APPENDIX 104: Fluid dynamics, Flow of gases and steam through nozzles, Calculation of cone Laval nozzle dimensions

The calculation here is based on the nozzle equations derived for ideal gas and lossless flow. EQUATION 703, (p. 10) is used to calculate the Laval nozzle dimensions.

Entered parameter of the problem is:

α
10

α [°]

A104/2: To calculate the radius of the nozzle, or its length, it is necessary to know the flow flow area at the inlet (see PROBLEM 102, p. 6) and at the outlet, which can be calculated from the mass flow rate through the nozzle, the gas parameters (PROBLEM 102, p. 6) and the continuity equation for the nozzle (EQUATION 334, p. 4). The state variables are calculated according to the equations for an ideal gas (isentropy equation, equation of state) [Škorpík, 2024], so for the specific volume v_e we can write:

$$p_{is} \cdot v_{is}^{\kappa} = p_e \cdot v_e^{\kappa} \Rightarrow v_e = v_{is} \left(\frac{p_{is}}{p_e} \right)^{\frac{1}{\kappa}}.$$

A^*	$\dot{m}$	κ	p_{is}	v_{is}	p_e	ε_s	r^*	V_e
15	2,8086	1,4	1,1848	158,44	0,25	0,2110	2,1851	686,73
v_e	A_e	r_e	r_r	t	r_t	l		
481,40	19,689	2,5034	0,8347	0,0727	2,1883	3,6747		

A [cm²]; m [kg·s^{-1}]; κ [1]; p [MPa]; v [dm^3·kg^{-1}]; ε [1]; r, t, l [cm]; V [m·s^{-1}]

A104/3: The Mach number and the speed of sound can be calculated using the equations given in the article Mach number and high velocity flow effects:

$$a_e = \sqrt{\kappa \cdot r \cdot T_e}; \; M_e = \frac{V_e}{a_e}.$$

The product $r \cdot T_e$ can be substituted by the gas equation of state $p_e \cdot v_e$:

a_e	M_e
410,48	1,6730

a [m·s^{-1}]; M [1]