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Laboratory for Fluid Flow and Heat Transport Phenomena
Department of Nuclear Engineering
The University of Michigan
Ann Arbor, Michigan

CAVITATION DAMAGE IN LIQUID METAL COOLED REACTOR POWERPLANTS

R. Garcia*

F. G. Hammitt**

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* Senior Engineer, Aerojet-General Corporation, Von Karman Center, Azusa, California

**Professor of Nuclear Engineering and Director of the Laboratory for Fluid Flow and Heat Transport Phenomena, Department of Nuclear Engineering, The University of Michigan, Ann Arbor, Michigan

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Pumping and handling of high-temperature liquid metals, wherein cavitation is a problem, is highly important in the space program, particularly regarding liquid metal SNAP systems. Cavitation attack can occur in bearings,[1] close-clearance passages,[2] pumps,[3,4] etc. For minimum size and weight and maximum temperature, velocities are high and suppression heads low. Operation in a cavitating regime may be necessary, even though long unattended life is required. These problems are also important in conventional liquid metal cooled nuclear powerplants.[2]

The cavitation resistance of various steels and refractory alloys has been measured in our laboratory in mercury at 70°F and 500°F and in lead-bismuth alloy and lithium at 500°F and 1500°F utilizing a high-temperature ultrasonic vibratory facility.[5,6,7,8] Of materials tested, tantalum-base alloys (T-111 and T-222) were the most cavitation resistant, except for mercury at 70°F, wherein stainless steel was best.

As expected, all materials tested in lead-bismuth sustained greater damage at 1500°F than at 500°F. However, in lithium the damage at 1500°F was in general an order of magnitude <u>less</u> than at 500°F, due primarily to "thermodynamic effects." These are important also in other high-temperature liquid metals, as sodium,[9,10] and result from the effects of fluid vapor which become significant at higher temperature. When cavitation bubbles collapse, the heat of condensation from the condensing vapor within the bubble must be conducted into the surrounding fluid. If this does not occur sufficiently

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rapidly, as may be the case with higher vapor densities at higher temperature, the temperature and pressure of the uncondensed vapor are raised, arresting the bubble collapse, and decreasing collapse pressures and damage.

Florschuetz and Chao[11] have recently considered both thermodynamic and inertial factors in bubble collapse, defining a dimensionless parameter, $B_{eff.}$, which characterizes such collapses as being inertia controlled or heat transfer controlled. In the latter case, "thermodynamic effects" are said to be operative. For the present purpose:

$$B_{eff.} = \left[\left(\frac{\rho_L^2 \, C_L}{\rho_v \, L}\right)\left(\frac{\Delta T}{\Delta P}\right)\right]^2 \frac{K_L}{R_0}(NPSH)^{3/2} \qquad (1)$$

Figure 1 shows our experimental data (type 304 stainless steel) in mercury, lead-bismuth, and lithium, and data obtained elsewhere[9,10] in sodium, as a function of $B_{eff.}$ Nominal values of unity have been used for R_0 and NPSH. For large values of $B_{eff.}$ the bubble collapse is not effected by "thermodynamic effects" and the damage obtained is in agreement with that expected on the basis of mechanical properties.[8] However, for values of $B_{eff.}$ less than about 1000, "thermodynamic effects" are significant, and the damage is considerably reduced. Figure 1 shows the resulting damage correction factor. This surprising reduction in damage may permit more aggressive design of high-temperature cavitating components.

Nomenclature

$B_{eff.}$ = Thermodynamic Parameter, dimensionless

= density, lbm./ft.^{3}

C = specific heat, Btu/lbm.°F

L = latent heat, Btu/lbm.

T/ p = reciprocal slope of vapor pressure curve, °F/(lbf./ft.^{2})

= thermal diffusivity, ft.^{2}/hr.

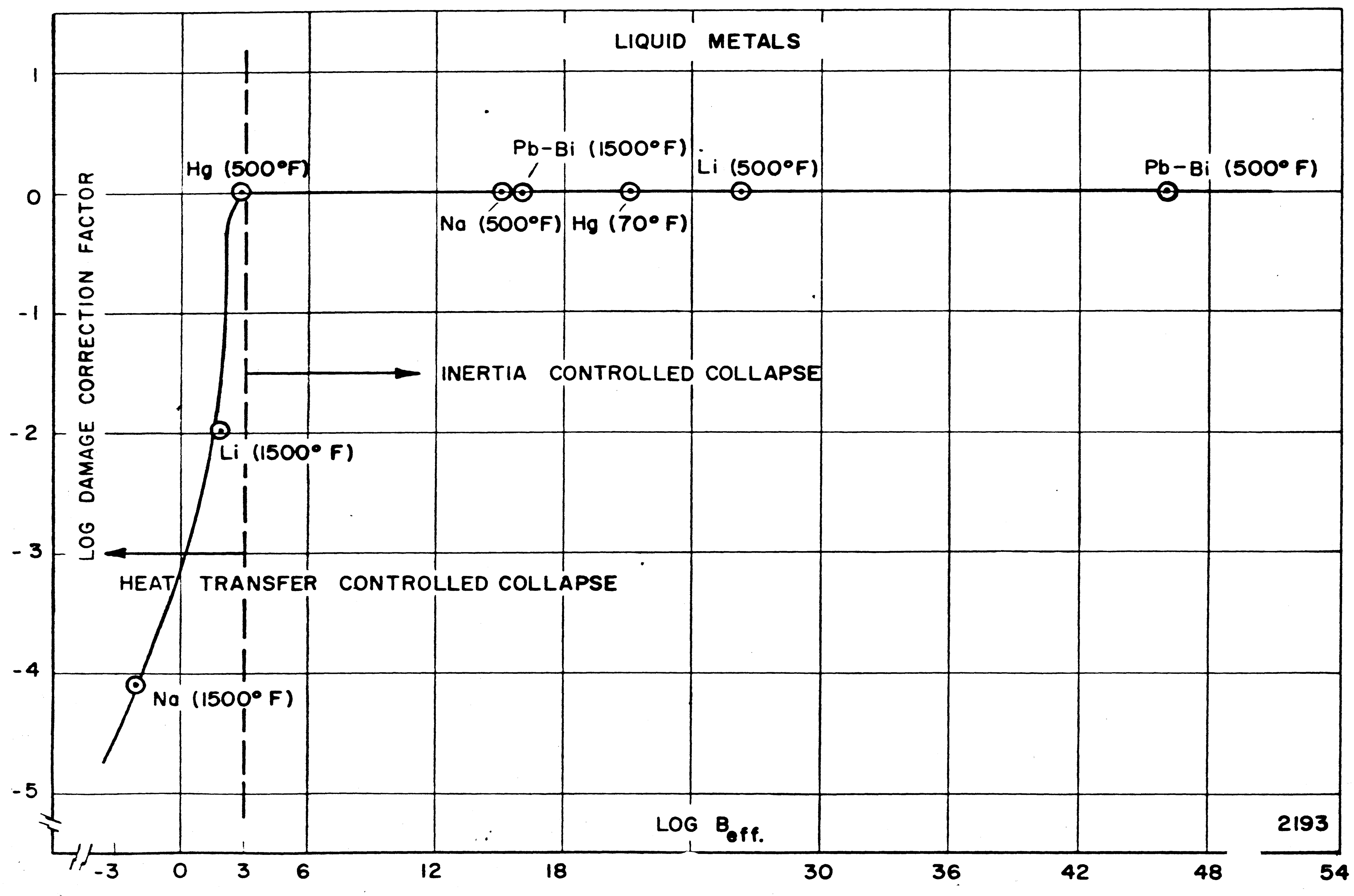
R_0 = characteristic bubble radius, ft.

NPSH = "net positive suction head", fluid head above vapor, ft.lbf./lbm.

Subscripts:

L = liquid

v = vapor


LIQUID METALS
LOG DAMAGE CORRECTION FACTOR
Hg (500°F)
Pb-Bi (1500°F)
Li (500°F)
Pb-Bi (500° F)
Na (500°F)
Hg (70° F)
INERTIA CONTROLLED COLLAPSE
Li (1500° F)
HEAT TRANSFER CONTROLLED COLLAPSE
Na (1500° F)
LOG $B_{eff.}$
2193
1
0
-1
-2
-3
-4
-5
-3
0
3
6
12
18
30
36
42
48
54

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