

Apparatus Competition
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Nitrogen Tower- Liquid to Gas Expansion Demo

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Abstract

Liquid nitrogen can be used to demonstrate properties of matter. In particular, liquid nitrogen expands almost 700 times its original volume when it is warmed to room temperature. In the demonstration described here, nitrogen gas is captured in a windbag. The windbag expands dramatically forming a tubular tower.

Construction of Apparatus:

Start with 3 one gallon jars, 2 jar lids, a plastic paint can, a windbag, 8 feet of stainless steel chain, 3 small Styrofoam cups, some vinyl electrical tape, some invisible tape, sandpaper, 8 screws, a number 5.5 rubber stopper, a piece of string 12 inches long, a piece of wood to make a 3inch diameter disk, some conduit, a masonite clipboard to make a 6.5 inch diameter disk, and a pie pan.

Comment on windbags and the tools to make holes:

Unfortunately the windbags are not all the same diameter. My blue bags were larger diameter and worked better than the yellow bags. In constructing this demo I found that some bags would not stretch and would split. I suggest that several bags be purchased in order to find a bag that works best.

Holes are made in the lids, in the bottom of the gallon jars, and in the side of a gallon Jar. They can be made with Greenlee Radio Chassis punches, hot metal conduit pipe, or Forster bits. A 1 inch Forster bit tended to split the jar so I used heated (hot) .75 inch EMT conduit to punch the hole. The conduit is heated with a propane torch or an equivalent torch. One can practice making holes in a spare 2 liter bottle. I used a .5 inch Forster bit to make the other holes.

Preparing the back to back lids:

Cut out a wooden disk using a three inch diameter hole-saw. Draw eight equidistant diameter lines on the disk. The lids will be held together back to back so that each cap thread portion is exposed (facing outward). Holding the lids back to back and holding them close together, tape the lids by going around just once with vinyl electrical tape. Attach two jars to the back to back lids. Air must not leak between the lids. Apply more tape until it covers both edges right up to the rims of both lids. Putting the tape on while

the lids are on the jars is best. This prevents the lids from being warped (out of round) from the tension of the tape. Place the wooden disk in the center of a lid. Mark eight equidistant spots on the lid near the outside of the wooden disk using the lines on the wooden disk as a guide. These spots will be used as a guide when drilling holes. Four screws are used to secure the lids together. A one eighth inch drill bit is used to make screw pilot holes in the lids. With the lids aligned back to back, drill a pilot hole. The pilot hole should be .5 inches in (towards the center) from the outer edge of the lids. This hole goes through both lids. Install a screw. Drill three more pilot holes. These should be equally spaced from each other and .5 inches in from the outer edge. Install three screws. Using a half inch diameter Forster bit, nine holes will be drilled through the lids. A conventional drill bit will work but a Forster bit makes a cleaner cut hole. Place the wooden disk under the lids. This is to prevent the lids from cracking as the bit drills through. Drill a hole through the center of the lids. Surround the central hole with eight equidistant holes. In the lid on the screw heads side write "Put Styrofoam cup here".

Preparing the chain jar:

Cut some .75 inch metal conduit pipe 1 foot long. Smooth the cut end. This will be used to put a hole in the side of a gallon jar about 2.5 inches down from the top. Heat the end with a torch. Push it through the jar while rotating the pipe. Remove the plastic from the hole and sand the hole smooth. Center the back to back lids over the center of the bottom of the jar. Use the holes in the lids as a pattern to mark the bottom of the jar for nine holes. Using a Forster bit, drill 9 holes (.5 inch diameter) in the bottom of the jar. Also drill 16 equally spaced holes in the bottom of the same jar just inside the outer edge of the jar. A pair of pliers can be used to remove any plastic disks still attached to the holes. Cut the bottom off of a different jar one and three fourths inches up from the bottom of the jar. Heavy duty scissors or tin snips can be used to do this. Put the stainless steel chain into this bottom. Fit the bottom of the jar with holes over top of the stainless steel chain. The chain will have to be spread out for the bottom to fit snug. Use vinyl electrical tape to seal and hold the bottoms together. A hole will be drilled through the side and out the other side of a number 5.5 rubber stopper. Use the one eighth inch drill bit to drill the hole. Make the hole about an eighth inch below the larger diameter end of the stopper. Push a 1 foot long string through the hole. This can be done with a small screw driver. Pull the string through the stopper long enough to tie a granny knot on top of another one. Melt the string by the granny and cool it by pushing it against some metal. This will keep the knot from coming undone. Tie two granny knots on the other end of the string and melt the end as described. Put the stopper in the hole in the side of the jar. Secure the other end of the string with vinyl electrical tape at the place where the jar bottoms are taped together.

Preparing the windbag jar:

The bottom end of the plastic paint can has a ridge around it. This ridge needs to be sanded down. I used a vibrating sander with 220 grit sandpaper. Only the bottom portion of the plastic paint can will be used. Cut off the bottom portion of the plastic paint can 3.5 inches up from the bottom. I used a band saw but it could be done with a jig saw. Sand the cut edge so it is even. I used a chisel to cut the burr off the edge. Smooth the cut edge by sanding it. The following method was used to attach the plastic paint can bottom to the bottom of the third gallon jar. Matching three inch diameter holes will be cut in the bottoms of the plastic paint can and the gallon jar. Using a .25 inch diameter drill bit or

whatever drill bit size that is attached to the 3 inch hole saw, drill a hole in the centers of the bottoms of the plastic paint can and the gallon jar. Place the plastic paint can bottom over the jar bottom. Use the quarter inch diameter drill bit to center the bottoms relative to each other. Drill an eighth inch pilot hole 2.25 inches out from the quarter inch hole. Put a screw into the pilot hole and tighten it. Do the same at three other equal spaced spots 2.25 inches out from the quarter inch hole. Remove the quarter inch drill bit. Using a three inch diameter hole-saw, cut a hole through both bottoms. A utility knife and sand paper can be used to smooth the hole in the plastic paint can. The inside hole of the jar does not need to be smooth. Put the windbag over the jar starting at the mouth end. The end of the windbag will be worked up and over the plastic paint can bottom. Attaching a small portion of the bag end with invisible tape will help hold the bag in place while the rest is worked over the lip of the plastic paint can. Another help is to moisten the hands with water and use a very small Phillips screw driver to ease the bag over the lip. Set the back to back lids aside so that the screw tips don't inadvertently puncture the bag. After the wind bag end is over the lip of the plastic paint can, set the windbag jar on top of the chain jar. Remove the rubber stopper from hole in the chain jar. Remove the invisible tape. With moistened hands (not too wet), keep sliding the bag down over the plastic paint can as even as possible. Slide it down until the end of the bag is 2 inches from the mouth of the windbag jar. Tape a small part of the bag to the jar. Fold the bag lip so that the lip fits tight and outlines the jar 2 inches from the mouth of the jar. Put a small amount of tape over the fold onto the jar. Now seal the lip of the bag to the jar using vinyl electrical tape. Turn both jars over carefully keeping them on top of each other. With moistened hands slide the windbag down over the windbag jar until the end of the windbag is at the top of the chain jar. Remove the chain jar. Tie a knot in the end of the windbag. Tighten the knot so that no gas will escape through it. Extra plastic above the knot can be cut off. With moistened hands slide the bag the rest of the way down over the jar. Turn the jar over and put the back to back lids on the jar. The heads of the screws on the lids and the note "Put Styrofoam cup here" should be showing on the outside of the jar. Tighten the lids firmly in place.

Preparing the masonite disk:

Cut a 6.5 inch diameter disk out of the clip board.

Preparing the Styrofoam cup:

Cut a hole one and one eighth inches from the bottom of an 8 ounce Styrofoam cup. I used a razorblade to cut out an equilateral triangle like hole with the base of the triangle being parallel to the bottom of the cup. The cup can only be filled to the level of the hole. The volume of water that this cup can hold turns out to be about 54 ml which is equivalent to the volume of a disk .1 inches thick and 6.5 inches in diameter.

Use of Apparatus:

This demonstration shows that when liquid nitrogen expands to a gas, it expands around 700 times its original volume. A disk with a diameter the same size as the windbag is shown to the students. The disk is roughly .1 inches thick, about the thickness of a clipboard. The students could be asked "If I have liquid nitrogen that is the same volume as this disk and it is changed to a gas and it keeps the same diameter as the

disk, how tall would the resulting column of gas be?" 700 times .1 inches is 70 inches or about 6 feet. The column of gas ends up being about 6 feet.

How to do the demonstration:

Note: While handling liquid nitrogen, gloves and eye protection are recommended. Large containers of liquid nitrogen are awkward to pour from. If a pitcher dewar is not available then transfer the liquid nitrogen to a small Styrofoam cup and use it for pouring.

Set the wind bag jar and the chain jar next to each other. Put an empty uncut Styrofoam cup onto the windbag jar right on top of the holes in the lid of the windbag jar. Put the cut Styrofoam cup in the metal pie pan. While steadying the cut Styrofoam cup, carefully pour liquid nitrogen into the cut Styrofoam cup until it overflows out of the cut out hole. This provides a measured amount of liquid nitrogen. Taking care not to spill any nitrogen out of the cup, carry it to the cup that is sitting on the windbag jar and set it inside the uncut cup without spilling any into the windbag jar. Turn the chain jar upside down and carefully place the mouth over the windbag jar and tighten the jar to the lids. Turn the jars over. As the gas fills the bag the windbag will expand dramatically into a column.

To do the demonstration again, the windbag needs to be slid down back over the windbag jar. It will be done by gripping both hands around the windbag covered jar and sliding the windbag down. Put water in a Styrofoam cup. Moistening the hands with a small amount of water helps the grip. Dip your fingers in the water and then rub your hands together. Immediately after removing the rubber stopper, slide the windbag down over the windbag jar. The nitrogen escapes through the rubber stopper hole. Put the stopper back into the jar and remove the chain jar from the lids. Now the demonstration can be repeated.

Comment: There are factors which influence the final volume of gas such as room temperature, small leaks, and the amount of pressure built up in the column. I'm not sure how quantitative this demonstration can be. However, the volume change is dramatic and the demo has great eye appeal.

Apparatus Photos:



Equipment ready for demonstration



Result of the demonstration- Nitrogen Tower
Cost of materials:

Source #1: Industrial Container and Supply Co. 1845 S. 5200 W. Salt Lake City Utah

Source #2: ABC/AIS (ABC Auto Paint Supply) 1437 West Center Street Orem, Utah

Source #3: www.SteveSpanglerScience.com or Steve Spangler Science 4400 South Federal Blvd Englewood, Colorado

Source #4: Lowe's HIW, INC. 140 West University Parkway Orem, Utah

Source #5: Smith's Grocery 350 North Freedom Blvd. Provo, Utah

Source #6: Chemistry Stockroom Brigham Young University Provo, Utah

Source #7: Home Depot 1550 S University Ave. Provo, Utah

\$ 5.70 for three 1 gallon clear round pet jars at \$1.90 each from source #1

\$.40 for two white ribbed caps linerless at \$.20 each from source #1

\$ 2.89 for one clear plastic gallon can from source #2

\$ 19.95 for 32 windbags from source #3

\$ 1.18 for pkg of fourteen 8x5/8 Pan Head Phillips Zinc Metal Screws from source #4

\$ 1.47 for 6 sheets Norton clamp on 220 grit sandpaper from source #4

\$ 2.98 for string TF 100' Line Reel from source #4

\$ 2.56 for pine wood (WHTWD) 1x4x4 from source #4

\$ 2.67 for five feet of 3/4" EMT conduit from source #4

\$ 2.77 for Scotch #33+ vinyl Electrical Tape from source #4

\$ 1.39 for fifty one 8 ounce Styrofoam cups from source #5

\$ 1.69 for invisible tape from source #5

\$ 1.89 for a Masonite Clipboard from source #5

\$ 2.99 for a pkg of 3 pie pans from source #5

\$.29 for a number 5.5 rubber stopper from source #6 (other sizes from Lowes)

\$12.80 for eight feet stainless steel chain at \$1.60 per foot from source #7

\$63.62 Total cost