Revision of the Advisory Note No. 3: Thermodynamic Derivatives from IAPWS Formulations

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1. Introduction

- Thermodynamic derivatives such as

$$\left(\frac{\partial h}{\partial p}\right)_v, \left(\frac{\partial u}{\partial p}\right)_v, \left(\frac{\partial s}{\partial p}\right)_v, \left(\frac{\partial T}{\partial p}\right)_h, \left(\frac{\partial T}{\partial p}\right)_s, \left(\frac{\partial v}{\partial h}\right)_p, \left(\frac{\partial v}{\partial s}\right)_p \ldots$$

  are required for:
  - Calculating non-stationary processes
  - Solving equation systems for stationary heat cycle calculations.
- All thermodynamic properties and derivatives can be determined from fundamental equations.

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Aim of the IAPWS Advisory Note No. 3: Description how to calculate any property or derivative from IAPWS Formulations.

2. Determination of Thermodynamic Derivatives

- Example: Fundamental equation of IAPWS-95:

  Helmholtz equation $f(\rho,T)$

  $\rho = 1/v$ and T are the input variables.

- All thermodynamic properties and derivatives can be formed as a function of v and T from $f(v,T)$ and from its derivatives

$$\left(\frac{\partial f}{\partial T}\right)_v, \left(\frac{\partial^2 f}{\partial T^2}\right)_v, \left(\frac{\partial f}{\partial v}\right)_T, \left(\frac{\partial^2 f}{\partial v^2}\right)_T, \left(\frac{\partial^2 f}{\partial T\,\partial v}\right).$$

- Common expression for forming any derivative $\left(\frac{\partial z}{\partial x}\right)_y$ from derivatives with respect to v and T

$$\left(\frac{\partial z}{\partial x}\right)_y = \frac{\left(\frac{\partial z}{\partial v}\right)_T \cdot \left(\frac{\partial y}{\partial T}\right)_v - \left(\frac{\partial z}{\partial T}\right)_v \cdot \left(\frac{\partial y}{\partial v}\right)_T}{\left(\frac{\partial x}{\partial v}\right)_T \cdot \left(\frac{\partial y}{\partial T}\right)_v - \left(\frac{\partial x}{\partial T}\right)_v \cdot \left(\frac{\partial y}{\partial v}\right)_T}$$

where x, y, z can represent one of the properties: p, T, v, h, u, s, g, or f

- Derivatives of these properties with respect to v and T

x, y, z	$\left(\frac{\partial x}{\partial v}\right)_T, \left(\frac{\partial y}{\partial v}\right)_T, \left(\frac{\partial z}{\partial v}\right)_T$	$\left(\frac{\partial x}{\partial T}\right)_v, \left(\frac{\partial y}{\partial T}\right)_v, \left(\frac{\partial z}{\partial T}\right)_v$
p	$-p\,\beta_p$	$p\,\alpha_p$
T	0	1
v	1	0
u	$p(T\alpha_p - 1)$	c_v
h	$p(T\alpha_p - v\beta_p)$	$c_v + p\,v\,\alpha_p$
s	$p\,\alpha_p$	$\frac{c_v}{T}$
g	$-p\,v\,\beta_p$	$p\,v\,\alpha_p - s$
f	$-p$	$-s$

Required quantities:

Pressure p

Specific entropy s

Specific isochoric heat capacity c_v

Relative pressure coefficient

$$\alpha_p = p^{-1}(\partial p/\partial T)_v$$

Isothermal stress coefficient

$$\beta_p = -p^{-1}(\partial p/\partial v)_T$$

3. History of the Advisory Note No. 3

- Adoption of the first version by IAPWS in Lucerne, 2007

  Description how to form any derivative from:
  - IAPWS-95
  - IAPWS-IF97
  - IAPWS-84 for Heavy Water
  - IAPWS-06 for Ice.

- Adoption of a Revision by IAPWS in Berlin, 2008

  Addition of the description how to form any derivative from:
  - IAPWS-08 for Seawater.

4. Preparation of a Further Extension

- Description how to form any derivative from:
  - IAPWS Supplementary Release on a Formulation for Liquid Water for Oceanographic Use (2008)
  - IAPWS Guideline on an Equation of State for Humid Air in Contact with Seawater and Ice (2010)
  - IAPWS Guideline on an IAPWS Formulation for Ammonia-Water Mixtures (2001)

Presentation of an Revision of AN 3 at the IAPWS Meeting in Greenwich