Status Report of Infrastructure for Cryostat

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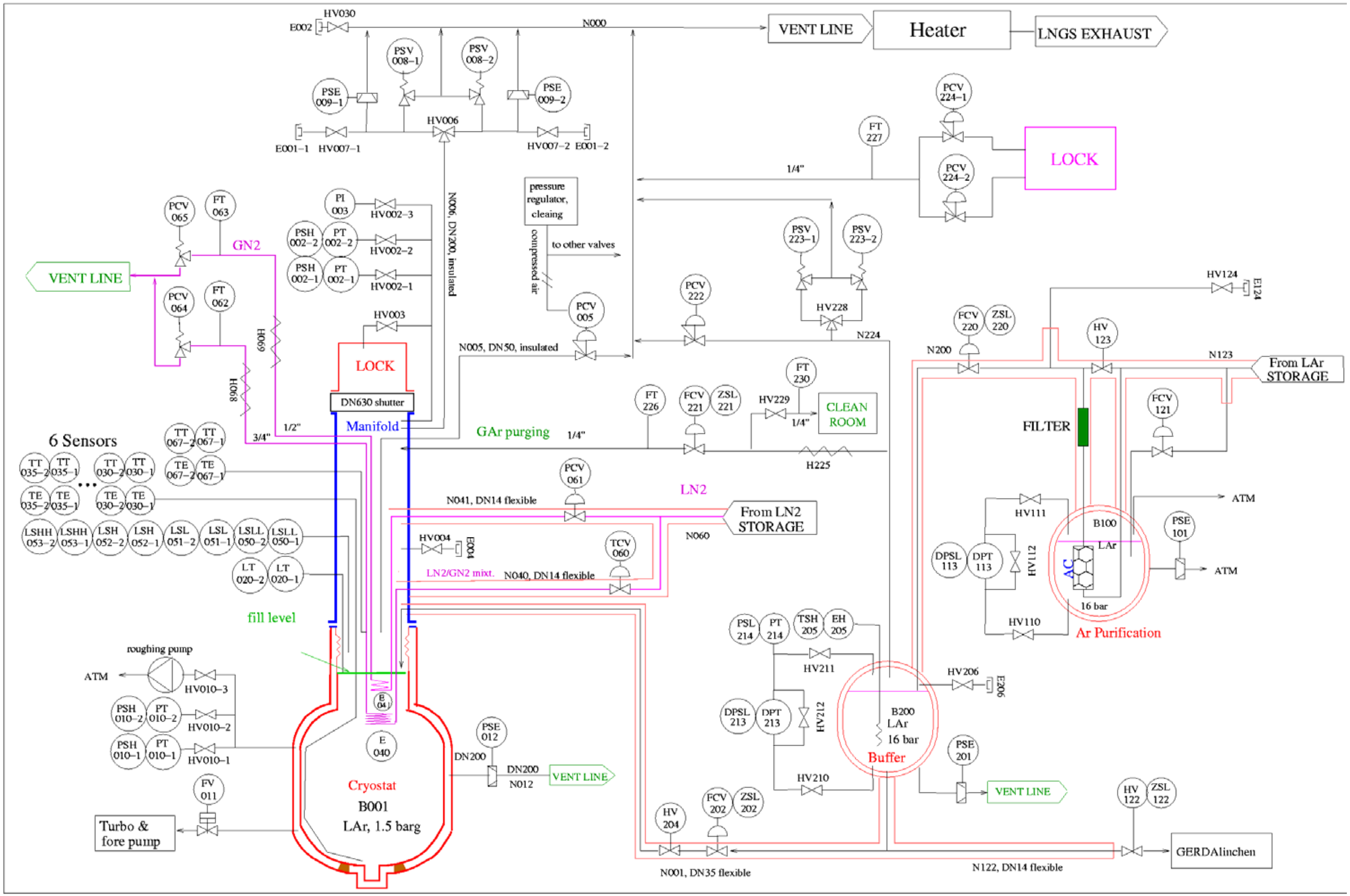
MPI Kernphysik

Usual PID Update: interfaces to clean room infrastructure include



HV006: DN200 change over valve

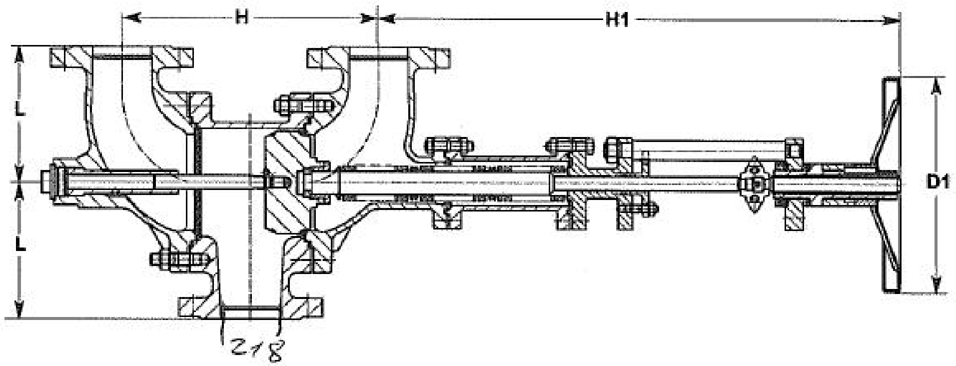
3-Wege-Faltenbalg-Wechselventil mit Flanschen — 11.8-FL

DN 65 - 200 / 2 1/2" - 8 "			
PN 40 / ANSi 150 - 300			
	Stahl	Edelstahl	Tieftemp.
Tmin.	-10°C	-200°C	-50°C
Tmax.	+450°C	+400°C	+300°C

Druck-Temperaturzuordnung nach EN 1092 - Teil 1

Lieferbedingungen DIN 3230/EN 12266-1

Detailinformationen und lieferbare Varianten im Technischen Anhang Teil 11



Benennung	Werkstoff Stahl 11.7-FL	Werkstoff Edelstahl 11.7-FL-A4	Werkstoff Tieftemp. 11.7-FL-TT
Gehäuse	1.0619	1.4408	1.1138
Gehäusesitz	1.4370	Stellit 21	1.4370
Oberteil	1.0619	1.4408	1.1138
Kegel	1.4021/1.0460	1.4571	1.4571
Kegelsitz	1.4021/St.21	Stellit 6	Stellit 6
Dichtungen	1.4571/Graphit		
Schrauben	A2/70	A2/70	A2/70
Sechskantmuttern	A2/70	A2/70	A2/70
Stopfbuchse	Reingraphit		
Stopfbuchsbrille	1.0420	1.4408	1.4408
Spindel-Oberteil	1.4122	1.4122	1.4122
Spindel-Unterteil	1.4571	1.4571	1.4571
Handrad	0.6020	0.6020	0.6020

Widerstandsbeiwerte (ξ-Werte) DN	Spindelseite	Gegenseite
65	0,93	0,90
80	0,93	0,90
100	0,89	0,94
125	0,94	0,98
150	0,91	0,89
200	0,94	0,92

DN	L [mm]	H [mm]	H1 [mm]	D1 [mm]	G [kg]
65	190	360	730	300	106
80	190	360	730	300	109
100	230	460	760	300	161
125	230	460	760	300	166
150	280	600	1070	400	338
200	370	800	1290	500	400

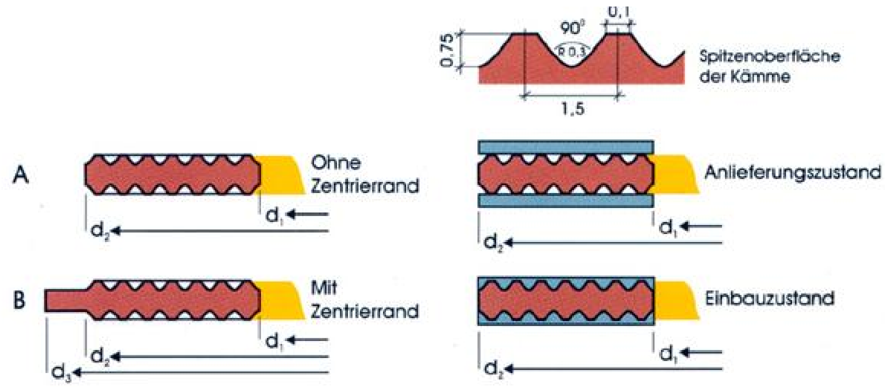
Standard:
- bellow sealed stem
- "Kammprofil" seals between different body parts
- DIN or ANSI flange

Options:
- CF flange
- all parts welded

→ almost factor 2 in price

→ will study "Kammprofil" seals

"Kammprofil" seal
316L body with 0.5 mm graphite/PTFE layer

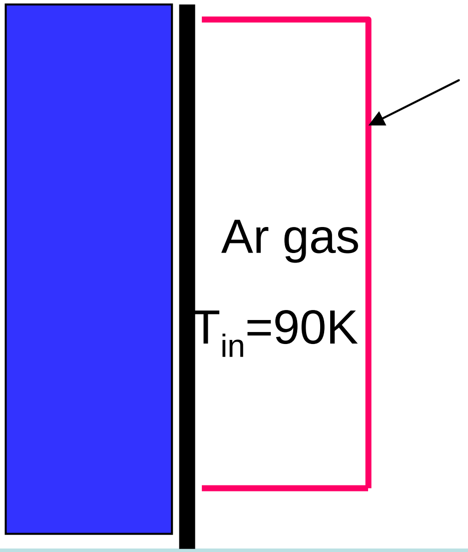


Exhaust gas heater: water tank surface

Water tank wall
7mm, λ=17 W/mK

rectangular shaped “pipe” 0.2m x 0.8m,
spiraling around the water tank, 3 mm thick wall

inside water
T = 293 K



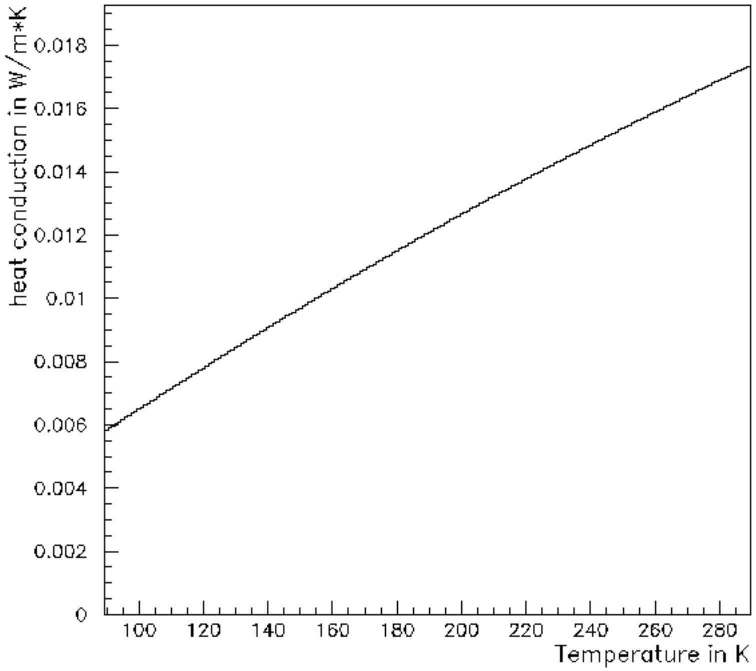
outside air of Hall A, T = 293 K
no cool down assumed, no humidity

Questions: - what is the power of such a heater?
convective heat exchange at inner WT steel surface
convective heat exchange to air of Hall A
turbulant flow of argon gas inside the “pipe”
heat conduction through WT steel and pipe
- what is the temperature of WT steel? → thermal stress
- will there be ice formation inside the water?

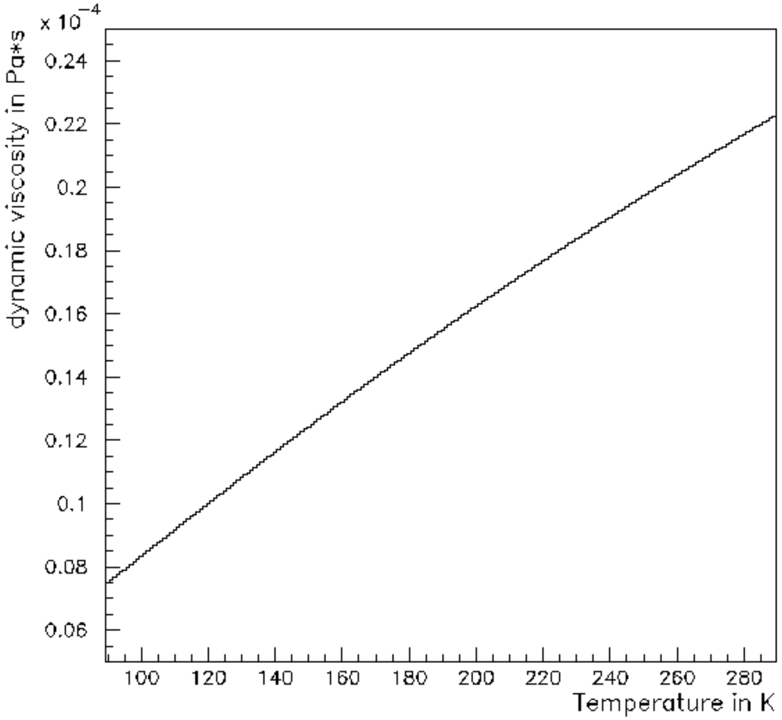
requirements: T_{out} = 5(?) Celsius, 4.5 kg/s mass flow, pressure drop ~ 100 mbar

Inputs: water properties at 288 K (average between 293 and 283)
air properties at 273 K
argon properties calculated between 90 K and 270 K
all equations and parameters from “VDI Wärmeatlas, 9. edition”

Argon heat conduction vs. Temp



Argon dynamic viscosity vs. Temp



Convective heat transfer to water (equivalently to air)

$$Ra = Gr \cdot \Pr = \frac{g \cdot H^3}{\nu^2} \beta \cdot \Delta T \cdot \Pr$$

$$Nu = \left(0.825 + 0.387 \cdot \left[Ra \cdot f_1(\Pr)\right]^{1/6}\right)^2$$

$$\alpha_{water} = \frac{Nu \cdot \lambda}{H}$$

α = heat transfer coefficient in $W/(m^2K)$
$1/\alpha$ = thermal resistance

H = "height" of exchanger = 0.8 m
g = earth acceleration
ν = dynamic viscosity water
β = thermal expansion coeff at p=const
ΔT = temperature diff steel – water
Pr = Prandtl number
Gr = Grashof number
Ra = Rayleigh number
Nu = Nusselt number
λ = heat conduction

turbulent flow heat transfer of argon gas

$$Nu_{pipe} = \frac{\mathrm{Re} \cdot \Pr \cdot \xi / 8}{1 + 12.7\sqrt{\xi / 8}\left(\Pr^{2/3} - 1\right)} \left(1 + \left(\frac{d}{L}\right)^{2/3}\right)$$

$$\xi = (1.8 \cdot \log_{10}(\mathrm{Re}) - 1.5)^{-2}$$

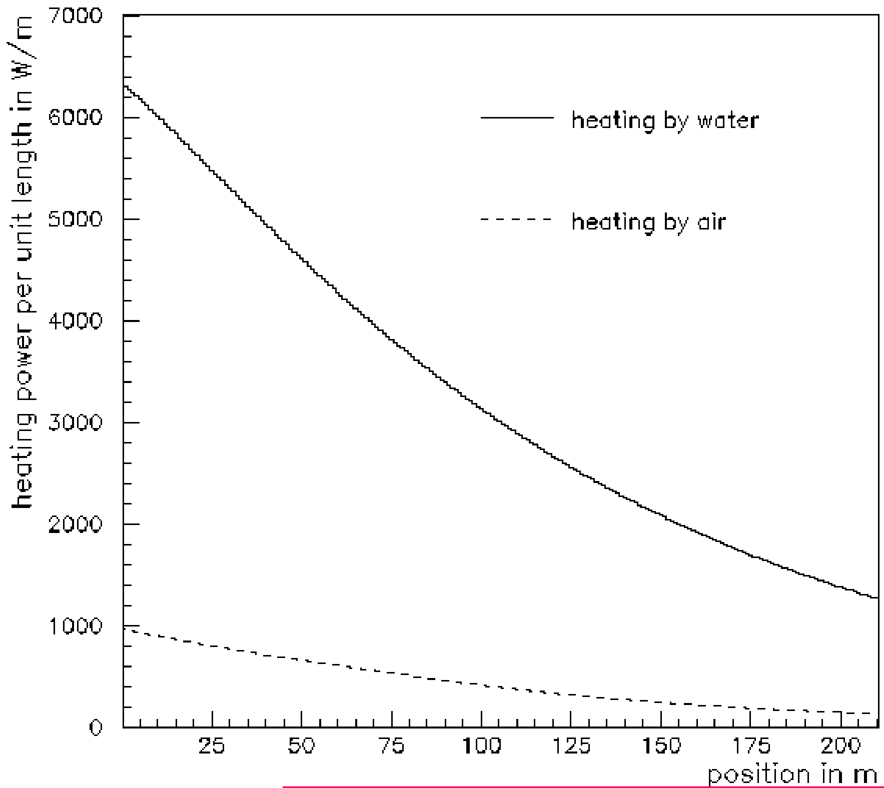
Re = Reynold number
d = hydraulic diameter of pipe
= 4 area / circumference
L = length of pipe

these are effective equations, conservative according to Mr Lannewehr total thermal resistance to water = $1/\alpha_{pipe} + 1/\alpha_{water} + t_{steel}/\lambda_{steel}$

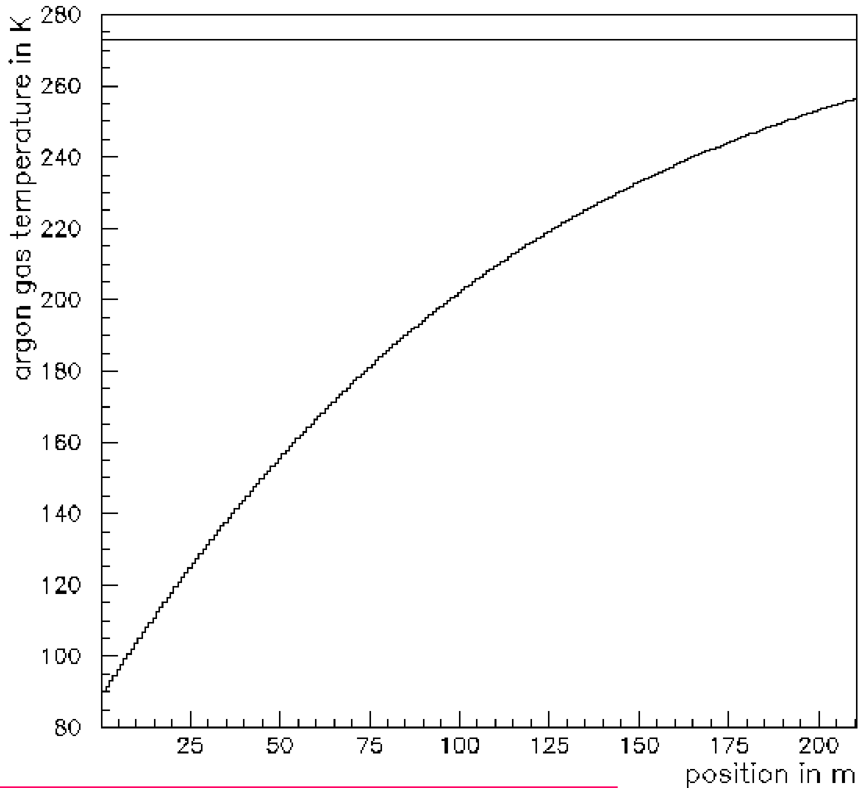
heating power = $(T_{water} - T_{argon})$ / resistance

calculation per unit length of pipe: heat input to argon gas → argon gas heats up

heating power vs position along pipe

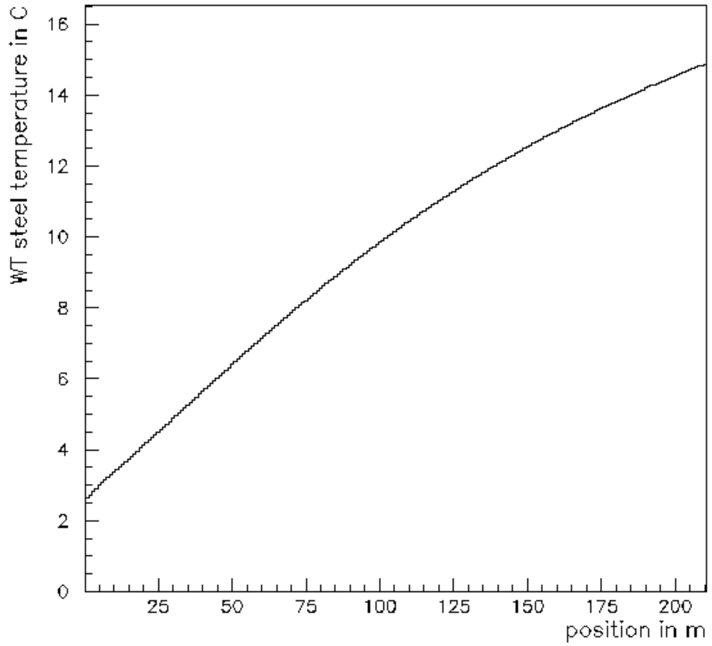


argon Temp vs position along pipe



after 210 m = 7 turns: argon temperature ~ -20 Celsius
mix with air in the LNGS ventilation system → T > 0 C (?)

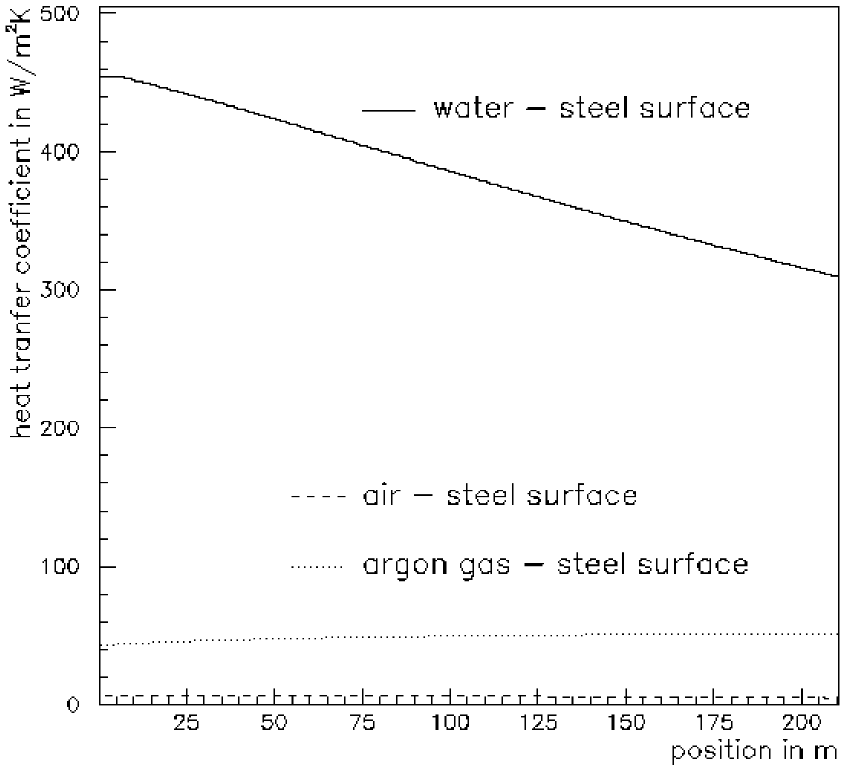
water tank steel temperature in C



$\alpha_{pipe} \sim 1/d$

→ small heat flux for large diameter
→ no ice formation
→ no thermal stress on steel
(temp difference in 7 mm steel < 10 K)

different α vs position along pipe



heat flux limited by argon-steel resistance

→smaller diameter will increase
heating of argon gas
BUT also increase pressure drop !!!
currently: close to 100 mbar already

Maybe: calculation shown too conservative

Summary

- PID diagram practically finished
- for all critical components (valves, …) suppliers identified
- first version of tendering document for infrastructure available
- tendering can start in 4-8 weeks

- discussion on heater for argon exhaust gas still ongoing
- different solutions are considered, all of them have important disadvantages
  a) pipe inside water tank: might leak → no argon can pass through
  b) “water tank surface heater”: not favored by LNGS / WT company
  c) external commercial water-argon heat exchanger: price??
  d) air-argon heat exchanger: size and cost

- discussion with LNGS will continue