Heating and Cooking with Wood

Ken Kern

The now-popular phrase, *do your own thing*, coined more than a century ago by Ralph Waldo Emerson, aptly expressed traditional Yankee values. More and more people today, seeking an alternative to "contemporary living," have romantically turned their gaze back to those "fine times" of realism and self-reliance. But with all its earthy nostalgia, to do your own thing in 19th century Emersonian fashion would be extremely arduous and, assuming 20th century men and women could and did succeed in mastering such a lifestyle, it would still leave them esthetically, culturally, and socially underfed. Consequently, at some point in our development during the last hundred years, Emerson's philosophy was scrapped in favor of a more comfortable and *technically* challenging existence: it was found that machines could do our thing for us.

In 19th century Massachusetts, Emerson did his own thing by chopping fireplace wood to keep his house warm. Fuel gathering was slow and difficult, fireplaces totally inefficient, houses inadequately insulated and improperly orientated. Little wonder his neighbors went forward to evolve new and improved methods of heating their homes. Typical of 20th century machine technology, heating methods were developed to give automatically controlled, equal, and evenly distributed heat flow by way of some umbilical fuel line. Dependence on the factory-produced furnace and radiator or ductwork, and on the distant fuel supply would, of course, be abhorrent to Emerson: not only his self-reliance reduced to a thermostat setting, but one's very freedom and independence in the hands of centralized fuel monopoly and/or government control.

A modern technologist, eager to succeed, would find little reward in re-designing and properly engineering Emerson's wood-burning system to make it a viable house-heating solution. Rather, the modern challenge lies in thermocouples and microswitches, heat pumps and convector converters. Even devising a sophisticated solar collector-storage system or fancy generator to produce methane fuel can be more fun and present a greater challenge to an engineer's superior mentality.

Actually there has been worldwide *behind-the-scenes* technological development to make wood-burning a viable method of house heating in colder climates. I stress behind-the-scenes because wood-burning technology in this country has been very much out of the heating and air-conditioning mainstream. Much of our knowledge on the subject has come out of or has been directed toward emerging third-world nations.

And the knowledge that we have gained in the past few decades would warm Emerson heartily: he could have created a comfortable living environment, heated entirely by prunings and thinnings from his woodlot, by merely combining the skills and materials then at his disposal with our present technical knowledge.

Emerson's New Concord House

Accordingly, I have re-designed Emerson's Concord house and heating system so that the entire unit can be fabricated by anyone well motivated toward mastering his existence. The revised house design is mine, but I have borrowed ideas for the building and equipment design developed through the years by others: Frank Lloyd Wright offered ideas on earth-berming insulation (using packed earth as insulation against the cold north wall); Wendell Thomas contributed greatly with his "no-draft floor" inventions; from India, Dr. Billig assisted with his plunger pile floor ideas; Peter van Dresser recalled the need and value of suntempering; the English scientist, Dr. P. O. Rosin contributed a wealth of information on the aerodynamics of open fires; Jack Bays showed how to make some truly low-cost, versatile building materials from waste materials; Scott Nearing demonstated how anyone with minimal skill can build well-insulated, native-stone walls. These are only a few of the people concerned with new-era housing; their expertise is described in detail in my book, *The Owner-Built Home.*[1]

At this point you may begin to realize that to efficiently heat Emerson's new Concord house with wood, much concern must be given to walls, floor, roof, insulation, and solar exposure, as well as to the wood-burning fixtures themselves. Glance for a moment at the plan: Notice, first of all, the circular shape. The northern half is curved so as to better withstand hydrostatic wall pressure exerted as a result of earth-berm insulation: the southern half is curve-angled and sloped so as to achieve maximum solar-ray incidence—from southeast to southwest radiants. The circular form also insures optimum warm air circulation, emanating from the centrally located heat source. The circulation system itself employs registers along the perimeter of the floors where the floor joins the outside walls. Heated air, cooling as it rises to the higher levels, falls and flows downward along the outside walls, through the registers and thence *under* the floor and back to the heating unit for recycling (as indicated in the drawing by flow arrows).

THE NO-DRAFT FLOOR

Additionally, this system provides for the unheard of "no-draft floor." Sudden rushes of cold air from open doors fall into the ventilation inlets (see Figure 42) by virtue of their weight, instead of blowing across the lower area of a room as they do in houses of

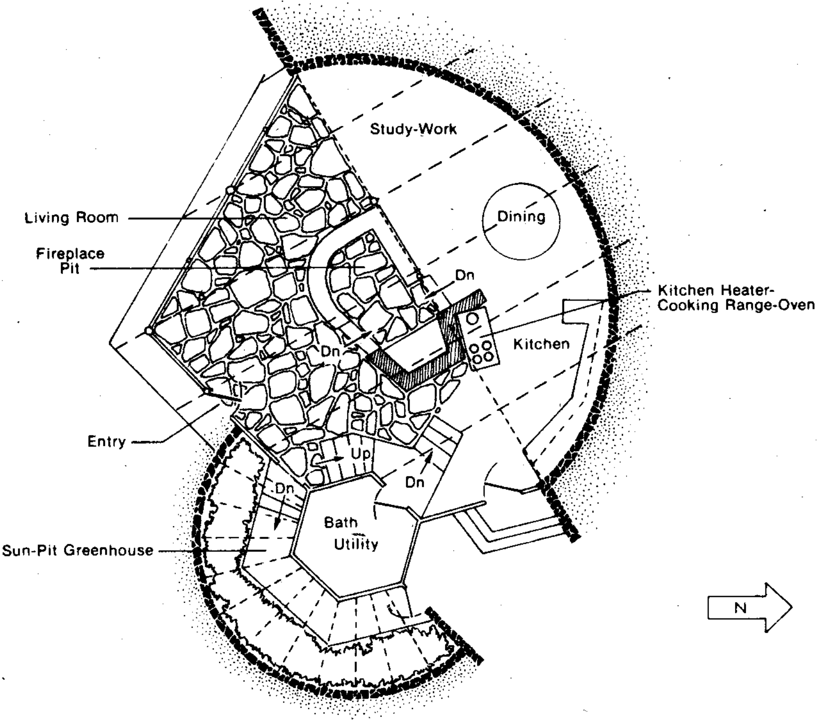


FIGURE 41. Floor plan for Emerson's New Concord house.

contemporary "design." Air space below the floor is achieved by casting the floor on loose, uncompacted earth fill between concrete plunger piles spaced every 3 feet each direction. The piles are made with a crowbar driven into the ground to a depth of 3 feet, then filled with concrete. After a few weeks the loose earth settles and an air space is formed under the slab which finally rests on the concrete piles. (See Figure 43.) The heat circulating through the stove or the inner chamber of the fireplace, across the ceiling, down the walls, and thence under the floor and back to the heat source is *convected* heat.

THE SUNKEN HEARTH

An equally valuable heat source is obtained from direct *radiation* around the fireplace hearth or wood heater. A 12-inch sunken

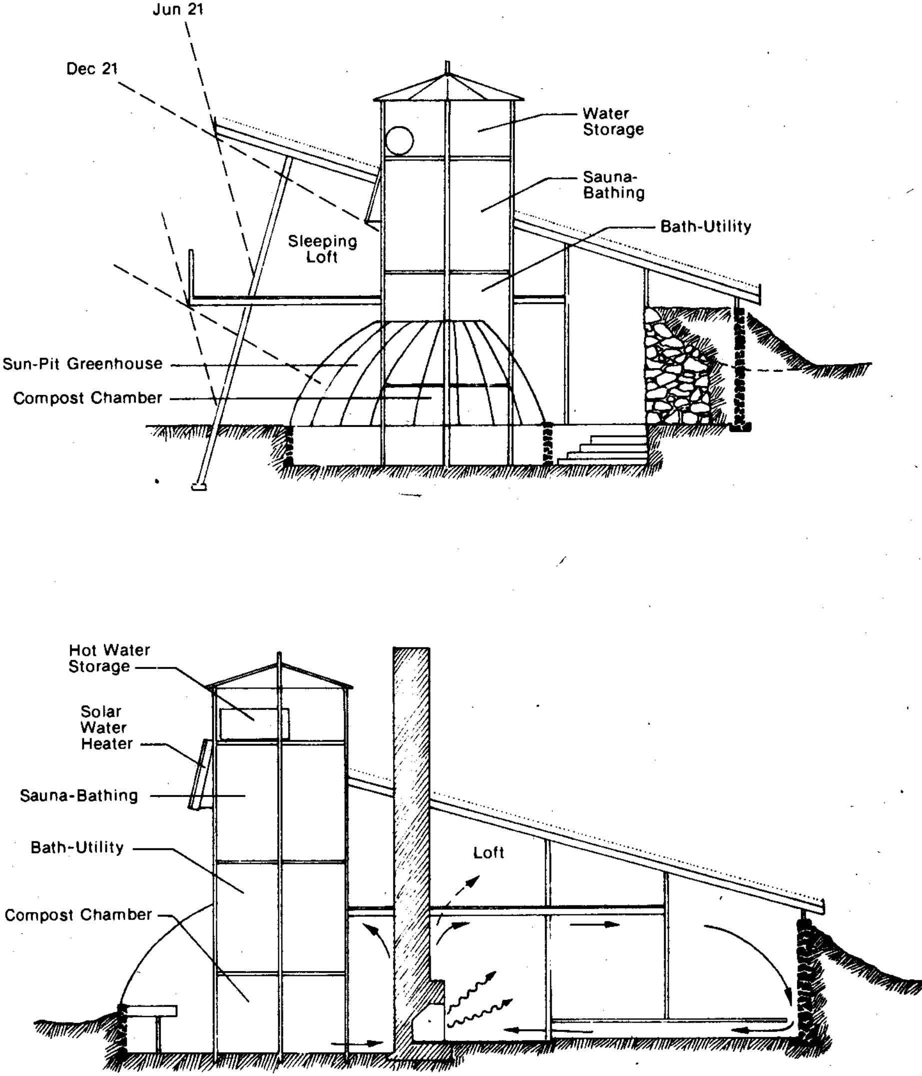


FIGURE 42. Side view of Emerson's New Concord house. Above, N-S section; below, E-W section.

fireplace hearth puts the heat radiation at floor level where it is most needed. It also creates an intimate seating arrangement and lessens the danger of flying sparks since the trajectory of a spark from a sunken hearth is considerably shorter than that from a raised one.

VENTILATION AND INSULATION

A smooth and optimum warm-air movement is possible in this house only if exterior drafts can be controlled and adequate insulation provided. Windows accordingly are fixed; ventilation is provided by separate louvre openings. South-facing windows slope to an angle commensurate with the latitude of the Concord site. Thus, during the winter equinox, solar rays strike the glass at a near right-angle incidence, providing maximum penetration to the dark, slate-covered masonry floor. As the floor becomes heated by the sun, air below the floor expands and creates an air movement there. With all warm-air outlets located at the fireplace, a down-draft principle draws cool and moist air from the exterior window and wall area, then under the floor and up at the fireplace outlets.

After sunset, or during winter storms, insulated panels—old-fashioned "shutters" if you will—hinge over the glass windows. Insulation of the cold north wall is provided by earth-berming the masonry wall. Elsewhere—on walls, ceilings, and roof—a heavy coating of asphalt-clay-fiber mixture is plastered onto wire mesh. (This mixture consists of equal parts of red clay and ground [through a hammermill or shredder] fiber, such as sawdust, straw, cardboard, corn cob, rice hull, etc. To this is added enough bitumul [emulsified asphalt] and water to stabilize the compound.) The same ground fiber is packed as insulation between the wall and between the roof-framing members. An 8-inch layer of sod covers the exposed roof surface.

Note on the plan that the sleeping facilities are provided in the loft. This is a sensible arrangement, heat-wise, especially in northeastern climate zones. A certain amount of heat naturally filters to the loft (registers are installed to control the amount). At bedtime the loft area is always comfortably warm.

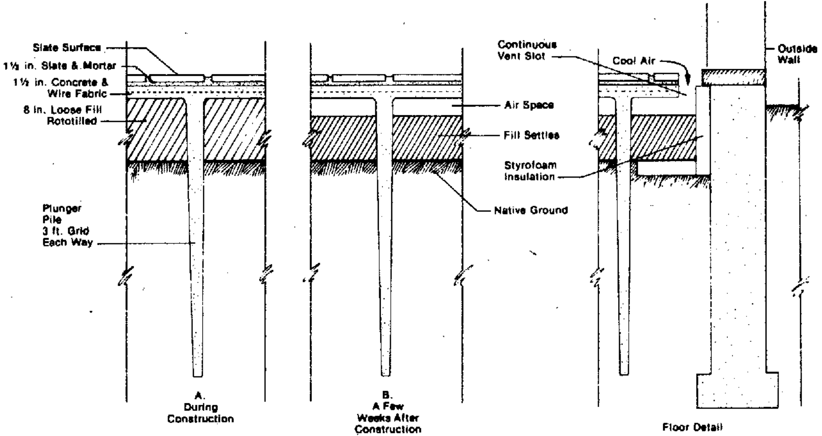
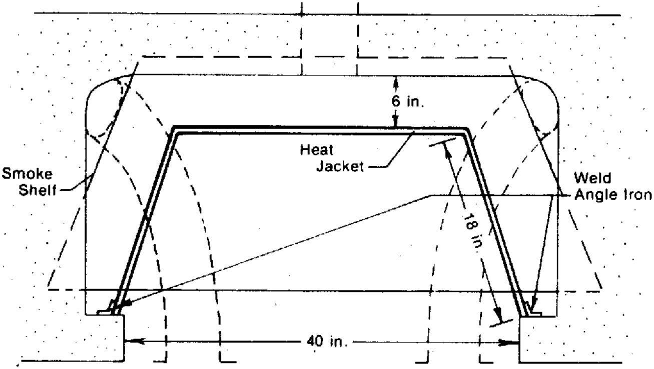


FIGURE 43. Detail of floor construction. Note the development of air spaces a few weeks after the floor is built.

The nucleus of the Concord house heating system is its central fireplace. The key factor relative to optimum functioning of the fireplace is its circulating heat chamber. Sheet iron is 12 times as conductive as stone masonry. A metal heat chamber will emit quantities of conductive heat that would otherwise be lost through absorption in the surrounding masonry or lost to the atmosphere via the chimney. Patented metal fireplace liners (Majestic, Heatilator, Heatform) became available long after Emerson's time. All, except for Heatform, are poorly built out of thin, 14-gauge metal and, unfortunately, the liner is unreasonably expensive. In keeping with the do-your-own-thing theme, I recommend that people build their own fireplace liner from my plans. (See Figure 44.)

The metal chamber is cut, bent, and welded out of a single 3-by-9-foot piece of sheet iron. A damper is welded to a pair of hinges which in turn are welded to the smoke shelf. Cool air inlets are provided along the upper front and rear of the fireplace.

Air-intake control is the key to efficient fireplace combustion. The ignition of a correctly proportioned gas-air mixture will give complete combustion of wood and emit gases containing only the



Plan

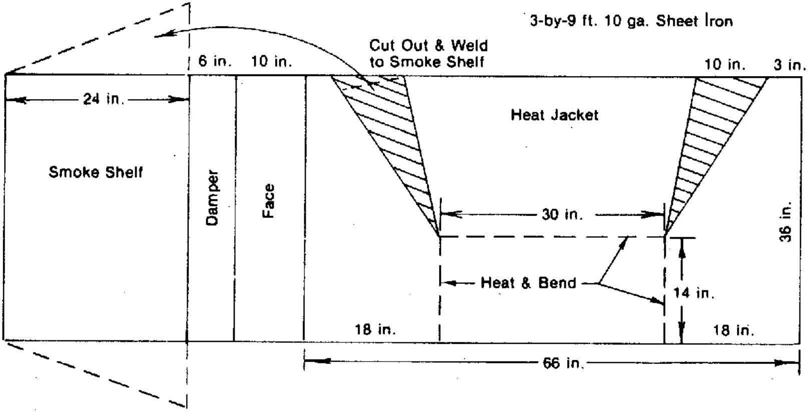


FIGURE 44. Heat jacket pattern.

non-combustible carbon dioxide, water vapor, oxygen, and nitrogen. When smoke and soot are observed coming out of a chimney, you can be sure that combustion is incomplete. What you actually see are small quantities of hydrocarbons and free carbon (soot) that are not burned. Thus, much of the heating capacity of the woodfuel is lost. The heat loss is twofold: in the hot gases that rise up the flue, and in the unburned combustible particles that escape with them.

It's common knowledge that green wood has less heating efficiency than well-seasoned wood. This is because freshly felled wood is 50 percent water, and a high moisture content interferes with the burning process. Water evaporating from wet wood forms a sheath of vapor around the fuel and blocks the entry of oxygen, thereby lowering ignition and combustion rates. The point of combustion of wet wood can be lowered to a reasonable level only by increasing the air intake. This, in turn, creates an excess draft through the fire with consequent heat loss via the flue. If you must burn wet wood you will need plenty of draft, but properly seasoned wood requires only a small amount of air for combustion. When burning dry wood, the draft must be controlled. This will now be explained.

A fire in a fireplace involves: (1) the motion of air toward the fire; (2) its passage through and over the fuel bed; (3) its admixture with combustion products; and finally (4) the flow of the mixture up the flue. Let's take these steps one at a time:

(1) The required air-volume flow toward the fire for the average fireplace opening is about 3,000 cubic feet per hour—which amounts to about four complete air changes per hour in an average-sized living room. Now the amount of fresh air required for proper ventilating by a family of four has been established at about 1400 cubic feet per hour. Thus, a standard fireplace will cause the displacement of over twice the amount of room air required for optimum ventilation. Hence half the amount of air needed for the fire should be drawn through duct-work directly from outside the room and not be permitted to pass through the room to the fireplace.

This is especially important when fireplaces are installed in our modern, tightly constructed, efficiently weather-stripped houses, because the amount of air available for supplying the chimney draft is insufficient! A partial vacuum results which, besides starving the fire, tends to pull smoke and combustion gases back into the room. This vacuum also causes foot-chilling drafts.

A sub-floor inlet for new air minimizes the cold air currents within the room. Combustion efficiency is thereby increased, especially if the incoming new air is heated before it reaches the firebed. This is best accomplished by routing the new air supply duct under the firebed with exit at the fire-grate. (See Figure 45 for illustration of this air flow.)

(2) A properly designed grate is critical to the second consideration—the passage of air through and over the fuel bed. A grate

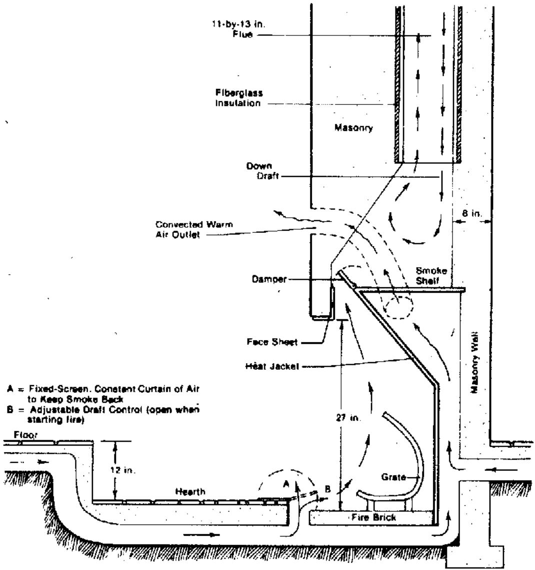


FIGURE 45. Cross-section of Kern's fireplace.

is used to raise the firebed a few inches above the hearth. It should be relatively small, as it is important that the wood charcoal which forms during combustion cover the grate completely. If the grate is too big so that too much wood is burned, the temperature of the gases escaping through the flue will be too high, resulting in heavy heat losses. On the other hand, too small a grate causes draft trouble and consequent incomplete combustion with the added risk of tar deposits in the chimney.

A 14-inch deep fuel grate adequately holds an ideally stacked triangle of three logs. It also insures that hot coals do not come in contact with the rear of the metal liner; thus, preventing red-hot metal-deteriorating temperatures.

One can easily fashion a fuel grate from a series of short pieces of 1-inch black iron pipe. (See Figure 46.) Horizontal members are attached to bent vertical pieces with a standard elbow connection. The six or more sections are then welded to two pieces of bar steel which have 3-inch high legs bent from both ends.

Fuel grates of similar design are made in many welding shops throughout the country, as well as by several manufacturers. One company claims that more than double the amount of heat output is achieved by using this "C" shape convection grate. Hot coals on the base and flames in contact with upper portions of the pipes cause heated air inside of each pipe to expand and to flow up and out into the room.

(3) We come, thirdly, to the admixture of ventilating currents with combustion products. The inside fireplace proportions are very important here. Deep fuel beds (long from front to back) produce more smoke than shallow beds, since there is scant combustion air at the back of the grate. Experience proves that the rate of smoke emission increases proportionally with the depth of the firebox, expecially in the early stages of firing. It is also apparent that radiation is more effective with a shallow firebox; with a deep box radiation is mostly upward. An inclined fireback, sloping forward as it goes up, also contributes to better radiation.

The throat opening should be sufficiently small—not over 4 inches wide—to constrain the effluent to pass at a speed high enough to discourage down-drafts. If the chimney throat is too large, then some cool air that does not participate in ignition or combustion will be drawn over the fire. This naturally results in increased smoke emission.

(4) The final aspect of a fireplace, the flow of gases up the flue, involves the chimney itself. A chimney performs a dual function: production of drafts and elimination of combustion residues. The chimney should be designed so that the draft is adequate to deliver just enough air for complete combustion within the firebox. Flue diameter or width should be as small as possible relative to its height. Its height is dependent upon the height of the building plus at least 3 feet above the roof, plus any additional footage required to clear the top of the flue of any obstructions within an approximate radius of 10 feet. (Figure 47 shows basic relationships between room size, fireplace proportion, and flue size for various chimney heights.)

The flue must also be insulated to maintain a high temperature and a near consistent temperature top to bottom. The masonry of which the chimney is constructed will not serve this purpose, as stone is a poor insulator. An insulation material like fiberglass should be used between the masonry and the flue lining. This improves draft and also retards condensation of tar and creosote

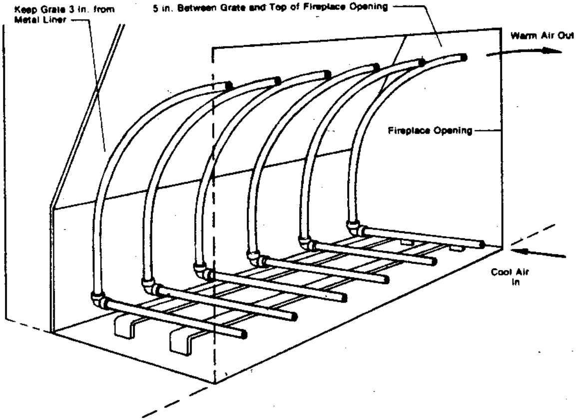
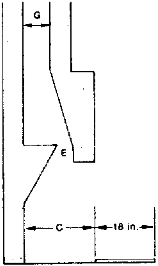


FIGURE 46. Fuel grate constructed from short pieces of iron pipe.

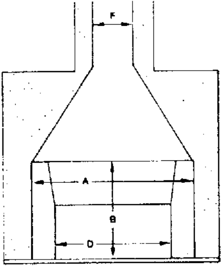
on the walls of the flue because condensation only occurs where low temperatures permit. Flue outlets for the wood range and auxiliary wood heater, as well as the fireplace, are also located in the masonry chimney, thus making it possible to use the safe and permanently installed fire-clay tile flue lining.

Some of the heat, which would otherwise be wasted up the flue, is used to heat water running through two sets of coiled pipes. One set of these pipes is attached to the inclined fireback of the fireplace and the other installed inside the heater stove. After being heated, the water is circulated to an insulated metal tank located within the masonry core.



Floor Space

No.	Square Feet	Cubic Feet
1.	70-240	1400- 2100
2.	240-320	2100- 3200
3.	320-430	3200- 4200
4.	430-540	4200- 6400
5.	540-750	6400- 8800
6	750-970	8800-12400



						Flue Size For Stack Heights					
						Up to 13 ft.		Up to 20 ft.		Up to 30 ft.	
No.	A	B	C	D	E	F	G	F	G	F	G
1.	24	20	13	14	4	10	10	8	8	8	8
2.	30	24	15	19	4	10	10	8	8	8	8
3.	36	27	16	24	5	15	10	10	10	10	8
4.	42	30	17	29	5	15	15	15	10	10	10
5.	48	33	19	33	6	15	15	15	10	10	10
6.	52	35	20	36	6	15	15	15	15	15	10

FIGURE 47. Fireplace proportions.

The Development of Wood Burners

Woodburning-fireplace and heater-cooking stove development have a history not unlike that of the development of many other of man's material acquisitions, such as his dwellings and his transport vehicles. Primitive (Paleolithic) solutions for fireplace or stove were crude, but they worked. "Civilized" (Neolithic) models were gross, wasteful, and worked poorly. Faint glimmerings of a new era (Biotechnic) lifestyle shine through our present-day morass. The light is carried by a few individuals who are able to see beyond the modern confines to a better future ahead.

Count Rumford was certainly one of these early, biotechnic torchbearers. In 1800, he published his comprehensive essay, "Chimney Fireplaces." His main contribution was in the alleviation of the smoking fireplace. One fault to the fireplaces of his time, he correctly asserted, was due to too large a chimney throat. He argued that if the chimney throat is too large then some cool air, not effecting ignition or combustion, will be drawn over the fire. This naturally results in an increase of smoke emission. The throat opening should be sufficient to constrain, venturi fashion, the passage of the escaping gases and unburned particles at a speed high enough to discourage downdrafts. Traditional chimney throat standards call for an 8-inch opening. Rumford recommended 4 inches. (It should be noted, however, that there is an alternative to reducing the throat size. A damper control, installed in the flue, can curb undesirable downdraft eddies.)

Rumford introduced the inclined fireback which increases fireplace efficiency by providing a greater radiation area. For the purpose of breaking up the current of smoke in the event of chimney downdraft, the back smoke shelf of Rumford's improved fireplace ended abruptly—a practice strictly adhered to by fireplace masons to this day. (See Figure 49.) He was also first to give extensive study to inside-fireplace proportions. According to Rumford, the fire-space proportion requires the *back* of the recess to be equal in size to the *depth* of the recess. Deep fuel beds produce more smoke than shallow beds since there is scant combustion air at the back of the grate. Experience proves that the rate of smoke emission increases proportionally with the increase in depth of the firebox, especially in the early stages of firing.

As I have already indicated, it is apparent that radiation is more effective with a shallow grate. With a deep grate radiation is mostly upward. Higher temperatures and consequent decrease of smoke emission results when the fireback becomes inclined toward the fire —another practice strictly adhered to by contemporary fireplace builders.

Rumford had an uncanny comprehension of fireplace aerodynamics, and, although he successfully cured the smoking fireplace, his prototype was far from being the heat efficient unit it could be. For this reason I am dismayed to see Rumford's ideas presented, as in *The Forgotten Art of Building a Good Fireplace* (by Vrest Orton, Yankee Inc., 1969), as the final authority on fireplace design. This book presents an excellent historical treatment, but modern fireplace builders, following the diagrams of this early proponent of fireplace design, realize only the disservice of half-truths for their labors. Much work preceded Rumford's revelations, and many advances have followed the Count's efforts.

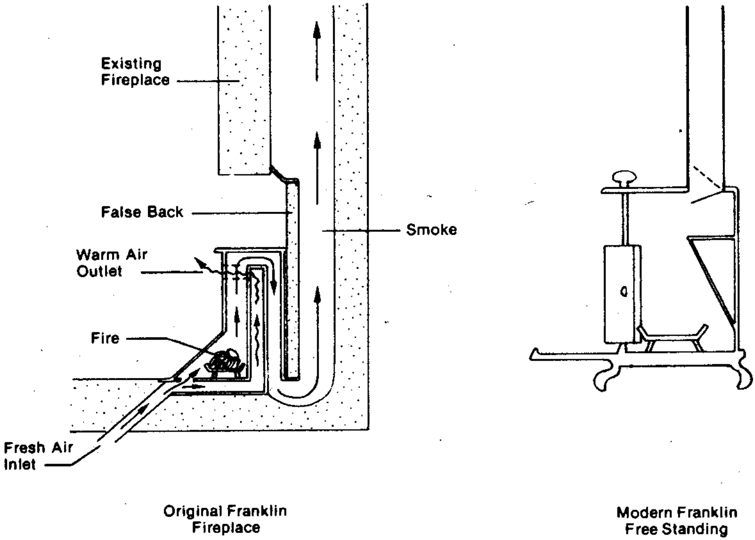


FIGURE 48. Two Franklin versions which can be installed in existing masonry fireplace.

For instance, Rumford apparently knew nothing about Louis Savat's heat circulating fireplace, installed in the Louvre 200 years before Rumford wrote his treatise. Savat's fireplace achieved an amazing 30 to 40 percent greater efficiency than present-day American tract-home fireplaces. He surrounded the grate with a metal air chamber which had warm air outlets above the fire opening. He also supplied the fire with air from under the floor, thereby subsequently reducing room drafts and further improving combustion efficiency.

Few people realize that practically all of the technical features of Ben Franklin's 1742 Pennsylvania Stove were copied from earlier inventors. Savat's concept of pre-heated draft was employed by Franklin with little change in design. The descending flue was also copied as follows: smoke rose in front of a hollow metal back, passed over the top and down the opposite side. Finally, at the same level as the hearth, the smoke ascended the flue.

Wood Stoves

The stove sold today as "The Franklin Stove" contains none of the ingenious heat-saving features that were incorporated in the original models. The only real saving grace of modern Franklin Stoves is the closeable open-fire, which enables one to get a more efficient stove heat from a fireplace merely by closing a set of folding metal doors. According to The British Research Station, a closed fireplace unit is 50 percent more efficient than an open fire.

The English scientist, Dr. P. O. Rosin, has done much significant research on the aerodynamics of open fires. He built scale models of fireplaces using celluloid sheets to visually reveal the behavior of gaseous flow associated with open fires. Rosin disproved Rumford's contention that a plumb line from the center of the chimney flue should extend, uninterrupted, to the center of the fireplace fuel bed. Rosin pointed out that downdrafts have to be considered: eddies of smoke-laden air will back up into the room if they have an opportunity to collect in the smoke shelf area. Actually, after the experience of building scores of fireplaces over the past 20 years, I find that some eddies occur where the smoke shelf is minimal, as in Rumford's design. Rosin is correct: eddies will *not* occur where the shelf is eliminated entirely. But neither will they occur where the shelf is ample enough to allow the downdraft a free return trip up the chimney. Rosin's design includes a curved, free-flowing chimney breast and throat. The principle is good but impossible for the backyard mechanic to weld into place.

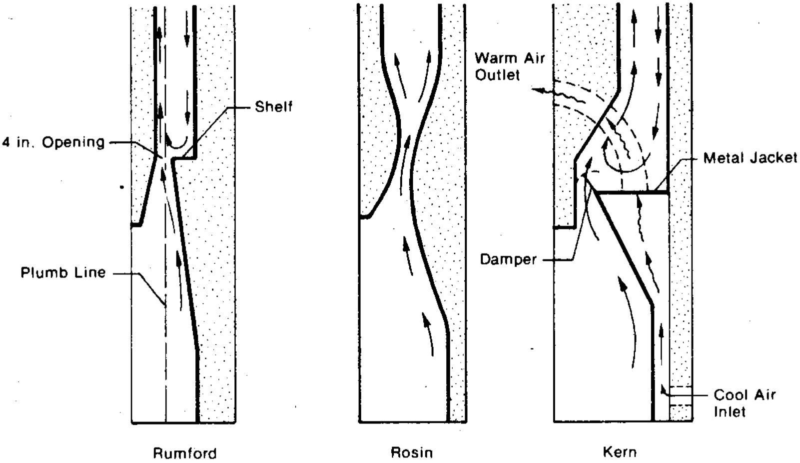


FIGURE 49. Three fireplace cross-sections.

WOOD COOKING RANGES

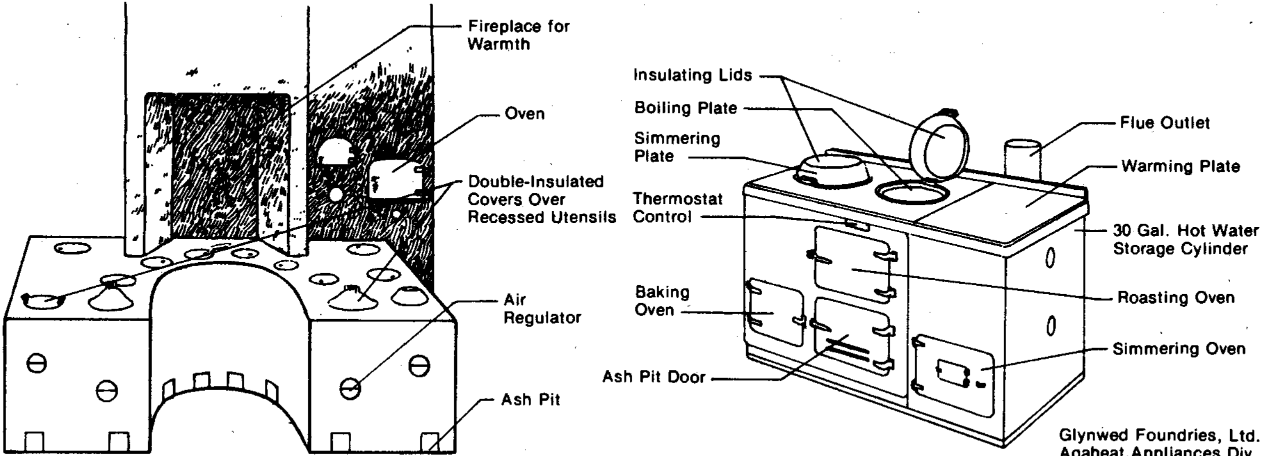
> A farm house should never be built without an ample open fireplace in its kitchen and other principally occupied rooms; and in all rooms where stoves are placed, and fires are daily required, the open Franklin should take the place of the close or airtight stove, unless extraordinary ventilation to such rooms be adopted also. The great charm of the farmer's winter evening is the open fireside, with its cheerful blaze and glowing embers; not wastefully expended, but giving out that genial warmth and comfort which, to those who are accustomed to its enjoyment, is a pleasure not made up by any invention whatever; and although the cooking stove or range be required which—in addition to the fireplace, we would always recommend, to lighten female labor—it can be so arranged as not to interfere with the enjoyment or convenience of the open fire.
>
> Lewis F. Allen, *Rural Architecture,* 1852.

Count Rumford was horrified at the dirty, inefficient, labor-making, fuel-devouring cooking range that adorned the English kitchen. Cooks at work over them, he said, "... looked and felt like buttered mummies," so great was the heat loss from the average range. Rumford solved the problem in 1800, but the solution has yet to trickle down to a 20th century biotechnic wood economy. The problem of heat emission was so well handled in Rumford's range that he later had to install a nearby fireplace grate to keep the cook warm! His principle was two-fold: produce heat only when needed, but not in excess; and, by insulating the range, use the heat before it is lost. His range was a massive brick affair. Cooking utensils were fitted into the masonry counter top and covered with insulating lids. Each utensil had its own separate fire source, grate, ash pit, and air regulator. His large ranges were built on a U-shape which certainly made a convenient work space for the cook. (See Figure 50.)

A hundred years elapsed between the time when Rumford made the first major breakthrough in range design and when a similarly efficient unit was produced in Sweden. During this interim millions of gross iron monsters were pawned off on an unsuspecting public. And, worst, possession of the ornate, grandmotherly iron range has become the personal dream today of nearly all back-to-the-landers, people who should know better! Like Rumford a hundred years before him, Dr. Gustaf Dalen had a chance to observe all the unnecessary chores associated with cooking. This one-time Swedish physicist and Nobel Prize winner was kept at home by blindness, and, while there, he made himself useful by developing what is perhaps the most efficient range ever built, the AGA. Again, like Rumford, Dalen's creation was so efficient that later models had to be modified to provide warmth for the cook. Pre-World War II models were advertised to run on about $10 worth of fuel—the cooking cost for a whole year! Dr. Dalen employed the same good–sense principles that Rumford laid down: produce heat only when needed and use it before it is lost. The same deep-well, insulated lids that Rumford proposed were incorporated in the AGA range.

WOOD FURNACES

Emerson's house in Concord, Old Manse, was originally built by his grandfather. Typical of houses of that era, it contained numerous wood-burning fireplaces, heater stoves, a cooking range, and even a laundry stove. Each of these heating units had to be kindled and stoked, and each contained an ash pan and a flue pipe requiring constant maintenance. Finally, every wood-burning unit in the house established a unique environment of convection currents. That is, throughout the house there resulted many separate currents of air circulation with an ensuing heat loss through the multitude of chimney flues. Little wonder that coal-burning, warm-air, gravity-



Rumford's Cooker 1800

Aga Cooker 1929

Glynwed Foundries, Ltd.
Agaheat Appliances Div.
Bx 30
Ketley, Telford, Shropshire
TF1-1BR England

FIGURE 50. Two wood cookers.

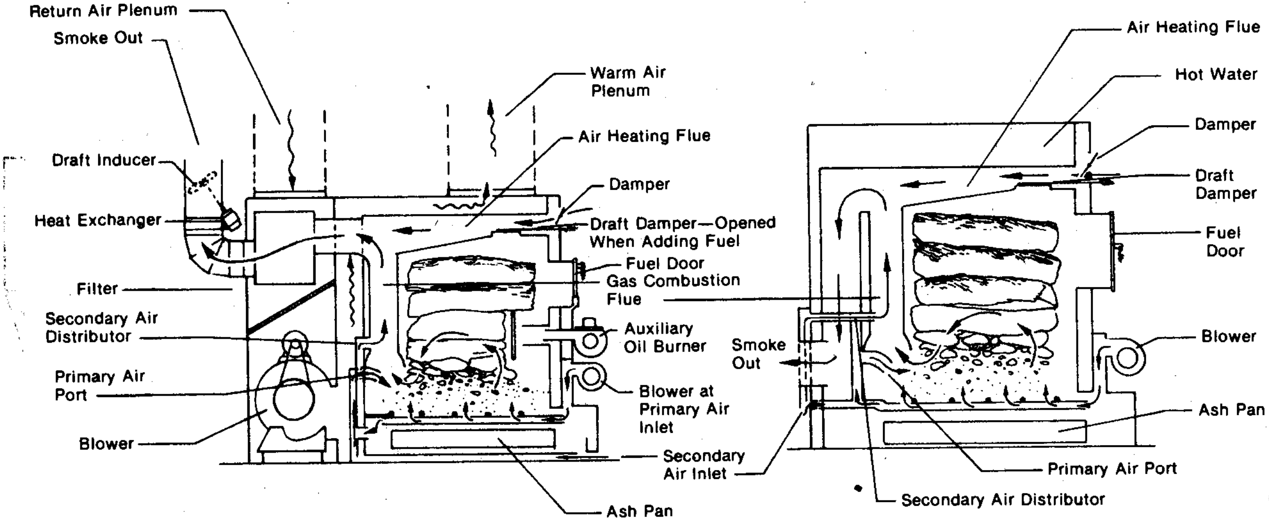


FIGURE 51. On the right, the Fuel-Master Wood-Burning Boiler; and on the left, the Fuel-Master Wood Furnace.

fed furnaces became the rage soon after Emerson's time. Located in the basement, this single facility provided heat and hot water for all the upper-level living and sleeping areas.

For years, an extremely efficient wood-burning furnace, the Riteway, was manufactured in this country. Until recently, however, the model was unavailable, but now, because of our recent energy shortages, the stove is again being manufactured.[2] Now called the Marco Fuel-Master, this furnace uses either hot air or hot water as a heat medium. Fans or pumps distribute the heat so that lower-level basement installation is not required. The hot-air furnace requires room-perimeter registers connected to the furnace plenum by insulated metal ducts. Hot water installation could be either in radiant pipe coils in concrete floors or in room-perimeter baseboard radiation coils.

The basic design features of both hot air or hot water furnaces were similar. First, and most important, the furnaces provided for a *complete fuel combustion.* This principle, described below, contrasts with the usual downdraft stoves, like the Ashley, in which fully 50 percent of the combustible gases leave the stove unburned, forming creosote and tars in the flue on the way out. Riteway and Fuel-Master furnaces and room heaters are equipped with a heavy cast-iron gas combustion flue located wholly inside the combustion chamber. This flue extends to the charcoal-burning level where wood gases accumulate. By providing several primary air jets over the charcoal bed, ignition of the wood gases is attained at the required 1200°F temperature. Preheated secondary air is then added to provide the necessary oxygen for complete combustion. Owners of Riteway and Fuel-Master stoves and furnaces report a fuel saving of up to 75 percent as a result of this complete combustion principle.

Both of these air-heating and water-heating furnaces have a wraparound jacket containing air or water. In addition, a heat exchanger is provided on the hot-air furnace. This consists of a large chamber through which hot smoke passes before reaching the flue. The main blower forces air across and around this hot smoke chamber, deriving additional warm air for the household in the process.

Speaking now of space-heating furnaces, Emerson would have heartily praised the efficiency of performance and the prudent design of the Riteway. He would, undoubtedly, flash on such special features as fire-brick lining in the heat chamber which gives the furnace a near-indestructible quality. The Riteway heater in our homestead home has been burning continuously throughout each of 15 consecutive winters, and it is still as good as the day we bought it. The self-sustaining, continuously burning feature of this heater makes it possible that only one fire need be built a season with only a few loadings every 24 hours to keep it going! An automatically maintained thermostat control, coupled with a heating unit that is completely airtight, makes fine control possible.

Building Your Own

This general background introduction to efficient wood heater design demonstrates how utterly wasteful the usual installation is. But it says more: by understanding the basic fundamentals of complete combustion we can design and build our own superior unit. I would wager the opinion that, in recent years, more wood heaters have been put together in small blacksmith and backyard welding shops than in all stove foundries combined. Cast-iron stoves were popular in Emerson's time because people liked the evenly distributed heat which they radiated. But cast-iron stoves cannot be made airtight, and, of course, they require factory techniques for their mass production. Cutting and welding metal is no longer the specialized craft it once was in our grandfather's time; simple arc and oxy-acetelyene equipment have replaced blacksmithing skills.

The traditional home-fabricated stove is made from a 55-gallon oil drum, laid horizontally. A pair of cradle legs made from bent angle iron is welded to the bottom side, and a fuel access door is cut out of the front end. The outlet flue is customarily located at the rear top of this lower-level barrel and connects to a second, upper-level, 55-gallon oil barrel which functions as both a heat chamber and an oven. The final flue outlet flows chimneyward at the upper back end of this heat chamber oven, although on more sophisticated barrel stoves the flue for this upper-level chamber is located above the front oven door and, thence, flows into the chimney. (See Figure 52.)

These stoves were so common in the Northwest territories at one time that they became known as Yukon stoves. To meet the popular demand for the Yukon barrel stove (also called the "belly stove"), manufacturers can supply conversion kits consisting of a cast-iron fuel door, legs, and a grate designed to fit the 55-gallon oil drum.[3]

This kind of heater installation is, at best, crude and inefficient, fuel-wise. But it does speak to one of the major shortcomings of American stoves; that is, to the lack of fuel capacity. Quite a number of 3-foot-long logs can be packed into the Yukon stove. The old-fashioned school stoves had this faculty, too. They were made from half a ton of cast-iron and could burn 24 hours with one loading. Logs 2 feet in diameter and 3 feet long could be packed into these stoves, which are now collectors' items. The epitome of limited fuel capacity is the traditional cast-iron—and the modern steel!—wood-burning stove.

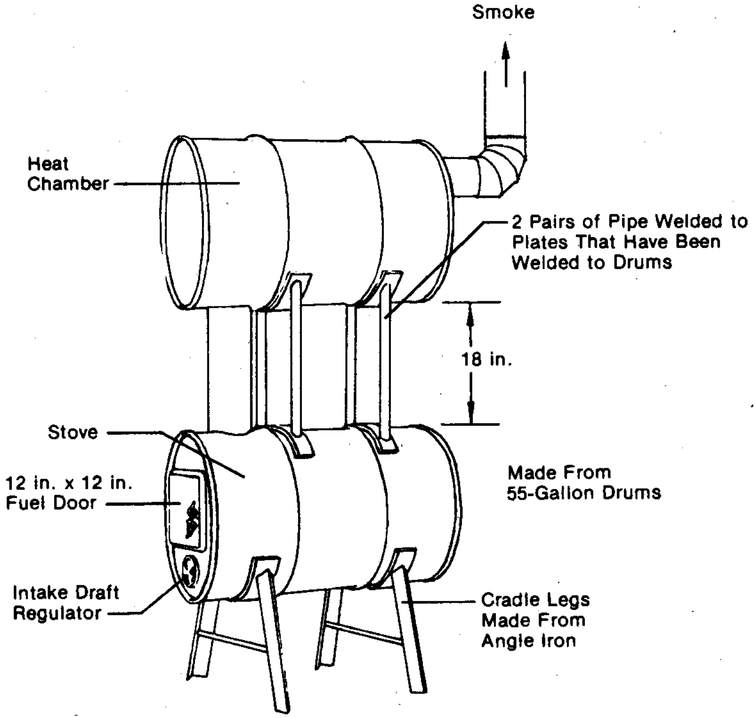


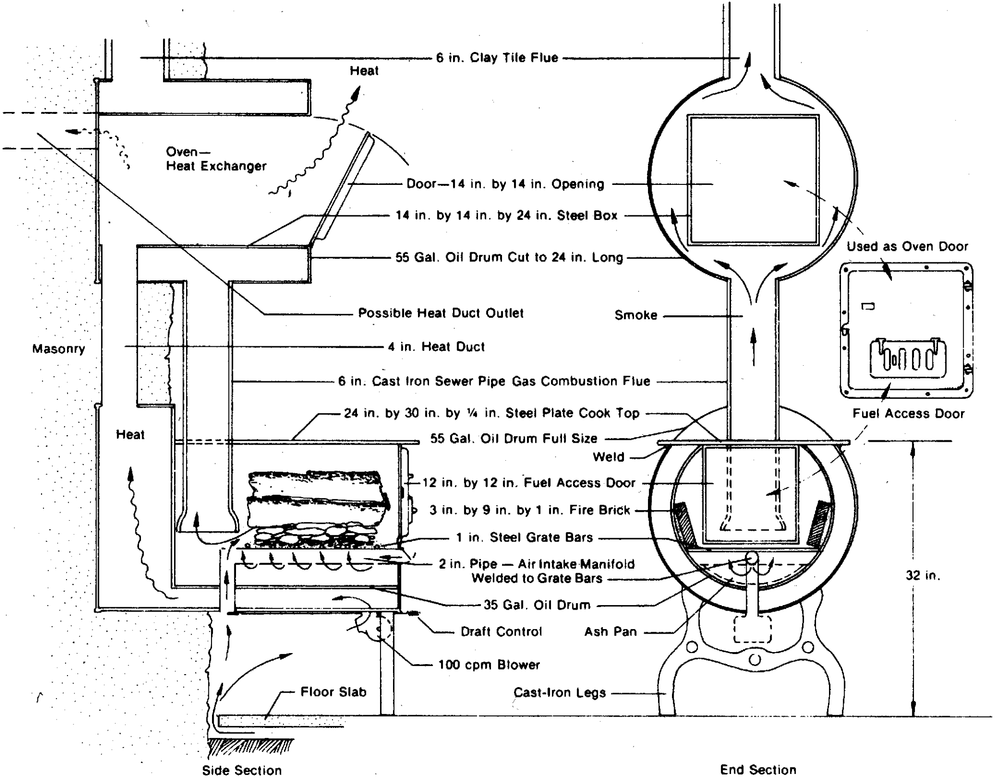
FIGURE 52. The common homemade stove, fashioned from two 55-gallon oil drums.

There is good reason to combine cooking and heating functions in one unit, especially for a compact, open-planned house such as my proposed Concord design. We already imagined how Emerson (or more likely his wife) must have trotted to keep half a dozen separate fires stoked on chilly days. And, remember, each fire required a separate flue, each hot metal flue contacting potentially flammable roofing material in the attic, compounding the risk of destructive fire.

Wood-to-flue joining substantially decreased the risk of fire danger if done properly, but the build-up of creosote and tar in the flue as a result of using an inefficient stove (or green wood) is another matter. Wood is one of the hottest burning fuels. Unburned gases condense in an uninsulated metal flue, forming caked layers of combustible creosote and tar. A spark will ignite this shaft of concentrated fuel, blasting flames out of a cherry-red chimney. This is why houses burn down in the middle of a cold winter.

For fire safety, as well as for economy, I recommend combining the cooking and stove heating functions into one facility. The flue from this dual-purpose unit should be clay tile, wrapped with fiberglass insulation and encased in the centrally located fireplace masonry.

Figure 53 illustrates some of the salient features of my proposed home-built cooking-heating unit. The combustion chamber consists of a 35-gallon oil drum set inside and welded to a 55-gallon oil drum outer shell. I chose oil drums because of their availability, their low cost, and their strong curvilinear construction. To provide a heat-absorbing cooking surface, a sheet of ¼-inch steel plate is welded to the top of the intersecting drums. Spaced bars of 1-inch reinforcing steel form the grate. Below the grate is welded a continuous length of 2-inch diameter steel pipe, perforated *at the bottom* with drilled holes to emit a continuous draft the full length of the fuel bed. Draft inlets are provided at the front of the stove for quick starting, and at the rear of the stove for the complete combustion of gases accumulating there. Both draft inlets are equipped with positive, fine-adjustment controls. The rear draft is supplied from under-the-floor air space, thereby creating a full-circle, no-draft convection current. During colder temperatures a front-mounted squirrel cage fan (almost silent) is activated to help circulate jacketed hot air into the room. A second 55-gallon drum encases the oven at a



Kitchen heater-cooking range-oven.

convenient level above the cooking surface of the lower-level drum. Both drums are cantilevered out of the masonry wall. Hot air flows from the central chamber of this upper-level drum through a metal-boxed heat exchanger, and from there into the room.

One of the most unique—and valuable—features of the Riteway or Fuel-Master stove is the gas combustion flue. The principle certainly should be included in our home-made version. Due to the high temperatures incurred at the point of gas combustion, a heat-resistant material, such as cast-iron, should be used. The ideal flue is made from a length of 6-inch sewer pipe with the hub down to augment the combustion capacity. It is connected directly to the heat exchanger.

Our total winter-time hot water needs are met because a thoughtful Riteway engineer provided space in the firebrick lining of the combustion chamber for a metal, water-heating collector. This one simple installation has, doubtless, saved enough electricity or gas to repay the original cost of the heater many times over through its uncomplicated, trouble-free, 15-year performance for my family. At one time Superior Fireplace Company, makers of the Heatform fireplace liner, offered a water-heating coil that fastened onto the metal fireback. Drawing hot water from heater and fireplace is an excellent idea and should certainly be included in the new Concord dwelling. Heated water naturally thermosiphons into an upper-level storage tank. In summer months a solar collector provides hot water. The solar unit, the fireplace, and the stove units are all tied into the same storage tank.

Lastly, if a sauna is desired (Emerson would have dug it!), an additional hot water supply can be provided with a Nippa woodburning sauna heater.[4] They come equipped with either a 20-gallon water jacket or a heat collector which can be connected to an insulated water storage tank. In the new Concord house I have located the sauna and bathing facilities on the upper level of a compost-privy core. When the room is not used as a sauna, the stove provides heated water and comfortable warmth. (See Figure 42.)

Woodlot Management

Wood-fueled heating and cooking is an especially attractive energy alternative when the homeowner has at his or her disposal some

—even just a few—acres of woodland to manage. An average-growth woodland managed on a sustained-yield basis will supply about one cord of wood per year per acre of woodland. The wood removed is in large part in the form of thinnings and prunings, although the term, "sustained yield," infers that the amount of wood removed each year is equal to the amount that grows back. Seedlings are nurtured or planted wherever mature trees are removed. In the instance where the homeowner has unplanted acres available, he or she can do no better than to plant a woodlot in the form of a windbreak.

The term "shelterbelt" is often used interchangeably with "windbreak," but a distinction should be made between the two terms. A windbreak is a protective planting around one's house and garden, whereas a shelterbelt is a long, planted barrier protecting large fields. During the Great Depression, the Prairie States' Shelterbelt Project under the auspices of the U.S. Forest Service was implemented, and over 30,000 separate shelterbelts were planted, reaching a total length of about 19,000 miles. Most of what we now know about planting trees for wind protection and for fuel supply has come out of the extensive research and experimentation done during this project.

SHELTERBELTS

Towards the end of the Shelterbelt Project (in 1942), plans were developed for an optimum, "standard shelterbelt" proposal. These plans included provision for planting varieties contributing early protection and for planting semi-permanent and permanent varieties. Rows of permanent, dense, low-growing shrubs and conifers were planted on the windward side of this "standard" belt. Rapidly growing, deciduous species were placed in the center of the belt, and, on the leeward side, longer-lived varieties were planted to provide early wind protection. (See Table 9.) A few rows of a shrubby species were also planted at the far end of the leeward side of the shelterbelt, bringing the total number of rows to about ten. (See Figure 54.) Shelterbelts of less than six rows failed to develop a desirable forest ecology.

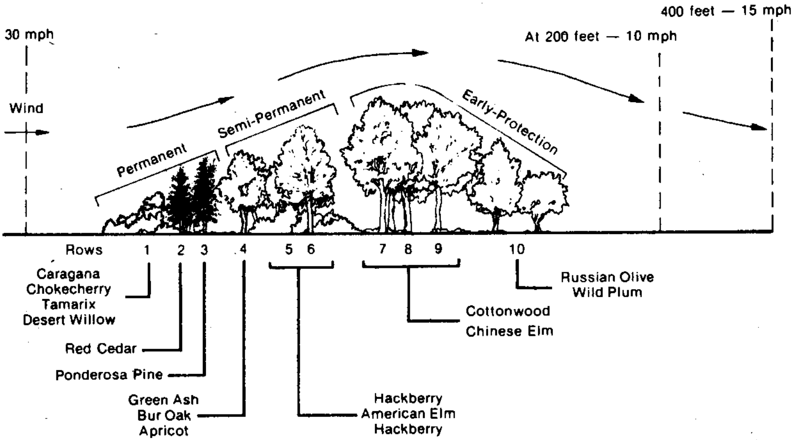


FIGURE 54. Suggested planting of tree varieties in a shelterbelt.

During the 6½ years of the Shelterbelt Project, it was found that the amount of growth of a tree's height increased from northern climates southward. In North Dakota the average growth in height for this period was 16 feet; in Nebraska it was 20 feet; and in Texas it was 24 feet.

Row spacing of 10 feet apart was established between the trees. Distance separating trees in each row was not over 8 feet, and shrubs were not over 4 feet distant from each other. During the six and one-half year project, the crowns of the rapidly growing species closed in fully, and a forest floor mulch an inch thick was formed during this same period.

Primarily as a result of the U.S. Forest Service efforts, there has

TABLE 9. Relative Diameter Growth

RAPID	MODERATE	SLOW
European Larch	Douglas Fir	Cedar
Loblolly Pine	Ponderosa Pine	Hemlock
Aspen	Redwood	Longleaf Pine
Black Locust	Spruce	Beech
Cotton Wood	Black Walnut	Oak-Black & White
Willow	Elm	Sugar Maple

developed a distinct but thorough science of shelterbelt planning. This science involves the designation of tree varieties, planting layout, and tree spacing. Poplars, for instance, are often used as windbreaks because they are able to withstand high-wind pressure, but they are also great soil robbers. So it becomes prudent to alternate poplars with the cultivation of a complimentary variety, such as the alder tree. The alder is one of the few non-legumes which provides nitrogen to the soil.

It is likewise important to combine coniferous and deciduous tree plantings. Conifers planted on eroded, compacted, humus-lacking soils will, in time, improve the soil and its humus content so that hardwood trees planted nearby can thrive on the increased soil nutriments. A mixed woodland is much less subject to insect damage, mainly because of the greater variety of trees. Insects are usually attracted to specific tree varieties. In a well-planned woodlot the extent of insect damage is limited because of the small number of any one type of tree in any one area. An example of woodlot mismanagement is the fatal Dutch elm disease which was introduced by the elm bark beetle and was responsible for killing mono-planted, roadside elm trees all over the East. Concentrated likeness invited and caused widespread destruction.

In addition, a mixed woodlot produces a mixed, well-balanced layer of leaves on the forest floor. This loose, crumbly layer of mulch is certainly superior to a dense, impermeable layer of a single variety of needles or leaves.

Someone once discovered that trees have three different shaped root systems; a *spear* shape found in the oak which taps minerals from great depths; a *heart* shape found in the birch which lifts huge quantities of water to its top; and a *flat* shape designed for the support required by such trees as the giant Sitka spruce. Obviously, a plantation of a single species of tree with identical root systems would offer fierce competition for food, moisture, and support at root level. This is another good reason why one should make certain that his or her woodland contains a mixed variety of trees, which has wide variance in age and in growth patterns. A dense monoculture of conifers may successfully break the force of prevailing winter winds, but, at the same time, they may obstruct the flow of cold air, impeding natural air drainage. The winter-bared branches of deciduous trees will not obstruct this important cold air movement.

WINDBREAKS

By far the most effective arrangement for a windbreak near one's dwelling is in the form of an "L," with the point of this "L"-planting directed at the prevailing winter winds. (See Figure 55.) This layout is best both for preventing evaporation of soil moisture, thus helping to raise soil temperatures, and for catching and preventing the drifting of snow around walks and buildings where it could otherwise be an annoying problem. (I should point out, however, that soil mois-

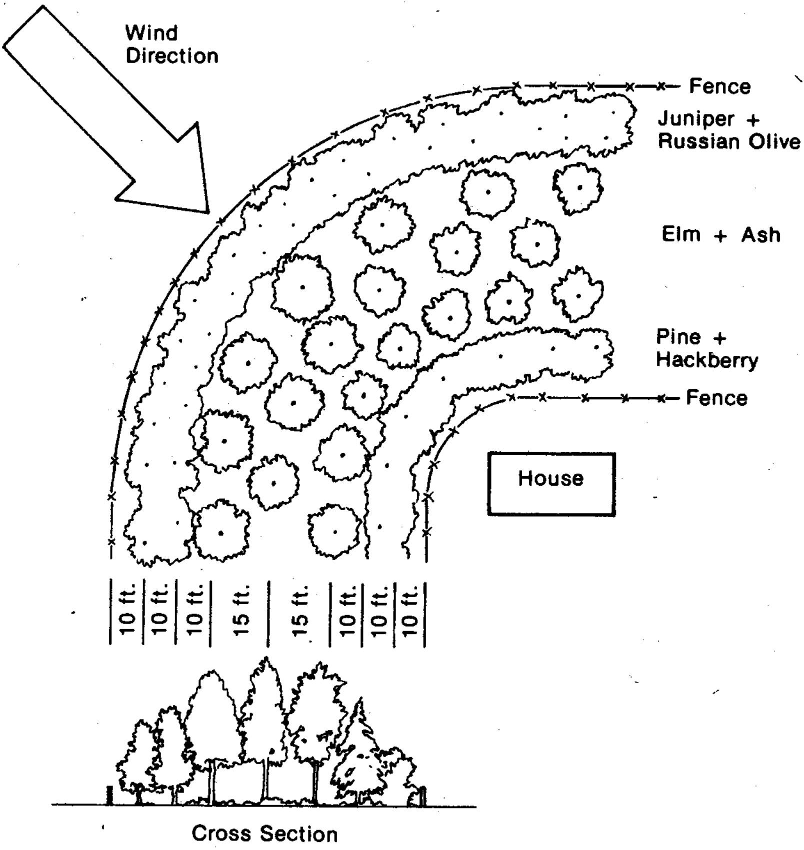


FIGURE 55. Ground plan for windbreak designed for Plains States.

ture for crops can be conserved if snow is held in the shade of shelter trees where it melts slowly in the spring.)

One of the more valuable experiments which evolved from the Prairie States' Shelterbelt Project subsequently resulted in remarkable savings in heating fuel from planted windbreaks. In these Nebraska experiments exact fuel consumption was recorded in two identical test houses. One of these houses was exposed to the winds and one was protected by a nominal windbreak. Both houses were maintained at a constant inside temperature of 70°F. The house having windbreak protection required *30 percent less fuel* than the exposed dwelling. It was also found that during a mild winter, animals in a tree-protected yard gained 35 percent more weight than those in an open area. It is, therefore, apparent that a windbreak not only provides fuel to burn, but fuel savings as well.

The process of selecting the best species of trees for a windbreak can be simplified by referring to charts of regions of natural vegetation prepared by the U.S. Forest Service. The species you choose must, first be climatically suited to your regional area. Selection also depends upon specific site factors. For example, the inherent capacity of a tree species to withstand shade becomes a major factor in determining the variety and the numbers of trees to be planted. The range of tolerance is very wide, as Table 10 indicates. Sugar maple seedlings require ony 2 percent full sunshine, while lobolly pine seedlings require nearly full sunlight to grow satisfactorily. Seedlings are generally more tolerant of shade than mature trees, especially if they are grown in a good exposure and on good soil. Shade-givers, growing near seedlings, can provide valuable physical protection to young trees.

TABLE 10. Relative Tolerance to Shade of Common Woodland Trees

TOLERANT	INTERMEDIATE	INTOLERANT
Cedar	Douglas Fir	Pine
Hemlock	Ash	Larch
Redwood	Birch	Aspen
Spruce	Chestnut	Black Walnut
Beech	Elm	Hickories
Maple	Oak	Willow

Fuel wood is usually measured by the cord. The standard cord is a pile 8 feet long, 4 feet wide and 4 feet high. Comprehensive labor studies in New York State found that an experienced woodchopper can fell, skid, saw, and split 2 cords per day. The study was made before chain saws came into common usage, so you can estimate that an inexperienced person using a power chain saw could cut this much a day. However, proper management of a windbreak could perhaps double the amount of time required to extract a cord of wood, for at least one-half the harvest should properly consist of small limb thinnings and prunings and it takes more time to gather a cord of these thinner pieces than it does regular logs.

Even at a cutting rate of one cord per day, a week's labor, spread over the winter months, should be sufficient to supply the fuel needs for a whole heating-cooking season in a cold, temperate climate. Of course, this estimate must be qualified to take into account the species of wood selected and its moisture content at the time of burning. Although wood substances are all fundamentally the same in chemical composition, some varieties contain more resins, oils, and gums than other varieties of wood and therefore have a higher calorific value. (See Table 11.) Calorific value represents the total amount of heat given off by the wood burned, and this value is greatly influenced by the amount of moisture in the wood. The British Thermal Unit (Btu) is a common measurement of heat quantity, taking one Btu to raise one pound of water 1°F.

TABLE 11. Heating Value per Cord of Different Woods

WOODS	WEIGHT AIR DRY	AVAILABLE HEAT MILLION BTU AIR-DRY
Ash	3440	20.0
Aspen	2160	12.5
Beech	3760	21.8
Birch	3680	21.3
Douglas Fir	2400	18.0
Elm	2900	17.2
Hickory	4240	24.6
Maple	3200	18.6
Oak, Red	3680	21.3
Oak White	3920	22.7
Pine-Eastern White	2080	13.3
Pine-Southern Yellow	2600	20.5

The need for a large storage area to properly air-dry firewood has been one of the major objections to using wood as fuel. A simple, covered storage area is all that is required to properly air-dry firewood. In areas having a high humidity, a full year of storage may be necessary to "cure" one's wood supply for fuel use. As Table 12 illustrates, the moisture content of the wood to be used dramatically affects the heat available from that wood. Air-dried wood with about a 20 percent moisture content will supply about five times more Btu's than will green wood.

TABLE 12. Heat Available From 1 Pound of Wood

PERCENTAGE OF MOISTURE CONTENT	AVAILABLE HEAT BTU
Ovendry— 0	7100
5	6700
10	6300
15	5800
Air-dry—20	5400
25	4800
30	4500
35	4000
40	3600
45	3400
50	2900
55	2500
60	2100
65	1500
70	1100

In Emerson's time the per capita consumption of wood fuel reached an all-time peak with an average yearly use of four and one-half cords per person. Over 150 million cords of wood were burned in 1880; in 1952, only one-third this amount was used. Very little cordwood cut today is seriously used for heating and cooking. It is, rather, limited to the grossly inefficient but, nevertheless, esthetically satisfying fireplace.

But esthetics need *not* be sacrificed to efficient function. I hope that I have succeeded in demonstrating here that highly efficient heating and cooking facilities *can* be installed by anyone who is eager and willing, and that they can be built in conjunction with an array of building design features that take advantage of solar heat and insulation and no-draft, warm air circulation. It is indeed gratifying to discover that the time and energy that is put into woodlot management and wood chopping is rewarded by the practicalities and pleasure one gets from efficient fireplaces, wood stoves, and furnaces. An acknowledgement of this gratification is reflected in the observation of Emerson's neighbor, Thoreau, who remarked that, "Wood heats you twice; once when you cut it, and once again when you burn it." I would add, ". . . and yet once again as one's wood fire is tended."