The INFLATOCOOKBOOK was first published in Jan. 1971 by Ant Farm. It was our attempt to gather information and skills learned in process and present it in an easily accessible format. That INFLATOCOOKBOOK came loose leaf in a vinyl binder that we fabricated in our warehouse in Sausalito. The first printing was 2000 copies.

The experiences that qualified us as 'Inflato-experts' occurred over an 18 month period in which we designed, built, and erected inflatables for a variety of clients and situations. Charley Tilford showed Ant Farm how to make fast, cheap inflatables out of polyethylene and tape and support them with used fans from Goodwill. That was in the fall of 1969. The first one built was the largest, a 100' x 100' white pillow that was built for the III Ripped Wild West Film Festival in San Francisco, then after being turned down for Stewart Brand's Liferaft Earth Event, finally had its day at Altamont. There followed a year in which we built numerous demo-inflatables at schools, conferences, festivals and gatherings around the state of California and beyond.

ANT FARM at that time was: Andy Shapiro, Kelly Gober, Fred Unterseher, Hudson Marquez, Chip Lord, Doug Hurry, Michael Wright, Curtis Schreier, Joe Hall, and Doug Michels.

The INFLATOCOOKBOOK was written, designed, and put together by Chip Lord, Curtis Schreier, Andy Shapiro, Hudson Marquez, Doug Hurry, Doug Michels with help from Sylvia Dreyfus, Charley Tilford, and Sotiti Kiterlakis.

This SECOND PRINTING (July 1973) takes on a new form for ease of printing and distribution. It gets a new cover and binding, and some material has been omitted for update. Still its a good buy at the original price of 3.00$, only at one place; thats Box 471 San Francisco Calif 94101.
THE WORLD'S LARGEST SNAKE

The World's Largest Snake Alphabet
Electrostatic-instant media &
The Universal Mass Consumption Grid
Erection American shopping centers
Livin' & jivin' - a & b
or university automatons/sto. - c & e
Ultrasound media blasts from d
Blow it up - f
The World's Largest Snake eats
videoscreens - g & a 5 man crew
explores limits, blows up buildings,
destroy Fat City, build real (G)lyt
Solar energy, dreams, enviroyesterday
mobiletomorrow AKD
We give 10X energy credits with fillup.
CONECTA NI CIERTO ALAFRAGAR MILVIL CASTAÑAS

DONALD DUCK

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CONECTA NI CIERTO ALAFRAGAR MILVIL CASTAÑAS

DONALD DUCK
KIDS
make your own bubble
EASY AS 1-2-3

1
Tape strips of poly together into a large square.......

2
Fold edges over and tape......

3
Make tube for fan, invite friends, inflate & cut entry slit... spend the night together....
Most plastic available comes in rolls or sheets. Here are several methods of making:

1. **Fold and Tape**
   - Cut out shapes from plastic sheet.
   - Fold along lines and tape in place.

2. **Cut and Glue**
   - Cut out shapes from plastic sheet.
   - Glue shapes together to create a model.

3. **Form and Weld**
   - Form plastic into desired shape.
   - Weld edges to create a seamless model.

*Note: Welding requires specific equipment and techniques.*

STICK ME ON TURTLE

CUT ME OUT

GLUE ME

90° - Flat toe

NEW SHOE SOLE

PERFECT TOP

BEING HELD
MATERIALS
We used polyethylene because of its low cost and easy handling. With material as abstract as a micro-thick plastic film, and as easy to join as polyethylene, one can transcend the entire design-build-process in such a short time as to be able to see the process as a whole. In this sense polyethylene can be a medium for learning about whole design processes.

POLYETHYLENE — (dictionary definition) impervious to moisture, lighter than water, tough, pliable, outstanding at dielectric high frequencies, excellent chemical resistance. We started out using four mil (0.004") for everything (it's cheapest) but now we use 6 mil whenever we can — 6 mil strikes a pretty good balance between cost and longevity. The lifespan of the membrane depends on 1) the surface the bubble will sit on (grass is best) 2) what the wind will do (high winds may destroy the plastics just by the force of the wind, but more often the damage is done by the wind ripping the poly on branches, corners of hangs, etc.) 3) the use it is put to. Public events with high energy sources such as rock music tend to wear hard — steelies such as greenhouses or sleeping places tend to wear well. Under optimum conditions (minimum sun & wind) the material should last about a year. 4) for public places particularly understanding of the nature of the material by the people using it. Users need to be made aware, somehow, to take off their shoes before entering, not to walk on or through the walls, not to tear the doors as they go through, and not to block the air-supply tunnels. Generally we try to reinforce areas of heavy usage and make air tunnels where you can't get to them or make them big enough to crawl in without blocking the air flow. It's better to design in durability than to have to police the vandalizable details (e.g., self-closing doors in Geology section).

COLOR or: COLOR
The most easily available colors are clear and black (used in concrete construction work) but white and colored poly can also be found. Clear is decidedly magical. Its drawbacks are that it gets tremendously hot inside if there is sun and it is a hot day. It can cook the people inside and the ground underneath. This can be turned to good edification in cool weather or for solar canopy. In warmer weather good for water environments, seashore baths, oil massages, etc. Be careful of leaving a clear bubble on a green lawn for too long as it will stain the grass in its own juice. In five hours if the sun is hot. White reflects heat, but it gets very bright inside. You can project on it at night or bounce colored light around inside it. One good design compromise is a half white/half clear bubble — you can put the white side up to the sun or the clear side up on cool or cloudy days. It's best to find shade, or bring your own — a big parachute over a bubble helps a great deal on hot days. Frosted poly is best for rear projection, white for front projection (although white will work for rear projection — it just isn't quite as bright an image). Some poly sold as clear is what is called "natural" which is slightly frosted, although not frosted enough to work well for rear projection. With usage, clear becomes frosted — you can facilitate the process by rubbing it until the static charge picks up dust. Colored poly gives a fine colored light inside. Sources for colored poly are 1) sheetrock and some other building materials are shipped on flats covered with 20"X20" sheets of colored poly. Talk to the people who unload the cars. Once we got a brand new red cover from the US Gymnasium factory in Houston. 2) Colored poly droplets/dict from paint or hardware stores. 3) Manufacturers of gas station and used our lot bannars. Bergmen Banners in San Francisco stocks nine colors in 16" wide (4 mil) and sells it for $0.03/lf. 4) Union Carbide will make any color for you in lots of 5,500 lbs. It is possible to buy colors that they already have in 1,000 lbs lots.

CONTACT PAPER (the stuff you put on the floor)
It's good reinforcing for places that get heavy stress or traffic, like doors and where tunnels join floors.

REINFORCED POLY
(See Sears catalog page.) This is fine, strong stuff, although a little difficult to tape due to texture. There is also a company in Houston named Griffinlon that produces this stuff. I don't know how their prices compare.

TAPING PROCESS or: TAPING PROCESS
This is best worked out by you, partly depending on the number of people you have taping together, AVOID WRINKLES in the tape as the wrinkles will gather water, particularly when the bubble is left unattended in the rain. This will eventually destroy the bond of any of three tapes.

HEAT SEALING
Someone from Oregon says you can seal poly with a regular clothes iron (Teflon if possible). The quality of the seam varies greatly with the skill of the person who is sealing, so practice first. I saw a dome bubble that got destroyed by the wind as the seams had been heat-sealed this way by amateurs. Put a couple pieces are cardboard together upright under the overlapping edges and run the iron along it smoothly and evenly.

POLYESTER (mylar is a trade name for polyester)
Silvered mylar is a good reflective surface and very magical. 2 mil mylar is roughly equivalent in strength to 6 or 8 mil poly and can be taped together like poly. John Reeves in Boston got a quantity of it from Elsar Industries in Revere, Mass. for $.20/sq. ft. He had to do a lot of talking to get it at that price. There are a lot of companies producing mylar now, but we haven't investigated. Again, let us know what you find out.

Building supply stores are the most widespread sources of polyethylene (good last minute, Saturday sources) but packaging houses and concrete construction supply companies usually can get cheaper and carry a larger stock of different weights and sizes of black and clear. They can usually order white (in San Francisco area, the Visqueen distributor has white.

Best prices we've found in the San Francisco Area (per sq.ft.)

<table>
<thead>
<tr>
<th>WEIGHT</th>
<th>CLEAR</th>
<th>WHITE</th>
<th>BLACK</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 mil</td>
<td>1.4</td>
<td>2.6</td>
<td>1.1</td>
</tr>
<tr>
<td>6mil</td>
<td>1.5</td>
<td>N.A.</td>
<td>1.6</td>
</tr>
<tr>
<td>8mil</td>
<td>2.4</td>
<td>N.A.</td>
<td>2.2</td>
</tr>
</tbody>
</table>

(Note: Prices in San Francisco aren't low for building materials. Price per square foot doesn't seem to increase for larger size pieces. White only comes in 4 mil.) Also see attached Sears price list.

TAPE or: TAPE
Polyethylene can be heat-sealed, but we use tape because it eliminates hardware, can be used in the field, and the technique can be mastered by large numbers of people. The most common kind of tape is 2" poly tape available from most polyethylene outlets, but it's not the best. Good tape comes in wider sizes, and is much stronger (if the seam is taped well, the poly will not rip before the seam). Mr. Zimmer is a fine guy. He doesn't like to fill orders smaller than $100. He can and order by UPS air freight to San Francisco in three days. He will cut his 9 mil vinyl tape (for use on polyethylene) to any width. Price is $1.20/lin'd for a 36 yd. roll in any color except clear (which comes in 4" only) and about $4.50/roll. The 4" clear stuff is very good for use on the spoo. patching. 3" width is good in the colored tape. Jim Cook (who has a good deal of experience in poly inflatables which he usually pretty open to sharing) sells 4" wide polyethylene tape (36 yd rolls) which is also excellent tape. The price is comparable to Arista's on 4" but clear the service isn't quite as fast.

Let us know of any other good sources and we will publish the info.

SAFETY CODES AND THE FIRE wipe

from Tenile Structures, Volume One by Frei Otto "... pneumatic buildings are safer than any other form of structure. The main advantage of the pneumatically stretched membrance is its small weight; even with spans of more than 100m, the weight of the structure does not exceed 3kg/ha.m. Even if the compressed air supply should fail, it would take a long time for large envelopes to collapse, since the enclosed air can leak out only slowly. Even large holes and tears are not dangerous. Although the pressure drops quite rapidly, the fire due to the weight of the membrane is so small that, in large inflatables, it may take days before the enclosed air escapes even if the openings are large."

We've never had any injuries due to structural failure. Fire codes are necessary, witnesses cicus test fire tragedies. They are usually primarily concerned with exits in public structures. Polyethylene inflatables have a virtual 360" exit because anyone can rip him out way, but this is sometimes hard to communicate to allowing that type of exit. He will also want to test the fire resistance of the membrane itself, usually by holding a small piece of it over a kerosen burner for ten seconds, then removing it. If it remains burning for more than two seconds it is not considered self-extinguishing. However, when the polyethylene is inflated, the structure has internal pressure which works to extinguish the flame as soon as it burns through the membrane. [Charley Titlow in New York has done research on this and has a film of his efforts.] Try to explain this. We put up inflatables in many public structures with mixed success — we did not get approval from the San Leandro Fire Marshal for Stewart Brand's hungry show, but we did get approval (with the diligent aid of Dr. Frank Oppenheimer) for an intermedia event in the Palace of Fine Arts in San Francisco. We didn't consult a fire marshal before Altamont, but remember you are responsible for the safety of your structure.

Good things to talk about with Fire Marshalls:
1) self-extinguishing properties of inflated polyethylene
2) rip through exit doors (thickness of the poly)
3) the huge number of doors which have
4) length of time required to deflate the building with holes in it
5) the pressure at which the buildings were designed
6) the number of 1500m of air you are providing per person
7) how powerful your back up fan is (this is a must for public events)
RECYCLING

The best way to recycle polyethylene is to reuse it, but when it gets many holes in it, it is no longer good as a rain cover. The worst thing you can do with it is to put it in a garbage can — it will probably end up as landfill and never decompose. The best thing you can do with it is BURN IT. When polyethylene burns it breaks down into CO₂, H₂O, and carbon which is the ugly black smoke produced but which will precipitate out of the air quickly and be absorbed by the earth.

It is possible to recycle polychemically, but it's an elaborate process and all the big manufacturers find it more profitable to make it from fresh natural resources (petroleum). We think inflatable shelter is a much better use for petroleum than burning it in an internal combustion engine. We also like inflatables because they aren't in any one place long enough to leave marks on the earth after they've gone.
Since polyethylene is so light (120 oz/4 m²) of a mill weigols about 20 lbs.) a fan usually is a better air source than a blower. A blower gives more pressure than is necessary to support the weight. Blowers tend to be high-pressure low-volume air sources; fans give more air at lower pressure. In measuring the output of a fan or blower there are two considerations: number of cubic feet per minute (CFM) of air delivered and the static pressure at which that air is delivered. A water manometer is an easy way to measure static pressure.

A manometer will give you a lot of interesting and useful information about your bubble. Wind effects, for example, do not always increase the pressure inside the bubble (see Anchooring section). You can tell how much pressure your seams will withstand. Make your seams strong enough to withstand 2/55 pressure, because windloading is best withstood by maintaining a tight skin. If the skin isn't tight, the wind will make a sail in the side of the bubble and then you are at the wind's mercy ...

Remember that for a public event it is necessary to have a back-up fan that will support the whole bubble if the number one fan should fail. Each fan must be capable of supplying at least 5 CFM per person inside the bubble. Having a working generator on hand is a good idea if your power source is at all dubious. (We have panicked when a fuse inside a locked building blew.)

This is the 100' pillow before we put a net on it. When it was half inflated, we stopped inflating it to patch up the little string we had taped to it for tie-downs. A storm blew up and the wind made the 40' X 100' sail that you see in this picture take off. We finally stopped it by cutting a 60' slit in the back side to release all the air. Imagining a sail boat with a sail that big will give you an idea of the magnitude of force involved. This was an extreme case of low pressure, but you get the idea ...

A good source of fans and specifications on fans is Gringeri's National chain of wholesalers. They sell a large variety of fans and blowers, each listed in the catalog with its output. I usually try to match up a used fan I am buying with something in their catalog for an output estimate. To get a catalog or buy from them you have to show some company credentials or a purchase order, but it is worth the hassle as their prices are about 1/2 to 3/8 retail. A new fan is usually cheaper than a used one in the long run if you get it wholesale, but any fan you can get for free can be made to work. ( Beware of used fans for public events, though, unless you are sure the fan is good.

About the best fan we've used for medium-sized inflatables is Charley Tifford's old-time office fan that he talked the city of New York out of when they air-conditioned some offices. This fan is a 24'' diameter, 3/4 HP, direct-drive, two-speed fan with a cast-aluminum, three-propeller motor and a sturdy, closed-gear guard. This fan probably puts out about 5,000 CFM at 0 HP pressure and maybe 4,000 at 1/2 HP pressure. Having a strong guard on any fan is important if there are to be any general public, little kids, or stone people.

Charley cut down the pedastal so that the fan was near to the ground for more stability. The easiest way to attach the air tunnel to this type of fan is to tape it directly to the blade guard (another reason for a strong guard). Since the building will probably move around -- especially if there is no net and the bubble is on a hill or in the wind -- it is a good idea to make the air supply tunnel long enough so that the building can move without pulling the fan over. We've lost some good fans this way. (A good invention might be some skins on the bottom of your fans.)

Our best fans for large bubbles (used on the 100' pillow) is a four-foot diameter, six-blade, 3/4 HP fan powered by a 1/3 HP motor. We scavenged this fan from a house that got air-conditioned. The original motor (1/3 HP) got burned out by a faulty generator, so we test your voltage ... if at all possible. If you are renting a generator get the rental people to test it for you. The replacement 1/3 HP motor we got from the all the fans and blowers we've gotten since has overload protection. This is simply a device inside the motor that shuts the motor off automatically when the motor overheats (due to overloading, incorrect voltage, etc.). The page from the Craftsman Motor Sales Catalogue is a good guide shows how motor speed relates to fan speed determined by pulley sizes. This is a good booklet you can get from Sears. HOW TO SELECT AND INSTALL ELECTRIC MOTORS: The attic fan puts out about 15,000 CFM at 0.3 HP and approximately 12,000 at 1/8 HP. A STRONG mesh guard highly recommended, 3/4'' screen is good. (Hinge pins are removable for transporting.)

Charley recommends this fan for medium to big inflatables. This frame is made with electrical conduit. Included are the specs for this fan from the Gringeri catalog.

12'' TO 24'' VENTURI-FRAME EXHAUST FAN KITS

1300 to 6000 CFM, 1 & 3-Speed Totally Enclosed Dayton Motor, Aluminum Blades

$27.69

Send for complete catalog.

All the little fans that we have here will produce a very strong exhaust fan effect, if the duct is in a strong wind. A venturi is a section of pipe with a narrowing in the middle. The narrowing will exert a pressure difference in the airflow, which will speed up the airflow. The pressure difference is dependent on the size of the opening, but is approximately 1 inch of water for each 2'' opening. Priced to go.

WARNING:

FUNKY GENERATORS.
EAT FAN MOTORS.
A belt should be just tight enough so that finger pressure midway between pulleys will deflect it about 1/4 inch. If too loose, slippage of the pulleys will wear it out. If too tight, it increases motor load and wears on the bearings.

**SELECTING PULLEYS**

Pulleys are manufactured from edge to edge (not in groove). The following table gives you the speeds of driven pulleys when using various combinations of drive and driven pulley sizes (in inches).

**DRIVEN PULLEY SPEEDS IN RPM**

| Drive Pulley Diameter | Driven Pulley Diameter | RPM
|-----------------------|------------------------|-----
| 15 x 10                | 12 x 10                | 1440
| 15 x 12                | 12 x 12                | 1200
| 15 x 14                | 12 x 14                | 1000
| 15 x 16                | 12 x 16                | 800
| 15 x 18                | 12 x 18                | 672
| 15 x 20                | 12 x 20                | 576
| 15 x 22                | 12 x 22                | 480
| 15 x 24                | 12 x 24                | 400
| 15 x 26                | 12 x 26                | 336
| 15 x 28                | 12 x 28                | 288
| 15 x 30                | 12 x 30                | 248

- UNIFORM pulley speed based on one of 1.777 in. diameter. Factor for 1.001 size where Kahn Book No. 731, 3rd edition for figuring other pulleys.

**PRECAUTIONS THAT WILL SAVE YOUR MOTOR**

**DON'T OVERLOAD MOTOR**

Overheating a motor can burn it out. Don't ex- ploit it to run continuously overloaded.

**DON'T LET VOLTAGE DROP**

When voltage at motor drops, exactly the same thing happens as when the motor is overloaded. With too little "fuel" it is (in effect) overworked — burns up — and will burn out. Use stable input wiring.

**DON'T "SOFTEN" MOTOR**

If fan connections are to a motor it is restricted (by dirt,ags or paper, or closing it up in a box) it overheats — may burn out. Keep motor room and dry.

If used where wood chips, dust, etc., can enter in side blow out the opening with dry compressed air — or use a vacuum cleaner.

**GROUND MOTOR PROPERLY**

The motor frame should be connected, by wire of some size that runs in line to motor, to a suitable ground (water pipe or a grounding rod properly installed) — both to protect you and to protect the motor in case of an internal short circuit.

**LUBRICATE MOTOR PROPERLY**

Motors with bronze bearings do require occa- sional lubricating — but not too frequently or excessive amounts. Most motors will need a few drops each month. Too much oil can cause trouble by getting out of the bearing.

**USE RE-SET PROPERLY**

If you have an overload protector with a manual reset button, always wait for motor to cool before using the reset. Never hammer the reset (if it is made to "stick"), as this will break off the switch parts. Any trouble with resetting will probably be due to dust between the contacts — and blow- ing away the dust, or simply holding the buttons in firmly, will correct this.

**SIZING FAN**

Figuring out what size fan to use, in a more thorough way than just referring to the chart, it involves taking into consideration all the demands on the fan. These are:

1) The pressure at which the bubble will be inflated. This is determined by the size and shape of the bubble in relation to the wind. This is dealt with in the "Anchoring" chapter. Running pressure is about 1 lb/sq. ft. (1/5" pressure in a water manometer).

2) Under heavy wind as much as 2 lb/sq. ft. may be needed.

3) Heat calculations. Unless you have access to a giant heating or cooling system, your only controls over the temperature inside will be:
   - a. color of the polyethylene — clearer gets the warmest, white is coolest
   - b. shade — getting the bubble into the shade is by far the easiest and generally the most successful way to cool a bubble; frequently this is impossible, though
   - c. how much air you pass through the bubble — these calculations are primarily what we are dealing with below

3) How fast you want to inflate the bubble. It is unusual that you would want to inflate the bubble so fast that the size fan required would be larger than that required by the cooling requirements. But if you do use this as a design factor, take a rough estimate of the volume of the bubble (in cubic feet), divide by the number of minutes you want to take to inflate the bubble, and the quotient is the required CFM output for the fan.

**Volume (cubic feet) x Inflation Time (minutes) = CFM required**

**WARNING**

If you are trying to get for the fan can be expressed as a performance curve. All the figures being dealt with here are approximations, so you will have to adjust your bubble operating condition according to what feels right when the bubble is up (more holes, choking the fan tunnel with a string, etc.). This curve is different for each fan. We will give as an example here the approximate curve for the 24" Venturi-Frame Exhaust Fan from the Grueber catalog.

Using the given working pressure of a bubble to be 1 " pressure (see "Anchoring") this particular fan will be putting out about 3600 CFM.
In order to arrive at how much air the fan is going to put into the bubble and how much area of holes it will take for this air to pass through the bubble while maintaining the proper pressure in the bubble requires a series of calculations. Since the amount of air we are going to pass through depends on the heating and cooling requirements, we must figure out what conditions are going to make it hotter and how much hotter, then balance this with the factors that are going to cool the bubble.

HEATING FACTORS

1) sunshine
2) people inside
3) conduction through the bubble skin
4) passing air through the bubble

COOLING FACTORS

1) sunset
2) people inside
3) convection from the bubble
4) passing air through the bubble

How to figure these follows:

1) HEAT GAIN DUE TO SUNSHINE
Heat gain due to sunshine is very approximately 300 BTU/sq.ft/hr. of direct sunshine (sun at 90 degrees to the surface of the bubble). Heat drops off towards sunset or as the angle the sun makes with the surface of the bubble diminishes.

It should be noted that if you're using white polyethylene, which you should be if you are doing anything in the sun in hot weather, the heat gain will be somewhat less, but we will design for the maximum heat so we will have a little more cooling power than necessary rather than a little less.

2) HEAT GAIN DUE TO PEOPLE INSIDE
Heat gain due to people inside is very approximately 400 to 1000 BTU/person/hr. This depends on the level of activity of the people. If the bubble is going to be in full sun, this figure will be negligible compared with the heat gain due to the sun.

3) HEAT LOSS
3) HEAT LOSS DUE TO CONDUCTION THROUGH THE BUBBLE SKIN

Q = (A) / (T) / (U)

where:
Q = conduction loss in BTU/hr
A = surface area of the bubble (not counting that which is on the ground)
T = the difference in temperature inside and outside the bubble in degrees Fahrenheit
U = heat transfer coefficient for polyethylene (about 1.2)

4) HEAT LOSS DUE TO PASSING AIR THROUGH THE BUBBLE

Q_Air = (W * C) / (T)

where:
Q_Air = heat loss in BTU/hr
W = cubic feet of air moved per hour
C = heat capacity of air (about .016 BTU/ft³)
T = difference between inside and outside temperature in degrees Fahrenheit

Now in order to use these figures, add together the gains from heat and people, subtract from this the heat loss due to conduction, and solve the 4th formula for W or the amount of air you are going to have to move.

In order to pass this much air through a bubble, it is necessary to have some holes for the air to flow out. To get a rough idea of how big these holes should be, we will use the fan performance curve (which has been determined by the above figuring) to figure out for the required number of CFM to be moved, and the following formula:

\[ P_a = \frac{(g) \cdot (p) \cdot (V)}{2G} \]

where:
P_a = pressure drop at a hole (about 1lb/sq.ft. under normal conditions)
p = density of air which is about 0.07 lb/ft³
V = air velocity at the hole (in ft/sec.)
G = acceleration due to gravity

Within the figures for V are the variables we are playing with:

\[ V = \text{CFM at which fan is operating} \]

\[ V = \text{square feet of opening} \]

HYPOTHETICAL PILLOW DESIGN

Example:

50' X 50' pillow, white on top. To be used in daytime — maximum exposure to the sun will be about half the pillow giving 45 degree angle sun for noon hours. There will probably be about 100 people at medium to high activity as there will be rock music. Outside temperature is about 80° Fahrenheit — temperatures up to 90° F are acceptable inside. O.K. Little sketches are helpful for getting rough estimates to...
ANCHORING

If your inflatable is going to be up outdoors in any wind, it will need an anchoring system. For small volume (500 sq.ft., of floor area or less) interior weights should work; otherwise, could be sand bags or water bags. Larger structures require heavier anchoring. There are a number of ways of doing it: integrally molded tie downs, buried edge, weighted edges, taped edge, or tension net anchors. Buried edge is good for a semi-permanent installation where you can dig a trench. A taped edge is good for a small installation on a smooth floor; tie downs and tension nets are good for sites with existing things to tie to (trees, fire hydrants), or where it would be easy to drive tent stakes or augers.

The anchoring system must withstand not only windloading but also the internal air pressure of the structure. Precise structural calculations should be left to 2 engineers, 3 Ph.D. mathematicians, and a computer, but a little rough math can give you a close enough estimate of what anchors to use. We will deal first with inflation pressure and second with wind loads.

PRESSURE LOAD... On any surface that is curved in one direction, e.g., a cylinder or a long pillow, the tension per unit of width is equal to the internal pressure multiplied by the radius of curvature. Work in pounds and feet. Some ball-park figures on figuring pressure: the highest pressure you are likely to get with a powerful direct drive fan is 2 pounds per sq. ft. (2lb/sq.ft.). A normal working pressure is 1lb/sq.ft. On a water monometer, 1" of water equals 6lb/sq.ft. (see monometer drawing). Indoors you can keep a structure up with as little as 1lb/sq.ft.

Make a sketch of the shape, find the radius of curvature by making a section through it, on this diagram the tension equals pressure times radius of curvature. The tension is the downward force you need per foot of edge.

\[
T/ft = (P)(R_c) \\
T/ft = \text{downward force needed per foot of edge} \\
P = \text{pressure (in lbs/sq.ft.)} \\
R_c = \text{radius of curvature (in feet)}
\]

EXAMPLE: The Earth Day Bubble by Charley Tilford in New York City was 20'x80', radius of curvature was 30'. The anchors were parking meters spaced at 8' along the long edges (the 20' dimension). The pressure which the bubble was designed to withstand was 2lbs/sq.ft. The ropes spanned between parking meters so the load on each rope was (tension per foot of width) (timespacing between meters), Tension = (30' x 2lbs/sq.ft.) and Tension per rope = (8') x (30' x 2lbs/sq.ft.) = 480 lbs per rope. 250 lbs test 3/8 inch dia nylon rope was used.

If you want to do an inflatable with the weighted edge (instead of a plastic floor): find the total downward force required, then divide by the perimeter to get force required per unit of length of the perimeter.

WINDLOADING

To figure windloads: find the area of resistance the structure presents to the wind, (length)x(height). The horizontal force from the wind blowing on the structure can be up to 10lbs/sq.ft., depending on the shape of the structure and the wind velocity. A lower, more shallow-stopping profile will create less resistance (and will create more negative pressure on the leeward side of the bubble).

Bubble I presents a large area to the wind. The negative pressure is concentrated on the back side. This negative pressure is created the same way as lift is created by an airplane wing. Bubbles II and III are actually getting some lift help from the wind. Bubble II would probably need less fan pressure in the wind because of the negative pressure on the outside created by the wind blowing over the low profile. A structure to be left up for more than say, an afternoon (or a structure for an event for which you don't want to have to pack up due to high wind) should be designed for 10lbs/sq.ft pressure. For a structure 20' long and 10' high, the design force would be (10'/10') x 10lbs/sq.ft. which is 7500 lbs force on the structure.

FORMULA (area presented to the wind x 10lbs/sq.ft.) = wind load

If 7500 lbs seems like a lot, think of the force on just the minimal area your body presents to the wind in a good, high wind.

TOTAL LOAD

This windload must be added to the inflation load to get the total load that the anchoring system has to counteract. It is possible that the whole wind-load could be on one anchor point (such as when a square net anchored down at each corner presents one corner to the wind), then the total windload must be added to the inflation load on each anchor. If the wind is coming directly against one side, then the windload divided by the number of anchors that will be under tension should be added to the inflation load for each anchor.

TYPES OF ANCHORING SYSTEMS

These systems have the structural advantage of distributing the forces evenly around the whole perimeter of the building. We used one with pieces of pipe taped into the edge over a watered-in environment so that we were able to remove the inflatable by lifting it over the bed without having to move the water bed which weighed 3000 lbs. Because the plastic floor is eliminated, this type of inflatable would also be good for a greenhouse, storage facility, pool cover, etc. These types might tend to last longer, too, because they are more static so people probably wouldn't walk through the walls or otherwise freak out at the expense of the plastic.

WEIGHTED EDGE

Weighted Edge is anything heavy that can be laid on the edge of the plastic or taped into the edge. See illustration.

I saw an interesting inflatable that John Reaves did in the SummerThing program in Boston that was an inflated hemisphere (out of 2 mil silver mylar) that tied down to a piece of telephone cable that he had gotten from the phone company to denote. A 20' diameter circle of this phone cable weighed about 200 lbs. The phone company usually just chops it up and melts it down again. John's bubble leaked air between the cable and the edge of the plastic. This could be desirable if you want to circulate a lot of air, but if you have pressure problems a flap could be taped on inside the bubble, like on giant Bird-Air and most commercial inflatables. A section of the detail might look like this

Looking at the elevation drawing of this, notice the catenary curves between each tied-down point. This is the natural configuration the line between two weighted points on an inflatable tacks, so it will strengthen your bubble to actually cut a curve to an approximate shape, reinforce the edge by tying a piece of cord into the edge and running the tie-down loops through the string. This will distribute the force of the tie-downs through the whole edge of the inflatable, rather than gathering the stress at the point where the tie-down meets the edge of the plastic. This will minimize wrinkles and tears due to concentrated stress. Inflatables that are to be tied to stakes can be made in the same way as this.
BURIED EDGE
Jim Cook at H.T. McGill Co. in Houston showed us this method of burying edges. He has had extensive experience with it. His company has done polyethylene swimming pool covers, Christmas tree warehouses, and other stuff. The holes in the bottom are important. Unless they are there, the underground poly collects water, makes mud, and the lubricated plastic slips out of the ground.

FRAME EDGE
Jim Cook also showed us pictures of a system he did with two by four frames.
Wrap the poly at least one time all the way around the smaller piece of wood before nailing or bolting this org to the 2X4. The frame will act as a tension ring containing the inflation pressure, as well as acting as a hold-down against the wind.

TAPPED ROPE
This is one of the few ways to make a poly bubble that has a plastic floor without a net. Another way is just to put some heavy things like people or bricks wrapped in something soft inside the bubble while inflating it.

THE 50 V NYLON PILLOW will require fewer wider spaced cords in the net, because the material is stronger. This net is of 10,000 lb. Strapping held by 10,000 lb. guyers.

NETS
Advantages of a plastic-floor building with a net are portability, total enclosure, large inflatables, and ease of construction of the anchoring system. In a large inflatable, it would be difficult to make a connection between a tie-down rope and polyethylene that could withstand the great forces on the bubble. Nets can also be very beautiful.

To design your net, make a model of your bubble and start playing with string. If you can, set up the model somewhere that you can nail into the floor (like a piece of plywood) to simulate anchoring points. If you already have a site for the bubble picked out, put nails in where there are natural anchors, like parking meters or trees or cars. If you are going to use your own anchors, then you are totally free to do anything with the net, spider webs, star shapes, giant grids, whatever. To test your model, get the fan that is going to hold up your big bubble and use it as a wind source. This testing can be very informative if you vary the wind and the pressure inside the inflatable. Nylon string (hardware store) is a nice model material.

Building a net can be a major job. We made a 100’ X 100’ net with a 5-foot grid by stapling down all the horizontal ropes, then tying slip knots every 5 feet in each rope, slipping the vertical ropes through and popping the knots.

The knots at the edge of the net were just square knots, tied onto loops in the edge rope. If you are tying knots, think about knots that don’t involve slipping the whole rope through each knot.

The 100’ pillow net: Our first net was this 100’ square. We used parachute cord for the bulk of the net, 1/4” nylon rope for the 2nd, 3rd, and 4th ropes from the edge, and 2/8” nylon rope for the edge. At each corner we had a “D” ring to avoid the rope rubbing and cutting itself at this stress point. From the D ring to the anchor we used some 10,000 lb. nylon strapping that we got from a surplus store with a double D ring on the end so that we could tighten and loosen the net. Tightening the net in the wind helped quite a bit in lowering the profile of the surface presented to the wind. We used 10,000 lb. guyers. Charley Tillford has since made another 100’ pillow out of 6 mil poly (the original was 4 mil) using a net with 20’ squares instead of 5’ squares.

ROPE STRENGTH
Charley sends from New York the accompanying approximate rope strength chart:

<table>
<thead>
<tr>
<th>DIAMETER</th>
<th>BREAKING POINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nylon</td>
<td></td>
</tr>
<tr>
<td>Parachute</td>
<td>500 lb</td>
</tr>
<tr>
<td>3/4”</td>
<td>1000 lb</td>
</tr>
<tr>
<td>5/6”</td>
<td>1800 lb</td>
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<td>2800 lb</td>
</tr>
<tr>
<td>3/8”</td>
<td>4000 lb</td>
</tr>
<tr>
<td>5/32”</td>
<td>1000 lb</td>
</tr>
<tr>
<td>9/32”</td>
<td>2100 lb</td>
</tr>
</tbody>
</table>

ANCHORS
We got our 10,000 lb. guyers from a telephone supply co. in Houston. Telephone supply co.’s are generally a good source for these. These guyers are about 6 feet tall, A.B. Chance Co., Jersey Ave., New Brunswick, N.J. has 10,000 lb (1” X 66” shaft, 8” helix) guyers for about $6.15. Big guyers generally have an eye at the top that you stick a long (6”) heavy pipe through and twist them into the ground. This generally takes 2 people. Small bubbles can be anchored with dog-anchors which cost about $1.25 each from a pet store or hardware store. Trees, light poles, fire hydrants, parking meters, cars, etc., are still the cheapest.

When you have your bubble up and the wind comes up, tighten your net and increase your inflation pressure. The increased air pressure will keep the side of the bubble from caving in and the tightened net will decrease the area presented to the wind. (See photo of bubble about to take us all for a ride in Air Supply Section)
Wrinkles in your pillow mean the plastic skin is stressed along the wrinkles. There are little or no stresses the other way.

**Reinforced Patch**

A slit cut across the wrinkles will tend to spread open and leak air. Not recommended.

**ENTRY**

A slit cut along a wrinkle will be a self-closing entrance.

A flap taped behind a circular or oval hole, no larger than a crawl through size, will automatically close due to the air pressure inside.

Curvature determines stress: a tiny plastic hose carries a hundred pounds pressure and a huge weather balloon has a pressure barely above atmospheric. Yet the stresses on both the hose wall and the balloon skin may be the same—the tiny tube wall is sharply curved and the weather balloon surface is flatter. If the earth were a giant balloon, imagine how little pressure would be needed inside to bend the horizon so tight!

Make a little cube out of thin plastic sheet. Then insert the corners sharply curved, hang it up, while the midpoints are taut enough to burst! But, better, these areas take more stress. The cube tries to become a sphere—a shape in which the skin curves to an equal amount in all directions. Clearly, the best shape is a sphere, and these pages are devoted to getting as close to spherical as possible with flat materials.

Airing or hula hoop taped around a circular hole will become a self-closing door if it is located so it rests flat on the ground when no one is entering.

**Geometric Diagram**

Surface is divided into polygons. The more polygons it takes, the closer the structure will approximate a spherical surface.

**Polygon Method**

Get ideas from: baseballs, volleyballs, soccer balls, geodesic domes, zonkeys, geometry books.

A form made of rhombus (diamond) is economical to make from rolls of plastic.

**Turbodome**

Surface is sliced into segments or gored.

Making the length of the gored equal to the circumference of the base gives a half-spherical shape.

**Gore Method**

Get ideas from: peeling tangerines, weather balloons, inner tubes, beach balls, inflatable warehouses, gloves, world globes.
**BURRED EDGE Inflatable**

**Her's How** - Use 6 mil Poly comes in 20 wide rolls. Figure the size in 20 modules.

**Dig a trench 24' deep 12 wide**

**Cut Poly** - See Pattern diagram. Note. 40% cut at corner allow for interior H its out wall holes in trench edge.


**Fans** - About 1000 cfm. Usually an attic fan or office fan will do one or the other may detail.

**Another SPARE TIRE**

Continue around, sliding the stars on the ground for the first section to work from taping. It's difficult; the shape structure will not lie flat, and the process is hard to depict.

**Geometry**
PNEUMATICS - A KEY TO NEW STRUCTURES

Air has been the key to many innovative ideas in architecture and engineering. Its properties of being relatively lightweight and capable of being manipulated and controlled make it an ideal material for a variety of structures. The use of air in architecture goes back to the ancient Greeks and Romans, who used inflated air-filled structures such as tents and domes. Today, the use of air structures is being explored in a variety of applications, from temporary shelters to permanent buildings.

Air structures can be used in a variety of applications, including:

1. Temporary shelters for events or disaster relief
2. Permanent buildings for educational or recreational purposes
3. Exhibition spaces for art or design
4. Public art installations
5. Residential or commercial buildings
6. Sports or entertainment venues

The versatility of air structures allows for a wide range of applications and designs, making them a popular choice for architects and engineers.

This year's conference is dedicated to the exploration of new ideas in the field of pneumatics and air structures. We aim to bring together experts from various disciplines to discuss the latest developments and challenges in this exciting field.

Join us for a day of presentations, workshops, and networking opportunities to learn about the latest innovations in pneumatics and air structures.
Faculty Urges U.C. Control of Air Labs

Some dared to enter, others just gaped at this huge plastic air container in lower Sproul Plaza at the U.C. Campus.

Breathing—That’s Their Bag

MIDPEL—A 46-by-60-foot plastic bag was the breathing bag and prop yesterday for a chillingly realistic bit of theater about a day when the air becomes too polluted to breathe.

"Air Emergency" was conceived and built by a Sausalito "family" of dropout architects called the Art Farm. The commune, touring American campuses with their Clean Air Pod (CAP 1000) performed outdoors at the University of California campus as part of a three-day Environmental Teach-in.

An air raid sirens drew U.C. students to lower Sproul Plaza, a commune loudspeaker voice informed them that an "air failure" had occurred and those who couldn't escape from the pollution would die within 15 minutes.

The voice invited onlookers to take shelter in the CAP 1000 which, it said, had been tested "as clean under government contract." The air system inflating CAP 1000 also removes and destroys pollutants, the voice said.

Those who didn't go into CAP 1000 were given "negative census forms" to fill out before dying.

White-jacketed Art Farm members wearing gas masks affixed small yellow circles to onlookers' foreheads. "These are lenses which can be monitored by a Human Resources Satellite which is tracking your final movements," it was amusingly explained by a man called "P-319," who described himself as a "human mental programmer only to answer questions from the press."
The nomad is a peculiar animal. He (big 'nifty with hair growing out) travels either in a tribe (the thunder of thousandrumblinghoofst alone in a never-ending search for nutrients. Were he to remain in one place alone, he surely perish because (iffy find a place to spend the night) he can't supply other needs necessary for survival, thus he seeks out multidimensional inputs from many environments (will-however) better being said are found in the wilderness). Today, it appears that there is a sampling of many environments in a given region, the media (goodnight! Is) only similar with varying content (if it's all good - as we see in edge City), people. Now, nutrients are in the form of high energy input sho to the psyche thr thru the senses from those who speak a language (approach Edge City and drink and swerve the darkness). The same goes for the present value judgments as expressed in outward visual appearance (like Walk in Ad and thrive, hoist with high energy output) to communicate similar viewpoints at a given time and place in the evolution of culture (lifestyle that are never) found (find) in the evolution of society. Thus we can see clearly that (through the haze of electronic screen) that the nomadic trend is in the (huh) travel to provide nutrients (grass/water/food to rich) necessary for their survival. The culture now induces (maxi-views) in (trousers, rich) at (huh) Xchange, not found at Beachwood High School. Super kid of today finds no maxi-nutrients in existing props, so he hits the road. He takes what he needs from different places, producing only one thing: HIMSELF, a system resource center for creating tools to solve any problem. Where he is going is where he writes by TL on his way to Uluru City.