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Three Proposed Typical House Designs For Energy Conservation Research

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U.S. DEPARTMENT OF COMMERCE
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Center for Building Technology
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THREE PROPOSED TYPICAL HOUSE DESIGNS FOR ENERGY CONSERVATION RESEARCH

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FOREWORD

This is one of a series of working reports documenting NBS research efforts to develop energy and cost data. The work described in this report was jointly funded through ERDA/NBS Mod. No. 2 of Contract E (49-1) 3800 and Task Order No. EA-77-A-01-6010 and through HUD/NBS Contract No. RT193-12.

The background work for this report was completed in support of two other reports "Geographic Variation in the Heating and Cooling Requirements of a Typical Single-Family House", and "Determination of Optimal Energy Conservation Designs in Single-Family Housing: Preliminary Results".

The house designs presented in this report are not intended as "model" houses which should be copied for any particular design qualities. Their purpose is merely to typify a large percentage of new house construction being built in the U.S. today. They are presented to provide a basis for comment with suggested revisions to improve their representativeness welcome.

ABSTRACT

The ability of various energy conservation design features to reduce residential energy consumption can only be judged by comparing houses with and without such features. Comparisons can be made based on measuring energy consumption of actual houses, or by computer modeling energy consumption. With either approach, if the houses being evaluated are the basis for estimating regional or national energy savings possible with a given change from current construction practice, it is important that the houses be typical of the given population of houses. For that purpose this report contains three house designs typical of new house construction for much of the nation.

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SI Conversion

In view of present accepted practice by the building industry in the United States, common U.S. units of measurement have been used throughout this paper. In recognition of the position of the U.S.A. as a signatory to the General Conference on Weights and Measures, which gave official status to the Metric SI System of units in 1960, the following conversion factors are provided to assist readers who use the SI units.

Length

1 inch (") = 0.0254 meter
1 foot (') = 0.3048

Area

1 square foot (ft^2) = 0.0929 $meter^2$

Volume

1 cubic foot (ft^3) = 0.0283 $meter^3$

Thermal Resistance

1 °F h ft^2/Btu = 0.1761m^2 °C/W

1. INTRODUCTION

House designs typical of today's construction practices are needed as a basis for comparing the effectiveness of various energy conservation strategies. This report proposes three typical houses as follows:

1) a compact "ranch style" house
2) a townhouse
3) a larger two story detached house

These are not intended to be "model" houses which should be copied because of any particular design qualities. Instead, they are intended to be typical of housing now being built in the U.S.A.

The design of the three houses was based upon the judgment of the author (an architect experienced in residential design) and upon a 1974 report by the National Association of Home Builders (NAHB) titled, "A National Survey of Characteristics and Construction Practices for All Types of One Family Houses." The survey data represented 84,000 homes built by 1600 builders selected randomly from the 27,000 builder members of NAHB.

The decision to present three house designs was based on the NAHB statistics on the frequency of various house configurations. Out of the total number of houses constructed by builders in the survey, 73 percent were detached, 19 percent were townhouses, and 8 percent were duplexes, quadruplexes, or "other." Given these percentages it was decided to present designs for the detached and townhouse categories but not for the duplex, quadruplex, and other category since the latter represented a small percentage comprised of diverse configurations. The decision to present two detached designs was based on the fact that of all detached houses in the survey, 52 percent were one-story and 17 percent were two-story. Since detached houses constituted such a large percentage of the houses, separate designs for one and two-story houses were deemed necessary. Separate designs were not presented for "split level" houses (bedroom area half a flight up from living area) nor for "bi-level" or "raised ranch" houses (ranch plan above a half out of the ground basement) because these configurations are merely a variation of the ranch design and can easily be derived, given the information for the ranch design.

Each of the three house designs presented varies slightly from the national average for all houses. The basementless ranch house, with 1176 sq.ft. of floor area, is smaller than the national average detached house of 1684 sq.ft. The smaller size was based on two judgment factors: First, the three-bedroom, one-story houses would tend to be smaller than the overall average floor area of all single-family detached houses which include two-story houses and houses with basements. Second, since 1974, the trend has been for new houses to be more compact and it is expected that this trend will continue. A final note regarding the ranch design, windows have been excluded from the side elevations. This is a common practice due to closeness of neighboring houses. Window areas for the front and rear elevations were selected as the minimum desirable for the room areas, given that orientation is unknown.

The ranch house design, as well as the other two house designs, is meant to be typical of today's home building practices and is not a house specifically designed for energy conservation.

The townhouse, with a floor area of 1315 sq.ft., is also smaller than the national average of 1393 sq.ft., again reflecting the trend towards more compact houses. Also, three bedrooms were included, rather than the national average of 2.2 bedrooms, because it was felt that this configuration has become prevelent as townhouses have become increasingly common.

The two-story house, with 1994 sq.ft. of finished floor area plus a basement, is slightly larger than the national average of 1684 sq.ft. This house design is included to represent a high-priced category of large houses.

2. Drawings

Schedule of Drawings

Ranch	plan
	elevations
	section
	schedule of component surface areas
Townhouse	plans
	elevations
	section
	schedule of component surface areas
Two-Story	1st floor plan
	2nd floor plan
	front elevation
	rear elevation
	section
	schedule of component surface areas

Key to Symbols Used in Drawings

2850 = 2'-8" W x 5'-0" H

TW = twin windows

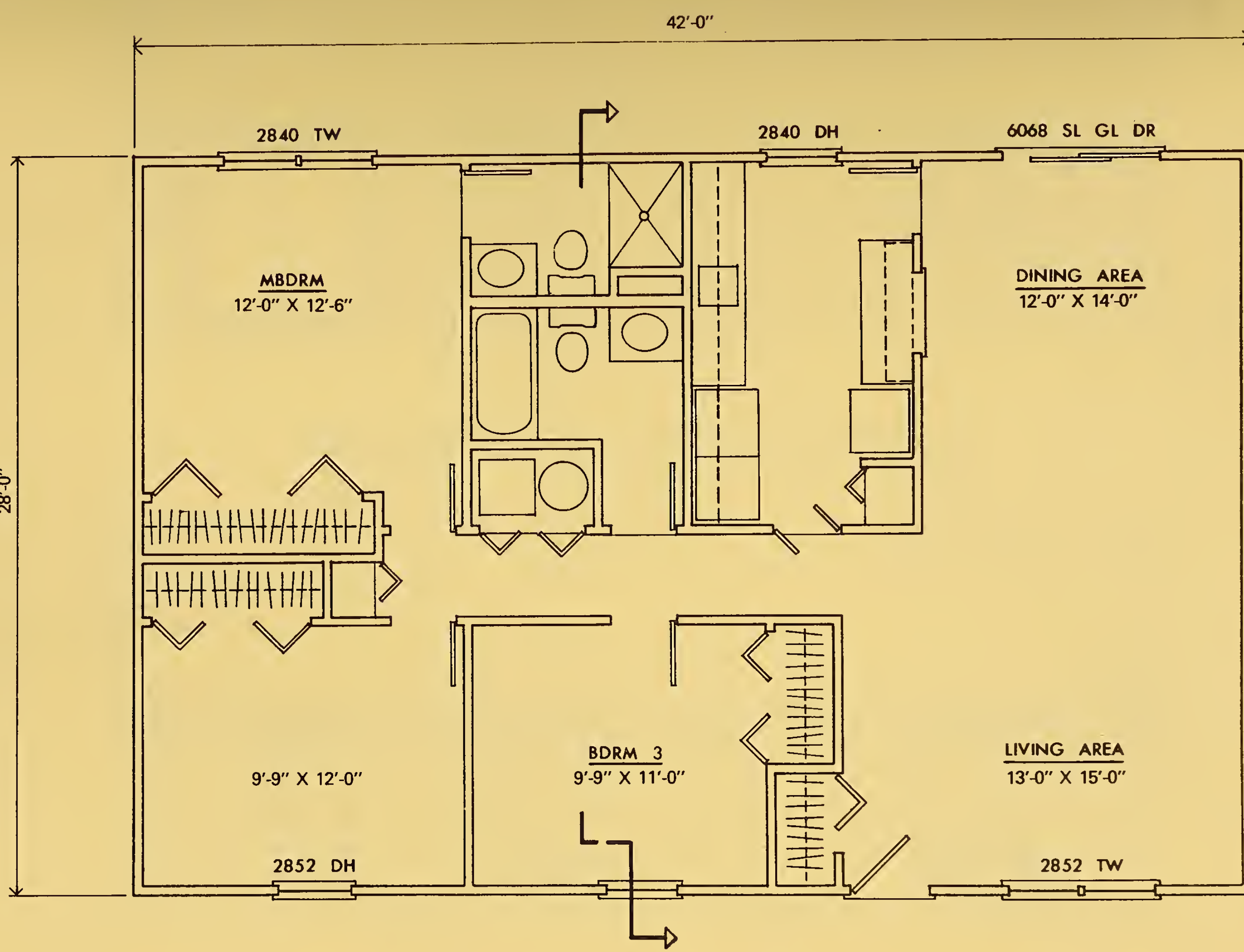
DH = doublehung

SL GL DR = sliding glass door

FG = fixed glass

HT = height

O.C. = on center



FLOOR PLAN OF A TYPICAL RANCH HOUSE

AUG.10,1977 0 2 4 8 NBS

REAR ELEVATION OF A TYPICAL RANCH HOUSE

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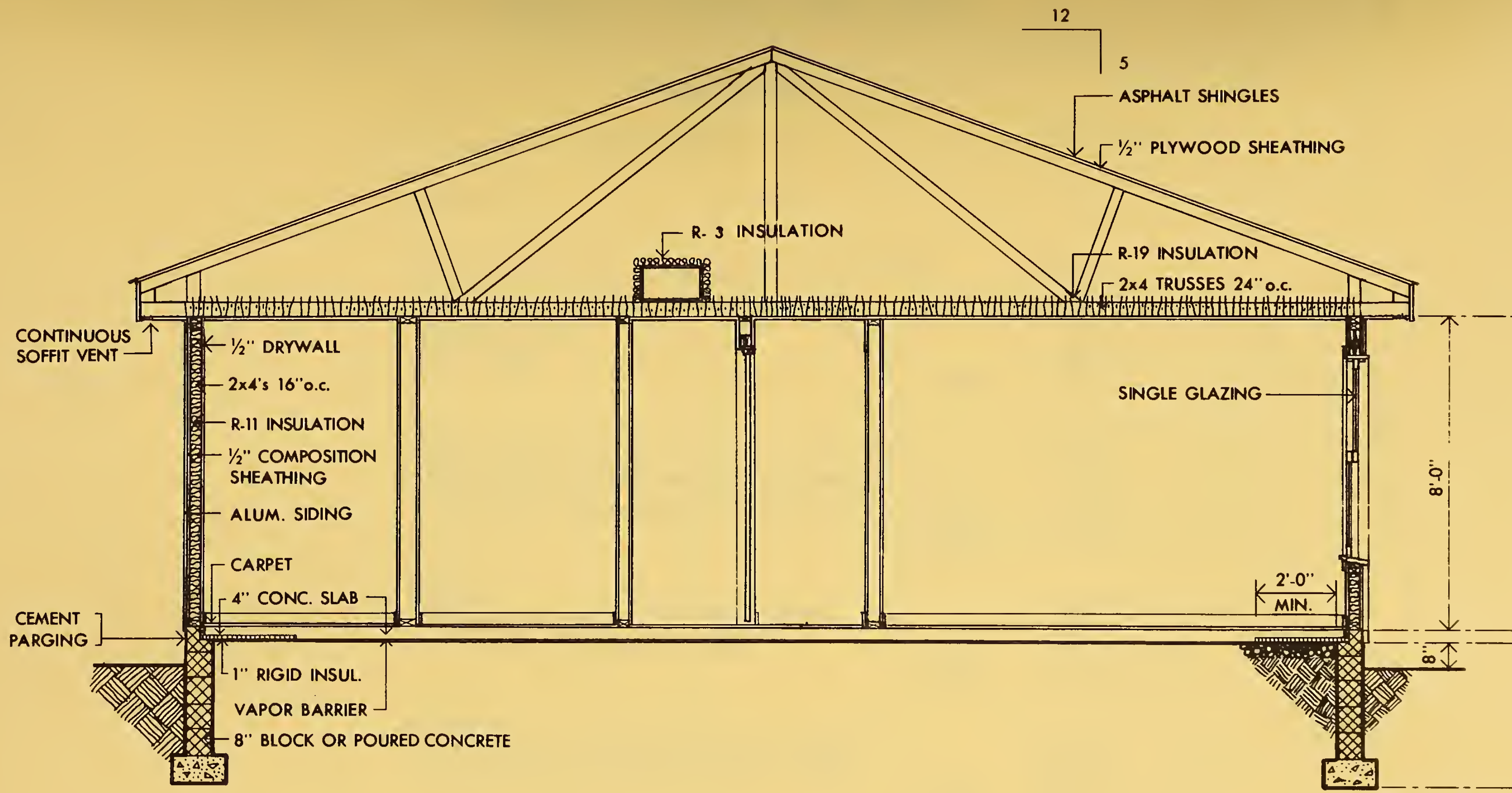
FRONT ELEVATION OF A TYPICAL RANCH HOUSE

AUG.10,1977 — 0 2 4 8 — NBS



SECTION THRU TYPICAL RANCH

0 2 4 8

AUG. 10,1977

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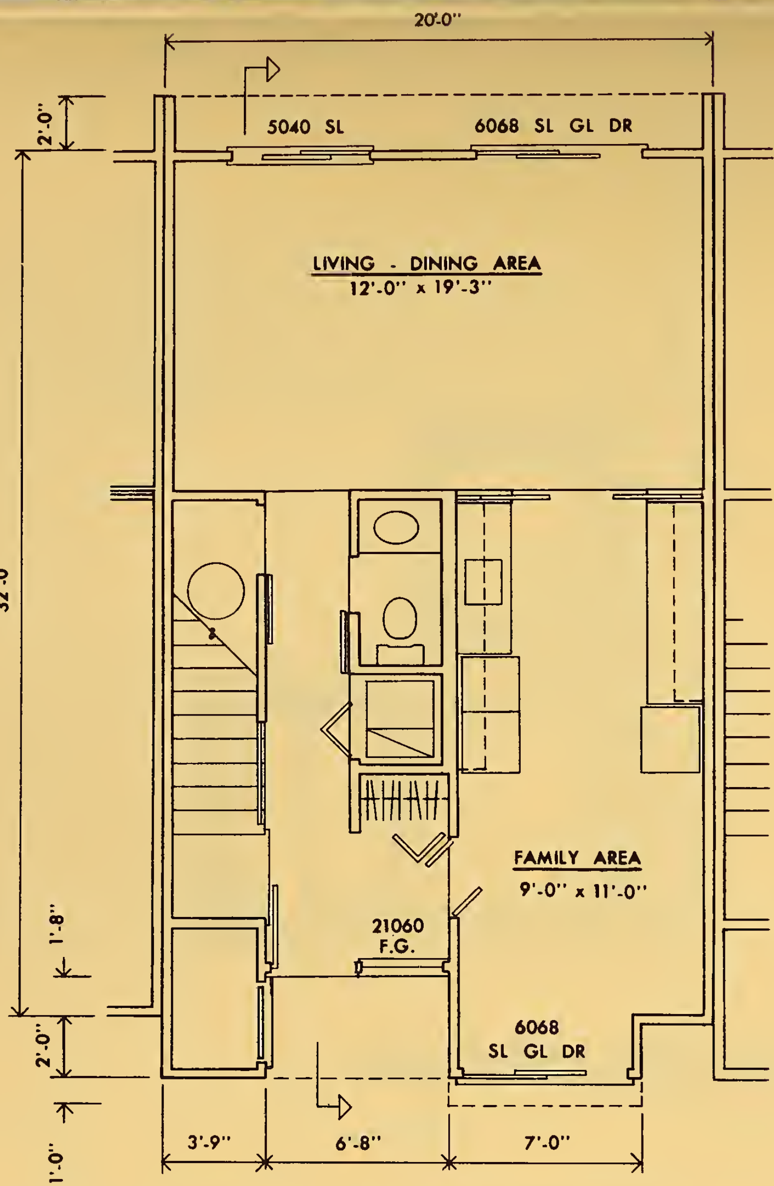
SCHEDULE OF COMPONENT SURFACE AREAS

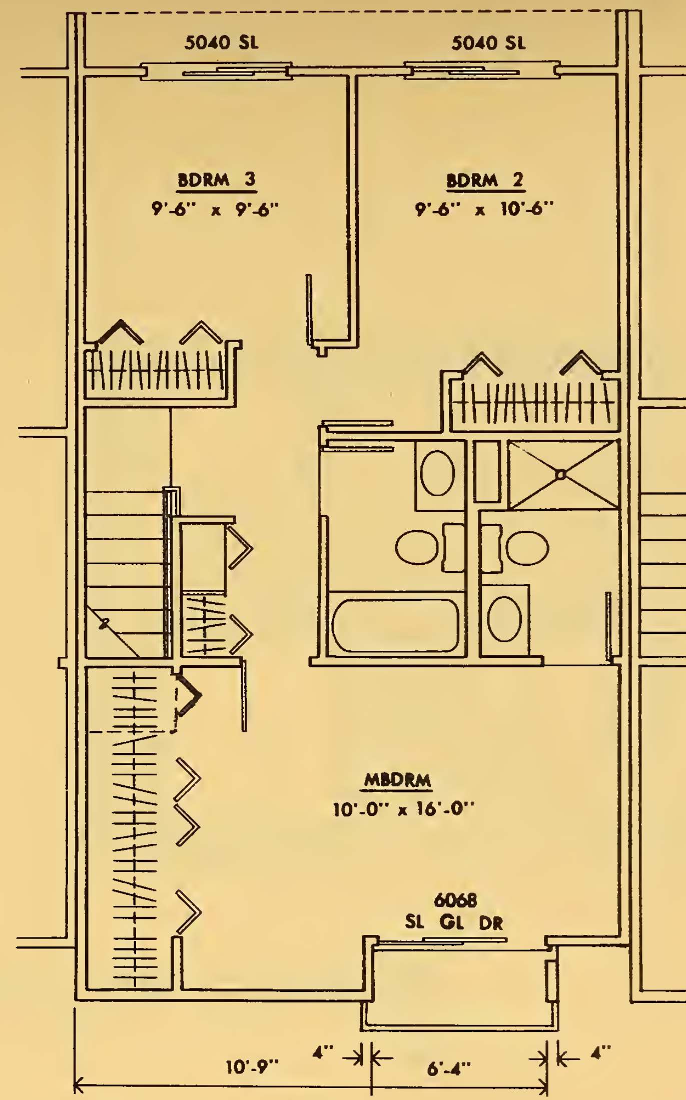
(Ranch House)

Slab (ground contact area)		1176 sq.ft.
Wall Areas		
Front		
Insulation Area (75% of net wall area)		196
Stud Area (25% of net wall area)		65
Window Area		55
Door Area		20
	Total	336
Rear		
Insulation Area (75% of net wall area)		198
Stud Area (25% of net wall area)		66
Window Area (including single-glass door)		72
	Total	336
Sides		
Insulation Area (85% wall area)		190
Stud Area (15% wall area)		34
	Total	224
Ceiling		
Insulation Area (90% floor area)		1058
Truss Cord Area (10% floor area)		118
	Total	1176



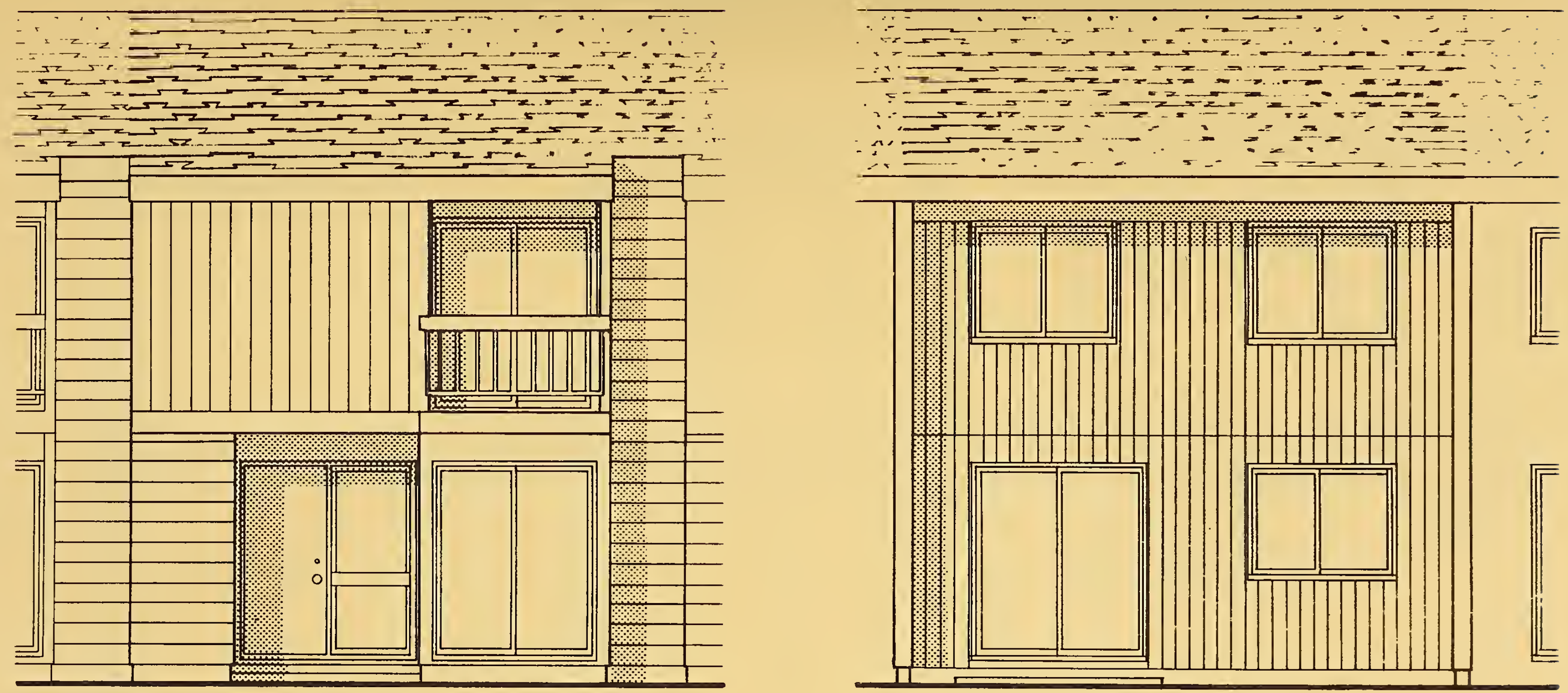
LOWER FLOOR PLAN OF A TYPICAL TOWNHOUSE

AUG. 10, 1977 NBS



UPPER FLOOR PLAN OF A TYPICAL TOWNHOUSE

AUG. 10, 1977 NBS

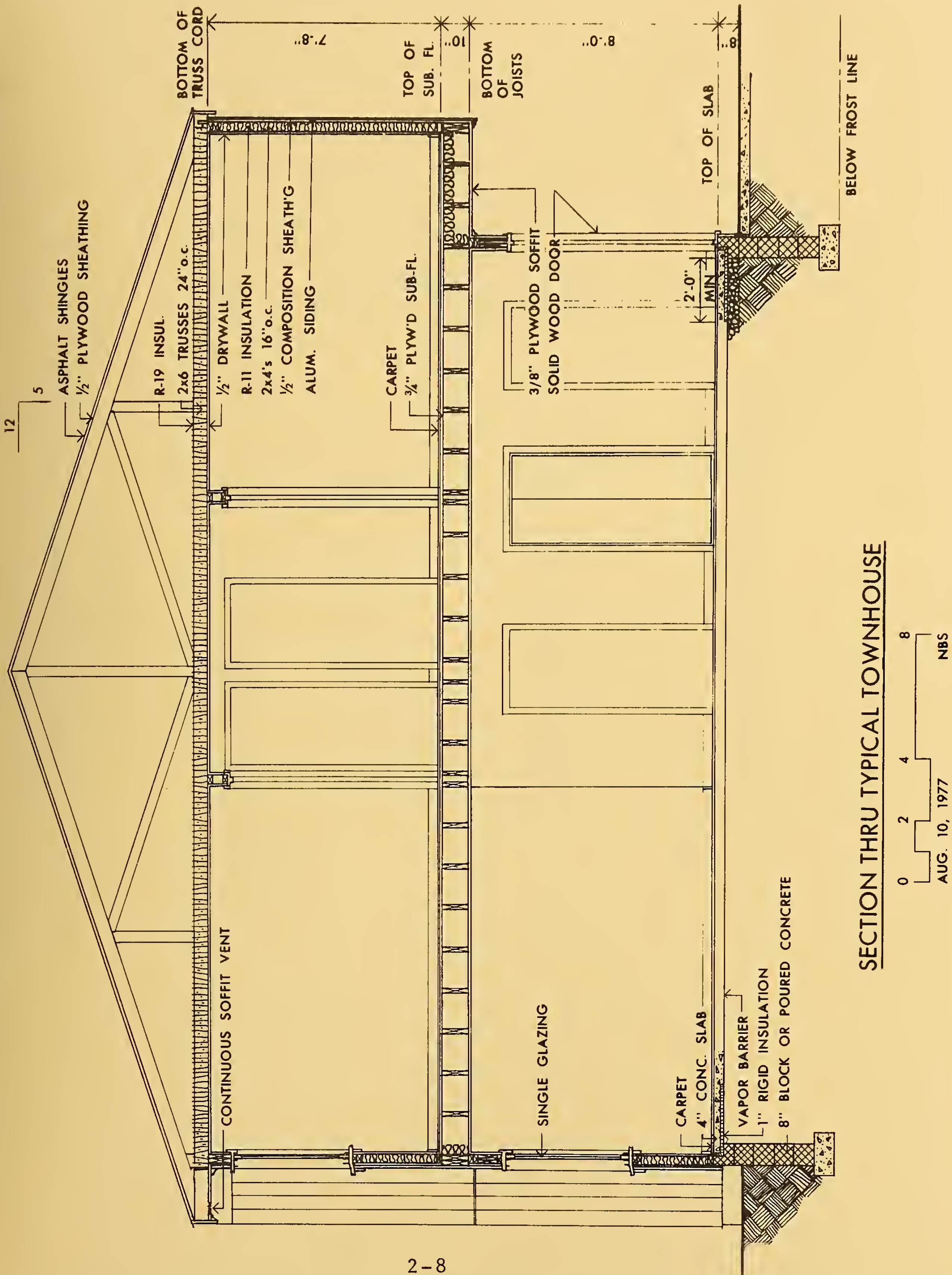


FRONT & REAR ELEVATIONS OF A TYPICAL TOWNHOUSE

AUG.10,1977

0 2 4 8

NBS

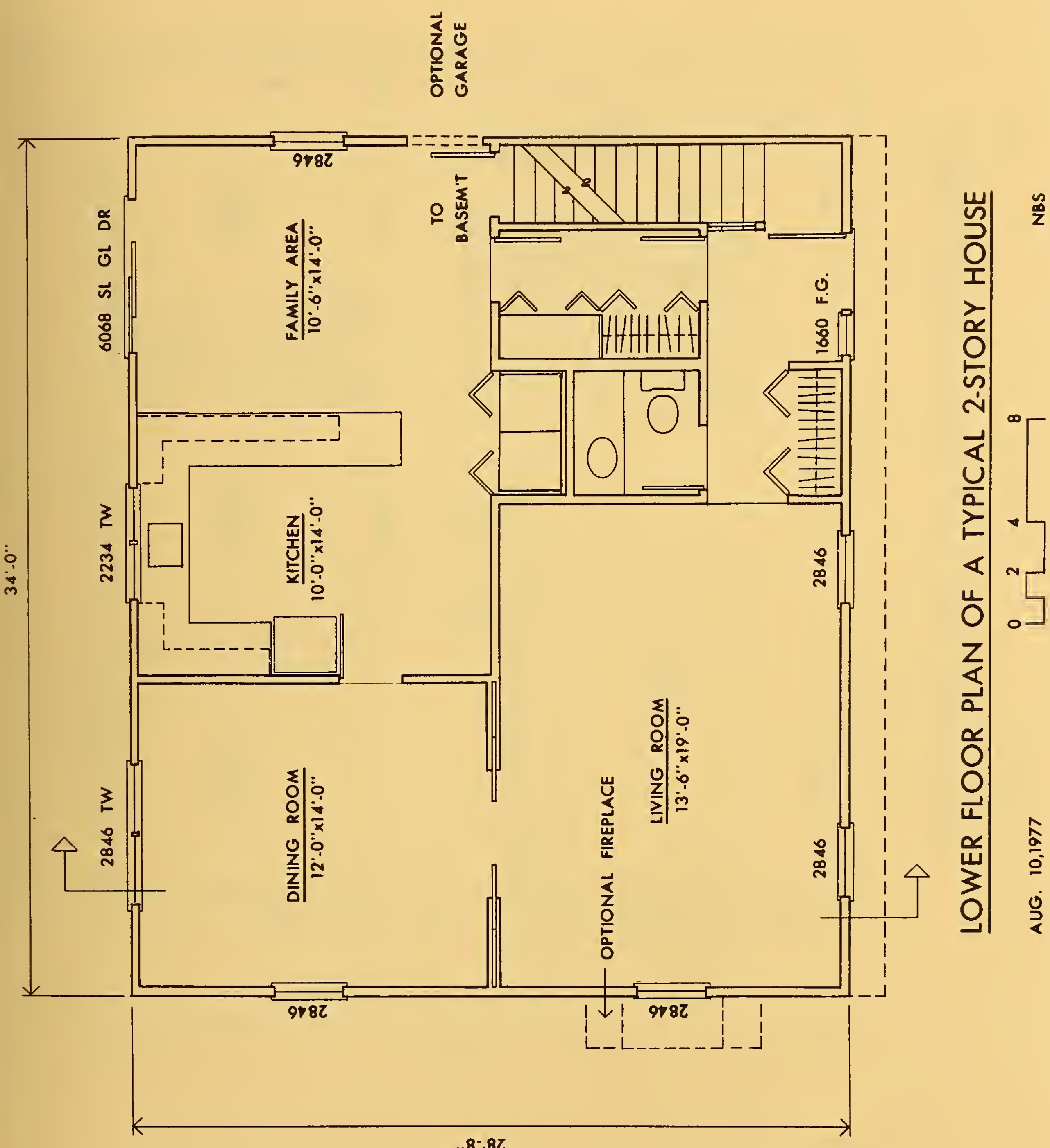


SECTION THRU TYPICAL TOWNHOUSE

SCHEDULE OF COMPONENT SURFACE AREAS

(Townhouse)

Slab (ground contact area)		654 sq.ft.
Wall Areas		
Front		
Insulation Area (75% net wall area)		160
Stud Area (25% net wall area)		53
Window Area		97
Door Area		20
	Total	330
Rear		
Insulation Area (75% net wall area)		172
Stud Area (25% net wall area)		58
Window Area (incl. sl. gl. dr.)		100
	Total	330
Sides - (Party walls)		
Ceiling		
Insulation Area (90% floor area)		595
Truss Cord Area (10% floor area)		66
	Total	661 sq.ft.



LOWER FLOOR PLAN OF A TYPICAL 2-STORY HOUSE

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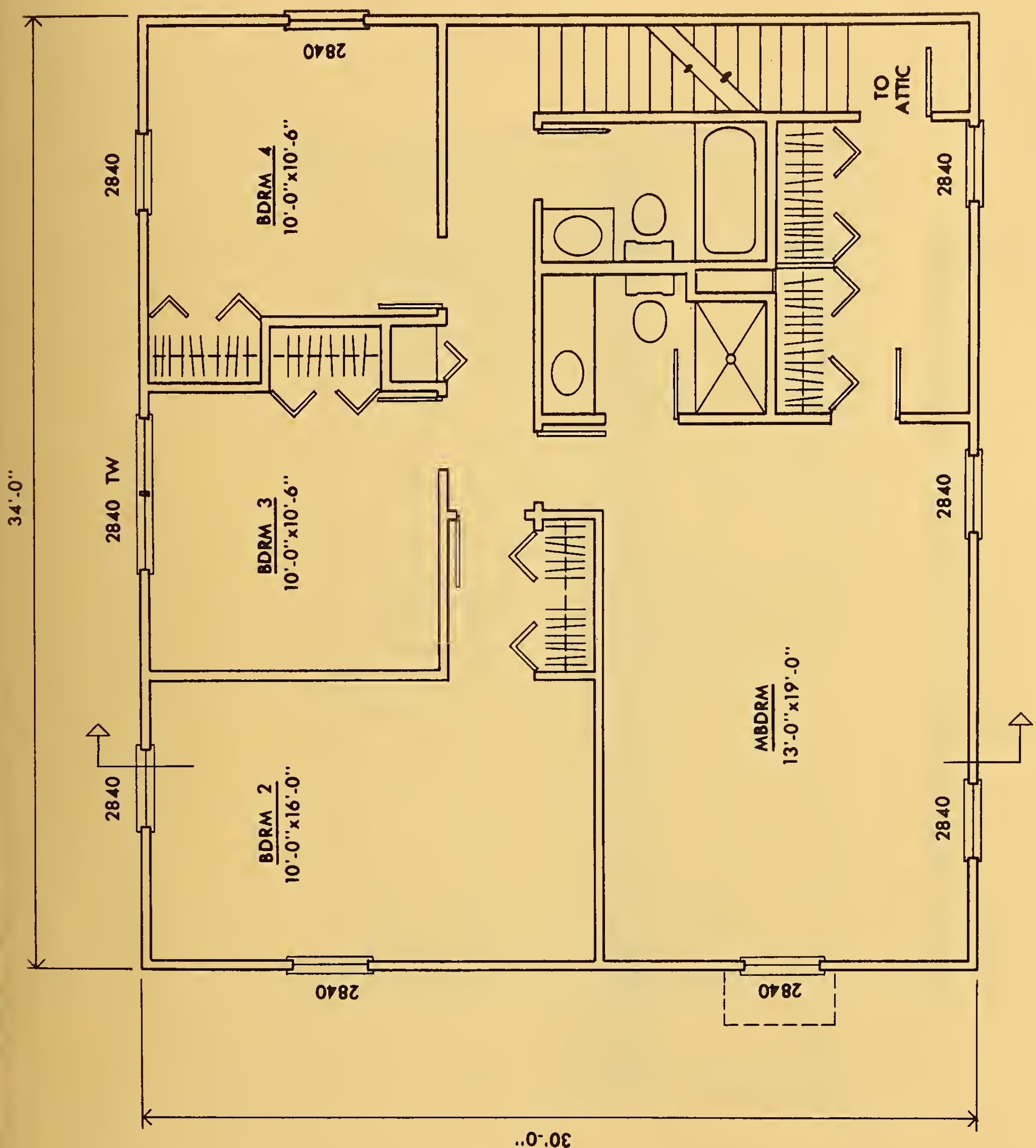

UPPER FLOOR PLAN OF A TYPICAL 2-STORY HOUSE

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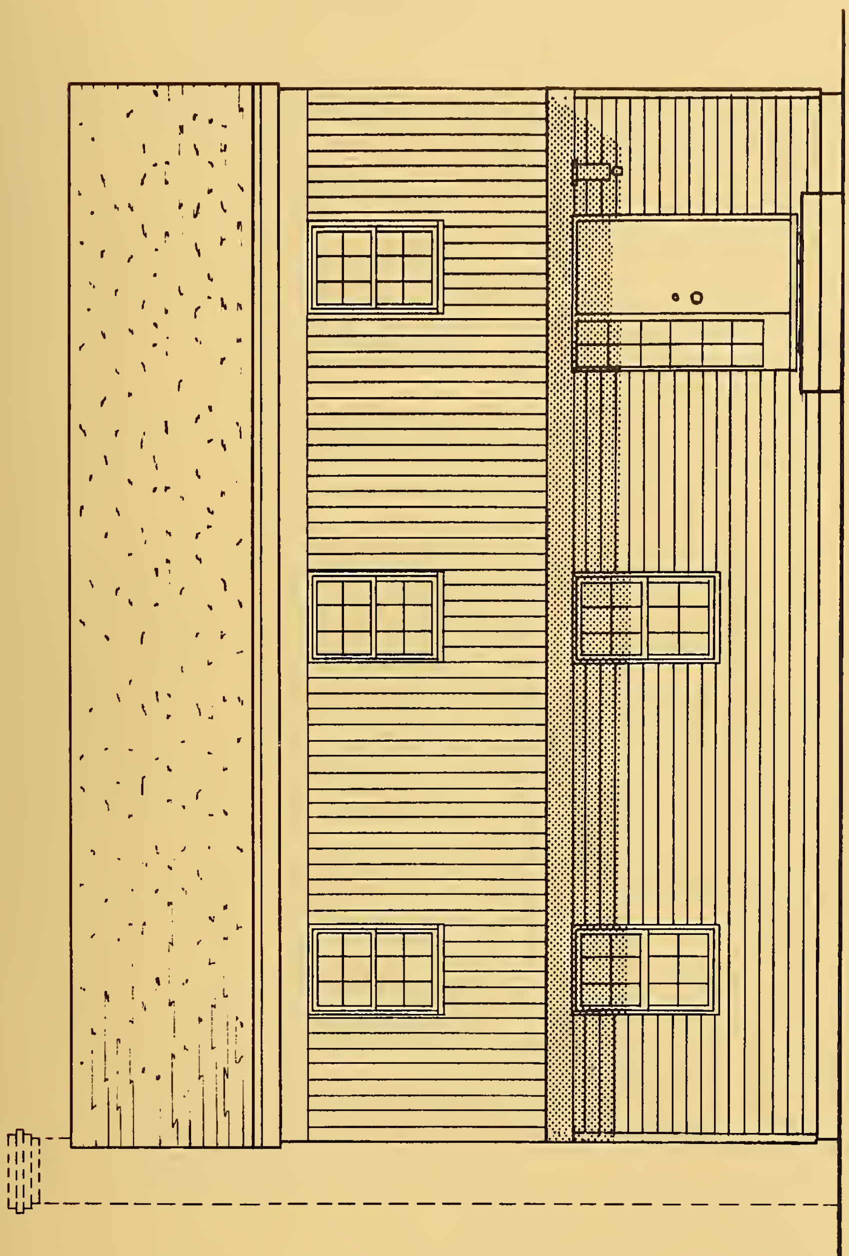

FRONT ELEVATION OF A TYPICAL 2-STORY HOUSE

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REAR ELEVATION OF A TYPICAL 2-STORY HOUSE

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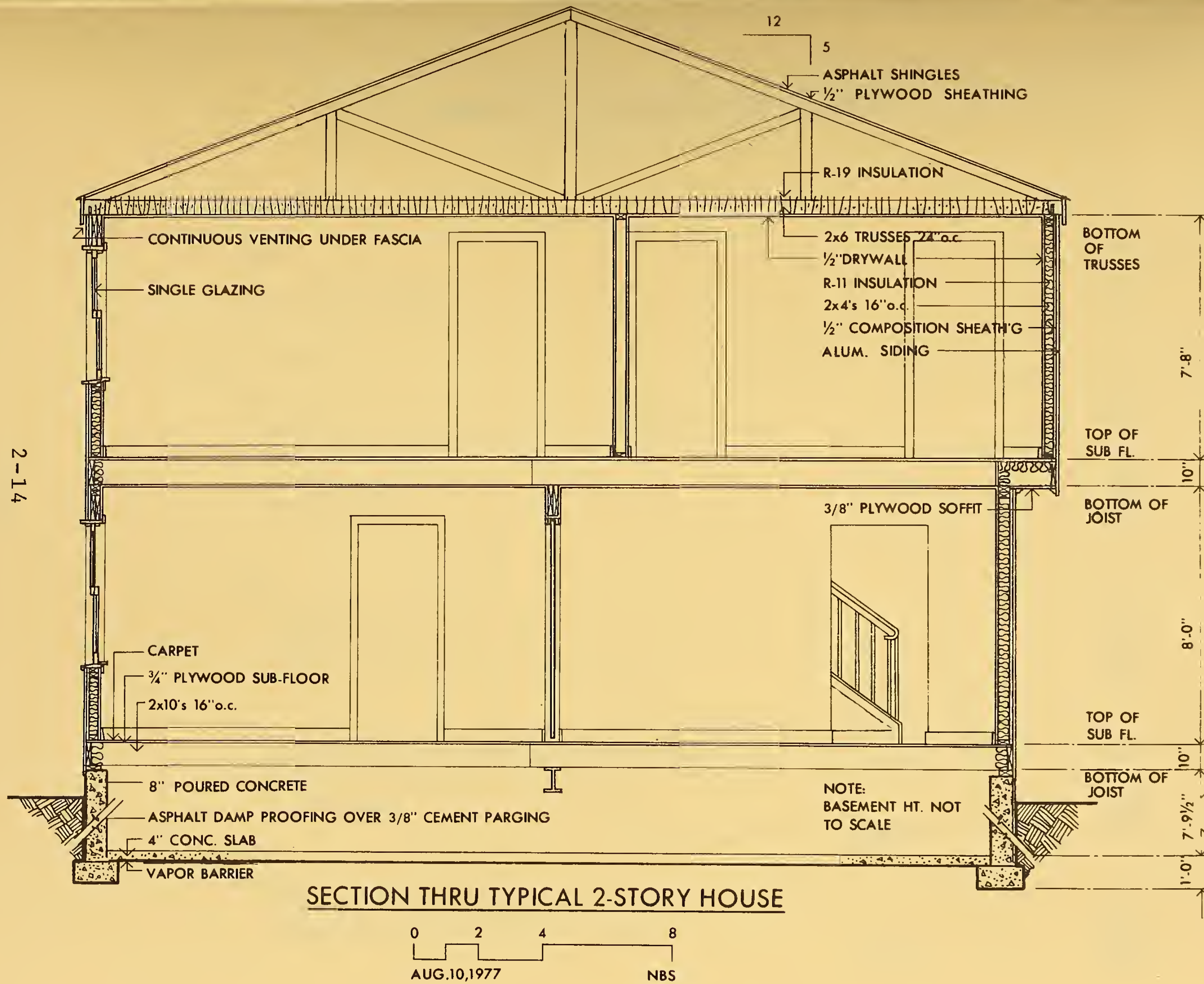

SECTION THRU TYPICAL 2-STORY HOUSE

SCHEDULE OF COMPONENT SURFACE AREAS

(Two-Story House)

Basement		
Slab		975 sq. ft.
Foundation Walls		977
Wall Areas		
Front		
Insulation Area (75% net wall area)		378
Stud Area (25% net wall area)		126
Window Area		65
Door Area		20
	Total	589
Rear		
Insulation Area		368
Stud Area		123
Window Area (incl. sl. gl. dr.)		98
	Total	589
Sides (right & left sides similar if optional fireplace built)		
Insulation Area (85% net wall area)		412
Stud Area (15% net wall area)		73
Window Area		23
	Total	508
Ceiling		
Insulation Area (90% floor area)		918
Truss Cord Area (10% floor area)		102
	Total	1020

3. MATERIAL SPECIFICATIONS

The following is a list of the materials noted on the drawings for the ranch and two-story houses (detached) and for the townhouse, along with the percentage of houses in the NAHB survey which were built using these materials. Also, included are design features incorporated in the three house designs with associated NAHB reported percentages from the same survey. In a few instances the material specified or the design feature included in the typical house designs do not represent the highest percentage reported in the NAHB survey. The basis for such deviation is the author's judgment of changes in building practice since the 1974 NAHB survey. In these cases, both the selected material or design feature and its associated percentage as well as the material or design feature with the highest survey percentage (shown in parentheses) are reported. In some instances the majority of responding builders did not answer a question regarding use of a material. This is indicated by "no answer" in the percentage column.

MATERIALS SPECIFIED	NAHB Reported Percent of Total	
First Floor (on grade):	Detached	Townhouses
1 inch perimeter insulation	no answer	
Carpet	85	89
First floor (above basement):		
no insulation	no answer	
5/8" plywood underlayment	17	40
Carpet	85	89
Exterior Walls:		
Aluminum siding	15	24
(Brick)	(34)	(24)
1/2" intermed. density insul. bd.	27	35
2 x 4 framing 16" o.c.	78	95
3 1/2" R-11 Batt insul.	71	81
Kraft paper vapor barrier	35	30
1/2" gypsum wallboard	82	78
Windows:		
Aluminum	64	78
Double-hung	33	--
Horizontal sliders	--	35
Single glazing	70	66
No storm sash	75	72
Doors:		
Solid wood (front entry)	67	43
No storm door	75	72
Sliding glass door (dining area)	not reported	

	NAHB Reported Percent of Total	
	Detached	Townhouses
Roof/Ceiling:		
Asphalt Shingle	85	77
1/2 inch plywood sheathing	55	51
2 x 4 (or 6) trusses 24 inches o.c.	63	72
R-19 loose fill (±6") insulation	41	29
R-19 batt (6") insulation	--	(39)
1/2 inch drywall	80	89
Plumbing/Mechanical:		
Warm air, ducted heating	79	80
Electric furnace	not reported	
Natural gas furnace	(49)	(40)
Central air conditioning	67	86
Electric domestic water heater	51	55

	NAHB Reported Percent of Total	
	Detached	Townhouses
DESIGN FEATURES		
Foundation:		
Slab-on-grade	34	70
(Full basement)	(34)	(25)
Number of floors:		
One-story	52	--
Two-story	17	73
Finished Floor Area:		
1200-1599	31	57
1600-2399	43	--
Garages:		
none	not reported	
one-car	--	29
two-car	(70)	--
Number of bedrooms:		
three	68	66
four	25	
Number of bathrooms:		
(one and one half)	--	(38)
two	50.1	--
two and one half	22	36.7
Roof form - gable	75	76
(Fireplace)	(57)	(50)

4. THERMAL RESISTANCE OF MATERIALS USED IN THE THREE HOUSES

COMPONENT	R (for thickness listed)
First Floor (on grade):	
Expanded polystyrene extruded (1")	5.00
Poured concrete slab (4")	0.32
Carpet and fibrous pad	2.08
Horizontal air film (still, heat flow down)	0.92
Total	8.32

First Floor (above basement):

The basement is assumed to be unheated. However, transient heat from the heating plant (located in the basement) warms the air near the basement ceiling sufficiently to make it unnecessary to calculate downward heat loss through the first floor according to the ASHRAE Handbook of Fundamentals, page 378, (see note 5).

COMPONENT	R (for thickness listed)
Walls (insulation area):	
Vertical air film (15 mph wind)	0.17
Aluminum siding	0.60
Intermediate density insulating sheathing (1/2")	1.22
Cavity insulation	11.00
Gypsum wallboard (1/2")	0.45
Vertical air film (still)	0.68
Total	14.12
Walls (stud area):	
Vertical air film (15 mph wind)	0.17
Aluminum siding	0.60
Intermediate density insulating sheathing	1.22
2 x 4 wooden studs	4.35
Gypsum wallboard (1/2")	0.45
Vertical air film	0.68
Total	7.47

Windows:		
Vertical air film (15 mph wind)		0.17
Architectural glass		0.03
Vertical air film (still)		0.68
	Total	0.88
Doors - (front entry)		
Vertical air film (15 mph wind)		0.17
Solid Hardwood (1 3/4")		1.59
Vertical air film (still)		0.68
	Total	2.44
Ceiling (insulation area)		
Horizontal air film (still, heat flow up)		0.61
Gypsum drywall (1/2")		0.45
Insulation		19.00
Horizontal air film (still, heat flow up)		0.61
	Total	20.67
Ceiling (truss cord area)		
Horizontal air film (still, heat flow up)		0.61
Gypsum drywall (1/2")		0.45
2 x 4 wooden truss cords		4.35
Horizontal air film (still, heat flow up)		0.61
	Total	6.02

Notes:

1. The resistances in the above table are calculated from tables given in Chapter 20 of the 1972 edition of the ASHRAE Handbook of Fundamentals published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., New York.

2. It could be inferred that since R-values were given for the ceiling and insulation only, the attic temperature is assumed to be

at the outside air temperature. This may or may not be true depending on the amount of attic ventilation. An ongoing National Bureau of Standards project recording attic temperatures for various attic ventilation conditions will provide more data to help quantify the extent the attic serves as a buffer in winter and a heat trap in summer.

3. Since the windows are specified to be aluminum, the R-value can be applied to the entire window area. It is unreasonable, however, to assert that the windows are typically left uncovered at night given the privacy concern in urban or suburban environments. A tight-weave drapery hanging to the floor and in loose contact with the walls at the sides of the windows could be expected to increase the resistance to heatflow of the window by 10 to 15 percent. This is substantial as the reduction occurs at night when winter outside-inside temperature differences are greatest.

4. In calculating the downward heatflow through the slab a resistance must be assigned to the earth immediately below the slab. The perimeter insulation isolates the earth below the slab from the earth beyond to the extent of the insulation's R-value. To calculate how much heat is lost laterally out of the sides of the slab see Table 2, page 378 of the 1972 ASHRAE Handbook of Fundamentals.

5. In calculating summer heat gain the resistance of the air film is considered to be 0.25 rather than 0.17 as a 7 1/2 mph wind is conventionally assumed rather than the 15 mph wind for winter. Similarly, the value for the air film at the attic surfaces would be slightly better (0.92) in the summer as the direction of heat flow is downward as apposed to upward in winter (0.61).

5. SUGGESTED APPLICATIONS FOR THE THREE TYPICAL DESIGNS

This report provides a basis for research in the areas of energy conservation, fire safety, security, and environmental behavior.

An example research project in the area of energy conservation would be to model the energy consumption of the houses in each of 10 different locations (selected to represent a sampling of the various climates in the U.S.) and quantify the effects of various climate variables on the energy consumption of typical new houses. Such a study has been completed for the ranch house (publication is expected in the near future), but needs to be done for the townhouse and the two-story house. Once these data have been calculated and tabulated they will provide a comparative basis for many energy conservation modifications. For example, the houses could be reanalyzed with the glass areas greatly increased on the elevation facing south and decreased to HUD minimum property standards on the elevation facing north. At the same time, double glazing could be substituted for single glazing. Included in the reports of these data could be illustrations of how energy efficient fenestration and orientation can be achieved while actually enhancing privacy through landscape planning. Examples include the use of trees and shrubs, definition of court spaces, and open space planning. Similar studies could be made to document the energy and cost effectiveness of builders providing external sun protection for the glazed areas of houses, be it sun screens, deciduous trees, awnings, or roof overhangs. Such a study, especially in conjunction with a study of the effectiveness of whole-house-fan ventilation, would document surprising energy savings as a result of the dramatic reduction in the dependence on mechanical air conditioning.

In the area of fire safety, the three house designs and material specification provide a standard basis to study rates of flame and smoke propagation, rates of release of toxic substances, containment of heat, air movement patterns, and egress behavior in conjunction with models of human decision making in fire situations.

Security issues need to be investigated concurrent with research of various energy conservation measures such as adding storm windows and storm doors, increasing glass area on the south-facing side (e.g., replacing a window with a sliding glass door), orientating houses away from the street when necessary to maximize south exposure, and landscaping to shade windows (which may reduce street surveillance of windows and doors).

Finally, in the area of environmental behavior, these three designs provide the starting point to study how trends in new house construction (such as reducing house size) necessitate rethinking the way interior and exterior spaces are divided and defined relative to life styles. As land costs, material costs, and labor costs increase first costs, and as energy costs increase operating costs, future new house design will change. A study is needed, starting, with the three house designes to forecast various design and construction changes as a result of these pressures and suggest the best alternatives. Such a study would help assure that houses of the future are affordable, energy conserving, and accomodate behavioral needs.

Each of these examples of further research benefits from using the same three house designs as a baseline. The designs provide the common denominator for evaluating how design modifications for one objective such as energy conservation may help or hinder the achievement of other objectives such as improved fire safety, security, or habitability.

6. CONCLUSION

The three typical house designs and material specifications described in this report provide a statistically documented basis from which energy savings for various improvements can be calculated.

Of the three houses, the ranch is the most easily typified. There are a limited number of permutations such as the "raised ranch" and the "split level." In the case of the townhouse, there are slightly more variations in design, including the substitution of the upstairs bath with a walk-in-closet, the placement of the kitchen to the front of the townhouse with the previous location of the kitchen becoming a dining area, and the front facade being flush with no overhangs and no sliding glass door off the breakfast area or upstairs master bedroom.

Two-story houses, larger in size and higher in price than the former two examples, are least easily typified. Typical variations from the design shown include: the location of the stair in the center of the house and either parallel or perpendicular to the run as shown, and the location of the upstairs baths in the location of the bedroom number 3 as shown. The interior partitioning in this design, as in the other two designs, is not presently a concern in modeling energy consumption, however. For both the two-story and the ranch it is common to see an attached one or two-car garage, sometimes with a family room to the rear of the garage.

It is apparent, in each of the three designs, that common cosmetic facade elements such as applied vinyl window shutters have not been shown. It should not be concluded that this reflects the commonness or rarity of such features. Rather, they have been omitted merely because they typically have no significant effect on energy performance.

Finally, any conclusions based on these designs must be qualified to reflect the fact that the designs are representative of new house construction at the time of this publication. These designs are not representative of the whole housing stock (pre World War II houses differ substantially), nor do the designs anticipate changes in future house construction. The author invites suggested modifications to the designs from the readers based on their experience of what is typical.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report provides three house designs typifying the majority of new house construction in the U.S. Includea are: scaled drawings detailing the construction of the houses, a breakdown of envelope components by surface area, a schedule of materials with supporting survey statistics from the National Association of Home Builders, a table of heat transfer properties of the specified materials, and recommendations for how these typical house designs can provide a basis for further work in the areas of fire research, durability, security, and environmental behavior in addition to energy conservation.

The background work for this report was completed in support of two other reports: "Geographic Variation in the Heating and Cooling Requirements of a Typical Single-Family House", and "Determination of Optimal Energy Conservation Designs in Single-Family Housing: Preliminary Results." This report is a wrap-up of the support to these two reports and provides a thorough documentation of the three designs to provide a basis for future work.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Building envelope, energy conservation base, insulation, residential design practices, typical construction characteristics, typical new house materials., windows.

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