

Analyses of Cryogenic Propellant Tank Pressurization based upon Experiments and Numerical Simulations

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Abstract

The active-pressurization of cryogenic propellant tanks for the launcher application was analyzed in this study. Therefore, ground experiments, numerical simulations and analytical studies were performed with the following important results: In order to minimize the required pressurant gas mass, a higher pressurant gas temperature is advantageous or the application of helium as pressurant gas. Numerical simulations of the pressurant gas mass using Flow-3D show good agreement to the experimental results. The dominating heat transfer during pressurization appears from the injected pressurant gas to the axial tank walls and the predominant way of phase change during the active-pressurization phase depends on the type of the pressurant gas. After the end of the pressurization phase, a significant pressure drop occurs. A theoretical model is presented for the analytical determination of this pressure drop.

Nomenclature

Roman letters

A	area
c_p	specific heat capacity at const. pressure
c_v	specific heat capacity at const. volume
D_t	thermal diffusion coefficient
H	fluid height
h	specific enthalpy
Δh_v	latent heat of evaporation
m	mass
R	tank radius
R_g	specific gas constant
r	radial coordinate
p	pressure
Δp	pressure drop
Q	heat
\dot{Q}	heat flow rate
T	temperature
t	time
U	internal energy
u	specific internal energy
v	velocity
z	height coordinate

Superscripts

-	nondimensional
-	mean

Greek letters

Θ	characteristic temperature difference
δ_T	thermal boundary layer thickness
λ	thermal conductivity
μ	dynamic viscosity
ρ	density

Subscripts

0	start
<i>cond</i>	condensation
<i>f</i>	end
<i>i</i>	initial
<i>l</i>	liquid
<i>m</i>	maximal
<i>relax</i>	relaxation
<i>pg</i>	pressurant gas
<i>p</i>	pressurization
<i>press</i>	pressurization
<i>ref</i>	reference
<i>sat</i>	saturation
<i>T</i>	relaxation end
<i>v</i>	vapor
<i>w</i>	wall
Γ	free surface

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