WATER PRESSURE AT 12500 FEET

The recent implosion tragedy which killed five people on the Titan submersible, has brought back the memory of the sinking of the Titanic back in 1912 where an estimated 1500 passengers died. Also the implosion has made it very clear that a functioning submersible at great water depth such as the 3800 meter depth of the Titanic wreckage and the 11521meter depths of the deepest portion of the Mariana Trench posse extreme risk and calls into question whether taking submersibles to one hundred atmospheres or higher external pressures makes any sense at all, especially for wealthy paying tourists. We want in this note to calculate the external pressure of salt water as a function of depth and to give a simplified model for what can be expected as far as the imploding mass movements in case of a submersible failure.

Let us begin with calculating the pressure in atmospheres as a function of depth below the ocean surface. The standard units for pressure in the MKS system is the bar equal to 100,000 N/m^2. One also often expresses the Newton/m^2 as a Pascal. One atmosphere of pressure at the earth's surface equals-

$$1 \text{ Atmosphere}=14.7 \text{ lb/in}^2=101{,}325 \text{N/m}^2=1013.25 \text{ mbar}$$

The millibar is the standard measure of pressure in weather forecasts. Thus in a strong hurricane, such as Katrina, we had wind speeds of 289km/hr (175mph) and a low pressure of 902 mbars.

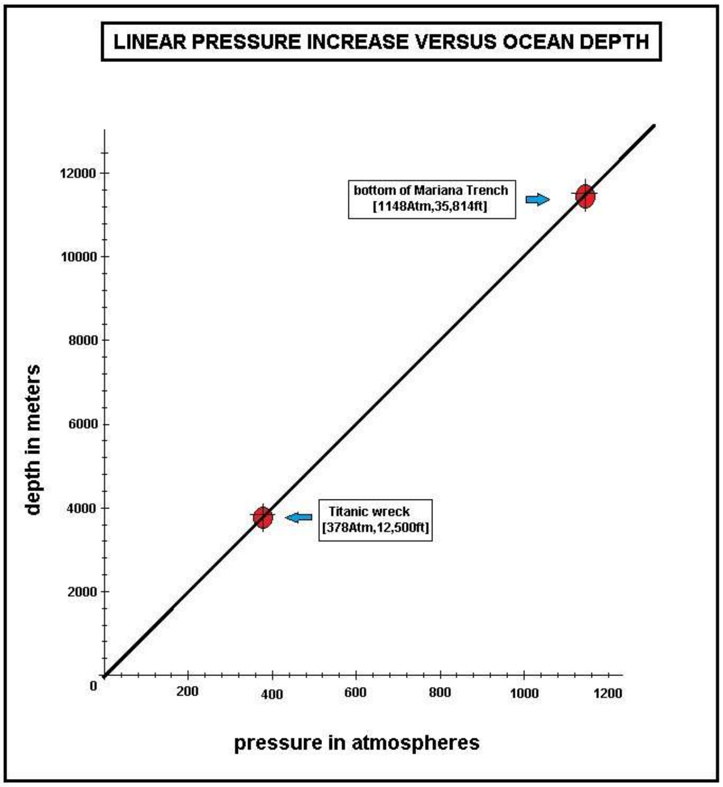
To calculate the pressure p at a depth D we use the formula –

$$p(\text{N/m}^2)=\rho g D=1.03*10^3(\text{kg/m}^3)*9.806\ (\text{m/s}^2)*D(\text{ m})$$

We have chosen the density for sea water to be about 1.03*10^3 kg/m^3.This number changes only slightly with change in salinity and water depth and so it is a good value for North Atlantic water. Multiplying out the above numbers yields a pressure in Atmospheres of-

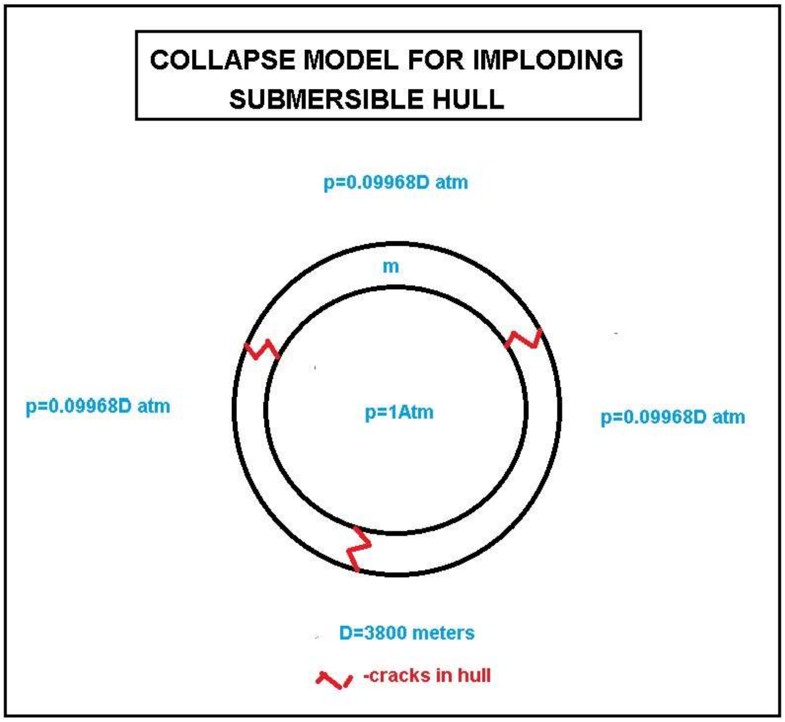
$$p(\text{Atm})=1.03*9.806/1.01325\ D(\text{m})=0.09968\ D(\text{m})$$

So a good rule of thumb is that ten meters of sea water equals about one atmosphere of pressure. The Titanic wreckage lies at 12500ft=3800m. This puts a pressure of 378 Atm on any submersible operating at this depth. We point out that Mt. Fuji has its peak located at about the same distance above sea level as the Titanic remains lie below sea level. The deepest part of the world's oceans is the Mariana Trench near Guam. There the depth reaches a value of 11521 meters below sea level at an external pressure of 1148 atmospheres. A graph of pressure in atmospheres versus depth in meters follows-



Note the linear relation between water pressure and water depth. Mt Everest at a height of 29000 ft is less in height than the Mariana Trench near Guam at 35.81x10^3 ft lies below sea level.

We next look at what happens during hull failure at great depth such as the Titanic wreck at 3800 meter below sea-level. Here is the model-



We look at the submersible as two concentric spherical shapes whose inter radial thickness is about d=50cm and made of light weight and high strength composites. The inside spherical shape has a radius of about two meters and maintained at one atmosphere pressure. The pressure difference between the surrounding salt-water and the inside of the submersible is around 400 Atm at Titanic depth. These pressure differences are not far removed from what one has in high powered air-rifles where pumps for projectile propulsion can produce pressures up to about 300 Atm.

Now envision a submersible which has been used numerous times in going between the Titanic wreck at 3800 meter depth and the surface. In engineering language this procedure is likely to produce cyclic fatigue which can cause structural failure. Once initiated the hull will implode inwards with an initial acceleration of wall parts at the very high inward acceleration of-

$$d^2r/dt^2=p*A/m$$

, where p is the external pressure in N/m^2, A the surface area of the imploding chunk of wall material in square meters and m the mass of the imploding material in kilogram. The whole collapse will be over with in a fraction of a second with parts colliding at the submersible center at a speed of about 1000 ft/sec. Survival under those conditions is zero. The noise produced by such a collapse can be easily detected by underwater sonar as the US Navy surely did but did not report leading to a futile multi-day search.

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