Leak rate calculation

This formula is valid for the throughput of a compressible fluid (gas) thru a leak in a pressurized vessel.
It is:

Mass flow: $$\dot{m} = A \cdot \Psi \cdot \sqrt{2 \cdot p_i \cdot \rho_i}$$

Volume flow: $$\dot{V} = \frac{\dot{m}}{\rho_a}$$

Leak rate: $$\rho_a \cdot \dot{V} = \frac{p_a \cdot V}{t} = \dot{m} \cdot R \cdot T_a$$

A: Leak area
Ψ: throughput function
p_i: pressure inside
ρ_i: density inside
p_a: pressure outside
ρ_a: density outside
R: specific gas constant (air: 287, Helium: 2078 [J/(kg*K)])
T_a: Temperature outside

Where the throughput function Ψ is:

$$\Psi = \sqrt{\frac{\kappa}{\kappa - 1}\left[\left(\frac{p_a}{p_i}\right)^{\frac{2}{\kappa}} - \left(\frac{p_a}{p_i}\right)^{\frac{\kappa+1}{\kappa}}\right]}$$

κ: Adiabatic exponent of test gas (1,4 for air, 1,66 for Helium)

With correction due to friction:

Mass flow: $$\dot{m} = \mu \cdot A \cdot \Psi \cdot \sqrt{2 \cdot p_i \cdot \rho_i}$$

μ: coefficient of friction

Example:
Water bath leak testing at 1350mbar (19,6psi) pressure inside and 1043mbar (15,1psi) pressure outside (considering the hydraulic pressure of the water too):

leak diameter in µm	leak rate in mbar·l/s
1	1,4E-04
5	3,5E-03
10	1,4E-02
15	3,1E-02
20	5,5E-02
50	3,5E-01
100	1,4E+00

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