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Property Libraries for Working Fluids for Calculating Heat Cycles, Turbines, and Boilers using Mathcad® 14

Contents

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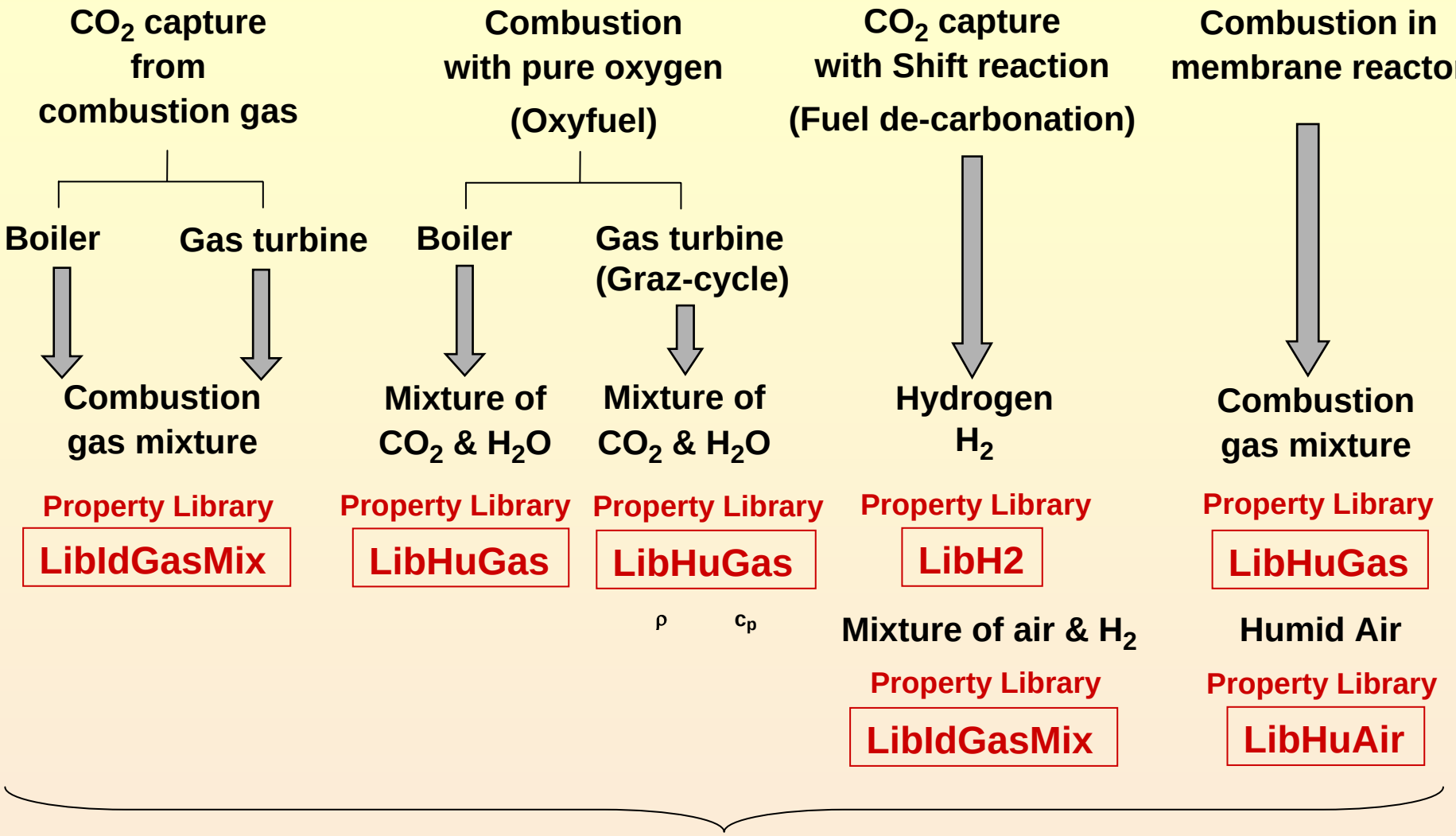
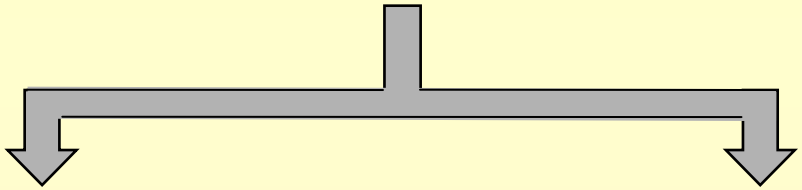
Energy Conversion Processes with CO_2 Capture



ORC Processes



Siloxanes

$C_6H_{18}OSi_2$

LibMM

$C_8H_{24}O_4Si_4$

LibD4

$C_{10}H_{30}O_5Si_5$

LibD5

$C_{14}H_{42}O_5Si_6$

LibMD4M

Refrigerants

Ammonia

LibNH3

R134a

Lib134a

Propane

LibPropane

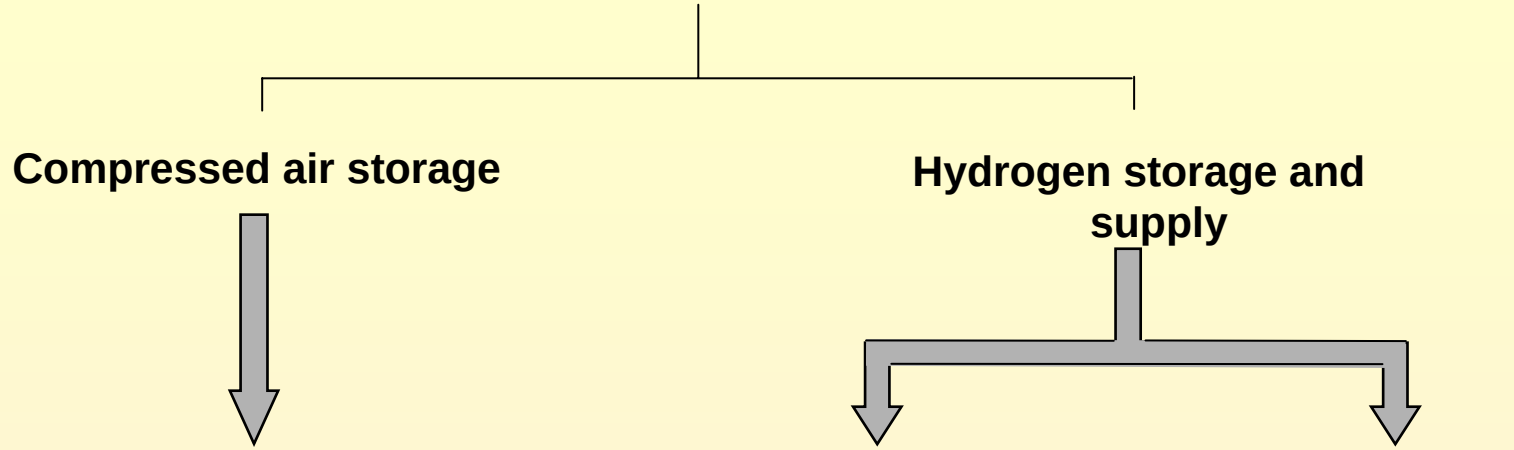
Iso-Butane

LibButan_Iso

n-Butane

LibButan_n

Energy Storage and Hydrogen Supply



Property Library

LibHuAir

Ideal mixture of the real fluids dry air and steam, water or ice

ρ c_p

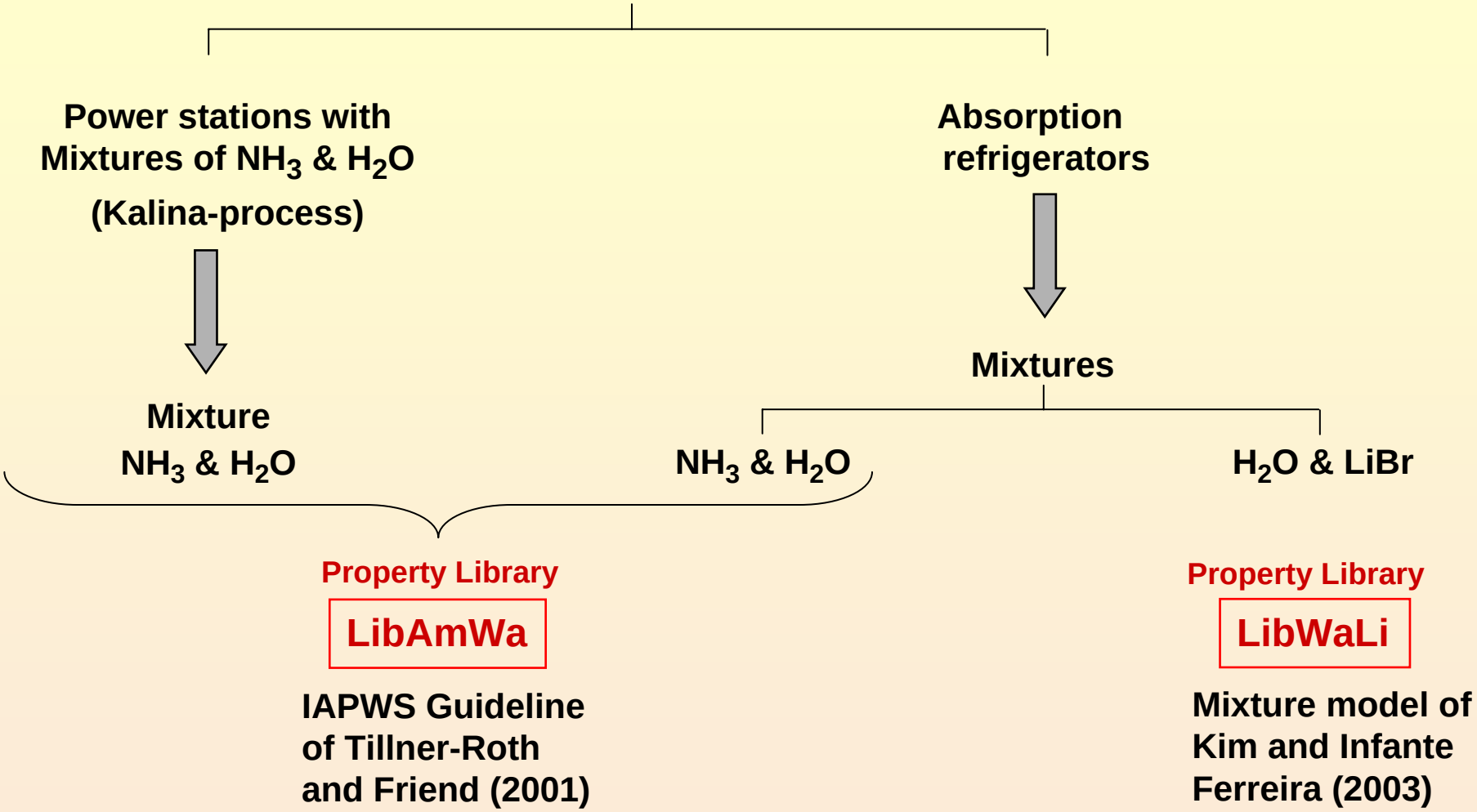
Property Library

LibH2

Equation of state of Leachman, Jacobson, and Lemmon

ρ c_p

Energy Conversion Processes with Working Fluid Mixtures



Overview of the Property Libraries

<table>
<tr>
<td>Water and Steam
Library LibIF97
Industrial Formulation
IAPWS-IF97</td>
<td>Humid Combustion Gases
Library LibHuGas
Ideal mixture of real fluids
Library LibIDGas
Ideal gas mixture (VDI-Guideline 4670)</td>
<td>Humid Air
Library LibAirWa
Ideal mixture of real fluids
Library LibIdAir
Ideal gas mixture</td>
</tr>
<tr>
<td rowspan="3">Carbon Dioxide
Library LibCO2

Hydrogen
Library LibH2

Helium
Library LibHe

Methanol
Library LibCH3OH</td>
<td>Ideal Gas Mixtures
Library LibIdGasMix
Ideal mixture of ideal fluids</td>
<td rowspan="3">Refrigerants

Ammonia
Library LibNH3

R134a
Library LibR134a

Propane
Library LibPropan

Iso-Butane
Library LibButan_Iso

n-Butane
Library LibButan_n</td>
</tr>
<tr>
<td>ORC Working Fluids
Siloxanes MM, D4, D5, MD4M
Libraries LibMM, LibD4,
LibD5, LibMD4M
Formulations of Colonna et al.</td>
</tr>
<tr>
<td>Mixtures in Absorption Processes

Ammonia & Water
Library LibAmWa

Water & Lithiumbromide
Library LibWaLi</td>
</tr>
</table>

The following thermodynamic and transport properties can be calculated:

Thermodynamic Properties

- Saturation pressure p_s
- Saturation temperature T_s
- Density ρ
- Specific volume v
- Enthalpy h
- Internal energy u
- Entropy s
- Exergy e
- Isobaric heat capacity c_p
- Isochoric heat capacity c_v
- Isentropic exponent κ
- Speed of sound w
- Surface tension σ

Transport Properties

- Dynamic viscosity η
- Kinematic viscosity ν
- Thermal conductivity λ
- *Prandtl*-number *Pr*

Backward Functions

- T, v, s (p,h)
- T, v, h (p,s)
- p, T, v (h,s)
- p, T (v,h)
- p, T (v,u)

Thermodynamic Derivatives

- All partial derivatives can be calculated.

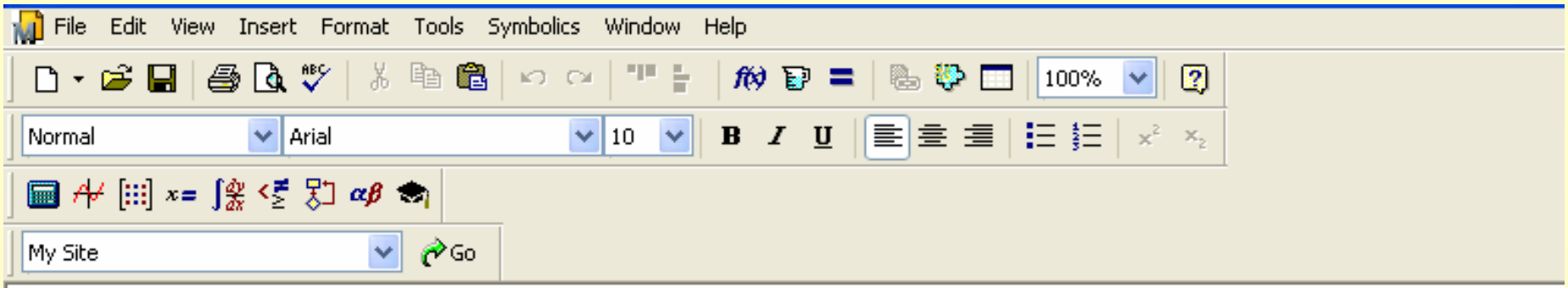
Using the Property Libraries in Mathcad®

Example:

Calculation of the specific enthalpy for

- **Steam**
- **Humid air**
- **Combustion gas mixtures**

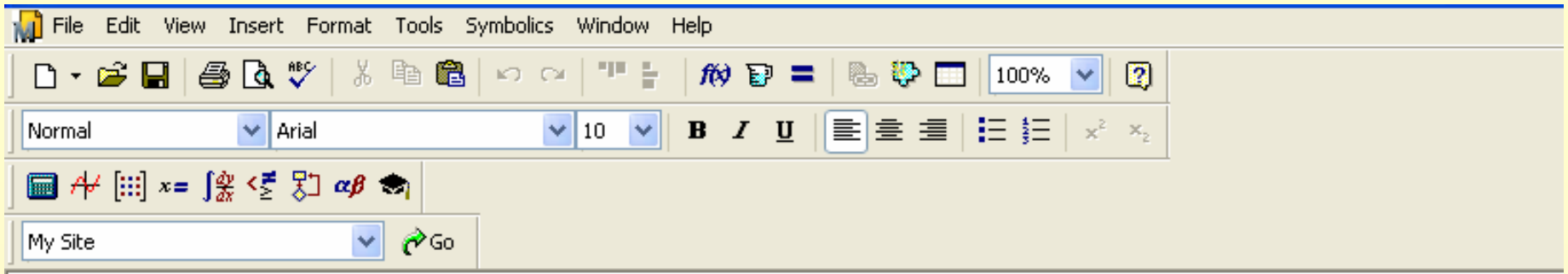
using the Add-On FluidMAT for



Using Add-On FluidMAT in Mathcad 14

Calculation of Specific Enthalpy for Steam using the Library LibIF97

$p := 10$	bar	given pressure
$t := 300$	°C	given temperature
$x := -1$	$\frac{kg}{kg}$	given vapor fraction (formally x = -1 for single-phase region)
$h := h\_ptx\_97(p, t, x)$		function call for specific enthalpy in FluidMAT
$h = 3051.70$	$\frac{kJ}{kg}$	result for specific enthalpy



Calculation of the Air-Specific Enthalpy for Humid Air using the Library LibHuAir

p := 1.01325	bar	given pressure
t := 20	°C	given temperature
phi := 60	%	given relative humidity
xw := xw_ptPhi_HuAir(p,t,phi)		function call for humidity ratio in FluidMAT
xw = 8.745	$\frac{g}{kg(Air)}$	result for humidity ratio (absolute humidity)
hl := hl_ptxw_HuAir(p,t,xw)		function call for air-specific enthalpy in FluidMAT
hl = 42.32	$\frac{kJ}{kg(Air)}$	result for air-specific enthalpy

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Calculation of Specific Enthalpy for an Ideal Gas Mixture from VDI-Guideline 4670 using the Library LibIDGAS

$p := 1.01325$ bar — given pressure

$t := 500$ °C — given temperature

mol_mass := 1 — = 0 for given mole fractions; = 1 for given mass fractions

$$Comp := \begin{pmatrix} 0.0028 \\ 0 \\ 0.7251 \\ 0.0236 \\ 0 \\ 0.0868 \\ 0.1617 \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad components \begin{pmatrix} Ar \\ Ne \\ N2 \\ O2 \\ CO \\ CO2 \\ H2O \\ SO2 \\ Air \\ Air\_N2 \end{pmatrix}$$

h := h_pt_id(p, t, mol_mass, Comp) function call for specific mixture enthalpy in FluidMAT

$h = 1007.09 \ \frac{kJ}{kg}$ result for specific enthalpy of the ideal-gas mixture

Summary

- **Property Libraries for working fluids used in energy conversion processes were developed.**
- **Thermodynamic properties, transport properties, thermodynamic derivatives, and backward functions can be calculated.**
- **The property libraries are available for**
  - **Mathcad®**
  - **Excel®**
  - **MATLAB®**
  - **Applications in Windows®, Unix® or Linux®**
- **The property libraries can be used by engineers, who routinely calculate heat cycles, turbines, boilers, or other thermal processes.**

More information at:

www.thermodynamics-zittau.de

www.thermodynamic-property-libraries.com

www.international-steam-tables.com