Recommended Insulation Retrofit Techniques

For Mobile Homes with a Simple Payback Analysis

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ABSTRACT

A study was conducted to identify techniques for reinsulating mobile home roofs, sidewalls, and floors and for investigating economic incentives that might lead the homeowner to take such action. Since mobile homes are significantly different than site built homes, this study went beyond conventional reinsulation techniques, as many of them would not be applicable to mobile homes.

Seven retrofit techniques were evaluated--four for the roof cavity, two for sidewalls, and one for floors,--using conventional insulation materials. Actual mobile homes or mock-up structures were used for the evlauation.

To determine the economic feasibility of reinsulating mobile homes, thermal and economic analyses were perpared. The thermal analysis was based on steady state one dimensional heat transfer, the economic anlaysis on "simple payback". Maximum existing insulation levels for which it would still be economically worthwhile to upgrade insulation were determined based on a sample 7-year payback period. The analyses examined four modes of heating and cooling and utilized 1978 utility rates. They were performed on mobile home roofs, sidewalls, and floors for 256 U.S. cities, with results summarized by six climatic zones.

Two of the retrofit techniques evaluated for roof cavities, one for sidewalls, and one for floors are recommended for use. The analyses have shown that candidate mobile homes will meet a 7-year payback criterion in most climatic zones when low-levels or no insulation exists in the roof, sidewall, and floor cavities.

INTRODUCTION

The residential sector of the U.S. economy accounts for approximately 25 percent of this country's total energy consumption. With a great deal of emphasis being placed on energy conservation, upgrading insulation levels in new and existing housing is becoming more prevelant. Mobile homes, however, have received little attention in the past with regard to energy conservation. Since mobile homes are significantly different than site built homes, conventional reinsulation techniques may not be applicable.

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Recent events make a closer look at retrofit insulation of these homes an important energy consideration. The rising costs of site built homes have created an increase in the use of mobile homes in the residential area; consequently, older mobile homes appear to be more in demand. Historically, these older mobile homes, e.g., 7 to 10 years and older, have had little or no insulation installed in the roofs, sidewalls, or floors. Only since 1976 has there been a federal standard for insulation levels in mobile homes. Earlier some states had building codes specifying insulation but many did not. There appears to be potential energy savings if these older mobile homes can be reinsulated in a cost effective manner.

Toward that end, this study had two objectives:

1) Identify the reinsulation (retrofit) techniques needed to upgrade the levels of insulation in existing mobile home roof cavities, floors, and walls.

2) Identify the maximum existing insulation levels for roof cavities, sidewalls, and floors under which mobile homes would be candidates for insulation upgrading.

Field trials were conducted on actual mobile homes or full size mock-up structures to develop and evaluate retrofit techniques. Several insulation materials were evaluated from an installation standpoint. The maximum insulation levels were determined using steady-state heat transfer calculations similar to those spelled out in the ASHRAE Handbook of Fundamentals (1)[1], and a 7-year simple payback. The analysis considered several modes of heating and cooling and was applied to 256 cities with results summarized by climatic zones.

RETROFIT TECHNIQUES

A. Roof Cavity Retrofit Techniques - A standard mobile home roof is 10 to 14 feet wide and can be as long as 70 feet. The typical roof system construction consists of a ceiling board material such as gypsum board, a 2 mil polyethylene vapor barrier, wooden bow trusses, and sheet-metal roof skin. The wooden bow trusses have an approximate 9-inch crown height and are made from 2 x 2-inch stock. They are spaced 16 inches on center and support the ceiling board. A 20 gauge sheet metal roof skin is rolled over the trusses and fastened with staples to the sides and ends of the mobile home. Unlike a site-built home, there is no easy access to the roof cavity. Consequently four rather innovative roof retrofit techniques were devised and evaluated.

1. Side Blow Technique - In this technique, illustrated in Figure 1, a loose fill insulation was applied using standard blowing wool equipment. First, the drip edge was removed from one side and both ends of the mobile home. Using a claw hammer or pinch bar, the roof staples along one end and side were removed. A 10 foot length of 2-inch-diameter PVC tubing attached to the blowing wool hose was then inserted under the roof skin from the side of the mobile home. With the tube placed in a truss cavity, the insulation was blown into the far side of that cavity. When the flow of insulation began to stagnate, the tube was slowly withdrawn until the flow resumed. This procedure was carried out for each truss cavity in the roof. Once the entire roof cavity was filled, the roof skin was restapled and the entire roof sealed with a standard mobile home roof sealant. Note that this technique did not allow full access to the roof cavity for visual inspection or repair of the vapor barrier.

2. End Blow Technique - In the end blow technique, illustrated in in Figure 2, the mobile home siding covering an end bow truss was first removed. Where a plywood covering was under the siding, a 2-inch-diameter hole was drilled near the center of the bow. Care was taken to avoid damaging truss webs during drilling. To apply the insulation, a 2-inch-

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[1] Numbers in parentheses refer to references at the back of the paper.

diameter PVC tube, approximately one half the length of the mobile home, was inserted for its full length into the drilled hole at the end of the mobile home roof cavity. Insulation was blown into the cavity with the PVC tube being withdrawn as the flow of insulation stagnated in the hose. When half of the roof cavity was insulated, the process was repeated on the other end. The holes were then sealed with wooden or plastic plugs and the siding was replaced. This technique also did not allow access to the roof cavity.

3. Rolled Roof Technique - The rolled roof technique, unlike the first two techniques, did allow full access to the roof cavity. The technique essentially reversed the steps used to attach the roof skin in manufacture. First, all roof vents and other roof attachments were removed. The drip edge was then removed from the roof ends and sides. Using a claw hammer or pinch bar, the roof staples along the two sides and one end of the home were removed so that one half the roof skin had been loosened. A 2 by 4-inch plank, the width of the home, was attached to the loosened end of the roof skin using small C-clamps. This plank allowed the roof skin to be rolled evenly and continuously. As illustrated in Figure 3, two 2 by 4-inch planks were laid on edge under the loosened sides of the roof skin. This helped to take out some of the crown in the roof skin caused by the bow trusses. Grasping the 2 by 4-inch plank attached to the end of the roof skin, an initial roll was made at a diameter of 12 to 18 inches. The roof skin was carefully rolled for half the length of the mobile home. The roof cavity was thus exposed to permit vapor barrier repair and installation of insulation batts. First a vapor-barrier-faced R-19 batt was installed with the facing down across the roof in each truss cavity. Since the bow truss was approximately 9-inches high, an additional R-11 unfaced batt was laid across the center two thirds of the roof width so that the roof cavity was completey filled.

Once the roof cavity was reinsulated, the roof skin was unrolled and carefully aligned to the mobile home sides. After unrolling, it was sometimes necessary to put the roof skin under tension to align it with the end of the mobile home. This was done using a winch attached to the service vehicle. Once in position, the roof skin was restapled.

This procedure was repeated for the other half of the home. Roof sealant was then applied over the entire roof.

4. Slit Roof Technique - The slit roof technique was perhaps most innovative and also allowed full access to the roof cavity. It is illustrated in Figure 4. All roof vents and other attachments were removed from the roof. The roof was slit down the center and across the two ends using an abrasive cutting wheel mounted in a rotary hand saw. Using a wood scissors jack, 8 to 10 foot sections of one half the roof skin were propped up to expose that portion of the roof cavity for inspection and installation of insulation batts as in the rolled roof technique. This procedure was carried out for the entire roof cavity.

Once the roof cavity was insulated, the roof skin was resealed. As shown in Figure 5, the sealing procedure was similar to the one used for sealing the roof seam on new double-wide mobile homes. Before the two halves of the roof skin were laid flat, a 15-inch-wide strip of 3/8-inch plywood was placed under the slit seam, running the entire length of the mobile home. A coat of mobile home roof cement was applied directly over the roof skin slit seam, which was then on top of the plywood. A 12-inch-wide strip of fiberglass mesh screen was placed directly over the seam and another coat of roof cement was applied over the mesh screen. A roof cap, made of approximately 20-gauge galvanized metal 12 inches wide running the length of the roof, was then applied over the screen. Before the metal cap was laid down, a bead of putty tape was applied to all edges of the underside of the metal cap. Using sheet metal screws, the metal cap was fastened every 8 to 10 inches through the roof skin into the plywood underlayment. The roof skin was not secured to the bow trusses because such attachment could cause tearing of the roof skin due to over the road racking if the mobile home were moved. The final step in this procedure was to apply a coat of mobile home roof sealant over the entire roof.

B. Sidewall Retrofit Techniques - The special construction techniques and materials used in mobile homes precludes use of conventional means of reinsulating sidewalls. For example, holes drilled in the aluminum siding to blow the sidewalls with a conventional double blow technique could not be patched to provide acceptable appearance. Consequently, two techniques were evaluated for retrofitting mobile home sidewalls.

1. Siding Removal Technique - This technique illustrated in Figure 6, allowed for reinsulating the sidewalls with conventional insulation batts. Window units were removed from the side of the home where reinsulating was to begin. Using a reversing screw gun with the appropriate bit, the screws holding the window frame to the sidewall were taken out and the window unit was removed and put in a safe place.

Starting at one end of the home, the screws holding the skirting and siding to the bottom plate and the screws holding the siding to the top plate and belt rails were removed. At the interlocking seams of the aluminum siding panels (approximately 4 by 7-foot sheets) a few staples were found. These were easily removed using a screw driver. The aluminum siding was carefully removed from the mobile home and put in a safe place. Note that it was only necessary to loosen the mobile home skirting to remove the siding. The exposed sidewall cavities were then reinsulated with kraft-faced batts using a press-fit technique. Although there were 2 by 3-inch studs in the sidewalls, the cavities were 3-1/2-inches thick because of the 2 by 4-inch framing surrounding the windows and doors. The 1 by 3-inch belt rails were notched into the 2 by 4-inch studs and sat on the surfaces of the 2 by 3-inch wall studs.

Many older mobile homes are plagued with excessive air infiltration rates due in large part to poorly designed windows and doors. Recent NBS studies have indicated that other avenues for infiltration are through wall electrical outlets and the floor wall interface. In an effort to reduce this portion of the air infiltration, an air-infiltration barrier was placed over the exterior side of the reinsulated wall, including window cavities before replacing the siding. A spun bonded polyolefin was used. This material is permeable to water vapor, but impermeable to air and liquid water. The barrier material was stapled to the top and bottom plates and belt rails. The siding was then replaced by fitting and securing the aluminum panels with siding screws to the top and bottom plates and belt rails. Once a window area had the siding replaced around it, the air-infiltration barrier was cut out with a utility knife. This was done so that the seam between the window casing and window jam was covered with the air-infiltration barrier. With new putty tape applied to the window casing, the window unit was replaced and secured with siding screws. This procedure was repeated as insulation continued to be added to the other sidewall cavities of the mobile home.

2. Sidewall Blow Technique - As previously stated, loose fill insulation cannot be blown into mobile home sidewalls in a conventional manner. To apply loose fill insulation, the facia molding and drip edge were removed from the top of the exterior side. Staples in the roof skin were removed as well as the top set of siding screws. The top of the aluminum siding was pulled far enough away from the top of the home to insert an installation hose down into the stud cavity. The cavity was filled from the bottom up, one section at a time. As the reinsulation proceeded, the

siding and roof skin were resecured.

C. Floor Retrofit Technique - The floor portion of mobile homes present the greatest variety of designs. Variations are found in the metal frame, airhandling duct, and undercarriage containment. In light of this, a floor reinsulating technique to accommodate practically any design was evaluated. This technique is illustrated in Figure 7.

Initially, the mobile home skirting was removed and placed in a safe location. A 6-mil spun bonded polyolefin air-infiltration barrier and 1-inch thick wood furring, were used to form a cavity under the mobile home. The cavity formation began at one end by placing a length of air-infiltration barrier under the width of the mobile home. This material was drawn snug against the mobile home chassis and attached to each side and one end by the wood furring, which was nailed to the underside of the band joist. This initial cavity section was approximately 10-feet long. As shown in Figure 7, this section was filled with blowing wool. When this portion of the section was full, a second section, overlapping previously applied material by 6 inches, was fabricated in the same way. The overlap joint was secured with standard duct tape. As with the first section, the second section was filled with blowing wool. As this process continues, water, gas or other connections from the underside of the home, were disconnected before construction of the barrier. Holes were cut in the air-infiltration barrier at the proper locations and all pipes and hoses were reconstructed through these holes when the barrier was in place. The axles were also removed while installing the air-infiltration barrier. The cavity construction procedure continued for the entire length of the mobile home. When reinsulation was complete and all furring was in place, including that on both ends, the skirting was replaced.

RETROFIT TECHNIQUE EVALUATION

1. Roof Cavity - The side blow technique was evaluated using a 12-foot wide by 16-foot-long mobile home roof section made from standard mobile home components with the exception of the roof skin. Six-mil polyethylene was used for the roof skin to allow visual inspection of the insulation installation. Local insulation contractors reinsulated the mock-up structure with fiberglass blowing wool, using the side blow technique. One hundred percent coverage was achieved.

Like the side blow technique, the end blow technique was evaluated using fiberglass blowing wool in a 12 by 16-foot roof section. Again, local contractors installed the insulation. Due to poor flow characteristics of the fiberglass approximate coverages of only 50 to 60 percent were achieved. This technique was evaluated in a way that the installer could not see how effectively the insulation was filling the cavity in order to simulate its practical application.

Two mobile home roof cavities were reinsulated in the field using the slit roof technique. This technique worked quite well, but sealing required a great deal of labor and would represent a large portion of the installation cost. The two mobile homes have been monitored for leaks or any other problems associated with this technique, and to date there have been none.

Similarly, two roof cavities were reinsulated in the field using the rolled roof technique. It was observed during the field trial, that the rolling of the roof and its alignment to the sides were critical. This procedure required two people to insure that the roof skin did not "kink" and cause a leak. This technique was not as labor intensive as the slit roof method.

2. Sidewall Retrofit Techniques - Reinsulating the sidewalls using the siding removal method was evaluated on two mobile homes. Two types of

aluminum siding were evaluated for ease of removal and replacement. One was a conventional vertical siding found on most mobile homes and the second was a horizontal mounted siding found on some other mobile homes. No problems were encountered with the removal or replacement of either siding. If the siding was handled with moderate care, denting was minimal. The remaining steps in this retrofit method were straightforward and produced completely filled cavities well sealed from air infiltration.

The sidewall blow technique was evlauated on a 4-foot wide by 8-foot tall mobile home wall section using fiberglass blowing wool. Each cavity had a 1-inch layer of fiberglass insulation to represent the low level of existing insulation found in many older homes. Due to the rather light construction materials used in mobile home walls (staples, glue, 3/16-inch paneling), reinsulation via this technique was very difficult. Even when a great deal of caution was taken while installing the insulation, the interior paneling always popped off the studs and extreme bulging occurred on the outside aluminum skin. When the siding was removed, the insulation exhibited nearly 100 percent coverage. However, when installation machine settings were varied to minimize wall damage, the coverage obtained in the wall cavities was unacceptable.

3. Floor Retrofit Technique - The cavity technique for reinsulating the floor was evaluated on one mobile home. There were no significant problems. Perhaps the most difficult portion of the procedure was lowering and raising the axle assembly, which required two people and small hydraulic jacks.

Recommended Retrofit Techniques

The following retrofit techniques are recommended based on physical limitations and effectiveness of insulation installation only.

1. Roof - Of the roof retrofit techniques evaluated, the side blow technique is most highly recommended. If there are no apparent moisture problems in the mobile home roof cavity, this technique offers the easiest installation and provides the highest R-value.

If there are moisture problems, such as interior ceiling stains, prior to reinsulating, the rolled roof technique is recommended. This technique allows full exposure of the roof cavity for vapor barrier repairs.

The slit roof technique is also effective, but it may pose a credibility problem with the home owner who may hesitate to have his roof cut open. For this reason, the slit technique is not recommended.

The end blow technique is not recommended under any circumstances. Since it does not allow the installer to check for proper coverage, the quality of the installation will be highly questionable.

2. Sidewalls - The siding removal method is recommended for reinsulating mobile home sidewalls. Because of the light construction materials used for the mobile home walls, the sidewall blow technique is not recommended.

3. Floors - The floor retrofit technique as outlined appears to be an acceptable way of reinsulating most mobile home floors. However, since a novel approach is required and since the technique should not be used if the mobile home will be moved, use of this method in the market place may be limited.

ECONOMIC ANALYSIS

In a stringent life-cycle cost analysis, future dollar savings as a result of energy conservation are discounted to current dollar values due to future changes in fuel and money rates. From such an analysis, one can predict the period of time needed to repay an energy conservation initial investment. This period of time is generally referred to as the "pay-back period." A simplified form of determining the payback period is to assume that fuel and money rates will equal each other in the future. Under this assumption, the first year energy dollar savings will remain constant over time. Therefore, the payback period is simply the total investment divided by the first year energy dollar savings. This simplified analysis is referred to as "simple payback."

In this study, since only a first order attempt was being made to determine which mobile homes may be candidates for reinsulation using the recommended retrofit techniques, only a simple payback analysis was performed. Seven years was assumed to be a reasonable payback period. The estimated consumer costs of reinsulation (initial investment) using the recommended retrofit techniques are listed in Table 1. Those costs were based on manpower and material estimates made during the field trials.

An annual heating and cooling dollar savings due to reinsulation as a function of existing cavity insulation was calculated for a single wide mobile home 14-feet wide and 66-feet long with an indoor heating temperature of 70°F. In keeping with the first order analysis, annual heating and cooling costs were determined using a simplified one dimensional, steady state, heat transfer model similar tothat described in ASHRAE (1). Note this simplified model does not represent the more complex transient models that are being developed and used within the insulation technology arena of today. A detailed description of the mobile home is given by Arnold et al (2). Yearly heating dollar savings were determined as follows:

$$\text{SAVINGS} = \frac{(U_f - U_i) \times A \times DD \times 24 \times ER \times CF \times CD}{EFF \times HV} \qquad \text{(Eq. 1)}$$

where:

U_f = reinsulation thermal transmission coefficient

U_i = existing thermal transmission coefficient

A = area

DD = degree days

ER = cost per unit energy

EFF = heating equipment thermal efficiency

HV = heating value of fuel type

CF = Interim part load correction factor for field systems only

CD = Interim correction factor for heating

vs. degree days

Due to the oversized heating systems in older mobile homes, it was assumed that CF x CD equals 1.0. This should result in conservative yearly heating fuel costs.

The yearly cooling dollar savings were determined as follows:

$$\text{SAVINGS} = (U_f - U_i) \times A \times ETD \times CH \times PF \times ER \times LLF \qquad \text{(Eq. 2)}$$

where:

ETD = equivalent temperature differential

CH = annual hours above $80^{o}F$

PF = performance factor

LLF = latent load factor

The R-values of the installed insulation after retrofit for each of the recommended techniques are given in Table 2. These values are based on the use of fiberglass batts and blowing wool. The difference in R-values in the two roof techniques is due to the difference in thermal conductivity at the installed density of fiberglass batts and blowing wool. Note that compression of the batts at the roof edges has been taken into account in the rolled roof installed R-value.

In the sidewall thermal analysis, air infiltration rates were estimated based on experimental results presented in a recent NBS study (3). It was assumed that air infiltration rates are reduced by 20 percent after the application of the sidewall air-infiltration barrier. This appears to be a conservative estimate based on the results presented by Teitsma et al (4).

These analyses were carried out for 256 urban locations across the United States and were summarized by climatic zones. A description of the climatic zones is given in Table 3.

Utilizing 1978 utility rates, the analysis considered four modes of heating and cooling.

1) Gas heat
2) Oil heat
3) Gas heat - electric cooling
4) Oil heat - electric cooling

Fuel costs are 1978 based and electricity costs reflect the lowest block price.

ECONOMIC ANLAYSIS RESULTS

With 7 years having been chosen as the payback criteria, Figures 8 through 11 show the maximum R-values of existing insulation in the mobile home roof, sidewall, and floor cavities under which reinsulation will still meet the payback criteria. The existing R-values refer to the actual installed R-value of the existing insulation. This means that an improperly installed R-11 fiberglass batt must be discounted, somewhat subjectively, to represent a more realistic installed value. With the exception of floors, all retrofit techniques meet the payback criteria at various levels of existing insulation when heating and cooling are considered in every zone.

Figure 8 illustrates the results for reinsulating the mobile home roof cavity using the side blow roof retrofit technique. This technique provides an installed insulation R-value of 22 at an estimated cost of $462.00. It appears that it would meet the payback criteria in all zones for many mobile homes with moderate to low levels of existing insulation.

Figure 9 illustrates the results for reinsulating the mobile home roof cavity using the rolled roof technique. This technique provides an installed R-value of 18 at a total cost of $671.00. As one can see, the additional cost and lower installed R-value has decreased the allowable R-values from those shown in Figure 8 for the side blow technique. Consequently, this technique may not meet the payback criteria for as many mobile homes, expecially in zones 5 and 6 However, many older mobile homes in these zones may have little or no insulation. The results for the sidewall retrofit are illustrated in Figure 10. Because of the lack or low levels of insulation and the poor installation workmanship in many early 1970 and older mobile homes, the sidewall retrofit technique the payback criteria in all zones for many mobile homes with lower levels of insulation, with the exception of gas heated homes in zones 4 and 5.

Figure 11 illustrates the results for the floor retrofit technique. Since the air space under the mobile home that is enclosed by the skirting can act as a heat sink, one may not want to reinsulate the floors in the higher cooling load areas. Therefore, the analyses for floors did not consider cooling. Under those assumptions, the floor retrofit technique can meet the payback criteria for many mobile homes in zones 1, 2, and 3.

By looking at the level of allowable existing R-values, one can see that the general descending order of retrofit is roof cavity, sidewalls, and floor, i.e. roof cavities should have top proprity for retrofit.

CONCLUSIONS

Four viable techniques have been identified for reinsulating single-wide mobile homes--two for the roof cavity, and one each for the sidewalls and floors. None of these techniques require any equipment or expertise that doesn't already exist within the mobile home manufacturer or insulating contractor industries.

Results of a simple payback analysis indicate that costs for reinsulation using the recommended techniques can be repaid by energy cost savings in 7 years or less for many mobile homes with low levels or no existing insulation in the roof, sidewall, and floor cavities.

Results of the economic analysis may be somewhat conservative since 1978 utility rates were used and Townsend Greenspan Inc. (5) predicts upwards of a 30 percent increase for fuel oil rates and an 8 percent increase for electricity rates for 1979.

The descending order of cost effective retrofit techniques is roof cavity, sidewalls, and floors.

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2) Arnold, T. R. and Associates, "Mobile Home Sub Component Cost and Efficiency Analysis, "A report to Owens-Corning Fiberglas, Toledo (1977).

3) Hunt, C. M., Treado, S. J. Peavy, B. A., "Air Leakage Measurements in a Mobile Home," Center for Building Technology, Institute for Applied Technology, National Bureau of Standards, Washington, D. C. (July, 1976) NBSIR 76-1063.

4) Teitsma, G. J., Peavy, B. A., "The Thermal Performance of a Two-Bedroom Mobile Home," Thermal Engineering Section, Center for Building Technology, Institute for Applied Technology, National Bureau of Standards, Washington, D. C. (January, 1977) NBSIR 76-1182.

5) Townsend Greenspan, Inc., Economic Consultant to Owens-Corning Fiberglas, A Verbal Communication from L. Wiltbank, New York, N.Y. (1978)

TABLE 1

RETROFIT COST SUMMARY

TECHNIQUE	TOTAL COST ($)	$/FT^2
ROOF		
SIDE BLOW	462.00	.50
ROLL	671.00	.73
SIDEWALL	755.00	.69
FLOOR	543.00	.59

TABLE 2

AVERAGE INSTALLED INSULATION R-VALUES

TECHNIQUE	R-VALUE
ROOF	
SIDE BLOW	22
ROLLED	18
SIDEWALL	11
FLOOR	15

TABLE 3

ZONE DESCRIPTION

ZONE	NUMBER OF CITIES	AVERAGE DEGREE DAYS	AVERAGE COOLING HOURS	AVERAGE UTILITY COSTS		
				GAS (¢/THERM)	OIL (¢/GAL)	ELECTRIC (¢/KWH)
1	22	8672	316	23.10	43.87	3.13
2	82	6641	532	23.41	44.58	3.39
3	66	4953	802	24.44	45.46	3.87
4	47	2774	1546	21.92	46.35	3.73
5	24	1241	1931	21.90	46.29	3.89
6	15	3845	217	23.54	46.62	3.03

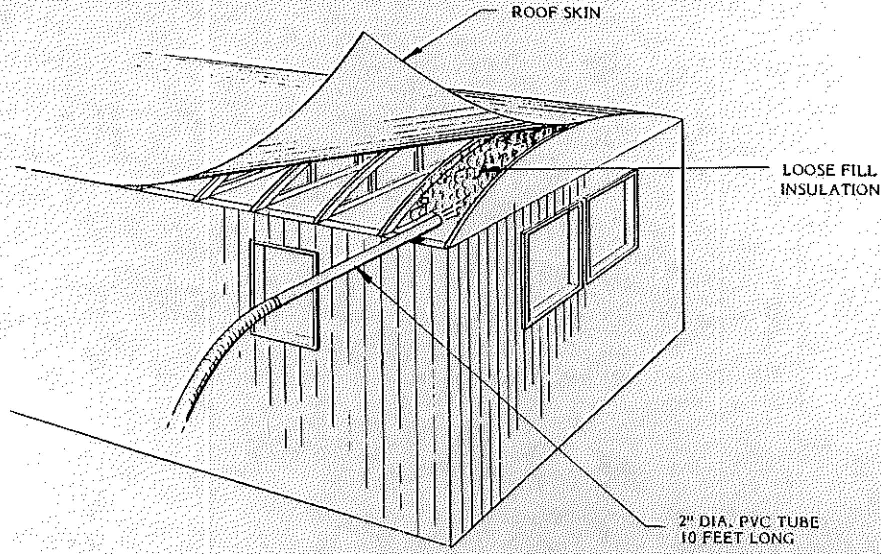

FIGURE 1

ROOF CAVITY RETROFIT - SIDE BLOW TECHNIQUE

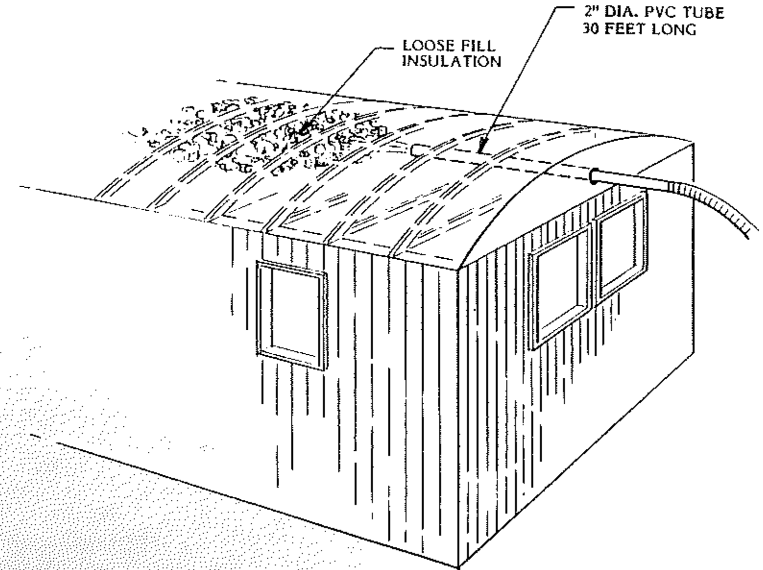

FIGURE 2

ROOF CAVITY RETROFIT END BLOW TECHNIQUE

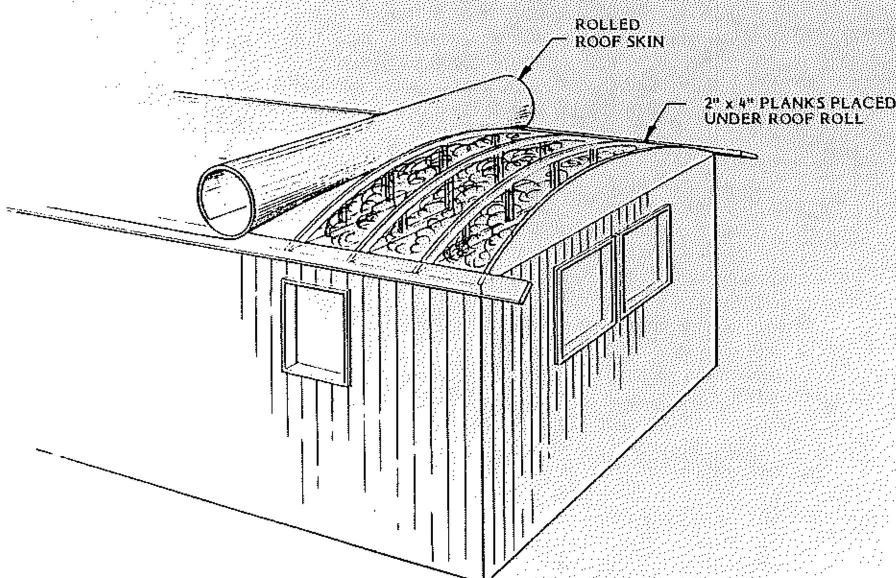

FIGURE 3

ROOF CAVITY RETROFIT - ROLLED ROOF TECHNIQUE

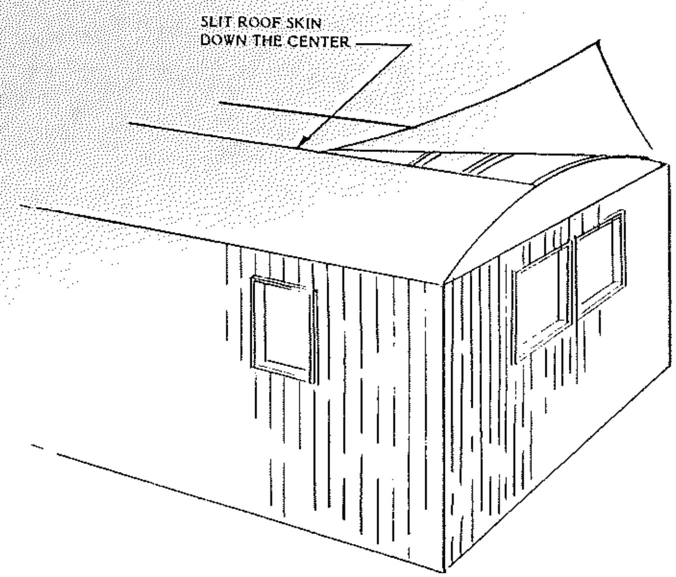

FIGURE 4

ROOF CAVITY RETROFIT - SLIT ROOF TECHNIQUE

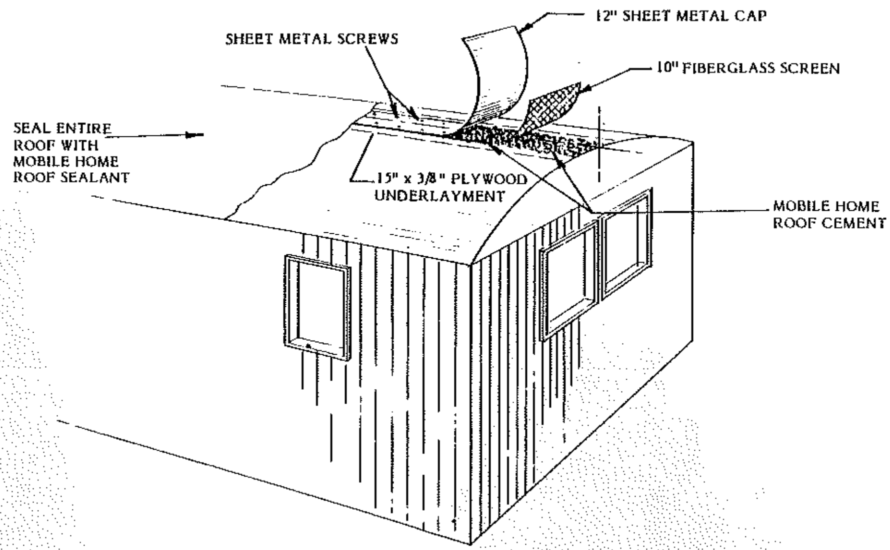

FIGURE 5

ROOF SLIT SEAL

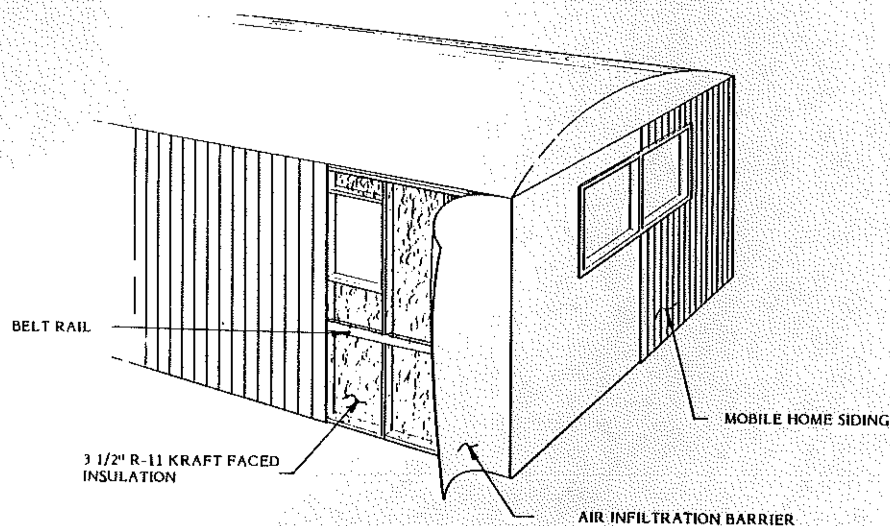

FIGURE 6

SIDEWALL RETROFIT - SIDING REMOVAL TECHNIQUE

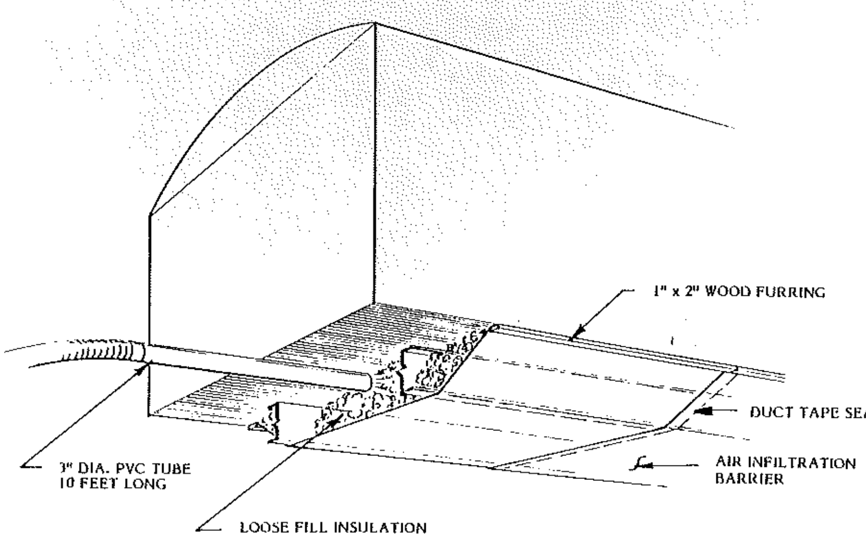

FIGURE 7

FLOOR RETROFIT TECHNIQUE

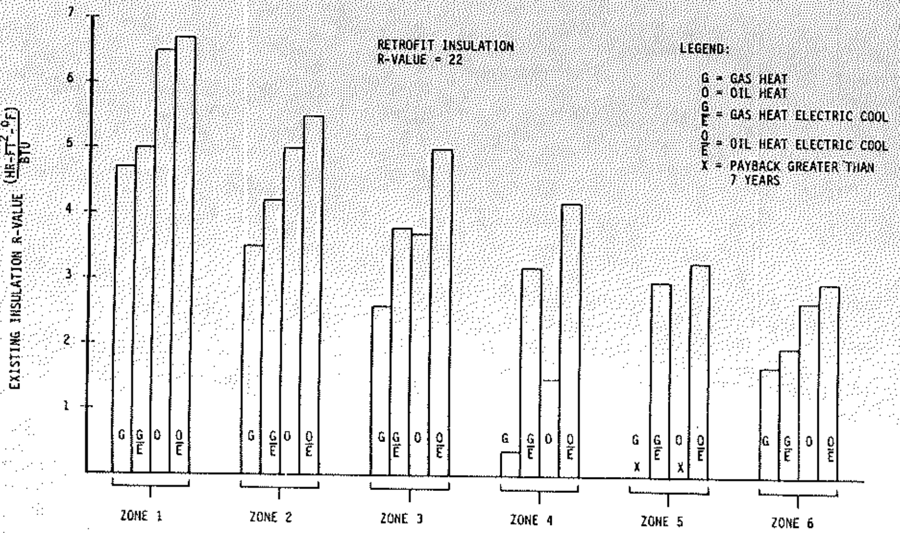

FIGURE 8

ALLOWABLE EXISTING ROOF INSULATION R-VALUES FOR A 7-YEAR INSTALLATION COST PAYBACK USING SIDE BLOW TECHNIQUE

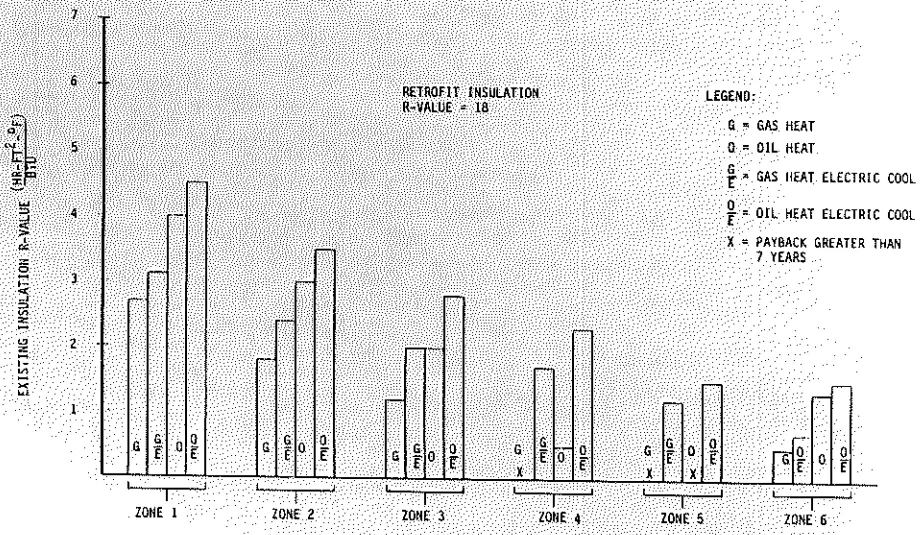

FIGURE 9

ALLOWABLE EXISTING ROOF INSULATION R-VALUES FOR A 7-YEAR INSTALLATION COST PAYBACK USING ROLLED ROOF TECHNIQUE

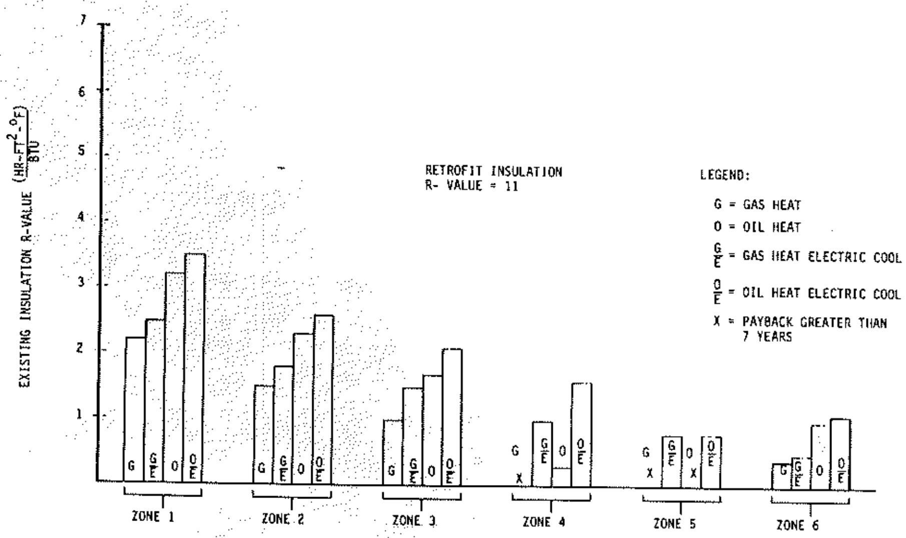

FIGURE 10

ALLOWABLE EXISTING SIDEWALL INSULATION R-VALUES FOR A 7 YEAR INSTALLATION COST PAYBACK

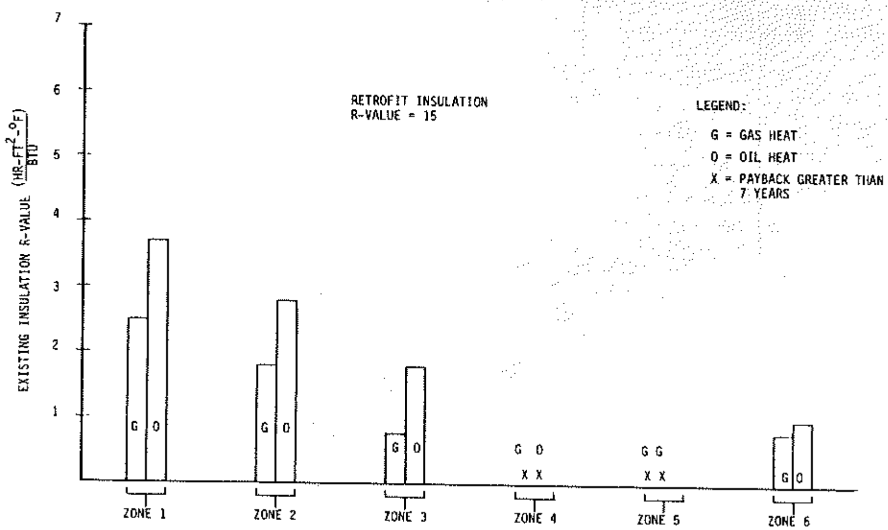

FIGURE 11

ALLOWABLE EXISTING FLOOR INSULATION R-VALUES FOR A 7 YEAR INSTALLATION COST PAYBACK