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EDITORIALS&OPINION

At a 1925 ice harvest in Maine, men separated the cut ice and guided it to an elevator at the ice house.

KEYSTONE VIEW COMPANY

The world that ICE built

How a business carved from frozen New England ponds shaped modern life

By Leon Neyfakh

SO A GUY FROM Boston walks into a bar and offers to sell the owner a chunk of ice. To modern ears, that sounds like the opening line of a joke: But 250 years ago, it would have sounded like science fiction—especially if it was summer, when no one in the bar had seen frozen water in months.

In fact, it's history. The ice guy was sent by a 20-something by the name of Frederic Tudor, born in 1783 and known by the mid-19th century as the "Ice King of the World." What he had done was figure out a way to harvest ice from local ponds, and keep it frozen long enough to ship halfway around the world.

Today, the New England ice trade, which Tudor started in Boston's backyard in 1806, sounds cartoonishly old-fashioned. The work of ice-harvesting, which involved cutting massive chunks out of frozen bodies of water, packing them in sawdust for storage and transport, and selling them near and far, seems as archaic as the job of town crier.

But scholars in recent years have suggested that we're missing something. In fact, they say, the ice trade was a catalyst for a transformation in daily life so powerful that the mark it left can still be seen on our cultural habits even today. Tudor's big idea ended up altering the course of history, making it possible not only to serve barflies cool mint juleps in the dead of summer, but to dramatically extend the shelf-life and reach of food. Suddenly people could eat perishable fruits, vegetables, and meat produced far from their homes. Ice built a new kind of infrastructure that would ultimately become the cold, shiny basis for the entire modern food industry.

As winter gathers strength, turning New England's swimming holes into skating rinks and rainwater into foot-long icicles, the idea of making a fortune by selling solid chunks of pond seems absurd. We will not be the first to laugh: In 1806, as Tudor prepared for his maiden voyage as an ice dealer, a Boston-area newspaper published a story under the headline, "No Joke, Ship Full of Ice Sets Sail for

ICE, Page K2

Ice

Continued from Page K1

Martinique." Subhed: "Let's Hope This Doesn't Prove to be a Slippery Speculation!"

Though the 130 tons of ice that Tudor took to Martinique that year melted before anyone could do anything useful with it, the lasting ripples caused by his eventual success serve as a reminder: What seems ridiculous today didn't necessarily used to be, and it might not be tomorrow. Though the ice trade is one of the most definitively obsolete industries ever to make a man rich, in many ways we are still living in Tudor's world.

THE ADVERTISEMENT was simple and direct, in the style of the time. "Today, March 7, and during three consecutive days, there will be put up for sale in small amounts a cargo of ice, brought into this port very well preserved, from Boston....This sale will take place immediately and will last three days only, the brig having to proceed at that time to another island. The price is ten cents a pound. It is necessary to bring a wool cloth or a piece of covering to wrap the ice; this means preserves it much longer."

So read the hand bill that Frederic Tudor circulated around Martinique, according to records housed at Harvard University's Baker Library and excavated by a group of researchers specializing in the history of accounting.

Tudor had cut ice out of a lake in Lynn and packed it below the ship's water line, using a mixture of sawdust and hay as insulation. An impressive amount of the ice survived the 20-day journey over the Atlantic Ocean. But because there was no place to store it in Martinique, much of it turned into worthless liquid before it could be sold. Tudor lost a small fortune, but also solved the problem. The following year, when he took his business to Havana, he first worked out a deal with the local authorities to construct an icehouse before he arrived. After some more trial and error, Tudor began to turn a profit, and with that, the ice industry was off to the races.

By the middle of the century, ice harvested by Tudor and his associate, Nathaniel Wyeth, was reaching the shores of Singapore, Hong Kong, and Calcutta. Copycats with dollar signs in their eyes rushed into the business, and the ice industry quickly expanded; at its height, during the 1850s, roughly 140,000 tons of ice were leaving Massachusetts every year, headed for more than 50 cities around the world.

Today, refrigeration is indispensable to our food economy, which is based on the movement of perishable goods across thousands of so-called food miles. Natural ice harvested from ponds and lakes was the first innovation to make that thing was possible before he started experimenting with it."

Tudor's innovation changed the game when it came to shipping meat, too, and in the process gave rise to a major new industry. Chicago's immense 19th-century meat business would never have been possible without an ice infrastructure. "Before ice, perishability placed strict limits on the scale of meatpacking," Freidberg said in a talk delivered at University of Massachusetts Dartmouth. "Plants had to close down during the hot summer months, to rely on raw materials that could walk themselves to market, and to throw out potentially useful byproducts simply for lack of means to store them."

Today the infrastructure that has grown up around the shipping of perishable food is known as the "cold chain," a phrase that refers to a series of containers, trucks, and rooms stretching across our commercial landscape and ensuring that, whether it's fresh or frozen, food can survive to reach consumers. It's not much of a stretch to say the whole system has Tudor's fingerprints all over it.

So does your whiskey on the rocks. To this day, Europeans rarely put ice in their drinks, but Americans do. Thanks to the low price of ice in the United States, Rees said, people here "developed a taste for cold drinks faster and stronger than anyone else." This required active involvement from Tudor, who sent operatives to go from bar to bar trying to convince owners to incorporate his product into drinks. To make the sale, Tudor committed to giving some bartenders free ice for a year, figuring that customers would so enjoy the clink in their glasses that other local bars would feel pressure to put in orders. "The object is to make the whole population use cold drinks instead of warm or tepid," Tudor wrote in his diary. "A single conspicuous bar keeper...selling steadily his liquors all cold without an increase in price, render it absolutely necessary that the others come to it or lose their customers." According to Gavin Weightman, who wrote a 2003 book about the New England ice trade, Tudor was celebrated for half a century after his death by scholars at the Harvard Business School, who "admired him for creating a demand where it didn't exist before."

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IF ITS DRAMATIC impact on food can be seen in every kitchen in America, the ice trade has left less tangible, but still substantial, traces in the realm of ideas. A notable federal court decision in Massachusetts involved Tudor's associate Nathaniel Wyeth, who sued a competitor over copying his design for an ice harvesting machine. The case, in which a judge ruled that a patent claim must describe the mechanism by which the object in question actually works, not just what it does, has had a durable afterlife in the legal system. Mark Janis, a professor at the Indiana University Maurer School of Law in Bloomington who specializes in intellectual property, says he teaches the case to students as part of an introduction to the hotly contested area of software patent law.

Another scholar has made a newer argument that the ice trade contains lessons on how to apportion property rights when different people lay claim to a natural resource. In a recent working paper, Ferris State University assistant professor of economics David Hebert tells the story of what happened when landowners with homes abutting Fresh Pond realized that the frozen water in their backyards could be worth significant money. The realization set off a self-defeating feeding frenzy, causing a "tragedy of the commons" situation in which everyone was racing everyone else to the ice. As a result, none of the harvesters—including Tudor—could wait long enough for the ice to freeze to the desired thickness. (The thicker the block of ice, the longer it takes to melt.)

Hebert writes admiringly of the grass-roots approach by which the locals resolved the problem, by devising an agreement in 1840 that gave individual residents around the pond jurisdiction over a slice of water proportionate to the length of shoreline they controlled. Allowing the locals to reach the arrangement themselves, without interference from the state, should be a model in situations where property rights are conflicted, he says. One place where such a system is currently needed, according to Hebert, is Washington State, where hunters, miners, and lumberjacks are getting in each other's way while pursuing the various natural resources contained in public forestland.

THERE IS SOMETHING beguiling about identifying the ghostly fingerprints of long-evaporated eras on our own lives: the way albums still clock in at just under 80 minutes, just because that's how long records could be back when they were pressed on vinyl, or the way our early port cities remain more cosmopolitan and globally connected, long after their actual shipping industries moved elsewhere.

In a story called "The Undertakers," Rudyard Kipling captured

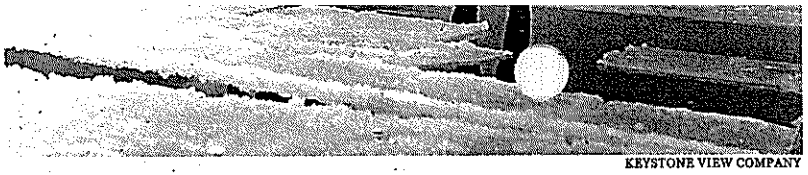
the races.

By the middle of the century, ice harvested by Tudor and his associate, Nathaniel Wyeth, was reaching the shores of Singapore, Hong Kong, and Calcutta. Copycats with dollar signs in their eyes rushed into the business, and the ice industry quickly expanded; at its height, during the 1850s, roughly 140,000 tons of ice were leaving Massachusetts every year, headed for more than 50 cities around the world.

Today, refrigeration is indispensable to our food economy, which is based on the movement of perishable goods across thousands of so-called food miles. Natural ice harvested from ponds and lakes was the first innovation to make that possible. In her book "Fresh: A Perishable History," Dartmouth College professor of geography Susanne Freidberg credits Tudor with setting the stage for the refrigeration revolution; as she sees it, the very concept of freshness was turned upside down by the world that Tudor made possible.

Before ice, people's dietary options were much narrower. Each fruit or vegetable made an appearance during harvest and then vanished; foods soured and spoiled quickly during the summer, and simply weren't available in winter unless they'd been salted, pickled, or otherwise preserved. Tudor took some of the first steps toward exploding those limitations. At various points during his career, he packed his ships with apples, butter, cheese, salmon, and lobster.

"Tudor pioneered the idea of [shipping] perishable foods," said Jonathan Rees, a historian at Colorado State University-Pueblo and the author of the 2013 book "Refrigeration Nation." "I don't think anybody would have imagined such a



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JACK SHEAHAN/GLOBE STAFF/FILE/1974

Top, in 1925, workers cut the ice following grooves made by a horse-drawn device. Above, a block heads toward the ice house in 1974 in Maine, where ice harvesting has survived as a community tradition.

public forestland.

THERE IS SOMETHING beguiling about identifying the ghostly fingerprints of long-evaporated eras on our own lives: the way albums still clock in at just under 80 minutes, just because that's how long records could be back when they were pressed on vinyl, or the way our early port cities remain more cosmopolitan and globally connected, long after their actual shipping industries moved elsewhere.

In a story called "The Undertakers," Rudyard Kipling captured the impact of the New England ice trade on the rest of the world by way of a scavenger stork, who tells the tale of seeing a ship unloading "great pieces of white stuff" and grabbing a chunk of it in its beak when it breaks off. "Never have I felt such cold," the stork recalls. "I danced in my grief and amazement till I could recover my breath, and then I danced and cried out against the falseness of the world." As the men from the boat laugh at the stork, the thing in its beak seems, mysteriously, to disappear.

Ice melts: It's one of the first things we learn about the natural world when we are children. But it's not until we hear a story like Frederic Tudor's—and then sip a cold Coca-Cola, or open a fridge full of crisp produce from thousands of miles away—that we realize just how much it leaves behind.

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Uncommon Knowledge

From Abracadabra to Zombies

fire walking

Fire walking refers to the activity of walking on hot coals, rocks or cinders without burning the soles of one's feet. In some cultures [e.g., India], fire walking is part of a religious ritual and is associated with the mystical powers of **fakirs**. In America, fire walking is part of New Age religion, i.e., self-empowering motivational activity.

Tony Robbins popularized fire walking as an activity for demonstrating it is possible for people to do things that seem impossible to them; the fire walk is a technique for turning fear into power. Robbins doesn't consider the power of the mind to overcome fear of getting burnt as **paranormal**, however. Overcoming this fear is presented as a step in restructuring one's mind, almost as if this trial by fire was some sort of initiation into an esoteric and very special group of risk-takers. To the timid and those who feel powerless amongst all the dynamic firebrands around them, such a feat as walking on hot coals must seem a significant event.

Robbins may have popularized fire walking but Tolly Burkan, founder of **The Firewalking Institute for Research and Education**, claims he was the first to introduce the practice to North America. According to Burkan, fire walking is "a method of overcoming limiting beliefs, phobias and fears."

Walking across hot coals without getting burned does seem impossible to many people, but in fact it is no more impossible than putting your hand in a hot oven without getting burned. As long as you keep your hand in the air and don't touch the oven, its metal racks or any ceramic or metal pots, you won't get burned even if the oven is extremely hot. Or, if you do touch the oven, metal racks or pots, and are wearing insulating gloves or using "hot pads," you won't get burned. Why? Because "the air has a low heat capacity and a poor thermal conductivity...." while "our bodies have a relatively high heat capacity...."(Leikind and McCarthy, 188). And an insulator will insulate! Thus, even if the coals are very hot (1,000 to 1,200 degrees), a person with "normal" soles won't get burned as long as he or she doesn't take too long to walk across the coals and as long as the coals used do not have a very high heat capacity. Volcanic rock and certain wood embers will work just fine.

Also, "both hardwood and charcoal are good thermal insulators.... Wood is just as good an insulator even when on fire, and charcoal is almost four times better as an insulator than is dry hardwood. Further, the ash that is left after the charcoal has burnt is just as poor a conductor as was the hardwood or charcoal" (**Willey**).

Nevertheless, some people do get burned walking across hot coals, not because they lack faith or willpower, but because the coals are too hot or are have a relatively high heat capacity, or because the firewalker's soles are thin or he doesn't move quickly enough. But even very hot coals with a high heat capacity can be walked over without getting burned if one's feet are insulated, e.g., with a liquid such as sweat or water. (Think of how you can wet your finger and touch a hot iron without getting burned.) Again, one must move with sufficient speed or one will get burned.

However, even armed with this knowledge, it still takes courage to fire walk. When **Michael Shermer** of *Skeptic* magazine did a fire walk for "The Unexplained" television program, he had the knowledge but the fear was obviously still there. Our instincts are telling us: *don't do this, you idiot!* Fire walking requires some faith as well as knowledge: faith that the coals were prepared properly, that you can move fast enough to avoid getting burned, and that something will work in practice as you know it should in theory. Even so, whether the firewalker gets burned depends on how the coals were prepared and on how fast the firewalker moves, rather than on willpower, the power of the mind to create a protective shield, or any other paranormal or supernatural force.

Michael Shermer Firewalking Across Hot Coals

Christopher F. Bauer, Principal Investigator.
This material is based upon work supported by the National Science Foundation under Grant No. 1245730.
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See also **est, Landmark Forum, large group awareness training program, neuro-linguistic programming** and **New Thought.**

reader comments

further reading

books and articles

Christopher,Milbourne. ***ESP, Seers & Psychics*** **(Thomas Y. Crowell Co. 1970).**

Leikind, Bernard J. and William J. McCarthy. "An Investigation of Firewalking," in ***The Hundredth Monkey and Other Paradigms of the Paranormal*****,ed. Kendrick Frazier (Buffalo, N.Y.: Prometheus Books, 1991).**

Salerno, Steve. (2006). ***Sham: How the Self-Help Movement Made America Helpless.*** **Three Rivers Press.**

websites

FIREWALKING Myth vs. Physics by David Willey

The Physics Behind Four Amazing Demonstrations by David Willey

Scientific study of Firewalking by Kjetil Kjernsmo

A Report on Two Experimental Firewalks, University of London Council for Psychical Investigation, Bulletin II, 1936 by Harry Price

Fire Walking -from Steve "Blackfoot" Roberts of the Australian Skeptics

Denver Dobbins' Firewalking Seminars

History of Firewalking -- 1977 to 2004 by Tolly Burkan

Firewalking by Nick Pullar

Guru Busters - order the film from Eagle & Eagle

news stories

new **21 people treated for burns after firewalk at Tony Robbins appearance** Amid inspirational talk, chanted mantras and shouts of victory at a late-night firewalking event attended by thousands Thursday came agonized shrieks from followers whose soles were scorched by the superheated coals, witnesses said.

At least 21 people were treated for burn injuries after taking part in the crowning event of the first day of a Tony Robbins function downtown, including at least three who went to the hospital, a San Jose fire captain said.

The people who suffered various second- and third-degree burn injuries were among more than 6,000 who attended the motivational speaker's event at the San Jose Convention Center called "Unleash the Power Within." [/new]

Shaman Trever McGhee burnt out May 10, 2007

KFC crew gets burned February 28 2002

About 12 Burger King employees burn feet while walking over white-hot coals in fire-walking ritual at seminar in Miami that was intended to promote bonding - Oct 6, 2001

Is it safe? Eli Tyler of El Cajon, California, was one of seven people hospitalized with severe burns to the bottoms of their feet from a fire-walking ceremony at an American Association for Nude Recreation convention in August, 2000.

Fred Gilbert, a professional fire-walker, apparently told a bare naked lie when he said that he was providing "a safe and spiritual experience where you walk through your past to arrive at your future."

Tyler is suing Gilbert for "using the wrong type of wood, starting the fire walk before ash formed on the wood and failing to have medical personnel present, among other things."

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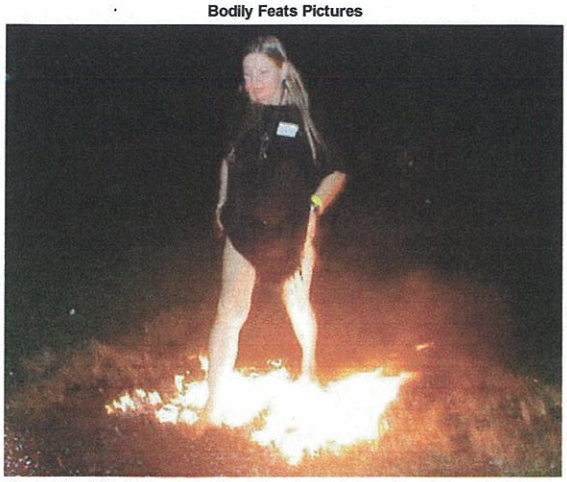
How Firewalking Works

by Marshall Brain

Bodily Feats Pictures



Firewalking barefoot over hot coals has been featured in movies and TV reality shows. See more bodily feats pictures.

UP NEXT TO SEE THIS AND OTHER TOPICS FROM A WHOLE NEW PERSPECTIVE, CHECK OUT SLOW-MOTION SCIENCE ON DISCOVERY CHANNEL'S "TIME WARP."

- How Fire Breathing Works
- How Sword Swallowing Works
- How Cirque du Soleil Works

I would like for you to imagine the following situation: You get a call one day offering you the chance to win a million bucks. It's a new reality show that takes ordinary people and asks them to do extraordinary things. All that you have to do to win $1 million is a little firewalking -- simply saunter across a bed of burning coals on live TV.

Bodily Feats Pictures

Would you do it? Firewalking is one of those strange things that lots of us wonder about -- people seem to be able to do it without getting burned. But could just *anybody* do it? Is there some kind of gimmick that makes firewalking possible?

If you ever watch a firewalking event on TV or in a movie, you know that what you always see is a large, glowing bed of burning coals. The bed may be 10 feet long or so. And the glowing coals are real. People actually do walk across the red coals in bare feet. The firewalker makes his way across the coals as though by magic. How is this possible, and can any other person do it just as easily?

In this article, you will learn exactly how "firewalkers" walk across a bed of glowing coals without getting burned!

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MORE TO EXPLORE

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How Firewalking Works

by Marshall Brain

The fire is lit long before the firewalking starts.
Photo courtesy The Florida Pagan Gathering

Firewalking Events

First of all, there is no gimmick to firewalking. It is not like a firewalker soaks his feet in water before going across the coals. And it is not like some extreme sweat reaction happens and his feet are suddenly soaked in sweat. His bare feet really do touch the red-hot coals.

What makes this possible is a combination of factors that play on certain qualities of the coals themselves...

Think about this. Let's say you took a 10-foot long iron plate and heated it up red-hot with blow torches. Now you walk across that. What would happen?

Walking across a red-hot metal plate would be insane. Think about a hamburger when it hits a hot iron skillet. Bare feet on red-hot metal would give you third-degree burns in milliseconds.

There are a couple of things to notice about any firewalking event:

- Firewalkers are not actually *fire*walkers. They are really **coalwalkers**. The fire is lit well ahead of time to allow the wood to burn down to non-flaming coals.
- The event is always held at **night**. If it were done during daylight, the bed of coals would look instead like a **bed of ashes**. There is always a layer of ash covering the coals. By doing it at night, the glowing red light is still visible through this layer of ash. Photo courtesy The Florida Pagan Gathering **The hot coals are covered with a layer of ash.**
- The firewalker never dawdles. Now, no self-respecting firewalker would run across the coals -- that would be undignified. But firewalkers certainly are **walking briskly**. You never see firewalkers standing on the coals.

So what is going on here? Firewalking depends on a combination of **poor conduction**, **insulation** and a **short time span**.

MORE TO EXPLORE


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Macys.com


How Fire Breathing Works


How can someone walk across broken glass without getting hurt?


10 Stars Who Died During the Filming of a Movie


Do you really stay conscious after being decapitated?

Christopher F. Bauer, Principal Investigator.
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How Firewalking Works

by Marshall Brain

Photo courtesy The Florida Pagan Gathering

Firewalking and Science

Why is it possible for bare feet to touch red-hot coals without getting burned? The coals start out as pieces of wood. The wood consists of lots of carbon, some "volatile organic molecules," and water.

A **volatile organic molecule** is a carbon-based molecule that evaporates when you heat it. Gasoline is a volatile organic chemical. We see these volatile organic molecules from wood as smoke rising from the fire. The heat of the fire evaporates all the volatile organics, as well as all the water. Because they've been burning for a while before the stunt, the coals have burned down to nearly pure **carbon**.

If you were to pick up one of these pure-carbon coals, you would notice that it is extremely light. Carbon is a lightweight element -- that's why carbon-fiber bike frames and tennis rackets don't weigh very much. A coal is mostly lightweight carbon atoms and air spaces (it does contain a few other elements, like potassium and calcium -- that's what left behind in the ash).

This lightweight carbon structure is a **poor conductor** of heat. It takes a relatively long time for heat to transfer from the glowing coal to your skin. If the coal were made of red-hot metal, heat transfer through conduction would be almost instantaneous -- you would get a severe burn.

Now, add to that the fact that ash is a very good **insulator**. People used to use ash to insulate ice boxes and such. The red-hot coals covered with ash transfer their heat even more slowly because the ash acts as a layer of insulation.

Then there is the **short time span**. Heat transfer from a red-hot coal is slow, but it still happens. If you were to stand still on the coals for several seconds, you would definitely get a burn. By walking briskly, you limit your contact with individual coals to a very short time span. You also get across the bed of coals very quickly, and that limits your total amount of coal time. So, your foot never gets hot enough to burn.

That's the whole story! For more information on firewalking and related topics, check out the links on the next page.

MORE TO EXPLORE

Bill Nye Has Changed His Mind - Should You?
The Washington Post

What Do Your Fingernails Say About Your Health?

How can you tell if you're mentally ill?

How Flirting Works

Why did people think 'The Blair Witch Project' was real?

Christopher F. Bauer, Principal Investigator.
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Theory

A FIREWALKING THEORY THAT CAN BENEFIT EVERYONE

Reprinted from EXTREME SPIRITUALITY: Radical Approaches to Awakening
by Tolly Burkan, founding father of the global firewalking movement

Over Three Million Westerners Have Firewalked

Knowing the secret behind firewalking can improve your life! Even if you never do it yourself, knowing how it works can bring you better health and increased personal power. Why? Because firewalking demonstrates how your thoughts impact everything else in your life. Thoughts change brain chemistry, and that results in an alteration of body chemistry as well. This is immediately apparent when you entertain a sexual fantasy. Firewalkers are instructed to pay close attention to their thoughts, since those very thoughts are the way in which we create our own realities. Positive thinkers literally live in a different chemical environment than negative thinkers. They impose less stress on their immune systems, and the result of that should be obvious.

I have been researching firewalking since 1977 and am considered to be the foremost authority on the subject. Because of this work, the United States now has the largest firewalking culture in history. Never before have so many common people participated in this ancient ritual which had previously been reserved for only a select few. My ideas regarding the phenomenon have evolved over time and it is only now, in the year 2000, that I feel enough confidence in my point of view to publish my own theory about why people are not burned when walking on glowing, red coals. My theory is remarkably different from all the others, but I have found each of the other theories flawed in one way or another.

Water Vapor Theory Dismissed

One theory I encountered on the subject was based on the "Leidenfrost Effect." Several physicists suggested that the moisture on the sole of the foot created a vapor barrier that prevented the foot from actually contacting the coals. The analogy was proposed that firewalking is similar to licking your finger and touching a hot iron to test whether or not it is up to a sufficient temperature to press a garment. When the iron is hot enough, it literally vaporizes the moisture on a fingertip, and the finger itself is repelled from the iron by water turning to vapor. This is termed the Leidenfrost Effect, named after the man who first described it.

The Leidenfrost Effect can also be easily observed by putting a few drops of water on a hot griddle... when the metal griddle is hot enough, the water beads up and dances around because the heat is so intense that the bottom of the water drop is vaporized before the drop reaches the heated surface and the rising water vapor pushes up against the underside of the drop, causing it to bounce off the escaping steam before it ever reaches the metal.

A physicist by the name of Jearl Walker was so convinced in the validity of this theory that he actually believed it was impossible to get burned while firewalking. After severely injuring himself on a coal bed, he lost faith in this theory. Once, during my early days of research, I observed someone getting burned during a firewalk, and back in the 1970s I rejected this theory that had been based on the Leidenfrost Effect.

Conductivity Not An Issue

Another theory physicists have proposed is the "Conductivity Theory." The analogy used to illustrate this idea was that of reaching into an oven to remove a hot cake pan. The air inside the oven is the same temperature as the metal cake pan, yet one can reach an unprotected hand into the oven without injury. However, if you were to grab the pan itself, the result would usually be a burn. The reason for this is that the air is a poor conductor of heat, while the metal pan is a better conductor. Physicists theorized that the coals were poor conductors and that was why a firewalker's foot was not burned in the coal bed, regardless of its temperature.

In 1994, physicist Bernard Leikind visited the Firewalking Institute and tried to dramatically illustrate this concept by strapping two sirloin steaks to his feet and then walking across a bed of coals while The Discovery Channel filmed the event. The steaks seemed to be unaffected by the coal bed. He then placed a metal grill in the coals and, when it was glowing red, he placed the same steaks on the grill and the

The other experiment was conducted by the United States government during the early days of research into space flight. When a spacecraft reenters the atmosphere, friction heats the craft to extremely high temperatures. It had to be determined whether the person at the controls could still function if the interior of the craft became very hot. To simulate this situation, scientists created a heat chamber. Volunteers entered the chamber and the inside temperature was raised. It was discovered that though an egg was cooking within this atmosphere, the human subjects were unharmed. In fact, the measured air temperature within the nose of a subject was actually cooler than the air in the chamber itself.

Mind in Matter

These two experiments form the basis of my own theory regarding firewalking. The reason Dr. Leikind's steaks were seared by the glowing metal while human feet were not is simply because the human foot was connected to a living, conscious being who is more than inert matter. The human body has a mechanism to cool itself. Respiration, perspiration and circulation all play a part in this process and all are connected to the brain, which is obviously influenced by the mind. Observe someone sucking on a lemon, or entertain a few sexual fantasies, and you yourself can instantly see how the mind can change the electro-chemical state of the brain and then the central nervous system relays that electro-chemical change to the body systems and cells of your being.

You can have physical experiences when nothing physical is impacting you. This is not "mind over matter," but rather: "mind in matter."

When a firewalker is in the proper state of mind, the blood flowing through his or her body is akin to the water in the paper cup. The blood is 98.6 degrees Fahrenheit. As it moves through the soles of the feet, it continually cools the tissue and prevents it from reaching its "kindling point," in the same way that the water maintained the temperature of the paper at 212.

Of course there are limits, and it has never been our intention at the Firewalking Institute of Research and Education to push the limits. Rather, we have simply looked for an explanation of the basic phenomenon of firewalking as it has been practiced throughout thousands of years and have sought new applications that can enhance the lives of those of us living in society today.

When humans walk on coals measured at 2,200 degrees Fahrenheit without harm, they are able to do so because the body is obviously capable of cooling and protecting itself up to a certain point. By-the-way, engine blocks for cars are made by pouring molten metal at 1,100 degrees!

My explanation of why people can walk on glowing coals without injury also implies why some people have in fact been burned. During the 1970s I set out to demystify firewalking and created the world's first firewalking seminar. I trained hundreds of instructors to conduct the seminar around the planet and, as of the year 2000, well over three million people have participated in the firewalking seminar. How many were seriously burned? About 50. Since people are sometimes injured, that too needs to be addressed. (I'm not counting those who've tried to stand still or linger on the coals.)

Injuries underscore that the mind, rather than the coal bed, represents the variable. When people are not in the state of mind that allows all body systems to operate at peak performance, the capillaries constrict and prevent the blood from moving freely through the tissue on the soles of the feet. When that occurs, the blood cannot carry heat away from the sole and cannot maintain the temperature required to prevent burning. The result can be blistering or charring of the skin. Aloe Vera has certain properties that can physically restore this circulation and, when applied immediately after a burn is sustained, blistering can frequently be prevented.

Dr. Andrew Weil, the renowned Harvard-trained physician

Christopher F. Bauer, Principal Investigator.
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without injury.

As soon as he said this, a number of people from our staff walked on the grill without harm.

The grill was so red-hot, the weight of people walking on it bent the softened metal and left impressions of the firewalkers' feet on the grill. We keep the grill with its molded footprints as a souvenir to help debunk the conductivity theory.

When a physicist experiments with fire, the objects of observation are usually not living, conscious subjects. Rules of conductivity can be applied in these instances. However, human beings are dynamic, self-regulating organisms... thus research into firewalking is really outside the physicist's realm of training. People who research the mind and body are more qualified to propose theories on firewalking than scientists who simply deal with static matter.

It has always been my belief that a person's state of mind is the crucial factor when exploring the science of firewalking. Just because a physicist can walk on the coal bed without harm does little to dismiss the idea that mental state is important. His belief in his theory gives him the confidence to walk on the coals. The "confidence" itself is a mental state. I suggested to Dr. Leikind that we blindfold him and lead him in various directions near the coal bed so that he would have no way of preparing himself mentally before actually stepping onto the embers. He refused. He also refused to walk on the metal grill, so I assumed that at some level he too must have realized there was more to the phenomenon than the conductivity of the coals and simple physics.

In fact, after years of insisting that firewalking was rather safe due to the low conductivity of the coals, with temperature being irrelevant, on May 9, 2000, Dr. Leikind finally signed a statement saying, "Any claim that the temperature of the coals is not important... is simply preposterous;" and adding, "it is my opinion that firewalking is an abnormally dangerous or 'ultrahazardous' activity."

Yet someone in America recently walked on coals measured at 2,200 degrees Fahrenheit without injury! Obviously, physicists still do not fully understand the process.

Typical firewalks that are open to the public involve coal beds ranging between 1,200 and 1,500 degrees Fahrenheit. Dr. Ron Sato, faculty member of the Stanford University Medical School and director of a nearby burn unit, says that human flesh momentarily exposed to 1,200 degree heat should sustain third-degree burns to the epidermis and dermis, charring the entire thickness of skin to a blackened carbon residue. Dr. Sato has treated people who have accidentally stepped on glowing coals and were so badly burned that they required skin grafts. When commenting about people who voluntarily firewalk without injury, Dr. Sato says, "There's no logical explanation."

Boiling Water In A Paper Cup
Two scientific experiments have helped me form my present theory.

One is a simple demonstration used by school teachers. Perhaps you saw it in your own science class when you were a teenager? The teacher fills a paper cup with water and places it over a flame. The water boils and the cup does not burn. The reason for this is that the water can only reach a temperature of 212 degrees Fahrenheit before it turns to steam. Since the water is in constant contact with the paper cup, the paper cannot get any hotter than 212 degrees. However, in order for the cup itself to burn, it must reach a kindling point... which happens to be higher than 212 degrees. The water maintains the temperature of the paper at a constant 212.

When the subject of conductivity comes up, I think of the times when I have patted the coals with a shovel to even out the embers. The shovel is metal and extremely conductive. As soon as the hot shovel is placed in a bucket of water, it creates an audible "hiss." The shovel is not in the coals any longer than our feet. So the coals obviously conduct the temperature just fine. It seems silly to consider the "conductivity" of a heat source; rather, the issue is about the conductivity of anything placed in contact with the heat source. The metal, being dense, conducts the heat from the source extremely well. Human flesh, however, is not very conductive.

When people burn, it may indicate that their states of mind have made them more "dense." A "fluid" mind-state translates into fluidity of the body itself. So what needs to be examined is not the conductivity of the coals, but why human flesh is sometimes more conductive than at other times.

Because of my extensive research, I now counsel prospective firewalkers to avoid walking on the embers until they take a moment to look inside themselves at all the conflicting inner voices. Some voices will be saying "Don't walk!" and others will be saying "Walk!" I tell people to first listen to each inner voice, then pay attention to the state of your body. Which decision makes your body more comfortable? If the decision to walk makes you feel more comfortable than the decision not to walk, then walk. Because if you are relaxed with your decision, you are in a certain bio-chemical state. Whether the relaxation with the decision to walk is based on a belief in physics or a belief in a higher power, it matters not. Both beliefs create the exact same physiology in the body. Unless their bodies are comfortable with the decision to cross the coals, I suggest people wait for another time.

The body itself is an excellent reflection of mental state. If the body is tense, that is an indication of thought processes that will interfere with the physical mechanisms employed by the body to protect itself. When I say that you must be "relaxed," I do not mean the same kind of relaxed feeling you have when lounging in a hammock! I believe that people who ultimately cross the coals unharmed have a deep sense of knowing that they won't burn their feet -- before they even take the first step. Obviously, if you think you're going to get hurt, then you would not step into the coals. You aren't stupid.

After people tell themselves "I can do this and not get burned," and they feel "comfortable" with that certainty, they proceed to walk with "confidence." All these states -- relaxed, comfortable, confident -- indicate a certain chemical condition within the brain and body. Thus, firewalking becomes an exercise in examining the mind/body connection.

This is why firewalking is so popular today among athletes, executives and healthcare providers. Anyone seeking to explore the mind/body connection, and ways to apply this information toward enhancing human potential, will find value in firewalking.

New firewalkers are amazed at the discovery that they themselves are such incredible beings. Firewalking reveals that being a mere human is nothing mere. Our minds are the new frontier and firewalking is just the beginning in the process of self-discovery. The implications of "mind in matter" are truly exciting and can offer new hope to people with severe illnesses as well as anyone seeking to overcome limitations imposed by old beliefs: salesmen, students, athletes... the list goes on and on... it may even include you!

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Consumer Guide to Home Energy Savings: Condensed Online Version

New Windows

Whether replacing windows in an older house or choosing windows for a new house, your decisions on what type of windows to buy will be among the most important decisions you will make in terms of energy use. Because of the impact windows have on both heat loss and heat gain, proper selection of products can be confusing. To add to the complexity, window glazing technology has changed tremendously in recent years. The best window glazings today insulate almost four times as well as the best commonly available windows from twenty years ago.

Features to Look for in Energy-Saving Windows

Window technology has improved dramatically in recent years, with the net result of lowering your energy bills. Some of the most important energy features of windows are explained below.

- *Multiple layers of glazing.* Until the 1980s the primary way manufacturers improved the energy performance of windows was to add additional layers of glazing. Double glazing insulates almost twice as well as single glazing. Adding a third or fourth layer of glazing results in further improvement. Some of these windows use glass only; others use thin plastic films as the inner glazing layer(s).

- *Thickness of air space.* With double-glazed windows the air space between the panes of glass has a big effect on energy performance. A very thin air space does not insulate as well as a thicker air space because of the conductivity through that small space. Many window manufacturers have increased the thickness of the air space in their double-glazed windows from ¼" to ½" or more. If the air space is too wide, however, convection loops between the layers of glazing occur. Beyond about 1", you do not get any further gain in energy performance with thicker air spaces.

- *Low-conductivity gas fill.* By substituting a denser, lower conductivity gas such as argon for the air in a sealed insulated glass window, heat loss can be reduced significantly. Most major window manufacturers offer argon-gas fill as an option in their most popular windows. Other gases that have been or are being used in windows include carbon dioxide (CO_2), krypton (Kr), and argon-krypton mixtures.

- *Tinted glass coatings.* Tinted glass and tinted window films have long been used in commercial buildings to reduce heat gain through windows. Improved, lightly tinted windows are becoming more common for the residential market in southern (cooling-dominated) climates. These new glazings reduce the solar heat gain without reducing visibility as much as older tinted glass and films.

- *Low-e coatings.* More than any other single improvement, the invention and commercial development of low-emissivity (low-e)

coatings in the 1980s revolutionized window technology. Thin, transparent coatings of silver or tin oxide permit visible light to pass through, but they effectively reflect infrared heat radiation back into the room. This reduces heat loss through the windows in the winter. A variety of low-e windows are now available for different climate zones and different applications in any particular location. Low-e windows with high solar heat gain coefficients are appropriate for northern climates where passive solar heating is advantageous, while "southern low-e" windows with low heat gain coefficients are appropriate in milder climates where summer cooling is more significant than winter heating.

- *Edge spacers.* The edge spacer is what holds the panes of glass apart and provides the airtight seal in an insulated glass window. Traditionally, these have been hollow aluminum channels, usually filled with desiccant beads. Aluminum has extremely high conductivity. That didn't matter when the glazing did not insulate very well, but as better performing glazings were developed, proportionately more heat was lost through the edges. Since about 1990, a number of improved edge spacers have come onto the market. Some are made of thin-walled steel and have a thermal break. Others are made of silicone foam or butyl rubber. Generally, better edge seals are a low-cost option when ordering windows, and worth considering.

To learn more about energy-efficient windows, visit the Efficient Windows Collaborative.

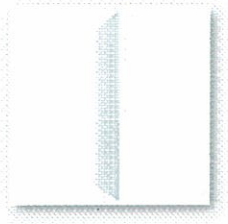
Selecting New Windows for Your Home

Three key measures are used to report window energy performance. **U-value (or "U-factor")** is the measure of the amount of heat (in Btus) that moves through a square foot of window in an hour for every degree Fahrenheit difference in temperature across the window. The lower the U-value rating, the better the overall insulating value of the window. **Solar heat gain coefficient (SHGC)** is the measure of the amount of solar energy that passes through the window; typical values range from 0.4 to 0.9, and the higher the SHGC the greater the solar energy that passes through the window system. Windows with high SHGC (above 0.7) are designed for colder climates, while windows with low coefficients are designed for hotter climates. **Air infiltration or air leakage** is given in terms of cubic feet of air per minute per foot of window edge. The best windows have air leakage rating between 0.01 and 0.06 cfm/ft.

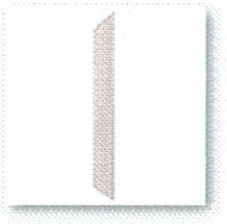
Two organizations offer guidance for consumers trying to make sense of the complicated windows market. The National Fenestration Rating Council (NFRC) provides objective data to help consumers make wise choices. The NFRC is a nonprofit collaboration of window manufacturers, government agencies, and building trade associations founded to establish a fair, accurate, and credible energy rating system for windows, doors, and skylights. Windows that have been rated by NFRC-approved testing laboratories and certified by independent certification and inspection agencies carry the NFRC label. The label includes window U-factor and SHGC and additional performance ratings (visible transmittance and air leakage).

Efficient Windows Collaborative

Window Technologies: Glazing Types



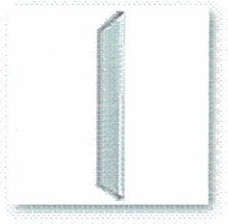
Single-glazed Clear



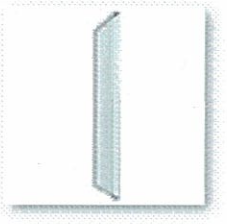
Single-glazed with Bronze/Gray Tint

Double-glazed Clear

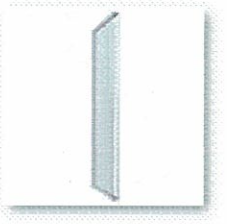
Double-glazed Bronze/Gray



Double-glazed with High Performance Tint

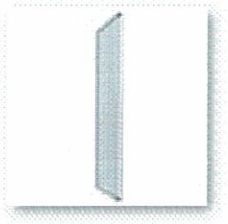


Double-glazed with High-Solar-Gain Low-E, Argon/Krypton Gas

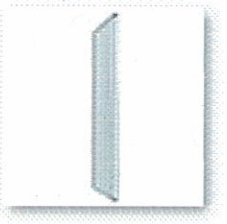


Double-glazed with Moderate-Solar-Gain Low-E, Argon/Krypton Gas

Double-glazed wit Solar-Gain Lov Argon/Krypton



Triple-glazed with Moderate-Solar-Gain Low-E, Argon/Krypton Gas



Triple-glazed with Low-Solar-Gain Low-E, Argon/Krypton Gas

There are three fundamental approaches to improving the energy performance of glazing products (two or more o approaches may be combined). The first approach is to alter the glazing material itself by changing its chemical composition or physical characteristics. An example of this is tinted glazing. The second approach is to apply a coa the glazing material surface. Reflective coatings and films were developed to reduce heat gain and glare, and mor recently, **low-emittance coatings** have been developed to improve both heating and cooling season performanc third approach is to assemble various layers of glazing and control the properties of the spaces between the layers strategies include the use of two or more panes or films, low-conductance **gas fills** between the layers, and therm improved **edge spacers**.

* Spectrally Selective
**Includes Double Glazing with Suspended Film

Christopher F. Bauer, Principal Investigator.
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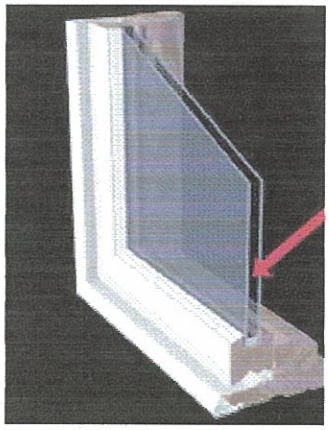
Efficient Windows Collaborative

Window Technologies: Argon or Krypton Gas Fills



An improvement that can be made to the thermal performance of insulating glazing units is to reduce the conductance of the air space between the layers. Originally, the space was filled with air or flushed with dry nitrogen just prior to sealing. In a sealed glass insulating unit, air currents between the two panes of glazing carry heat to the top of the unit and settle into cold pools at the bottom. Filling the space with a less conductive, more viscous, or slow-moving gas minimizes the convection currents within the space, conduction through the gas is reduced, and the overall transfer of heat between the inside and outside is reduced.

Manufacturers have introduced the use of **argon** and **krypton** gas fills, with measurable improvement in thermal performance. Argon is inexpensive, nontoxic, nonreactive, clear, and odorless. The optimal spacing for an argon-filled unit is the same as for air, about 1/2 inch (11-13 mm). Krypton has better thermal performance, but is more expensive to produce. Krypton is particularly useful when the space between glazings must be thinner than normally desired, for example, 1/4 inch (6 mm). The optimum gap width f krypton is 3/8" (9mm). A mixture of krypton and argon gases is also used as a compromise between thermal performance and cost.

Glazing Types | Frame Types | Operating Types | Lowe-E Coatings | Gas Fills | Spacers | Emerging Technologies

This site was developed jointly by the University of Minnesota, Alliance to Save Energy, and Lawrence Berkeley National Laborato

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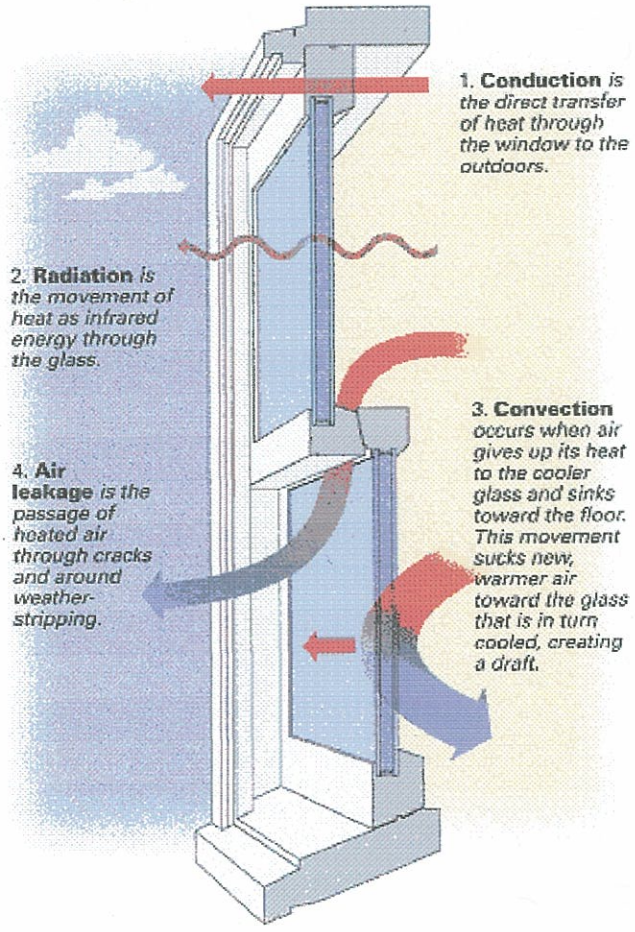
can be offset because you'll probably need a smaller, less expensive heating and cooling system. And more-durable windows may cost less in the long haul because of lowered maintenance and replacement costs. Plus, you'll be more comfortable the whole while you live with them.

Keeping heat in (or out)

Windows lose and gain heat by conduction, convection, radiation and air leakage. This heat transfer is expressed with U-values, or U-factors. U-values are the mathematical inverse of R-values. So an R-value of 2 equals a U-value of 1/2, or 0.5. Unlike R-values, lower U-value indicates higher insulating value.

Conduction is the movement of heat through a solid material. Touch a hot skillet, and you feel heat conducted from the stove through the pan. Heat flows through a window much the same way. With a less conductive material, you impede heat flow. Multiple-glazed windows trap low-conductance gas such as argon between panes of glass. Thermally resistant edge spacers and window frames reduce conduction, too.



Windows lose heat in four ways. The rate at which a window loses heat through the combination of the four is called its U-value. It is the inverse of the R-value, so the lower the U-value, the greater the insulative value of the window.

Convection is another way heat moves through windows. In a cold climate, heated indoor air rubs against the interior surface of window glass. The air cools, becomes more dense and drops

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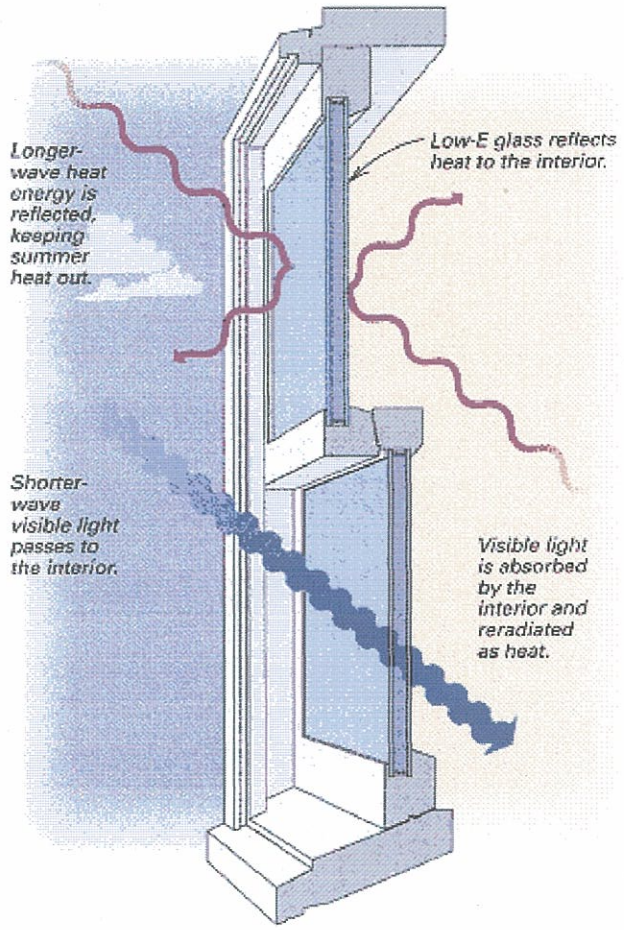
toward the floor. As the stream of air drops, warm air rushes in to take its place at the glass surface. The cycle, a convective loop, is self-perpetuating. You recognize this movement as a cold draft and turn up the heat. Unfortunately, each 1°F increase in thermostat setting increases energy use 2%. Multiple panes of glass separated by low-conductance gas fillings and warm edge spacers, combined with thermally resistant frames, raise inboard glass temperatures, slow convection and improve comfort.

Radiant transfer is the movement of heat as long-wave heat energy from a warmer body to a cooler body. Radiant transfer is the warm feeling on your face when you stand near a woodstove. Conversely, your face feels cool when it radiates its heat to a cold sheet of window glass. But radiant-heat loss is more than a perception. Clear glass absorbs heat and reradiates it outdoors. Radiant-heat loss through windows can be greatly reduced by placing low-E coatings on glass that reflect specific wavelengths of energy. In the same way, low-E coatings keep the summer heat out.



Low-E glass reflects heat energy while admitting visible light. This keeps heat out during the summer and during the winter. In the winter, low-angle visible light passes into the house and is absorbed by the home's interior.

Air leakage siphons about half of an average home's heating and cooling energy to the outdoors. Air leakage through windows is responsible for much of this loss. Well-designed windows have durable weatherstripping and high-quality closing devices that effectively block air leakage. Hinged windows such as casements

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Staying Cool on the ISS

Staying Cool on the ISS

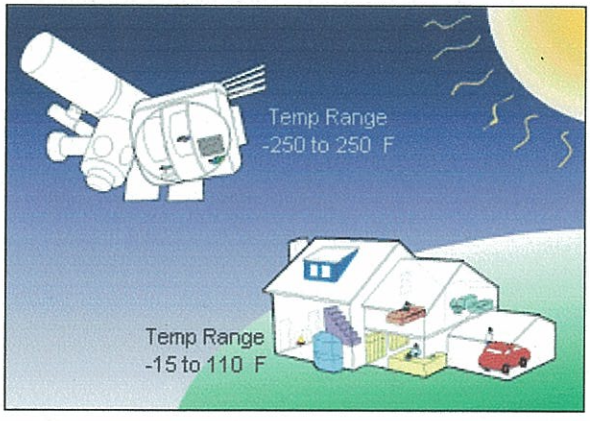
In a strange new world where hot air doesn't rise and heat doesn't conduct, the International Space Station's thermal control systems maintain a delicate balance between the deep-freeze of space and the Sun's blazing heat.

This is the second in a five-part series of articles about the construction of the ISS. The first examined the Station's architecture and structural design. Future installments will explore the power, plumbing, and ergonomics of the Station.

Listen to this story (requires RealPlayer)

March 21, 2001 -- The universe is a place of wide extremes: light, dark... wet, dry... air, vacuum... hungry, fed. Human life tends to flourish in the balance. We feel most comfortable in places that are not too hot or too cold, not too light or too dark -- in other words, places that are "just right."

Most of our planet fits that description. As long as you stay away from the South Pole and don't fall into a volcano, Earth is a pretty comfortable world. But now that humans are venturing into space -- not as visitors, but as homesteaders -- finding the right balance is more of a challenge.



Consider, for example, the International Space Station (ISS).

Without thermal controls, the temperature of the orbiting Space Station's Sun-facing

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side would soar to 250 degrees F (121 C), while thermometers on the dark side would plunge to minus 250 degrees F (-157 C). There might be a comfortable spot somewhere in the middle of the Station, but searching for it wouldn't be much fun!

Fortunately for the crew and all the Station's hardware, the ISS is designed and built with thermal balance in mind -- and it is equipped with a thermal control system that keeps the astronauts in their orbiting home cool and comfortable.

The first design consideration for thermal control is insulation -- to keep heat in for warmth and to keep it out for cooling.

Here on Earth, environmental heat is transferred in the air primarily by conduction (collisions between individual air molecules) and convection (the circulation or bulk motion of air).

"This is why you can insulate your house basically using the air trapped inside your insulation," said Andrew Hong, an engineer and thermal control specialist at NASA's Johnson Space Center. "Air is a poor conductor of heat, and the fibers of home insulation that hold the air still minimize convection."

"In space there is no air for conduction or convection," he added. Space is a radiation-dominated environment. Objects heat up by absorbing sunlight and they cool off by emitting infrared energy, a form of radiation which is invisible to the human eye.

As a result, insulation for the International Space Station doesn't look like the fluffy mat of pink fibers you often find in Earth homes. The Station's insulation is instead a highly-reflective blanket called Multi-Layer Insulation (or MLI) made of Mylar and dacron.

Above, left: Common home insulation on Earth. **Above, right**: Multi Layer Insulation -- or MLI -- for the International Space Station. The reflective silver mesh is aluminized Mylar. The copper-colored material is kapton, a heavier layer that protects

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the sheets of fragile Mylar, which are usually only 0.3 mil or 3/10000 of an inch thick. Photo courtesy Andrew Hong, JSC.

"The Mylar is aluminized so that solar thermal radiation can't get through it," explains Hong. Here on Earth, we use blankets containing aluminized Mylar to wrap people who have been exposed to cold or trauma. Such blankets are especially popular among hunters and campers!

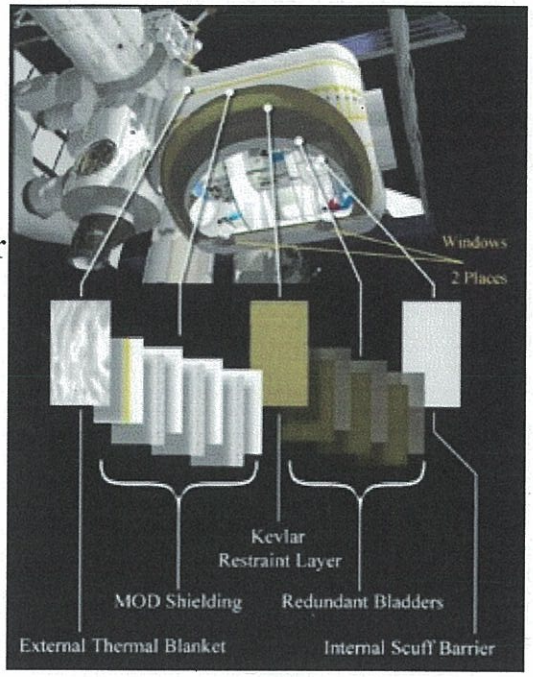
"Layers of dacron fabric keep the Mylar sheets separated, which prevents heat from being conducted between layers," he continued. "This ensures radiation will be the most dominant heat transfer method through the blanket."

Except for its windows, most of the ISS is covered with the radiation-stopping MLI.

"Windows are a tremendous heat leak," said Hong, "but astronauts need them for ergonomics and also for their research. It's something we have to design around."

MLI insulation does a double-duty job: keeping solar radiation out, and keeping the bitter cold of space from penetrating the Station's metal skin.

It does its work so well that the ISS presents another thermal challenge for engineers -- dealing with internal temperatures that are always on the rise inside this super-insulated orbiting laboratory fully stocked with many kinds of heat-producing instruments.



Right: MLI thermal blankets are just one of the many space-age materials that protect the ISS from the harsh elements of space. [more information]

Imagine that "your house was really, really well insulated and you closed it up and shut off the air-conditioning," said Gene Ungar, a thermal fluid analysis specialist at NASA's Johnson Space Center. "Almost every watt of power that came through the electric wires would end up as heat."

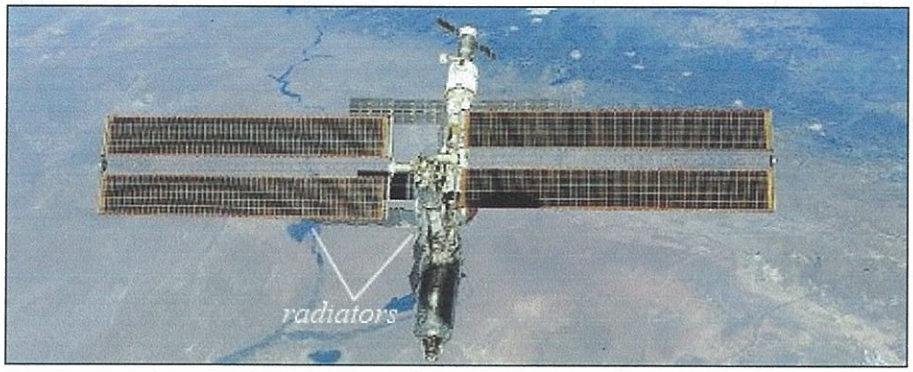
This is just what happens on the Space Station. Energy from the solar arrays flows into the ISS to run avionics, electronics ... all of the Station's many systems. They all produce heat, and something has to be done to get rid of the excess.

The basic answer is to install heat exchangers. Designers created the Active Thermal

Control System, or ATCS for short, to take the heat out of the spacecraft.

Waste heat is removed in two ways, through cold plates and heat exchangers, both of which are cooled by a circulating water loop. Air and water heat exchangers cool and dehumidify the spacecraft's internal atmosphere. High heat generators are attached to custom-built cold plates. Cold water -- circulated by a 17,000-rpm impeller the size of a quarter -- courses through these heat-exchanging devices to cool the equipment.

"The excess heat is removed by this very efficient liquid heat-exchange system," said Ungar. "Then we send the energy to radiators to reject that heat into space."



Above: This picture of the International Space Station, captured last month by the crew of STS-98, shows the station's outstretched aluminum radiators. Click for a close-up view.

But water circulated in pipes outside the space station would quickly freeze. To make this fluid-based system work, waste heat is exchanged a second time to another loop containing ammonia in place of water. Ammonia freezes at -107 degrees F (-77 C) at standard atmospheric pressure. The heated ammonia circulates through huge radiators located on the exterior of the Space Station, releasing the heat as infrared radiation and cooling as it flows.

The Station's outstretched radiators are made of honeycomb aluminum panels. There are 14 panels, each measuring 6 by 10 feet (1.8 by 3 meters), for a total of 1680 square feet (156 square meters) of ammonia-tubing-filled heat exchange area. Compare that majestic radiator with the 3-square-foot grid of coils found in typical home air conditioners and you can begin to appreciate the scope and challenge of doing "routine" things in space.

Finally, thermal control engineers must address air flow within the Space Station. The movement of air is a major factor in achieving the balance between hot and cold.

The ATCS works in tandem with the Environmental

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Control and Life Support System (ECLSS) that controls air quality and flow in the ISS. In orbital free-fall conditions -- equivalent to zero-G -- hot and cold air don't rise and fall as they do on Earth. Proper air circulation helps prevent unwanted cold spots that could produce condensation, electrical shocks, serious corrosion and even biological problems such as microbial growth. Corrosive fungi were a nagging problem on Russia's Mir space station, and ISS mission planners want to avoid a repeat infestation.

Above: Floating through space in short sleeves and bare feet? It must be comfortable up there!

It is indeed a strange new world on the ISS. Hot air that doesn't rise ... heat that doesn't conduct ... radiators too cold for liquid water ... it's enough to give a thermal engineer gray hairs! But thanks to the Station's efficient integrated thermal control systems, the crew needn't worry -- staying cool on the ISS is no problem!

Editor's note: One reader asks, "If the temperature of the shadowed side of the Space Station can plunge to -250 F and if the freezing point of ammonia is only -107 F, why doesn't the ammonia in the station's radiators freeze?" The reason is that the heat-bearing ammonia can't lose heat fast enough to reach its freezing point before the liquid circulates back inside the warmer confines of the Space Station. If (as a thought experiment) we turned off the pumps and oriented the Station so that the radiator was in the shadow of, say, a solar panel, the ammonia would likely freeze after some period of time.

Web Links

International Space Station -- home page by NASA

Seeing the International Space Station from your own backyard -- ***Science@NASA article***: With the aid of free NASA software you can spot the International Space Station from your own back yard.

Looking Forward to the ISS -- ***Science@NASA article***: Scientists at a recent media forum say they are eager to begin using the International Space Station as an innovative orbiting research laboratory.

Wheels in the Sky -- ***Science@NASA article***: The pioneering space station concepts of the mid-1950's don't look much like the erector-set habitat in orbit today.

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