The Vortex Tube of Ranque (1931) & Hilsch (1945) Thermodynamics and New Applications

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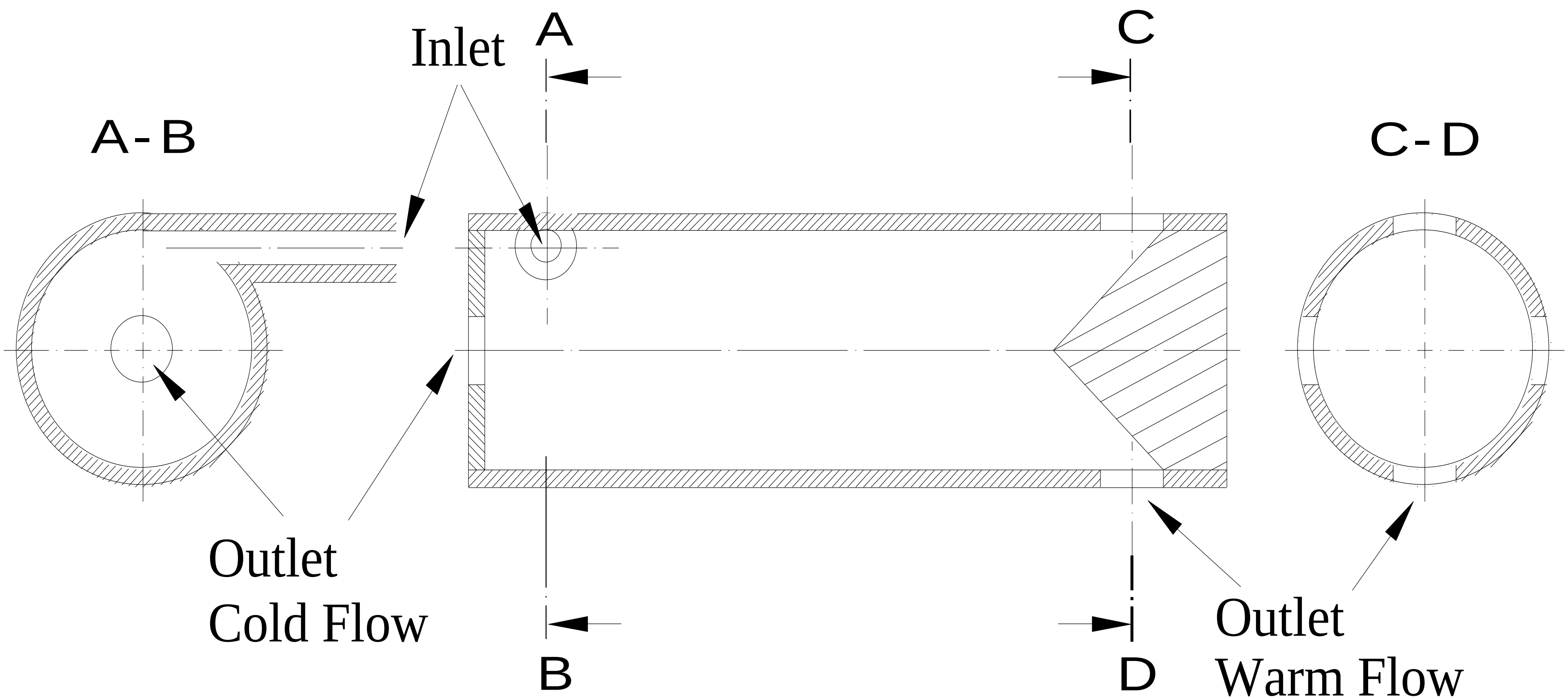
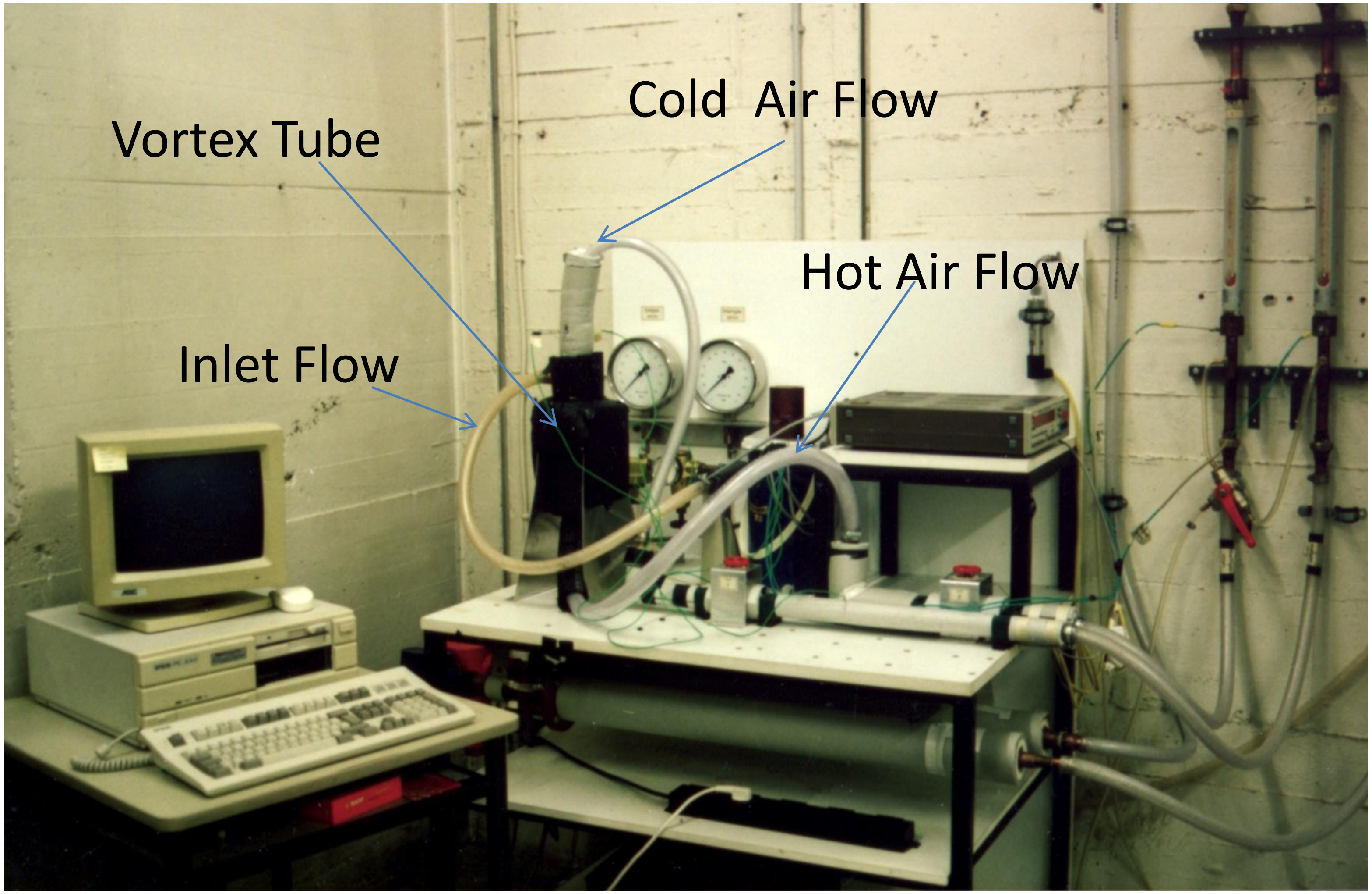
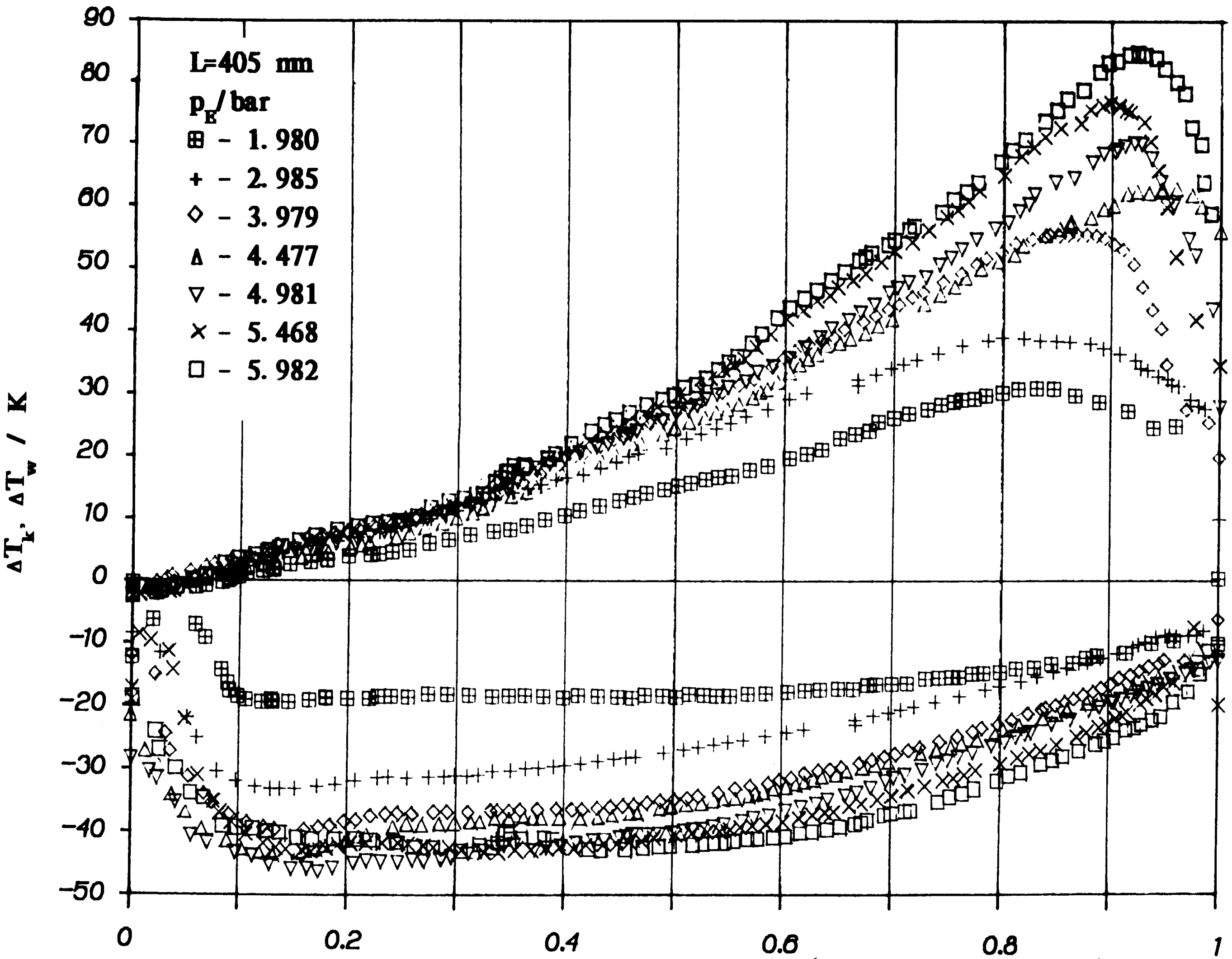


Experimental setup for expansion of compressed air in a vortex tube by Ranque & Hilsch.



Thermal Separation Effect in a Vortex Tube

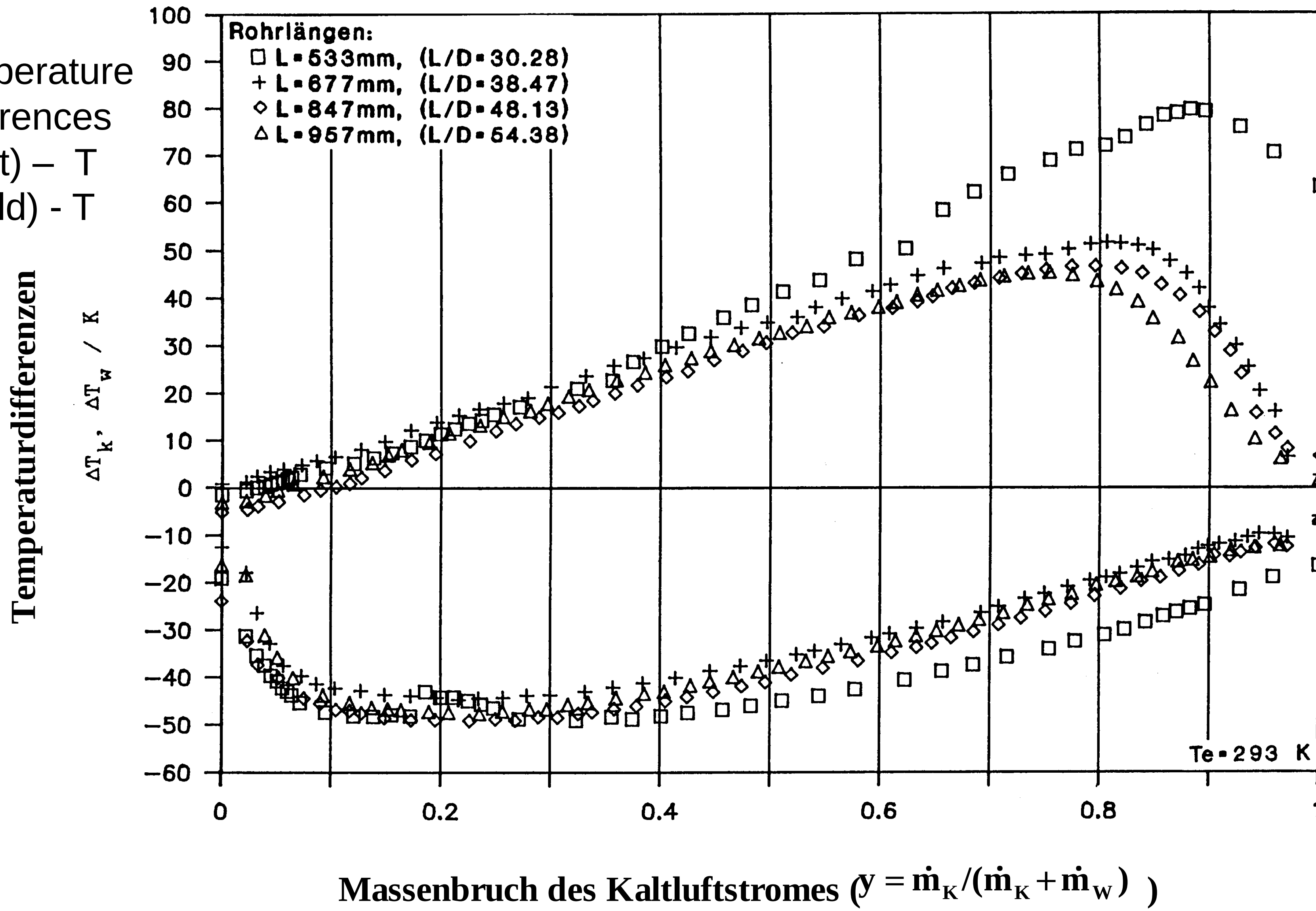
Temperature Differences
T(hot) – T
T(cold) - T



Mass Fraction of Cold Flow $\left(y = \frac{\dot{m}_C}{\dot{m}_C + \dot{m}_H} \right)$

Thermal Separation Effect, Dependence on Tube Length

Temperature Differences
T(hot) – T
T(cold) - T



Inlet Nozzles for Air Expansion in a Vortex Tube*

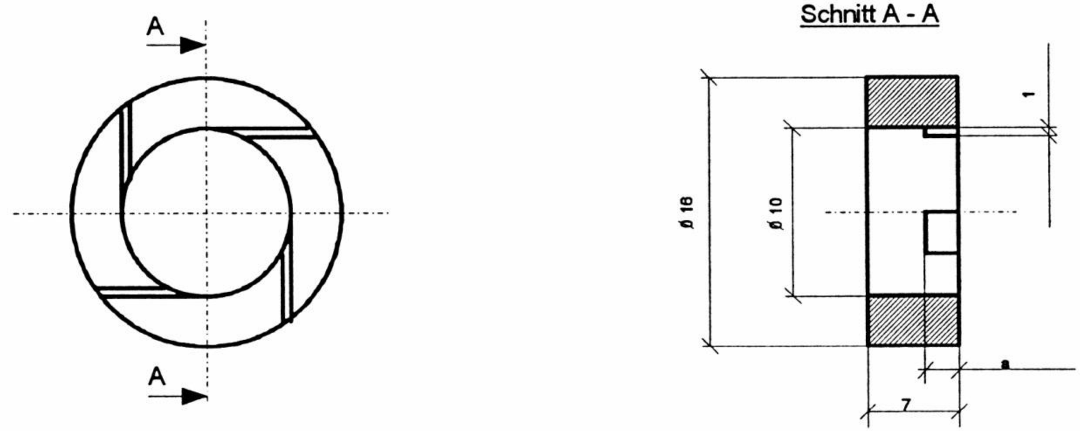
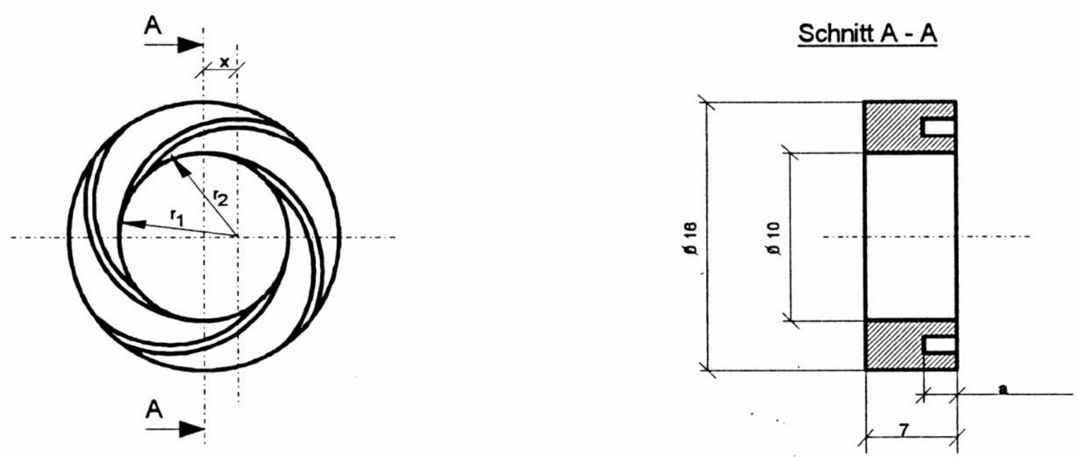


Abb.2: Düse mit geradem Einlauf und konstantem Querschnitt.

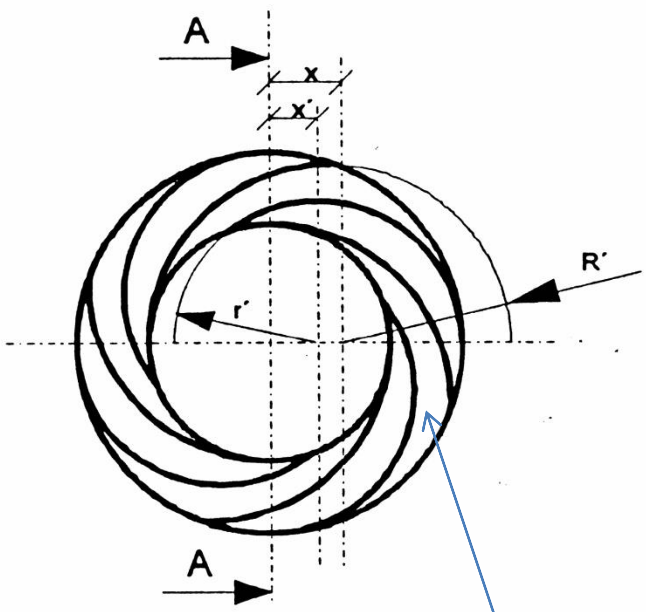
Best for
hot air flow
generation

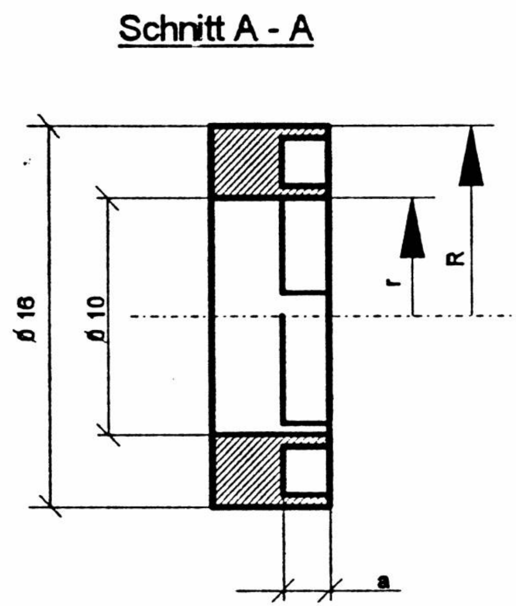


Intermediate
performance

*Merz,H.:Experimental Investigation of the Air Expansion Process in a Vortex-Tube Using Different Types of Inlet Nozzles, IFT, U-Siegen, 1995.

Inlet Nozzles for Air Expansion in a Vortex Tube*



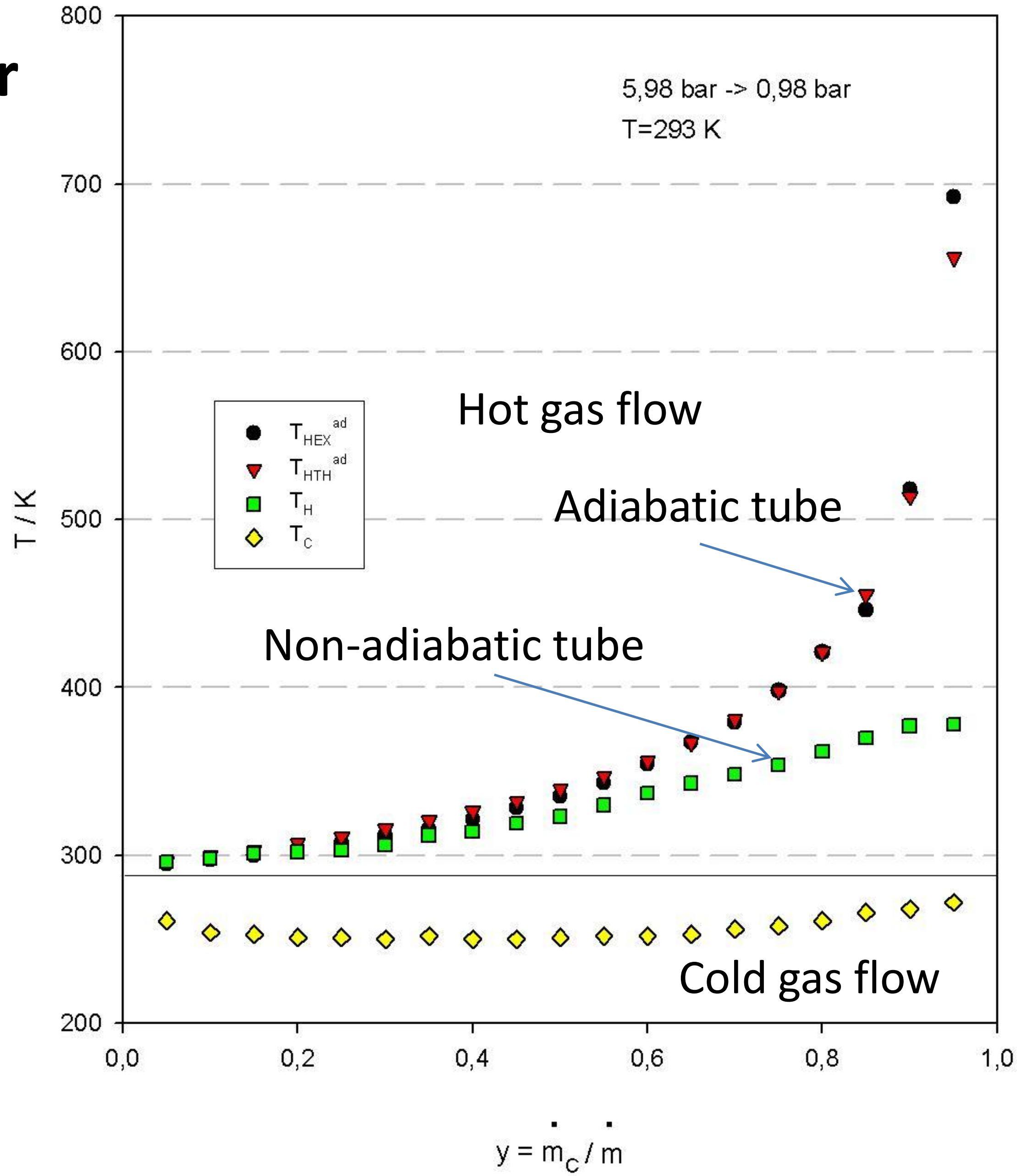


4 Spiral conic chanels:
Best performance for cold air flow generation.

*Merz,H.:Experimental Investigation of the Air Expansion Process in a Vortex-Tube Using Different Types of Inlet Nozzles, IFT, U-Siegen, 1995.

Effect of Heat Transfer From the Vortex Tube

Expansion of Dry Air
p(0)= 5.98 bar
p* =0.98 bar



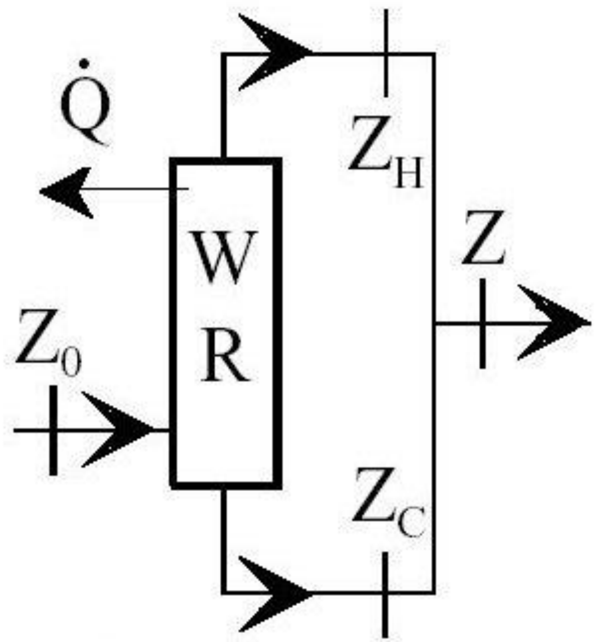
Vortex Tube Gas Expansion Process Thermodynamic Model

Mass balance

$$\dot{m}_0 = \dot{m}_C + \dot{m}_H \quad (1)$$

Mass flow

$$\dot{m}_i = A_i w_i \rho(p_i, T_i) \quad (1a)$$



Energy balance

$$\hat{h}_0 \dot{m}_0 = \hat{h}_C \dot{m}_C + \hat{h}_H \dot{m}_H + \dot{Q} \quad (2)$$

$$\hat{h} = h + w^2/2$$

Entropy Balance, Stationary States

…. Specific entropy of incoming fluid

…. Specific entropy of merged outgoing fluid flows

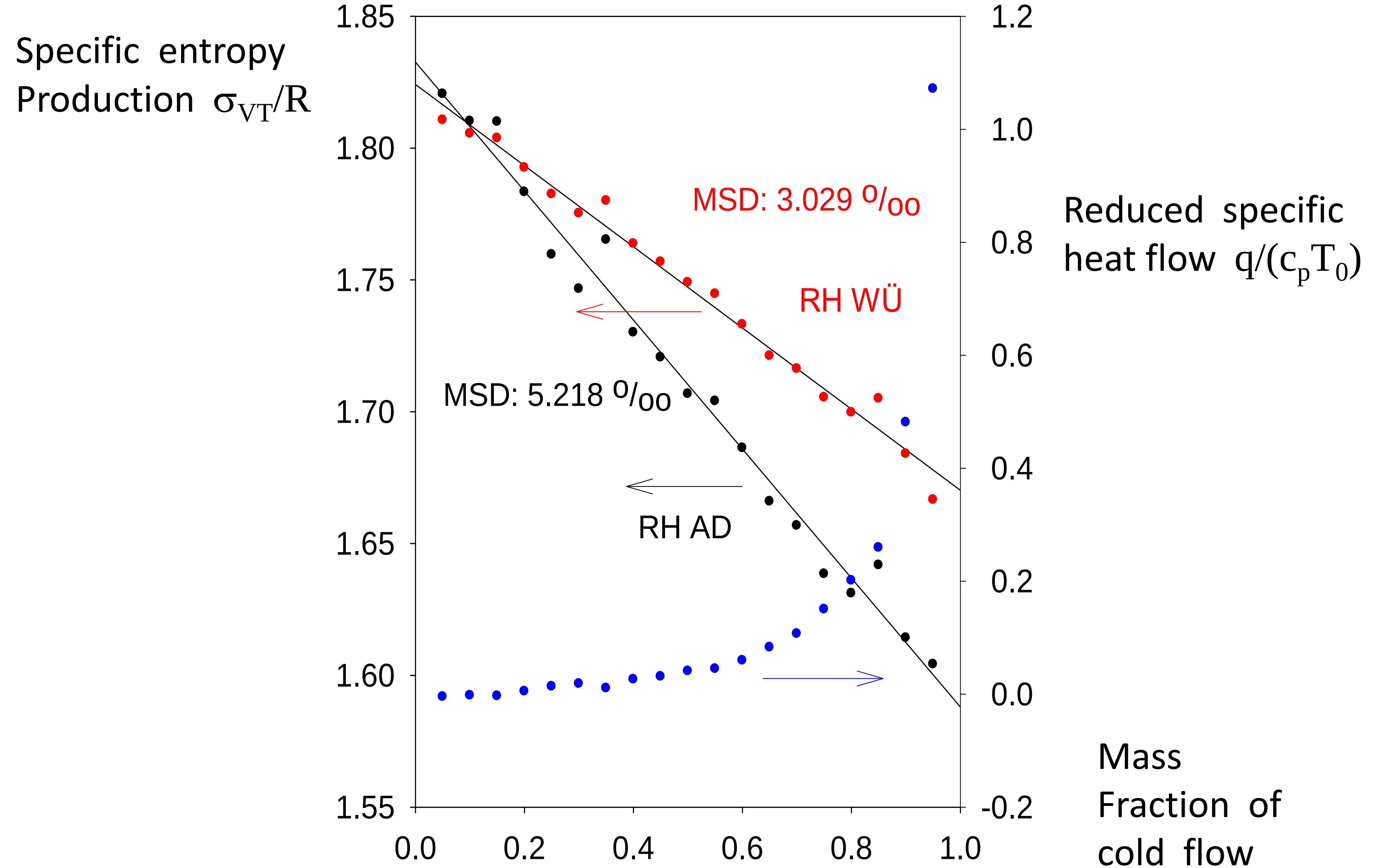
Equations of state

$$h_i = h(T_i, p_i) \quad , s_i = s(T_i, p_i) \quad , i = 0, C, H \quad (4,5)$$

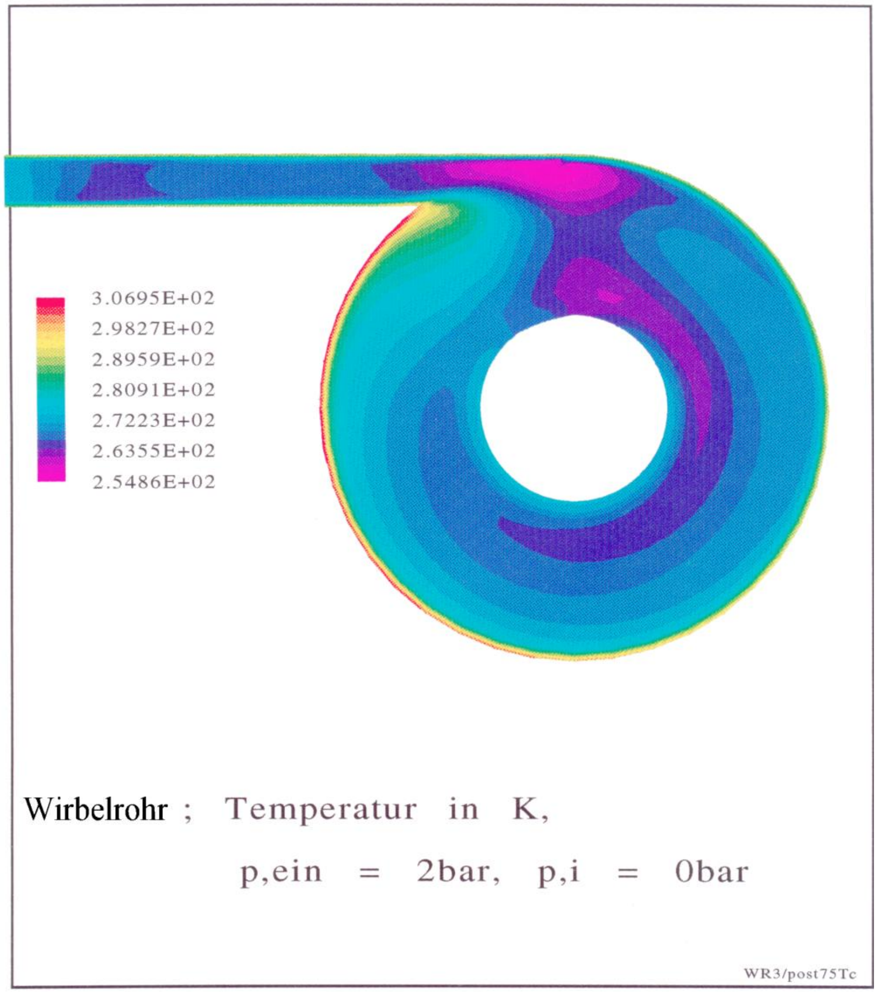
Known quantities : m_0, m_C, T_0, p_0, $p_C = p_H = p^*$

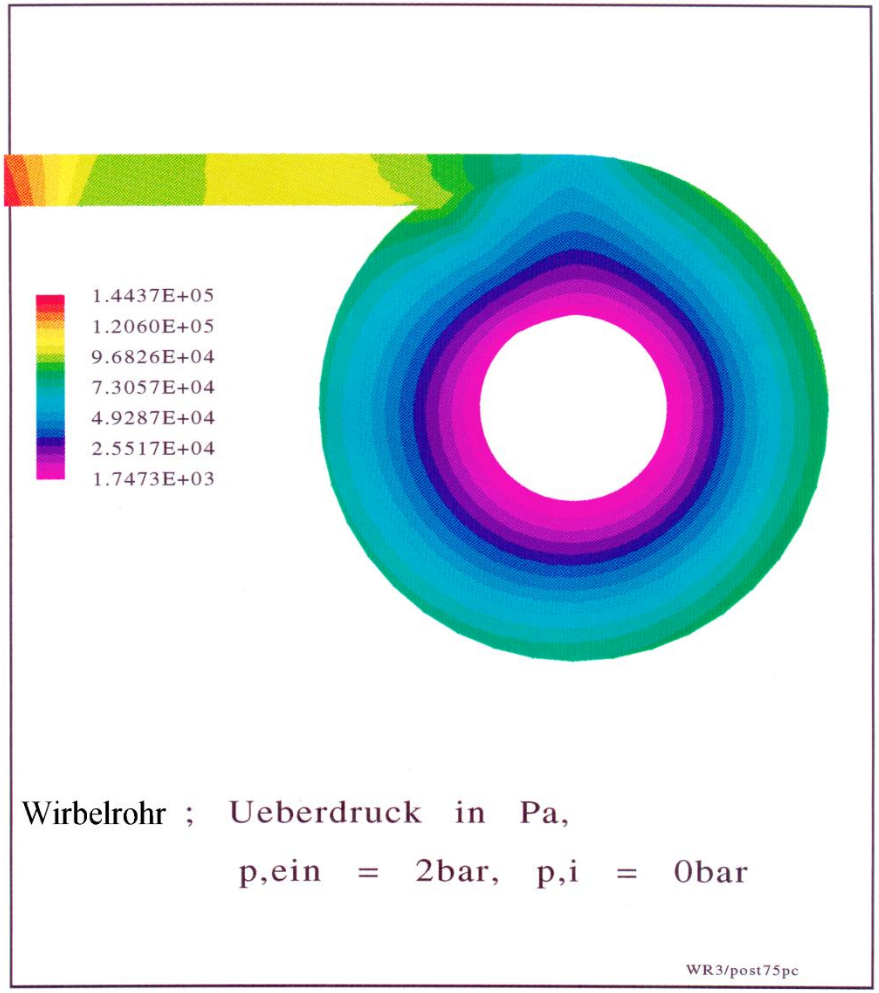
Unknown quantities : T_C, T_H … (2, 3)

Vortex Tube Process: Entropy Production, Heat Release



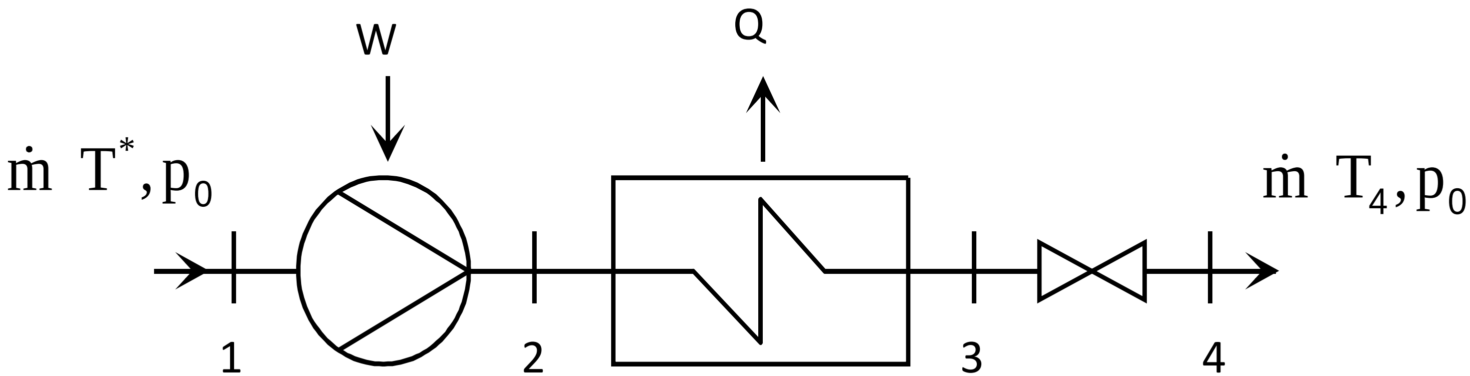
Numerical Simulation of the VT-Process

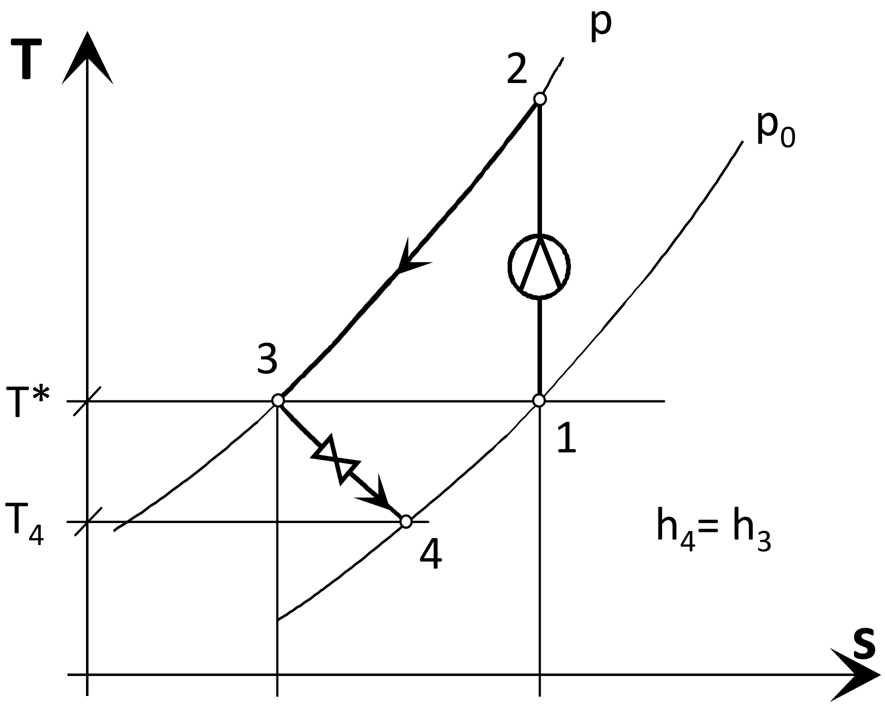




2-D Flow , Expansion of dry air. Distribution of temperature and pressure
Ref.: H. Fröhlingsdorf, PHD, University of Bochum, 2001.

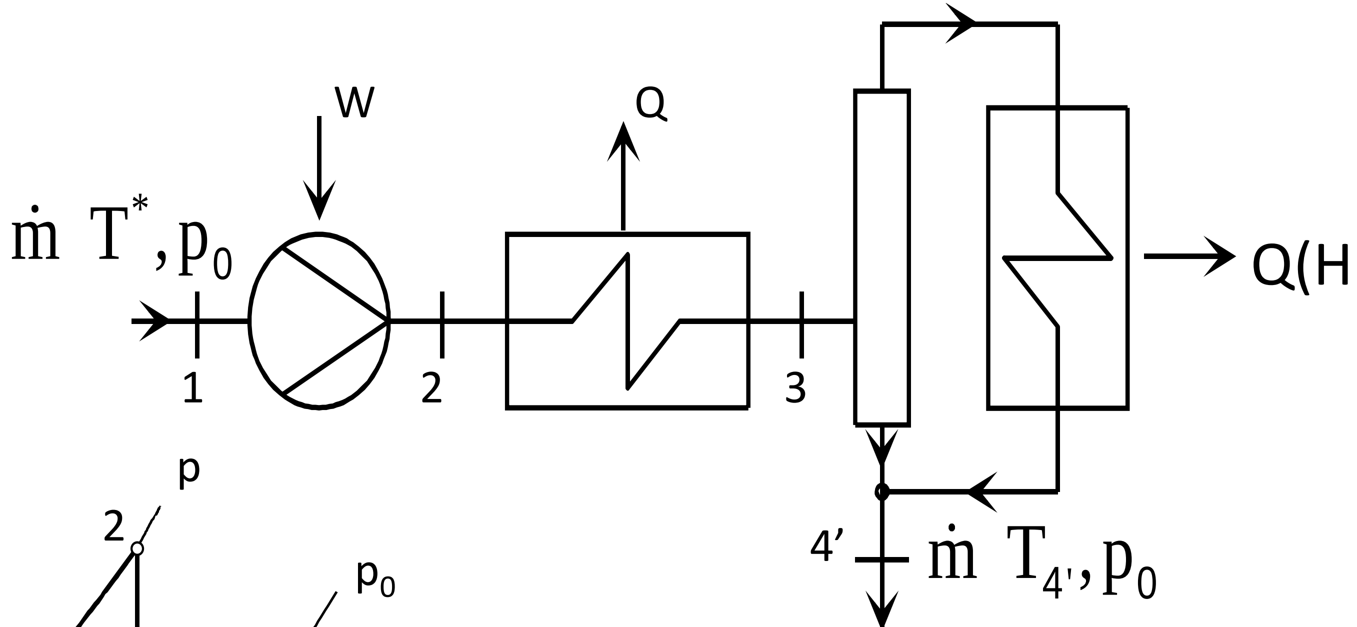
Claudé Gas Cooling Process

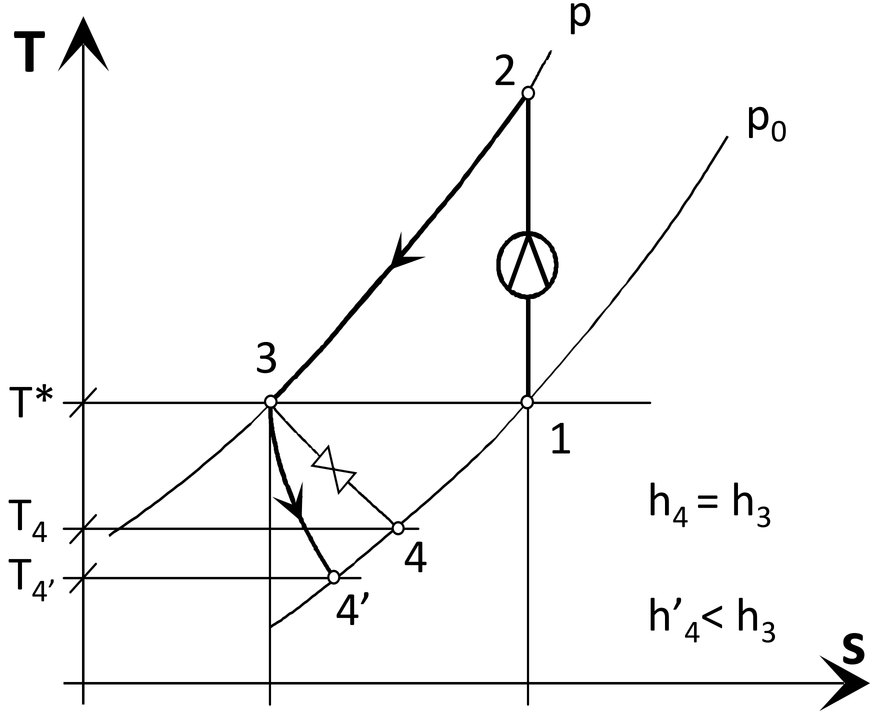




Improvement:
Substitute the Expansion Valve by a **Vortex Tube**

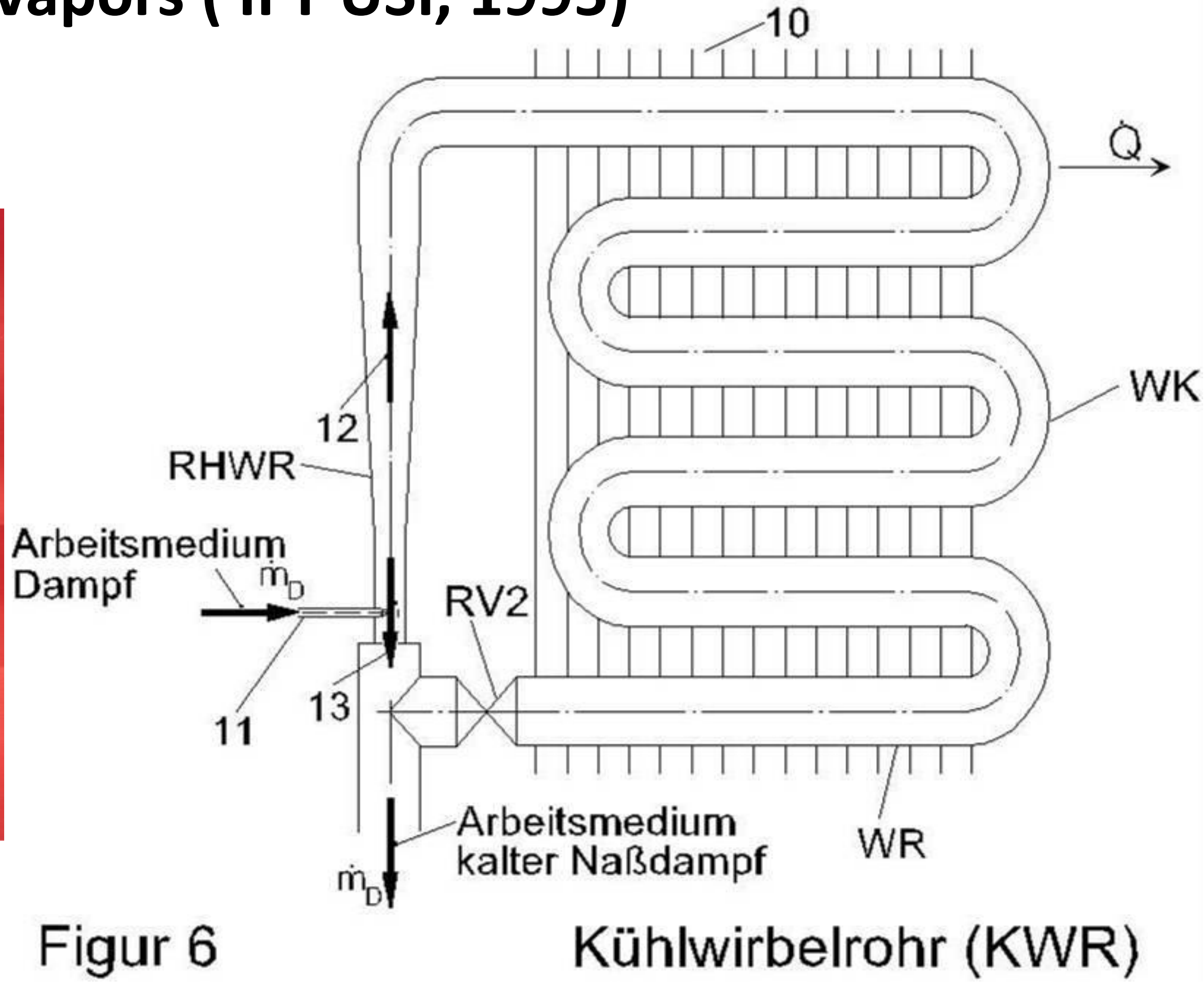
Gas Cooling Process using a Vortex Tube





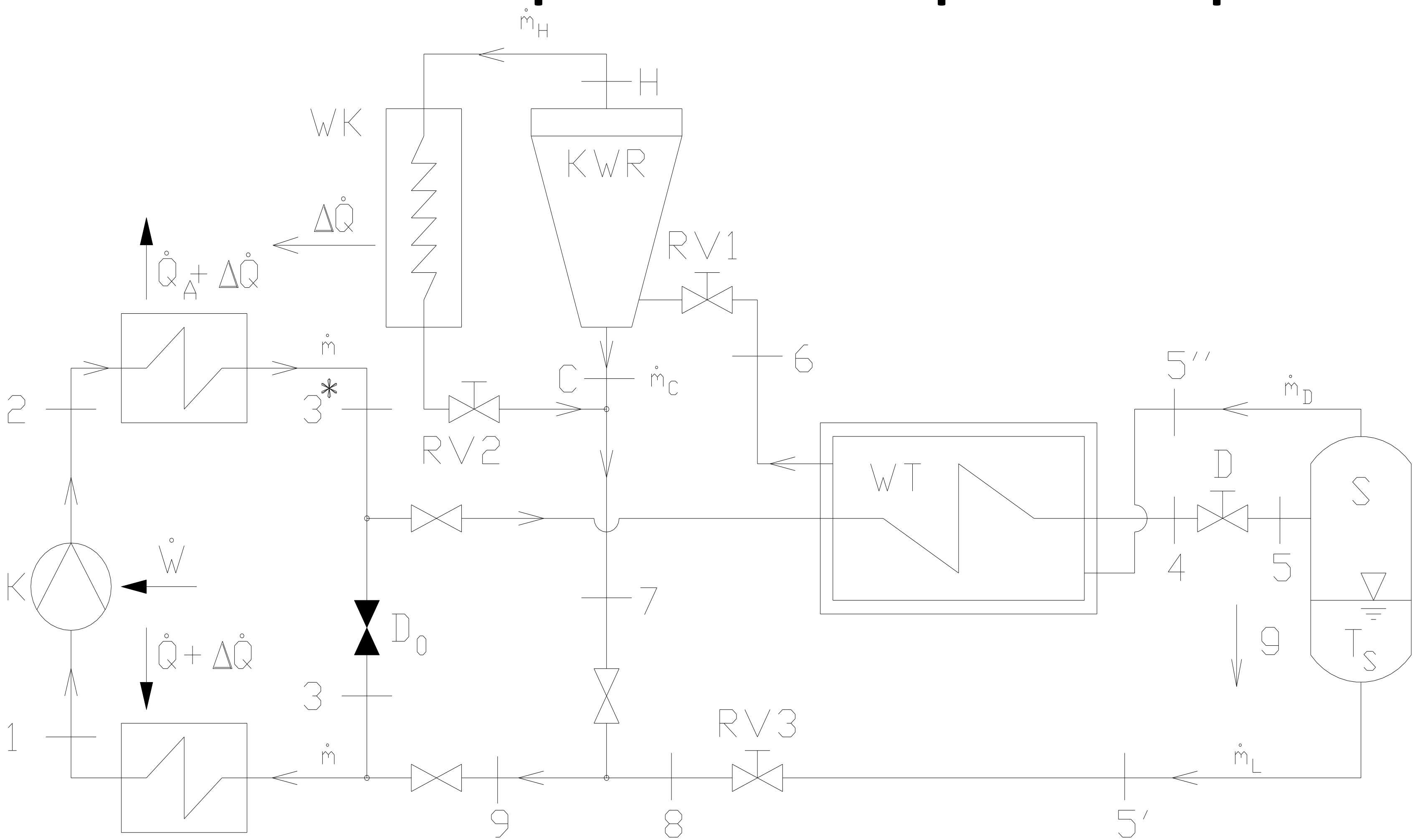
Improvement:
Compression energy savings: (3-10)%

Cooling Vortex Tube* for non-adiabatic expansion of gases and vapors (IFT USI, 1995)



*Patent DE 4345 137 A1, 1993

Non-adiabatic Expansion of Compressed Liquids



Refrigeration cycle

Expansion valve

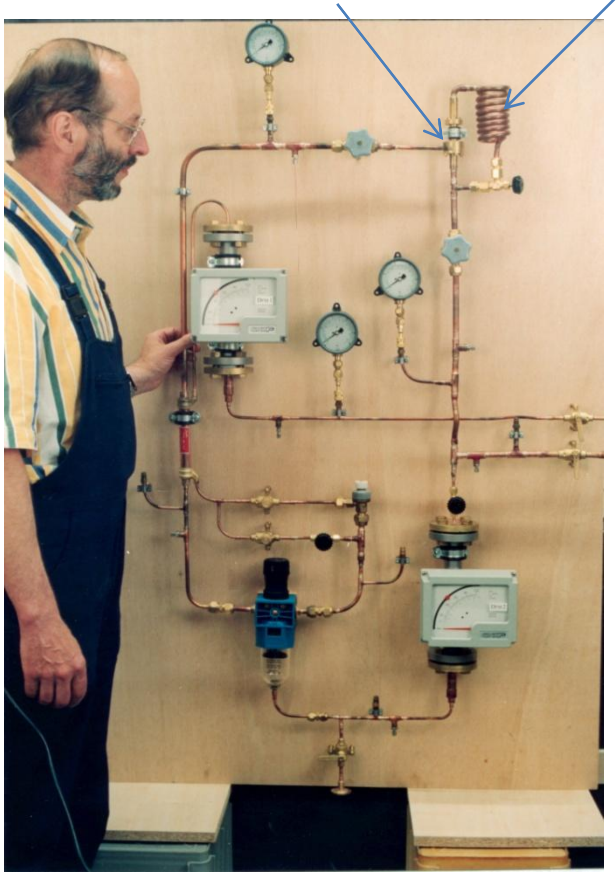
Thermovalve: Heat exchanger Valve

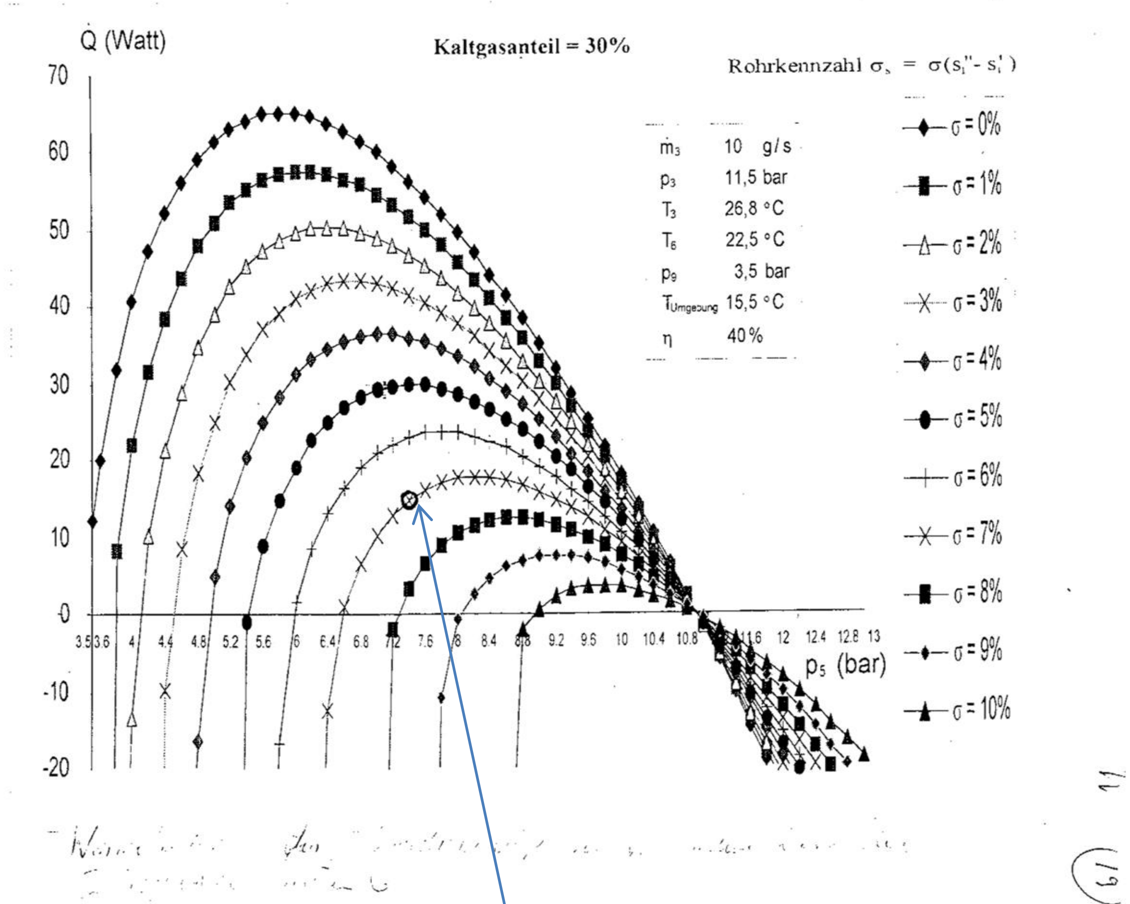
Vortex tube

Phase separator

Thermo-Valve*: Non-adiabatic Expansion of Compressed Liquids (R22, CO2 etc.)

Vortex tube   Heat exchanger





* Patent DE4343 088 A1, 1993

Measurement, R22 Refrigeration process


J.S.BACH
SONATEN

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Die Expansion von Gasen im Zentrifugalfeld als Kälteprozess,
Zeitschrift für Naturforschung, 1 (1946), 208-214.

[3]Schäfer, M.
Untersuchung von Entspannungsvorgängen komprimierter Luft am Wirbelrohr nach Ranque und Hilsch, Studienarbeit,
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http://www.uni-siegen.de/fb11/tts/personen/juk/?lang=de