THE UNIVERSITY OF MANITOBA

METHODS OF REDUCING HEAT LOSS FROM SINGLE FAMILY DWELLINGS

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARCHITECTURE

DEPARTMENT OF ARCHITECTURE

MAY 1976

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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THIS PAPER IS A STUDY OF TWO METHODS OF REDUCING THE WINTER HEAT LOSS FROM WOOD FRAME, SINGLE FAMILY DWELLINGS. THE FIRST METHOD INVOLVES CALCULATIONS TO DETERMINE THE THERMAL VALUES OF THE SKIN COMPONENTS OF TEST BUILDINGS. THIS ANALYSIS REVEALS THE SKIN COMPONENTS MOST IN NEED OF ADDITIONAL THERMAL RESISTANCE. ONCE THIS ADDITIONAL RESISTANCE HAS BEEN INCORPORATED, A FURTHER ANALYSIS INDICATES THE MAGNITUDE OF REDUCTION OF HEAT LOSS THAT HAS BEEN ACHIEVED.

THE SECOND METHOD EMPLOYED TO REDUCE HEAT LOSS INVOLVES A REARRANGEMENT OF THE TRADITIONAL LOCATIONS OF ROOMS WITHIN THE BUILDING ENVELOPE OF THE SINGLE FAMILY DWELLING. THE INTENT OF THIS REARRANGEMENT IS TO LOCATE ROOMS WITHIN THE ENVELOPE WHERE THEY ARE MOST LIKELY TO FUNCTION EFFECTIVELY IN RELATION TO ENVIRONMENTAL CONDITIONS. BY CONTRASTING TRADITIONAL ROOM LOCATIONS WITH THESE ALTERNATE LOCATIONS, THE MAGNITUDE OF HEAT LOSS SAVINGS TO BE ACHIEVED CAN BE CALCULATED.

ONCE THESE TWO METHODS HAVE BEEN INVESTIGATED, AND THEIR MERITS ASSESSED, AN EXPERIMENTAL HOUSE, SPECIFICALLY DESIGNED TO TAKE ADVANTAGE OF THE INFORMATION GATHERED IN THE FIRST TWO SECTIONS OF THE PAPER, IS INTRODUCED. BY CALCULATING THE RATE OF HEAT LOSS FROM THIS EXPERIMENTAL HOUSE, AN INDICATION OF THE OVERALL EFFECTIVENESS OF THE METHODS EMPLOYED TO REDUCE HEAT LOSS MAY BE SEEN.

AUTHOR'S NOTE

WHEN THIS THESIS WAS BEGUN IN THE FALL OF 1973, THE IMPERIAL SYSTEM OF MEASUREMENT WAS STILL IN COMMON USAGE IN CANADA. CLIMATOLOGICAL DATA, ENGINEERING COMPUTATIONS, BUILDING DIMENSIONS, AND ARCHITECTURAL SCALES WERE ALL BASED ON IMPERIAL UNITS. THE TIMETABLE FOR METRIC CONVERSION HAD BEEN ESTABLISHED AT THIS TIME, AND IT WAS QUITE EVIDENT THAT I WAS GOING TO COMPLETE THE PAPER JUST AS THE RECORDING OF AIR TEMPERATURES WAS BEING CHANGED FROM FAHRENHEIT TO CELSIUS. THEREFORE, I CONSIDERED DOING THIS STUDY IN THE METRIC SYSTEM. THERE WERE, HOWEVER, TWO IMPORTANT CONSIDERATIONS THAT INDICATED OTHERWISE. FIRST, THE DATA THAT I NEEDED WAS ALL RECORDED IN THE IMPERIAL SYSTEM, AND WOULD HAVE TO BE CONVERTED. SECOND, INDIVIDUALS READING THE THESIS SHORTLY AFTER ITS COMPLETION WOULD BE UNFAMILIAR WITH THE METRIC SYSTEM, AND WOULD NOT FULLY COMPREHEND THE DATA PRESENTED. THEREFORE, ALL THE CALCULATIONS IN THIS STUDY ARE DONE IN THE IMPERIAL SYSTEM. MY APOLOGIES TO THE NEW GENERATION.

I DO NOT MEAN TO SAY THAT THE INFORMATION IN THIS PAPER IS OBSOLETE OR IRRELEVENT. BECAUSE IT IS A COMPARATIVE STUDY, THE MOST TELLING FIGURES ARE PERCENTAGE REDUCTIONS IN HEAT LOSS, AND THESE ARE INDEPENDENT OF ANY PARTICULAR SYSTEM OF MEASUREMENT. THE ENGINEERING CALCULATIONS ARE A MEANS TO AN END, AND THAT END IS THE SAME WHETHER THE CALCULATIONS ARE DONE IN THE IMPERIAL SYSTEM OR THE METRIC SYSTEM.

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FIG. 1

SECTION B, THE DATA, IS SHOWN HERE AS A MATRIX CONSISTING OF ALL THE MAJOR VARIABLES PRESENTED IN THIS THESIS. THE HORIZONTAL GRID IS A LIST OF THE HOUSE TYPES STUDIED, AND THE VERTICAL GRID IS THE TRANSFORMATIONS THROUGH WHICH THE HOUSE TYPES PASS. EACH HOUSE TYPE, BEGINNING WITH THE BUNGALOW, IS EXAMINED IN ALL OF ITS VERSIONS, FROM INITIAL TO MODIFIED, BEFORE THE NEXT TYPE IS INTRODUCED.

THE WORD 'INITIAL' IN THE MATRIX REFERS TO THE HOUSES AT THE BEGINNING OF THE STUDY, BEFORE EITHER METHOD OF REDUCING HEAT LOSS HAS BEEN APPLIED. THE INITIAL HOUSES ARE THE BASE DATA. THE REVISED HOUSES ARE A RESULT OF THE APPLICATION OF THE FIRST METHOD OF REDUCING HEAT LOSS, WHICH IS TO INCREASE THE THERMAL VALUES OF PARTICULAR COMPONENTS OF THE SKIN. THE MODIFIED HOUSES HAVE BEEN EXPOSED TO THE SECOND METHOD OF REDUCING HEAT LOSS, WHICH INVOLVES A REARRANGEMENT OF ROOMS WITHIN THE BUILDING ENVELOPE.

THE NUMBERS AT NODAL POINTS WITHIN THE MATRIX ARE PAGE NUMBERS ON WHICH PERTINENT DATA MAY BE FOUND. FOR EXAMPLE, DATA PERTAINING TO THE REVISED SPLIT LEVEL HOUSE IS ON PAGE 104.

SECTION A

METHODOLOGY

TO FULLY COMPREHEND THE ANALYSES INVOLVED IN THIS STUDY, THE READER MUST HAVE SOME UNDERSTANDING OF THE NATURE OF HEAT LOSS FROM A BUILDING. HEAT FLOWS FROM WARMER AREAS TO COOLER AREAS. THEREFORE, HEAT LOSS OCCURS AT THE SKIN OF A BUILDING WHEN THE OUTSIDE AIR TEMPERATURE IS LOWER THAN THE INSIDE AIR TEMPERATURE. THE ABILITY OF A COMPONENT OF THE SKIN TO RESIST THIS FLOW OF HEAT IS THE RESISTANCE VALUE, OR R-VALUE, OF THAT COMPONENT. THE R-VALUE OF A WALL OR ROOF IS THE SUMMATION OF THE R-VALUES OF THE MATERIALS MAKING UP THAT WALL OR ROOF. THE GREATER THE R-VALUE, THE GREATER THE THERMAL RESISTANCE OF THE ASSEMBLY.

OTHER FACTORS INFLUENCING THE RATE OF HEAT LOSS FROM A BUILDING INCLUDE THE SPEED AND DIRECTION OF THE WIND, THE NUMBER OF UNPROTECTED OPENINGS IN THE SKIN WHICH ALLOW FOR INFILTRATION, THE AREA OF WALL EXPOSED TO THE ELEMENTS, AND THE TEMPERATURE DIFFERENCE THROUGH THE WALL FROM INSIDE TO OUT. THE FORMULA U X A X ΔT YIELDS A RATE OF HEAT LOSS THROUGH A GIVEN WALL, MEASURED IN BRITISH THERMAL UNITS[1] PER HOUR (BTU/HR.), WHERE U, THE RECIPROCAL OF R, IS THE

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1. THE AMOUNT OF HEAT REQUIRED TO RAISE THE TEMPERATURE OF ONE POUND OF WATER ONE DEGREE FAHRENHEIT.

RATE OF HEAT LOSS PER SQUARE FOOT OF WALL PER DEGREE FAHRENHEIT TEMPERATURE DIFFERENCE, A IS THE AREA OF THE WALL, AND ΔT THE DIFFERENCE IN TEMPERATURE THROUGH THE WALL. THE ONLY WAYS OF DECREASING THE RATE OF HEAT LOSS THROUGH A WALL ARE TO INCREASE THE THERMAL RESISTANCE OF THE WALL, DECREASE THE AREA OF THE WALL EXPOSED TO THE ELEMENTS, OR REDUCE THE TEMPERATURE DIFFERENCE THROUGH THE WALL.

THE VELOCITY AND DIRECTION OF THE WIND AFFECT THE U-VALUE OF THE WALL. A MICROSCOPIC LAYER OF STILL AIR, CLINGING TO THE WALL THROUGH FRICTION, HAS A SPECIFIC THERMAL VALUE, SINCE IT TENDS TO ISOLATE THE OUTSIDE SURFACE OF THE WALL FROM THE AMBIENT AIR. IF THE WIND IS BLOWING, IT REMOVES THIS LAYER OF AIR, OR PART OF IT, AND THEREBY LESSENS THE THERMAL VALUE OF THE WALL.

THE INFILTRATION OF COLD AIR INTO THE BUILDING CONTRIBUTES TO HEAT LOSS BY DISPLACING WARM INSIDE AIR. SINCE ACTUAL RATES OF INFILTRATION ARE SELDOM EQUAL TO RECOMMENDED RATES OF VENTILATION, THE RECOMMENDED VENTILATION RATE OF 75 CUBIC FEET PER MINUTE[2] OF FRESH OUTSIDE AIR WILL BE USED IN THIS STUDY.

THERE ARE ADDITIONAL CRITERIA THAT ARE SOMETIMES USED IN CALCULATING RATES OF HEAT LOSS FROM BUILDINGS. THESE ARE ESSENTIALLY SOURCES OF HEAT GAIN, AND INCLUDE SOLAR GAIN,

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2. CARRIER SYSTEM DESIGN MANUAL, CARRIER CORPORATION 1972.

AND GAINS FROM PEOPLE, LIGHTS, MOTORS, AND APPLIANCES. ALTHOUGH THESE HEAT GAINS AFFECT THE AMOUNT OF HEATING REQUIRED IN A BUILDING, THEY HAVE NO DIRECT AFFECT UPON THE RATES OF HEAT LOSS THROUGH THE SKIN OF A BUILDING, AND WILL THEREFORE BE EXCLUDED FROM THIS STUDY.

S C O P E

SINCE IT IS NOT POSSIBLE WITHIN THE SCOPE OF THIS INVESTIGATION TO TEST ACTUAL HOUSE, THEORETICAL HOUSES, SUBJECT TO THEORETICAL CLIMATIC CONDITIONS, ARE USED INSTEAD. THE PLANS OF THESE THEORETICAL HOUSES HAVE BEEN SELECTED FROM THE CENTRAL MORTGAGE AND HOUSING CORPORATION'S (CMHC) BOOK OF HOUSE DESIGNS, AND ARE INTENDED TO REPRESENT TYPICAL CANADIAN SINGLE FAMILY DWELLINGS.[3] THE THREE HOUSES ARE REPRESENTATIVE OF THE THREE MAJOR HOUSE TYPES BEING BUILT IN CANADA TODAY - BUNGALOW, SPLIT LEVEL, AND TWO STOREY. ALL THREE HOUSES HAVE THREE BEDROOMS, A SINGLE WASHROOM, KITCHEN, AND COMBINED LIVING - DINING ROOMS. SOME MODIFICATIONS HAVE BEEN MADE TO THE BUILDINGS, PARTICULARLY THE TWO STOREY HOUSE, TO ENSURE THAT ALL THREE HOUSES HAVE EQUAL PLAN AREAS AND EQUAL WINDOW OPENINGS. THESE CHANGES WERE MADE TO ENSURE THAT ANY COMPARISONS STEMMING FROM AN EVALUATION OF THE THERMAL PERFORMANCES OF VARIOUS HOUSES WOULD BE VALID. CONSTRUCTION DETAILS OF THE THREE HOUSES, INCLUDING INSULATION STANDARDS USED, ARE TO BE FOUND ON PAGES 50, 52, AND 54 FOR THE BUNGALOW, 88, 90, AND 92 FOR THE SPLIT LEVEL, AND 126, 128, AND 130 FOR THE TWO STOREY HOUSE.

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3. HOUSE DESIGNS PREPARED BY CANADIAN ARCHITECTS FOR CENTRAL MORTGAGE AND HOUSING CORPORATION

CLIMATIC CONDITIONS USED IN THIS STUDY ARE THOSE OF WINNIPEG, MANITOBA. THE OUTSIDE WINTER DESIGN TEMPERATURE USED IS -30° F.,[4] AND THE WIND IS ASSUMED TO BE COMING OUT OF THE NORTH-WEST AT 15 MPH.[5] OTHER DATA PERTINENT TO THE CALCULATIONS OF HEAT LOSS FROM BUILDINGS MAY BE FOUND IN THE APPENDIX.

THE FIRST METHOD OF REDUCING HEAT LOSS IS TO INCREASE THE THERMAL VALUE OF THE SKINS OF THE CMHC TEST BUILDING, ALL OF WHICH ARE OF WOOD FRAME CONSTRUCTION. ON THIS CONTINENT, WOOD HAS ALWAYS BEEN ABUNDANT, AND THEREFORE INEXPENSIVE. IT IS LIGHT, STRONG, EASILY CUT, AND SIMPLE TO ERECT. WITH ALL OF THESE FACTORS IN ITS FAVOUR, WOOD FRAME CONSTRUCTION HAS BECOME THE STANDARD METHOD OF HOUSE BUILDING THROUGHOUT NORTH AMERICA. HOWEVER, BECAUSE OF THE WIDE VARIETY OF CLIMATIC CONDITIONS TO BE FOUND FROM ONE END OF THE CONTINENT TO THE OTHER, VARIATIONS AND ADAPTATIONS TO THE METHOD HAVE EVOLVED. IN A CLIMATIC ZONE THAT IS COLD FOR A GOOD PART OF THE YEAR, SUCH AS WESTERN CANADA'S, THE ADAPTATIONS INCLUDE INSULATION IN THE WALLS, AND CEILING, A VAPOUR BARRIER, DOUBLE GLAZED WINDOWS, AND FOUNDATIONS EXTENDING INTO THE GROUND BELOW THE DEPTH OF FROST PENETRATION. HOWEVER, ONLY THOSE VARIATIONS NECESSARY TO ALLOW THE INDIVIDUAL TO HEAT HIS HOME ECONOM-ICALLY HAVE BEEN INCORPORATED INTO THE BUILDING TECHNIQUE. OTHER POSSIBLE VARIATIONS THAT WOULD REDUCE HEAT LOSS EVEN

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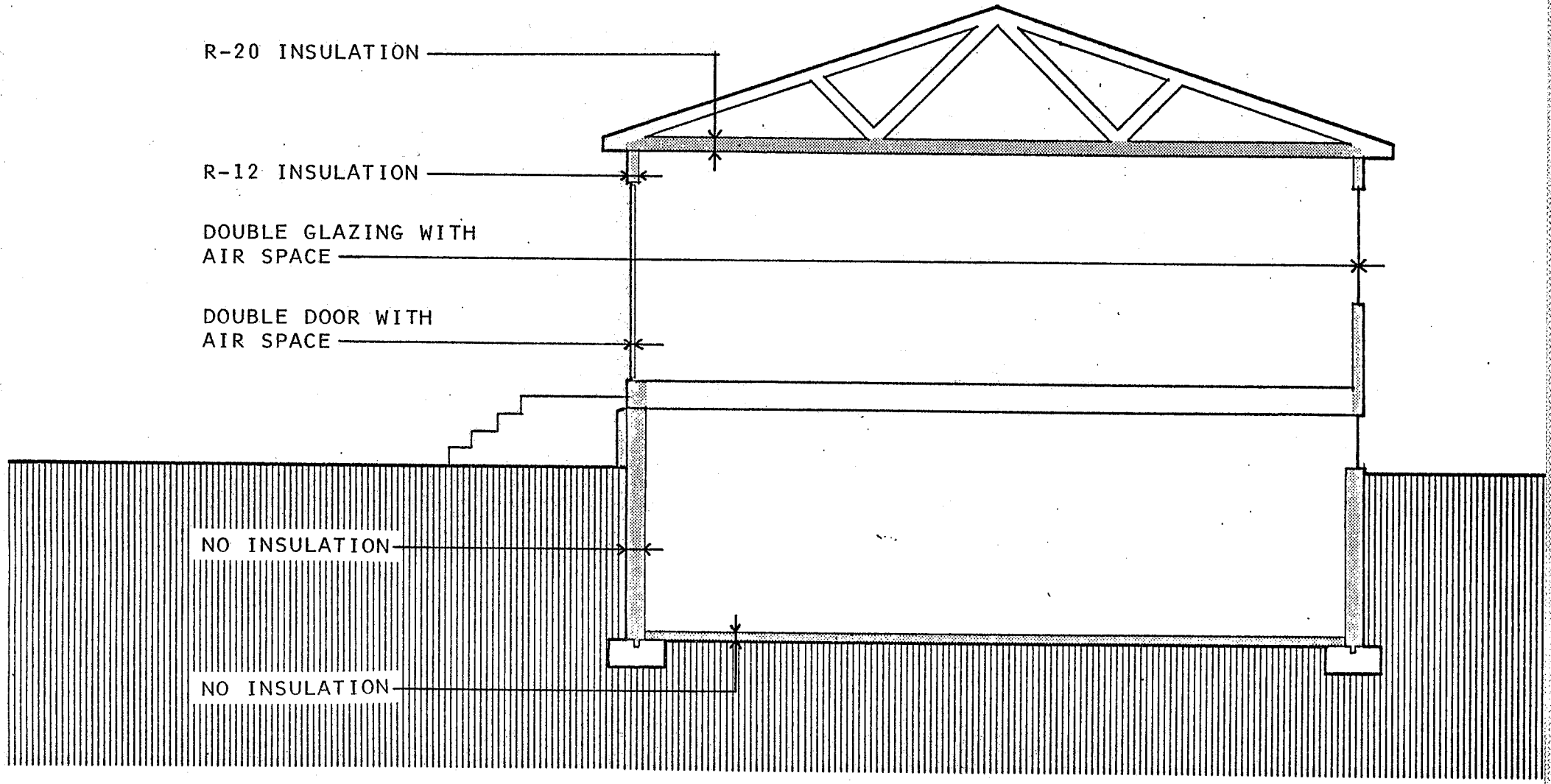
4. CARRIER SYSTEM DESIGN MANUAL, CARRIER CORPORATION, 1972

5. IBID.



TYPICAL TRANSVERSE SECTION

SCALE : 3/16" = 1'-0"

FIG. 2

FURTHER HAVE NOT OCCURRED BECAUSE THEY WOULD INVOLVE ADDITIONAL EXPENSE TO INSTITUTE, AND ENERGY IN THE FORM OF HEATING FUELS HAS BEEN READILY AVAILABLE, AND INEXPENSIVE. IN OTHER WORDS, THE QUESTION OF WHAT THICKNESS OF INSULATION TO BE PLACED IN THE WALLS, OR HOW MANY PANES OF GLASS TO BE PLACED IN THE WINDOWS, IS RESOLVED THROUGH THE USE OF AN ECONOMIC EQUATION. THE LONG TERM COST OF HEATING THE HOUSE MUST BALANCE THE SHORT TERM COST OF INSULATING THE HOUSE. IF ONE SIDE OF THIS EQUATION, THE VALUE OF ENERGY, INCREASES, THE OTHER SIDE, THE THERMAL VALUE OF THE SKIN OF THE HOUSE, MUST INCREASE SUCH THAT THE EQUATION WILL CONTINUE TO BALANCE.

SINCE ACTUAL ENERGY COSTS ARE CHANGING VERY RAPIDLY AT THE PRESENT TIME, IT IS POINTLESS TO ATTEMPT IN THIS PAPER TO DEFINE THESE COSTS. INSTEAD, HEAT LOSS, IN BTU/HR., SHALL BE USED AS THE CONSTANT FACTOR. AT ANY GIVEN MOMENT, HEAT LOSS AND ENERGY COSTS ARE DIRECT FUNCTIONS OF ONE ANOTHER, SINCE THE ENERGY REQUIRED TO HEAT A BUILDING IS EXACTLY EQUAL TO THE ENERGY OF THE HEAT LOST FROM THE BUILDING. AT THE PRESENT TIME, THE COST OF ENERGY DICTATES THAT A HOUSE BE INSULATED AS ILLUSTRATED IN FIG. 2 . AS THE COST OF ENERGY CONTINUES TO INCREASE, FURTHER ADAPTATIONS TO THE SKIN OF THE SINGLE FAMILY DWELLING WILL OCCUR. BY CALCULATING THE PATTERN OF HEAT LOSS OCCURRING FROM THE THREE HOUSE TYPES, IT SHOULD BE POSSIBLE TO DETERMINE WHICH COMPONENT OR COMPONENTS ARE MOST IN NEED OF GREATER THERMAL RESISTANCE WHEN INCREASED ENERGY COSTS DICTATE A FURTHER ADAPTATION OF THE SKIN

OF THE SINGLE FAMILY DWELLING.

THE CALCULATIONS OF HEAT LOSS FROM THE THREE TYPICAL HOUSE TYPES MAY BE FOUND ON PAGES 60, 98 , AND 136. IN THE BUNGALOW, THE GREATEST HEAT LOSS, 32.0% OF THE TOTAL, OCCURRED AT THE FOUNDATION, AND THE LARGEST COMPONENT OF THE FOUNDATION HEAT LOSS WAS THE TWO FOOT STRIP OF CONCRETE EXTENDING ABOVE GRADE, WHICH ACCOUNTED FOR FULLY 80% OF THE TOTAL HEAT LOST BY THE FOUNDATION. THE NEXT GREATEST HEAT LOSS FROM THE BUNGALOW OCCURRED THROUGH THE WINDOWS, AND REPRESENTED 26.2% OF THE TOTAL HEAT LOSS.

IN THE SPLIT LEVEL HOUSE, THE GREATEST PERCENTAGE HEAT LOSS OCCURRED AT THE WINDOWS, AND REPRESENTED 30.0% OF THE TOTAL HEAT LOSS FROM THIS HOUSE. THE ACTUAL HEAT LOSS OF 15,594 BTU/HR. IS VERY SIMILAR TO THE HEAT LOST THROUGH THE WINDOWS OF THE BUNGALOW. THE FOUNDATION HEAT LOSS OF 10,836 BTU/HR., OR 20.8% OF THE TOTAL, IS SOMEWHAT SMALLER THAN THAT OF THE BUNGALOW. AGAIN, THOUGH, THE WINDOWS AND FOUNDATION WALLS REPRESENT THE POINTS OF GREATEST HEAT LOSS FROM THE HOUSE.

THE SAME HOLDS TRUE IN THE CASE OF THE TWO STOREY HOUSE. THE WINDOW HEAT LOSS OF 15,227 BTU/HR., OR 29.9% OF THE TOTAL, IS VERY SIMILAR TO THE VALUES CALCULATED IN THE OTHER TWO HOUSE TYPES. THE FOUNDATION LOST 11,135 BTU/HR., OR 21.9% OF THE TOTAL HEAT LOSS. THIS VALUE IS VERY SIMILAR TO THAT OF THE SPLIT LEVEL, SINCE THE TWO HOUSES HAVE ALMOST EQUAL

AMOUNTS OF FOUNDATION WALL.

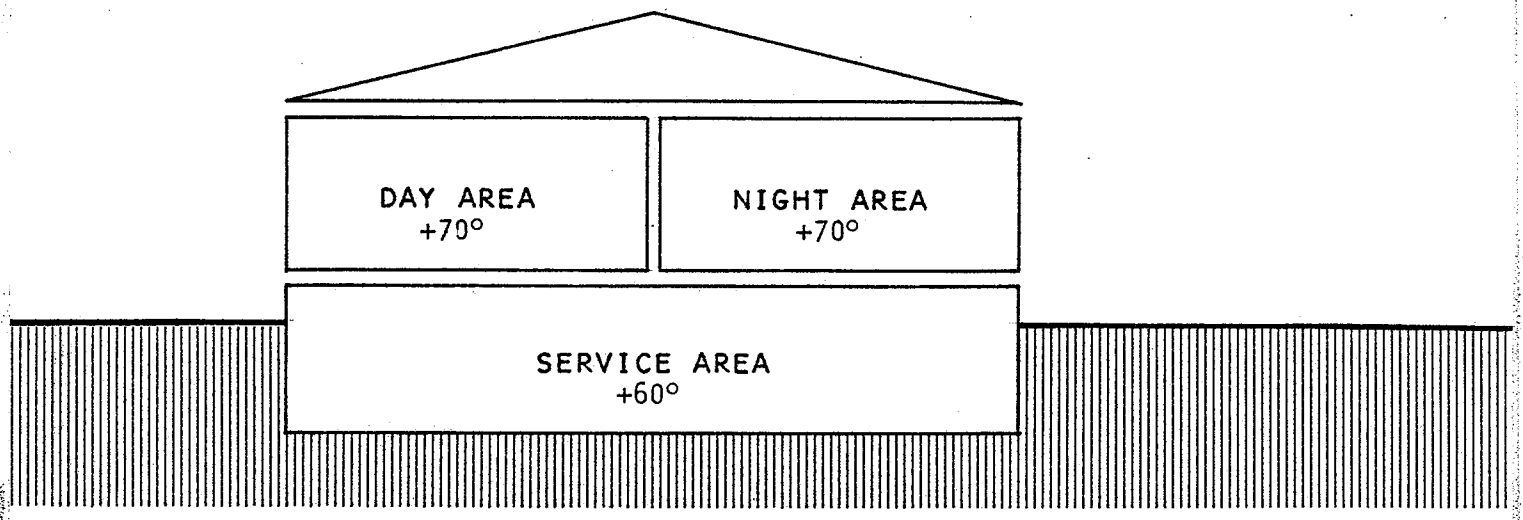
THE CONCLUSION TO BE DRAWN FROM THIS ANALYSIS IS THAT THE WINDOW AND FOUNDATION WALL COMPONENTS OF THE SKIN OF THE SINGLE FAMILY DWELLING ARE THE POINTS AT WHICH ADDITIONAL THERMAL RESISTANCE SHOULD BE APPLIED TO REDUCE HEAT LOSS. IT IS PROBABLY SAFE TO ASSUME THAT MOST HOMEOWNERS ARE AWARE THAT RELATIVELY LARGE QUANTITIES OF HEAT ARE LOST THROUGH WINDOWS, AND THAT THEY ARE WILLING TO BEAR THE COST OF THIS HEAT LOSS IN RETURN FOR THE AESTHETIC ADVANTAGES OF HAVING WINDOWS IN THEIR HOMES. ON THE OTHER HAND, IT IS PROBABLY EQUALLY SAFE TO ASSUME THAT RELATIVELY FEW HOMEOWNERS WOULD BE AWARE OF THE MAGNITUDE OF HEAT LOSS THAT IS OCCURRING THROUGH THE FOUNDATION OF THEIR HOMES, AND THAT WERE THEY AWARE OF THIS FACT, THEY WOULD BE IN A POSITION TO DECIDE WHETHER OR NOT THEY WISHED TO INSULATE THE FOUNDATION.

IN ORDER TO DETERMINE THE POTENTIAL SAVINGS THAT MAY BE REALIZED BY INCREASING THE THERMAL RESISTANCE OF THE WINDOWS AND FOUNDATION WALLS, THE THREE TYPICAL HOUSE TYPES HAVE BEEN REVISED. THE CHANGES ARE FROM DOUBLE GLAZING TO TRIPLE GLAZING IN ALL WINDOWS, AND FROM NO INSULATION TO 2" OF RIGID INSULATION ON THE OUTSIDE FACE OF THE FOUNDATION WALLS ABOVE GRADE. THE HEAT LOSS CALCULATIONS RESULTING FROM THESE CHANGES ARE TO BE FOUND ON PAGES 66, 104, AND 142.

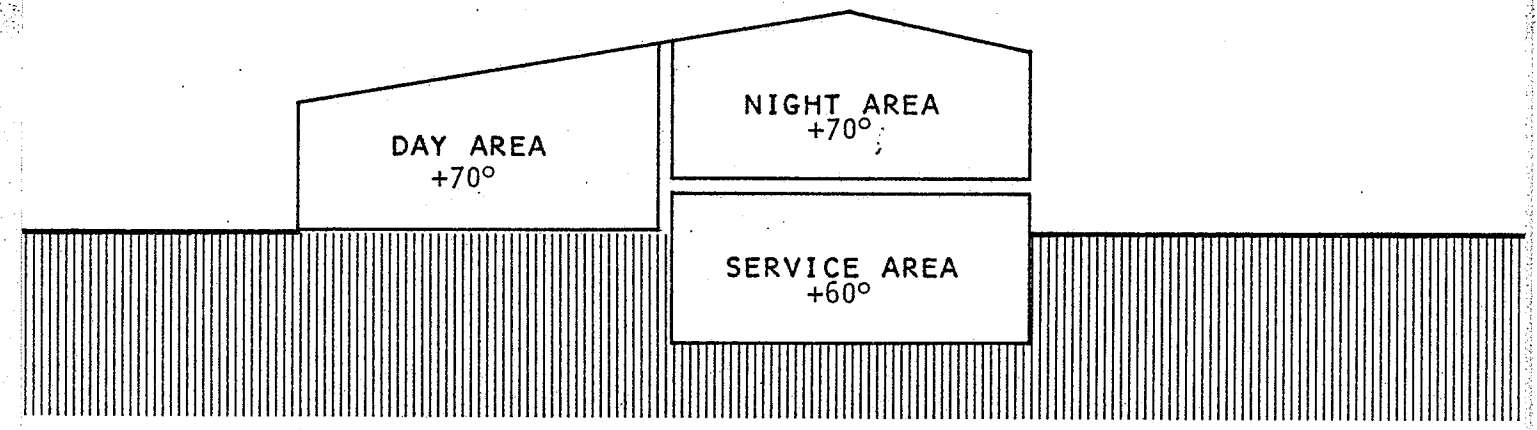
THIS POINT IN THE PAPER MARKS THE END OF THE INVESTIGATION OF THE FIRST METHOD OF REDUCING HEAT LOSS FROM WOOD FRAME, SINGLE FAMILY DWELLINGS. IT HAS BEEN ESTABLISHED THAT THE TWO POINTS OF GREATEST HEAT LOSS FROM TRADITIONALLY CONSTRUCTED HOUSES ARE THE WINDOWS AND THE FOUNDATION WALLS. WHEN THE THERMAL RESISTANCE OF THESE TWO COMPONENTS IS INCREASED AS DESCRIBED EARLIER, HEAT LOSS FROM THE HOUSE DROPS BY AN AVERAGE OF 27.7%

THE SECOND METHOD EMPLOYED TO REDUCE HEAT LOSS INVOLVES A REARRANGEMENT OF THE TRADITIONAL LOCATIONS OF ROOMS WITHIN THE BUILDING ENVELOPE. UNLIKE THE PREVIOUS METHOD EXPLORED, THIS INVESTIGATION HAS LITTLE RELEVANCE TO THE OWNER OF AN EXISTING HOUSE.

THE "PERFECT" ENERGY CONSERVING HOUSE IN TERMS OF HEAT LOSS WOULD BE LOCATED ENTIRELY BELOW GRADE, SO THAT ITS SKIN WAS COMPLETELY SURROUNDED BY A BLANKET OF EARTH PROTECTING IT FROM AIR AT -30° F., FOR ALTHOUGH THE GROUND IN WINNIPEG IS FROZEN FOR APPROXIMATELY SEVEN MONTHS OF THE YEAR, THE TEMPERATURE OF THIS FROZEN SOIL REMAINS CONSIDERABLY HIGHER THAN THAT OF THE OUTSIDE AIR . THEREFORE, IN A HOUSE LOCATED BELOW GRADE, THE TEMPERATURE DIFFERENCE FROM INSIDE TO OUT WOULD BE MUCH LOWER, AS WOULD THE HEAT LOSS FROM THE HOUSE. IT IS THE OPINION OF THE AUTHOR, HOWEVER, THAT A HOUSE



B U N G A L O W



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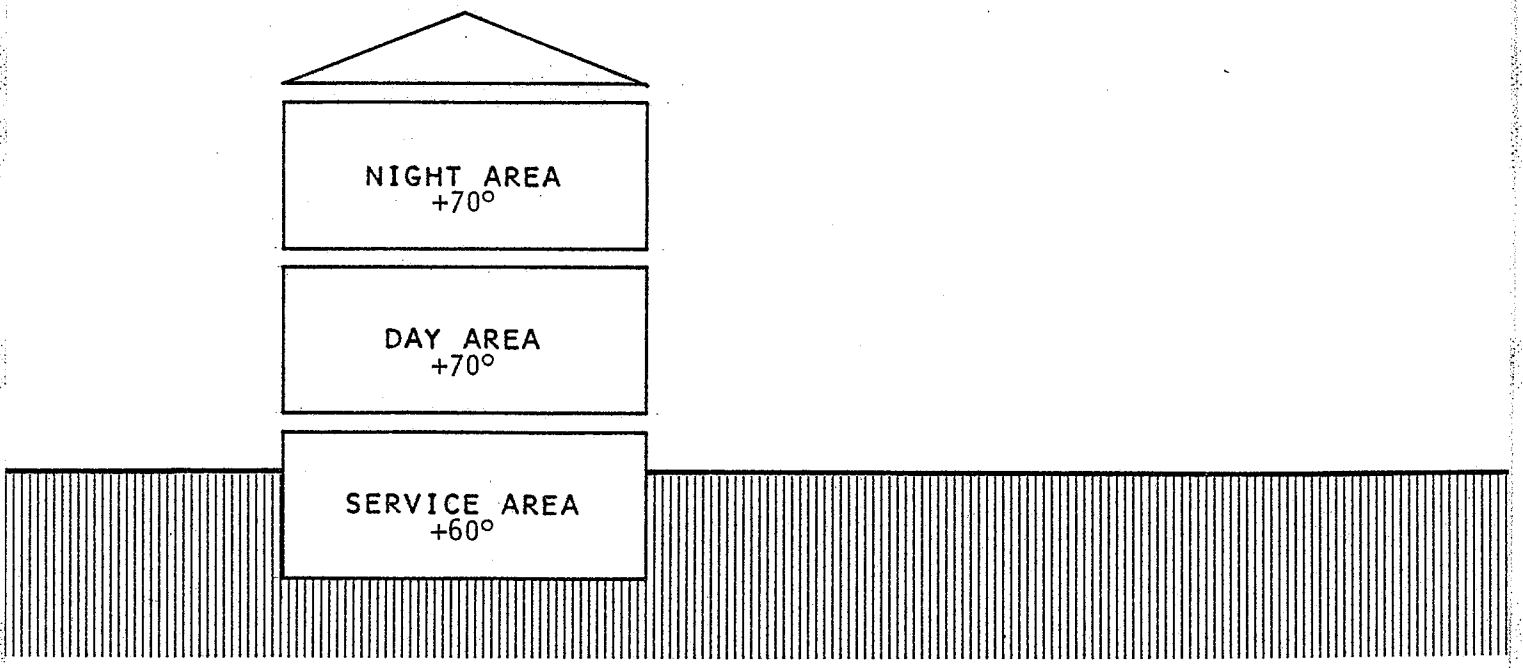


T W O S T O R E Y

FIG. 3

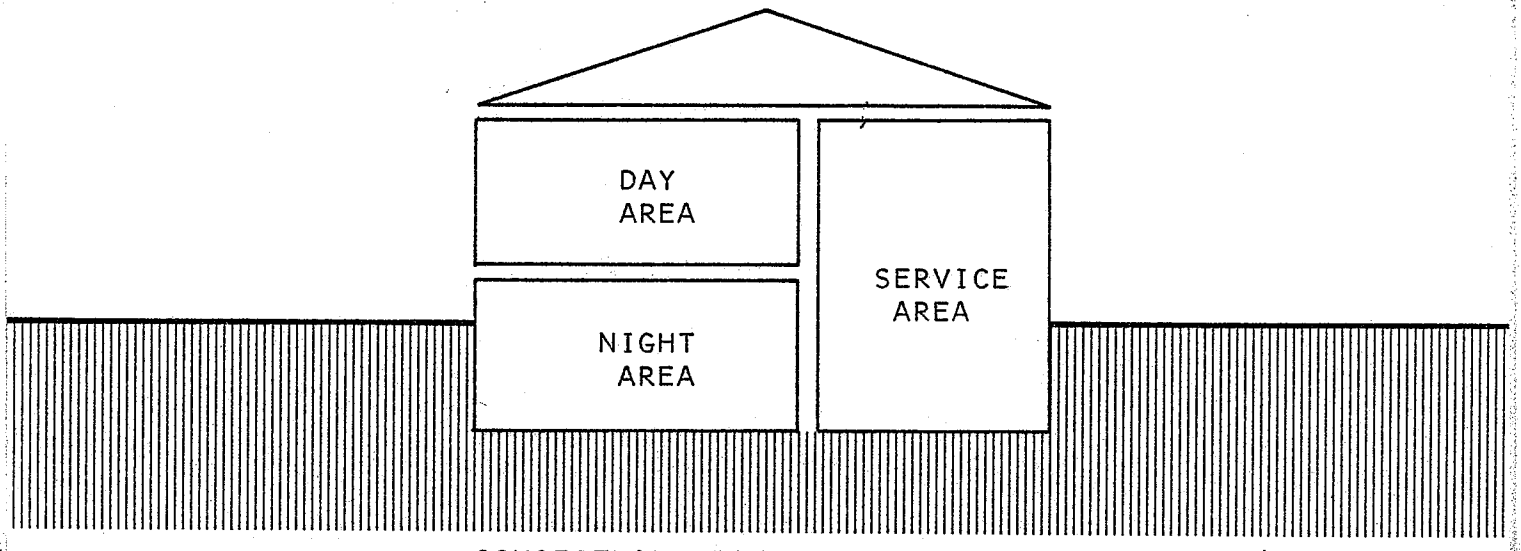
LOCATED ENTIRELY BELOW GRADE WOULD BE A TOTALLY UNACCEPTABLE DWELLING UNIT FOR A VAST MAJORITY OF THE POPULATION. THUS IT IS THE INTENT IN THIS SECTION OF THE STUDY TO DETERMINE WHICH ROOMS OF A HOUSE WOULD NOT ONLY FUNCTION EFFECTIVELY BELOW GRADE FROM THE POINT OF VIEW OF ENERGY CONSERVATION, BUT WOULD BE ACCEPTABLE BELOW GRADE TO THE GENERAL PUBLIC.

THE DIAGRAMS ON PAGE 26 ARE CONCEPTUAL SECTIONS THROUGH THE THREE BASIC HOUSE TYPES, ILLUSTRATING TRADITIONAL ROOM ARRANGEMENT WITHIN THE BUILDING ENVELOPE. EACH BUILDING SECTION IS BROKEN INTO THREE MAJOR AREAS; IN EACH AREA A TYPICAL INSIDE TEMPERATURE FOR THAT GROUP OF ROOMS IS INDICATED. THE THREE AREAS ARE: A DAY AREA, MADE UP OF A LIVING ROOM, DINING ROOM, AND KITCHEN, ALL AT +70° F., A NIGHT AREA, MADE UP OF BEDROOMS AND WASHROOMS, ALSO AT +70° F., AND A SERVICE AREA, CONTAINING LAUNDRY FACILITIES, WORKROOM, RECREATION AND STORAGE, ALL AT +60° F. IN ALL THREE TYPICAL EXAMPLES, THE DAY AND NIGHT AREAS ARE ABOVE GRADE, AND THE UTILITY AREA IS BELOW GRADE, WHERE ITS 60° TEMPERATURE CAN BE MAINTAINED WITHOUT ANY DIRECT INPUT OF HEAT. THIS ARRANGEMENT OF ROOMS HAS BEEN STANDARD PRACTISE FOR A GREAT MANY YEARS, AND FROM A TRADITIONAL POINT OF VIEW MAKES A GOOD DEAL OF SENSE.

HOWEVER, IF THIS TRADITIONAL ARRANGEMENT IS EXAMINED IN THE LIGHT OF REDUCING HEAT LOSS FROM THE BUILDING, CERTAIN ANOMALIES BECOME APPARENT. IN ORDER TO FULLY COMPREHEND

THESE, IT IS NECESSARY TO REVIEW THE NATURE OF HEAT LOSS. HEAT FLOWS FROM WARM TO COOL, AND THE GREATER THE DIFFERENCE IN TEMPERATURE, THE GREATER THE FLOW OF HEAT. BECAUSE THE TEMPERATURE DIFFERENCE FROM INSIDE TO OUTSIDE IS MUCH GREATER ABOVE GRADE THAN BELOW GRADE, THE FLOW OF HEAT FROM THE HOUSE IS MUCH GREATER ABOVE GRADE THAN BELOW GRADE. THEREFORE, ONE WAY OF REDUCING THE HEAT LOSS ABOVE GRADE IS TO REDUCE THE TEMPERATURE DIFFERENCE FROM INSIDE TO OUTSIDE. HAVING NO CONTROL OVER THE OUTSIDE TEMPERATURE, IT IS EVIDENT THAT THE SOLUTION LIES IN LOWERING THE INSIDE TEMPERATURE OF AS MANY ROOMS AS POSSIBLE THAT ARE LOCATED ABOVE GRADE.

HOWEVER, WHATEVER SOLUTION IS REACHED MUST BE ACCEPTABLE TO THE POTENTIAL HOMEOWNER. OF THE THREE MAJOR AREAS OF THE HOUSE, THE ONE THAT IS MOST FLEXIBLE IN TERMS OF ITS LOCATION WITHIN THE BUILDING ENVELOPE IS THE SERVICE AREA. IN ADDITION, THIS AREA HAS THE LOWEST AMBIENT AIR TEMPERATURE OF THE THREE. THEREFORE, IT APPEARS TO BE PERFECTLY SUITED TO BE LOCATED ABOVE GRADE, IN ORDER TO REDUCE THE ΔT THROUGH THE ABOVE GRADE WALLS. THE LIVING ROOM, DINING ROOM AND KITCHEN ARE NOT AS FLEXIBLE IN THEIR LOCATIONS. BECAUSE THIS AREA OF THE HOUSE BEARS A STRONG RELATIONSHIP TO THE OUT-OF-DOORS, IS USED PRIMARILY DURING DAYLIGHT HOURS, AND IS THE PRIMARY LIVING AREA OF THE HOUSE, IT MUST BE ASSUMED THAT ALTHOUGH ITS RATE OF HEAT LOSS WOULD BE REDUCED WERE IT LOCATED BELOW GRADE, THIS AREA OF THE HOUSE IS BEST LEFT ABOVE GRADE. ON



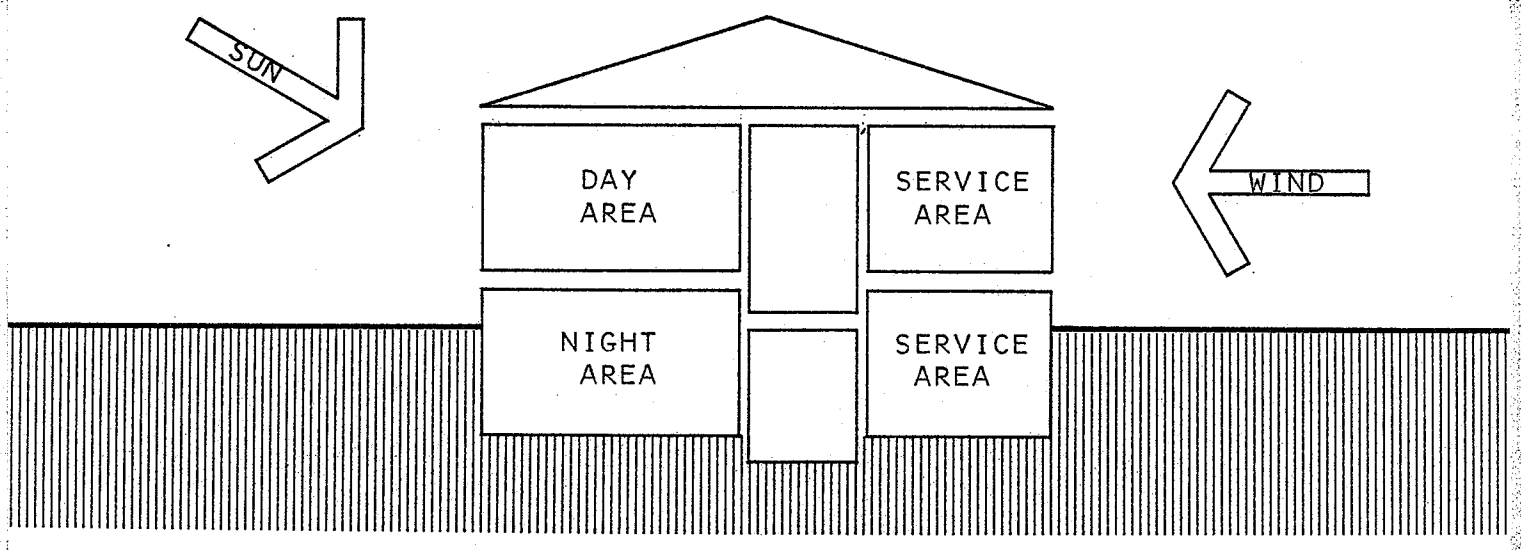
CONCEPTUAL SECTION FIG. 4

THE OTHER HAND, THE BEDROOMS HAVE LITTLE OR NO RELATIONSHIP TO THE OUT-OF-DOORS, ARE USED PRIMARILY DURING NIGHTTIME HOURS, AND ARE THE SECONDARY AREAS OF THE HOUSE. THEREFORE IT SHALL BE ASSUMED THAT THESE ROOMS COULD BE LOCATED BELOW GRADE.

THIS NEW RELATIONSHIP OF AREAS TO EACH OTHER AND TO THE BUILDING ENVELOPE IS SHOWN AS A CONCEPTUAL SECTION IN FIG. 4.

IN ORDER TO TEST THE VALIDITY OF THIS NEW CONCEPT, THE AREAS OF THE THREE TYPICAL CMHC HOUSE TYPES USED IN THE FIRST SECTION WILL BE REARRANGED TO CORRESPOND AS CLOSELY AS POSSIBLE TO THE CONCEPTUAL SECTION SHOWN IN FIG. 4 . CALCULATIONS OF HEAT LOSS FROM THE HOUSES SO REARRANGED MAY THEN BE CONTRASTED WITH THE HEAT LOSS CALCULATIONS OF THE SAME HOUSES BEFORE REARRANGEMENT, THEREBY INDICATING THE MAGNITUDE OF SAVINGS POSSIBLE.

CONCEPTUAL SECTIONS THROUGH THE THREE ORIGINAL CMHC HOUSE TYPES, AND THE SAME THREE HOUSE TYPES MODIFIED, MAY BE FOUND ON PAGES 70, 108, AND 146. THE ACTUAL CALCULATIONS OF HEAT LOSS FROM THE MODIFIED HOUSES ARE TO BE FOUND ON PAGES 82, 120, AND 158. IN ALL CASES, THE HEAT LOSSES FROM THE MODIFIED HOUSES ARE LOWER THAN THE HEAT LOSSES FROM THE ORIGINAL HOUSES, INDICATING THAT THERE IS SOME ADVANTAGE TO BE ATTAINED IN REARRANGING THE SPACES WITHIN THE BUILDING ENVELOPE.



EXPERIMENTAL

FIG. 5

THIS POINT MARKS THE END OF THE INVESTIGATION OF THE SECOND METHOD OF REDUCING HEAT LOSS FROM WOOD FRAME, SINGLE FAMILY DWELLINGS. IT HAS BEEN ESTABLISHED THAT BY REARRANGING THE LOCATIONS OF VARIOUS AREAS OF THE TYPICAL HOUSE, HEAT LOSS FROM THAT HOUSE CAN BE REDUCED BY AN AVERAGE OF 2.3%

THE STUDY JUST COMPLETED INVOLVED THE REARRANGEMENT OF SPACES WITHIN TRADITIONAL HOUSES. IT MUST BE ASSUMED THAT AN EVEN GREATER REDUCTION IN HEAT LOSS COULD BE ACHIEVED WERE A HOUSE DESIGNED INITIALLY WITH ENVIRONMENTAL DETERMINANTS IN MIND. TO DISCOVER JUST WHAT MAGNITUDE OF REDUCTION IS POSSIBLE, AN EXPERIMENTAL HOUSE HAS BEEN DESIGNED TO SPECIFICALLY RESPOND TO THE CRITERIA PRESENTED IN PART TWO. FIG. 5 IS A CONCEPTUAL SECTION THROUGH THIS HOUSE, SHOWING NOT ONLY THE RELATIONSHIP OF THE VARIOUS AREAS OF THE HOUSE TO EACH OTHER WITHIN THE ENVELOPE, BUT ALSO THE RELATIONSHIP OF THE AREAS TO EXTERNAL ENVIRONMENTAL CONDITIONS. THE AREAS OF THE HOUSE ORDINARILY USED AS LIVING SPACES, BOTH DURING THE DAY AND AT NIGHT, ARE ORIENTED TOWARDS THE SUN, AND ARE PROTECTED FROM THE COOLING EFFECT OF THE WIND BY THE SERVICE AREA, WHICH ACTS AS A BUFFER. THE PLANS AND BUILDING SECTION OF THIS HOUSE ARE TO BE FOUND ON PAGES 164, 166, AND 168. IN ORDER TO HELP ENSURE THE VALIDITY OF COMPARISONS, THE AREA OF THIS EXPERIMENTAL HOUSE IS EQUAL TO THE AREAS OF THE THREE CMHC HOUSES. HEAT LOSS CALCULATIONS FOR THE EXPERIMENTAL HOUSE ARE ON PAGE 174, AND THE TOTAL IS LOWER THAN THOSE OF ANY OF THE THREE MODIFIED CMHC HOUSE. A SUMMARY OF HEAT LOSS DATA FROM

THE EXPERIMENTAL HOUSE IS PRESENTED WITH HEAT LOSS DATA FROM THE THREE MODIFIED CMHC HOUSES ON PAGE 176 .

C O N C L U S I O N S

WITHIN THE FRAMEWORK OF THE LIMITED VARIABLES INVESTIGATED IN THIS PAPER, IT WOULD APPEAR THAT A SIGNIFICANT REDUCTION IN HEAT LOSS COULD BE ACHIEVED NOT ONLY IN NEW HOUSING, BUT MORE IMPORTANTLY, IN THE EXISTING HOUSING STOCK, THROUGH A JUDICIOUS AUGMENTATION OF THE THERMAL VALUES OF PARTICULAR COMPONENTS OF THE SKIN OF SINGLE FAMILY DWELLINGS. IN THE FIRST METHOD OF REDUCING HEAT LOSS STUDIED, A LARGE PROPORTION OF THE TOTAL HEAT LOSS FROM THE GIVEN HOUSE TYPES IS SHOWN TO OCCUR THROUGH THE WINDOWS AND THE APPROXIMATELY TWO FOOT HIGH STRIP OF FOUNDATION WALL ABOVE GRADE. THE METHODS USED IN THIS PAPER TO REDUCE THAT HEAT LOSS RESULTED IN AN AVERAGE SAVINGS OF 27.7%. OTHER POSSIBLE METHODS OF REDUCING HEAT LOSS THROUGH THE WINDOWS AND FOUNDATION WALLS, NOT EXAMINED HERE, INCLUDE THERMAL SHUTTERS TO BE PLACED OVER THE WINDOWS AT NIGHT, BERMING EARTH AGAINST THE FOUNDATION WALL ON THE EXTERIOR OF THE HOUSE, STRAPPING AND INSULATING THE INTERIOR SURFACE OF THE FOUNDATION WALL, OR PLACING RIGID INSULATION ON OR JUST BELOW GRADE AT THE FOUNDATION WALL. ALL OF THESE METHODS COULD BE EMPLOYED ON EXISTING HOUSES, AS WELL AS NEW, THE RESULT OF WHICH WOULD BE A SIGNIFICANT REDUCTION IN HEAT LOSS.

IN ADDITION, THESE FINDINGS NEED NOT BE CONFINED TO SINGLE FAMILY DWELLINGS. ANY BUILDING WITH WINDOWS, OR A BASEMENT,

COULD BENEFIT IN TERMS OF HEAT LOSS BY EMPLOYING THE METHODS JUST MENTIONED. THIS OF COURSE, WOULD INCLUDE ALMOST ALL THE BUILDINGS IN A TYPICAL CANADIAN CITY. THE POTENTIAL FOR ENERGY SAVINGS IS, THEREFORE, ENORMOUS.

UNLIKE THE FIRST METHOD EMPLOYED, THE SECOND MEANS OF REDUCING HEAT LOSS STUDIED IS NOT APPLICABLE TO EXISTING HOUSING. INDEED, THE REARRANGEMENT OF SPACES CARRIED OUT IN THE SECOND PART OF THE PAPER IS INTENDED TO INDICATE A DIRECTION ONLY, RATHER THAN BEING A DIFINITIVE END UNTO ITSELF. IN THAT REGARDS, THE EXPERIMENT IS SUCCESSFUL. IN ALL THREE HOUSE TYPES, THE HEAT LOSS FOLLOWING THE REARRANGEMENT OF THE SPACES IS SMALLER THAN THAT BEFORE REARRANGEMENT. THE AVERAGE REDUCTION IN HEAT LOSS OF 2.3% FROM THE REVISED HOUSES TO THE MODIFIED HOUSES IS SMALL, BUT INDICATES THAT THERE ARE POTENTIAL SAVINGS TO BE REALIZED.

IN THE CASE OF THE EXPERIMENTAL HOUSE, WHICH IS DESIGNED TO CAPITALIZE ON THESE POTENTIAL SAVINGS, THE TOTAL HEAT LOSS OF 32,236 BTU/HR. IS 16% LESS THAN THE AVERAGE HEAT LOSS OF THE MODIFIED HOUSES, 18% LESS THAN THE AVERAGE OF THE REVISED HOUSES, AND 40% LESS THAN THE AVERAGE OF THE INITIAL HOUSES. IT MUST THEREFORE BE CONCLUDED THAT SIGNIFICANT SAVINGS IN HEAT LOSS MAY BE ACHIEVED BY DESIGNING A HOUSE IN SUCH A WAY THAT ITS ARRANGEMENT OF ROOMS WITHIN THE BUILDING ENVELOPE IS RESPONSIVE TO EXTERNAL ENVIRONMENTAL CONDITIONS.

IN ADDITION, WHERE THE BEDROOMS ARE BELOW GRADE, AND PROTECTED FROM THERMAL EXTREMES BY THE MASS OF EARTH ABOUT THEM, NOT ONLY IS WINTER HEAT LOSS REDUCED, BUT SUMMER HEAT GAIN IS ALSO REDUCED. THIS RESULTS IN BEDROOMS THAT ARE SLIGHTLY COOLER THAN THE DAY LIVING AREAS ON A YEAR-ROUND BASIS, WHICH IS AN IDEAL SITUATION.

THIS, IN TURN, SUGGESTS THAT AIR CONDITIONERS, WHICH CONSUME LARGE QUANTITIES OF ENERGY, AND ARE USED IN WINNIPEG FOR A VERY SHORT PERIOD IN THE SUMMER ONLY, WOULD IN ALL LIKELYHOOD BE UNNECESSARY IN THE EXPERIMENTAL HOUSE. IF THE BEDROOMS ARE COOL, AND ONE IS ABLE TO GET A GOOD NIGHT'S SLEEP, SUMMER HEAT IN THE REST OF THE HOUSE CAN BE BETTER TOLERATED.

IN CONTRAST TO THE FIRST METHOD OF REDUCING HEAT LOSS STUDIED, WHICH WAS SHOWN TO BE APPLICABLE TO ALMOST ALL BUILDING TYPES, THE REARRANGEMENT OF SPACES WITHIN THE BUILDING ENVELOPE HAS A MUCH MORE LIMITED RANGE. HOWEVER, IT IS NOT BOUND TO THE SINGLE FAMILY DWELLING. ALL HORIZONTAL MULTIPLE HOUSING SYSTEMS COULD BENEFIT IN TERMS OF HEAT LOSS FROM THE APPLICATION OF THE PRINCIPLES OF REARRANGEMENT PRESENTED IN THIS PAPER. IN FACT, THE EXPERIMENTAL HOUSE, WHICH IN THIS STUDY IS SHOWN AS A SINGLE FAMILY DWELLING ONLY, COULD, WITH A RELATIVELY SMALL AMOUNT OF RE-DESIGN, BE A VERY ACCEPTABLE ROW HOUSE. AS SUCH, ITS HEAT LOSS WOULD BE EVEN LOWER, SINCE IT WOULD HAVE ONLY TWO SIDES EXPOSED TO THE ELEMENTS, AS OPPOSED TO THE FOUR EXPOSED IN A FREE-STANDING DWELLING UNIT.

R E C O M M E N D A T I O N S

1. THAT INDIVIDUALS WISHING TO UPGRADE THE THERMAL RESISTANCE OF THEIR HOUSE CONCENTRATE ON WINDOWS AND THE FOUNDATION WALLS ABOVE GRADE.

2. THAT INDIVIDUALS CONSIDERING BUILDING A HOUSE FOR THEMSELVES, OR HAVING A HOUSE BUILT FOR THEMSELVES, SERIOUSLY CONSIDER LOCATING THE ROOMS WITHIN THAT HOUSE IN SUCH A WAY THAT THEY RESPOND POSITIVELY TO EXTERNAL ENVIRONMENTAL CONDITIONS.

3. THAT THE AUTHORITIES RESPONSIBLE FOR HOUSING IN CANADA ENCOURAGE MAJOR HOUSE BUILDING COMPANIES TO CONCENTRATE ON PROVIDING HOUSES THAT RESPOND TO THEIR ENVIRONMENT, IN THE NAME OF ENERGY CONSERVATION, AND THEREFORE IN THE INTEREST OF ALL CANADIANS.

4. THAT ADDITIONAL STUDIES BE CARRIED OUT TO DETERMINE WHAT FURTHER METHODS OF REDUCING HEAT LOSS FROM SINGLE FAMILY DWELLINGS MAY BE EMPLOYED.

5. THAT ADDITIONAL STUDIES BE CARRIED OUT TO DETERMINE WHAT RATE OF VENTILATION IS ACTUALLY REQUIRED FOR HEALTHFUL LIVING IN HUMAN HABITATIONS. IN THIS STUDY, A CONSTANT RATE OF 75 C.F.M. OF FRESH OUTSIDE AIR IS USED. THIS RESULTS IN A HEAT LOSS OF 8,100 BTU/HR. FOR ALL HOUSE TYPES.

AS HEAT LOSS FROM THE VARIOUS HOUSES IS REDUCED THROUGHOUT THE STUDY, INFILTRATION AND VENTILATION CLAIM A LARGER AND LARGER PROPORTION OF THE TOTAL. IN THE CASE OF THE INITIAL BUNGALOW, WHICH HAS THE LARGEST INDIVIDUAL HEAT LOSS, EQUAL TO 57,177 BTU/HR., INFILTRATION AND VENTILATION REPRESENTS 14.2% OF THE TOTAL. IN THE EXPERIMENTAL HOUSE, WHICH HAS A TOTAL HEAT LOSS OF 32,236 BTU/HR., THE LOWEST OF ALL HEAT LOSSES, INFILTRATION AND VENTILATION REPRESENTS 25.1% OF THE TOTAL. AT THIS POINT, WHERE IT IS CONTRIBUTING ONE QUARTER OF THE TOTAL HEAT LOSS, IT BECOMES EVIDENT THAT FURTHER STUDY IS REQUIRED TO DETERMINE JUST EXACTLY WHAT VOLUME OF AIR CHANGE IS REQUIRED IN SINGLE FAMILY DWELLINGS TO ENSURE HEALTHFUL LIVING CONDITIONS.

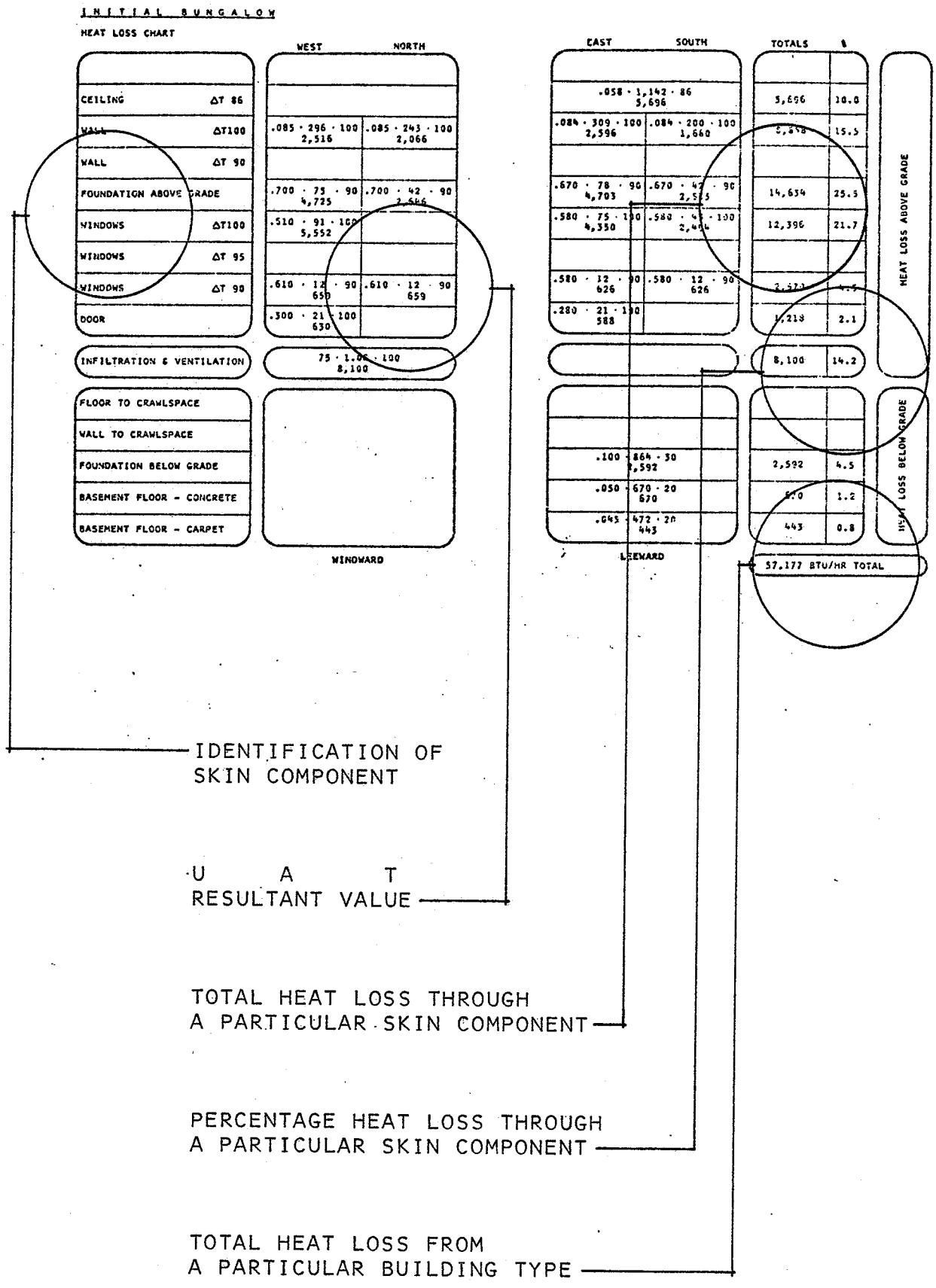

60
61
INITIAL BUNGALOW
HEAT LOSS CHART
WEST
NORTH
EAST
SOUTH
TOTALS
%
CEILING ΔT 86
WALL ΔT100
WALL ΔT 90
FOUNDATION ABOVE GRADE
WINDOWS ΔT100
WINDOWS ΔT 95
WINDOWS ΔT 90
DOOR
.058 · 1,142 · 86
5,696
5,696
18.8
.085 · 296 · 100
2,516
.085 · 243 · 100
2,066
.084 · 309 · 100
2,596
.084 · 200 · 100
1,660
4,703
14,634
25.5
4,350
12,396
21.7
626
626
588
INFILTRATION & VENTILATION
75 · 1.08 · 100
8,100
8,100
14.2
HEAT LOSS ABOVE GRADE
FLOOR TO CRAWLSPACE
WALL TO CRAWLSPACE
FOUNDATION BELOW GRADE
BASEMENT FLOOR - CONCRETE
BASEMENT FLOOR - CARPET
.100 · 864 · 30
2,592
2,592
4.5
.050 · 670 · 20
670
443
0.8
HEAT LOSS BELOW GRADE
WINDWARD
LEEWARD
57,177 BTU/HR TOTAL
IDENTIFICATION OF SKIN COMPONENT
U A T RESULTANT VALUE
TOTAL HEAT LOSS THROUGH A PARTICULAR SKIN COMPONENT
PERCENTAGE HEAT LOSS THROUGH A PARTICULAR SKIN COMPONENT
TOTAL HEAT LOSS FROM A PARTICULAR BUILDING TYPE

FIG. 6

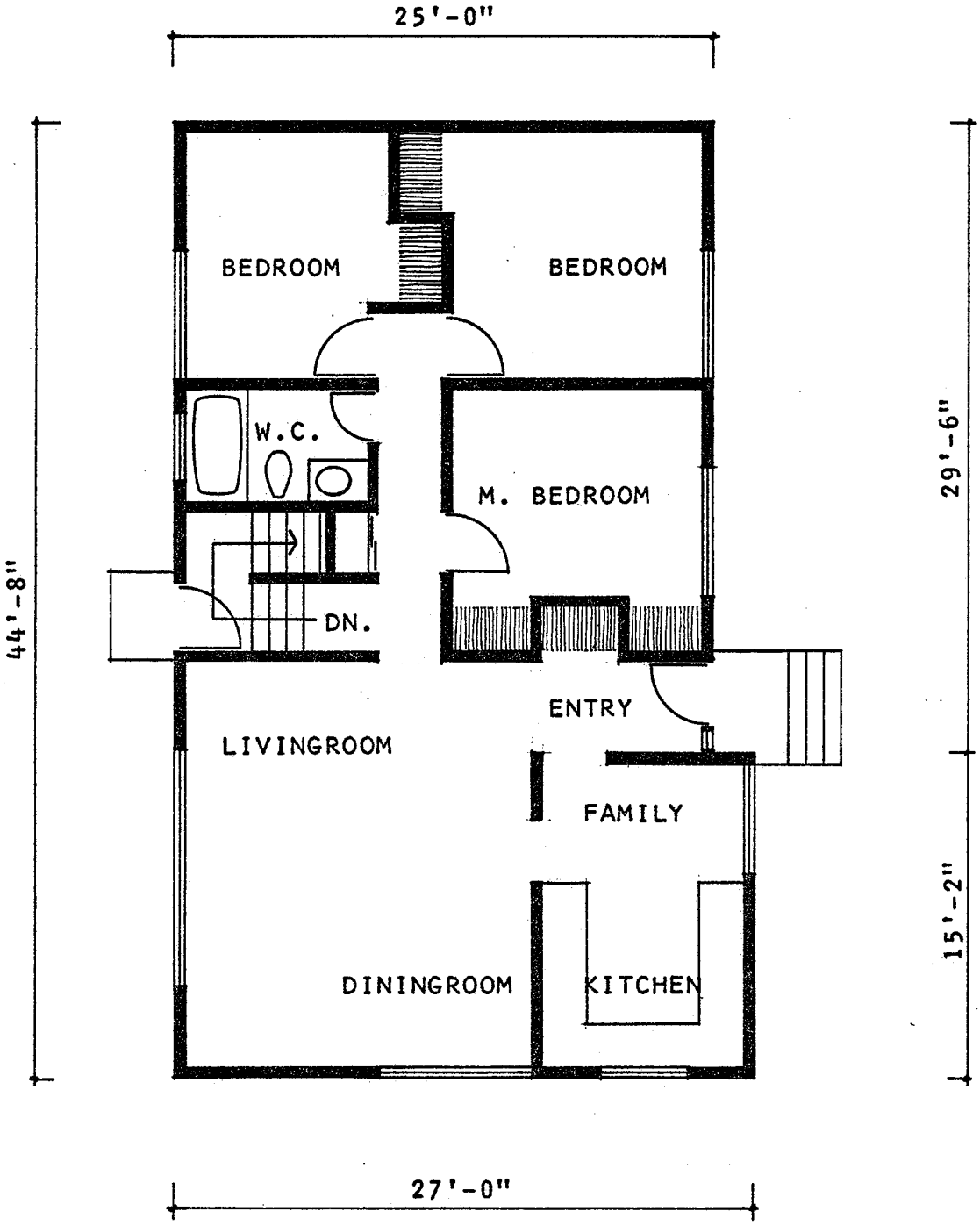
ON THE FOLLOWING PAGES THE THREE CMHC HOUSE TYPES AND THE EXPERIMENTAL HOUSE ARE PRESENTED IN DETAIL. EACH TYPE IS EXAMINED IN ITS ENTIRETY. IN THE CASES OF THE CMHC HOUSES, THIS INVOLVES FOLLOWING EACH TYPE THROUGH ITS TRANSFORMATION FROM INITIAL TO REVISED TO MODIFIED. THERE IS ONLY ONE VERSION OF THE EXPERIMENTAL HOUSE.

FOLLOWING EACH VERSION OF ANY PARTICULAR HOUSE TYPE IS A HEAT LOSS CHART, WHICH ITEMIZES THE FLOW OF HEAT THROUGH THE SKIN OF THAT BUILDING. SOURCES FOR MANY OF THE CALCULATIONS USED IN THIS CHART, INCLUDING U-VALUES OF SKIN COMPONENTS, ARE TO BE FOUND IN THE APPENDICES AT THE BACK OF THE THESIS. FIG. 6, ON THE PAGE OPPOSITE, IDENTIFIES THE VARIOUS COMPONENTS TO BE FOUND IN THE HEAT LOSS CHART. IMMEDIATELY FOLLOWING THE CHART IS A PAGE SUMMARIZING THE FLOW OF HEAT THROUGH MAJOR SKIN COMPONENTS, ALONG WITH A BRIEF ANALYSIS OF THE PATTERN OF HEAT LOSS FROM THAT PARTICULAR HOUSE TYPE.

SECTION B

PART ONE

CALCULATIONS OF HEAT LOSS FROM THE BUNGALOW HOUSE TYPE



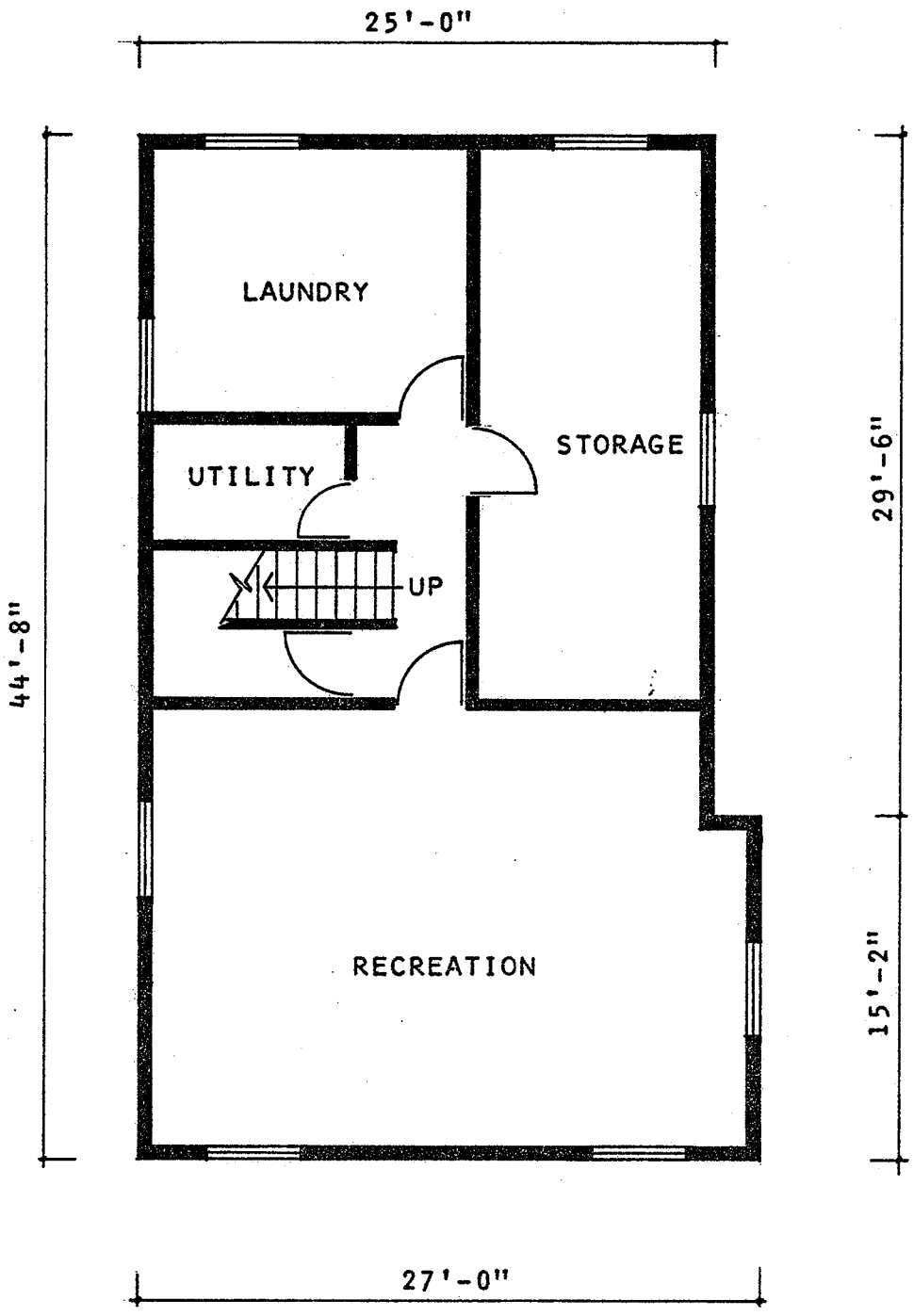
GROUND LEVEL PLAN

SCALE : 1/8" = 1'-0" FIG. 7

INITIAL BUNGALOW

THE BUNGALOW GROUND LEVEL PLAN SHOWN ON THE OPPOSITE PAGE IS AN ADAPTION OF DESIGN 2300 OF THE CMHC HANDBOOK OF HOUSE DESIGNS, SIMPLIFIED IN SOME RESPECTS. A FIREPLACE HAS BEEN REMOVED FROM THE LIVING - DINING AREA, A SMALL CLOSET TAKEN OUT OF THE KITCHEN, AND THE WINDOWS HAVE BEEN MODIFIED TO CONFORM TO THE OTHER HOUSE TYPES USED IN THIS STUDY. THERE IS CLEAR ZONING BETWEEN THE DAY AREA AND THE NIGHT AREA. DINING AND LIVING SHARE ONE LARGE ROOM AT THE SOUTH - WEST CORNER OF THE HOUSE. THE PRINCIPAL ENTRY IS ON THE EAST; THE SECONDARY ENTRY ON THE WEST.

AREA OF GROUND LEVEL	1,142 SQ. FT.
AREA OF CEILING	1,142 SQ. FT.
AREA OF ROOF	1,180 SQ. FT.



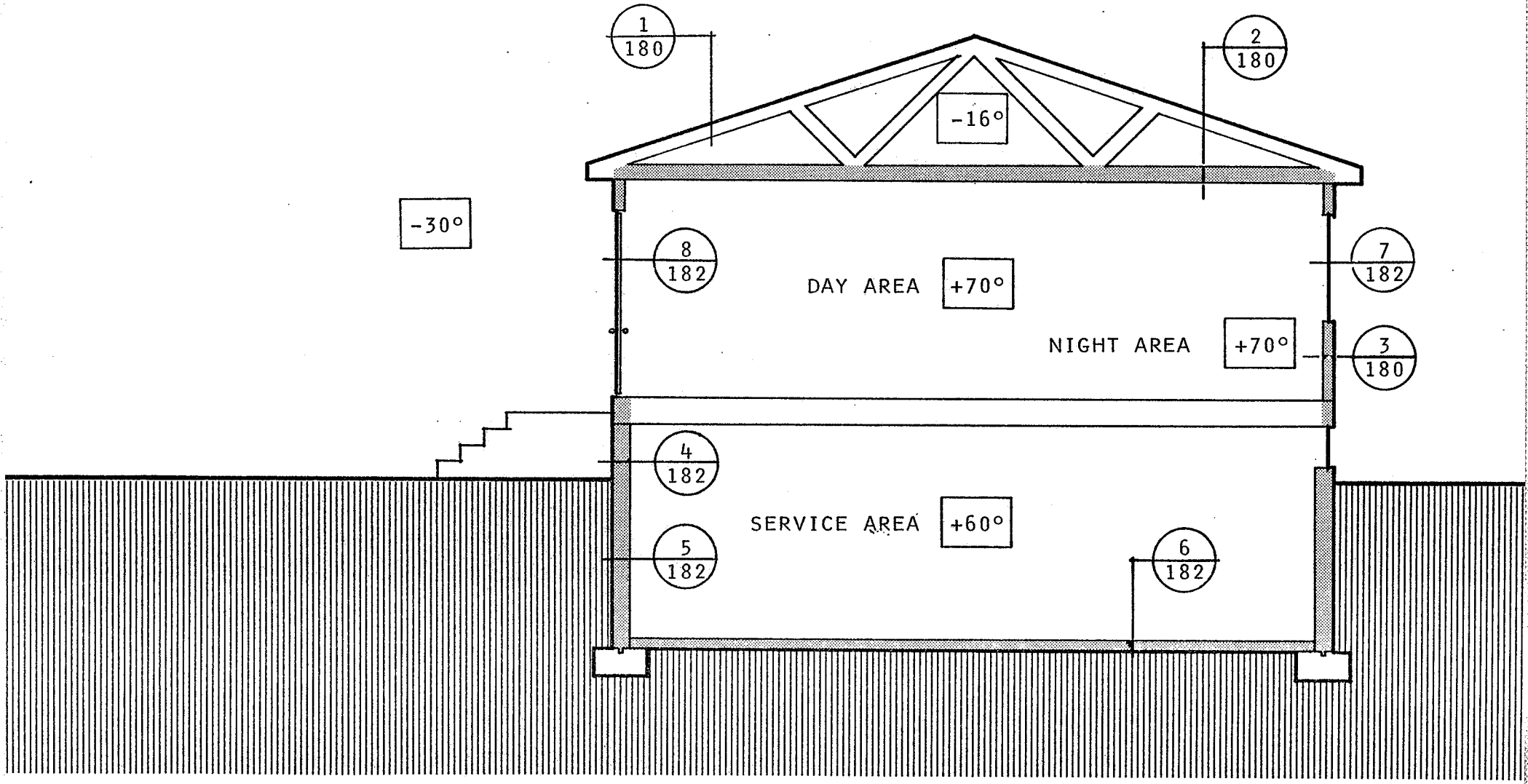
LOWER LEVEL PLAN

SCALE : 1/8" = 1'-0" FIG. 8

I N I T I A L B U N G A L O W

THE BUNGALOW LOWER LEVEL PLAN, SHOWN ON THE OPPOSITE PAGE, IS DIVIDED INTO FOUR MAIN AREAS: LAUNDRY, UTILITY, STORAGE AND RECREATION. IN ADDITION, THERE IS A STORAGE AREA UNDER THE STAIRS. THE AREA OF THE RECREATION ROOM IS EQUAL TO THAT OF THE LIVING ROOM, DINING ROOM AND KITCHEN ABOVE.

AREA OF LOWER LEVEL	1,113 SQ. FT.
AREA OF FOUNDATION WALLS	864 SQ. FT.



TYPICAL TRANSVERSE SECTION

SCALE : 3/16" = 1'-0"

FIG. 9

INITIAL BUNGALOW

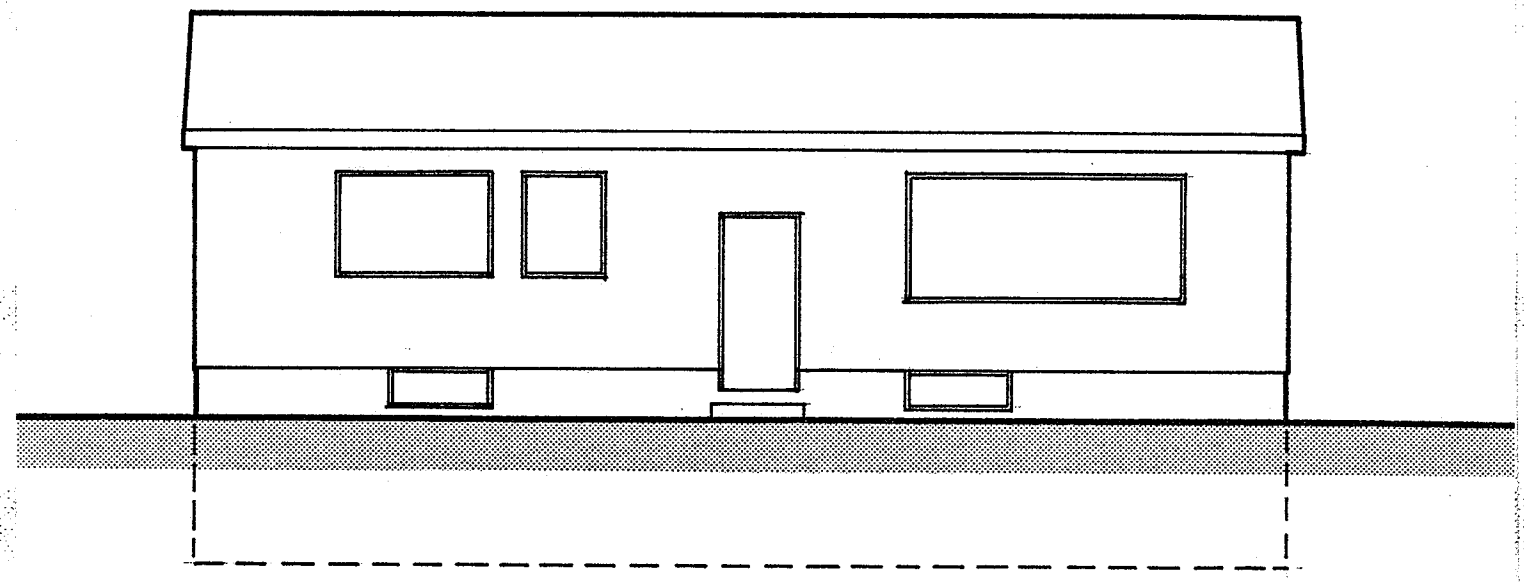
A TYPICAL SECTION CUT THROUGH THE BUNGALOW IS SHOWN ON THE OPPOSITE PAGE. THIS SECTION REVEALS ALL OF THE PRINCIPAL ELEMENTS OF THE HOUSE, INCLUDING ALL EXTERIOR SKIN COMPONENTS RESPONSIBLE FOR THERMAL CONTROL (SHOWN SHADED EXCEPT FOR DOORS AND WINDOWS). DETAIL SECTIONS, USED TO CALCULATE U VALUES, AND SHOWN THUS; $\frac{2}{180}$, ARE TO BE FOUND IN APPENDIX 1, PAGE 179. THE DRAWING ALSO SHOWS THE RELATIONSHIP OF THE BUILDING TO THE GROUND.

CONSTRUCTION OF THE BUNGALOW IS AS FOLLOWS:

- ASPHALT SHINGLES, PLYWOOD DECK, WOOD TRUSSES @ 4:12, R20 INSULATION, 1/2" DRYWALL.
- STUCCO FINISH EXTERIOR, PLYWOOD SHEATHING, 2 X 4 STUDS, R12 INSULATION, DRYWALL INTERIOR.
- 8" CONCRETE FOUNDATION WALLS, EXTENDING 7' BELOW GRADE. NO INSULATION.
- 4" CONCRETE BASEMENT FLOOR. NO INSULATION.
- DOUBLE GLAZE WINDOW, 1/2" AIRSPACE.
- SOLID CORE DOOR AND STORM DOOR.

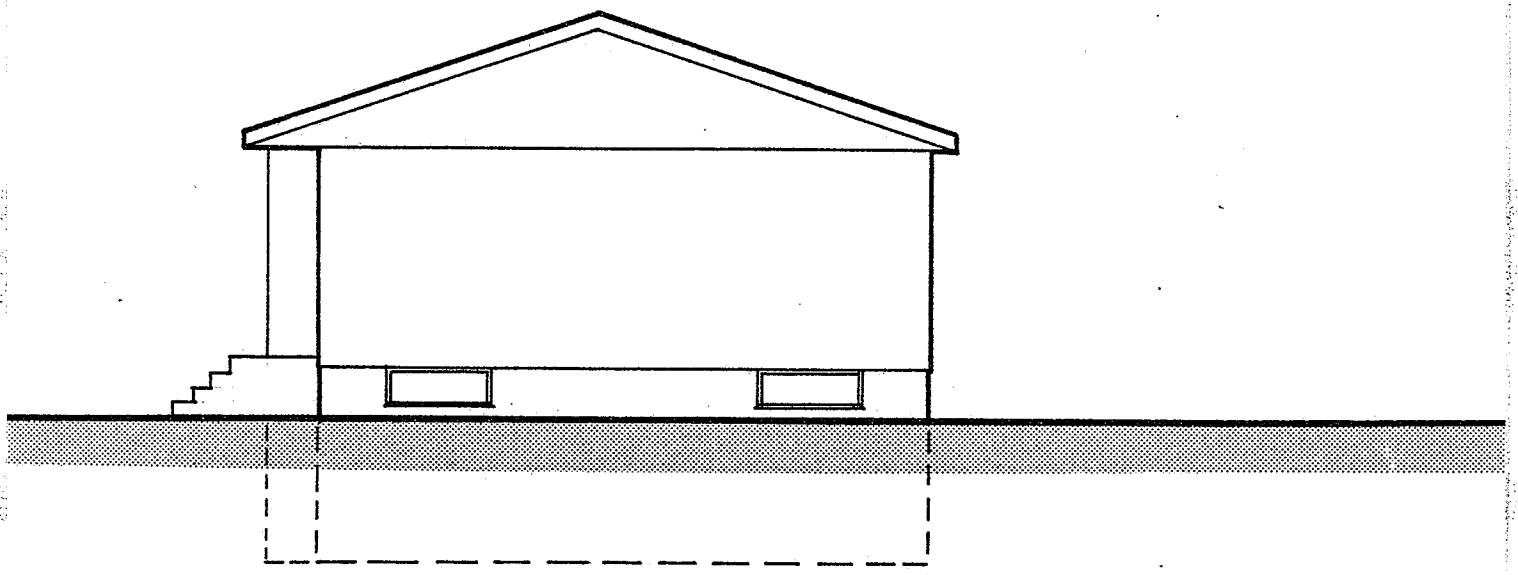
ALSO SHOWN IN THE SECTION ARE AMBIENT AIR TEMPERATURES, BOTH INSIDE AND OUTSIDE THE HOUSE. IT IS NECESSARY THAT THESE TEMPERATURES BE DEFINED IN ORDER TO CALCULATE ΔT, THE TEMPERATURE DIFFERENCE ACROSS A GIVEN COMPONENT OF THE EXTERIOR SKIN. AMBIENT AIR TEMPERATURES ARE SHOWN IN A $\boxed{-30°}$ SYMBOL.

SEE APPENDIX 2 RE TEMPERATURE OF AMBIENT AIR IN ATTIC.



WEST ELEVATION

SCALE : 1/8" = 1'-0"

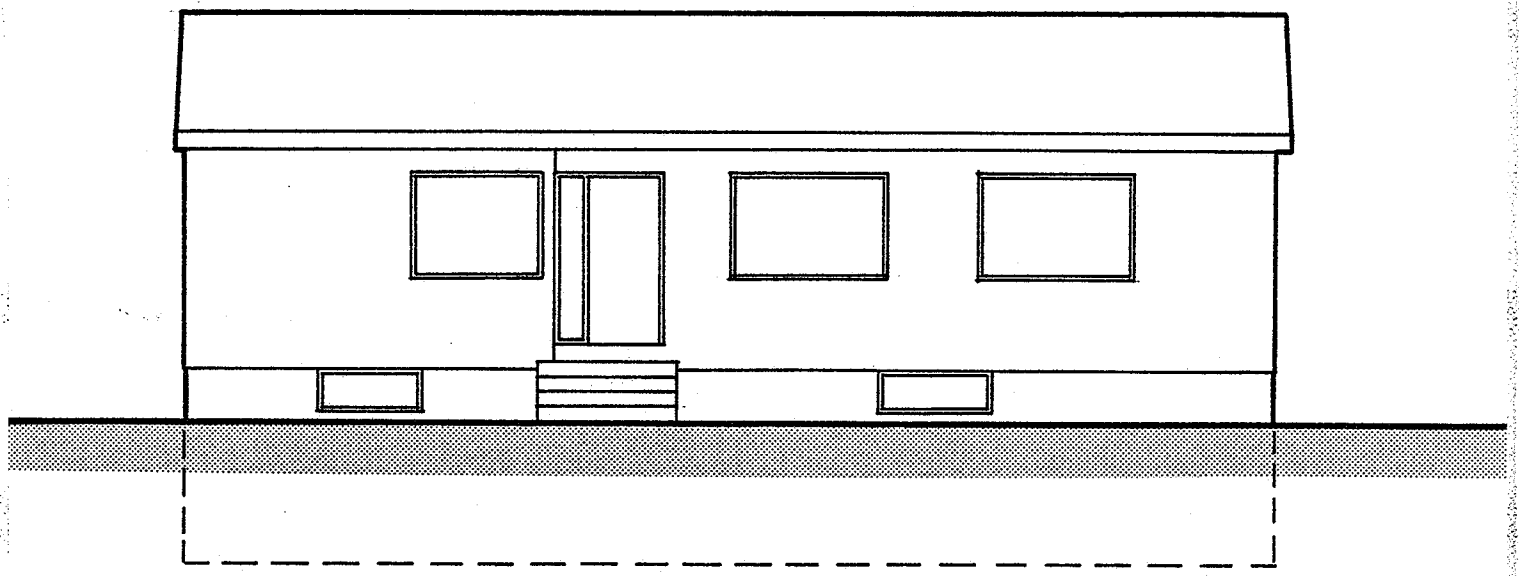


NORTH ELEVATION

SCALE : 1/8" = 1'-0"

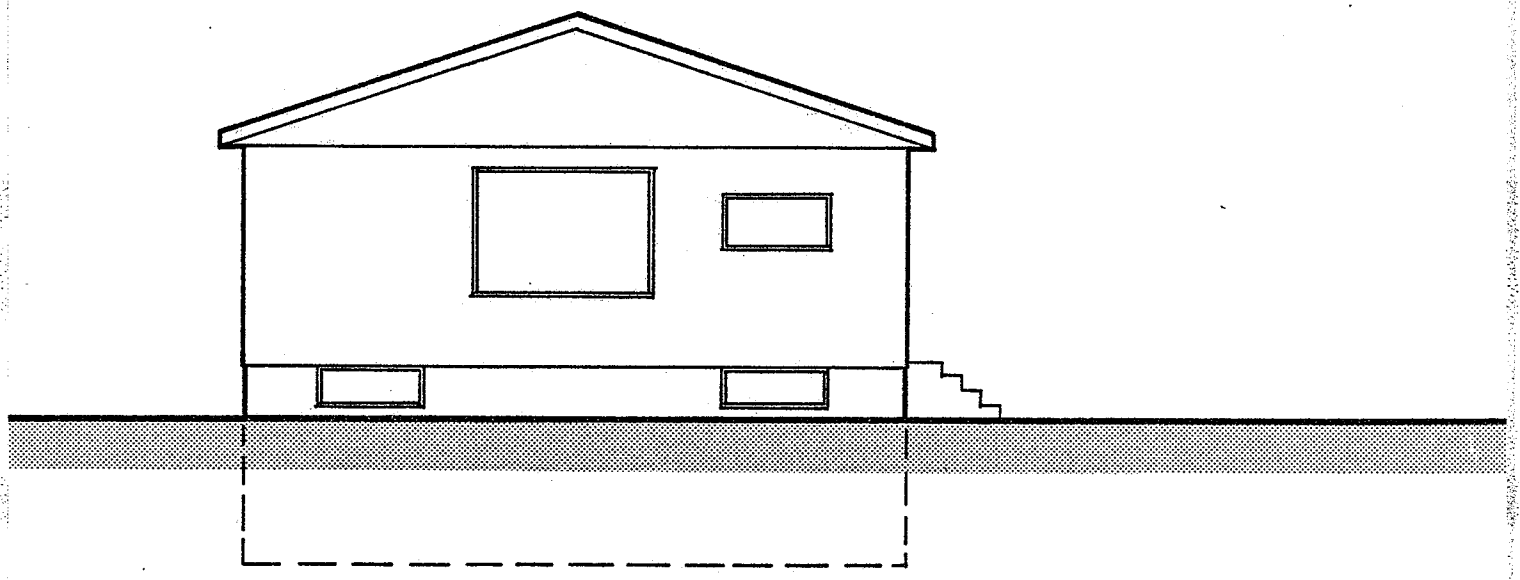
FIG. 10

		SURFACE AREA (SQUARE FEET)
WEST ELEVATION		
WALL		296
FOUNDATION ABOVE GRADE		75
FOUNDATION BELOW GRADE		270
WINDOWS	ΔT100	91
WINDOWS	ΔT 90	12
DOOR		21
NORTH ELEVATION		
WALL		243
FOUNDATION ABOVE GRADE		42
FOUNDATION BELOW GRADE		162
WINDOWS	ΔT 90	12



EAST ELEVATION

SCALE : 1/8" = 1'-0"



SOUTH ELEVATION

SCALE : 1/8" = 1'-0"

FIG. 11

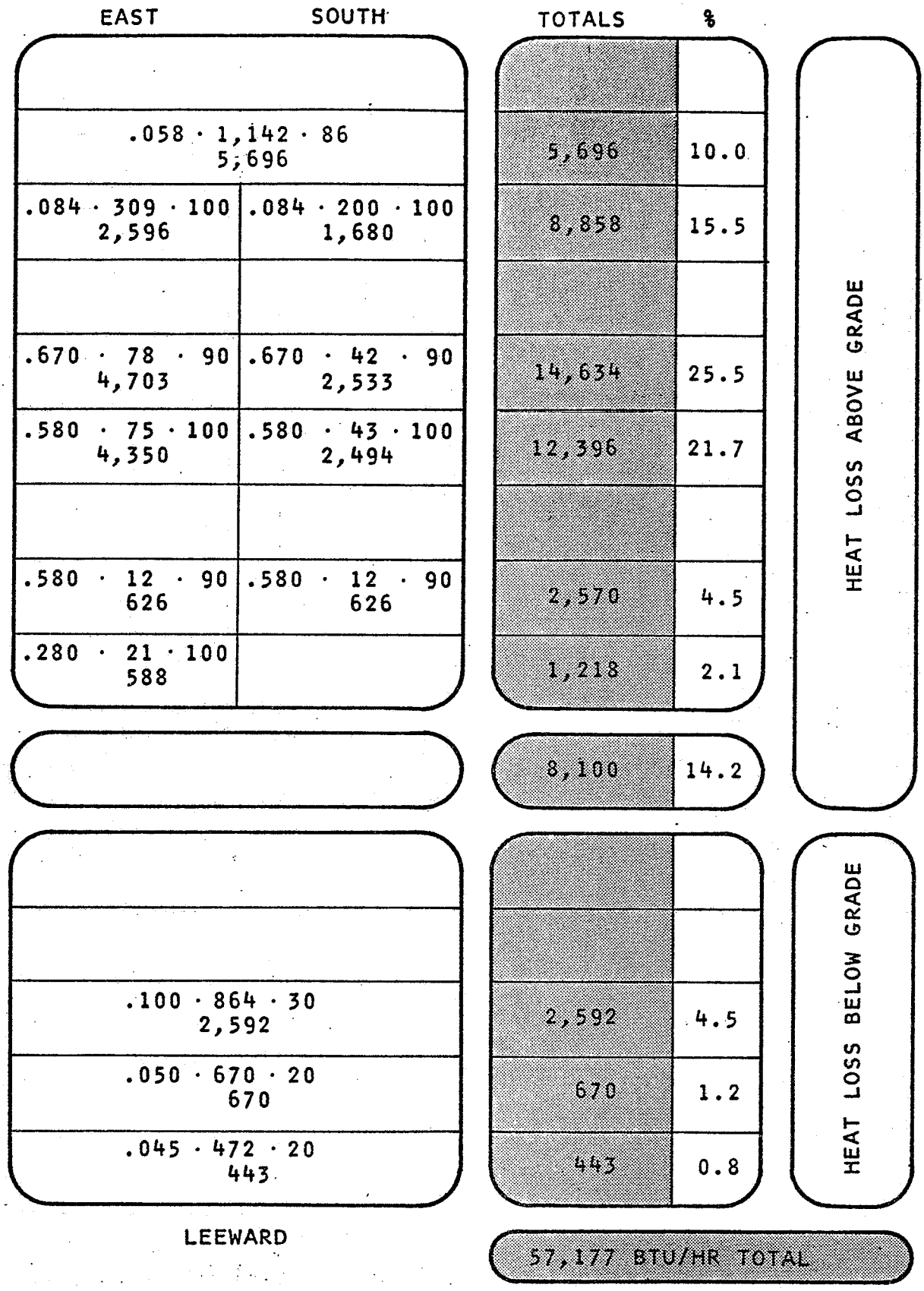
		SURFACE AREA (SQUARE FEET)
EAST ELEVATION		
WALL		309
FOUNDATION ABOVE GRADE		78
FOUNDATION BELOW GRADE		270
WINDOWS	ΔT100	75
WINDOWS	ΔT 90	12
DOOR		21
SOUTH ELEVATION		
WALL		200
FOUNDATION ABOVE GRADE		42
FOUNDATION BELOW GRADE		162
WINDOWS	ΔT100	43
WINDOWS	ΔT 90	12

INITIAL BUNGALOW

HEAT LOSS CHART

		WEST	NORTH
CEILING	ΔT 86		
WALL	ΔT100	.085 · 296 · 100 2,516	.085 · 243 · 100 2,066
WALL	ΔT 90		
FOUNDATION ABOVE GRADE		.700 · 75 · 90 4,725	.700 · 42 · 90 2,646
WINDOWS	ΔT100	.610 · 91 · 100 5,552	
WINDOWS	ΔT 95		
WINDOWS	ΔT 90	.610 · 12 · 90 659	.610 · 12 · 90 659
DOOR		.300 · 21 · 100 630	
INFILTRATION & VENTILATION		75 · 1.08 · 100 8,100	
FLOOR TO CRAWLSPACE			
WALL TO CRAWLSPACE			
FOUNDATION BELOW GRADE			
BASEMENT FLOOR - CONCRETE			
BASEMENT FLOOR - CARPET			

WINDWARD


EAST
SOUTH
TOTALS
%
.058 · 1,142 · 86
5,696
5,696
10.0
.084 · 309 · 100
2,596
.084 · 200 · 100
1,680
8,858
15.5
14,634
25.5
.670 · 78 · 90
4,703
.670 · 42 · 90
2,533
12,396
21.7
.580 · 75 · 100
4,350
.580 · 43 · 100
2,494
2,570
4.5
.580 · 12 · 90
626
.580 · 12 · 90
626
1,218
2.1
.280 · 21 · 100
588
HEAT LOSS ABOVE GRADE
8,100
14.2
.100 · 864 · 30
2,592
2,592
4.5
.050 · 670 · 20
670
670
1.2
.045 · 472 · 20
443
443
0.8
HEAT LOSS BELOW GRADE
LEEWARD
57,177 BTU/HR TOTAL

INITIAL BUNGALOW

SUMMARY OF HEAT LOSS

	INITIAL	REVISED	MODIFIED
CEILING	5,696 10.0%		
WALLS	8,858 15.5%		
FOUNDATION	18,339 32.0%		
DOORS & WINDOWS	16,184 28.3%		
INFILTRATION & VENTILATION	8,100 14.2%		
TOTALS	57,177		

ALL VALUES IN BTU/HR.

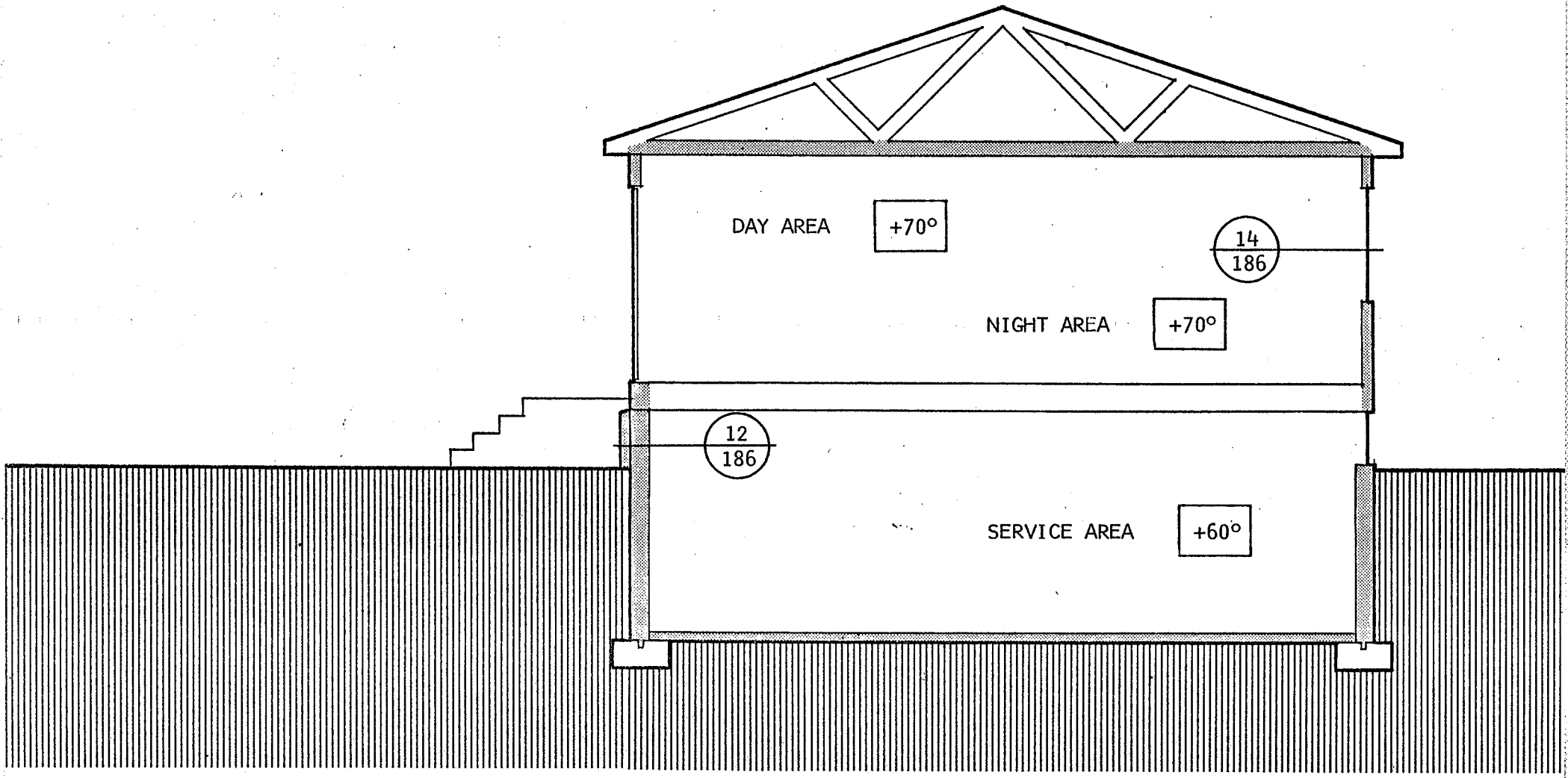
A N A L Y S I S

THE GREATEST FLOW OF HEAT FROM THE INITIAL BUNGALOW, 18,339 BTU/HR. OR 32.0% OF THE TOTAL HEAT LOSS, OCCURS THROUGH THE FOUNDATION. OF THIS AMOUNT, 14,634 BTU/HR. FLOWS THROUGH THE APPROXIMATELY THE TWO FOOT HIGH STRIP OF FOUNDATION WALL EXPOSED ABOVE GRADE. THIS ACCOUNTS FOR FULLY 80% OF THE HEAT LOST THROUGH THE FOUNDATION. THE OTHER 20% ESCAPES THROUGH THE WALLS BELOW GRADE, AND THE FLOOR.

THE NEXT GREATEST FLOW OF HEAT FROM THE INITIAL BUNGALOW OCCURS THROUGH THE DOORS AND WINDOWS, AND TOTALS 16,184 BTU/HR. OR 28.3% OF THE TOTAL HEAT LOSS. OF THIS AMOUNT, 14,966 BTU/HR. ESCAPE THROUGH THE WINDOWS, AND 1,218 BTU/HR. THROUGH THE DOORS.

THE REMAINING ASSEMBLIES, IN SEQUENCE OF THEIR MAGNITUDE OF HEAT LOSS, ARE WALLS, INFILTRATION AND VENTILATION, AND THE CEILING. NONE OF THESE APPEARS TO BE THE SOURCE OF AN UNDUE AMOUNT OF HEAT LOSS.

THEREFORE, IT IS EVIDENT THAT THE TWO POINTS OF GREATEST CONCERN IN THE INITIAL BUNGALOW ARE THE FOUNDATION WALL ABOVE GRADE AND THE WINDOWS. IN ORDER TO REDUCE THE TOTAL HEAT LOSS FROM THIS HOUSE TYPE, THESE TWO ASSEMBLIES MUST BE REVISED.



TYPICAL TRANSVERSE SECTION

SCALE : 3/16" = 1'-0"

REVISIONS

FIG. 12 ON THE OPPOSITE PAGE IS A SECTION TAKEN THROUGH THE REVISED BUNGALOW. DETAIL SECTIONS ARE SHOWN THROUGH THE TWO ASSEMBLIES WHICH HAVE BEEN REVISED FROM THE INITIAL BUNGALOW. THESE ARE THE FOUNDATION WALL ABOVE GRADE, AND THE WINDOWS, WHICH WERE SHOWN ON THE PREVIOUS PAGE TO HAVE BEEN THE TWO POINTS OF GREATEST HEAT LOSS FROM THE INITIAL BUNGALOW.

THE DETAIL SECTIONS, SPECIFYING THE CHANGES THAT HAVE BEEN MADE, ARE TO BE FOUND IN APPENDIX 1, PAGE 179. IN BRIEF, THE FOUNDATION WALL ABOVE GRADE HAS BEEN COVERED WITH 2" OF RIGID INSULATION, AND THE WINDOWS HAVE BEEN CHANGED FROM DOUBLE GLAZING TO TRIPLE GLAZING.

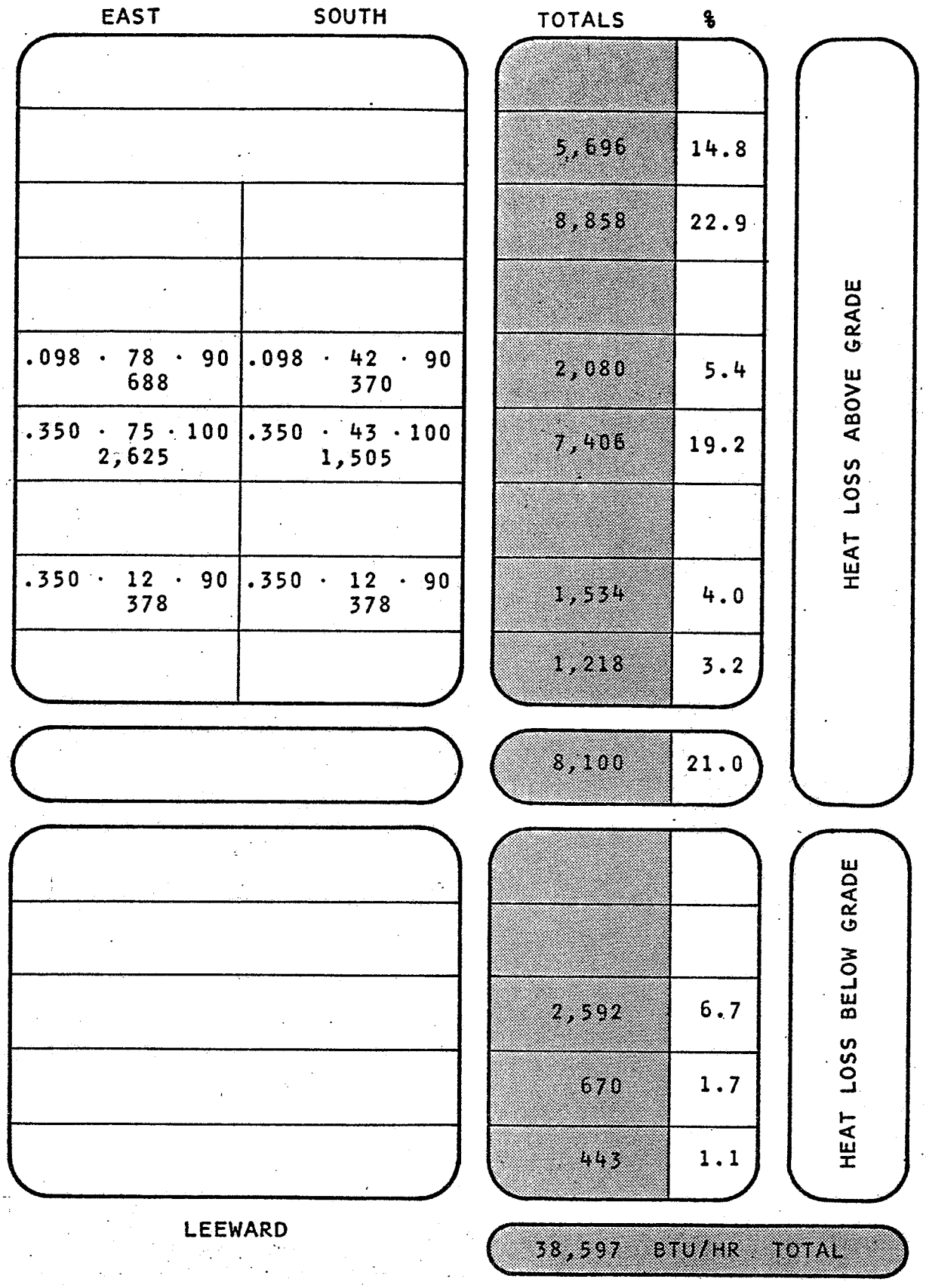
ON THE FOLLOWING PAGES, THE HEAT LOSS CALCULATIONS FOR THE REVISED BUNGALOW ARE PRESENTED. DETAIL CALCULATIONS ARE SHOWN ONLY FOR THOSE ASSEMBLIES THAT HAVE BEEN CHANGED FROM THE INITIAL BUNGALOW. UNCHANGED ASSEMBLIES ARE RE-PRESENTED BY A TOTAL HEAT LOSS ONLY.

REVISED BUNGALOW

HEAT LOSS CHART

		WEST	NORTH
CEILING	ΔT 86		
WALL	ΔT100		
WALL	ΔT 90		
FOUNDATION ABOVE GRADE		.099 · 75 · 90 = 668	.099 · 42 · 90 = 374
WINDOWS	ΔT100	.360 · 91 · 100 = 3,276	
WINDOWS	ΔT 95		
WINDOWS	ΔT 90	.360 · 12 · 90 = 389	.360 · 12 · 90 = 389
DOOR			
INFILTRATION & VENTILATION			
FLOOR TO CRAWLSPACE			
WALL TO CRAWLSPACE			
FOUNDATION BELOW GRADE			
BASEMENT FLOOR - CONCRETE			
BASEMENT FLOOR - CARPET			

WINDWARD


EAST
SOUTH
TOTALS
%
.098 · 78 · 90
688
.098 · 42 · 90
370
.350 · 75 · 100
2,625
.350 · 43 · 100
1,505
.350 · 12 · 90
378
.350 · 12 · 90
378
5,696
14.8
8,858
22.9
2,080
5.4
7,406
19.2
1,534
4.0
1,218
3.2
8,100
21.0
2,592
6.7
670
1.7
443
1.1
HEAT LOSS ABOVE GRADE
HEAT LOSS BELOW GRADE
LEEWARD
38,597 BTU/HR TOTAL

REVISED BUNGALOW

SUMMARY OF HEAT LOSS

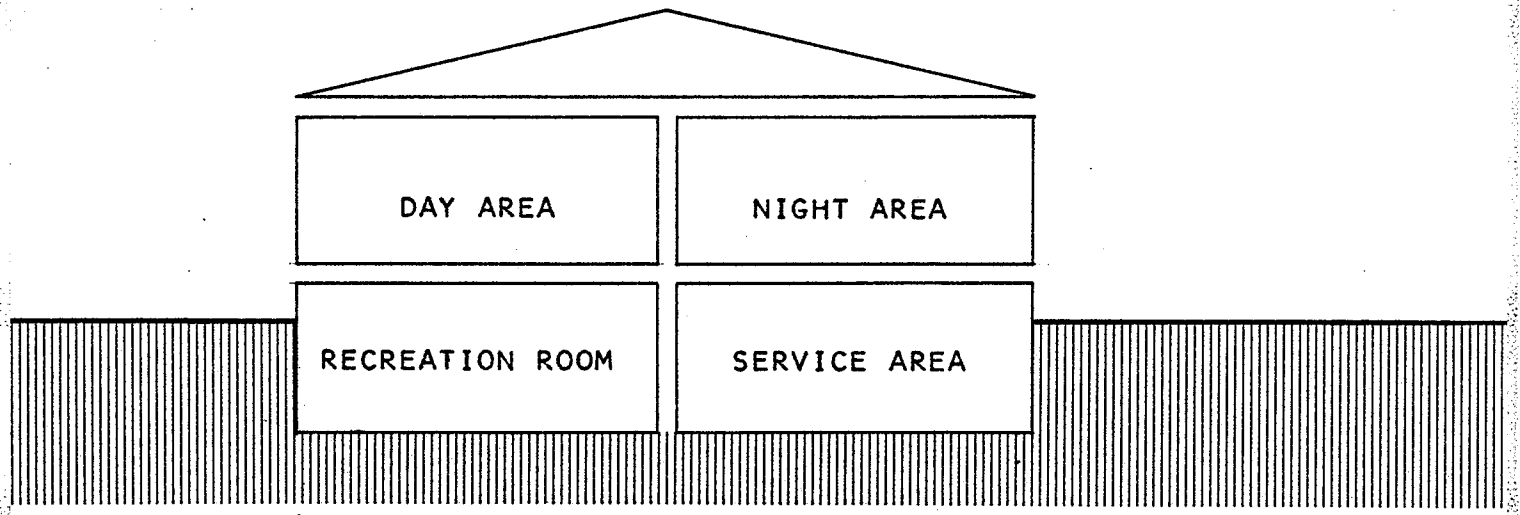
	INITIAL	REVISED	MODIFIED
CEILING	5,696 10.0%	5,696 14.8%	
WALLS	8,858 15.5%	8,858 22.9%	
FOUNDATION	18,339 32.0%	5,785 14.9%	
DOORS & WINDOWS	16,184 28.3%	10,158 26.4%	
INFILTRATION & VENTILATION	8,100 14.2%	8,100 21.0%	
TOTALS	57,177	38,597	

ALL VALUES IN BTU/HR.

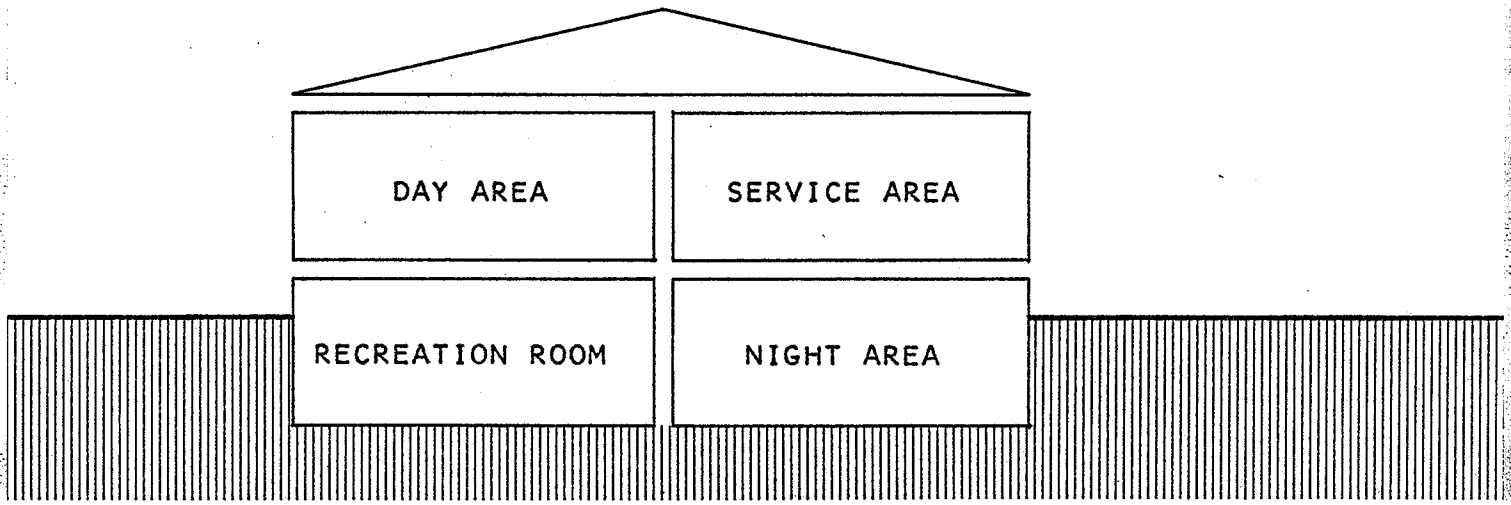
A N A L Y S I S

BY COMPARING THE REVISED COLUMN IN THE CHART ON THE OPPOSITE PAGE WITH THE INITIAL COLUMN, IT CAN BE SEEN THAT THE TOTAL HEAT LOSS THROUGH THE FOUNDATION, AND DOORS AND WINDOWS, HAS BEEN DRASTICALLY REDUCED AS A RESULT OF THE REVISIONS MADE. THE ABSOLUTE VALUES OF THE OTHER THREE ASSEMBLIES ARE UNCHANGED, BUT THE PERCENTAGE VALUES OF ALL FIVE ARE NEW DUE TO A LOWER HEAT LOSS.

THE REVISED TOTAL OF 38,597 BTU/HR. IS A 33% REDUCTION IN HEAT LOSS FROM THE INITIAL TOTAL OF 57,177 BTU/HR.



INITIAL & REVISED BUNGALOW



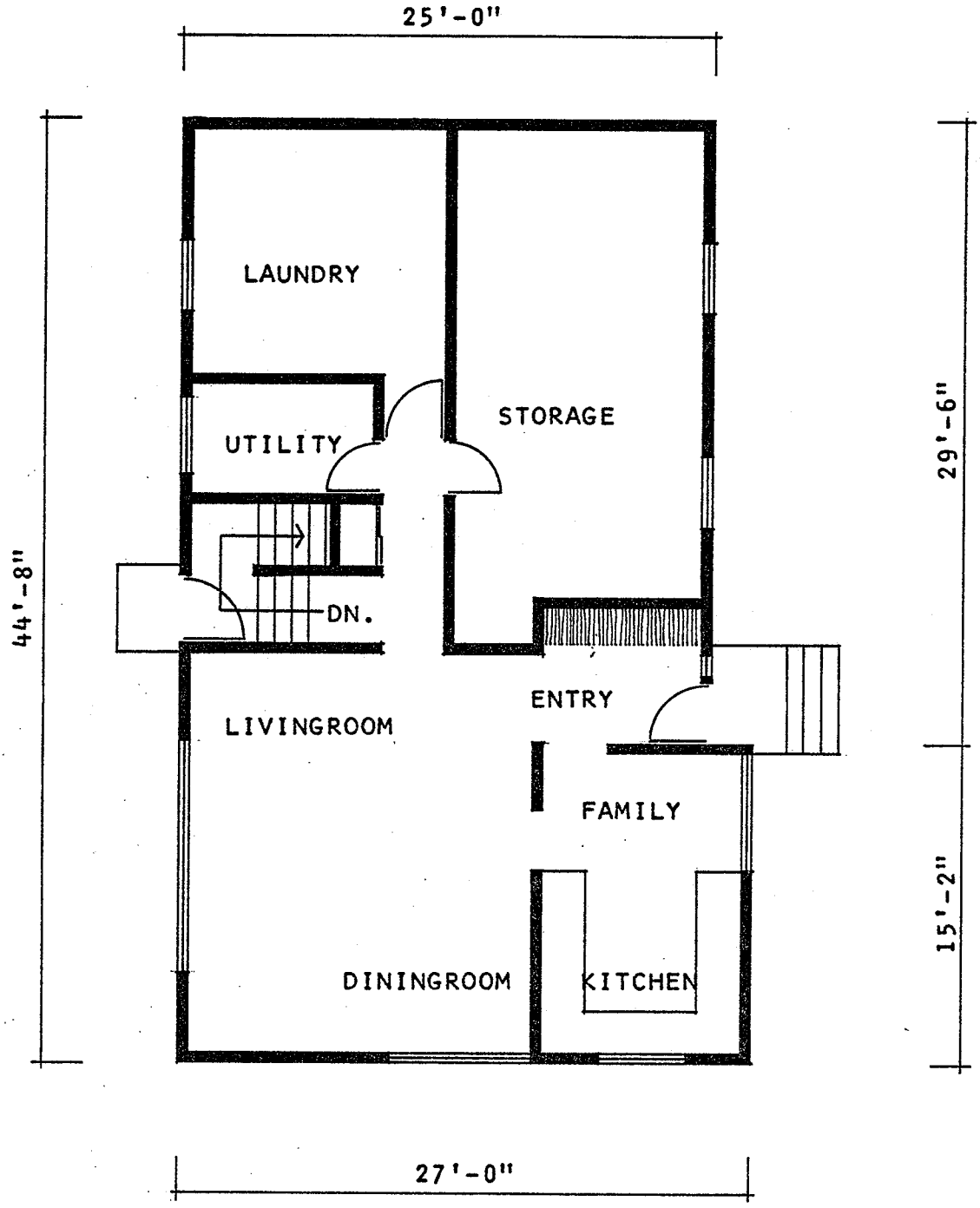
MODIFIED BUNGALOW

FIG. 13

MODIFICATIONS

FIG. 13 ON THE OPPOSITE PAGE IS A GRAPHIC EXPLANATION OF THE MODIFICATION OF THE BUNGALOW TO FURTHER REDUCE HEAT LOSS. THE TOP ILLUSTRATION SHOWS THE ORGANIZATION OF THE INITIAL AND REVISED BUNGALOWS, WITH BOTH THE DAY AND NIGHT AREAS ON THE GROUND LEVEL, AND THE RECREATION AND SERVICE AREAS ON THE LOWER LEVEL. THE BOTTOM ILLUSTRATION SHOWS THE MODIFIED BUNGALOW, IN WHICH THE AREAS HAVE BEEN REARRANGED ACCORDING TO THE PRECEPTS SET OUT IN THE INTRODUCTORY TEXT. THERE, THE DAY AREA AND SERVICE AREA ARE ON THE GROUND LEVEL, AND THE RECREATION AREA AND NIGHT AREA ARE ON THE LOWER LEVEL.

ON THE FOLLOWING PAGES, DETAIL DRAWINGS OF THIS REORGANIZATION, PLUS RESULTING HEAT LOSS CALCULATIONS, ARE PRESENTED.



GROUND LEVEL PLAN

SCALE : 1/8" = 1'-0" FIG. 14

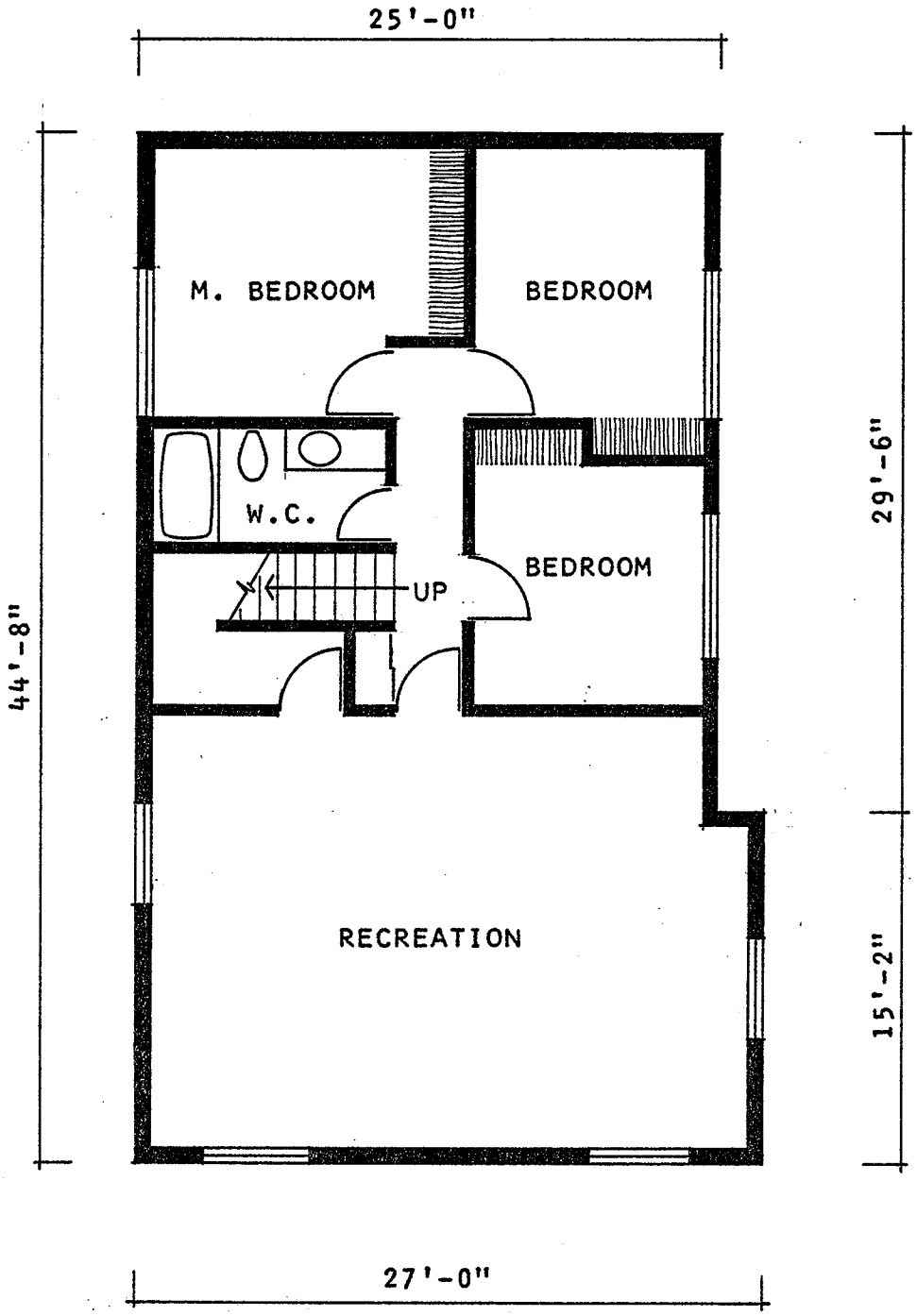
M O D I F I E D B U N G A L O W

THE GROUND LEVEL NOW CONSISTS OF THE DINING, LIVING, AND KITCHEN AREAS, AS IN THE INITIAL BUNGALOW PLAN, AND THE LAUNDRY, UTILITY AND STORAGE AREAS, RATHER THAN BEDROOMS.

BECAUSE OF THE MODIFICATIONS IT BECAME POSSIBLE TO ENLARGE THE COAT HANGING AREA AT THE FRONT DOOR OVER THAT OF THE INITIAL PLAN (SEE PAGE 50), AND AS A RESULT THE DOOR HAS BEEN MOVED TO SWING THE OTHER WAY TO BETTER ACCOMODATE THIS ENLARGED CLOSET.

THE WINDOWS INTO THE LIVING, DINING AND KITCHEN AREAS ARE UNCHANGED; OTHER WINDOWS HAVE BEEN MODIFIED TO SUIT THE ROOMS THEY NOW SERVE. SEE ELEVATIONS ON PAGES 56 & 58 .

THE OVERALL EXTERIOR DIMENSIONS REMAIN THE SAME AS THE INITIAL BUNGALOW PLAN.



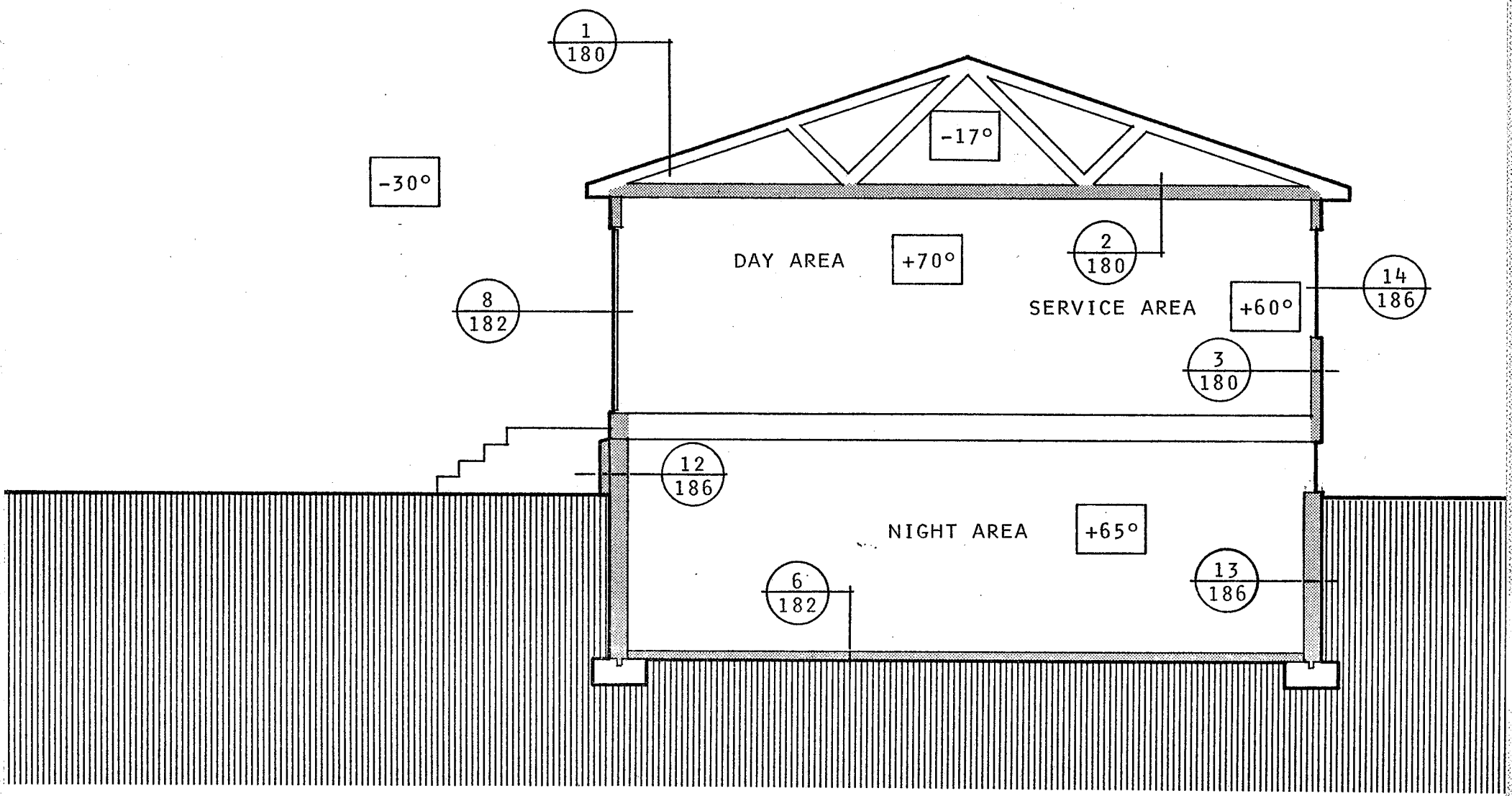
LOWER LEVEL PLAN

SCALE : 1/8" = 1'-0" FIG. 15

MODIFIED BUNGALOW

THE BEDROOMS NOW OCCUPY THAT PORTION OF THE LOWER LEVEL FORMERLY HOUSING THE SERVICE AREA. BECAUSE OF THE LENGTH OF RUN OF THE STAIR, THE CENTRAL CORRIDOR IS FURTHER TO THE EAST THAN WAS THE CASE WHEN IT WAS ON THE GROUND LEVEL. AS A RESULT, THE SIZE AND PROPORTIONS OF THE BEDROOMS HAVE CHANGED SOMEWHAT, AND THE MASTER BEDROOM IS NOW IN A DIFFERENT LOCATION. CLOTHES STORAGE IN THE TWO SMALLER BEDROOMS IS ALSO DIFFERENT FROM THAT FOUND IN THE INITIAL BUNGALOW PLAN.

AN ADVANTAGE OF THIS PLAN UNRELATED TO ENERGY CONSERVATION IS THAT THE CHILDRENS' BEDROOMS ARE IMMEDIATELY ADJACENT TO THEIR MAJOR INDOOR PLAY AREA, THE RECREATION ROOM.



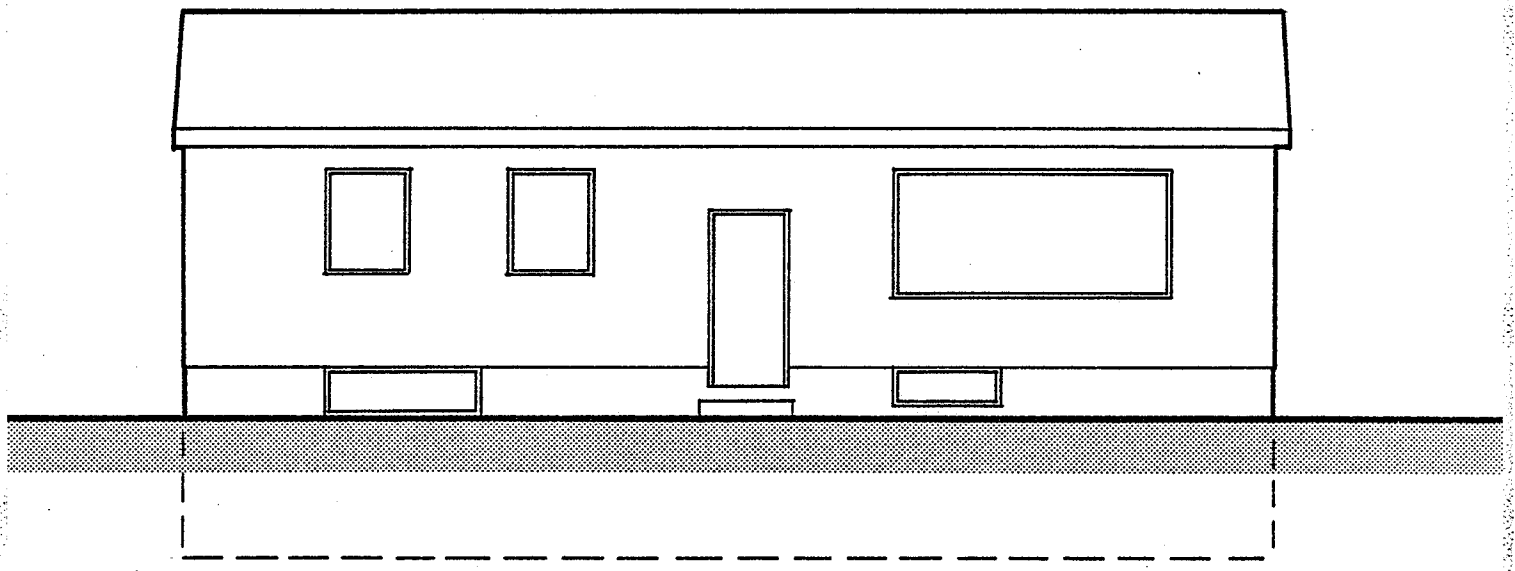
TYPICAL TRANSVERSE SECTION

SCALE : 3/16" = 1'-0"

FIG. 16

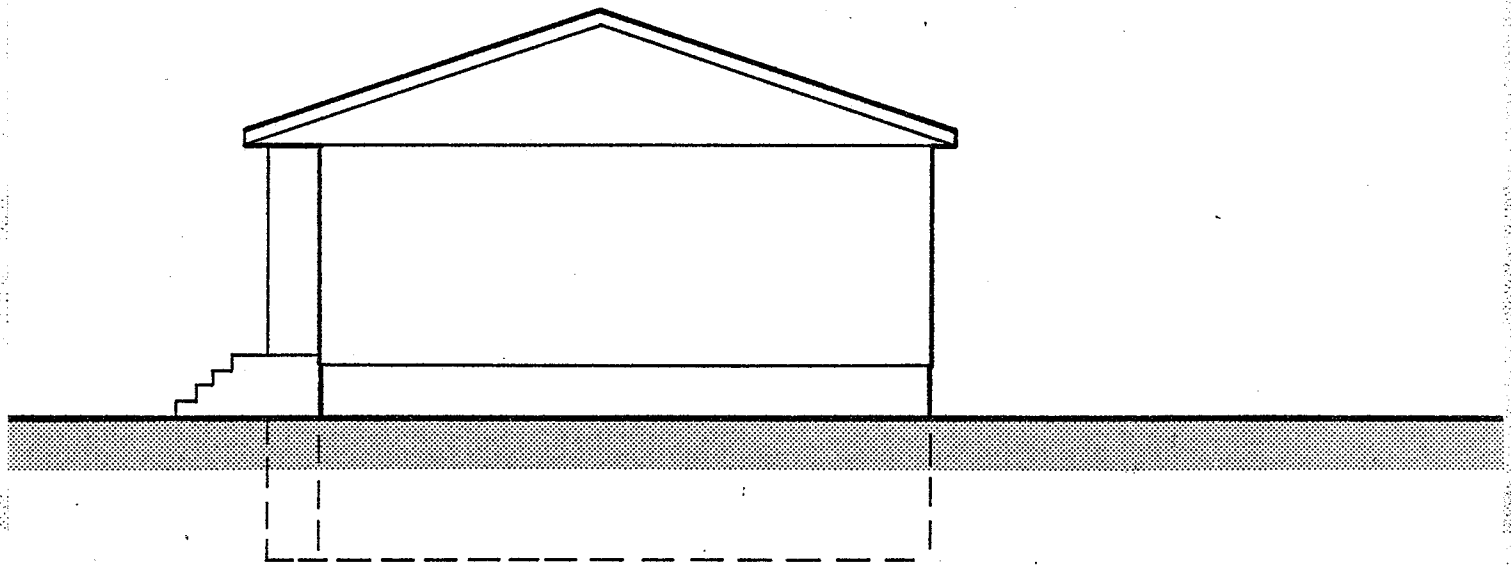
MODIFIED BUNGALOW

FIG.16 IS A TYPICAL SECTION TAKEN THROUGH THE MODIFIED BUNGALOW. AS CAN BE SEEN BY COMPARING THIS SECTION TO THE ONE TAKEN THROUGH THE INITIAL BUNGALOW ON PAGE 54 , THERE HAVE BEEN NO SIGNIFICANT CHANGES MADE TO ANY SKIN COMPONENTS NOR ANY CONSTRUCTION TECHNIQUES. THE ONLY CHANGES MADE THAT CONCERN OUR HEAT LOSS CALCULATIONS ARE THOSE TO THE AMBIENT AIR TEMPERATURES OF SOME OF THE ROOMS. AS WAS DISCUSSED EARLIER, THE AIR TEMPERATURE OF THE SERVICE AREAS ON THE GROUND LEVEL IS TO BE 60° F, WHICH MEANS THAT THE TEMPERATURE DIFFERENTIAL ACROSS THESE WALLS FROM INSIDE TO OUT WILL BE ONLY 90° F. BECAUSE THE LOWER LEVEL NOW CONTAINS THE BEDROOMS, ITS AMBIENT AIR TEMPERATURE RISES FROM 60° F TO 65° F, WHICH MEANS THAT THE ΔT THROUGH THE BASEMENT WALLS AND FLOOR INCREASES, AS DOES THE HEAT LOSS.



WEST ELEVATION

SCALE : 1/8" = 1'-0"

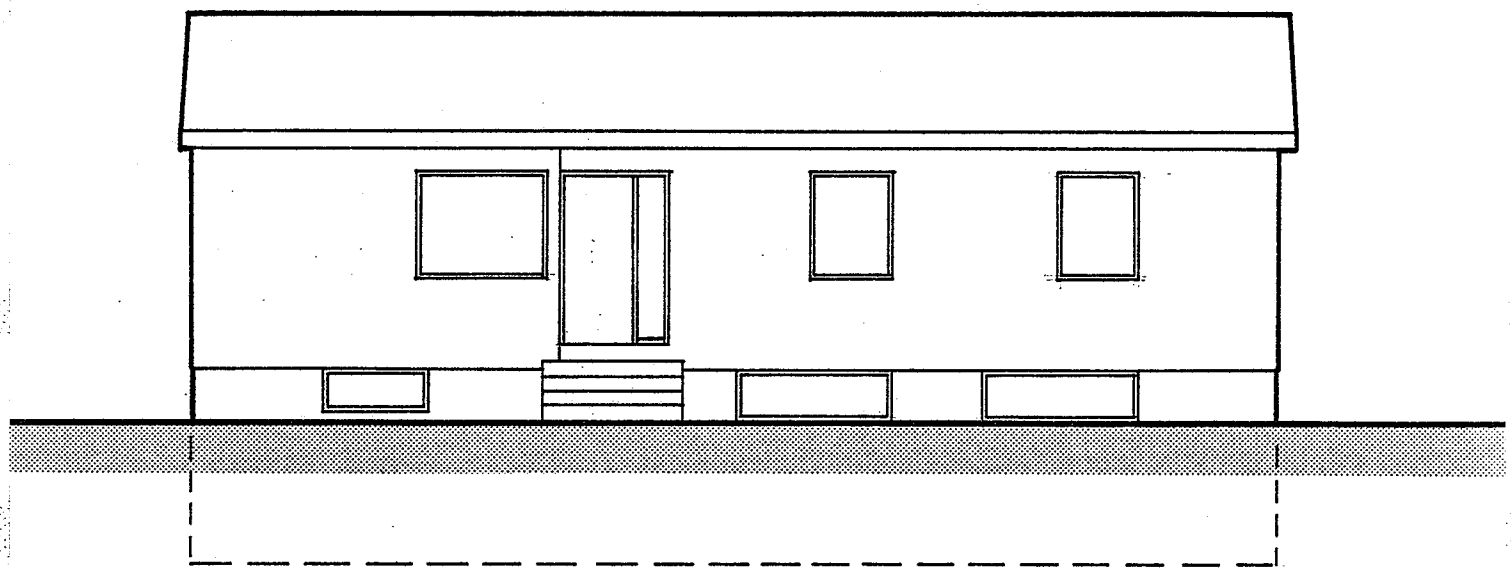


NORTH ELEVATION

SCALE : 1/8" = 1'-0"

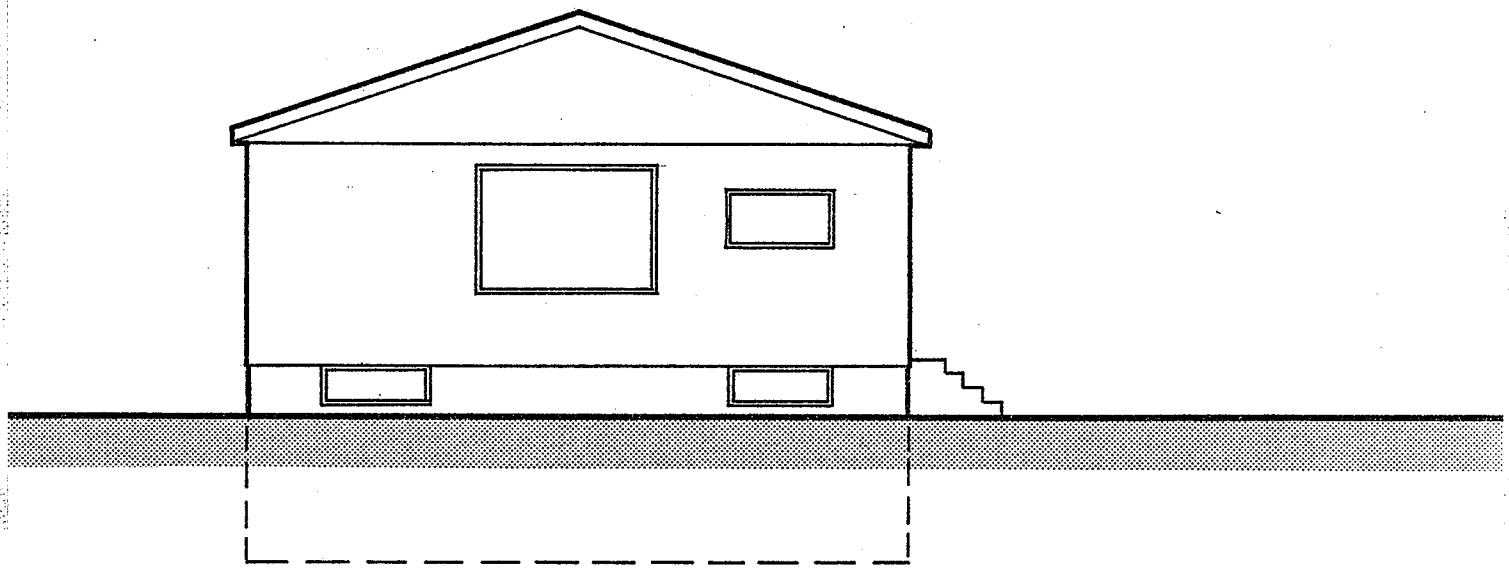
FIG. 17

		SURFACE AREA (SQUARE FEET)
WEST ELEVATION		
WALL	ΔT100	170
WALL	ΔT 90	138
FOUNDATION ABOVE GRADE		69
FOUNDATION BELOW GRADE		270
WINDOWS	ΔT100	55
WINDOWS	ΔT 95	18
WINDOWS	ΔT 90	24
DOOR		21
NORTH ELEVATION		
WALL	ΔT100	17
WALL	ΔT 90	225
FOUNDATION ABOVE GRADE		54
FOUNDATION BELOW GRADE		162



EAST ELEVATION

SCALE : 1/8" = 1'-0"



SOUTH ELEVATION

SCALE : 1/8" = 1'-0"

FIG, 18

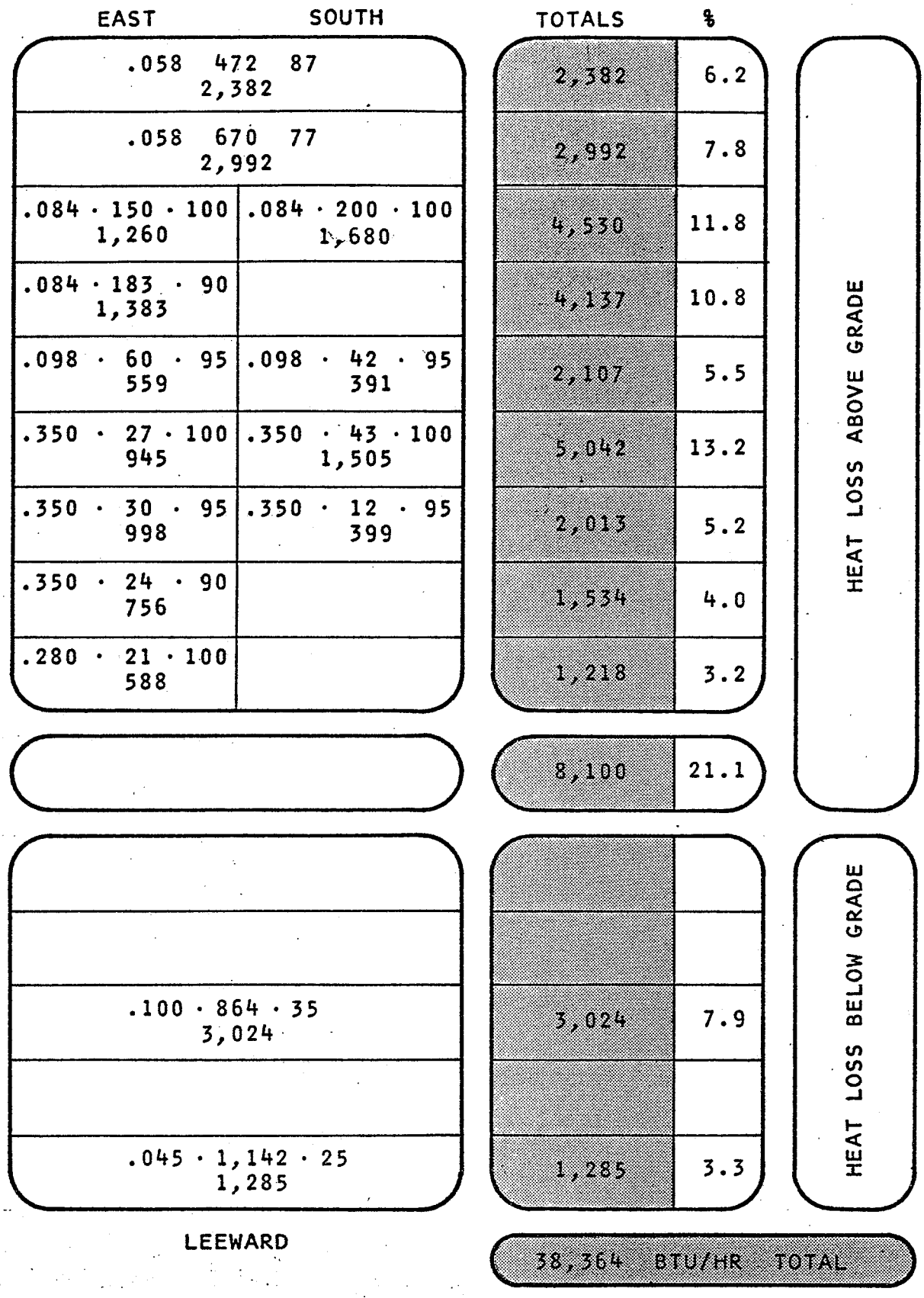
		SURFACE AREA (SQUARE FEET)
EAST ELEVATION		
WALL	ΔT100	150
WALL	ΔT 90	183
FOUNDATION ABOVE GRADE		60
FOUNDATION BELOW GRADE		270
WINDOWS	ΔT100	27
WINDOWS	ΔT 95	30
WINDOWS	ΔT 90	24
DOOR		21
SOUTH ELEVATION		
WALL		200
FOUNDATION ABOVE GRADE		42
FOUNDATION BELOW GRADE		162
WINDOWS	ΔT100	43
WINDOWS	ΔT 95	12

MODIFIED BUNGALOW

HEAT LOSS CHART

		WEST	NORTH
CEILING	ΔT 87		
CEILING	ΔT 77		
WALL	ΔT100	.085 · 170 · 100 1,445	.085 · 17 · 100 145
WALL	ΔT 90	.085 · 135 · 90 1,033	.085 · 225 · 90 1,721
FOUNDATION ABOVE GRADE		.099 · 69 · 95 649	.099 · 54 · 95 508
WINDOWS	ΔT100	.360 · 55 · 100 1,980	.360 · 17 · 100 612
WINDOWS	ΔT 95	.360 · 18 · 95 616	
WINDOWS	ΔT 90	.360 · 24 · 90 778	
DOOR		.300 · 21 · 100 630	
INFILTRATION & VENTILATION			
FLOOR TO CRAWLSPACE			
WALL TO CRAWLSPACE			
FOUNDATION BELOW GRADE			
BASEMENT FLOOR - CONCRETE			
BASEMENT FLOOR - CARPET			

WINDWARD


EAST
SOUTH
.058 472 87
2,382
.058 670 77
2,992
.084 · 150 · 100
1,260
.084 · 200 · 100
1,680
.084 · 183 · 90
1,383
.098 · 60 · 95
559
.098 · 42 · 95
391
.350 · 27 · 100
945
.350 · 43 · 100
1,505
.350 · 30 · 95
998
.350 · 12 · 95
399
.350 · 24 · 90
756
.280 · 21 · 100
588
.100 · 864 · 35
3,024
.045 · 1,142 · 25
1,285
LEEWARD
TOTALS
%
2,382
6.2
2,992
7.8
4,530
11.8
4,137
10.8
2,107
5.5
5,042
13.2
2,013
5.2
1,534
4.0
1,218
3.2
8,100
21.1
3,024
7.9
1,285
3.3
HEAT LOSS ABOVE GRADE
HEAT LOSS BELOW GRADE
38,364 BTU/HR TOTAL

MODIFIED BUNGALOW

SUMMARY OF HEAT LOSS

	INITIAL	REVISED	MODIFIED
CEILING	5,696 10.0%	5,696 14.8%	5,374 14.0%
WALLS	8,858 15.5%	8,858 22.9%	8,667 22.6%
FOUNDATION	18,339 32.0%	5,785 14.9%	6,416 16.7%
DOORS & WINDOWS	16,184 28.3%	10,158 26.4%	9,807 25.6%
INFILTRATION & VENTILATION	8,100 14.2%	8,100 21.0%	8,100 21.1%
TOTALS	57,177	38,597	38,364

ALL VALUES IN BTU/HR.

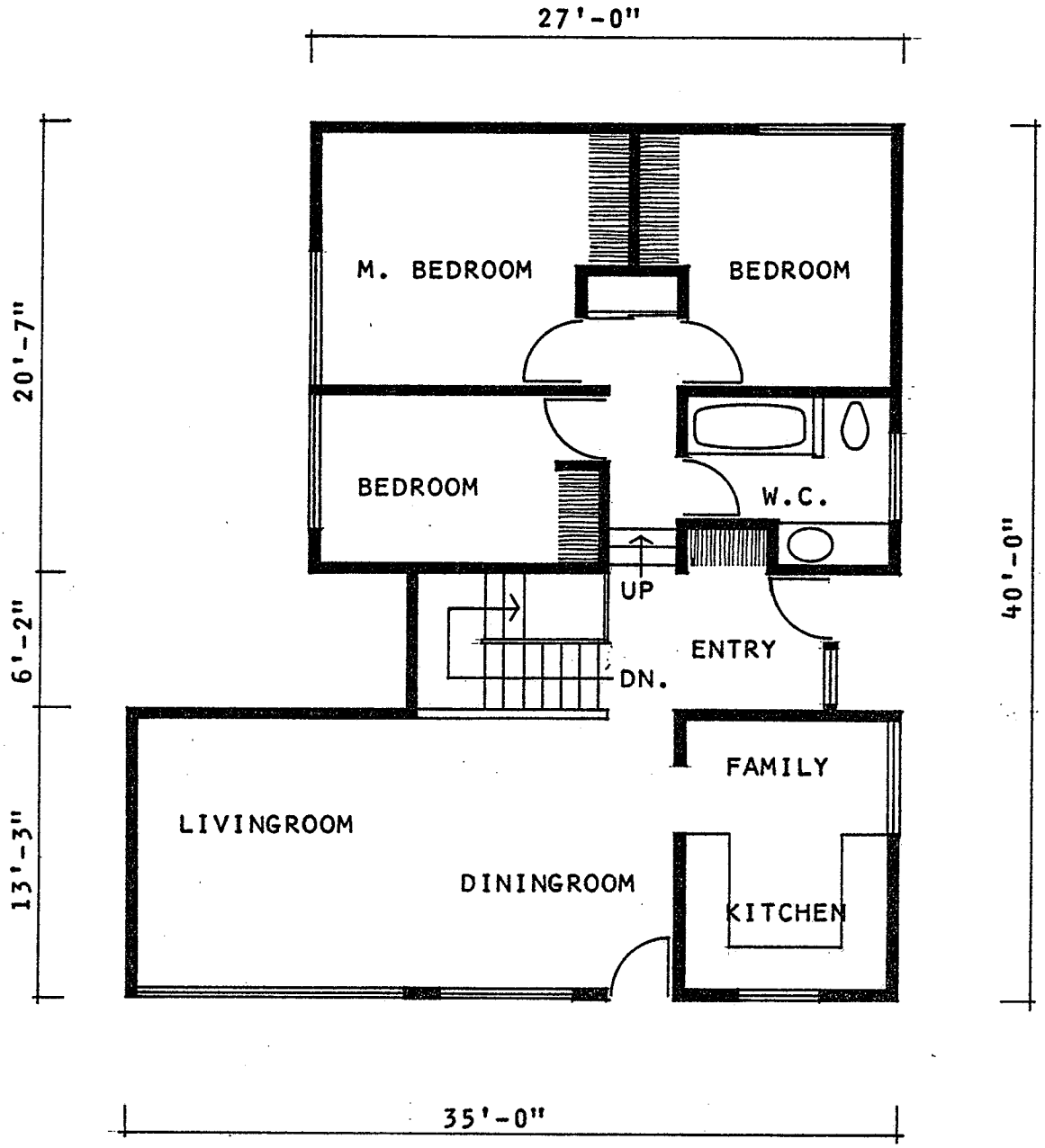
A N A L Y S I S

BY COMPARING THE MODIFIED COLUMN IN THE CHART ON THE OPPOSITE PAGE WITH THE REVISED COLUMN, IT CAN BE SEEN THAT HEAT LOSS THROUGH THE CEILING, WALLS, AND DOORS AND WINDOWS HAS DECREASED, AND THROUGH THE FOUNDATION IT HAS INCREASED. INFILTRATION AND VENTILATION IS UNCHANGED. THE TOTAL HEAT LOSS FROM THE MODIFIED BUNGALOW IS DOWN BY ONLY 233 BTU/HR. FROM THE REVISED BUNGALOW. THIS SMALL REDUCTION IS DUE ENTIRELY TO THE FACT THAT THE FOUNDATION WALL, ALTHOUGH INSULATED ABOVE GRADE, DOES SIMPLY NOT HAVE THE THERMAL RESISTANCE REQUIRED WHEN THE BEDROOMS ARE BELOW GRADE. IF THE ENTIRE FOUNDATION WALL WERE INSULATED, THE REDUCTION OF HEAT LOSS WOULD BE MUCH GREATER. NONETHELESS, EVEN WITHOUT THIS ADDITIONAL INSULATION, THERE IS A REDUCTION IN THE HEAT LOSS FROM THE MODIFIED BUNGALOW, AND THIS SUPPORTS THE GENERAL PRINCIPAL OF MOVING THE SERVICE AREA ABOVE GRADE, AND THE NIGHT AREA BELOW GRADE.

SECTION B

PART TWO

CALCULATIONS OF HEAT LOSS FROM THE SPLIT LEVEL HOUSE TYPE



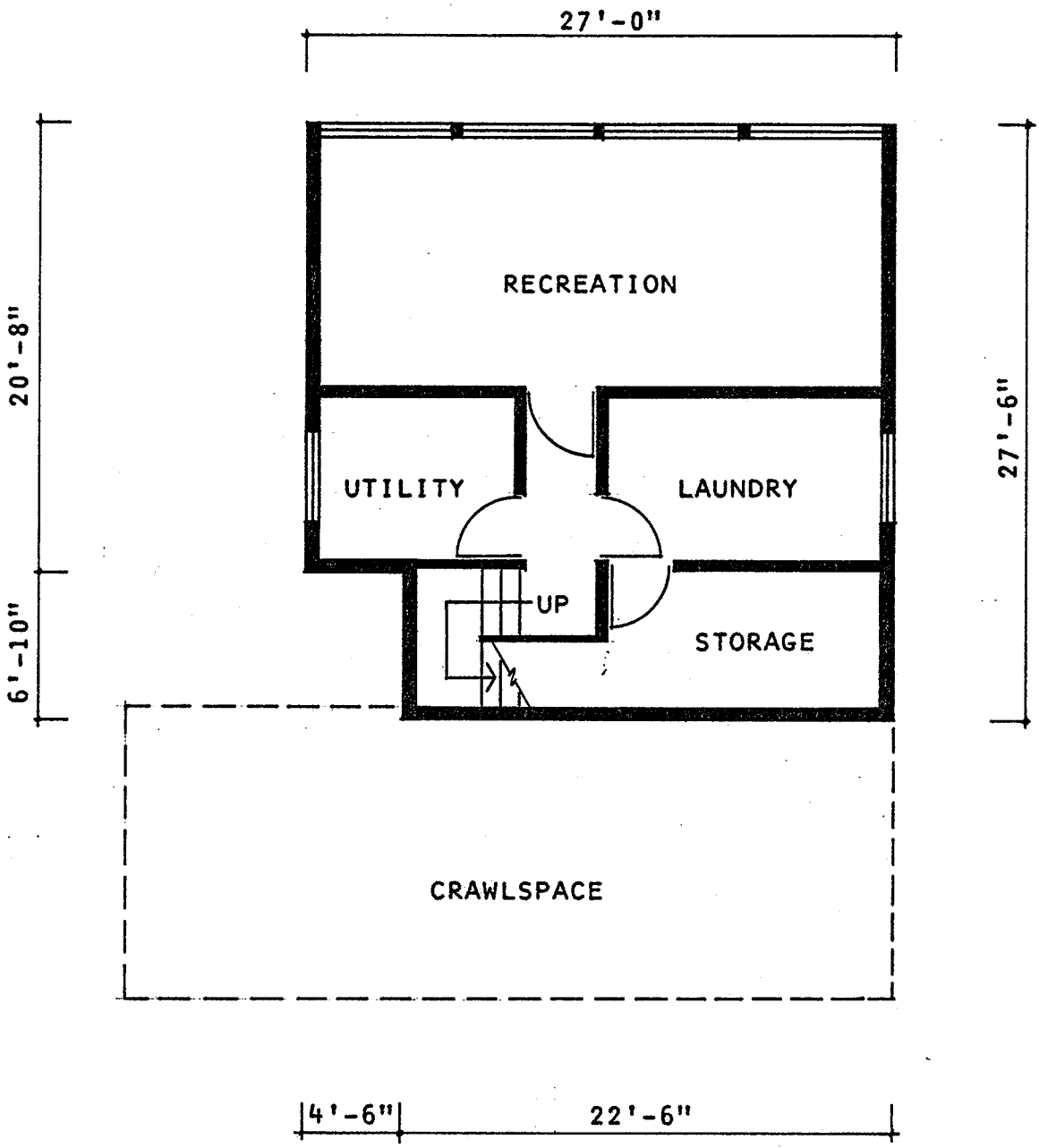
GROUND LEVEL PLAN

SCALE : 1/8" = 1'-0" FIG. 19

INITIAL SPLIT-LEVEL

THE GROUND LEVEL PLAN SHOWN ON THE OPPOSITE PAGE IS AN ADAPTION OF DESIGN 764 OF THE CMHC HANDBOOK OF HOUSE DESIGNS. IT HAS BEEN SIMPLIFIED IN SOME RESPECTS. A CLOSET HAS BEEN REMOVED FROM THE KITCHEN, AND SLIDING GLASS DOORS FROM THE DINING ROOM TO THE OUT-OF-DOORS HAVE BEEN REPLACED WITH A SWINGING DOOR. THE WINDOWS HAVE BEEN MODIFIED TO CONFORM TO THE OTHER HOUSE TYPES. THE MAIN FLOOR PLAN IS VERY SIMILAR TO THAT OF THE BUNGALOW, WITH THE SAME CLEAR ZONING BETWEEN DAY AND NIGHT AREAS. IN THIS CASE, THE NIGHT ARE IS UP THREE RISERS FROM THE LEVEL OF THE DAY AREA. THE ENTRY HALL AND STAIRS TO THE LOWER LEVEL FORM A BUFFER ZONE BETWEEN THE DAY AND NIGHT AREAS. THE PRINCIPAL ENTRY IS IN THE EAST; THE SECONDARY ENTRY IN THE SOUTH.

AREA OF GROUND LEVEL	1,140 SQ. FT.
AREA OF ROOF	1,155 SQ. FT.



LOWER LEVEL PLAN

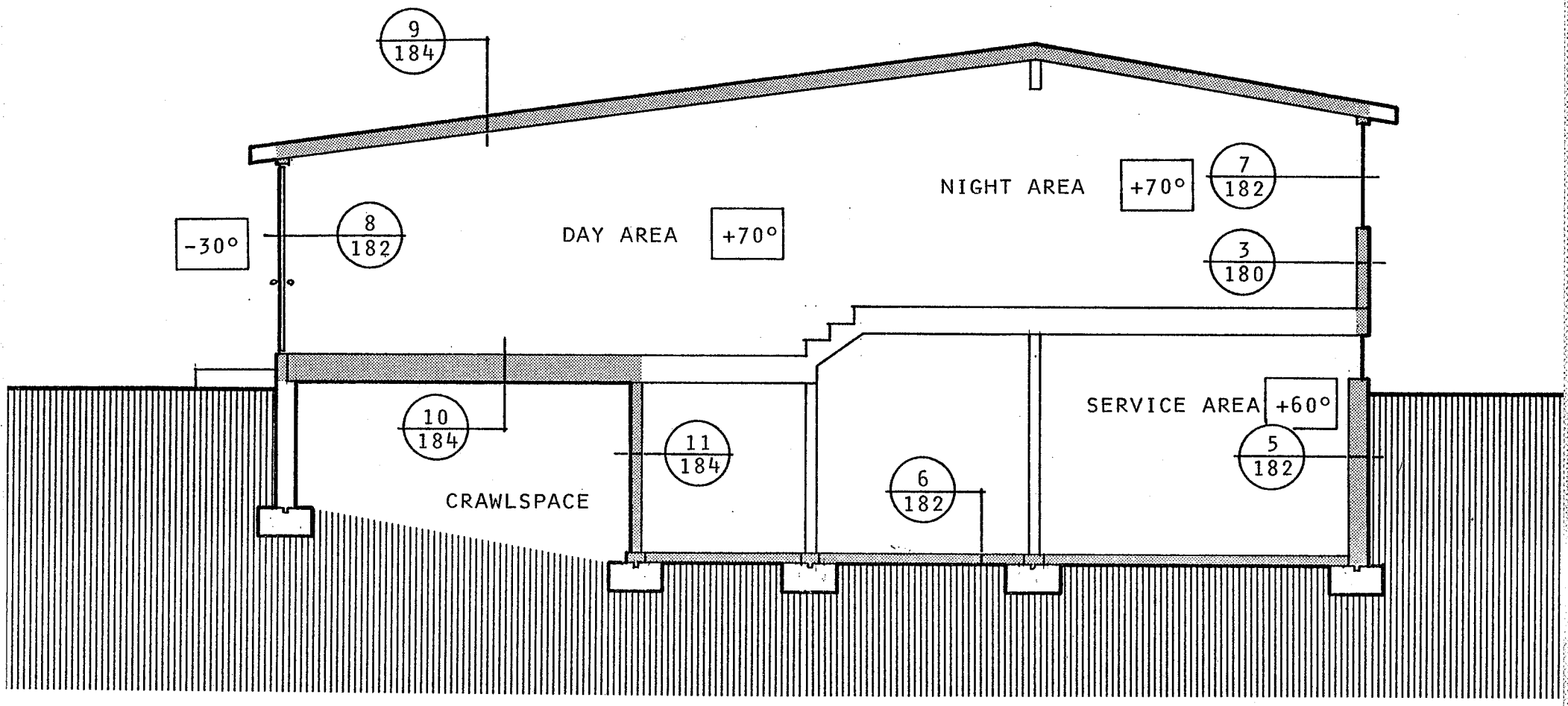
SCALE : 1/8" = 1'-0" FIG. 20

INITIAL SPLIT-LEVEL

THE LOWER LEVEL PLAN, SHOWN ON THE OPPOSITE PAGE, DOES NOT EXTEND BENEATH THE ENTIRE UPPER LEVEL BECAUSE THE FLOOR LEVEL OF THE LIVING - DINING - KITCHEN AREA IS TOO LOW TO ALLOW FOR HEADROOM BENEATH IT. SUBSEQUENTLY, THERE IS A CRAWL SPACE UNDER THIS PORTION OF THE HOUSE.

THERE ARE FOUR ROOMS ON THE LOWER LEVEL; A UTILITY ROOM, RECREATION, LAUNDRY AND A LOW STORAGE AREA UNDER THE ENTRY HALL.

AREA OF LOWER LEVEL (EXCLUDING CRAWL SPACE)	728 SQ. FT.
AREA OF FOUNDATION WALLS	531 SQ. FT.



TYPICAL TRANSVERSE SECTION

SCALE : 3/16" = 1'-0"

FIG. 21

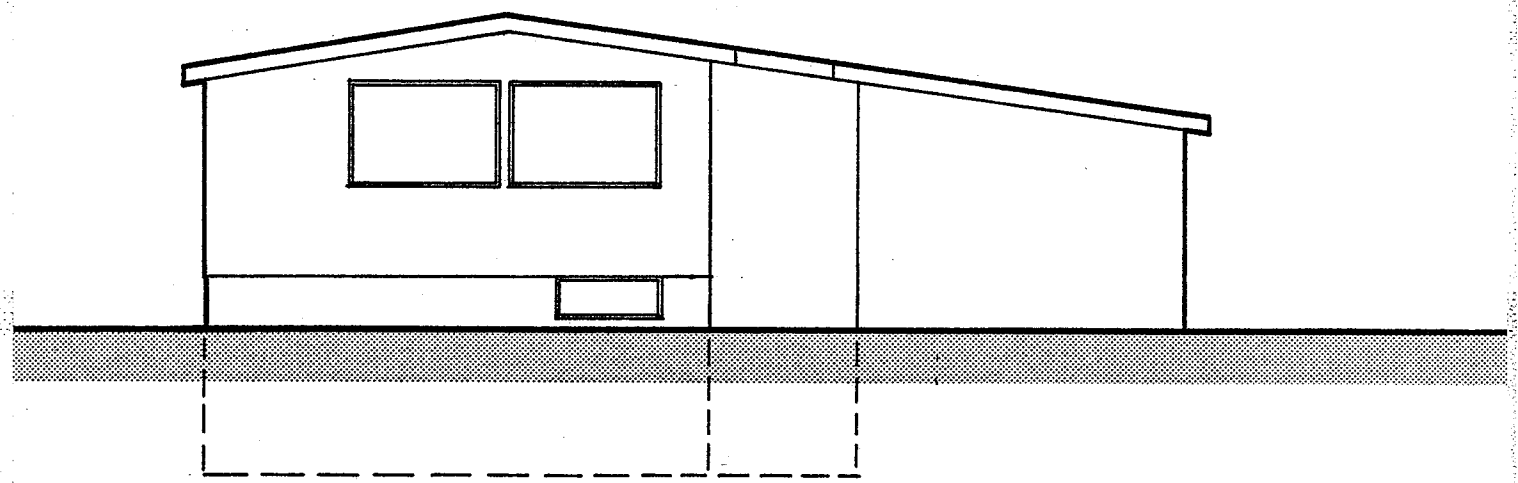
INITIAL SPLIT-LEVEL

FIG.21 IS A TYPICAL SECTION CUT THROUGH THE SPLIT - LEVEL SHOWING ALL OF THE PRINCIPAL ELEMENTS OF THE EXTERIOR WALLS, (SHOWN SHADED) AND THE RELATIONSHIP OF THE BUILDING TO THE GROUND. DETAIL SECTIONS HAVE BEEN TAKEN THROUGH THE EXTERIOR WALL COMPONENTS SO THAT THEIR U VALUES MAY BE CALCULATED. THESE DETAILS ARE TO BE FOUND IN APPENDIX 1 , PAGE 179.

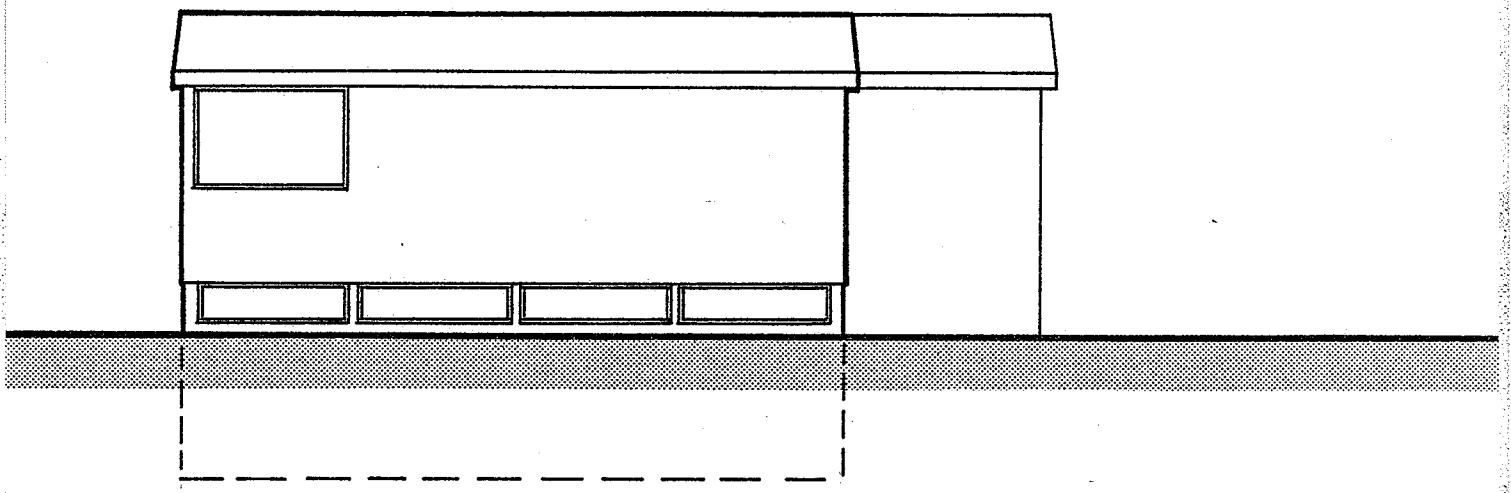
CONSTRUCTION OF THE SPLIT - LEVEL HOUSE IS AS FOLLOWS:

- BUILT - UP ROOF, PLYWOOD SHEATHING, 2 X 8 ROOF RAFTERS. R20 INSULATION, 1/2" DRYWALL INTERIOR.
- STUCCO FINISH EXTERIOR, PLYWOOD SHEATHING, 2 X 4 WALLS, R12 INSULATION, 1/2" DRYWALL INTERIOR.
- 3/4" PLYWOOD, 2 X 10 FLOOR JOISTS, R10 INSULATION OVER CRAWLSPACE, CARPET OR HARDWOOD.
- 8" CONCRETE FOUNDATION WALLS, EXTENDING 7' BELOW GRADE BASEMENT AND 5' AT CRAWLSPACE. NO INSULATION.
- 4" CONCRETE BASEMENT FLOOR. NO INSULATION. AREA OF FLOOR OVER CRAWLSPACE = 408 SQ. FT.
- DOUBLE GLAZE WINDOWS, 1/2" AIRSPACE.
- SOLID CORE DOOR AND STORM DOOR.

AMBIENT AIR TEMPERATURES ARE SHOWN IN A [-30°] SYMBOL.



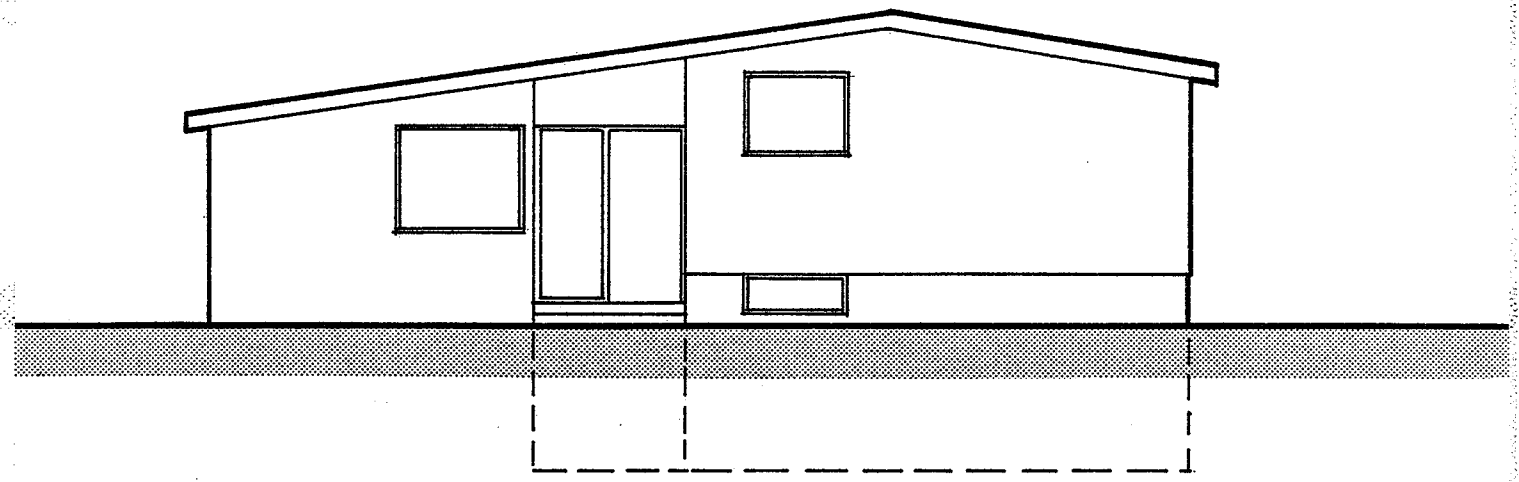
WEST ELEVATION
SCALE : 1/8" = 1'-0"



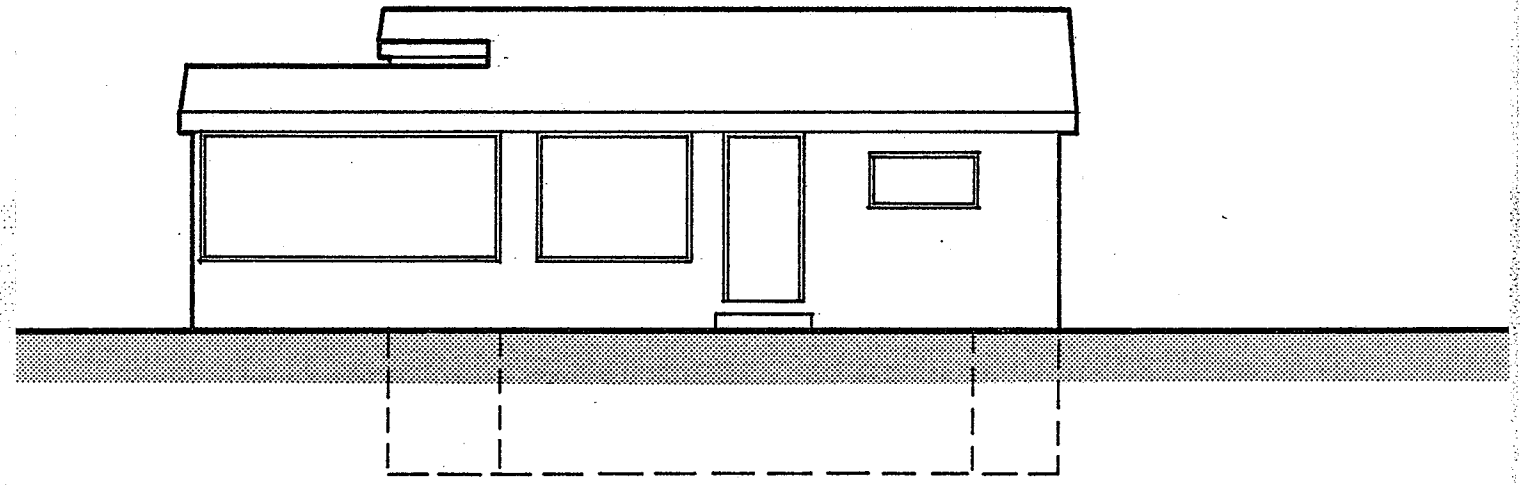
NORTH ELEVATION
SCALE : 1/8" = 1'-0"

FIG. 22

		SURFACE AREA (SQUARE FEET)
WEST ELEVATION		
WALL		324
FOUNDATION ABOVE GRADE		41
FOUNDATION BELOW GRADE		162
WINDOWS	ΔT100	48
WINDOWS	ΔT 90	6
NORTH ELEVATION		
WALL		347
FOUNDATION ABOVE GRADE		18
FOUNDATION BELOW GRADE		162
WINDOWS	ΔT100	24
WINDOWS	ΔT 90	36



EAST ELEVATION
SCALE : 1/8" = 1'-0"



SOUTH ELEVATION
SCALE : 1/8" = 1'-0"

FIG. 23

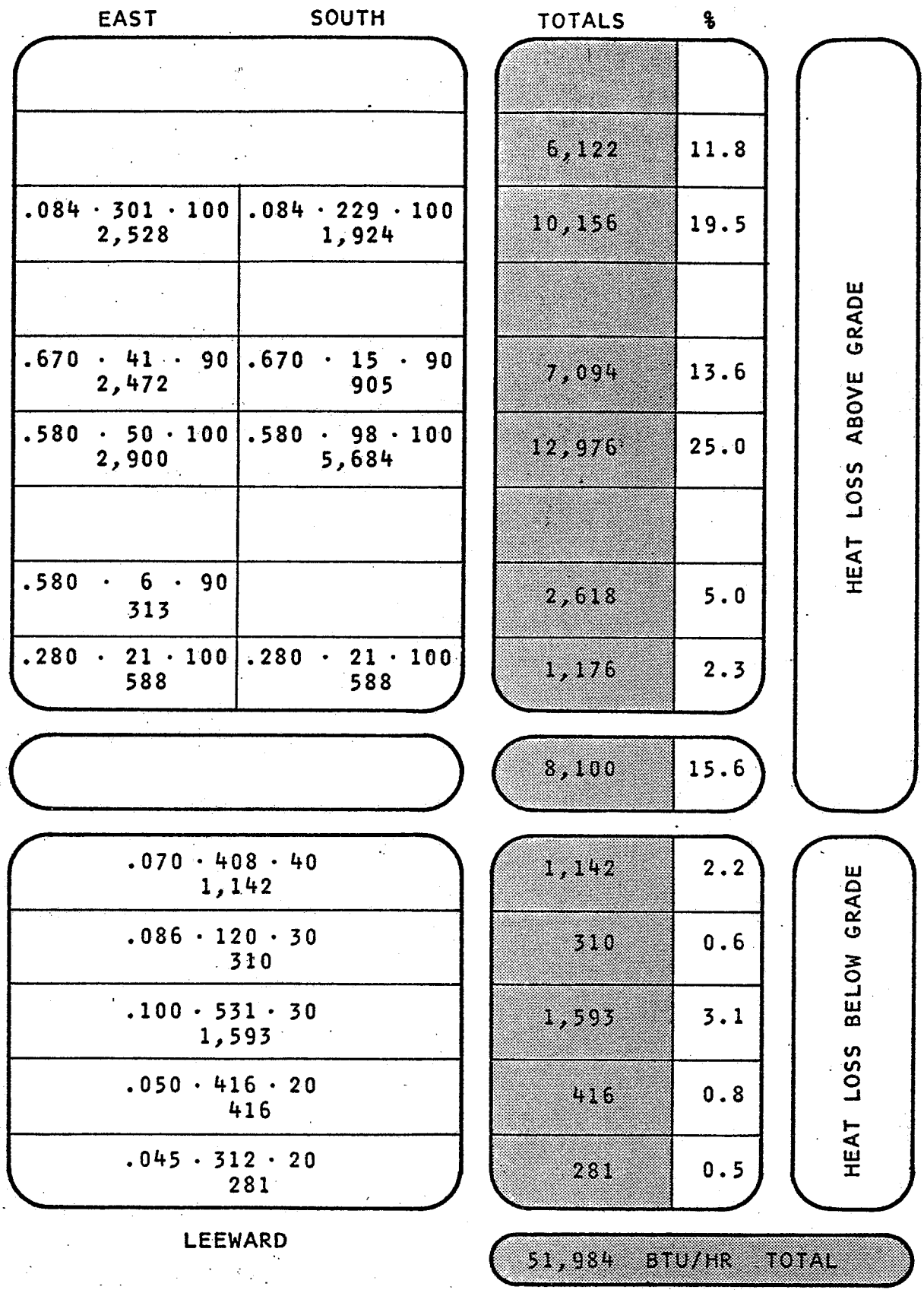
		SURFACE AREA (SQUARE FEET)
EAST ELEVATION		
WALL		301
FOUNDATION ABOVE GRADE		41
FOUNDATION BELOW GRADE		162
WINDOWS	ΔT100	50
WINDOWS	ΔT 90	6
DOOR		21
SOUTH ELEVATION		
WALL		229
WALL TO CRAWLSPACE		120
FOUNDATION ABOVE GRADE		15
FOUNDATION BELOW GRADE		45
WINDOWS		98
DOOR		21

INITIAL SPLIT LEVEL

HEAT LOSS CHART

		WEST	NORTH
ROOF	ΔT 100	.053 · 1,155 · 100 6,122	
WALL	ΔT100	.085 · 324 · 100 2,754	.085 · 347 · 100 2,950
WALL	ΔT 90		
FOUNDATION ABOVE GRADE		.700 · 41 · 90 2,583	.700 · 18 · 90 1,134
WINDOWS	ΔT100	.610 · 48 · 100 2,928	.610 · 24 · 100 1,464
WINDOWS	ΔT 95		
WINDOWS	ΔT 90	.610 · 6 · 90 329	.610 · 36 · 90 1,976
DOOR			
INFILTRATION & VENTILATION		75 · 1.08 · 100 8,100	
FLOOR TO CRAWLSPACE			
WALL TO CRAWLSPACE			
FOUNDATION BELOW GRADE			
BASEMENT FLOOR - CONCRETE			
BASEMENT FLOOR - CARPET			

WINDWARD


EAST
SOUTH
TOTALS
%
.084 · 301 · 100
2,528
.084 · 229 · 100
1,924
.670 · 41 · 90
2,472
.670 · 15 · 90
905
.580 · 50 · 100
2,900
.580 · 98 · 100
5,684
.580 · 6 · 90
313
.280 · 21 · 100
588
.280 · 21 · 100
588
6,122
11.8
10,156
19.5
7,094
13.6
12,976
25.0
2,618
5.0
1,176
2.3
8,100
15.6
HEAT LOSS ABOVE GRADE
.070 · 408 · 40
1,142
.086 · 120 · 30
310
.100 · 531 · 30
1,593
.050 · 416 · 20
416
.045 · 312 · 20
281
1,142
2.2
310
0.6
1,593
3.1
416
0.8
281
0.5
HEAT LOSS BELOW GRADE
LEEWARD
51,984 BTU/HR TOTAL

INITIAL SPLIT LEVEL

SUMMARY OF HEAT LOSS

	INITIAL	REVISED	MODIFIED
ROOF	6,122 11.8%		
WALLS	10,156 19.5%		
FOUNDATION	10,836 20.8%		
DOORS & WINDOWS	16,770 32.3%		
INFILTRATION & VENTILATION	8,100 15.6%		
TOTALS	51,984		

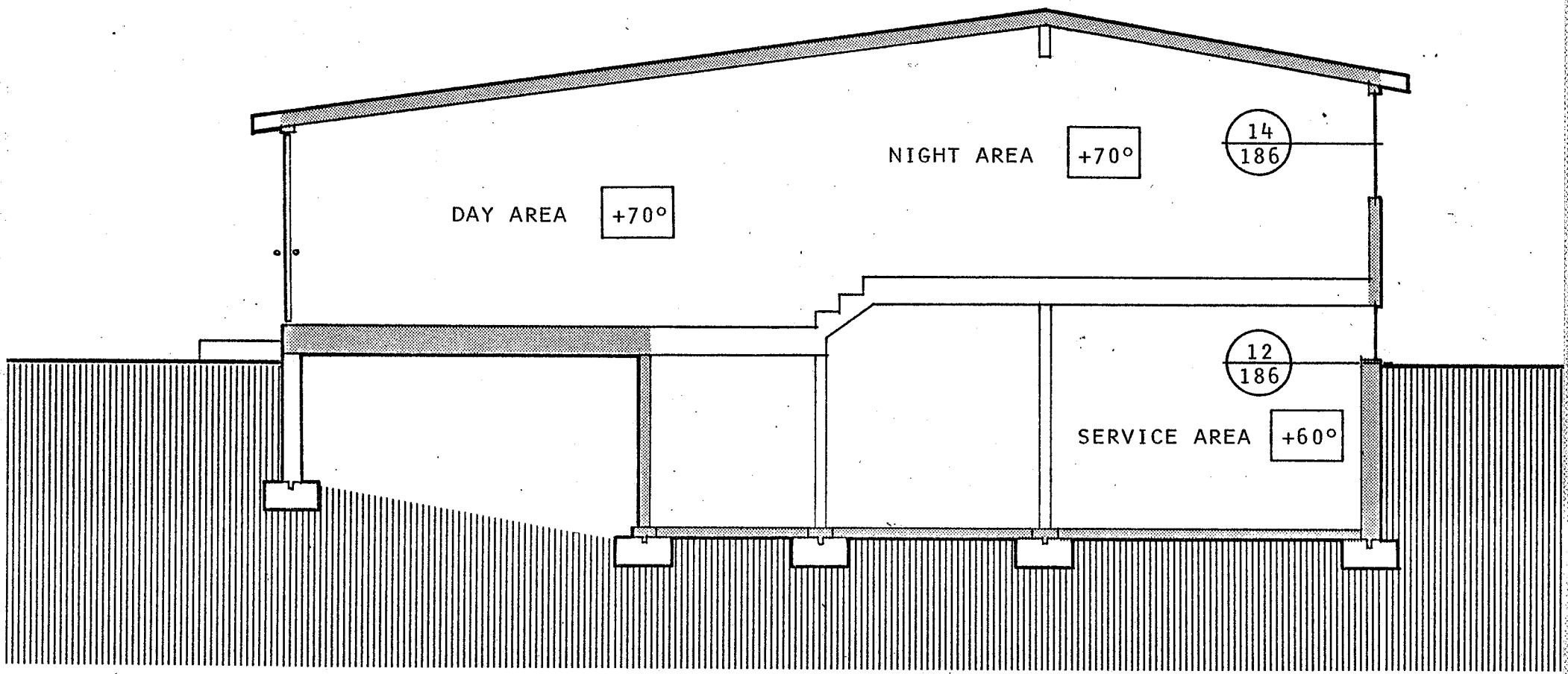
ALL VALUES IN BTU/HR

A N A L Y S I S

THE GREATEST FLOW OF HEAT FROM THE INITIAL SPLIT LEVEL, 16,770 BTU/HR. OR 32.3% OF THE TOTAL, OCCURS THROUGH THE DOORS AND WINDOWS. OF THIS AMOUNT, 15,594 BTU/HR. ESCAPE THROUGH THE WINDOWS. THIS ACCOUNTS FOR A FULL 30% OF THE TOTAL HEAT LOSS FROM THE INITIAL SPLIT LEVEL.

THE NEXT GREATEST FLOW OF HEAT FROM THE INITIAL SPLIT LEVEL OCCURS AT THE FOUNDATION, AND EQUALS 10,836 BTU/HR. OR 20.8% OF THE TOTAL. OF THIS AMOUNT, 7,094 BTU/HR. ESCAPE THROUGH THE STRIP OF FOUNDATION WALL EXPOSED ABOVE GRADE.

THESE TWO ASSEMBLIES ARE THE SAME THAT WERE SHOWN TO ALLOW THE GREATEST FLOW OF HEAT FROM THE BUNGALOW, ALTHOUGH IN THE REVERSE ORDER. THE WINDOWS LOSE AN ALMOST IDENTICAL AMOUNT OF HEAT IN THE TWO HOUSE TYPES; THE FOUNDATION OF THE SPLIT LEVEL LOSES CONSIDERABLY LESS THAN THAT OF THE BUNGALOW BECAUSE IT IS A GOOD DEAL SMALLER. IN FACT, FOUNDATION HEAT LOSS IN THE SPLIT LEVEL LOSES ONLY SLIGHTLY MORE HEAT THAN THE WALLS. HOWEVER, BECAUSE SUCH A LARGE PORTION OF THIS HEAT LOSS OCCURS THROUGH A VERY SMALL AREA, THE FOUNDATION ABOVE GRADE SHALL AGAIN BE REVISED TO INCREASE ITS THERMAL RESISTANCE.



TYPICAL TRANSVERSE SECTION

SCALE : 3/16" = 1'-0"

FIG. 24

R E V I S I O N S

FIG.24 ON THE OPPOSITE PAGE IS A SECTION TAKEN THROUGH THE REVISED SPLIT LEVEL. DETAIL SECTIONS ARE SHOWN THROUGH THE TWO ASSEMBLIES WHICH HAVE BEEN REVISED FROM THE INITIAL SPLIT LEVEL, THE WINDOWS, AND THE FOUNDATION WALL ABOVE GRADE.

THE DETAIL SECTIONS ARE TO BE FOUND IN APPENDIX 1 , PAGE 179. THESE REVISIONS MADE ARE THE SAME AS IN THE CASE OF THE BUNGALOW; THE FOUNDATION WALL ABOVE GRADE HAS BEEN COVERED WITH 2" OF RIGID INSULATION, AND THE WINDOWS HAVE BEEN CHANGED FROM DOUBLE GLAZING TO TRIPLE GLAZING.

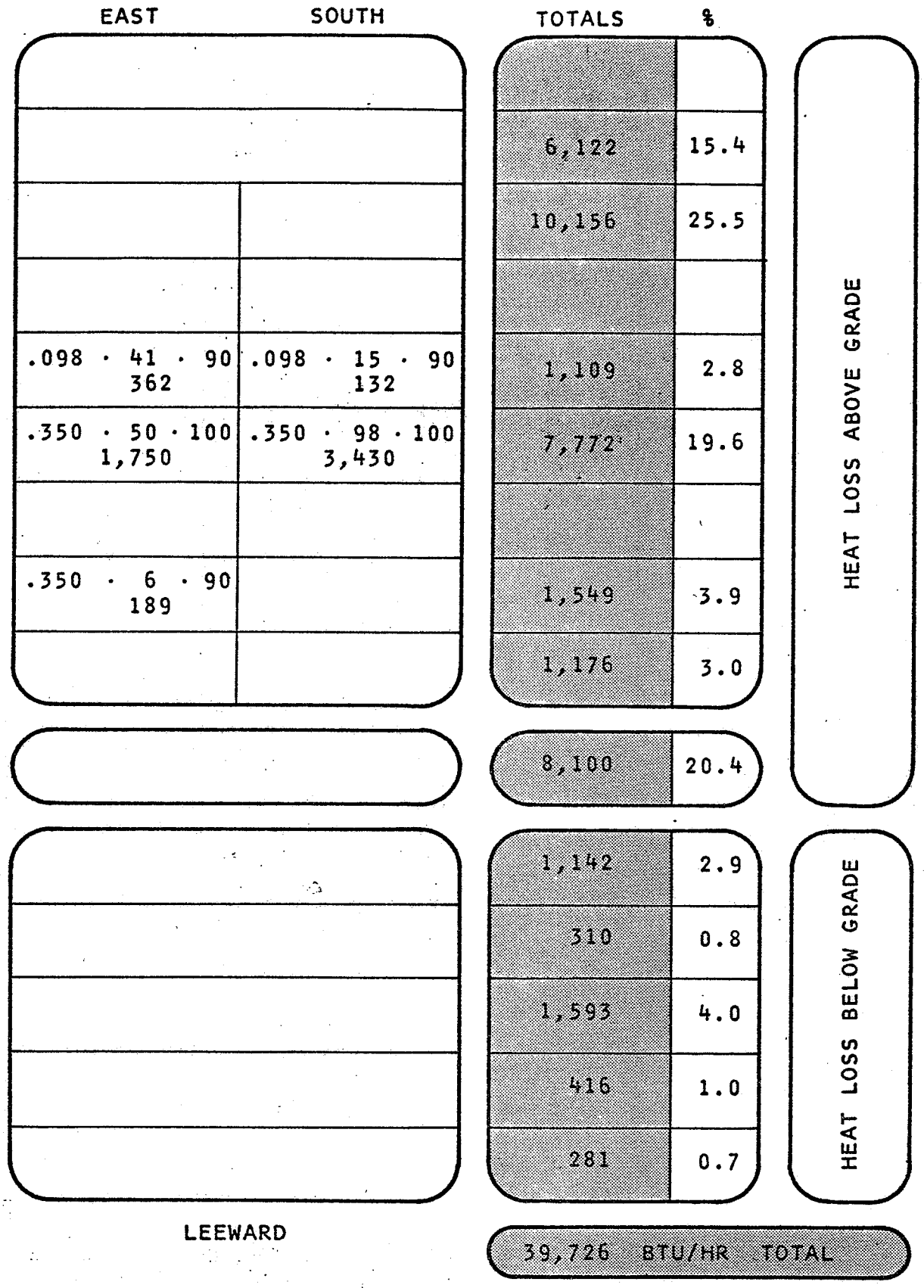
ON THE FOLLOWING PAGES, THE HEAT LOSS CALCULATIONS FOR THE REVISED SPLIT LEVEL ARE PRESENTED.

REVISED SPLIT LEVEL

HEAT LOSS CHART

		WEST	NORTH
ROOF	ΔT100		
WALL	ΔT100		
WALL	ΔT 90		
FOUNDATION ABOVE GRADE		.099 · 41 · 90 = 365	.099 · 18 · 90 = 160
WINDOWS	ΔT100	.360 · 48 · 100 = 1,728	.360 · 24 · 100 = 864
WINDOWS	ΔT 95		
WINDOWS	ΔT 90	.360 · 6 · 90 = 194	.360 · 36 · 90 = 1,166
DOOR			
INFILTRATION & VENTILATION			
FLOOR TO CRAWLSPACE			
WALL TO CRAWLSPACE			
FOUNDATION BELOW GRADE			
BASEMENT FLOOR - CONCRETE			
BASEMENT FLOOR - CARPET			

WINDWARD


EAST
SOUTH
TOTALS
%
.098 · 41 · 90
362
.098 · 15 · 90
132
.350 · 50 · 100
1,750
.350 · 98 · 100
3,430
.350 · 6 · 90
189
6,122
15.4
10,156
25.5
1,109
2.8
7,772
19.6
1,549
3.9
1,176
3.0
8,100
20.4
1,142
2.9
310
0.8
1,593
4.0
416
1.0
281
0.7
HEAT LOSS ABOVE GRADE
HEAT LOSS BELOW GRADE
LEEWARD
39,726 BTU/HR TOTAL

REVISED SPLIT LEVEL

SUMMARY OF HEAT LOSS

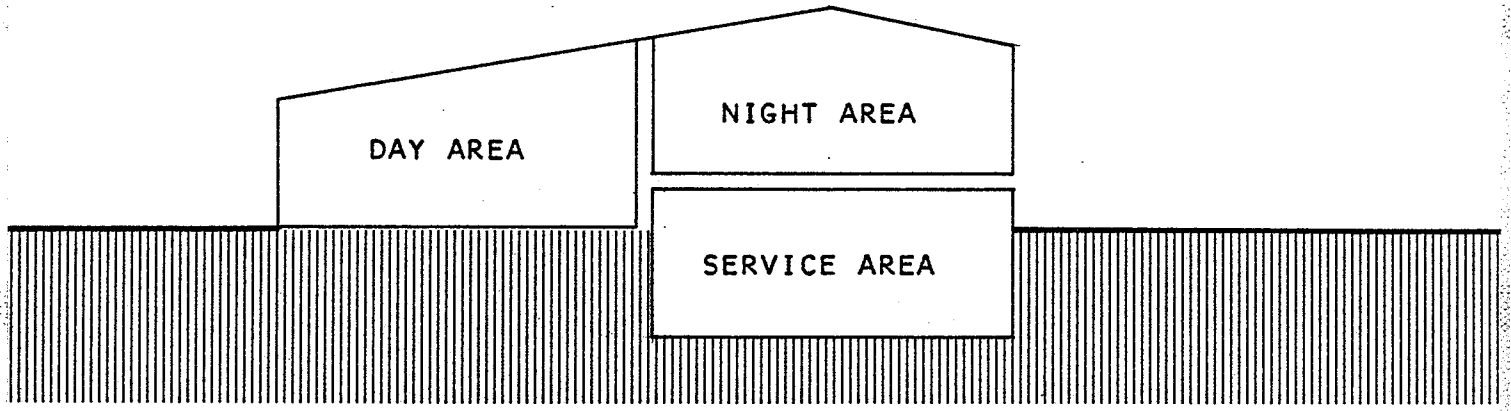
	INITIAL	REVISED	MODIFIED
ROOF	6,122 11.8%	6,122 15.4%	
WALLS	10,156 19.5%	10,156 25.5%	
FOUNDATION	10,836 20.8%	4,851 12.2%	
DOORS & WINDOWS	16,770 32.3%	10,497 26.5%	
INFILTRATION & VENTILATION	8,100 15.6%	8,100 20.4%	
TOTALS	51,984	39,726	

ALL VALUES IN BTU/HR

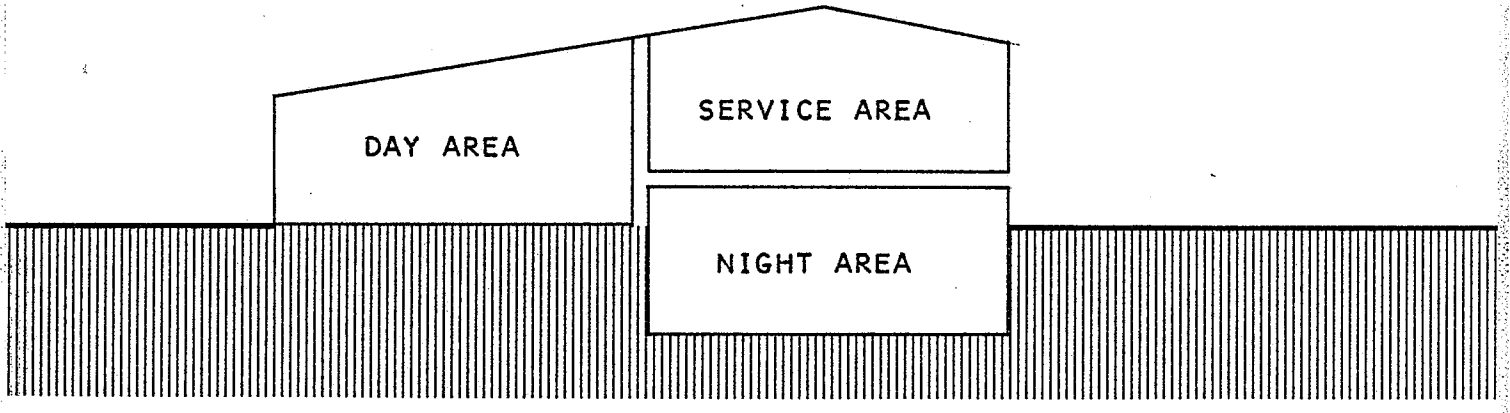
A N A L Y S I S

BY COMPARING THE REVISED COLUMN IN THE CHART ON THE OPPOSITE PAGE WITH THE INITIAL COLUMN, IT CAN BE SEEN THAT THE HEAT LOSS THROUGH BOTH THE FOUNDATION AND THE DOORS AND WINDOWS HAS BEEN REDUCED AS A RESULT OF THE REVISIONS MADE. THE ABSOLUTE VALUES OF THE OTHER THREE ASSEMBLIES ARE UNCHANGED, BUT THE PERCENTAGE VALUES OF ALL FIVE ARE NEW AS A RESULT OF THE LOWER TOTAL HEAT LOSS.

THE REVISED TOTAL OF 39,726 BTU/HR. IS A 24% REDUCTION IN HEAT LOSS FROM THE INITIAL TOTAL OF 51,984 BTU/HR.



INITIAL & REVISED SPLIT LEVEL



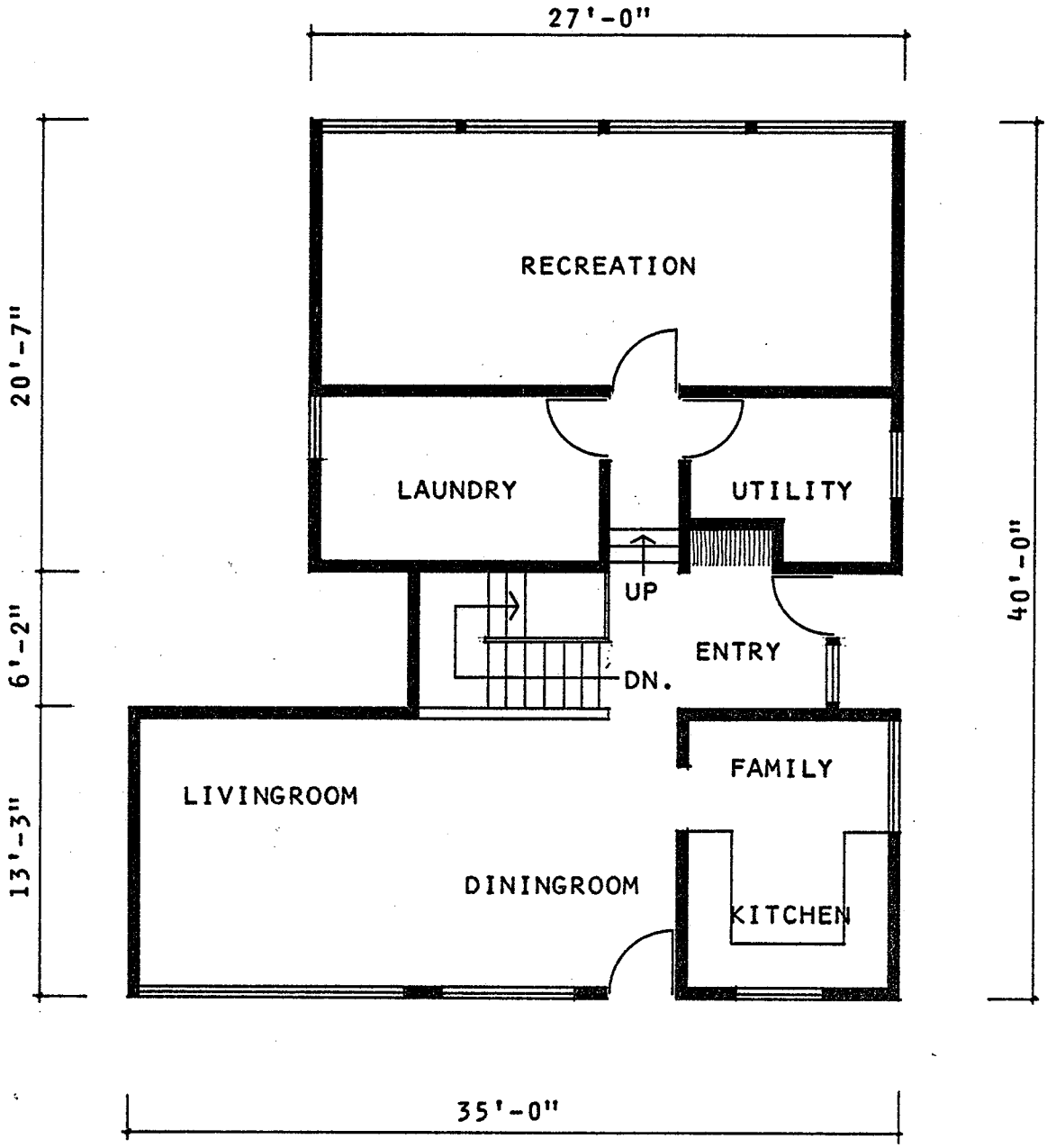
MODIFIED SPLIT LEVEL

FIG. 25

MODIFICATIONS

FIG. 25 ON THE OPPOSITE PAGE IS A GRAPHIC EXPLANATION OF THE MODIFICATION OF THE SPLIT LEVEL TO FURTHER REDUCE HEAT LOSS. THE TOP ILLUSTRATION SHOWS THE ORGANIZATION OF THE INITIAL AND REVISED SPLIT LEVEL SCHEMES, WITH THE DAY AREA ON THE GROUND LEVEL, THE NIGHT AREA A FEW RISERS ABOVE IT, AND THE SERVICE AREA ON THE LOWER LEVEL. THE BOTTOM ILLUSTRATION SHOWS THE MODIFIED SPLIT LEVEL, WITH THE DAY AREA UNCHANGED, THE SERVICE AREA A FEW RISERS ABOVE IT, AND THE NIGHT AREA ON THE LOWER LEVEL.

ON THE FOLLOWING PAGES, DETAIL DRAWINGS OF THIS REORGANIZATION, PLUS RESULTING HEAT LOSS CALCULATIONS, ARE PRESENTED.



GROUND LEVEL PLAN

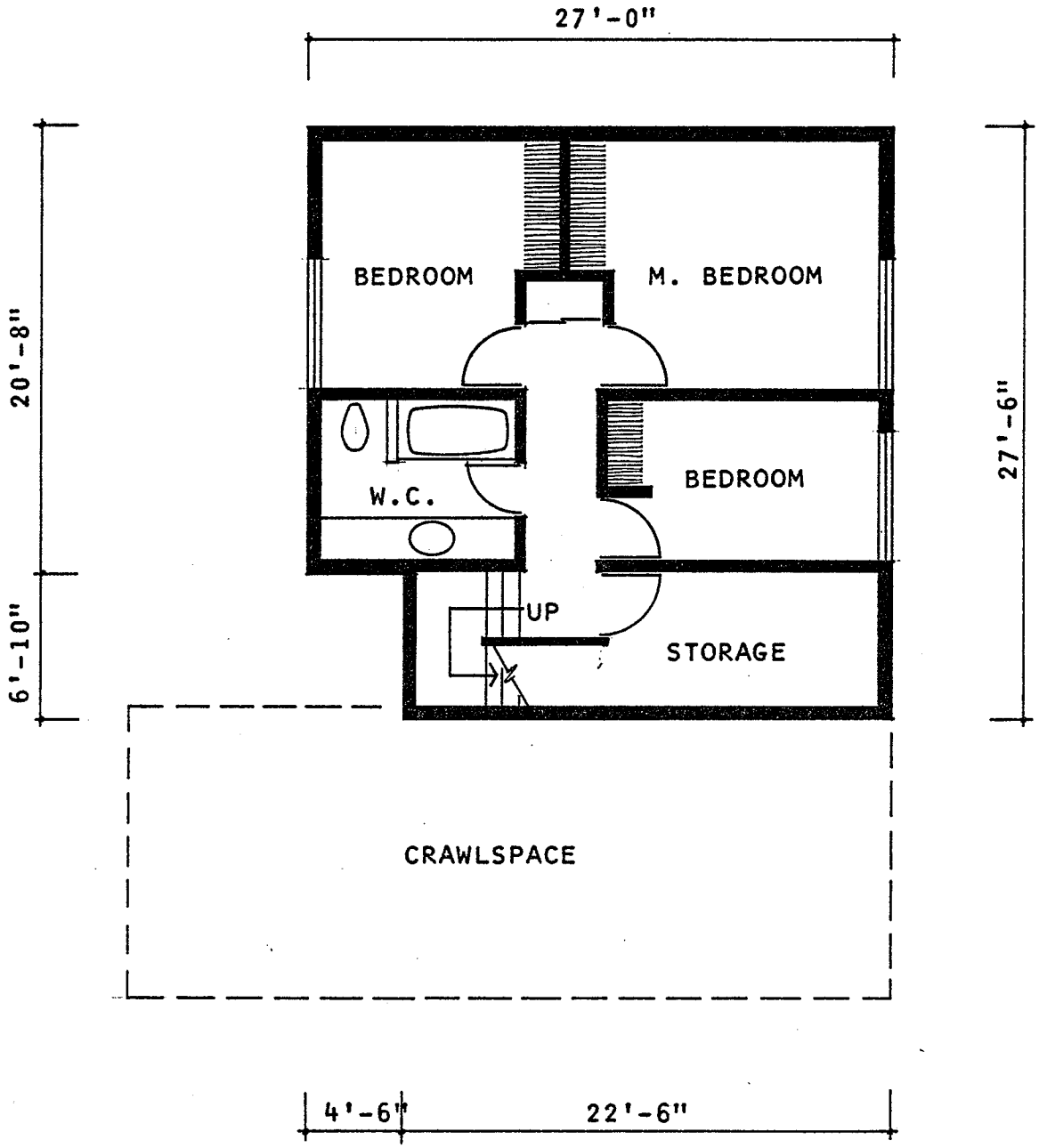
SCALE : 1/8" = 1'-0" FIG. 26

M O D I F I E D S P L I T - L E V E L

AS WAS THE CASE IN THE BUNGALOW, THE SERVICE AREAS OF THE SPLIT - LEVEL NOW OCCUPY THAT PART OF THE HOUSE FORMERLY HOUSING THE BEDROOMS. IN THIS CASE, PRACTICALLY THE ENTIRE LOWER LEVEL HAS BEEN MOVED TO THE UPPER LEVEL, WHEREAS IN THE BUNGALOW THE RECREATION ROOM REMAINED BELOW GRADE.

THE WINDOW AREAS OF THE DAY LIVING ZONE ARE IDENTICAL TO THOSE OF THE INITIAL SPLIT - LEVEL. WINDOWS INTO THE SERVICE AREAS HAVE BEEN MODIFIED TO SUIT THEIR NEW LOCATIONS.

THE OVERALL DIMENSIONS OF THE PLAN REMAIN UNCHANGED FROM THE INITIAL VERSION.



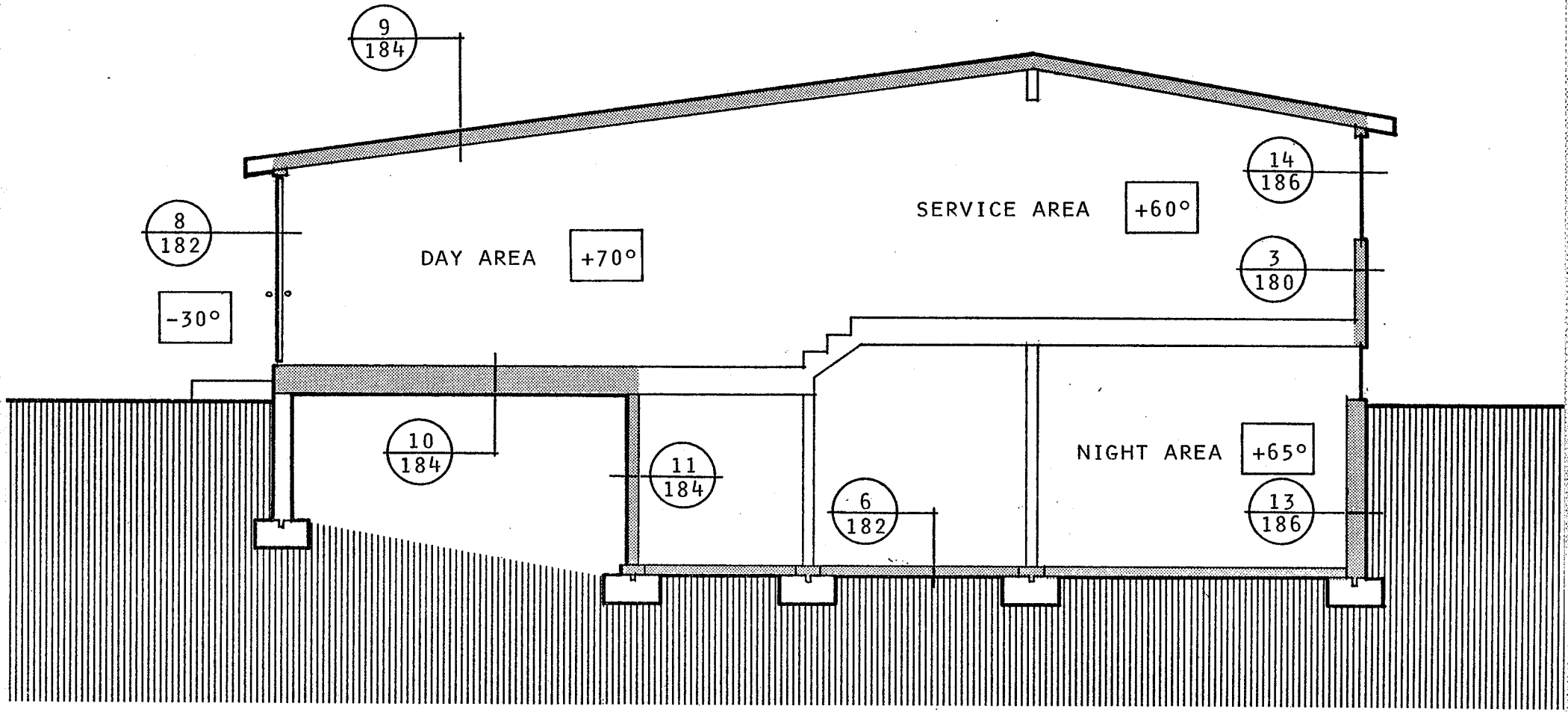
LOWER LEVEL PLAN

SCALE : 1/8" = 1'-0" FIG. 27

MODIFIED SPLIT-LEVEL

BECAUSE THE CENTRAL CORRIDOR IS FURTHER TO THE WEST THAN WAS THE CASE WHEN THE BEDROOMS WERE ON THE GROUND LEVEL, THE ENTIRE BEDROOM ARRANGEMENT HAS BEEN FLIPPED FROM THAT WHICH WAS SHOWN IN THE INITIAL PLAN: THIS HAS RESULTED IN THE WASHROOM BEING ON THE WEST SIDE OF THE HOUSE, AS OPPOSED TO THE EAST, AS IT WAS PREVIOUSLY, IN ADDITION, THE DOOR TO THE STORAGE AREA UNDER THE ENTRY HALL HAS BEEN MOVED TO MAKE THE STORAGE ACCESSIBLE FROM THE LOWER HALL.

WINDOWS HAVE BEEN MODIFIED TO SUIT THEIR NEW LOCATIONS. SEE ELEVATIONS, PAGES 94 & 96.



TYPICAL TRANSVERSE SECTION

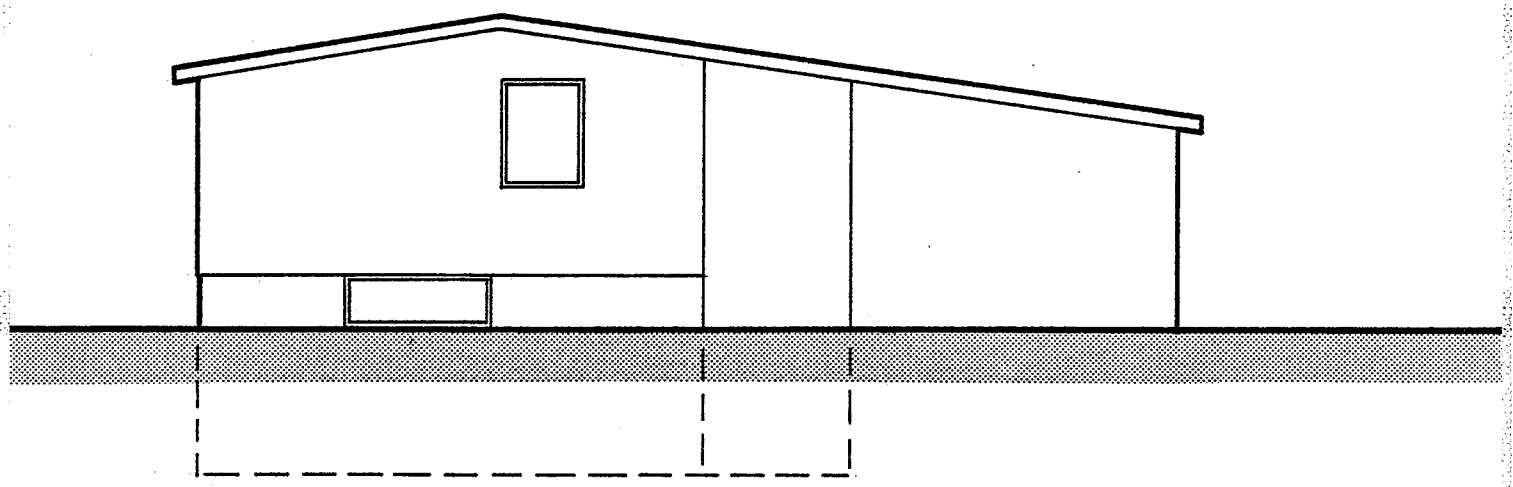
SCALE : 3/16" = 1'-0"

FIG. 28

MODIFIED SPLIT-LEVEL

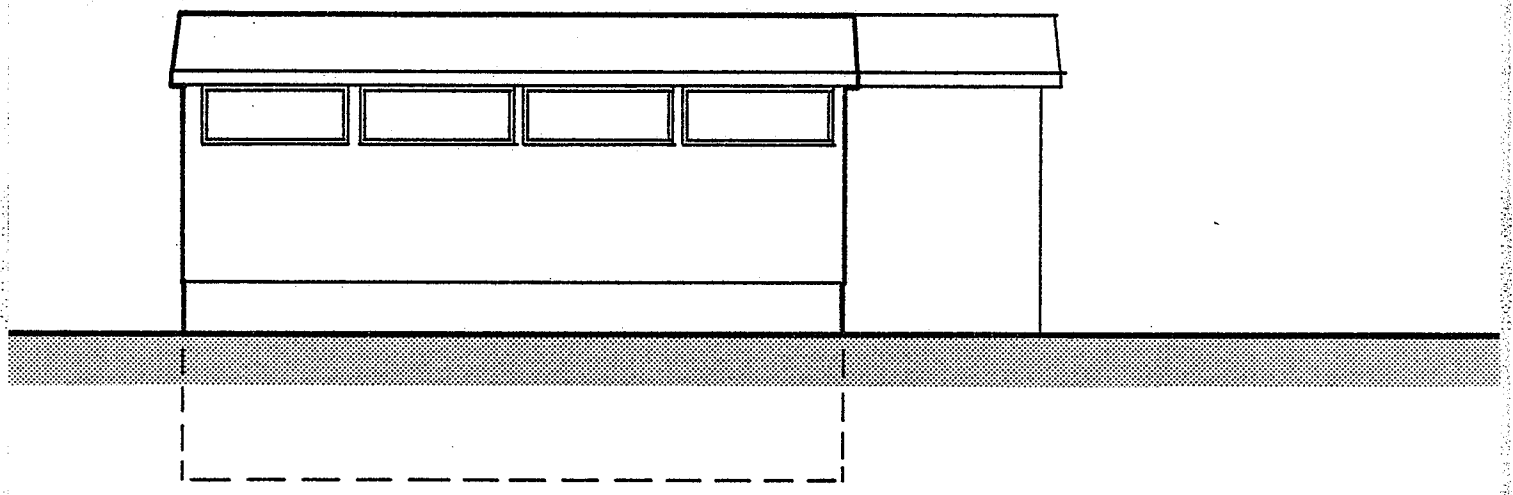
FIG.28 IS A TYPICAL SECTION TAKEN THROUGH THE MODIFIED SPLIT - LEVEL. BY COMPARING THIS SECTION TO THE ONE TAKEN THROUGH THE INITIAL SPLIT - LEVEL, IT CAN BE SEEN THAT NO CHANGES HAVE BEEN MADE TO EITHER SKIN COMPONENTS OR CONSTRUCTION TECHNIQUE.

THE AMBIENT TEMPERATURE OF SERVICE AREA IN THE GROUND LEVEL IS NOW 60° F. THE AIR TEMPERATURE OF THE BEDROOMS ON THE LOWER LEVEL IS 65° F.



WEST ELEVATION

SCALE : 1/8" = 1'-0"

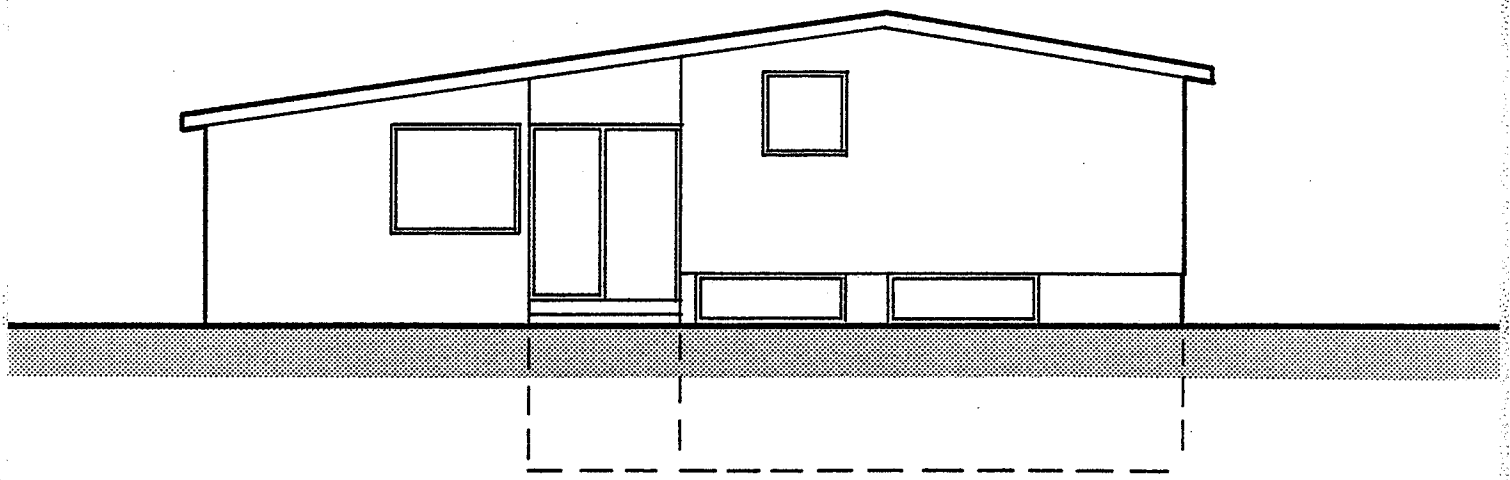


NORTH ELEVATION

SCALE : 1/8" = 1'-0"

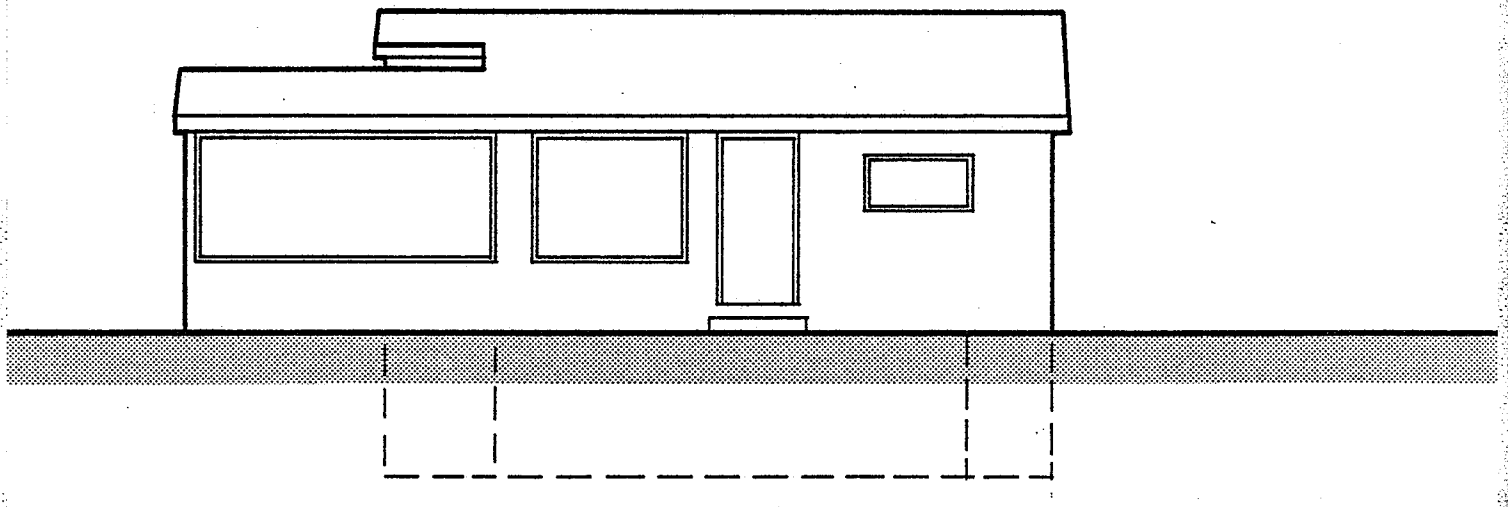
FIG. 29

		SURFACE AREA (SQUARE FEET)
WEST ELEVATION		
WALL	ΔT100	183
WALL	ΔT 90	177
FOUNDATION ABOVE GRADE		35
FOUNDATION BELOW GRADE		162
WINDOWS	ΔT 95	12
WINDOWS	ΔT 90	12
NORTH ELEVATION		
WALL	ΔT100	155
WALL	ΔT 90	168
FOUNDATION ABOVE GRADE		54
FOUNDATION BELOW GRADE		162
WINDOWS		48



EAST ELEVATION

SCALE : 1/8" = 1'-0"



SOUTH ELEVATION

SCALE : 1/8" = 1'-0"

FIG. 30