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DESIGN OF AN ENERGY CONSERVATION BUILDING

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ABSTRACT

This paper summarizes the concepts in designing and predicting energy consumption in a low energy use building at NASA Langley Research Center (LaRC), Hampton, Va. The building will use less than 342,000 kJ/m^2-yr (30,000 Btu/ft^2-yr) of border energy and will have features that will require a low electrical demand. The building is a small 330-m^2 (3570-ft^2) single story structure which will house personnel who produce various types of graphics and technical illustrations. The building's primary energy conservation features include heavy concrete walls with external insulation and a highly insulated ceiling. Extensive window area is provided on the north wall for natural lighting. A solar collector air system, integrated into the south wall will be an important factor in saving energy. Calculations for energy conservation features were performed using NASA's Energy-Cost Analysis Program (NECAP). The building's design and the predicted energy savings is detailed.

INTRODUCTION

A typical office building in the United States requires energy of about 2,850,000 kJ/m^2-yr (250,000 Btu/ft^2-yr) (ref. 1). This value is being reduced to 1,105,800 kJ/m^2-yr (97,000 Btu/ft^2-yr) by the implementation of building standards and procedures outlined in ASHRAE Standard 90-75. A facility was built at Langley Research Center (LaRC) which will use less than 342,000 kJ/m^2-yr (30,000 Btu/ft^2-yr). The operating experience of the building will be used to evaluate concepts which can be added to LaRC's buildings and building modification program. Construction began in May 1979 and was completed in December, 1980.

The Graphics Building, Building 1163, is located at NASA Langley Research Center (LaRC), Hampton, Va. The building was designed in 1978/1979 to house personnel responsible for graphic arts at LaRC. Architectural and mechanical energy conservation features were calculated to use about 1/3 the energy of a typical building. The building is a 330-m^2 (3570-ft^2) single story structure as shown in Figure 1. The relatively small size and cost of the facility make it an ideal unit for "radical" design changes. The design includes concepts not traditionally used at LaRC or that are beyond the normal construction practices used in the area. The building's primary function is to house graphics personnel. The second objective is to incorporate energy conservation concepts to reduce energy consumption and the electrical demand while complying with standard building criteria, and third, to determine the practicality of the incorporated energy conservation concepts.

Two unique provisions were necessary for the job related tasks in the building. They included natural lighting for color correction in the drawing room and ventilation in the silkscreen room. Otherwise, the space needs are shown in Figure 2 and provide for:

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Drawing Room:	153-m^2	(1655-ft^2)	with natural lighting
Office Area:	60-m^2	(645-ft^2)	
Silkscreen:	49-m^2	(530-ft^2)	with exhaust and process hot water
Misc:	48-m^2	(520-ft^2)	for restrooms, halls, and vestibule
Mechanical Equipment:	20-m^2	(220-ft^2)	including solar energy storage

ENERGY CONSERVATION CONSIDERATIONS

The features in the building to accomplish the low energy are listed below:

- heavy walls
- lightweight roof with thick ceiling insulation
- vestibules
- insulated glass
- natural lighting
- variable lighting
- high COP heat pump
- nighttime temperature set back
- room temperature ramping
- nighttime precooling
- economy cycle on air handlers
- heat exchanger on exhaust system
- solar energy system for heating
- solar preheat of domestic hot water

SOLAR SYSTEM

Seventy eight square meters (840-ft^2) of air type solar panels are integrated into the south wall of the structure. The collector system provides for general heating and preheat for the domestic and process water. It provides heat to the makeup air for the silkscreen room exhaust. It may be used for a future source of heat to the outside coil (evaporator) of the heat pump. The collectors and 24,000 kg (27-ton) rock energy storage bin are interconnected using separate air circulators. The system flow schematic is shown in Figure 3. Details, about the mechanical and solar system, and it's performance, will be developed in future reports.

There was some concern about adding the solar system to this facility since the original intent was to develop only energy conservation concepts. The concern was that energy from conservation items could be confused with energy from the solar system. Nevertheless, the solar system was added to demonstrate the effectiveness of heavy walls as a secondary storage media for a solar system. Sufficient instrumentation is to be added that will separate the energy flows between the building and the solar system.

BUILDING SIMULATIONS

To embark on this energy conservation project a method was required to quantitize the required energy consumption of the design and control features for the facility. NASA's Energy Cost-Analysis Program (NECAP) was selected (ref. 2). This program utilizes the response factor technique to determine the heat gain and loss through surfaces, which includes the delaying effects of heat flow due to mass. LaRC has used the NECAP program for 5 years; results show a close correlation between actual and predicted data.

ENERGY CONSUMPTION MODELS

The computer model considered the two conditioned rooms--the drawing/office space and the silkscreen room. The heat load calculation was used in the design and sizing of the mechanical system. The calculated load characteristic of different building components is shown in Table 1.

For purposes of modeling, the facility was divided into 5 spaces (See Figure 4); the two main occupied rooms were separated with an internal heat transfer surface. These rooms were separated from the attic (Space 3) with additional internal surfaces. Since NECAP does not include the capability to include the effects of an attached solar system, a simulated zone (Space 5) was modeled on the front wall with interconnecting walls to the occupied spaces. Also included was a simulated storage chamber (Space 4) with connecting internal heat transfer surfaces.

EQUIPMENT SIZING

Figure 5 shows the energy consumption for various air conditioning sizes in (Space 1) and shows that a 14-kW (4-ton) system is the best size. This figure, along with most other figures in this report, indicates the energy or size requirement for the "base run", see arrow. It also shows the percent of predicted energy consumption for various features as compared to the base features included in the building. Figure 5 shows that undersized equipment, with excessively long run periods, may actually result in slightly higher energy consumption. This figure also shows that energy use will decline with much smaller equipment as would be expected; however the number of hours that loads cannot be met by the equipment goes up. (Loads Not Met - The NECAP calculated hours that the equipment can not provide the cooling or heating required by the building to maintain specified comfort conditions). The air conditioner for the silkscreen room is sized at 7.04 kW (2-tons). Electric resistance heaters are installed in each heat pump system. Although, this study illustrates that energy savings cannot be obtained by undersizing equipment in this building, larger buildings having smaller equipment may very well produce cost benefits by the reduction of high electrical demands.

RESULTS OF THE ENERGY CONSERVATION STUDY - BUILDING MASS

Wall Mass

The facility design uses 304-mm (12-inch) thick, concrete filled block walls with 76-mm (3-inches) of exterior styrofoam insulation and an outside protective coating as shown in Figure 6A. The mass of the wall construction is therefore projected into the interior of the structure and is used as a thermal fly wheel. Ordinarily, wall construction at LaRC (shown in Figure 6B) uses a 100-mm (4-inch) brick veneer, air gap, 200-mm (8-inch) concrete block, and an internal finish gypboard. Since LaRC's energy conservation program was implemented several years ago, insulation is often installed between the concrete block and the interior finish surfaces. Alternate construction procedure for the new mass wall, such as sand filled concrete blocks or solid concrete walls, were considered but were not viable due to costs or construction problems. However, many alternate methods could produce cost savings in larger facilities.

The use of heavy mass walls with exterior insulation is known to limit temperature swings inside residential buildings and may result in improved comfort conditions. The benefits are transferable to commercial buildings especially when there are low internal loads or large daily ambient temperature swings. The heavy wall concept is not a common energy conservation design feature in most commercial buildings because of factors that can cause negative results, such as:

1. High internal loads
2. Geographic location
3. Nighttime cooling potentials

The calculated energy effect of concrete mass, or wall thickness is shown in Figure 7. The figure describes an expected reduction of energy as the wall mass increases. The corresponding drop in the loads not met by the mechanical system indicates a sharp improvement in comfort conditions with a wall thickness of between 150-and 300-mm (6-and 12-inches) of concrete.

Wall Mass and Weather

Different wall concepts are examined in Table 2. Each of 5 wall types were analyzed for four locations in the country. Four of the wall types have identical "U" factors. This data shows the effects on energy consumption for typical weather patterns and daily temperature swings in each of the selected localities. The study includes the reversing of the heavy wall; that is, the simulation is developed with the insulation on the inside. In this case, practically no energy reduction is realized in a heavy wall as compared with a standard wall whereas the heavy wall with exterior insulation will produce a 7 percent savings in the LaRC area. In this small building, the largest energy savings using massive walls with exterior insulation was in heating energy. In uniform climates like Florida, the energy savings are minimal: in Minnesota, although, the actual savings are substantial, the percent saved is small.

The building mass concept apparently works best when the building is allowed to have a temperature ramp; that is, the temperature is allowed to rise from morning to afternoon. The mass of the wall then acts as a thermal flywheel.

Wall Mass and Internal Loads

The computer study illustrates the effect of mass and internal loads, such as, lights on the building. In Figure 8A, the total energy used by the building is increased with larger internal loads, as would be expected. The heavy mass wall reduces the total consumption in every case. However, Figure 8B shows only the environmental energy consumed; it shows that the 21 W/m^2 (2 W/ft^2) internal load has actually decreased the mechanical system's energy consumption since the light energy is being used as a heat source. The lowest environmental energy is actually obtained at 24 W/m^2 (2.2 W/ft^2) lighting load.

This figure also illustrates by the slope of the curves, that with low building loads the effect of the more massive wall is greater; that is, the slope in Figure 8B of the equipment energy consumption line for 64 W/m^2 (6 W/ft^2) is not as great as with 10 W/m^2 (1 W/ft^2). It can be concluded that, as building internal loads are reduced as the result of less lights, the affect of wall mass could become more important in the design of commercial buildings. On the other hand, large interior loads could cause longer equipment run times and more uncomfortable conditions in heavy wall buildings. An energy penalty could be imposed on heavy wall buildings with high internal loads.

Mass Wall and Insulation

In the mass wall design concept, the amount of exterior insulation must be examined. In Figure 9, various insulation thickness on a 12-inch concrete wall versus the energy for HVAC is shown. The figure shows that there is little to be gained using more than the 3 inch thickness of styrofoam on the subject building.

Wall Mass and Economics

It is estimated that the initial cost of the specified wall is estimated to be more than the standard wall used at LaRC. This added cost is largely because the contractors in the area are not equipped for or experienced in the specified construction. However, it is suspected that the mass wall cost could be significantly reduced by using simplified techniques such as cheaper outside surfaces to protect the insulation, the use of cheaper filler materials in the block, etc.

Obviously, the combination of wall mass and thickness of insulation should be optimized. This study, however, will not attempt to determine the most practical thickness combination of wall and insulation due to the lack of known building costs and techniques. Material optimization will be applied to the wall construction as techniques and costs are better known. Nevertheless, the data can be used as a relative indicator of energy needs and potential savings in a facility.

CEILING/ROOF DESIGN

The building will have 12-inches of lightweight fiber glass, batt insulation suspended over the ceiling as shown in Figure 10. The attic space is ventilated to reduce summertime attic temperatures and to minimize dangers of condensation. The cost effectiveness of the insulation raised above the ceiling in this particular design can only be justified when heat from the lighting fixtures can be dumped into the resulting cavity. Standard roof construction at LaRC is a low slope type (1/4-inch per foot) using 76-mm (3-inches) of cellular insulation and builtup roofing on a metal pan deck. Low slope roof construction has high life cycle costs due to initial cost and maintenance problems associated with water buildup and penetration. LaRC has used a cellular insulation on roofs; although it is more expensive than fiberglass, its use prevents the loss of thermal efficiency where water leaks do occur. Roof leaks associated with low slope roofs are difficult and expensive to repair and often cause damage or interruption to the normal activities in the facility.

Lower life cycle roof costs can be achieved by using more, but less expensive insulation located in a less vulnerable position. One solution is to substitute a sloping roof and to use very thick, low density fiberglass insulation at the ceiling. This construction technique is not new and is often used in commercial buildings in colder climates.

The energy of the building is very dependent on the attic crawl space insulation thickness as shown in Figure 11. The data indicates that little is gained in insulation thickness exceeding 6 inches of fiberglass. However, it has been observed that insulation greater than 6 inches reduces ceiling surface temperatures and reduces the resultant discomfort effects due to radiation.

Figure 11 also describes the calculated effects of natural ventilation in the attic cavity. In the figure, two values of building environmental energy is given, one for 2 air changes per/hr and one for 0.33 air changes per/hr in the overhead cavity. The infiltration value is based on a 16 km/hr (10-mph) wind; when the wind speed drops the attic air change rate or ventilation drops proportionally. There is no adjustment for ventilation rates due to temperature in the space incorporated in the calculations. The effects of larger natural ventilation rates appear to have a minimal influence on energy, which supports the contention that power ventilation of attic space is not cost effective.

Various roof/ceiling construction techniques can be effective in energy conservation. However, the calculated difference between LaRC standard practice of a low slope insulated roof compared to an insulated ceiling is unexpectedly small as shown in Figure 12. The use of ceiling plenums for return air is effective in yielding a 5-or 6-percent savings in both the insulated roof or insulated ceiling design. The savings are achieved by taking light heat into the return air, resulting in a more effective mechanical system operation.

NATURAL LIGHTING

A large double glazed window was incorporated into the north wall of the drawing room because of the illustrator's need for a nonglare natural light. In addition, two large south windows (See Figure 10) are provided with reflectors to increase the sunlight penetration into the building. This lighting technique has been measured in a test chamber at LaRC before construction and was proven effective.

A general lighting of 50 footcandles is allowed by regulation at LaRC. Drawing board light can be as high as 100 footcandles. Prior to the energy crises, the power used for lighting had been as high as 75 W/m^2 (7 W/ft^2). The first round of energy conservation delamping at LaRC reduced this lighting load to about 21-to 38-W/m^2 (2-to 3-1/2-W/ft^2) and 70 footcandles with further reductions still underway. Task lighting was considered for this building but satisfactory lighting fixtures could not be obtained. As an alternative, the spaces are provided with general lighting at a little less than 21 W/m^2 (2 W/ft^2). This lighting system will provide 100 footcandles with a minimum of glare and contrast without the need for window light. The light output will be reduced at some future time to compensate for the natural lighting from the windows with an automatic rheostat. As much natural lighting as possible is to be used in the drawing room/office area. The effectiveness of the glass as a substitute for electrical lighting power will be established by measuring the supplemental light energy needed.

It is recognized that glass, even double glazing, will have a large influence on the need for HVAC energy. Unfortunately, energy programs which simulate large glass areas do not correspondingly respond to the human comfort factors, such as, drafts and the radiant effects off large glass areas. An estimate of the effect of variable glass areas on the north side of this building in the HAVC energy is shown in Figure 13. The calculations were based on double glass windows. It would be interesting to expand this window study to other walls in the future.

The resultant energy needs for the HVAC due to lighting power loads are shown in Figure 14A and 14B. The environmental equipment energy curve in Figure 14B dips to a low at 24 W/m^2 (2.2 W/ft^2) since lighting energy is used as a building heat source.

INFILTRATION

Infiltration is usually proportional to the wind velocity about the structure. It also is dependent on the direction of the wind and the crack locations, and is countered by the amount of makeup air that is brought in by the air handler. The NECAP energy program has the capability to calculate infiltration through simulated cracks, around windows, and through surfaces, and to simulate the leakage reduction due to makeup air. Altering the infiltration factor influences energy consumption as shown in Figure 15. This figure was developed using the air change method instead of the crack procedures so that the figure's air changes axis could be more accurately defined. It is apparent that increased infiltration will alter the building heating energy proportionally. Cutting infiltration is very influential on the building energy use and is highly cost effective. Vestibules, weatherstripping, and proper caulking should be used on all buildings.

OUTSIDE AIR COOLING

The ability to obtain ambient cooling is helpful in reducing energy use. The use of an economy cycle in the air conditioning system has proven to be beneficial not only in reduction of cooling energy needs but to keep refrigeration system off during cool ambient temperatures. However, air conditioning economy cycles have also been a major cause of unnecessary energy use in buildings when they are used without regard to the needs inside the building; for example, when the economy cycle is used to keep air temperatures at the fan at a constant cool temperature even though the building needs reheat to maintain comfort.

TEMPERATURE CONTROL

The method of temperature control within the facility is critical with reference to energy conservation. To accomplish various control mode calculations including nighttime setback and temperature ramping, the NECAP energy program was used. The NECAP energy program includes the mass effect of the building and allows simulation of dead band thermostat operation. The program determines the temperature levels within the spaces and adjusts the heat losses or gains based on temperature set point criteria. This technology is very useful, especially in buildings having heating or cooling equipment, whose capacity is not equal to the load and results in a temperature ramping during the day.

The basic method used in the simulation program provides on/off control of the heat pump compressor, using a 21°C to 25°C (70°F to 77°F) temperature range during occupied periods and a 18.8°C to 26.6°C (66°F to 80°F) limit at night and weekends. Figure 16 shows the effect of energy consumption of several different temperature control options. It is apparent that the largest energy waste in the building operation would be to keep fans and comfort control running 100 percent of the time. Thus, nighttime set back and shutdown of fans is a prime consideration for an energy conservation control logic.

As the Figure also shows, a tight daytime control band of 1-degree will double the environmental energy needs over a 21°C to 25°C (70°F to 77°F) temperature band; on the other hand an 18.3°C to 26.6°C (65°F to 80°F) daytime temperature limit with no nighttime temperature limits could save 15 percent of the environmental energy, although comfort conditions at these limits are far from optimum.

The building will be equipped with a thermostatic device that will gradually raise the temperature set point as shown in Figure 17, before the building is occupied, starting the equipment at a time only early enough to establish comfort conditions when needed. The amount of time will be proportional to the difference between the room design temperature and the ambient condition. A typical reset thermostat control would cause resistance heaters to be activated whenever the room set point temperature is reset - thus causing high demands and extra consumption by the use of inefficient resistance heaters. The modified temperature control with slow morning temperature set point adjustment will be a major factor in keeping electrical demands low and resistance heaters off.

CONCLUSION

This paper has outlined some of the factors used in the design of the LaRC's Graphics Building. The predicted energy consumption is 71.7 kW-hr/m^2-yr, well within our original goal of 94 kW-hr/m^2-yr (30,000 Btu/ft^2-yr). The breakdown of this energy is:

Lights	=	15,850 kW-hr/yr	=	14,900 Btu/ft^2-yr
Cooling	=	3,226 kW-hr/yr	=	3,030 Btu/ft^2-yr
Heating	=	3,980 kW-hr/yr	=	3,760 Btu/ft^2-yr
Fan Power	=	600 kW-hr/yr	=	580 Btu/ft^2-yr
Total	=	23,656 kW-hr/yr	=	71.7 kW-hr/m^2-yr
			=	254,000 kJ/m^2-yr
			=	22,270 Btu/ft^2-yr

An estimate of process energy for hot water and exhaust is 3,000 kW-hr/yr. A preliminary estimate of solar supplement to the above data is that the electrical energy for heating will be reduced by 2,000 kW-hr/yr and the process and domestic hot water energy reduced by 1,200 kW-hr/yr.

The construction techniques utilized in the Graphics Building should prove to be cost effective. The design is simple and not necessarily novel. The theoretical data from the Graphics Building will be compared to the actual operation of the building in future reports. These techniques and operating experiences should give insight to more effective construction methods and operating techniques for energy conservation in buildings at LaRC.

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September 2, 1981

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2. Little, Arthur D. Inc.; Energy and Economic Impact Study.
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	SPACE 1			SPACE 2		
	***** SUMMER LOAD *****		WINTER	***** SUMMER LOAD *****		WINTER
	SENSIBLE (BTUH)	LATENT (BTUH)	LOAD (BTUH)	SENSIBLE (BTUH)	LATENT (BTUH)	LOAD (BTUH)
WALLS	674.	0.	-3431.	418.	0.	-1187.
CEILINGS	0.	0.	0.	0.	0.	0.
WINDOW CONDUCTANCE	2078.	0.	-9749.	0.	0.	0.
WINDOW SOLAR	8194.	0.	416.	0.	0.	0.
QUICK SURFACES	44.	0.	-183.	45.	0.	-134.
INTERNAL SURFACES	525.	0.	525.	1125.	0.	1125.
UNDERGROUND WALLS	0.	0.	0.	0.	0.	0.
UNDERGROUND FLOORS	796.	0.	-6633.	324.	0.	-3240.
OCCUPANTS	2419.	1962.	0.	555.	781.	0.
LIGHT TO SPACE	12847.	0.	1.	5002.	0.	3.
EQUIPMENT TO SPACE	0.	0.	0.	0.	0.	0.
INFILTRATION	1613.	5212.	-9665.	651.	1907.	-5482.
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TOTAL	29190.	7174.	-28720.	8121.	2688.	-8915.
TOTAL SPACE COOLING	36364. BTUH			10809. BTUH		

TABLE 1 COMPUTER LOAD CALCULATION

TABLE 2 EFFECTS OF WALL MASS AND LOCATING OF ENERGY CONSUMPTION

LOCATION	TYPE WALL CONSTRUCTION	ENERGY CONSUMPTION (KWH) HEATING	COOLING	FAN	TOTAL ENVIR. ENERGY
Hampton, VA	Light	7345	3602	784	11731
	Standard Med.	10610	3588	920	15118
	Modified Med.	7292	3517	789	11598
	12" LW Block	6376	3301	1033	10710
	Inversed Heavy	7036	3517	773	11326
	* Heavy	3980	3226	599	7805
Minneapolis, Minn.	Light	153285	2376	2024	157685
	Standard Med.	162540	2232	2109	166881
	Modified Med.	153381	2290	2025	157696
	Inversed Heavy	152769	2233	2008	157010
	* Heavy	144647	2016	1881	148544
Tampa, Fla.	Light	1238	5781	662	7681
	Standard Med.	1292	5898	669	7859
	Modified Med.	1203	5711	661	7575
	Inversed Heavy	1191	5699	651	7541
	* Heavy	1123	5203	598	6924
Albuquerque, N.M.	Light	12474	5413	1009	18896
	Standard Med.	16686	5560	1198	23444
	Modified Med.	12192	5329	1010	18531
	Inversed Heavy	11839	5295	983	18117
	* Heavy	7967	4863	775	13605

Wall Construction (Inside surface as shown first)

Light: 1/2-inch Gypboard, 3-inch Insulation, 1-inch Wood siding (U Factor = 0.084)

Standard Med.: 1/2-inch Gypboard, 1-inch Insulation, 8-inch Concrete Block, 1-inch Airspace 4-inch Brick (U Factor = 0.15)

Modified Med.: 1/2-inch Gypboard, 2.6-inch Insulation, 8-inch Concrete Block, 1-inch Airspace, 4-inch Brick (U Factor = 0.084)

12" LW Block 12 inch LW Concrete Block, 3" Insulation, Surface Material (U Factor = 0.072)

Inversed Heavy: Surfacing Material, 3-inch Insulation, 12-inch Concrete (U Factor = 0.084)

*Heavy: 12-inch Concrete, 3-inch Insulation, Surfacing Material, (U Factor = 0.084)

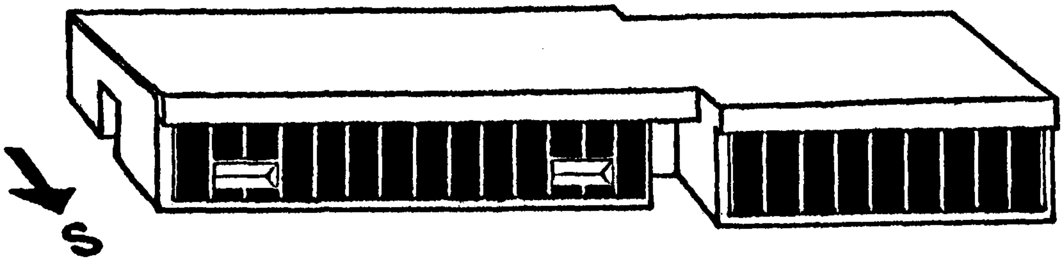


FIG. 1 BUILDING SCHEMATIC

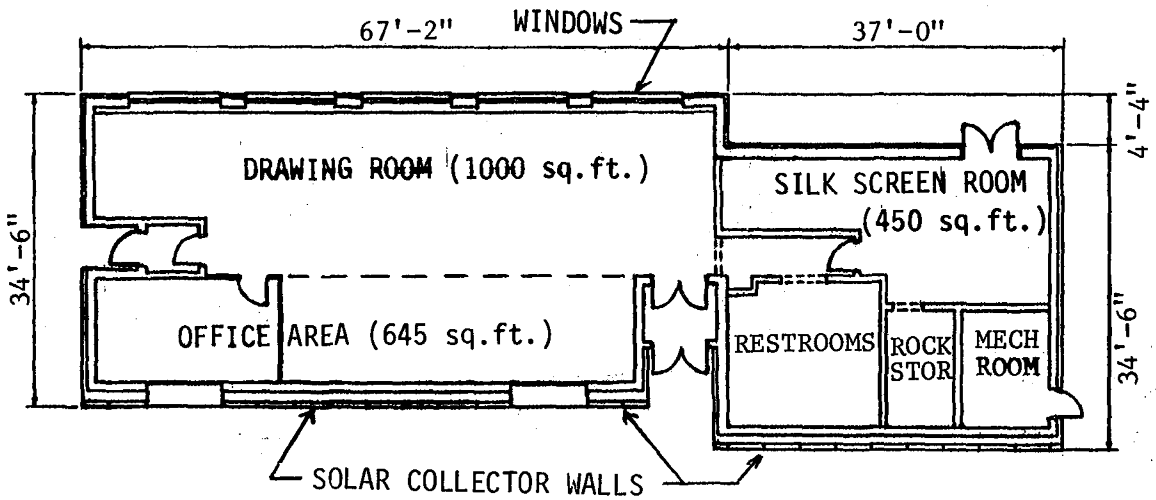


FIG. 2 FLOOR PLAN

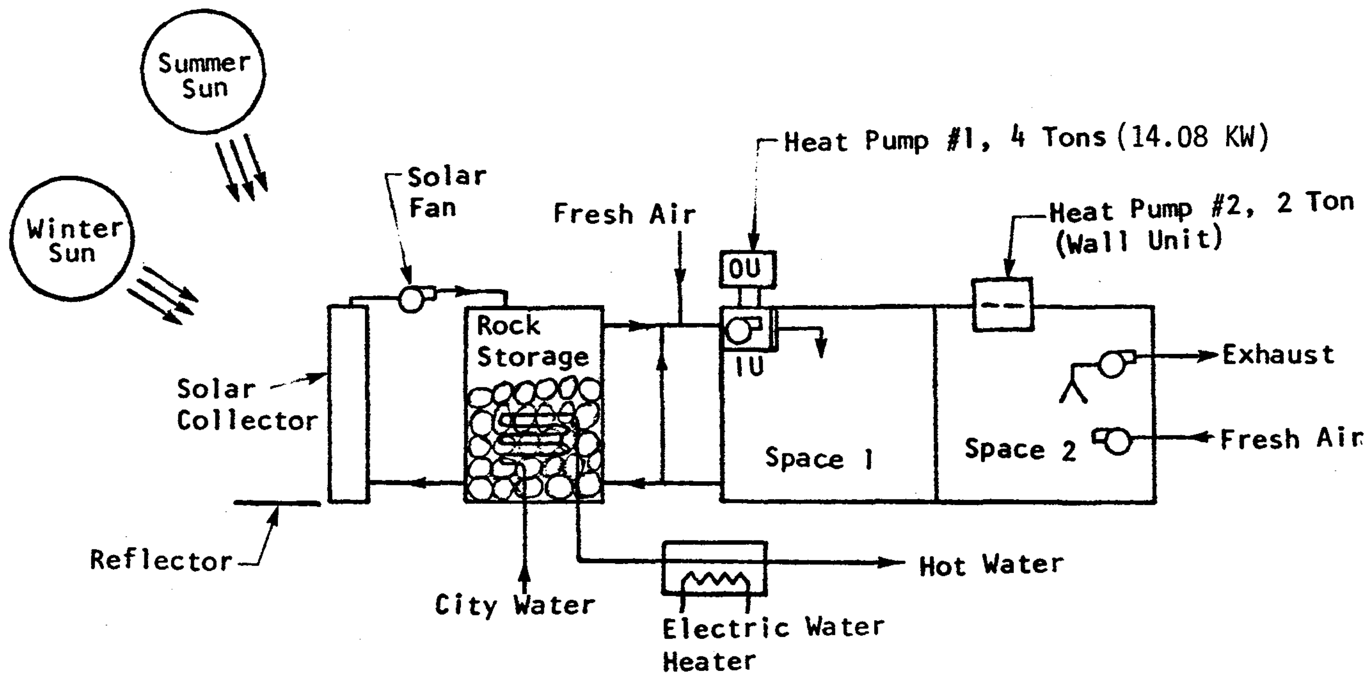


FIG. 3 SOLAR SYSTEM FLOW SCHEMATIC

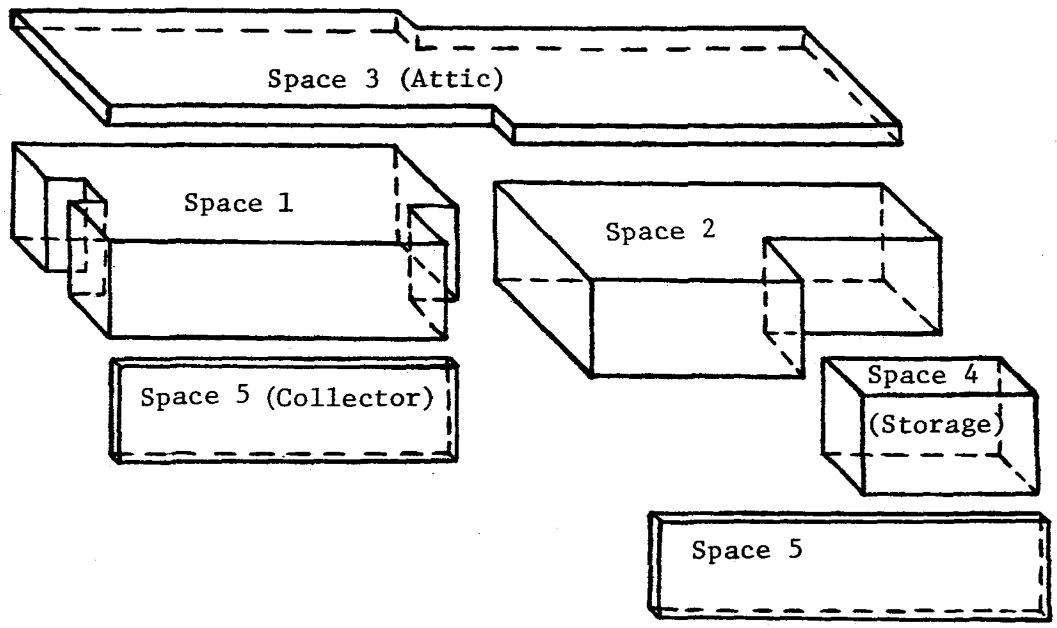
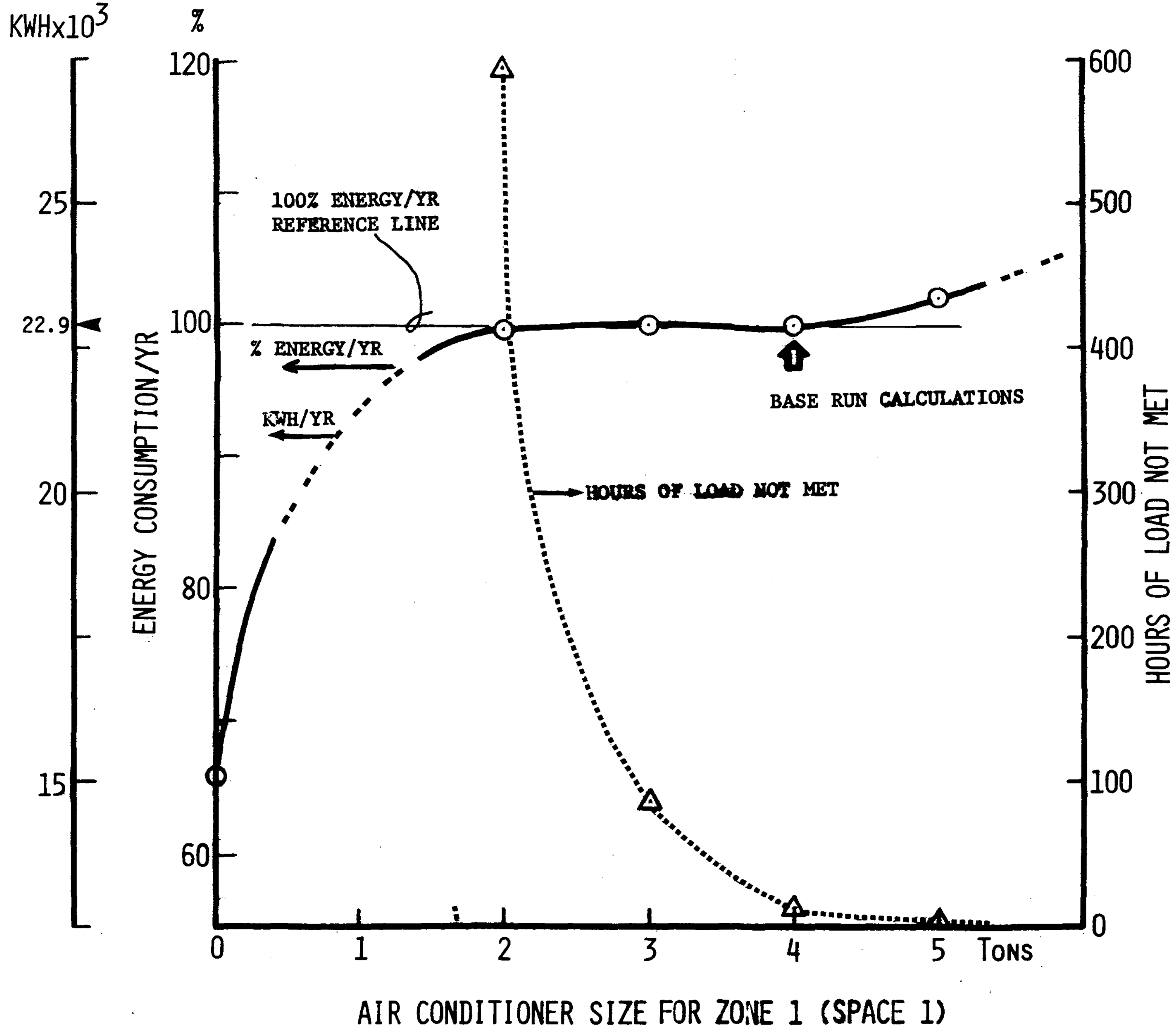
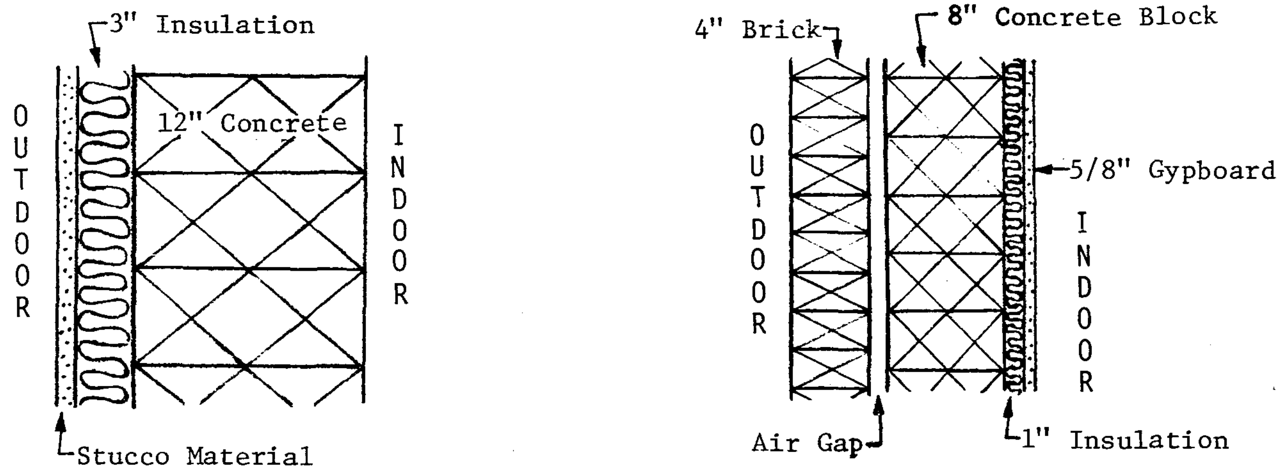


FIG. 4 COMPUTER MODELING

FIG. 5 ENERGY CONSUMPTION vs AIR CONDITIONER SIZE



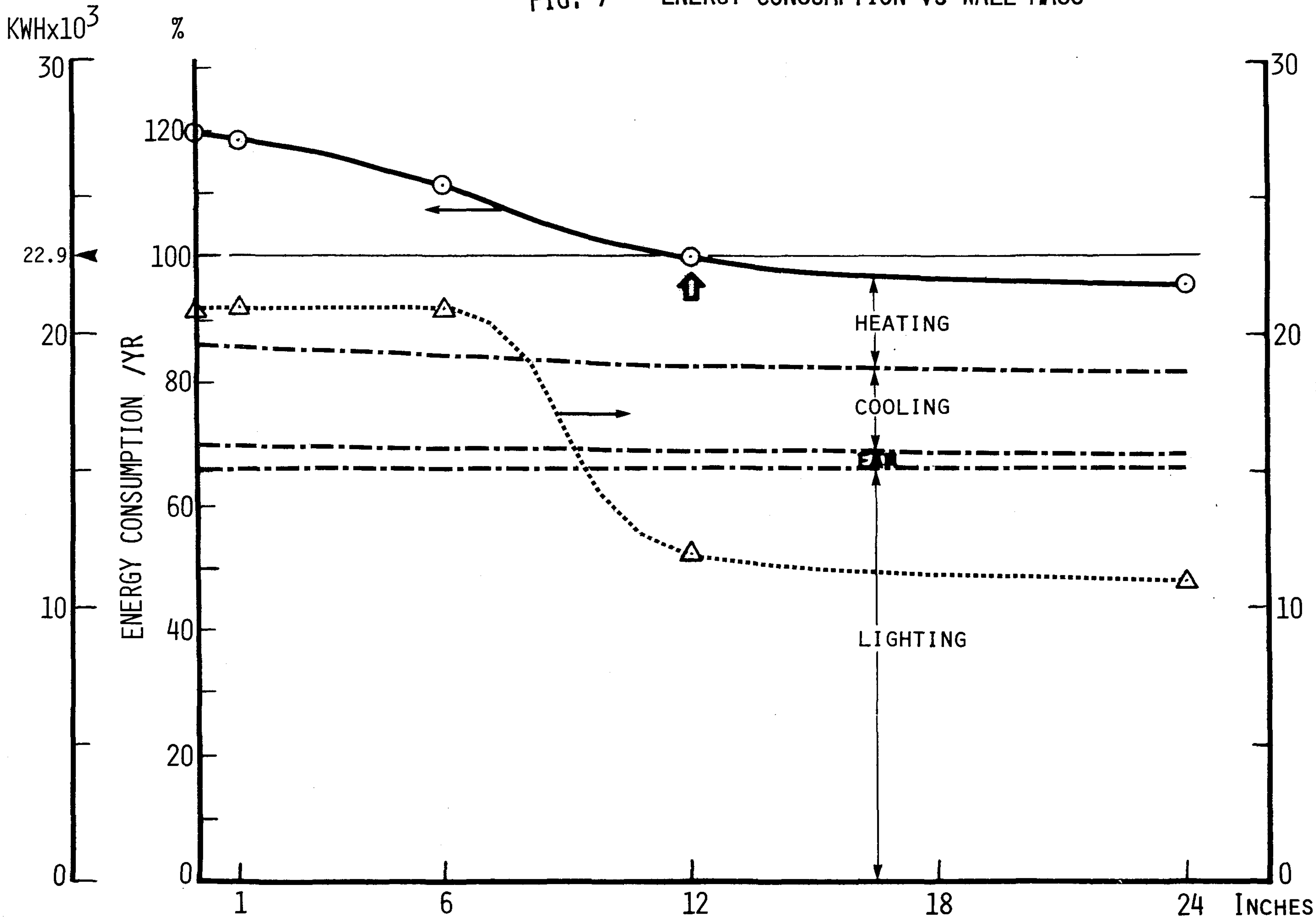


DESIGNED WALL (A)

NORMAL CONSTRUCTION (B)

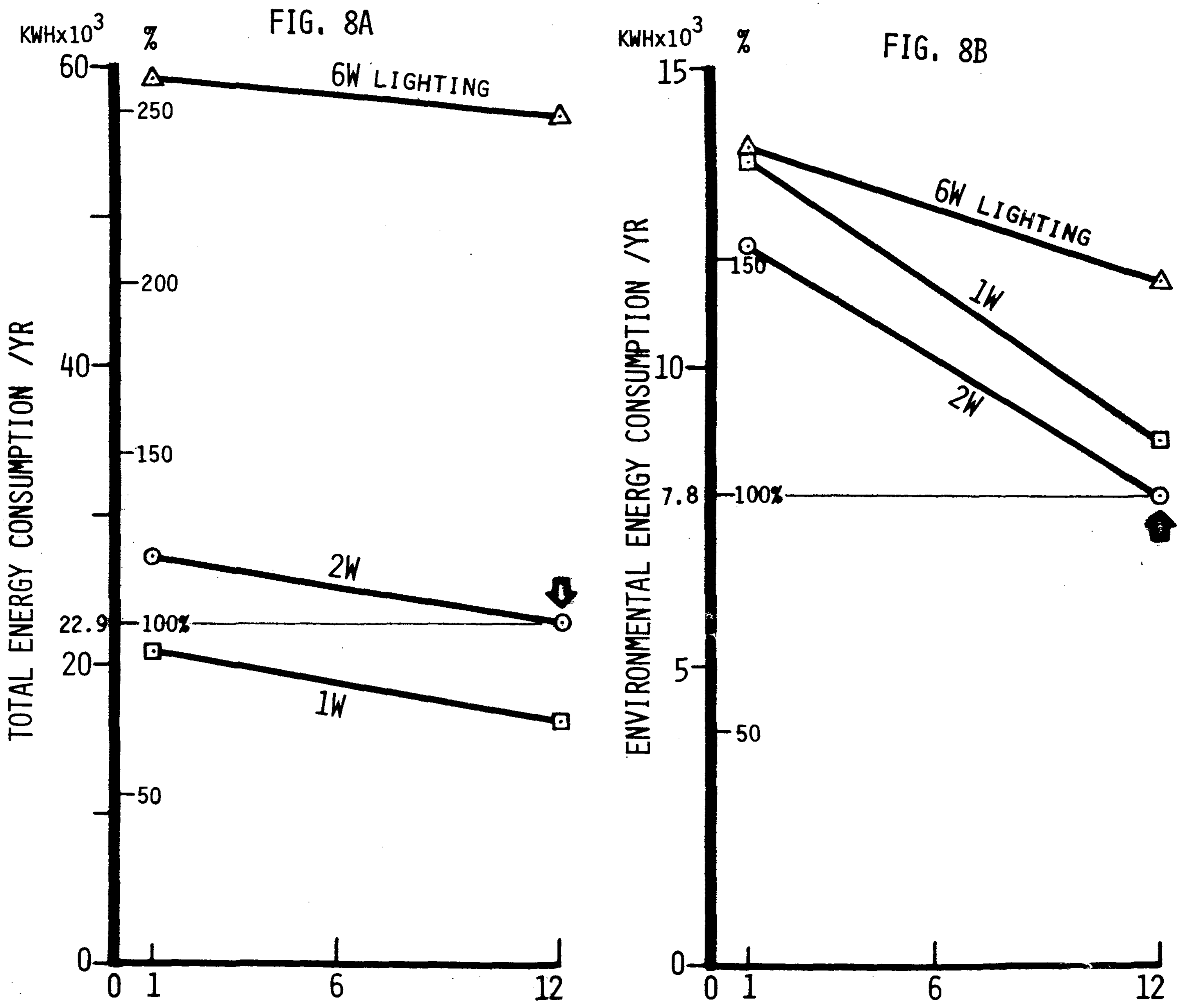
FIG. 6 WALL CONSTRUCTION

FIG. 7 ENERGY CONSUMPTION vs WALL MASS



CONCRETE THICKNESS

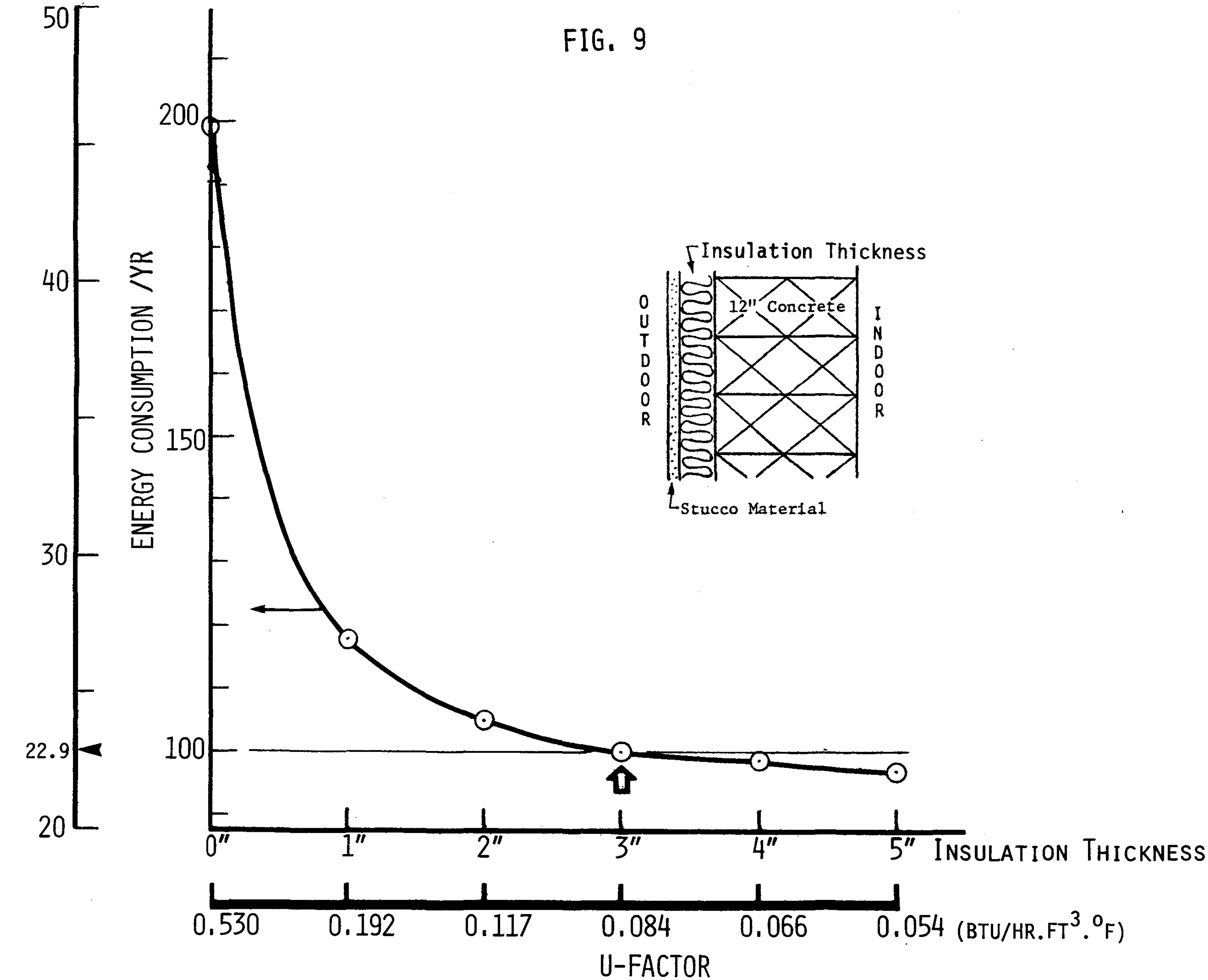
ENERGY CONSUMPTION vs WALL MASS & LIGHTING POWER



WALL THICKNESS -- INCHES OF CONCRETE

ENERGY CONSUMPTION vs WALL INSULATION

FIG. 9



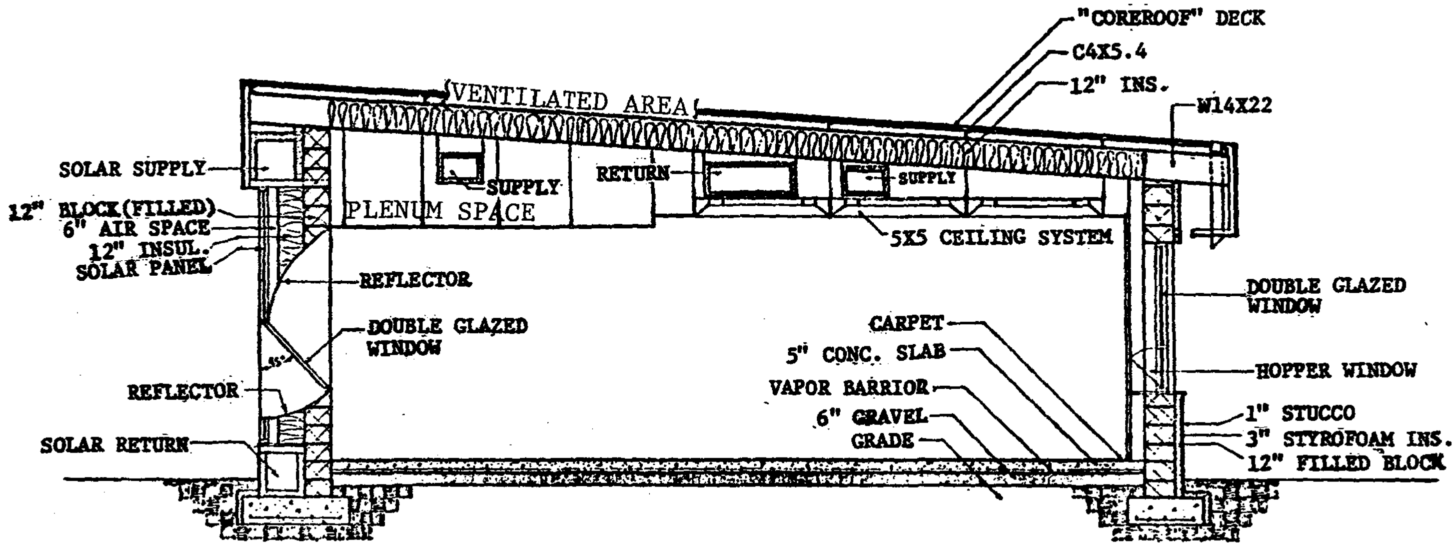


FIG. 10 BUILDING SECTION

FIG. 11 ENVIRONMENTAL ENERGY CONSUMPTION vs ATTIC INSULATION

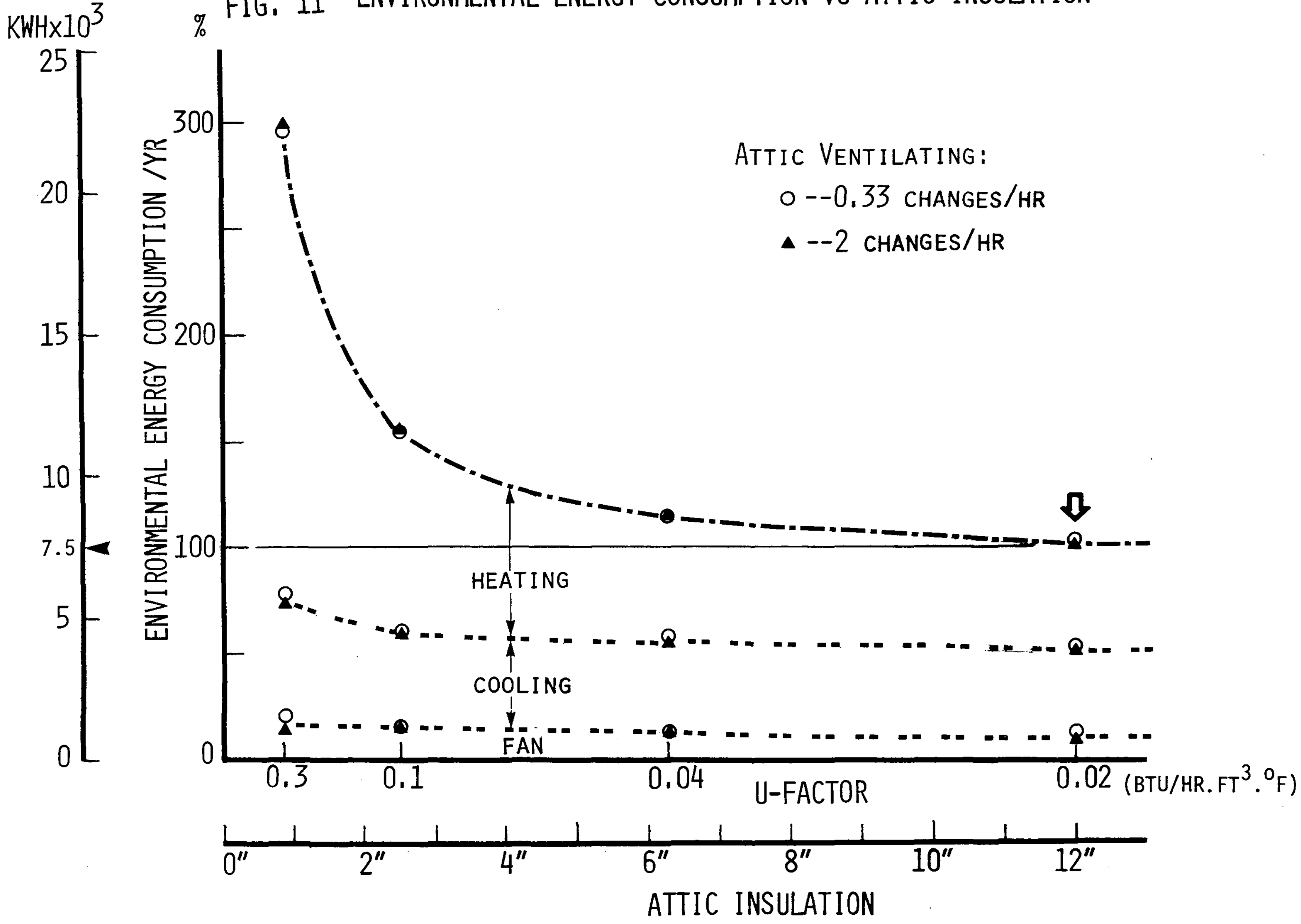


FIG. 12 ENVIRONMENTAL ENERGY CONSUMPTION vs ROOF CONSTRUCTION

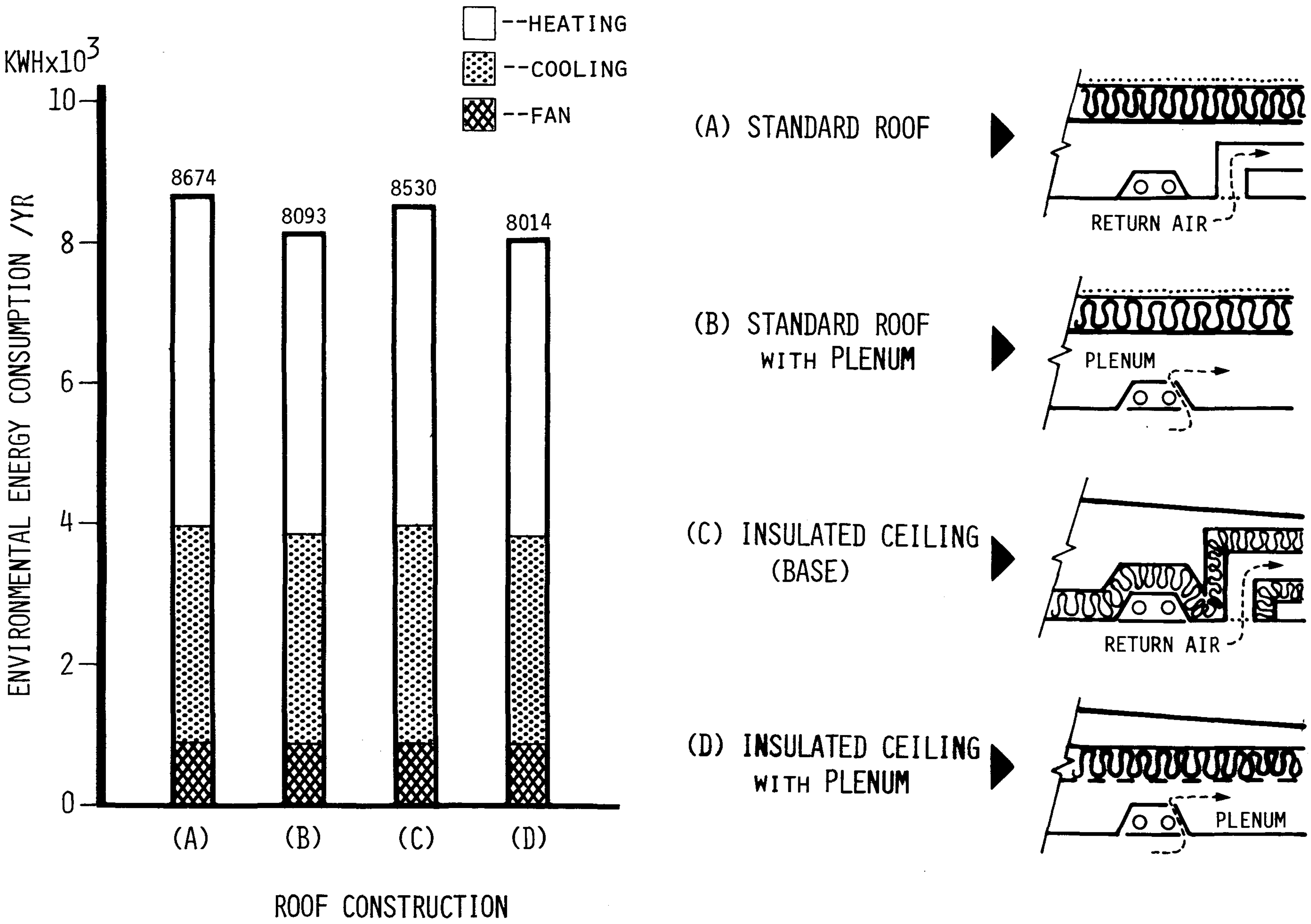
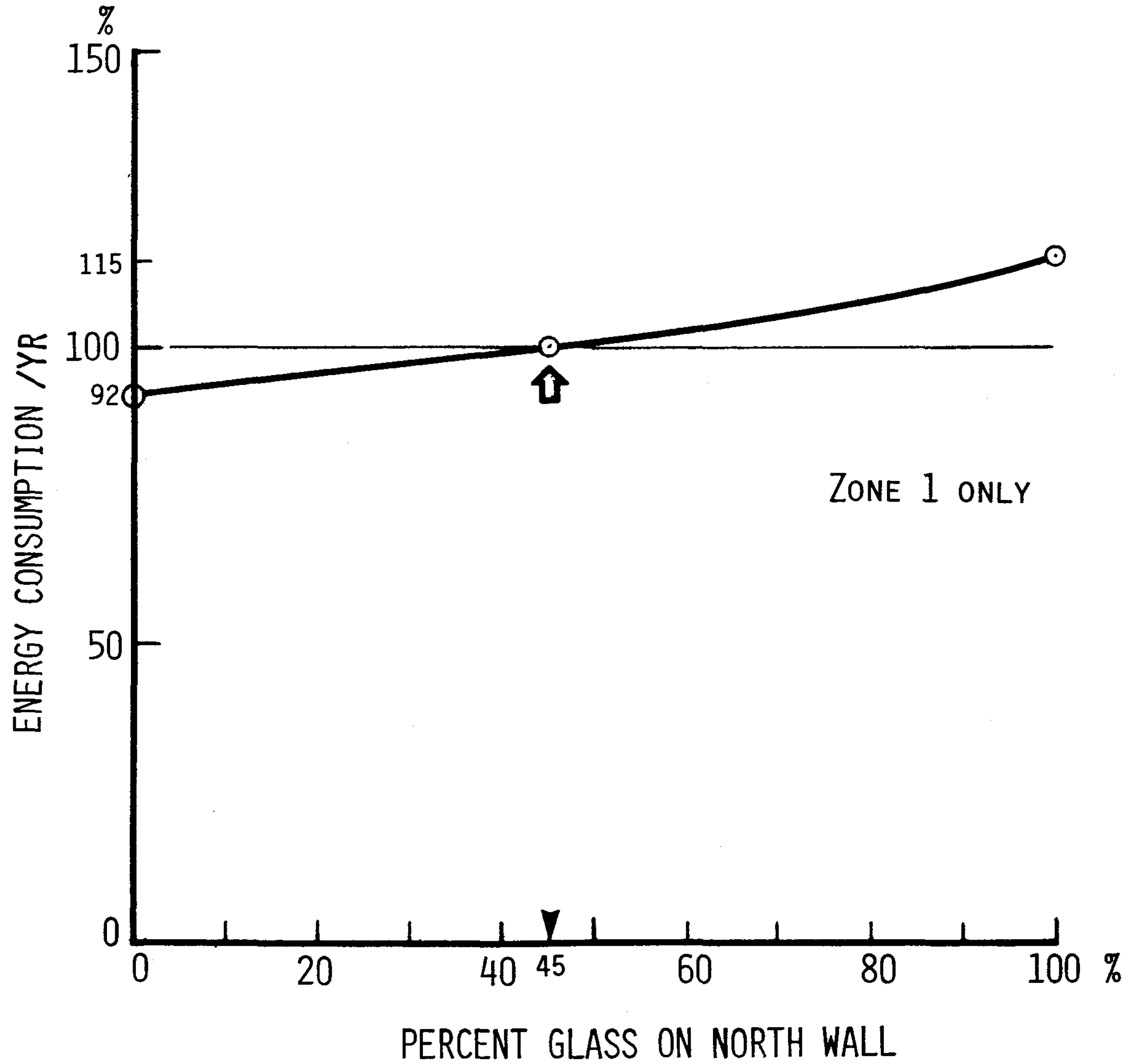
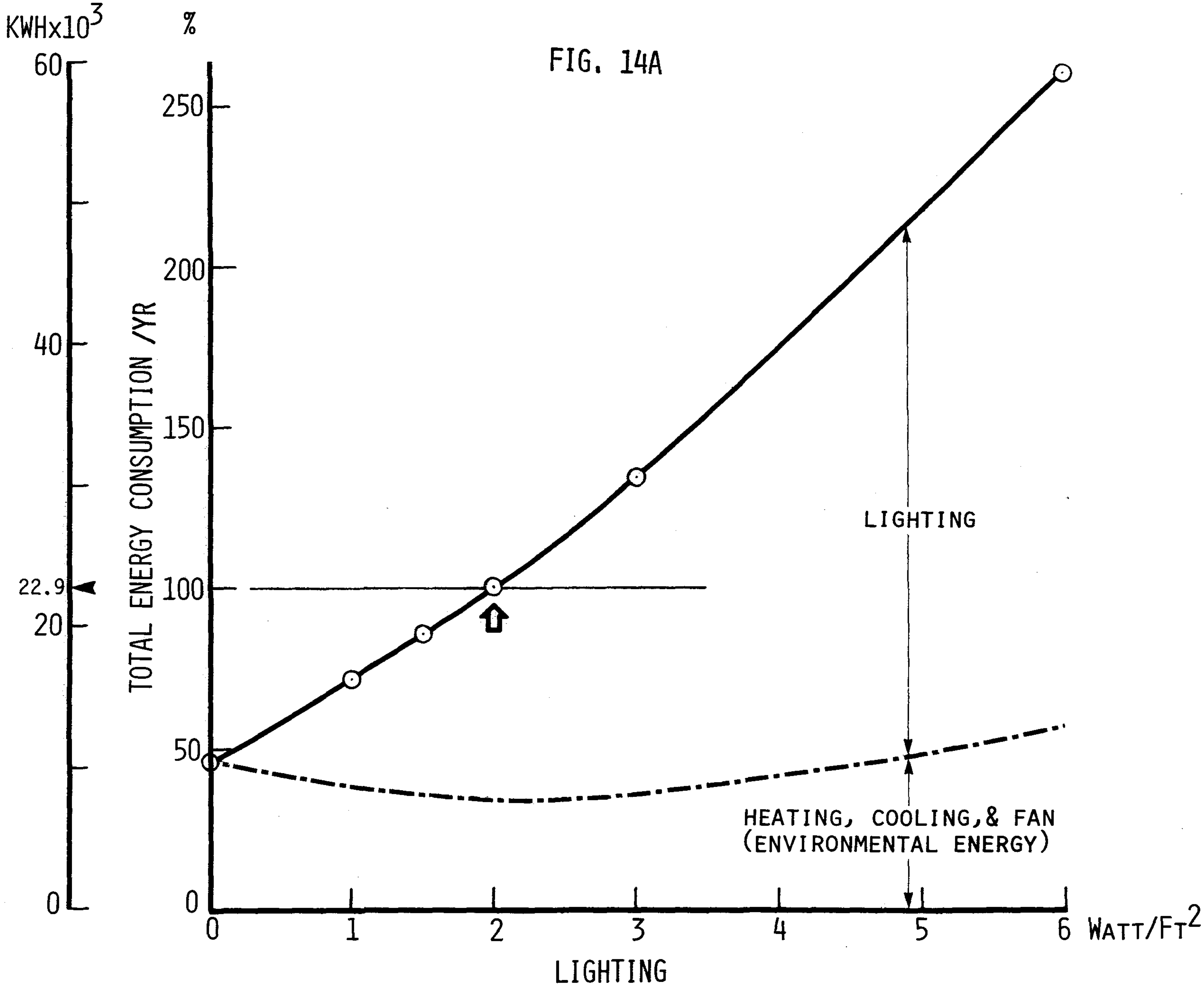


FIG. 13 ENERGY CONSUMPTION vs % GLASS



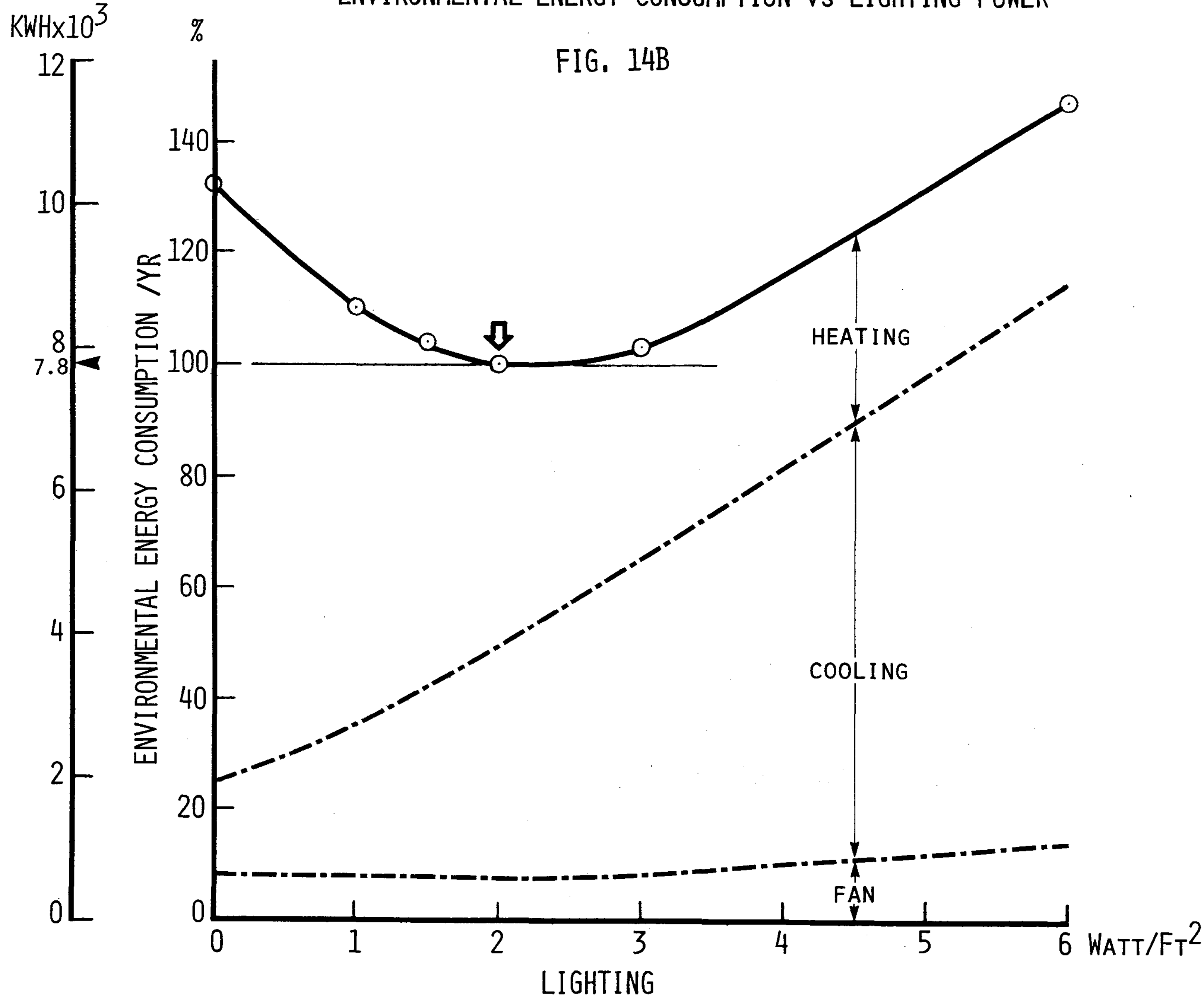
TOTAL ENERGY CONSUMPTION vs LIGHTING POWER

FIG. 14A



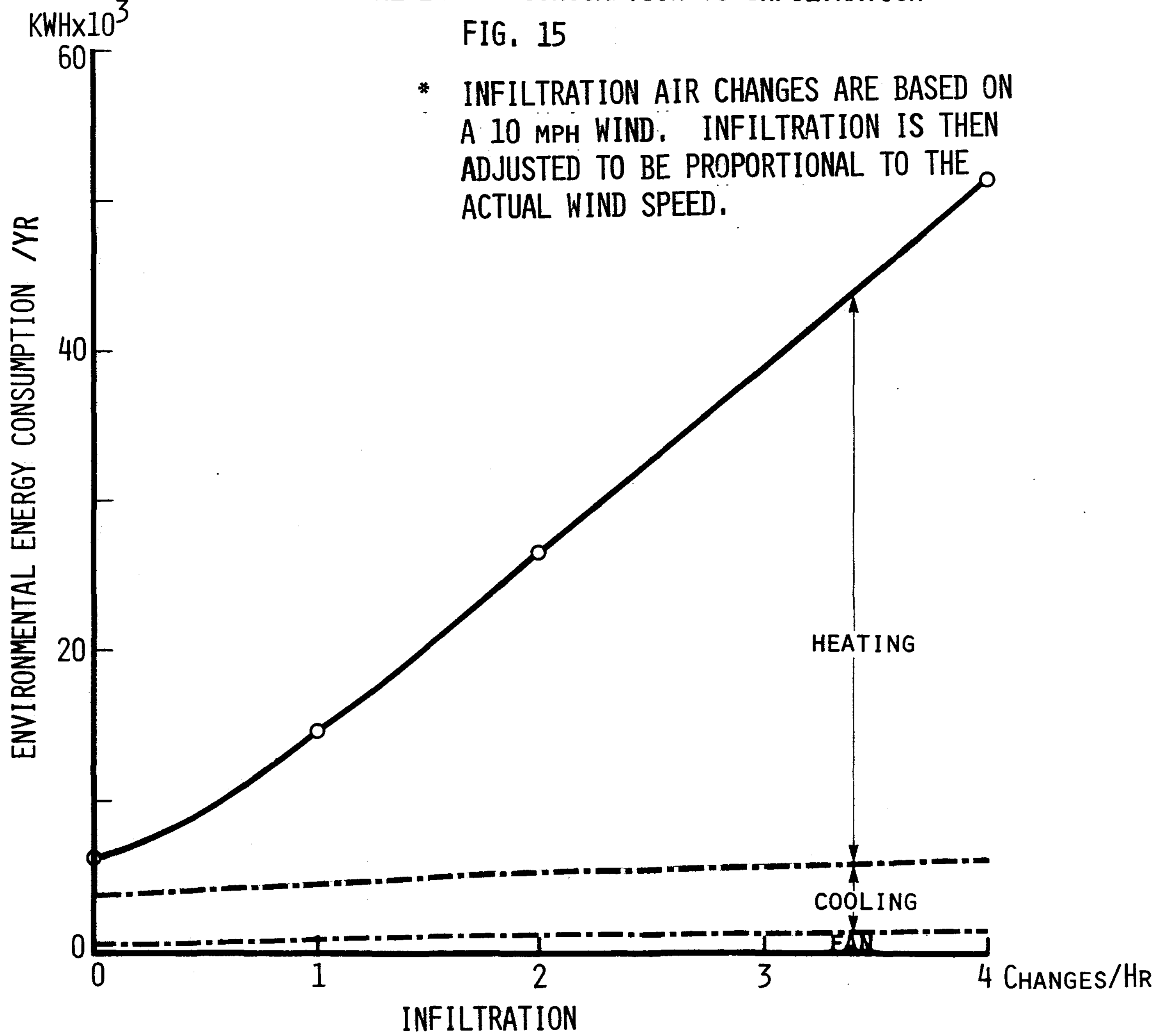
ENVIRONMENTAL ENERGY CONSUMPTION vs LIGHTING POWER

FIG. 14B



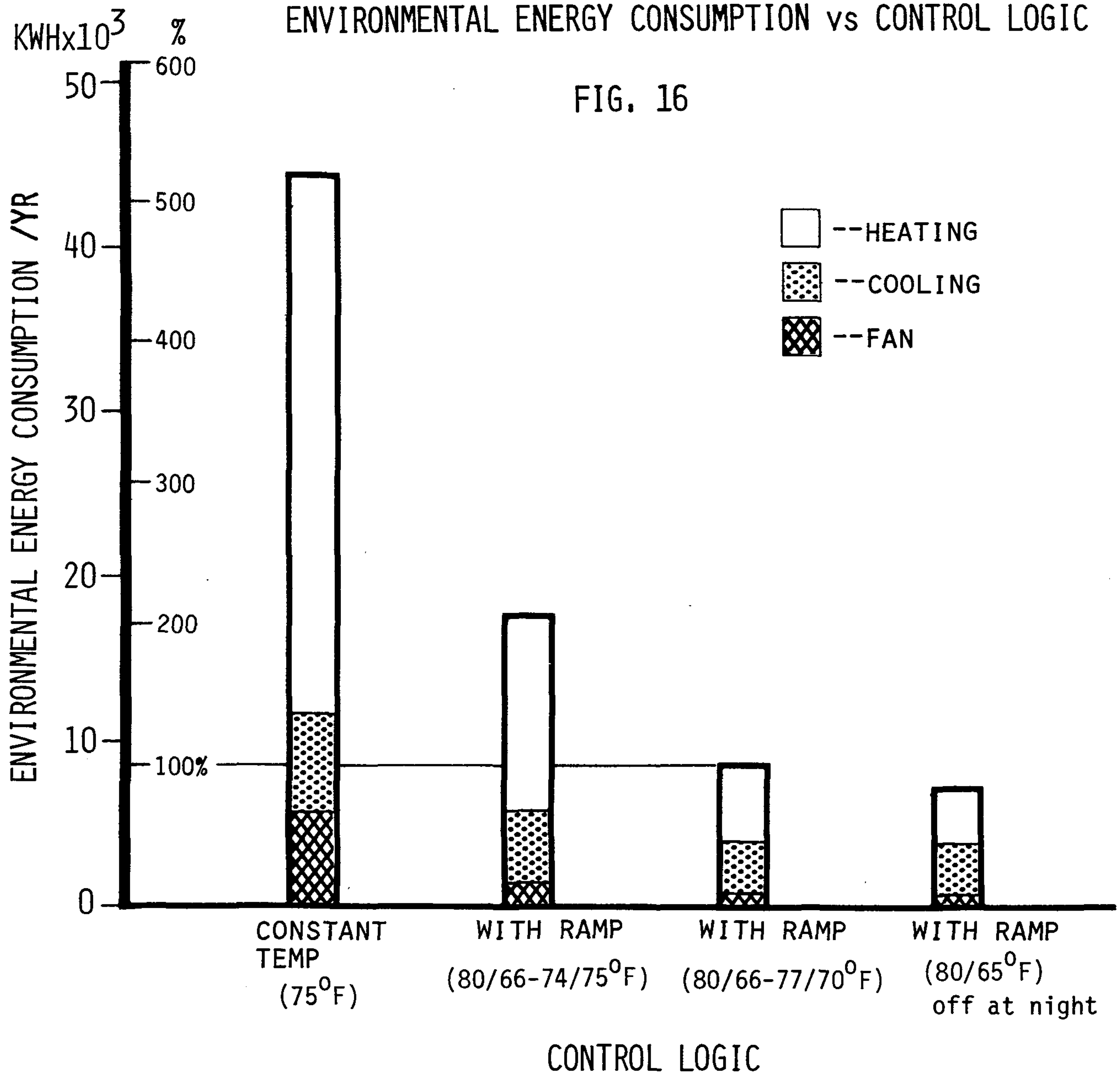
ENVIRONMENTAL ENERGY CONSUMPTION vs INFILTRATION

FIG. 15



ENVIRONMENTAL ENERGY CONSUMPTION vs CONTROL LOGIC

FIG. 16



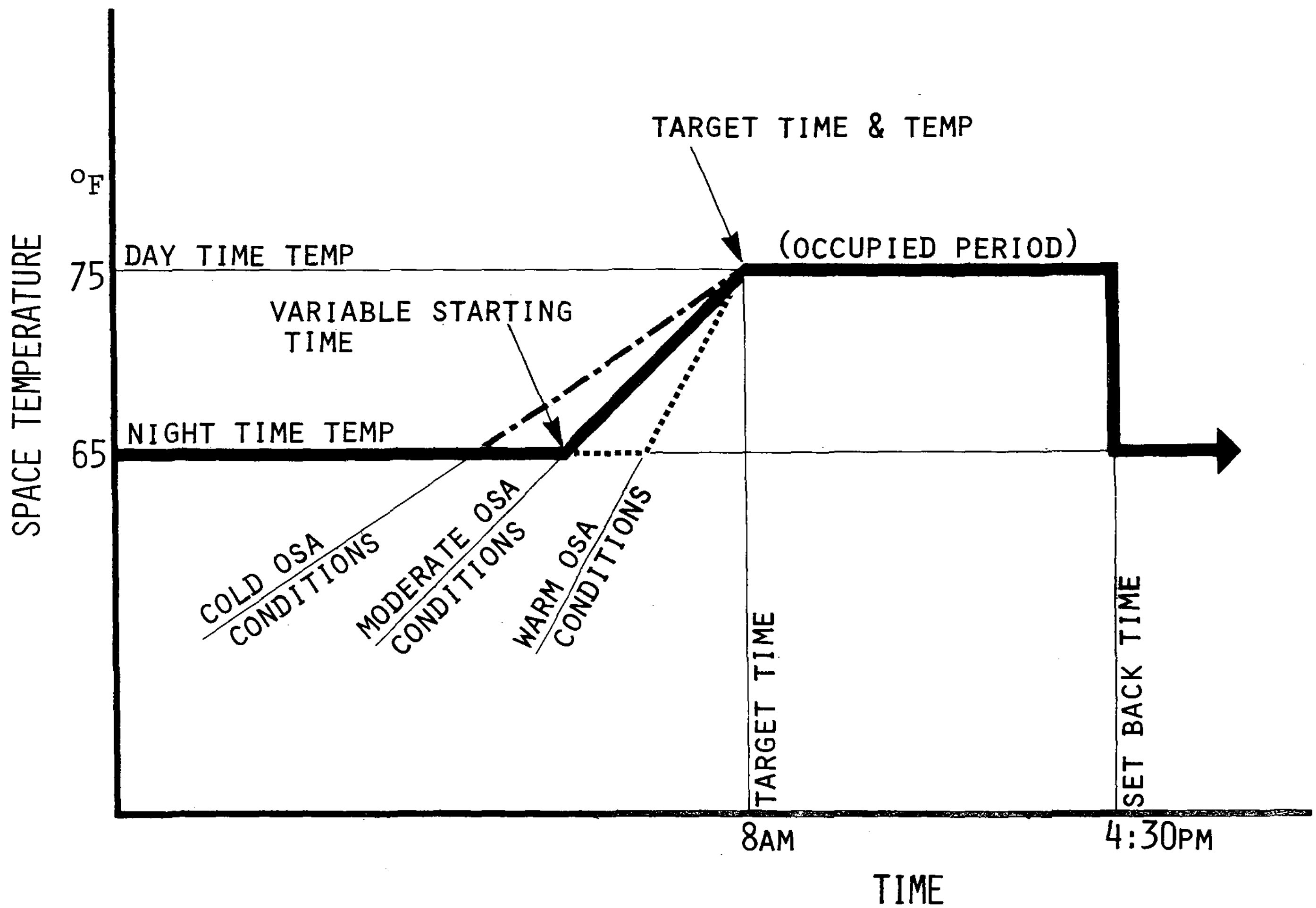


FIG. 17 START-UP CONTROL

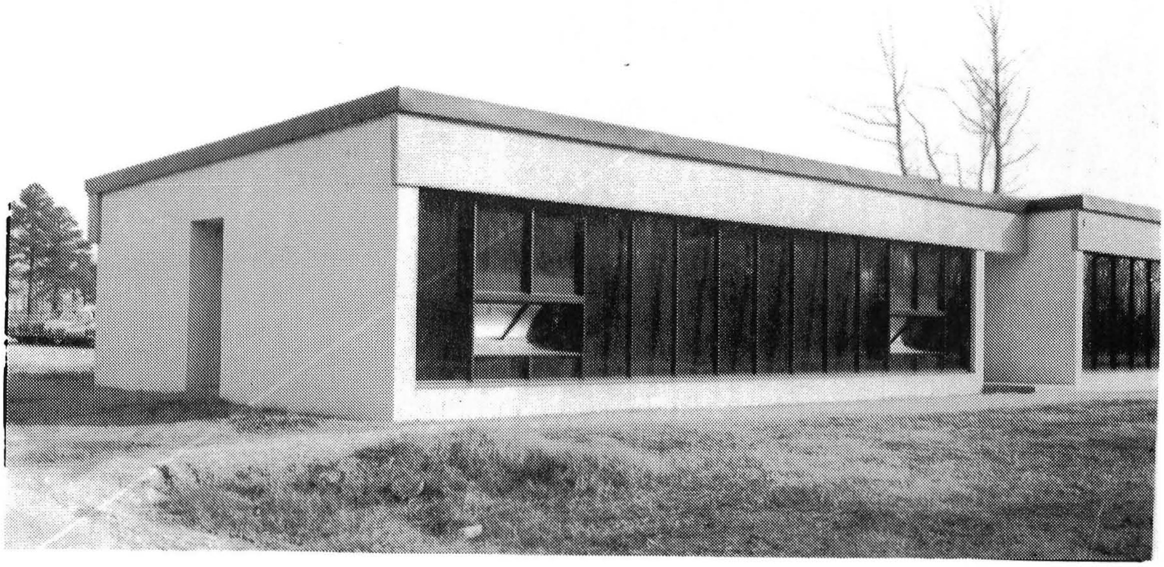


FIG. 18 PHOTO OF FRONT SHOWING SOLAR PANELS AND SPECIAL FRONT WINDOWS

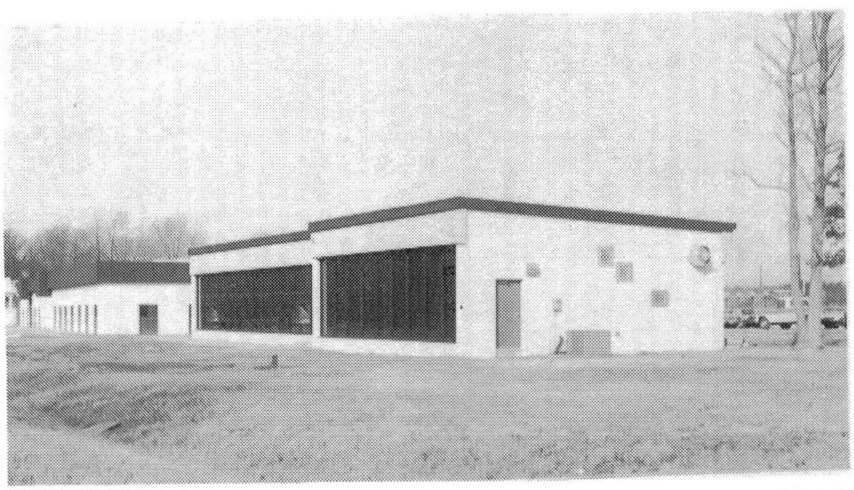


FIG. 19 PHOTO OF FRONT AND EAST WALL SHOWING COLLECTOR PANELS AND AIR CONDITIONING EQUIPMENT

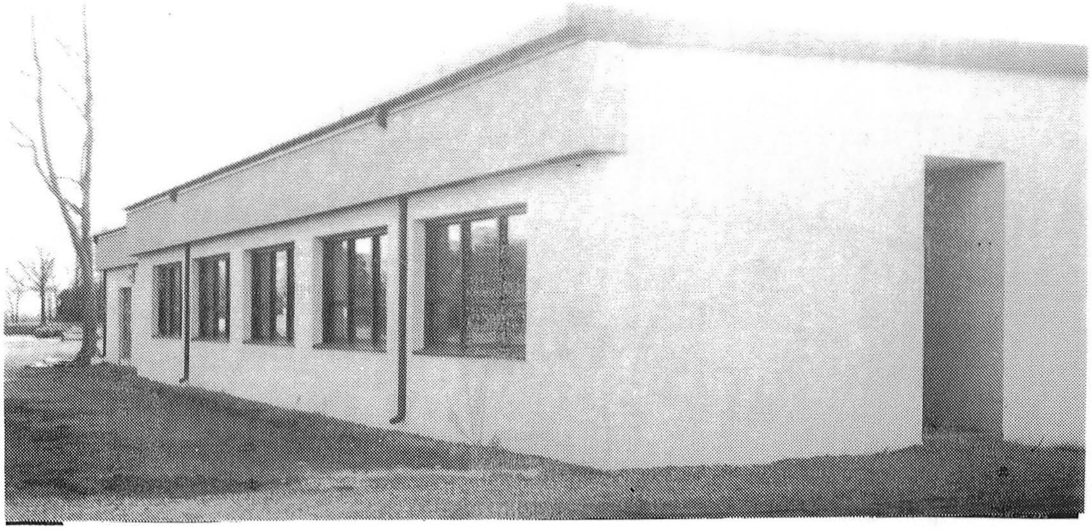


FIG. 20 PHOTO OF REAR SHOWING WINDOWS

FIG. 21 PHOTO OF INTERIOR

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16. Abstract

This paper summarizes the concepts in designing and predicting energy consumption in a low energy use building at NASA's Langley Research Center (LaRC), Hampton, VA. The building will use less than 30,000 Btu/sq.ft./yr. of boarder energy. The building's primary energy conservation features include heavy concrete walls with external insulation, a highly insulated ceiling, and large amounts of glass for natural lighting. A solar collector air system is integrated into the south wall. Calculations for energy conservation features were performed using NASA's NECAP Energy Program.

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