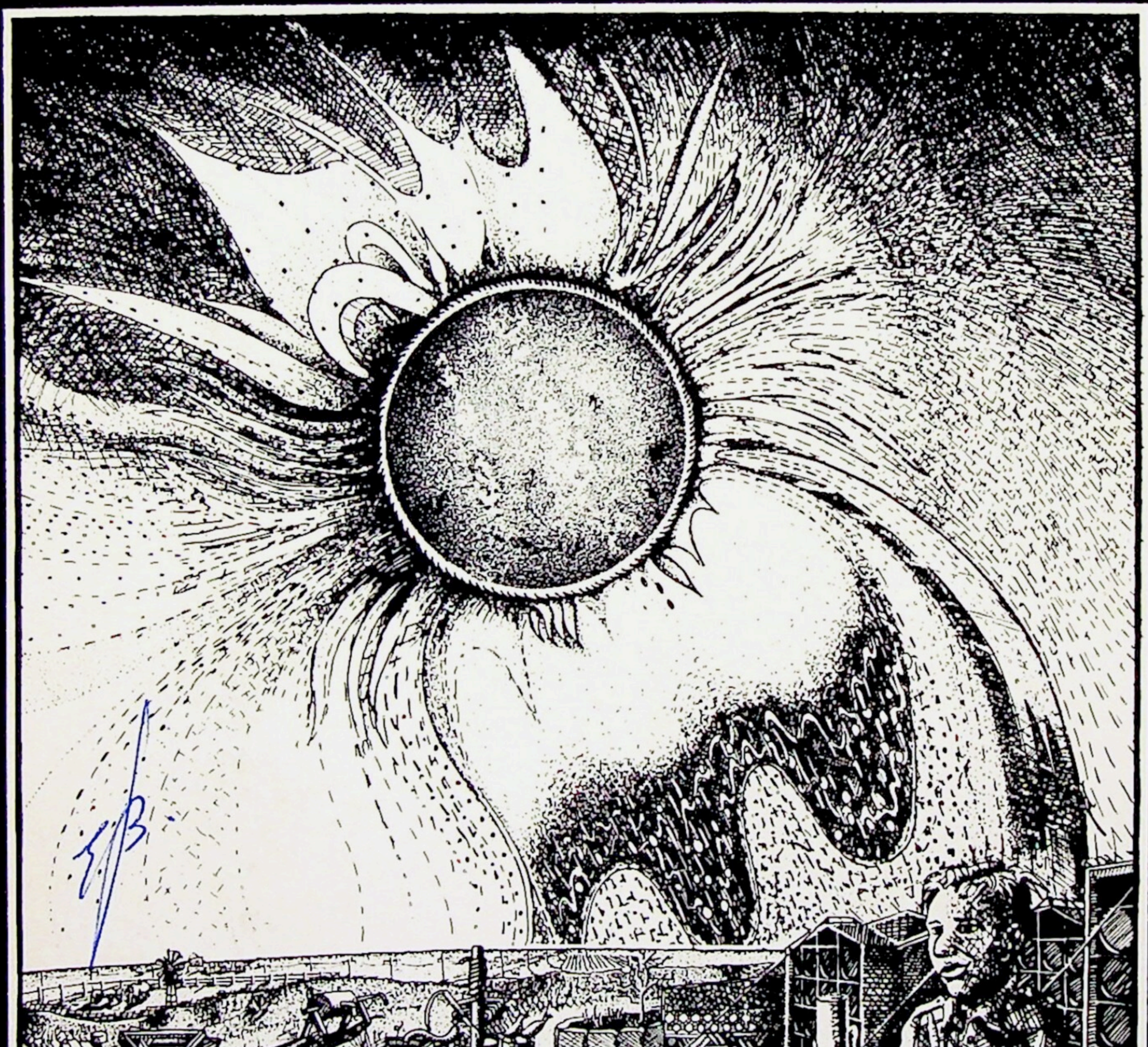
$3.00

# SUNSPOTS



## Steve Baer

Illustrated by Criss-Cross Art Workshop

# Sunspots

Collected Facts and Solar Fiction

**Steve Baer**
Illustrated by Criss-Cross Art Workshop

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**TO**
**Theodore Baird**

**BY THE SAME AUTHOR**

*Dome Cookbook*

Lama Foundation (out of print)

*Zome Primer*

Zomeworks Corporation

# Contents

**What shape is the earth?**

# 1 THE SUN

Different layers of the sun are at different temperatures, but the sun radiates heat much like a body at 10,000° F. Not all of the sun's radiation reaches the earth. The short ultraviolet rays are largely absorbed by $O_3$—ozone—in the upper atmosphere. And much of the radiation at other wave lengths is also absorbed, depending on one's altitude and the condition of the atmosphere. If it is heavily cloudy, very little of the sun's radiation reaches the earth.

The path of the earth around the sun is an ellipse, with the sun at one of the foci. The ellipse is not very pronounced. The closest that we come to the sun is 91,350,000 miles and the farthest is 94,455,000 miles. This small difference in distance of 3.4% makes an appreciable difference of about 7% in the intensity of the radiation, which decreases with the square of the distance.

The earth is closest to the sun in January and farthest away in July. As the earth draws closer to the sun, it speeds up. During this half of its elliptical path, the Southern Hemisphere is slanted towards the sun; and consequently the summers in the Southern Hemisphere and the winters in the Northern Hemisphere are shorter and warmer than the corresponding seasons in the opposite hemisphere.

This imbalance between the seasons of opposite hemispheres is not easy to detect in climatological data because the Southern Hemisphere is much more completely covered by water than the Northern Hemisphere; and this evens out temperatures from one season to the next.

Of the year's 365 days, the sun is in the Northern Hemisphere for about 186 days and in the Southern Hemisphere for the remaining 179 days.

Geometrical relationships between the sun and the earth—the daily rotation, the yearly journey around the sun, the tilt of the earth's axis that creates our seasons—are very complex and hard to understand.

## 1.1 THE EARTH IS AN ORANGE AND THE SUN IS A GRAPEFRUIT

I have always found it difficult to imagine the earth as an orange moving around the sun which is a grapefruit. How could our world, which all of us who live on it can see is flat, be instead like an orange? Faith in science, geography, Magellan, and the shadow you see cast on the moon as the earth eclipses it. And how could the sun, which all of us can see is a tiny spot this big • (if your eye is 14 inches from this page), be the big yellow grapefruit?

Perhaps this was the first trick of science. If you can soften people's brains to where they will say the earth is round instead of what obviously appears to them when they step out and look at it, then they are ready to believe anything. (I owe this observation to Clark Richert who has often brought up the point that the earth is flat instead of round.)

## 1.2 MORNING FRONT WINDSHIELD —EVENING BACK WINDSHIELD

The earth is spattered by meteorites as it makes its year-long tours around the sun. It is going very fast; and just like raindrops on a car, more meteorites hit the front of the earth than hit the back. More meteorites fall in the morning than in the evening, because in the morning you have been spun to the leading side of the earth as it circles the sun.

## 1.3 23-$1/2$ DEGREE TILT

The table below lists approximately how far above or below the equator the sun is on the twentieth day of each month.

You can see that the sun lingers at its highest position, hardly changing in the sky for two months; then rushes through the fall towards winter where it will again linger.

The sun follows a giant spiral in our sky. Each day it cuts a new thread winding its way up or down. The threads are closest together at the sun's upper and lower limits and farthest apart midway between.

| 20th of | degrees |
|---|---|
| Jan. | -20 |
| Feb. | -11 |
| Mar. | 0 |
| April | 11 |
| May | 20 |
| June | 23 |
| July | 21 |
| August | 13 |
| Sept. | 1 |
| Oct. | -10 |
| Nov. | -20 |
| Dec. | -23 |

Table 1.1: Position of the sun above or below the equator on the 20th day of each month.

Almost anything that fluctuates between two extremes lingers at the extremes and rushes between them.

## 1.4 AUTUMN ON URANUS

Other planets in our solar system have completely different relationships with the sun. Venus and Jupiter have their equators almost parallel with the plane of their orbit; and, thus, they could have warm and cold times of the year only if their orbits about the sun were eccentric and they moved significantly closer and farther away during the course of a year.

Venus's orbit is an even better circle than the earth's. Jupiter's distance from the sun varies enough to change the intensity of radiation by almost 20%.

Uranus's equator is tilted all of 98 degrees to the plane of its orbit. Its year is about 80 earth years long and the tilt of its equator causes extremes of the seasons one would not soon forget.

## 1.5 A SHADOW GIVES THE DATE

From a photograph of a building on a sunny day with clear shadows, the day of the year can be determined by examining the positions of the shadows. There may be confusion as to whether the position of a shadow indicates a day in the summer or a day in the spring, and the same confusion could exist between days in the fall and winter. An extremely accurate film could distinguish since in one case the sun is slowly rising and in the other case it is slowly sinking.

## 1.6 ANTARCTIC HEAT COLLECTOR

Surfaces with different orientations have different climates. Heat collectors copy their orientations from warm parts of the planet. A south wall collector in Albuquerque is parallel to the earth's horizon at a point about 700 miles north of the Antarctic. The closest land is Dougherty Island.

The collector, therefore, receives plenty of winter sun but little during our summer. A collector tilted 45 degrees in Albuquerque is parallel to the horizon at a point 1200 miles north of Easter Island in the Pacific.

## 1.7 THE VALUE OF ORIENTATION

A surface intercepts the greatest possible amount of sunshine when it is oriented perpendicular to the sun's rays.

The following table (simply a cosine table) lists the percent of possible sunshine intercepted by a plane misaligned the given number of degrees:

Evidently, when orienting planes to receive sunlight, pretty close is close enough. If your angle is off as much as 25 degrees, you still are intercepting over 90% of the possible sunlight.

An interesting tool to have when investigating the exposure of a given plane to sunlight is a bull's eye with a rod sticking out of it that reads by the shadow cast from the rod (which is called a gnomon) the efficiency of the orientation.

**Sun Bull's Ey**

| **degrees** | **percent** |
|---:|---:|
| 0 | 100.0 |
| 5 | 99.6 |
| 10 | 98.5 |
| 15 | 96.5 |
| 20 | 94.0 |
| 25 | 90.6 |
| 30 | 86.6 |
| 40 | 76.6 |
| 45 | 70.7 |
| 50 | 64.3 |
| 55 | 57.4 |
| 60 | 50.0 |
| 65 | 42.3 |
| 70 | 34.2 |
| 75 | 25.8 |
| 80 | 17.4 |
| 85 | 8.7 |
| 90 | 0.0 |

Table 1.2: Percentage of sunshine intercepted at various angles, following the cosine relationship.

## 1.8 SHADOWS

After dawn the helicopters took off from the base and headed down the valley. Their gigantic shrouds billowed as they were towed through the air.

The ominous shadows passed over the streets and rooftops of the town. No one looked up even though the noise of the helicopters was deafening. On the outskirts of town the helicopters wheeled and took up stationary positions—you could see the crewmen struggling with lines as the shrouds were lowered.

A large white patch of frost and snow, an island of grey and white amid greenish brown, marked their target.

It was a method of non-violent control for dissidents who were disconnecting from the power system and going solar. No solar energy if you are in the shade. The used helicopters of previous wars were now a familiar sight.

Of course, some of the enraged people in the shadows had at first shot at the helicopters, but the helicopters were so heavily armed it was no battle.

A few weeks in the shade and the solar houses were out of commission, gripped by a chill like that which you find in a deep-shaded alley, the plants in their greenhouses turning yellow like grass under a board.

No one could take it for long —the chilliness and the continual throbbing roar of the helicopters; the bored crewmen showering you with wrappers, orange peels, and soft drink cans; the terrifying sight of the machine guns (with whose performance they were all familiar after watching ten years of war on television).

With the rationing of gasoline, this extravagant use of fuel was insult added to injury.

The local governments used the shrouds skillfully—shading a house, a demonstration, or even, as in the case of X, a family picnic; as little as ten minutes would often bring results.

## 1.9 THE SUN RIOTS

The lower floor offices of city hall and the police department have been gutted by fire. Black streaks surround the windows which are now shiny with aluminum foil. The police are still unable to confiscate mirrors; the matter is in the courts.

A week earlier at a demonstration, a large van was driven next to the crowd. The driver, a swarthy man of about 40, opened the backdoors and began passing out foot square mirrors. “Give ‘em some sunshine.”

A few dozen mirrors began playing beams of sunlight on a police car that had been dogging the rear end of the demonstration. The officers were caught by surprise. The driver managed to back the car down the street, but not before his partner, panicked by the glare and the rapidly rising temperature, had jumped out and run. More and more mirrors were out in the crowd now. The crowd glinted like a bank of crystals.

The mirrors couldn’t reach the police car, which had found protection behind a drive-up liquor store. The man with the van now stood on top of the store. “Let’s burn it up, yeh—this!”

His voice is hoarse and breaking. A few mirrors flit across the van and the man on top. More focus on the tin side. The man climbs off. People are pulling the last mirrors from inside the van as the others begin to focus on it. There are 800 mirrors out in the street.

The crowd is silent. The blob of brilliant light on the side of the truck is fringed with trembling squares of light flitting in and out of target. You can hardly hear a noise. Then the sheet metal side of the van “oil cans” as the van swells. A few more moments and smoke appears. The crowd has results. That was at 11 :00 a.m.—by dark there have been 100 fires.

The police appear with arc welders’ masks. They fire on the demonstrators. The demonstrators disperse, but the light keeps coming. More mirrors appear on the street. Funny shaped mirrors—mirrors with ornamental frames, tiny pocket mirrors in the hands of children.

Smoke is seen from another part of town. Television crews arrive. The footage in the evening news across the nation is overexposed —an occasional clear image and then the picture goes white and overexposed.

The mirror crowds are completely silent. They move everywhere on foot.

A secretary at City Hall says, “They just looked so funny—a whole crowd of them standing just as still as could be holding onto those mirrors and then pretty soon the store across the street was burning.”

“Get those damned kids with the mirrors off the street.”

“But officers, I’m just usin’ this mirror ‘cause I’m combin’ my hair—no law against combin’ your hair, is there?”

Dozens of youths in the street combing their hair peering into gigantic foot square mirrors.

# 2 ENERGY

## 2.1 ENERGY IN A CAR CRASH

Even a huge amount of mechanical energy seems pathetically insignificant when it subsides to thermal energy. If you came upon a smashed automobile that had collided with a concrete retaining wall at 60 mph, all of its kinetic energy would have recently been converted to heat. Yet neither the car nor the retaining wall would be very hot.

The kinetic energy of an object weighing m pounds and going $v$ feet per second equals:

$$\frac{mv^2}{2\,\mathrm{g}}$$

The car weighs 2000 pounds. It is 2g travelling 60 mph, which is the same rate as 88 feet per second. Gravity increases the speed of a falling body 32 feet per second, each second that it is falling. The kinetic energy for the car then equals:

$$\frac{2000\,\mathrm{lbs}(88\,\mathrm{ft/sec})^2}{(2)32\,\mathrm{ft/sec}^2} = 242000\,\mathrm{foot\ pounds} = 311\,\mathrm{Btu} \tag{2.1}$$

Three hundred eleven Btu is very nearly the same amount of energy that falls on a square foot directed at the sun, in one hour.

We could store the same amount of energy, 242,000 foot-pounds, by lifting the 2000 pound car 121 feet in the air. The 242,000 foot-pounds of potential energy could then be cashed in as kinetic energy by dropping the car the 121 feet. It would reach a speed of 60 mph just before it hit. When the car hits, the kinetic energy turns into heat energy.

## 2.2 ACQUAINTANCE WITH ENERGY UNITS

A British thermal unit, Btu, is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit. The precise definition states that it is the heat required to raise the temperature one degree when water is at its densest, or at a temperature of 39.2°F. Water takes about the same amount of heat for each degree step that it climbs in temperature, and most of our work will be within the comfortable and predictable range between freezing and boiling.

The mechanical equivalent of one Btu is 778 foot-pounds:' A weight of one pound lifted 778 feet in the air has had one Btu invested in it as potential energy. Or, to store one Btu as mechanical energy, we could lift 778 pounds one foot.

Jacking up a car to change a tire requires increasing the potential energy of the car one or two Btu (lifting 1000 pounds one foot or so). You are not able to store all the work you have done as potential energy, since some of the work goes into friction. But the stored potential energy is all you have to show for your work, since the warm parts of the jack won't do you much good. (Hydraulic jacks are probably more efficient than mechanical ones.)

Drink a pint of beer (a 16-ounce can). The beer is largely water and, therefore, will take close to one Btu for each one degree Fahrenheit that it rises in temperature. You can drink the beer at 40°F, and it warms in your stomach to 98°F or 99°F. This takes 58 or 59 Btu, which is an enormous amount of energy compared to the raised automobile.

## 2.3 DAMS AND HYDROELECTRIC STATIONS

Look at dams and hydroelectric stations. They produce enormous amounts of electricity. It amounts to several percent of the national consumption. Yet if this electrical energy were returned to heat the river—with gigantic electric resistance heaters below the dam, it would change the temperature of the river very little. The hydroelectric plant or the waterfall is the perfect scene to compare thermal energy and mechanical energy.

If a pound of water fell 778 feet, when it hit its kinetic energy would be converted to thermal energy and the temperature would rise one degree Fahrenheit. Then a dam 778 feet high is a one degree Fahrenheit dam.

Boulder Dam on the Colorado River is 725 feet high. Bridal Veil Falls is 620 feet high. Neither of them is high enough to heat its water one degree Fahrenheit on impact.

The water going through the turbines of a hydroelectric plant can do two things. It can give its energy to the turbine wheels, then to the generators, and finally to someone's light bulb. (Given the speed of electricity, this happens very fast.) Or, if the turbine wheels stall, the water churns and splashes and warms itself up.

One could test the efficiency of a turbine by checking with a very accurate thermometer the temperature difference between the incoming and outgoing water. Heat in such situations is a measure of the mistakes and inefficiencies of the generating mechanisms.

James Joule was the first person to measure the equivalent amount of mechanical energy to a given amount of thermal energy. He did this in the 1840's by means of churning water mechanically, using falling weights, and measuring the rise in temperature. Joule also visited waterfalls with a thermometer, but had difficulty because of spray at the bottom.

As we have seen, there are no large hydroelectric plants in the United States high enough to warm the rivers that power them even one degree Fahrenheit. Why then is there all the fuss about thermal pollution of rivers by coal, oil, or gas-fired power generating plants? In an electric generating plant, for each unit of energy delivered as electricity about two units have to be thrown away as heat because of the inefficiency of the generating process. This heat is dissipated in the rivers, which are evidently too small for the size of the generating plants. So far no one seems to have complained about hydroelectric power plants robbing rivers of heat.

## 2.4 WATERFALLS OF LEAD, COPPER, FREON, AND MERCURY

If we had lead b-b's going over the 778-foot-high falls instead of water, the lead b-b's would warm 32°F; a waterfall of copper b-b's would be 11°F warmer; a waterfall of freon would warm 4°F; and wood balls would rise 2°F. The variations in temperature change are because different materials differ in their reluctance to change temperature; a pound of lead changes its temperature 32 times as much as a pound of water on absorbing the same amount of heat. This quality of a material is spoken of as its specific heat. Light materials generally have high specific heats and dense materials, such as lead, have lower specific heats. The rule of Dulong and Petit states that for solid elementary substances (with atomic weights above 35) the product of heat capacity per gram and the atomic weight is approximately 6.2 cal/°C.

## 2.5 EVAPORATING WATER

It takes one Btu to raise one pound of water one degree Fahrenheit. However, it takes about 1000 Btu to boil away or evaporate one pound of water.

A quart of gasoline gives off about 30,000 Btu when burned. Burning a quart of gasoline could boil away about four gallons of water. It could also boil away about 12 gallons of alcohol and about 25 gallons of gasoline. Water is very reluctant to evaporate. When water condenses it gives back the 1000 Btu used in evaporating it. Clouds, which arc made up of condensed droplets, are gigantic heat dumps. As clouds grow, heat is released.

If the oceans were gasoline we could expect to have much more gasoline rain than we now have water rain. Gasoline evaporates and condenses so much more easily.

## 2.6 A 50 WATT DOG

How much energy is used by burning a 100 watt light bulb? A 100 watt light bulb uses 1/10 of a kilowatt-hour (a kilowatt = 1000 watts) of electricity each hour. One kilowatt-hour is equivalent to 3413 Btu. (You can't compare watts to Btu, but only watt-hours. Btu is a measure of heat or energy and watts are a measure of the flow of energy.) Btu is the British measure of heat. Calories are the metric measure of heat. Who has ever heard of a person's diet described as so many Btu per day?

Different terms and units have come to be used in different fields and, thus, discourage comparisons between one and the other. The diet of an automobile and that of a man are certainly very distinct: the one is gasoline and the other food. (The calorie content of one quart of milk is about 660 kilocalories or 2640 Btu—about 1/10 the calorie value of one quart of gasoline.) In a way it is more comfortable to give the light bulb and hot plate species their own terminology to describe their energy diets. It places a protective distinction around the human and his necessities.

However, in terms of energy, human metabolism and burning light bulbs can be compared quite accurately. A 1000 calorie diet is equivalent to a 3970 Btu/day diet or a

$$\frac{3970}{3413} = 1.16\,\text{kilowatt} - \text{hour/day}$$

diet or a steady

$$\frac{1.160}{24} = 48.4\,\text{watts}$$

. So it makes sense to let the dogs inside on a cold night, not just for their sake, but to help heat the house. They may be creating heat at 50 or 100 watts.

## 2.7 GRAM CALORIES AND KILOGRAM CALORIES

A gram calorie is the quantity of heat required to raise one gram of water one degree Centigrade. Gram calories are the calories you see referred to in the physics and chemistry books. They are not the same as the calories used in describing a person's diet, which are kilogram calories, being equal to 1000 small calories. A diet of 3000 small calories a day would not be enough energy to warm up the liquids you drink.

One kilogram calorie equals 3.97 Btu. Then a 3000 kilogram calorie-a-day diet is approximately 12,000 Btu per day, which is equal to about 3-½ kilowatt-hours of electricity a day, or the rate at which a 150 watt light bulb burns. A south-facing window in a house can easily pick up 1000 Btu per square foot during a winter day. So we see that a $3x4$ foot window could admit as much energy each day as that required to feed a man.

## 2.8 PORTRAIT OF A GASOLINE DRINKER

Jerry was a small, quiet fellow in his twenties from Louisiana. His boss at the service station on the outskirts of a large midwestern city at first liked him. Even in cold and wet weather Jerry needed no prompting to go out and man the pumps.

Early in the morning they would find him at the station in the same soiled blue overalls as the day before. Did he sleep there? He lacked the strong body odor of someone who slept in cars and never bathed. When he did not lock up himself, he usually left with the words that he'd stop back by later to pick something up.

Eventually the others at the station identified an occasional peculiar, vile odor in the restroom with Jerry. But it was only a suspicion.

It was several weeks before anyone realized that Jerry, who seemed to subsist on an occasional chocolate bar and never brought a lunch or wasted quarters on the large soft drink machine, was actually drinking gasoline.

When one of the other attendants questioned him about this he replied that he "only liked the smell of it."

He generally fed a few times a week and, if he could arrange it, in the mid-afternoon before the five o'clock rush. His favorite prey were the large, expensive, new automobiles driven by people who were unlikely to get out of the car to chat or inspect their tires.

At 4:00 P.M. a new Cadillac curved into the station from the east entrance steered by an old and uncertain driver. Jerry knelt in the shadow by the rear bumper after properly topping off the tank. He squeezed the trigger again with his left hand, spooning the chilly gasoline up with his cupped right hand, like a man drinking from a stream. He quickly swallowed seven or eight handfuls.

Jerry was dismissed from his job. The other attendants had become uneasy about him though he'd only been seen to drink once. His strange pleasantness about the difficulties of the station and the suspicion about the odor in the restroom—a strange mixture of acetone and ammonia—made the boss decide that Jerry "just didn't fit in."

## 2.9 HOW MUCH IS ONE MAN WORTH?

How much work can a man do? A man running up a flight of stairs can develop a couple of horsepower. Let us say he weighs 200 pounds. If he climbs 2-3/4 feet each second, this is one horsepower.

$$200\,\text{lbs} \times 2.75\,\text{ft/sec} = 550\,\text{foot} - \text{pounds/second} = 1\,\text{horsepower}$$

A horse obviously can do much more than one horsepower for a short time; 550 foot-pounds per second is the rate at which a horse can work continuously for one day. A man can work at approximately one-tenth this rate.

How does work done by a man compare with the energy produced by sunlight? If a man can do $\frac{1}{10}$ horsepower of work for a period of eight hours, and we wish to duplicate the heat the sun pours down on the ground by having men rub the ground with blocks to create heat, we will need at least one man for every square foot.

## 2.10 BUBBLE WORK

In our table what does one cubic foot atmosphere mean? Why is this equivalent to an amount of energy? This is the work required to puff something out against the pressure of the earth's atmosphere to a volume of one cubic foot. You do not do this work when you breathe since the air flowing down your throat to fill your lungs is precisely as eager to do this as the air around your chest is reluctant to make room for your chest swelling.

If you breathe through a tube while you are underwater, you can feel that it is a different matter. Your chest must push out against the water, which is at a higher pressure than the incoming air from above the pool. You must do work in order to blow bubbles underneath water, but none to blow soap bubbles in the air except the slight amount you do in stretching the soapy film.

## 2.11 SUNLIGHT

The sun does such enormous quantities of heating each day that an owner of a piece of land might exclaim at the enormous energy flo,vs that occur to keep his night and day temperatures flowing normally. A farmer could talk about his 10,000 kilowatt production plant.

How much energy do you suppose is delivered by the Gulf Stream to England and Northern Europe? The Caribbean countries, from whose vicinity much of Europe's heat is drawn, cannot send a bill to Europe for this heat. People don't call sunny weather thermal pollution.

The strength of sunlight is a variable. The closer the sun is to being directly overhead and the clearer the sky, the warmer the sun. You can concentrate sunlight with lenses, reflect it with mirrors or white paint, stop it dead with black paint, or let it go to hit the trees, shrubs, weeds, and dirt.

At sea level the sun may give energy at a rate of 1.5 calories per square centimeter per minute, which translates to 332. t Btu per square foot each hour. One calorie per square centimeter is called a Langley, after an early investigator of solar radiation. The radiation recording stations use the Langley as their measure of radiation. To convert Langleys to Btu per square foot, multiply by 3.69. On high mountains the radiation may be as strong as t .75 Langleys per minute, or 387.45 Btu per square foot per hour.

## 2.12 MECHANICAL EQUIVALENTS OF SOLAR ENERGY

One thousand Btu per day per square foot is a conservative average for solar radiation absorbed by the earth. How deep a pool could this sunshine raise 778 feet above the ground against the force of gravity?

Water weighs about 62 pounds per cubic foot. If all the energy reaching the earth could be converted to mechanical energy to raise water above the earth, it would be possible to raise a layer 16 feet deep 778 feet.

If a person were able to use all the sunlight falling on his body for his own metabolism, what share of his diet would be sunlight? Let us say that a man is able to shade an area of six square feet. By lying flat on the ground it would be quite a simple matter to pick up half of one ·s energy needs on a fairly sunny day. Then by positioning - moving to well-exposed slopes and changing as the sun orientation changes, the way lizards do during the day - it would be easy to multiply this pickup by two or three depending on the time of year.

## 2.13 THE BASKERS

Spread it on, the super sun oil, then stand out in the sun. That’s all you need to do. When you are exposed to sunlight your oily skin produces the materials your body needs.

The ultimate in solar energy devices, but you must practice. The more you use it the better it works. The first week it only takes the edge off your hunger, but after a year of use you don't need to eat any more often than a snake.

The history of the oil's development is obscure. It was first tested as a weed killer and is knovm to be poisonous to plants. Mrs. Beverly, a middle-aged nudist, had toured the country touting the oil which she at first claimed to have invented and patented. Her heavy body became a familiar sight on TV talk shows where she appeared in her bikini glistening with the oil. The public, perhaps partly because she thrived under the strong studio lights, had believed her and began purchasing the oil. Vegetation suffered wherever the oil was used. When it spilled the plants died, and the oil's users had no regard for plants. Flowers and bushes in city parks were trampled and flattened by the baskers finding a good spot. And the limbs of trees were broken off by oily bodies climbing towards the sun.

There was a great migration to the Southwest. But it wasn't any kind of boom. The baskers didn't stay in motels or eat or build houses or buy clothes. It was difficult to know what to think. Some saw it as a cure to mankind's problems. Others formed vigilante groups, murdering dozens of the lethargic baskers. Many family disputes followed the oil's introduction. "Damn it, Ray, you go out and look for a job today!"

"Sure, Dad."Later in the day Ray had done nothing. He was on the roof of the carport, stripped to his shorts, starting in on the oil. Several years after its introduction, the oil was discovered to 16

*become very slightly radioactive after prolonged exposure to sunlight, and habitual users were found to have become sterile.*

*After these horrifying disclosures the domestic market shrank, but production was increased for use in "underdeveloped countries." Large shipments were made to India, Pakistan, and Nigeria where a plague of baskers solved the food shortage and population explosion.*

## 2.14 RETRIEVING MECHANICAL ENERGY

*You can always turn mechanical energy into thermal energy, but It 1s not so easy to turn thermal energy into mechanical energy. An equation that reads 2546.14 Btu = 1 horsepower hour can be* *misleading. I can supply you with heat - let us say a bathtub full of hot water - but it is no easy matter, after you agree that you have been presented with such and such a quantity of Btu, to balance the equation by converting this to mechanical energy. Mechanical energy can be taken back f rom thermal energy, but only as a kind of tax on the transfer of heat between two temperatures. It is a difficult tax to collect; it requires very careful contrivances and can never exceed very definite limits.*

## 2.15 EQUATIONS ARE STRANGE

Why should two plus four equal two times three? You object to such an equation,

$$2 + 4 = 2 \times 3$$

, saying that you understand that to be equal the two sides must be just the same. Then you are told that it is the abstractions derived from both sides which are equal; it is missing the point to belabor such trivial matters as that of the two sides not looking the same. You press your point. How can two things born of different processes possibly be the same?

Standing a car in the sunshine for one minute and crashing a car at the bottom of a 120 foot cliff are equal thermally, but the results of the two operations are very different

What sense can it make to *wrn* to numbers and equations when it is heat or energy that we want and not numbers? In house solar heating systems the final test is how the inhabitants feel about the house. With a solar water heater the test of the system is not just how many gallons of hot water you get each day, but how you feel about it - how you use the hot water. With a conventional heating system, when you take a long shower, you feel guilty because the gas or electricity bill will be higher that month. With a solar hot water heater, you take long hot showers when it is sunny and feel fine about it. When it is cloudy you take a short shower, or, if it continues cloudy for several days you don't sho,.,'cr at all.

## 2.16 ROBOTS IN COMMAND

Science, engineering, and technology can be wonderful arts. Often they are practiced very sloppily. Much of this has to do with poor handling of equations and equivalences. After a thousand simple equations have been employed in manufacturing and designing things, they gain a kind of momentum. Those involved in the design and use are reluctant to give up a good thing, namely the simple equation, and deal with how they feel. Even the users feel obliged to try and become the way the contraption or machine was designed to have them be.

If you doubt this, notice what happens the next time you are in a store and the telephone rings. The customer who has walked in with his head and body is left standing while the business of the person who has called on the telephone is taken care of. The hierarchy in c1 drive-up liquor store is usually the car, the telephone, and finally the human.

## 2.17 OLD ENGINEERING BOOKS

Dave Boyd has collected a number of old engineering books which I find more useful than today's engineering books. For instance, the 11th edition of Kent's *Mechanical Engineer's Handbook* is easier to understand than the 12th edition. I don't think that the older books are any more accurate or filled with information, but their terms and language are less specialized.

I find it easier to understand a table in which a quantity is expressed as .0815 lbs. rather than .815 xl0-1 lbs. I am comforted by the 11th edition's description: "volume in cubic feet of 1 lb. of dry air vapor" as opposed to the 12th edition's "Vm, ft.' of mixture/lb. of dry air." These tiny differences in style make the tone of the two editions very different. The earlier edition has such fine manners! The generalist, the non-specialist, the half-educated immediately feel welcome in its pages. It is such a pleasure to have them explain the difference between the specific heat of air at constant volume and at constant pressure by working out a short example in simple arithmetic.

Often I have been disappointed to find that those who have succeeded in mastering the specialized language of a part of engineering have forgotten or never discovered the numerous simple relationships that exist between the behavior or the system they are describing and the everyday world of the rest of us.*The* horror of it is that the reader or student, rejected by specialty after specialty and book after book, in defense of himself and whatever it is that he is familiar with, begins to get back at the specialists by expressing himself in an equally incomprehensible style.

P.W .Bridgeman, the American physicist and philosopher, filled his books with lengthy descriptions and explanations and very few equations. I quote a passage from his book *Dimensional Analysis.*

" ...\"-'C have treated the dimensional formula as if it expressed operations actually performed on physical entities, as if we took a certain number of feet and divided them by a certain number of seconds.Of course, *we* actually do nothing of the sort.It is meaningless to talk of dividing a length by a time; what we actually do is to operate with numbers which are the measure of these quantities. We may, however, use this shorthand method of statement, if we like, with great advantage in treating problems of this sort, but we must not think that we are actually operating with the physical things in any other than a symbolical way."

*Dimensional Analysis*

P. W Bridgeman Yale Press, 1922

*Energy and Society*

Fred Cotrell McGraw-Hill, 1955

BOOKS

CONVERSION sectionTABLE

**To Convert From To Multiply By**

Btu Gram calories 251.9958

Gram calories Btu .00397

Btu Kilogram calories .2519958

Kilogram calories Btu 3.97

Btu Cubic centimeter atmospheres 10405.6

Btu Cubic foot atmospheres .36747

Cubic foot atmospheres Btu 2.721

Btu Foot pounds 777.694

Foot pounds Btu .001284

Btu Horsepower hrs. 0003927
Horsepower hrs. Btu 2546.14
Horsepower yrs. Btu 22,304,186.4
Btu Kilowatt hrs. 00029287
Kilowatt hrs. Btu 3413.
Kilowatts Horsepower 1.34124
Horsepower Kilowatts Horsepower Watts Horsepower Foot pounds/ minute 33,000.
Horsepower Foot pounds/ second 550.
Horsepower Foot pounds/ hour 1,980,000.
Langleys Btu/square foot 3.69
Btu/square foot Langleys .271

# 3 BASIC TECHNOLOGY

It is difficult for us to see ourselves in relationship to the machinery, equipment, and gadgets of our technology. What would the Board of Directors of IBtvJ think if they visited their headquarters and found that their scientists and businessmen had abandoned work with computers and were engrossed in elaborate yo-yo contests?

Our own absorption in our technology abandoning, interest in human and moral problems, is similar to the scientists and businessmen leaving their jobs to play with yo-yos. Except that our games with technology are perverse and dangerous.

Then, what do you do?

You try to improve the situation. One problem today is that we are burning our oil and coal at a terrific rate to provide our economy with energy. The end of the supply of such fuels is in sight. Burning large quantities of oil and coal fills the air with smoke; in many parts of the country you can hardly see. Precious energy is used to light enormous and hideous advertisements, to manufacture and transport junk that people most certainly do not need; it is used by a gigantic military organization which has already perverted the society it claims to defend. Can anyone believe that feeding this sick monster is an urgent task?

If someone's body is using energy rapidly to maintain a fever, the first order of business is to cure the fever not to feed it. Our culture is crying that it is almost out of its favorite food. For its health it should eat less and also change its diet. Today it is important for us to find new ways to heat and cool buildings, new ways to move about, less extravagant ways to enjoy ourselves.

The answers to energy problems are different for different parts of the country. Some places have abundant sunshine, some have wind or geothermal energy or hydraulic power. Other parts of the world are barren of energy sources and must import coal, oil, gas, or electricity. One of the most dangerous traits of our government, engineers, and businessmen is the compulsion for single nation or world-wide solutions. A heating system is uninteresting to the engineers if it would have application only in the Southwest. They feel compelled to think big; and working on products for specific local problems is a humiliation. How absurd this is! Such thinking would lead a man to refuse to buy shoes since they don't fit on his head or his hands.

The response of our government to the energy crisis has been to pour hundreds of millions of dollars each year into atomic energy research and almost nothing into wind, solar, or geothermal energy research. Atomic energy would be the answer if the sun were going to black out, but no one is predicting this. The people doing the work with atomic energy admit that it is dangerous and produces radioactive wastes that must be carefully guarded for thousands of years. Who will benefit from this competition with the sun?

## 3.1 SCIENCE AND TECHNOLOGY

Our large corporations and the war department grasp "science" like a bandit with a hostage. "If you are going to attack us, you are also going to harm our innocent friend, science." Many scientists have been only too ready to relax in the grasp of their captor - confident that no one would risk injuring them. This is no longer certain. Perhaps it is time to begin throwing rocks at the pair.

There has been a perversion of the direction taken by invention and technical development;

it has developed in directions that we now are beginning to judge dangerous. But we may take comfort in this: technology branches again and again;

it is ready to sprout and branch at numberless past forgotten junctions.

As an example I would mention the Yis-sol pump. At the 1968 Solar Energy Convention Levi Yessir demonstrated a very simple and elegant solar-powered pump that did not greatly differ from Savery steam engines used to pump out the mines in England in 1700. Its promise lies in the huge range of inexpensive liquids with different thermodynamic properties available today that were not available to James Watt and Thomas Savery. When people such as Levi Yessir or Harold Hay return to old principles in their work with solar energy, they are undercutting more elaborate work done by others.

ICE

One business that needlessly consumes millions of dollars of electrical energy is the production of ice. It used to be common practice to harvest ice from ponds and rivers, but with the advent of refrigeration and machinery this fell out of fashion. We should get back into the business, this time exploiting modern insulation and methods of moving materials.

Over the entire country ice is made with mechanical refrigerators powered by electricity. Here in Albuquerque, ice sells for 3¢ a pound in blocks and 7¢ a pound crushed. Firewood, hauled from miles away and cut into stove-sized pieces, sells for $.015/pound; adobe bricks, cured and stacked, sell for $.005/pound. It is strange that ice is so expensive. In Albuquerque, at least six feet of ice can be harvested from shallow ponds or water-filled trays during a year. This is over 300 pounds per square foot of pond. If the value of ice were !¢/pound, each square foot would yield a harvest of $3, or S125,000 per acre. The production of ice with electrically powered refrigerators requires approximately $.15 per 100 pounds of ice; so an acre of ice ponds would save approximately $19,000 in electricity each year.

What work must one do to make the ice? One method is to fill plastic trays with a hose during the afternoon and to lift off the ice in the morning. During very cold weather two layers can be harvested each day. Some people would object at first to shards of ice from the top of a pond. "Why this looks like it was pulled off the top of a puddle." Eventually users of such ice would realize that the texture of a bag of ice chunks is interesting itself; it can tell them of the severity of the previous winter, just as the variety of a bag of oranges is more interesting than a can of orange juice.

The storage of such an ice harvest is the most difficult part. If the ice were stored in a huge insulated pit, the mass of ice might lose a rind two feet thick during a year as heat travelled through the walls and melted it. An efficient ice ranch would require considerable capital to make the insulated storage shed and would also require an efficient way to handle the daily harvesting of the ice. Who wouldn't rather work at an ice ranch, with its own peculiar reversed harvesting weather, than in a refrigeration plant?

There is a texture to reality, good and bad, a mixture of fortune and misfortune. If this texture is presented to people always through other people, machinery, or prices, then eventually we become bitter about our own species. If it appears as an unavoidable part of reality, a result of the weather, we do not have others to blame.

An enterprise such as an ice ranch, especially if the activities are

This kind of thinking would moderate the enormous rush into new scientific fields, where people rightly expect that the pickings in new ideas will be easy, and would instead encourage contemplation of older, more basic problems.

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# 4 BUBBLES, WATER, HEAT PIPES

## 4.1 BUBBLES

I enjoy playing with bubbles very much and have often tried to use them in various projects. Bubbles are such perfect things: perfect spheres, if they are alone, perfect hemispheres, if they are against a wet surface. And then, a foam of bubbles adjusting to each other in a forest of perfect 120° angles linking dozens of different curvatures is perhaps even more marvelous. You would suspect that anything with a form as perfect as a single bubble would be a prima donna, but bump bubbles together and they leap into cooperative forms as if they had planned it ahead of time.

There are excellent books about soap bubbles. C.V. Boy's *Soap Bubbles,* Dover Press, is a lovely book. Darcy Thompson has many interesting things to say about bubbles in On Growth and Form; and, more recently, Peter Steven's *Patterns in Nature* Little, Brown, shows a proper love and appreciation for the bubble. Why should anyone go to school when he or she can stay home with a pan of water, some soap, and a straw?

Bubbles can even stop you from smoking. Blow some smoke bubbles—compared to clear bubbles they look like pus-filled cells. When they pop, the collapsing films are brown and gummy, unmistakably the same stuff that collects in your mouth and lungs.

## 4.2 A SIMPLE BUBBLE MACHINE *

I got a bicycle pump, an inner tube as an air reservoir, some surgical tubing, and a valve and found that bubbles were even more interesting if they Oo,ved endlessly and effortlessly from such a simple mechanism. Later I replaced the bicycle pump with a tiny air compressor used for spray painting and the small inner tube with a gigantic tube (on which we had floated down the Rio Grande) from an earth mover. You simply lay the air nozzle in a pan of soapy water and turn it on. A small nozzle blows small bubbles, a large nozzle blows large bubbles. If the bubbles are exposed to the outside dry air, they soon pop, but if the bubbles are blown into a compartment, the air in the compartment becomes saturated and the bubbles live for hours and hours.

## 4.3 BUBBLE SOLAR COLLECTOR *

My idea for a bubble solar collector was to use soap bubbles as a clear insulating material in the space between the collecting surface and a pane of glass. The solar collector designer's great problem is that as he exposes his black surface to collect sunlight, he simultaneously exposes it to lose heat. It is very important to design something that will let the sun in but will not let the heat out. This seemed a wonderful place for the soap bubble. Why not fill a space with a clear foam? The sun can pass through, but when the heat tries to leave, it finds itself trapped by the same material sold commercially to insulate freezers, ice chests, and buildings—foam.

M. Kudret Selcuk published an article in the Solar Energy Journal, Vol. 8, No. 2, 1964, showing the excellent performance of a clear plastic foam Styrocel, as a glazing material for solar collectors. Why couldn't soap bubbles replace plastic?

## 4.4 REFRACTIVE INDICES *

In solar collector design there are many variables to play with. Every time you add a layer of glass to a solar collector, you help it retain the heat it has gained, but you simultaneously cut down its supply of heat because the new layer of glass absorbs light, and *more* important, reflects light. A perpendicular ray going from one medium to another medium has a portion reflected as it crosses the interface. This portion equals (n - 1/2) where n is the refractive index between the |*n+i* two media. The refractive index between air and water is about 1-1/3 and between air and glass about 1-1/2; then the refractive index between water and glass is about 1-1/8.

To explain the 1-1/8 to yourself, pick 12 to name the velocity of light in air—it then follows that 8 and 9 are the velocities of light in glass and water respectively. Between the two substances the index of refraction is then 1-1/8.

The reflection from air to glass is:

(1-1/2-1)**2**

(***5/2*** ) = 25 = 4%

The reflection from air to water is: 1-1/3 + 1 - 7 / 3- 49 -

The reflection from water to glass is:

=(1:!JsY = ***2e9*** = e %

The total reflection going through a dry pane is about 8% and through a wet pane is about 4-2/3%; and the reflection going through a layer of water is 4%. If we keep our glass wet, we can cut down the reflective losses by a great deal. Two wet panes can replace one dry pane and hardly reflect any more light. 29

The equations show that each bubble wall is also approximately half as reflective as a pane of glass.

But we are misusing some of our equations. These equations tell us the reflection of light if the materials ar·e relatively thick compared to a wavelength of light; and it turns out that bubbles are often as thin as wavelengths of visible light - one fifty-thousandth of an inch. With films as thin as this our equations are no longer accurate. Soap bubble films in great numbers reflect very little light.

## 4.5 BUBBLE TRAY RACE

filled trays partly full of soapy water, placed black mats under the water so that light would be absorbed, then put panes of gl,1ss over the trays. I raced one tray against another. One tray had the space between the water and the glass filled with bubbles; the other had no bubbles. The water in the two trays gained heat at approximately the same rate. The tray without bubbles pulled slightly ahead of the bubble tray at the beginning. This made sense. The 'water in the two trays was close to the ambient temperature. In such conditions there is no point in providing insulation to protect a collector against heat loss, for it has no place to lose heat to. Any added glazing make5 the collector pay a price by reflecting light away without giving benefit. (Swimming pool heaters used during mild times of year need no glazing, since the pool' water is usually so close to the air temperature that glass offers no advantage.) However, the difference in the rates of heat gain at the beginning was not great. This demonstrated that all the bubble walls through which light had to pass (an average of 6 to 10- really took very little toll in reflection. After a time, the two trays reached equilibrium with the bubble tray slightly warmer than the tray without the bubbles. There was a marked difference in the glass temperature of the two trays. The bubble tray's glass was noticeably cooler.

Why wasn't there a dramatic difference? Here I'd found an insulating material that stopped the convection of air by breaking it into tiny parcels and which was extraordinarily clear, yet it seemed to make hardly any difference. The problem finally became apparent. All the time I was working with bubbles I was counting on their selective transmissivity. Water is like glass - it allows visible light through, but blocks infrared radiation. (Thin films of plastic are transparent to infrared - test this by getting a stove or a hot plate and first passing a pane of glass and then a sheet of plastic between the hot plate and your face - the glass blocks the heat completely, but the thin plastic hardly at all.) Evidently the bubbles are so thin - a small 30

fraction of the infrared wavelengths—that the infrared goes right through them. Radiant transfer is such an important part of the heat loss of a collector that my failure to halt it left the collector poorly insulated.

Another possible cause for the poor performance of the bubbles was the continual now of new air into the bubble space. The air arrived dry and cool and became hot and wet as it filled bubbles. It then squeezed them out an exhaust hole at the opposite side of the bubble pan to float away in the wind, carrying heat away with them. Often failures such as the bubble collector turn out to be very satisfactory in other strange ways, when you begin to tinker with interesting sidelights. I believe that to do good design work you must love the materials. When they do not cooperate in their first arrangement, by giving you exactly v,1 l1at you want, you must realize that you probably have not understood the materials and processes before your eyes.

The bubbles in the trays migrate slowly from one end of the chamber to the other, looking like some kind of magic fleece. As bubbles age, they thin, and interference patterns cause them to reflect all the colors of the rainbow. The foam winks and twinkles as it slowly moves behind the wet glass. I am convinced that someone someday will find a way to use these beautiful forms in insulating walls - the entire walls alive with migrating, refracting bubbles. Who cares whether or not they collect solar energy!

## 4.6 PLAYING WITH BUBBLES, WATER, AIR

You may have noticed while washing dishes that if you take a hot wet glass and place it on a slightly wet drain board, as it cools it blows bubbles inside itself around the rim. Here you have a demonstration of the contraction of air as it cools. The volume of a gas is proportional to its absolute temperature. The large volume of bubbles blown inside a cooling glass seems a bit extreme, considering the small change in temperature of the glass. Something else is happening in the glass. The water vapor is condensing and this adds dramatically to the shrinkage of the air. One can feel the reverse of this process by partly filling a bottle with hot water and shaking it. Evidently the water sitting in the bottom fails to humidify the air completely, for when the bottle is shaken you can feel the surge of pressure against your hand as the gas expands.

A year after my first experiments with soap bubble collectors, Day Chahroudi arrived in Corrales and began a number of experiments using bubbles and boiling liquids. Day's extensive knowledge of 31

chemistry plus an unspoiled love of such beautiful things as bubbles greatly added to the excitement. Day has now worked with many clear insulating membranes, going on to use selective reflective films and different geometries within quilted fabrics controlled by air pressure.

The events that take place with air and water at different temperatures are fascinating to observe. I would recommend getting a large clear bottle - quart beer bottles are very nice - filling it almost full of water and admiring it. When you touch a bottle filled with water you become aware of its insistence on maintaining its own temperature. You feel a calm authority as a cool bottle steadily takes heat from your hand or a warm bottle supplies it with heat. Water is able to hold as much heat as an equal volume of metal and twice as much as equal volumes of stone or masonry. It has a very stable disposition.

Picking up an old bottle from the trash, cleaning it, filling it with water, and playing with it is exciting in another way. It is evidence of the beauty and inexpensiveness of machine-made products. Spilled water is such a completely different substance. Containers are true marvels.

With a thermometer you can take the temperature of the water in your bottle. A quart bottle holds two pounds and, therefore, a 1°F. rise in temperature indicates a gain of 2 Btu. Take the temperature of everything: the dirt, the air, your shower water (both at the showerhead and the drain), your coffee, your soup, your own urine as you urinate. A thermometer can be placed outside the windshield of a car so that you can read it through the glass. Small clips siliconed to the outside of the windshield will hold a thermometer (with a tin shield for the bulb) in place even at high speeds. Such a thermometer acquaints you with the variations in temperature associated with different microclimates. Early in the morning, valley Ooors are noticeably colder than sidehills. More dramatic is a drive into or out of a city during the evening. There is commonly a 10° F. difference in temperature between downtown and the suburbs (buildings store heat). The zone of changing temperature on the edge of a downtown is called a ”heat cliff” by micro meteorologists.

I would recommend that anyone interested in solar energy play extensively with such simple things as bubbles, bottles of water, stones, pieces of metal, and thermometers. Our society’s approach to problems today is often to leap-frog the simple, obvious solution and land in the midst of computer programs and complicated machines where they are really not needed.

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## 4.7 STOCK POND MELTER

At about the same time I was playing with soap bubble collectors (1967 and 1968) I also played with some other properties of water. A rancher near Drop City, Colorado mentioned that what we needed was a way to use solar energy to keep stock ponds thawed. Ranchers spend a great deal of time every winter driving about ,with an axe and breaking ice so their cattle can drink. I made some elaborate devices to circulate warm air through a pipe embedded in the ice. They were expensive and inefficient. Later while working with a company manufacturing heat pipes I realized that the bottom of a frozen pond is an ideal source of heat for melting a hole in its own ice.

The ice is on top of the pond; below is the warmer water.

Water is such a peculiar substance! When it freezes it expands 8- 1/2%. (Almost nothing else expands when it freezes.) This makes it logical to find ice on top of a pond - it is lighter than water. At room temperature and above, water behaves like any other liquid: when it warms it expands—when it cools it shrinks. Below room temperature water begins to shrink less rapidly as it cools. By the time it has cooled to 40°F., it has almost stopped shrinking. At 39.2°F. it is at its most dense. As the temperature drops below 39.2°F the water begins to swell. Just before it freezes at 32°F. it has expanded enough to have returned to the same density as water at 47°F.

It is awe-inspiring to watch this most common of materials behave in such an uncommon way. Quietly, at the last minute before freezing, a pool of water changes its properties and with the cooperation of gravity decides to protect its warm portion by sinking it to the bottom and sacrificing the upper layer by changing it to ice. Any other liquid would behave in the opposite manner.

Here is something for any human (or other animal for that matter—we are all composed largely of water) to contemplate.

Who can scoff at the religious when they speak of miracles? We are composed of material which has performed those kinds of tricks countless times!

In order to melt a hole in the ice I made a large loop from sections of aluminum pipe and rubber hose. I filled the loop with methyl alcohol and positioned it in a frozen pond so that the top section sat half submerged in the ice, which was about 10 inches thick, and the bottom section was near the bottom of the pond. I had tested the temperatures of the bottoms of a number of frozen ponds and found them to be between 40°F. and 42°F. I reasoned that the methyl alcohol would be warmed at the bottom of the loop and rise by convection to the top, where it would melt the ice or prevent freezing of the water near the top of the loop. The next morning when we returned the loop had indeed functioned, for there was a narrow rind of clear water all about the top portion of the tube—while another hole we had broken had frozen solid.

During sunny winter weather a frozen pond is a lovely work place. These ponds, north of Taos, were surrounded by dormant willows which had branches like vibrant bristles against the blue sky. The glare reflecting off the ice immediately warms you when you step from bare ground onto the ice. The ice holds you up but much of the sun passes through. This pond was clear - 8 feet down you could see pebbles and twigs all brilliantly lit and colored. Summer ponds always seem dim and cool whereas this frozen pond w vas bright; and even though I knew the bottom temperature to be about 40°F. it appeared like some strange vision of life after death, warm and inviting.

As long as the ice is relatively clear and free of snow a great deal of light passes through and reaches the bottom. This warms the bottom layer, giving an ample supply of heat for stock pond melters or other uses for 40°F. water.

After my work with the stock pond melter I saw mentioned a device which consisted merely of a propane tank with a tube thrust to the bottom of a pond. Propane bubbled slowly from the end of the tube, lifting the warm bottom water with it and thus preventing freezing above the end of the tube.

I obtained a patent (United States Patent No. 3,6 I 8,569) on the stock pond melter, but never built any more than the prototype. After much correspondence with agricultural schools about the stock pond melter I have come to suspect that the cowboys enjoy their winter icebreaking expeditions.

## 4.8 A NEW KIND OF HEAT PIPE

Heat pipes conduct heat by using the evaporation and condensation of a liquid inside a closed tube. Normally such a cycle can only work if the heat is introduced at a lower level than where it is taken out. The low liquid boils; the vapor rushes to the cold end where it condenses; and the liquid condensate drips back to boil once more. The heat pipe ignores this requirement of gravity by using a wick. Even if the heat is applied at the top end of a heat pipe the cycle of evaporation and condensation will continue. The wick within the tube pumps the cold condensate back up to the hot end to be boiled av„ay again cycle after cycle. If the wick were not there the top end of the pipe would stay hot and the cold end cold, and there would be no evaporation or condensation and thus very little heat transport. (Conduction down the tube would continue at its relatively slow rate, as , would radiant transfer within the tube.) The heat pipe is a wonderful invention, but it has great limitations. \1\licks cannot lift the liquids more than a few inches. We can never put the heat in very much higher than we take it out.

One day while looking at a diagram of a semipermeable membrane in Enrico Fermi's *Thermodynamics* I realized that heat pipes could be built with enormous differences in elevation using a semipermeable membrane to return the liquid from the low cold end to the high hot end.

Impurities - such as a salt - must be added to the solution so that there will exist a concentration gradient across the membrane. The pure distilled condensate collecting at the low end will then be driven through the semipermeable membrane to re-enter the solution. Although I obtained a patent on this heat transport device (United States Patent No. 3,561,525), I am ashamed to say I never once tried out the idea.

## 4.9 BOOKS

Lawrence Henderson, *The Fitness of the Environment* (an inquiry into the biological significance of the properties of matter), The MacMillan Co.: 1963. Available as a Beacon Press paperback. It has an excellent section on the properties of water and is a book with a fascinating point of view. Henderson was a friend of Alfred North Whitehead.

J.C. Speakman. *Molecules,* McGraw-Hill: 1966. This covers some of the same ground as *The Fitness of the Environment.*



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# 5 HEAT EXCHANGERS

## Counterflow Heat Exchanger

There is no better place to educate yourself in the matter of heat exchangers than a junkyard. Heat exchangers, along with axles, pulleys and gears, make up a surprisingly large portion of the metal you find in junkyards. It would take several days to visit all the equipment, installed at work or displayed in a salesroom, that you can see, pick up, and closely examine in a few minutes at a large junkyard. (Most of the pictures in this section were taken at the ACME metal junkyard on North Second Street in Albuquerque.)

Unfortunately, heat exchangers are among the last things to catch the interest of a curious person poking around a junkyard. A broken or rusted-out radiator seems to be more thoroughly a piece of junk than a warn shaft or a sprocket with a bad tooth.

One danger in visiting junkyards is that it encourages backwards design. The pieces of junk suggest uses for themselves rather than the needs suggesting the design of the equipment. Sometimes an interesting visit to the junkyard proves to be emotionally tiring in the same way that a visit to the pound can exhaust an animal lover.

Axles transfer energy by torque. The rigid shaft, turned at one end, commands the other end to do the same. In heat exchangers it is again a motion transferred through metal. But in this case it is by a molecular trembling, heat passing through the walls and along the fins of the exchanger. It is simple to pass energy by turning a shaft. The forms suitable for exploiting energy transfer by rotation and reciprocation seem monotonous and restricted after having come to appreciate the beauty of heat exchangers.

## 5.1 HEAT CONDUCTION

Metals vary greatly in their ability to conduct heat. Below are listed various materials with the quantity of heat (in Btu) that will now through a one foot square, one inch thick sheet in one hour if the temperature on one side is one degree F. higher than on the other side.

***Co/J/Jcr*** *2700 Btu*

*Lrad 250 Btu*

*Cold 2060 Btu*

*Silver 2900 Btu*

*,<.inc 750 Btu*

*Aluminum 7500 Btu*

*Iron ,JOO Btu*

*Air ( still) 0.163 Btu*

*Water (still) 3.85 Btu*

*Oil (still) Btu*

*Class 5.8 Btu*

*Styrofoam 0.25 Btu*

*Class wool 0.25 Btu*

As an example of what these rates of heat now mean in terms of the strength of sunlight, we can see that a one inch thick piece of lead, to pass the heat of the direct sun through itself, would have to be only slightly hotter (about 1°F.) on the sunny side than on the shaded side, for the sun gives about 300 Btu per square foot per hour. Lead is a relatively good conductor. For this same quantity of heat to pass through a good insulator such as styrofoam, the temperature would have to be more than 1000°F. hotter on one side than the other, long before which the styrofoam would have burned up.

You'll notice in the headings under the pictures of the heat exchangers such titles as liquid-to-air, liquid-to-liquid, etc., but a glance at our list of conductivity of materials shows that air, water, and oil are all very poor conductors. So what sense is there in building a heat exchanger to pass heat to these substances when they can't move it once they have it? The trick is that these substances, gases and liquids, must now past or through the heat exchanger to make the exchanger function. For instance, radiators on automobiles rely on the radiator fan and the motion of the car to push the air past the cooling fins; in addition there is a water pump to circulate the water within the radiator.

This is usually the difficult part of the heat's journey - into and out of the exchanger, not through it. To accomplish this, pumps, agitators, and fans are used to keep presenting the surfaces of the exchanger with fresh matter to be heated or cooled.

It is quickly apparent after a glance at a liquid-to-gas heat exchanger that the transfer to gas is more difficult than to liquid; for much more surface is exposed to the oustide air than to the inner circulating liquid. All in all, the progress of heat into and out of a heat exchanger is like that of a jet traveller who must fight his way through traffic jams arriving at and departing from the rapid leg of his trip.

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I. **Liquid to air.** This is a section of fin tube. Every inch there are 4-1/2 fins, so that there are 27 square inches of fin per inch of pipe. The relative areas suggest how much harder it is for the heat to get out of the aluminum fins into the air than it is for the heat to enter the copper pipe from the circulating water.

It is also obvious that the heat has no trouble passing through the press fit from the copper to the aluminum. Consider the press fit. The coefficient of expansion of aluminum is .0000124 per unit length per degree F., while the coefficient of expansion of copper is .00000900 per unit length per degree F. It would seem that as the pair heat up, the aluminum fin would expand and part from the copper; if it does part from the copper, it will lose its source of heat and then cool and tighten again around the hot pipe. The relative coefficients of expansion of aluminum and copper would seem to leave the aluminum fin always somewhat uncomfortable and undecided about what to do. Actually, the aluminum has enough spring so that even when it is hot it grips the pipe firmly and continuously (even though we know it must have relaxed its hold somewhat).

It's possible that if we tried to move heat from the fins into the pipe, the hot fins would expand and never touch the cold pipe. Thus a mechanical heat exchanger could be a one-way heat valve.

## 5.2 THE WAY HEAT MOVES

Heat is measured in Btu or calories. It is a quantity like pounds or gallons; and, as with other quantities, you can point to something and say, "That contains so much heat." But with heat you have to be fast, for it is always moving from hotter to colder. It refuses to be domesticated to fit our usual idea of a quantity. It is rather like the animals you see at the zoo which still want to get out; and heat succeeds - slowly, if well guarded by insulation - but nevertheless eventually it escapes if there is a cooler place nearby.

You can take comfort in the fact that heat is not clever. It does not invent new ways to move; it cannot leapfrog barriers. It is always predictable.

Heat transfer is generally broken into three categories: conduction, convection, and radiation. We have listed values for conductive transfer and mentioned the function of convection in moving matter past hot or cold surfaces. Radiation is another powerful transfer mechanism wherever there are marked differences in temperature between two surfaces. All of our energy from the sun arrives by radiation. There is no material between us and the sun to carry heat by conduction or convection.

*0 e*--.---,-I - --*,ee-*

0 ° 40 ° 80 ° 120 ° 160 ° 200 ° 240°F

Radiant Energy From a Black Surface

2. Liquid to air. This is a part of a freezer compartment. Cold liquid circulates through the flow channels, cooling the metal plates.

This exchanger is made by bonding two formed pieces of sheet steel together. This kind of design is very suitable for solar heat collectors. Notice the larger header which feeds into many small channels.

3. **Gas to liquid.** A boiler. Hot gases pass through these pipes, from one end of the tank to the other, and heat the tank's contents.

4. Gas to gas. This exchanger is composed of hundreds of small (about 3/16 inch) tubes. One stream of gas blows across the tubes while the other goes through the tubes from manifold to manifold.

5 **Gas to gas.** This is the head of a piston. The finned head helps to dissipate heat by transferring it to outside air.

**6. Crankshafts amid other junk.**

# 6 HEAT COLLECTORS AND HOUSES

## 6.1 EARTH AS HEAT COLLECTOR

The earth that the sun strikes in the morning is an excellent heat collector; the heat is given to the soil itself and the air in contact with it. We are so used to this, and the resulting daily swing in temperature from the before da,-vn low to the afternoon high, that we don't.even think about it. Some of the light is reOected immediately back into space, and the earth itself radiates heat into space. Clouds act as blankets to retain heat. Clouds also act as reflectors to keep heat out. Cloudy days and clear nights drop earth temperatures rapidly. The rise and fall of temperature during the day is a good indication of the relative magnitude of the heat losses from the earth and of the heat gains from the sun.

Generally the highest temperature during the day is recorded in the afternoon; the temperature always begins to drop before the sun sets. The sun, when it drops below a certain angle, is unable to sustain the temperature. Evidently the rate at which heat is arriving is not so great as its rate of loss. The elevation of the sun above the horizon at the time of daily maximum temperatures indicates the amount of sunlight necessary to sustain these temperatures in our own gigantic static collector, the earth. These high temperatures and their associated angles can give us a crude answer to the question of how hot it might be in particular zones of exposure if the earth were to stop turning.

## 6.2 EFFICIENCIES AND LOSSES

When you first start playing with heat collectors you are often impressed with the qualities of the heat collector that turn out to be its faults. When something gets very hot it impresses you—later, when you are capturing heat and moving it somewhere or storing it, you will continually strive to keep collector temperatures as low as possible, while still having the heat be useful. High temperatures mean high heat losses.

The efficiency of a heat collector is judged by the percentage of the available energy that the heat collector absorbs. The main losses, the percentage not captured, consist of 1) the radiation that is reflected from the outside glass or the inside collecting surface back through the clear cover; and 2) the heat given off by the warm front glass or plastic glazing. There are also losses from the back and the sides of the collector, which can be decreased by adding insulation to these surfaces.

Like a parent checking the health of a child by feeling its forehead and looking in its eyes, one can judge a heat collector by looking for glare and feeling for hot glass. An efficient collector is dark and its outer glazing is cool. These are the only tests you need to make on a flat plate collector. Your eye or a light meter can be used to measure the reflection; and, by touching, you can distinguish between the warmer of two exterior glazings if you are testing different collector designs by racing them side by side. This is often the easiest way to test heat collectors - race them.

## 6.3 STATIC TEST

In a static test you do not take the heat away from a collector; that is, you do not store it in a large body of water or stone and you do not pipe it off in hot water or hot air. You let the heat build up in the collector and measure the temperature with a thermometer. This shows how hot the absorbing surface of the collector will get before the losses through the back, the sides, and the front glass equal the incoming sunlight. Never expect the outer part of the collector to get any hotter than other objects of the same color around it. They are all doing the same thing - warming in the sun until they reach equilibrium - giving off their heat as fast as they take it in. A flat plate collector is hot on the inside, never especially hot on the outside.

**Figure 1**

If two such collectors are put in a static test - facing the sun side by side in the same orientation - the double glass collector will reach a higher temperature than the single pane. (See Fig. 1) This is because the two layers of glass provide a better front insulation than one layer of glass. However, if you expose the two collectors at the same time you will notice that at first the single pane collector will be warmer than the double pane. Only later, at higher temperatures, will the double pane pass the single pane. The single pane is at first warmer because it admits more sunlight than the double pane, since the second pane reflects about 10% of the sunlight that passes through the first pane.

## 6.4 WINDOWS AND SKYLIGHTS

A window or a skylight opening directly into a room and oriented south with the appropriate tilt is a very excellent heat collector. Why is this so? It is very difficult for a ray of light, after it has come through a window, to find its way by reflection back out the window. Of course, if the entire side of the room is glass, then the geometry of the room is like that of a collector as in Fig. 1; and if part of a ray reflects from the first surface it is likely to escape back through the glass.

A room in which you wish to collect heat need not be painted dark colors in order to act as a very efficient absorber for the sunshine entering through relatively small windows. **A** succession of reflections where half of the light is lost each time soon absorbs almost all of the light.

The other method by which heat can escape directly out the front is by direct losses through the glass. This effect is slight in the case of a window, since its own temperature is near room temperature.

Curtains, blinds, and insulated doors on the inside or outside may be used for insulating windows and skylights at night. All these methods have been used in the past, but very little ingenuity has been applied to this very old problem. For some reason, generations of inventors, scientists, and architects all living in houses of one kind or another have evidently never noticed the problem.

It is very difficult for a ray of light after it has come through a window, to find its way by reflection back out the window.

## 6.5 THE BEADWALL

The ”beadwall” (patent applied for), invented by Dave Harrison, is an excellent method of preventing heat loss through a window. The first picture shows styrofoam beads being blown into the cavity between two clear glazings; the second shows them being sucked out. The power for emptying and filling is provided by an ordinary vacuum cleaner. The insulating value can be made whatever one wishes by increasing or decreasing the thickness of the space between the glass. The beads themselves are almost as effective per inch of thickness as the best commercial insulation.

Such elegant inventions as the beadwall indicate that the healthy response of architecture to increasing energy costs may be increased use of glass in building walls rather than a retreat to underground buildings. For more on the wonders of the beadwall see Zomeworks' beadwall plans and Harrison's forthcoming article in *Solar Energy.*

## 6.6 PROPER DESIGN AND MATERIALS

If you use windows or skylights for heat collection, where will you put all the heat? Fifty square feet of south-facing window in a 200 square foot room made of frame and stucco with a wood floor will soon become intolerably hot. On a sunny day, the windows may be admitting 10,000 Btu per hour; and this flood of heat will soon warm up the walls, the floors, and the furniture to an uncomfortable level. A large south window for such a conventionally constructed room does not make sense. It is difficult to keep the room in a comfortable range because the materials change temperature so quickly.

If, instead, the room has a brick or slab floor and adobe or brick walls, its temperature is slow to change. A 200 square foot concrete slab warmed 10° F. to a depth of 4 inches holds about 18,660 Btu. And, if the walls are also masonry or adobe, they will have a similar capacity to hold heat. If the room is 10 feet by 20 feet and the walls are 10 feet high, after subtracting the 50 square feet of south window, there are 550 square feet of wall. If each square foot can store about 100 Btu with a temperature rise of 10° F. (like the floor) we find that we do have the capacity to store the energy coming through the south window by warming the walls and floor.

The .Monte Vista Beadwall Greenhouse. _Top: Filling. Bottom: Emptying.

It is obvious that this scheme of utilizing solar energy coming through windows depends' on a temperature swing between morning and evening. The larger the mass within the house, the smaller the temperature s,ving required to absorb incoming heat.

In Albuquerque, if each room of a properly designed house is given a skylight or south facing window equal in area to 1/5 of the floor area, very little heating will be necessary during sunny weather in winter. What do I mean by ”properly designed”? That is designing the walls, floor, and their relationship to the south windows, skylights, or clerestories so that they may absorb the heat without making the room uncomfortable.

The floor should be brick, concrete slab, mud, or tile on concrete. Such a floor provides a large heat reservoir for a room. The floor should not be covered with carpets, since this insulates the room from its valuable heat battery. (A few rugs make little difference.) The floor should be insulated, not from the ground below it, for this adds to its capacity to store heat, but from the ground around it. This is most commonly done by placing rigid foam insulation to a depth of a couple of feet around the footings.

The inside walls should be of stone, adobe, brick, concrete, or containers filled with water. The outside walls should be similarly constructed but with insulation on the outside of the masonry. Dow Chemical describes ways to do this with their board insulation in Form No. 172-580-71. Another simple way is to build a separate wall on the outside of the masonry wall.

Many of the recently constructed adobe houses in Albuquerque have adobe for outside walls but frame walls on the inside. Adobe used this way makes little sense thermally. Adobe is poor insulation, therefore in this kind of house, the heat loss is great through the walls and the thermal storage is little better than in an ordinary house.

It is most important to have the walls that are exposed to direct sunlight be masonry or water since these are in the best position to absorb solar energy. But the flux of sunlight can be dispersed all through the room so that walls that never get direct sunlight nevertheless receive heat from the sun.

A general rule: the floor should be dark; the walls can be any color - except the walls with little thermal mass that are exposed to the direct sun, which should be painted a light color in order to disperse the heat to the other walls or the floor (where it can be absorbed over a greater surface area). The walls that the direct sun is dispersed to may also be light colored, since once the sunlight is inside the room it will be absorbed by the walls and floor regardless of their colors.

The direct sun should not strike a dark surface of small thermal mass because it will soon make this surface hot; the hot surface will heat the air, which will rise up to the skylight and lose heat to the outside. While this part of the room is hot, other parts are cold. It is true that if a dark wall becomes hot it will radiate its heat to the rest of the room even though no sunlight is reflected.

## 6.7 SOMETIMES THERMAL MASS IS A DISADVANTAGE

If you build a building as I have described, with great thermal mass in the floor and walls, then it will change temperature very slowly. What if you planned to use such a building only during the daytime? It wouldn't make a great deal of sense to store heat in the walls or floor since these surfaces would insist on heating the building all night long when you didn't need it. The simple methods of solar tempering that I have been describing make sense for houses, but not necessarily for shops, offices, and schools.

## 6.8 TEMPERATURE FLUCTUATION

What is it like to live in houses where the temperature changes during the day? What is it like to do without a thermostat to control the temperature within a degree or two? It is only very recently that there have been thermostats for controlling the temperature in houses; and still today almost everyone alive in the USA has spent some time in buildings without automatic thermostats.

I believe that it is perfectly satisfactory to have the temperature change during the course of each day, from a high in the afternoon to a low in the morning, and to have the temperature change from week to week according to how cloudy or sunny it is. The variations in temperature keep your blood circulating.

What extremes of temperature within a house are comfortable? In a dry climate like Albuquerque I believe year lows and highs of 55°F and 85°F are perfectly easy to live with inside a house—especially if you have warm spots such as fireplaces or stoves to stand next to when it is chilly. But what is the advantage of having temperature variation within the house? The advantage is not that such a house places you at the lead in some kind of contest; rather, it is the advantage of *not* going to great lengths - as most present day heating and cooling systems do - to achieve something that you don't really need or enjoy that much. Now that all of us are plagued with the pollution resulting from the overabundance of devices we have purchased, perhaps government or church groups should sponsor a series of "you don't need it" commercials. Instead of the bright uniformed "service personnel" of the Ace Air Conditioning Company briskly delivering and installing the latest gadgets, the commercials would show the expensive equipment misused: a bored housewife growing geraniums in her new dishwashing machine; a small child casually dismantling a TV-stereo combo with a claw hammer.

## 6.9 REPTILES NEED MAMMAL HOUSES

The reptile is at a disadvantage because he cannot regulate his body temperature, but, instead, equilibrates near to the temperature of his surroundings. If it is cold he cannot think or move fast. The regulatory function of the mammal is a great advantage since he can keep his body temperature constant.

Does this apply to houses and temperature regulation? Is it the same kind of improvement when a thermostat and gas heating system are installed? If the temperature outside one's body - the temperature of the house - is regulated to within 1/2°F., of what use is the sophisticated temperature regulating metabolism of the mammal? Obsession with temperature control seems more like Reptile Technology than Mammal Technology. The reptile badly needs it - the mammal does not.

This leads to the general question of what view one should take of equipment manufactured to do for you what your body is equipped and prepared to do for itself. Certainly we are all grateful for the discovery of fire, but the thermostat—I don't know. A persons' body has already incorporated the muscles, organs, etc., to steer him through dangers and difficulties. Yet we cleverly make them unnecessary by an entirely new level of design and invention. What is the result of this?

The now unnecessary organs are not removed from the body; instead they are simply unemployed - hanging around, so to speak in one's body, talking to the brain, being fed by the heart and bloodstream.

For the utmost in design I can imagine the equipment manufacturers' surgical teams removing now unnecessary organs with the installation of their automatic control systems. Perhaps the now outdated glands and organs could be sold to reptiles on another planet.

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# 7 FLAT PLATE COLLECTORS

Although I have been stressing the efficiency of the window or skylight as a heat collector, in solar engineering these two are not usually spoken of as heat collectors. The term is usually reserved for panels through which a liquid or a gas flows to pick up the heat. These panels are called flat plate collectors.

The most common form of flat plate collector consists of a flat sheet of metal facing the sun, with tubes bonded to it by solder, welding, or other means. Liquid is pumped or flows by natural convection through the tubes. The sun warms the plate, the plate warms the tubes, the tubes warm the liquid. Heat only flows from warmer to colder, therefore we can backtrack through the argument - the pipe is hotter than the liquid, the plate is hotter than the pipe, and the more distant the plate is from the pipe the hotter it is.

After sunshine falls on the plate it either finds its way into the liquid or escapes from the collector out the front through the glazing, through the back, or through the sides. A collector is a heat trap. If we put a pane of glass over the front this makes the heat we have caught less likely to escape once it is trapped, but it cuts down by about 10% the amount of energy that reaches the collecting surface. Usually this is worth it. ;\n ideal way to collect energy is at a low temperature - if possible at a temperature below air temperature. In this case you would not want any glass over the collector because the air movement across the collector prevented by the glass would be bringing new heat to the collector rather than taking it away. This situation often occurs with swimming pool solar heaters.

## 7.1 SWIMMING POOL HEATERS

A pool may be uncomfortably cold during warm weather because it is cooled by evaporation and/or chilly nights. Pool temperatures can be raised considerably by covering them with a sheet of plastic when they are not in use. The plastic prevents all evaporation, changing a wet sweating surface to a dry plastic skin.

Paul Sturges in New York has made several swimming pool heaters which are not exposed to the sun and also have no heating elements. They are exactly like car radiators: the pool water flows through the radiator, the water is warmed by the air. Such a device collects solar heat from the entire neighborhood where the air has been warmed. It of course only works when the air temperature is above the pool temperature; but at such times a pool left alone may actually be losing heat by evaporation, especially in places like Albuquerque with low humidity. The wet bulb temperature in Albuquerque (the temperature a moist surface will reach) is almost always below 70°F, even during the hottest days of the summer.

## 7.2 SOME COLLECTOR COMPARISONS

(Note: all drawings are cross sections.)

(I) and (2): (2) is better than ( 1) because the tubes are more frequent and the heat docs not have so far to travel to reach the liquid.

(2) & (3) - (3) is better than (2) since the tubes in this case are placed in front, directly in the sun, and thus some of the heat needn't take the detour through the plate.

(4) & (5) - If you are exposing a certain area to the sun it is best to make the side insulation thin, perhaps 1 inch, rather than thick, since the area is more useful in picking up heat itself rather than protecting the loss of heat picked up somewhere else.

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6. & (7) - Sometimes (6) is better than (7). Sometimes (7) is better than (6). Generally, if the collector temperature is more than 100 ° hotter than outside (6), double glazing is best.

7. & (8) - Generally (8) is better than (7) since there is liquid circulating directly behind the collecting plate everywhere.

(9) & ( 10) - Generally (9) will be a better collector than (10). This is because collectors grow cold or fall asleep when the sun goes behind a cloud or during the night. A heavy collector with a large mass of water has a great deal of heat to lose as it assumes the temperature of the air around it. Then when the sun comes up it takes a long time to wake up, for its mass must be warmed up above the useful collecting temperature before you circulate the liquid through it.

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Each layer of water 3/16 inch thick weighs approximately 1 pound. If a collector has much more mass than this it is probably too heavy to be effective on days when the sunlight is intermittent.

In trying to decide the best kind of heat collector to use, all this advice may be wisely disregarded if a collector that does not follow these lines is cheap and/or easy to build.

## 7.3 HEAT COLLECTORS MUST BE AWAKENED IN THE MORNING

Everything in the collector has to be warmed up in the morning to a useful temperature, only to cool back down again at night. This is wasted heat. Often this warming must occur more than once a day since clouds frequently interrupt the sun and let the collector cool during the day. If you multiply the weights of the parts of a heat collector by their specific heats you can calculate how much heat must be invested in warming a collector up in the morning.

A heat collector for a hot water heater may fall to 15°F during the night and have to rise to 115 F before it contributes any heat to the tank. Thus, if there is a thermal mass in the collector equivalent to a sheet of steel Vi inch thick, 100 Btu/day will be used just to wake up the collector in the morning. Intermittent cloudiness can cause frequent minor versions of this throughout the day.

One standard design of heat collector is a sheet of corrugated galvanized iron riveted to a flat back-up sheet and with headers at either end. This is a very efficient collector design. The heat must never travel any farther than the thickness of the metal since liquid is circulating behind the entire sheet. The one drawback this design has is that there is considerable thermal mass.

## 7.4 HEAT CONDUCTION THE MORE THE BETTER

When you are designing something it is important to know what you must be careful about and where you needn't be careful. Rafts are extremely simple to build. You can add anything you want—so long as it will float.

Bridges are not like rafts; enough weight added in the wrong place can break the bridge. Building a heat conductor is more like building a raft than a bridge. Anything added in parallel to a path along which heat is being conducted is an aid to the transport of the heat. So that in fabricating a heat exchanger, if you had some scraps of metal left over, you might just solder or weld them on the exchanger rather than throw them away.

## 7.5 SACRIFICED HEAT

What happens to sunlight that enters a solar collector but doesn't hit the metal conducting surface of a flat plate collector?

This is a common occurrence in collectors since there are usually spaces at the edge of the collector and perhaps spaces between separate metal panels. One needs to know how careful one must be. Can these spaces be large, or is that wasteful? You often hear people mention that the energy falling in the spaces heats the flat plate collector anyway. There are many circumstances: sunlight entering a cavity, being absorbed, and reradiating to the flat plate; sunlight entering a cavity and reflecting back into the flat plate, etc. I am going to consider only the case of sunlight absorbed by a black non-conducting material on the same plane as the flat plate, as in the diagram.

The heat picked up in small gaps cannot itself flow into the circulating fluid but instead is sacrificed in heating the glass. This allows some of the energy that falls on the collector to be picked up by the circulating fluid rather than lost to the glass.

Heat gain by fluid= sacrificed heat x Uo / (Ui + Uo). Uo is the J factor between the glass and the outside; Ui is the U factor between ;he flat plate and the glass. (This equation will be explained in more detail later.)

Why can't this heat, or part of it, be collected directly? In such a collector, under normal circumstances, the outside air is colder than the glass, the glass is colder than the inside air, and the inside air is colder than the flat plate. A gap between flat plates, although it will become the hottest place in the collector, has no way to give its heat directly to the flat plate. It cannot ”see” the flat plate and thus radiate heat to it because the flat plate is beside it rather than in front of it. (This, of course, is a special case. Usually there is some radiation to the metal collector.) Because the black material is non-conducting, it cannot conduct heat to the flat plate. Instead these hot spaces heat the air they are in contact with by conduction and also the glass in front of them by radiation. Both the air and the glass are cooler than the flat plate. The heat given to them cannot now uphill to the collector. Thus, all of this heat is eventually sacrificed in heating the glass. The energy absorbed by the pane of glass as the sun passes through it is also sacrificed and is therefore useful in the same proportion as the above fraction.

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Exactly how much does this energy reduce the loss by the flat plate, assuming the flat plate remains at the same temperature T? We determine this by finding the equilibrium temperatures of *the* glass when I-Is and when Hs= O. Hs is *the* energy introduced to *the* glass from a source other than the flat plate, measured in Btu/square foot/hour. To is the outside temperature.

**(Tf-Tg) Ui + Hs = (Tg-To) Uo**

**-TfUi + TgUi-Hs =-TgUo + ToUo**

**Tg(Ui + Uo) = TfUi + Hs + ToUo**

**Tg _ TfUi + T+oUo + Hs**

**- Ui Uo**

6Tg = **Hs**

**Ui + Uo**

Heat saved by sacrificing Hx= UiHs /(Ui + Uo). Typical values for Uc and Uo would Uc = I, and Uo = 2, so that the cracks between the collecting fins would be only 1 /1 +2 = 1/3 as efficient as the rest of the collector. *I*| ½ inch wide gap around the perimeter of a 4 square foot collector amounts to about 4% of *the* total area, a sizeable loss, which should be taken into consideration.

## 7.6 TRAPPING SUNLIGHT

The performance of gaps can be increased by indenting the insulation behind the gaps so that the ray of sunshine heats a space much of which is bounded by the collector fins. In this way some of the heat can flow directly into the collector fins.

Glazing for the collector should, whenever possible, be lifted slightly off its supports by spacers so that the area taken up by the supports is largely used as a collector rather than becoming a dead spot.

**Racing two air collectors**

Corrugated steel (left) 5 layers of expanded metal lath (right)

Air from mesh collector ran about 10°F hotter than corrugated collector while cover glass for mesh collector was about l0°F cooler. 10:00 A.M. 22June 1972

**Bread box water heater**

Reflectors wrap the sun around tanks. Insulating doors are closed at night. Tanks are plumbed in series.

32 ft flat plate collector for 50 gallon water heater. Insulated lines connect ro jacket heat exchanger which surrounds water tank.

# 8 AIR LOOP ROCK STORAGE SYSTEMS

Much work still needs to be done on the behavior of convective air loop rock storage systems. The way they work flies in the face of the typical air conditioning engineer who can't believe such systems could operate without fans.

At a solar energy conference in 1968, Farrington Daniels men tioned the letters he had received from someone in New Mexico building solar chimneys that pushed air through rock storage bins. He was told by an engineer in the audience that the chimneys would have to be as tall as the Empire State Building. I was very pleased to report on the performance of the just-completed Drop City heater where the chimney was only 14 feet high.

More recently, Paul Davis and I were told by engineers at the Los Alamos Lab, who have been studying fan-driven air loop rock storage systems, that convective systems were "way down in the mud," with little to recommend them. Paul Davis' house is heated by such a system and functions satisfactorily with no fans. After talking to the Los Alamos group we found that they had never actually ex perimented with any rocks but instead were using only computer simulations.

I can't help dwelling on these petty slights at the hands of the engineers, probably because there is an element of truth to what they say. Designing a convective air loop system is a somewhat tricky and difficult task. If you aren't very respectful of the will of the air, the system won't work.

Drop City air loop rock storage heater The collector should have a great deal of surface area through which to transfer heat to the slow flowing air stream. We have found that multiple layers of expanded metal lath work well for this purpose. The flow channel within the collector should have a large cross section so that even at slow velocities enough air moves co transport the heat. The rocks should be arranged so that they place little resistance in the path of the air.

During experiments at Zomeworks in 1969 we were able to demonstrate that, with a collector and storage bin at the same elevation, it is possible to store an average of about 750 Btu/square foot during December weather in Albuquerque. I believe this can be greatly improved. Readings on the Davis convective system indicate an average collection of above 1000 Btu/square foot per day.

It is very easy to measure collection efficiency and quantity of heat stored in water systems: a tank of water can be mixed and its temperature measured with one thermometer; with air and rock systems you need numerous temperature probes that can be placed within the rock bin.

All of our experiments have been done with crude instrumentation;

because of this we have not yet done a thorough report on such systems. In 1973 we applied to the National Science Foundation for a grant of $30,000 to do a complete study of such systems but were turned down. \1Vhen I mentioned this to some acquaintances who work at the Sandia Laboratories and Los Alamos, they comforted me by telling me they had their first two proposals to NSF turned down also. A day or so later I realized that we taxpayers are paying the bills for both groups as they submit and reject proposals to one another.

## 8.1 SOLAR CHIMNEY

Air heated by the sun in a sloping, glass-covered channel acts like air in any chimney - it rises. But solar chimneys differ from other chimneys. The heat is added to the air as it travels along the chimney rather than at the bottom. This complicates chimney design. In a normal chimney you have a round channel With smooth sides so that the air may flow quickly to the top. A solar chimney would like to be this same shape, but it must also collect sunlight and transfer the heat to the flowing air.

**Figure 1**

There are contradictions that must be balanced. You want to put surfaces in the path of the moving air in order to transfer heat; but then you are sorry to have to do this because the added surfaces in the flOW channel slows the air down.

The air has a limited budget of energy that it can spend circulating itself from one place to another. It is fairly easy to calculate what this is. The air is warmed as it rises in the solar chimney and it is cooled as it descends through a storage bin. The difference in the average absolute temperatures on the two sides of this loop creates the

**Bernalillo, New Mexico, 1967. This 80' long solar chimney was constructed of auto backglasses placed over a 42" wide trough with an insulated black bottom. The chimney fed into the top of a *50* cubic yard rock bin underneath the zome at the top of the hill. There was no return air duct. Fresh air was drawn in at the chimney bottom. After the air had travelled through the rock bin it left by a 2' wide pipe connected to a plenum at the base of the bin. The system never worked properly because it was poorly insulated. A few months after the chimney was completed people began removing certain backglasses and then later vandals shattered m any others.**

The pressure drops through ventilating ducts and other resistances to atmospheric air arc normally given in inches of water. Inches of air become the natural units for the solar chimney designer. It is very convenient that water weighs 62.5 lbs per cubic foot ,incl air weighs about 1/1000 this amount.*

Example: if a solar chimney is 8 feet high, the average temperature of the air rising in the chimney is 130°F., and the average temperature of the air descending on the storage side is 90°F., then the pressure difference driving the loop is 5**4**4**0**0 x 96 inches ::: 7 **inches** of air, or about .005 inches of water. Unfortunately engineering tables rarely give figures for flow rates with such low resistances.

**Figure 2**

Convective systems balance themselves. The chimney side will continue to increase in temperature until the air flow increases enough to carry away the heat from the collector. IF IT IS SELF BALANCING, 'A'HAT'S THE PROBLEM?

A poorly designed convective air loop system may have to get so hot in order to transport heat to storage that the collector losses become large and the whole system becomes inefficient. The problem is how to have low resistance to air flow and also to have rapid heat transfer from the collector to the air and from the air to storage.

- At sea level, air at J 75° F. weighs .0625 lbs./cubic foot. At 5000 ft. air .it 62° weighs .0625 lbs./cubic foot.

## 8.2 CHIMNEY DESIGN

We have found that multiple layers of expanded metal lath work well as heat exchangers in convective systems. The sunlight filters through the layers and warms up each of them. Heat is transferred from the sunny exposed spots in the matrix to the shaded parts, so that the entire surface transfers heat.

Each square foot of lath (counting both sides) has about 3/4 square foot of transfer surface. We have successfully used 5 layers of mesh. Counting the channel back and sides, the total transfer area to the air stream is about 5 square feet per square foot of glass.

The U factor between the slow moving air and the mesh is probably only about 1.5. The .6.t between the mesh and the air when the solar flux equals 240 Btu/square foot/hour is then equal to 32°F.

The mesh should be placed diagonally across the collector so that the rising air must flow through it before it leaves (see Figure 3.). The mesh can also be placed in repeated diagonals (see Figure 4.). I do not know which arrangement is best.

**Figure 3 Figure 4**

## 8.3 BOOKS

For more on heat transfer in rock piles see D.J. Close, "Rock Pile Thermal Storage for Comfort Air Conditions," *Mechanical and Chemical Engineering Transactions of the Institution of Engineers, Australia,* Vol. MC 1, No. 1, May 1965, pp. 11-22.

## 8.4 DESIGN TIPS

1. i***1*** 1 ake d = at least 1/15 L.
2. Make rocks (h) 2 feet deep if small gravel (1") and up to 4 feet deep if large rock (6").
3. Make collector slant at least $45^{\circ}$.
4. Insulate storage box with at least 6 inch batt.

5. efake collector at least 6 feet long.
6. Keep all flow channels at least 1/15 of collector area.
7. Avoid corners in flow channels.
8. efake storage cross section at least 2/3 of collector area.
9. Insulate divide between down flow and up flow with at least inch duct board.
10. Double glaze collectors if 7000 degree day climate or more.
11. Hand place rock if possible to avoid layers of dirt in bin.
12. Place all of storage rocks above collector.
13. Build house above storage bin.
14. Build vent flap at top of collector to open during summer to prevent overheating.
15. Heat house with trap door to rock bin and duct to cold under for return air.

(Most of these rules are probably too strict while some may not be strict enough).

# 9 ENGINES

If you want to move something or turn something you have to either do it yourself, get another animal to do it, or use an engine. Engines and mechanical power are a big factor in our lives. It seems to me we should be building many varieties of engines today to see which ones people get along with, which ones are more trouble than they are worth, and which ones are too dangerous. There are some things which people will do without in order to be free of fear or in order to be free of control by others.

Perhaps someday mechanical energy will be hard to get; today no one seems to know what will happen after oil and coal become scarce. Probably windmills and perhaps also solar-powered engines will then be widely used. Cells which convert sunlight to electricity, such as the silicone solar cells, may become much cheaper and more widely used, but then again they may not.

I feel very comfortable with equipment which is simple, easy to understand, and easy to repair. I feel uncomfortable with equipment which is complicated, dangerous, and requires enormous varieties of parts. I feel a love toward waterwheels and windmills, but I fear nuclear power plants. I believe most people agree with me.

Directly solar-powered engines are very interesting. When you design such an engine you create a kind of mechanical empire where in order for the engine to be successful there must be the proper relationships among the society of parts. The density of sunshine and the cost of intercepting it set the limits, which must be carefully respected.

Most present day heat engines are unsatisfactory when they are coupled to solar collectors because there is no understanding between the collector and the engine. I believe that in successful solar engines of the future there will be mixed roles for the components. Many of the functions that now take place in the tiny spaces of today's engines - such as expansion and compression of gases and heat transfer to and from regenerators - will take place throughout the entire collectorengine: the design we might get if one of today's solar heat engines had its collector walk out on it with the words, ”Go collect your own heat. I'm sick of working for you,” and the engine did just that - its various components bloating until they themselves intercepted the necessary sun.

## 9.1 GRAVITY AT WORK

Gravity is the most beautiful of forces - it never sleeps, it never forgets you - it spends forever attempting to finally rank everything within its field - heavier down, lighter up. While it is slowly shifting mountains or bringing rotten branches to the ground, it is also shaping clouds in the sky above them. It takes on the shortest and the longest jobs, holding the moon forever in its orbit or bringing down another raindrop. When a scale says ”no springs” you have confidence in its accuracy because masses are pulled by gravity balancing against other masses pulled by gravity.

A gravity engine is an engine that relies on gravity to function - it is not a perpetual motion machine any more than an engine which uses a flywheel or a spring in its mechanism is a perpetual motion machine. Gravity engines don't run off gravity, but they need it to function. Gravity is a necessary but not sufficient condition for their operation. Gravity engines require a certain orientation of their parts; they use gravity as a gigantic spring to push and pull against. This spring doesn't wear out; nothing can slip past it; it is free. It is an energy bank that can't be robbed; it always gives back all of what you gave it.

Gravity engines would not work aboard a spacecraft. An electric motor attached to a battery, a gasoline engine, or a turbine would work. Hydroelectric power plants are gravity engines; waterwheels are gravity engines, too. Wind is part of the most enormous gravity engine. Probably the most fascinating gravity engines are convection engines, which are discussed in a later section.

I would like to suggest that some species of solar-powered gravity engines may be particularly useful and pleasant. They would be stationary, but this might turn out to be a relief to almost everyone. I think the divir.g engine is the most promising of the gravity engines to be shown here. There are many different forms in which it can be built. They are easy to construct and easy to repair.

I am afraid a commercial market for something as big and bulky—however silent and long-lived—as the diving engine is more than a few years away in the USA; but this may not be true in other countries. Our luck at Zomeworks with proposals to the National Science foundation has been 0 - actually less than 0 figuring the time wasted writing proposals. Who will step forward to pay for the development of something as unfashionably slow, huge, and silent as the diving engine?*

## 9.2 THE PATENT OFFICE

In the spring of 1973 I visited the U.S. Patent Office at Crystal City, Virginia. The patent office is like a mixture of a public library and a pool hall. The men searching the shoes (that's what the files are called) are largely in late middle age or old age. They are stooped; many have mustaches, pot-bellies, and bald heads. Unlike people in a library, they do not work quietly unless they have no reason to make noise. They call out to each other and speak loudly while standing next to others ,who are reading. At first I was shocked that they made no effort to keep quiet. But later I realized that there were very few people there who needed it to be quiet. Most work in the patent office consists in flicking through endless stacks of patents glancing at the illustrations.

I felt a kind of numb hopeless weariness after two hours of sorting through the shoes. What about these men who spend thirty or forty years here? They all stoop - first it is just in their faces; but by the time they are thirty-five, both the face and posture have slumped. How else could the patent office be? Who else would the patent office attract?

Einstein worked in the Swiss patent office, which I puzzle about.

In my day and a half I. found several patents on perpetual motion machines in the no. 60 class. They may in fact have been perpetual

- This last winter and spring under a contract with OPTII, we have made considerable progress with the diving engine.

motion machines to be used as paper weights or bird cages or something of the sort, that finally allowed some man to have a copy of his dreams placed in the patent office. But the illustrations were of machines that were powered from the forces of ”gravity and bouyancy.” I questioned an examiner sitting next to me, and he admitted that some such patents slip through. He remarked, ”What harm can they do?” with which one must agree,

I also discovered two patents issued in 1972 and 1973 which had whole drawers full of prior art already describing exactly all their features. Since one had to do with an idea I was experimenting with, I brought it to the attention of Mr. Ostrager, who was assistant examiner in the case. He was surprised; and he pointed out that the prior art I'd found was in section no. 60–22 which, as noted at the top of the new patent, had not been searched. They missed it! All this leads to a lack of faith in the patent office. The examiners do not seem alert or diligent; but, perhaps more important, they are friendly. Their rooms are decorated not like men's offices in a business, but more like temporary offices in the military - a guard house or a CQ's office. They tape pictures on the concrete block walls in an attempt to crud over with personal signs a powerful and permanent superstructure which they feign a distance to, but nevertheless are completely dependent upon.

The patent shoes with old patents were ragged and torn. Certainly with our present state of technology the patent office could be indexed and cross-indexed and preserved on microfilm - as I am sure it will be - but there is an attraction in the tattered papers, the ·old stooped men slapping each other on the back, and the jive-talking black secretaries and clerks.

Most of the secretaries are young black girls who, I am told, were hired after the riots in the 1960 's. They don't make as much noise as the old searchers among the shoes, but they are always talking spade jive talk. Again, like the examiners, they are friendly. Rather than being officious, as you'd expect in a place like the U.S. Patent Office, the black secretarial staff is perceptive and human. They don't give a damn about patent numbers. At least 25% of my orders for copies of patents have been filled by the wrong number patents. It's interesting reading anyway.

U.S. patent laws seem to me to be very good. They encourage openness and quick disclosure of new ideas. You can publicly disclose an idea and still have a year in which to file a patent (which I may do with the diving engine). Many countries have laws which force you to keep your work secret until you have filed a patent. Unfortunately filing patents is expensive and it is almost never worth the money. Even if you do get a patent it doesn't mean much until you have defended it 111 court. Patents are often granted when they shouldn't be; and this comes out when a patent is challenged by people who have done their research.

## 9.3 ISKE ENGINES

(I don't know if this is the proper name. I doubt that he was the first to invent them, but he was one of the earliest.)

**Figure 1**

Here is a gravity engine patented in 1882 by A. & A. Iske. A series of pairs of chambers are connected by tubes across the diameter of a wheel. Each chamber is heated when it is at the bottom of a revolution. Vapor forms in the liquid and the vapor pressure drives the liquid to the other chamber at the top. The weight at the top proceeds to turn the wheel. It is like a water wheel which supplies itself with its own water. No engine of this type can function well unless the containers and connecting tubes are purged of foreign gas - leaving only the working liquid and its vapor inside the containers.

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This device has been invented and reinvented for years. The most recent patent that I saw issued for this idea was no. 3,659,4 I 6 - 1972. It would be nice if these engines, solar-powered, were used to run clocks in public places. Then their delightfulness could be appreciated by all. And ingenious inventors, assured that the idea was already born, wouldn't need to reinvent it.

This type of engine is extremely inefficient since the bubble of hot gas that expands, pushing the liquid upwards, can't expand until the container and the liquid are heated. Likewise the top container and the liquid entering must be cool to allow the previous old bubble, born 1/2 a revolution before, to condense.

This is an enormous amount of heating and cooling to lift a tiny amount of liquid. One could move towards greater efficiency in such a design by using lightweight containers, large diameter wheels, special liquids - even some very special heat exchangers could be employed. But I think it is best left alone to be inefficient, very reliable, and intriguing. What turns it? If, for every action there is a reaction, where is the reaction to this wheel turning by itself?

Stronger gravity could make these engines more efficient, because, with every cycle of vaporization in the bottom cylinder and condensation in the top, there would be a greater reward in the delivery of the now heavier liquid in the top container. With stronger gravity the bottom container would, it is true, have to be heated to a slightly higher temperature. But we haven't struck at the basic flaw in the design, which is having to heat and cool so much mass just because it is in contact with what we are interested in. Later I will show a design which solves these problems.

## 9.4 THE DIPPING BIRD

***B1RD 0\JH!)S***

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**DR>J... e uc:.1<.. e &, 1-11-** The dipping bird is also a gravity engine. It is similar to the Iske engine, but it is much more efficient, because the boiler stays the boiler and the condenser stays the condenser. This is a big gain over the lske engine where the same containers are both boilers and condensers. With the dipping bird, we don't need to throw away energy heating the condenser every cycle so it can become a boiler and vice versa. I think there is promise in the dipping bird as an engine. Some of the problems are: 1) purging containers of foreign gas; 2) sealing containers; 3) building containers large enough to deliver useful power that can still withstand the crushing pressure of the atmosphere; 4) wasting boiler gas when the bird dumps; and 5) drag of liquid through pipes.

## 9.5 BUBBLE WHEELS

Bubbles are like negative weights - they rise in liquids with a force equal to the weight of the liquid they displace. Figures 3 and 4 are examples of bubble wheels, which can be used to produce mechanical energy. The great disadvantage of these devices is that the top condenser keeps receiving heat which has in no way contributed to powering the wheel. Only the vapor from the bubbles should be allowed to condense. The other flaw in these designs is that pressure increases with depth, and thus it is harder to boil liquid at the bottom of a deep container than it is at the top. This design stirs the liquid continually, keeping a fairly constant temperature, and thus promoting the formation of bubbles near the top that won't deliver work by flowing into the rising cups.

**Figure 3**

One partial remedy to the inefficiencies of the bubble wheel is the two-liquid bubble wheel. Here there are two immiscible liquids such as hexane and water. The liquid with the higher boiling point is used as the bath for the wheel. The other liquid is used as the propellant. In this way boiling at useless points in the bath can be prevented and the machine can be turned on and off, or its rate controlled by the valve shown.

**Figure 4**

It is simplest with such engines if the propellant is lighter than the bath; this prevents it from ever stalling by finding a cool position at the bottom of the bath and settling there. If the propellant is lighter than the bath, as hexane is lighter than water, it will float on top of the bath even after the engine has stopped - waiting to respond to the first heat introduced to the bath. A light propellant must have a tall tube below the condenser in which it can build up head and force its way into the bath. In a sense its trip as vapor to the condenser is like the power stroke of the more conventional feed pump in a steam engine.

The bubble engine becomes more efficient as it becomes larger and also as the vapor pressure of the bath decreases. Its efficiency is also controlled by the difference in temperature between the bath and the condenser. But these mechanisms are helpless to exploit the efficiency available past a certain point. The pump version of the same idea, shown below, could be useful in solar heating systems that re

**Figure *5***

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What is wrong with the bubble wheel gravity engines? They must turn through baths, and baths have a great deal of resistance. The wheel in the bath must turn very slowly or there will be a great deal of friction. When the wheel slows, the friction disappears and the efficiency rises, but the rate of delivery of power falls.

The engines shown in Figures I through 5 require clean tanks purged of foreign vapors. They require some method to transport mechanical energy through the wall of a closed container. There exist good seals that allow, this with little friction; and there are magnetic couplings that transport torque without ever so much as suggesting a place for a leak. But they aren't that easy to make. There is also the danger of explosions if the engines are overheated; and liquids like hexane can burn. The true spirit of the gravity engine will not tolerate such fussy techniques as vacuum purging and vacuum seals or such vulgar dangers as explosions and fires.

## 9.6 DIVING ENGINE

As the flywheel spins the pistons go up and down. The hot piston is placed ahead of the cold piston when the wheel rotates. When both pistons descend the hot piston is ahead of the cold piston.

**COLD**

**Figure 6**

The air is free to pass between the two pistons and, in the cold piston (because it is higher than the hot piston). This is what we want: the air compressed in the cold cylinder. At the bottom of the revolution the cold piston comes even with the hot piston, passing the air to it through the regenerator. The air then rises in the hot piston where its volume and thus its buoyancy are increased. The difference between the work required to compress the gas on the cold side and the work available from the larger rising bubble on the hot side is the If the temperatures are low the volumes found at equal depths on the hot and cold sides are nearly proportional to the absolute temperatures of the two sides. As the temperature goes up so does the vapor pressure of the water. The air is invaded by water vapor and the bubble swells rapidly. J\t atmospheric pressure a saturated with water vapor will be 50% larger at 140 quantity of gas

F. than at 60F working at such temperatures, the engine takes on characteristics of a steam engine rather than a hot air engine. If this is undesirable, the pistons can be enclosed in a bag of another liquid with less vapor tm.

Regenerator: the air passes back and forth between pistons. Each it tries to cool the hot piston and heat the cool piston. This process is useless to the engine and a waste of energy. A regenerator along the tube corrects this by robbing the gas of its heat as it flows toward the cold piston, but returning it as it flows back. And, likewise, in a wave at the other end of the same regenerator, cold is being stored as the gas moves to the cold piston. The regenerator also alternately humidifies and dries the air. Hot, moist air passing to the cold piston condenses its water within the regenerator. On the next stroke cold air passing to the hot piston picks up the heat and water together. The engine will run without a regenerator, as we proved with the engine constructed at Zomeworks—but it cannot attain great efficiency.

In some ways a regenerator seems to work in defiance of the laws of thermodynamics, for it steps in and very simply and positively transforms the entire cycle of a hot air engine. The universe trains us so well to expect things to run down—hot mixing with cold to with the retention of heat.

**ADVANTAGES**

What are the advantages of the engine I have described? This is very difficult to discuss. Perhaps there are no advantages whatsoever. Perhaps the drag of parts moving in water will be so large that it couldn't possibly make sense. And aren't there always unforeseen difficulties?

The engine uses some of the same parts for different functions. The cylinders in which the pistons move are also the heat or cold storage tanks; the cylinders themselves can be the heat collectors or heat radiators, by using movable insulation in front of them. Such techniques have been proved to be successful. The engine can be turned by outside power, such as the wind, to store heat, for the engine can be an efficient heat pump.

The pressures everywhere are low. The temperatures are also low, typically under 160°F. The components used are familiar and don't require research to fit them for unusual stresses. The cycle is simply one of heating and cooling air and evaporating and condensing water.

The noises such machines make are slow and peaceful: gurgling and thumping noises rather than high speed whining noises. The parts are easy to repair - some tape, some solder, a stick whittled to shape, some chewing gum.

This is the kind of technology that doesn't depend on long chains of other specialties for its day-to-day survival. Of course, it's true that if the engine includes sheet metal, you won't be able to build it without steel mills (but why not make the steel mills as small as possible?).

A recurring problem with heat engines is the heat transfer to the working gas. The normal stroke of an engine occurs very rapidly and the surface area available to give heat to the gas is limited. Consequently, you pay for high temperatures but aren't given the efficiencies you pay for. With the type of engine described here, the inside of the pistons can be filled with what we have named ”seaweed,” a material that dangles inside the cylinder to promote heat transfer and rapid vaporization of water. The ultimate enemy in such an engine is drag. Bill Mingenbach has suggested using a ”seaweed” that would float inside the pistons and, thus, not retard the filling or emptying of the pistons.

What brand of engine is this? It has similarities to the famous Stirling engine, where gas is passed back and forth between hot and cold pistons through a regenerator. But it differs from the Stirling engine in two respects. The gas is passed back and forth through the regenerator at approximately constant pressure rather than at constant volume as in the Stirling engine. What does this mean? the Stirling engine the gas is caged between two pistons as it passes through the regenerator. If it is heated the temperature rises, but the volume does not change. In our engine, as soon as the gas is heated it begins to expand because the liquid surrounding it cannot confine it with a force greater than that given by gravity. The other difference is the presence of a liquid and a vapor and the use of evaporation and condensation to exaggerate the expansion and contraction of the bubble. The cycle in the engine is perhaps most similar to the less well-known Ericson engine, where hot air is sent through a regenerator at constant pressure rather than constant volume.

**EFFICIENCIES** Let us assume that we can capture 2000 Btu/sq ft as heat in a solar collector. (This is very optimistic. It’s a good number for us to take because it puts a high energy density demand on the engine.) Let us also assume that because of the cold tank and hot tank temperatures, we should be able to convert 15% of the heat energy to mechanical energy. We don’t expect to get all the 15%—in fact, we should be happy with between 5% and 10%—but it is a good figure to use to see what demands the engine should meet. A 15% maximum possible conversion corresponds to the following pairs of hot and cold tank temperatures

*Winter: Summer:*

*in accordance with Carnot’s*

*45 °*

*135 °*

*70°*

*165 °*

*F. (sink)*

*F. (source) F.*

*F.*

$$E_{max} = \frac{T_{source} - T_{sink}}{T_{source}}$$

Let us agree that we have twenty-four hours in which (\) nH\\'c'l't our 2000 Btu of heat to (.15) (2000) = 300 Btu of mechanic:, Can our type of equipment do this? Is the power density ton eI lenthe engine to convert?

= 233,400 ft. lbs.

Round this off for convenience to 240,000 ft. lbs./day or 10,000 ft. lbs./hour, which is equal to 167 ft. lbs./minute or 2.75 ft. lbs./second mechanical energy per square foot of engine.

Let's assume that in one half of our square foot air is submerging and in one half it is emerging 15% larger. The larger the bubbles, the more slowly they can move. What is the product of the bubble depth (in $H_1O$) times velocity that we need in order to deliver our 2.75 ft. lbs./second? It seems we need 1 + 1.5 = 14.3 times the volume displaced by 2.75 lbs. of water moving at one ft./second. Written out, we say, "If under every square foot of horizontal surface we have a bubble about 7 ½ inches deep moving at 1 ft./second submerging in the cold half of the engine and emerging (about 1 inch thicker) in the hot half, then we have a chance of directly capturing 15% of 2000 Btu/square foot as mechanical energy during 24 hours." Our .64 sq. ft./second can also be supplied by a bubble 4 times as deep - about 30 inches - moving at ¼ the velocity 1/1 ft./second or 15 ft./minute) or any other pair with this same product of thickness X velocity.

## 9.7 A DISCUSSION OF ASSUMPTION

Encouraging: We have assumed our hot bubble is only 15% larger than our cold bubble. It must be at least this different since our starting point was to assume the absolute temperatures differed by this amount. If we are using air bubbles and water, the difference is going to be much larger - perhaps an increase of 50% rather than 15%. This lets us decrease the thickness X speed product about three fold.

Discouraging: Whatever mechanical contrivance it is that submerges and emerges our bubbles must move through the water on its return stroke. Thus the drag of our pistons or containers is about double what we might calculate as an optimum. Above and beyond the drag of our pistons or containers moving through water we have the drag of the air moving back and forth through the tube and regenerator - between the hot and cold containers - and we have the friction of bearings and mechanical couplings.

Such hasty calculations as these do not guarantee any kind of success in a project, but they often can show that a design simply won't work. I believe that this is not the case here—that these calculations show that the energy density of sunlight is compatible with the possible density of production of mechanical power of a gravity engine here on our planet using water and air and slow moving (6 ft. to 60 ft./minute) containers.

## 9.8 CONVECTION

All liquids change density with temperature. Each volume of liquid in a gravitational field is thus an engine, whether it is as tiny as a drop of water or as immense as the atmosphere. It is an almost universal property of fluids that they expand upon being heated. (The very instrument which tells us temperature, the thermometer, is merely a gauge for reading the expansion of a liquid.) Thus most fluids rise when heated and sink when cooled. Our planet, with all the liquids captured in its gravitational field (except for anomalies such as water and heavy water), is continually moving heat outwards.

The flame burns at the bottom of the tea kettle; the heating element is at the bottom of the hot water tank. The entire contents warm. If one wishes to contain cool fluids, an open-topped pool is sufficient. Thus, in supermarkets the freezers are open on the top, a pool of cold air resting within. Citrus growers fight this property of air with fans set within groves that lie in valleys, blowing out the coldest air which tries to settle.

## 9.9 COOLING BUILDINGS WITH CONVECTION

A house is a shade sandwich - the roof on one side, the earth on the other. If we wish to cool a house we can place a loop of tubing through the house and then onto the roof and fill the loop with liquid.* During the day the sun shines on the portion of the loop that rests on the roof, and the liquid within grows hot. Where does the heat go? It stays on the roof, since the hot liquid is lighter than the cool liquid within the shaded portion of the loop. During the night heat Throughout this discussion I am omitting any mention of heat transport by radiation or conduction. Heat is an enormous subject radiation and conduction are equally as important as convection radiates into space.

After some time the roof will be cooler than the inside of the house; now convection starts. The house gives heat to the loop and its fluid. The fluid rises to the roof, loses its heat to the night sky,grows denser by shrinking, and circulates back down within where it again picks up more heat. A combination engine-refrigerator. Thus we have readily available engines which can cool buildings (provided there are low enough nighttime temperatures). But what of the reverse - can we exploit one of these convection engines to heat our buildings? We can if our heat source is below the building. This is generally inconvenient. Our source of heat (unless we have built on top of a warm springs) is sunlight and it falls on the walls and the roof of the structure rather than on the floor. If we wish to convect heat downwards we need a liquid that convects backwards, a reverse juice.

## 9.10 REVERSE JUICES

Is there such a juice? Water below the temperature of 39°F. and deuterium oxide (heavy water) below 52°F. are reverse juices. I know of no others. Rubber contracts on being heated, but it is a solid rather than a liquid. The reverse juice can hide heat. This quality of water, which causes it to sink below 39°F. instead of convecting heat to the stars, protects pond life every winter.

Could we use water as a reverse juice to prevent freezing of collectors at night?

For construction of water heaters in cold climates such as Albuquerque, I have mentioned the necessity of having a two-liquid system where an anti-freeze mixture circulates through the collectors instead of water. If water freezes in a pipe it can burst the pipe because the ice is 8% larger than the water from which it is formed. Water is at its most dense at 39°F. A quick examination of the diagram of a typical water heater shows that there should be no problem of freezing in the collector even without the two-liquid system, because water, before it freezes, expands slightly and thus rises, to be replaced by heavier water at 39°F.

Water really does act this way if it has enough space to move in. Ponds freeze at their tops. Then it would.seem we could rely on this property to keep our heat collector, which is below a supply of warm water, above 32°F. Every time water got close to this freezing temperature it would swell slightly and escape upwards toward the storage tank, where it would be warmed and shrink and sink to replace colder water again.

The problem with utilizing this property is that the expansion and contraction between 39°F. and 32°F. is very slight and the convective forces are thus weak. To supply enough heat to a collector by this reverse convection on a cold night would require large flow channels. In normal collectors this reverse convection dies because of flow constriction. The slightest failure of the reverse convection causes icing, which then further restricts the flow and causes a complete failure. As far as I know no one has experimented with this particular problem.

The advantage of such a collector would be great since there would be no need for a heat exchanger. During the day the collector would deliver heat to the tank at its own temperature rather than at the lower temperature which results if the heat must flow through an exchanger. A disadvantage of such a system would be the drain of heat during the night from the storage tank to maintain the temperature near 39°F. This would not be a serious problem in many climates where there are only occasional heavy frosts.

## 9.11 BUILDING THINGS

The world needs engines that operate with air, water, sunlight, and the simplest mechanisms possible. It needs engines that could be breeding stock for other engines. If the world were desolate of equipment, the only remnant of today an enormous library in a dry cave showing us the past, and we wished to rebuild, where would we start? We could hardly start with nuclear reactors or internal combustion engines. We would first use water wheels and windmills, and from them go on to heat engines. It is an interesting challenge to invent useful new devices which could appear very early in the development of technology.

There are humans and creatures wandering around on the globe which spins as it slowly circles the sun. The humans climb on top of each other and breed, producing more humans. The creatures climb on top of each other. and breed, producing more creatures. The humans also pick things up with their hands and build other things. Very slowly the things they build with other things become complicated until their origin from the other things is not clear. That they are things is only established when they are never discovered to be breeding and reproducing as creatures do, but are discovered to be produced by other different things. There are, of course, always some doubts.

God is happy to renew the contracts of the creatures; they take care of themselves and each other in their own ways. God does not know what to do about the things. They don't answer when God speaks to them, so God speaks to the humans; but the humans are so busy building things with other things that they hardly ever answer. "Just a minute, I've got to fix this thing."

# 10 SKYLIDS

(United States Patent No. 3,884,414)

Skylids are insulated louvers which fit beneath skylights or behind windows. They open ·and close by themselves in response to temperature differences. The louvers are balanced on bearings and have pairs of canisters connected by tubing attached to them: one canister on the outside near the edge of the louver, the other canister on the inside near the opposite edge of the louver.

The pair of canisters contain enough liquid to fill one canister and the pair is purged of gasses other than the liquid's vapor. The vapor pressure drives the liquid to the coolest canister, tipping the louvers open or closed. The system is useful because it is a combination thermostat and engine and needs no outside power. The two canisters compare temperatures rather than acting at a set temperature. This is usually an advantage with solar heating systems. Pairs of canisters can also be used to open and close insulating doors on hot water tanks.

## 10.1 THE FRANKLIN PULSE-GLASS

The skylid uses the principle of the Franklin pulse-glass. This is not the first time the Franklin pulse-glass has appeared in connection with solar energy. Hugh W. Brodie used such a device in constructing the Wig-Wag solar radiation instrument in 1929.

Charles Willard Geer patented a self-orienting heliotropic device in 1959, U.S. Patent No. 2,999,943, which again uses the Franklin pulse-glass. By changing the skylid it can be made to exploit Geer's ingenious invention, and the louvers will follow the sun throughout the day.

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**Skylids m dining room of Utton house, Albuquerque, N.M.**

Our work at Zomeworks on the skylid began in 1971. It has been brought to its present state by the work of David Boyd, Dick Henry and the author.

## 10.2 GRAVITY ENGINES

The skylid is a very simple example of a gravity engine, one that uses the rotation of the earth or cloud cover as a kind of valve. There are many species of gravity engines. A common example of a more efficient and sophisticated gravity engine is the drinking bird sold at airport magazine stands and novelty shops. (See pg. 78)

## 10.3 SKYLID CONFIGURATIONS

The typical skylid configuration is a louver beneath a south sloping skylight v.1ith one canister on the outside and one on the inside. (See Figs. I and 2.)

Sizes of louvers can vary a great deal. \fost of our louvers have been 22in wide. The airfoil cross-section is formed by bowing sheet aluminum C sections over wood ribs. The louvers gain great rigidity by their depth while losing very little sun. The airfoil shape bounces the sun past the louvers.

Typical louvers weigh less than 2 lbs. per sq. ft. and rotate easily on ball bearings. The space between the two aluminum skins is filled with fiberglass. The 22 in. wide louvers with a maximum depth of 5 in. easily span 12 ft. Vl/e have not tested 48 in. wide louvers, but believe that, with an airfoil cross-section 12 in. thick, they should span 20 ft.

There are endless variations of geometry for the louvers, the canisters and appropriate counterweights. (See Figs. 1-6).

Ball bearings are so sensitive that weights of 20 to 40 lbs. can be placed on a pair of 5/ l 6 in. bearings and only a few foot-ounces of torque are required to move the bearings. Generally, we place at least 2 or 3 lbs. of liquid in the canisters, even when only a few ounces are needed to turn the bearings. This weight is needed to close the cloth seals.

In balancing both simple and complex systems of skylids, we have found direct experimentation with adjustable weights to be the simplest design method. All such systems can easily be analyzed mathematically, but direct experimentation with weights reveals precisely how much weight it takes to overcome the friction of bearings and seals, etc.

**Fig. 1 and 2: Typical skylid underneath a sloping skylight. If the slope of the skylight is very steep, or if it is perpendicular, the positions of the driving canisters must be shifted slightly so that the flooded outside canister can hold the louvers closed.**

cw **Fig. 3: The skylid system can be used on doors hinged as shown. The counterweight can be moved to a remote position by using more pulleys. Here, the balanced position of the door shifts gradually as more refrigerant is pumped to the outer canister. The door opens and closes gradually and may not open all the way.**

**Fig. 4: By using a more complicated counterbalance the same door can be made to open and close, completely with the movement of a small volume of freon.**

Fig. 5: Pairs of doors can be linked and then balanced with a single counterweight. This drawing shows how the doors are operated on our "bread box" water heater. The refrigerant canisters are not shown. One is placed on the counterweight arm 45° ahead of the top door; the other is placed as close to the axis of the top door as possible. In Fig. 1, 2 and 6, the refrigerant is active on both sides of the axis or rotation - either fighting to open or close the louver. In Figs. 3, 4 and 5, one canister is placed next to the axis of rotation and the refrigerant retires to let a counterweight act. This makes poor use of the weight of the liquid and larger canister must be used to achieve the same torque.

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**Fig. 6: Secondary doors can be attached to a refrigerant driven louver in numerous ways.**

## 10.4 DRUMWALLS

Fig. 7: The inside of the author's house showing a drumwall The ideal room for skylights is a room with a great deal of thermal mass where the temperature can fluctuate. Thermal mass can be added to rooms by building walls such as the drumwall shown in Fig.

7. Drumwalls are walls composed of drums clipped together and filled with water. Each drum holds 450 lbs. of water. The drums are good heat containers because the thermal transfer between the walls and their contents is so excellent.

The one drawback with drumwalls is the lifetime of the waterfilled drum. Container manufacturers will guarantee water stored in plastic liners, but not water in contact with steel. Rheem Manufacturing Co. produced a steel drum with plastic liners for storing drinking water in bomb shelters during the 1950's. Anti-corrosion additives can be added to water in drumwalls, but it remains to be seen what their lifetime will be.

## 10.5 MASONRY WALLS

Masonry can be used to store heat, but even a very thick masonry wall will have trouble swallowing direct sunlight if it is exposed throughout the day. The R factor of masonry is about 1.2 per inch. Thus, to pass 250 Btu per sq ft through masonry requires a temperature gradient of 50 deg F per inch. A masonry wall that is swept briefly by a beam of sunlight may never become uncomfortably hot, but a masonry wall exposed to direct solar radiation for a long time becomes an inefficient heat sink.

## 10.6 GABIONS

Gabions are wire baskets used to hold river rocks in retaining walls and dam spillways. Air is able to circulate through gabions and the rocks they hold. Gabions appear to be much more promising than conventional masonry walls for storing heat. The transport of heat to the interior of the wall is by air. The surface area within the wall is huge and the cross section available for air Oow into the wall is about a third of the total cross-section. We have completed plans for a 1000 sq. ft greenhouse using gabions for heat storage.

Thermal mass within a room is also useful for cooling since the cool of the night can be used to chill the mass and this used as a heat sink in the daytime. It is an easy matter to keep the maximum daytime temperatures inside the house below that of the average outside temperature.

## 10.7 SIZING SKYLIGHTS AND SKYLIDS

A building or a room can easily be overloaded with skylights. If, on a normal sunny winter day, the room becomes uncomfortably warm from the radiation entering through the skylight, there is too much skylight. A remedy for this is to block off the skylight by having skylids you can pull closed; or, to provide the room with more thermal mass so that the room's temperature shifts more slowly. The second solution makes sense; the first does not. Why pay for the skylights and skylids when you only rarely use the sunlight they are ready to admit? In any given room there is a point beyond which the addition of more skylight doesn't make sense. Here is a typical example:

A 200 sq. ft. room's 4 in. concrete slab floor has a thermal mass of 4 in./12 in. x 140 lb. per cu. ft. x 200 sq. ft. x 0.2 Btu per lb. of concrete per deg F., which is the equivalent of 1866 lb. water. If we are willing to let the slab temperature swing 10°F., we can carry 18,600 Btu gained by a skylight during the day into the night.

Let us assume that the net gain during the day for the skylight is 1000 Btu per sq. ft. Then, a 19 sq. ft. skylight is right if it can deliver its heat into our storage slab. Let us also consider the heat losses during the day. Why buy this heat from a source other than the skylight? I 'II assume a load of 1.3 Btu per sq. ft. of floor per deg. F. and an average daytime 6.t of 20°F. We find a total load during the eight hours of 9600 Btu.

Thus, it might make sense to have a 30 sq. ft. skylight in our 200 sq. ft. room. Obviously, there are many ways to extend this. Our slab could be thicker, our walls could be masonry, or, better yet, we could have a drumwall to accept the heat.

On a cold, cloud)' day, when the skylids do not open, converting a snug roof with an R factor of 20 to an expensive skylight with skylids having a total R factor of perhaps 5, seems to have been a bad choice. On such a day the sky lids must go into debt to another source of heat.

Loss through roof: 50°F. x 1/20 Btu per sq. ft. per deg F. x 24 hr. = 60 Btu per sq. ft. per day.

loss through skylight with closed skylids: 50°F x 1/5 Btu per hr per sq. ft. per deg. F. x 24 hr. = 240 Btu per sq. ft. per day.

Such days are very rare in a climate like Albuquerque's, where skylids open at least 95% of winter days. A skylight is an ideal flat plate collector. Light entering the room is unlikely to find its way out regardless of the color of the room. The skylight collector operates at room temperatures, and thus has small losses. There are no extra losses from the back of a collector since the back of the collector is the house.

## 10.8 SEPARATING HEAT SOURCES

When a person shifts from gas, oil, coal, or electricity to solar energy, he is likely to settle for a cooler house and less hot water. This is especially so if the back-up systems are clearly distinct from the solar system, and if one must make some obvious effort to turn the back-up systems on, such as starting a fire or lighting a pilot light. Fortunately, people find the intervention of God, who may have scheduled a few cloudy days, more acceptable than the failure of a furnace or a propane shortage. People may be less disturbed than one expects with occasional lukewarm showers and cold living rooms.

Certainly, the solar engineer should encourage such an attitude and always install as simple and as small a system as it appears his clients can live with happily.

## 10.9 OUTSIDE REFLECTORS

A skylid heating system may be aided by the addition of an adjustable outside reflector made of sheet aluminum or any flat material painted white. The reflector is adjusted a few times a year as the seasons change. In winter it is raised high to reflect a low sun down through the skylight and, in summer, it is lowered to shade the skylight. (See Fig. 8.)

Rough tests made by Ron Shore and the author in February, 1974 lead us to believe that a white colored or dull aluminum reflector of width equal to that of the skylight below it can increase heat gain by more than 30% during the hours the skylight faces the sun. The reflected light ”gets in free”, so to speak, since the exposed glass area remains the same size and, essentially, the same temperature. Losses through the glass may actually be decreased because the reflector acts as a windbreak and discourages the wind from scouring heat away from the skylight.

The advantage of the summer shade provided by the reflector is obvious. In a climate with mild winters and warm summers, adjustable reflectors alone are probably more valuable than skylids alone. Since there are enormous windloads on them, such reflectors must be of sturdy construction.

## 10.10 THE IMPORTANCE OF SEALS

Seals are very important with skylids. No matter how much insulation you have in the louvers, a steady flow of warm air up and cold air down· through cracks between louvers will spoil any attempt at good insulation.

We have found that light floppy fabrics work best. They must be extremely flexible, since the force to seal them is on the order of a fraction of an ounce per foot of seal.

Care must be taken to seal the skylight above the skylid. The job of containing inside air against the pressure differences frequently found between inside and outside should not be left to the skylid seal.

*If the seal around and between the louvers is perfect, the R factor through the combination skylid and skylight is at least 10. In practice, this is hard to achieve. Crude tests have led us to predict a total R factor of 5 in skylights with skylids closed.*

## 10.11 COLORS AND MATERIALS

Aluminum is a natural choice for skylid louvers. An airfoil-shaped louver depends on the reflectivity of its skins to shed radiation down when it is open. Likewise, when the louvers are tied closed in the summer, the outer reflective skin prevents heat gain by reflecting much of the radiation out. Aluminum skin is also useful since its low emissivity allows the roof and ceiling to become relatively warm without rapid radiative transfer of the heat to the floor of the room.

Fig. 8: Outside reflector with skylids.

*There are perhaps advantages to painting the outside of the louvers white since this color reflects well and also is better at reradiating toward the outside what heat it does absorb.*

## 10.12 DRIVING CANISTERS

*Any liquid that will pass back and forth from liquid to gas to liquid by vaporization and condensation can be used as the driving liquid for the skylid. Some liquids are more favorable than others. Qualities to look for: non flammable, readily available, inexpensive, non poisonous, dense, low specific heat, and low boiling point. Refrigerant 12 meets all our specifications except that, if it is burned, it turns into a poisonous gas.*

*At room temperature, Refrigerant 12 has the following properties: Density: 83 lb. per cu. ft.; Vapor pressure: 82 psia; Specific heat: (liquid) 0.23.*

*We also need a liquid whose vapor pressure increases rapidly enough with rising temperatures to be able to pump liquid through a head of a few feet with a small temperature difference. Refrigerant 12's vapor pressure increases about 1.5 psi for each degree Fahrenheit r:se in temperature at room temperature and the gradient is steeper at higher temperatures.*

*A low boiling point is convenient because it makes the system easy to purge. A small amount of energy is required to form the bubble of vapor which drives the liquid from one canister to the other. At a given pressure, the energy required to form a bubble by vaporizing liquid is almost the same for all liquids. This turns out to be tiny com pared to the energy normally required to shift the temperature of the metal canister and the liquid. (3.).*

A typical canister has a diameter of 2 1/2 in., a length of 16-1/2 in., a volume of 80 cu. in., walls of 0.065 in. steel, weighs 2.5 lbs., and is filled with 3 lbs. of R-12. It intercepts about 1/4 sq. ft. of sunlight directly and also receives reflected radiation. The thermal mass of the full canister is about 1 Btu per deg F. On a winter morning, the full outside canister must gain between 40 and 80 Btu to pump the refrigerant to the inside container. This may take an hour or two. Much faster responses can be obtained by soldering fins to the canister.

It should be remembered that there is no inherent reason why the entire mass of liquid must be heated. The liquid is moved by the vapor pressure of a bubble at the very top of the canister. Stratification

then works to our advantage and we may succeed in getting a bubble ”t the canister top hot enough to move the liquid without waiting for the mass of liquid to warm.

## 10.13 OTHER FEATURES

Skylids are completely silent. Skylids do not stop functioning when there is a power failure. Skylids allow one to control the light level in a room. Skylids are docile; one can contradict them by pulling them to where they don't want to go without any noise, breakage, or other familiar grim consequences.

If, for some reason, the refrigerant leaks out or something else goes wrong with the canisters, the louvers can still be opened and closed manually until the refrigerant is replaced. The death or breakdown of the automatic system leaves the mechanism helpless, but not inoperable. This is a rare advantage; most automated equipment is completely and utterly useless if the motor or thermostat breaks. For instance, if a pump motor burns out there is no way to reach in and spin the shaft by hand.

## 10.14 NIGHTWALL

In May of 1975 we did a number of experiments with nightwall—an insulating system where sheets of light rigid plastic foam insulation are pressed directly against the window. The foam panels can be hinged on one side or on the top using tape, and they can be made to hug the window pane by magnetic clips or simply by gravity. Such an insulating system has many advantages. The problem of air leaks between the glass and the insulation is reduced because the two flat surfaces are easy to bring into close contact. The material is easy to cut and can be fabricated on site. The material is very light and panels are relatively easy to automate using the skylid principle. Last of all, rigid foam insulation is very cheap.

Nightwall light as a feather

## 10.15 BOOKS

**(1.) Hugh W. Brodie, The Wig-Wag,** *Solar Energy Journal* **- Vol. 9, No. 1, 1965, Pergamon Press, Maxwell House, Fairview Park, Elmsford, New York 10523.**

**(2.) Steve Baer, Gravity Engines and the Diving Engine** *Coevolution Quarterly,* **Summer 1974, pp. 80-87, Box 428, Sausalito, California. (3.) R.C. Hall, The Use of Latent Energy of Vaporization in Energy Reservoirs,** *Solar Energy Journal,* **Vol. 8, No.· 3, 1964, Pergamon Press, Maxwell House, Fairview Park, Elmsford, New York 10523.**

# 11 SOLAR ENERGY CONFERENCES

The first solar energy convention I attended was in Palo Alto in October 1968. There were only about 65 people there, and the talks were given in a rather small room with wooden chairs. The 1974 meeting was in Fort Collins, Colorado. There were about 1000 people there, and the talks were given in a large auditorium. The more meetings I go to, the less time I spend in the conference hall listening to talks. It is usually more interesting to simply mill about in the lobby, the cafeteria, or especially outside in the exhibit space.

## 11.1 A MEETING IN WASHINGTON, D.C. (March 21–23, 1973)

I have just attended a meeting on solar heating and solar air conditioning of buildings sponsored by the National Science Foundation and the University of Maryland.

The representatives of industry were assembled for a panel discussion at a long table on a raised platform before us. I think somewhere around $30,000,000 sales per year was the minimum; less than that and you are not considered part of American industry. The men for the most part knew nothing about solar energy. Alcoa Aluminum and Texas Instruments did however have interesting comments and news of products.

Harry Thomason and his son Jack have built three successful solar heated houses in Washington, D.C. They live in one and rent the other two. This is certainly a successful small solar energy industry; but Harry was kept in the audience. He has not received money from NSF or any other government agency.

We listened to hours of double-talk. It is a mark of wisdom and farsightedness to recommend and study solar energy. But if you live in or build solar heated houses, you are probably somewhat crazy. A comment from Industry:

"...The worst thing in the world to do would be to rush ahead and build solar houses prematurely—before all the bugs are worked out—it will give solar heating a bad name."

The general attitude is that enormous corporations must enter the field of solar heating in order for it to become "feasible." Harry Thomason had a completely different perspective on large corporations entering the field. He commented that now he and his son Jack can climb up on their roof and hammer together a heat collector for $1 or $2 a square foot, but that after the corporations begin mass production, these simple methods will be forgotten and ignored and the price will climb upwards.

Representative McCormick from the State of Washington gave a brief, but fairly intelligent, talk.The day before, we had been told at some length how to behave when McCormick attended our final meeting. They'd want us grouped for certain pictures - get there early, just in case. It reminded me of the Army. Clearly men's careers were at stake - or so they must have thought.

I sensed quite strongly that both Donovan and Herwig, the top men in NSF for solar heating, saw exactly what was happening, but neither man was going to be so bold as to try and change it.

## 11.2 SOLAR INSECTICIDE

Last year the National Science Foundation gave grants totalling hundreds of thousands of dollars for solar energy research and development. This year the total will be $3.2 million and next $12 million.

Money attracts university and industry experts. I am suspicious of such experts. After listening to the meeting for three days I think I understand the mechanics of the government's grants for work on solar energy.

When people want to get rid of a kind of insect, one method is to not directly kill the insect, but to raise and release vast quantities of sterile male insects. The sterile insects make up the major portion of the male insect population and thus, after mating, most females are infertile. After a few generations the insect population is down to a handful. I see the projects and research teams chosen by the government as sterile.

When someone is interested in solar energy he is likely to bump publicity or people associated with such projects. Result: he is advised that solar heating, cooling, or power are ”not feasible at this time.” l can’t find any one person who has planned this solar insecticide scheme; I do not think he exists. Rather, these techniques seem to naturally grow out of an unspoken understanding that oil, coal, gas, and atomic power are the proper energy sources. If the sun is so good, why doesn’t it belong to GE, GM, ITT, or the AEC?

## 11.3 SOLAR VACCINATION

Another way to look at the money now spent on solar energy research is that it is being used as a vaccination against the full-blown disease of solar energy utilization. A certain amount of solar energy activity is encouraged so that the country can reach an actively immune state. Those who own or control the competing energy sources—coal, oil, gas, nuclear—can then become familiar with the threat - solar energy. Projects can be undertaken that will result ir failure or extraordinarily high prices. Reports—stacks of them—will indicate hopeless bottlenecks and contradictions in the design and manufacture of solar heating equipment.

I would expect many of the projects to be undertaken in the midst of huge government laboratories primarily devoted to other activities, such as nuclear energy. There the avid solar energy worker is likely to find himself transferred when he becomes too productive.

It is certainly fortunate that a great deal of success is within reach of the backyard inventor and the small shop.

## 11.4 IMPARTIAL STUDIES?

The tone and spirit of the work of those with grants to study solar energy is very much like what I imagine you might find if the Ford Motor Company were given the job of studying Chevrolet cars. If they were given the position of impartial tester they would of course play the role to the last serious words of their last expert. Test drivers, comfort experts, efficiency engineers, and other experts would be assigned to the project. A large amount of money would be set aside for this serious question.

What would they discover? That the Chevrolet was a piece of junk that should be dismantled, garaged, or burned? No, of course not. The reports, carefully worded by committees to strain out any nuances of individual opinion, would find great promise in many of the features of the Chevrolet. In interviews, members of the Ford research teams would nod their heads. ”Yes, in 20 years we feel that the automobile industry will definitely be ready for the Chevrolet. Clearly many of its features are beneficial and much needed by the public.”

”Sir, can you tell us what you have chosen after your long study of the Ford and the Chevrolet?”

”Well, Hal, with today’s options in the automobile field, I’ll have to say that the car I have found to be feasible is the Ford. Although, of course, I’ll grant you that someday my kids will probably be driving Chevrolets.”

## 11.5 MEETING OF THE INTERNATIONAL SOLAR ENERGY SOCIETY (October 1973)

I recently returned from the U.S. Section meeting of the International Solar Energy Society. There I encountered most of the elements working in the field of solar energy: representatives of large corporations such as Exxon and Texas Instruments, swarms of scientists and professors—like enormous schools of minnows in a pond; and then, of course, the rest of us: crack pots, dreamers, small business people.

The first talks were by representatives of the National Science Foundation. The NSF has given A.D. Little $200,000 to study the possible impact of solar technology on society. If this kind of study is necessary I can’t help wondering why they don’t award A.O. Little another $20,000 to study the possible impact of their report on the possible impact of solar technology on society. Evidently one can’t be too careful! For whose benefit is this money spent? The consumer? Do we need to make sure the energy crisis is not solved too quickly?

A.O. Little has already received a large grant to study Peter Glaser’s scheme of orbiting a satellite which will collect energy in an enormous dish and beam it back to the earth in microwaves. This project seems not only a waste of money but also a clear danger to all of us, for it certainly can be used as a weapon, if not by us, then by the Russians or Chinese (for they certainly would need their own orbiting energy collector once ours was in the sky). How can one organization be trusted to judge what is sensible for the government to spend money on when it so clearly has pressures to bias it? Perhaps they would reassure us that we have nothing to fear because all this work is being done by computers.

The pressures that steer all of those present at the meeting seem to work from great distances, for there were no villains present and certainly no heroes. There is no one to blame for the fact that there has not been enough action in the field of solar energy. If the money is being given to the large companies, who have no prior experience and no real commitment to the technology, then we must understand the position of those in NSF: they can't give the money to kooks; they can't begin to follow unconventional paths.

Here is my recommendation - that the government stop subsidizing the education and research directly. Let the government promise to buy, at a high price, power from neW power generating stations that use solar, wind, tides, and geothermal energy. Let us agree that such power is worth more to us than power derived from burning oil and let us promise a market for electricity or other energy produced. Let us arrange it so that those who undertake these studies and construction projects are taking a chance - they can win or they can lose. There is nothing more discouraging than to see, at a time of crisis, money spent to subsidize lethargic pointless projects, whose engineers are going to be paid whether they win or lose.

At the conference there appeared an excited middle-aged reporter from Nation magazine who handed out questionnaires asking us how long we felt it would take to supply this country's energy needed by solar energy if there were unlimited funds. I felt discouraged to see this kind of question asked ivly feeling is that if there were unlimited funds it would take an unlimited length of time. Those working on the problem would just keep working and working on it. Why should they worry?

They'll always have work and good pay—enough to buy the last gallons of oil. The country seems to regard itself as the custodian to an increasing number of scientists and experts who are rewarded with grants and contracts and the avid attention of the rest of us even when they repeatedly take the wrong turns. If the captain of a ship has sunk it through negligence, better to throw him to the floor of the lifeboat and let the amateurs take a try at sailing than to help him to the tiller again.

What was interesting at the meeting? Exxon Corporation is selling small silicone cells, about the size of a sheet of paper folded in half the long way, each one producing 11/2 watts. The cells are enclosed in clear polycarbonate and have an expected life of over 15 years. They are beautiful but terribly expensive. Each one costs $30 or $20 per watt. The researchers would not talk about hov,1 cheap these might become in the future. They showed slides of these cells coupled to batteries on offshore oil rigs in the Gulf where warning lights and fog horns must be supplied with energy. An interesting and vital part of these instaHat-ioAs-wa-s-th@-gF@as; ba-Ad strung above each panel of cells - seagulls don't like greasy rubber bands and therefore perch elsewhere. I was surprised that the solar cells could supply energy more chec1.ply than a small wind generator.

One particularly distressing talk was given by a young man from Texas: ”Shaping the Society to Fit Solar Energy.” He had the hair-do of a rock star, and as he adjusted the mike I expected to hear some unusual theories and proposals. But, no, nothing of the kind. It was like seeing a bird open its mouth to sing, but hearing only the sound of an electric motor. The talk consisted of the description of a computer analysis of the possible design of solar power stations. Nowhere was there any mention of shaping society. In fact, the plan called for an almost entirely automated system, independent of people.

At the end of the meeting a man was outside sweating and laboring to set up a demonstration of a small solar-powered steam engine. The concentrating collector consisted of two racks of shaving mirrors (some of the shaving mirrors with plain rims and others with gold curlicue designs on the rims). The boiler kept running out of water; the mirrors had to be adjusted constantly as the earth turned. Scattered clouds blocked the sun periodically. The man wrestled with the device, explaining that it was a model of a large power plant he wished to build. It seemed wonderful that there on the neat lawn in front of the NASA Lewis Research Center (an institute to make other institutes feel ashamed of their lack of guards and government limousines) there was a demonstration relying on hardware purchased at two different drugstores which carried different brands of shaving mirrors.

## 11.6 THE SUN TAX

Someday someone is going to demand that you pay him or his organization for your weather—the sunshine and the rain.

If you have a solar collector, they are going to claim credit for a certain fraction of the sunshine you have collected. You'll say, "OK, if you control the weather, what's it going to be like tomorrow?" And the organization will reply, "We don't deal in specific short range forecasts."

"If you can't tell me what the weather's going to be tomorrow, why should I pay my sun tax? You have nothing to do with whether the sun shines or not."

"There's really very little question left about it. We have incontrovertible evidence that our weather modification is successful and that over $10^3$ day periods we modify rainfall, cloud cover, and sunshine by at least 3%. The tax you pay to support these important weather modification programs 1s tiny compared to the benefit you gain."

## 11.7 THE GARBAGE CAN

Trojan Solar Equipment had been an irritant at solar energy conferences for years. There was old Ralph - a tall, thin man who never sat down during the hours of talks, but always stood by the side door, his light colored face visible to most of the audience. The university professors and corporation engineers aroused in him a spectrum of facial expressions ranging from the mild disgust of someone rejecting a bad piece of fruit to the horrified look of someone being offered a plate of dog shit. Occasionally he would rush out the door during the middle of a presentation. Gene, under whose name most of Trojan's amateurishly documented articles appeared, constantly heckled speakers representing government agencies and large corporations. Or, alternately, he cheered enthusiastically and stamped his feet at the sketchy reports of a small group of determined backyard investigators.

Trojan's continual stream of accusations against the engineering establishment, and their claims of superiority for the rather peculiar equipment they turned out sporadically from their small shop, had helped push the international solar energy society to stage a collector race. Here the various competing companies, including Trojan and several of the nation's largest weapons contractors, would test their equipment side by side on the same day.

The night before the test, something happened. Gene was arrested for drunken driving and thrown in jail. The van in which the collector had been locked was badly damaged in an accident.

This was a great relief to many of the other participants, who had irritated in the past by Gene's loudly expressed opinions and his disagreeable personality. Although none of the engineers admitted it, there was even a slight relief that they wouldn't have Trojan's collector entry—whatever it was—racing against them.

Shortly after the start of the contest, Eddie, the third man from Trojan, (an inarticulate mechanic who wore cowboy boots) arrived and insisted that Trojan was still going to enter the race. As they watched Eddie, a hush fell over the group of technicians and engineers standing behind the bleachers on which the collectors were mounted. (Were the slight limp and the bandage on his forearm from last night's accident?) Eddie nervously but resolutely emptied a nearby garbage can and then hoisted it up to Trojan's space in the bleachers.

Ralph arrived out of breath with a can of black auto body paint, and Eddie filled the garbage can with a hose.

The next day the picture of Eddie with his bad teeth standing beside the triumphant garbage can appeared in newspapers around the World. The engineers soon explained it to their peers as a mistake brought about by a too literal interpretation of simplistic competition rules which allowed a trivial solution to appear as the competition winner.

A month later, rather than having brought contracts and official recognition, Trojan's victory at the International Collector Races was regarded in the profession as a bad joke. The incident had simply widened the already large gap between their equipment and the government agencies which were purchasing solar hardware.

## 11.8 SECOND SUN

Recently the government gave A.D. Little a grant of $200,000, mentioned earlier, to study and evaluate the plan of Peter Glaser to orbit a large satellite which could collect solar energy away from the inconsistencies of the earth's atmosphere and the inconvenience of nighttime.

What is this really about? Are we that short of energy? Why not burn wood? Wouldn't it be cheaper to build collectors on the ground and accept the occurrence of cloudiness and nighttime?

I don't think these projects have anything to do with energy shortages. They are dreams that don't make any sense.

## 11.9 THE DREAM

Why settle for a sun that goes out at night and is interrupted by clouds? \!Vhy be dependent on a sun with an uncertain past?

Who owns that thing anyway? Why not build a second sun that can beam its energy even at night and through clouds? Why not build a sun that you own? Think of it!

Why not build one yourself and know how and why it works? Never mind that it only relays the other sun's energy. Why not have a sun that you can control from a console like a stereo set of TV set? Why not hav.e .a sun ,that is your friend? Why not make a sun with which you could burn up other people if they were bad? Why go backwards in work with solar energy so that you end up like an old farmer farming the sky, worrying about the weather? Why not transform the sun itself into a commodity, like a big tank of propane?

## 11.10 BOOKS


1. **Atmospheres,** Richard M. Goody, James C.G. Walker, Prentice-Hall, Inc. This is an excellent book that discusses the climates and atmospheres of other planets.

2. **Sun, Earth, Time and Man,** Harrison, Rand McNally: 1960.

3. **Solar Radiation,** Ed. by N@. Robinson, Elsevier Publishing Company.

## 11.11 ABOUT THE AUTHOR

Steve Baer was born in 1938 in Los Angeles, California. He studied at Amherst College, U.C.L.A. and in the Mathematics and Physics department at the E.T.H. in Zurich, Switzerland. He has long been interested in geometry and the weather. These interests have led to the development of a structural system and various solar heating devices. Baer has been President of Zomeworks Corporation for six years. He is a member of the Board of Directors of the U.S. Section of the International Solar Energy Society and is a Director and past Vice Chairman of the New Mexico Solar Energy Association. He lives with his wife and two children in a cluster of solar heated zomes in Corrales, New Mexico.

## 11.12 ABOUT THE ILLUSTRATOR

Criss-Cross Foundation is an organization formed by the same people who built and lived in the experimental community of Drop City, Trinidad, Colorado, 1965-1969. Criss-Cross and Baer have been working together since 1966. Criss-Cross Foundation publishes a **magazine,** *Criss-Cross Communications,* and operates an art workshop **near Boulder,** Colorado. They have experimented with group art **works, Their aim** is to promote creativity.

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## 11.13 ABOUT THE PUBLISHER

Zomeworks Corporation has its office and shop in Albuquerque, New Mexico. As a general contractor, Zomeworks builds zomes and solar heating systems which it designs and fabricates. There is also a consulting and design service for architects and clients wishing to include energy conserving devices in new designs or in existing buildings. Since its beginning Zomeworks has been working with people who like to ”do-it-themselves.” Plans (which include diagrams, discussions of materials and specific instructions) for building;

SOLAR HOT WATER HEATERS BEADWALL SYSTEMS DRUMWALLS are sold by mail order. Zomeworks hopes that *SUNSPOTS* will inspire the imaginative reader to innovative designs.

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