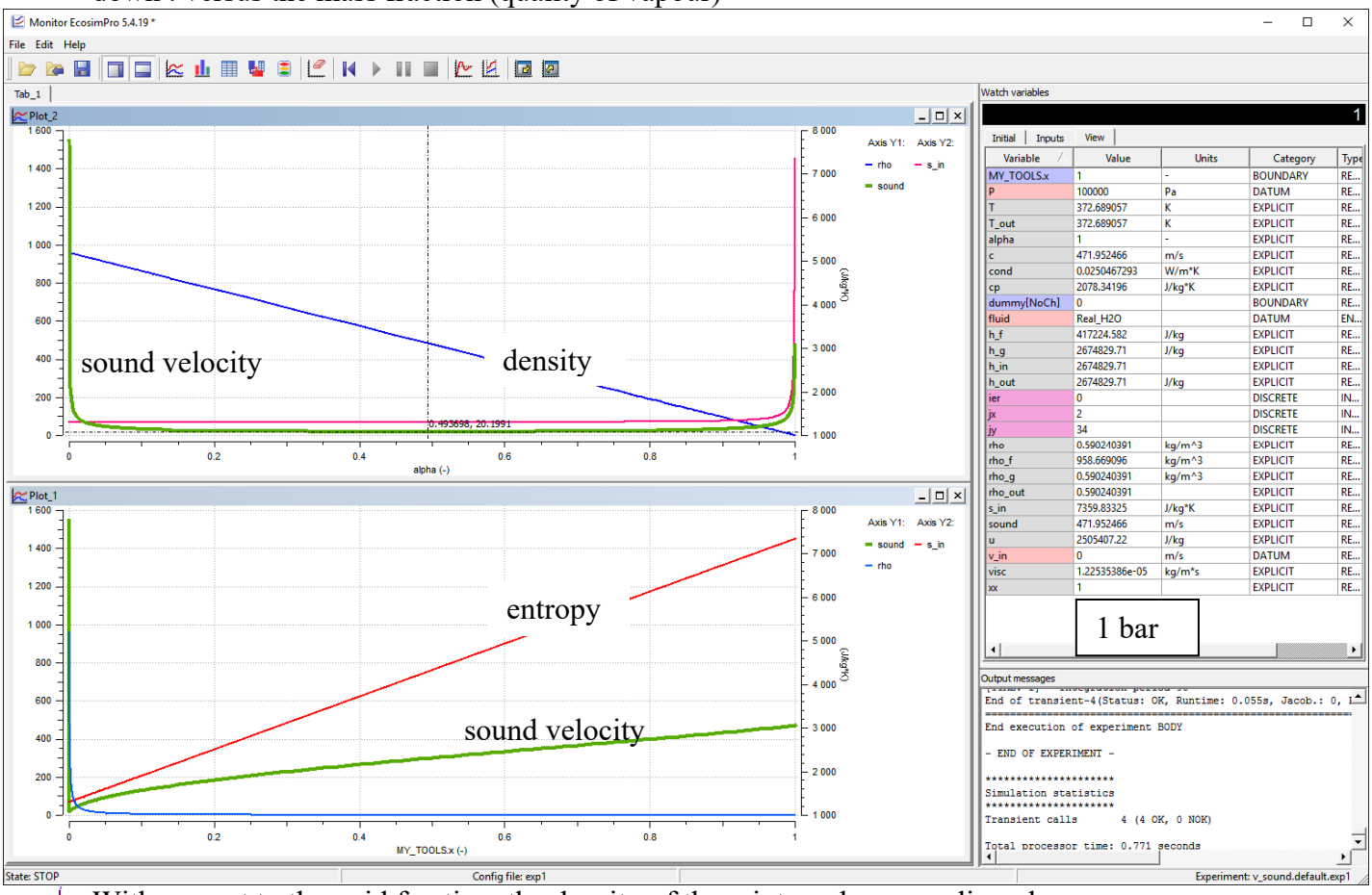
Checks of real water properties in 2 phases (liquid+vapour)

Sommaire

1. Example properties of water in 2 phases conditions

For a pressure of 1 bar (1E5 Pa) and full range of mixtures, on get the two plots

- up : versus the void fraction (alpha)
- down : versus the mass fraction (quality of vapour)



- With respect to the void fraction, the density of the mixture decreases linearly.
- With respect to the quality, the entropy of the mixture increases linearly.

The sound velocity in the two phases mixture has a minimum of 20 m/s. According to the reference *"Susan Werner Kieffer -- Sound Speed in Liquid-Gas Mixtures' Water-Air and Water-Steam--, JOURNAL OF GEOPHYSICAL RESEARCH JULY 10, 1977; VOL. 82, NO. 20",* this dramatic phenomenon occurs because the two-phases system has the density of a liquid but the compressibility of a gas. The sound speed is even less in a water-steam mixture than in a water-air mixture..."

2. Comparison of Sound velocities wrt reference

With respect to the same reference paper, the sound velocity curve wrt the void fraction is well simulated into ESPSS, including for low and very low void fraction.
First a comparison with the reference curve for water with air is performed:

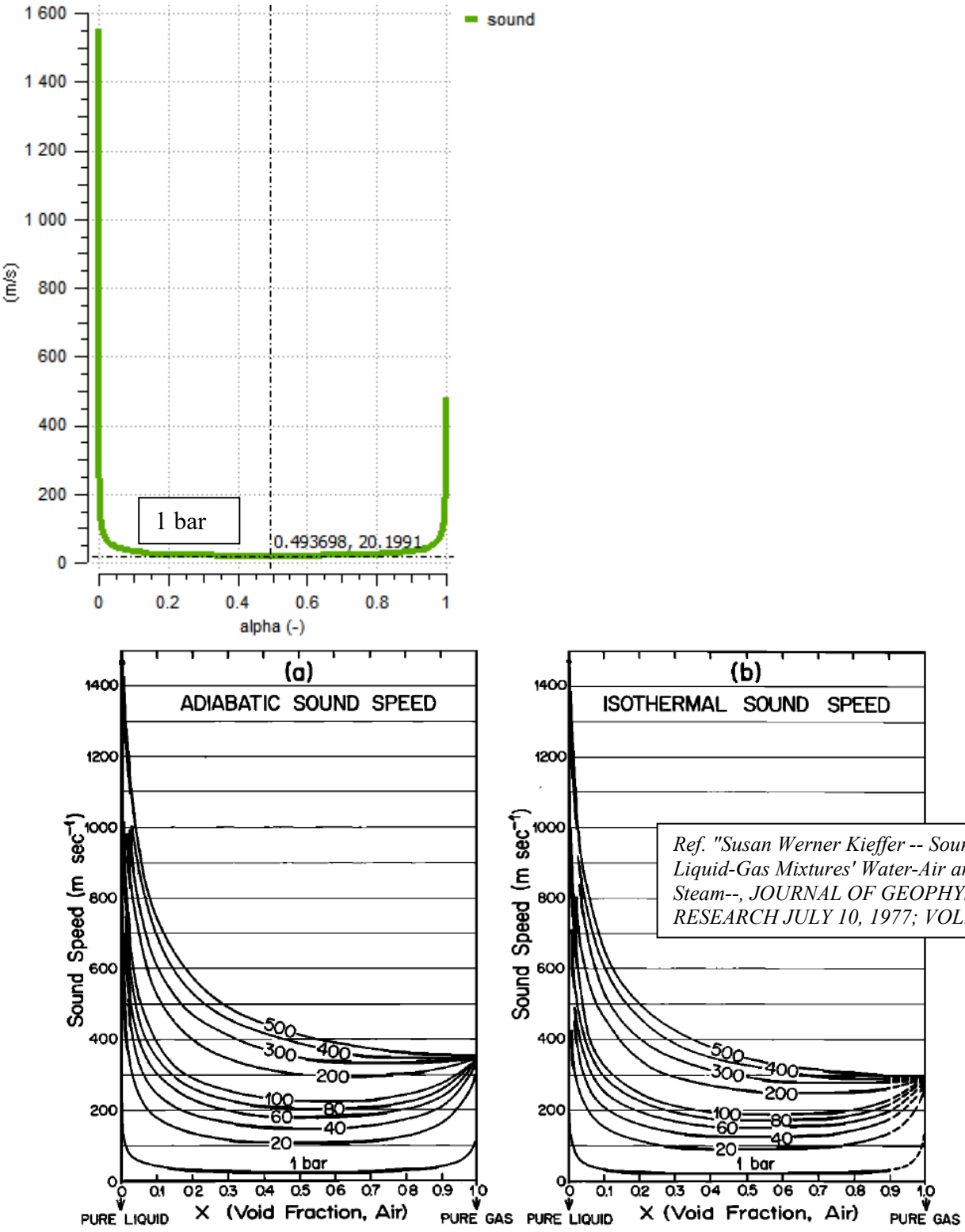
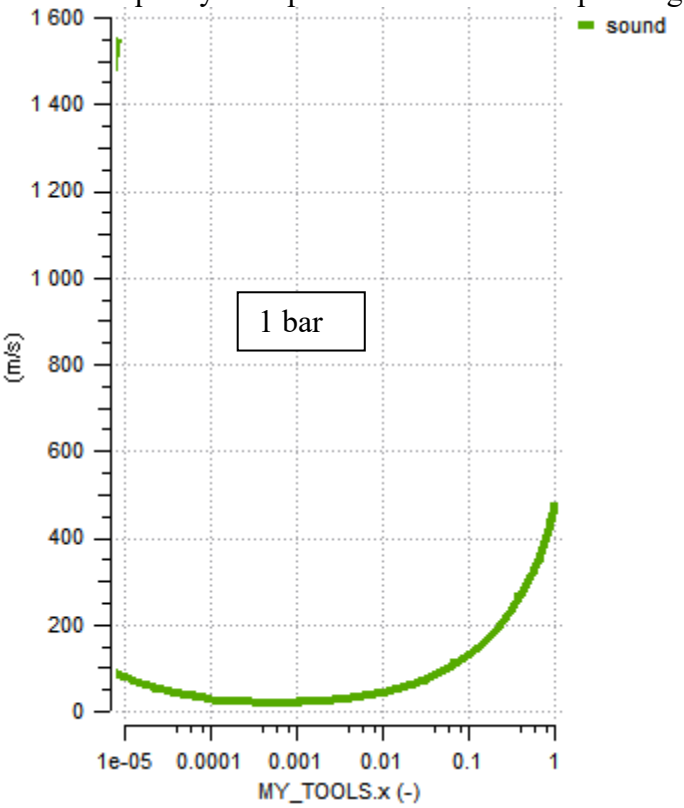
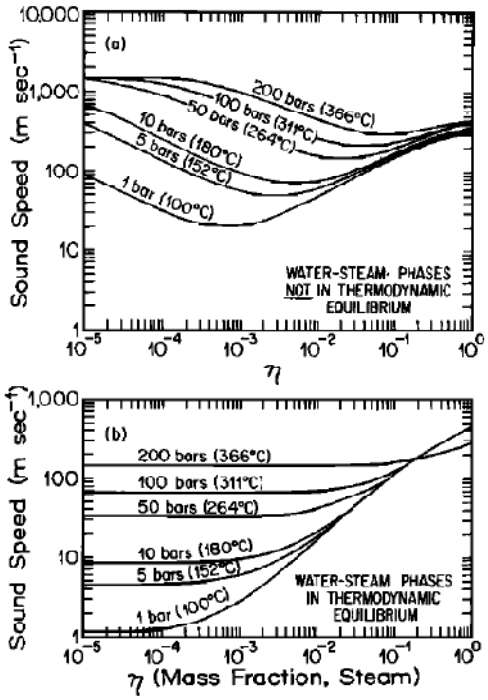


Fig. 3. Calculated dependence of (*a*) adiabatic and (*b*) isothermal sound speed of water-air mixture on volume content of gas and on pressure. Surface tension is neglected.

The two plots are very similar for a pressure of 1 bar.

Second, for pure water vapour and liquid mixtures comparison, the reference paper exhibits curves given wrt the mass fraction quality of vapour. Hence the corresponding plot with EcosimPro is output as well.





Ref. "Susan Werner Kieffer -- Sound Speed in Liquid-Gas Mixtures' Water-Air and Water-Steam--, JOURNAL OF GEOPHYSICAL RESEARCH JULY 10, 1977; VOL. 82, NO. 20"

Fig. 9. Calculated sound speed of water-steam mixture (*a*) not in equilibrium and (*b*) in equilibrium as a function of mass fraction and pressure.

Again, the plots are quite similar for a pressure of 1 bar.

CONCLUSIONS

There is a good "acceptable" fit between the simulation results and the reference for water 2 phases mixtures (fluid+ vapour) at 1 bar.

3. Traceability: Basic component used

A simple component has been defined for the output of the properties od water

```
/*-------------------------------------------------------------------------------
LIBRARY: MY_TOOLS
FILE: v_sound
CREATION DATE: 25/08/2016
-------------------------------------------------------------------------------*/
USE MATH
USE THERMO_TABLE_INTERP
USE PORTS_LIB
USE FLUID_PROPERTIES
USE FLUID_FLOW_1D
-- '  25/08/2016  17:08:46
--use a bound for a parametric curve versus x
BOUND REAL x=0.1 UNITS "-"--Vapor mass fractions (quality, "x" variable) includes the non-condensable gases and the vapor masses --the quality (x = vapor_mass / (vapor_mass+ liquid_mass))
COMPONENT v_sound
DATA

ENUM FluidKeys fluid=Real_H2O --Real_hydrazine
REAL P=1e5 UNITS "Pa"
REAL v_in=0 UNITS "m/s"
DECLS
REAL s_in=1 UNITS "J/kg*K"
REAL T_out UNITS "K"
REAL h_out UNITS "J/kg"
REAL rho_out,xx --Quality –gas mass fraction- including vapour and non-condensable gases
REAL sound UNITS "m/s"
INTEGER ier
INTEGER jx
INTEGER jy
REAL dummy[noBurnGases]
REAL T "temperature (K)"
REAL rho "Density (kg/m^3)"
REAL u "Internal energy (J/kg)"
REAL c "Speed of sound (m/s)"
REAL alpha "Vapour void fraction = (vapour+gas) volume / total_volume (-)"
REAL rho_f "Liquid density (kg/m^3)"
REAL rho_g "Vapor density (kg/m^3)"
REAL h_f "Specific enthalpy of liquid phase (J/kg)"
REAL h_g "Specific enthalpy of vapor phase (J/kg)"
REAL visc "Viscosity of mixture (kg/m*s)"
REAL cond "Thermal conductivity of mixture (W/m*K)"
REAL cp "Cp of mixture (J/kg*K)"
REAL h_in
INIT
FL_init_vs_Px(fluid,P, x,T,rho, u,c,alpha, rho_f, rho_g, h_f, h_g, visc, cond,cp, jx,jy, ier)
CONTINUOUS
FL_init_vs_Px(fluid,P, x,T,rho, u,c,alpha, rho_f, rho_g, h_f, h_g, visc, cond,cp, jx,jy, ier)
h_in=P/rho+u
s_in = FL_prop_vs_ph (noBurnGases, dummy, fluid, P, h_in-0.5*v_in**2, fprop_entropy, 300, ier)
c_vs_Ps(fluid, P, s_in, T_out, h_out, rho_out, sound, ier, jx, jy, xx)
END COMPONENT
```

4. Traceability: Experiment used

```
/*-------------------------------------------------------------------------------
LIBRARY: MY_TOOLS
COMPONENT: v_sound
PARTITION: default
EXPERIMENT: exp1
TEMPLATE: TRANSIENT
CREATION DATE: 25/08/2016
-------------------------------------------------------------------------------*/
-- '  25/08/2016  18:05:25
EXPERIMENT exp1 ON v_sound.default
DECLS
OBJECTS
INIT
  BOUNDS
  -- Set equations for boundaries: boundVar = f(TIME;...)
  FLUID_PROPERTIES.MinMolarFr = 1e-009
  FLUID_PROPERTIES.VDW_option = 0
  dummy[NoCh] = 0
  MY_TOOLS.x = TIME
BODY
  DEBUG_LEVEL= 1
  IMETHOD= DASSL
  setStopWhenBadOperation(FALSE)
  REL_ERROR = 1e-006
  ABS_ERROR = 1e-006
  TOLERANCE = 1e-006
  REPORT_MODE = IS_CINT -- by default report at every CINT time or event detection
  TIME = 0
'--Itt is needed to get results for very small values of x
  INTEG_TO(0.0001,0.000001)
  INTEG_TO(0.01,0.0001)
  INTEG_TO(0.1,0.001)
  INTEG_TO(1,0.01)
END EXPERIMENT
```
