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Details of the First-Round Retrofits at Twin Rivers

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The first-round retrofits at Twin Rivers were directed to isolating the attic from the living area and basement, reducing air flow around windows and doors, and reducing heat flow from the forced-air distribution system to the basement. Details of materials used and their placement are presented. The design of the first experiment is also given. These retrofits were grouped into four packages and were deployed in phases over a single winter in twenty-four instrumented townhouses of identical floor plan.

INTRODUCTION

Preliminary models of the energy balance in a Twin Rivers townhouse led to estimates of savings from a variety of retrofits, and consultations with contractors led to corresponding estimates of costs. We decided to group those retrofits that appeared cost effective into four packages (labeled A, B, C, D) to be discussed in detail below. In the period from January to March, 1976, we performed the retrofits in twenty-four nearly identical townhouses (and in the following months we added six other townhouses). Several months before the time of retrofitting, the "Omnibus" instrumentation package [1] was placed in each townhouse, to permit before-and-after comparisons.

The implementation of the retrofits was phased to permit comparison across houses in different stages of retrofit, and packages were implemented in variable sequence. The design of the 1976 winter retrofit experiment is displayed as a schedule in Table 1.

Detailed results have been presented elsewhere [2 - 4]. Moreover, data reduction and evaluation are still in progress. We have found the winter gas consumption to be reduced between 20 and 30% by the full package of retrofits, and we have clear evidence that the attic retrofit packages (A and D) led to the largest savings. Moreover, the retrofits appeared to make the townhouses more comfortable, by reducing temperature differentials between downstairs (warm) and upstairs (cold) [5].

The remainder of this article presents the details of the four retrofit packages. Most of these details can be expected to have applicability in a broad spectrum of buildings, including many altogether different from the Twin Rivers townhouse.

RETROFIT A (ATTIC)

The final specification to the contractors for retrofit A (the attic retrofit) included the following: (1) roll unbacked fiberglass and stuff openings that exist between the outer attic floor joists (two-by-fours) and the masonry fire wall. For an interior townhouse unit, this involved two walls between the front and rear of each dwelling; (2) cover the hatch door to the attic space with 20 cm (8 in.) of fiberglass insulation, stapling or glueing in place; (3) protect against blown insulation moving into the soffit areas or through the attic hatch opening by using unbacked insulation around the hatchway and along the front and rear portions of the attic floor that are adjacent to the soffit areas. In the case of the blown cellulose, this barrier was formed by fire retardant corrugated cardboard walls stapled into place; (4) install either cellulose or fiberglass insulation by blowing into place (blowing avoided the problem of the many cross braces supporting the roof) to achieve a total value of thermal resistance of at least 5.28 m^2 °C/W (R-30).

TABLE 1.

Schedule followed in retrofitting (1976)

Omnibus*	Jan. 19 - 23,	26 - 30	Feb. 16 - 20,	23 - 27	Mar. 15 - 19
1			ABCD		
2			AD		
3	ACD		B		†B outside
4	ACD		B		
5			C		
6				BD	A
7	ABCD				
8	C	BD	A		
9			ABCD		B outside
10	C	BD	A		
11	ACD	B			
12				BD	A
13	ABD				
14	ABD		C		
16			C	BD	
**17			BD	A	
**18			C	BD	
19			AD		
**21			CAD	B	
Hit*	Dec. 15 - 19,	22 - 26	Jan. 12 - 16,	19 - 23	Mar. 15 - 19
1	B	C	D	AB	B outside
2	AD	C		B	
3	ABD				C partial

*Omnibus and Hit refer to instrumentation packages [1].
**Quad III townhouses — gas appliances.
†Outside caulking on batton-board siding homes.

This has meant that, in addition to the initial value of 1.936 m^2 °C/W (R-11) for the 9 cm (3.5 in.) vapor-barrier-backed fiberglass, a value of 3.344 m^2 °C/W (R-19) of additional insulation must be added. For cellulose, with an R-value of 0.257 m^2 °C/W/cm (3.7/in.), we have called for 14 cm (5.5 in.). With fiberglass, with an R value of 0.159 m^2 °C/W/cm (2.3/in.), we have called for 22 cm (8.75 in.). The area covered is 67 m^2 (720 ft^2). The cost for this retrofit, winter 1976, was between \$155 and \$225 depending upon the choice of insulation.

RETROFIT D (SHAFT TO ATTIC)

The purpose of retrofit D was to eliminate a noticeable channel for air flow between basement and attic. In conjunction with retrofit A, it placed a "thermal lid" on the house, but even without retrofit A it was designed to markedly reduce the heat loss due to circulation between attic and basement. A plug of unbacked fiberglass was used to seal, at the attic floor, the shaft which surrounds the furnace flue. The cross-section of the shaft was approximately 40 cm (16 in.) square. The temperature of the surface of the flue at this elevation was measured to be less than 54 °C (130 °F). Since fiberglass has a char temperature greater than 430 °C (800 °F) this retrofit presented no local danger of fire whatsoever, and in fact would inhibit fire spread from a basement conflagration. (Indeed the temperatures are greater on the ducting in the basement — see retrofit C.) To perform this sealing operation, a 1.2 m (4 ft) section of 15 cm (6 in.) unbacked fiberglass insulation was wrapped around the flue and pressed into the shaft opening. The elimination of any vertical air movement up the shaft was readily detected using one's hand as a probe after the seal had been completed. The cost of this item is included in retrofit A.

RETROFIT B (BASIC LIVING SPACE AND OTHER GAPS AND CRACKS)

The object of this retrofit is to limit the amount of air infiltration resulting from crack openings, especially around windows and doors. The leakage around windows has been traced to three causes: (1) the lack of squareness of the window frames, leading to open spaces even with the windows shut, either these frames were installed as a parallelogram (see Fig. 1) or the house settled after the window installation; (2) the poor condition of the seal between the glass and aluminum frame; (3) air channels past the molding surrounding the window. Leakage around the patio door was found to have similar origins. Leakage around the front door was found to be the result of a poor alignment at the threshold and the poor condition of the magnetic seal strips on the sides and top of the door.

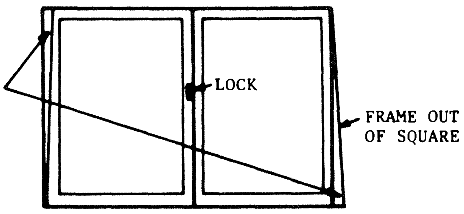

Fig. 1. Poor fit of window in its frame.

The windows were improved in the following manner. The normal seal on the sliding window, which relies on a stiff fuzz strip, was augmented by the use of closed cell vinyl foam strips 0.5 cm × 1.0 cm (3/16 in. × 3/8 in. cross-section) attached to the sliding windows (see Fig. 2). The lock mechanism was also adjusted to force the windows into the frame. Where the metal frames were attached to the wood frame, where the glass was attached to the metal frame, and where the wood molding was attached to the wall-

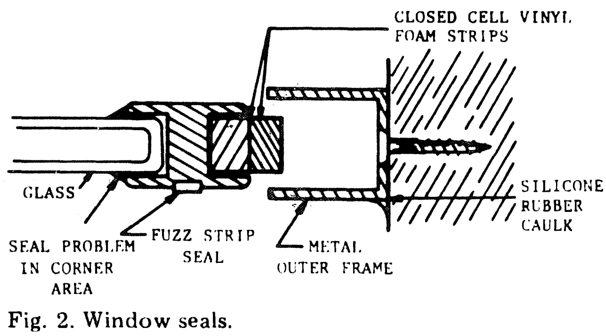

Fig. 2. Window seals.

board, a fillet of silicone caulking was placed on any suspicious areas. This material is clear, long-lasting (10-year guarantee), and almost invisible, thus matching any decor. This same material was used on the panels of the patio door and in the overhanging closets of the back upstairs bedrooms wherever air leakage was present. The patio door received a more substantial foam strip (1.3 cm × 1.9 cm or 0.5 in. × 0.75 in.) to aid in sealing.

The front door sill was adjusted in height to meet the original seal surface on the lower portion of the door. When this alone was inadequate, an additional strip of vinyl with aluminum backing was screwed to the door (see Fig. 3).

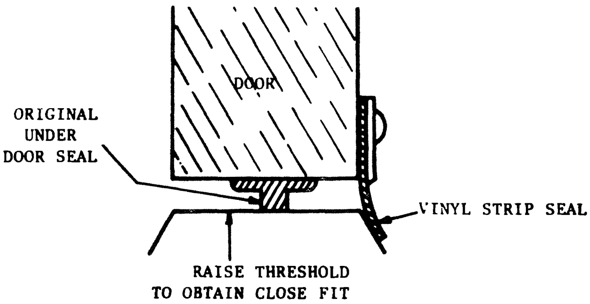

Fig. 3. Door seals — bottom.

The magnetic seals on the sides and top of the door opening were repaired where problems, particularly corner gaps, were found. In a few cases an additional lip seal was added (see Fig. 4).

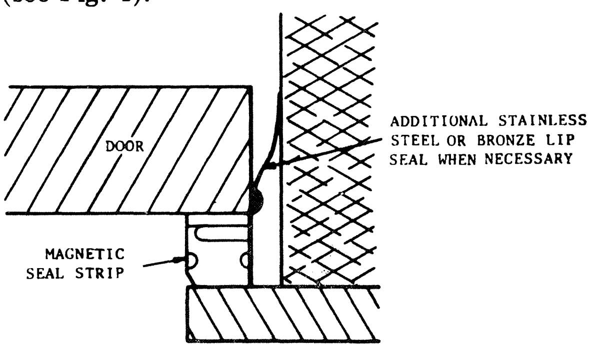

Fig. 4. Door seals — sides.

The attic hatch cover also received a rim made from the foam vinyl strips to seal against vertical air flow.

Exterior caulking was used around the patio door frame and the closet overhang. When the vertical joint between masonry and frame was inspected, it was found that the principal cause for infiltration (as first suggested by the infrared photographs) was warping of the batten in the batten-board homes (see Fig. 5). In these homes a caulking joint was made, using the appropriate color polysulfide synthetic rubber sealant or clear silicon rubber sealant.

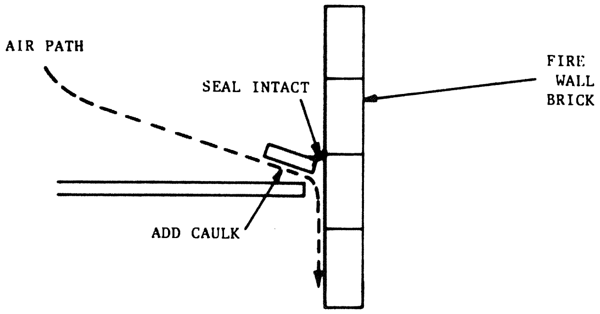

Fig. 5. Passage for outside air at edge of facade.

The last item under retrofit B was the sealing of openings in the basement. The openings between basement ceiling joists (5 cm × 20 cm or 2 in. × 8 in.) and the fire wall were addressed. As in item (1) of retrofit A, fiberglass was forced into the openings. Among other basement openings that required sealing were gaps at the corners and spaces around the piping to the kitchen, the dryer exhaust, and the service wiring. Caulking was used along the sill joint and for smaller wall openings. Costs for materials for retrofit B was approximately $28.

RETROFIT C (CELLAR)

This retrofit concentrated exclusively on the cellar (or basement) and included: (1) insulating the furnace and its warm air distribution system, (2) wrapping the water heater, and (3) packing the overhang area under the living room window, which includes two ducts.

The furnace plenum, the main left and right supply ducts, and the nine individual 13 cm (5 in.) diameter room ducts were wrapped with 5 cm (2 in.) fiberglass backed by aluminum foil with reinforcing thread. Where the 13 cm (5 in.) ducts ran between the 5 cm × 20 cm (2 in. × 8 in.) ceiling joists, 9 cm (3.5 in.) aluminum foil-backed fiberglass was stapled across the beams. At first, ordinary duct tape was used, but a superior product was discovered by one of the contractors, a tape with the same reinforcing thread plus a bonding surface that eliminated problems of peeling with repeated heating of the ducts. Insulation was extended to completely cover the underside of the registers as well; the insulation was stapled to the underside of the floor.

The same 5 cm (2 in.) fiberglass* was used on the water heaters, again using the new tape. On gas water heaters, *care must be taken to use the insulation only on the sides of the tank*, staying away from the air inlet on the bottom, the exhaust at the top and the controls.

The last cellar item was the overhang under the front living room window. Here two ducts extend between the beams to the registers and the insulation was either marginal or missing. The retrofit included blowing cellulose or fiberglass into the openings, or (where blowing equipment was not available) hand packing of fiberglass insulation into these cavities. Gaps to the outside are a particular problem in this location which was difficult for the builder to complete properly (since it is only one foot above ground level).

The cost for retrofit C ranged from $125 to $145 depending on the contractor performing these tasks.

ACKNOWLEDGMENTS

The retrofit procedures depended upon assistance from a number of sources. Kenneth Gadsby and Roy Crosby worked to perfect solutions to many of the sealing problems encoutered at Twin Rivers. Representatives from Owens Corning Fiberglas and Certainteed assisted us in sealing a variety of openings in the attic and in achieving solutions to duct wrapping problems and water heater retrofitting. This work has been supported in part by the U.S. Department of Energy, Contract No. EC-77-S-02-4288.

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*Where 9 cm (3.5 in.) fiberglass can fit, the additional heat resistance 1.94 *vs.* 1.23 m^2 °C/W (R-11 *vs.* R-7) is worthwhile.