1. In deep oil fields in Louisiana one occasionally encounters a fluid pressure of 10,000 psig at a depth of 15,000 ft. If this pressure is greater than the hydrostatics pressure of the drilling fluid in the well the result may be a well blowout which is dangerous to life and property. Assuming that you are responsible for selecting the drilling fluid for an area where such pressures are expected, what is the minimum density drilling fluid you can use? Assume a surface pressure of 0 psig.

2. The conditions at sea level are 14.7 psia and 59 F. Calculate the pressure at 10,000 ft assuming:
   a) An isothermal atmosphere
   b) An isentropic atmosphere $g = 1.4$
   c) A linear temperature gradient of 5 C / 1000 meters

3. An oil storage tank has a flat, horizontal, circular roof 120 ft in diameter. The tank has a vent which allows air to move in and out of the tank head space. Snow has clogged the vent line while oil is being pumped out of the tank. The gauge pressure in the tank has fallen to –1.0 psig. What is the net force on the tank roof?

4. The open end of a cylindrical tank 2 ft in diameter and 3 feet high is submerged in water as shown in Figure P4. If the tank weights 250 lbs, to what depth (h) will it submerge? The local barometric pressure is 14.7 psia. The thickness of the tank may be neglected. What additional force is required to bring the top of the tank flush with the water surface?

Figure P4
Problem No. 1

\[ \rho = \frac{\Delta P}{gh} = \frac{10,000 \text{ lbf} / \text{in}^2}{\frac{32.17 \text{ ft}}{\text{s}^2}} \cdot \frac{144 \text{ in}^2}{\text{ft}^2} \cdot \frac{32.17 \text{ lbm ft}}{\text{lbf s}^2} = 96.0 \text{ lbm/ft}^3 \cdot \frac{1538 \text{ kg}}{\text{m}^3} \]

Ask the students how one would get such dense drilling fluids? The answer is to use slurries of barite, (barium sulfate) s.g. = 4.499. In extreme cases powdered lead, s.g. = 11.34 has been used.

The great hazard is that high pressure gas will enter the drilling fluid, expand, lower its density, and cause it all to be blown out. Most deep drilling rigs have mechanical "blowout presenters", which can clamp down on the drill stem and stop the flow in such an emergency. Even so one of the most common and deadly drilling accidents is the blowout, caused by drilling into an unexpected zone of high-pressure gas. If the gas is rich in H\(_2\)S, the rig workers are often unable to escape the toxic cloud.

Problem No. 2

(a) 0.697 atm.

(b) \[ T_2 = T_1 \left[ 1 - \frac{k - 1}{k} \frac{gM\Delta z}{RT} \right] = T_1 \left[ 1 - \frac{0.4}{1.4} (0.3616) \right] = 519 \cdot 0.8967 = 465.4^\circ R = 5.7^\circ R \]

\[ P_2 = P_1 \left( \frac{T_2}{T_1} \right)^{\frac{1}{k-1}} = 14.7 \text{ psia} \left( 0.8964 \right)^{\frac{1}{0.4}} = 10.04 \text{ psia} = 0.683 \text{ atm} \]

(c) See the solution to Problem 2.17

\[ T = 59 + \left( -0.00356 \frac{^\circ R}{\text{ft}} \right) (10^4 \text{ ft}) = 23.4^\circ F = 483.1^\circ R \]

\[ P = P_0 \left( \frac{T}{T_0} \right)^{-\frac{gM}{hR}} = 1 \text{ atm} \left( \frac{483.1^\circ R}{519^\circ R} \right)^{5.272} = 1 \text{ atm} (0.685) = 10.07 \text{ psia} \]
Problem No. 3

\[
F = P A = \frac{\pi}{4} (120 \text{ft})^2 \cdot \frac{1 \text{lbf}}{\text{in}^2} \cdot \frac{144 \text{in}^2}{\text{ft}^2} = 1.63 \cdot 10^8 \text{lbf} = 7.24 \text{MN}
\]

This is normally enough to crush such a tank, which explains why such vents are of crucial importance, and why prudent oil companies pay high prices to get one that always works!
Problem #4

\[ P_0 = 14.7 \text{ psi} \]

\[ \text{CSA} = \frac{\pi (2)^2}{4} = 3.1416 \text{ ft}^2 \]

\[ 250 \text{ lbf} = P_a A = h \cdot g \cdot A \]

\[ 250 \text{ lbf} = h \left( \frac{62.4 \text{ lbf}}{\text{ft}^2} \right) \left( \frac{32.2 \text{ ft}}{\text{sec}^2} \right) \left( 3.1416 \text{ ft}^2 \right) \]

\[ h = 1.275 \text{ ft} \]

\[ P_{\text{act}} = P_0 - \frac{P_g \Delta h}{g} = \delta g h (\delta g) = P_g \delta g \]

\[ P_g = \frac{14.7 \text{ lbf}}{\text{in}^2} + \frac{62.4 \text{ lbf}}{\text{ft}^2} \left( \frac{1.275 \text{ ft}}{\text{sec}^2} \right) \left( \frac{32.2 \text{ ft}}{\text{sec}^2} \right) \left( \frac{144 \text{ in}^2}{\text{ft}^2} \right) \]

\[ P_g = 15253 \text{ lbf/in}^2 \]

\[ 14.7 (3) = 15253 (\delta g) \quad \delta g = 2.89 \text{ ft} \]

\[ h_D = x + h, \quad x = (3.0 - 2.89) \text{ ft} \]

\[ x = 0.11 \text{ ft} \]

\[ h_D = 0.11 \text{ ft} + 1.275 \text{ ft} = 1.385 \text{ ft} \]
\[ h_p = 3 \text{ ft} \]

\[ P_s \downarrow w = ? \]

\[ 3 = h + x = l_s + x \]

\[ \frac{P_0 l_0}{P_s} = l_s = h = \frac{F}{e g A} \]

\[ P_s = P_0 + e h g \]

\[ \frac{P_0 l_0}{P_0 + e h g} = \frac{F}{e g A} = h \]

\[ \frac{14.7 \text{ lb/sq ft}}{1 \text{ sq ft}} \left( \frac{144 \text{ lb/sec}^2}{\text{sq ft}} \right) \left( 3 \text{ ft} \right) = h \]

\[ \frac{14.7 \text{ lb/sq ft}}{1 \text{ sq ft}} \left( \frac{144 \text{ lb/sec}^2}{\text{sq ft}} \right) + \frac{62.4 \text{ lb}}{\text{ft}^3} \left( \frac{13 \text{ ft}}{100 \text{ ft}^3} \right) h \]

\[ -6350.4 \frac{13 \text{ ft}}{\text{ft}^2} = 2116.8 \frac{13 \text{ ft}}{\text{ft}^2} + 62.4 \frac{13 \text{ ft}}{\text{ft}^3} \left( h^2 \right) \]

\[ \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]

\[ h = 2.773 \text{ ft} \]
\[
F = F_\text{Total} = 543.6 \text{ lb}
\]

Net Extra over weight = 293.6 lb

\[
F_1 = \frac{P_0 \cdot l_0}{l_1} = \frac{14.7 \text{ (lb)}}{2.773} = 5.2 \text{ lb}
\]

\[
P_f = 15.9 \text{ lb/ft}^2 \left( \frac{144 \text{ in}^2}{\text{ft}^2} \right) = 2290 \text{ lb/ft}^2
\]

\[
P_f (\text{water side})
\]

\[
P_f = e g h + P_0
\]

\[
P_f = \frac{62.4 \text{ lb/ft}^2}{\text{ft}^2} \left( 2.773 \text{ ft} \right) \left( \frac{14.7 \text{ lb}}{\text{ft}^2} \right)
\]

\[
+ 14.7 \text{ (lb/ft}^2) \cdot \frac{14.7 \text{ (lb)}}{\text{ft}^2}
\]

\[
P_f = 2290 \text{ lb/ft}^2
\]