Investigations on Thermophysical Properties of Humid Air

—

Part of the Project

Advanced Adiabatic Compressed Air Energy Storage

AA-CAES

of the European Union

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Objective of the EU Project AA-CAES

Development of an economically viable pure storage technology based on compressed air

- ⇨ Storage efficiency of electrical energy > 70 %
- ⇨ Specific investment cost < 12 € / kWh at 30 MW
  Corresponding to power-output related investment cost < 1200 € / kW at 30 MW

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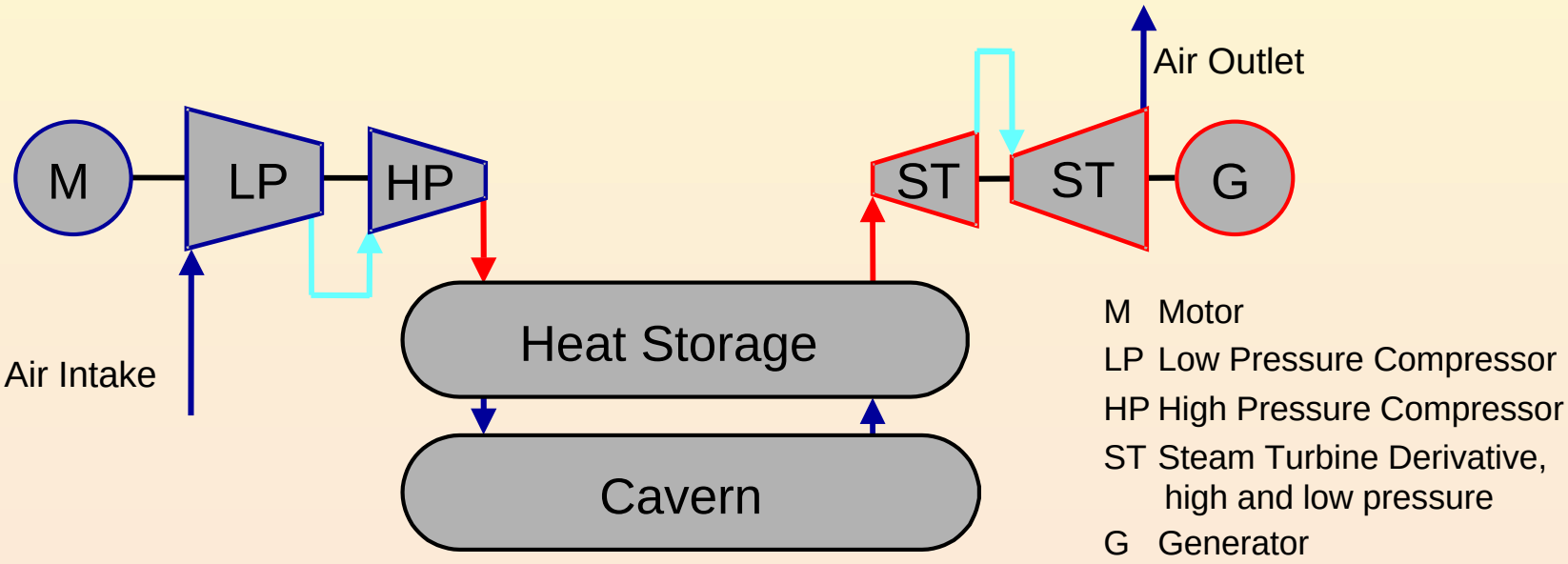
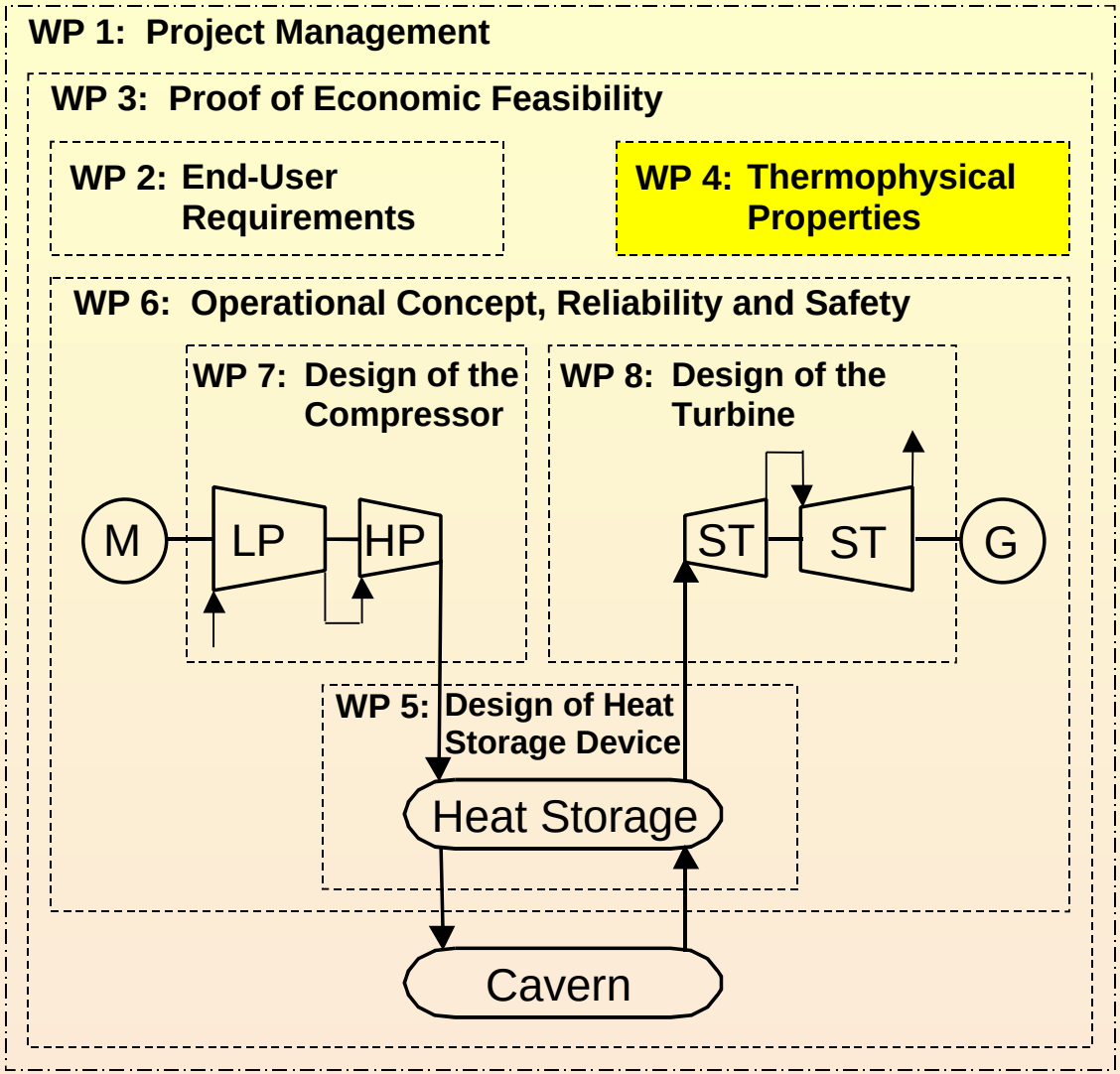
Technical Concept

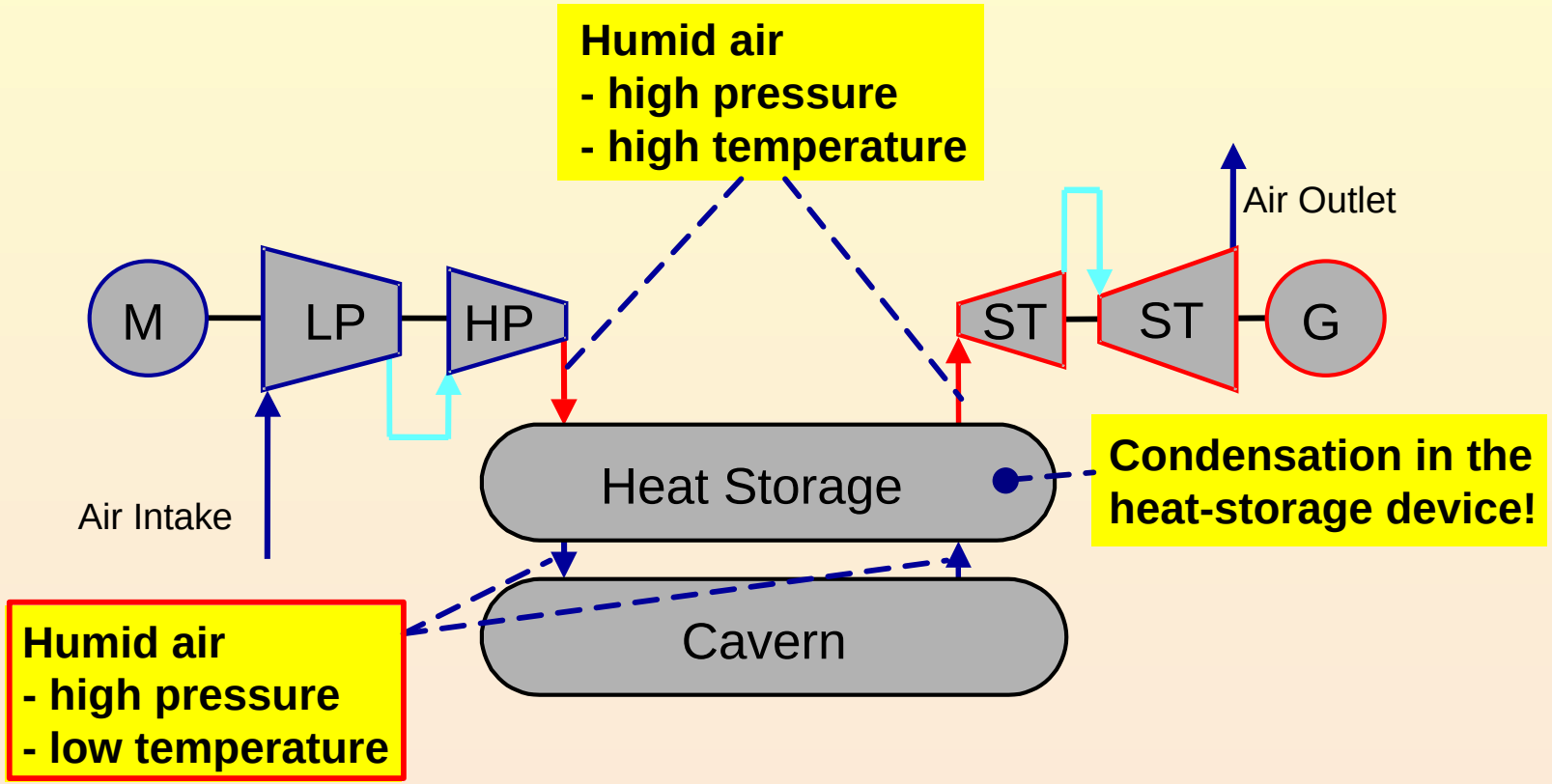


Structure of the EU Project AA-CAES

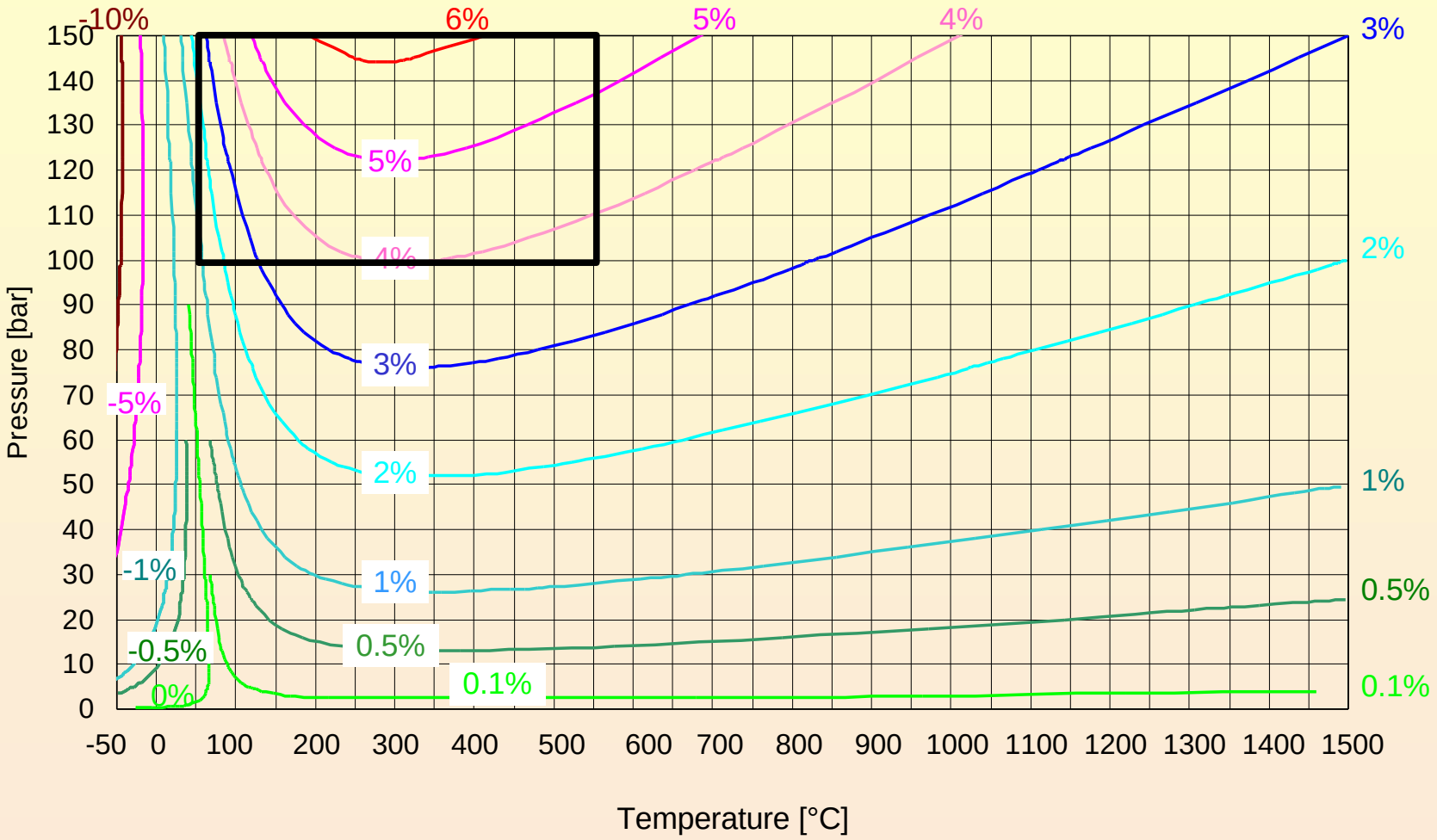


WP 4: Thermophysical Properties

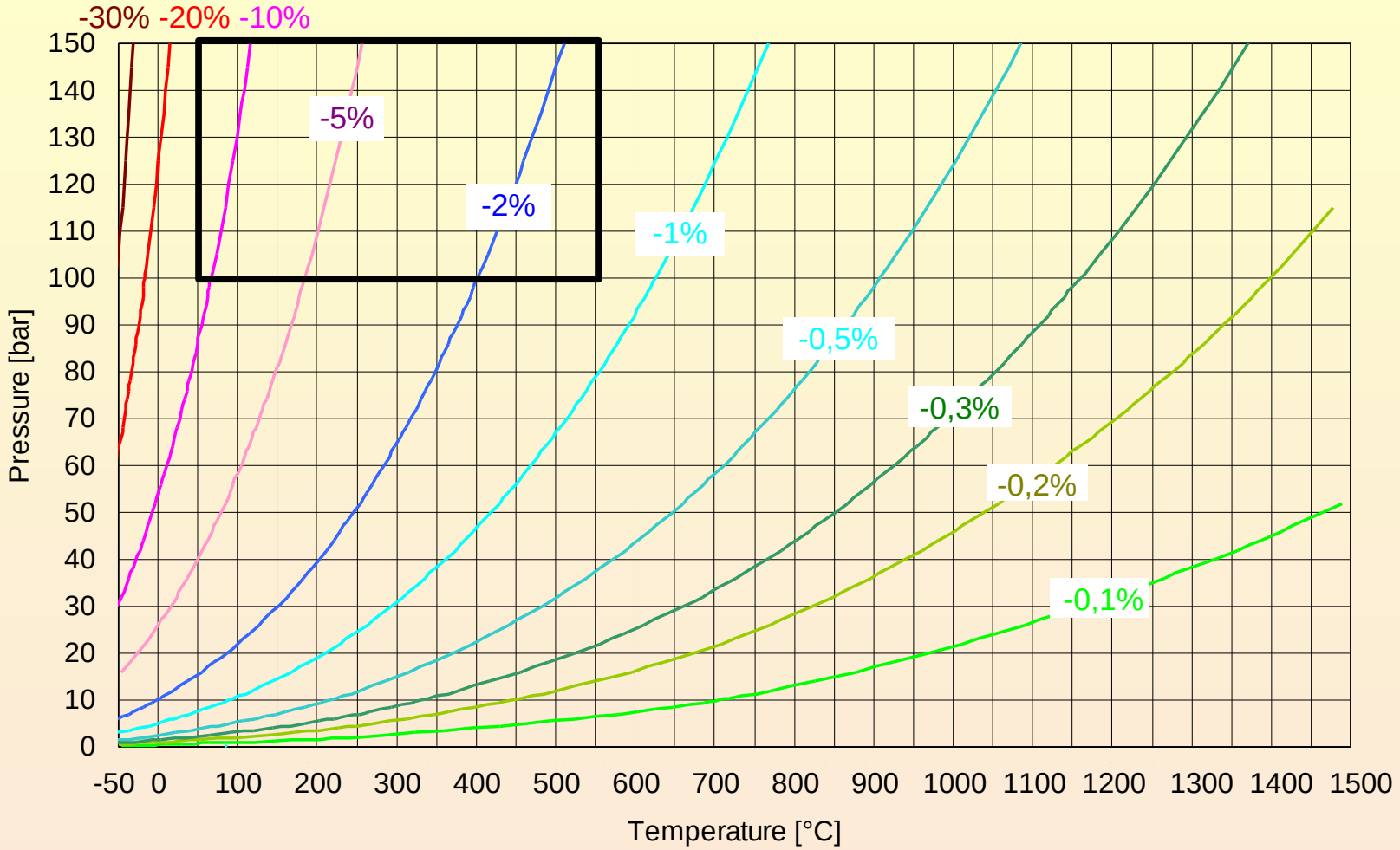
Working Fluid: Humid air at pressures from ambient to 150 bar
at temperatures from ambient to 550 °C
at water content up to 10 ... 20 (40) % (mass)



Real Gas Behavior of the Density r of Dry Air



Real Gas Behavior of the specific Heat c_p of Dry Air



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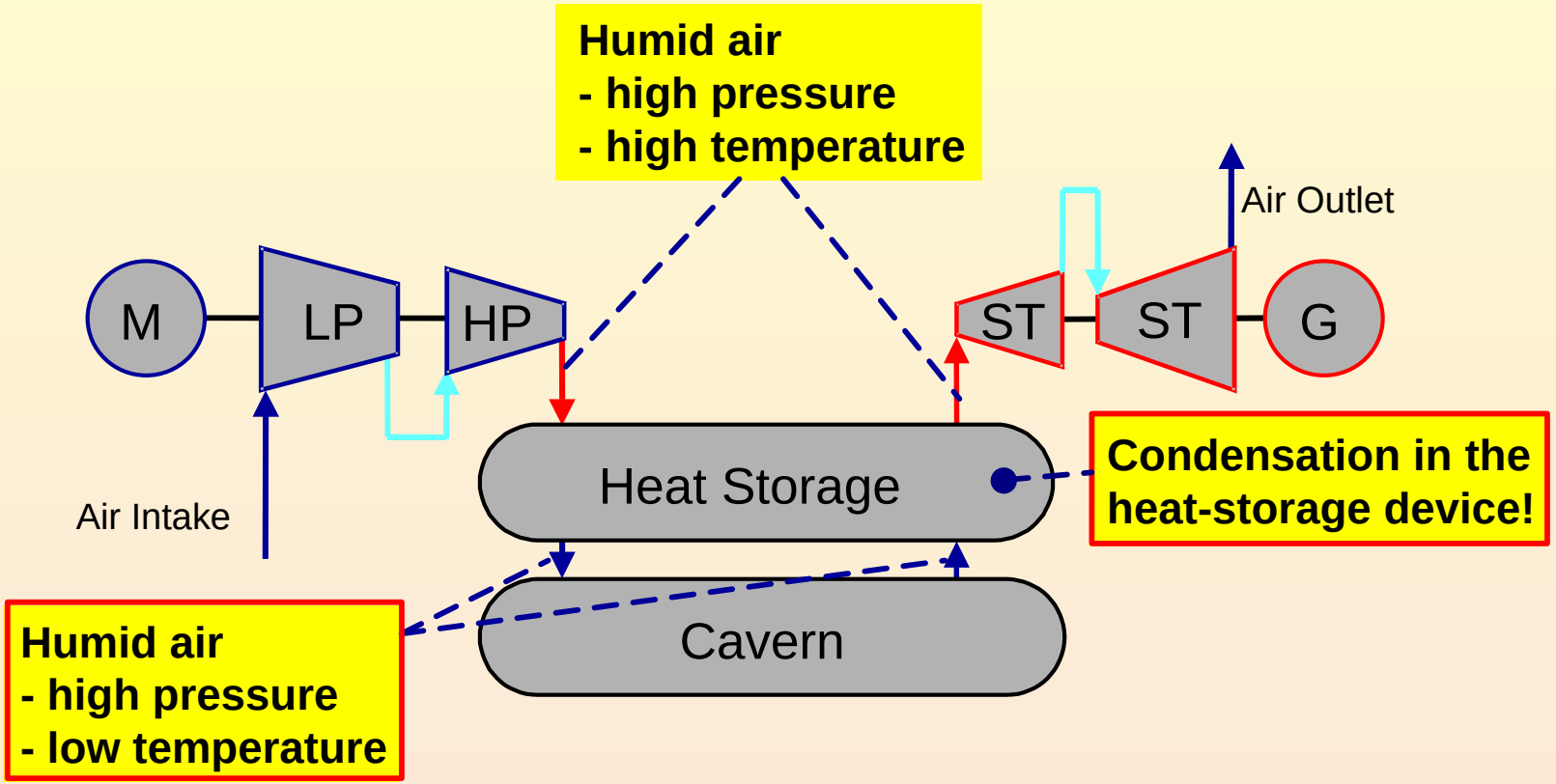

Tasks of WP 4: Thermophysical Properties

Task 4.1	Task 4.2	Task 4.3
Generation of Experimental Reference Data	**Development of a Data Base**	**Identification/Development of Suitable Models, Exploitation of Results**
Imperial College of London (UK) Univ. for Agriculture of Wien (A) Univ. of Lisboa (P) PTB Braunschweig (D) Ruhr-Univ. of Bochum (D)	Univ. Appl. Sc. of Zittau (D) Univ. of Rostock (D)	Univ. of Stockholm (S) Univ. Appl. Sc. of Zittau (D) Univ. of Rostock (D) Univ. of Paderborn (D)
(December 2004)	(March 2005)	(December 2005)

Task 4.1: Generation of Experimental Reference Data

Property	Institution	Temp. Range [K]	Pressure Range [MPa]	Comments
Density	PTB - National Metrology Institute of Germany	298 ... 520	0,1 ... 15	T_{max} may be extended to 670 K
	Ruhr-Univ. of Bochum (D)	240 ... 520	0,1 ... 30	
Speed of sound	Imperial College of London (UK)	100 ... 450	0,1 ... 20	T_{max} may be extended to 475 K
	Univ. for Agriculture of Wien (A)	230 ... 470	0,1 ... 15	
Dew point	Imperial College of London (UK)	298 ... 700	0,1 ... > 20	
	Univ. for Agriculture of Wien (A)	278 ... 420	0,1 ... 15	Two methods tested
Viscosity	Ruhr-Univ. of Bochum (D)	240 ... 520	0,1 ... 30	
Thermal conductuvity	Univ. of Lisboa (P)	298 ... 620	0,5 ... > 30	T_{max} may be extended to 720 K
Mole fractions of steam: 0 %, 1 %, 3 %, 5 %, 10 %, 25 %				

Call for measurements of heat capacity !

Task 4.2: Development of a Data Base for Humid Air

- **Installing work group server including Secure FTP-System in Zittau**
- **Collection of experimental data from literature**
  - ⇨ for thermodynamic properties in Zittau (Hans-Joachim Kretzschmar)
  - ⇨ for transport properties in Rostock (Eckhard Vogel)
- **Setting up property data base for humid air in MS-Excel in Zittau**

Table_References_Data_Files.xls

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You are invited to use the data base for humid air.
Please contact me for user name and password.

Task 4.3: Identification/Development of Suitable Models, Exploitation of the Results

Thermodynamic Properties

Comparing existing property models with data from literature and new experimental data

Evaluating different property models

Recommendation for the calculation of thermodynamic properties

Assumption for the development of a new standard for calculating thermodynamic properties of humid air

Transport Properties

Comparing existing property models with data from literature and new experimental data

Evaluating different property models

Development of a new standard for calculating transport properties of humid air

Evaluation of Thermodynamic Property Models for Humid Air

Ideal mixture of ideal gases - Library LibFLUFT_FLT of Zittau

- VDI Guideline 4670

Ideal mixture of real fluids - Library LibHuGas of Zittau

- Nitrogen: Span et al. (2000)
- Oxygen: Schmidt and Wagner (1987)
- Argon: Tegeler et al. (1999)
- Steam: IAPWS-95

Ideal mixture of the real fluids dry air and steam - Library LibHuAir of Zittau

- Dry air: Lemmon et al. (2000)
- Steam: IAPWS-IF97

Real mixture of real fluids

- Virial equations of Rabinovich and Beketov (1995) and Hyland and Wexler (1983)
- Modified Redlich-Kwong equation of Yan (2003), Library MoistAirTab^{TM} of ChemicaLogic (USA)
- Multifluid model of Wagner et al.

→ Modification of fundamental equation for natural gas