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The Value of Thermal Insulation in Residential Construction: ECONOMICS and the CONSERVATION of ENERGY

John C. Moyers

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The Value of Thermal Insulation in Residential Construction: ECONOMICS and the CONSERVATION of ENERGY

John C. Moyers

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PRESS-HOLD PREFACE

As this report was undergoing editorial review, the Federal Housing Administration revised the thermal insulation requirements in their Minimum Property Standards for One and Two Living Units (FHA No. 300, Interim Revision No. 51a, dated April, 1971, effective June 1, 1971). The stated purpose of the revision "...is to fulfill the Department's [HUD] commitment to the national air pollution control and fuel conservation programs. Its implementation will also provide the homeowner with more economical operating costs in most areas."

In this report, all references to the FHA Minimum Property Standards (FHA-MPS) pertain to the unrevised (pre-June, 1971) Standards. Savings in cost and energy consumption of different insulation systems are given, compared to systems that comply with the unrevised Standards. Those comparisons are still valid and show the worth of increments of additional insulation. Construction of homes in compliance with FHA requirements after June 1, 1971, will provide a large part of the savings shown in the report, particularly in the northern climatic region represented by Minneapolis.

Table i gives the estimated monetary and energy savings resulting from the use of either the revised FHA-MPS requirements or the economically optimum amount of insulation as determined in this study, as compared with the use of the older, unrevised, FHA-MPS requirements. The revised FHA-MPS make no distinction between electrically heated and combustion-heated homes. As a result, the potential electricity saving provided by the revised Standards is only 30% of the saving provided by the economically optimum

insulation system in the southern region where electric heat has its greatest popularity, and only 40% in the central region.

The results of this study substantiate the need for the recent revision of the FHA Minimum Property Standards and indicate that a further increase in insulation requirements, particularly for those sections of the country with mild or moderate winters, is probably worthwhile from a cost-to-owner point of view in addition to the socially desirable gains of energy resource conservation.

MONETARY AND ENERGY SAVINGS FROM USING REVISED FHA-MPS STANDARDS
OR
ECONOMICALLY OPTIMUM AMOUNT OF INSULATION INSTEAD OF UNREVISED (PRE-JUNE 1971) FHA-MPS REQUIREMENTS

	Revised FHA-MPS Savings			Economically Optimum Savings		
	$/yr	Gas, %	Electricity, %	$/yr	Gas, %	Electricity, %
Atlanta						
Gas heat	6	16	—	6	31	—
Gas heat + A-C	3	12	0	6	20	7
Electric heat	36	—	16	87	—	53
Electric heat + A-C	21	—	10	63	—	39
New York						
Gas heat	28	29	—	32	49	—
Gas heat + A-C	28	24	10	37	50	26
Electric heat	75	—	19	155	—	47
Electric heat + A-C	47	—	13	135	—	42
Minneapolis						
Gas heat	37	37	—	42	43	—
Gas heat + A-C	39	37	11	45	43	18
Electric heat	80	—	22	119	—	29
Electric heat + A-C	82	—	22	122	—	29

ABSTRACT

As a part of the ORNL-NSF Environmental Program's effort toward conservation of energy, potential monetary and energy savings through the use of additional thermal insulation in residential construction were estimated. Insulation systems as required by Federal Housing Administration Minimum Property Standards for a southern, a central, and a northern region of the U.S. were used as the basis for comparison. Whereas the owner of a gas-heated home would generally realize small monetary savings from increased insulation, his energy savings could be as high as 30-50% at no economic penalty. The owner of an electrically heated home can save as much as approximately 1/3 of the cost of heating his home by using additional insulation and, at the same time, reduce the energy consumption by 30-50%.

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THE VALUE OF THERMAL INSULATION IN RESIDENTIAL CONSTRUCTION: ECONOMICS AND THE CONSERVATION OF ENERGY

I. INTRODUCTION

Widespread concern over the preservation or restoration of our environmental quality has exerted pressure on governmental agencies, mining and transportation industries, and electrical utilities to reduce both the quantities of air and water pollutants released during power generation and the devastation of the landscape associated with fuel extraction and transportation. A wide range of activities is underway in these areas, under both governmental and industrial sponsorship.

Another way to diminish the environmental impact of energy production is to reduce the consumption of energy. Effort in this direction is essentially unexplored and somewhat counter to the promotional activities of the utilities; yet it need not lead to a lower standard of living. Rather, it can lead to using energy more efficiently to attain the same result with a smaller expenditure of energy.

The residential sector of our economy, while accounting for approximately one third of the electrical energy consumed in the U.S., probably has the least expertise of any of the sectors in the conservation of energy and economic optimization. Commercial and industrial enterprises, because of their need to realize a profit, continually review their operations from an overall cost-conserving viewpoint. Conversely, the individual resident of a housing unit may be unaware of his options, let alone know how to analyze them effectively. Or he may, in fact, have little control over the efficiency of his residence. Then again, he may suffer at the

hands of the builder who seeks to maximize his own profit, or he may misguidedly opt for small savings in initial capital investment instead of much larger savings in operating costs over the long run.

In the residential sector, more electricity is used for space heating and cooling than for any other purpose. In considering this function, we divide residential occupants into 3 categories: the renter; the purchaser of a speculatively-built home; and the purchaser of a custom-built home.

The renter has no choice or control over the heating system or thermal quality of construction of the residential unit. The landlord may or may not have an interest in energy utilization efficiency, depending upon whether the heating system is a central type serving several units or a unit type with the tenant paying for utilities.

The purchaser of a speculatively-built home has a choice of thermal design only as broad as the local real estate market - and often this is subsidiary to other considerations, such as architecture and location. The saleability of a new home more often revolves around down payment, arrangement, and appearance than thermal efficiency. Thus, the builder has little incentive to exceed whatever minimal standards may apply.

The purchaser of a custom-built home has the most control over the thermal efficiency of his residence. However, he is hampered in making a wise selection by the unavailability of data on capital and operating costs for alternative heating and insulation systems for a specific location and circumstance. Recommendations by utilities on the degree of insulation to be used tend toward just keeping their commodity competetive.

The Federal Housing Administration, in its Minimum Property Standards (FHA-MPS),[1] establishes thermal design criteria that must be met if the residence is to qualify for an FHA-insured mortgage. This document comes close to setting a nationwide standard for thermal quality of construction, but it is not imposed upon an appreciable fraction of new homes constructed through conventional financing. The FHA-MPS is recognized as being quite minimal in its requirements. In the "Purpose" section of the FHA-MPS, the following statements are made:

> "They [the FHA-MPS] are intended to obtain those characteristics in a property which will assure present and continuing utility, durability and desirability as well as compliance with basic safety and health requirements. To provide this assurance, these standards set forth the minimum qualities considered necessary in the planning, construction and development of the property which is to serve as security for an insured mortgage.
>
> "As these standards define the minimum level of quality acceptable to FHA, a property complying with them is considered technically eligible in all FHA insuring office jurisdictions...
>
> "Planning and construction which exceed the minimums set forth herein and which will result in increased marketability of the property or which will reduce the expense of maintenance or early replacement of equipment, will be reflected in the FHA estimate of value...
>
> "These standards are not intended to serve as a building code. Such codes are primarily concerned with factors of health and safety and not the many other aspects of design and use which are included herein as essential for mortgage insurance determinations."

As a part of the Oak Ridge National Laboratory-National Science Foundation Environmental Program, a study was undertaken to determine the monetary cost or saving and the energy saving that would result from application of various amounts of thermal insulation to a residential unit. Climatic conditions for 3 cities, representing essentially equal-population regions of

the country, were included in the study. For each region, the differential energy consumption and annual cost were estimated for varying amounts of insulation, assuming gas heat or electric heat, each with and without electric air conditioning.

Although not considered in this study, the habits of the residents can have an appreciable effect on the energy requirements for heating or cooling the residence. In a study conducted by The Peoples Gas Light and Coke Company of the energy consumption of 30 modular housing units in Chicago,[2] the annual cost of the total gas consumption (in gas-heated homes) for the largest user was 47% greater than that for the smallest user. In the all-electric units included in the study, the cost of electricity for the largest user was 126% greater than that for the smallest user. Although the actual quantities of gas or electricity consumed were not reported, the largest-to-smallest consumption ratios would be even higher than the cost ratios because both gas and electricity were priced by graduated rate schedules. The gas or electricity in these homes was used for other purposes as well, but space heating was the largest single use. Such large variations in energy use emphasize the need for both education and motivation of the inhabitants in the ways of conserving energy.

Various utilities and the National Bureau of Standards have published pamphlets that offer advise on ways of reducing energy consumption for heating and cooling.[3,4,5,6] These stress the importance of minimizing infiltration of outside air, proper maintenance of equipment, and avoiding thermostat settings that are unnecessarily warm in the winter and cool in the summer. Further research to determine additional conservation methods

available to residents and to quantify the benefits to be derived should be conducted. In addition, existing knowledge on the subject should receive much wider dissemination.

Energy losses arising from wasteful practices by the occupants are additive to losses through the structure itself and do not add to or reduce the benefits derivable from additional insulation. For the ultimate in energy conservation, both good construction and conservative habits are needed.

II. ORGANIZATION OF THE STUDY

A. The Problem

The heat loss (or gain) from a residence that must be countered by the heating (or cooling) system to maintain a condition of comfort within occurs through several essentially parallel paths. These include the walls, the ceiling-attic-roof, the floor, the windows and doors, and the cracks and pores of the structure, through which outside air infiltrates. Heat loss (or gain) through each of these paths can be reduced by the use of additional thermal insulation, double glazing or storm windows and doors, and weather-stripping. (These will henceforth be referred to collectively as insulation.) Although storm windows and doors, weather-stripping, and in some cases, ceiling insulation may be installed in an existing residence to improve its thermal efficiency, the ideal time to provide adequate insulation is during initial construction.

Each increment of insulation will reduce the design heat loss of the residence, from which the heating and air conditioning equipment is sized, and the annual amount of energy required to heat and cool the

residence. The net additional investment required for the additional insulation is the difference between the installed cost of the increment of insulation and the reduction in cost of the heating and cooling equipment. The net annual benefit or cost of the increment of insulation is the annual cost of the energy saved less the annual equivalent of the net additional investment.

The annual equivalent of the investment includes the additional mortgage payment, additional property taxes, and additional insurance cost, all of which are proportional to the additional investment. Property taxes and interest on the mortgage may be deducted from income in computing Federal income tax, an effect that reduces the annual equivalent of the investment. Since the amount of interest paid each year on the mortgage decreases year-to-year, a levelizing technique is required to determine the constant annual equivalent of the interest payment.

The types of additional thermal treatment considered in the study included glass fiber batts of various commercially available thicknesses for the walls and ceiling, storm windows, and air-gap-and-foil under the floor. Insulation in the walls was limited to 3-1/2 in. to conform to normal framing dimensions. Other, more efficient, insulation, such as low-conductivity-gas-blown plastic foam, was not included because it has not been widely used and cost information is sparse. Storm windows were included instead of double glazing of windows because the cost is generally lower and storm windows reduce infiltration of outside air through the cracks around moveable windows while double glazing does not. Glass fiber batts can be installed under floors, but foil is simpler to install, cheaper, and remarkably effective in retarding heat flow.

B. Assumed Climatic Conditions

Three cities, Atlanta, New York, and Minneapolis, were selected as having climatic conditions representative of three regions of the country (a southern, a central, and a northern region) with approximately equal populations. Table 1 gives the applicable climatic data for these cities as taken from publications of the American Society of Heating, Refrigerating and Air-Conditioning Engineers[7,8] (ASHRAE).

Table 1. Climate Characteristics of 3 Cities

	Atlanta	New York	Minneapolis
Heating degree-days per year	2826	5050	7853
Air conditioning hours per year	750	350	350
Winter outside design temp., °F	11	5	-23
Summer outside design temp., °F	95	90	93
Average outside heating season temp., °F	50	44	35

C. FHA Minimum Property Standards Requirements

The Federal Housing Authority's Minimum Property Standards (FHA-MPS) establishes guidelines to assist appraisers in determining the salable value of a housing unit. As such, they do not impose a legal requirement for design or structural excellence. However, because they are used by appraisers of conventional loan organizations, as well as those of FHA, they exert considerable influence on the residential construction industry.

The FHA-MPS thermal requirements are of two types: general restrictions on the structure's total hourly heat loss or gain, as determined at

design inside-outside temperature differences; and specified maximum values of overall heat transfer coefficients ($\equiv$U, Btu/ft^2-hr-°F) or heat loss per unit area for various components of the structure. There is no regional variation in these requirements; one set applies to the entire country. (One minor exception to this is a small variation in total allowable heat gain as a function of outside design temperature, if air conditioning is to be used.) The restrictions, as extracted from Section 714 of the FHA-MPS, are given in Table 2.

The FHA-MPS requirements are not universally recognized as providing acceptable thermal design characteristics. The inadequacies from the standpoint both of economy and comfort are discussed by Rogers.[5] The National Electrical Manufacturers Association (NEMA) issued its own manual[6] which provides recommendations for the thermal design of electrically-heated buildings. The NEMA recommendation for maximum total heat loss varies from 27 to 34 Btu/hr-ft^2 floor area as the climate varies from 3000 to 8000 degree-days per heating season. Ceiling, wall, and floor (over unheated basements) U-value recommendations are 0.05, 0.07, and 0.09, respectively, and double glazing (or storm windows) is recommended if the winter design temperature is below 7°F or the heating season consists of more than 4500 degree-days.

D. The Model Home

The economically optimum amount of insulation to be used in any component of a residence can be mathematically determined on a unit area basis only if heating and cooling equipment are available with any desired rating. Such is not the case in air conditioning equipment; ratings usually are in 1/2-ton (6000 Btu/hr) steps. Nor is insulation readily

available in any desired thickness. For these reasons, we based our study on a hypothetical model home and determined the effects of varying amounts of insulation in the various components on annual energy consumption and total annual cost.

Table 2. Thermal Requirements for Dwellings
(as specified in FHA Minimum Property Standards)

Total maximum heat loss, Btu/hr-ft^2 floor area	
Non-electric heat	50
Electric heat	40
Total maximum heat gain with air conditioning, Btu/hr-ft^2 floor area	
For conditioned areas of more than 1500 ft^2	18-22
Total maximum heat loss through vertical surfaces (excluding infiltration losses), Btu/hr-ft^2 floor area	30
Total maximum heat loss through floors over unheated spaces, Btu/hr-ft^2 floor area	15
Maximum ceiling U, Btu/ft^2-hr-°F	
Non-ceiling heat (upward heat flow)	0.15
Ceiling heat (" " ")	0.06
Air conditioning (downward heat flow)	0.08

In cases where more than one restriction applies, the more stringent prevails.

The model home is a single-story, ranch-style structure, 60 ft. long and 30 ft. wide (1800 $ft.^2$ floor area), with an unheated basement. The details of construction are given in Table 3.

Table 3. Construction Details of Uninsulated Model Home

Wall construction	Wood siding, rigid 25/32-in sheathing insulation board, 3 5/8-in air space, 1/2-in gypsum board.
Ceiling	1/2-in gypsum board.
Roof construction	Asphalt shingles, building paper, 25/32-in wood sheathing.
Attic	Natural ventilation (0.1 cfm/ft^2).
Floor	3/4-in hardwood floor, felt, 25/32-in wood subfloor (over unheated basement).
Windows	Double-hung wood North 80 ft^2 East 30 ft^2 South 100 ft^2 West 50 ft^2 South windows receive 50% shading during summer.

The heat transfer characteristics of the wood-siding walls are quite similar to those of the walls of a brick veneer home, with the wood siding performing slightly better. In addition, the hardwood floor is thermally similar to a plywood plus tile or linoleum floor. Thus, the results have wider application than might appear.

The window areas shown are gross, including both glass and sash area. The glass area is assumed to be 80% of the total area. If aluminum windows are used, Reference 7 recommends increasing the estimated conduction heat transfer rate by approximately 22%.

E. Calculated U Values and Assumed Costs

Overall heat transfer coefficients (U values) for the several components of the building were calculated with different amounts of insulation, using thermal conductivity data and techniques given in the ASHRAE Guide and Data Books.[7,8] Incremental unit costs for insulation are primarily from Means,[11] but adjusted upward at 10% per year to 1971 to reflect escalating costs of materials and labor, and including 25% (as recommended by Means) for overhead and profit. Costs assumed for heating and air conditioning equipment are based on catalog data for furnaces, electric heaters, and air conditioning units; they are intended to reflect the effect of a changed rating on cost and cannot be used to determine the total cost of an installed system. The values of U and the assumed incremental costs are given in Table 4.

F. Calculational Procedure

A computer program was written to permit parametric evaluation of relative energy consumption and net annual cost as functions of insulation systems, climate, and financing situation. The program listing and detailed information on required input are given in Appendix C. In general, the input information includes:

Building dimensions and window orientation

Mortgage and personal investment interest rates

Property tax and insurance rates

Electricity and gas unit costs

U values and their associated incremental costs

Climate data

Table 4. U Values and Assumed Incremental Costs Resulting from Additional Insulation

Component	Insulation	U, Btu/ft^2-hr-°F	Installed Cost, \$/ft^2
Ceiling	None	0.61 (0.44-0.14)[a]	Base
	1-7/8-in glass fiber	0.12 (0.11-0.072)	0.14
	2-1/2-in glass fiber	0.092 (0.087-0.061)	0.155
	3-1/2-in glass fiber	0.068 (0.066-0.050)	0.17
	6-in glass fiber	0.042 (0.041-0.034)	0.23
Wall	None	0.19	Base
	1-7/8-in glass fiber	0.082	0.14
	2-1/2-in glass fiber	0.069	0.155
	3-1/2-in glass fiber	0.055	0.17
Floor	None	0.28	Base
	1-in glass fiber	0.138	0.16
	2-in glass fiber	0.091	0.18
	Foil with air gap	0.093	0.06
Windows	Plain	1.02 + 0.44[b]	Base
	Double glazed, 1/4-in air gap	0.58 + 0.44	1.85
	Storm windows	0.48 + 0.22	1.50

Assumed incremental cost of heating equipment \$1.50 per kBtu/hr.

Assumed incremental cost of air conditioning equipment \$60 per 1/2 ton.

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a. Values in parentheses are for heat flow downward (during cooling). First value is for ceiling; second value includes effect of attic and roof.

b. First value is conduction U; second value is infiltration equivalent U calculated on basis of 3-ft x 5-ft window. Effective U is sum of two.

As many as 4 values each for ceiling, wall, and floor U's may be examined in all combinations in a single run of the program. The choice of whether to include storm windows is made prior to the run. Output information includes, for each combination of insulation, the hourly heating and cooling loads at design conditions, the annual heat loss, and the required air conditioning rating. In addition, differential capital cost, differential annual fixed cost, annual energy cost saving, and total net saving for each combination, using the least-insulation, no-storm-windows, case as the basis for comparison, are provided for gas heat and electric heat, each without and with air conditioning.

The hourly heat loss, hourly heat gain, and annual heat loss are calculated in accordance with the recommendations in the ASHRAE Guide and Data Books.[7,8] A utilization efficiency of 70% was assumed for the gas heating system, and a value of 18.5 was used for the factor C with electric heat. The factor C is an experience factor that takes into account the less-than-theoretical amount of electrical energy required to heat a residence. As used in the calculational procedure, it has units of hr/day, and should have a value of 24 for a 100%-efficient system. Reference 8 attributes the apparently more-than-100% efficiency to overly conservative estimates of heat loss from heavily insulated buildings and cites the probable reduction of infiltration when more insulation is used as a reason for the conservativeness. Better room-to-room control of temperature, with direct and positive response to internal or solar heating inputs, may be another contributing factor. Also, the electrically warmed resident's awareness of the inherently higher unit cost of electrical energy may result in lower consumption.

In calculating the hourly heat loss, an infiltration rate (exclusive of the window infiltration) of 1/2 volume air change per hour was assumed, regardless of the amount of insulation used. This assumed rate is probably too high for the heavily insulated cases, but some artificially induced ventilation may be desirable for comfort and freshness in those cases.

The annual fixed cost due to investment would be quite simple to calculate if credit for income tax deduction were ignored. It would consist of the annual mortgage payment, calculated by using the appropriate capital recovery factor, plus property taxes and insurance. However, since interest on the mortgage and property taxes are normally deductible, this effect should be considered. The method used for determining fixed charge rate is described in Appendix B.

Examination of the FHA-MPS requirements as given in Table 2 and the U values for the building components with various amounts of insulation as given in Table 4 shows that a minimum of 1-7/8 in of insulation is required for the ceiling for gas or non-ceiling electric heat. Therefore, the no-insulation case for the ceiling was not included in the calculations. For reasons already stated, glass fiber insulation for the floor and double glazing for the windows were also not included.

Assumed interest, tax and insurance rates and energy costs are as follows:

Mortgage interest rate, %	7.0
Mortgage lifetime, years	30
Personal interest rate, %	4.5
Property tax rate, %	2.5

Property insurance rate, %	0.4
Income tax bracket, %	25
Resulting fixed charge rate, %	8.99
Cost of gas, $/MBtu	1.00
Cost of electricity, mills/kW-hr	15

An indoor year-round design temperature of 75° was also assumed. The assumed costs of electricity and gas were selected as being fairly representative of those prevailing throughout the country for the portions of the rate schedules that are applicable to space heating and cooling. They are not intended to apply precisely to each of the 3 cities selected for climate data.

A sample calculation depicting the calculational method is included in Appendix B.

III. RESULTS

Complete computer tabular output for the 3 regions is included as Appendix A. For each region, there are 4 sets of tables: a set for each combination of the 2 window treatments and the 2 floor treatments. Within each set, there are 5 tables. The first includes, for each combination of wall and ceiling insulation, the hourly design cooling load, the hourly design heating load, the annual heat loss, and the required air conditioner rating. The remaining 4 tables in each set provide fixed cost, annual energy cost saving, and net annual saving information for all combinations of wall and ceiling insulation for (a) gas heat, (b) gas heat with electric air conditioning, (c) electric heat, and (d) electric heat with electric air conditioning. The savings given in the computer output tables are with reference to the least-insulation, no-storm-window case.

Annual heat losses from the model home for the 3 regions, with uninsulated floor and both with and without storm windows, are shown in Figures A.1-A.3 in Appendix A. Not all of the combinations shown are acceptable under FHA-MPS requirements, however. Under those requirements, only the 3-1/2-in and the 6-in ceiling insulation cases (ceiling U's of 0.066 and 0.041) are acceptable for air conditioning, and the model home, having 1800 ft^2 of floor area, is limited to overall hourly heat losses of 90 kBtu/hr with gas or electric heat, respectively, and to 34.2 kBtu/hr heat gain if air conditioned. For each region and type of heat with or without air conditioning, the combination of insulation that has the lowest capital cost and thermal properties (as given in Appendix A) complying with the MPS requirements was selected as the reference case and used as such for the determination of possible savings. The reference cases are shown in Table 5.

Net annual savings offered by systems having additional insulation, compared to the applicable reference case, were determined and are shown in Figures A.4-A.9 in Appendix A. Foil insulation for the floor proved advantageous in all cases; no bare floor cases are included in the figures. Storm windows also afforded savings in all cases except for Atlanta with gas heat either with or without air conditioning; unless otherwise noted, the figures are based on the use of storm windows. The economically optimum insulation combinations and resulting annual monetary and energy savings are given in Table 6.

Reductions in energy consumption afforded by the various systems, compared to the applicable reference cases, were also determined from the data in Appendix A and are included in Figures A.4-A.9.

Table 5. Reference Insulation System Cases

Region and Type of Heat	Amount of Insulation			
	Windows	Floor	Ceiling	Walls
Atlanta				
Gas heat	P	O	1-7/8	0
Gas heat with A-C	P	O	3-1/2	1-7/8
Electric heat	P	O	1-7/8	0
Electric heat with A-C	P	O	3-1/2	1-7/8
New York				
Gas heat	P	O	1-7/8	0
Gas heat with A-C	P	O	3-1/2	0
Electric heat	P	O	1-7/8	1-7/8
Electric heat with A-C	P	O	3-1/2	1-7/8
Minneapolis				
Gas heat	P	O	3-1/2	1-7/8
Gas heat with A-C	P	O	3-1/2	1-7/8
Electric heat	P	F	6	2-1/2
Electric heat with A-C	P	F	6	2-1/2

P - plain windows

F - foil and air gap

Table 6. Economically Optimum Insulation and Resultant Savings

Region and Type of Heat	Economically Optimum Insulation				Annual Monetary Saving, $/yr	Reduction of Energy Consumption, %	
	Windows	Floor	Ceiling	Walls		Gas	Electricity
Atlanta							
Gas heat	P	F	3-1/2	3-1/2	6	31	-
Gas heat with A-C	P	F	6	3-1/2	6	20	7
Electric heat	SW	F	6	3-1/2	87	-	53
Electric heat with A-C	SW	F	6	3-1/2	63	-	39
New York							
Gas heat	SW	F	3-1/2	3-1/2	32	49	-
Gas heat with A-C	SW	F	6	3-1/2	37	50	26
Electric heat	SW	F	6	3-1/2	155	-	47
Electric heat with A-C	SW	F	6	3-1/2	135	-	42
Minneapolis							
Gas heat	SW	F	6	3-1/2	42	43	-
Gas heat with A-C	SW	F	6	3-1/2	45	43	18
Electric heat	SW	F	6	3-1/2	119	-	29
Electric heat with A-C	SW	F	6	3-1/2	122	-	29

P - plain windows
SW - storm windows
F - foil insulation

IV. DISCUSSION

A. Electrically Heated Homes

The owner of an electrically heated home in each of the 3 regions will realize appreciable monetary savings through the use of maximum insulation (within the range covered by this study) in all components of his home. The only marginally advantageous increase in insulation thickness occurs when going from 3-1/2 in. to 6 in. of insulation in the ceiling of the Atlanta residence. As shown in the upper portion of Figure A.4, however, even that increase is accompanied by a small positive monetary saving. The maximum monetary saving is possible for the New York resident, due to the combination of ample room for improvement beyond the FHA-MPS requirements and the longer and more severe heating season.

Possible energy savings range from approximately 53% for Atlanta downward to 29% for Minneapolis. The reason for the lower potential saving in Minneapolis is that the FHA-MPS requirement for insulation is greater, allowing less room for improvement.

B. Gas-Heated Homes

The monetary savings available to the owner of a gas-heated home in either of the regions is small, compared to those available to the electric home owner, ranging from approximately $6 per year in Atlanta to just over $40 per year in Minneapolis. Storm windows cannot be economically justified in the Atlanta region, and 6-in. ceiling insulation is preferable to 3-1/2-in. insulation only in the Minneapolis region. Wall insulation cannot be justified economically in Atlanta but the justification for it increases with colder climate.

Potential savings in energy consumption (which are accompanied by monetary savings) are greater for the gas-heated home than for the electrically heated home because the FHA-MPS requirements for insulation are lower, allowing more room for improvement. The exception to this is the Atlanta region where, because storm windows cannot be economically justified, the room for improvement is figuratively limited from the top. Maximum economically justified energy savings range from 31% in Atlanta, to 43% in Minneapolis, and 49% in New York.

C. Electrically Heated and Air-Conditioned Homes

The monetary savings available to the owner of an electrically heated and air-conditioned home in the Atlanta and New York regions are somewhat less than those for the non-air-conditioned homes, due to additional insulation in the reference FHA-MPS-compliance homes. This difference exists even though a reduction in energy requirement for air conditioning results because of better insulation. In the Minneapolis region, the reference home has the same insulation either with or without air conditioning, and the saving available to the air-conditioned home owner is slightly greater.

Potential energy savings for the Atlanta and New York homes are somewhat lower for the air-conditoned cases for the same reason. For the Minneapolis home, the potential energy saving is 29%, the same as that for the non-air-conditioned home.

D. Gas Heated and Air Conditioned Homes

The potential monetary saving available to the owner of a gas-heated, electrically air-conditioned home in any of the 3 regions is quite small,

but is maximized in all three cases with the maximum insulation thicknesses in ceiling and walls. As in the non-air-conditioned, gas-heated case, storm windows are not economically justified in the Atlanta region.

Potential energy savings, both in gas for heating and electricity for air conditioning, are appreciable. Gas consumption savings range from approximately 20% in Atlanta to 43% in Minneapolis and 50% in New York. Corresponding electrical consumption savings in the 3 regions are 7%, 18%, and 26%.

E. Effects of Increased Cost of Insulation or Energy

In order to determine the sensitivity of the monetary and energy savings resulting from the use of the economically optimum amount of insulation, computer runs were made with the capital cost of the insulation or the costs of gas and electricity increased by 33%. The results are summarized in Table 7.

An increase in the capital cost of insulation tends to reduce the optimum amount of insulation and the potential savings in annual cost and energy consumption, particularly in the warmer climates and with the cheaper energy source (gas). However, positive savings are still possible in all regions when the cost of insulation is increased by as much as one-third.

An increase in the cost of energy tends to increase the optimum amount of insulation. This effect is somewhat masked in comparing Tables 6 and 7 because the maximum amount of insulation included in the range of this study is economically justified in so many of the cases with the normal energy costs. As energy costs increase to reflect the costs of

pollution abatement and other social costs, more efficient (and more costly) insulation systems will become increasingly justified from the economic standpoint.

V. SUMMARY AND CONCLUSIONS

Appreciable monetary savings accrue to the owner of an electrically heated home, with or without air conditioning, when the insulation of this home exceeds the requirements of the FHA Minimum Property Standards. The economically optimum amount of insulation is in excess of 3-1/2 in. of glass fiber material in the walls and 6 in. in the ceiling. Storm windows and foil insulation for the floor are justified.

Potential monetary savings for the owner of a gas-heated home through use of additional insulation are quite small compared to those available to the owner of an electrically heated home, but are generally positive. A ceiling insulation thickness of 6 in. is justified only in the northern region or when air-conditioning is included. Storm windows are not economically justifiable in the southern region.

Energy conservation and economic optimizations of the amount of insulation to be installed in a residence generally do not conflict within the range of insulation treatment included in this study. Exceptions are with gas heat in the southern region where neither storm windows nor 6-in. ceiling insulation is justified, and in the central region where 6-in. ceiling insulation is not justified.

In the interest of conserving the nation's energy resources, the FHA Minimum Property Standards should be upgraded to require the use of more insulation, particularly in non-electrically heated homes. If

Table 7. Economically Optimum Insulation and Resultant Savings with Increased Insulation or Energy Costs

Region and Comfort System	Insul. Cost x 1.33							Energy Cost x 1.33						
	Windows	Floor	Ceiling	Walls	Annual Saving, $	Gas Consumption Reduction, %	Electricity Cons. Reduction, %	Windows	Floor	Ceiling	Walls	Annual Saving, $	Gas Consumption Reduction, %	Electricity Cons. Reduction, %
Atlanta														
Gas Heat	P	O	3-1/2"	0"	2	6	-	P	F	3-1/2"	3-1/2"	18	31	-
Gas Heat + A-C	P	O	3-1/2"	3-1/2"	1	4	3	SW	F	3-1/2"	3-1/2"	15	38	14
Electric Heat	SW	F	3-1/2"	3-1/2"	63	-	49	SW	F	6"	3-1/2"	131	-	53
Electric Heat + A-C	SW	F	6"	3-1/2"	44	-	39	SW	F	6"	3-1/2"	94	-	39
New York														
Gas Heat	P	F	3-1/2"	3-1/2"	20	32	-	SW	F	3-1/2"	3-1/2"	64	49	-
Gas Heat + A-C	P	F	3-1/2"	3-1/2"	22	27	12	SW	F	6"	3-1/2"	69	50	26
Electric Heat	SW	F	6"	3-1/2"	134	-	47	SW	F	6"	3-1/2"	218	-	47
Electric Heat + A-C	SW	F	6"	3-1/2"	116	-	42	SW	F	6"	3-1/2"	189	-	42
Minneapolis														
Gas Heat	SW	F	3-1/2"	3-1/2"	25	38	-	SW	F	6"	3-1/2"	73	43	-
Gas Heat + A-C	SW	F	3-1/2"	3-1/2"	28	38	14	SW	F	6"	3-1/2"	77	43	18
Electric Heat	SW	F	6"	3-1/2"	107	-	29	SW	F	6"	3-1/2"	165	-	29
Electric Heat + A-C	SW	F	6"	3-1/2"	109	-	29	SW	F	6"	3-1/2"	168	-	29

this upgrading would include provision for regional variations, the homeowner would actually realize a small but positive economic advantage, and the energy needed for space heating would be reduced by 40-50% in the regions having more severe heating seasons and therefore heavier fuel consumption.

In the interest of conserving fuel and of providing the homeowner with marked savings in operating cost, the FHA-MPS requirements for insulation in electrically heated homes should also be increased. Net annual savings of 25-38% of the annual electrical cost of heating the MPS-compliance home will accrue to the homeowner if maximum insulation is specified.

Upgrading of the requirements should be urgently pursued. After several years of lagging home construction activity, the pent-up demand for new housing is high, and an upswing in new housing starts has been predicted and may be underway. Much of the new housing is aimed at the low income market, via Federal rent and purchace-financing subsidies. It is this segment of the population that will benefit most from reduced operating costs.

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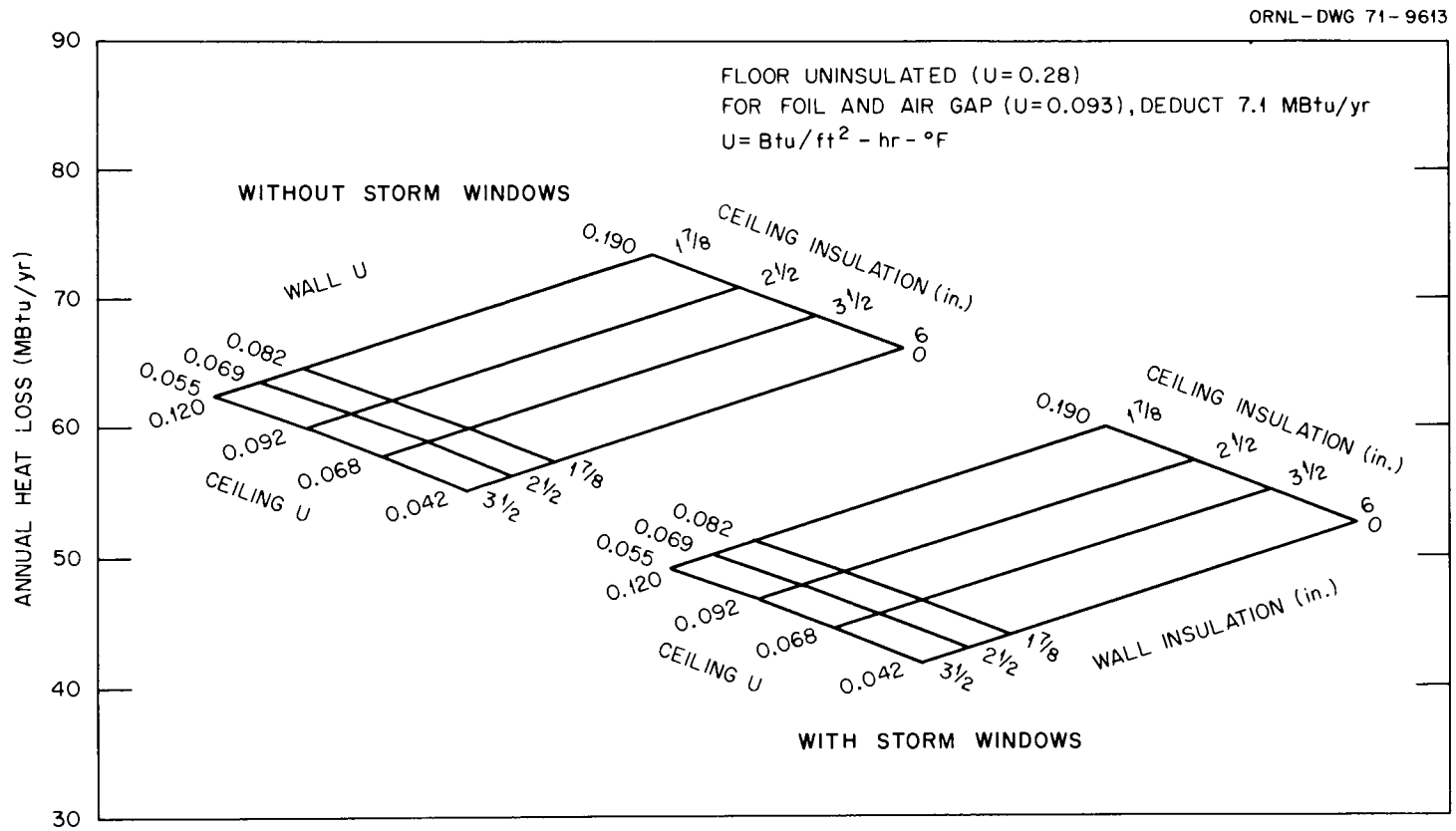
APPENDIX A

COMPUTER OUTPUT TABLES

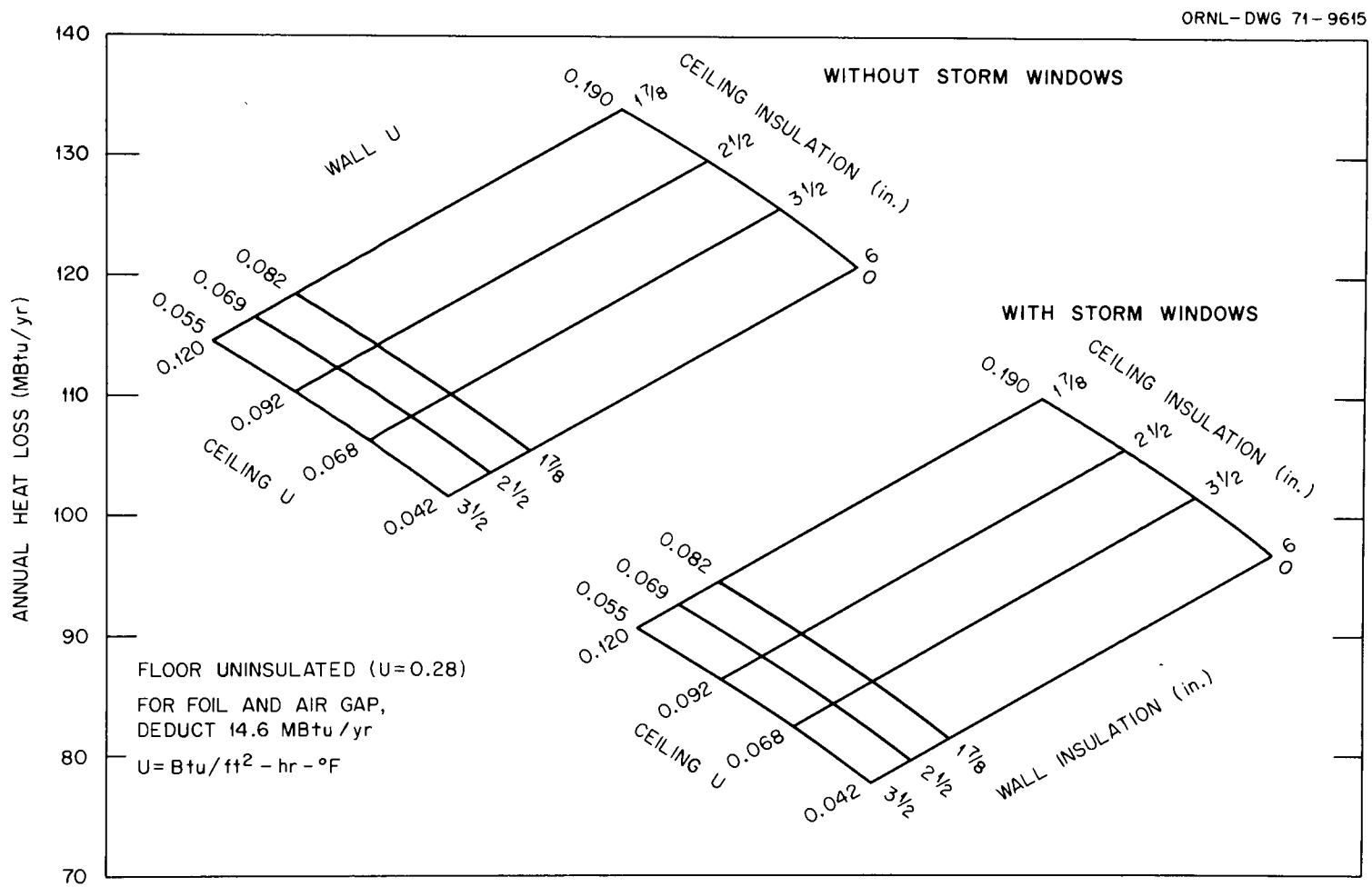
AND

ANNUAL COST AND ENERGY SAVINGS



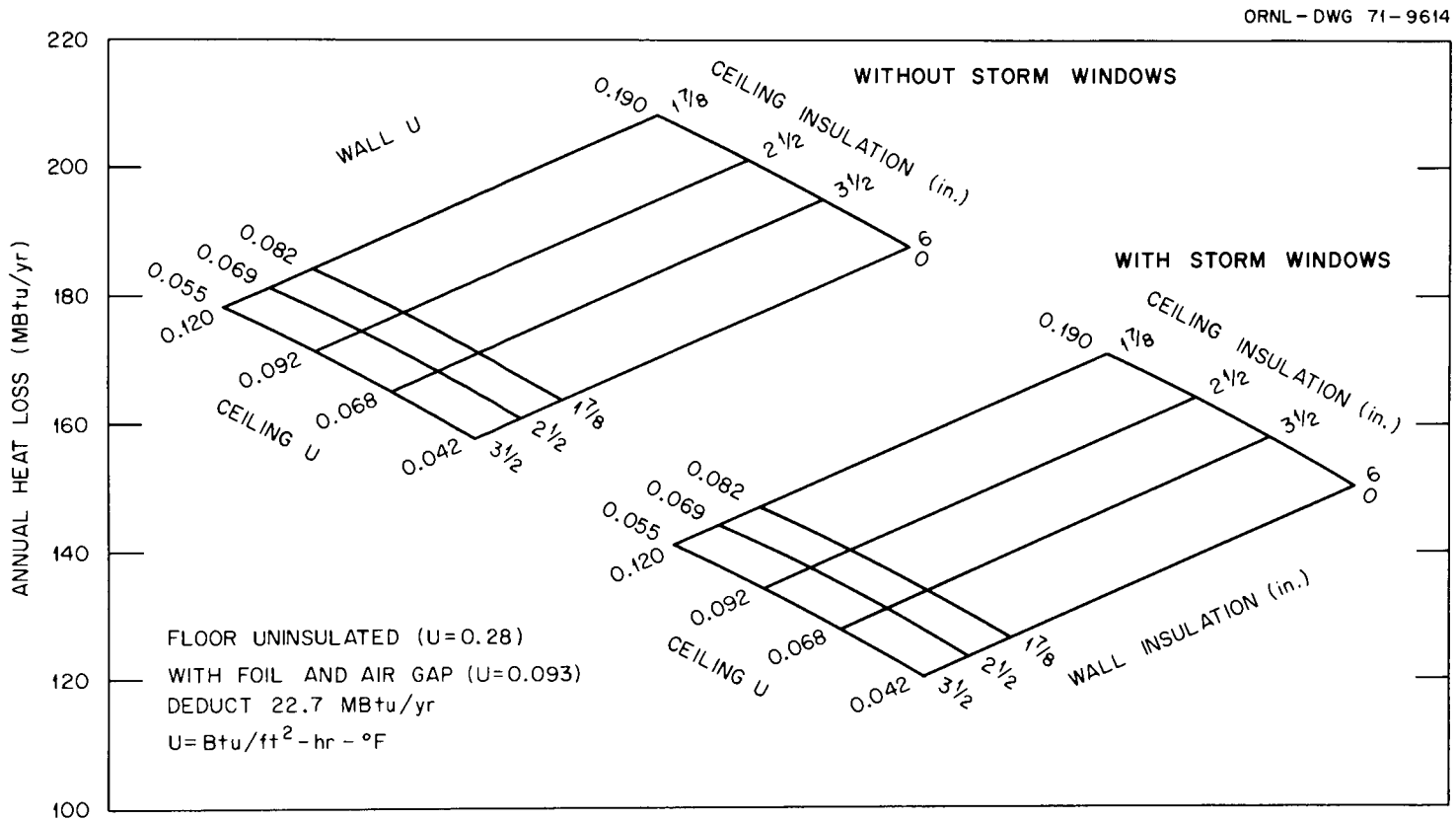
Annual Heat Loss: Atlanta Residence.

Fig. A.1



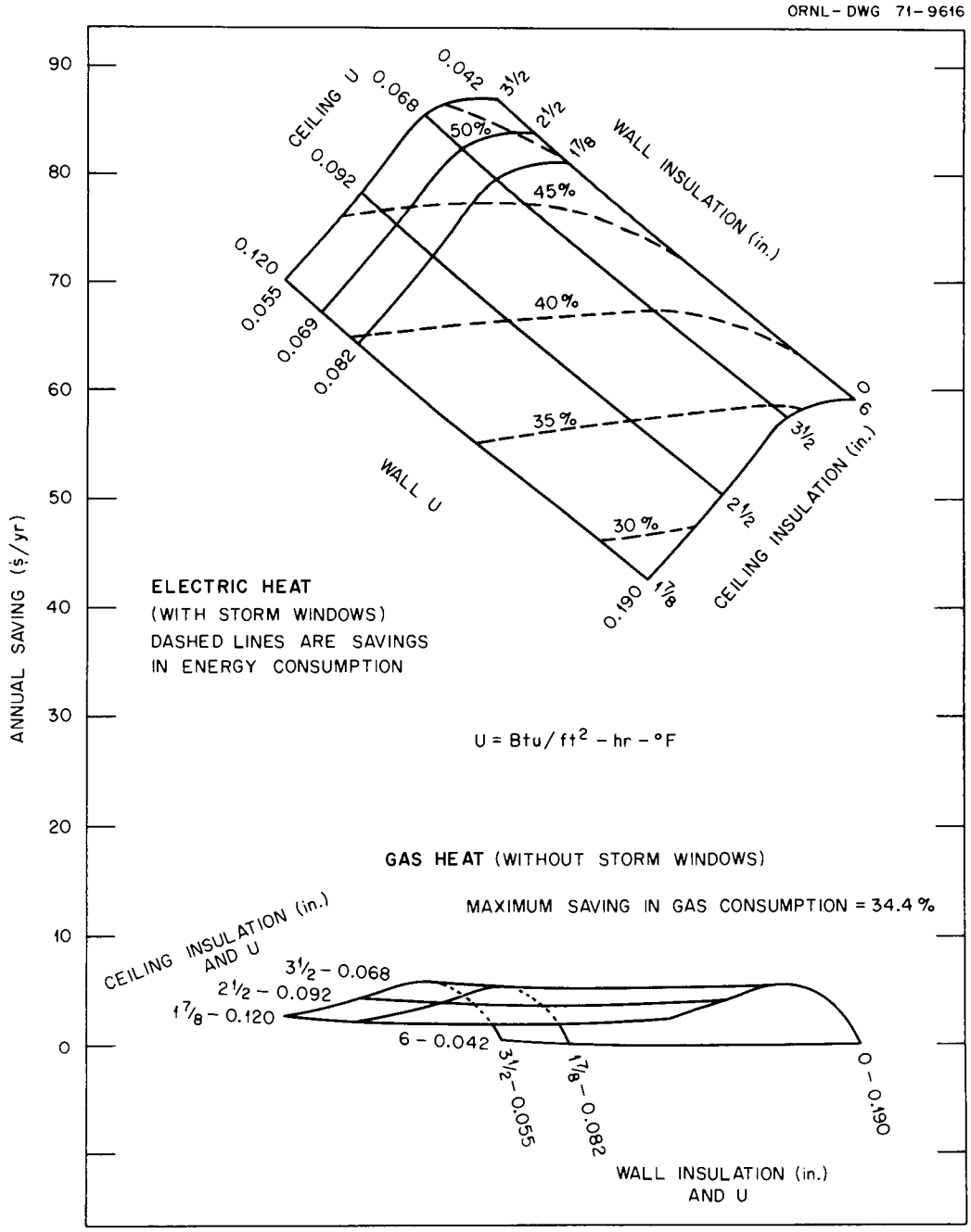
Annual Heat Loss : New York Residence .

Fig. A.2



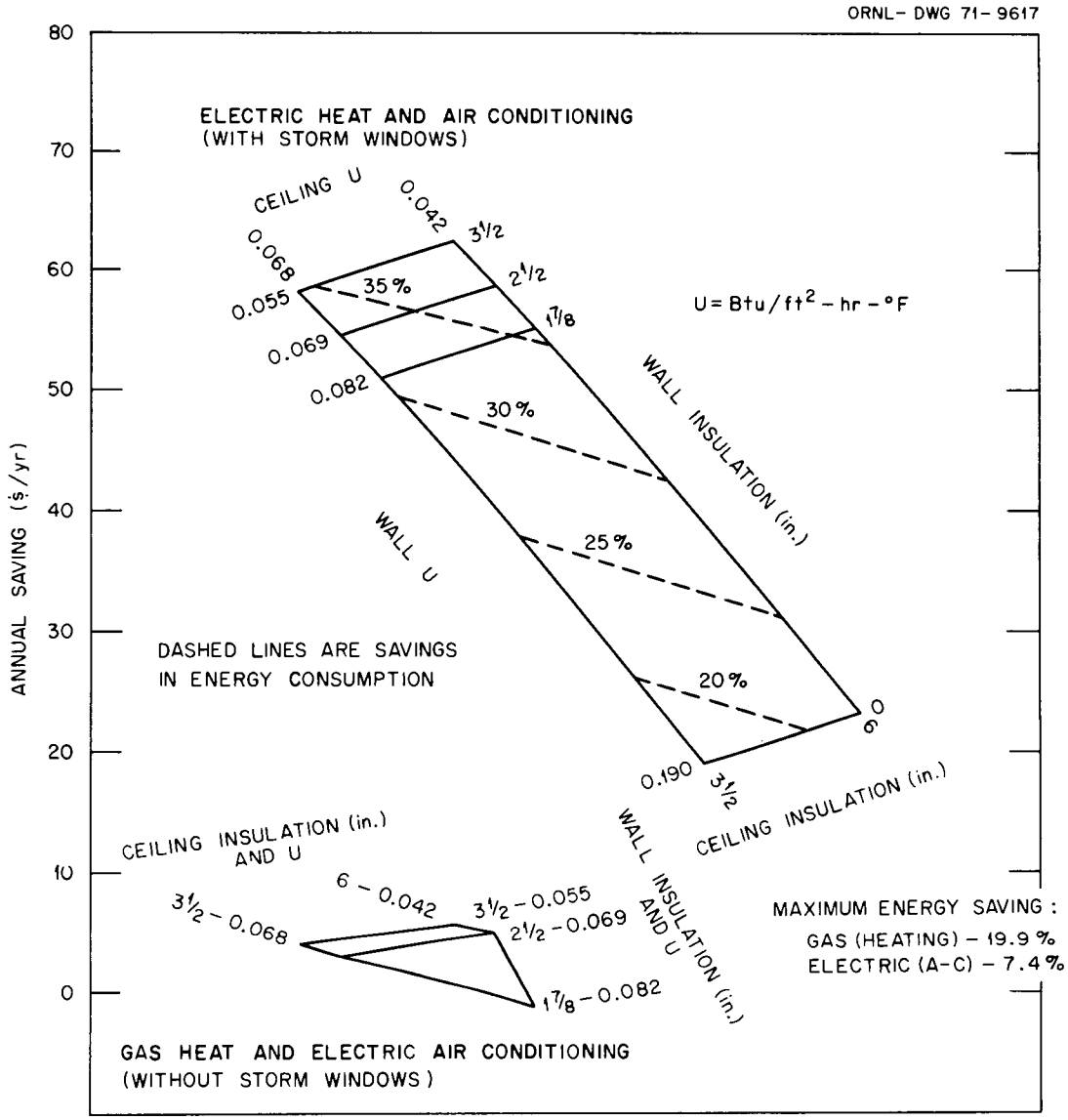
Annual Heat Loss: Minneapolis Residence.

Fig. A.3



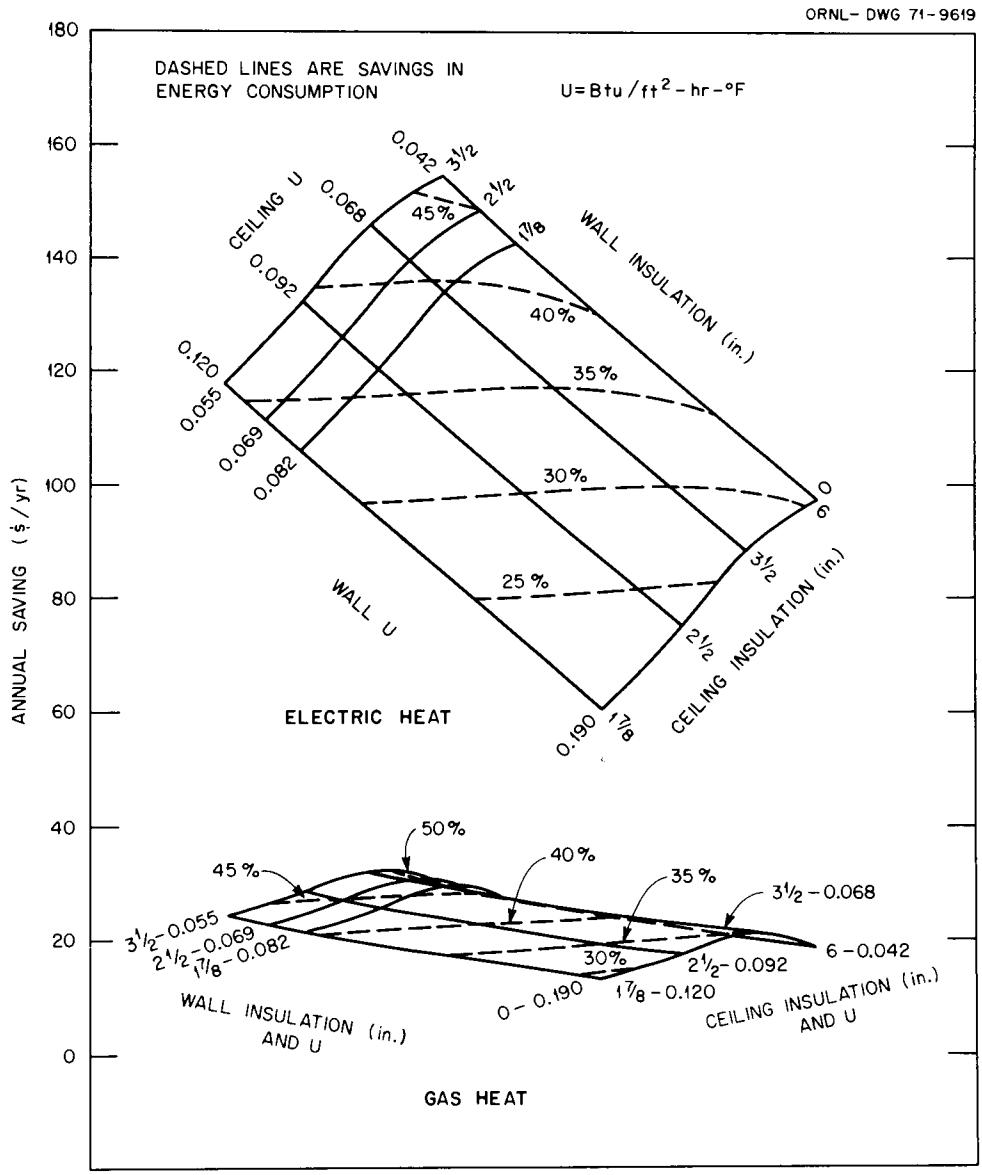
Annual Saving Due to Insulation, Atlanta Residence - Heating Only.

Fig. A.4



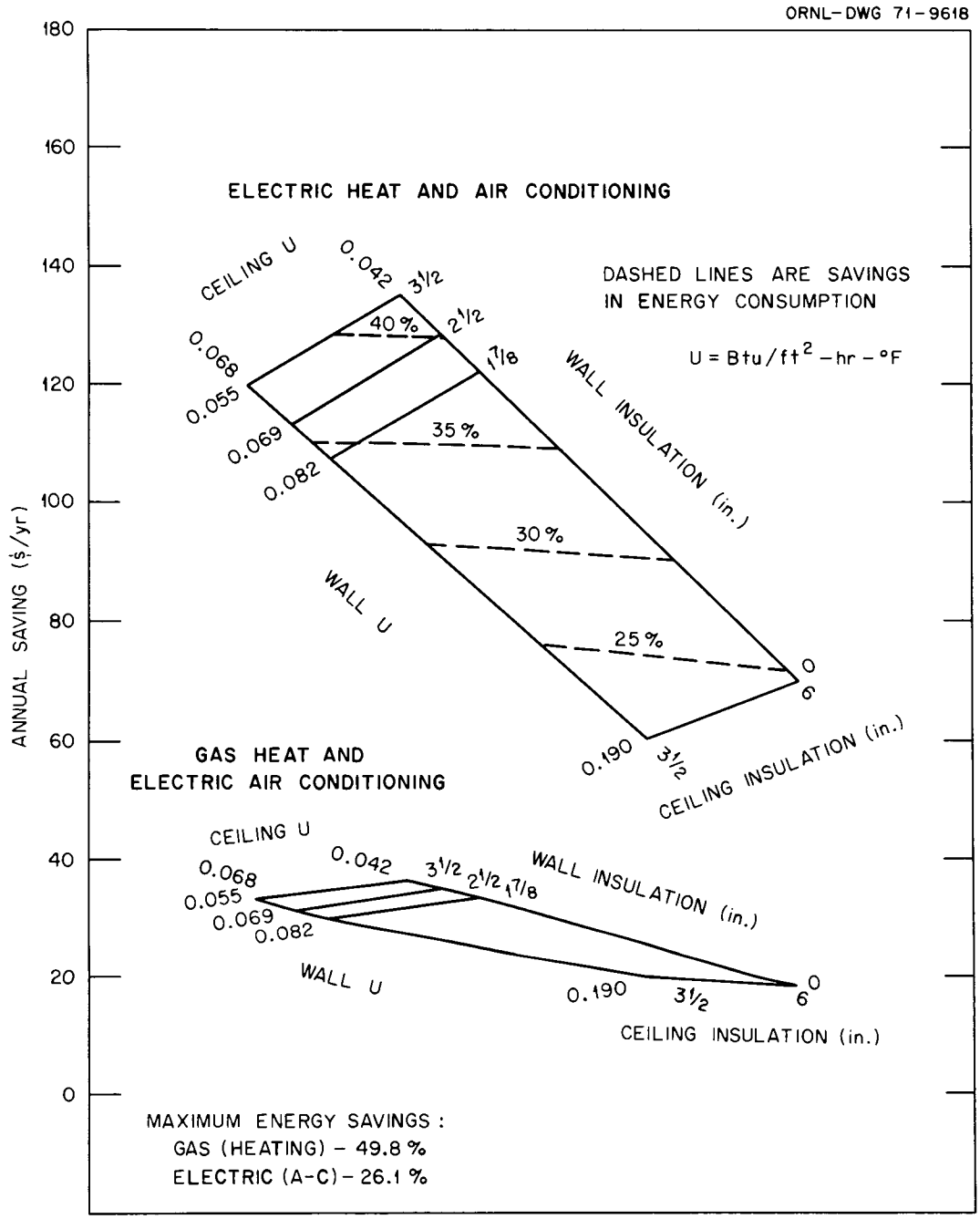
Annual Saving Due to Insulation, Atlanta Residence – Heating and Air Conditioning.

Fig. A.5



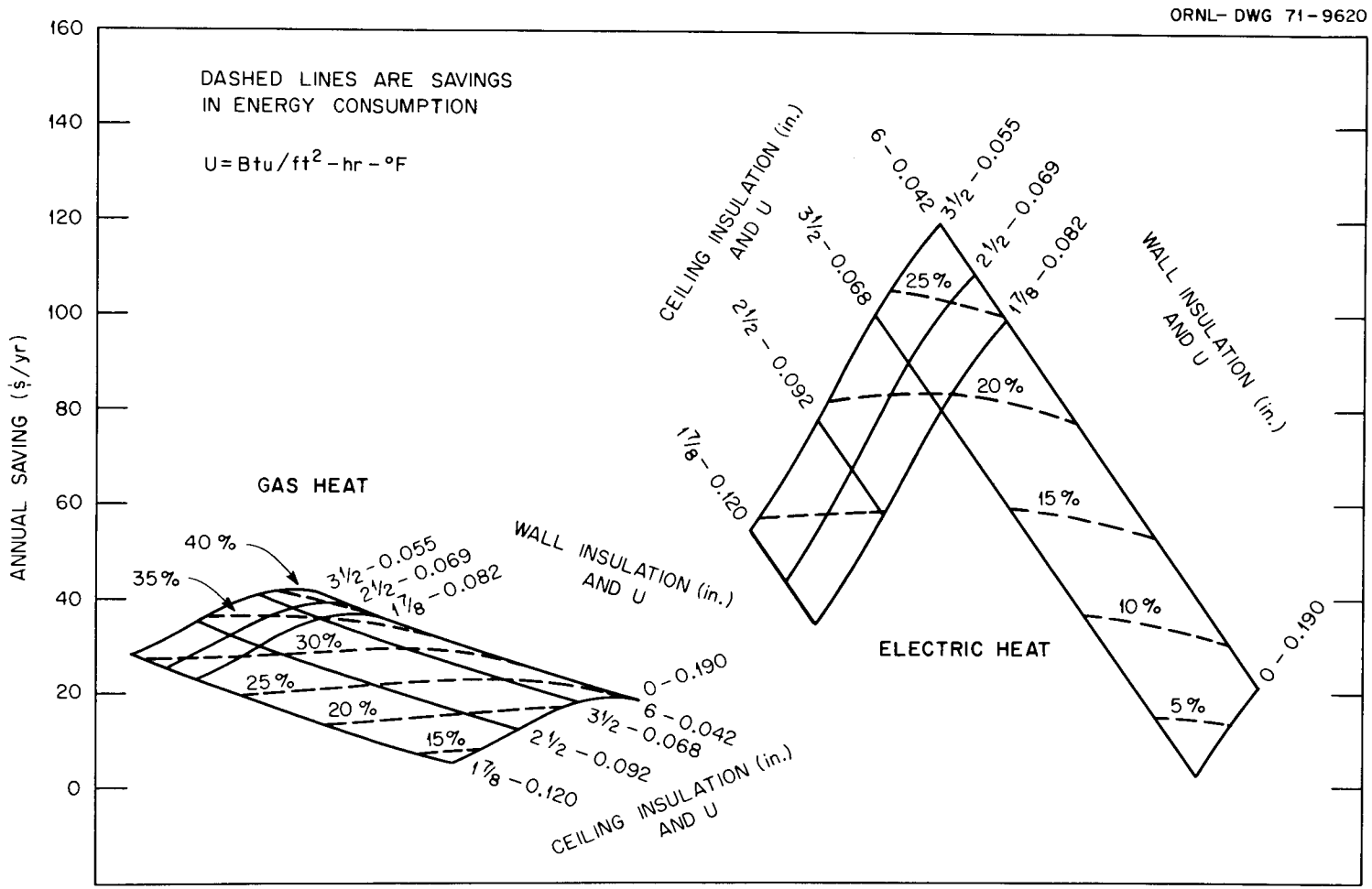
Annual Savings Due to Insulation and Storm Windows, New York Residence – Heating Only.

Fig. A.6



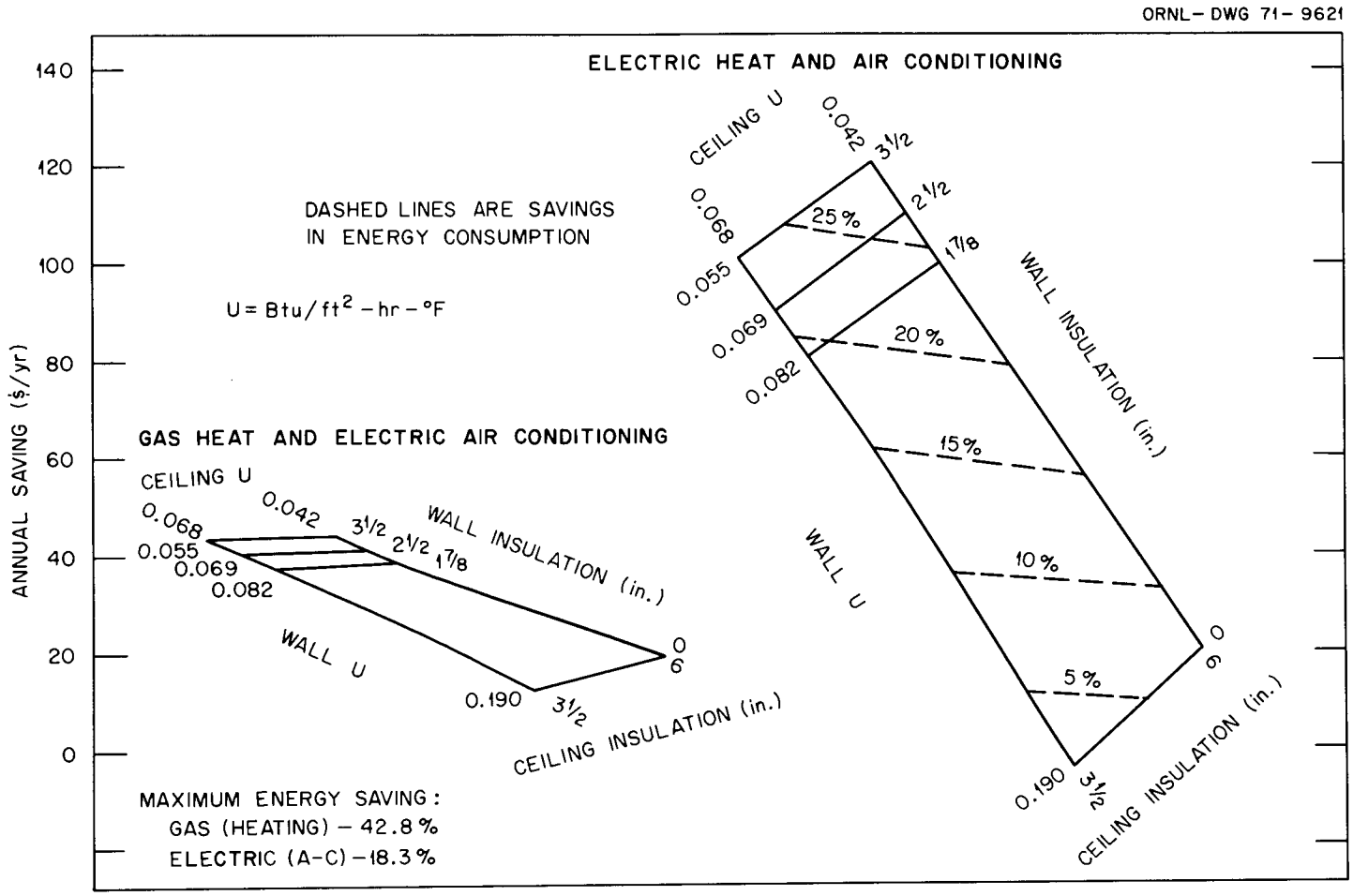
Annual Saving Due to Insulation and Storm Windows, New York Residence - Heating and Air Conditioning.

Fig. A.7



Annual Savings Due to Insulation and Storm Windows, Minneapolis Residence – Heating Only.

Fig. A.8



Annual Saving Due to Insulation and Storm Windows, Minneapolis Residence - Heating and Air Conditioning.

Fig. A.9

THERMAL AND ECONOMIC EVALUATION OF ADDITIONAL INSULATION

REGION IS ATLANTA
MORTGAGE RATE = 0.070
MILLS/KW-HR = 15.0

WITHOUT STORM WINDOWS
PERSONAL RATE = 0.045
GAS $/MBTU = 1.00

FIXED COST COEFFICIENT = 0.08990

PAGE 2 ATLANTA

* * * FOR A FLOOR U OF 0.280 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	37.27 69.33 73472.00 3.50	33.36 61.17 64828.53 3.00	32.89 60.19 63788.13 3.00	32.38 59.13 62667.67 3.00
0.092	36.34 67.02 71022.19 3.50	32.43 58.86 62378.80 3.00	31.96 57.88 61338.38 3.00	31.45 56.82 60217.92 3.00
0.068	35.41 64.88 68755.00 3.00	31.50 56.72 60111.55 3.00	31.03 55.74 59071.13 3.00	30.53 54.68 57950.69 3.00
0.042	34.07 62.38 66102.69 3.00	30.16 54.22 57459.20 3.00	29.69 53.24 56418.78 2.50	29.18 52.18 55298.33 2.50

PAGE 3 ATLANTA WITH FLR U OF 0.280

GAS HEAT - ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	152.97	169.19	185.31
	0.0	13.75	15.21	16.66
	0.0	13.58	15.22	16.98
	0.0	-0.17	0.01	0.32
0.092	23.53	176.50	192.73	208.84
	2.12	15.87	17.33	18.77
	3.85	17.43	19.07	20.83
	1.73	1.56	1.74	2.05
0.068	47.32	200.29	216.52	232.63
	4.25	18.01	19.46	20.91
	7.41	20.99	22.63	24.39
	3.16	2.99	3.17	3.48
0.042	151.57	304.53	320.76	336.88
	13.63	27.38	28.84	30.29
	11.58	25.16	26.80	28.56
	-2.05	-2.21	-2.04	-1.73

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	92.97	109.19	125.31
	0.0	8.36	9.82	11.27
	0.0	4.88	5.46	6.09
	0.0	10.10	10.86	11.81
0.092	23.53	116.50	132.73	148.84
	2.12	10.47	11.93	13.38
	1.16	6.03	6.62	7.25
	2.89	12.99	13.75	14.70
0.068	-12.68	140.29	156.52	172.63
	-1.14	12.61	14.07	15.52
	2.31	7.19	7.77	8.40
	10.86	15.57	16.33	17.28
0.042	91.57	244.53	200.76	216.88
	8.23	21.98	18.05	19.50
	3.99	8.87	9.45	10.09
	7.34	12.05	18.20	19.15

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ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	82.01	89.69	96.61
	0.0	7.37	8.06	8.69
	0.0	29.28	32.81	36.60
	0.0	21.91	24.74	27.92
0.092	3.42	85.43	93.11	100.03
	0.31	7.68	8.37	8.99
	8.30	37.58	41.11	44.90
	7.99	29.90	32.74	35.91
0.068	8.60	90.61	98.29	105.21
	0.77	8.15	8.84	9.46
	15.98	45.26	48.79	52.58
	15.21	37.12	39.95	43.12
0.042	91.07	173.08	180.76	187.68
	8.19	15.56	16.25	16.87
	24.97	54.25	57.77	61.57
	16.78	38.69	41.52	44.70

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	22.01	29.69	36.61
	0.0	1.98	2.67	3.29
	0.0	4.88	5.46	6.09
	0.0	32.18	35.60	39.41
0.092	3.42	25.43	33.11	40.03
	0.31	2.29	2.98	3.60
	1.16	6.03	6.62	7.25
	9.15	41.33	44.75	48.55
0.068	-51.40	30.61	38.29	45.21
	-4.62	2.75	3.44	4.06
	2.31	7.19	7.77	8.40
	22.91	49.70	53.12	56.92
0.042	31.07	113.08	60.76	67.68
	2.79	10.17	5.46	6.08
	3.99	8.87	9.45	10.09
	26.16	52.95	61.76	65.57

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* * * FOR A FLOOR U OF 0.093 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	37.27 62.60 66337.75 3.50	33.36 54.44 57694.31 3.00	32.89 53.46 56653.89 3.00	32.38 52.40 55533.44 3.00
0.092	36.34 60.29 63888.06 3.50	32.43 52.13 55244.58 3.00	31.96 51.15 54204.14 3.00	31.45 50.09 53083.69 3.00
0.068	35.41 58.15 61620.80 3.00	31.50 49.99 52977.31 3.00	31.03 49.01 51936.89 3.00	30.53 47.95 50816.45 3.00
0.042	34.07 55.64 58968.45 3.00	30.16 47.49 50324.95 3.00	29.69 46.51 49284.55 2.50	29.18 45.45 48164.09 2.50

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GAS HEAT - ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF.	FIXED COST/FUEL	SAVING/NET	SAVING
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	97.90	250.87	267.09	283.21
	8.80	22.55	24.01	25.46
	11.21	24.79	26.43	28.19
	2.41	2.24	2.42	2.73
0.092	121.43	274.40	290.63	306.74
	10.92	24.67	26.13	27.58
	15.06	28.64	30.28	32.04
	4.14	3.97	4.15	4.46
0.068	145.23	298.19	314.42	330.53
	13.06	26.81	28.27	29.71
	18.62	32.21	33.84	35.60
	5.57	5.40	5.57	5.89
0.042	249.47	402.44	418.66	434.78
	22.43	36.18	37.64	39.09
	22.79	36.37	38.01	39.77
	0.36	0.19	0.37	0.68

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF.	FIXED COST/ELEC	SAVING/NET	SAVING
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	97.90	190.87	207.09	223.21
	8.80	17.16	18.62	20.07
	0.0	4.88	5.46	6.09
	2.41	12.51	13.27	14.22
0.092	121.43	214.40	230.63	246.74
	10.92	19.27	20.73	22.18
	1.16	6.03	6.62	7.25
	5.30	15.40	16.16	17.11
0.068	85.23	238.19	254.42	270.53
	7.66	21.41	22.87	24.32
	2.31	7.19	7.77	8.40
	13.27	17.98	18.74	19.69
0.042	189.47	342.44	298.66	314.78
	17.03	30.79	26.85	28.30
	3.99	8.87	9.45	10.09
	9.75	14.46	20.61	21.56

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ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	39.33	121.34	129.03	135.94
	3.54	10.91	11.60	12.22
	24.17	53.45	56.98	60.77
	20.63	42.54	45.38	48.55
0.092	42.76	124.76	132.45	139.36
	3.84	11.22	11.91	12.53
	32.47	61.75	65.28	69.07
	28.62	50.53	53.37	56.54
0.068	47.93	129.94	137.63	144.54
	4.31	11.68	12.37	12.99
	40.15	69.43	72.96	76.75
	35.84	57.75	60.58	63.76
0.042	130.40	212.41	220.10	227.01
	11.72	19.10	19.79	20.41
	49.13	78.42	81.94	85.74
	37.41	59.32	62.16	65.33

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	39.33	61.34	69.03	75.94
	3.54	5.51	6.21	6.83
	0.0	4.88	5.46	6.09
	20.63	52.81	56.23	60.04
0.092	42.76	64.76	72.45	79.36
	3.84	5.82	6.51	7.13
	1.16	6.03	6.62	7.25
	29.78	61.96	65.38	69.19
0.068	-12.07	69.94	77.63	84.54
	-1.08	6.29	6.98	7.60
	2.31	7.19	7.77	8.40
	43.54	70.33	73.75	77.56
0.042	70.40	152.41	100.10	107.01
	6.33	13.70	9.00	9.62
	3.99	8.87	9.45	10.09
	46.80	73.58	82.40	86.20

THERMAL AND ECONOMIC EVALUATION OF ADDITIONAL INSULATION

REGION IS ATLANTA
MORTGAGE RATE = 0.070
MILLS/KW-HR = 15.0

WITH STORM WINDOWS
PERSONAL RATE = 0.045
GAS $/MBTU = 1.00

FIXED COST COEFFICIENT = 0.08990

PAGE 2 ATLANTA

* * * FOR A FLOOR U OF 0.280 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	33.77 56.68 60070.02 3.00	29.86 48.53 51426.53 2.50	29.39 47.55 50386.13 2.50	28.88 46.49 49265.67 2.50
0.092	32.84 54.37 57620.28 3.00	28.93 46.22 48976.80 2.50	28.46 45.23 47936.38 2.50	27.96 44.18 46815.92 2.50
0.068	31.92 52.23 55353.05 3.00	28.01 44.08 46709.55 2.50	27.54 43.09 45669.13 2.50	27.03 42.04 44548.69 2.50
0.042	30.57 49.73 52700.69 3.00	26.66 41.57 44057.19 2.50	26.19 40.59 43016.77 2.50	25.68 39.53 41896.31 2.50

PAGE 3 ATLANTA WITH FLR U OF 0.280

GAS HEAT - ANNUAL COSTS AND SAVINGS

WALL U / CEIL U	DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING			
	0.190	0.082	0.069	0.055
0.120	371.03	524.00	540.22	556.34
	33.36	47.11	48.57	50.01
	21.06	34.64	36.28	38.04
	-12.30	-12.46	-12.29	-11.98
0.092	394.56	547.53	563.76	579.87
	35.47	49.22	50.68	52.13
	24.91	38.49	40.13	41.89
	-10.56	-10.73	-10.55	-10.24
0.068	418.35	571.32	587.55	603.66
	37.61	51.36	52.82	54.27
	28.47	42.06	43.69	45.45
	-9.14	-9.31	-9.13	-8.82
0.042	522.60	675.56	691.79	707.91
	46.98	60.73	62.19	63.64
	32.64	46.22	47.86	49.62
	-14.34	-14.51	-14.33	-14.02

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

WALL U / CEIL U	DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING			
	0.190	0.082	0.069	0.055
0.120	311.03	404.00	420.22	436.34
	27.96	36.32	37.78	39.23
	4.36	9.24	9.82	10.45
	-2.54	7.56	8.32	9.27
0.092	334.56	427.53	443.76	459.87
	30.08	38.43	39.89	41.34
	5.52	10.39	10.98	11.61
	0.35	10.45	11.21	12.16
0.068	358.35	451.32	467.55	483.66
	32.22	40.57	42.03	43.48
	6.67	11.55	12.13	12.76
	2.93	13.03	13.79	14.73
0.042	462.60	555.56	571.79	587.91
	41.59	49.95	51.40	52.85
	8.35	13.23	13.81	14.45
	-0.60	9.50	10.27	11.21

PAGE 4 ATLANTA WITH FLR U OF 0.280

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	261.01	343.01	350.70	357.62
	23.46	30.84	31.53	32.15
	45.40	74.69	78.21	82.01
	21.94	43.85	46.68	49.86
0.092	264.43	346.44	354.12	361.04
	23.77	31.14	31.84	32.46
	53.70	82.98	86.51	90.30
	29.93	51.84	54.67	57.85
0.068	269.61	351.61	359.30	366.22
	24.24	31.61	32.30	32.92
	61.38	90.67	94.19	97.99
	37.15	59.06	61.89	65.06
0.042	352.08	434.08	441.77	448.69
	31.65	39.02	39.72	40.34
	70.37	99.65	103.18	106.97
	38.72	60.63	63.46	66.63

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	201.01	223.01	230.70	237.62
	18.07	20.05	20.74	21.36
	4.36	9.24	9.82	10.45
	31.69	63.87	67.29	71.10
0.092	204.43	226.44	234.12	241.04
	18.38	20.36	21.05	21.67
	5.52	10.39	10.98	11.61
	40.84	73.02	76.44	80.25
0.068	209.61	231.61	239.30	246.22
	18.84	20.82	21.51	22.13
	6.67	11.55	12.13	12.76
	49.21	81.39	84.81	88.62
0.042	292.08	314.08	321.77	328.69
	26.26	28.24	28.93	29.55
	8.35	13.23	13.81	14.45
	52.46	84.64	88.06	91.87

PAGE 5 ATLANTA

* * * FOR A FLOOR U OF 0.093 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	33.77 49.95 52935.80 3.00	29.86 41.80 44292.30 2.50	29.39 40.81 43251.88 2.50	28.88 39.76 42131.44 2.50
0.092	32.84 47.64 50486.06 3.00	28.93 39.48 41842.56 2.50	28.46 38.50 40802.14 2.50	27.96 37.44 39681.69 2.50
0.068	31.92 45.50 48218.81 3.00	28.01 37.34 39575.33 2.50	27.54 36.36 38534.89 2.50	27.03 35.30 37414.44 2.50
0.042	30.57 43.00 45566.44 3.00	26.66 34.84 36922.95 2.50	26.19 33.86 35882.55 2.50	25.68 32.80 34762.09 2.50

PAGE 6 ATLANTA WITH FLR U OF 0.093

GAS HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	468.93	621.90	638.13	654.24
	42.16	55.91	57.37	58.82
	32.27	45.85	47.49	49.25
	-9.89	-10.05	-9.88	-9.57
0.092	492.46	645.43	661.66	677.77
	44.27	58.02	59.48	60.93
	36.12	49.70	51.34	53.10
	-8.15	-8.32	-8.14	-7.83
0.068	516.26	669.22	685.45	701.56
	46.41	60.16	61.62	63.07
	39.68	53.27	54.90	56.66
	-6.73	-6.90	-6.72	-6.41
0.042	620.50	773.47	789.69	805.81
	55.78	69.53	70.99	72.44
	43.85	57.43	59.07	60.83
	-11.93	-12.10	-11.92	-11.61

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	408.93	501.90	518.13	534.24
	36.76	45.12	46.56	48.03
	4.36	9.24	9.82	10.45
	-0.13	9.97	10.73	11.68
0.092	432.46	525.43	541.66	557.77
	38.88	47.24	48.70	50.14
	5.52	10.39	10.98	11.61
	2.76	12.86	13.62	14.56
0.068	456.26	549.22	565.45	581.56
	41.02	49.38	50.83	52.28
	6.67	11.55	12.13	12.76
	5.34	15.44	16.20	17.14
0.042	560.50	653.47	669.69	685.81
	50.39	58.75	60.21	61.65
	8.35	13.23	13.81	14.45
	1.81	11.91	12.68	13.62

PAGE 7 ATLANTA WITH FLR U OF 0.093

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	300.34	382.35	390.03	396.95
	27.00	34.37	35.06	35.69
	69.57	98.85	102.38	106.17
	42.57	64.48	67.32	70.49
0.092	303.76	385.77	393.46	400.37
	27.31	34.68	35.37	35.99
	77.87	107.15	110.68	114.47
	50.56	72.47	75.31	78.48
0.068	308.94	390.95	398.63	405.55
	27.77	35.15	35.84	36.46
	85.55	114.83	118.36	122.16
	57.78	79.69	82.52	85.70
0.042	391.41	473.42	481.10	488.02
	35.19	42.56	43.25	43.87
	94.54	123.82	127.34	131.14
	59.35	81.26	84.09	87.27

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	240.34	262.35	270.03	276.95
	21.61	23.59	24.28	24.90
	4.36	9.24	9.82	10.45
	52.33	84.50	87.93	91.73
0.092	243.76	265.77	273.46	280.37
	21.91	23.89	24.58	25.21
	5.52	10.39	10.98	11.61
	61.47	93.65	97.07	100.88
0.068	248.94	270.95	278.63	285.55
	22.38	24.36	25.05	25.67
	6.67	11.55	12.13	12.76
	69.84	102.02	105.44	109.25
0.042	331.41	353.42	361.10	368.02
	29.79	31.77	32.46	33.09
	8.35	13.23	13.81	14.45
	73.10	105.27	108.70	112.50

THERMAL AND ECONOMIC EVALUATION OF ADDITIONAL INSULATION

REGION IS NEW YORK
MORTGAGE RATE = 0.070
MILLS/KW-HR = 15.0

WITHOUT STORM WINDOWS
PERSONAL RATE = 0.045
GAS $/MBTU = 1.00

FIXED COST COEFFICIENT = 0.08990

PAGE 2 NEW YORK

* * * FOR A FLOOR U OF 0.280 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	32.87	29.78	29.41	29.01
	77.40	68.48	67.41	66.25
	134019.75	118574.13	116714.88	114712.69
	3.00	2.50	2.50	2.50
0.092	32.07	28.99	28.62	28.22
	74.88	65.96	64.88	63.72
	129642.19	114196.44	112337.31	110335.13
	3.00	2.50	2.50	2.50
0.068	31.27	28.19	27.82	27.42
	72.54	63.62	62.54	61.38
	125590.63	110145.00	108285.81	106283.56
	3.00	2.50	2.50	2.50
0.042	30.11	27.03	26.66	26.26
	69.80	60.88	59.80	58.65
	120850.94	105405.31	103546.06	101543.88
	3.00	2.50	2.50	2.50

PAGE 3 NEW YORK WITH FLR U OF 0.280

GAS HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	151.82	167.91	183.87
	0.0	13.65	15.09	16.53
	0.0	22.07	24.72	27.58
	0.0	8.42	9.63	11.05
0.092	23.21	175.03	191.12	207.08
	2.09	15.73	17.18	18.62
	6.25	28.32	30.97	33.84
	4.17	12.58	13.79	15.22
0.068	46.70	198.52	214.61	230.57
	4.20	17.85	19.29	20.73
	12.04	34.11	36.76	39.62
	7.84	16.26	17.47	18.89
0.042	150.59	302.41	318.50	334.46
	13.54	27.19	28.63	30.07
	18.81	40.88	43.53	46.39
	5.27	13.69	14.90	16.33

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	91.82	107.91	123.87
	0.0	8.25	9.70	11.14
	0.0	1.79	2.01	2.24
	0.0	15.60	17.03	18.69
0.092	23.21	115.03	131.12	147.08
	2.09	10.34	11.79	13.22
	0.46	2.26	2.47	2.71
	4.63	20.24	21.66	23.32
0.068	46.70	138.52	154.61	170.57
	4.20	12.45	13.90	15.33
	0.93	2.72	2.94	3.17
	8.77	24.38	25.80	27.46
0.042	150.59	242.41	258.50	274.46
	13.54	21.79	23.24	24.67
	1.60	3.40	3.61	3.85
	6.88	22.48	23.91	25.56

PAGE 4 NEW YORK WITH FLR U OF 0.280

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	74.21	80.96	86.86
	0.0	6.67	7.28	7.81
	0.0	52.33	58.63	65.41
	0.0	45.66	51.35	57.60
0.092	1.21	75.42	82.17	88.07
	0.11	6.78	7.39	7.92
	14.83	67.16	73.46	80.24
	14.72	60.38	66.07	72.32
0.068	4.34	78.55	85.30	91.20
	0.39	7.06	7.67	8.20
	28.56	80.88	87.18	93.96
	28.17	73.82	79.51	85.76
0.042	84.42	158.63	165.38	171.28
	7.59	14.26	14.87	15.40
	44.61	96.94	103.24	110.02
	37.02	82.68	88.37	94.62

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	14.21	20.96	26.86
	0.0	1.28	1.88	2.41
	0.0	1.79	2.01	2.24
	0.0	52.84	58.75	65.23
0.092	1.21	15.42	22.17	28.07
	0.11	1.39	1.99	2.52
	0.46	2.26	2.47	2.71
	15.19	68.03	73.94	80.42
0.068	4.34	18.55	25.30	31.20
	0.39	1.67	2.27	2.81
	0.93	2.72	2.94	3.17
	29.09	81.94	87.84	94.33
0.042	84.42	98.63	105.38	111.28
	7.59	8.87	9.47	10.00
	1.60	3.40	3.61	3.85
	38.63	91.47	97.38	103.86

PAGE 5 NEW YORK

* * * FOR A FLOOR U OF 0.093 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	32.87 68.99 119449.88 3.00	29.78 60.07 104004.19 2.50	29.41 58.99 102145.00 2.50	29.01 57.84 100142.75 2.50
0.092	32.07 66.46 115072.19 3.00	28.99 57.54 99626.56 2.50	28.62 56.47 97767.31 2.50	28.22 55.31 95765.13 2.50
0.068	31.27 64.12 111020.75 3.00	28.19 55.20 95575.06 2.50	27.82 54.13 93715.81 2.50	27.42 52.97 91713.63 2.50
0.042	30.11 61.38 106281.06 3.00	27.03 52.46 90835.31 2.50	26.66 51.39 88976.13 2.50	26.26 50.23 86973.88 2.50

PAGE 6 NEW YORK WITH FLR U OF 0.093

GAS HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	95.38	247.20	263.29	279.25
	8.57	22.22	23.67	25.10
	20.81	42.88	45.54	48.40
	12.24	20.66	21.87	23.29
0.092	118.59	270.40	286.49	302.46
	10.66	24.31	25.76	27.19
	27.07	49.13	51.79	54.65
	16.41	24.82	26.03	27.46
0.068	142.08	293.89	309.98	325.95
	12.77	26.42	27.87	29.30
	32.86	54.92	57.58	60.44
	20.08	28.50	29.71	31.13
0.042	245.97	397.79	413.88	429.84
	22.11	35.76	37.21	38.64
	39.63	61.69	64.35	67.21
	17.51	25.93	27.14	28.57

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	95.38	187.20	203.29	219.25
	8.57	16.83	18.28	19.71
	0.0	1.79	2.01	2.24
	12.24	27.84	29.27	30.93
0.092	118.59	210.40	226.49	242.46
	10.66	18.92	20.36	21.80
	0.46	2.26	2.47	2.71
	16.87	32.48	33.90	35.56
0.068	142.08	233.89	249.98	265.95
	12.77	21.03	22.47	23.91
	0.93	2.72	2.94	3.17
	21.01	36.62	38.04	39.70
0.042	245.97	337.79	353.88	369.84
	22.11	30.37	31.81	33.25
	1.60	3.40	3.61	3.85
	19.12	34.72	36.15	37.80

PAGE 7 NEW YORK WITH FLR U OF 0.093

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	22.17	96.38	103.12	109.03
	1.99	8.66	9.27	9.80
	49.36	101.69	107.98	114.77
	47.37	93.02	98.71	104.97
0.092	23.38	97.59	104.33	110.24
	2.10	8.77	9.38	9.91
	64.19	116.52	122.82	129.60
	62.09	107.74	113.44	119.69
0.068	26.51	100.72	107.47	113.37
	2.38	9.05	9.66	10.19
	77.92	130.24	136.54	143.32
	75.53	121.19	126.88	133.13
0.042	106.59	180.80	187.54	193.45
	9.58	16.25	16.86	17.39
	93.97	146.30	152.60	159.38
	84.39	130.05	135.74	141.99

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	22.17	36.38	43.12	49.03
	1.99	3.27	3.88	4.41
	0.0	1.79	2.01	2.24
	47.37	100.21	106.12	112.60
0.092	23.38	37.59	44.33	50.24
	2.10	3.38	3.99	4.52
	0.46	2.26	2.47	2.71
	62.55	115.39	121.30	127.79
0.068	26.51	40.72	47.47	53.37
	2.38	3.66	4.27	4.80
	0.93	2.72	2.94	3.17
	76.46	129.30	135.21	141.70
0.042	106.59	120.80	127.54	133.45
	9.58	10.86	11.47	12.00
	1.60	3.40	3.61	3.85
	85.99	138.84	144.74	151.23

THERMAL AND ECONOMIC EVALUATION OF ADDITIONAL INSULATION

REGION IS NEW YORK
MORTGAGE RATE = 0.070
MILLS/KW-HR = 15.0

WITH STORM WINDOWS
PERSONAL RATE = 0.045
GAS $/MBTU = 1.00

FIXED COST COEFFICIENT = 0.08990

PAGE 2 NEW YORK

* * * FOR A FLOOR U OF 0.280 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	29.71 63.57 110070.81 2.50	26.63 54.65 94625.06 2.50	26.25 53.58 92765.88 2.50	25.86 52.42 90763.63 2.50
0.092	28.91 61.04 105693.13 2.50	25.83 52.12 90247.44 2.50	25.46 51.05 88388.25 2.50	25.06 49.89 86386.00 2.50
0.068	28.11 58.70 101641.63 2.50	25.03 49.78 86195.94 2.50	24.66 48.71 84336.75 2.50	24.26 47.55 82334.50 2.50
0.042	26.95 55.97 96901.94 2.50	23.87 47.05 81456.19 2.00	23.50 45.97 79597.00 2.00	23.10 44.82 77594.81 2.00

PAGE 3 NEW YORK WITH FLR U OF 0.280

GAS HEAT - ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	369.25	521.07	537.16	553.13
	33.20	46.84	48.29	49.73
	34.21	56.28	58.93	61.79
	1.02	9.43	10.64	12.07
0.092	392.46	544.28	560.37	576.33
	35.28	48.93	50.38	51.81
	40.47	62.53	65.19	68.05
	5.18	13.60	14.81	16.24
0.068	415.95	567.77	583.86	599.82
	37.39	51.04	52.49	53.92
	46.25	68.32	70.98	73.84
	8.86	17.28	18.49	19.91
0.042	519.84	671.66	687.75	703.72
	46.73	60.38	61.83	63.26
	53.03	75.09	77.75	80.61
	6.29	14.71	15.92	17.34

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	309.25	461.07	477.16	493.13
	27.80	41.45	42.90	44.33
	1.84	3.63	3.85	4.08
	8.25	18.46	19.88	21.54
0.092	332.46	484.28	500.37	516.33
	29.89	43.54	44.98	46.42
	2.30	4.10	4.31	4.54
	12.88	23.09	24.52	26.17
0.068	355.95	507.77	523.86	539.82
	32.00	45.65	47.09	48.53
	2.77	4.56	4.78	5.01
	17.02	27.23	28.66	30.31
0.042	459.84	551.66	567.75	583.72
	41.34	49.59	51.04	52.48
	3.44	5.24	5.45	5.68
	15.13	30.73	32.16	33.81

PAGE 4 NEW YORK WITH FLR U OF 0.280

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	248.91	323.12	329.87	335.77
	22.38	29.05	29.66	30.19
	81.13	133.46	139.76	146.54
	58.76	104.41	110.10	116.36
0.092	250.12	324.33	331.08	336.98
	22.49	29.16	29.76	30.29
	95.96	148.29	154.59	161.37
	73.48	119.13	124.83	131.08
0.068	253.26	327.46	334.21	340.12
	22.77	29.44	30.05	30.58
	109.69	162.02	168.32	175.10
	86.92	132.58	138.27	144.52
0.042	333.33	407.54	414.29	420.19
	29.97	36.64	37.24	37.78
	125.75	178.07	184.37	191.16
	95.78	141.44	147.13	153.38

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	188.91	263.12	269.87	275.77
	16.98	23.65	24.26	24.79
	1.84	3.63	3.85	4.08
	65.99	113.44	119.35	125.83
0.092	190.12	264.33	271.08	276.98
	17.09	23.76	24.37	24.90
	2.30	4.10	4.31	4.54
	81.18	128.62	134.53	141.02
0.068	193.26	267.46	274.21	280.12
	17.37	24.05	24.65	25.18
	2.77	4.56	4.78	5.01
	95.08	142.53	148.44	154.92
0.042	273.33	287.54	294.29	300.19
	24.57	25.85	26.46	26.99
	3.44	5.24	5.45	5.68
	104.62	157.46	163.37	169.85

PAGE 5 NEW YORK

* * * FOR A FLOOR U OF 0.093 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	29.71	26.63	26.25	25.86
	55.16	46.24	45.16	44.01
	95500.81	80055.13	78195.88	76193.69
	2.50	2.50	2.50	2.50
0.092	28.91	25.83	25.46	25.06
	52.63	43.71	42.63	41.48
	91123.19	75677.50	73818.25	71816.06
	2.50	2.50	2.50	2.50
0.068	28.11	25.03	24.66	24.26
	50.29	41.37	40.29	39.14
	87071.69	71625.94	69766.75	67764.50
	2.50	2.50	2.50	2.50
0.042	26.95	23.87	23.50	23.10
	47.55	38.63	37.56	36.40
	82332.00	66886.25	65027.07	63024.84
	2.50	2.00	2.00	2.00

PAGE 6 NEW YORK WITH FLR U OF 0.093

GAS HEAT - ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF.	FIXED COST/FUEL	SAVING/NET SAVING	
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	464.63	616.45	632.54	648.50
	41.77	55.42	56.87	58.30
	55.03	77.09	79.75	82.61
	13.26	21.67	22.88	24.31
0.092	487.84	639.66	655.74	671.71
	43.86	57.51	58.95	60.39
	61.28	83.35	86.00	88.86
	17.42	25.84	27.05	28.48
0.068	511.33	663.15	679.23	695.20
	45.97	59.62	61.06	62.50
	67.07	89.13	91.79	94.65
	21.10	29.52	30.73	32.15
0.042	615.22	767.04	783.13	799.09
	55.31	68.96	70.40	71.84
	72.84	95.91	98.56	101.42
	18.53	26.95	28.16	29.58

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF.	FIXED COST/ELEC	SAVING/NET SAVING	
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	404.63	556.45	572.54	588.50
	36.38	50.02	51.47	52.91
	1.84	3.63	3.85	4.08
	20.49	30.70	32.12	33.78
0.092	427.84	579.66	595.74	611.71
	38.46	52.11	53.56	54.99
	2.30	4.10	4.31	4.54
	25.12	35.33	36.76	38.41
0.068	451.33	603.15	619.23	635.20
	40.57	54.22	55.67	57.10
	2.77	4.56	4.78	5.01
	29.26	39.47	40.90	42.55
0.042	555.22	647.04	663.13	679.09
	49.91	58.17	59.62	61.05
	3.44	5.24	5.45	5.68
	27.37	42.97	44.40	46.05

PAGE 7 NEW YORK WITH FLR U OF 0.093

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	271.08	345.29	352.04	357.94
	24.37	31.04	31.65	32.18
	130.49	182.82	189.12	195.90
	106.12	151.78	157.47	163.72
0.092	272.29	346.50	353.25	359.15
	24.48	31.15	31.76	32.29
	145.32	197.65	203.95	210.73
	120.85	166.50	172.19	178.45
0.068	275.42	349.63	356.38	362.28
	24.76	31.43	32.04	32.57
	159.05	211.38	217.68	224.46
	134.29	179.94	185.64	191.89
0.042	355.50	429.71	436.46	442.36
	31.96	38.63	39.24	39.77
	175.11	227.43	233.73	240.52
	143.15	188.80	194.49	200.75

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	211.08	285.29	292.04	297.94
	18.98	25.65	26.25	26.78
	1.84	3.63	3.85	4.08
	113.36	160.80	166.71	173.20
0.092	212.29	286.50	293.25	299.15
	19.09	25.76	26.36	26.89
	2.30	4.10	4.31	4.54
	128.54	175.99	181.90	188.38
0.068	215.42	289.63	296.38	302.28
	19.37	26.04	26.64	27.18
	2.77	4.56	4.78	5.01
	142.45	189.90	195.81	202.29
0.042	295.50	309.71	316.46	322.36
	26.57	27.84	28.45	28.98
	3.44	5.24	5.45	5.68
	151.98	204.83	210.73	217.22

THERMAL AND ECONOMIC EVALUATION OF ADDITIONAL INSULATION

REGION IS MINNEAPOLIS
MORTGAGE RATE = 0.070
MILLS/KW-HR = 15.0

WITHOUT STORM WINDOWS
PERSONAL RATE = 0.045
GAS $/MBTU = 1.00

FIXED COST COEFFICIENT = 0.08990

PAGE 2 MINNEAPOLIS

* * * FOR A FLOOR U OF 0.280 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	35.37 108.37 208407.13 3.00	31.79 95.88 184388.56 3.00	31.36 94.37 181497.25 3.00	30.90 92.75 178383.81 3.00
0.092	34.50 104.83 201600.00 3.00	30.92 92.34 177581.00 3.00	30.49 90.83 174689.94 3.00	30.02 89.21 171576.31 2.50
0.068	33.62 101.55 195299.56 3.00	30.04 89.06 171280.81 2.50	29.61 87.56 168389.56 2.50	29.15 85.94 165276.06 2.50
0.042	32.35 97.72 187929.13 3.00	28.77 85.23 163910.38 2.50	28.34 83.73 161019.13 2.50	27.87 82.11 157905.56 2.50

PAGE 3 MINNEAPOLIS WITH FLR U OF 0.280

GAS HEAT - ANNUAL COSTS AND SAVINGS

WALL U / CEIL U	DIF. CAP. COST/DIF.	FIXED COST/FUEL	SAVING/NET	SAVING
	0.190	0.082	0.069	0.055
0.120	0.0	146.47	161.91	177.18
	0.0	13.17	14.56	15.93
	0.0	30.88	34.60	38.60
	0.0	17.71	20.04	22.67
0.092	21.69	168.16	183.60	198.87
	1.95	15.12	16.51	17.88
	8.75	39.63	43.35	47.35
	6.80	24.52	26.84	29.48
0.068	43.78	190.24	205.69	220.96
	3.94	17.10	18.49	19.86
	16.85	47.73	51.45	55.45
	12.92	30.63	32.96	35.59
0.042	146.03	292.49	307.94	323.21
	13.13	26.30	27.68	29.06
	26.33	57.21	60.93	64.93
	13.20	30.91	33.24	35.87

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

WALL U / CEIL U	DIF. CAP. COST/DIF.	FIXED COST/ELEC	SAVING/NET	SAVING
	0.190	0.082	0.069	0.055
0.120	0.0	146.47	161.91	177.18
	0.0	13.17	14.56	15.93
	0.0	2.08	2.33	2.60
	0.0	19.80	22.38	25.28
0.092	21.69	168.16	183.60	138.87
	1.95	15.12	16.51	12.48
	0.51	2.59	2.84	3.11
	7.31	27.11	29.69	37.98
0.068	43.78	130.24	145.69	160.96
	3.94	11.71	13.10	14.47
	1.02	3.10	3.35	3.62
	13.94	39.13	41.71	44.61
0.042	146.03	232.49	247.94	263.21
	13.13	20.90	22.29	23.66
	1.76	3.84	4.09	4.36
	14.96	40.15	42.73	45.63

PAGE 4 MINNEAPOLIS WITH FLR U OF 0.280

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	37.81	40.18	41.36
	0.0	3.40	3.61	3.72
	0.0	81.37	91.16	101.71
	0.0	77.97	87.55	97.99
0.092	-9.10	28.71	31.07	32.26
	-0.82	2.58	2.79	2.90
	23.06	104.43	114.23	124.77
	23.88	101.85	111.43	121.87
0.068	-15.52	22.29	24.66	25.84
	-1.40	2.00	2.22	2.32
	44.41	125.78	135.57	146.12
	45.80	123.77	133.35	143.80
0.042	53.39	91.20	93.57	94.75
	4.80	8.20	8.41	8.52
	69.38	150.75	160.54	171.09
	64.58	142.55	152.13	162.57

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	0.0	37.81	40.18	41.36
	0.0	3.40	3.61	3.72
	0.0	2.08	2.33	2.60
	0.0	80.05	89.89	100.60
0.092	-9.10	28.71	31.07	-27.74
	-0.82	2.58	2.79	-2.49
	0.51	2.59	2.84	3.11
	24.39	104.44	114.28	130.38
0.068	-15.52	-37.71	-35.34	-34.16
	-1.40	-3.39	-3.18	-3.07
	1.02	3.10	3.35	3.62
	46.82	132.27	142.10	152.81
0.042	53.39	31.20	33.57	34.75
	4.80	2.80	3.02	3.12
	1.76	3.84	4.09	4.36
	66.33	151.78	161.61	172.33

PAGE 5 MINNEAPOLIS

* * * FOR A FLOOR U OF 0.093 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	35.37 96.58 185750.31 3.00	31.79 84.10 161731.50 3.00	31.36 82.59 158840.38 3.00	30.90 80.97 155726.88 3.00
0.092	34.50 93.05 178942.81 3.00	30.92 80.56 154924.06 3.00	30.49 79.05 152033.00 3.00	30.02 77.43 148919.50 2.50
0.068	33.62 89.77 172642.56 3.00	30.04 77.28 148623.94 2.50	29.61 75.78 145732.69 2.50	29.15 74.16 142619.19 2.50
0.042	32.35 85.94 165272.19 3.00	28.77 73.45 141253.44 2.50	28.34 71.94 138362.19 2.50	27.87 70.33 135248.69 2.50

PAGE 6 MINNEAPOLIS WITH FLR U OF 0.093

GAS HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	90.33	236.79	252.24	267.51
	8.12	21.29	22.68	24.05
	29.13	60.01	63.73	67.73
	21.01	38.72	41.05	43.68
0.092	112.02	258.49	273.93	289.20
	10.07	23.24	24.63	26.00
	37.88	68.76	72.48	76.48
	27.81	45.53	47.85	50.48
0.068	134.11	280.57	296.02	311.29
	12.06	25.22	26.61	27.98
	45.98	76.86	80.58	84.58
	33.93	51.64	53.97	56.60
0.042	236.36	382.82	398.27	413.54
	21.25	34.42	35.80	37.18
	55.46	86.34	90.06	94.06
	34.21	51.92	54.25	56.88

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	90.33	236.79	252.24	267.51
	8.12	21.29	22.68	24.05
	0.0	2.08	2.33	2.60
	21.01	40.81	43.39	46.29
0.092	112.02	258.49	273.93	229.20
	10.07	23.24	24.63	20.61
	0.51	2.59	2.84	3.11
	28.32	48.12	50.70	58.99
0.068	134.11	220.57	236.02	251.29
	12.06	19.83	21.22	22.59
	1.02	3.10	3.35	3.62
	34.95	60.14	62.71	65.61
0.042	236.36	322.82	338.27	353.54
	21.25	29.02	30.41	31.78
	1.76	3.84	4.09	4.36
	35.97	61.16	63.74	66.64

PAGE 7 MINNEAPOLIS WITH FLR U OF 0.093

ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	-12.17	25.65	28.01	29.20
	-1.09	2.31	2.52	2.62
	76.76	158.13	167.92	178.47
	77.85	155.82	165.40	175.84
0.092	-21.27	16.54	18.91	20.09
	-1.91	1.49	1.70	1.81
	99.82	181.19	190.98	201.53
	101.73	179.70	189.28	199.72
0.068	-27.68	10.13	12.49	13.68
	-2.49	0.91	1.12	1.23
	121.16	202.53	212.33	222.88
	123.65	201.62	211.20	221.65
0.042	41.22	79.04	81.40	82.59
	3.71	7.11	7.32	7.42
	146.13	227.50	237.30	247.84
	142.43	220.40	229.98	240.42

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	-12.17	25.65	28.01	29.20
	-1.09	2.31	2.52	2.62
	0.0	2.08	2.33	2.60
	77.85	157.90	167.74	178.45
0.092	-21.27	16.54	18.91	-39.91
	-1.91	1.49	1.70	-3.59
	0.51	2.59	2.84	3.11
	102.24	182.29	192.13	208.23
0.068	-27.68	-49.87	-47.51	-46.32
	-2.49	-4.48	-4.27	-4.16
	1.02	3.10	3.35	3.62
	124.67	210.12	219.95	230.66
0.042	41.22	19.04	21.40	22.59
	3.71	1.71	1.92	2.03
	1.76	3.84	4.09	4.36
	144.18	229.63	239.46	250.18

THERMAL AND ECONOMIC EVALUATION OF ADDITIONAL INSULATION

REGION IS MINNEAPOLIS WITH STORM WINDOWS

MORTGAGE RATE = 0.070 PERSONAL RATE = 0.045

MILLS/KW-HR = 15.0 GAS $/MBTU = 1.00

FIXED COST COEFFICIENT = 0.08990

PAGE 2 MINNEAPOLIS

* * * FOR A FLOOR U OF 0.280 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	32.04 89.00 171165.44 3.00	28.46 76.51 147146.69 2.50	28.03 75.01 144255.56 2.50	27.57 73.39 141141.94 2.50
0.092	31.17 85.46 164358.00 3.00	27.59 72.97 140339.19 2.50	27.16 71.47 137448.06 2.50	26.69 69.85 134234.56 2.50
0.068	30.29 82.19 158057.63 3.00	26.71 69.70 134038.88 2.50	26.28 68.19 131147.75 2.50	25.82 66.57 128034.19 2.50
0.042	29.02 78.35 150687.31 2.50	25.44 65.86 126668.44 2.50	25.01 64.36 123777.31 2.50	24.55 62.74 120663.75 2.50

PAGE 3 MINNEAPOLIS WITH FLR U OF 0.280

GAS HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	360.95	507.42	522.86	538.14
	32.45	45.62	47.01	48.38
	47.88	78.76	82.48	86.48
	15.43	33.15	35.48	38.11
0.092	382.64	529.11	544.55	559.83
	34.40	47.57	48.96	50.33
	56.63	87.52	91.23	95.24
	22.24	39.95	42.28	44.91
0.068	404.73	551.20	566.64	581.91
	36.39	49.55	50.94	52.31
	64.74	95.62	99.33	103.34
	28.35	46.06	48.39	51.02
0.042	506.98	653.45	668.89	684.16
	45.58	58.74	60.13	61.51
	74.21	105.09	108.81	112.81
	28.63	46.35	48.68	51.31

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	360.95	447.42	462.86	478.14
	32.45	40.22	41.61	42.98
	1.94	4.02	4.27	4.54
	17.37	42.56	45.14	48.04
0.092	382.64	469.11	484.55	499.83
	34.40	42.17	43.56	44.93
	2.45	4.53	4.78	5.05
	24.68	49.87	52.45	55.35
0.068	404.73	491.20	506.64	521.91
	36.39	44.16	45.55	46.92
	2.95	5.04	5.29	5.56
	31.31	56.50	59.07	61.97
0.042	446.98	593.45	608.89	624.16
	40.18	53.35	54.74	56.11
	3.70	5.78	6.03	6.30
	37.72	57.52	60.10	63.00

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ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	192.48	230.29	232.66	233.84
	17.30	20.70	20.92	21.02
	126.17	207.54	217.33	227.88
	108.86	186.83	196.42	206.86
0.092	183.37	221.19	223.55	224.74
	16.49	19.88	20.10	20.20
	149.23	230.60	240.39	250.94
	132.74	210.72	220.30	230.74
0.068	176.96	214.77	217.14	218.32
	15.91	19.31	19.52	19.63
	170.57	251.94	261.74	272.29
	154.67	232.64	242.22	252.66
0.042	245.87	283.68	286.05	287.23
	22.10	25.50	25.72	25.82
	195.54	276.91	286.71	297.26
	173.44	251.41	260.99	271.43

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	192.48	170.29	172.66	173.84
	17.30	15.31	15.52	15.63
	1.94	4.02	4.27	4.54
	110.80	196.25	206.08	216.79
0.092	183.37	161.19	163.55	164.74
	16.49	14.49	14.70	14.81
	2.45	4.53	4.78	5.05
	135.19	220.64	230.47	241.18
0.068	176.96	154.77	157.14	158.32
	15.91	13.91	14.13	14.23
	2.95	5.04	5.29	5.56
	157.62	243.07	252.90	263.61
0.042	185.87	223.68	226.05	227.23
	16.71	20.11	20.32	20.43
	3.70	5.78	6.03	6.30
	182.53	262.58	272.41	283.13

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* * * FOR A FLOOR U OF 0.093 * * *

THERMAL PROPERTIES OF RESIDENCE

HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)

WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	32.04 77.22 148508.56 3.00	28.46 64.73 124489.69 2.50	28.03 63.23 121598.56 2.50	27.57 61.61 118485.00 2.50
0.092	31.17 73.68 141701.06 3.00	27.59 61.19 117682.25 2.50	27.16 59.69 114791.13 2.50	26.69 58.07 111677.56 2.50
0.068	30.29 70.40 135400.75 3.00	26.71 57.92 111381.94 2.50	26.28 56.41 108490.75 2.50	25.82 54.79 105377.25 2.50
0.042	29.02 66.57 128030.25 2.50	25.44 54.08 104011.44 2.50	25.01 52.58 101120.31 2.50	24.55 50.96 98006.75 2.50

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GAS HEAT - ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/FUEL SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	451.28	597.75	613.19	628.46
	40.57	53.74	55.13	56.50
	77.01	107.89	111.61	115.61
	36.44	54.16	56.49	59.12
0.092	472.97	619.44	634.88	650.15
	42.52	55.69	57.08	58.45
	85.77	116.65	120.36	124.37
	43.25	60.96	63.29	65.92
0.068	495.06	641.52	656.97	672.24
	44.51	57.67	59.06	60.43
	93.87	124.75	128.46	132.47
	49.36	67.07	69.40	72.03
0.042	597.31	743.78	759.22	774.49
	53.70	66.87	68.25	69.63
	103.34	134.22	137.94	141.94
	49.64	67.36	69.69	72.32

GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

	DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/NET SAVING			
WALL U CEIL U	0.190	0.082	0.069	0.055
0.120	451.28	537.75	553.19	568.46
	40.57	48.34	49.73	51.10
	1.94	4.02	4.27	4.54
	38.38	63.57	66.15	69.05
0.092	472.97	559.44	574.88	590.15
	42.52	50.29	51.68	53.05
	2.45	4.53	4.78	5.05
	45.69	70.88	73.46	76.36
0.068	495.06	581.52	596.97	612.24
	44.51	52.28	53.67	55.04
	2.95	5.04	5.29	5.56
	52.31	77.51	80.08	82.98
0.042	537.31	683.78	699.22	714.49
	48.30	61.47	62.86	64.23
	3.70	5.78	6.03	6.30
	58.73	78.53	81.11	84.01

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ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS

WALL U / CEIL U	DIF. CAP. COST/DIF. FIXED COST/POWER SAVING/NET SAVING			
	0.190	0.082	0.069	0.055
0.120	180.31	218.12	220.49	221.68
	16.21	19.61	19.82	19.93
	202.92	284.29	294.09	304.64
	186.71	264.68	274.27	284.71
0.092	171.21	209.02	211.39	212.57
	15.39	18.79	19.00	19.11
	225.99	307.36	317.15	327.70
	210.59	288.57	298.15	308.59
0.068	164.79	202.61	204.97	206.16
	14.81	18.21	18.43	18.53
	247.33	328.70	338.50	349.04
	232.52	310.49	320.07	330.51
0.042	233.70	271.51	273.88	275.07
	21.01	24.41	24.62	24.73
	272.30	353.67	363.46	374.01
	251.29	329.26	338.84	349.28

EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND SAVINGS

WALL U / CEIL U	DIF. CAP. COST/DIF. FIXED COST/A-C ELEC SAVING/NET SAVING			
	0.190	0.082	0.069	0.055
0.120	180.31	158.12	160.49	161.68
	16.21	14.22	14.43	14.53
	1.94	4.02	4.27	4.54
	188.65	274.10	283.93	294.64
0.092	171.21	149.02	151.39	152.57
	15.39	13.40	13.61	13.72
	2.45	4.53	4.78	5.05
	213.04	298.49	308.32	319.03
0.068	164.79	142.61	144.97	146.16
	14.81	12.82	13.03	13.14
	2.95	5.04	5.29	5.56
	235.47	320.92	330.75	341.46
0.042	173.70	211.51	213.88	215.07
	15.62	19.02	19.23	19.33
	3.70	5.78	6.03	6.30
	260.38	340.43	350.26	360.98

APPENDIX B

METHOD USED IN DETERMINING FIXED CHARGE RATE

AND

SAMPLE CALCULATION

METHOD USED IN DETERMINING FIXED CHARGE RATE

The net annual cost due to an additional investment of $1.00 is determined as follows:

The annual mortgage payment required is

$$R_1 = \frac{I_m}{1 - (1 + I_m)^{-L}}$$

where I_m is the mortgage interest rate (fraction) and L is the mortgage lifetime (yrs).

The annual property tax payment required is

R_2 = T, where T is the property tax rate, $/$-yr.

The annual insurace payment required is

R_3 = C, where C is the insurance rate, $/$-yr.

The mortgage interest paid at the end of Year n is

$$M_n = I_m \times P_n$$

where P_n is the principal remaining during Year n. For an initial principal of 1,

$$P_n = (1 + I_m)^{n-1} - R_1 \frac{(1 + I_m)^{n-1} - 1}{I_m}$$

In order to account for the time variation of the worth of money to the homeowner, this series of variable annual interest payment must be converted to a level (constant) annual series of payments that is equivalent to the variable series when computed at an interest rate, I_p, applicable to the homeowner's investment or saving experience. This is accomplished in the following manner.

The present worth, at the beginning of Year 1, of the mortgage interest paid at the end of Year n is

$$P.W.\ M_n = \frac{M_n}{(1 + I_p)^n} .$$

The total present worth of all of the interest payments is

$$\sum_{n=1}^{L} P.W.\ M_n = \sum_{n=1}^{L} \frac{M_n}{(1 + I_p)^n} .$$

This total present worth of the interest is then converted to a series of L equal annual payments, where the annual amount is

$$R_4 = \frac{I_p}{1 - (1 + I_p)^{-L}} \sum_{n=1}^{L} \frac{M_n}{(1 + I_p)^n} .$$

If the homeowner is in the income tax bracket where his tax on an extra dollar earned is computed at X fraction of that dollar, the net total annual cost of an incremental investment of $1 is then

$$R_T = R_1 + R_2 + R_3 - X(R_2 + R_4)$$

As an example of the magnitude of the effect of income tax credit, with mortgage and personal interest rates of 7 and 4.5%, respectively, a property tax rate of 2.5%, an insurance rate of 0.4%, and a 30-year mortgage lifetime, the annual cost per dollar invested would be $0.10959 if tax credit is ignored. With tax credit computed for the 25% tax bracket, the annual cost becomes $0.0899, or a reduction of 18%.

SAMPLE CALCULATION

In this sample calculation, a comparison will be made of the model home, located in the New York region with gas heat and air conditioning, insulated to meet the MPS requirements versus with the amount of insulation that yields the maximum monetary saving to the owner. In this way, the methodology carried out by the computer program for the many cases will be demonstrated.

1. The MPS-Compliance Home

From Tables 5 and 4 of the main report, the model home built in compliance with the MPS requirements has the following insulation and U values:

Component	Insulation	U, Btu/ft^2-hr-°F Heating	Cooling
Ceiling	3-1/2 in.	0.068	0.050
Walls	none	0.19	0.19
Floor	none	0.28	-
Windows	plain	1.46	-

The cooling U value for the ceiling includes the effect of the attic and roof. The heating U value for the windows includes the loss due to infiltration. The heat gain through glass areas during the cooling season is calculated on the basis of cooling load values tabulated in Reference 7, Chapter 26, Table 35, as a function of orientation, exposure, and outside air temperature. The values, for single glass and outside air temperature of 90°F, are:

North	27 Btu/ft^2-hr
East and West	85 " " "
South	44 " " "

Shaded portions of glass area are treated as north-facing.

a. Heating Load and Annual Energy Consumption

1) Ceiling

First, the temperature of the attic must be determined. Assume the attic air is well-mixed (uniform temperature) and is ventilated at the rate of 0.1 cfm/ft^2 with outside air. Assume roof U is 0.44 and the roof slope is 4 to 12. (Roof area = 1.054 x ceiling area.)

Let:

t_a = attic temperature, °F

t_i = inside room temperature, °F

t_o = outside air temperature, °F

U_c = ceiling U value, Btu/ft^2-hr-°F

Specific heat of air = 0.02 Btu/ft^3-°F

Heat flow through ceiling = Heat flow through roof + Ventilation loss

$$U_c(t_i - t_a) = 0.44 \times 1.054(t_a - t_o) + 0.1 \times 60 \times 0.02(t_a - t_o)$$

$$U_c(t_i - t_a) = 0.584(t_a - t_o)$$

Solving for the attic temperature, '

$$t_a = \frac{U_c t_i + 0.584 t_o}{U_c + 0.584}$$

or, for our case,

$$t_a = \frac{0.068 \times 75 + 0.584 \times 5}{0.068 + 0.584} = 12.3°F$$

The ceiling heat loss

$= AU\Delta t$

$= 0.068 \times 1800 \times (75 - 12.3)$

$= 7674$ Btu/hr

2) Walls

The net wall area

$= 2 \times (60 + 30) \times 8 - 260 = 1180\ ft^2$

The wall heat loss

$= 0.19 \times 1180 \times (75 - 5) = 15{,}694$ Btu/hr

3) Floor

A basement temperature of 50°F is assumed. The floor heat loss

$= 0.28 \times 1800 \times (75 - 50) = 12{,}600$ Btu/hr

4) Windows

A composite U value was derived for the windows, consisting of a conduction U of 1.02 and an infiltration U of 0.44 Btu/ft^2-hr-°F. The infiltration value is precisely correct only for a 3-ft x 5-ft double-hung window and should vary with the square root of area for other window sizes having the same proportions. However, it is adequate for the purpose of this study, and this approach simplifies the determination of the effectiveness of storm windows.

The total heat loss from the windows

$= 1.46 \times 260 \times (75 - 5) = 26{,}572$ Btu/hr

of which the infiltration loss

$= 0.44 \times 260 \times (75 - 5) = 8{,}008$ Btu/hr.

5) General infiltration

A general infiltration rate, in addition to that from the windows, equivalent to 1/2 volume air change per hour was assumed. The heat loss from this source

$$= \frac{1800 \times 8}{2} \times 0.02 \times (75 - 5) = 10{,}080 \text{ Btu/hr}$$

6) Total hourly heat loss and annual heat loss

The hourly heat loss, at design conditions, is summarized below.

Component	Heat Loss, Btu/hr	% of Total
Ceiling	7,674	10.6
Walls	15,694	21.6
Floor	12,600	17.3
Windows	26,572	36.6
General infiltration	10,080	13.9
Total	72,620	100.0

Using one of the methods given in References 6 and 7, the annual heat loss

$$= \frac{\text{Hourly heat loss} \times 24 \times \text{Degree days}}{\text{Design temperature difference}}$$

$$= \frac{72{,}620 \times 24 \times 5050}{(75 - 5)} = 125.74 \times 10^6 \text{ Btu/yr}$$

b. Cooling Load and Annual A-C Energy Consumption

1) Ceiling-attic-roof

The U value for the combined ceiling-attic-roof of the model home, with heat flow downward, is 0.050 Btu/ft^2-hr-°F. Reference 7, Chapter 26, Table 34, lists equivalent temperature differences, as a function of outside temperature, daily temperature range, and type of construction, that are recommended for use in determining cooling load. For New York, with

a summer design temperature of 90°F and a daily temperature range of 16°F, the roof-ceiling equivalent temperature difference is 31°F.

The heat gain through the ceiling is then

= 0.050 x 1800 x 31 = 2790 Btu/hr.

2) Walls

The equivalent temperature difference given for New York conditions with frame and veneer construction is 18.6°F.

The wall heat gain

= 0.19 x 1180 x 18.6 = 4170 Btu/hr.

3) Floor

The heat gain from the floor over an unheated basement is considered to be negligible.

4) Windows

North - 80 x 27	=	2,160 Btu/hr
East and West - 80 x 85	=	6,800 "
South - 50 x 27 + 50 x 44	=	3,550 "
Total windows		12,510 "

5) Infiltration

Reference 7, Chapter 26, Table 37, lists recommended values for infiltration heat gain, in terms of Btu/hr-ft^2 gross wall area, as a function of summer design temperature. For 90°F design temperature, the infiltration heat gain is 1.1 Btu/ft^2-hr.

The total infiltration heat load

= 1.1 x 2 x (30 + 60) x 8 = 1584 Btu/hr.

6) Occupancy load

Reference 7, Chapter 26, recommends an occupancy load of 300 Btu/hr per person (more recent editions recommend 225 Btu/hr per person) and a kitchen load of 1200 Btu/hr. A suggested guide for estimating the number of occupants is 2 persons per bedroom.

A total occupancy load of 3000 Btu/hr was assumed.

7) Latent heat load

All of the above estimated cooling loads are limited to sensible heat gains. Reference 7, Chapter 26, recommends adding 30% to the total to cover the latent heat load.

8) Total cooling load and annual energy consumption

The hourly cooling load is summarized below.

Component	Cooling Load, Btu/hr	% of Total
Ceiling	2,790	11.6
Walls	4,170	17.3
Windows	12,510	52.0
Infiltration	1,584	6.6
Occupancy	3,000	12.5
Total sensible cooling load	24,054	100.0
Latent heat load	7,216	
Total cooling load	31,270	

The required air conditioner rating, at 12,000 Btu/ton-hr, is 3 tons.

New York has a seasonal air conditioning operating time of 350 hr/yr. With an assumed requirement of 1.33 kW/ton power input, the annual power consumption

$$= 31{,}270 \times 1.33 \times 350 / 12{,}000 = 1{,}213 \text{ kW-hr/yr.}$$

9) Check for MPS compliance

Item	MPS	Model Home
Total heat loss, Btu/hr-ft^2 floor	50	20.3
Total heat gain, Btu/hr-ft^2 floor	19	17.4
Vertical surface heat loss, Btu/hr-ft^2 floor	30	19.0
Floor heat loss, Btu/hr-ft^2 floor	15	7.0
Ceiling U, Btu/ft^2-hr-°F	0.08	0.068

2. The Optimally-Insulated Home

From Figure 7 of the main report, the maximum monetary saving to the owner of an air conditioned, gas heated, home in New York results when the following insulation is used:

Component	Insulation	U, Btu/ft^2-hr-°F Heating	U, Btu/ft^2-hr-°F Cooling
Ceiling	6 in.	0.042	0.034
Walls	3-1/2 in.	0.055	0.055
Floor	Foil with air gap	0.093	-
Windows	Storm windows	0.70	-

Tabulated heat gain rates for storm windows for New York conditions are:

North	21 Btu/ft^2-hr
East and West	70 " " "
South	35 " " "

a. Heating Load and Annual Energy Consumption

1) Ceiling

$$t_a = \frac{0.042 \times 75 + 0.584 \times 5}{0.042 + 0.584} = 9.7°F$$

Ceiling heat loss

= 0.042 x 1800 x (75 - 9.7) = 4937 Btu/hr

2) Walls

Wall heat loss = 0.055 x 1180 x (75 - 5) = 4543 Btu/hr

3) Floor

Floor heat loss = 0.093 x 1800 x (75 - 50) = 4185 Btu/hr

4) Windows

Total window heat loss = 0.070 x 260 x (75-5) = 12,740 Btu/hr of which the infiltration loss = 4,004 Btu/hr.

5) General infiltration

In all likelihood, a reduction in the general infiltration rate would result from the additional insulation in the walls, ceiling, and floor. However, since some infiltration is desirable for ventilation purposes and because the reduction in infiltration rate is unknown, no reduction was assumed. The infiltration heat loss, as before, is 10,080 Btu/hr.

6) Total hourly and annual heat loss

The hourly heat loss, at design conditions, is summarized below.

Component	Heat Loss, Btu/hr	% of Total	% Reduction
Ceiling	4,937	13.5	36
Walls	4,543	12.4	71
Floor	4,185	11.5	67
Windows	12,740	34.9	52
General infiltration	10,080	27.7	-
Total	36,485	100.0	49.8

The annual heat loss = $\frac{36,485 \times 24 \times 5050}{(75 - 5)} = 63.17 \times 10^6$ Btu/yr.

b. Cooling Load and Annual A-C Energy Consumption

1) Ceiling-attic-roof

Heat gain through ceiling = 0.034 x 1800 x 31 = 1897 Btu/hr.

2) Walls

Heat gain through walls = 0.055 x 1180 x 18.6 = 1207 Btu/hr.

3) Windows

North - 80 x 21	=	1,680 Btu/hr
East and West - 80 x 70	=	5,600 "
South - 50 x 21 + 50 x 35	=	2,800 "
Total window heat gain	=	10,080 "

4) Infiltration

As before, infiltration heat gain = 1,584 Btu/hr.

5) Occupancy load

As before, occupancy heat gain = 3000 Btu/hr.

6) Total cooling load and annual energy consumption

The hourly cooling load is summarized below.

Component	Cooling Load, Btu/hr	% of Total	% Reduction
Ceiling	1,897	10.7	32
Walls	1,207	6.8	71
Windows	10,080	56.7	19
Infiltration	1,584	8.9	-
Occupancy	3,000	16.9	-
Total sensible cooling load	17,768	100.0	26.1
Latent heat load	5,330		
Total cooling load	23,098		

Required air conditioner rating = 2 tons.

Annual power consumption = 23,098 x 1.33 x 350 / 12,000 = 896 kw-hr.

3. Economic Comparison

Required additional investment, $

Ceiling insulation, 1800 x (0.23 - 0.17)	= 108.00
Wall insulation, 1180 x 0.17	= 200.60
Floor insulation, 1800 x 0.06	= 108.00
Storm windows, 260 x 1.50	= 390.00
Reduction in furnace cost, (72.62 - 36.485) x 1.50	= (54.20)
Reduction in A-C cost, (3.0 - 2.0) x 120.00	=(120.00)
Total additional investment	632.40

Fixed cost coefficient = 0.08990

Assumed gas heat utilization efficiency = 70%

Annual costs and savings, $/yr

Fixed cost due to additional investment, 0.08990 x 632.40	= 65.85
Saving in gas cost, (125.74 - 63.17) x 1.00/0.7	= 89.38
Saving in power cost, (1213 - 896) x 0.015	= 4.75
Total net annual saving	37.28

In summary, the additional insulation, above that which is required to comply with MPS requirements, reduces the gas consumption required for heating by 49.8%, reduces the power consumption required for air conditioning by 26.1%, and results in a net annual saving to the homeowner of $37.28 per year.

APPENDIX C

PROGRAM FOR COMPUTING VALUE

OF

ADDITIONAL INSULATION IN RESIDENCES

INPUT DATA FORMAT

Card	1 - 10	11 - 20	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80
1	NCASE -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	- - - - - -	
2	DLWN	DWID	AWN	AWS	AWEW			
3	IF*	IW*	IC*	RINT	RPERS	RELEC	RGAS	RTAX
4	RINS							
5	UFL(1)	UFL(2)						
6	CFL(1)	CFL(2)						
7	UCH(1)	UCH(2)	UCH(3)	UCH(4)				
8	UCC(1)	UCC(2)	UCC(3)	UCC(4)				
9	CC(1)	CC(2)	CC(3)	CC(4)				
10	UW(1)	UW(2)	UW(3)	UW(4)				
11	CW(1)	CW(2)	CW(3)	CW(4)				
12	NREG -	- - - - -	T1	T2	T3	DD	TB	T4
13	HAC	TINS						
14	W1	W2	W3	BW1	BW2	BW3	JWIN*	

Triads of cards equivalent to Cards 12, 13, and 14 are added here for additional regions or for different storm window choice.

* These integer items must be right justified within field.

INPUT DATA NOMENCLATURE

Item	Description	Value Used
NCASE	Any desired title for run, up to 68 characters	
CLEN	Building length, ft	60.
DWID	Building width, ft	30.
AWN	Window area facing north, ft^2	80.
AWS	Window area facing south, ft^2	100.
AWEW	Window area facing east and west, ft^2	80.
IF	No. of floor U's to be investigated, up to 4	2.
IW	No. of wall U's to be investigated, up to 4	4.
IC	No. of ceiling U's to be investigated, up to 4	4.
RINT	Mortgage interest rate, fraction	0.07
RPERS	Personal interest rate, fraction	0.045
RELEC	Cost of electricity, mills/kW-hr	15.
RGAS	Cost of gas, $/MBtu	1.
RTAX	Property tax rate, fraction	0.025
RINS	Property insurance rate, fraction	0.004
UFL(i)	ith floor U, Btu/ft^2-hr-°F (Ref: a-1)	See Table 4
CFL(i)	Incremental cost of its floor, (CFL(1)=0), $/$ft^2$	" " "
UCH(k)	kth ceiling U with heat flow up, Btu/ft^2-hr-°F (Ref: a-1)	" " "
UCC(k)	kth ceiling U with heat flow down, Btu/ft^2-hr-°F (Ref: a-1)	" " "
CC(k)	Incremental cost of kth ceiling, (CC(1)=0), $/$ft^2$	" " "
UW(j)	jth wall U, Btu/ft^2-hr-°F (Ref: a-1)	" " "
CW(j)	Incremental cost of jth wall, (CW(1)=0), $/$ft^2$	" " "
NREG	Region name, up to 20 characters	Atlanta
T1	Outside winter design temperature, °F (Ref: a-2)	11.
T2	Equivalent temp. difference across walls, cooling (Ref: a-3)	23.6
T3	Equivalent temp. difference across roof-attic-ceiling, cooling (Ref: a-3)	36.
DD	Degree days of heating season (Ref: b-1)	2826.
TB	Basement air temperature, °F	55.
T4	Outside summer design temperature, °F (Ref: a-4)	95.

INPUT DATA NOMENCLATURE (continued)

HAC	Seasonal air conditioning operating time, hr (Ref: b-2)	750.
TINS	Inside design temperature, summer and winter, °F	75.
W1	Heat gain through north-facing windows for storm window choice, Btu/ft^2-hr (Ref: a-5)	24.
W2	Heat gain through east- and west-facing windows for storm window choice, Btu/ft^2-hr (Ref: a-5)	73.
W3	Heat gain through south-facing windows for storm window choice, Btu/ft^2-hr (Ref: a-5)	38.
BW1	Heat gain through plain north-facing window, Btu/ft^2-hr (Ref: a-5)	31
BW2	Heat gain through plain east- and west-facing window, Btu/ft^2-hr (Ref: a-5)	89.
BW3	Heat gain through plain south-facing window, Btu/ft^2-hr (Ref: a-5)	48.
JWIN	Storm window choice (0 - no; 1 - yes)	

REFERENCES

a. ASHRAE Guide and Data Book, 1963, Fundamentals and Equipment

-1. Chapter 23

-2. Chapter 25, Table 1

-3. Chapter 26, Table 34

-4. Chapter 26, Table 1

-5. Chapter 26, Table 35

b. ASHRAE Guide and Data Book, 1964, Applications

-1. Chapter 16, Table 2

-2. Chapter 17, Table 2

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**FTN,L,E,M,G.
C FORTRAN COMBINATION OF RESID SERIES
      DIMENSION UFL(4),CFL(4),UCH(4),UCC(4),CC(4),UW(4),CW(4),R(4,4),
     1  TCN(4,4),H(4,4),S(4,4),CAPGH(4,4),CAPEH(4,4),CAPGAC(4,4),
     2  CAPEAC(4,4),FIXGH(4,4),FIXEH(4,4),FIXGAC(4,4),
     3  FIXEAC(4,4),SAVGAS(4,4),SAVELH(4,4),SAVEAC(4,4),TOTGH(4,4),
     4  TOTEH(4,4),TOTGAC(4,4),TOTEAC(4,4),NCASE(17),NREG(5)
C READ CASE TITLE
      READ(50,900)NCASE
  900 FORMAT(17A4)
C  READ BUILDING DIMENSIONS
      READ (50,980)DLEN,DWID,AWN,AWS,AWEW
  980 FORMAT(5F10.0)
C  CALCULATE BUILDING AREAS
      AWALL=16.*(DLEN+DWID)
      AFLR=DLEN*DWID
      AWIN=AWN+AWS+AWEW
      READ(50,1000)IF,IW,IC,RINT,RPERS,RELEC,RGAS,RTAX,RINS
 1000 FORMAT(3I10,5F10.0/F10.0)
C CALCULATE INVESTMENT COST COEFFICIENT ASSUMING 25 PCT. IRS BRACKET
      PWCUM=0
      PAYMTG=RINT/(1.-(1.+RINT)**(-30))
      PRIN=1.
      DO   2,IY=1,30
      CINT=PRIN*RINT
      PRIN=PRIN+CINT-PAYMTG
      PWCINT=CINT/((1+RPERS)**IY)
    2 PWCUM=PWCUM+PWCINT
      ANNINT=PWCUM*RPERS/(1.-(1.+RPERS)**(-30))
      CAPCOF=PAYMTG+RTAX+RINS-(ANNINT+RTAX)*.25
C READ FLOOR U AND COST VALUES
      READ(50,1010)(UFL(J),J=1,IF)
      READ(50,1010)(CFL(J),J=1,IF)
C READ CEILING U AND COST VALUES
      READ(50,1010)(UCH(J),J=1,IC)
      READ(50,1010)(UCC(J),J=1,IC)
      READ(50,1010)(CC(J),J=1,IC)
C READ WALL U AND COST VALUES
      READ(50,1010)(UW(J),J=1,IW)
      READ(50,1010)(CW(J),J=1,IW)
 1010 FORMAT(5F10.0)
C READ REGIONAL DATA
   50 READ(50,1020,END=99)NREG,T1,T2,T3,DD,TB,T4,FAC,TINS,W1,W2,W3,
     1 BW1,BW2,BW3,JWIN
 1020 FORMAT(5A4,6F10.0/2F10.0/6F10.0,I10)
      WRITE(51,950)NCASE
  950 FORMAT(1H1/1H0,2X,17A4)
C WRITE SUBTITLE AND INPUT INFO.
      IF(JWIN-1)66,67,67
   66 WRITE(51,1030)NREG
      GO TO 68
   67 WRITE(51,1035)NREG
 1030 FORMAT(1H0/1H0,7X,'REGION IS ',5A4,' WITHOUT STORM WINDOWS')
 1035 FORMAT(1H0/1H0,7X,'REGION IS ',5A4,' WITH STORM WINDOWS')
   68 WRITE(51,1040)RINT,RPERS,RELEC,RGAS
 1040 FORMAT(1H ,10X,'MORTGAGE RATE = ',F5.3,10X,'PERSONAL RATE = ',
     1  F5.3/1H ,10X,'MILLS/KW-HR    = ',F5.1,10X,'GAS $/MBTU     = ',
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    2  F5.2)
      WRITE(51,1045)CAPCOF
 1045 FORMAT(1HC,10X,'FIXED COST COEFFICIENT = ',F7.5)
C BEGIN CALCULATION, INDEXING BY FLOOR U
      DO   30,I=1,IF
      IPAGE=3*I-1
      WRITE(51,1050)IPAGE,NREG,UFL(I)
 1050 FORMAT(1H1,2X,' PAGE ',I2,2X,5A4/1H0,10X,
     1  '* * * FOR A FLOOR U OF ',F5.3,' * * *')
      DO  25, J=1,IW
      DO  25, K=1,IC
C CALCULATE COOLING LOAD AND AIR CONDITIONER TONS
      R1=((AWALL-AWIN)*UW(J)*T2 +AFLR*UCC(K)*T3 +AWN*W1 +AWEW*W2
     1  +AWS*W3 +AWALL*(.7+.4*(T4-85.)/5.) +3000.)*1.3
      R(J,K)=R1/1000.
      TON1=R(J,K)/12.
      INT=TON1/.5+.99
      XINT=INT
      TON(J,K)=XINT/2.
C CALCULATE DESIGN HEAT LOSS AND ANNUAL HEAT LOSS
      T5=(UCH(K)*TINS + .584*T1)/(UCH(K) + .584)
      IF(JWIN-1)76,77,77
   76 H1=(AWALL-AWIN)*UW(J)*(TINS-T1) +AWIN*1.46*(TINS-T1) +AFLR*UFL(I)
     1  *(TINS-TB) +AFLR*UCH(K)*(TINS-T5) +AFLR*.07933*(TINS-T1)
      GO TO 78
   77 H1=(AWALL-AWIN)*UW(J)*(TINS-T1) +AWIN*.7*(TINS-T1) +AFLR*UFL(I)
     1  *(TINS-TB) +AFLR*UCH(K)*(TINS-T5) +AFLR*.07933*(TINS-T1)
   78 H(J,K)=H1/1000.
      S(J,K)=H(J,K)*24.*DD/(TINS-T1)
      IF(I+J+K-3)5,5,6
    5 IF(JWIN-1)86,87,87
   86 HO=H(1,1)
      RO=R(1,1)
      SO=S(1,1)
      TONO=TON(1,1)
      GO TO 6
   87 HO=H(1,1) +AWIN*(1.46-.7)*(TINS-T1)/1.E3
      RO=R(1,1)+1.3*(AWN*(BW1-W1)+AWEW*(BW2-W2)+AWS*(BW3-W3))/1.E3
      SO=HO*24.*DD/(TINS-T1)
      INT2=RO/6.+.99
      XINT2=INT2
      TONO=XINT2/2.
C CALCULATE DIFFERENTIAL CAPITAL COSTS
    6 CAPGH(J,K)=(AWALL-AWIN)*CW(J)+AFLR*(CC(K)+CFL(I))-1.5*(HO-H(J,K))
      CAPEH(J,K)=CAPGH(J,K)-(10.2-1.5)*(HO-H(J,K))
      CAPGAC(J,K)=CAPGH(J,K)-(TONO-TON(J,K))*120.
      CAPEAC(J,K)=CAPEH(J,K)-(TONO-TON(J,K))*120.
      IF(JWIN-1)7,8,8
    7 GO TO 9
    8 CAPGH(J,K)=CAPGH(J,K)+1.5*AWIN
      CAPEH(J,K)=CAPEH(J,K)+1.5*AWIN
      CAPGAC(J,K)=CAPGAC(J,K)+1.5*AWIN
      CAPEAC(J,K)=CAPEAC(J,K)+1.5*AWIN
C CALCULATE DIFFERENTIAL FIXED COSTS
    9 FIXGH(J,K)=CAPGH(J,K)*CAPCOF
      FIXEH(J,K)=CAPEH(J,K)*CAPCOF
      FIXGAC(J,K)=CAPGAC(J,K)*CAPCOF
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      FIXEAC(J,K)=CAPEAC(J,K)*CAPCCF
C CALCULATE ENERGY COST SAVINGS
      IF(DD-3500.)10,11,11
   10 SAVGAS(J,K)=(SO-S(J,K))*1.1*PGAS/(1.E3*.7)
      GO TO 14
   11 IF(DD-6500.)12,12,13
   12 SAVGAS(J,K)=(SO-S(J,K))*PGAS/(1.E3*.7)
      GO TO 14
   13 SAVGAS(J,K)=(SO-S(J,K))*.9*PGAS/(1.E3*.7)
   14 SAVELH(J,K)=(SO-S(J,K))*PELEC*18.5/(24.*3413.)
      SAVEAC(J,K)=(RO-R(J,K))*HAC*1.33*RELEC/12.E3
C CALCULATE TOTAL ANNUAL SAVINGS
      TOTGH(J,K)=SAVGAS(J,K)-FIXGH(J,K)
      TOTEH(J,K)=SAVELH(J,K)-FIXEH(J,K)
      TOTGAC(J,K)=SAVGAS(J,K)+SAVEAC(J,K)-FIXGAC(J,K)
   25 TOTEAC(J,K)=SAVELH(J,K)+SAVEAC(J,K)-FIXEAC(J,K)
C OUTPUT RESULTS
      WRITE(51,1060)
 1060 FORMAT(1HC/1HC,7X,'THERMAL PROPERTIES OF RESIDENCE'/1HO,10X,
     1  'HOURLY COOLING LOAD/HOURLY HEATING LOAD/ANNUAL HEAT'/1H ,10X,
     2  'LOSS/AIR CONDITIONER TONS (LOADS AND LOSS IN KBTU)')
      WRITE(51,1070)UW(1),UW(2),UW(3),UW(4)
 1070 FORMAT(1HC,7X,'WALL U',7X,F5.3,8X,F5.3,8X,F5.3,8X,F5.3/1H ,7X,
     1  'CEIL U')
      DO 15,JR=1,IC
   15 WRITE(51,1080)UCH(JR),R(1,JR),R(2,JR),R(3,JR),R(4,JR),H(1,JR),
     1 H(2,JR),H(3,JR),H(4,JR),S(1,JR),S(2,JR),S(3,JR),S(4,JR),
     2 TON(1,JR),TON(2,JR),TON(3,JR),TON(4,JR)
 1080 FORMAT(1HC,8X,F5.3,4X,F9.2,4X,F9.2,4X,F9.2,4X,F9.2/1H ,17X,F9.2,
     1  4X,F9.2,4X,F9.2,4X,F9.2/1H ,17X,F9.2,4X,F9.2,4X,F9.2,4X,F9.2/
     2  1H ,17X,F9.2,4X,F9.2,4X,F9.2,4X,F9.2)
      IPAGE=IPAGE+1
      WRITE(51,1090)IPAGE,NREG,UFL(I)
 1090 FORMAT(1H1,' PAGE ',I2,2X,5A4,' WITH FLR U OF ',F5.3/1HO,7X,
     1  'GAS HEAT - ANNUAL COSTS AND SAVINGS'/1HO,10X,'DIF. CAP. COST/',
     2   'DIF. FIXED COST/FUEL SAVING/NET SAVING')
      WRITE(51,1070)UW(1),UW(2),UW(3),UW(4)
      DO 16,JR=1,IC
   16 WRITE(51,1080)UCH(JR),CAPGH(1,JR),CAPGH(2,JR),CAPGH(3,JR),
     1  CAPGH(4,JR),FIXGH(1,JR),FIXGH(2,JR),FIXGH(3,JR),FIXGH(4,JR),
     2  SAVGAS(1,JR),SAVGAS(2,JR),SAVGAS(3,JR),SAVGAS(4,JR),TOTGH(1,JR),
     3  TOTGH(2,JR),TOTGH(3,JR),TOTGH(4,JR)
      WRITE(51,1100)
 1100 FORMAT(1HC,7X,'GAS HEAT AND AIR CONDITIONING ANNUAL COSTS AND ',
     1  'SAVINGS'/1HC,10X,'DIF. CAP. COST/DIF. FIXED COST/ELEC SAVING/',
     2  'NET SAVING')
      WRITE(51,1070)UW(1),UW(2),UW(3),UW(4)
      DO 17,JR=1,IC
   17 WRITE(51,1080)UCH(JR),CAPGAC(1,JR),CAPGAC(2,JR),CAPGAC(3,JR),
     1  CAPGAC(4,JR),FIXGAC(1,JR),FIXGAC(2,JR),FIXGAC(3,JR),FIXGAC(4,JR)
     2  ,SAVEAC(1,JR),SAVEAC(2,JR),SAVEAC(3,JR),SAVEAC(4,JR),
     3  TOTGAC(1,JR),TOTGAC(2,JR),TOTGAC(3,JR),TOTGAC(4,JR)
      IPAGE=IPAGE+1
      WRITE(51,1110)IPAGE,NREG,UFL(I)
 1110 FORMAT(1H1,' PAGE ',I2,2X,5A4,' WITH FLR U OF ',F5.3/1HO,7X,
     1  'ELECTRIC HEAT - ANNUAL COSTS AND SAVINGS'/1HO,10X,'DIF. CAP. ',
     2  'COST/DIF. FIXED COST/POWER SAVING/NET SAVING')
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      WRITE(51,1070)UW(1),UW(2),UW(3),UW(4)
      DO 18,JR=1,IC
   18 WRITE(51,1080)UCH(JR),CAPEH(1,JR),CAPEH(2,JR),CAPEH(3,JR),
     1  CAPEH(4,JR),FIXEH(1,JR),FIXEH(2,JR),FIXEH(3,JR),FIXEH(4,JR),
     2  SAVELH(1,JR),SAVELH(2,JR),SAVELH(3,JR),SAVELH(4,JR),
     3  TOTEH(1,JR),TOTEH(2,JR),TOTEH(3,JR),TOTEH(4,JR)
      WRITE(51,1120)
 1120 FORMAT(1H0,7X,'EL. HEAT AND AIR CONDITIONING ANNUAL COSTS AND ',
     1  'SAVINGS'/1H0,10X,'DIF. CAP. COST/DIF. FIXED COST/A-C ELEC ',
     2  'SAVING/NET SAVING')
      WRITE(51,1070)UW(1),UW(2),UW(3),UW(4)
      DO 19,JR=1,IC
   19 WRITE(51,1080)UCH(JR),CAPEAC(1,JR),CAPEAC(2,JR),CAPEAC(3,JR),
     1  CAPEAC(4,JR),FIXEAC(1,JR),FIXEAC(2,JR),FIXEAC(3,JR),
     2  FIXEAC(4,JR),SAVEAC(1,JR),SAVEAC(2,JR),SAVEAC(3,JR),
     3  SAVEAC(4,JR),TOTEAC(1,JR),TOTEAC(2,JR),TOTEAC(3,JR),TOTEAC(4,JR)
   30 CONTINUE
      GO TO 50
   99 CALL EXIT
      STOP
      END
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