CONF-800438--1

MASTER

AN EARTH INTEGRATED DESIGN: OFFICE DORMITORY FACILITY*

H. B. Shapira and P. R. Barnes
Solar and Special Studies Section
Energy Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

---

*Research sponsored by the U.S. Department of Energy under contract W-7405-eng-26 with the Union Carbide Corporation.

DISCLAIMER

AN EARTH INTEGRATED DESIGN: OFFICE DORMITORY FACILITY*

H. B. Shapira and P. R. Barnes
Solar and Special Studies Section
Energy Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

1. INTRODUCTION

The solar applications group at Oak Ridge National Laboratory (ORNL) was in the process of studying designs incorporating earth-sheltering and passive solar when an opportunity came to test our ideas in the form of an office-dormitory facility. The purpose of the facility as well as the design concept were new for ORNL. Several attempts were made before the final design scheme was accepted. Important considerations were the user's requirements and energy conservation. The maximum energy savings benefit from passive solar and earth-sheltering can be obtained only if the importance of the relationship between architectural design considerations and expected energy consumption of the structure is understood.

This paper will attempt to show the generation process of the design of the Joint Institute For Heavy Ion Research (JIHIR). Architectural and energy considerations will be discussed.

2. USER AND SITE REQUIREMENTS

The Holifield Heavy Ion Facility is now being built at ORNL, and its completion is expected in the near future. When it starts operating, many guest scientists will come to Oak Ridge to conduct short experiments. The

*Research sponsored by the U.S. Department of Energy under contract W-7405-eng-26 with the Union Carbide Corporation.

demanding schedule in such "runs" requires that living and sleeping quarters be provided on site. JIHIR (construction to begin April 1980) will provide such quarters.

The building design requirements called for:

1. Approximately 409 m^2 (4400 ft^2) interior space.
2. The structure should house three defined activities:
   a. Office area with eight offices, mechanical room, storage, computer terminal and xerox machine.
   b. Lounge, dining room, and kitchen. For use both by visiting scientists and Physics Division personnel for special activities.
   c. Work and sleep rooms for visiting scientists as well as sleeping alcoves for local researchers on long experimental shifts.
3. The structure must be located within the Physics Division complex.
4. The unconventional sleep and work schedules need to be considered in the design process.

JIHIR is to be very close to the main traffic route (Bethel Valley Rd., on the north). It will be located on a stretch of land which extends the park-like scenery from Swan Lake to the east (see Fig. 1).

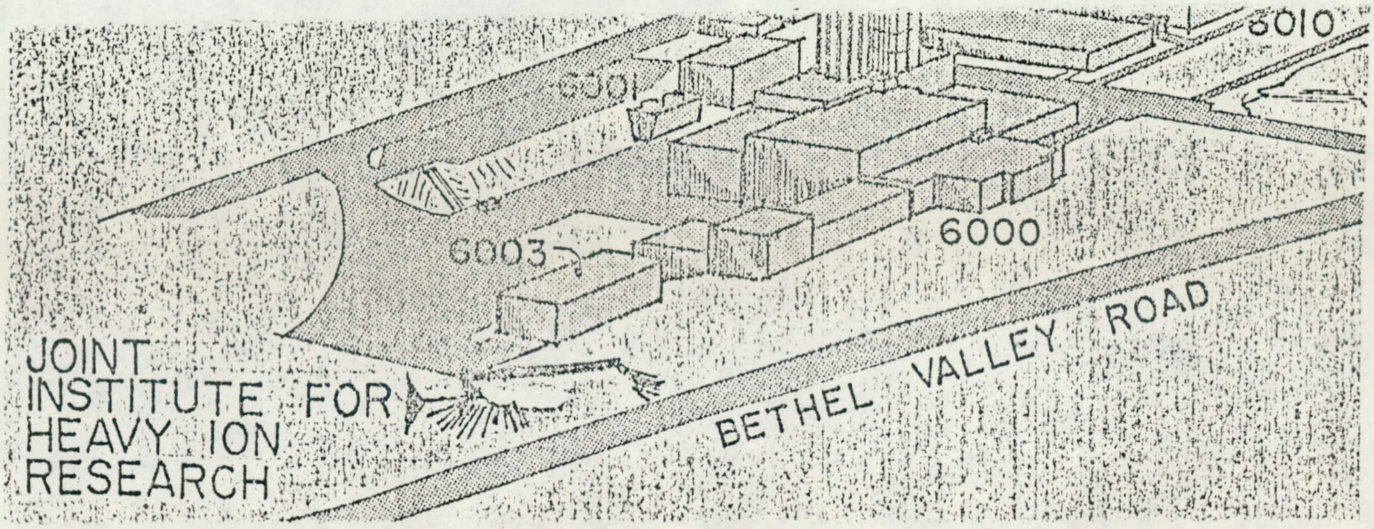

Fig. 1. Aerial View Indicating JIHIR's Siting.

Only an innovative approach such as earth-sheltering could preserve the "green" image as well as screen the parking lot and partially hide Building 6003 from Bethel Valley Rd. Careful attention was given to the shading pattern produced by Building 6003. The occupants of JIHIR may find the psychological as well as the acoustical isolation from the main traffic artery advantageous.

3. DESIGN APPROACH

JIHIR provides the solar applications group with an opportunity to evaluate experimentally the benefits of earth-sheltering and passive solar heating. The combination of large south-facing windows and the high mass normally associated with earth-sheltering could be designed to become an effective collecting and storing mechanism of passive solar energy. Additional energy savings can be expected due to the benign temperature environment provided by earth-sheltering. The latter results from the fact that the diurnal as well as seasonal temperature fluctuation of the earth are lower than that of the ambient air. Figure 2 depicts the mean daily air temperature and earth temperatures at depths of 1.5 m (5 ft) and 3.0 m (10 ft) for Oak Ridge, Tennessee. Earth-sheltering provides a favorably tempered "envelope" that will reduce energy loss.

4. OFFICE/DORMITORY DESIGN SCHEMES

The 409-m^2 (4400-ft^2) Scheme I design called for 3 walls (east, north and west) to be completely bermed by earth as well as a 45-cm (1.5-ft) earth cover on the roof. The windows, which are at the south face of the building, have a total glazing of approximately 43 m^2 (460 ft^2). During the winter, the sun is low enough that its warmth can penetrate to the interior spaces through the south-facing windows. The excess heat is absorbed by the thermal mass and during cooler hours is radiated back into the interior space. The

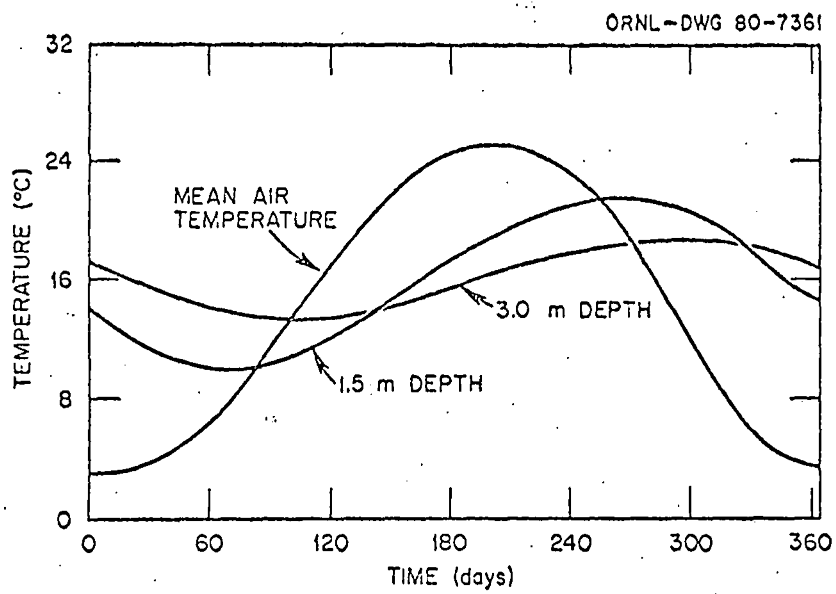

Fig. 2. Approximate Mean Daily Temperatures for Oak Ridge, TN.

ORNL-DWG 78-18092

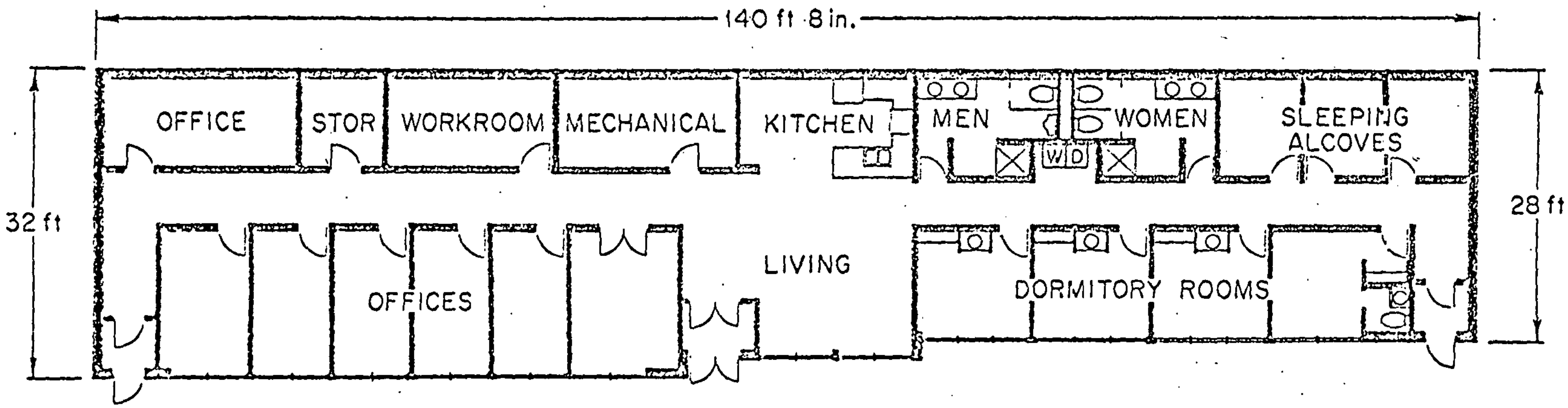

Fig. 3. Joint Institute for Heavy Ion Research - Scheme I.

ORNL-DWG 79-9845R

JOINT INSTITUTE FOR HEAVY ION RESEARCH — SCHEME I

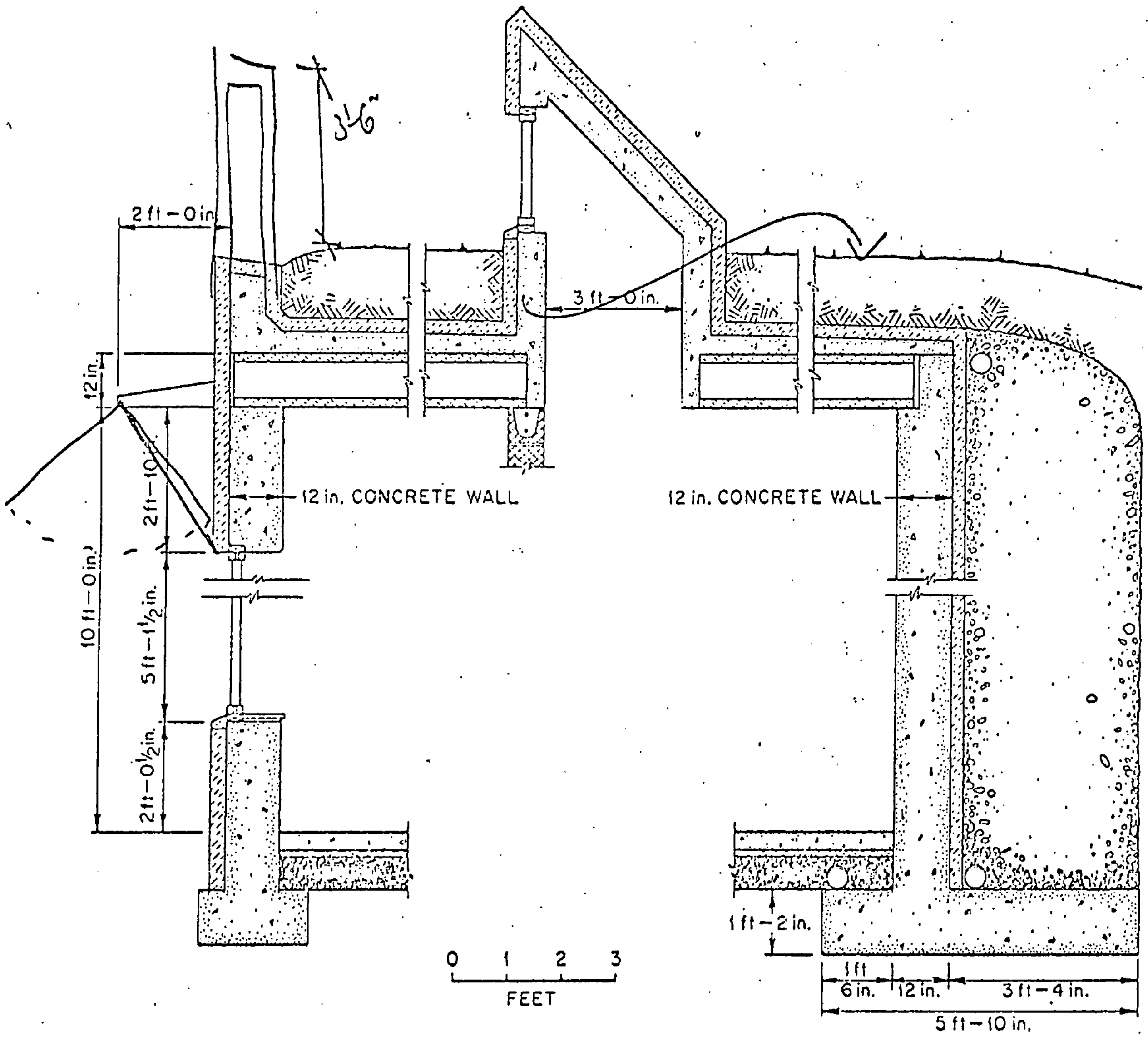

Fig. 4. Cross Section - Scheme I.

skylight at the rear allows additional solar gain and admits natural light. Excess heat from front spaces can be transferred to deeper interior areas by air circulation through the hollow cores in the prefabricated ceiling planks (Spandeck). At night the windows are insulated, thus ensuring reduction of heat loss. In the summer an extendable overhang[1] shades the south-facing windows and thus reduces the cooling load (see Section 5.4). An opening in the skylight would increase ventilation. Nighttime cool air flushing was planned for cooling. The materials selected are described in Table 1.

The floor plan in Fig. 3 reflects our desire to locate as many offices and living spaces as possible in the south portion of the building. Thus occupants are provided with an external view, which is known to be psychological and physiological desireable.[2] Spaces that house mechanical equipment, xerox machine, computer terminal, and the cooking facility, all of which generate internal heat, were placed at the back of the structure. The disadvantages of the direct gain windows in the offices, though, were the glare produced by the sun and the lack of flexibility in furniture arrangement common to small offices--these problems could result in occupants' discomfort. Our solution was the development of Reflective Insulating Blinds (RIB). A description of RIB, which both provides nighttime window insulation and directs insolation to the ceiling, is provided in Section 5.2.

Design refinements and revisions were necessitated by high costs as well as conflicts between user needs and passive solar heating requirements. These are detailed below:

1. The high cost of the skylight seemed unjustified for a structure utilizing forced-air circulation.

Table 1. Materials for Schemes I & II

	Scheme I		Scheme II	
Unit	Materials	Dimension	Materials	Dimension
Exterior Walls	North: Poured in place concrete, reinforced Styrofoam insulation on exterior Waterproofing 1/16 Butyl Sheeting	30 cm 12 in. 7.5 cm 3 in.	North: Poured in place concrete, reinforced Styrofoam insulation Waterproofing, Bituthene by W. R. Grace	25 cm 10 in. 7.5 cm 3 in.
	East: "	" "	East: North of exit door - same as above South " " " concrete block wall Finish: Dryvit System	 20 cm 8 in. 7.5 cm 3 in.
	West: "	" "	West: Concrete Block Wall Dryvit System Finish	20 cm 8 in. 7.5 cm 3 in.
	South: Poured in Place Reinforced load columns Poured in place Lintel & Base Dryvit Finish over Insulation Windows - Awning Double pane with thermal break. Extend between columns	30x30 cm 12x12 in. 30 cm wide 12 in. 7.5 cm 3 in. 1.5 m 5 ft	South: Steel Columns and Steel Load bearing beams Under windows East wing - Trombe Wall Central & West wing concrete blocks Dryvit System Finish	 20 cm 8 in. 7.5 cm 3 in.
Roof	Prestressed, precast concrete planks w/hollow cores (Spandeck) Skylight with operable window Waterproofing 1/16 Blityl Sheeting Insulation Styrofoam Earth Cover	12 in. 91 cm deep 3 ft 7.5 cm 3 in. 46 cm 1.5 ft	Spandeck 7.22 - wide planks Waterproofing - Bituthene by W. R. Grace Styrofoam Boards Earth Cover - sloping	30 cm 12 in. 7.5 cm 3 in. 76 to 46 cm 2.5 to 1.5 ft
Floor	Concrete Slab Poured in place Insulation Styrofoam Vapor Barrier .006 Polyethylene Sheeting	10 cm 4 in. 7.5 cm 1 in.	Same as Scheme I	
Interior Partitions	Concrete Blocks, sand filled	6 to 8 in.	North of Corridor: Metal studs & Sheetrock South of Corridor: Concrete Blocks	 15 to 20 cm 6 to 8 in.

2. The extendable overhang[1] was not cost-effective for a custom commercial application; also, the client was concerned about the maintenance it would require.
3. There is a likelihood that the dormitory rooms will be frequently used in a manner precluding direct gain space heating. A person sleeping during the daytime, if not requiring darkness, will at least need privacy which can be obtained only by reducing or completely blocking window openings.
4. The cost estimation also dictated a 10% space reduction.

Figures 5 and 6 depict the final design which will be constructed during FY 1980. It is expected to be completed early in 1981. The basic design strategy and floor layout have not changed. The building site, however, was reduced to 373 m^2 (4010 ft^2). Much of the space reduction was obtained by reducing the corridor space by resorting to exterior penetration on east and west walls. The reduced energy savings which resulted from the increased fraction of envelope exposed to ambient air was offset by a reduction in construction costs which were affected by less interior area wasted on corridors and shorter linear footage of retaining wall. The decision to partially expose east and west walls also improved the building's appearance by adding the necessary visual depth (see Fig. 7).

The skylights were eliminated and the extendable overhang has been replaced by a compromise fixed overhang. (See Section 5.4). The dormitory area has a combined direct-gain/Trombe wall passive solar design which is further discussed in Section 5.3. Our assumption is that at all times privacy has to be preserved and even when complete darkness is desired during daytime some solar gain will

ORNL-DWG 80-7757

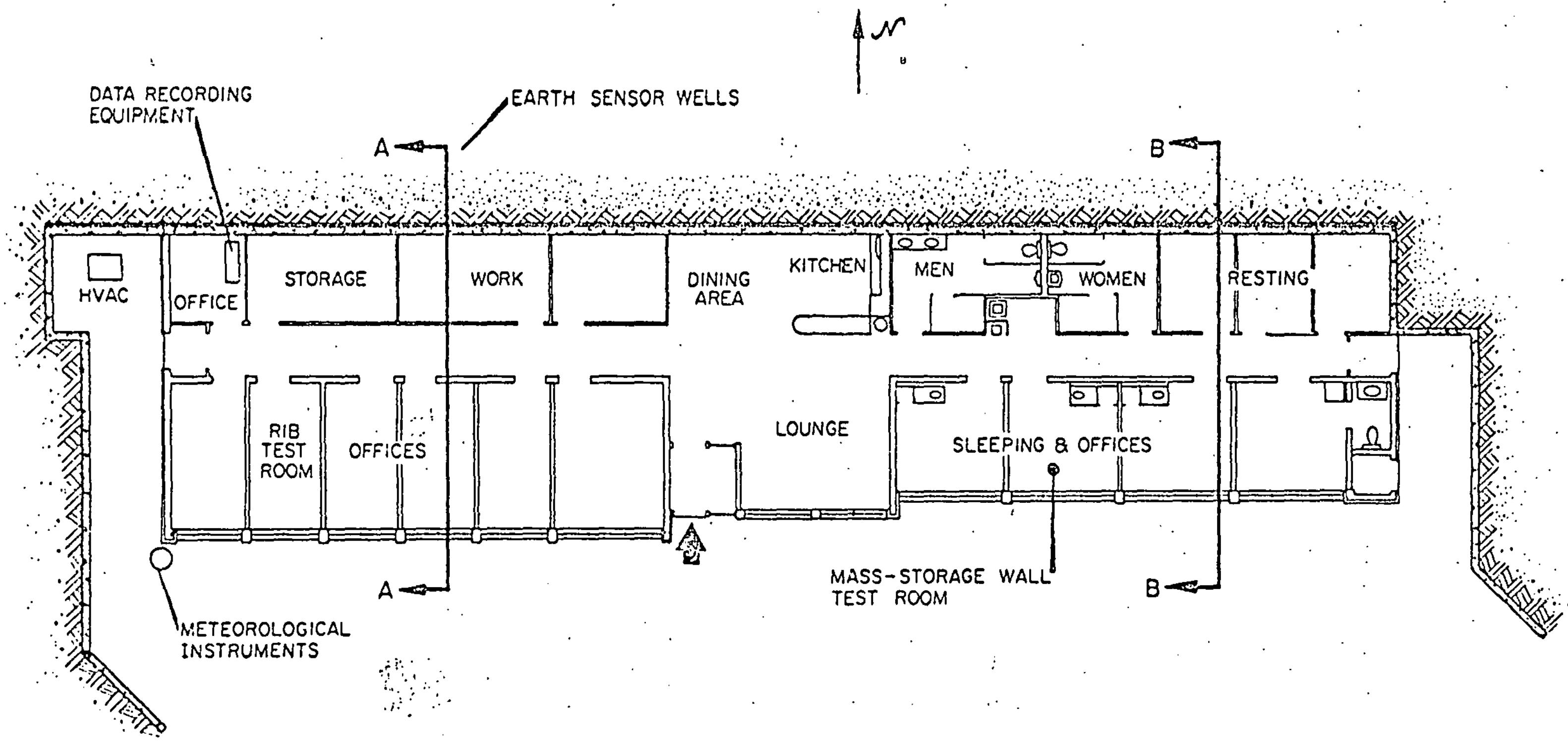

Fig. 5. Scheme II - Floor Plan.

ORNL-DWG 80-7756

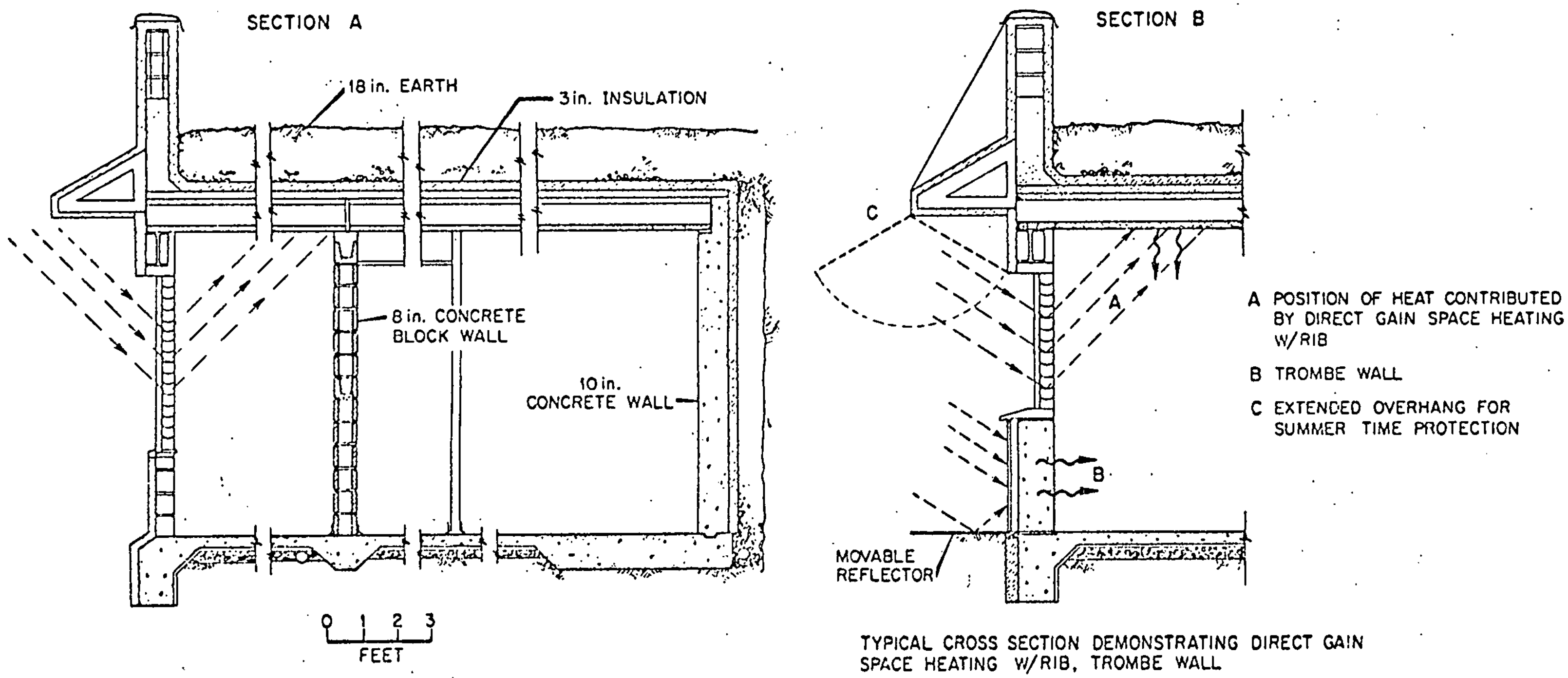

Fig. 6. Typical Cross Sections.

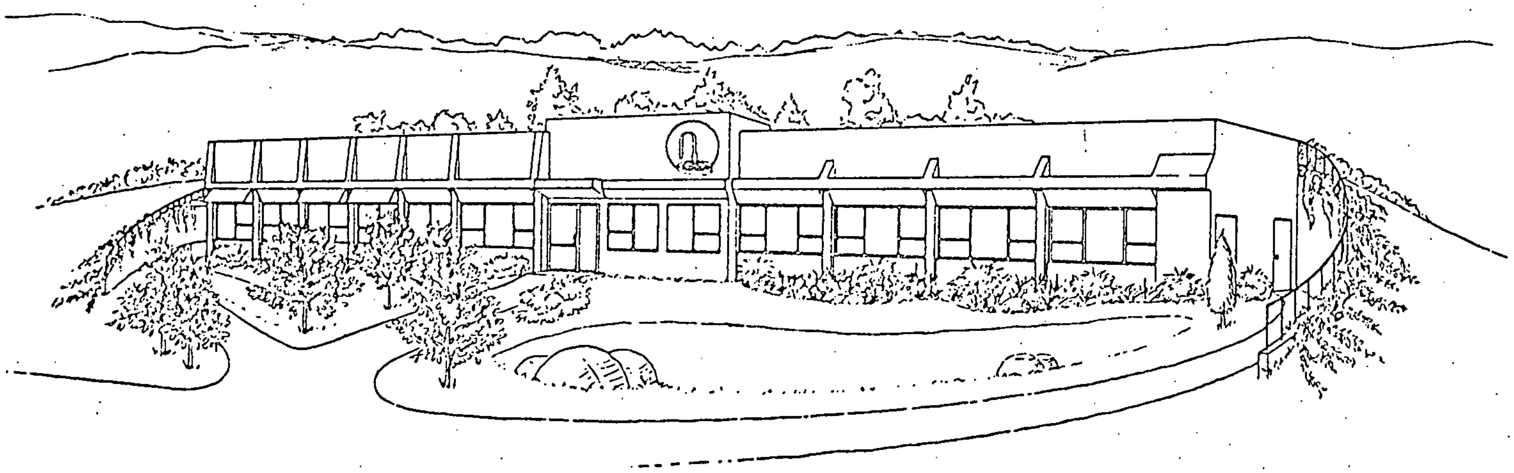

Fig. 7. Scheme II - Facade.

be attained via the Trombe wall (See Fig. 6). Computer simulation indicated that replacing the 15 cm to 20 cm (6-8 in.) interior partitions north of the corridor by sheetrock over metal studs would not greatly hurt the energy balance. The window* height was increased to 1.8 m (6 ft). Table 1 lists the materials used and points out some differences between the schemes.

5. ENERGY-CONSERVING FEATURES

The design of the energy-conserving features was refined along with the architectural changes. Extensive energy analyses and simulations were performed.[3] The following is a brief description of these features and the expected energy savings.

5.1 Earth-Sheltering. The benefits from earth-sheltering coupled with the high thermal resistance provided by 7.6 cm (3 in.) of styrofoam and the effects of the building mass result in a very low winter heat loss and negative summer gain from the earth-sheltered walls. The insulation will also prevent the walls from cooling down to earth temperatures, thus reducing condensation problems. Earth-sheltering in Oak Ridge, Tennessee saves annually about 25 $kWhr/m^2$ of wall area for heating and 8 $kWhr/m^2$ for cooling.

5.2 Reflective-Insulating Blinds (RIB). Reflective insulating blind (RIB) units which reflect insolation to the ceiling as well as insulate windows at night will be installed.[4] The RIB unit (see Fig. 8) is mounted on the inside just behind the window glass and operates much like a venetian blind. In the winter daytime mode, direct radiation striking the reflective surface of each slat is directed to the ceiling. The slats are curved so that frequent changes in the slant are not necessary. Problems of glare,

---

*Windows will be donated by Anderson Windows. Perma Shield awning was selected.

ORNL-DWG 79-9930

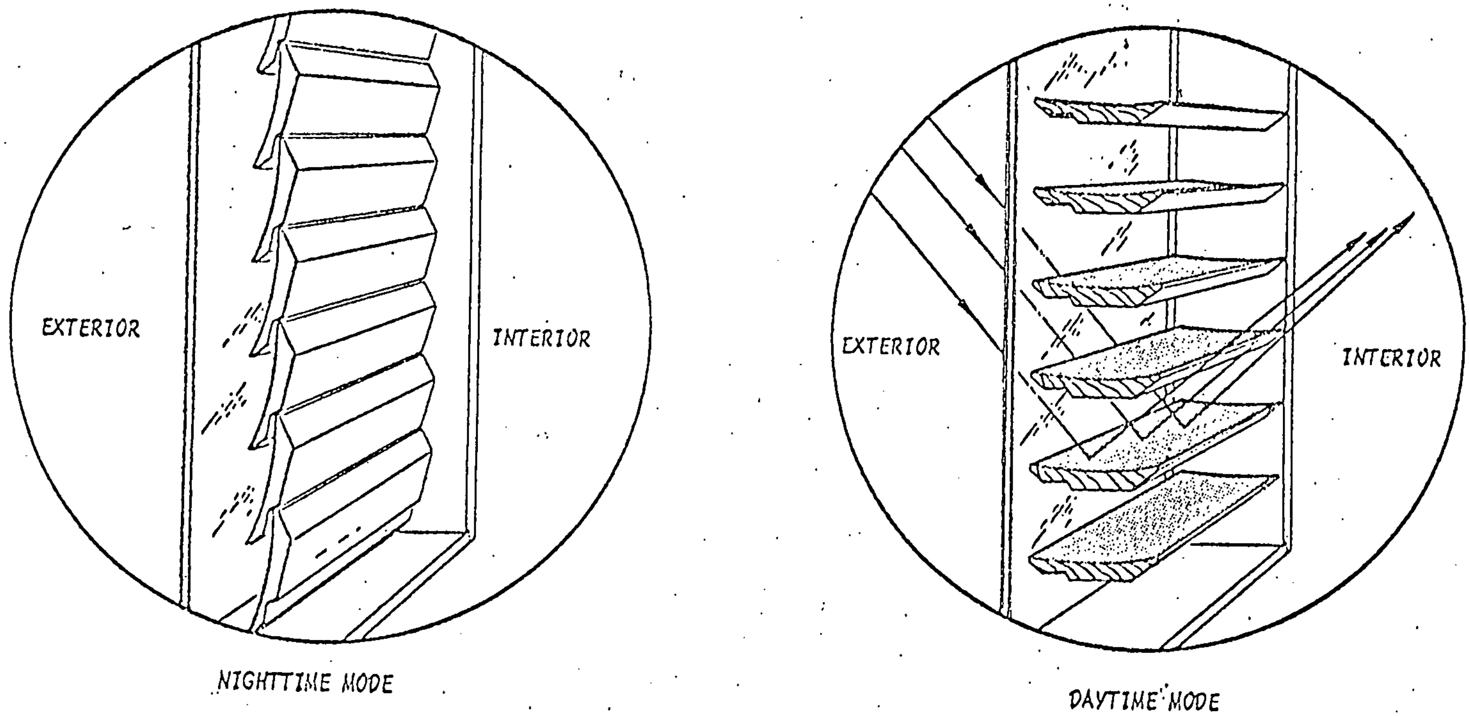

Fig. 8. REFLECTING-INSULATING BLINDS

fading and bleaching of materials, and spot overheating which are common to direct gain designs are thus reduced. In the winter nighttime mode, the slats, which have an insulating body, are tilted closed to form an insulative shutter. The heat loss through the large south-facing windows is thus reduced due to a combination of slats, window glazing and air gap. In the Oak Ridge, Tennessee area RIB can save about 80 kWhr/m^2 for a heating season by reducing heat loss through the windows. Contribution to cooling load reduction will be discussed in 5.4.

5.3 Passive Solar Heating. Direct gain space heating (Fig. 6, Section A) will be utilized in the office and lounge sections. A combined direct gain/mass storage wall unit was designed for the dormitory section (Fig. 6, Section B). The unvented wall (B) is a 30-cm (12-in.) thick concrete wall extending to a height of 1.07 cm (3 ft 7 in.). Figure 9 depicts the comparison between the heating contribution of mass storage wall, direct gain without nighttime window insulation and direct gain with nighttime window insulation. The solar heating fraction for the Trombe wall will be increased by the use of a reflector (Fig. 6, Section B) and the application of selective coating. A reflector can be used to shade the mass storage wall during the summer.

A heat pump with approximately 3 tons capacity will augment the passive solar systems by providing additional heating (or cooling) as required for the building. The mean monthly auxiliary energies required during the heating season for the different designs are shown in Fig. 10. For comparison purposes, a standard building design is also shown. The standard building design is an aboveground building with windows on all four sides comprising 13% of the wall area. The wall, including the windows, and the ceiling of the standard building both have an insulative value of 1.76 m^2 · k/W

ORNL-DWG 80-7362

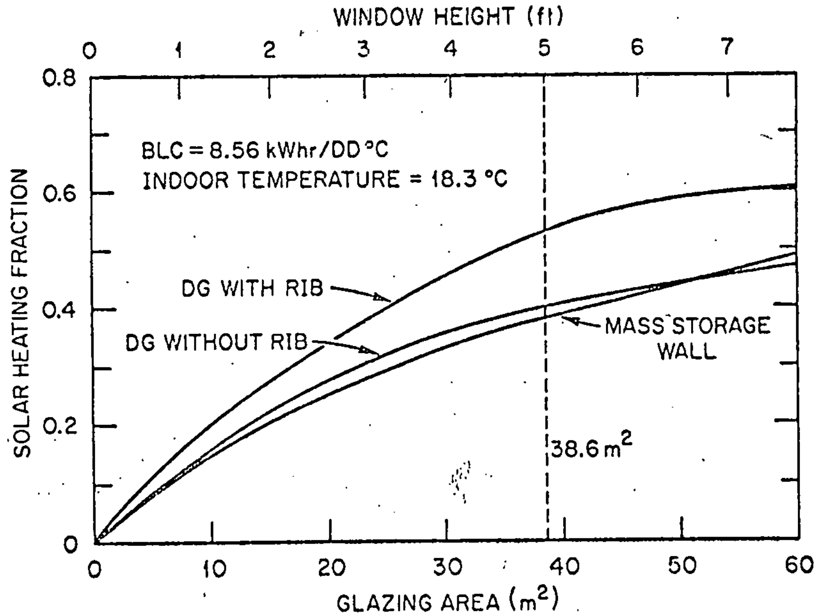

Fig. 9. Solar Heating Fraction as a Function of Glazing Area

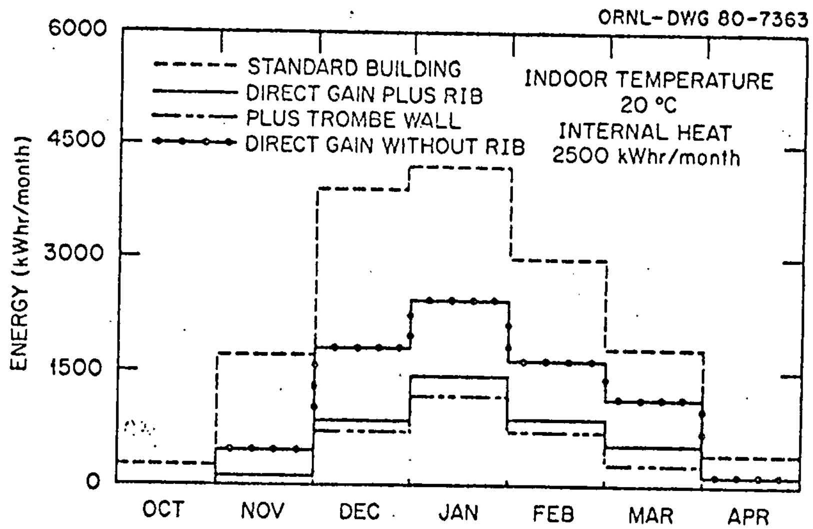

Fig. 10. Auxiliary Heat Required During Winter Months

(equivalent to R-10). The standard building was designed for total office use with internal heat gains higher than the 1500 kWhr used in this calculation and thus is not an optimum design for this application. All the values represented are for an effective internal heat generation of 1500 kWhr/month and an indoor temperature of 20°C (68°F).

The energy savings for the heating season contributed by earth-sheltering and other energy saving features for a structure similar to JIHIR is demonstrated in Fig. 11.

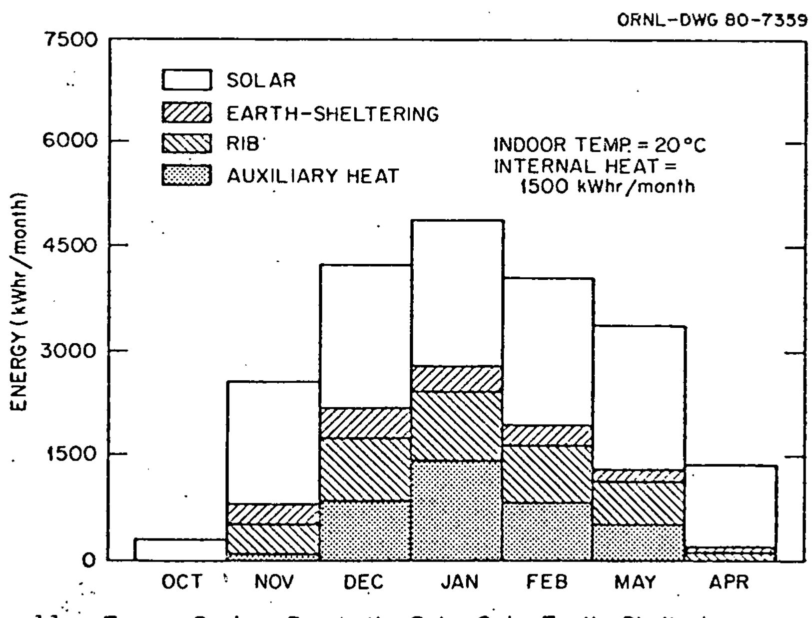

Fig. 11. Energy Savings Due to the Solar Gain, Earth-Sheltering, and Reflective-Insulative Blinds.

5.4 Summer Cooling and Shading. An overhang for solar control will be employed on the building. The fixed overhang is a compromise between winter heating and summer cooling. In addition, a vine-covered arbor for shading the exposed west-facing wall is planned. The RIB unit can be adjusted to reflect the direct solar radiation from the lower portion of the window while the middle and upper portions can be opened for ventilation and natural lighting. The use of natural lighting will save on the direct use of electricity for lighting, and it will reduce the summer cooling requirements by reducing internal heat generation.

An economizer cycle of the heat pump unit will use ambient air to cool the building when the temperature and humidity of the outside air are suitable. Night air flushing of the building will lower the temperature of the structure's mass to a level below the normal set temperature for cooling. In this way "coolth" can be stored and thus reduce the mechanical cooling required for the building during the following day. Outside air will also be used to prevent the building from overheating during periods in the fall when the weather is mild and the solar gain is generally high.

6. CONCLUSION

The Joint Institute for Heavy Ion Research is designed with innovative features that will greatly reduce its energy consumption for heating, cooling, and lighting.

A figure of merit for commercial buildings is the total annual energy consumption per unit area of floor space. A highly efficient office building in the Oak Ridge area typically uses 120 to 160 kWhr/m^2. Analysis for JIHIR which considers design with natural lighting, earth-sheltering, an annual energy heat pump coefficient of performance (COP) equal to 1.8, RIB and an extendable overhang*

*Deleted from final design

uses 71 $kWhr/m^2$. The mass storage wall and ambient air cooling will reduce energy consumption still further. The combined savings of the innovative features in JIHIR are expected to result in a very energy-efficient design.

The building will be instrumented to monitor its performance, and the measured data will provide means of evaluating the energy-savings.

We feel that the inclusion of passive solar and earth-sheltering design will provide positive environment for the occupants due to the thorough consideration of potential problems in the design phase. We will verify the efficiency of the design over the next few years.

7. REFERENCES

1. Paul R. Barnes, "Roof Overhang Design for Solar Control," Proceedings of the 4th National Passive Solar Conference, Kansas City, Missouri, October 3-5, 1979.

2. Belinda Lowenhaupt Collins, "Windows and Human Satisfaction," Solar Radiation Considerations in Building Planning and Design Proceedings of a Working Conference, National Academy of Sciences, Washington, DC, 1976.

3. Paul R. Barnes and Hanna B. Shapira, "Passive Solar Heating and Natural Cooling of an Earth Integrated Design," Earth Sheltered Building Design Innovations, Oklahoma City, Oklahoma, April 18-19, 1980 (to be published).

4. Hanna B. Shapira and Paul R. Barnes, "RIB - Reflecting Insulating Blinds," Proceedings of the 4th National Passive Solar Conference, Kansas City, Missouri, October 3-5, 1979.