APPENDIX 336: Fluid dynamics, Flow of gases and steam through nozzles, Calculation of Laval nozzle dimensions for steam flow

In this problem, we first check whether critical flow occurs and whether the Laval nozzle design is reasonable. The pressure ratio behind and in front of the nozzle is 1:8, and the critical pressure ratio of water vapor depends on the moisture content of the vapor. From the given problem parameters, it can be seen that the steam temperature is well above the critical temperature (374,15 °C), so that superheated steam, which has a critical pressure ratio of about 0,546, can be expected to expand in the nozzle (see page 5). We proceed with the calculation by first determining the state variables in the critical flow area and at the nozzle exit and the steam dryness. From these quantities we calculate the nozzle dimensions. The calculation will be performed for lossless flow according to the h-s charts in FIGURES 103, (p. 8) and 101, (p. 4) The dimension calculations can be based on EQUATIONS 703, (p. 10).

Entered parameters of the problem are:

p_i	t_i	p_e	m	α
80	500	10	0,3	10

p [bar]; t [°C]; m [m·kg^{-1}]; α [°]

A336/2: From the input parameters we can read the enthalpy h_i, entropy s_i specific volume v_i, while the steam velocity V_i, is not given, so we will consider these parameters as total parameters as well. The reading of these states can be taken from thermodynamic tables of H_2O, for example from [Mares et al., 1999].

The parameters in the nozzle throat can be determined from the critical pressure p^* , which can be determined from the critical pressure ratio given in A515/1 and the pressure p_i . In the *h-s* diagram of H_2O it is now possible to subtract other state variables from the intersection of the isobar p^* and the isentropy si. In the same way, the parameters at the nozzle exit can be deduced from the intersection of isobar p_e and isentrope s_i:

s_i	h_{is}	v_i	p^*	h^*	v^*	v_e	h_e	x
6,7266	3399,5	41,767	43,68	3210,1	66,977	209,44	2843,1	1 (overheated)

s [kJ·K^{-1}·kg^{-1}]; h [kJ·kg^{-1}]; v [dm^3·kg^{-1}]; p [bar]; x [1] steam dryness

A336/3: The critical velocity V^* can be calculated using EQUATION 516, (p. 6) and the outlet velocity can be calculated using EQUATION 101, (p. 4):

V^*	V_e
615,42	1054,9

[$m \cdot s^{-1}$]

A336/4: The flow areas A and A_e can be determined from EQUATION 334, (p. 4). The individual radii can be obtained from the equation for the area of a circle:

$$r = \sqrt{\frac{A}{\pi}}.$$

A*	A_e	r*	r_e	r_r	t	r_t	l
32,650	59,560	3,2238	4,3542	1,2315	0,1073	3,2285	12,974

A [mm^2]; r, t, l [mm]