Chapter 2
Introduction to Thermomechanical Effects

This part of the book builds upon the classical conservation laws of fluid dynamics. These conservation laws (the conservation of mass, the conservation of linear momentum, and the conservation of energy, also known as the Navier–Stokes equations) are summarized in Chap. 21 after a brief presentation of the main notations and rules for the scalar, vector, and tensor quantities needed to define the fluid motion. In the present part of the book, as we are mainly interested in the transient and stationary nonequilibrium states of the near-critical fluids described in the previous introductory chapter, the most important assumption we make is local thermodynamic equilibrium, since local equilibrium must be present for the hydrodynamic equations presented in Chap. 21 to be valid. Readers interested in a more detailed discussion of the foundational axioms of near-critical fluid dynamics should refer to [1, 2].

The three chapters comprising Part I therefore focus on explicitly deriving the analytical methods needed to solve the Navier–Stokes equations that can be used to calculate the exact fluid motion of a one-dimensional van der Waals fluid in the absence of a gravitational field. The equations that describe the 1-D motion of the near-critical fluid are derived in Chap. 3 using the van der Waals equation of state and the mean field behaviors of the transport coefficients (see Sect. 1.11), in order to completely specify the problem as the critical point is approached. Therefore, this chapter considers the case of a compressible fluid described by the perfect gas equation of state. After that, in Chap. 4, we make use of the asymptotic expansions technique to explore the response of a near-critical one-component fluid in a 1-D, slab-like container to an increase in the wall temperature (parietal temperature step). We show that the bulk temperature evolves more quickly than heat diffusion due to acoustic heating. We obtain the analytical solutions of the equations on the three characteristic timescales of the problem: the acoustic time, the piston-effect time, and the heat diffusion time. Then, in the final chapter of this part (Chap. 5), we make use of the asymptotic expansions technique to explore the response of a near-critical one-

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component fluid in a 1-D, slab-like container to a heat flux at the boundary (parietal heat flux). We show that the bulk phase behaves as a thermal short circuit, and we obtain working formulae that can be used to analyze the corresponding experimental results; the latter are discussed in more detail in Part II.

References

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2. Ortiz de Zarate JM, Sengers JV (2006) Hydrodynamics fluctuations in fluids and fluid mixtures. Elsevier, Amsterdam

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