1) Calculation of Pressurisation Flow-rate:

From R.F. Barron "Cryogenic Systems", translation from English language, Energoizdat, 1989.

Mass of gaseous Hydorgen required for Pressurisation to expel the liquid in the required time is Δmb.

$\Delta mb = Vf * \varrho_b^o * ((T_o/Tsat - 1) * F1 * F2 + 1) * \exp(-F3)$,

where

Vf =	8.6	m^3 – the volume of displaced fluid
T_o =	320	K – the inlet temperature of pressurization gas;
$P_{sat\text{-}subcool}$=	--	kPa-min pressure during subcooling
T_{sat}=	15.0	K – the saturation temperature of Methane @ 30 kPa at initial pressure in the vessel;
P_{pz} =	2.20.E+07	Pa – the pressure of pressurization;
R =	4.1245	J/kg * K – the gas constant;
ϱ_b^o =	14.77208895	kg/m^3-the density of pressurant gas @ T_o and P_{pz}
Υ_{pr}=	1.416441341	-specific heat ratio of pressurant hydrogen gas
Υ_{liq}=	1.241342342	-specific heat ratio of methane liquid

The functions F1, F2, F3 are determined as follows:

$F1 = 1 - \exp(-0.330 * N1^{0.281})$;

$F2 = 1 - \exp(-4.260 * N2^{0.857})$;

$F3 = N3 * N2^{0.25} * ((1+N1) * (1+N2))^{0.25}$.

The dimensionless factors N1, N2, N3 are determined as follows:

$N1 = \rho_w * c_w{}^o * t_w * T_{sat} / (\rho^o{}_d * c_d{}^o * D * T_o)$;

$N2 = hc * \Theta * T_{sat} / (\rho^o{}_d * c_d{}^o * D * T_o)$;

$N3 = Q * \Theta / (\rho^o{}_d * c_d{}^o * D * T_o)$;

where

ρ_w =	7800	kg/m3 – the density of vessel material;
$c_w{}^o$ =	465	J/kg * K – the heat capacity of vessel material at T_o;
t_w =	0.11	m – the thickness of vessel wall;
$c_d{}^o$=	14745.63	J/kg * K – the heat capacity of pressurization gas at T_o;
$\varrho^o{}_d$ =	14.77	kg/m3 – the density of pressurization gas;
D =	1.6	m – the inner diameter of vessel;
Θ =	50	s – the time of liquid outflow;
L =	2.35	m – the average height of vessel wall, which is flowed around by gas.

The average heat – transfer factor may be determined from the conditions of turbulent free convection near the vertical surface:

$Nu = hc * L / \lambda = 0.13 * (Gr * \Pr)^{1/3}$.

The behavior of gas at T avg = $\dfrac{(To + T_{sat})}{2}$ = 167.5 K and P_{pz}= 2.20.E+07 Pa

ρ =	26.47629809	kg/m^3 – the density of gas;
λ =	1.44E-01	W/m*K – the thermal conductivity of gas;
μ =	7.10E-06	$N*s/m^2$ – the gas dynamic viscosity;
Pr =	0.70	– the Prandtl criterion;
ν =	2.68E-07	m^2 /s– the gas kinematic viscosity;
β =	5.97E-03	Coefficient of volume expansion equals (1/T) for ideal gases

The criterion Gr is the following:

$Gr = \beta * L3 * g * (T_o - T_{sat}) / \nu^2$ = 3.22612E+15

Nu = 1.71E+04

hc = Nu*λ/L= 1044.46 W/m^2*K – the convective heat transfer between the vessel wall and gas;

Q = hc*(To – Tsat) = 3.19E+05 W/m2 – the heat transfer related to surface area unit;

N1=	0.053660692	$N1 = \rho_w * c_w{}^o * t_w * T_{sat} / (\rho^o{}_d * c_d{}^o * D * T_o)$;
N2=	0.007023921	$N2 = hc * \Theta * T_{sat} / (\rho^o{}_d * c_d{}^o * D * T_o)$;
N3=	0.142819732	$N3 = Q * \Theta / (\rho^o{}_d * c_d{}^o * D * T_o)$;
F1=	0.135029514	$F1 = 1 - \exp(-0.330 * N1^{0.281})$;
F2=	0.058991839	$F2 = 1 - \exp(-4.260 * N2^{0.857})$;
F3=	0.041963168	$F3 = N3 * N2^{0.25} * ((1+N1) * (1+N2))^{0.25}$.
Δmb =	141.5500938 kg	**$\Delta mb = Vf * \varrho_b^o * ((T_o/Tsat - 1) * F1 * F2 + 1) * \exp(-F3)$,**

The average flow rate of pressurization is Gpz = $\Delta mb/\Theta$ = 2.83 kg/s

$Nu = hc*L/\lambda = 0.13*(Gr * \Pr)^{1/3}$.

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Δmb = 141.5500938 kg **$\Delta mb = Vf * \varrho_b{}^o * ((T_o/Tsat - 1) *F1* F2 + 1)* \exp(- F3)$,**

The average flow rate of pressurization is Gpz = Δ mb/Θ = 2.83 kg/s