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PASSIVE SOLAR TECHNIQUES FOR THE MOBILE/MODULAR HOUSING INDUSTRY

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DEPARTMENT OF ENERGY

APPROPRIATE TECHNOLOGY SMALL GRANTS PROGRAM

GRANT NO. DE-FG4481R410461

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DANIEL C. OSBORN

HUNTSVILLE, ALABAMA

31 JANUARY 1983

MASTER

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PASSIVE-SOLAR TECHNIQUES FOR THE MOBILE/MODULAR HOUSING INDUSTRY

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Huntsville, AL

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INTRODUCTION

Although much has been written about and much has been accomplished with passive solar techniques and typical/conventional residential construction, there has been very little attention given to the mobile home sector. This is, perhaps, the result of certain limitations or the uncertain variables which one may encounter when addressing this particular issue.

This publication does address Passive Solar Techniques for the Mobile Housing Industry. The goal is to show that with proper planning and some thought, this sector of the residential market can do its part in developing and marketing alternative energy systems.

This research and idea development is not intended for the purpose of creating any new technology or manufacturing processes within the mobile home industry. It is an attempt to address and integrate the current "state-of-the-art" in mobile housing and passive solar techniques.

This is not intended to be the end product, but rather a stimulus for thought and development within the mobile home industry. The ideas and information presented on the following pages still need further refinement and analysis. There are no real life model homes to cite as examples of performance as there are with conventional housing, therefore, there is no performance data to use, only the computer simulations presented herein and basic common sense which has been passed from generation to generation of man.

PASSIVE SOLAR SYSTEMS

"Passive solar systems" may be easily described in contrast to "active solar systems." Active systems generally employ hardware components and mechanical equipment such as fans, flat plate or focusing collectors, pumps, etc., to collect and transport heat. Passive systems, on the other hand, collect and transport heat by nonmechanical means. While active systems use energy to power fans, pumps, etc., passive systems operate on energy available in the environment.

A good definition of passive solar heating and cooling system is a system in which thermal energy flows by natural means such as radiation, conduction and natural convection. There are no separate collectors, storage units or mechanical systems because the building structure or elements within are the system.

There are three basic concepts in passive systems: 1) direct gain, 2) indirect gain, and 3) isolated gain. Briefly described, these concepts are:

- 1) Direct Gain:
this can be described as a "live-in" solar collector. A living space or spaces is directly heated by the sun. An example of this concept is any south facing glazing which is exposed to the winter sun.

DIRECT GAIN

- 2) Indirect Gain:
this concept is where sunlight strikes a thermal mass which is located between the sun and the living space. The mass absorbs the sun's energy and it is converted to thermal energy and transferred to the living space. A typical example of this concept is the Trombe Wall.

INDIRECT GAIN

- 3) Isolated Gain:
a description of this concept is one in which solar collection and thermal storage are "isolated" from the living spaces. With this system, heat is drawn from the system when needed. An example of this concept is a natural convective loop.

ISOLATED GAIN

This is a simple and concise description of passive system concepts. It must be understood that the ways and means of incorporating these concepts into design are quite numerous and may vary from design to design based on variables such as climate, geographic location, designer's choices, etc.

PROJECT PROCEDURE

In order to make this project realistic and to complete as much analysis as possible, one mobile home unit was selected as a "Standard" for this project. This unit is a 14'x76' unit manufactured by Bonnell Enterprises of Athens, Alabama. This particular unit was selected because it would probably reflect a fairly typical living space for a typical family. The unit is a three bedroom, two bath, 1064 square foot mobile home.

All research and analysis is based on this one unit as the "standard". This approach was chosen in order to get accurate comparisons of information and data generated from research materials and computer analysis. The following two pages show the floor plan and typical wall section of this "standard unit".

FLOOR PLAN of
"STANDARD" UNIT
scale: 1/8"= 1'-0"

THE SITE

The major portion of the material contained in this publication deals with specific techniques related to the mobile home itself, however, passive solar concepts must begin with the site. This is the key to the entire thinking for every passive solar system.

Location, layout and orientation are key elements in proper passive solar system design and future performance.

One issue which must be addressed is the mobile home park. While the individual land owner generally has the flexibility to make the correct decisions on location, layout and orientation, the mobile home park developer must begin to understand and address this issue also. Hopefully, proper planning and development will be encouraged by the mobile home industry. If any of these techniques are to be successful and perform as they are outlined, site issues must be planned carefully and correctly.

The next five drawings illustrate some site development techniques for mobile home parks and individual land owners.

This drawing represents orientation for mobile home park sites in relation to south. Slight deviation from due south is permissible up to 15° either way. However, east of south is much preferable to west of south.

This drawing represents criteria for location of mobile homes next to each other. A minimum distance must be maintained in order to allow winter sun to reach each home.

This drawing represents a diagrammatic layout for a mobile home park using landscaping for winter buffers and summertime shading.

This drawing represents site strategies such as winter buffers and summer shading using landscaping.

This drawing represents a diagram showing location of deciduous trees on south side of home.

COMPUTER SUMMARY - HEAT LOSS/HEAT GAIN

The following two pages are the heat loss/heat gain calculations for the "standard unit" as previously described. The computer program used for these load calculations is the "Carrier Residential Load Estimating Program".

The only difference in the input data for these two summaries is orientation. Although the heat loss (btu/hr.) is not affected by orientation, heat gain is affected. Simply by orienting the "standard unit" on an East-West axis, the heat gain total is reduced by over 2500 btu/hr. This represents a 15% reduction in heat gain.

The information from this computer analysis will be used for comparison purposes when presenting ideas which will follow.

Note: All computer analysis for this research uses Huntsville, Alabama climatic data base information.

1 ** DESIGN CONDITIONS - SUMMER WINTER

* OUTSIDE TEMPERATURE (DEG. F.) 95 10
 * INSIDE TEMPERATURE (DEG. F.) 78 70
 * DAILY TEMPERATURE RANGE (DEG. F.) 15-25 --
 * SUMMER SWING TEMP (DEG. F.) 4.5 --

2 ** BUILDING -

* TYPE: SINGLE-STORY
 * EXTERIOR WALLS: UNCONDITIONED ENCLOSED CRAWL SPACE
 WITH 1-INCH FLEXIBLE INSULATION.
 * WINDOWS: DOUBLE PANE, WEATHERSTRIPPED
 DOUBLE-HUNG
 * WINDOW SHADING: NO INSIDE SHADING
 * DOORS: WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR
 * FIRST FLOOR:
 * OVER OPEN OR VENTED SPACE OR GARAGE
 * INSULATION: 3-INCH INSULATION, R = 11
 * ROOF/CEILINGS: ROOF COLOR IS LIGHT
 * CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE
 * INSULATION: 6-INCH INSULATION, R = 19
 * DUCT LOCATED IN:
 * NUMBER OF SPACES HEATED AND COOLED 1

3 ** SPACE HEATING & COOLING LOADS

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
1	** 1ST FLOOR				
		WINDOWS	110	6,710	10,518
		DOORS	21	1,974	378
		WALLS	1,440	6,660	5,400
		FLOORS	1,064	5,852	1,490
		ROOF/CEILING	1,064	3,511	2,468
		INTERNAL LOAD			4,000
		SUB TOTAL	1,064	24,707	24,254
		H/C FACTOR		1.000	0.808
		TOTALS	1,064	24,709	19,585

COMPUTER SUMMARY OF STANDARD UNIT
 ORIENTED ON A NORTH-SOUTH AXIS

1 ** DESIGN CONDITIONS - SUMMER WINTER

* OUTSIDE TEMPERATURE	(DEG. F.)	95	10
* INSIDE TEMPERATURE	(DEG. F.)	78	70
* DAILY TEMPERATURE RANGE	(DEG. F.)	15-25	--
* SUMMER SWING TEMP	(DEG. F.)	4.5	--

2 ** BUILDING -

* TYPE:	SINGLE-STORY
* EXTERIOR WALLS:	UNCONDITIONED ENCLOSED CRAWL SPACE WITH 1-INCH FLEXIBLE INSULATION.
* WINDOWS:	DOUBLE PANE, WEATHERSTRIPPED DOUBLE-HUNG
* WINDOW SHADING:	NO INSIDE SHADING
* DOORS:	WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR
* FIRST FLOOR:	
* OVER OPEN OR VENTED SPACE OR GARAGE	
* INSULATION:	3-INCH INSULATION, R = 11
* ROOF/CEILINGS:	ROOF COLOR IS LIGHT
* CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE	
* INSULATION:	6-INCH INSULATION, R = 19
* DUCT LOCATED IN:	
* NUMBER OF SPACES HEATED AND COOLED	-1-

3 ** SPACE HEATING & COOLING LOADS

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
1	** 1ST FLOOR				
		WINDOWS	110	6,710	6,460
		DOORS	21	1,974	378
		WALLS	1,440	6,660	5,400
		FLOORS	1,064	5,852	1,490
		ROOF/CEILING	1,064	3,511	2,468
		INTERNAL LOAD			4,000
		SUB TOTAL	1,064	24,707	20,196
		H/C FACTOR		1.000	0.808
		TOTALS	1,064	24,709	16,308

COMPUTER SUMMARY OF STANDARD UNIT
ORIENTED ON AN EAST-WEST AXIS

COMPUTER SUMMARY - "STANDARD UNIT" SOLAR

The following computer analysis shows the amount of solar energy used by the "standard unit". This analysis is obtained from the "Solar 1" program by Documan Software of Kalamazoo, Michigan. The calculations accomplished by this program are all based upon ASHRAE standards, and the climatic data base information for Huntsville, Alabama.

The numbers which we will use for comparing the "standard unit" to ideas presented in this publication will primarily involve "Total Heating Season Loss", "Total Heating Season Gain", "Total Auxillary Heat Req'd", "Season Solar Contribution" and "Total Summer Gain".

For definition purposes, "Season Solar Contribution" is the percentage of total heat loss that solar provides. This percentage will be used because it is a more accurate reflection of that part of the total heat loss which solar energy can provide.

=====

DESIGN DATA: (HUNTSVILLE)

LATITUDE (DEG)	34.39	ROOF OVERHANG (FT)	0.00
LONGITUDE (DEG)	86.46	ROOF HT (FT)	8.00
GLASS AZIMUTH (DEG)	0.00	GLASS HEIGHT (FT)	7.00
GLASS TILT ANGLE (DEG)	90.00	GLASS WIDTH (FT)	11.00
BLDG LOSS (BTU/HR)	22,000	GLASS SILL HT (FT)	2.50
DESIGN TEMP (DEG)	60.00	GLASS SHADE COEFF	0.88
STORAGE MASS COEF	5.00	GLASS 'U' VALUE	0.55
GROUND REFL COEF	0.20	GLASS AREA	49.50

=====

-----MILLION BTU-----											
MONTH	DEG DAYS	AV TEMP	% SUN	SOL ALT	GAIN PSF	SOL GAIN	HEAT LOSS	AUX FUEL	CORE FACT	SOL CONT	OPT GLA
OCT	87	62.2	83	47	1,514	1.70	0.82	0.00	0.82	100	0
NOV	456	50.3	78	37	1,655	1.74	4.31	2.56	0.76	36	64
DEC	701	42.4	67	32	1,684	1.52	6.62	5.10	0.76	17	124
JAN	747	40.9	59	34	1,690	1.35	7.06	5.72	0.83	13	136
FEB	599	43.6	57	42	1,638	1.14	5.66	4.53	0.93	14	118
MAR	440	50.8	64	53	1,346	1.16	4.16	3.00	0.94	23	76
APR	99	61.7	70	65	883	0.81	0.94	0.13	1.09	85	0

TOTAL HEATING SEASON GAIN	9,420,730
TOTAL HEATING SEASON LOSS	29,575,900
TOTAL AUXILLARY HEAT REQ'D	21,031,600
SEASON SOLAR CONTRIBUTION	24
SEASON PER CENT SOLAR	29

AVER	OIL	(@ 70% EFFIC):	215 GALLONS	=	\$300 @ \$1.40
FUEL	GAS	(@ 75% EFFIC):	280 THERMS	=	\$109 @ \$0.39
USED:	ELECT	(@100% EFFIC):	6,162 KWH	=	\$308 @ \$0.05

MIN STORAGE, GALS OF WATER	178
CU FT OF CONCR	54

MAY	0	69.6	76	74	597	0.61	0.00	0.00	1.29	100	0
JUN	0	76.9	77	79	508	0.51	0.00	0.00	1.40	100	0
JUL	0	79.5	77	77	540	0.56	0.00	0.00	1.31	100	0
AUG	0	79.0	82	70	725	0.80	0.00	0.00	1.10	100	0
SEP	0	72.9	82	58	1,115	1.19	0.00	0.00	0.89	100	0

TOTAL SUMMER GAIN	3,682,460
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COMPUTER SUMMARY OF STANDARD UNIT - SOLAR

GLAZING ORIENTATION

Location and sizes of windows play a major role in a building's energy consumption. Windows placed without thought given to their effect on heat loss and heat gain usually end up having a negative impact on the building's total energy consumption.

The general "rule-of-thumb" for passive solar design, is that the major window areas face southeast, south and southwest, with due south being the optimum.

With this idea in mind we will examine our "standard unit". Using the computer again we will simulate the moving of all windows to the south face and see the results.

The following page shows total heat loss/heat gain with all of the windows on our standard unit moved to a south facing wall. The unit is again oriented on an east-west axis.

If we look at the previous load calculations:

- 1) "Standard Unit" on North-South axis where heat loss was 24,709 btu/hr. and heat gain was 19,585 btu/hr.
- 2) "Standard Unit" on East-West axis where heat loss was 24,709 btu/hr. and heat gain was 16,308 btu/hr.

we find that simply by orienting the mobile home on an east-west axis and properly placing the windows we can further reduce our heat gain to 15,888 btu/hr. This represents a 19% reduction in heat gain over the standard unit on a north-south axis, and a further 3% reduction in heat gain over the standard unit on an east-west axis. Again, heat loss is not affected because this number is calculated based on winter night conditions.

Now if we look at the next page, Computer Summary of "Standard Unit" with all glass on south face - Solar, we will see that by moving the windows to the south face, we can now provide approximately 51% of the heating needs with solar energy, providing there is sufficient mass within the mobile home. This represents a 27% increase in the amount of heat provided by solar energy over our "standard unit" with windows typically placed.

We need to take note of summer gain shown in our solar analysis. The "standard unit" solar summary shows a total summer gain of 3,682,460 btu's while our "standard unit" with all south glass has a total summer gain of 7,369,220 btu's. This seems to conflict with our total heat gain calculations, which shows a reduction in heat gain. There is an explanation. Our solar program only analyzes south facing glass while the total heat gain calculation is representative of the total mobile home. Therefore, although it is true that by moving all of the glass to the south wall we increase the summer gain on that wall, we have eliminated the east and west windows which have a far greater impact on heat gain than south facing windows.

So far we have reduced the total heat gain of our "standard unit" by 19% and we can possibly provide 51% of the heating needs of the mobile home with solar energy. Not a bad start considering we have only moved some windows and have given proper attention to site orientation.

1 ~~** DESIGN CONDITIONS -~~ SUMMER WINTER

* OUTSIDE TEMPERATURE	(DEG. F.)	95	10
* INSIDE TEMPERATURE	(DEG. F.)	78	70
* DAILY TEMPERATURE RANGE	(DEG. F.)	15-25	--
* SUMMER SWING TEMP	(DEG. F.)	4.5	--

2 ~~** BUILDING -~~

* TYPE: SINGLE-STORY

* EXTERIOR WALLS: UNCONDITIONED ENCLOSED CRAWL SPACE
WITH 1-INCH FLEXIBLE INSULATION.

* WINDOWS: DOUBLE PANE, WEATHERSTRIPPED
DOUBLE-HUNG

* WINDOW SHADING: NO INSIDE SHADING

* DOORS: WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR

* FIRST FLOOR:

* OVER OPEN OR VENTED SPACE OR GARAGE

* INSULATION: 3-INCH INSULATION, R = 11

* ROOF/CEILINGS: ROOF COLOR IS LIGHT

* CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE

* INSULATION: 6-INCH INSULATION, R = 19

* DUCT LOCATED IN:

* NUMBER OF SPACES HEATED AND COOLED 1

3 ~~** SPACE HEATING & COOLING LOADS~~

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
1	** 1ST FLOOR				
		WINDOWS	110	6,710	5,940
		DOORS	21	1,974	378
		WALLS	1,440	6,660	5,400
		FLOORS	1,064	5,852	1,490
		ROOF/CEILING	1,064	3,311	2,468
		INTERNAL LOAD			4,000
		SUB TOTAL	1,064	24,707	19,676
		H/C FACTOR		1.000	0.808
		TOTALS	1,064	24,709	15,888

COMPUTER SUMMARY OF "STANDARD UNIT"
WITH ALL GLASS ON SOUTH FACE

=====

DESIGN DATA: (HUNTSVILLE)

LATITUDE (DEG)	34.39	ROOF OVERHANG (FT)	0.00
LONGITUDE (DEG)	86.46	ROOF HT (FT)	8.00
GLASS AZIMUTH (DEG)	0.00	GLASS HEIGHT (FT)	7.00
GLASS TILT ANGLE (DEG)	90.00	GLASS WIDTH (FT)	18.00
BLDG LOSS (BTU/HR)	18,000	GLASS SILL HT (FT)	1.00
DESIGN TEMP (DEG)	60.00	GLASS SHADE COEFF	0.81
STORAGE MASS COEF	5.00	GLASS 'U' VALUE	0.50
GROUND REFL COEF	0.20	GLASS AREA	108.00

=====

MONTH	DEG DAYS	AV TEMP	% SUN	SOL ALT	GAIN PSF	-----MILLION BTU-----					
						SOL GAIN	HEAT LOSS	AUX FUEL	CORE FACT	SOL CONT	OPT GLA
OCT	87	62.2	83	47	1,514	3.41	0.74	0.00	0.89	100	0
NOV	456	50.3	78	37	1,655	3.50	3.87	0.37	0.83	89	57
DEC	701	42.4	67	32	1,684	3.06	5.95	2.89	0.82	43	110
JAN	747	40.9	59	34	1,690	2.70	6.35	3.64	0.90	32	121
FEB	599	43.6	57	42	1,638	2.29	5.09	2.80	1.01	35	104
MAR	440	50.8	64	53	1,346	2.34	3.74	1.40	1.02	56	68
APR	99	61.7	70	65	883	1.62	0.84	0.00	1.18	100	0

TOTAL HEATING SEASON GAIN	18,919,300
TOTAL HEATING SEASON LOSS	26,580,600
TOTAL AUXILLARY HEAT REQ'D	11,113,500
SEASON SOLAR CONTRIBUTION	51
SEASON PER CENT SOLAR	58

AVER	OIL	(@ 70% EFFIC):	113 GALLONS	=	\$159 @ \$1.40
FUEL	GAS	(@ 75% EFFIC):	148 THERMS	=	\$58 @ \$0.39
USED:	ELECT	(@100% EFFIC):	3,256 KWH	=	\$163 @ \$0.05

MIN STORAGE, GALS OF WATER	389
CU FT OF CONCR	119

MAY	0	69.6	76	74	597	1.23	0.00	0.00	1.40	100	0
JUN	0	76.9	77	79	508	1.03	0.00	0.00	1.52	100	0
JUL	0	79.5	77	77	540	1.13	0.00	0.00	1.42	100	0
AUG	0	79.0	82	70	725	1.61	0.00	0.00	1.19	100	0
SEP	0	72.9	82	58	1,115	2.40	0.00	0.00	0.97	100	0

TOTAL SUMMER GAIN	7,395,350
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SOLAR COMPUTER SUMMARY OF "STANDARD UNIT"
WITH ALL GLASS ON SOUTH FACE

This drawing shows the "standard unit" with all glass areas relocated to one wall which could then be oriented to face south. This unit, oriented properly on the site and with proper thermal mass provided could have approximately 51% of its heating needs provided by solar energy.

SHADING

One of the most fundamental concepts and techniques of passive solar systems is shading. The idea of keeping the sun out of our shelter in the summer-time and allowing the sun to shine in in the winter-time has been a part of man's thinking since he began walking this earth. Only in modern times has man deserted this idea in favor of inexpensive power which was available to drive machines to heat and cool the dwellings he built. Now that the power necessary to operate the heating and cooling machines is becoming more and more expensive, the idea of shading has emerged again as a fundamental design tool.

Man's goal, then, is to integrate this technique into the dwellings of today. Since mobile housing is a major segment of man's dwelling structures he must address this technique to the mobile house concept.

Exterior shading has been proven to be the most effective technique. Although internal or surface devices, such as drapes, blinds, special glazings, etc., are effective at reducing heat gain, they are not nearly as effective as a device which can control solar exposure on walls, glass, and roof of a structure.

The following pages present some shading techniques which could be very useful for both passive heating and passive cooling of mobile homes.

OVERHANGS AND EXTERIOR SHADES

One of the best ways to prevent the heating up or overheating of a structure is to interrupt the sun's rays before they strike the surface of that structure. Louvers, overhangs and vertical shades offer just such tools to accomplish this feat.

By simple definition, an overhang is simply a projection of the roof, usually past the line of the exterior wall. In passive solar designs this feature can be used to block the sun in the summer, while, when designed properly, allowing the sun to shine onto and into the structure during the winter in order to take advantage of the solar energy.

Although fixed overhangs are very practical and very useful, moveable or adjustable types of overhangs offer an advantage in passive solar designs. A moveable or adjustable overhang can be positioned to take full advantage of the conditions at a given time during the year.

This concept fits well when examining the potentials of overhangs being incorporated into the mobile home. With a moveable overhang, not only are we afforded excellent solar access, but this also maintains the home as a mobile unit.

Exterior shades which are lightweight and flexible offer us another tool to use in blocking excessive sunlight. Materials such as canvas, bamboo, wood slats, etc., can be mounted on the face of a structure.

A major advantage in considering exterior shades as a passive solar tool is the ability to roll, fold, etc., these devices to allow only the desired amount of solar exposure.

Advantages which make such a device attractive for incorporating it into mobile home design is that it is lightweight, flexible and generally economical. Another important consideration is that an exterior shade would take up very little room on the exterior of the home and could either be self contained and permanently attached to the home or it could be easily removed.

One type of moveable overhang would be a solid overhang which would be hinged to the mobile home. This would allow the sun to be controlled year round by simply positioning the overhang to the proper position.

This type of overhang would also solve the problem of keeping the home mobile. By "flipping" the overhang up onto the roof, there would be no projection to worry about while moving the home.

Another type of exterior shade device is a retractable covering such as canvas, etc. This device also controls solar exposure, and it goes a step further by controlling more accurately just how much sun strikes the surface of the home.

With only a small projection from the side of the home, this device would still be in keeping with the "mobile" concept of the home.

Now that we have presented a couple of overhang/shading devices, let's see if any of this is worthwhile. It should be noted that there are many ways to provide overhangs. What is presented here is the concept and a couple of approaches.

The following two pages are computer summaries analyzing this shading technique. The first summary is the Heat Loss/Heat Gain of the "Standard Unit" with all glass on the south face and an exterior shading device at the windows. Our total heat gain is now 14,956 btu/hr. a 24% reduction over the "standard unit" on a north-south axis, an 8% reduction over the "standard unit" on an east-west axis and a 6% reduction over the "standard unit" with all glass facing south.

If we look at the next page, the Solar Computer Summary of the "Standard Unit" with all glass on the south face and an overhang, we see that the Season Solar Contribution is 50% with adequate mass storage and the total summer gain is now 5,672,640. This represents a 24% decrease in solar gain during the summer season as a result of the overhang.

To this point we have 1) properly oriented the mobile home, 2) moved all windows to face south, and 3) have provided an overhang for summer shading of the south glass. By doing this we have reduced the total heat gain by 24% over the "standard unit" on a north-south axis and we can possibly provide 50% of the mobile home's heating needs with solar energy.

One item to note on our solar calculations is the "Opt Gla" or optimum glass area in square feet. The optimum glass area shown, ranges from 55 to 115 to 81 square feet during the winter months. We have been using the amount of glass that came with the "standard unit" for all of our calculations and, looking at the optimum glass area recommended by the computer analysis, it appears that the 110 square feet we have been using is very satisfactory.

Another important element to address at this point is the possibility of using a full length overhang on the mobile home which would shade the entire wall during the summer months, and not just the glass areas. Although neither computer program allows an input to analyze this possibility, common sense tells us that if the whole wall is shaded on a hot summer day, the total heat gain for that wall would be significantly reduced. This situation is analogous to parking your car during the summer. If there is a shaded spot in the parking lot, everyone will try to get that spot. Why? Because your car will be substantially cooler when you return, as a result of being shaded.

1 ** DESIGN CONDITIONS -- SUMMER WINTER

* OUTSIDE TEMPERATURE	(DEG. F.)	95	10
* INSIDE TEMPERATURE	(DEG. F.)	78	70
* DAILY TEMPERATURE RANGE	(DEG. F.)	15-25	--
* SUMMER SWING TEMP	(DEG. F.)	4.5	--

2 ** BUILDING

* TYPE:	SINGLE-STORY
* EXTERIOR WALLS:	UNCONDITIONED ENCLOSED CRAWL SPACE WITH 1-INCH FLEXIBLE INSULATION.
* WINDOWS:	DOUBLE PANE, WEATHERSTRIPPED DOUBLE-HUNG
* WINDOW SHADING:	NO INSIDE SHADING
* DOORS:	WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR
* FIRST FLOOR:	
* OVER OPEN OR VENTED SPACE OR GARAGE	
* INSULATION:	3-INCH INSULATION, R = 11
* ROOF/CEILINGS:	ROOF COLOR IS LIGHT
* CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE	
* INSULATION:	6-INCH INSULATION, R = 19
* DUCT LOCATED IN:	
* NUMBER OF SPACES HEATED AND COOLED	1

3 ** SPACE HEATING & COOLING LOADS

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
1	** 1ST FLOOR				
		WINDOWS	110	6,710	4,785
		DOORS	21	1,974	378
		WALLS	1,440	6,660	5,400
		FLOORS	1,064	5,852	1,490
		ROOF/CEILING	1,064	3,511	2,468
		INTERNAL LOAD			4,000
		SUB TOTAL	1,064	24,707	18,521
		H/C FACTOR		1.000	0.808
		TOTALS	1,064	24,709	14,956

HEAT LOSS/HEAT GAIN OF THE "STANDARD UNIT"
WITH ALL GLASS ON THE SOUTH FACE AND AN EXTERIOR SHADING DEVICE AT THE WINDOWS

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DESIGN DATA: (HUNTSVILLE)

LATITUDE (DEG)	34.39	ROOF OVERHANG (FT)	2.00
LONGITUDE (DEG)	86.46	ROOF HT (FT)	8.00
GLASS AZIMUTH (DEG)	0.00	GLASS HEIGHT (FT)	7.00
GLASS TILT ANGLE (DEG)	90.00	GLASS WIDTH (FT)	18.00
BLDG LOSS (BTU/HR)	18,000	GLASS SILL HT (FT)	1.00
DESIGN TEMP (DEG)	60.00	GLASS SHADE COEFF	0.88
STORAGE MASS COEF	5.00	GLASS 'U' VALUE	0.55
GROUND REFL COEF	0.20	GLASS AREA	108.00

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-----MILLION BTU-----											
MONTH	DEG DAYS	AV TEMP	% SUN	SOL ALT	GAIN PSF	SOL GAIN	HEAT LOSS	AUX FUEL	CORE FACT	SOL CONT	OPT GLA
OCT	87	62.2	83	47	1,321	3.23	0.75	0.00	0.94	100	0
NOV	456	50.3	78	37	1,576	3.62	3.93	0.31	0.80	91	55
DEC	701	42.4	67	32	1,649	3.26	6.04	2.79	0.77	45	104
JAN	747	40.9	59	34	1,641	2.85	6.44	3.59	0.85	33	115
FEB	599	43.6	57	42	1,502	2.28	5.17	2.89	1.01	33	107
MAR	440	50.8	64	53	1,073	2.02	3.80	1.77	1.18	44	81
APR	99	61.7	70	65	564	1.12	0.85	0.00	1.70	100	0

TOTAL HEATING SEASON GAIN	18,384,800
TOTAL HEATING SEASON LOSS	26,986,100
TOTAL AUXILLARY HEAT REQ'D	11,353,700
SEASON SOLAR CONTRIBUTION	50
SEASON PER CENT SOLAR	58

AVER	OIL	(@ 70% EFFIC):	116 GALLONS	=	\$162 @ \$1.40
FUEL	GAS	(@ 75% EFFIC):	151 THERMS	=	\$59 @ \$0.39
USED:	ELECT	(@100% EFFIC):	3,327 KWH	=	\$166 @ \$0.05

MIN STORAGE, GALS OF WATER	389
CU FT OF CONCR	119

MAY	0	69.6	76	74	388	0.87	0.00	0.00	1.98	100	0
JUN	0	76.9	77	79	413	0.91	0.00	0.00	1.72	100	0
JUL	0	79.5	77	77	411	0.93	0.00	0.00	1.72	100	0
AUG	0	79.0	82	70	446	1.08	0.00	0.00	1.79	100	0
SEP	0	72.9	82	58	807	1.89	0.00	0.00	1.23	100	0

TOTAL SUMMER GAIN	5,672,640
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SOLAR COMPUTER SUMMARY OF "STANDARD UNIT"
WITH ALL GLASS ON SOUTH FACE AND A SHADING DEVICE

DOUBLE ROOF

Double roof construction is a familiar type of construction in some areas of the world. In hot and tropical climates this type of roof has been used successfully to guard the living spaces from direct daytime solar exposure. This technique is also known as an "icehouse roof" because of its use on structures used for storage of large quantities of ice.

It is a fact of life that the roof of a structure is the major source of summer heat gain. The double roof type of construction provides a relief from this heat gain.

The upper roof acts as a shading device for the lower roof which is next to the living spaces. The space between the two roofs is left open in order to allow the heat build up between the roofs to be removed by natural ventilation.

Since this technique would mean only a small increase in the height of the mobile home, it would have no effect on the mobility of the home.

Double Roof

The following pages present computer summaries of a double roof applied to the "standard unit" on an east-west axis.

Since the computer does not have an input to consider this as an exact measurement, by increasing the "R" value of the roof/ceiling system, we can perhaps get close to analyzing the impact of this technique.

The total heat gain with a double roof is 13,560 btu/hr. This represents a 31% reduction over the "standard unit" on a north-south axis and a 17% reduction in the heat gain of the "standard unit" on an east-west axis. Some published reports suggest that a double roof could possibly save as much as 46% on total energy consumption when applied to conventional housing, so perhaps our percentages are in line.

It should also be noted that the total heat loss has been reduced to 23,295 btu/hr. This represents a 6% reduction over the total heat loss of the "standard unit". This resulting reduction would also represent an increase in the Season Solar Contribution percentage.

The second computer summary presented here represents the "standard unit" oriented on an east-west axis with a double roof and all glass placed to face south with an overhang. The resulting totals indicate a 35% reduction in heat gain over the "standard unit" on a north-south axis and a 22% reduction in heat gain over the "standard unit" on an east-west axis.

1 ** DESIGN CONDITIONS - SUMMER WINTER

* OUTSIDE TEMPERATURE	(DEG. F.)	95	10
* INSIDE TEMPERATURE	(DEG. F.)	78	70
* DAILY TEMPERATURE RANGE	(DEG. F.)	15-25	--
* SUMMER SWING TEMP	(DEG. F.)	4.5	--

2 ** BUILDING -

- * TYPE: SINGLE-STORY
- * EXTERIOR WALLS: UNCONDITIONED ENCLOSED CRAWL SPACE
WITH 1-INCH FLEXIBLE INSULATION.
- * WINDOWS: DOUBLE PANE, WEATHERSTRIPPED
DOUBLE-HUNG
- * WINDOW SHADING: VENETIAN BLINDS OR DRAPES
- * DOORS: WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR
- * FIRST FLOOR:
 - * OVER OPEN OR VENTED SPACE OR GARAGE
- * INSULATION: 3-INCH INSULATION, R = 11
- * ROOF/CEILINGS: ROOF COLOR IS LIGHT
- * CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE
- * INSULATION: 12-INCH INSULATION, R = 35
- * DUCT LOCATED IN:
- * NUMBER OF SPACES HEATED AND COOLED 1

3 ** SPACE HEATING & COOLING LOADS

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
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1 ** 1ST FLOOR

	WINDOWS	110	6,680	4,079
	DOORS	21	1,974	378
	WALLS	1,440	6,660	5,400
	FLOORS	1,064	5,852	1,490
	ROOF/CEILING	1,064	2,128	1,447
	INTERNAL LOAD			4,000
	SUB TOTAL	1,064	23,294	16,793
	H/C FACTOR		1.000	0.808
	TOTALS	1,064	23,295	13,560

COMPUTER SUMMARY OF "STANDARD UNIT"
WITH DOUBLE ROOF

1 ** DESIGN CONDITIONS - SUMMER WINTER

* OUTSIDE TEMPERATURE	(DEG. F.)	95	10
* INSIDE TEMPERATURE	(DEG. F.)	78	70
* DAILY TEMPERATURE RANGE	(DEG. F.)	15-25	--
* SUMMER SWING TEMP	(DEG. F.)	4.5	--

2 ** BUILDING -

* TYPE:	SINGLE-STORY
* EXTERIOR WALLS:	UNCONDITIONED ENCLOSED CRAWL SPACE WITH 1-INCH FLEXIBLE INSULATION.
* WINDOWS:	DOUBLE PANE, WEATHERSTRIPPED DOUBLE-HUNG
* WINDOW SHADING:	VENETIAN BLINDS OR DRAPES
* DOORS:	WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR
* FIRST FLOOR:	
* OVER OPEN OR VENTED SPACE OR GARAGE	
* INSULATION:	3-INCH INSULATION, R = 11
* ROOF/CEILINGS:	ROOF COLOR IS LIGHT
* CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE	
* INSULATION:	12-INCH INSULATION, R = 35
* DUCT LOCATED IN:	
* NUMBER OF SPACES HEATED AND COOLED	1

3 ** SPACE HEATING & COOLING LOADS

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
1	** 1ST FLOOR				
		WINDOWS	110	6,710	3,190
		DOORS	21	1,974	378
		WALLS	1,440	6,660	5,400
		FLOORS	1,064	5,852	1,490
		ROOF/CEILING	1,064	2,128	1,447
		INTERNAL LOAD			4,000
		SUB TOTAL	1,064	23,324	15,905
		H/C FACTOR		1.000	0.808
		TOTALS	1,064	23,326	12,843

COMPUTER SUMMARY OF "STANDARD UNIT"
WITH ALL GLASS ON SOUTH FACE WITH OVERHANG AND DOUBLE ROOF

INTERIOR SHADING AND NIGHT INSULATION

Sometimes interior shading devices are preferred over exterior types. Shades such as drapes, blinds, panels or louvers can aid in reducing summer heat gain. Although interior shades are not nearly as effective as exterior shades, they can provide some relief from solar exposure.

An advantage to interior shading is the possibility of using the same device as night time insulation. If materials such as reflective membranes, insulated panels or flexible insulations are used, these interior shades can be very effective at reducing heat loss during cold winter nights.

When used as an integral part of a total passive solar system, an interior shading device doubling as night insulation can vastly improve the efficiency and effectiveness of the total system.

The following two pages are heat loss/heat gain summaries of our "standard unit" using interior shade devices such as drapes or venetian blinds. Although these two types of interior shading devices offer relief from heat gain during the summer, other devices such as insulated panels, insulated drapes and flexible insulation would have a greater impact on reduction of heat gain. Our computer program, however, will only allow us to analyze common drapes and venetian blinds.

The first summary is the "standard unit" oriented on an east-west axis with interior shading. By using this interior shade we have reduced the total heat loss from 16,308 btu/hr. to 14,569 btu/hr. This represents an 11% reduction over the "standard unit" oriented east-west with no inside shading.

The second summary analyzes the "standard unit" oriented east-west with all windows located on the south wall and having an interior shade. Again we find a further reduction in total heat loss from 16,308 btu/hr. to 14,290 btu/hr. This represents 12%-13% reduction in total heat loss over the "standard unit" oriented on an east-west axis.

1 ** DESIGN CONDITIONS - SUMMER WINTER

* OUTSIDE TEMPERATURE	(DEG. F.)	95	10
* INSIDE TEMPERATURE	(DEG. F.)	78	70
* DAILY TEMPERATURE RANGE	(DEG. F.)	15-25	--
* SUMMER SWING TEMP	(DEG. F.)	4.5	--

2 ** BUILDING -

* TYPE: SINGLE-STORY

* EXTERIOR WALLS: UNCONDITIONED ENCLOSED CRAWL SPACE
WITH 1-INCH FLEXIBLE INSULATION.

* WINDOWS: DOUBLE-PANE, WEATHERSTRIPPED
DOUBLE-HUNG

* WINDOW SHADING: VENETIAN BLINDS OR DRAPES

* DOORS: WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR

* FIRST FLOOR:

* OVER OPEN OR VENTED SPACE OR GARAGE

* INSULATION: 3-INCH INSULATION, R = 11

* ROOF/CEILINGS: ROOF COLOR IS LIGHT

* CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE

* INSULATION: 6-INCH INSULATION, R = 19

* DUCT LOCATED IN:

* NUMBER OF SPACES HEATED AND COOLED 1

3 ** SPACE HEATING & COOLING LOADS

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
1	** 1ST FLOOR				
		WINDOWS	110	6,710	4,327
		DOORS	21	1,974	378
		WALLS	1,440	6,660	5,400
		FLOORS	1,064	5,852	1,490
		ROOF/CEILING	1,064	3,511	2,468
		INTERNAL LOAD			4,000
		SUB TOTAL	1,064	24,707	18,043
		H/C FACTOR		1.000	0.808
		TOTALS	1,064	24,709	14,569

"STANDARD UNIT" - E-W WITH
INTERIOR SHADING

1 ** DESIGN CONDITIONS - SUMMER WINTER

* OUTSIDE TEMPERATURE	(DEG. F.)	95	10
* INSIDE TEMPERATURE	(DEG. F.)	78	70
* DAILY TEMPERATURE RANGE	(DEG. F.)	15-25	--
* SUMMER SWING TEMP	(DEG. F.)	4.5	--

2 ** BUILDING -

* TYPE:	SINGLE-STORY
* EXTERIOR WALLS:	UNCONDITIONED ENCLOSED CRAWL SPACE WITH 1-INCH FLEXIBLE INSULATION.
* WINDOWS:	DOUBLE PANE, WEATHERSTRIPPED DOUBLE-HUNG
* WINDOW SHADING:	VENETIAN BLINDS OR DRAPES
* DOORS:	WOOD DOOR, WEATHERSTRIPPED AND WITH STORM DOOR
* FIRST FLOOR:	
* OVER OPEN OR VENTED SPACE OR GARAGE	
* INSULATION:	3-INCH INSULATION, R = 11
* ROOF/CEILINGS:	ROOF COLOR IS LIGHT
* CEILING UNDER VENTED ROOF OR UNCONDITIONED SPACE	
* INSULATION:	6-INCH INSULATION, R = 19
* DUCT LOCATED IN:	
* NUMBER OF SPACES HEATED AND COOLED	1

3 ** SPACE HEATING & COOLING LOADS

NO.	ROOM NAME	ITEM	AREA (SQ FT)	HEAT LOSS (BTU/HR)	HEAT GAIN (BTU/HR)
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1 ** 1ST FLOOR

	WINDOWS	110	6,710	3,960
	DOORS	21	1,974	378
	WALLS	1,440	6,660	5,400
	FLOORS	1,064	5,852	1,490
	ROOF/CEILING	1,064	3,511	2,468
	INTERNAL LOAD			4,000
	SUB TOTAL	1,064	24,707	17,696
	H/C FACTOR		-1.000	-0.808
	TOTALS	1,064	24,709	14,290

"STANDARD UNIT" - E-W WITH ALL GLASS
SOUTH FACE AND INTERIOR SHADING

OPERABLE WINDOW SHUTTERS

Real, operable window shutters can have a significant value for energy savings. This simple device, which has been used for years as a shade device when insulated and weather-stripped properly can act as a deterrent to heat gain and heat loss.

THERMAL STORAGE

For any passive solar system to perform properly, the ability to collect and store the sun's heat energy until needed is essential. During a clear sunny winter day, there is usually more energy available from the sun than is needed to heat a given structure. By storing this excess energy it can be used at the times when the sun is not shining. Or during periods of cloudy weather this stored heat can be used to supplement the shortfall in solar gain.

The basic storage media consist of rock, concrete, masonry, adobe, water or eutectic salts. The problem we encounter here is that most of these storage media involve the addition of large amounts of weight. Mobile homes are lightweight structures and are generally intended to stay lightweight. So then, how can we consider thermal storage as a feasible part of a mobile home? The answer, hopefully, lies in water storage and eutectic (or phase change) salts.

We must remember that the computer summaries, showing solar calculations, has predicted that as much as 50% of the heating needs of the mobile home can be provided with solar energy collection and storage. The important concept to understand is that unless we provide the necessary thermal storage quantities suggested by the computer, this unit will not come close to the 50% figure.

If water storage is proposed as a possible solution, there are some questions to be answered. How is the added weight to the structure handled? How is the mobile home still kept truly mobile? How can we provide the necessary water storage without infringing heavily into the space of the home? Space, as anyone who has lived in a mobile home knows, is a premium item.

What is proposed as the solution and answer to the questions presented, is the placement of 12" diameter clear plastic water storage tubes

throughout the home. These tubes could be filled with water when the home has been placed on a site, and then drained whenever the home needs to be moved. The additional weight can be handled by simply providing a few extra piers when setting the home in place. By using these 12" diameter tubes and scattering them throughout the home, no large amount of space will be taken in any one room of the home.

As mentioned, eutectic or phase change salts could also be a possible solution to our storage problem. The major advantage to this material for storage is that it takes up a small amount of space. There are some disadvantages though. One disadvantage is cost, relative to other heat storage materials. Another is the corrosive qualities of these salts. Special precautions must be taken in order to contain the salts.

Although thermal storage mass does present a problem when thinking of mobile homes, either of the two solutions presented could solve the problem.

This drawing represents the placement of thermal mass in the "standard unit". Realizing that space is at a premium in a mobile home, the solution shown here is for placing 12" diameter x 8' high plastic water tubes at various areas of the home. Not only does this afford better distribution of the mass, but it also keeps from having a lot of space taken in any one room.

● Water storage tubes
±47 gallons each.

CONCLUSION

For years now people have been becoming more aware of ways to conserve energy, tap renewable energy sources, use the warmth of the earth, produce power from the winds and gain heat from the sun. The sad part is that this only began to happen on a large scale when an energy crisis was upon us. Even though warnings had been coming from high places, very little action was taken until we were in trouble.

Although solar energy has been with us since the beginning of time, it has now surfaced again into the mainstream of thought. The rising costs and questionable availability of conventional fuels has made the use of solar energy an attractive alternative.

The use of solar energy has been making significant strides forward in the conventional residential marketplace during the past few years as more people realize the benefits financially, environmentally and from a human comfort standpoint.

So then, with the mobile home industry gaining a significant percentage of the residential marketplace, why has this industry been so relectant to pursue the concept of solar energy?

It should be obvious that the ideas presented in this publication have been used before, with success in conventional construction. It was not my intent to "reinvent the wheel" with this project, but to simply take existing information and circumstances and apply the knowledge to an industry which, to date, has done very little in addressing these ideas.

With the computer simulations, I hope that this report will also be taken as a fairly accurate representation of techniques which will work when applied by the industry. I do realize that conditions vary throughout the country,

but I believe that given proper attention, these ideas could be implemented by the mobile home industry and could prove to be techniques which could substantially reduce energy consumption by mobile homes.

I do not claim to have presented all of the answers. Nor do I claim to have presented all of the possibilities involved in such a matter. This is simply a presentation of some ideas which I believe could prove to be feasible passive solar techniques for the mobile home industry to develop.

The ideal situation would occur if this report could prompt some response and further study by people involved in the decision making positions within the mobile housing industry. If that can happen, this will have been a success.

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