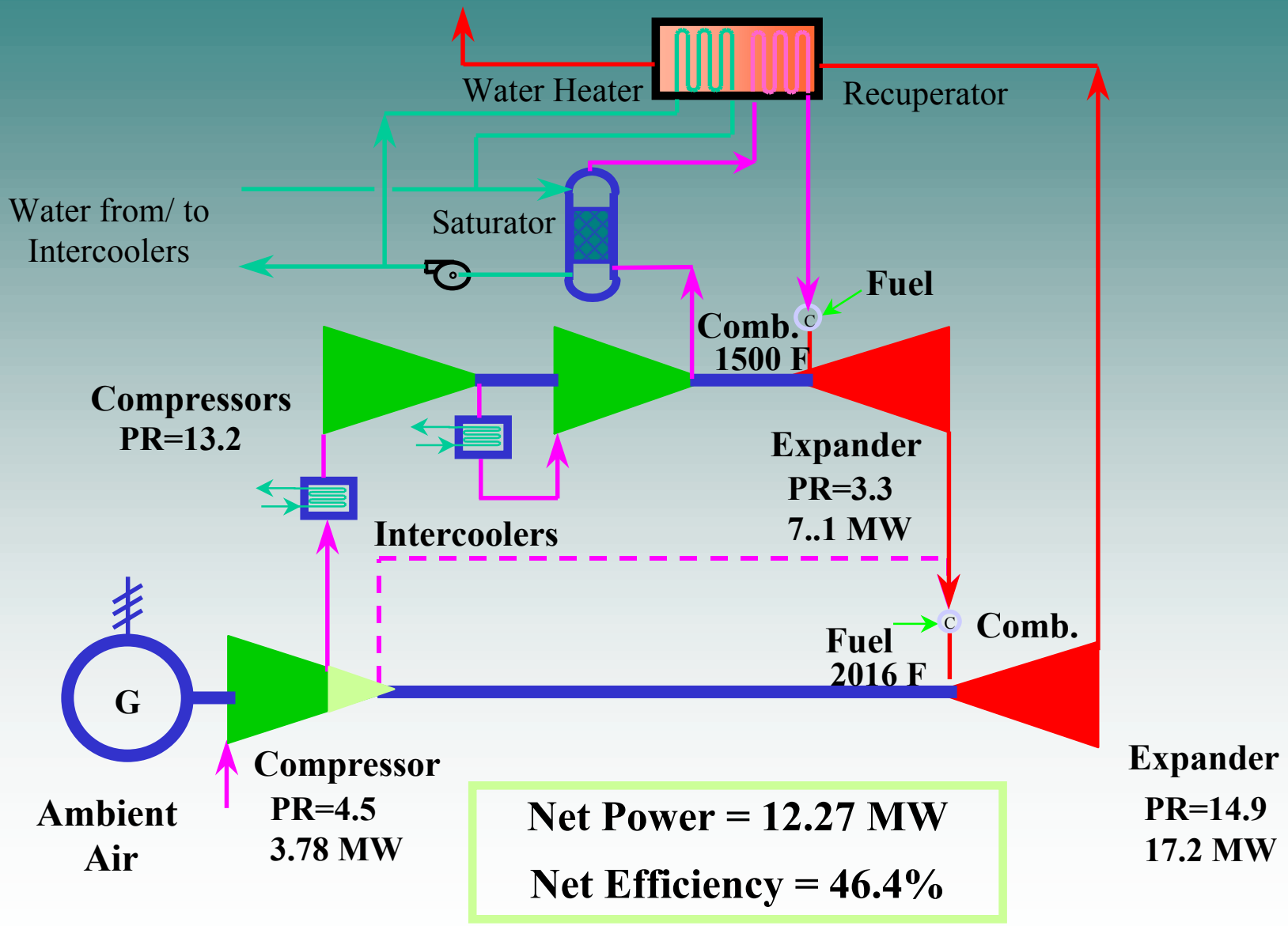
Allison 501KB7 CT Simple Cycle Diagram



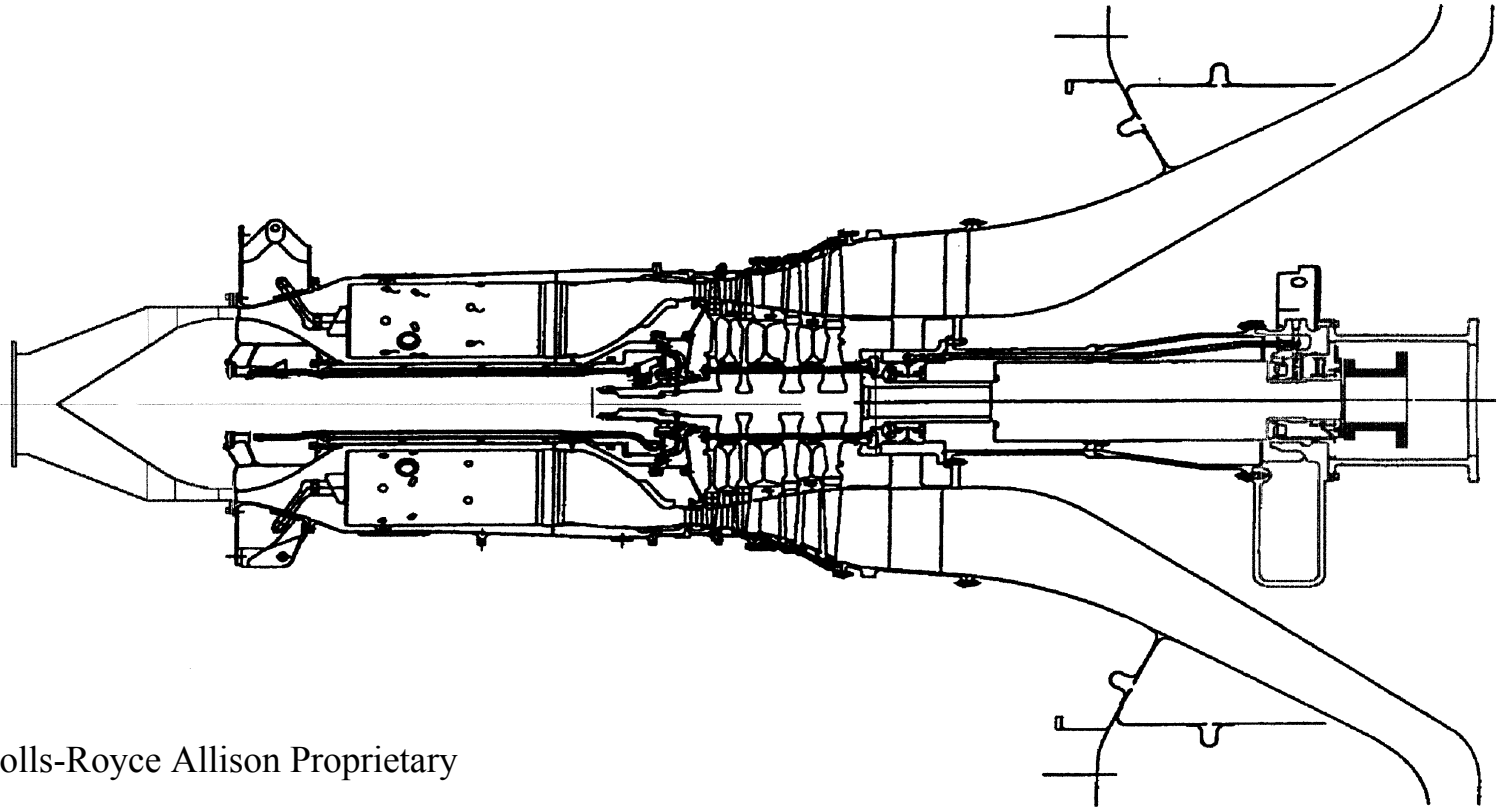
Net Power = 4.77 MW

Net Efficiency = 28.85%

CHAT Cycle Diagram

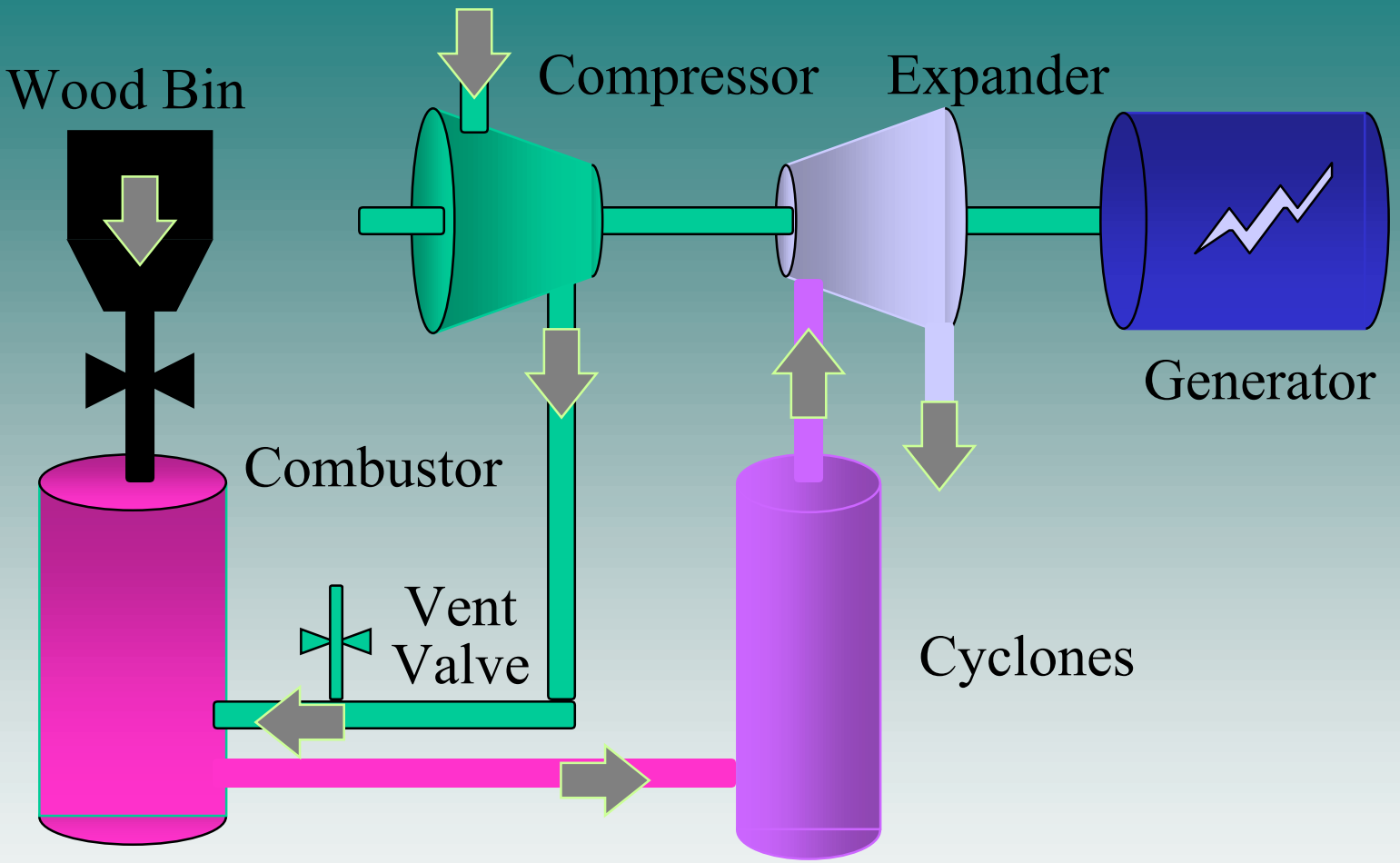


Rolls-Royce Allison Model 501-KCS5 Turboexpander



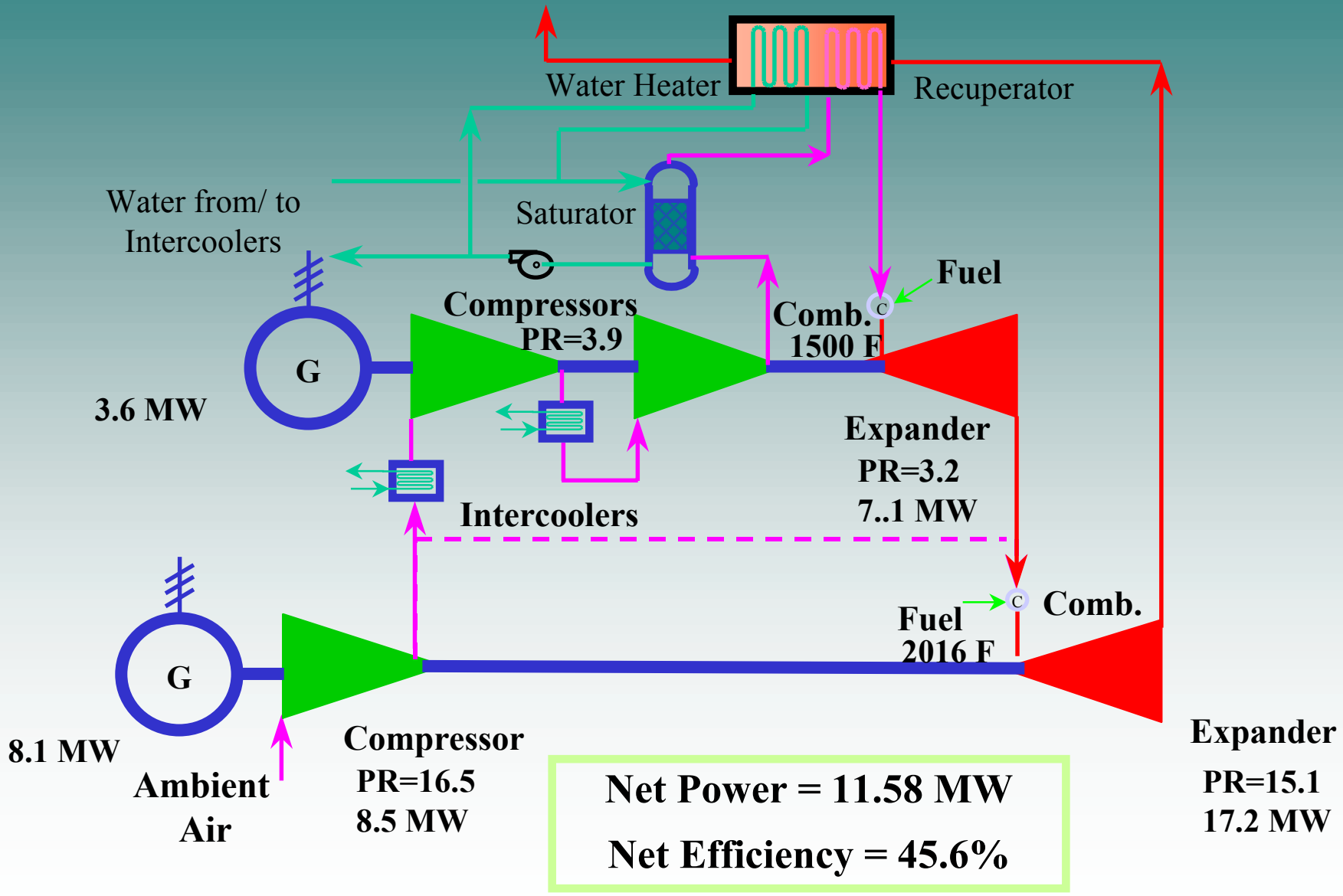
Rolls-Royce Allison Proprietary

Allison KM7 Gas Turbine

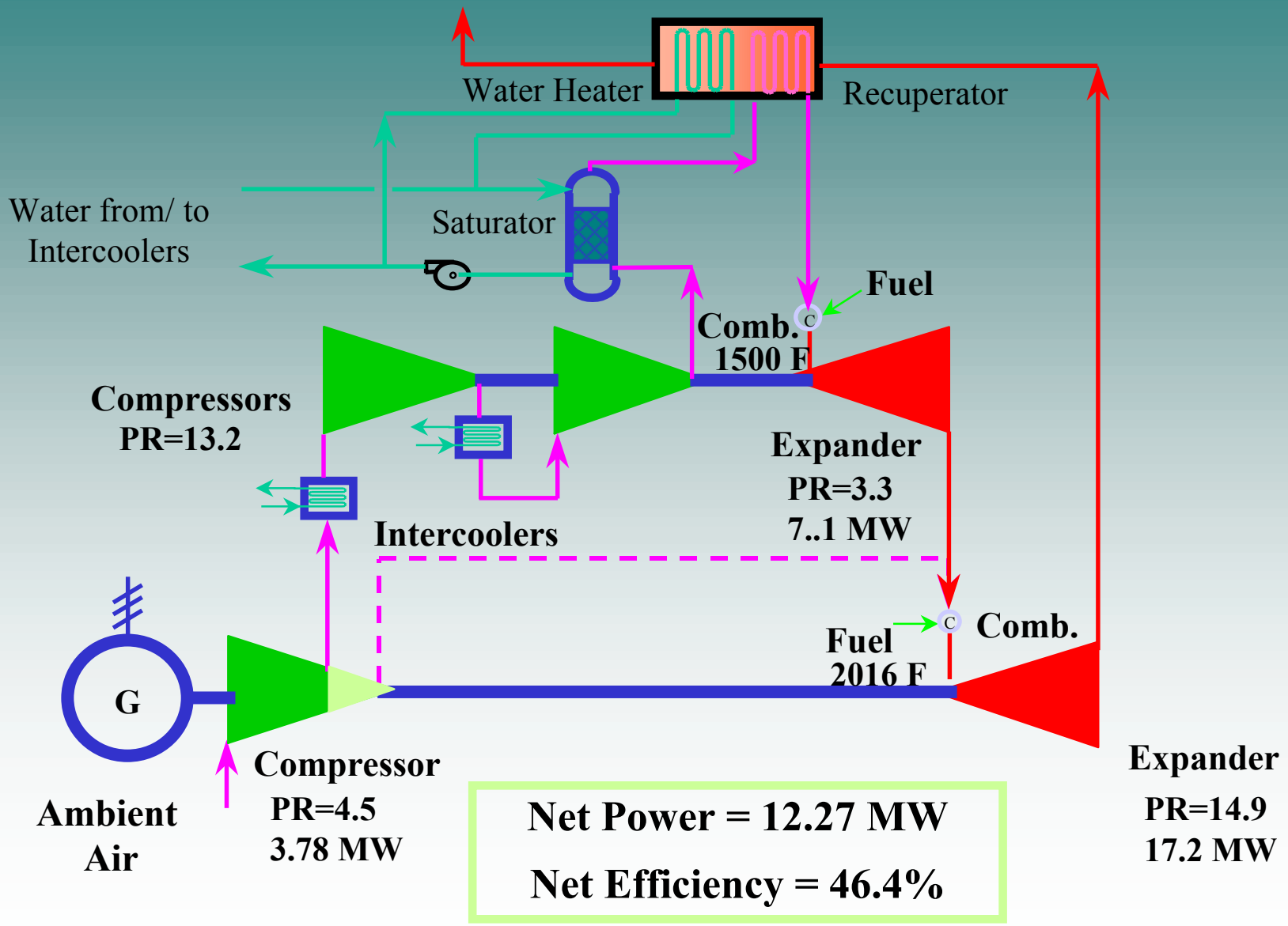


Turbomachinery Supplier: Allison
Sponsored by: DOE
Owner: Cogeneration of Tennessee, Inc.
Location: Red Boiling Springs, TN
Power Sold to TVA

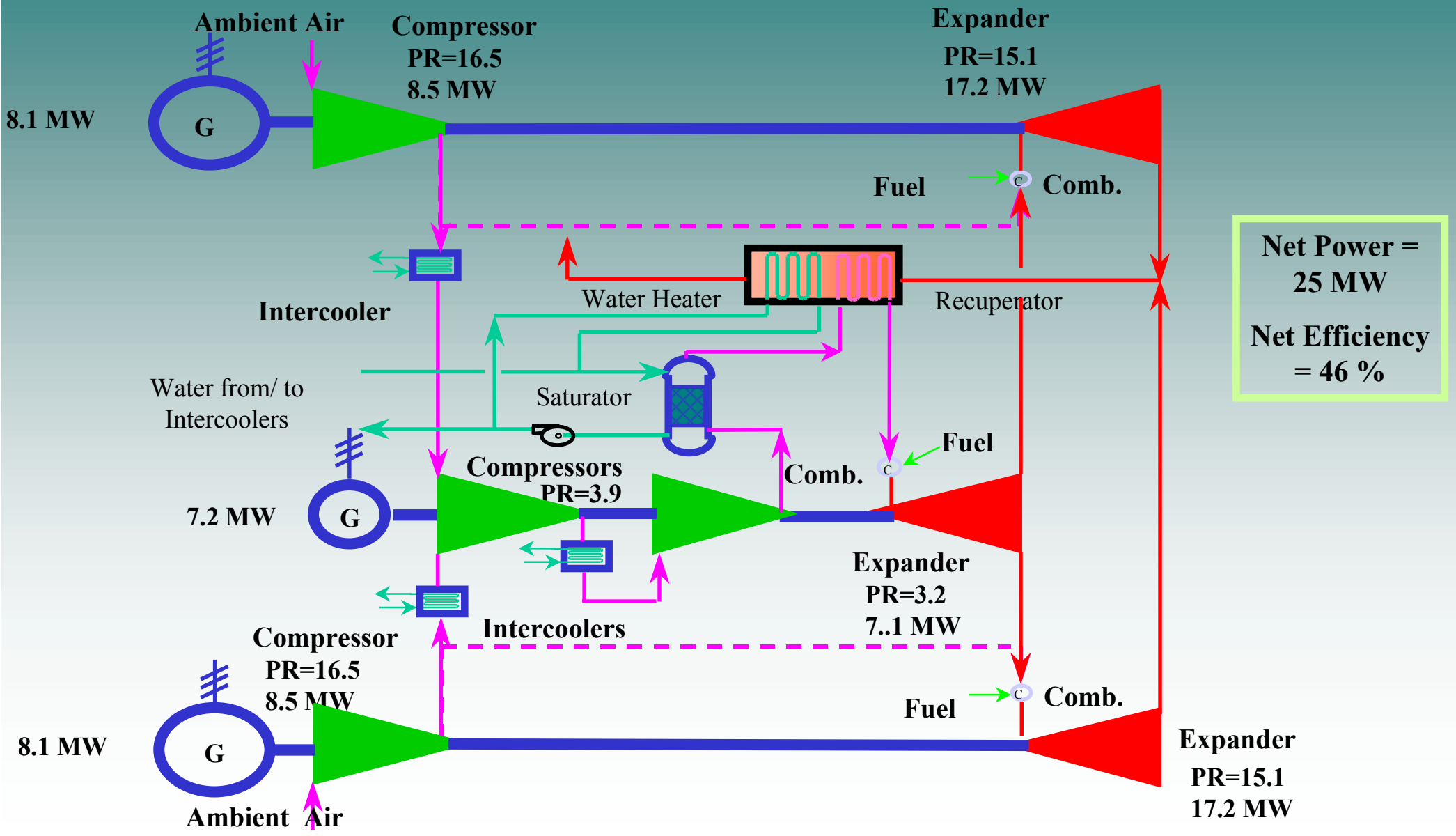
CHAT Cycle Diagram Based on KM7 CT



CHAT Cycle Diagram



CHAT Cycle Diagram



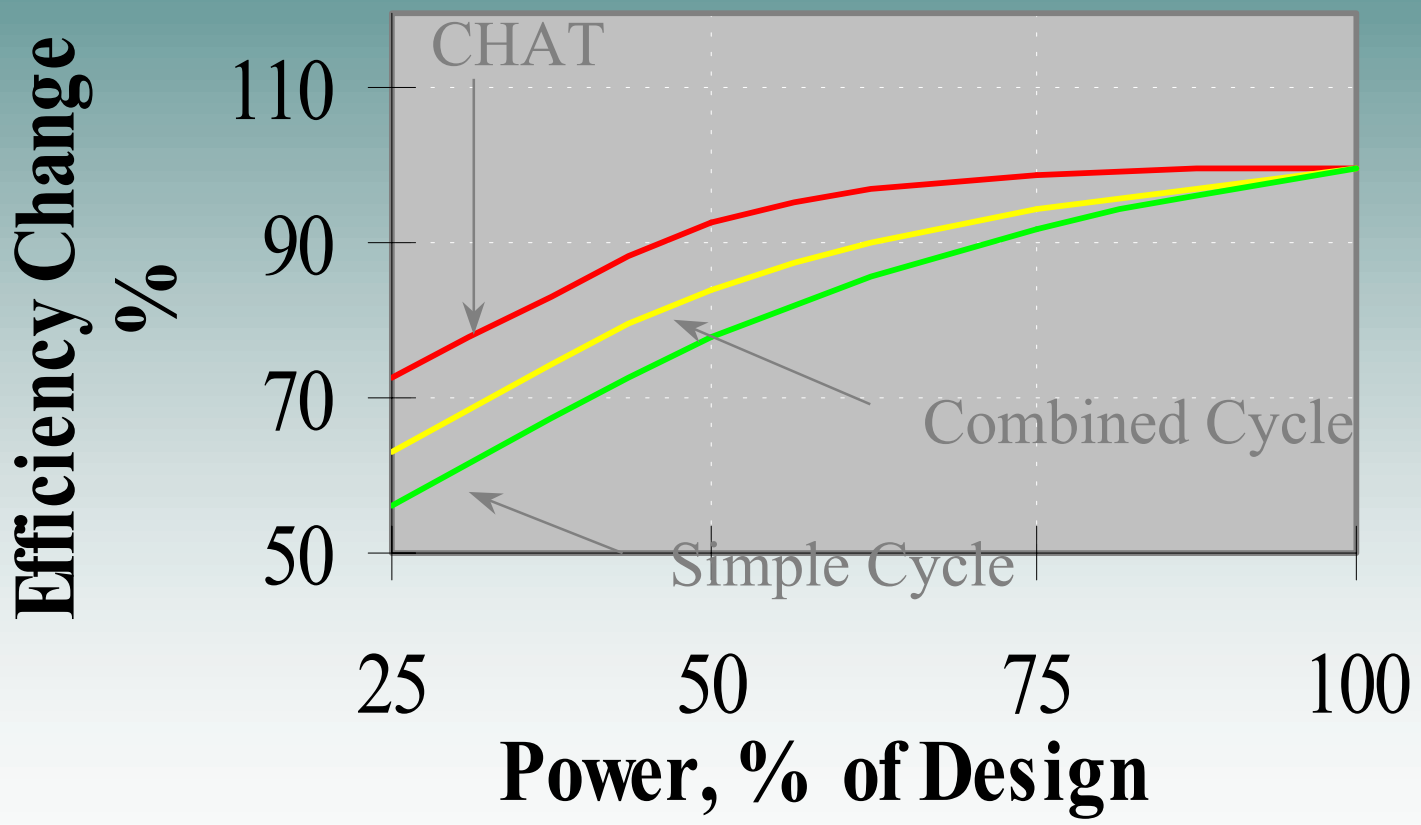
Net Power = 25 MW

Net Efficiency = 46 %

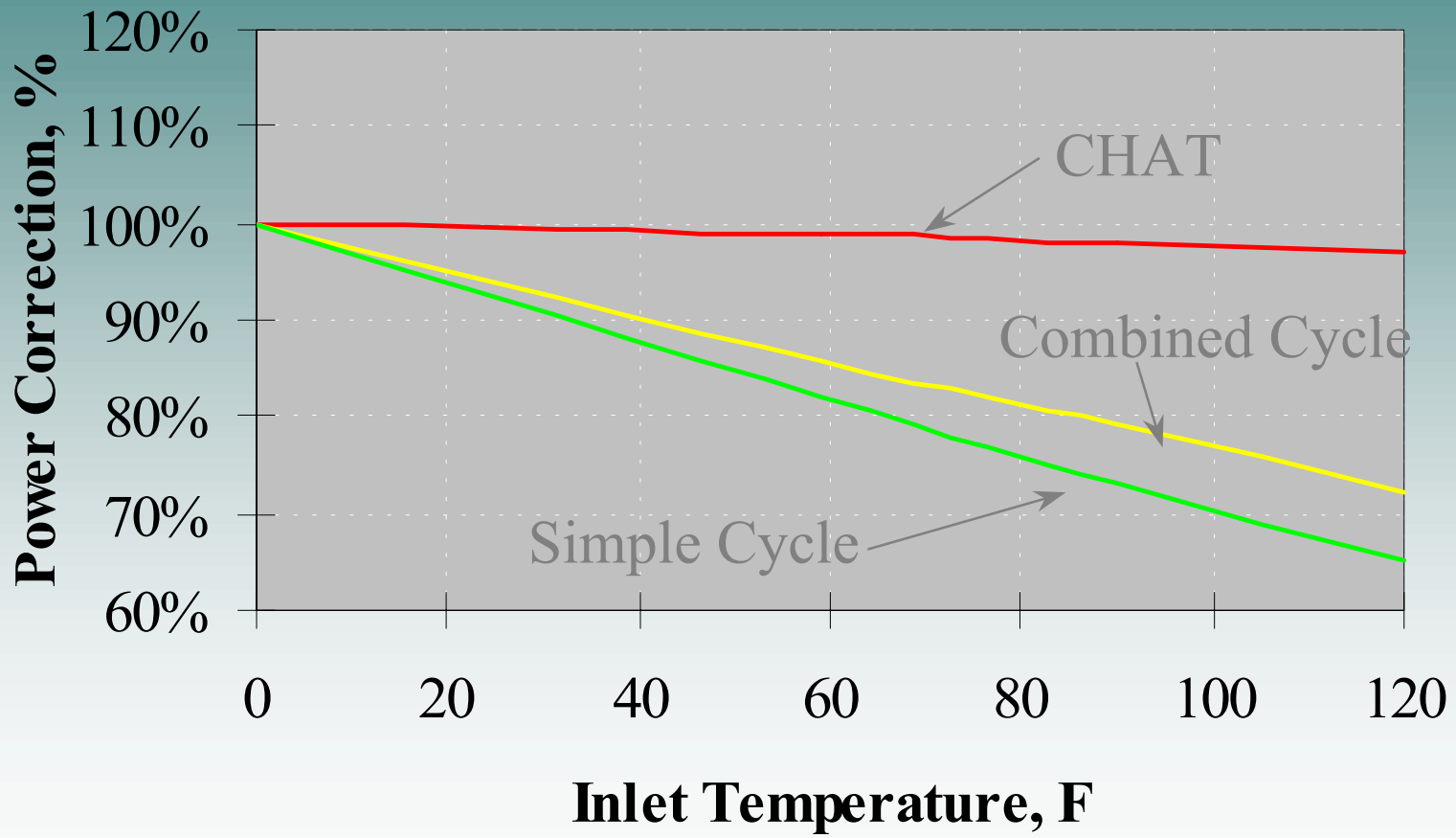
Performance Comparison of Simple Cycle and CHAT Based upon Allison 501-KB7

Concept	Simple Cycle	CHAT	CHAT 2 Generator
Operating Conditions	ISO	ISO	ISO
Net Power, MW	5	12	11.5
Net Heat Rate, Btu/kWh	11,823	7,356	7,500
Net Efficiency, %	29	46.5	45.5

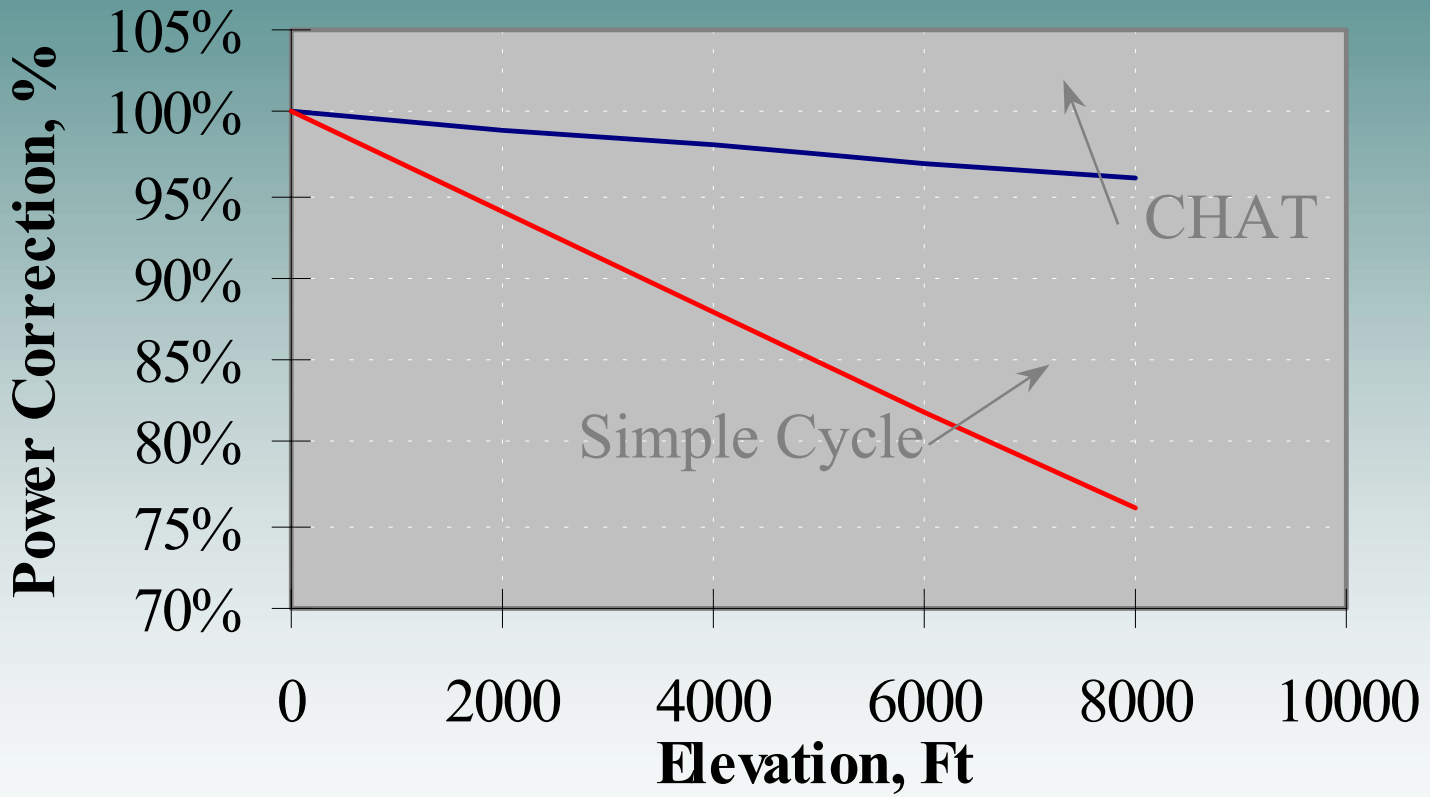
Efficiency Versus Power



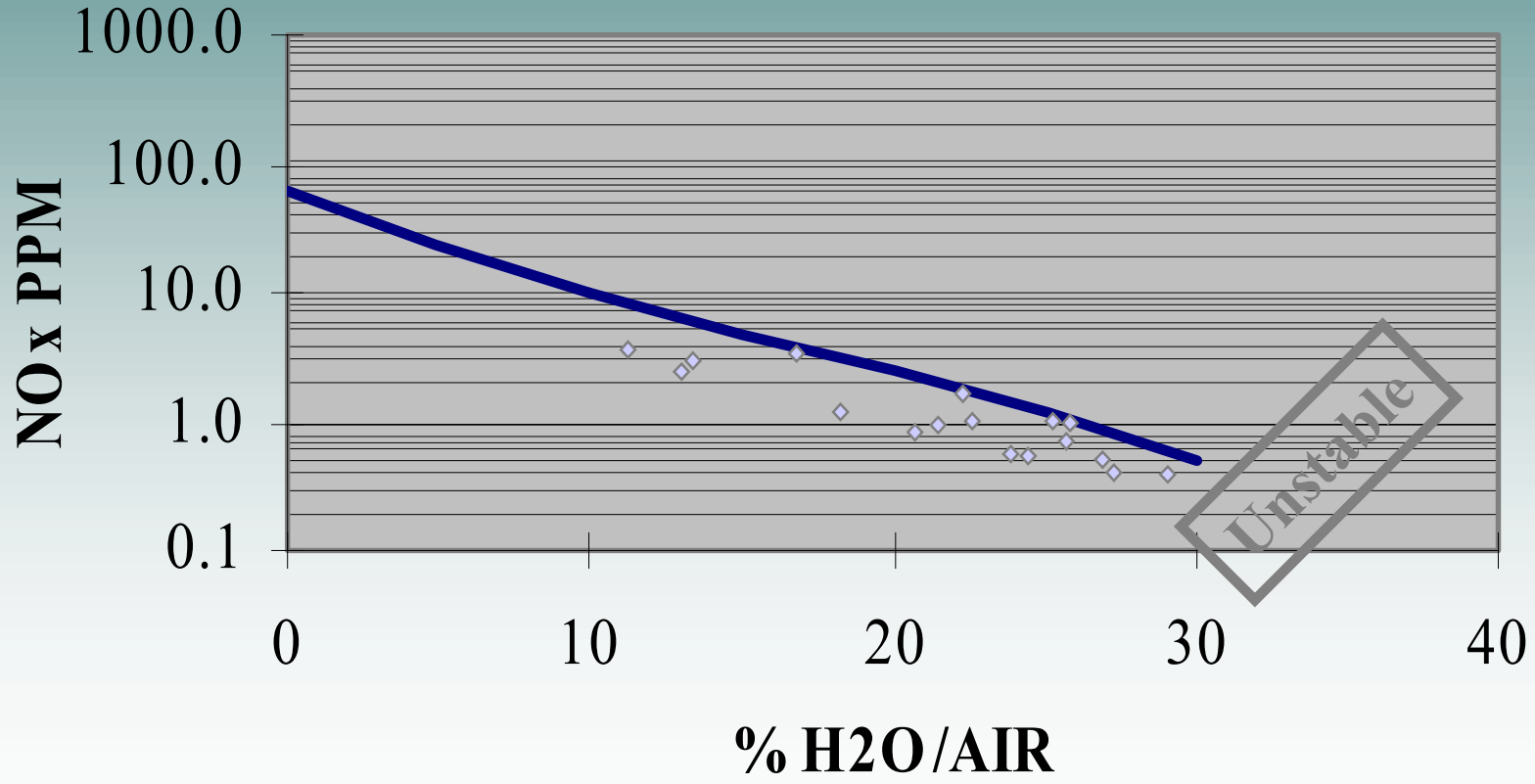
Temperature Correction



Elevation Correction



Emissions Tests



Summary

- 12 MW CHAT plant is a high efficiency (45-46%) sophisticated thermal cycle with intercooling, reheat, recuperation and humidification
- It is flexible for a range of operations:
  - **high part-load efficiency,**
  - **negligible power degradation at high temperatures and elevations**
  - **single digit NOx emissions**
  - **Quick start-up**

Summary

- Utilizes components with proven experience
- CHAT technology is ready for the demonstration project
- Incremental technology- applicable to any CT with proper adjustments

CHAT Technology Development

- *Phase 1:Proof of Concept*
- The CHAT demonstration project to demonstrate the sophisticated thermal cycle with intercooling, reheat, recuperation and humidification features,
- Eliminates the need for extensive and expensive development due to use of current CT's and industrial components with proven and reliable operating experience
- Objectives: To demonstrate the sophisticated thermal cycle, performance, emissions,operating flexibility
- *Phase 2: CHAT Plant with Use of State of the Art Components*
- *Phase 3: Development of Components Specific to Sophisticated Cycles (CHAT)*

CHAT Technology Development

- *Phase 2: CHAT Plant with Use of State of the Art Components*
- The CHAT plant integrated with “G,” “H” and ATS technology
- Expected efficiency of 62-65%
- Combustion turbine operating flexibility
- Development is limited to proper integration of CHAT cycle with advanced components
- Objectives: To demonstrate the sophisticated thermal cycle with advanced CT components

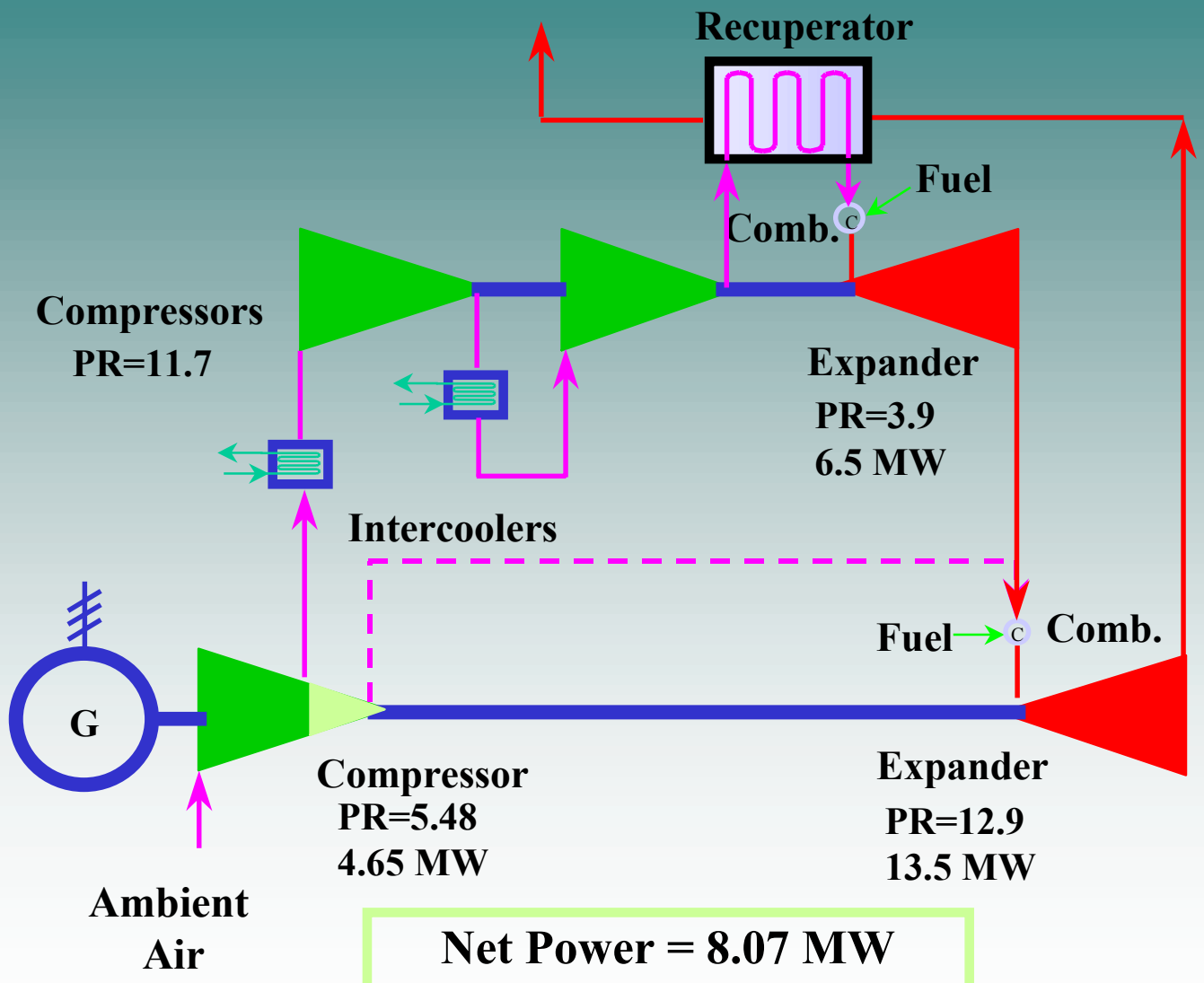
CHAT Technology Development

- *Phase 3: Development of Components Specific to Sophisticated Cycles (CHAT)*
- Development of the HP expander with 2000-2100F TIT
- Development of the LP combustor with 1200-1300F inlet temperature
- Water recovery from the exhaust
- Expected efficiency higher than 62-65%
- Objectives: To demonstrate the sophisticated thermal cycle with advanced CT components and newly developed components

CHAT Technology Development

- *Phase 1:Proof of Concept*
- The CHAT plant with intercooling, reheat, recuperation and humidification features,
- Use of current CT's ("F" technology) and industrial components with proven and reliable operating experience
- Eliminates the need for extensive and expensive development
- Objectives: To demonstrate the sophisticated thermal cycle, performance, emissions,operating flexibility

CAT - Cycle Diagram



Net Power = 8.07 MW

Net Efficiency = 37.8%

CHAT Plant based on Allison KM(KB7) CT
Estimated Turnkey Plant Cost
(Net Power 11,300 kW - Net HR 7800 Btu/kWh (LHV)

- Total for Turbomachinery and Auxiliaries $4,461,000
  - Power Shaft (Allison KM (KB7) $2,790,000
  - Combustors $100,000
  - Second Shaft and Auxiliaries $1,571,000
- Major Cycle Equipment $1,436,000
  - Recuperator and Stack
  - Intercoolers
  - Fuel Heater and NG Booster Compressor
  - Saturator
  - Cycle Pumps
  - Cooling Tower

CHAT Plant based on Allison KM(KB7) CT
Estimated Turnkey Plant Cost
(Net Power 11,300 kW - Net HR 7800 Btu/kWh (LHV)

- Auxiliary Mechanical Equipment $380,000
  - Piping , Insulation and Plumbing/HVAC
  - Raw Water Storage and Water Treatment
  - Fire Protection
  - Fuel Oil System
  - Effluent Treatment and EPA Emissions Monitoring
- Auxiliary Electrical Equipment $250,000
  - Instruments and Controls
  - Step-Up and Auxiliary Transformers
  - HV Breaker
  - Electrical Distribution

CHAT Plant based on Allison KM(KB7) CT
Estimated Turnkey Plant Cost
(Net Power 11,300 kW - Net HR 7800 Btu/kWh (LHV)

• Total Equipment Cost	$7,527,000
• Direct and Indirect Construction Labor, Material and Equipment	$1,700,000
• Engineering and Technical Services	$300,000
• Contingency, Fee, Taxes, Bonds, Insurance	$500,000
Total Estimate (1996, US):	$9,027,000
Specific Capital Cost, $/kW	770