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Energy Design update

NEWSJOURNAL FOR THE BUILDING PROFESSIONAL

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In this issue:

J.D. Ned Nisson, Managing Editor
Diana Amsterdam, Associate Editor

FROM OUR READERS

(Regarding your news item on page 2 of the July - August issue of Update reporting a measured R-Value of 0.2 for a certain double glass aluminum framed window), "it is generally agreed, I believe (see, for example, my book Thermal Shutters and Shades, Brick House Publ. Co., 1981) that the air film adjacent to a sheet of glass is very effective (indoor airfilm, I mean) and has an R-value of about 0.68. If the sheet were completely of shiny aluminum (with emissivity for far-IR of about 0.05, instead of near-unity as for glass), the combination of airfilm and shiny surface would have an R-value of about 1.35. (I believe this information comes from an article by Yellott, --see p. 95 of Proceedings of the Third National Passive Solar Conference, San Jose, CA 1979. By AS/ISES.)

This means that if someone built a "window" consisting just of one sheet of shiny aluminum, the sheet would have an R-value of about 1.35 -- or slightly more if one includes the airfilm on the outdoor face of the sheet.

Therefore I find it hard to believe that a glass window -- with two sheets of glass and an airspace between -- with an aluminum frame (no matter how badly designed this frame is) would have an R-value as low as 0.2

William Shurcliff
Cambridge, Mass.

The Editor replies: Your point is well taken. The source of that news item was Professor A. Berlad at the State University of New York at Stoney Brook. We have not been able to get in touch with Prof. Berlad. The only explanation we can think of is that the test was done in a way which reduced or eliminated the thermal resistance of the air films.

To the Editor:
Congratulations on your first edition. It is very helpful.

I'd like to comment on one area of moisture in insulation, page 10, paragraph 1 in which it is stated that cellulose R value is reduced 15% when the moisture content is 20% and that fiberglass is probably less affected. In my experience, research, studies and tests, I have found that Class 1 cellulose treated with Borax and Boric Acid loses much less than 15%, maybe 5% while fiberglass has always shown to reduce its R-value much more than Class 1 cellulose. Also in most cases you won't find 20% moisture in Class 1 cellulose if installed properly with attic ventilation and soffit - eave ventilation.

Angelo M. Aiello, Jr.
AA Insulation
Johnston, RI

ENERGY DESIGN UPDATE welcomes comments, tips and opinions from readers. Address to: Editor, Energy Design Update, Box 1709, Ansonia Station, New York, NY 10023.

NEWSBITS

PASSIVE SOLAR HOMEOWNERS SATISFIED

Results of a two-year survey conducted by the Northeast Solar Energy Center show that 86% of passive solar homeowners are "very satisfied" with their homes. When queried about the source of their satisfaction, 48.5% cited economic benefits, while 45.5% reported a combination of comfort and aesthetics. Areas of dissatisfaction revealed by the study were condensation (cited by 46%), overheating (cited by 43.5%), and keeping the glazing clean (31.5%). These problems were considered serious by 25% of the respondents.

HOMEOWNERS WHO INSTALLED UF FOAM MAY GET HELP

According to a report in RSI magazine, Representative Ben Rosenthal (D-NY), chairman of the House Commerce, Consumer and Monetary Affairs Subcommittee, is considering backing legislation to either provide tax credits, low-interest loans or even outright grants to homeowners for removal of urea formaldehyde foam. The Canadian government is now providing grants of $5,000 per home for UF foam removal.

NEW INSULATION INFORMATION CENTER

The Manville Corporation has set up an information center for architects and builders. If you have a question on insulation, write to Manville Insulation Center, Drawer 17L, Denver, CO 80217 (303) 978 4800

STANDARD R-VALUE FOR URETHANE INSULATION

Insulation manufacturers group moves to standardize "aged" R-value of urethane board stock for roofing applications. The Roof Insulation Committee of the Thermal Insulation Manufacturers Assn. (RIC/TIMA) announced a conditioning procedure that, if followed by all manufacturers, will help standardize the whole business of measuring, publishing and promoting thermal values for urethane board stock. The procedure specifies that the materials be stored for 180 days at 73.4F and in 50% relative humidity prior to undergoing ASTM Test Methods C236 and C518. RIC/TIMA also adapted a standard R-value of 6.25 as a refence point for urethane board stock. For further information, contact

Thermal Insulation Manufacturers Association (TIMA), 7 Kirby Plaza, Mt. Kisco, NY 10549 (914) 241 2284.

NEW FIBERGLASS PRODUCT

A new product called "SCRIM" will be released soon by Owens Corning Fiberglas: a high density fiberglass batt with wire mesh on it for applying a surface parging coat right onto the insulation. This product should reduce the time and costs for exterior retrofits where exterior parging often requires two or three steps.

TIME TO TAKE A LOOK AT APARTMENT BUILDINGS

Aren't apartment buildings supposed to be more energy efficient than single family homes? The average apartment unit in pre-war buildings in New York City uses 70,000 to 100,000 Btu per sq. ft. per year according to Mary A. Brennan, Assistant Commissioner of the Office of Energy Conservation in NYC. This is about the same as the average single family home in New England. Also, according to Steve Morgan of T.D.C., Boston, the average oil heated two to four family unit in New England uses more oil per unit than typical single family homes.

UTILITIES "BUY" CONSERVATION AS A SOURCE OF ENERGY

Conserving energy is the same as producing energy. This is the approach being professed by the Bonneville Power Administration (BPA) in the Pacific Northwest. In a talk at the ACEEE conference in Santa Cruz last month, Steve Hickock of BPA explained that under a regional act of Congress, BPA is required to buy the cheapest energy resource first. Their priorities are 1. conservation, 2. renewables, 3. high efficiency production such as cogeneration, and 4. coal or nuclear generating facilities. BPA sells electricity to 130 utilities. In their service area, 80% of the homes are heated by electricity which sells for under $.03 per Kwh.

RENTERS' ATTITUDES TOWARD ENERGY COSTS

How important are energy costs to prospective renters of houses and apartments? According to a nationwide study conducted by the University of Colorado, the answer is hazy. In Atlanta renting agents reported that 76% of prospective tenants ask about energy costs. In relating energy costs to rental fees, the study indicates that each additional $1 in energy costs correlated with about $.50 decrease in rent. For information on the study, contact Lou McClelland, Institute of Behavioral Science, University of Colorado, IBS#5 - Campus Box 468, Boulder CO 80309 (303) 492 6746.

RESIDENTIAL GAS METERS' ACCURACY QUESTIONED

Gas meters in homes can sometimes be in error as much as 15% to 20%. This was discovered by researchers at the Solar Energy Research Institute (SERI) during their Class B monitoring program of passive solar homes. The meters were found not to be reliable for accurate measurements of household gas consumption. This information also makes one wonder how reliable they are for paying one's bill. For more information on the study, contact Kelvin Harr, Building Systems Research Branch, Solar Energy Research Institute, 1617 Cole Blvd., Golden, CO 80401.

TRICKY TENANTS AND BAD NEIGHBORS

One of the best ways to induce energy conservation in apartment houses seems to be to meter each unit individually and have each tenant pay for his or her own heat. But, you may ask, what if someone who is surrounded by other apartments simply turns off his/her heat and lets the neighbors supply the warmth? Good question, and a serious one. In Germany, if a landlord has individual metering for heat, then only 50% of the bill can be based on meter reading. The rest is based on the size of the apartment.

SUPER RETROFIT IN SASKATCHEWAN

The Canadian National Research Council, known for its pioneering work in super energy efficient new construction is now forging ahead with a dramatic and radical retrofit of a house in Saskatchewan. The 1250 square foot house (with 1250 square feet of basement) is being fitted with a complete second skin over the roof, walls and foundation. When the project is finished, the roof will be insulated to R53, the above grade walls to R50 and the below grade foundation walls to R40. The basement floor may also be insulated at a later time. The entire house, which was already airtight by American standards, has been carefully sealed to attain levels of infiltration as low or lower than current new construction in Canada. An air to air heat exchanger will be installed to provide about 0.3 air changes per hour of fresh air ventilation. The existing 88,000 Btu per hour furnace and associated chimney were removed and will be replaced by a mere 4 Kw of electric baseboard heat. Why is this so significant? Because it demonstrates that an existing house, even one which is already reasonably energy efficient, can be retrofitted to achieve levels of efficiency previously thought possible only in new construction.

NEW SUPERINSULATED WALL SYSTEM

Gene Leger, who was one of the first builders in the Northeast to build superinsulated houses with a double wall has been working on a new system. This past summer, he has built two houses with a single 6" wall insulated with spray urethane foam. The wall has six inch top and bottom plates with staggered 2" x 3" studs 24" on center. No performance data is in yet on these houses but Gene feels that the system will work well. Since the wall is made airtight by an exterior sheet of Tyvek (see July-Aug. Update), he feels that it may be possible to eliminate the interior vapor barrier completely. Leger will present the details of this new system at the Energy Design seminars this October (see Calendar).

RESEARCH AND IDEAS

WIND MAY NOT EFFECT INFILTRATION ON NEW HOUSES

Swedish researchers are finding that with properly constructed buildings, wind and temperature have no effect on air infiltration into the building. This means that the new building methods being used on superinsulated houses give the designer and builder the freedom to build and orient houses as they please without undue concern for protecting the building from the wind. Infiltration is caused by two factors: 1) pressure caused by wind, and 2) pressure caused by the stack effect produced when warm air in a building rises and tries to escape out near the top. Wind pressure increases as windspeed increases (obviously) and stack pressure increases with the difference between outside and inside temperature and with building height. Leaky houses will leak more as the pressure increases and most design texts will show ways to avoid those pressure differences. The Swedish research shows that with tight buildings, neither factor has a significant effect. This is yet another discovery which might have implications for the validity of computational techniques which predict natural infiltration rates based on wind data and terrain. For more information, contact: Arne Elmroth, The National Swedish Institute for Building Research, Box 785, 801 29 Gavle, Sweden.

BREAKING THE BUBBLE ABOUT NO COST/LOW COST ENERGY IMPROVEMENTS

The payback time for typical "no cost/low cost" energy conservation improvements may not be as good as is often believed. Recent field tests performed by researchers at both Princeton University and Lawrence Berkeley Laboratory are showing that standard improvements such as caulking and weatherstripping often have very limited effects on energy consumption and are sometimes not worth the trouble. In one instance, weatherstipping was shown to have a calculated payback period of almost 60 years. Other tests led by David Harrje of Princeton have shown that even retrofitting leaky old windows may not produce significant energy savings. Obviously some improvements will have payback times much less than 0.5 years (broken glass repairs for example). Savings from low cost/no cost measures is almost impossible to predict. For more information, contact: Lawrence Berkeley Lab, Energy Efficient Buildings, Building 90H, Berkeley, CA 94720 or Princeton University Center for Energy and Environment, Princeton, NJ 08544.

AIR LEAKAGE AROUND WALLS

Windows and doors are probably not the worst source of air leakage into and out of a house. According to Robert Dumone of the Canadian National Research

Council, 25 to 50% of infiltration is at the ceiling and 25 to 50% is at the floor. Only 10 to 15% was found to be through windows and doors. These numbers were derived from controlled pressurization tests on Canadian houses. For more information, call NRC at (306) 665 5248.

CLEANING INDOOR AIR

The best way is the simplest way to clean indoor air. A recent study published in "New Shelter" magazine (July/August, 1982) showed a comparative evaluation of various types of air cleaning devices. In a tightly closed room where the primary air pollutant is cigarette smoke, negative ion generators were considerably more effective than fan and filter type of cleaners. The best ion generator eliminated all the smoke in the test room in one hour and 46 minutes. As a postscript to the study, the air cleaners were compared to an ordinary circulator fan; the results - the fan compared favorably with the room sealed. But, open the door and the fan removed all the smoke in under six minutes. Conclusion? The best way to rid indoor air of pollutants is to ventilate with fresh air (as your mother said).

AIR LEAKAGE THROUGH INTERIOR PARTITIONS

Air leakage into and out of houses is not limited only to the outside walls and roof. Many researchers, using pressurization devices, have found significant air leakage through interior partitions. One study at Lawrence Berkeley Laboratories, published by ASHRAE, found that "Leakage was evident in interior partitions around light switches and outlets, indicating good communication between the interior partitions and the attic or crawl space and hence to the outside." The identification of hidden pathways for air leakage is one of the cornerstones of the Princeton House Doctor approach to energy retrofit. For more information, contact Lawrence Berkeley Labs, Energy Efficient Buildings, Building 90H, Berkeley, CA 94720.

Another unexpected source of air leakage can be through basement floor drains. Harold Orr of the National Research Concil of Canada actually found enough air current coming through a cellar floor drain to put out a match. It seems the air was entering the drain through perimeter foot drains buried around the foundation.

AIR BOUNCES

It is common understanding among designers that air rises and falls when it is heated or cooled. In fact, one can visualize air as a fluid which can be channeled and drained; cool air will sink and flow to the lowest point of a container. Solar designer Norman Saunders took advantage of this phenomenon in the greenhouse he designed for the Shrewsbury house. It has a "cold air gutter" below the south glass which is sloped to the west to carry cool air falling from the glass over to an outlet duct in the corner. The only problem is that the cold air bounces out of the gutter before it can begin flowing to the corner. The solution - a partial cover over the gutter to trap the cold air. It should work and will keep the cool air from spreading across the floor.

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FEATURES

Testing for Airtightness

by J.D. Ned Nisson

WHY TEST FOR AIRTIGHTNESS

Air leakage is not always easily spotted. It is the movement of an invisible substance (air) by forces which are unfamiliar (wind pressure, stack effect). It won't even occur until after the house is finished. No wonder construction or retrofit crews experience difficulties learning to plug up every air leak.

That's why some tests have been developed for airtightness.

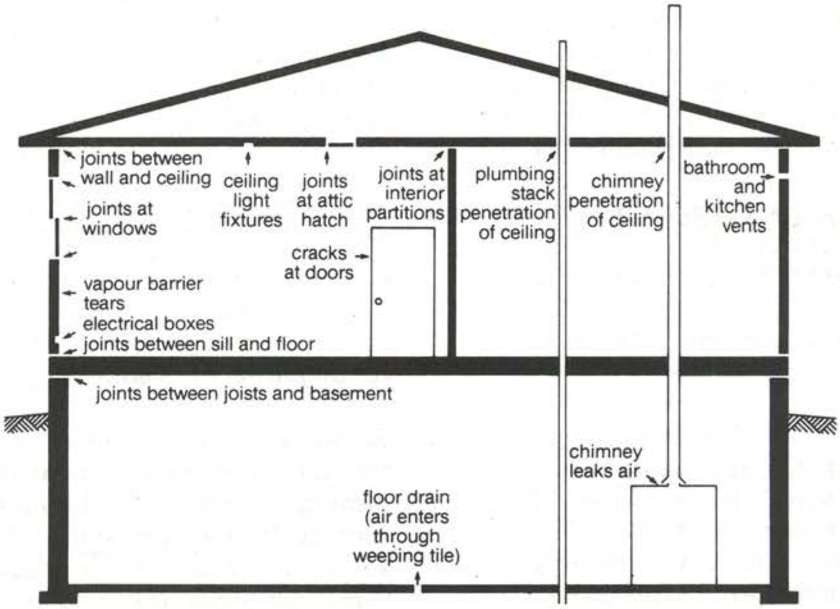
We used to think that most leakage occurred around windows and doors; all we needed to achieve airtightness, we thought, were caulking and weatherstripping. We now know that there are less obvious leakage points such as joints between sill and floor, plumbing stack penetrations, joints between wall and ceiling, and many more. Not only are these sometimes hard to think of or detect: it is also hard to know whether they were successfully sealed. For example, many workers still like to use fiberglass insulation to seal wide cracks. This doesn't work. Fiberglass is an excellent insulation and a good air filter but it is a lousy air sealant. A test for airtightness would immediately show this.

So we test for airtightness to assure quality control. There are also other reasons to test: airtightness is a way to express a house's energy efficiency for marketing purposes. Some day, probably in the near future, houses will have "energy efficiency labels" which include measured airtightness. We may also soon see airtightness requirements in building codes. Sweden already has such a code; Canada is considering it. The U.S. has some energy efficiency requirements in building codes: airtightness may become one of them. As issues of indoor air quality become resolved and as testing methods become easier, we may very well see such a code in this country.

Only with proper testing can we be certain a house is super airtight, and an airtight house is a better house. Airtight construction helps prevent moisture condensation problems in wall and ceiling cavities, and, of course, it minimizes heating and cooling requirements.

HOW TIGHT IS AIRTIGHT?

The most common unit of measure of air leakage is air changes per hour (ach/hr). One ach/hr means that one house volume of outside air is



AIR LEAKAGE SPOTS IN CONVENTIONAL HOUSING

Source: Energy Efficient Housing: A Prairie Approach, by Energy Research Development Group, Univ. of Saskatchewan, p. 3.

leaking into the house every hour. A 2000 square foot house with 8' ceilings has a volume of 16000 cubic feet. If that house has a leakage rate of 1 ach/hr, then it is leaking 16000 cubic feet of air per hour (267 cfm).

An extreme example of an airtight house is the Saskatchewan Conservation House built by the National Research Council of Canada in 1977. It has a natural infiltration rate of about 1 air change every three days or 0.014 ach/hr. The average house in the U.S. has a leakage rate between 0.5 and 1.0 ach/hr. A carefully built superinsulated house should have an air change rate between 0.1 and 0.2 ach/hr.

NOTE - Before going further, we should clarify one point. These airchange rates refer to the uncontrolled infiltration through building seams and defects. Any tight house should also have intentional and controlled ventilation through a mechanical ventilation system and/or windows. That ventilation rate may be 0.5 ach/hr or higher depending on the need to remove pollutants from the interior air.

It should also be noted that the mere fact that one ach/hr of air is leaking into a house doesn't necessarily mean that the whole house is being ventilated every hour. Some of the new air goes right back out; some of the stale air never leaves. For a complete discussion of this effect, we refer you to W. Shurcliff's book on air to air heat exchangers (see review, this issue of the Update).

THE BLOWER DOOR

The "blower door" test described below provides the builder or retrofit contractor with visual pointers of every leak area that has been missed. On a new house, the test is performed before the sheetrock goes up. The air barrier actually inflates under the depressurization and leaks are easily located. The test should be performed with the crews present so they may see their oversights and learn for the next time.

The blower door is a portable device used to exaggerate air leaks in a building envelope. It is basically a high flow fan mounted on an expandable panel which is temporarily installed in an exterior door of a house. The house can then be either pressurized or depressurized, providing steady air leakage through cracks and openings. The leaks are located using a variety of sensing devices including infrared cameras, smoke pencils and the back of the hand. (See Tom Blandy's article in this issue for a description of house doctors' use of the blower door.)

There are several blower doors now commercially available. Most come with instrumentation which measures the amount of pressure (or vacuum) being applied to the house and also the volume of air (calculated from fan speed) which is being moved to maintain that pressure. Some of the units are sold as part of a marketing package which includes retrofit materials, marketing literature, etc. They range in price from $2000 to $5000.

The blower door has two purposes. The first, and most practical, as described above, is to exaggerate air leaks so they can be plugged. The second purpose is to measure the amount of leakage in a building. The blower door is also used in some advanced energy auditing techniques, such as house doctoring to locate other forms of obscure but important energy leaks.

MEASURING AIR LEAKAGE WITH THE BLOWER DOOR

It is important for the concerned building professional to at least be familiar with the basic concepts and vocabulary of measuring air leakage.

Using the blower door, air is sucked out of the house, creating a partial vacuum inside. The amount of vacuum (actually the pressure difference between inside and outside) is measured with the blower door instruments. The unit of pressure most commonly used in this test is the "Pascal" (named after the mathematician). Usually the house is depressurized until the difference in pressure between inside and outside is 50 Pascals. How much pressure is that? It is 0.007 pounds per square inch or the amount of pressure exerted by a column of water 2" high. It is approximately equivalent to the force exerted by a 20 mph wind blowing onto all sides of a house.

The blower door instrumentation includes a tachometer to measure fan speed. Given the fan speed, one can then calculate the volume of air flowing through the fan (which represents the amount of air flowing into the building.) The rate of air leakage in cubic feet per hour divided by the house volume equals the leakage rate in air changes per hour.

Unfortunately life is never simple and neither are engineers. Some researchers prefer to express leakage in a completely different manner referred to as ELA (equivalent leakage area). Simply put, it is the area of one single hypothetical hole in the building envelope which would allow the same amount of leakage to occur. Neither method is yet considered the standard. For this discussion however, we will refer to measured leakage rates only in ach/hr.

WHAT IS THE RELATIONSHIP BETWEEN MEASURED LEAKAGE USING THE BLOWER DOOR AND THE NATURAL INFILTRATION RATE?

It is very difficult to accurately predict natural infiltration rate using blower door data. According to Gautam Dutt of Princeton University, a best estimate for natural infiltration is simply the measured leakage rate under 50 Pascals divided by 20. Simple. He adds, however, that this is a very rough approximation and that natural infiltration can be affected by microclimate, building proportions, location of openings, bypasses and internal flow resistance in the building. Researchers at Lawrence Berkeley Laboratory take a more complex approach which is beyond the scope of this article.

Why the difficulty? Because many of the factors affecting natural infiltration are complex and difficult to model mathematically. Also, the blower door test creates an artificial situation which doesn't exactly duplicate the natural situation. Here are a few examples of factors which confound attempts to predict natural infiltration from blower door measurements:

1. The blower door test is not standardized. Is the cellar included in the test? Were the measurements taken under pressurization or depressurization? Were the "intentional" openings such as furnace flue and exhaust fans sealed or unsealed during the test?

2. Since it creates very high pressure differences, the blower door may induce leaks through very small cracks which don't ordinarily leak under natural conditions.

3. The results of the blower door test are affected by wind at the site during the test.

4. (Submitted by William Shurcliff, Cambridge, MA) The blower door test is not affected by location of the leaks. As an exaggerated example, consider a three story house with no interior partitions which is completely airtight except for two large holes. In Case 1, one hole is in the east wall on the first floor and one hole is in the west wall on the third floor. In Case 2, both holes are in the east wall on the first floor.

Under natural conditions, the Case 1 house will leak lots of air, especially when it is cold outside or when the wind is blowing from the east or west. The air goes in one hole and out the other. The Case 2 house will leak much less air under natural conditions. All the forces are pushing air in through both holes but there is no path for it to flow out. There is practically no airflow through either hole.

The blower door test, on the other hand, doesn't see any difference between Case 1 and Case 2. It will pump equal amounts of air through both holes in either case.

This problem has also been pointed out in research at Princeton University. In a paper by David Harrje of Princeton (ASHRAE

Transactions 1979, Vol. 85, Part 1), it was pointed out that changing the location of openings in a test house could increase the natural ventilation by 100% or more.

Despite this apparent shortcoming, the blower door is still an incredibly useful diagnostic tool. It vastly expands the energy auditor's ability to evaluate the leakiness of a house. If a house has a measured leakage rate of 3.0 air changes per hour under 50 Pascals of pressure, it is a tight house. Period. Who cares whether the natural infiltration rate is 0.10 or 0.15 ach/hr. Either value represents a very tight house; the difference is academic. We present the above information so that you understand the limitations of the test and do not inadvertently misuse the tool beyond its limits.

WHAT ARE SOME TYPICAL VALUES OF MEASURED LEAKAGE RATES USING THE BLOWER DOOR?

At the ASHRAE meeting in Toronto last June, Robert Dumont of the Canadian National Research Council presented a summary of reported leakage rates from several studies. We present some of them here (all are measured rates at 50 Pascals pressure):

tightest measured (Winnipeg)	0.12 ach/hr
tightest Saskatchewan house	0.37 "
average of 40 special Sask. houses	1.50 "
Swedish building code standard	3.0 "
average of 97 Canadian houses built between 1961 and 1980	3.6 "
average of 20 Canadian houses built between 1946 and 1960	4.6 "
average of 19 Canadian houses built before 1945	10.4 "
average of 204 American low income houses (Grot)	22.5 "
a house in South Carolina	549 "

The last house on the list obviously needed work!

WHERE DO YOU GET A BLOWER DOOR?

First of all, you don't have to buy your own blower door to get a test done. Testing is becoming available through specialized retrofit companies, most of which perform the test and retrofit work as a package. There are also services available for new house construction which include testing and construction consultation and supervision to assure airtightness.

The cost for just a test is usually about $75 to $175. The cost for the test and retrofit work (1 day) is typically $600 to $1000 per house. The cost for new house testing and consultation varies with the scope of the work.

It is often difficult to find a testing service. Try the yellow pages under insulation contractors. There is a growing network of "house doctors" whose training is derived from the original house doctor procedures developed at Princeton University. For information or referral about house doctoring, contact:

Princeton Energy Partners, Inc.
Princeton, New Jersey

The Energy Doctor
Lubbock, Texas

The Energy Detective

Philadelphia, Penn.

Enercorp
Winnipeg, Manitoba, Canada

Below is a list of blower door manufacturers. It is not a complete list. We will add to it in future issues of the Update. We will also run short articles about users' experiences with the various doors (See Tom Blandy's article for experience with the Gadzco Door).

The Gadzco Blower Door
Contact Princeton Energy Partners, Inc., Box 1221 Princeton, NJ 08540 (609) 924 1177.

Retrotec Door Fan
Manufactured by Retrotec, 176 Bronson Ave., Ottawa, Canada K1R 6H4 (613) 234 3280.

Infiltec Air Leakage Measurement System
Manufactured by Infiltec, a Division of Saum Enterprises, Inc., Box 1533, Falls Church, VA 22041 (703) 820 7696

The Energy Door and Energy Auditor Package
Manufactured by TWV Enterprises, 4216 50th Suite F, Lubbock, TX 79413 (806) 794 4815.

Infilseal Corporation, 4660 Beechnut, Suite 248, Houston, Texas 77006 (713) 522 2656

OTHER METHODS OF TESTING FOR AIRTIGHTNESS

There are other tools and techniques for testing for airtightness and locating leakage in a house.

1. Tracer gas technique. This is mainly a research tool. It measures natural infiltration rate. A tracer gas (often sulphur hexafluoride), is injected into the house and allowed to mix well with the indoor air. An instrument called a chromatograph measures the concentration of the tracer gas in the air. As air leaks into the house, the tracer gas becomes diluted. The chromatograph continuously measures the decrease in concentration. From that data, we are able to calculate the infiltration rate.

This technique is not practical or even useful for builders or insulaton contractors. Not only is it expensive, but the measured infiltration rate is dependent upon outside weather conditions. It also doesn't help find leaks.

2. Sound detection method. This is an interesting method, based on the principle that sound waves and air pass readily through many of the same openings in building envelopes. Therefore such air infiltration can be detected by acoustic means. The method is still experimental and not widely used. At the ASHRAE conference on the Thermal Performance of the Exterior Envelopes of Buildings in 1979, David N. Keast of Bolt Beranek and Newman Inc., Cambridge, MA presented a method for building the necessary instruments from ordinary low cost "hi-fi shop" equipment. There is also a listing in the Products section of this issue of the Update for a very expensive version of the same instrument.

3. The Pressure Pulse Method. This is another new idea which looks interesting on paper but obviously still needs work. It was presented by G. Yuil of Unies Ltd., Canada at the ASHRAE meeting in Toronto last June.

The pressure pulse method works like this: one single blast of air is suddenly released from a compressed air cylinder placed inside the living space. A recording instrument measures and records the decay of the induced pressure over time (how long it takes for the pressure to die down to zero). The tighter the house, the longer the decay will take. According to Yuil, a leaky house will have a decay time of about 1.2 seconds, a typical recently built house about 5.6 seconds, and an airtight house about 24.5 seconds.

The attractiveness of the idea is that it is very quick, easy and relatively inexpensive. Its most useful application would be for building inspectors (if airtightness became a code requirement) or for a builder's final evaluation of his own work. It is not useful for finding leaks.

There are a few problems. Some have been worked out, some not. First of all, the initial pulse is equivalent to an instantaneous 20 mph gust of wind on all surfaces of the house - possible damage. The initial nozzle design pointed up. This created a downward thrust of 3500 lbs - too much for any floor. This problem was overcome with new nozzle design. A third problem was the refrigeration effect - air suddenly released through a small hole gets very cold. Finally, there is a problem with flexibility of the building walls - sheetrock and even glass will bend a little under the sudden pressure; this will introduce error into the calculation.

Yuil added finally that the test had not actually been performed on a real house yet. Any volunteers?

The House Doctor's View of the Blower Door

by Thomas Blandy

House doctoring is distinguished from other energy audit services by the use of the blower door. With a blower door, house doctors are actually able to quantify the air infiltration rate of a house. Not only can infiltration be measured, but every source can be easily located using the blower door in conjunction with other detection devices (infra-red scanner, smoke gun, back of one's hand, eyes, etc.) Once the leaks are plugged, the retrofit job can be evaluated by remeasuring infiltration.

SETTING UP THE DOOR

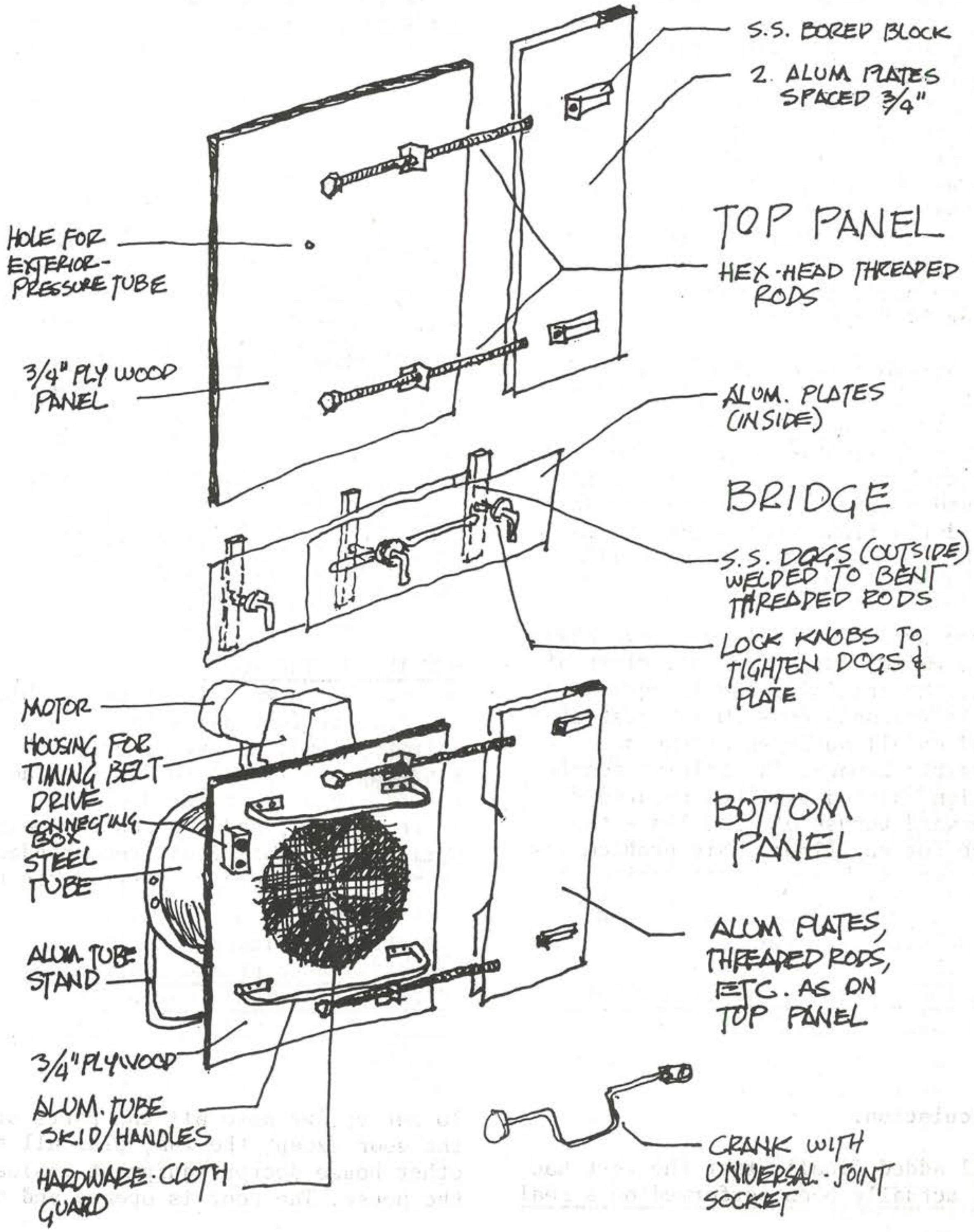
We use the Gadzco blower door, which consists of four parts (see illustration): a lower panel with the fan, an upper panel to fill in the top of the door, a "bridge" to fill in the middle, and the control panel. Optional but definitely recommended is a good photographic tripod for the instruments.

The door is designed to fit any doorway from 32" x 78" to 36" x 84". It can be used in other sized doorways, both larger and smaller, by jury-rigging.

To set up, we move all the parts of the door except the fan, plus all the other house-doctor equipment inside the house. The door is opened and the screen/storm blocked open. We then

THE GADZCO BLOWERDOOR

Illustration by Thomas Blandy



lug the fan up to the doorway (it weighs about 100 pounds) and maneuver it into position next to the stops. It takes two people, one in, one outside. The outside person holds it in place as the inside person tightens two long hex-head threaded rods with a crank socket wrench. The threaded rods fit snugly into two bored blocks of stainless steel which, in turn, are mounted on a double aluminum plate which slips over the 3/4" plywood panel making the adjustable closure. The lower panel having been snugged up, the outside person must step over the panel which takes a little agility. He then grabs the upper panel and fits it to the top of the opening while it is cranked into place. This leaves a gap between the panels which is filled with the aluminum plate "bridge". The plates lap the plywood above and below, and expand horizontally to make up the width. The sliding plate arrangement is flexible enough to close even out-of-square doorways. Nonetheless, small gaps may remain, but this does not usually matter since these will be small in relation to the openings in the house. Next, we set up the tripod and mount the control panel on it. Then plug in the power supply, RPM wire, and pressure tubing between panel and door. Finally, plug in the power wire to the house receptacle, check for open windows and exterior doors, turn off the heater - and we're ready to test.

The whole setting up process takes about 5 or 6 minutes.

MEASURING LEAKAGE

We take a total of four readings with the blower door: fan blowing in (pressurization), basement door open; fan blowing in, basement door closed; fan blowing out (depressurization), basement door open; fan blowing out, basement door closed. Interior room doors always remain open. You get slightly different readings under depressurization and pressurization. With the Princeton technique we usually stick with depressurization to standardize the test. Also, with a very leaky house, it is easier to get up to pressure with depressurization than with pressurization. A large difference in readings between basement door open and closed is an indication of a leaky basement.

We try to get the pressure up to 0.2" water then use the RPM reading to calculate cubic feet of air per hour through the house. We divide the cubic feet per hour by the volume of the house and we have air changes per hour. In practice, it is often impossible to reach 0.2" of pressure at the maximum speed of 2500 to 2600 RPM, since some houses are very leaky, or on the big side, or both. The blower door is fitted with a 10-amp fuse so as not to strain 15-amp house circuits, and this limits fan speed. Even if you can't get up to pressure there are ways to extrapolate and still calculate leakage.

LOCATING LEAKS

Measuring infiltration is only half the usefulness of the blower door. Locating the leakage is the real payoff. Under pressurization (or depressurization) leakage is amplified and easy to locate using an infrared (IR) viewer and an assortment of other tools.

The typical routine includes the following three procedures:

a. With the house under pressurization, we go up into the attic. Warm air that is forced up into the attic through the building seal can be detected by a technician with the infrared viewer.

b. Next the house is depressurized and we go to the living space. We use the infrared camera to detect cold air entering around baseboards, coming down interior partitions, etc.

c. The house is then pressurized again and we go around the living space with a smoke gun looking for suspected cracks. The smoke gun is wonderfully handy, also dramatic for demonstrations. The smoke just zips into the cracks. In addition to this, there are a number of more informal procedures. We watch the movement of cobwebs, and use our hands and even faces to detect air flows. We tug or push on attic and other interior doors to determine if major amounts of air are leaking out or into the spaces behind. Often in doing our caulking, stuffing, or polyethylene sealing we leave the fan on as we work to check our progress. For locating leaks, you don't need to maintain 0.2" pressure; 0.05" to 0.1" is usually sufficient.

We work as we go, sealing as many of the leaks as possible in the time allowed (usually one half to one day).

EVALUATING THE RETROFIT WORK

The final step is to test for results. The blower door is used to measure the new leakage rate after improvements are done. Sometimes we get air leakage reduced by 25 to 35%; more often it is less unless we can spend more time in the house.

We should note here, however, that the house doctor analysis and retrofit work detects and fixes more than simple air leaks. Energy savings from house doctor work can therefore be greater than that simply represented by reduction in air leakage rate.

SIDE EFFECTS AND DIFFICULTIES

-- The house can get very cool during winter visits, especially using pressurization. We try to get our testing done as fast as possible, but in a larger house it can go on for some time. The inhabitants are usually cheerful about it, or go away. However, once finished and the heater turned on, the house will warm up quickly. We have done jobs in near zero weather without problems.

-- Objects near the fan can get blown around. Plants and anything delicate should be moved out of the way.

-- In any case, the blower door location is out of action for access during our visit.

-- For depressurization, it's important for the heater or wood stove to be turned off or closed up as the negative pressure can pull smoke into the room, or wood ashes from a fireplace with the damper open.

THE GADZCO DOOR

We are not familiar with any other but the Gadzco blower door. We have been quite satisfied with it. It is a very handsome and suitable piece of industrial design. Many little details have been thoughtfully worked out such as the controls/instrument set, neatly packaged onto aluminum plates with a carrying handle cut in; it is tapped on the bottom for tripod mounting. Other house doctor teams have built a box for the unit, but we haven't bothered as it is reasonably rugged. The panels mount to the doorway without disturbing the existing stops or weatherstripping, and install reasonably quickly. The fan unit is a bit cumbersome and heavy, but this is not a major problem since most of the time it is a short trip from the vehicle to the front door of the house. One person can just manage to get it out of the vehicle and carry it a short, level distance, but two people is normal. It is no fun getting it up a flight of steps. I believe it will just fit in an airline seat space next to a bulkhead. One reason for the weight is the tube for air flow, around the fan. The fan is mounted on a streamlined hollow strut across the tube; both tube and strut are fairly heavy gauge steel. The bridge unit sometimes gives trouble if the gap is at the maximum. The plate just barely laps and must be held just so as the lock handles are tightened. Any bigger gap (doorway higher than 7'-0") and it is useless; one resorts to cardboard and tape. Ken Gadsby, of Gadzco, tells me he is working on lightening up the unit and providing a larger bridge. The motor has sealed lubricants. The plywood panels get dents and minor scrapes and one needs to do minor repairs and touch up. (Ken Gadsby says newer models have formica over the plywood.) Generally, however, it has been trouble free.

Tom Blandy is an architect, freelance writer and owner of Princeton Energy Technicians of the Capitol District, Albany, NY. He is also author of the book All Through The House by McGraw Hill.

Radon: First in a Series on Indoor Air Quality
by J.D. Ned Nisson

Indoor air quality must be considered when building an energy efficient building. If not correctly dealt with, it becomes a problem.

A stuffy room has an air quality problem. The solution is simple - open a window. Not only was the solution simple, but the problem was easy to detect.

Not so simple to detect or solve are the potential problems associated with indoor air pollutants such as formaldehyde, nitrogen oxides, organic fumes, particulates and radon. These substances are often undetectable by the average person, even when they are present in harmful quantities.

In this article, the first in a series, we will discuss radon. What is it? Where does it come from? What harm does it do and, most important, what should the concientious designer/builder do about it. Much of this information is from Air to Air Heat Exchangers by William Shurcliff.

WHAT IS RADON?

Radon is a naturally occurring radioactive gas. It is a disintegration product of radium which itself is a decay product of uranium or thorium.

WHERE DOES IT COME FROM?
Radon is continuously being formed in the earth. It can get into our homes from several sources:

From the earth.
As a gas, radon is constantly leaking out of the earth. If not stopped it rises up into crawl spaces and basements.

From groundwater.
Radon is water soluble. It may dissolve in groundwater and travel long distances until finally reaching the surface. It may also be in well water.

From natural gas.
Much of the natural gas you purchase for cooking and/or heating contains radon. This is of particular concern with gas cook stoves which are not vented to the outside.

From concrete and masonry.
If these materials contain rock with uranium or radium in it, then radon will be produced and given off to the air. This may be of considerable concern in some passive solar buildings which employ rock or concrete thermal storage.

HOW RADIOACTIVE IS RADON?
When we talk about radioactivity, we are usually referring to the emission of highly charged particles called alpha particles and of energy given off as gamma radiation. Radon atoms in the air each give off one alpha particle and one photon of gamma radiation. The total amount of radiation given off depends upon how much radon is in the air.

Radon has a "half life" of four days, meaning that every four days, half of any collection of radon atoms will disintegrate, each yielding one alpha particle and one photon of gamma radiation. When the radon atom disintegrates, it ceases to exist as radon and is transformed into a "daughter" element which itself is radioactive, which also disintegrates (giving off radiation) and, which we shall see, is possibly the major health concern.

For a more in-depth discussion of the radioactivity of radon, the reader is referred to William Shurcliff's book referenced at the end of this article.

WHAT ARE THE HEALTH PROBLEMS ASSOCIATED WITH RADON IN HOUSES?
Radioactivity is dangerous. Alpha particles are highly charged particles which travel at high speeds. When they hit human tissue, they can cause chemical disruptions which may result in cancer or mutations. Gamma radiation is less serious but also potentially damaging.

Since radon is in the air, we breathe it in. Some of it is immediately exhaled, some of it dissolves in the water in our lungs. That which stays in our lungs will disintegrate, giving off radiation and forming "radon daughters" which also disintegrate giving off more radiation.

When radon disintegrates in the air, the radon daughters, which are particles, not gases, often tend to adhere to dust particles. We may breathe in some of those dust particles which then become lodged in the lungs. Current thinking is that these radon daughters are actually much more dangerous than radon itself.

DOES THIS MEAN THAT AIRTIGHT HOUSES ARE DANGEROUS?

This is the most important and most difficult question to answer. Several recent articles in the news media have portrayed the new generation of super energy efficient homes as glowing infernos of cancer causing radioactivity. This is certainly not the case. On the other hand, responsible members of the building community must consider the worst case and design buildings which will avoid all health hazards to the greatest extent possible (or practical). The worst case would be a house built in an area with a high soil uranium content. An airtight house with a concrete floor and no ventilation system would be asking for trouble. At the other extreme would be a house built in an area with very little naturally occuring radium or radon in which case there would probably be very little cause for concern no matter how the house was built.

Unfortunately all the answers are not in yet. Standards for acceptable limits of radiation doses are often vague and there are no definitive standards for acceptable radon levels for housing in this country. In Sweden the standard is 6.7 pCi/l (picocuries per litre) for old houses and 1.9 pCi/l for new houses (for an explanation of these units, see Shurcliff book). Only now is there any significant serious work being done on this topic. The issue is particularly difficult since the effects of radiation are not immediate and may take many years to manifest.

WHAT SHOULD WE DO WITH HOUSES BEING BUILT TODAY?

As with any pollutant, there are three ways to limit concentrations:

1. Stop or decrease the source of radon.

-- Protect the living space from the ground with an air barrier such as polyethylene under the floor. As Shurcliff points out in his Air to Air Heat Exchanger book, radon has a relatively short half life and the radon daughters are not gases. Thus merely slowing down the radon's travel may suffice.

-- Limit the amount of exposed concrete or rock in the living space, particularly if the materials are known to contain high concentrations of uranium or thorium.

-- Avoid gas stoves.

2. Remove the pollutant from the air.

There is no easy way to remove radon from air. However, radon daughters attach themselves to dust particles in the air. Filters and/or electrostatic precipitators which remove dust will also remove the radon daughters.

3. Ventilate the house.

This is the most important measure. Proper ventilation is an absolute must for airtight houses (not just for radon removal). A well designed ventilation system should distribute fresh air to all parts of the house at a rate of about 0.25 to 0.5 air changes per hour. For a 2000 square foot house, that would be about 70 to 140 cfm. An air to air heat exchanger should be installed to recover waste heat from the exhaust air. While no one at this point can definitely say how much ventilation is required and, in fact, it will vary depending upon the amount of pollutant given off to the air, 0.5 air changes per hour is probably quite safe.

IS THERE A WAY FOR THE LAYPERSON TO MEASURE RADON?

Terradex Corporation sells a radon detection unit which is hung in the home for three months, then sent to the lab for analysis. The units sell for $50 each, including analysis. Contact: Terradex Corporation, 460 N. Wiget Lane, Walnut Creek, CA 94598.

HOW CAN YOU LEARN MORE?

Here are a few references for further reading:

Air to Air Heat Exchangers by William Shurcliff, 19 Appleton St., Cambridge, MA 02138. $14.00

Proceedings of the International Symposium on Indoor Air Pollution. Contact Prof. John D. Spengler, Harvard School of Public Health, 665 Huntington Ave., Boston, MA 02115

Radiation and Human Health by J.W. Gofman, Sierra Club Books, 530 Bush St., San Francisco, CA 94108. 910 p. $29.95

Radiation Protection by Prof. Jacob Shapiro, Harvard University Press, Cambridge MA 02138. 1981, 500 p. $25.

CONSTRUCTION TIPS

When applying fiberglass batt insulation to the outside of below grade foundation walls, don't try to seal the bottom. If you do, you will prevent water from draining down the outside of the batt. It is best to leave the bottom open.

* * *

A very efficient way to insure a good ceiling air/vapor barrier is to install it and the ceiling sheetrock before putting up the interior partitions. This can probably only be done where truss rafters are used which span from exterior wall to exterior wall. Not only do you avoid damage to the air/vapor barrier but you will probably end up spending less since the sheetrock crew can use long pieces and zip right through the entire ceiling without dealing with partitions. When you do put up the interior partitions, they will have to be slightly short; otherwise you won't be able to stand them up. Once in place, they are shimmed and nailed in place. This method was used in several houses in the Energy Showcase houses in Saskatchewan.

If interior partitions must be installed before the ceiling polyethylene is applied, an extra air/vapor barrier strip (see Fig. 1) has to be added to maintain continuity.

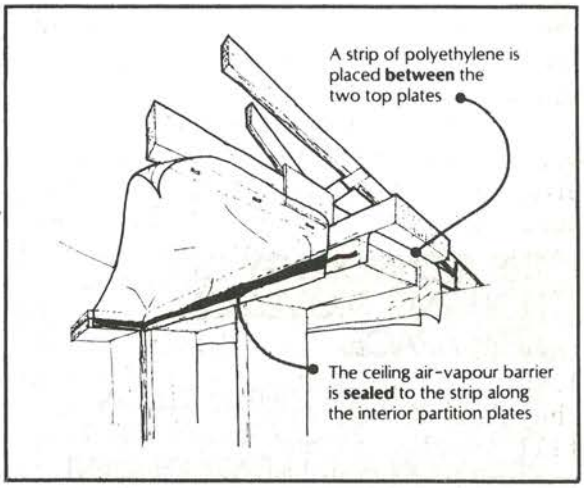


FIG. 1 SEALING AIR/VAPOR BARRIER AROUND INTERIOR PARTITIONS

* * *

WORKMANSHIP, WORKMANSHIP, WORKMANSHIP
No matter how carefully you design and plan a building, the bottom line will always depend upon the quality of the workmanship. It is particularly important for the general contractor to make sure that

one sub-trade doesn't damage the energy efficiency work of another sub-trade. Usually we hear about the ruthless electricians and plumbers who attack air/vapor barriers with chain saws and flame throwers. However there are more subtle possibilites which you must also watch for. The National Bureau of Standards in Washington recently built an experimental house for an energy study. The house was carefully built with meticulous attention to detail. When the house was monitored, they found some unexplainable heat loss. Upon inspection of the building they found that some of the loose fill insulation had been lost from one wall when the holes were drilled for the air conditioning line. While this may seem like an insignificant matter, it is precisely these small imperfections which can substantially decrease the overall energy efficiency of a building.

* * *

Ceiling mounted exhaust fans often cause problems because they are difficult to seal and even the built-in dampers don't always seal well, allowing warm air to rise up and out of the house by the "chimney effect". One way around both these problems is to install the fans on interior walls and run the ducts down the wall and out through the floor joist space. This prevents warm air from escaping and cold air from coming in. The exhaust duct can also be easily joined to an air to air heat exchanger.

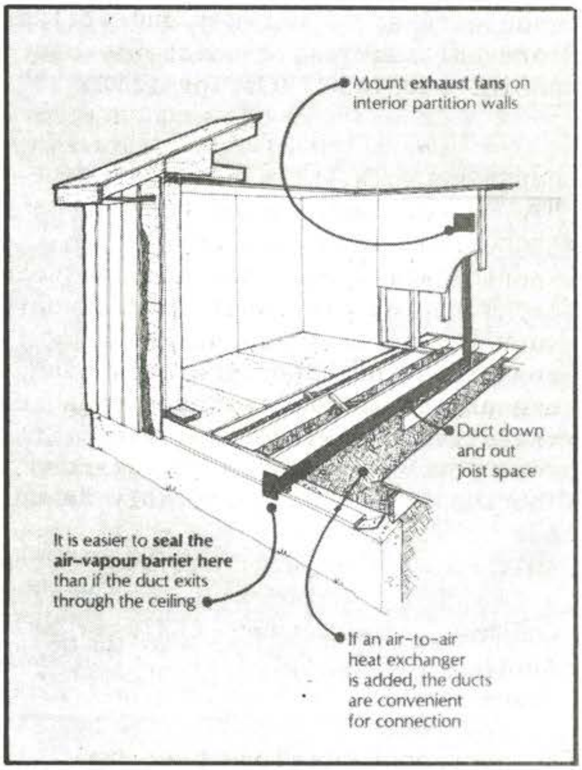


FIG. 2 EXHAUST FAN VENTING
Source Figs. 1 and 2: Low Energy Home Designs, by the Home and Community Design Branch, Alberta Agriculture, pps. 73 and 72.

PRODUCTS

HEAT REFLECTIVE WALL COVERING

Thermodecor is a new heat reflective wall covering manufactured by Enertec Systems, Inc., Barrington, IL. Similar in appearance to ordinary wallpaper, Thermodecor is coated with an ultra thin layer of reflective aluminum. The aluminum layer, which is not visible, reflects long wave infrared radiation (heat radiation) back into the room during winter. According to Dr. Charles Roberts, consulting engineer who tested the material, it will reduce heat loss by around 5% on an R4 wall. It would probably be cost effective for renovation projects where wall retro-insulation is not feasible. On the other hand, if applied to an R30 wall, Thermodecor will make essentially no difference at all and would not be cost effective. The material is manufactured in Germany and will sell for about $.50 per square foot. For more information, contact Enertec Systems, Inc., Box 127, Barrington, IL 60010. (800) 323 4966 or (312) 382 5033.

UNDERGROUND PIPE INSULATION

"Try to wet me" is the imprint on the small plastic sample bag of Gilsulate 500 which comes with their promotional brochure. Gilsulate 500 is a powdered inorganic material for insulating underground pipes. It is impossible to wet it. We tried. The white hydrophobic powder has an R factor of about 1.7 per inch (k = 0.6 at 175F). Its advantages are ease of use and durability. To insulate a small underground pipe, you simply pour the Gilsulate into a trench, lay the pipe down, then cover with more Gilsulate and pack down. For industrial applications, where it is commonly used, the procedure requires more design and care. The disadvantages of the product are cost and low R factor. It could conceivably be used underneath slabs and around foundations but it would cost quite a bit more than either polystyrene or urethane foams (although it should last longer than either foam). The cost is roughly $11.00 - $13.00 per cubic foot. For more information, contact American Gilsonite Company, 1150 Kennecott Bldg., Salt Lake City, Utah 84133 801 328 0311. Another similar product is Protexulate, sold by Protexulate Inc., One World Trade Center, Suite 2173, New York, NY 10048

A NEW RIPOFF

Here's one to stay away from. Every couple of years someone calls asking about "Ceramic Insulation" with an incredibly high R value. Perlite

Developers Inc., St. Anne, Illinois makes a product called Ceramic Attic Fill Insulation. They claim that 3" of the stuff has an R value of 70!!!! The best way to save money with this product is not to buy it. If you want to see for yourself, contact PDI Products, Box 101, St. Anne, IL, 815 427 8341.

ELECTRIC STORAGE HEATERS

Many designers and builders of super energy efficient homes are turning to electric resistance heating since the ultra low heating load makes it hard to justify a full blown central heating system. One variation of this approach is electric thermal storage heaters which heat a storage medium electrically at night when off peak rates are in effect and then use the stored heat during the day with the electric element off. One such unit is the Stiebel Eltron, distributed by Stiebel Eltron North America, 84 State Street, Suite 516, Boston, MA 02109.

RIGID FOAM INSULATION BOARDS

Apache Building Products has introduced two polyisocyanurate foam insulation boards for steel roof decks. Both foam boards, Apache Pyrox and Apache Isofoil, have rigid, closed-cell foam structures with no perlite or fiberglass components. Polyisocyanurate boards do not ordinarily require extra materials such as perlite for fire protection. The Pyrox boards have a coated fiberglass facing and the Isofoil boards have aluminum foil facing. Prices range from about $.50 per square foot for the 1.2 inch board to about $1.10 for the 3 inch board. For more information, contact: Apache Building Products Co., 2025 Linden Ave., Linden, NJ 07036

PHASE CHANGE THERMAL STORAGE MATERIALS

Below is a partial list of manufacturers of phase change thermal storage products.

"Boardman Tube", Boardman Energy Systems, Inc., Box 4299, Wilmington, DE 19807 (302) 995 4164

"Energy Rod", Certified Energy Systems Inc., 24147 Juanita Street, San Jacinto, CA 92383 (714) 654 0895

"Thermal Energy Storage Rods", Energy Materials, Inc., 2622 S. Zuni, Englewood, CO 80110 (303) 934 2444

"Phase Change Storage Pods", Solar Components Corporation, Box 237, Manchester, NH 03105 (603) 668 8186

TEXXOR (tm) HEAT CELL, Texxor Corp., 9910 N 48th Street, Omaha, NE 68152 (402) 453 7558

"The Rodwall", Sunwood Energy Products, Inc., 1520C Edom Road, Harrisonburg, VA 22801 (703) 434 5596

NEW KIT SOLAR GREENHOUSE

A new solar greenhouse kit is being marketed by English Greenhouse Products Corp. This is a high quality greenhouse kit for places where looks are more important than just energy efficiency. The units are double glazed and have metal glazing bars with built in condensate drains. The 8' x 13' unit costs $4413 unassembled. They say you can put it together yourself. Contact: English Greenhouse, 11th and Linden Streets, Camden, NJ 08102 (800) 828 9081

INSULATING PLASTER FOR EXTERIOR RETROFIT

Thorowall insulating plaster, manufactured by Thoro System Products, Miami, FL, is a two or three component insulation and plastering system for insulating the outside of buildings. A surface conditioner, an insulating plaster (R2 per inch) and a finish coat are applied in steps to almost any type of wall except metal buildings. According to Vincent J. Prestileo, of Thoro System Products, it can be applied even to existing lap siding, forms an airtight seal, and is the only external insulation which is completely fireproof. The cost, including materials and labor ranges from $4.50 to $6.00 per square foot. For more information, contact: Thoro System Products, 7800 38th Street, Miami, FL 33166 (305) 592 2081

ULTRASONIC INFILTRATION DETECTOR

Ultrasonic energy leak detector manufactured by Modern Products Ltd. is a new (and expensive) entry into the flurry of tools and methods for locating energy leaks in all types of buildings. The #113 detector is available for $1500 from Modern Products Ltd., Box 683, Victoria, British Columbia, Canada, V8W 2P3.

BRUSH ON AIR BARRIER

A product called Decadex, manufactured by Pentagon Plastics, is an elastomeric surface coating which can be brushed, rolled or sprayed onto wood or concrete to form an airtight but not vapor tight seal (According to Whit Dobyns of Pentagon Plastics, the permeance is 0.7). They also sell a flexible elastic reinforcing tape to use over large cracks and/or at construction seams. For more information, contact Whit Dobyns, Pentagon Plastics, 905 North Railroad Avenue, West Palm Beach, FL 33401, (305) 655 2111.

COMPUTER SOFTWARE

A review of "Building Loads", a new program by Microcomputer Design Tools Inc.

In our opinion this is one of the most useful, sensible and elegant microcomputer design tools available. It is the first program we have seen that uses hourly weather data on a microcomputer. Not only is the main program useful, but the hourly TMY weather data supplied on 5.25" floppy disks by MicroComputer Design Tools can be easily accessed and used for a variety of innovative energy calculations and displays.

WHAT DOES THE PROGRAM DO?

BUILDING LOADS is a pre-design tool. It was inspired by a manual method of graphic energy analysis - the "Energy Graphics Method" prepared by Booz-Allen & Hamilton Inc. The manual method's use and importance and the development of similar main-frame computer programs are documented in the proceedings of both the 1980 AS/ISES Passive Solar Conference and the 1981 AS/ISES Annual Meeting.

It calculates the heating losses and gains of a building, hour by hour, using actual (average) weather data, for any four days of the year.

The primary output of BUILDING LOADS is graphical. There are two types of plots; both plot hourly energy flows for any selected day(s) of the year. The first type is "rainbow plots" of the components of the energy flow including solar and internal gain, conduction heat loss/gain, and ventilation and infiltration heat loss/gain. The second type are "bar charts" which provide a separate series of bar graphs for each of the above components as well as one integrated graph showing total net energy flows. Drawing conclusions from graphs is much easier than wading through long lists of numbers to get answers. The program also generates long lists of numbers if that's what you want.

WHAT DOESN'T IT DO?

This program does not calculate annual fuel consumption (it could be modified to do that but the program author, Ray Bahm told us that the calculations would take about five hours on a Radio Shack TRS-80 Model I computer); does not consider the effects of thermal mass or wall lag times in any of the calculations; does not consider sol-air temperature or any effect of solar radiation on the exterior opaque walls; not does it allow for window shading coefficients or consider latent cooling load (dehumidification). Each hourly calculation is simply a steady state calculation of the heat loss or gain during that hour.

While this may seem like a limitation, we consider it an asset because the program avoids many of the least validated calculation routines and sticks to cut and dry steady state calculations. There are no black boxes. Everyone would like a computer program which, upon the press of a single button, proceeds to predict exactly how the building will behave day by day and exactly how many units of energy it will consume over the year. Unfortunately, that has proven very difficult to do accurately, even on large mainframe computers.

The BUILDING LOADS program takes a different approach. It uses very simple calculations. If you understand basic conduction and infiltration calculations, you understand everything this program does. It simply does a lot of calculations, does them very fast, and presents them in a way which is clear and useful to you and your client.

If you must calculate annual loads, you can use the hourly weather data to calculate actual degree days and then use basic degree day calculations.

FOR WHAT IS IT USEFUL?

This is a pre-design tool. It was written for commercial buildings and is probably a bit of overkill for houses although it handles them just as well. The features for commercial buildings include variable occupancy schedules, variable lighting loads, ventilation rates, and the important ability to handle up to ten functional use areas, each with its own set of physical characteristics and occupancy patterns.

Given a specific building description, the program shows you how that building will react to typical and/or extreme weather conditions for your city. You get to see excess heat from morning solar gain through east facing windows or afternoon overheating due to west facing windows. You can then move those windows, add overhangs, or eliminate them and run the program again to see the difference.

You can have up to ten different wall or ceiling types and ten different glass types, each with a different orientation, tilt, R-Value and area.

You can increase the ventilation rate to see how it affects the total net load or to see if it overcomes overheating from solar gain.

You can run the program for a sunny day and a sunless day to see how the building will react under the two extremes. (There is a separate program which will go through all the weather data and select days of any month which are either "typical" or "extreme" weather days.)

You can cut the house into two or more (up to ten) "functional use areas" and analyze them each separately. You can then combine them into one unit to get integrated results.

You can take the same house and run it in many different cities to see the difference in reaction.

Also, as mentioned above, the hourly weather data can be used for a number of other useful tasks. For example, one short program which is included when you buy the Building Loads program plots out daily temperature ranges in three day increments for the entire year. One glance at this gives the designer a feel for daily swings in temperature as well as annual ranges.

HOW DOES IT WORK?

The following is a sample input and partial output of one very simple run using the BUILDING LOADS program. It does not use the full power of the program but will give you an idea of how it works and what the output looks like.

```
USE-TYPE :  RESIDENCE

FLOOR AREA= 2000 SQ FT          CEILING HEIGHT= 8 FT
OCCUPANCY PATTERN (0=EMPTY, 1=OCCUPIED)
 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
OCCUPANCY LEVEL= 1000 SQ-FT/PERS                ACTIVITY LEVEL= 300 BTU/PERS/HR
LIGHTING LEVEL= 0 WATTS/SQ FT   EQUIPMENT= 0 BTU/SQ FT
INFILTRATION= .1 AIR CHANGES/HR VENTILATION= 12 CU FT/PERS/MIN

SOLID SKIN TYPES :
 1224  SQ FT    R- 22     WALLS
 2000  SQ FT    R- 33     CEILING

WINDOW AREAS :
 50   SQ FT   R- 1.82    180 -DEG AZ     90 -DEG EL   NORTH GLASS
 50   SQ FT   R- 1.82     0 -DEG AZ     90 -DEG EL   SOUTH GLASS
 50   SQ FT   R- 1.82   -90 -DEG AZ     90 -DEG EL   EAST GLASS
 50   SQ FT   R- 1.82    90 -DEG AZ     90 -DEG EL   WEST GLASS
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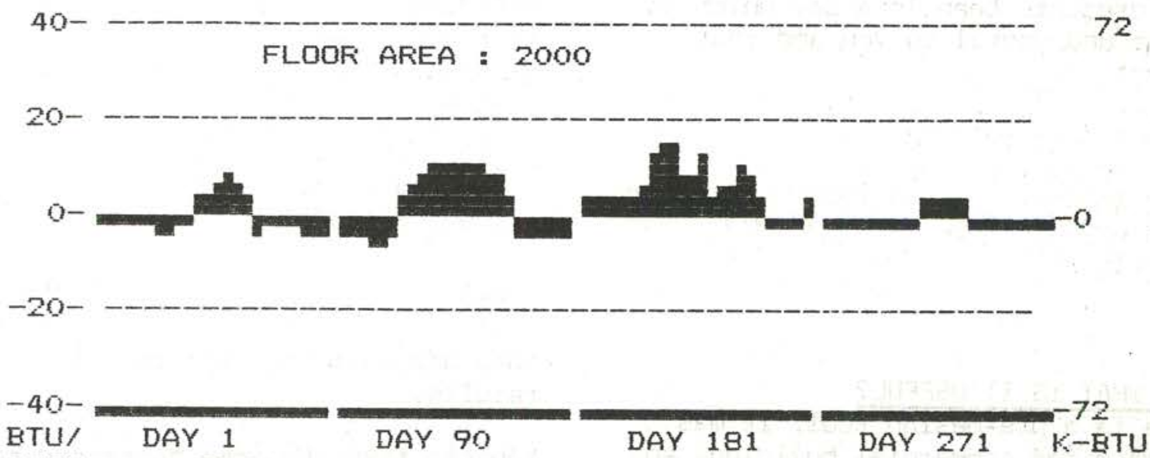
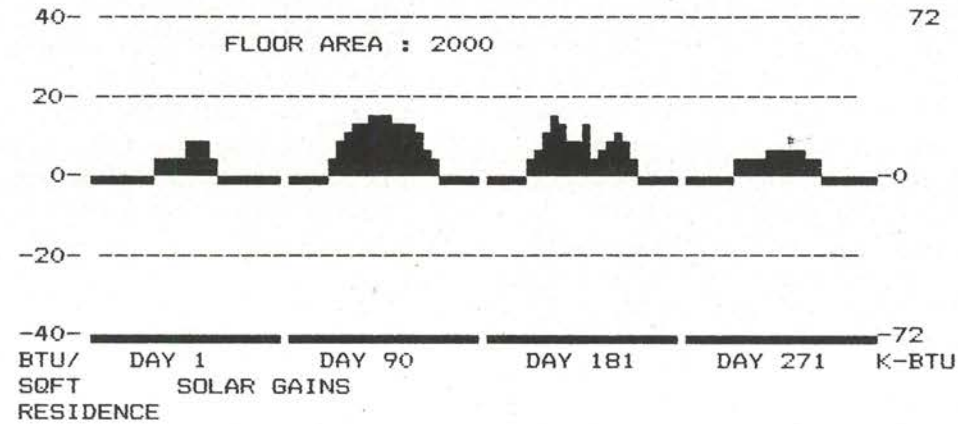
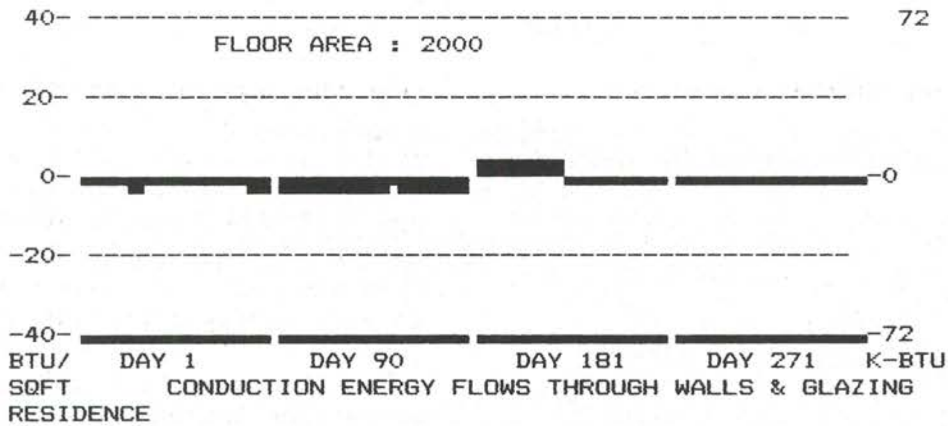


TOTAL NET ENERGY FLOW

RESIDENCE





<u>IS IT EASY TO USE?</u>
Yes. The program requires only a minimal familiarity with your microcomputer. Everything is self-explanatory and very well thought out. We did encounter some difficulty with one of the graphics routines but found the people at Microcomputer Design Tools very helpful and willing to provide any assistance needed.

The documentation provided with the program is clear and well written. One deficiency is that it doesn't explain how the program calculates loads. Even though it uses simple ASHRAE methods, it should be set forth in the documentation. We are told by Microcomputer Design Tools that future revisions will include that.

<u>WHAT KIND OF COMPUTER WILL IT RUN ON?</u>
BUILDING LOADS is available for the Radio Shack TRS-80 Models I and III and the Apple II computer. It requires at least 48K of memory and two disk drives. A printer is also needed.

<u>Available from:</u>
MicroComputer Design Tools, Inc.
2513 Kimberley Ct. NW
Alburquerque, NM 87120
(505) 831 3911

<u>Cost - $500.00</u> Includes hourly TMY weather data for one city. Additional weather data is available for $50.00 per city. The weather data comes with additional software for conversion from serial to random files and for accessing the weather data from your own programs.

BOOKS REVIEWED

Air to Air Heat Exchangers by William A. Shurcliff, 19 Appleton St., Cambridge, MA 02138. 1981 $14 paperback. (About to be published by Brickhouse Publishing Company).

Five years ago, very few residential builders even heard of air to air heat exchangers. Today, most progressive builders, particularly those interested in energy efficient housing are being asked or forced to include them in their new buildings.

Very few builders or architects however, have even the foggiest idea how to properly design an air to air heat exchanger installation. Recently I saw an advertisement for a new superinsulated house with two wall mounted air to air heat exchangers in the two bathrooms. That's fine but it doesn't do anything about ventilating the rest of the house. Last July, I was retained as energy consultant for an architectural design competition in the Washington DC area. The rules required that if the design included heavy insulation, it must also include an air to air heat exchanger (no mention of air/vapor barriers). The rules also required, however, that the heat load of the building be calculated with an air exchange rate of 1.0 air changes per hour. The competition was run by experts who obviously knew little about the use of air to air heat exchangers other than the fact that they were needed in very energy efficient housing.

O.K., it's easy to criticize, but where does the builder or architect in the field learn about air to air heat exchangers? Read William Shurcliff's new book. As far as I know it's the only show in town. I don't think there is another general text devoted to residential applications of heat exchangers.

This is not an installation manual. I am sure that Shurcliff has never actually installed an air to air heat exchanger. It is a combination of general text and product directory. If you read and understand everything in the first eighteen chapters, you will know more than enough to specify and select a heat exchanger for small building applications.

The first five chapters provide an excellent practical overview of indoor air quality: the properties of air, a survey of indoor air pollutants, a special section on radon, water and humidity considerations, and natural infiltration. Chapters 7 and 8 deal with ventilation and are, in my opinion, the most valuable section of the book. Shurcliff explains the term "replacivity" which refers to the rate at which fresh air is being introduced and stale air is being exhausted. Unless you understand the meaning of this term, you can't design an effective ventilation system, with or without air to air heat exchanger. It is not an esoteric concept. In fact it is quite simple. Replacivity is a measure of "new" or "fresh" air in a building after a period of time (in a certain house with a certain ventilation system running). It is the real measure of how effective a ventilation system is.

Chapters 9 through 14 deal with the physics and design of air to air heat exchangers. Some of the information is beyond the practical need of the average builder or architect. For example, there is a section on Reynolds numbers and the analysis of laminar versus turbulent air flow. Also there is an instructional section on the use of psychometric charts. These sections are interesting and well written but hardly necessary for the field practitioner. Although Shurcliff has taken obvious care to present the material in a clear and understandable sequence, some of these technical sections might be difficult for non engineers.

Chapter 15 covers design strategies for air distribution systems - location of inlet and exhaust ducts, how to determine ventilation rates, etc. In his typical style, Shurcliff is quick to question established engineering design guidelines. For example, health code ventilation rates are often expressed in cubic feet of air per minute per occupant. "This makes good sense if the pollutants are generated by the occupants or by occupant-related activities. It makes no sense if the pollutants come from the earth or concrete basement, or Trombe wall, or furnishings containing formaldehyde."

Chapters 19 through 28 are really part two of the book. They constitute a product directory and buying guide. Individual commercially available heat exchangers are listed with technical specifications, drawings, performance specifications and prices. Manufacturers and distributors addresses are also included. The list is quite extensive and must include virtually every small unit on the market.

Finally, the appendices include an excellent bibliography on indoor air quality and heat exchangers, directories of organizations and individuals working in the field, and a list of common trade names.

Shurcliff has answered hundreds of practical questions that the building professional or his client may have about the control of indoor air quality with ventilation and air to air heat exchangers. It is a timely book and a necessary tool for the building community.

PUBLICATIONS

Proceedings of the American Council for an Energy Efficient Economy (ACEEE) 1980 Summer Study "Improving Energy Efficiency in Buildings: Progress and Problems" are now available. Over 100 university and government researchers, architects, building contractors, and representatives of utilities and government agencies participated in the summer study which was held at the University of California, Santa Cruz for two weeks in August, 1980.

The primary purpose of the workshop was to assemble up-to-date technical information on the potential for saving energy in buildings, and to share ideas and experiences about the practical problems of implementing energy efficiency in buildings. Areas where further information and research are needed were also highlighted. The proceedings contain papers on the technical possibilities and problems for improving building energy efficiency by some of the leading experts in this field. Subjects covered include new methods of building design, construction and retrofit for both residential and commercial buildings. The technical discussions also cover the environmental consequences of energy efficient design, including indoor air quality.

The Proceedings of the Summer Study, which are approximately 770 pages in length, are available for $13 from ACEEE. Checks should be made out to "1980 Summer Study" and mailed to Dr. Jeffrey Harris, Energy Efficient Buildings Program, Bldg. 90-3058, Lawrence Berkeley Laboratory, Berkeley, CA 94720.

Progress in Passive Solar Energy Systems, Editor-in-Chief: John W. Hayes, Ph.D., Marlboro College.
(The following description is excerpted from a promotional flyer produced by the publisher)
The archival quality of this expanded continuation of the Proceedings of the National Passive Solar conference offers an important new perspective on the fields of energy, building, and architecture. Edited by an outstanding panel of leading scientists and technical experts, the annual publication of Progress in Passive Solar Energy Systems aims to provide the most extensive and perhaps unique coverage of current research and development. Both passive and hybrid systems are covered in papers by hundreds of authors. These are now supplemented by major reviews by leading authorities, extended references, examinations of policy and discussions of future directions for research, development, commercialization, public policy and law to provide a

primary resource for every researcher, educator, technical professional and student.

The major topical headings range from the theoretical to the applied and include design, construction techniques, monitoring, performance evaluation, optimization, design tools, computer simulation, emerging architecture, super insulation, integrated heating and cooling, daylighting, community projects, commercial buildings, residential applications, retrofitting, education and outreach, comfort, international exchange, greenhouses, hot water supply, marketing and commercialization. Available for $145.00 from American Solar Energy Society, Inc., Publications Office, 110 West 34th Street, New York, NY 10001.

"Solar Index," published by Solar Index, Inc., is a guide to alternate energy periodicals. It lists by subject all articles on alternate energy and energy conservation appearing in twelve well known periodicals. It is very well thought out, easy to use and a valuable tool for anyone working in energy efficient research, design or construction. It is available for $18.00 per year from Solar Index, Inc., Vox 6933, Denver, CO 80206.

An assortment of technical and marketing literature about polyurethane and polyisocyanurate foams is available from the Society of the Plastics Industry (SPI). A sample of titles are: "Fire Safety Guidelines for Use of Rigid Polyurethane Foam Insulation in Building construction", "Model Code Provisions Pertaining to Rigid Foam Plastics Insulation", "An Assessment of the Thermal Performance of Rigid Polyurethane and Polyisocyanurate Foam Insulations for Use in Building Construction", "Using Flexible Polyurethane Foams Safely".

These and many other titles are available for usually less than $1.00 from The Society of the Plastics Industry, Inc., 355 Lexington Avenue, New York, NY 10017 (212) 573 9400.

Rammed earth construction is not likely to take over the housing market (one friend said it can never catch on because you can't sell dirt! But who would have thought you could sell fancy water from France in designer bottles). For those who are interested, there is some information available: Handbook on Rammed Earth available for $11.50 from Rammed Earth Works, Blue Mountain Rd., Wilseyville, CA 95257 (they also offer workshops). "Rammed Earth Builders' Packet" available for $35.00 from Richard Day, Box 614A, Palomar Mountain, CA 92060.

"Photovoltaics, The Solar Electric Mazazine" is a new publication dealing with the technologies, products and projects of the photovoltaics industry. The first issue was June/July, 1982. Subscription price for one year (9 issues) is $15.00. Write: Fore publishers, Inc., Box 3269, Scottsdale, AZ 85257

COMING EVENTS

September - December. American Institute of Architects has scheduled several workshops on "Energy in Architecture" for the summer and fall. Three different workshops will be offered on Techniques, Process, and Practice. The cost to attend the two-day sessions is $150 for the Techniques and $275 for the Process or Practice. For more information, contact: Brenda Henderson, A.I.A., Washington, D.C. (202) 626 7300.

October 4-8, 1982. Role of the Energy Manager, University of Wisconsin-Extension, Madison. Contact: John C. Jenkins, Program Director, University of Wisconsin, Department of Engineering, 432 N. Lake Street, Madison, WI 53706 (608) 263 5523.

October 4-5, 1982. Energy Auditing Seminar, Chicago, IL. Sponsored by the Association of Energy Engineers. Fee: $440 for members, $495 for non-members. For information, call: (404) 447 6452.

October 4-7, 1982. Sheet Metal & Air Conditioning National Association (SMACNA), Annual meeting, Sheraton Waikiki, Honolulu, Hawaii. Contact: Mary Lou Taylor, (703) 790 9890

October 4-8, 1982. Roofing Industry Educational Institute (RIEI) Roofing Symposium, Bloomington Marriott, Bloomington, MN. Contact: Sue Mathews, RIEI, 6851 S. Holly Circle, Suite 250, Englewood, CO 80112, (303) 770 0613.

October 6-7, 1982. Cogeneration: Current Prospects and Future Opportunities, Crystal City Hyatt Regency Hotel, Arlington, VA. Contact: Martin Heavner, Government Institutes, Inc., Box 1096, Rockville, MD 20850 (301) 251 9250.

October 7-8, 1982. "Forum on the Guarded Hot Plate and Heat Flow Meter - State of the Art", sponsored by the Division of Building Research of the National Research Council of Canada, and the C16.30 Thermal Measurements Subcommittee of ASTM C16. Quebec City, Quebec, Canada. Contact: Ron P. Tye, Energy Materials Testing Laboratory, a Division of Fiber Materials, Inc., Biddeford Industrial Park, Biddeford, ME 04005.

October 8-9, 1982. National Innovation Workshops, organized by the Office of Energy Related Inventions of the National Bureau of Standards. Intended for inventors in all fields. Attendance fee $55. For information, call Sandy Wien, OERI, National Bureau of Standards, Washington, DC 20234, (301) 921 3694.

<u>October 11-12, 1982.</u> "<u>Superinsulation Retrofit Techniques For Building Professionals</u>". Philadelphia. Fee: $235.00. Contact: Energy Design Associates, Inc. Box 1709, Ansonia Station, New York, NY 10023 (212) 662 7428.

<u>October 13-14, 1982.</u> "<u>Superinsulation Retrofit Techniques for Building Professionals</u>". New York City. See listing under October 11-12.

<u>October 13-15, 1982.</u> <u>Efficiency Testing Seminar</u>, Santa Fe, NM. Focus on stack loss methods, proposed Wood Heating Alliance standards, in house testing. Contact: Sara Gaines, Administrative Director, Shelton Energy Research, Box 5235, Santa Fe, NM 87502 (505) 983 9457.

<u>October 14-16, 1982.</u> <u>National Renewable Energy Technologies Conference.</u> Denver. Contact: Linda Bouwkamp, Jordan College, 360 West Pine St., Cedar Springs, MI 49319. Fee: $150. (616) 696 1180.

<u>October 15-16, 1982.</u> <u>Western Regional Home Improvement Conference</u>, Sahara Tahoe Hotel, Lake Tahoe, NV. Contact American Building Contractors Association (ABCA), 8727 West Third St., Suite 203, Los Angeles, CA 90048. (213) 278 2533.

<u>October 15-16, 1982.</u> "<u>Superinsulation Retrofit Techniques for Building Professionals</u>". Boston. See listing under October 11-12.

<u>October 15-17, 1982.</u> <u>The Ottawa Energy Show</u>, Lansdowne Park, Ottawa, Ontario. Contact: The Ottawa Energy Show, 403-396 Cooper St., Ottawa, Ont. K2P 2H7, (613) 236 8388.

<u>October 15-17, 1982.</u> <u>3rd Annual Connecticut Energy Expo</u>, Hartford Civic Center, Hartford, CT. Contact: Robert Dennis Productions, Inc., 196 New London Turnpike, Box 802 Glastonbury, CT 06033 (203) 633 5885.

<u>October 18-21, 1982.</u> <u>Meeting of the American Society for Testing and Materials (ASTM) Committee E-6 on Performance of Building Construction</u>. ASTM Headquarters, Phildelphia, PA. Contact: Ken C. Pearson, (215) 299 5520.

<u>October 22-24, 1982.</u> <u>Energy Lifestyle Show</u>, International Centre, Toronto, Ontario. Contact: Synergic Media Ltd., 1 Sparks Ave., Willowdale, Ontario M2H 2W1 (416) 496 0551.

<u>October 24-27, 1982.</u> <u>1982 National Conference of the American Wind Energy Association</u>. Amarillo. Contact: AWEA Publication Center, Box 5659, Norman, OK 73070 (802) 446 2575.

<u>October 24-27, 1982.</u> <u>American Gas Association, Annual meeting</u>, Crown Center, Kansas City, MO. Contact: Delores Harrison, (703) 841-8400

October 25-26, 1982. "Superinsulation Design and Construction Techniques For Building Professionals". Two-day seminar. Philadelphia. Fee: $235.00. Contact Energy Design Associates, Inc., Box 1709, Ansonia Station, New York, NY 10023 (212) 662 7428.

October 25-27, 1982. THERMOSENSE V - An International Conference on Thermal Infrared Sensing Diagnostics, Cadillac Hotel, Detroit, MI., sponsored by SPIE - The International Society for Optical Engineering. Contact: SPIE, P.O. Box 10, Bellingham, WA 98227, (206) 676 3290.

October 27-28, 1982. "Superinsulation Design and Construction Techniques For Building Professionals", New York City. See listing under October 25-26.

October 29-30, 1982. "Superinsulation Design and Construction Techniques For Building Professionals", Boston. See listing under October 25-26.

November 5, 1982. Training Seminars in Instrumented Energy Diagnosis and Retrofit, Future Resources Associates, Inc., 2000 Center St., Suite 418, Berkeley, CA 94704 (415) 526 5111. Fee: $150.

November 7-10, 1982. International Hotel/Motel and Restaurant Show, New York City. Will discuss ways to combat the rising costs of heat, cooling and lighting. For information, call: (212) 481 4488.

November 7-10, 1982. Solar Energy Industries Association 8th Annual conference. Mariott Hotel, Atlanta, Georgia. Contact: SEIA, 1001 Connecticut Ave., N.W., Suite 800, Washington, DC 20036

November 15-16, 1982. "Superinsulation Design and Construction Techniques For Building Professionals", Chicago. See listing under October 25-26.

November 16-18, 1982. Infrared diagnostics course, Shelburne, VT. Contact: Paul Grover, The Infraspection Institute, Hullcrest Drive, Shelburne, VT 05482. (802) 985 2500.

November 17-18, 1982. "Superinsulation Retrofit Techniques for Building Professionals", Chicago. See listing under October 11-12.

November 19-20, 1982. Training Seminars in Instrumented Energy Diagnosis and Retrofit. Future Resources Associates. Fee: $300. See listing under Nov. 5.

November 19-21, 1982. Energy Conserving Greenhouse Conference. Dunfey Hotel, Hyannis. Contact Alex Wilson, NESEA, Box 778 Brattleboro, VT 05301 (802) 254 2386

November 29-30, 1982. Energy Auditing Seminar, Anaheim, CA. See October 4-5 for details.

EDITORIAL

Good-bye to the Payback Analysis

Let's face it, the bottom line is: "How many Btu's of energy have to be bought to heat, cool, light and ventilate a building?" Next to that bottom line, let's not forget that it must also be a nice place to live, not unhealthy, not unsafe, not ugly, and not too expensive. If you can build a house with a total energy bill of $100 or $150 dollars per year, then you've reached the bottom line - zero or near zero energy. After that, who cares.

We now have quite a few examples of houses that achieve zero energy using various approaches: high levels of insulation (superinsulation), airtight construction (supertight??), passive solar, active solar, earth bermed, underground, double envelope and so on (see William Shurcliff's new book about Saunder's Shrewsbury House for an example of a house using everything).

How does a designer choose the best approach? And then how does he or she decide where to stop, i.e. how thick insulation, how big solar window?

In the past we would use "payback analyses." We would start with a leaky uninsulated house and slowly add insulation or solar heaters and compare each incremental cost with the associated dollar savings in energy. Each new feature had to "pay its own way" by saving a certain number of Btu's for every dollar invested. This often resulted in a patchwork combination of features which didn't really make sense.

Now we have a new opportunity. Let's only build houses which cost a maximum of ten or fifteen cents per square foot per year to heat and cool. Let's start with any of the proven techniques now available and modify them to reduce construction costs and/or to improve aesthetics or other design considerations. For example, take the Saskatchewan Conservation House and move it to Boston. It won't have any heating bill at all! Now how can we modify that design to reduce cost without sacrificing energy efficiency? How can we design along contemporary architectural lines without sacrificing energy efficiency? How can we apply it to multifamily housing?

As a shining example of one firm taking this approach, consider the work being done by Ted Bakewell III of Reshelter Research, St. Louis, Missouri. He has developed a very innovative technique for superinsulation retrofit of inner city buildings in St. Louis using prefabricated foam sandwich panels. The system is economical and easy to install. We spoke to Bakewell at the National Passive Solar Conference in Knoxville and asked him how he sized the insulation system. His answer was simple: the insulation system was designed so that the calculated heat load was low enough to be totally satisfied by the intrinsic heat generated in the building (lights, applicances, people, etc.). In other words, little or no auxiliary heat needed. From there they proceeded to design a system which would meet that requirement and then looked at ways to modify the system to reduce costs, to facilitate installation, and to make the technique adaptable to more types of installations. Simple.

As more and more super energy efficient houses are built, the less energy efficient houses will begin to decrease in value. Eventually the difference in market value between a "conventional" house and a super energy efficient house will be so great that it will drown out all the economic fine tuning of payback analyses. In other words energy efficiency is worth more than just the Btu's saved and the payback analysis should be retired from the residential housing design process.

Energy Design update
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