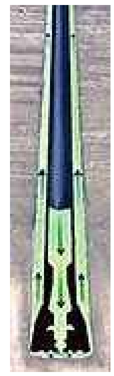
Science Lab

SEED

# Oil Well Blowout Simulator

## Background

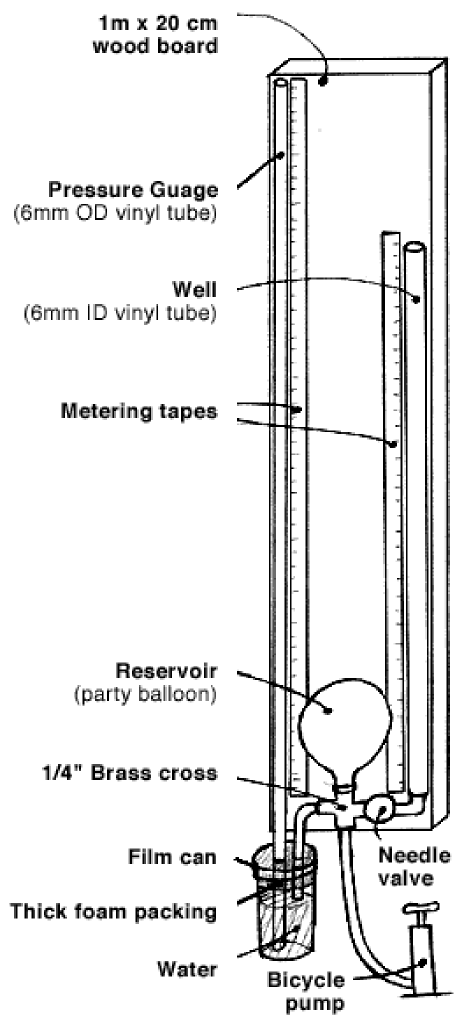
I prepared this experiment for my daughter's class in elementary school once when I was invited to animate a full day activity on the World of Oil. The experiment was intended to put "Physics in Motion" in the midst of maps, videos and geologic descriptions. It was so successful that I had to repeat it several times!



Drilling mud is pumped down through the center of the drill pipe and returns to the surface in the space between the drill pipe and the wall of the borehole.

This experience illustrates one of the major risks in drilling an oil well, a Blowout, which occurs when gas pressure inside the well suddenly forces out the oil.

The demonstration is also useful to illustrate the concepts of Drilling Mud, Blowout Prevention, Hydrostatic Pressure, Pressure Balance, Gas Compressibility and Density.




## Tools & Materials

As the diagram shows, the model is built out of commonly available materials. Perhaps a visit to a home improvement or hardware shop will be needed for some parts. The basic idea is to simulate a Well by using a transparent vinyl tube (6mm inside diameter). A party balloon simulates the Reservoir and a second transparent tube serves as Pressure Gauge. In my setup I used aquarium air pump tubing (6 mm outside diameter) for the manometer (pressure gauge) although it results in a small capillary error. Larger tubes can be used (but not too large for the setup to remain practical). I fixed the tubes to a wood board using round electric wire staples. Ribbon tape measures from a furniture shop worked very well as graduated scales to measure the water level on Well and Gauge. Care must be taken to align them to the same horizontal reference. I used a photographic film can as the water tank for the manometer. Forcing the aquarium hoses through a thick foam packing under the lid made the entries airtight. I used a _ inch (6 mm) cross connection and a needle valve that I happened to have, but I believe that similar results can be obtained using crosses and needle valves from an aquarium supplier.

On top of the above preparations, the experience will also require some fresh water, kitchen salt and a kitchen scale. A small funnel or glass with pouring spout will be useful.

Some creativity will be needed to make the connections air tight with more or less makeshift fittings, Teflon tape, elastic bands and duct tape. Rehearsal is recommended to familiarize oneself with the small errors of such simple setup.

**Experiment #1:**

1. Close the needle valve. Fill the tube simulating the Well with fresh water up to the top edge. Also fill the Gauge tank with fresh water.

2. Operate the pump and bring the water level in the Gauge just below the water level in the Well tube. If the balloon inflates too much, install two balloons, one inside the other.

3. Stop the pump and make sure that it does not leak. Gently open the needle valve. The water level on the Well will decrease slightly to the same height as in the Gauge. At this moment we are at equilibrium, the Hydrostatic Pressure of the water column in the Well matching exactly the Reservoir Pressure and keeping the fluids (in this case air) in place.

4. (Remarks: Mark the exact level on the Gauge tape for future reference. If the level drops far below the edge of the Well tube, close the needle valve, replenish the Well and put a slightly higher pressure before opening the needle valve again)

5. Let's now simulate an under-balance. Gently press the balloon (increasing slightly the Reservoir Pressure) and observe the first air bubble entering the tube. Observe how its size increases in its travel up the tube, as the Hydrostatic Pressure decreases.

6. The increase in volume of the air bubble displaces water that spills out of the Well tube. As the amount of water in the well decreases, so does the Hydrostatic Pressure, and more air enters the tube, displacing more water and · very quickly all the water will be spilled out showering on everyone around!

This scenario might well happen while drilling an oil well, resulting in a so-called Blowout of catastrophic consequences. In fact, primitive drilling consisted in hammering a peg in the ground until the reservoir was hit and the fluid blew out. Apart from being dangerous, wasteful and polluting, this technique (or rather lack of it!) could only be used for shallow wells. In modern rotary drilling, especially formulated mud is used in the well to keep the reservoir fluids in place, among other functions. The Drilling mud is constantly circulated in the well through the drill pipe and out of the well through the annular space between the drilling pipe and the well bore. The returning drilling fluid is continuously monitored to detect the presence of gas.

If gas is detected, the driller immediately lowers the drill pipe as low as possible and clamps it with the Blowout Preventor Pipe Rams, stopping fluid loss from the well. Then, mud of higher density is injected through the drill pipe and annulus fluid is choked out to remove the gas and the lighter mud while maintaining the pressure. The heavier mud travels down the drill pipe and up through the annulus. As the mud column gets heavier, less and less gas is detected at surface. Once the heavier mud is in place and the reservoir fluids contained, the Pipe Rams are opened and drilling resumes. We can model this in our simulator too.

**The Experiment #2:**

1. Place a container of enough capacity for the liquid required to fill the Well tube on the kitchen scale and set it to zero. Fill with fresh water and weigh.

2. Add kitchen salt until the weight is increased by 5% or 10%. Stir to dissolve the salt completely

3. Close the needle valve and fill the Well tube with the salted water.

4. Operate the pump until the level in the Gauge tube is 5% or 10% higher than in Experiment 1 (according to the amount of salt added in step 2).

5. Gently open the needle valve and observe how a shorter column of heavier (more dense) fluid in the Well balances a taller column of lighter fluid in the Gauge tube.

6. If air bubbles enter the well it means that the pressure is too great - you've pumped too much and the level of the gauge is too high. Conversely, if fluid from the Well tube is lost, it means that the Reservoir is overcompensated - the pressure in the well is too great. (A little loss is unavoidable because of the relatively low accuracy of our measurements. Rehearse).

7. Of course, we are now again at equilibrium and a slight pressing on the balloon will produce the same result as in Experiment 1.

## Final Remarks

It is easy to infer that, to drill safely, the Hydrostatic Pressure exerted by the Drilling Mud column must slightly overcompensate the Reservoir Pressure. But this pressure can only be guessed at best before drilling; therefore, we need to build some safety margin. We have also seen that overcompensation in the Well column results in fluid loss in the Reservoir. This is dangerous too because it will lead to equilibrium, which is the preceding stage to a Blowout. To avoid this situation, drilling mud's are formulated to plug the pores of the reservoir. Part of the more fluid elements seep into the reservoir pores, constituting the filtrate, but the larger solid particles in suspension block the pores forming what is known as mud-cake, preventing the entry in the reservoir of any more fluid. Drilling fluid loss is also a parameter closely monitored during oil well drilling.