MEC516/BME516: Fluid Mechanics I

Chapter 1: Introduction

Part 3: Vapor Pressure & Cavitation

RYERSON UNIVERSITY
Department of Mechanical & Industrial Engineering

Overview

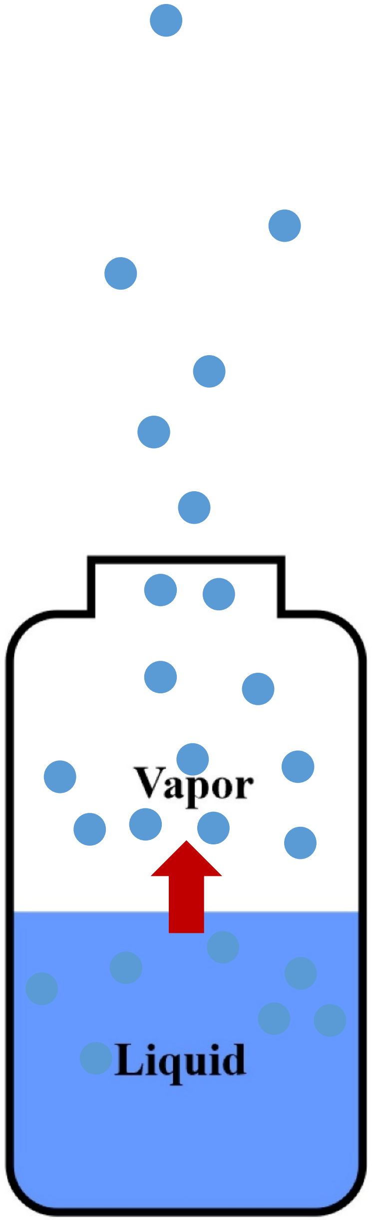
- Fluid Properties Continued

Part 3:

- Vapor Pressure
  - Cavitation

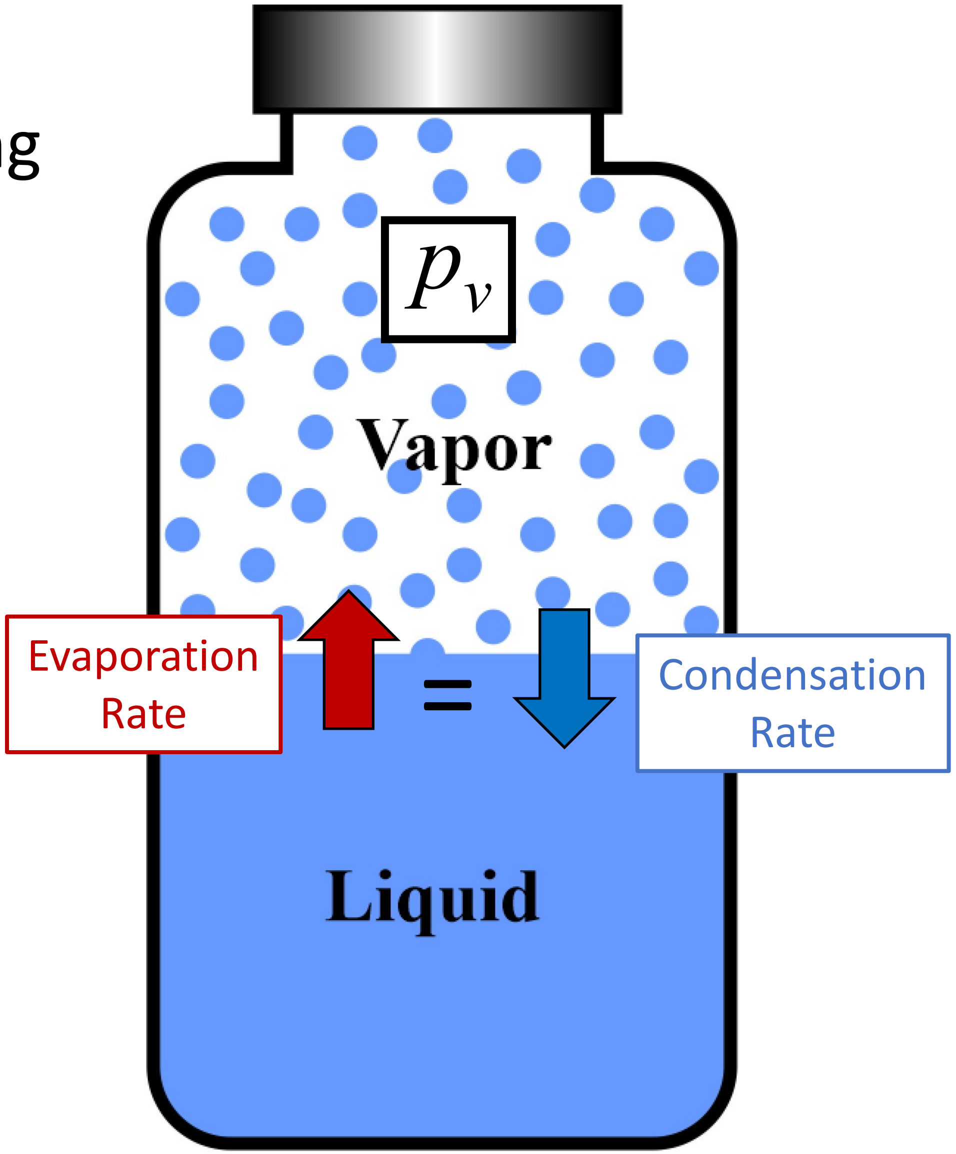
Vapor Pressure

- A liquid in an open container will evaporate
- Some molecules have enough momentum to overcome the intermolecular cohesion
- Evaporation rate increases as temperature increases → more molecular kinetic energy



Vapor Pressure

- With a lid, the molecules will build up in the vapor until the number of molecules entering and leaving the liquid surface are EQUAL
- An *equilibrium* is reached. Mixture is *saturated*
- The pressure that builds up in the vapor is called the *vapor pressure*, p_v
- Vapor pressure increases with temperature



Vapor Pressure

- A liquid with a higher vapor pressure will evaporate at a higher rate
- A measure of *volatility*

Vapor Pressure at 20 °C:

Ethanol (Alcohol)	p_v = 5.8 kPa
Water	p_v = 2.3 kPa
Ethylene Glycol	p_v = 0.60 kPa

Time-lapse video of an evaporating droplet

Vapor Pressure of Water with Temperature

Another way to look at it:

- Vapor pressure is the pressure at which a liquid boils for a given temperature

e.g. At atmospheric pressure, p=101.3 kPa

Water boils at 100 °C

- As pressure decreases, water boils at a lower temperature. Water can boil at 0 °C!

Table A.5

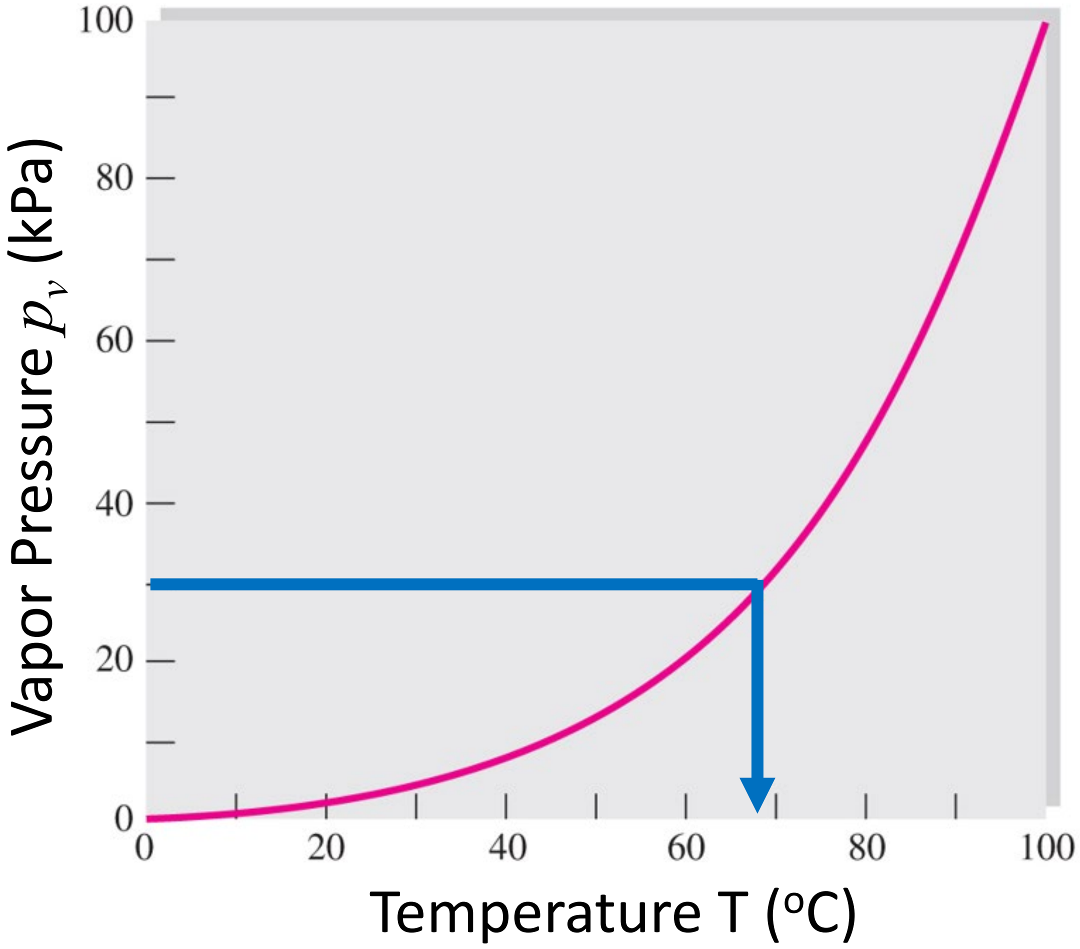
T, °C	p_v, kPa
0	0.611
10	1.227
20	2.337
30	4.242
40	7.375
50	12.34
60	19.92
70	31.16
80	47.35
90	70.11
100	101.3

1 atm=101.3 kPa

Effect of Pressure on the Boiling Temperature

- At the top of Mt. Everest (8,848m; 29,029 ft)

  $p \approx$ 30kPa, Water boils at ~70 ^oC

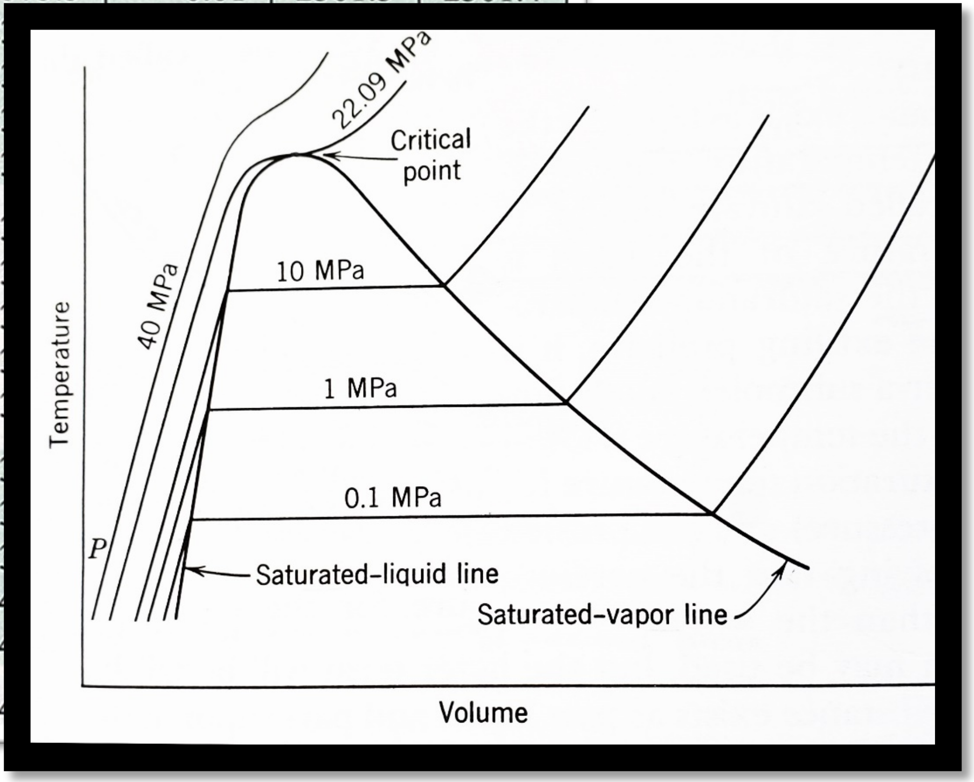


<u>Saturated</u> Steam Table (Thermodynamics Textbook)

Same vapor pressure data

TABLE A-2 Properties of Saturated Water (Liquid–Vapor): Temperature Table

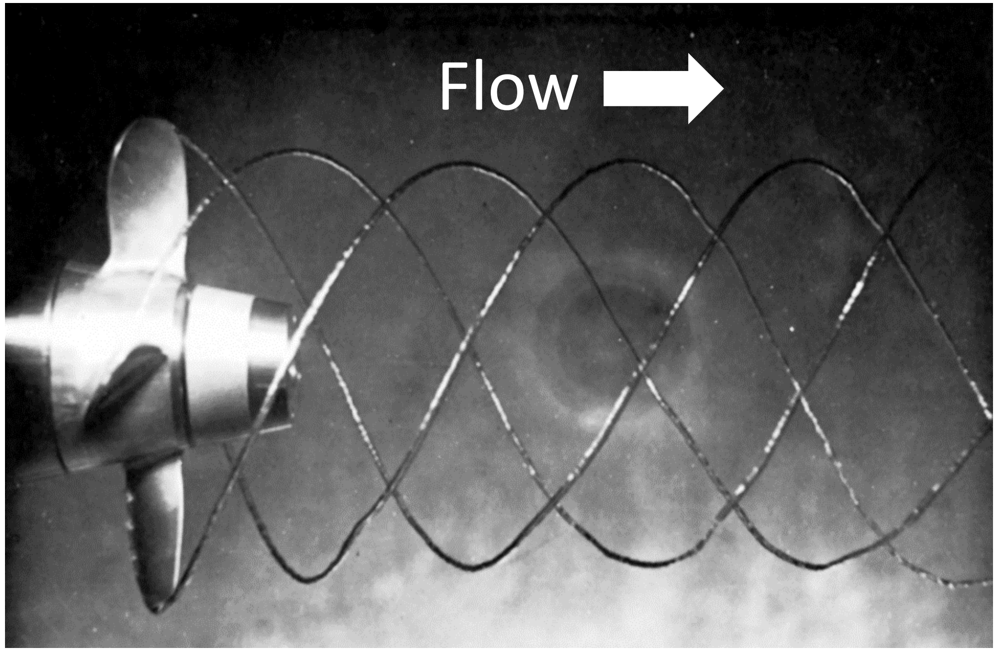
Temp. °C	Press. bar	Specific Volume m³/kg: Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Internal Energy kJ/kg: Sat. Liquid u_f	Sat. Vapor u_g	Enthalpy kJ/kg: Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g
.01	0.00611	1.0002	206.136	0.00	2375.3	0.01	2501.3	2501.4
4	0.00813	1.0001	157.232	16.77	[illegible]			
5	0.00872	1.0001	147.120	20.97	[illegible]			
6	0.00935	1.0001	137.734	25.19	[illegible]			
8	0.01072	1.0002	120.917	33.59	[illegible]			
10	0.01228	1.0004	106.379	42.00	[illegible]			
11	0.01312	1.0004	99.857	46.20	[illegible]			
12	0.01402	1.0005	93.784	50.41	[illegible]			
13	0.01497	1.0007	88.124	54.60	[illegible]			
14	0.01598	1.0008	82.848	58.79	[illegible]			
15	0.01705	1.0009	77.926	62.99	[illegible]			
16	0.01818	1.0011	73.333	67.18	[illegible]			
17	0.01938	1.0012	69.044	71.38	[illegible]			
18	0.02064	1.0014	65.038	75.57	[illegible]			
19	0.02198	1.0016	61.293	79.76	[illegible]			
20	0.02339	1.0018	57.791	83.95	[illegible]			



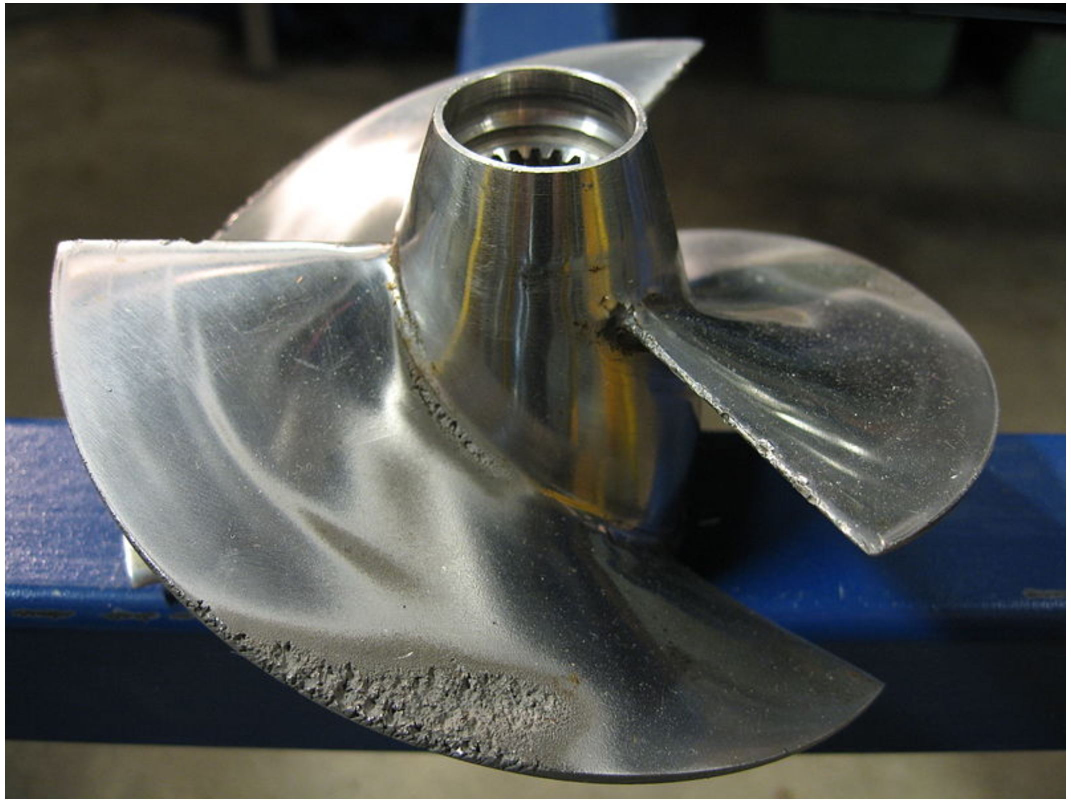
Vapor Pressure Demo: Boiling Water with an Ice Cube

Cavitation: A Consequence of Vapor Pressure

- In pipes, valves and rotating machinery the *local* pressure can drop below the vapor pressure of the liquid
- Causes local boiling, called *cavitation*



Marine propeller cavitation

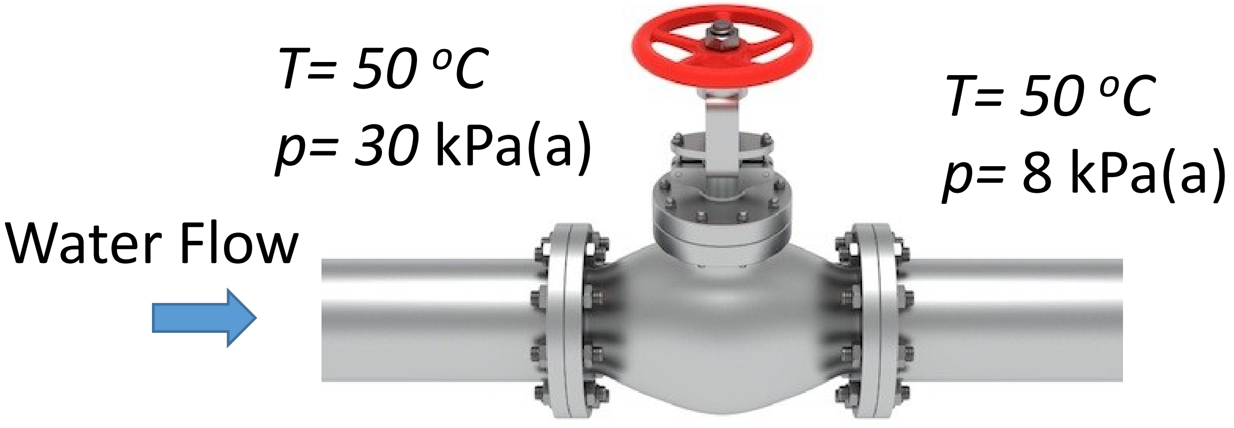


Collapsing bubbles damages the propeller

Example

Liquid water flows through a gate valve at 50 ºC. The valve is partly closed, causing the absolute pressure downstream of the valve to fall to 8 kPa.

Will cavitation occur under these conditions?



Yes. Boiling will occur at pressures lower than 12.3 kPa

Table A.5: Vapor pressure of water

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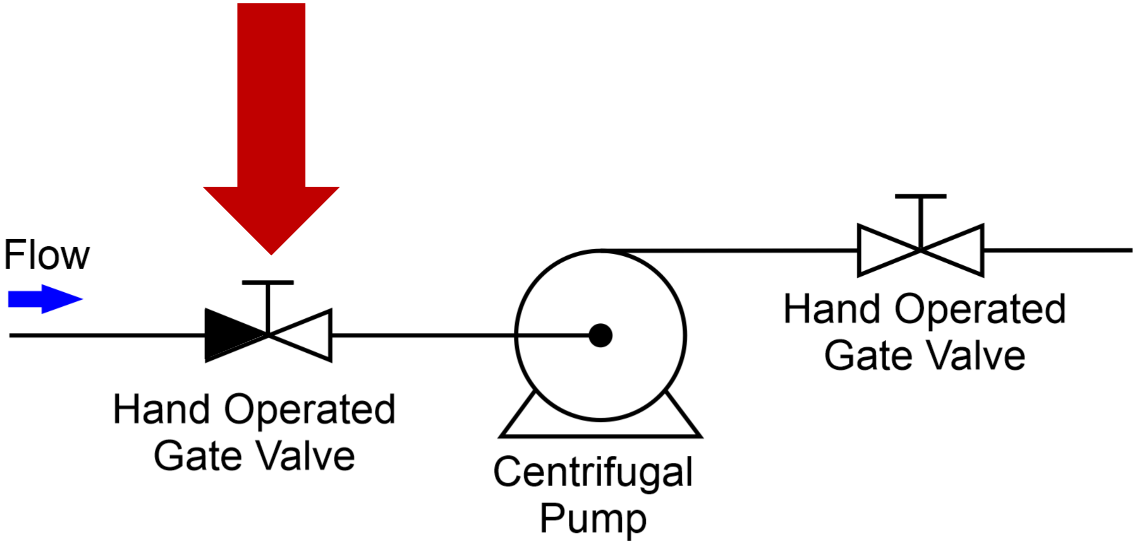
Cavitation Damage to a Water Pump Impeller

Mechanic accidentally left this valve partly closed



Damaged pump impeller

The Leidenfrost Effect

Credit: https://youtu.be/M2CMH57hXmY

END NOTES

Presentation prepared and delivered by Dr. David Naylor