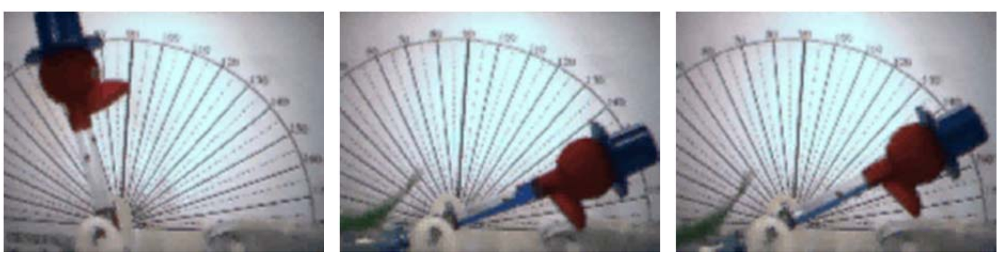
The Dipping Happy Bird

The Dippy Bird is made of **glass** filled with a fluid (methylene chloride), a gas phase (**Freon**, a chlorofluorocarbon) and a really penetrating **dye**. Take care of your Bird by keeping it in a place where it will be protected from strong sunlight and will not tip over. Furthermore, you should use distilled water in its dipping cup to avoid mineral stalactites developing on its lower bulb. Try not to get fingerprints on it, because that will interfere with its temperature exchanges.



FAR LEFT: Behind vertical rest, because momentum of the recovery swing has moved the bird past resting position.
MIDDLE: Beginning of a **HEAT EXCHANGE** packet or bubble of Freon gas. The blue fluid can be seen around the Freon bubble (note it extends clear to the bulb under the green feather of the tail).
FAR RIGHT: The finished heat exchange of a packet of warm Freon to the evaporatively cooled head end.

The **heat exchange** occurs in two thirds of a second (20 frames at 29.95 frames per second), too fast for the transferred packet of Freon vapor to come to equilibrium with its surroundings. This is analogous to the adiabatic heating of a packet of air at the ground on the afternoon of a humid sunny day. The packet of heated air rises too quickly to come to equilibrium with surrounding air. When it reaches cool air aloft, the moisture in the packet condenses and starts to form a cloud. The bases of clouds mark a boundary between air masses.

For the bird, the equilibration presumably occurs during the smaller dips between reset dips and may well be reflected in their number and frequency.

Counter-Intuitive Department for gases on the move...
Question: Is a packet of dry air heavier or lighter than the same packet (same number of molecules of gas) of wet air?
Answer: Consider a group of 12 "air" molecules (OK, I know that the gases are molecular nitrogen at 28 g/mole and molecular oxygen at 32 g/mole), so we will simplify this by assuming an average molecular weight of "air" molecules of 29 grams per mole. We have also decided to use the same fraction (12) of a gram molecular weight, which is Avogadro's Number or 6.02 x 10^{23} thingies in a mole of anything. Then that packet of dry air weighs 12 x 29 or 348 units. If we substitute 4 water molecules for 4 of the "air" molecules keeping the NUMBER of entities the same, they weigh 18 g/mole. So the arithmetic is (8 x 29) + (4 x 18) = (232) + (72) = 304 units for the whole "wet" packet! This is lighter than a neighboring packet of 12 "air" molecules that has no water molecules. Wowie! No wonder those lighter wet packets of humid air on a summer afternoon scoot aloft to make cumulus, which then may nimbus...

OK, what does this cute analogy have to do with the Bird? One of its working criteria is that the working fluid should not evaporate significantly into the gas phase. Or that the gas phase should not be soluble in the liquid phase, so volumes inside the Bird system react mainly to temperature differences (the Freon does not become "wet" with methylene chloride molecules) and changes in packet mass are insignificant.

What is a Dippy Bird, and How is it Used?

by Blair P. Houghton (blair@world.std.com)

The Anatomy and Habits of a Dippy Bird:

1. The armature: The body of the bird is a straight tube attached to two bulbs, approximately the same size, one at either end. The tube flows into the upper bulb, like the neck of a funnel, and extends almost to the bottom of the lower bulb, like the straw in a soda.

2. The pivot: At about the middle of the tube is clamped a transverse bar, which allows the apparatus to pivot on a stand (the legs). The bar is bent very slightly concave dorsally, to unbalance the bird in the forward direction (thus discouraging dips to the rear). The ends of the pivot have downward protrusions, which hit stops on the stand placed so that the bird is free to rock when in a vertical position, but can not quite rotate enough to be horizontal during a dip.

3. The wick: The upper bulb is coated in fuzzy material, and has extended from it a beak, made of or covered in the same material.

4. The tail. The tail has no significant external features, except that it should not be insulated (skin-oil deposited on the bird's glass parts from handling will insulate it and can affect its operation).

5. The guts: The bird is partially filled with a somewhat carefully measured amount of a fluid with suitable lack of viscosity and density and a low latent heat of evaporation (small d(energy)/d(mass), ld). For water, ld is 2250 kJ/kg; for methylene chloride, ld is 406; for mercury, ld is a wondrous 281; ethyl alcohol has an ld of 880, more than twice that of MC. Boiling point is not important, here; evaporation and condensation take place on the surface of a liquid at any temperature.

6. The frills: Any hats, eyes, feathers, or liquid coloring have been added purely for entertainment value. (An anecdote: as it stood pumping in the Arizona sun on my kitchen windowsill for several days, the rich, Kool-Aid red of my bird's motorwater faded to a pale peach. I have since retired him to the mantelpiece in the family room).

7. Shreddin': The bird is operated by getting the head wet, taking care not to make it so wet that it drips down the tube. (Water on the bottom bulb will reverse the thermodynamic processes.) The first cycle will take somewhat longer than the following cycles. If you can keep water where the bird can dip it, the bird will dip for as long as the ambient humidity remains favorable.

Come on, how does it really work?

Short answer: Thermodynamics plus Mechanics.

Medium answer (and essential clues): Evaporative cooling on the outside; **pV=nRT**, evaporation/condensation, and gravity on the inside. Long answer: Initially the system is at equilibrium, with T equal in both chambers and pV/n in each compensating for the fluid levels.

Evaporation of water outside the head draws heat from inside it; the vapor inside condenses, reducing pV/RT. This imbalances the pressures, so the vapor in the abdomen pushes down, which pushes fluid up the thorax, which reduces V in the head. Since p is decreasing in the abdomen, evaporation occurs, increasing n, and drawing heat from outside the body.

The rising fluid raises the Center of Mass above the pivot point; the hips are slightly concave dorsally, so the bird dips forward. Tabs on the legs and the pivot maintain the angle at full dip, for drainage. The amount of fluid is set so that at full dip the lower end of the tube is exposed to the vapor. (***The tube reaches almost to the bottom of the abdomen, like a straw in a soda, but flows into the head like the neck of a funnel.***)

A bubble of vapor rises in the tube and fluid drains into the abdomen. The rising bubble transfers heat to the head and the falling fluid releases gravitational potential energy as heat into the rising bubble and the abdomen. The Center of Mass drops below the pivot point and the bird bobs up. The system is thus reset; it's not quite at equilibrium, but is close enough that the process can repeat this chain of events. The beak acts as a wick, if allowed to dip into a reservoir of water, to keep the head wet, although it is not necessary for the bird to drink on every dip.

Is that all there is to know about dippy birds?
Of course not. Research continues to unravel these unanswered questions about the amazing Dippy Bird:

1. All of the energy gained by the rising fluid is returned to the system when the fluid drops; where does this energy go, in what proportions, and how does this affect the rate at which the bird operates? My comment: watch the movie! There are wobbles and chaotic behaviors!
2. The heat that evaporates the water comes from both the surrounding air and the inside of the head; but, in what proportion?
My comment - Ha! I figured out how to measure the heat and put it in the Carnot Equation:
Efficiency = T_{high} - T_{low}/T_{high} x 100
(convert Celsius to Kelvin by adding 273 before making the calculation. Will not reveal the insanely simple temperature difference determination technique...
3. Exactly what should the fluid be? Methylene Chloride is an excellent candidate, since it's listed in the documentation for recent birds sold by Edmund Scientific Corp. (trade named Happy Drinking Bird), and because its latent heat of evaporation (ld) is 406 kJ/kg, compared to 2250 kJ/kg for water (a 5.5:1 ratio of condensed MC to evaporated water, if all water-evaporating heat comes from inside the bird). Ethanol, at 880 kJ/kG, is only half as efficient.

Mercury would likewise be a good prospective choice, having an ld of 281 kJ/kG (8:1!), but is expensive and dangerous, and its density would require careful redesign and greater quality control in the abdomen and pivot-stops to ensure proper operation at full dip; this does, however, indicate that the apparatus could be made in miniature, filled with mercury, and sold through a catalog-store such as The Sharper Image as a wildly successful yuppie desk-toy (Consider the submission of this FAQ entry to be prior art for patent purposes). 4. Does ambient temperature have an effect on operation aside from the increase in rate of evaporation of water? I.e., if the temperature and humidity can be controlled independently such that the rate of evaporation can be kept constant, what effect does such a change in ambient temperature and humidity have on the operation of the bird? Is the response transient, permanent, or composed of both?

Dippy Bird Tips:
They have real trouble working at all in humid climates (like around the U. of Md., where I owned my first one), but can drive you bats in dry climates (aside from the constant hammering, it's hard to keep the water up to a level where the bird can get at it...). The evaporation of water from the head depends on the diffusibility of water vapor into the atmosphere; high partial pressures of water vapor in the atmosphere translate to low rates of evaporation. If you handle your bird, clean the glass with alcohol or Windex or Dawn or something; the oil from your hands has a high specific heat, which damps the transfer of heat, and a low thermal conductivity, which attenuates the transfer of heat. Once it's clean, grasp the bird only by the legs or the tube, which are not thermodynamically significant, or wear rubber gloves, just like a real EMT. The hat is there for show; the dippy bird operates okay with or without it, even though it may reduce the area of evaporation slightly. Ditto the feathers and the eyes.

Bibliography:
Chemical data from Gieck, K., *Engineering Formulas*, 3d. Ed., McGraw-Hill, 1979, as translated by J. Walters, B. Sc.
I've also heard that *Scientific American* had an "Amateur Scientist" column on this technology a few years ago. Perhaps someone who understands how a library works could look up the year and volume... My comment: Well, the redundancy on this is interesting, as every site seems to have replicated Houghton's article. Kool-Aid is a trademark of some huge corporation (Kraft Foods) that makes its money a farthing at a time... My comment: Did you know it was originally called "Fruit Smack?"

My addenda:
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