Modul 1

① $v = \frac{s}{t} = \frac{42{,}195\,km}{4{,}25\,h} = 9{,}93\,\frac{km}{h} = 2{,}76\,\frac{m}{s}$

② 1 $v = \frac{s}{t} = \frac{1500\,m}{42\,s} = 35{,}7\,\frac{m}{s} = 129\,\frac{km}{h}$

2 $t = \frac{s}{v} = \frac{2900\,m}{35{,}7\,m/s} = 81\,s$

3 $s = v \cdot t = 35{,}7\,\frac{m}{s} \cdot 25 \cdot 60\,s = 53{,}57\,km$

③ 1 $t = \frac{s}{v} = \frac{12800\,m}{6{,}11\,\frac{m}{s}} = 2095\,s = 34\,min\,55\,s$

2 $s = v \cdot t = 6{,}11\,\frac{m}{s} \cdot 47 \cdot 60\,s = 17{,}23\,km$

3 $a = \frac{\Delta v}{t} = \frac{6{,}11\,\frac{m}{s}}{4\,s} = 1{,}53\,\frac{m}{s^2}$

④ 1 $t = \frac{2 \cdot s}{v} = \frac{2 \cdot 2300\,m}{75\,\frac{m}{s}} = 61{,}3\,s$

2 $a = \frac{\Delta v}{t} = \frac{7{,}5\,\frac{m}{s}}{61{,}3\,s} = 1{,}22\,\frac{m}{s^2}$

⑤ $a = \frac{v^2}{2s} = \frac{(27{,}8\,\frac{m}{s})^2}{2 \cdot 38\,m} = 10{,}15\,\frac{m}{s^2}$

$t = \frac{2 \cdot s}{v} = \frac{2 \cdot 38\,m}{27{,}8\,\frac{m}{s}} = 2{,}7\,s$

⑥ $a = \frac{v^2}{2s} = \frac{(8{,}33\,\frac{m}{s})^2}{2 \cdot 0{,}2\,m} = 173{,}5\,m/s^2 = 17{,}7\,g$

⑦ $d = \frac{v}{n \cdot \pi} = \frac{1{,}5\,\frac{m}{s}}{40\,\frac{1}{s} \cdot \pi} = 0{,}0119\,m = 11{,}9\,mm$

⑧ $v = d \pi n = 2 \cdot 0{,}12\,m \cdot \pi \cdot 173{,}3\,\frac{1}{s} = 130{,}7\,\frac{m}{s}$

(9) 1 $t = \frac{s}{v} = \frac{18m}{0{,}45\frac{m}{s}} = 40s$

2 $n = \frac{v}{d\pi} = \frac{0{,}45\frac{m}{s}}{0{,}4m \cdot \pi} = 0{,}358\frac{1}{s} = 21{,}5\frac{1}{min}$

3 $z = n \cdot t = 21{,}5\frac{1}{min} \cdot \frac{24}{60} min = 8{,}6$

4 $\frac{n_1}{n_2} = \frac{z_2}{z_1}$ $\quad n_1 = 0{,}358 \cdot \frac{200}{34} = 2{,}1\frac{1}{s}$

(10)

$n_4 = \frac{v}{d\pi} = \frac{15\frac{m}{min}}{0{,}4m \cdot \pi} = 11{,}94\frac{1}{min}$

$n_2 = n_3 = n_4 \cdot \frac{z_4}{z_3} = 11{,}94\frac{1}{min} \cdot \frac{150}{17} = 105{,}4\frac{1}{min}$

$n_1 = n_2 \cdot \frac{z_2}{z_1} = 105{,}4\frac{1}{min} \cdot \frac{70}{12} = 615\,min^{-1}$

(11)

$s_1 = \frac{v_a^2 - v_e^2}{2a} = \frac{(36{,}11\frac{m}{s})^2 - (22{,}22\frac{m}{s})^2}{6\,m/s^2} = 135m$

$t_1 = \frac{2s}{v_a + v_e} = \frac{270m}{36{,}11\frac{m}{s} + 22{,}22\frac{m}{s}} = 4{,}63s$

$s_2 = 2000m$

$t_2 = \frac{s}{v} = \frac{2000m}{22{,}22\,m/s} = 90s$

$s_3 = 250m$

$t_3 = \frac{2s}{v_a + v_e} = \frac{500m}{22{,}22\frac{m}{s} + 36{,}11\frac{m}{s}} = 8{,}57s$

$t_B = t_1 + t_2 + t_3 = 103{,}2$

$t_{o.B.} = \frac{s}{v} = \frac{2385m}{36{,}11\frac{m}{s}} = 66s$

$\Delta t = 37{,}2s$

① $m = \frac{G}{g} = \frac{1200\,N}{9{,}81\,\frac{m}{s^2}} = 122{,}3\,kg$

② $a = \frac{F}{m} = \frac{296\,N}{80\,kg} = 3{,}7\,\frac{m}{s^2}$

③ 1 $F = m \cdot g = 2800\,kg \cdot 9{,}81\,\frac{m}{s^2} = 27{,}5\,kN$

2 $F = m \cdot g + m \cdot a = 27{,}5\,kN + 2800\,kg \cdot 2\,\frac{m}{s^2} =$

$= 27{,}5\,kN + 5{,}66\,kN = 33{,}16\,kN$

④ $F = D \cdot s \Rightarrow D = \frac{F}{s} = \frac{20\,N}{5\,mm} = 4\,\frac{N}{mm}$

⑤ $F = \frac{m v^2}{r} = \frac{85\,kg \cdot (16{,}67\,\frac{m}{s})^2}{40\,m} = 591\,N$

⑥ 1 $a = \frac{\Delta v}{t} = \frac{(33{,}33\,\frac{m}{s})}{180\,s} = 0{,}185\,\frac{m}{s^2}$

$F = m\,a = 60000\,kg\ 0{,}185\,\frac{m}{s^2} = 11{,}1\,kN$

2 $F_R = \mu F_N = \mu \cdot m \cdot g = 0{,}01 \cdot 60000\,kg\,9{,}81\,\frac{m}{s^2} = 5{,}9\,kN$

$F = 11{,}1\,kN + 5{,}9\,kN = 17\,kN$

⑦ $F_G = F_Z \qquad m \cdot g = m \frac{v^2}{r}$

$v = \sqrt{g \cdot r} = \sqrt{9{,}81\,\frac{m}{s^2} \cdot 25\,m} = 15{,}7\,\frac{m}{s}$

(8) 

$\frac{1}{2} F_{res} = 1200N \cdot \cos 55^0 \quad F_{res} = 1377N$

(9) $F_{resx} = 100N \cdot \cos(-60°) + 0 + 100N \cos 210^0 = -36,6N$

$F_{resy} = 100N \cdot \sin(-60°) - 100N + 100N \cdot \sin 210^0 = -236,6N$

$F_{res} = \sqrt{(-36,6N)^2 + (-236,6N)^2} = 239,4\,N$

$\alpha = \arctan \frac{-236,6}{-36,6} - 180^0 = -98,8^0$

(10) 1 $\frac{1}{2} F_{res} = 50kN \cdot \cos 20^0 \quad F_{res} = 94,6kN$

2 $\alpha = 20^0 - 90^0 = -70^0$

(11) $G = 2 \cdot 12000N \cdot \cos 60^0 = 12000N$

$m = \frac{G}{g} = \frac{1200N}{9,81 \frac{m}{s^2}} = 122,3kg$

12 $\alpha = \tan^{-1} 0,12 = 6,84^0$

$F = m \cdot g (\mu \cos\alpha + \sin\alpha)$

$= 1250kg \cdot 9,81 \frac{m}{s^2} (0,05 \cdot \cos 6,84^0 + \sin 6,84^0) = 2069N$

(13) 1 $\mu = \frac{F_R}{m \cdot g} = \frac{618N}{1050kg \cdot 9,81 \frac{m}{s^2}} = 0,06$

2 $a = g(\sin\alpha - \mu\cos\alpha) = 9,81(\sin 12^0 - 0,06\cos 12^0)$

$= 1,46 \frac{m}{s^2}$

3 $F = m \cdot a = 1050N \cdot 1,46 \frac{m}{s^2} = 1533\,N$

(14) 1 $F = \mu \cdot m \cdot g = 0{,}06 \cdot 1100\,kg \cdot 9{,}81\,\frac{m}{s^2} = 647{,}5\,N$

2 $\alpha = \tan^{-1} 0{,}07 = 4°$

$F = 647{,}5\,N - mog \cdot (\sin\alpha + \mu \cos\alpha)$

$= 647{,}5\,N - 1100\,kg \cdot 9{,}81\,\frac{m}{s^2} (\sin 4° + 0{,}06 \cdot \cos 4°)$

$= -751\,N$

$a' = \frac{751\,N}{1100\,kg} = 0{,}683\,\frac{m}{s^2}$

$s = \frac{v^2}{2a'} = \frac{(22{,}22\,\frac{m}{s})^2}{2 \cdot 0{,}683\,\frac{m}{s^2}} = 361\,m$

① $m = \frac{W}{g\,h} = \frac{9420\,J}{9{,}81\,\frac{m}{s^2} \cdot 1{,}2\,m} = 800\,kg$

② $W = \frac{m v^2}{2} = \frac{1200\,kg \cdot (25\,\frac{m}{s})^2}{2} = 375\,kJ$

③ $W_{zu} = 42\,\frac{MJ}{kg} \cdot 410\,\ell \cdot 0{,}85\,\frac{kg}{\ell} = 14637\,MJ$

$W_{ab} = \eta \cdot W_{zu} = 14637\,MJ \cdot 0{,}40 = 5855\,MJ$

$F = \frac{W}{s} = \frac{5855000\,kJ}{1600\,km} = 3659\,N$

$\mu = \frac{F}{m\,g} = \frac{3659\,N}{8500\,kg \cdot 9{,}81\,\frac{m}{s^2}} = 0{,}044$

④ $P = \frac{F \cdot s}{t} = \frac{300\,kg \cdot 9{,}81\,\frac{m}{s^2} \cdot 18\,m}{20\,s} = 2649\,W$

$P_{zu} = \frac{P_{ab}}{\eta} = \frac{2649\,W}{1 - 0{,}31} = 3839\,W$

⑤ 1 $P = F \cdot v = 0{,}03 \cdot 2000\,kg \cdot 9{,}81\,\frac{m}{s^2} \cdot 0{,}9\,\frac{m}{s} = 530\,W$

2 $W_{kin} = \frac{1}{2} m v^2 = \frac{1}{2} \cdot 2000\,kg \cdot (0{,}9\,\frac{m}{s})^2 = 810\,J$

$s = \frac{1}{2} v \cdot t = \frac{1}{2} \cdot 0{,}9\,\frac{m}{s} \cdot 2\,s = 0{,}9\,m$

$W_{Reib} = F_R \cdot s = 0{,}03 \cdot 2000\,kg \cdot 9{,}81\,\frac{m}{s^2} \cdot 0{,}9\,m = 530\,J$

$W = 810\,J + 530\,J = 1340\,J$

(6) $P_{ab} = 0{,}9\,0{,}8 \cdot 1400\,W = 1008\,W$

$$t = \frac{W}{P} = \frac{20000\,kg \cdot 9{,}81\,\frac{m}{s^2} \cdot 6{,}8\,m}{1008\,W} = 1324\,s$$

$= 22\,min$

(7) 1 $$\dot{m} = \frac{815\,\ell \cdot 0{,}93\,\frac{kg}{\ell}}{24\,h} = 28{,}2\,\frac{kg}{h}$$

2 $$P_{zu} = \frac{W}{t} = \frac{Q}{t} = \frac{41{,}9\,\frac{MJ}{kg} \cdot 28{,}24\,kg}{3600\,s} = 328\,kW$$

$$\eta = \frac{132\,kW}{328\,kW} = 0{,}402$$

(8) 1 $$F = \mu \cdot m \cdot g = 0{,}01 \cdot 600000\,kg \cdot 9{,}81\,\frac{m}{s^2} = 58{,}86\,kN$$

2 $$a = \frac{F}{m} = \frac{130000\,N - 5886\,N}{600000\,kg} = 0{,}12\,\frac{m}{s^2}$$

3 $$P_{ab} = F \cdot v = 58{,}86\,kN \cdot 12{,}5\,\frac{m}{s} = 736\,kW$$

$$P_{zu} = \frac{736\,kW}{0{,}92 \cdot 0{,}88} = 909\,kW$$

(9) 1 $t = \frac{\Delta v}{a} = \frac{66{,}67\,\frac{m}{s}}{1{,}1\,m/s^2} = 60{,}6\,s$

2 $s = \frac{1}{2} v_c \cdot t = \frac{1}{2} \cdot 66{,}67\,\frac{m}{s} \cdot 60{,}6\,s = 2020\,m$

3 $W = \frac{1}{2} m v^2 = \frac{1}{2} \cdot 377000\,kg \cdot \left(66{,}67\,\frac{m}{s}\right)^2$
$= 838\,MJ$

4 $W_{pot} = m g h = 377000 \cdot 9{,}81\,\frac{m}{s^2} \cdot 30000\,m$
$= 33817\,MJ$

$W_{kin} = \frac{1}{2} \cdot 377000\,kg \cdot \left(\left(250\,\frac{m}{s}\right)^2 - \left(66{,}67\,\frac{m}{s}\right)^2\right)$
$= 10943\,MJ$

$W_{ab} = W_{pot} + W_{kin} = 44760\,MJ$

$W_{zu} = \frac{44760\,MJ}{1 - 0{,}6} = 112\,GJ$

(10) $P_{zu} = \frac{5\,kW}{0{,}6} = 8{,}33\,kW$

$Q_{zu} = P \cdot t = 8{,}33\,kW \cdot 24\,h = 200\,kWh$

$H = \frac{14000\,kJ}{kg} \quad \frac{3{,}89\,kWh}{kg}$

$m = \frac{Q}{H} = \frac{200\,kWh}{3{,}89\,\frac{kWh}{kg}} = 51{,}4\,kg$

Modul 4

(1) $\Delta \ell = 20m \cdot 0{,}000012 \frac{1}{K} \cdot 55K = 0{,}0132m = 13{,}2mm$

(2) $\Delta V_{Rohr} = 600\ell \cdot 3 \cdot 0{,}000012 \frac{1}{K} \cdot 70K = 1{,}5\ell$

$\Delta V_{H_2O} = 600\ell \cdot 0{,}0004 \frac{1}{K} \cdot 70K = 16{,}8\ell$

$\Delta^2 V = 15{,}3\ell$

(3) $m_{Holz} = \rho \cdot V = 800 \frac{kg}{m^3} \cdot 2m \cdot 0{,}35m \cdot 0{,}15m = 84kg$

$m_{Wasser} = 1000 \frac{kg}{m^3} \cdot 2m \cdot 0{,}35m \cdot 0{,}15m = 105kg$

$\Delta m = 21kg$

(4) $p = \rho \cdot g \cdot h = 1018 \frac{kg}{m^3} \cdot 9{,}81 \frac{m}{s^2} \cdot 459m = 4583840Pa$

$\hat{=} 45{,}84 bar$

(5) 1 $v_2 = \frac{A_1 v_1}{A_2} = \frac{(22{,}2mm)^2 \cdot \frac{\pi}{4} \cdot 1{,}2 \frac{m}{s}}{120mm^2} = 3{,}87 \frac{m}{s}$

2 $\dot{V} = A \cdot v = 120mm^2 \cdot 3{,}87 \frac{m}{s} = 120 \cdot 10^{-4} \cdot 38{,}7 \frac{dm}{s} \cdot 60 \frac{s}{min}$

$= 27{,}9 \frac{\ell}{min}$

(6) $R_i = \frac{R}{M} = \frac{8315}{58} \frac{J}{kgK} = 143{,}4 \frac{J}{kgK}$

$m = \frac{p \cdot V}{R_i \cdot T} = \frac{94000Pa \cdot 500m^3}{143{,}4 \frac{J}{kgK} \cdot 288K} = 1138kg$

(7) $R_i = \frac{8315}{40} \frac{J}{kgK} = 208 \frac{J}{kgK}$

$p = \frac{m R_i T}{V} = \frac{4{,}582kg \cdot 208 \frac{J}{kgK} \cdot 294K}{0{,}02m^3} = 14009923Pa$

$\hat{=} 140 bar$

(8) 1 $R_i = \frac{p \cdot V}{m \cdot T} = \frac{68 \cdot 10^5 \text{ Pa} \cdot 0{,}025 \text{ m}^3}{3 \text{ kg} \cdot 300 \text{ K}} = 188{,}9 \frac{\text{J}}{\text{kg K}}$

$M = \frac{R}{R_i} = \frac{8315}{188{,}9} \frac{\text{kg}}{\text{kmol}} = 44 \frac{\text{kg}}{\text{kmol}}$

2 nach Tab in FS evtl. CO_2

(9) 1 $\text{Vol\%} = \frac{24 \text{ bar}}{160 \text{ bar}} \cdot 100\% = 15\%$

2 $R_i = \frac{8315}{0{,}85 \cdot 40 + 0{,}15 \cdot 44} \frac{\text{J}}{\text{kg K}} = 204{,}8 \frac{\text{J}}{\text{kg K}}$

3 $m = \frac{p_{CO_2} \cdot V}{R_i \cdot T} = \frac{0{,}15 \cdot 210 \cdot 10^5 \text{ Pa} \cdot 0{,}050 \text{ m}^3}{189 \frac{\text{J}}{\text{kg K}} \cdot 291 \text{ K}}$

$= 2{,}86 \text{ kg}$

Modul 5

① $\Delta\vartheta_2 = \frac{c_1 m_1 \Delta\vartheta_1}{c_2 m_2} = \frac{4,19 \cdot 0,763 \cdot 84K}{0,128 \cdot 2} = 104,9K$

$\vartheta_S = 106,4K$

② $m_2 = \frac{c_1 m_1 \Delta\vartheta_1}{c_2 \Delta\vartheta_2} = \frac{2,4 \cdot 4,3kg \cdot 21}{4,19 \cdot 29} = 1,78kg$

③ $c_2 = \frac{c_1 m_1 \Delta\vartheta_1}{m_2 \Delta\vartheta_2} = \frac{4,19 \frac{kJ}{kgK} \cdot 3,5}{2,15} = 2,1 \frac{kJ}{kgK}$

④ $\Delta\vartheta_2 = \frac{0,45 \cdot 210 \cdot 0,32 \cdot 73,5K}{4,19 \cdot 180} = 29,5K$

$\vartheta_2 = 15,5°C$

⑤ $P_{ab} = \frac{Q}{t} = \frac{4,19 \cdot 1,7 \cdot 86 kJ}{312s} = 1,963kW$

$\eta = \frac{1,963}{2,2} = 0,89$

⑥ $P = \frac{Q}{t} = \frac{4,19 \frac{kJ}{kgK} \cdot 7kg \cdot 53K : 0,9}{60s} = 28,8kW$

⑦ $t = \frac{Q}{P} = \frac{4,19 \frac{kJ}{kgK} \cdot 1,5kg \cdot 86K}{2,2kW} = 246s = 4min\,6s$

⑧ $t = \frac{Q}{P} = \frac{(1,5 \cdot 2,1 \cdot 18 + 1,5 \cdot 335 + 1,5 \cdot 4,19 \cdot 95) kJ}{(1 - 0,55) \cdot 1,8kW}$

$= 1428s = 24min$

(9) $Q = \frac{(2 \cdot 2{,}1 \cdot 18 + 2 \cdot 335 + 2 \cdot 4{,}19 \cdot 80)\,kJ}{1 - 0{,}1} = 2360\,kJ$

(10) $Q_1 = 0{,}1 \cdot 4{,}19 \cdot 23\,kJ = 38{,}55\,kJ$

$Q_2 = m_{Eis}(2{,}1 \cdot 18 + 335)\frac{kJ}{kg} = 372{,}8\frac{kJ}{kg} \cdot m_{Eis}$

$m_{Eis} = \frac{38{,}55\,kJ}{372{,}8\,\frac{kJ}{kg}} = 0{,}103\,kg = 103\,g$

$m = 5 \cdot 27\,cm^3 \cdot 0{,}92\,\frac{g}{cm^3} = 124\,g$

$\Delta m = 21\,g$

(11) 1 $Q = (0{,}45 \cdot 50000 \cdot 1516 + 276 \cdot 50000)\,kJ$

$= 47910000\,kJ = 47910\,MJ = 13308\,kWh$

2 $m = \frac{Q}{H} = \frac{47910\,MJ}{0{,}55 \cdot 19\,MJ/kg} = 4585\,kg$

(12) $P \cdot t = Q$

$3kW \cdot 0{,}6 \cdot 1200s = m \cdot (2{,}1 \cdot 18 + 335 + 4{,}19 \cdot 70)\frac{kJ}{kg}$

$2160\,kJ = m \cdot 666{,}1\,\frac{kJ}{kg}$

$m = 3{,}24\,kg$

Modul 6

(1) $R_T = \left(0{,}04 + \frac{0{,}03}{0{,}7} + \frac{0{,}49}{0{,}45} + \frac{0{,}015}{0{,}7} + 0{,}13\right) \frac{m^2K}{W} = 1{,}323 \frac{m^2K}{W}$

$U = \frac{1}{R_T} = 0{,}76 \frac{W}{m^2K}$

(2) $R_T = \frac{1}{U} = 1{,}33 \frac{m^2K}{W}$

$1{,}33 \frac{m^2K}{W} = 0{,}04 \frac{m^2K}{W} + \frac{0{,}02\,m}{0{,}87 \frac{W}{mK}} + \frac{0{,}01\,m}{0{,}8 \frac{W}{mK}} + 0{,}13 \frac{m^2K}{W} + \frac{d_2}{0{,}323 \frac{W}{mK}}$

$d_2 = 0{,}323 \frac{W}{mK} \cdot 1{,}126 \frac{m^2K}{W} = 0{,}364\,m \triangleq 36{,}5\,cm$

(3) $R_T = \frac{1}{U} = 2 \frac{m^2K}{W}$

$2 \frac{m^2K}{W} = 0{,}04 \frac{m^2K}{W} + 0{,}03 \frac{m^2K}{W} + \frac{0{,}24\,m}{0{,}5 \frac{W}{mK}} + \frac{d}{0{,}04 \frac{W}{mK}} + 0{,}02 \frac{m^2K}{W} + 0{,}13 \frac{m^2K}{W}$

$d = 0{,}04 \frac{W}{mK} \cdot 1{,}3 \frac{m^2K}{W} = 0{,}052\,m = 5{,}2\,cm$

(4) $U = \frac{1}{\frac{1}{580} + \frac{0{,}003}{60} + \frac{1}{7}} \frac{W}{m^2K} = 6{,}91 \frac{W}{m^2K}$

$\Delta T = \frac{\Phi}{U \cdot A} = \frac{930\,W}{6{,}91 \frac{W}{m^2K} \cdot 2{,}5\,m^2} = 53{,}8\,K$

$\Theta = 22°C + 53{,}8°C = 75{,}8°C$

(5) 1 $A = 2(12 \cdot 10 + 12 \cdot 6 + 10 \cdot 6)\,m^2 = 504\,m^2$

$\Phi = 0{,}85 \cdot 504 \cdot 46\,W = 19{,}76\,kW$

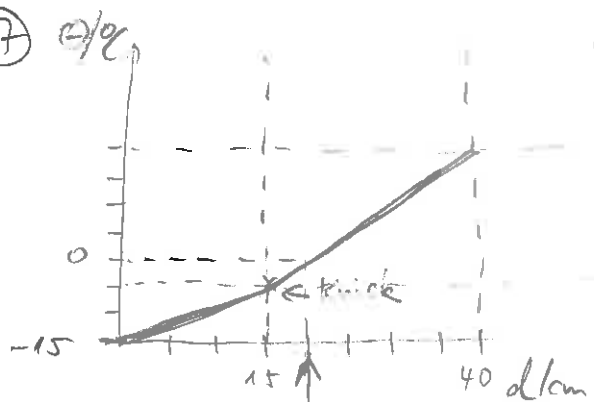
2 $t = \frac{Q}{\Phi} = \frac{1 \cdot 258000 \cdot 0{,}5\,kJ}{19{,}7\,kW} = 6548\,s = 1{,}82\,h$

$\Delta\Theta = 0{,}5°C \triangleq$ durchschnittliche Temperaturänderung des Wand

(6) $A = 2(0{,}65 \cdot 0{,}6 + 0{,}65 \cdot 1 + 0{,}6 \cdot 1)\,m^2 = 3{,}28\,m^2$

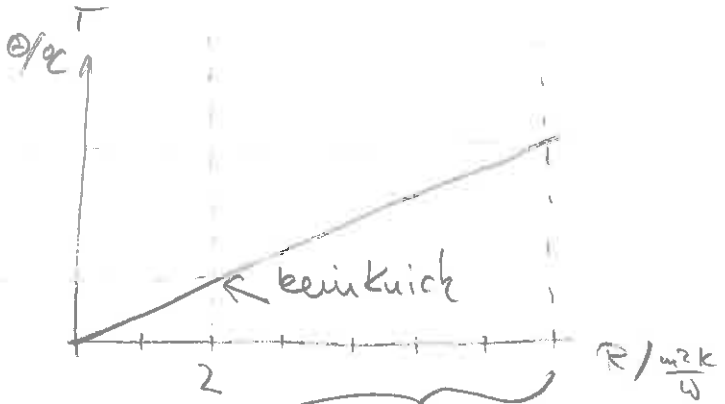
$$U = \frac{130\,W}{3{,}28\,m^2 \cdot 50\,K} = 0{,}79\,\frac{W}{m^2 K}$$

(7)



Frostgrenze

2: 5 cm (20cm-15cm)



1: $R_i = 5\,\frac{m^2 K}{W}$

(8) $R_1 = 0{,}13\,\frac{m^2 K}{W} + \frac{0{,}010\,m}{0{,}9\,\frac{W}{mK}} = 0{,}141\,\frac{m^2 K}{W}$ $\quad U_1 = 7{,}09\,\frac{W}{m^2 K}$

$R_2 = 0{,}17\,\frac{m^2 K}{W}$ $\quad U_2 = 5{,}88\,\frac{W}{m^2 K}$

$A_1 = 0{,}6\,m \cdot (1{,}5 + 0{,}6)\,m \cdot 2 = 2{,}52\,m^2$ $\quad A_2 = 0{,}6 \cdot 1{,}5\,m^2 = 0{,}9\,m^2$

$$\Phi = (7{,}09 \cdot 2{,}52 + 5{,}88 \cdot 0{,}9) \cdot 5\,W = 116\,W$$

(9) $A_{ges} = 36\,m^2$, $A_W = 4{,}2\,m^2$ $\quad A_{MW} = 31{,}8\,m^2$

$U_{MW} = 0{,}396\,\frac{W}{m^2 K}$ $\quad U_W = 1{,}8\,\frac{W}{m^2 K}$

$$U_m = \frac{0{,}396 \cdot 31{,}8 + 1{,}8 \cdot 4{,}2}{36}\,\frac{W}{m^2 K} = 0{,}56\,\frac{W}{m^2 K}$$

(10) $A_{ges} = 22{,}4\,m^2$, $A_D = 2\,m^2$, $A_W = 5\,m^2$, $A_{MW} = 15{,}4\,m^2$

$U_D = 2{,}7\,\frac{W}{m^2 K}$, $U_W = 1{,}6\,\frac{W}{m^2 K}$, $U_{MW} = 0{,}628\,\frac{W}{m^2 K}$

$$U_m = \frac{2{,}7 \cdot 2 + 1{,}6 \cdot 5 + 0{,}628 \cdot 15{,}4}{22{,}4}\,\frac{W}{m^2 K} = 1{,}03\,\frac{W}{m^2 K}$$

(11) 1 $A_W = 6{,}93\,m^2$, $A_{mW} = 33{,}07\,m^2$, $A_F = 31{,}92\,m^2$

$A_{ges} = 71{,}92\,m^2$

$U_W = 1{,}9\,\frac{W}{m^2K}$ $U_{mW} = 0{,}437\,\frac{W}{m^2K}$ $U_F = 0{,}691\,\frac{W}{m^2K}$

$$U_m = \frac{1{,}9 \cdot 6{,}93 + 0{,}437 \cdot 33{,}07 + 0{,}691 \cdot 31{,}92}{71{,}92}\,\frac{W}{m^2K} = 0{,}69\,\frac{W}{m^2K}$$

$R_T = 1{,}45\,\frac{m^2K}{W}$

2 $\Phi = 0{,}69\,\frac{W}{m^2K} \cdot 71{,}92\,m^2 \cdot 43\,K = 2134\,W$

(12) 1 $A_{ges} = 25\,m^2$ $A_W = 3{,}25\,m^2$ $A_{mW} = 21{,}75\,m^2$

$U_W = 2{,}7\,\frac{W}{m^2K}$ $U_{mW} = 0{,}742\,\frac{W}{m^2K}$

$\Phi = (2{,}7 \cdot 3{,}25 + 0{,}742 \cdot 21{,}75) \cdot 35\,W = 876\,W$

2 $R_T = \frac{1}{2{,}7}\,\frac{m^2K}{W} = 0{,}37\,\frac{m^2K}{W}$

$\frac{35\,K}{0{,}37} = \frac{\Delta T}{0{,}13} \Rightarrow \Delta T = 12{,}3\,K \Rightarrow \Theta = (22 - 12{,}3)^\circ C = 9{,}7^\circ C$

(1) 1 Tabelle Taupunkttemperatur $\Theta_T = 14{,}2\,°C$

2 $c_S(21°C) = \text{Tabelle} = 18{,}3\,\frac{g}{m^3}$

$c = 0{,}65 \cdot 18{,}3\,\frac{g}{m^3} = 11{,}9\,\frac{g}{m^3}$

$m = 11{,}9\,\frac{g}{m^3} \cdot 100\,m^2 = 1{,}19\,kg$

(2) $\Theta_T = \text{Tabelle} = 14{,}4\,°C \quad \Delta T_{ges} = 35\,K \quad \Delta T_{Scheibe} = (20-14{,}4)\,K = 5{,}6\,K$

$\frac{35\,K}{R_T} = \frac{5{,}6\,K}{0{,}13\,\frac{m^2K}{W}} \Rightarrow R_T = 0{,}81\,\frac{m^2K}{W}$

(3) $c_S(-10°C) = 2{,}1\,\frac{g}{m^3} \quad c = 0{,}6 \cdot 2{,}1\,\frac{g}{m^3} = 1{,}26\,\frac{g}{m^3}$

$c_S(20°C) = 17{,}3\,\frac{g}{m^3} \quad \varphi = \frac{1{,}26}{17{,}3} \cdot 100\,\% = 7{,}3\,\%$

(4) $\frac{35\,K}{R_T} = \frac{(20-15{,}4)\,K}{0{,}13\,\frac{m^2K}{W}} \Rightarrow R_T = 0{,}989\,\frac{m^2K}{W}$

$0{,}989\,\frac{m^2K}{W} - 0{,}13\,\frac{m^2K}{W} + \frac{0{,}25\,m}{0{,}75\,\frac{W}{mK}} + \frac{d}{0{,}075\,\frac{W}{m^2K}} + 0{,}04$

$d = 0{,}0364\,m$

(5) $R_T = 0{,}325\,\frac{m^2K}{W}$

$\frac{1{,}6\,K}{0{,}325\,\frac{m^2K}{W}} = \frac{\Delta T}{0{,}13\,\frac{m^2K}{W}} \Rightarrow \Delta T = 6{,}4\,K$

$\Rightarrow T_{Scheibe} = (18-6{,}4)\,°C = 11{,}6\,°C$

Taupunkttabelle: $65\,\% \triangleq 11{,}3\,°C \quad 70\,\% \triangleq 12{,}5\,°C$

$\varphi = 65\,\% + \frac{11{,}6-11{,}3}{12{,}5-11{,}3} \cdot 5\,\% = 66\,\%$

(6) 1 $p_s(20°C) = \text{Tabelle} = 2340\,Pa = 23{,}4\,hPa$

$p = p_{umf} + p_s = 976\,mbar + 23{,}4\,mbar = 999{,}4\,hPa$

2 $c_s(20°C) = 17{,}3\,\frac{g}{m^3}$ davon fehlen noch 40 %

$m = 0{,}4 \cdot 17{,}3\,\frac{g}{m^3} \cdot \frac{1}{1000}\,m^3 = 0{,}0346\,g$

(7) $c_1 = 0{,}65 \cdot 20{,}6\,\frac{g}{m^3} = 13{,}39\,\frac{g}{m^3}$

$c_2 = 0{,}7 \cdot 18{,}3\,\frac{g}{m^3} = 12{,}81\,\frac{g}{m^3}$

$\Delta c = 0{,}58\,\frac{g}{m^3}$ $V_0 = 2{,}4\,bar \cdot 10\,m^3/bar = 24\,m^3$

$m = 0{,}58\,\frac{g}{m^3} \cdot 24\,m^3 = 13{,}9\,g$

(rundet man c auf eine Nachkommastelle, erhält man 14,4 g)

(8) $c_1 = 0{,}78 \cdot 27{,}2\,\frac{g}{m^3} = 21{,}2\,\frac{g}{m^3}$

$c_2 = 0{,}55 \cdot 18{,}3\,\frac{g}{m^3} = 10{,}1\,\frac{g}{m^3}$

$\Delta c = 11{,}1\,\frac{g}{m^3}$

$m = 756\,m^3 \cdot 11{,}1\,\frac{g}{m^3} = 8{,}4\,kg$

(9) 1 $V = 4\,mm \cdot 1\,km^2 = 4000\,m^3$

$m = 4000000\,kg$

2 $c_{s1} = 14{,}5\,g/m^3$ $c_{s2} = 6{,}8\,g/m^3$ $\Delta c = 7{,}7\,\frac{g}{m^3}$

$V = \frac{4000000000\,g}{7{,}7\,g/m^3} = 519480519\,m^3$

$h = \frac{V}{A} = \frac{519480519\,m^3}{1000000\,m^2} = 519\,m$

10

$R_T = 3{,}30 \frac{m^2K}{W}$ $\quad \Theta_T = 22{,}3°C$

$\frac{\Delta T}{3{,}30 \frac{m^2K}{W}} = \frac{2{,}7\,K}{0{,}17 \frac{m^2K}{W}}$ $\quad \Delta T = 52{,}4\,K$

$\Theta_{Keller} = 25°C - 52{,}4°C = -27{,}4°C$

in Mitteleuropa unmöglich

11

$T_i = 22\,°C$ $\quad T_e = -8\,°C$

$\varphi_i = 60\,\%$ $\quad \varphi_e = 35\,\%$

$p_{si} = 2645\,Pa$ (Tabelle) $\quad p_{se} = 310\,Pa$ (Tabelle)

$p_i = \varphi_i \cdot p_{si} = 1587\,Pa$ ✓ $\quad p_e = \varphi_e \cdot p_{se} = 109\,Pa$ ✓

mit $R_i = \frac{d_i}{\lambda_i}$:	mit $s_{d,i} = \mu_i \cdot d_i$:	s_d kumuliert:
$R_1 = 0{,}01 \frac{m^2 \cdot K}{W}$	$s_{d,1} = 35\,cm$	$s_{k,1} = 35\,cm$
$R_2 = 0{,}84 \frac{m^2 \cdot K}{W}$	$s_{d,2} = 245\,cm$	$s_{k,2} = 280\,cm$
$R_3 = 1{,}43 \frac{m^2 \cdot K}{W}$	$s_{d,3} = 150\,cm$	$s_{k,3} = 430\,cm$
$R_4 = 0{,}02 \frac{m^2 \cdot K}{W}$ ✓	$s_{d,4} = 30\,cm$ ✓	$s_{k,4} = 460\,cm$
$R_{ges} = 2{,}30 \frac{m^2 \cdot K}{W}$ ✓	$s_{d,ges} = 460\,cm$ ✓	

Temperaturunterschiede in den Schichten mit $\Delta T = R \cdot \frac{\Delta T_{ges}}{R_{ges}} = R \cdot \frac{30\,K}{2{,}30 \frac{m^2 \cdot K}{W}}$ ✓

$T_0 = 22\,°C$ $\quad p_{s,0} = 2645\,Pa$ (Tabelle)

$T_1 = 21{,}9\,°C$ $\quad p_{s,1} = 2629\,Pa$

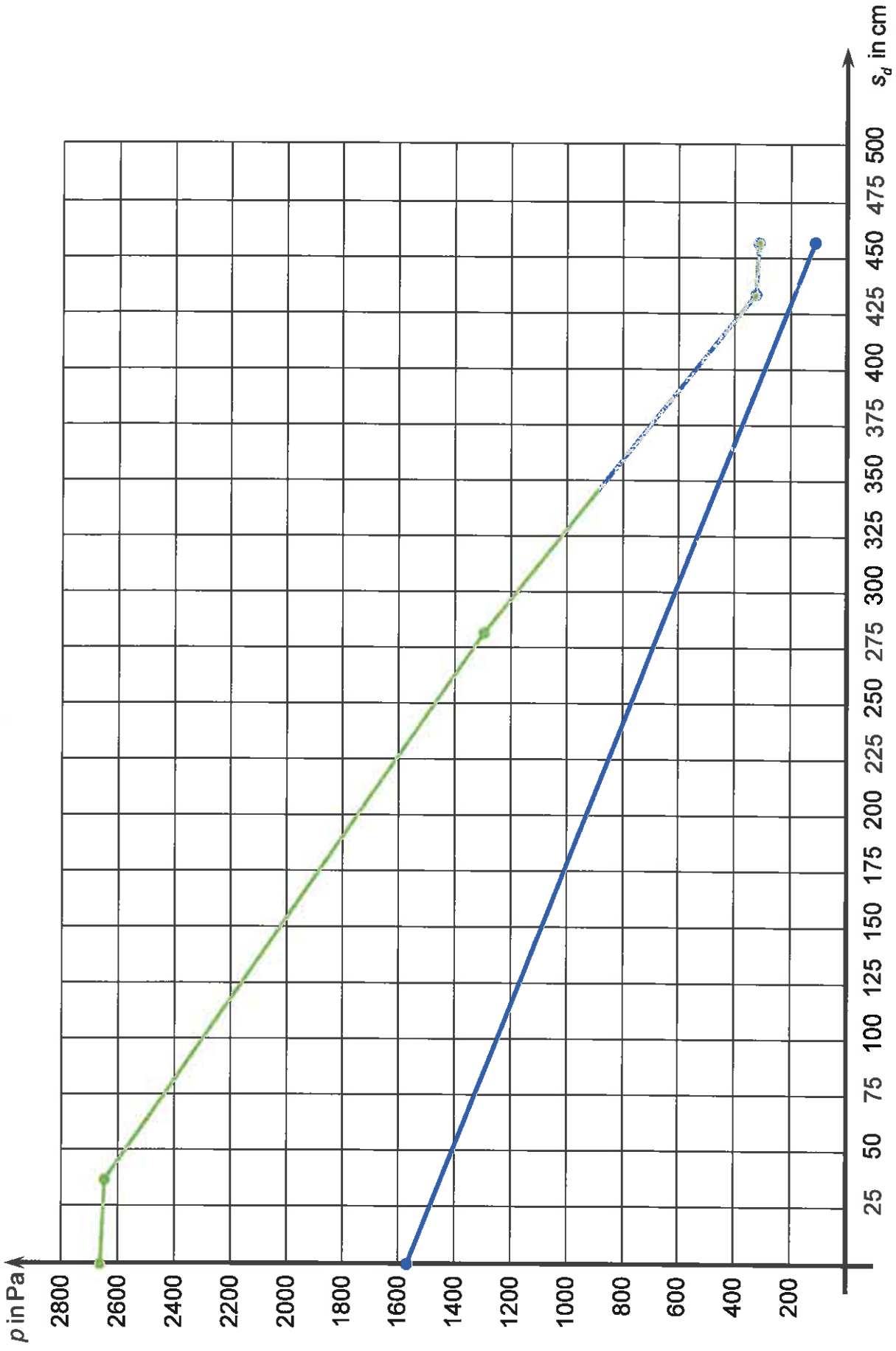
$T_2 = 10{,}9\,°C$ ✓ $\quad p_{s,2} = 1304\,Pa$ ✓

$T_3 = -7{,}8\,°C$ $\quad p_{s,3} = 315\,Pa$

$T_4 = -8\,°C$ ✓ $\quad p_{s,4} = 310\,Pa$ ✓

Es bildet sich kein Tauwasser.

noch 11


p in Pa
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
s_d in cm
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500

12

$T_V = 18\ °C$	$T_K = 2\ °C$
$\varphi_V = 80\ \%$	$\varphi_K = 85\ \%$
$p_{sV} = 2065\ Pa$ (Tabelle)	$p_{sK} = 705\ Pa$ (Tabelle)
$p_V = \varphi_V \cdot p_{sV} = 1652\ Pa$ ✓	$p_K = \varphi_K \cdot p_{sK} = 599\ Pa$ ✓

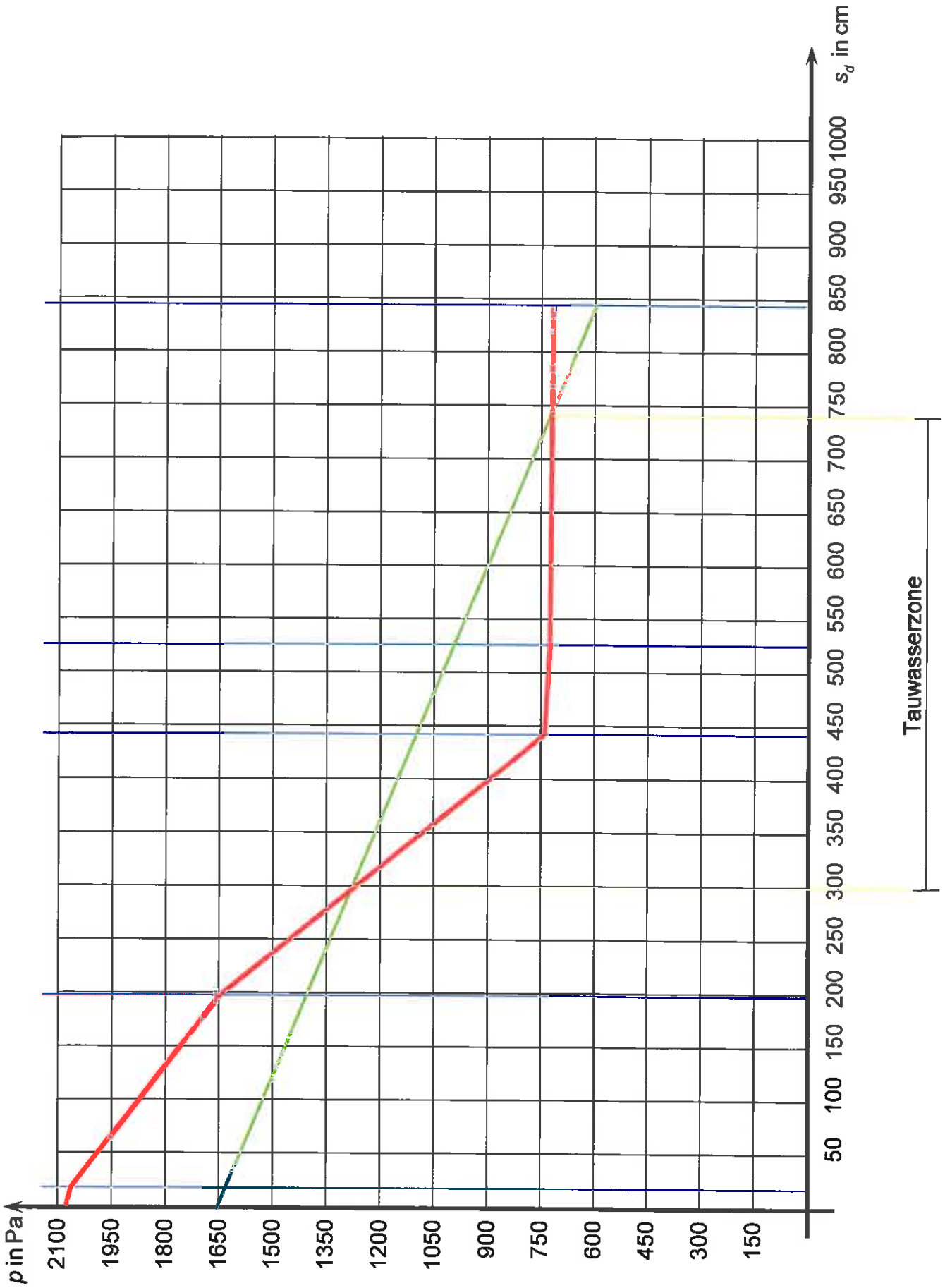
Mit $R_i = \frac{d_i}{\lambda_i}$:	Mit $s_{d,i} = \mu_i \cdot d_i$
$R_1 = 0{,}01\ \frac{m^2 \cdot K}{W}$	$s_{d,1} = 15\ cm$
$R_2 = 0{,}63\ \frac{m^2 \cdot K}{W}$	$s_{d,2} = 183\ cm$
$R_3 = 2{,}29\ \frac{m^2 \cdot K}{W}$ ✓	$s_{d,3} = 240\ cm$ ✓
$R_4 = 0{,}03\ \frac{m^2 \cdot K}{W}$	$s_{d,4} = 88\ cm$
$R_5 = 0{,}01\ \frac{m^2 \cdot K}{W}$	$s_{d,5} = 320\ cm$
$R_{ges} = 2{,}97\ \frac{m^2 \cdot K}{W}$ ✓	$s_{d,ges} = 846\ cm$ ✓

Sofern auch noch Übergangswiderstände berücksichtigt wurden, ergeben sich leicht abweichende Werte, die entsprechend zu bewerten sind.

Temperaturunterschiede in den Schichten mit $\Delta T = R \cdot \frac{\Delta T_{ges}}{R_{ges}} = R \cdot \frac{16\ K}{2{,}97\ \frac{m^2 \cdot K}{W}}$ ✓

$T_0 = 18\ °C$	$p_{s,0} = 2065\ Pa$	(Tabelle)
$T_1 = 18\ °C - 0{,}05\ °C = 17{,}9\ °C$	$p_{s,1} = 2052\ Pa$	
$T_2 = 17{,}9\ °C - 3{,}4\ °C = 14{,}5\ °C$	$p_{s,2} = 1653\ Pa$ ✓	
$T_3 = 14{,}5\ °C - 12{,}3\ °C = 2{,}2\ °C$	$p_{s,3} = 716\ Pa$	
$T_4 = 2{,}2\ °C - 0{,}1\ °C = 2{,}1\ °C$	$p_{s,4} = 710\ Pa$ ✓	
$T_5 = 2{,}1\ °C - 0{,}1\ °C = 2{,}0\ °C$	$p_{s,5} = 705\ Pa$	

noch 12


p in Pa
2100
1950
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
s_d in cm
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
Tauwasserzone

(1) $I_1 = 10^{0,1 \cdot 57 - 12} \frac{W}{m^2} = 5,01 \cdot 10^{-7} \frac{W}{m^2}$

$I_2 = 2,00 \cdot 10^{-6} \frac{W}{m^2}$

$I = I_1 + I_2 = 2,50 \cdot 10^{-6} \frac{W}{m^2}$

$L = 10 \cdot lg(2,50 \cdot 10^{-6+12}) = 64 dB$

(2) 1 $p = 2 \cdot 10^{0,05 \cdot 130 - 5} Pa = 63,2 Pa$

2 $L = 20 \cdot lg\left(\frac{\frac{1}{2} \cdot 63,2}{20 \cdot 10^{-6}}\right) = 124 dB$

$\Delta L = 124 dB - 130 dB = -6 dB$

(3) 1 $p_1 = 2 \cdot 10^{0,05 \cdot 50 - 5} Pa = 0,0063 Pa$

$I_1 = 10^{0,1 \cdot 50 - 12} \frac{W}{m^2} = 1 \cdot 10^{-7} \frac{W}{m^2}$

2 $A = 4r^2 \cdot \pi = 4 \cdot (3m)^2 \cdot \pi = 113 m^2$

$P = I \cdot A = 1 \cdot 10^{-7} \frac{W}{m^2} \cdot 113 m^2 = 1,13 \cdot 10^{-5} W$

3 $A_2 = 4 \cdot (10m)^2 \cdot \pi = 1256,6 m^2$

$I = \frac{P}{A} = \frac{1,13 \cdot 10^{-5} W}{1256,6 m^2} = 9,0 \cdot 10^{-9} \frac{W}{m^2}$

$L = 10 \cdot lg(9,0 \cdot 10^{-9+12}) = 39,5 dB$

$L' = 39,5 dB - 36 dB = 3,5 dB$

(4) $m' = 720 \frac{kg}{m^3} \cdot 0{,}11\,m + 1860 \frac{kg}{m^3} \cdot 0{,}015\,mm \cdot 2 = 135 \frac{kg}{m^2}$

Tabelle LB BPhy-3 S19 $R' = 40\,dB$

Tabelle LB BPhy-3 S18 normal min 37 dB, also ok
erhöht min 42 dB, also nicht ok

(5) $m_1' = 1000 \frac{kg}{m^3} \cdot 0{,}0095\,m = 9{,}5 \frac{kg}{m^2}$

$m_2' = 1600 \frac{kg}{m^3} \cdot 0{,}175\,m = 280 \frac{kg}{m^2}$

$f_0 = \frac{1000}{2\pi} \sqrt{10 \cdot \left(\frac{1}{9{,}5} + \frac{1}{280}\right)}\,Hz = 166\,Hz$

(6) $m' = 1000 \frac{kg}{m^3} \cdot 0{,}0125\,m = 12{,}5\,kg/m^2$

$f_0 \approx 160 \cdot \sqrt{\frac{60}{12{,}5}}\,Hz = 351\,Hz \in [100\,Hz; 3200\,Hz]$

$\Rightarrow$ ungünstig

(7) $m_1' = 12{,}5 \frac{kg}{m^2}$ $m_2' = 2100 \frac{kg}{m^3} \cdot 0{,}365\,m = 766{,}5 \frac{kg}{m^2}$

$f_0 = \frac{1000}{2\pi} \sqrt{3 \cdot \left(\frac{1}{12{,}5} + \frac{1}{766{,}5}\right)}\,Hz = 79\,Hz$

$f_0 \approx 160 \sqrt{\frac{3}{12{,}5}}\,Hz = 78\,Hz \notin [100\,Hz; 3200\,Hz]$

$\Rightarrow$ günstig