WINDOW TREATMENTS FOR ENERGY SAVINGS IN A COLD CLIMATE

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In most homes 15 to 20 percent of the total wall area is composed of windows. Windows offer very little resistance to heat transfer. It can be estimated that of the total heat loss from a home 20 to 80 percent is through the windows, so reduction of heat loss through the windows could be expected to result in a significant reduction in heating cost.

Most of the information that has been published about control of heat loss by use of window treatments apparently has been based on four or five research studies. The studies have used different experimental systems, but none have used the temperature extremes which are experienced in North Dakota.

A study at the University of Georgia (Haynes et al., 1967) used a two-chamber box (each 4 inches × 4 inches × 6 inches) with a wall section between containing the window and test treatment. The window had double thickness fixed glass. Cold side temperatures varied from 24.5 to 31.4°F and the warm side was from 67 to 72°F. A tightly stapled roller shade was found to reduce heat loss by 25.6 percent. Heat loss increased by 2.4 percent when loose drapes were used; this was attributed to the inverse chimney effect. Dix and Lavan (1974) at Illinois Institute of Technology found similar results except draperies reduced heat losses by 6 percent. They used a single pane window between twin rooms. A 10 inch diameter fan was used to simulate a 7 MPH wind against the window.

A study at Cornell (Cukierski and Buchanan, 1979) used a single glazed double hung window set in an 8 inch × 8 inch wall. Electric heating plates were set 2-4 inches from the window to provide "outside" temperatures of 120 or 105°F. With temperature difference of 30 or 50°F, the following heat reductions were found: roman shades, 25-33 percent; venetian blind, 11-13 percent; drapery 6-18 percent; and foam backed shutter, 59-62 percent. Addition of an opaque shade to an unlined drapery reduced heat loss by 48 percent in studies at the Unviersity of Missouri (Feather, 1980).

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Since none of these reported studies had used very low temperatures, there was some concern about extrapolating the data to North Dakota conditions (Hassoun, et al., 1982). It was decided to develop an experiment which would evaluate window treatments when exposed to "outside" temperatures of -15°F (temperature difference of at least 80°F). The objectives of the study were: (1) to evaluate the effects of various window treatments on energy conservation in a cold climate, (2) to determine the cost of the window treaments, and (3) to compare the aesthetic acceptability and convenience of the different treatments.

Description of Apparatus

The basic requirements for the experimental apparatus were first to control the temperature on each side of the window and second to measure the heat transfer across the window. This was accomplished by constructing an insulated box with a removable wall which contained the window. A commercially available wooden double-hung window plus a storm window was used. Outside window frame dimensions were 30 inches × 44 inches. The box was constructed of 2 × 4 framing sheathed with ½ inch plywood. Fiberglass insulation was used to fill the cavities; an additional layer of 1 inch extruded polystyrene insulation board was used to line the interior of the box. The inside dimensions of the box were: height 65 inches; width 52 inches; and depth 23 inches (Figure 1).

A first attempt to provide a cold environment "outside" the window was to place the entire system in a walk-in-freezer at the campus dining center. Unfortunately, wide fluctuations in temperature were experienced as the walk-in door was opened for extended periods while food was being moved in and out. Air currents against the box and thus the heat transfer rate appeared to be altered as boxes of food were stacked between the experimental box and the forced air evaporators cooling the freezer. These variations prevented conducting a controlled experiment, so confidence in the results was not possible.

A dedicated refrigeration system was developed to provide a controlled "outside" temperature (Figure 2). This system provided a cold exposure to the window. The entire system was located in a laboratory, so there

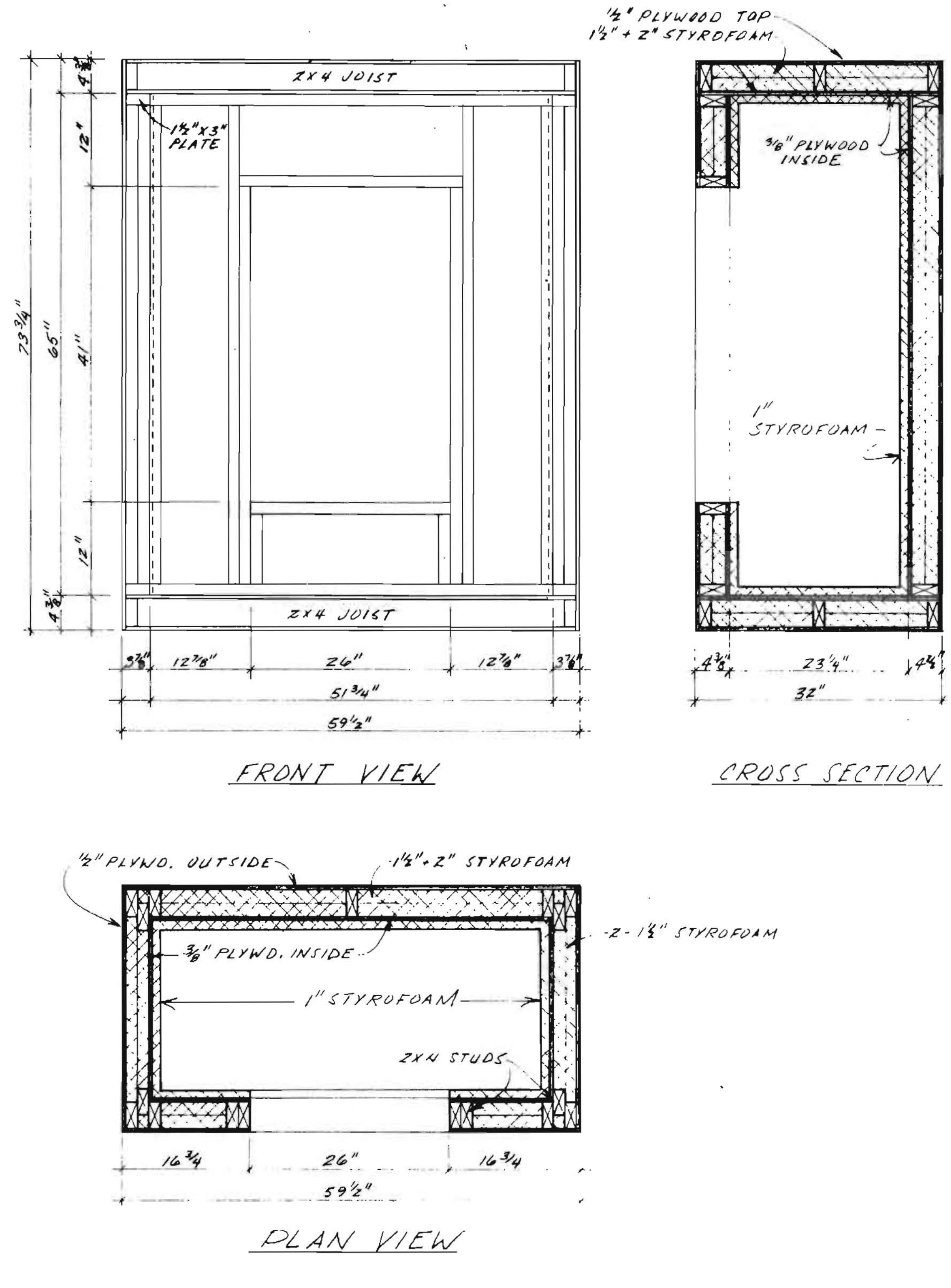

Figure 1. Structural Design of Warm Box for Testing Window Treatments.

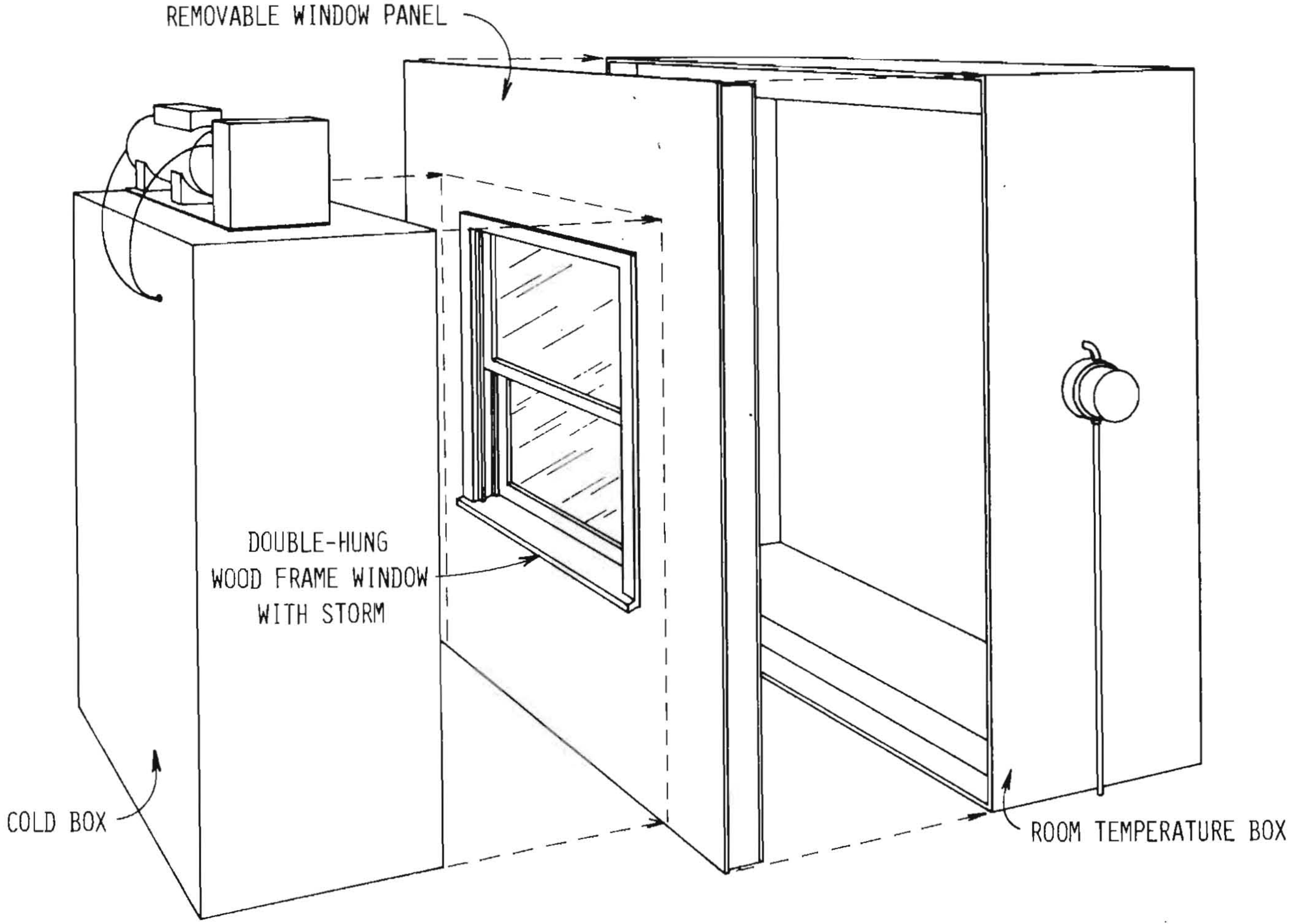

Figure 2. Window Treatment Test System.

was little if any temperature difference across the walls. The lower difference minimized the effect of any error in estimating heat loss through the box walls.

Heat was provided by use of an electric resistance heater. A digital watt-hour meter was used to measure the energy input. Thermocouples were located at various points in the box, on the window, and outside the system. A multi-point recorder was used to accumulate temperature data.

Methods and Procedures

The treatments were selected to consider several different types of window coverings. These ranged from simple inexpensive homemade treatments to more expensive purchased ones. Several combinations were also evaluated. All window treatments were off-white or beige to eliminate color as an aesthetic or energy factor. Draw draperies were custom constructed to measure 2½ times the window's width with 3 inch pinch pleated headings and 3½ inch hems. A sheer casement curtain, which measured slighty more than three times the width of the window, was shirred onto a standard rod. A removable Roclon liner was developed to hang on the back of the draperies and lie flat against the window frame.

Roller shades were all custom designed to fit either inside or outside the window frames.

Roman shades were developed to fit flush against the window frame and extend 1 inch over the frame. A concealed wooden bracing with metal eyelets secured the shades inside the top of the window frame. Vertical rows of plastic rings and 1/8 inch cord provided standard pulley systems on the back of the shades.

Paper strips and tacks secured both plastic films taut against the inside window frame. This inside installation created a 2 inch airspace between film and glass.

Wooden shutters were installed within the window frame as was the metal movable blind.

Table 1 lists all treatments.

Table 1. Description of Treatments

Number	Description
A.	Draperies:
1	Rayon/acetate antique satin pinch pleated, lined
2	Cotton/rayon pinch pleated, coated insulated, unlined
3	Cotton/acrylic open weave pinch pleated, unlined
4	Roclon insulated pinch pleated, unlined
5	Polyester sheer casement curtain, triple width shirred heading
6	Drapery liner, removable
B.	Roller Shades:
1	Mylar backed, installed inside frame
2	Room darkening, vinyl, installed outside frame
3	"Home Energy," metallic back, magnetized installation, sides & bottom, outside frame
C.	Roman Shades:
1	Coated nylon rip-stop cover (1½ oz) with aluminized mylar needlepunched polyester fiber as filler
2	Cotton/polyester broadcloth cover, 2 layer CS-100 thinsulate, vinyl film vapor barrier as filler
3	Cotton/polyester broadcloth cover with 10 oz. Fortrel Polyguard fiberfill as insulation
4	Window Quilt: Commercially quilted insulated shade, side channel installation
D.	Films:
1	Warp's coverall plastic, 4 mil, polyethylene
2	Warp's flex-o-glass, 6 mil, polyethylene
E.	Other:
1	Two framed wooden insert shutters with hanging strips. Cardboard insert, insulated with one layer of CS thinsulated filler and covered with cotton/polyester broadcloth.
2	Levelor type, metal movable blind, side channel installation
3	Extruded polystyrene board (1"), friction fit into window frame

Effect of Window Treatments on Heat Loss Through the Window

The method used to evaluate heat transfer was as follows: (1) the specified treatment was installed to start the test, (2) temperatures and electricity used were monitored, and (3) each test was run for at least two days.

Window treatment effectivneess was measured by comparing the heat loss with each treatment to the control (or bare window). Figure 3 illustrates the energy inputs and outputs and the normal operating temperatures. The heat loss through the window was calculated by subtracting the estimated heat transfer through the box walls from the electric heat input. Heat transfer through the box walls was estimated by multiplying the measured temperature difference times the net wall area and the specific thermal conductivity. Based on the construction of the box the thermal conductivity factor, UA (wall), can be estimated to be equal to 2.42 W/°K (4.6 Btu/Hr-°F). The heat loss through the window was then divided by the temperature difference across the window to give the thermal conductivity for the window.

The thermal conductivity factor for the window assembly was not calculated on a heat transfer rate per unit area basis. If the window assembly is considered to include the rough framing and the trim, the thermal conductivity is estimated to be 1.58 W/°K (3.0 Btu/Hr-°F). This value was experimentally verified periodically during the testing. The treatment effectiveness was measured by percent reduction of heat loss from the box (or energy demand). Cost estimates were determined for each treatment. These estimates included the cost of construction and installation materials. For comparison purposes the unit cost was divided by the effectiveness rating.

Aesthetics Acceptability and Convenience

A panel of five observers drawn from university staff evaluated the treatments on the basis of aesthetics and convenience (ease of handling). Each member of the panel rated aesthetic acceptability on a five-point scale. A five-point scale was also used to rate convenience after each member of the panel had an opportunity to open and close the movable window treatments.

RESULTS

Effectiveness

Window Treatments:

The average heat conductance values for the various treatments are listed in Table 2. Figures 4 through 6 provide comparisons of the treatments within categories.

The draperies tested did little to reduce heat loss. Average heat reduction effectiveness of from 1 to 10 percent was measured for these treatments. A statistical analysis did not indicate a significant difference in heat flux when draperies were used compared to bare window. Coatings and drapery opacity had little effect on heat loss. Note that the triple width casement sheer tested about the same as some heavier draperies. Apaprently the many folds of the sheer drapery trapped air to provide similar insulative values.

Wide variation was found in the roller shades tested. A Krushal-Wallis test indicated that a significant difference ($\alpha = 0.25$) between types of shades. Effectiveness of the mylar shade was 6.3 percent. The Knox room darkening roller shade was not very effective (9 to 10 percent) when not taped down, but almost doubled in effectiveness (22 percent) when fastened to the frame. Magnetized strips on the "Home Energy" shade resulted in the most effective roller shade system (38 percent).

Roman shades, as a group, appeared to be the most effective heat loss barriers, particularly when the edges were sealed to the window frame. Edge sealing more than doubled the reduction of heat loss when applied to the mylar insulated roman shade. Shade thickness was not found to be related to effectiveness. The extremely

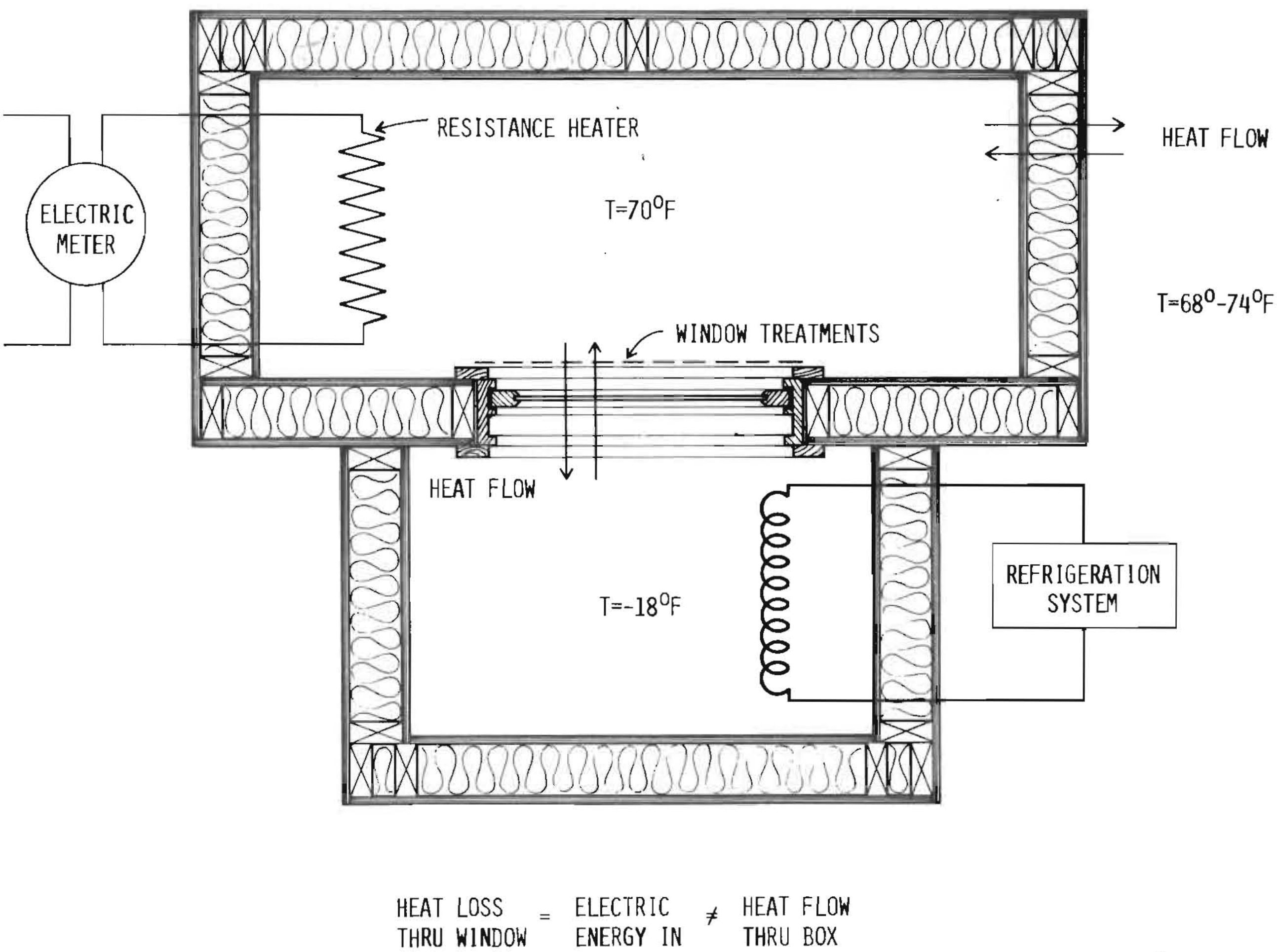

Figure 3. Energy Flows and Temperatures for Test System.

bulky Polarguard shade was slightly less effective than the much thinner and more flexible thinsulate shade and the mylar/polyester shade. The only commercially available product tested in the roman shade category was "Window Quilt." Plastic channels prevented air circulation at the edges. Heat loss reduction was slightly less than the home produced roman shades when they were edge-fastened.

Polyethylene films provide greater heat loss reduction than draperies. Films and insulated shutter provided about 20 percent reduction in heat loss; the heavier film was slightly more effective than the thin film. The levelor type, metal movable blind was found to be similar to draperies as a heat flow barrier.

Combinations of treatments did not necessarily result in energy savings equal to the sum of their parts. For instance, the movable blind, used alone, reduced heat loss by 8.2 percent. When combined with two different types of draperies, heat loss reduction improved to at best 9.5 percent. Minimal improvement was measured with several other combination treatments including the lightweight vinyl film combined with the sheer casement curtain. Slightly better results were achieved when the coated insulated drapery was combined with the removable liner. This layered system probably not only trapped air to increase insulative value, but also fit the window frame fairly closely due to the flat surface of the liner.

Effect of Cornice:

All window treatments that did not fit flush against the window surface were tested with and without a covered wooden cornice. The cornice did not appear to affect heat loss capabilities of these treatments either when tested singly or as combinations.

Window Treatment Costs

Approximate costs of each treatment are listed in Table 3. Roller shades as well as films and shutters varied a great deal in price, whereas draperies and roman shades were priced fairly consistently within each category. Price appeared to have little relationship to

Table 2. Heat Transfer Through Window

Treatment	No Modifications	With Cornice	Edge Sealed
	Thermal Conductance, w/°k		
Bare Window	1.58		
A. Draperies			
1. Antique Satin	1.43	1.42	
2. Coated back	1.49	1.51	
3. Open weave	1.51	1.52	
4. Roclon insulated	1.51	1.56	
5. Sheer	1.52	1.45	
B. Roller Shades			
1. Mylar backed	1.48		
2. Room darkening	1.44		1.23
3. "Home Energy"			0.98
C. Roman Shades			
1. Mylar/polyester fill	1.31		0.92
2. Thinsulate	1.20		0.87
3. Polarguard fill	1.25		0.97
4. Window quilt			1.02
D. Films			
1. 4 mil film	1.30		
2. 6 mil film	1.21		
E. Other			
1. Shutter	1.26		
2. Movable blind	1.45		
3. 1" extruded polystyrene	0.66		
F. Combination			
1. (A.1 + A.5) Antique & Sheer		1.43	
2. (A.1 + A.6) Antique & Liner	1.50	1.45	
3. (A.2 + A.6) Coated back & Liner		1.46	
4. (A.2 + E.1) Coated & Movable Blind	1.44	1.43	
5. (A.3 + E.1) Open Weave & Movable		1.47	
6. (A.5 + D.1) Sheer & 4 ml film	1.19	1.27	
7. (A.1 + B.2) Antique & Room Darkening	1.24	1.16	

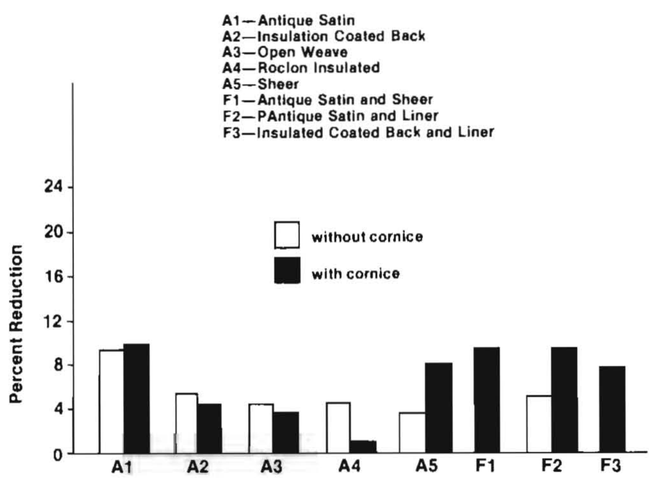

Figure 4. Reduction of Heat Loss by Draperies.

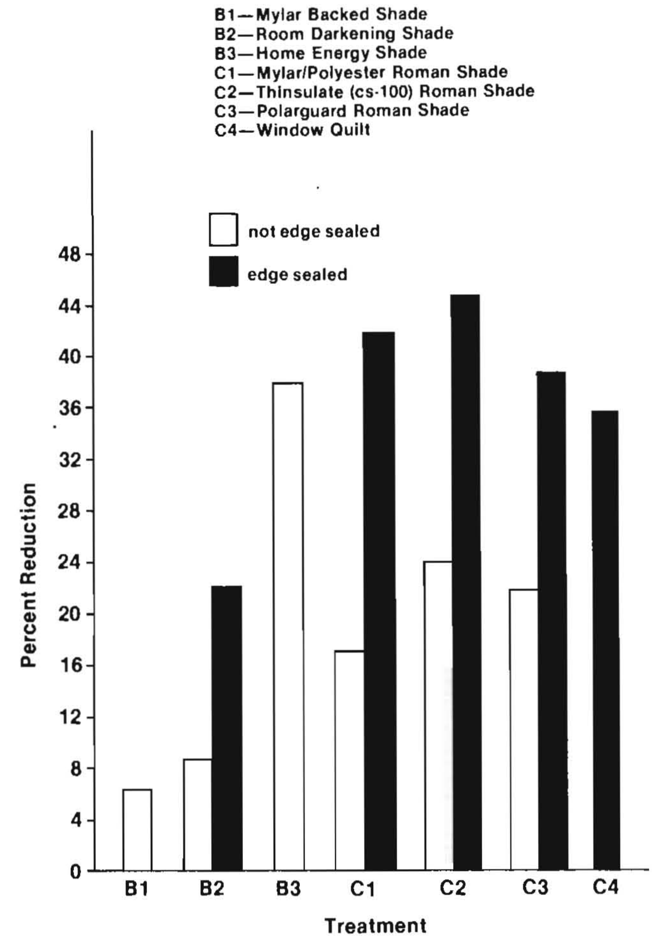

Figure 5. Reduction of Heat Loss by Shades.

heat loss effectiveness. Note that the most expensive window treatment, the $50.00 movable blind, provided little protection against heat loss. The least expensive window covering, lightweight polyethylene film, provided more than twice the heat loss reduction for a fraction of the cost.

To provide a basis for evaluating the cost effectiveness of the window treatments, the installation cost was calculated on the basis of percent heat loss reduction. This can then be compared to the value of energy saved over the life of the treatment. If the calculated cost is less than the present value of the annual energy cost, then using the treatment would be economically desirable.

In determining the present value of energy saved it was assumed that energy cost would increase at the same rate as general inflation (zero energy escalation rate). The cost of energy to replace heat loss through the bare window, using a design temperature of 20°C, heating degree days for Fargo, North Dakota and fuel oil at $1.15 per gallon (65 percent furnace efficiency), would be about $10 per year. Assuming a 10 percent interest rate, the value of a 1 percent reduction in heat loss is calculated to be $.09 if the treatment life is one year. For

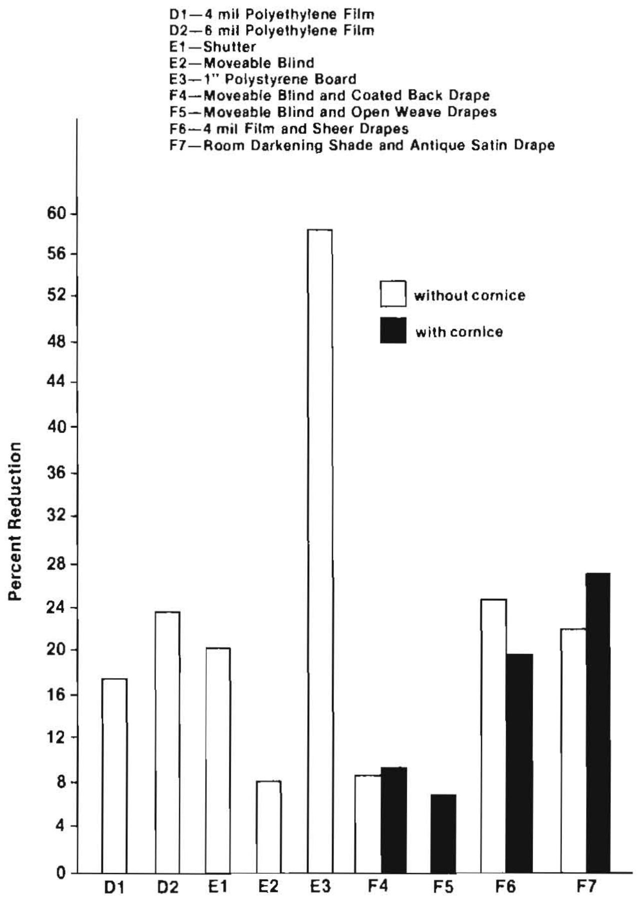

Figure 6. Reduction of Heat Loss by Films, Blinds, Shutter, etc.

Table 3. Cost of Window Treatments

Treatment	Cost/ Window	Approx. Cost/%	Reduction
A. Draperies			
1. Antique Satin	$28	2.95	(2.75)*
2. Coated back	20	3.45	(4.44)
3. Open weave	23	5.11	(6.05)
4. Roclon insulated	25	5.56	(16.67)
5. Sheer	15	3.95	(1.83)
B. Roller Shades			
1. Mylar backed	25	3.57	
2. Room darkening	4	.47	.18**
3. "Home Energy"	42	1.12	
C. Roman Shades			
1. Mylar/polyester fill	18	1.03	.43**
2. Thinsulate	18	.75	.40**
3. Polarguard fill	18	.83	.47**
D. Films			
1. 4 mil film	1	.06	
2. 6 mil film	4	.17	
E. Other			
1. Shutter	45	2.14	
2. Movable blind	50	2.56	
3. Extruded polystyrene	2	.03	
F. Combinations			
1. Antique & Sheer	43	4.53	(4.39)
2. Antique & Liner	38	7.17	(4.37)
3. Coated & Liner	30		(3.75)
4. Coated & Movable	70	7.37	(7.00)
5. Open Weave & Movable	83		(10.92)
6. Sheer & 4 mil film	16	.63	(.76)
7. Antique & Room Darkening	32	1.45	(1.19)

*Values in parentheses refer to effective cost if used with a cornice.
**If edges are taped.

treatment lives of two, three, five and 10 years, the present value of annual energy cost will be $.17, $.25, $.38, and $.62 respectively.

Using the above values as critiera for evaluation, the draperies are not cost effective. The inexpensive room darkening roller shade would be economical if the edges were sealed and the shade used more than two years. Roman shades can be cost effective if used six or seven years. The 4-mil film and the polystyrene board could be thrown away and replaced each year and still be economical.

The most cost effective treatment appears to be polystyrene board, which has the disadvantage of blocking out the light. The films are inexpensive but may not be accepted aesthetically. The costs listed are materials only.

Aesthetic Acceptability and Convenience

An examination of the data revealed at times an inverse relationship between aesthetic acceptability and heat loss reduction. For example, the movable blind which has enjoyed considerable popularity in recent years for both home and commercial installation ranked high in aesthetics and convenience but did little to prevent heat loss. Observers appreciated diffused light and ease of handling. Roman shades were criticized for their opacity, bulk, and failure to admit light when in a closed position. The Home Energy shade was considered easy to operate, but austere without decoration. Similar assessments of the other roller shades were made. As expected, traditional draw draperies were rated high in aesthetics and convenience. Vinyl films were viewed as "cheap" when not obscured by a casement curtain, but favored for allowing the admittance of light. Questions were raised as to lack of permanence and convenience of the vinyl films because these coverings need to be removed and reinstalled when changing seasons. The wooden shutter received moderate ratings.

SUMMARY

1. Non-bulky roller shades may provide similar heat conserving capabilities as bulkier, less convenient window treatments.
2. Roller shade heat conserving capabilities may be doubled if edge sealing devices are installed.

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ment in decision making relative to the farm and ranch operation, at least weekly contact with friends, weekly church attendance, a relatively well-educated husband and perceived control over what happens in one's own life were found to positively influence farm and ranch women's mental health.

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3. Home constructed roman shades may provide similar heat conserving capabilities as a commercially quilted shade for about half the cost.
4. All draperies, including insulation models, provide little protection against heat loss.
5. A sheer casement curtain, shirred to triple fullness across a window may provide similar energy conserving capabilities as an insulated draw drapery. Also, filtered light is admitted to the room.
6. The levelor type, movable blind may not be an effective heat loss barrier, although it is often advertised as "energy conserving."
7. Draperies installed over a movable blind do little to improve heat conserving capabilities.
8. Inexpensive polyethylene films may perform more effectively as heat loss barriers than several more expensive and less convenient window treatments.
9. A combination of casement sheer curtain over a polyethylene film does not necesarily increase heat loss effectiveness over the film used alone, but does increase aesthetic acceptability.
10 A wooden frame shutter with insulated filler appears to provide similar heat loss reduction with a thin (4 mil) polyethylene film.
11. A covered cornice is an ineffective means of attempting to reduce heat loss.

CONCLUSIONS

Window treatments can be used to reduce heating energy requirements in cold climates. All treatments provided some reduction in heat loss, but the effectiveness of commonly used draperies was very low. Shades, shutters, and blinds varied in effectiveness according to fabrication, design and edge sealing. Polyethylene films were moderately effective. A 1-inch polystyrene board provided the greatest reduction in heat loss. Combinations of treatments did not result in savings equal to the sum of their parts.

A cornice at the top of the window was not an effective means of reducing heat loss. Edge seaming of treatments by magnetic strips, taping, tacking, or tracks improved effectiveness.

Window treatment costs do not appear to be related to effectiveness in heat loss reduciton. Aesthetic acceptbility was related to management ease, light transmittance, and system design. Energy savings ratings do not coincide with aesthetic ratings.

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