Conditions for Bubble Formation

in

Porous Regions and Narrow Channels

Craig E. Nelson - Consultant Engineer

Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

The Two kinds of Bubble Nucleation

Homogeneous nucleation is bubble nucleation without use of a nucleation site

Heterogeneous nucleation is bubble nucleation at a nucleation site

Nucleation sites are typically small dust particles or crevices in a wall

Homogeneous nucleation does not occur as easily as Heterogeneous nucleation

This means that if homogeneous nucleation can occur, bubbles will form

Therefore:

The following analysis is concerned with homogeneous nucleation only.

Note:

In unusual circumstances, bubbles do not form as predicted by the following analysis. The liquid then becomes supersaturated. A supersaturated liquid may spontaneously "boil" in a violent manner. Any small disturbance of the liquid can set this off.

Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

Critical Diameter

There is a critical diameter for bubbles in a liquid

If the bubble is larger than the critical diameter, it will grow in size until buoyant and-or other forces carry it away

If the bubble is smaller than the critical diameter, it will shrink in size until is has been completely dissolved or contaminants in the liquid prevent it from shrinking away completely

The critical diameter is determined by the balance of three forces:

Force 1 = Ambient pressure … causes shrinking
Force 2 = Surface tension (Young-Laplace force) … causes shrinking
Force 3 = Chemical pressure (Henry's Law force) … causes expansion

Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

Force Balance

Pambient = 10^5 Pascals - STP

Young-Laplace = 2 * surface Tension / Bubble Radius

Henry's Law = $\sum_{i}$ K henry i * Concentration i

Bubbles will not form if :

$\sum_{i}$ K henry i * Concentration i < Pambient + 2 * surface Tension / Bubble Radius

Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

Max Pore Size that Prevents Homo-Nucleation

To prevent homogeneous nucleation, the maximum pore size that a chance collection of small colliding bubbles could grow too must be less than the critical bubble diameter.

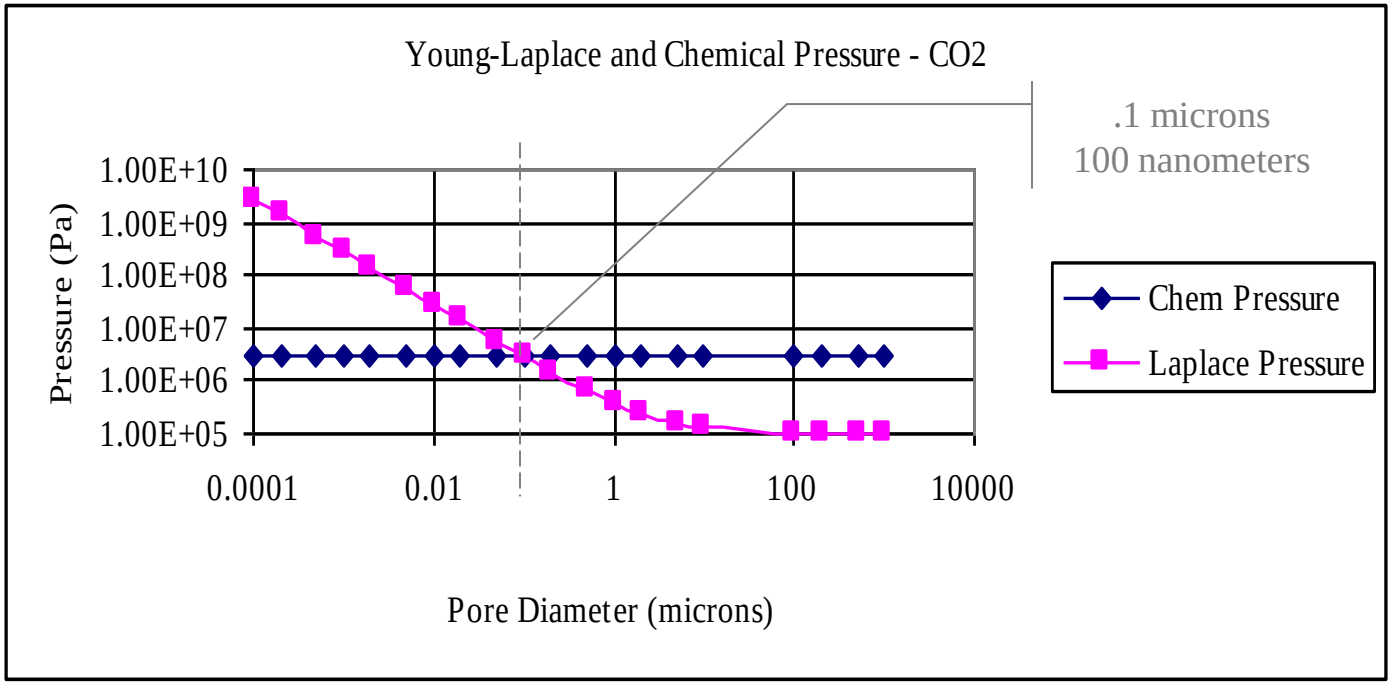
When the pore diameter is less than the critical bubble diameter, even if a bubble grows to the full diameter of the pore that it forms within, it will quickly-spontaneously shrink and dissolve back into the liquid from which it emerged.

When the pore diameter is greater than the critical diameter, when a bubble grows to the full diameter of the pore that it forms within, It will stay there and block that region thereafter.

Alternatively, the bubble may leave its pore region of origin and move a small distance toward a narrow passageway … where it might get permanently stuck.

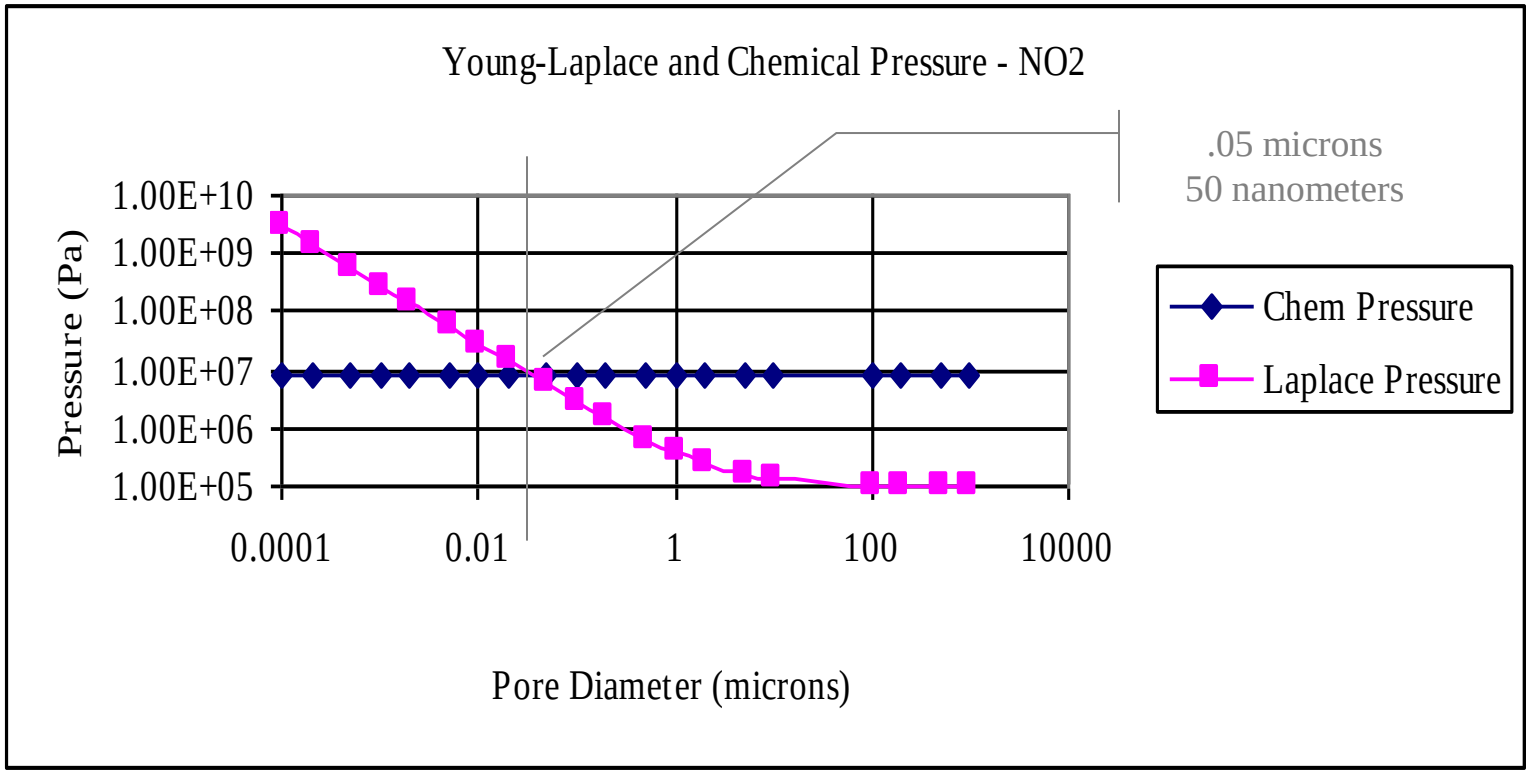
Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

Critical Diameter – 1 M CO2 in H20 at STP



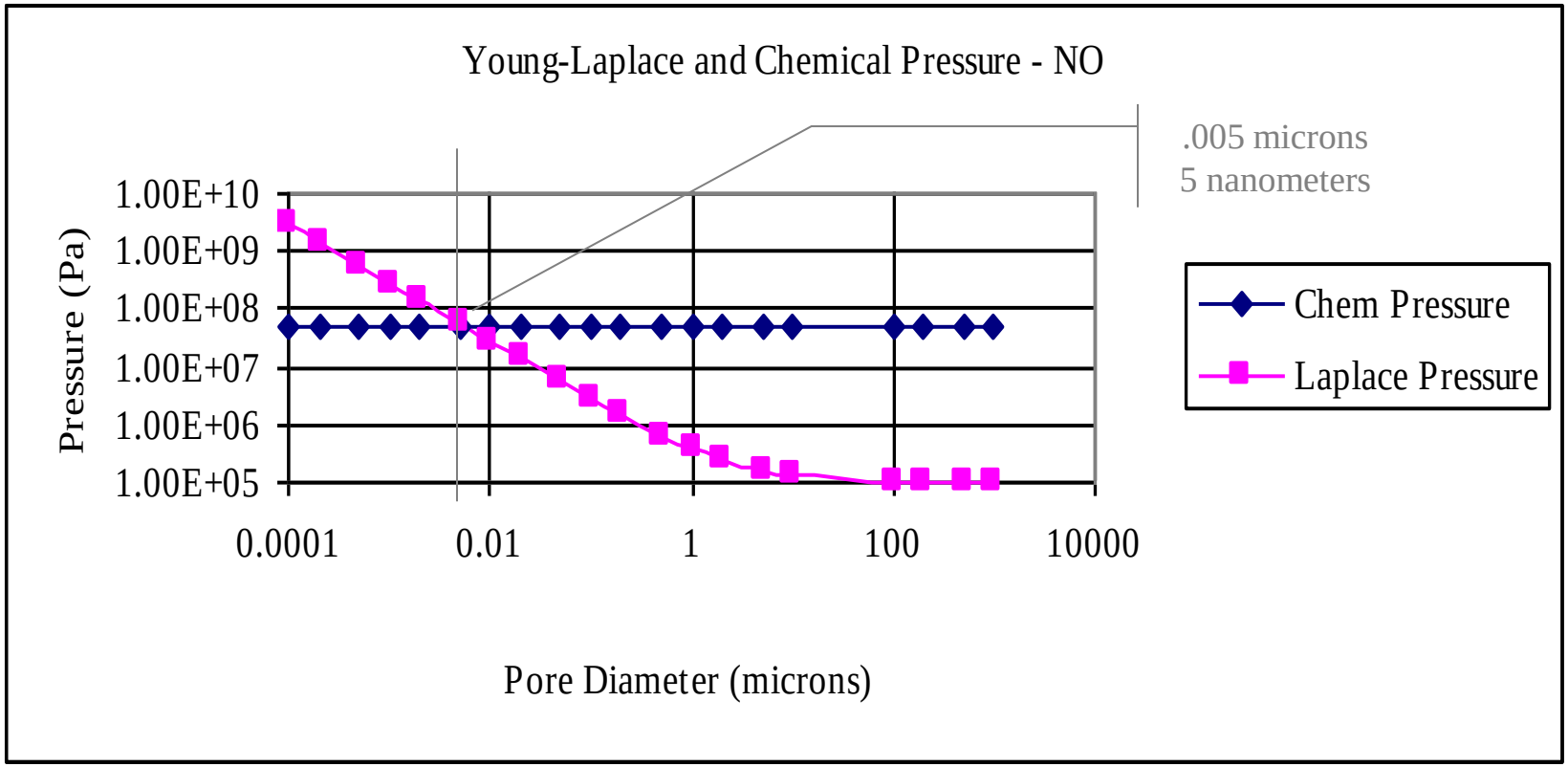
Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

Critical Diameter – 1 M NO2 in H20 at STP



Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

Critical Diameter – 1 M NO in H20 at STP



Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com

Summary

If you can't prevent homogeneous bubble nucleation, you are going to have bubbles

Pores that are small enough will prevent homogeneous bubble nucleation

Supersaturated gas-liquid solutions will form bubbles if pore size increases above the critical diameter. Calculated critical diameters for 1 M concentrations at STP are: CO_2 < 100 nanometers NO_2 < 50 nanometers NO < 5 nanometers

Nelson Research, Inc. 2142 – N. 88th St. Seattle, WA. 98103 USA 206-498-9447 Craigmail @ aol.com