The Daylit Array :
Strategies for daylighting the deep-plan office

by

Chittaranjan David Leonard Swamidasan

Diploma in Architecture
The Academy of Architecture, Bombay, India : 1984
Bachelor of Architecture
The University of Bombay, Bombay, India : 1985

SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE
MASTER OF SCIENCE IN ARCHITECTURE STUDIES
AT
THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY
JUNE 1987

Signature of the author ______________________
Chittaranjan David Leonard Swamidasan
Department of Architecture
May 7, 1987

Certified by ______________________
Ranko Bon
Assistant Professor of Economics in Architecture and
George Macomber Career Development Professor of Construction Management
Thesis Supervisor

Accepted by ______________________
Beinart
Chairman, Departmental Committee for Graduate Students

This thesis document was produced on the Apple Macintosh Plus personal computer and Apple LaserWriter Plus printer; using MacWrite, MacDraw, Lotus Jazz and Aldus PageMaker software. My thanks are due to the inventors of this great machine and its software programmers.

The Daylit Array :
Strategies for daylighting the deep-plan office

by
Chittaranjan David Leonard Swamidasan

Submitted to the Department of Architecture on May 7, 1987
in partial fulfillment of the requirements for the degree
Master of Science in Architecture Studies

ABSTRACT

This thesis is basically concerned with improving the environment in which office workers go about their business. In the first chapter - *The office environment* - the extent of the problem and the neccessity for improving the environment is discussed. Deep-plan buildings and associated interior layouts like the "bull-pen" and open planning are defined. Chapter 2 - *Daylighting* - deals with issues relating to the incorporation of daylighting into buildings. Here, the advantages of daylighting - both in quantitative measurements as well as qualitative aspects - are put forward; and the implications on interior planning discussed.

Chapter 3 - *The courtyard array* - brings together the ideas of the preceeding chapters and proposes a broad, low building with multiple atria as a solution to the problem of daylighting the deep-plan office. Earlier studies dealing with illumination, thermal comfort, view content, acoustics and economic evaluation are discussed in relation to the proposed array.

A discussion on the importance of physical scale models in the evaluation of a building's lighting performance is at the beginning of Chapter 4: *Daylighting models*. This chapter continues with a description of the models made; and ends with tables of illumination measurements and daylight factor calculations from the physical models. These measurements show the validity of the daylit array concept for daylighting a deep-plan building. In Chapter 5 - *Economic evaluation* - the thermal performances of a non-daylit and a daylit building are compared, using the computer program Solar 5. The operating costs of the two alternatives show the extent of potential savings from the use of daylighting.

The concluding chapter of this thesis puts in perspective issues relating to the daylighting of deep-plan offices. It discusses the economic trade-offs inherent in the design of a different type of building form. The final question - whether the non-daylit module or the daylit module will be built - can only be decided by the management of the office. The purpose of my thesis is to give them an idea of what daylighting can mean to their company: in creating a better work environment **and** lowering operating costs.

Thesis Supervisor: Ranko Bon
Title: Assistant Professor of Economics in Architecture and
George Macomber Career Development Professor of Construction Management

Harvey Bryan	Associate Professor of Architecture at Harvard University, for introducing me to the world of daylighting, and being a thoughtful and understanding thesis advisor.
Ranko Bon	for taking upon himself the difficult role of thesis supervisor, and always stimulating thought with ideas from a different viewpoint.
George Clark, Tim Johnson, Peter Jurgensen and Jacqueline Wool	Professors at MIT, for brilliantly-taught courses which helped me enjoy my studies at the institute.
John de Monchaux	Dean of the School of Architecture and Planning, for granting me the Cabot Award for 1986-87.
Joseph Ferreira **Michael Joroff**	Director of the Computer Resource Laboratory, Director of the Laboratory of Architecture and Planning, for helping me pay my way through MIT with teaching assistantships and part-time projects.
Gayle Epp and Polly Welch	for introducing me to the worlds of behavioral architecture and Macintosh desktop publishing through an exciting summer project.
Mukesh, Constantin and friends on the 5th floor of Ashdown House	for putting up with my often unpredictable behavior and always being there when I needed them.
Papa, Amma, Freda, Robin, Mignonne, Rajeev and Yamini	for unconditional support, encouragement and love at all times. To all of you ... **Thanks!**

Contents

Before I plunge into details of what this thesis is all about, I think some background on how I became interested in this topic would be of help. So here goes ... It all started with my undergraduate final architectural design project. The project was the design of a major city hotel. Thrilled with such an exciting project, after reading extensively on hotel design I visited several hotels in Bombay. While I realised that the "front" of a hotel would be far better finished than the "back", it came as a shock to see the working conditions of the majority of hotel staff. A large proportion worked in basements, and many of those above ground worked in deep interior spaces totally cut off from the world around them. At that moment, I resolved to make my design different - one in which all hotel employees would be in daylit spaces, close to the exterior. My sole criterion was that employees should be at most 25 feet from a window. While I succeeded in this objective, it was clear to me that my design was not really sophisticated from an energy conservation point of view. I needed to learn a lot more about orientation, fenestration and atriums before a truly worthwhile design could come about. This realization was a major reason in my deciding to study further in this country.

This master's thesis started out as an investigation of daylighting possibilities in hospitals, and so I set out to visit hospitals in the Boston area. It was with a strange sense of *deja vu* that I went around Beth Israel Hospital that cold day in January. I had seen all this before - in another climate, in another country - but the same attitudes and the same reactions to their working environment. People were unhappy. They did not like working in this deep-plan artificially-lit building, isolated from the city around them.

How, I asked myself, could people be doing a good job under these circumstances? I had indeed come a full circle in my investigations.

My thesis is thus basically concerned with improving the environment in which office workers go about their business. In the first chapter - *The office environment* - the extent of the problem and the necessity for improving the environment is discussed. Deep-plan buildings and associated interior layouts like the "bull-pen" and open planning are defined. Chapter 2 - *Daylighting* - deals with issues relating to the incorporation of daylighting into buildings. Here, the advantages of daylighting - both in quantitative measurements as well as qualitative aspects - are put forward; and the implications on interior planning discussed.

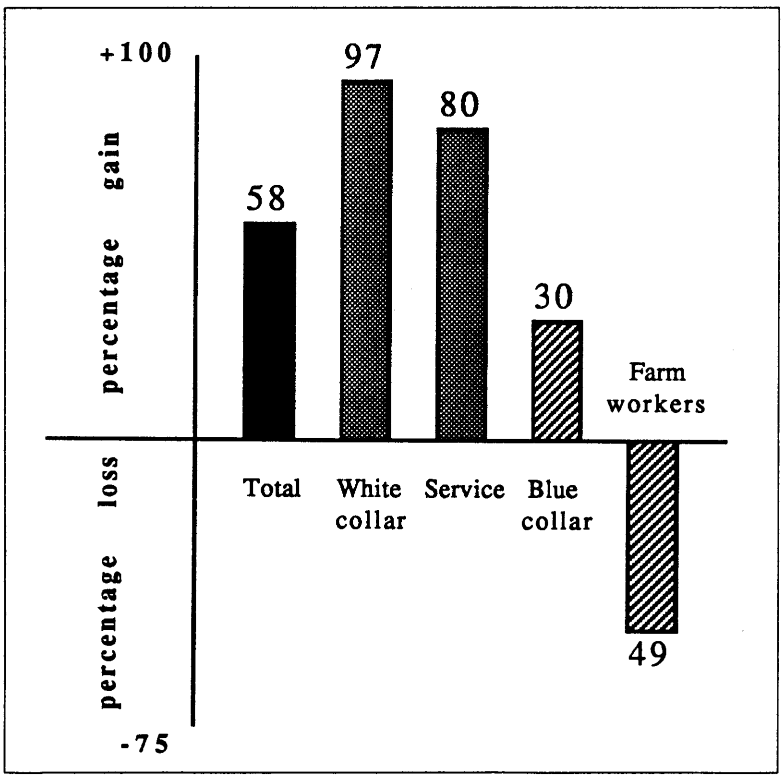
Chapter 3 - *The courtyard array* - brings together the ideas of the preceeding chapters and proposes a broad, low building with multiple atria as a solution to the problem of daylighting the deep-plan office. Earlier studies dealing with illumination, thermal comfort, view content, acoustics and economic evaluation are discussed in relation to the proposed array.

A discussion on the importance of physical scale models in the evaluation of a building's lighting performance is at the beginning of Chapter 4: *Daylighting models*. This chapter continues with a description of the models made; and ends with tables of illumination measurements and daylight factor calculations from the physical models. These measurements show the validity of the daylit array concept for daylighting a deep-plan building. In Chapter 5 -

Economic evaluation - the thermal performances of a non-daylit and a daylit building are compared, using the computer program Solar 5. The operating costs of the two alternatives show the extent of potential savings from the use of daylighting.

The concluding chapter of this thesis puts in perspective issues relating to the daylighting of deep-plan offices. It discusses the economic trade-offs inherent in the design of a different type of building form. The final question - whether the non-daylit module or the daylit module will be built - can only be decided by the management of the office. The purpose of my thesis is to give them an idea of what daylighting can mean to their company - on one hand lower operating costs; and on the other and most important, the creation of a better work environment.

This thesis is basically concerned with improving the environment in which office workers go about their business. A starting point would be to determine the extent of the problem: why we should care specifically about office workers. This is in part because there are so many of them (or us - depending upon the way you look at it). As factories and farms became more mechanised and more productive, the growing American population began to enter the office and service sectors. This ongoing phenomenon was aided by women demanding their place within the office hierarchies and also by that huge bulge in the population known as the baby boom. The nation's job pattern has thus altered dramatically over the last 25 years. While the total labor force is up 58%, white collar workers are up 97% and service workers up 80%. Meanwhile, blue collar workers are up only 30% and farmworkers down 49%[1]. As the



Changes in the composition of the American labor force over the last 25 years white collar and service workers are those who work in the "office" type of environment, we are talking about a considerable number of people. In fact, the early eighties were watershed years in the history of how Americans make their livings. For the first time, a majority of the labor force worked in an office setting. More and more of what's being done, even when it doesn't take place in an "office" looks like office work. Indeed, a recent study found that workers in labs spend only 13% of their time operating equipment. A "scientist's day" consists largely of talking face to face (35%), reading (12%), writing (12%) and talking by telephone (7%)[2]. Even production lines for computer boards call for office-like settings: technicians stationed in clean and discrete "offices", surrounded by small piles of chips ready to be assembled - not unlike production workers who process claims at Blue Cross. Precisely because the office environment influences the livelihood and mental health of so many millions working there, we all need to lobby for environments that both support the work of organizations and the people performing that work.

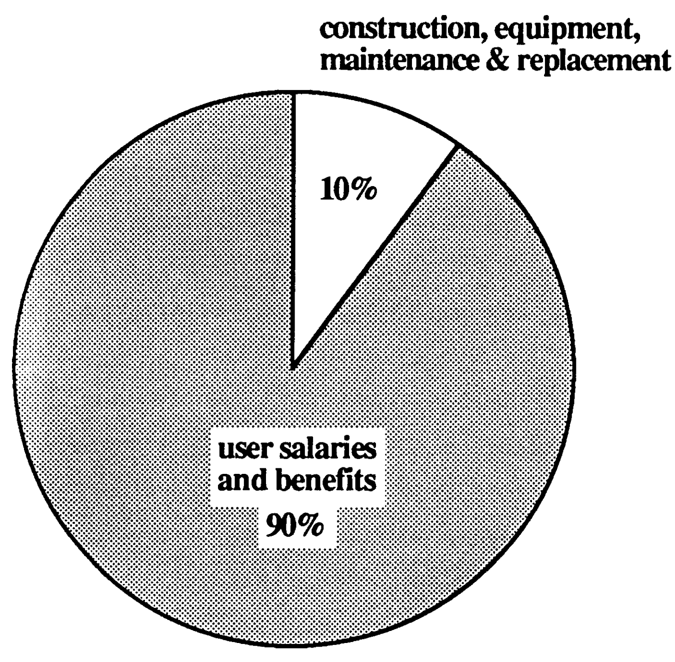
Some people go to work simply because they have to. When they get to the office, they labor, not for the fun of it, but for the sake of making a living. But most people bring a degree of motivation to their jobs. Though the office environment will not create enthusiasm where none existed before, they can satisfy or dissatisfy the worker - leading to more enthusiasm or less. Offices have traditionally been grim, serious places; but attitudes towards office management are changing rapidly. Just a few years ago, the very notion of making an office environment a comfortable one seemed a needless luxury. The chairman's view was - *Those folks in the lower echelons are always expendable,* *aren't they? They aren't hard to replace, are they?* Even though we have not moved very far along the path to a post-industrial society, we have made enough headway to see that what once worked for an organization no longer does. It is not that the pragmatists who run America's corporations have experienced a profound spiritual awakening. On the other hand, they have seen that an organization's survival depends upon the environment it provides. Everybody is awakening to the possibility that offices need not be vocational jail houses. An organization that is indifferent to its employees is not going to attract the skills it needs - at any echelon. The workforce now is highly mobile and not particularly loyal. In some white collar sectors, the turnover rate approaches 25% - one out of every four people leaves his or her job and seeks other employment every year[3]. This is because people insist in being treated, not as units of labor, but as people.

A big reason for this change is the changing composition of the office labor force. Tasks once handled by people are being phased out in favor of computer and telecommunication programs. Some clerical operations are already on the verge of disappearing, while technical, professional, managerial and executive operations seem to be expanding. More and more office workers are "knowledge workers", well-educated and aware of their strengths. These workers demand what they consider their rights. In addition, lacking the concrete and palpable rewards of crafting a product, knowledge workers desire some sign - in addition to money - that signals achievement.

As Peter Drucker (1973) says:

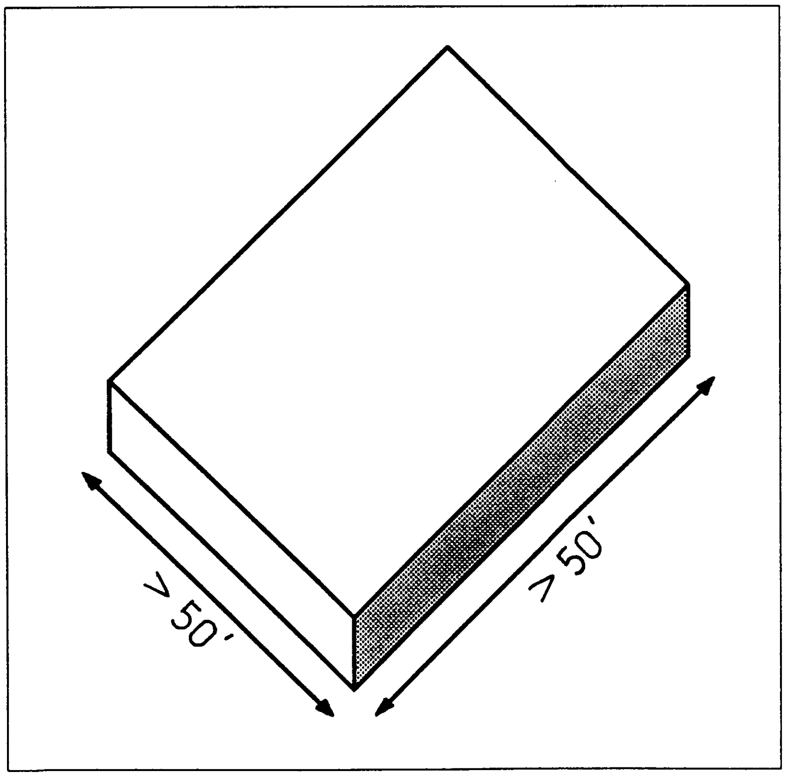
"Managing knowledge work and knowledge worker will ... be a far more demanding task than managing the manual worker was until very recently. For the weapon of fear - fear of economic suffering, fear of job security, physical fear of company guards or the state's police power - which for so long substituted for managing manual work and the manual worker, is simply not operative at all in the context of knowledge work and the knowledge worker. The knowledge worker, except on the very lowest levels of knowledge work, is not productive under the spur of fear; only self-motivation and self-direction can make him productive."[4]

On a larger scale, one can see that nearly all industrial nations are experiencing rising expectations among their citizens. It is clear that people want, and will demand, the "good life".



Costs associated with a building over its life span

Organizational life in 1987 is already complex and it is continuing on the road to more complexity. People are demanding more subtle and more comprehensive responses from their company. The management is obliged to improve the physical environment, like every other part of an organization, to live up to the expectations of the office worker. A look at the way dollars are spent over the life of a building show that it is only sensible to care about these expectations. If the cost of construction of the building, equipment, maintenance and replacement are added together, their sum will still be only a tenth of the dollars spent on user salaries and benefits[5]. This ratio clearly points out the importance of identifying and fulfilling user needs in all areas in order to improve efficiency and productivity. But what is the *typical* physical environment of the American office worker? The American office building is generally a



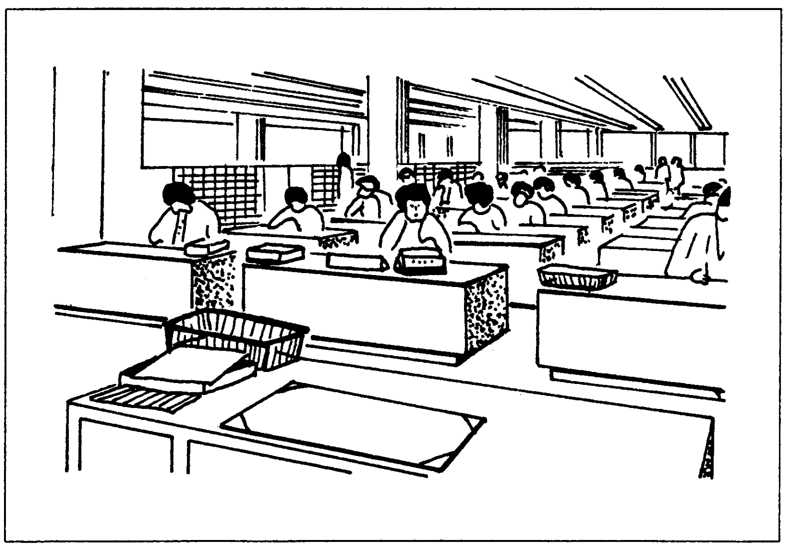
What is a deep-plan building?

deep-plan one. For the purposes of this thesis, let us consider deep-plan buildings to be those with at least one plan dimension greater than fifty feet. Such buildings will have non-daylit spaces since without conscious design or skylights, daylight has little chance of penetrating so deep into a structure. Deep-plan buildings are a relatively recent phenomenon in architecture, since by their very nature they have been possible only since the invention of the artificial light. At about the time that incandescents gave way to fluorescents in commercial buildings, other trends, such as rising urban land costs, the advent of building air-conditioning systems, improved methods of structural design and low-cost electricity combined to make deep-plan buildings a common occurence in modern office design.

Deep-plan buildings are favored because they maximize the two ratios of built-up area to site area; and of net usable space to gross building space. These two factors largely determine the number of floors in the building, which affects total cost to a great extent. As the ratio of linear feet of wall space to floor area increases as floor area decreases, there are adverse implications to small, separate structures with small, inflexible internal spaces. In addition, the ratio of net area to the corridor space it borders varies directly with the depth of the net space. The implication is that corridors - normally double-loaded - should service the deepest net space on each side that is functionally feasible. Construction areas are increased by the use of short spans and small bays. Mechanical space needs are also increased by small span and bay sizes, due to requirements for a greater number of vertical chases and ducts.

Though this building form is undeniably efficient in terms of the above-stated ratios, the quality of the resulting space leaves much to be desired. The design results in a maze of corridors, with no distinguishing characteristics, leading to dull spaces. Working in such a space leads to an overpowering feeling of isolation - with no sense of orientation, time, or links to the outside world. This feeling of is exacerbated by typical office layouts which tend to negate the individual and make him subserve his interests to the "greater good" of the organization.

Until the 1950s the typical office layout featured enclosed offices around the periphery of the space and clerical desks in the center. The clerical employees were seated in what is now called the "bull-pen": row upon row of desks, situated in the interior and monitored by supervisors. Everything and everybody was in full view. This effectively diminished a person's sense of worth and made the corporation appear to be a "Big Brother". This effect was often counter-productive. Another disadvantage was that the layout rarely took paper flow or job functions into consideration.



The "bull-pen"

The open plan was a later development. An open plan layout does not contain any enclosed offices. Furniture and equipment are used to divide space and facilitate work flow instead. Systems furniture panels or whole units, less than ceiling high, define the spaces. In a true open plan, there are no doors. Occasionally labyrinthine entrances to certain workstations are used to minimize visual and acoustical distractions. The idea is to facilitate paper flow and to enhance intra-office interaction, and allow easy reconfiguration as tasks change. Getting rid of a layout with enclosed offices means that hard-walled corridors are discarded as well. The benefit is that additional assignable space is gained for the office. Open layouts also save energy dollars, as on the average partitioned spaces require more light than open spaces do. Walls absorb light, particularly of their surfaces are not white, and partitions prevent fixtures from aiding one another in spreading light. On the other hand, however, occupant on-off switching is better controlled in partitioned spaces. Since open plans are the norm in this country today, let us assume such a layout for the purposes of this thesis. While the open plan is certainly meritorious, it should be noted that such open plans are not

The open plan

the panacea for all the ills of the office physical environment. Even modern open plans, unless the rest of the environment and the organization itself support a certain individuality, can soon degenerate into mere systems furniture and modular walls which presuppose that people and things are interchangeable. It is in creating a quality environment that I believe daylighting has an important role to play. We shall look specifically at daylighting issues in the next chapter.

References:

[1] Cohen and Cohen, 1983, p. 7.

[2] Hermann Miller Research Corporation, 1985, p. 24

[3] Cohen and Cohen, 1983, p. 7.

[4] Other interesting quotes:

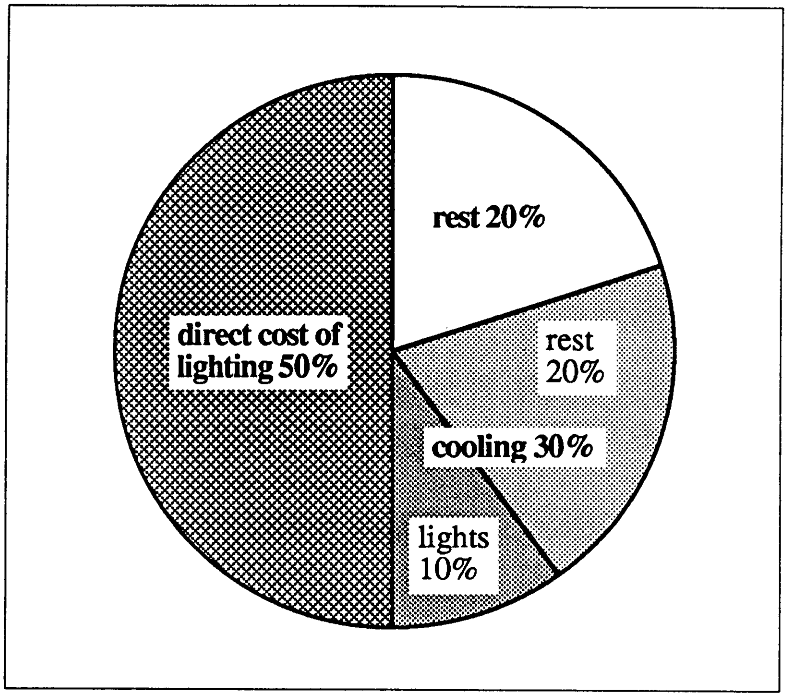
"I get up about noon, I would only consider myself outside the norm because of the way other people live. They're constantly reminding me I'm abnormal. I could never bear to live the dull lives that most people live, locked up in offices." - Bud Freeman, jazz musician. (Terkel, 1972, p. 458).

"The job is boring. It's a real repetitive thing. I don't notice the time. I could care less about the time. I don't really know if it's 5 o'clock until I see somebody clean up their desk. At five I leave. It's always the same." - Ernest Bradshaw, Audit department head. (Terkel, 1972, p. 400).

[5] Cohen and Cohen, 1983, p. 11.

Before the invention of the electric light, daylight was a preferred source of light compared to artificial sources like candles and oil lamps. Even though architecture was constrained by heavy construction materials and structural span limitations, the architects found ways to create small openings in the massive building envelope. Several creative and ingenious ways of using daylighting were developed. It was only after the modern technological innovations detailed in the discussion of deep-plan buildings (Chapter 1), that daylighting faded into the background. As a result, there has been little serious interest in daylighting in the US since the 1950s. In this chapter the pros and cons of re-introducing daylight in office buildings will be discussed.

Artificial lighting now consumes a substantial portion of the electrical energy generated in the nation. This is partially due to the promotion of cheap energy by utility companies before the energy crises of the 1970s, and lighting standards which tended to benefit the illumination industry. US codes for lighting also specified unnecessarily high levels of illumination, far above comparable international standards[1]. Consequently, the single use of lighting takes about 20% of total electrical energy consumption and represents over 5% of total national energy consumption[2]. On a smaller scale, lighting accounts for a large percentage of the energy dollar spent to operate the office. Office buildings are characterised by daytime use patterns, long hours of lighting use, relatively high lighting levels and high installed watts per square foot. Lighting for most office spaces was planned by electrical engineers who excelled in the use of large quantities of raw illumination. This resulted in that characteristic of the office physical environment - the luminous ceiling, which needlessly



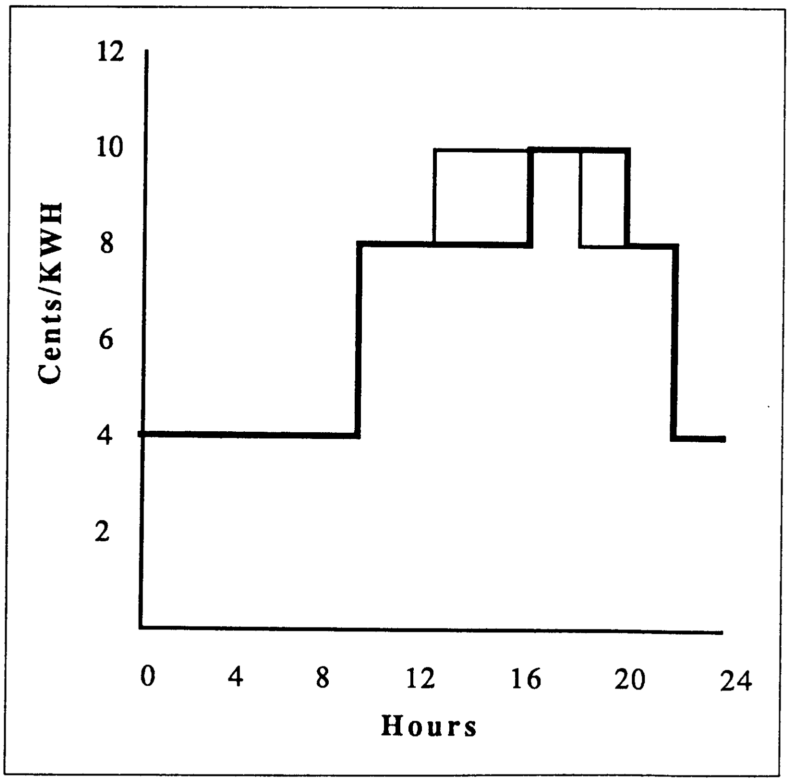
Break-up of the operating costs for an office building

consumes a lot of electricity. Energy is used not only for the electricity to actual light the building but also to cool the artificial lights which cause internal heat gain. In most offices, lighting now amounts to approximately 60% of total building energy costs: 50% as direct lighting costs and a high percentage of the 30% cooling load[3].

The energy crises made architects and all others connected with the building process concentrate on the importance of designing energy-efficient buildings. With lighting such an important contributor to the total load, it was clearly the focus. The initial temporary solution was de-lamping, in other words consciously doing without the high lumen levels originally prescribed. However since then, there has been considerable disagreement as to the best approach that new office building design should take. At first, the emphasis was on making the building thermally tight, with as little surface area and as few penetrations as possible. Windows were assumed to be a source of uncontrolled heat loss and gain, and therefore a burden to mechanical heating and cooling systems. This approach, exemplified by the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) 90-75 regulations, contributed to the continuing popularity of deep-plan office buildings to no small degree.

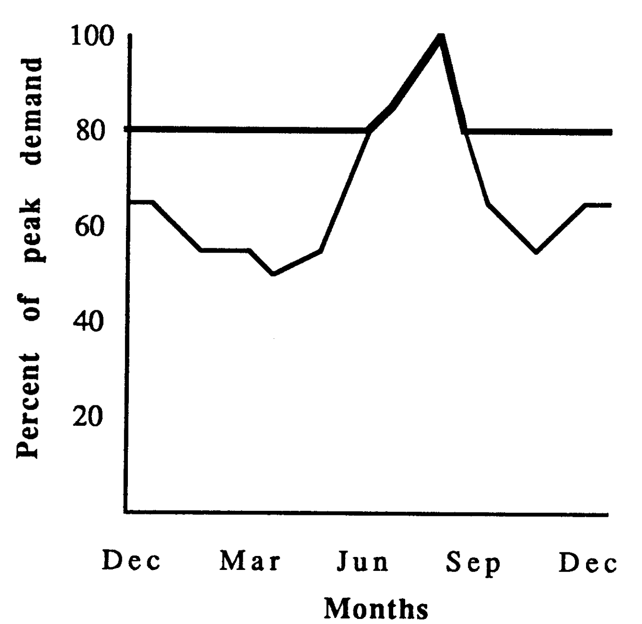
Later, using active and then passive solar energy to cut heating and cooling costs became identified with energy-conscious design. Some designers argued that as commercial buildings were dominated by internal loads, the architect should concentrate on reducing these loads by all possible means. As the sophistication of designers increased, it became apparent that using natural daylight as far as possible would allow building users to save on expensive electricity for artificial lighting as well as on expensive fuels for cooling the artificial lights which cause internal heat gain. Component based standards like the ASHRAE 90-75 regulations limiting glass area ran directly counter to this. Later performance oriented standards, which relate to the behavior of a whole building and do not specify the performance of individual building components are far more sympathetic to daylight design strategies. These standards do not specify the design of a building, but only its performance, and allow designers the freedom to explore a variety of options related to the skillful use of daylight.

Daylighting has several less well known advantages too. One of them relates to the issue of power conservation, as against mere reduction of annual energy consumption. Utilities nowadays are finding it difficult to site and build new power plants for reasons ranging from equipment capital costs and rising fuel costs to environmental concerns. This results in tremendous pressure to restrict growth of new demand, and the response has been to create a demand-sensitive rate structure. Commercial building owners and operators now pay not only for the energy they consume, but also for a time-of-day charge which reflects their daily power consumption profile. Many utilities use a "ratchet clause", which requires that a high percentage of the year's maximum demand be extended as a fixed demand charge for the rest of the year too. Such charges encourage building owners to make modifications in the operation of their buildings so that their energy requirements are more or less level at all times of the day and throughout the year. Peak building loads frequently occur in the afternoon and in summer, when both air conditioning and lighting are on. Coincidentially, the availability of daylight also peaks at

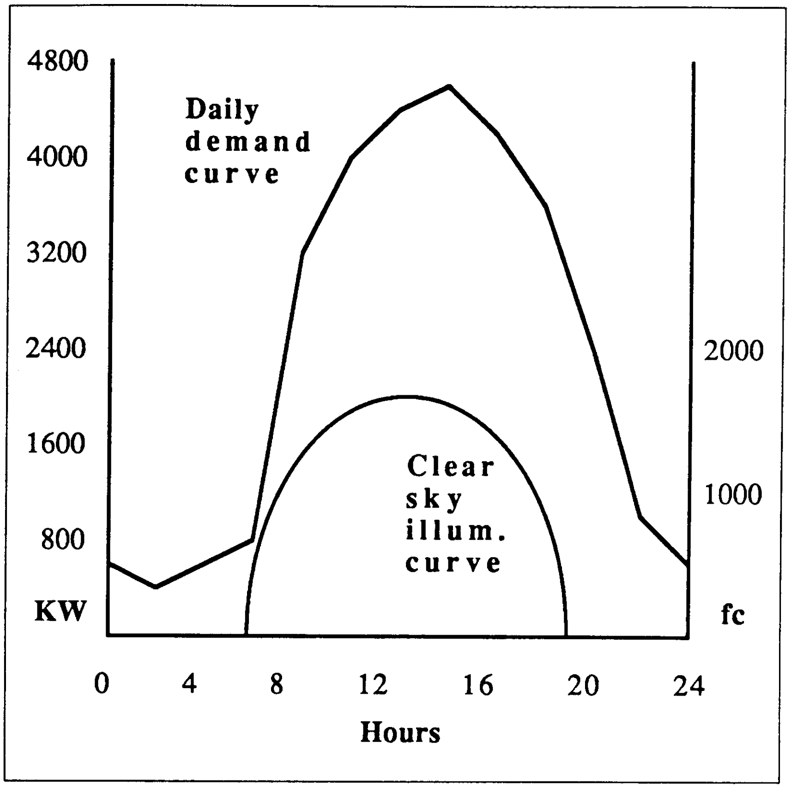


Time-of-day electricity rates

around the same time. As a result, a daylit building in which the lights are dimmed or turned off will reduce the peak demand, and thus have an addtional benefit for the owners. A recent Solar Energy Research Institute study quantifies this on a national level by estimating that two to three times more renewable energy can be saved by reducing the peak rate of energy use in commercial buildings than by equivalent expenditures that focus on limiting annual energy consumption[4]. It should be noted that artificial task-ambient lighting systems now available operate in the range of 1-1.5 watts/sq.ft. installed power. With improved lamps, ballasts and controls, we can expect to see lighting systems with efficiencies of 100 lumens per watt. As a result, concentrating our attention on the issue of annual energy savings from daylighting is clearly less relevant than the reduction of peak power demand.



Electricity charges using an 80% ratchet clause

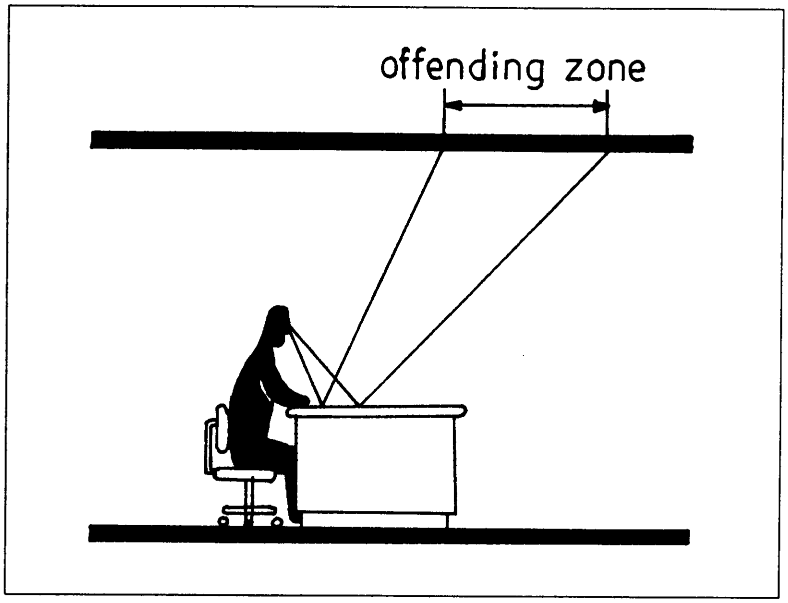


The coincidence of a building's daily demand curve and the clear sky illumination curve

The provision of natural light in a space makes the occupant less dependent upon mechanical systems for his comfort. Compare an office worker in a room with no windows, totally dependent upon electric lighting and mechanical ventilation, to a worker in a perimeter office with operable windows and daylight. During a power failure, the worker in the interior office would have to quit working and leave the building, while the other worker could continue productive work. The value of a worker's productivity for one hour per year is approximately equal to the annual energy cost of lighting his workspace[5]. It is clear that the ability to continue working for just an hour more would equal the entire potential annual energy savings that daylighting could hope to provide.

Every indication is that electric costs will continue to rise at rates equal to or exceeding the general rate of inflation. Thus, reducing the use of electric energy for lighting provides a degree of inflation protection. Once the initial capital costs for daylit design have been paid, the owner can only reap benefits, irrespective of the economic climate. However, one must remember that no energy savings will occur unless lights are turned off or dimmed. Lighting systems must be controlled over both space and time to achieve these savings. On/off or dimmable systems with either automatic or manual operation are neccessary for these projected savings through daylight to be actually achieved.

Lighting should be designed as a combination of art and science. Until recent years, lighting for most office spaces was planned by electrical engineers who used a quantitative design approach. The major emphasis was placed on the use of large quantities of raw illumination with little or no consideration for the user's comfort, color rendition of the source or the aesthetics of the system. Lighting layouts traditionally resulted in fluorescent luminaires equally spaced across the room, attempting to produce equal illumination for a majority of task positions. This arrangement wasted a lot of electricity by keeping unnecessarily high illumination levels throughout the space, irrespective of need. In addition, the luminous ceiling caused problems of glare. Glare is defined by the Illuminating Engineering Society as "the sensations produced by illuminance within the visual field that are significantly greater than the luminance to which the eye is adapted to which causes annoyance, discomfort or loss in visual performance and visibility"[6]. Ceiling lights cause both direct glare due to excessive brightness from the visible

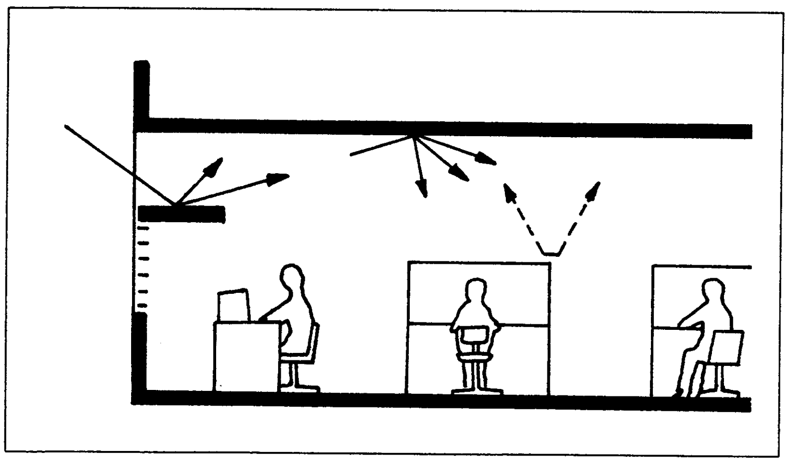


Reflected glare from ceiling lights

source, and reflected glare from polished or glossy surfaces like desktops and magazines. With more emphasis being placed on visual comfort, aesthetics and energy conservation, this quantitative approach of blanket ceiling illumination is no longer considered valid. There has been an attempt in recent years to use a more qualitative design approach. With this approach, an attempt is being made to emphasize the quality of the light being provided, a more pleasing visual atmosphere and at the same time stay within the bounds of reasonable energy usage.

A consensus of opinion is emerging that light can best be delivered as a combination of two components known as ambient light and task light. Task light is needed to provide the right level of acuity at the heart of the workplace; ambient light provides background illumination. This approach is based on the theory that the definition of appropriate, visually defined foci in the luminous environment simplifies tasks and facilitates concentration. The need for task lighting was given a fillip by the growing trend toward open-office planning and modular systems. Open-office workstations cannot be effectively illuminated by overhead lighting alone due to the shadows caused by partitions and shelves. If task lighting is provided by flexible luminaires, the user can control veiling reflections on the task by moving the fixture from the offending zone. One of the biggest advantages of this system is its ability to save an enormous amount of costly, scarce energy which would otherwise be wasted in providing unnecessary levels of illumination throughout entire offices regardless of needs.

A high proportion of the ambient light component can be achieved with daylighting in a well-designed building. The combination of ambient daylighting and artificial task-lighting, creates a relaxed atmosphere as well as order and relevance in the work environment. The most comfortable and pleasant spaces are those in which the users retain control over the fine-tuning of the lighting system. In large, open office landscapes (which are coincidentially the most appropriate for daylit spaces), the office-workers define and identify their particular location by the task-light under their personal control. Light is thus balanced and related to the unique needs of each person's physiology and the activities



Daylighting providing part of the ambient light component in which each engages. Flexibility and quality, not sheer quantity, become the essentials of a good luminous environment.

Beyond these perfectly adequate reasons for the open office lie the ramifications of the investment tax credit. According to the Internal Revenue Service, construction materials affixed to the building - and thus immovable - may be depreciated over twenty years. But if they are movable, they can be redefined as equipment and depreciation may take place over less than half the time[7]. Task and ambient lighting attached to furniture has thus received an unexpected boost.

A note of caution is appropriate with regard to the simultaneous acoustical and lighting performance of the office ceiling. It is an assumption in most calculations for indirect sources that the ceiling surface is of a flat, diffuse nature. In reality, the acoustical tile that is commonly used has a porous surface that does not reflect light in the same way. A careful balance must be struck between these two conflicting requirements.

So far, issues relating to daylighting in architecture have been largely dealt with in a quantitative way and most research in this area has concentrated on energy-saving calculations. While one does not propose to argue against this outlook, daylit buildings are more than just energy-conscious designs. Beyond the energy related issues of daylighting, there are important qualitative issues to be addressed. Architects are intuitively more at home with the visual and behavioral advantages this approach offers, than with calculations.

Let us first take a look at conditions in non-daylit spaces. From the British Labor Council come reports that windowless factories have been directly related to complaints of claustrophobia and the consequent resignation from jobs[8]. There have been complaints of headache, fatigue and depression in Swedish underground factories. In these factories, rest periods in naturally lit rooms or outside have proven necessary[9]. Russian and Czech labor experts have noted higher absenteeism coupled with more headaches, fainting and sickness in non-daylit spaces[10]. In a windowless US factory, employees broke wall panels in an effort to be visually in contact with the outside world[11]. As a consequence, many British factory owners have had to provide more lavish facilities in an attempt to counteract this depression - ranging from better color schemes to improved canteens and sports facilities[12]. It must be remembered that people who are being paid on a piece rate have a different attitude towards work and their environment than those receiving regular salaries in offices. In offices, where the incentive to work does not apply there seems to be a stronger opposition to the total exclusion of daylight. In Ruys' 1970 study of US offices, though 90% of those surveyed said there was enough light in their office, another 90% were dissatisfied with the lack of windows. In fact 50% said that this affected their work adversely and 35% responded that it was the one thing they disliked most about their office. The degree of dislike seemed greater in offices where it was perceived that there was no good reason for cutting out daylight except profit to the management[13].

The illumination on a horizontal surface expressed in footcandles is the commonly used measure of lighting design. In fact, this measure tells us very little about the ability to see or perform a visual task. Daylighting from windows contributes to the quality of interior lighting by providing a directional component. It is generally considered that lighting from an angle of about 30° to 40° produces the optimal modelling of forms with soft shadows. Such modelling rarely occurs with electric lighting installations where all fixtures are in the ceiling and their light is cast vertically. Studies have shown that one footcandle from a sidelighting source will provide visibility equivalent to three footcandles from overhead[14]. In addition, one should compare the efficacy of sunlight to artificial light sources. The efficacy of sunlight, or the number of lumens of light delivered per watt of energy, varies from about 90 lumens per watt for direct sunlight to as much as 150 lumens per watt for light coming from a deep blue sky. Daylight is as efficient as the best electric lighting systems[15].

Man has a biological need to be aware of relevant information about his environment. We are monitoring information at all times, even though we are frequently not conscious of some information we receive. We seek facts of orientation: where we are, the shape and structure of the space, the nature and quality of furnishings and finishes, the identity of our neighbors, who they are and what they are doing, the time of day and the weather. Our senses are constantly monitoring the environment for signs of change. Daylight and the view from clear windows help orient the office worker by providing a continuous flow of information about the world around. Daylight, as a source of illumination, varies over time in a predictable manner (daily and seasonal cycles) as well as in unpredictable patterns due to cloud cover and other climatic variables. The variable nature of this source might appear to be an undesirable feature for indoor environments characterised by uniform temperatures and light levels. In point of fact, variation in experience is the normal condition of human behavior[16]. We need to be aware of the state of the diurnal cycle, since luminous conditions in interiors are evaluated with reference to external conditions and because the changing color, direction and quality of daylight help us orient ourselves. There is evidence to suggest that people value and even prefer the changes and variability introduced by daylight in a room. Artificially lit buildings too often create poor and monotonous visual environments insulated from the natural world outside. Attempts to produce a variability effect by electric lighting seem strangely artificial and annoying.

Light is a true environmental factor, as much as air, water and temperature. It seems reasonable that the light sources to which we expose people should not deviate markedly from the lighting environment under which people evolved in nature. The spectral quality of both light transmitted through special solar glasses and electric light is different from daylight, particularly at the short wavelength end. It is only logical that changes in lighting will have some effect on the human being. A good percentage of white collar workers have daylit homes but artificially-lit offices. However during most of the day they are in their offices working, not at home. During the winter months, the daylight hours are so short that many people, particularly those who must work inside, are not exposed to sunshine and daylight for long stretches of time. As a result, they are deprived of important ultra-violet and other short wavelength light. Daily light-dark cycles are associated with numerous rhythmic changes in physiological functions such as sleep, food consumption, water intake, body temperature and the secretion of many hormones[17]. Several photobiologists have been working to clarify the issues regarding the importance of light to human beings. Dr. Richard Wurtman, who directs the Laboratory of Neuroendocrine Regulation at MIT, has hypothesised that the daily cycle in a human being is regulated by light - specifically by light entrainment to the eye. Other photobiologists are concentrating their research on related issues such as treatment of the Seasonal Affective Disorder (SAD) through phototherapy.

The information brought through the medium of daylight results in a more relaxed worker, who knows where he or she is in his or her environment. This in turns makes for a more motivated person, better able to concentrate on the work in hand. If, on the other hand, the incoming sensory data is ambiguous, as in deep-plan buildings, the worker is at best uneasy, and at worst gloomy. Apart from the biological information needs, productivity increases are likely to come about from the feeling that the management cares about working conditions[18]. This "message" will be received through the medium of light.

A good activity environment creates a natural focus on the task, while providing alternative foci which may serve as visual rest centers during periods of inactivity or relaxation. Even in factory production work, the eyes are not glued continuously to the task at hand. They are constantly scanning the environment for the information which one consciously or unconsciously needs to know. Feelings of comfort are thus affected by everything in the visual field. Interesting visual foci or rest centers such as sculpture, plants and paintings are needed to help relax the body and mind during work. Therefore, openings which help orient by daylight penetration can also help by offering contact with nature and distant views to relax eye muscles. Daylight can bring sparkle to a space. This sparkle has often been confused with glare, and brightness restrictions have been misused to eliminate windows and to lower the transmission value of window glass to such a degree that even sunny days appear dark and gloomy from inside the building.

Apart from economic reasons, internal non-daylit spaces, introduced by the planning of deep-plan buildings have been justified by suggesting that people work better in spaces where there are no "distractions" (such as a pleasant view out of a window). It must be remembered that people are brought up in environments with a lot of natural light - in their homes, schools and play spaces. Transplanting such people into a windowless environment - or a viewless though daylit one - does not help them concentrate. Far from it. In fact, when there is no "file" of relevant, analogous information in the visual memory to which the incoming stimulus may be successfully compared and given meaning, the attention is drawn to the unclassifiable element[19]. Thus an artificial environment, strange to any human being, will distract him more than the view from a window, which will subconsciously make him relax and give of his best. When the desk worker looks out of the window instead of down at his work, he is not "wasting time": he is seeking psychic as well as optical relief from a highly structured and monochromatic experience. Despite its tremendously high luminance, the sun is not distracting, unless it lies close to our line of sight, because we expect it to be in the sky. We know what it is, it always behaves consistently with our expectations, and the highlights and shadows which it causes give us a continuous orientation to its location.

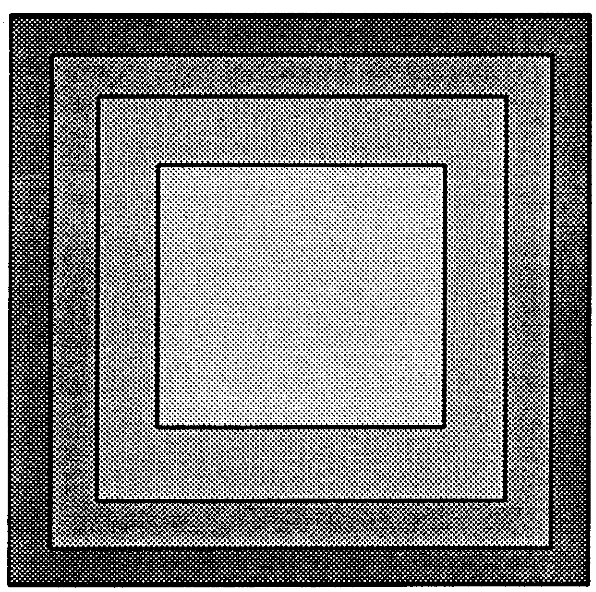
Researchers have also looked into the issues of safety in windowless buildings. Juillerat (1964) reviewed a number of serious fires in windowless buildings and concluded that their severity was accentuated by the inability to open windows to vent smoke and fire. People were unable to leave the building and firemen unable to enter. The total reliance on artificial illumination and ventilation also means that any emergency involving loss of power is a potentially dangerous. Consequently, there is a lurking fear of being trapped in such a building.

It is clear that people need daylight - zoning laws were originally formulated to ensure adequate light and air to the urban dweller. This started centuries ago with the Greeks and Romans and became written law in mid-nineteenth century Britain. However, with an increasing confidence in the abilities of modern environmental technology has come an attitude of designing buildings without regard to the environment around. This in turn has led to modifications of zoning laws which now do not preserve light and air as urban amenities. It is interesting to compare this situation with that in European countries, some of which need proof that a non-daylit workspace requires daylight to be absent in order to allow its activities to be carried out. The default status in Europe is a daylit workspace. Daylight implies a relationship between the user and the natural variations and tempos of day and season, something that has been lacking in most modern urban environments. For many people concerned with the quality of urban life, the bond that daylight can forge between people and natural cycles is its most critical contribution.

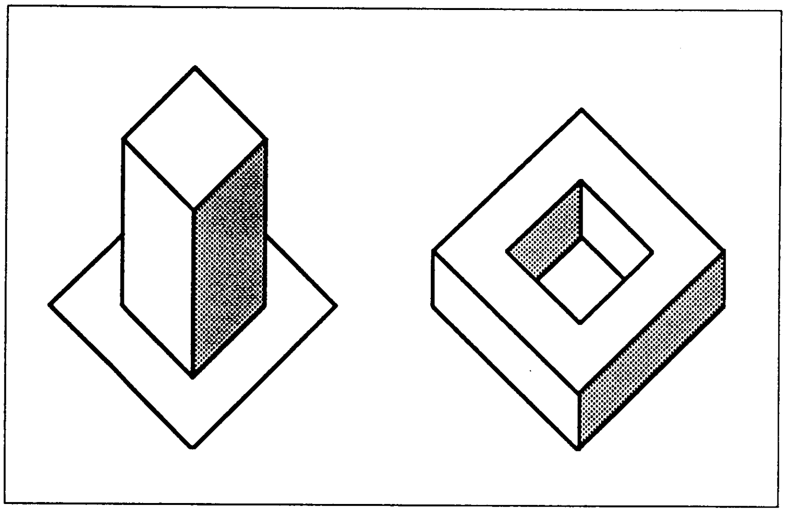
References :

[1] Robbins, 1986, pp. 26-27
[2] Selkowitz, in Bryan et. al., 1981, p. 3-23
[3] Robbins, 1986, p. 7
[4] Bryan, 1983.
[5] Villecco, in Bryan et. al., 1981, p. 5-11
[6] Harris et. al., 1981, p. 90
[7] Cohen and Cohen, 1983, p. 13
[8] Anon, 1964, pp. 265-269
[9] Hollister, 1968
[10] Plant, 1970, pp. 292-296
[11] Hollister, 1968
[12] Manning, 1967, pp. 20-25
[13] Ruys, 1970
[14] SolarVision, 1982, p. 10
[15] SolarVision, 1982, p. 9
[16] Dietz et. al., 1976, p. 66
[17] Wurtman, 1975, pp. 68-77
[18] Dietz et. al., 1976, p. 58
[19] Dietz et. al., 1976, p. 122

Now that the need for a daylit office environment has been established, how do we go about designing one in the most efficient way? This chapter will address how one can bring together two often conflicting requirements - a deep-plan building and the need for daylight. The solution lies not in the expensive high-rise building but in an essentially broad, low building with multiple atria. In the mid-1960s, professors at Cambridge University were involved in some interesting studies on efficient land use, which resulted in the publishing of *Land Use and Built Form* by Professors Leslie Martin and Lionel March in 1966. It specifically addressed what might be called the "classical" comparisons between court and pavilion forms of building, and set out the relative efficiency of courtyard forms of development compared to tower and slab forms. They used the example of a Fresnel square - a square divided into concentric bands of decreasing



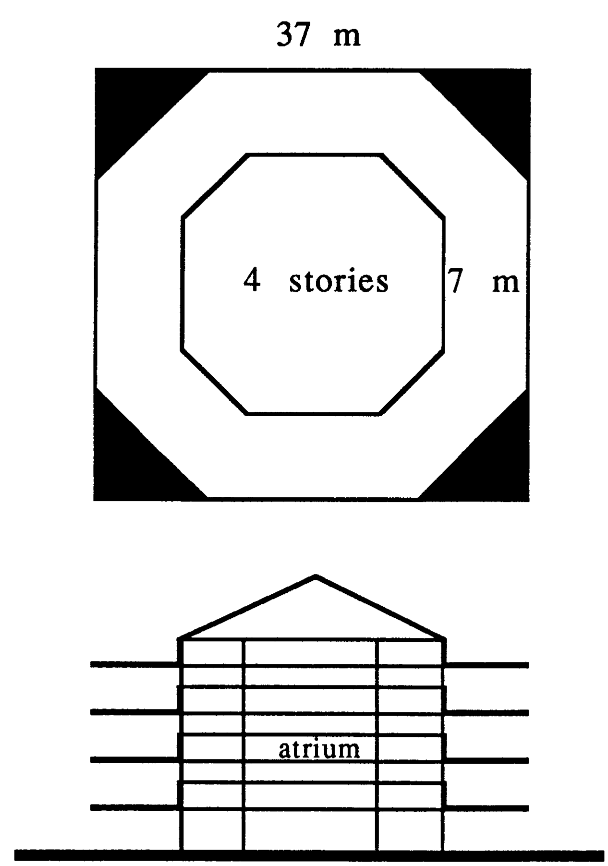
A Fresnel square. Each shaded space is of equal area



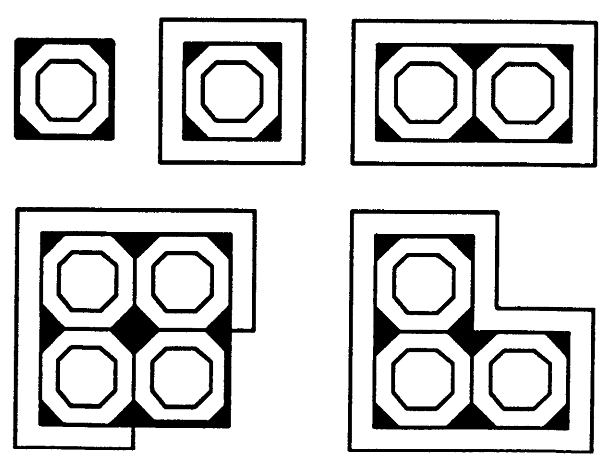
Both alternatives have the same floor area, but the courtyard one is 1/3rd as high

width outwards. All bands are however of equal area and equal to the area of the central square. The eye finds this hard to perceive; it sees a central quadrangle as of apparently greater area than an equal area of pavement around a building. This demonstrated clearly that land and energy had been wasted in piling up space set back from plot boundaries. The generous set-backs, verges and plazas of the mid-century town-planner were shown to be the mathematical complement to high building. The same floor-space could be delivered in relatively low buildings by arranging them around the perimeter of the site, and resulting in a generous quadrangle in the middle - the plan of a typical medieval Cambridge college. This "land use and built form" theory encouraged a reaction against high-rises in Britain and Europe e.g. Frederick Gibberd built Arundel Great Court in London of six stories where previously he would have had 15-story towers.

The 1978 studies by Dean Hawkes and Richard MacCormac which studied the minimum size court needed for daylighting surrounding space, have suggested a discipline for building up multiple court layouts[1]. This project started from an enthusiasm for the quality of rooflit courts - ambiguous inside/outside spaces such as in Wright's Larkin building or Aalto's Rautatalo building. The potential of the court as an efficient user of energy was the main subject of examination and the study is a critique of conventional wisdom that the thermally most efficient built form is one shaped closest to a cube. The question was whether a balance could be achieved between the variables of built form which would offer both the inherent economy of a daylit and naturally ventilated building and the low external surface area of a deep-plan arrangement. Initial studies concentrated on a single court and the space associated with



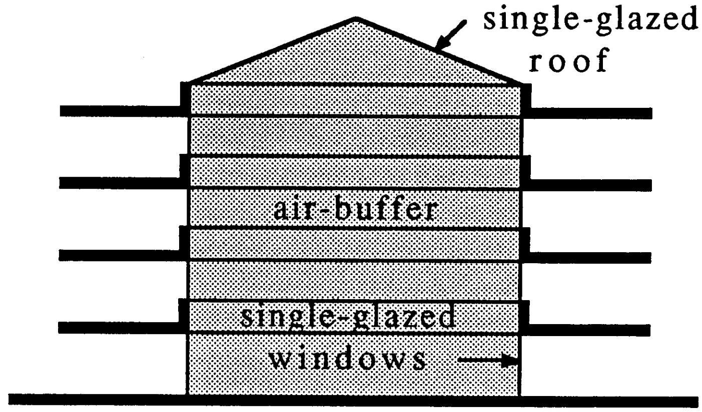
Plan and section of a single court and the space associated with it it. Using models, the authors developed a module of space able to be naturally lit to office background illumination levels for the months of April to September in the U.K. The court was 21m square, daylighting a four storied building upto a depth of 7m. Next, the thermal conditions in both the court and the office space were estimated mathematically. It was assumed that the office roof was well insulated, the court roof was double glazed and that the windows between the office space and the court were single glazed. The results showed that the summer temperature in both spaces would be acceptable provided that most direct solar gain could be excluded from the court. This could be achieved by a variety of means and detailed analysis showed that a reversed north-light configuration would offer an acceptable compromise between solar control and the admission of daylight. With this, the peak temperature in the court would be of the order of 25°C and in the top floor offices less than 24°C. The winter analysis showed that the temperature in the court due to heat lost to it from the offices would be of the order of 13°C. The study did not allow for the benefits of passive solar gain in the winter months. Despite this, the



Suggested possibilities for multiple-court layouts annual energy consumption calculations showed an 80% savings over a conventional office building and even a surprisingly large 68% savings over a deep-plan office. Of course, these calculations are based on an infinite series of courts in both directions. In actual buildings, the edge condition will inevitably increase the energy consumtion of the building as a whole, and the savings over deep plans would be 38%, 44% and 50% in one, two and four court plans respectively. These results show the economies of scale which one would expect from those forms which maximize court-side office space relative to perimeter space.

MacCormac's Spitalfields Study is also based on the "courtyard array" concept developed at Cambridge University. He employed atria at the smallest possible scale to generate intricate ground-covering development[2]. The ability of such a plan to light space from inside the block overcomes the lack of light on boundary lines which restricts development on many city sites.

If covered, these courts could be used to create a buffer effect. The full force of external climate - air temperature, radiation, wind and water - would no longer fall on the membrane protecting the occupants (the court wall), but be dissipated on the buffer surface (the court roof). The atrium concept uses as little outer surface to buffer as much inner surface as possible. In a cube-shaped atrium with roof-glazing, the roof area buffers four times as much wall. The savings on wall-insulation and waterproofing can probably pay for the roof[3]. The British Building Regulations also recognise the beneficial effect of unheated buffer space, and treat the atrium as a form of giant double-glazing. As the atrium wall + the enclosed space +



Buffer thinking - a giant double-glazing!

the atrium roof will together form a system of insulation, walls do not need to have specific insulation value where they divide full heated space from partially or completely unheated enclosed space. Unheated space does not need insulation from outside. Thus a glazed court can have minimal walls between it and occupied space and be within the regulations.

It should be noted that the energy economy of buffer spaces is only fully achieved if no attempt is made to keep the spaces themselves comfortable all year round. They should be lightly constructed and will be colder in winter and warmer in summer than the fully-conditioned spaces they protect. Uses in the buffer zone need therefore to be seasonally appropriate - perhaps being used only for circulation on the first floor all year round. Buildings with expensively heated and cooled courts are missing the energy point.

One of the advantages of a deep-plan building is that it is quiet inside, unlike many tower buildings which are affected by noise from the streets around. However, the courtyard array can ensure a quiet office in a far more humane environment. Courtyard planning is known to be acoustically good, and sound absorbers like court vegetation can only help improve this.

In this thesis, we are considering relatively small courts, ones which will suffice for daylighting purposes. They will not provide distant panoramic views, but the view content is not so crucially important when one considers that the attempt is to improve upon a space which has no windows at all. A view may be good or bad, beautiful or ugly, dynamic or stable, but it is always different from the scene within the interior space. Most people will be satisfied if they can look out, even if the view is somewhat restricted.

The economics of atrium buildings are very competitive with those of conventional building forms. This generalized claim may surprise, given the established and often repeated subjective assessment that atrium buildings are "extravagant", that they "waste space", and are "luxurious". Indeed, there are many atrium buildings - often hotels - laid out in an opulent manner. Neverthless, it should be noted that the underlying concept is not the cause of the high cost - it is the lavish finishings needed in the hotel industry and the air-conditioning of the atrium which contribute to the escalation of costs.

As a broad generalization, construction costs per square foot tend to rise with building height and decrease with increasing plan-depth. Of all the ways of arranging a given amount of space, the likely lowest cost version will be the deep-plan low-rise solution; the most expensive will be a slim tower. We have discussed at length the physiological and psychological reasons for maintaining access to daylight and thus limiting plan-depth. Besides, a deep-plan has a strong effect on operating cost and often on commercial value. To show the comparison between deep- and shallow-planning, Goran Lundquist's Swedish study[4] compared a low-rise linear atrium office with a deep-plan form of the same number of floors. The atrium building was 6.5% more expensive in capital terms but overtook the deep-plan building on life-cycle costing. If plan-depth is limited for these reasons, the courtyard array layout will deliver larger and thus fewer floors than the slab or tower equivalent. This is its basic capital-cost advantage. It will have a simpler frame, less "real" external wall and fewer elevators and stairs. These savings more than offset any higher costs due to fire-defence systems. It will be constructed more easily and rapidly, reducing the effects of inflation and interest charges[5].

The courtyard array plan should be looked at not only as an investment value in terms of life-cycle costing, but also as an investment in the welfare of the organization's employees and thus an investment in the company's future. The focal space created by a court may in addition combat the fragmentation of decentralized organizations. Planning departments or sections around a court may well help create that group spirit and company loyalty so beloved of all managers!

References :

[1] Hawkes and MacCormac, 1978, p. 246-248

[2] Saxon, 183, pp. 52-53

[3] Saxon, 183, p. 57

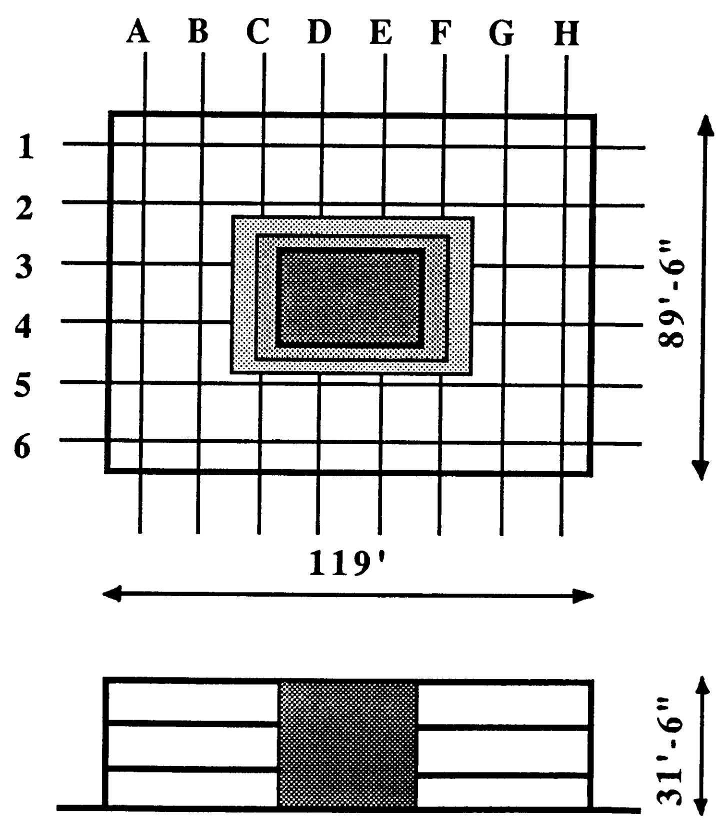
[4] Lundquist, 1980

[5] Saxon, 183, p. 159

Now that we have decided to use a scheme with multiple courts, the next step is to determine efficient dimensions for such courts. A court which is too small may not suffice for ambient daylighting levels within the building, and a too large court wastes valuable site area. A major obstacle to daylighting design is the lack of simple and accurate design analysis methods. Many design methods have been developed - these range from tables to protractors and computer programs, but none provides the combination of reliability, accuracy and dynamic response that an architect needs. Calculations are at best a representation, or simplification, of reality. All computer programs are thus constrained models of reality, and do not take into account important elements of daylit design like light shelves and reflections off adjacent buildings. The daylight designer must therefore approach all such programs and calculations as useful, but not conclusive information. Physical modelling of a daylight design is therefore critical. Such a model is valuable for predicting both the quality and quantity of daylight and can reveal lighting gradients, specific glare problems and the effects of building form and finishes.

A physical scale model is the most reliable daylighting evaluation tool as the physics of light deems that an exact scale model tested under the same sky will yield identical results. Relatively crude models can give surprisingly accurate results - both in a quantitative evaluation of daylight by light meter measurements and a qualitative evaluation of the quality of light. Physical models are especially useful when a single design element is varied, with all the others kept constant.

To evaluate the lighting and energy performance of a courtyard array, it is clearly necessary to carry out model studies. These studies will be done using physical models for daylighting and computer simulations for calculating overall energy performance and operating costs. Physical daylighting models are needed to make the first strategic design decision - the proportions of the court itself. This aspect ratio, the ratio between its width, length and depth, will govern the rate of decay of light levels in the court. To measure this, three daylighting models were constructed. As the models had to be large enough to use with a light meter, but small enough to carry to the site, they were constructed to a scale of 1/4" to 1'. The models were only for daylight testing, and so were simple, quick and dirty compared to



Plan and section of the daylighting model showing the 15' measurement grid and the three court sizes conventional architectural models and dealt only with basic dimensions, openings and surfaces. Opaque, white modelling boards were used to construct all major components which were then glued together. Each model consisted of one "courtyard array" module - a court surrounded by a three-storied building with the far walls assumed adiabatic in nature. Only the sectional proportions of the court were varied in the models. The ratio of court wall height to court breadth were 4:3 at first, then 1:1 and finally 4:5 in the third model. Physical scale models require a degree of flexibility to allow for easy manipulation of single-element design comparisons. By means of some careful planning, one basic model was used as the starting-point for all three models.

The following factors remained constant in every case:

1. All three models had 3 stories resulting in a total height of 31'-6". This is because we are dealing with low-rise office layouts in the "courtyard array" style. An open office layout free of interior partitions and thus conducive to daylighting was assumed.

2. All models had a central rectangular court. The plan proportion of each court was 1:2, with the longer sides facing north and south. Thus the court in the first model was 23'-9" x 35'-6" in plan; in the second 31'-6" x 47'-3"; and in the third 39'-6" x 59'. In locations north of the Tropic of Cancer, the sun is always in the southern half of the sky. As a result, having a longer wall facing south is advantageous for daylight penetration. Besides, as the sun rises in the east and sets in the west, the east and west facades get low morning and evening sun which is difficult to control. Shorter east and west facades clearly mean smaller areas have to be controlled with shading devices in this way. It should be clarified that all direct sun is not a nuisance. Careful and intentional use of daylight can result in a sparkling court which significantly enhances the overall environment.

3. The office building around the court had a single 30 foot deep bay in all directions, simulating a single module of the courtyard array. Daylighting has little chance to penetrate beyond this already great depth. The clear floor height in each model was 9 feet and the floor-to-floor height was 10'-6", as this is normal U.S. design practice for multi-story office buildings.

4. The court walls were in one plane for each side i.e. they did not step in any manner. Many atria have stepped sections, with floors moving closer together down the court. While this improves lighting near the windows, stepped sections have disadvantages too. Floors get deeper towards the base of the block, exactly where least daylight is available to them. They are also structurally problematic.

5. The walls were designed to maximize daylight penetration. For this, the reflectivity of the sides is very important. For the lower stories lit from an atrium, the "sky" is the reflective wall opposite them. If the walls are of floor-to-ceiling glass, or are completely open, very little light will bounce off them to travel downwards to lower stories. At the theoretically opposite extreme, if there are no openings, and a highly reflective surface to the walls, light will lose very little intensity in its travels. The logical outcome of this concept is that the fenestration for each floor level should differ. Consequently, the top story should have had very little window, with lower down progressively more glass until full glazing was reached at the lowest level. However, the benefit from such a wall treatment would be difficult to measure without a base case. As a result, the fenestration at each level was kept constant in the experiments. Each window had a sill height of 2'-6" and head height of 9', and extended in a continuous band around the court except for structural supports. All opaque walls were white, as white is the most reflective color and will maximize daylight availability.

Sidelighting through windows generally utilizes only diffuse radiation. Direct solar gain, although occassionally pleasant, often leads to overheating and thermal discomfort. Therefore, solar controls were needed. The model used light shelves 3' wide on the south-facing window, positioned 7' above floor level. A light shelf is a horizontal or inclined baffle in the window, placed just above eye level but as far below ceiling level as possible. Sunlight is stopped from passing straight to the floor close to the window, and reflected back onto the ceiling by the shelf. Much more even distribution of light within the room is achieved, and views of the bright upper part of the window are cut off, easing contrast problems. The light shelf optimizes daylighting efficiency and control from upper window without compromising the view and visual comfort below.

External shading devices (like the light shelf) and not reflective or tinted glass were used to control problems of excessive heat and glare. Reflective glass, because it tends to lower the apparent brightness of the outside, tends to depress people. In addition, buildings with this glass need artificial illumination even when the external wall is over 60% glazed. When exterior illumination is low, as at night, the glass becomes a mirror and reflects the interior. This effect, which is intermittent even during the day, results in peripheral distraction to the occupant. It is a common misconception that low transmission glass eliminates the need for shielding from direct sun glare. Even glass of 10%

transmission will not help, and shading devices are always required to ensure comfortable conditions[1]. Clear glass has the highest benefit of heat and light received versus thermal loss.

Before testing, the plan orientation of the space in relation to North was noted, and hatches / access holes in the walls created to allow for the introduction of the light meter. As there was no glazing in the model itself, measurements were factored to reflect actual glazing conditions. The models were tested outdoors, in MIT's Killian Court. A large space like Killian Court is necessary to avoid local obstructions like trees and buildings. Field measurements were taken in absolute footcandle values, and later converted to relative measurements as the relative approach accounts for varying sky conditions. The daylight factor method, which uses the ratio of interior illumination to horizontal sky illumination was considered the most appropriate. A photometer with a remote photosensor was used for accurate measurements. As the meter was color corrected, it was sensitive only to the visible portions of the spectrum. It was also cosine corrected so that the photosensor response was in accordance with the cosine law of illumination. A reference grid marked on the floors helped position the sensor within the model. All hatches and access holes were tightly sealed before reading the value from the photometer.

[There are several other techniques for increasing daylight penetration e.g. silvered reflective Venetian blinds and controllable reflecting or refracting devices. No attempt was made to use these piped or beam daylighting techniques for deeper penetration into the office, as I believe that an essential component of a person's desire for a daylit office environment is the need to look out and away occassionally. As a person's distance from the window increases, the window appears smaller, and there is a change in sensation. From being part of the external world, the person becomes a mere observer and the view becomes just another picture on the wall, not a three dimensional reality. Beam daylighting, with people 40 feet away from a window faces this problem. Piped daylighting is an even more extreme case, with often no windows at all and "daylight" being radiated out of light fixtures much like an electric light. Another important issue is achieving simplicity and low cost in these devices without sacrificing performance[2].]

Tables of the absolute illumination levels in the models appear on the following pages. The values are in footcandles, and have been reduced by 40% to correct for the reduced transmittivity of double-glazing, the presence of window framing members and dirt collection on glazed surfaces. Since these readings were taken on three successive spring afternoons, the light levels on the east side are higher than those on the west. In some cases, direct sun caused interior illumination levels to exceed 1000 footcandles. This generally occurs on the east side of the court. In this context it must be emphasized that the purpose of the experiment was to get a general idea about good proportions for a daylighting court. The readings are not meant to be taken as absolute evidence upon which other major conclusions can be drawn.

The tables of illumination levels are followed by three corresponding tables of daylight factors. The daylight factor at an interior point is the ratio of interior illumination at that point to the horizontal sky illumination measured outside the model at the same time. Since each session of model readings took almost three hours, the horizontal sky illumination level was taken every half-hour; and while determining the daylight factors, the corresponding horizontal sky illumination levels were used. The Appendix contains tables of the standard horizontal global clear and overcast sky illumination levels in Boston over the entire year.

The United States does not have a minimum requirement for daylight factor levels in a building. However, comparable British standards require a daylight factor of 2.0 for offices without any electric lighting. These standards have been derived using an overcast sky illumination of 500 footcandles, far less than the typical sky illumination in Boston. For these models, as we are assuming that only the ambient light component will be provided by daylight, a daylight factor of 1.0 will be more than sufficient. It must be remembered that the derived daylight factors are somewhat specific to the time of day and season, and if used to project interior illumination levels at other times of the year are likely to result in partly warped estimates. Again, this is largely due to the clear sky conditions which increase by large amounts the light levels where direct sun is visible.

From a study of the daylight factor values, and the standard clear and overcast sky illumination measured on a horizontal plane in Boston over the entire year; it can be seen that all three models performed well. The physical scale modelling proves that every point in a module of a courtyard array with these proportions will get sufficient daylight for its ambient light requirements. At this juncture, it must be reemphasised that daylight levels in only a small portion of such a module will be able to meet both ambient and task lighting requirements. In the rest of the area, permanent supplementary artificial task-lighting will be required. In all areas, daylighting is assumed to eliminate the ambient lighting load, thus reducing the overall lighting load from 2 Watts/sq.ft. to 1 Watt/sq.ft. This is, of course, in addition to offering the physiological and psychological benefits detailed in earlier chapters. The effect of this load reduction on energy consumption and operating costs will be determined by computer simulations in the next chapter.

References :

[1] Egan, 1983, p. 190
[2] Selkowitz, in Bryan et. al., 1981, p. 3-25

		A	B	C	D	E	F	G	H
	3	71	67	71	79	74	61	50	31
1	2	49	59	64	69	62	53	37	27
	1	36	52	56	59	52	38	32	28
	3	80	156	162	135	116	85	67	40
2	2	65	106	112	103	91	76	61	32
	1	52	62	76	91	68	51	38	30
	3	88	304	2736			222	144	37
3	2	83	223	2622			193	99	31
	1	61	120	235			166	67	29
	3	56	180	221			237	131	51
4	2	68	148	169			199	100	48
	1	50	92	127			161	74	46
	3	91	159	188	174	122	94	79	67
5	2	67	103	136	121	92	66	53	44
	1	41	63	91	62	46	38	27	24
	3	58	106	130	113	101	71	59	55
6	2	50	82	92	71	58	48	38	32
	1	41	59	61	48	40	35	32	28

Illumination levels (in foot-candles) for Model 1. The court height to breadth ratio was 4:3

		A	B	C	D	E	F	G	H
	3	88	97	101	89	79	55	44	40
1	2	62	83	77	72	62	47	37	31
	1	24	28	37	40	35	29	25	26
	3	147	187	188	202	169	103	58	47
2	2	106	160	155	185	151	103	60	50
	1	50	56	105	144	124	91	43	32
	3	368	1800					97	33
3	2	308	1770					91	30
	1	32	47					53	21
	3	373	1830					91	32
4	2	319	1800					61	28
	1	33	51					50	24
	3	246	312	338	296	229	116	53	44
5	2	204	292	316	270	141	92	53	43
	1	136	199	213	142	94	62	45	34
	3	132	163	175	154	101	68	51	40
6	2	109	153	151	130	91	64	45	41
	1	89	116	112	106	69	49	37	34

Illumination levels (in foot-candles) for Model 2. The court height to breadth ratio was 1:1

		A	B	C	D	E	F	G	H
	3	127	158	166	155	145	115	80	68
1	2	129	157	182	178	146	111	95	77
	1	102	117	129	125	103	80	62	52
	3	203	308	345	322	278	207	116	78
2	2	179	263	349	324	264	208	124	95
	1	154	217	293	280	217	166	92	70
	3	326	2796					231	88
3	2	311	2406					217	91
	1	315	1428					200	89
	3	432	3372					239	93
4	2	421	3126					225	92
	1	422	2130					193	90
	3	241	406	488	427	370	241	116	74
5	2	259	473	606	524	422	199	114	84
	1	274	550	714	589	314	143	89	67
	3	151	238	280	232	202	146	91	67
6	2	164	272	298	272	229	140	92	67
	1	180	324	364	310	220	127	76	59

Illumination levels (in foot-candles) for Model 3. The court height to breadth ratio is 1:1

		A	B	C	D	E	F	G	H
	3	1.0	1.0	1.0	1.2	1.1	0.9	0.7	0.5
1	2	0.7	0.9	0.9	1.0	0.9	0.8	0.5	0.4
	1	0.5	0.8	0.8	0.9	0.8	0.6	0.5	0.4
	3	1.3	2.5	2.6	2.1	1.8	1.4	1.1	0.6
2	2	1.0	1.7	1.8	1.6	1.4	1.2	1.0	0.5
	1	0.8	1.0	1.2	1.4	1.1	0.8	0.6	0.5
	3	1.7	5.7	51.6			4.2	2.7	0.7
3	2	1.6	4.2	49.5			3.6	1.9	0.6
	1	1.2	2.3	4.3			3.1	1.3	0.6
	3	1.1	3.4	4.2			4.5	2.5	1.0
4	2	1.3	2.8	3.2			3.8	1.9	0.9
	1	0.9	1.7	2.4			3.0	1.4	0.9
	3	1.4	2.5	3.0	2.8	1.9	1.5	1.3	1.1
5	2	1.1	1.6	2.2	1.9	1.5	1.1	0.8	0.7
	1	0.7	1.0	1.4	1.0	0.7	0.6	0.4	0.4
	3	0.9	1.6	1.9	1.7	1.5	1.0	0.9	0.8
6	2	0.7	1.2	1.4	1.0	0.9	0.7	0.6	0.5
	1	0.6	0.9	0.9	0.7	0.6	0.5	0.5	0.4

Daylight Factor levels for Model 1. The court height to breadth ratio is 4:3

		A	B	C	D	E	F	G	H
	3	2.0	2.2	2.3	2.0	1.8	1.3	1.0	0.9
1	**2**	1.5	2.0	1.8	1.7	1.5	1.1	0.9	0.7
	1	0.6	0.7	0.9	1.0	0.9	0.7	0.6	0.7
	3	3.0	3.8	3.8	4.1	3.4	2.1	1.2	0.9
2	**2**	2.2	3.4	3.2	3.9	3.2	2.2	1.3	1.1
	1	1.1	1.2	2.3	3.1	2.7	2.0	0.9	0.7
	3	9.8	48.1					3.2	1.1
3	**2**	8.8	50.5					3.3	1.1
	1	1.0	1.4					2.1	0.8
	3	10.0	48.9					3.0	1.1
4	**2**	9.1	51.4					2.2	1.0
	1	1.0	1.6					2.0	0.9
	3	4.4	5.6	6.1	5.3	4.1	2.1	1.0	0.8
5	**2**	3.8	5.4	5.9	5.0	2.6	1.7	1.0	0.8
	1	2.6	3.8	4.1	2.7	1.8	1.2	0.9	0.7
	3	2.1	2.6	2.8	2.2	1.5	1.1	0.8	0.7
6	**2**	1.8	2.6	2.5	2.2	1.5	1.1	0.8	0.7
	1	1.5	2.0	1.9	1.8	1.2	0.9	0.6	0.6

Daylight Factor levels for Model 2. The court height to breadth ratio is 1:1

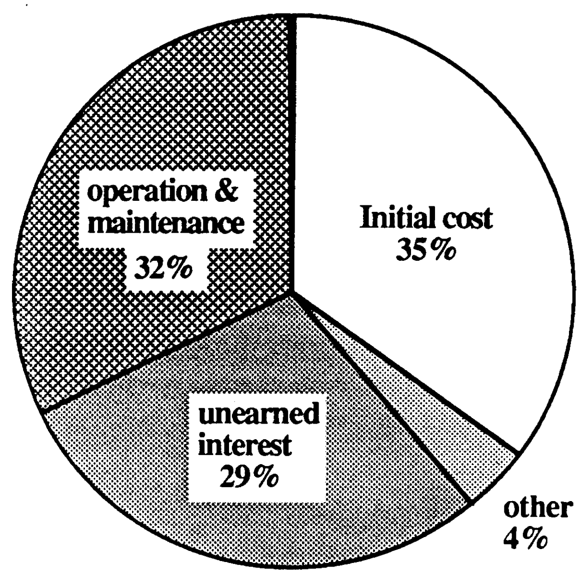
		A	B	C	D	E	F	G	H
	3	1.8	2.3	2.4	2.2	2.1	1.7	1.2	1.0
1	2	1.8	2.3	2.6	2.6	2.1	1.6	1.4	1.1
	1	1.6	1.8	2.0	2.0	1.6	1.3	1.0	0.8
	3	3.0	4.5	5.1	4.7	4.1	3.0	1.7	1.1
2	2	2.6	3.8	5.1	4.7	3.9	3.0	1.8	1.4
	1	2.2	3.2	4.3	4.1	3.2	2.4	1.3	1.0
	3	5.5	47.5					4.3	1.7
3	2	5.5	42.1					4.2	1.8
	1	5.7	25.8					4.0	1.8
	3	7.3	57.2					4.5	1.7
4	2	7.4	54.8					4.4	1.8
	1	7.6	38.5					3.9	1.8
	3	3.5	5.9	7.1	6.2	5.4	3.5	1.7	1.1
5	2	3.8	6.9	8.9	7.7	6.2	2.9	1.7	1.2
	1	4.0	8.1	10.5	8.7	4.6	2.1	1.3	1.0
	3	2.2	3.4	4.0	3.3	2.9	2.1	1.3	1.0
6	2	2.4	3.9	4.3	3.9	3.3	2.0	1.3	1.0
	1	2.6	4.7	5.2	4.5	3.2	1.8	1.1	0.9

Daylight Factor levels for Model 3. The court height to breadth ratio is 4:5

This thesis has approached the issue of improving the office environment in an attempt to find an economic solution which can be easily implemented. There are many factors which affect the economic evaluation of a building scheme. As pointed out in Chapter 1, the major component of life-cycle operating costs for an office building is the salaries of people working in the building. Any scheme which is proved to result in even a marginal increase in productivity should be summarily preferred. Intuitively it appears that a scheme with daylighting would create a better work environment in which the worker would be encouraged to give of his or her best. However, productivity estimates are difficult to quantify; and behavioral scientists are faced with no simple task in addressing this problem.

Other costs incurred relate to the first costs of constructing the building and recurring costs of operating and maintaining the building. A daylit scheme would have greater first costs than a deep-plan non-daylit one simply because of increased external wall and glass areas. There then remains the operating costs factor. As can be seen from the accompanying pie-diagram, these operation and maintenance costs are a significant fraction of the non-salary life-cycle costs of an office building[1]. As the issue of productivity levels seems to be unquantifiable at this time, this chapter will see whether a daylit building will prove cheaper to operate than a non-daylit one, and thus be of advantage over the life-cycle of the building.

Daylighting implies large windows or skylights. Though windows are beneficial in this sense, as their insulation values are low many architects are concerned that



Non-salary costs associated with an office building over its life span

the heat loss and gain through them will lead to an imbalance in the overall thermal equation. They fear that a daylit building will gain too much heat in summer and lose too much heat in winter; without an equivalent and thereby cost-effective reduction in the lighting load. The issue of power conservation through daylighting has been discussed in Chapter 2, but not in a quantitative way. The physical and mathematical daylight analysis methods discussed in the Chapter 4 have also dealt only with the illumination aspects of daylight design. As daylighting involves thermal trade-offs which need evaluation it would be useful to quantify the thermal performance and operating costs of such a building. To this end, two computer simulations were run using Solar 5[2], an excellent microcomputer program which calculates the energy performance of a building. As the physical models described in Chapter 4 proved sufficient to meet ambient daylighting standards, one such daylit module was compared with a non-daylit deep-plan module.

Solar 5 has several input screens which request the user to enter comprehensive data about the building. The first screen asks the user to enter the location of the project, the building type and its total floor area. Successive screens handle climate data (site conditions and thermal design conditions); sunshade, window and glazing design; envelope design; internal loads; HVAC system design and rates for electricity and gas. The input tables from the Solar 5 simulations are on the following pages. To compare the energy performance of two buildings, several factors had to be constant.

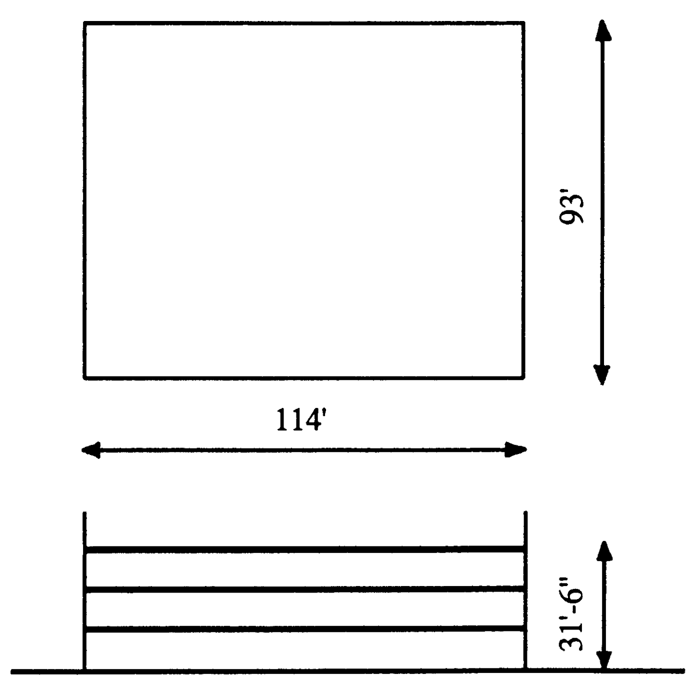
1. Clearly the most important is the usable square footage of the building. The total floor area of the non-daylit module was 31,806 sq.ft. and of the daylit module was 31,824 sq.ft. The marginal difference is due to the different number of floors in each module (the reason for this is explained in detail below).

2. Another important factor is the "footprint" of the building - the area of the site it will require. For any building with a constant total floor area, its footprint is inversely proportional to its height. This means that a non-daylit building covering an entire site would have less floors than court-daylit building on the same site. Conversely, if the number of floors is the same, a court-daylit building will have larger plan dimensions than a non-daylit one. For the purpose of this simulation, it was considered more critical to keep the footprint constant rather than to retain the same number of floors. This is because in many cases the footprint issue is of critical importance to developers. Also, since a developer would be interested in building an entire floor rather than just a part of it, the module (and court) sizes were modified to ensure that in both alternatives complete floors were constructed.

3. All other details e.g. climate data, orientation of the building, thermal design conditions, U-values of building components, internal loads (except lighting power density), HVAC system design and electricity and gas rates were kept constant in both alternatives. The input data is typical of a lowrise office building in Boston.

These factors resulted in the following module configurations:

Non-daylit : plan dimensions 113' x 92', with the longer sides facing North and South. 3 stories, with a total height of 31'-6"; and no windows.

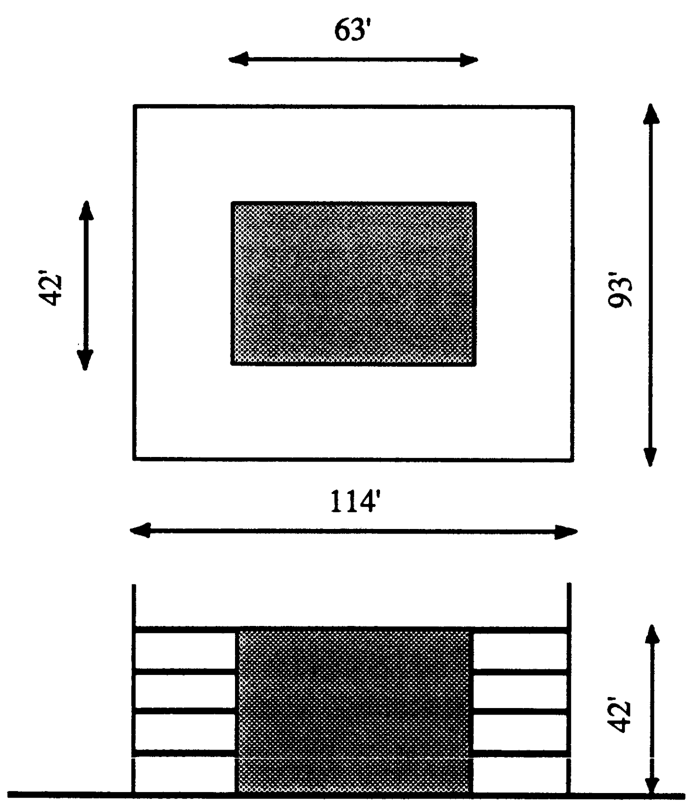


Plan and section of the non-daylit module

Total area 31,806 sq.ft., with
10,602 sq.ft. per floor.

Daylit : plan dimensions 113' x 92', with
an internal court 63' x 42' having its
longer sides facing North and South.
4 stories, with a total height of
42'; and courtside windows similar to
the physical models.
Total area 31,824 sq.ft., with
7,956 sq.ft. per floor.

In the daylit configuration, the court height to breadth ratio was 1:1 and the breadth to length ratio 2:3; both values



Plan and section of the daylit module with its internal court identical to the median physical scale model ratio. It was assumed that daylight can provide ambient illumination upto a depth of 25' from the window. This assumption is supported by data collected from the physical scale models as well as Richard MacCormac's form studies (see Chapter 3). This leads to a difference in the Solar 5 input value for lighing power density. In the non-daylit module this was input as 2 Watts/sq.ft. and in the daylit module was 1 Watt/sq.ft.

Three types of non-graphical output from Solar 5 have been included in the Appendix. The hourly summary tells us how each component of the module will perform on every hour of a typical day for each month. It also summarises the operating cost on the basis of the electricity and gas rates input earlier.

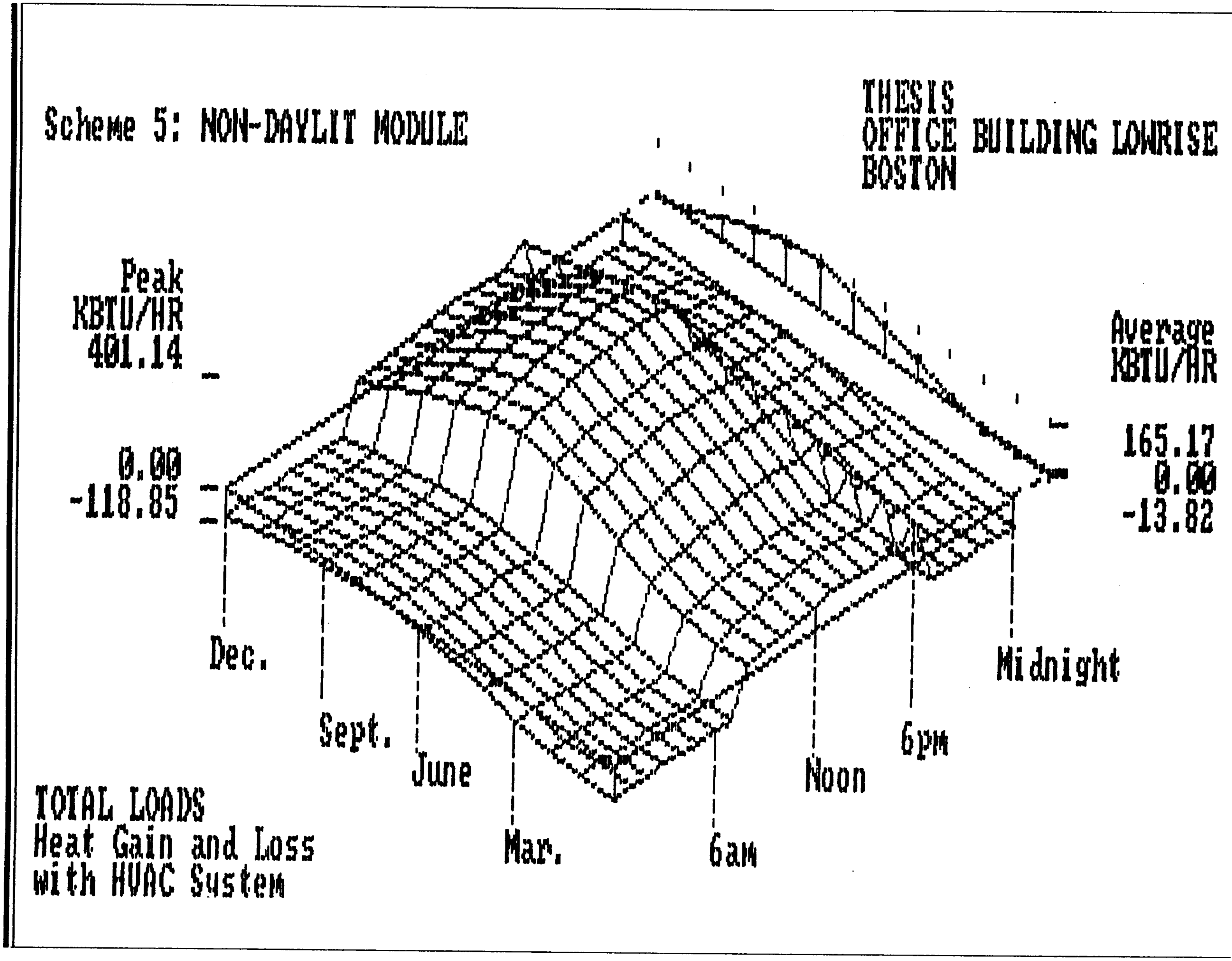
The monthly summary tells us what will be the heat loss and gain each month, component by component. The program also computes gross and net heat gains and losses.

The annual summary shows the annual heat loss, heat gain, and gross and net gains and losses. It also computes these values in terms of KBtu per square foot of the building.

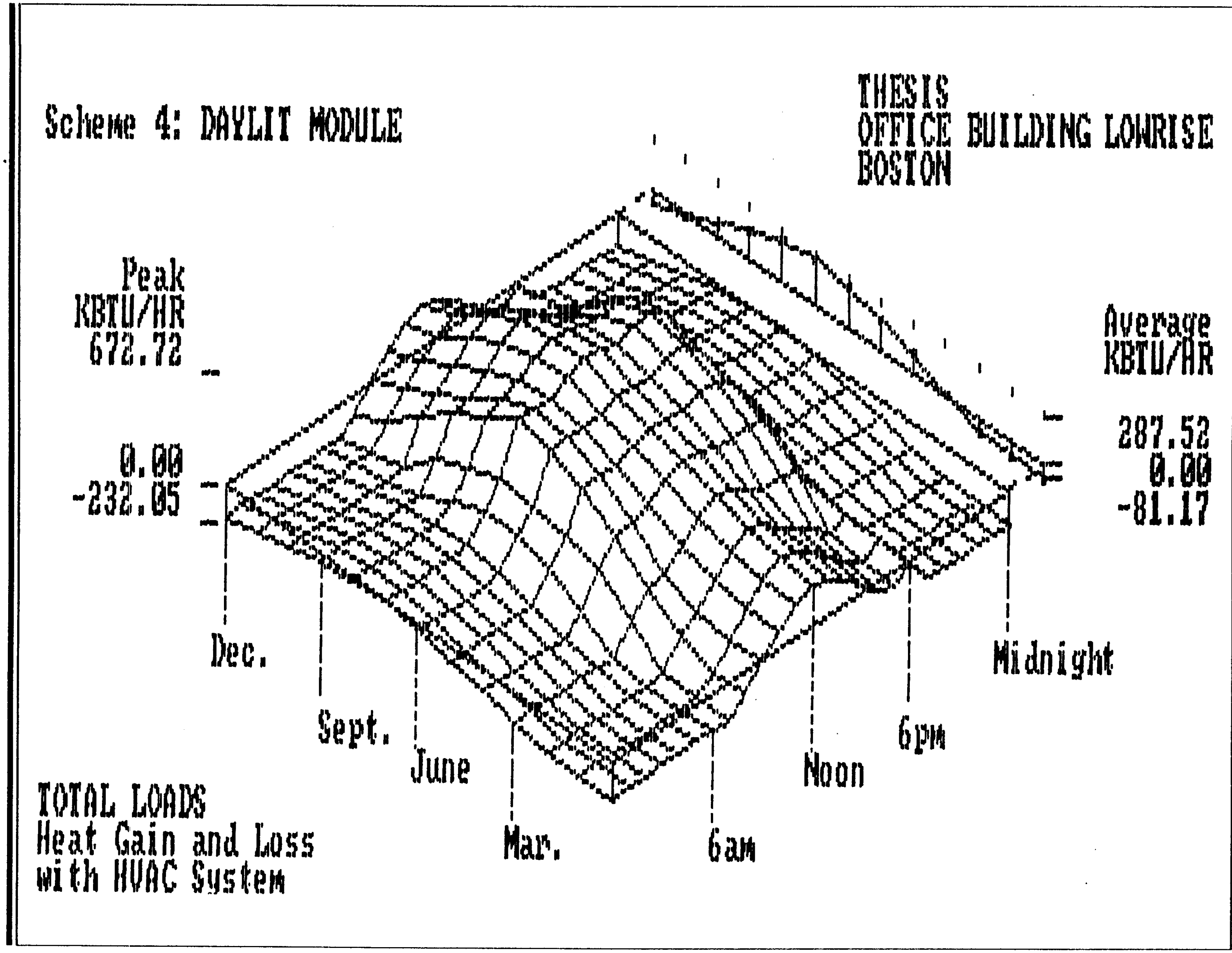
On the basis of these hourly calculations, Solar 5 derives several types of 3-dimensional graphs. These show the annual performance of any selected variable - for every hour of a typical day of each month. Two such graphs for each alternative are on the following pages: the first showing the total energy loads, and the second the total energy cost for a single module. All variables are measured from a base plane equal to zero, with positive values above it and negative values below. These graphs must be read with care as the vertical scales are normalized and therefore vary from plot to plot depending on the overall magnitude of the values.

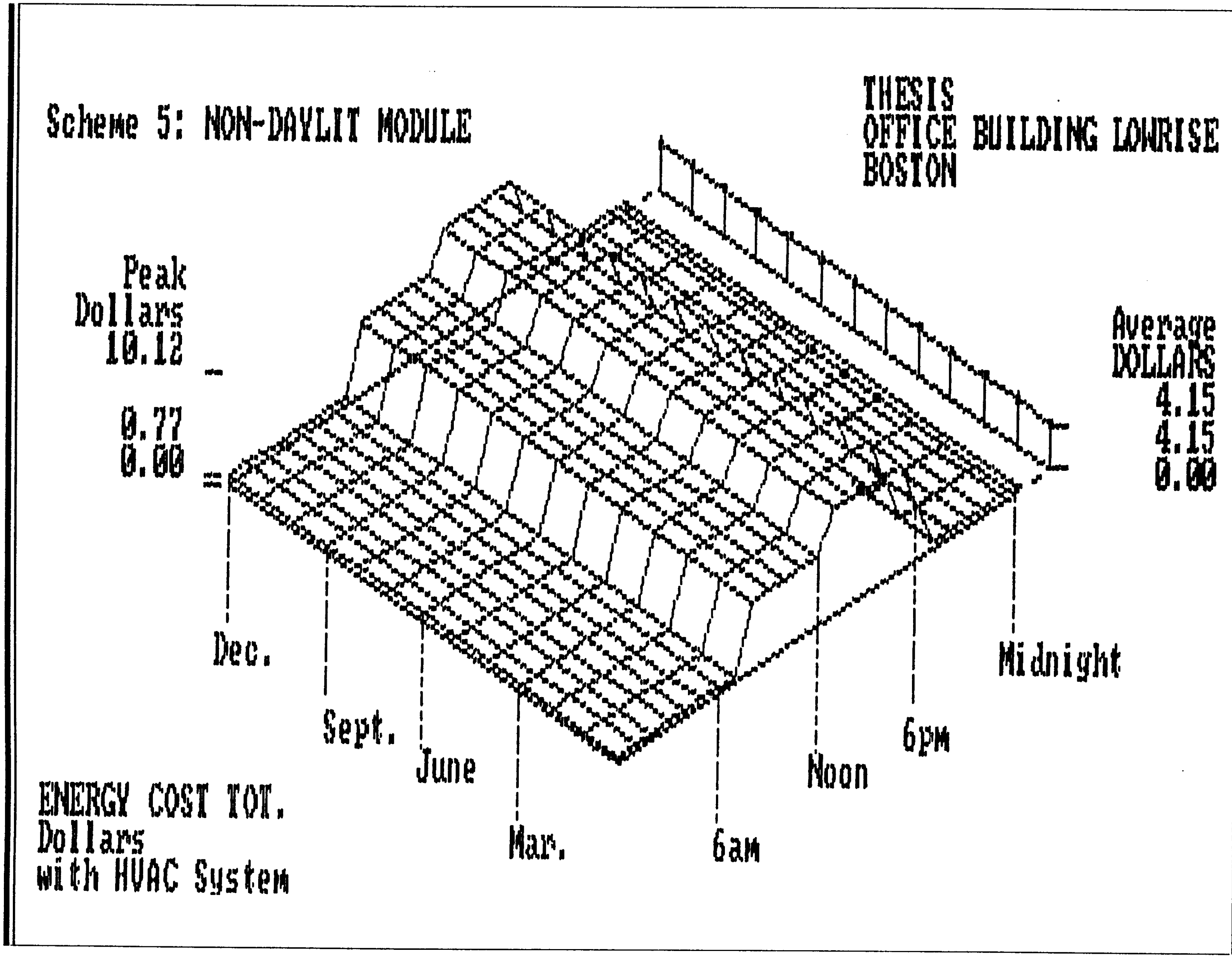
From the Solar 5 output two comparisons can be made between the alternatives - one comparing gross heat loss and gain per square foot; and the other comparing the operating cost per square foot. The gross heat loss and gain for the daylit module works out to 1869 MBtu, or 58.73 KBtu per square foot. This compares with a gross heat and gain of 1174 MBtu for the non-daylit module, or 36.91 KBtu per square foot. However, gross heat loss and gain values are no indication of the amount of energy which will actually be consumed, or - as we shall see - even give an idea of the operating cost of the building.

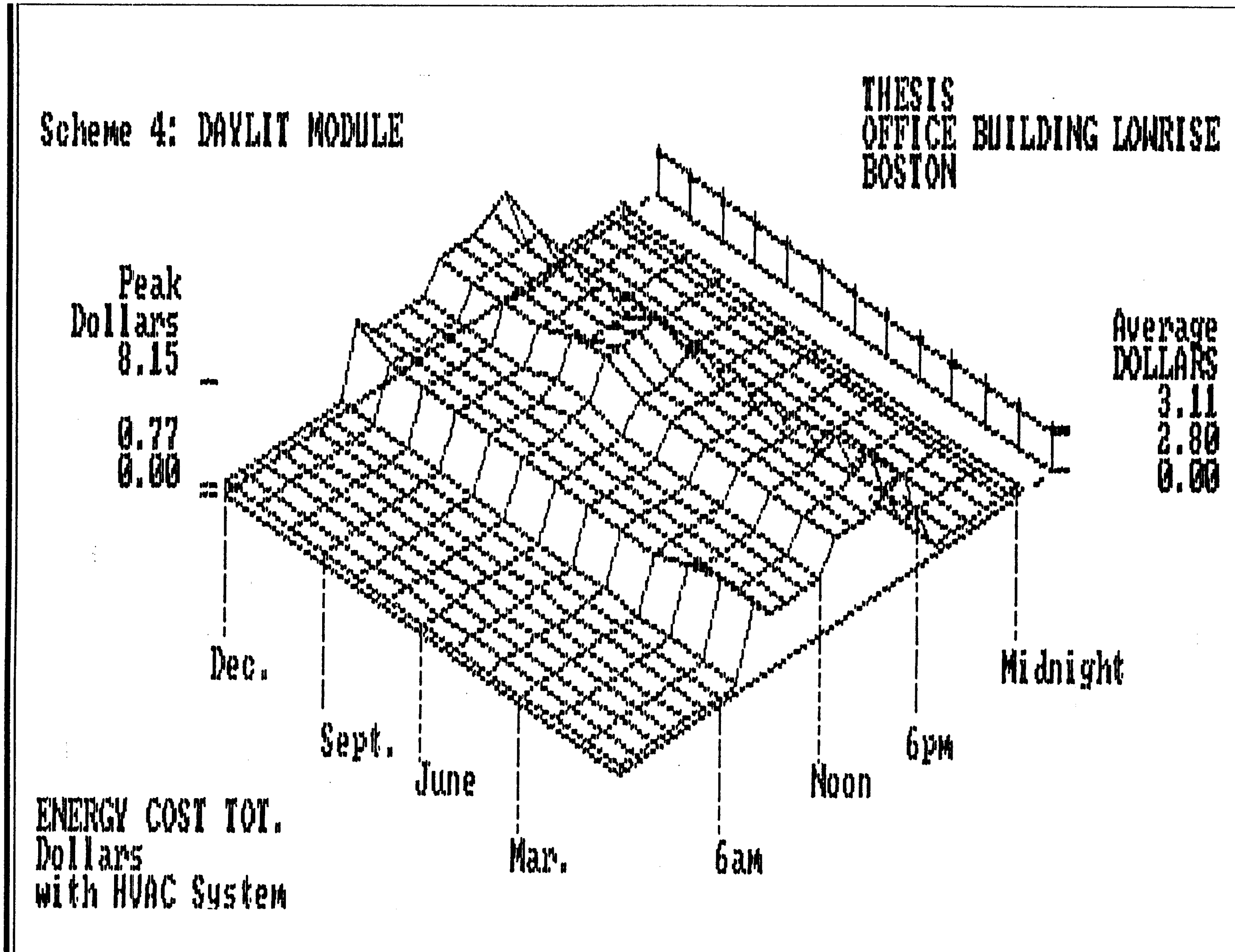
A look at the output tables in the Appendix shows that neither alternative uses the HVAC system to any great extent, and the primary component of the operating cost should therefore be the direct cost of lighting the building. As one alternative is partially daylit while the other relies totally upon electricity for all its lighting needs, one can expect a clear difference in operating costs. The daylit module shows an overall operating cost of $25,112, or $0.79 per square foot. This compares with an overall operating cost of $36,354 for the non-daylit module, or $1.14 per square foot. This saving of 35¢ per square foot, i.e. over 30% in operating costs is a remarkable one, directly attributable to the use of daylight in the building. Other graphs show that during office hours the lighting and cooling costs (electricity costs) decrease by $1.20 per square foot from the non-daylit scheme to the ambient daylit one; while heating costs (gas costs) increase by only 16¢ per



Scheme 5: NON-DAYLIT MODULE
THESIS
OFFICE BUILDING LOWRISE
BOSTON
Peak
KBTU/HR
401.14
0.00
-118.85
Average
KBTU/HR
165.17
0.00
-13.82
Dec.
Sept.
June
Mar.
6am
Noon
6pm
Midnight
TOTAL LOADS
Heat Gain and Loss
with HVAC System


Scheme 4: DAYLIT MODULE
THESIS
OFFICE BUILDING LOWRISE
BOSTON
Peak
KBTU/HR
672.72
0.00
-232.05
Average
KBTU/HR
287.52
0.00
-81.17
Dec.
Sept.
June
Mar.
6am
Noon
6pm
Midnight
TOTAL LOADS
Heat Gain and Loss
with HVAC System


Scheme 5: NON-DAYLIT MODULE
THESIS
OFFICE BUILDING LOWRISE
BOSTON
Peak
Dollars
10.12
0.77
0.00
Average
DOLLARS
4.15
4.15
0.00
Dec.
Sept.
June
Mar.
6am
Noon
6pm
Midnight
ENERGY COST TOT.
Dollars
with HVAC System


Scheme 4: DAYLIT MODULE
THESIS
OFFICE BUILDING LOWRISE
BOSTON
Peak
Dollars
8.15
0.77
0.00
Average
DOLLARS
3.11
2.80
0.00
Dec.
Sept.
June
Mar.
6am
Noon
6pm
Midnight
ENERGY COST TOT.
Dollars
with HVAC System

square foot. This is partly because with current utility rates it costs only a third as much to produce a unit of heating as it costs to produce the same amount of cooling.

It must be noted that the effect of every additional KWHr consumed by the non-daylit building is magnified by the structured electricity rates. In our simulation, a three-level electricity rate with off-peak, mid-peak and on-peak rates and time-of-use surcharges was used. To determine the effect of the stepped rate structure, two more computer simulations were run using a flat rate throughout the day. (The average of the three rates - 7.129 ¢ per KWHr was used). The daylit module now shows an overall operating cost os $20,887, or 66¢ per square foot. This compares with an overall operating cost of $29,470 for the non-daylit module, or 93¢ per square foot. This saving of 27¢ per square foot is less than the 35¢ obtained with the structured electricity rate. Clearly, such a rate structure encourages the use of daylighting to help reduce peak power consumption. With more encouragement from the utility companies through a rate structure with larger steps, the incentive for the use of daylighting wil be even greater. (Please note that the tables and graphs for the flat rate runs have not been included in this thesis document.)

The hypothesis that a reduction in lighting loads due to daylighting would by far outweigh any additional heat gains and losses through the building envelope stands proved. This chapter has thus addressed the last outstanding issue against the incorporation of daylight into office buildings. However, there are many more economic variables the discussion of which is far beyond the scope of this thesis. An attempt has been made to discount their effect by comparing similar alternatives. For example, comparing schemes which have the same "footprint", thus eliminating the cost of land as a variable. To see where we stand after the initial chapters on "soft" qualitative issues and the final ones on "hard" quantitative calculations, the next - and concluding - chapter will recapitulate the advantages of a daylit building in a final summing-up.

References :

[1] Dell 'Isola, 1981, p. 3

[2] Solar 5 was developed by Professor Murray Milne with Denwun Lin and Rosemary Howley at the UCLA Graduate School of Architecture and Urban Planning; with support from the Building Systems Division of the U.S. Department of Energy and the UCLA Academic Senate.

The purpose of this thesis was to determine an economical way of improving the office environment. We have seen that the office environment affects an ever increasing number of people, a large proportion of whom are "knowledge workers", well educated and aware of their strengths. These workers are conscious of what they consider their rights, one of which is the right to a better workplace. From our initial studies of the cost of labor, it is clear that it is not economically sensible to coop people up in an environment where they cannot give of their best. This is because 90% of the life-cycle costs for an office building are in the salaries of the people working there, and a mere 10% for construction, maintenance and replacement of the facility. However, the American office worker in general continues to work in a deep-plan artificially-lit building, isolated from the environment around. While research on the exact quantitative effect of the environment on productivity has got bogged down in methodological issues, management should go ahead to improve the environment and thus make for happier employees. A more motivated person is better able to concentrate on the work in hand. The need to lobby for environments that both support the work of organizations and the people performing that work is apparent.

Every person has a biological need to be aware of relevant information about his or her environment, and light is a true environmental factor as much as air, water and temperature. We have seen that daylight and the view from clear windows help orient the office worker by providing a continuous flow of information about the world around. The daylighting research referenced showed us that the absence of windows causes disturbing side-effects, and their presence is beneficial in more than one physiological and psychological way. Researchers in the biological sciences continue to work on issues relating to the effect of light on the human being. It is clear that access to windows and daylighting has been considered the privilege of a managerial class for far too long.

However, daylighting is still commonly viewed as a fascination of only an isolated group of researchers who have little idea of the economic pressures and realities of the architecture profession. To determine if this view was really true, it was decided to adopt a quantitative approach from the mid-point of this thesis. As lighting-related costs account for 60% of total energy costs, and daylight is available exactly when the lighting load reaches its peak, it was hypothesised that an increased use of daylight would help reduce operating costs. This quantitative approach is in no way intended to devalue the important qualitative aspect of daylighting. It is meant to satisfy those who need a definite dollar value advantage to justify the incorporation of daylighting into their buildings.

The Cambridge University courtyard-array studies gave us the basic framework upon which the rest of this thesis developed. Physical daylighting model studies were carried out to determine an optimum size of court, and the resultant hard data used to drive computer simulations of energy consumption and operating costs. The physical model studies showed that a scheme consisting of a combination of small daylit courts lighting the adjacent office space is sufficient for ambient illumination levels. The computer runs comparing daylit and non-daylit alternatives with similar input data came out clearly in favor of the daylit scheme which had a 30% saving in operating costs. These savings are partly due to the stepped electricity rate structure recently adopted by utility companies. A more pronounced stepping system will further encourage the use of daylighting as a power conservation tool. The "daylit array" solution finally proposed is within the overall framework of a deep-plan and visualizes a grid of daylit courts upon which actual buildings can be planned.

Of course, every step to improve the office environment has its trade-offs. On a limited site, for example, a court-daylit building will necessarily be higher than a non-daylit building with the same floor area. In our computer simulations the daylit module is 4-storied, one floor higher than the non-daylit one. However, this thesis addresses the design of a deep-plan low-rise office building; and its extra floor will not push the daylit scheme out of this construction class. Building regulations and construction costs are therefore likely to be similar for both types of buildings. The economic evaluation did not propose to address every factor in an economic comparison. By eliminating the important "footprint" variable by careful planning of the alternatives, it presented a reasonable basis for comparison. The final trade-off will be between a somewhat increased initial construction cost on one hand, and lower operating costs coupled with the potential for dramatic productivity increases on the other.

What we have now is essentially a question for the management of the office to decide upon. We have proved that the theory of a daylit office space for all users is no pipe-dream, it is a sensible alternative well suited to the American corporation. It must be kept in mind that all construction, operation and maintenance costs are minor compared to the major costs associated with user salaries and benefits over the life of a building. It is clear that even the 30% saving in operating costs pales in comparison with the potential for increases in employee productivity by creating a good activity environment.

Seen in perspective, a daylit office implies a relationship between a worker and the natural variations and tempos of day and season, something that has been lacking in most urban environments. We must now lobby for zoning regulations which limit height and bulk and thus preserve the city dweller's right to daylight in an office as an urban amenity. For many people concerned with the quality of urban life, the bond that daylight can forge between people and natural cycles is its most critical contribution.

Month	Time	Global clear	Global overcast
	9	22346	5578
	10	34138	10348
	11	41567	13705
	12	44101	14909
JAN	13	41567	13799
	14	34138	10546
	15	22346	5616
	16	7439	876
	9	35450	9222
	10	47740	14230
	11	55462	17508
	12	58095	18664
FEB	13	55462	17446
	14	47740	14106
	15	35450	8972
	16	19471	3256
	17	2427	41
	9	49497	17641
	10	61905	23544
	11	69693	27161
	12	72348	28437
MAR	13	69693	26646
	14	61905	22938
	15	49497	17252
	16	33284	9586
	17	14434	2504

The values in the left column are horizontal global clear sky illumination levels (in lux) for Boston.

The values in the right column are horizontal global overcast sky illumination levels (in lux) for Boston.

Month	Time	Global clear	Global overcast
	9	63359	18188
	10	75524	22481
	11	83153	25421
	12	85752	26435
APR	13	83153	25421
	14	75524	22608
	15	63359	17757
	16	47428	11446
	17	28711	4879
	9	70366	18573
	10	81643	22710
	11	88707	25003
	12	91113	25809
MAY	13	88707	25275
	14	81643	22814
	15	70366	18671
	16	55563	13052
	17	38085	6847
	9	74228	17361
	10	85520	21220
	11	92595	23441
	12	95005	24193
JUN	13	92595	23558
	14	85520	21333
	15	74228	17336
	16	59414	12139
	17	41950	6520

Month	Time	Global clear	Global overcast
	9	69751	16272
	10	80736	20230
	11	87609	22528
	12	89949	23312
JUL	13	87609	22628
	14	80736	20278
	15	69751	16315
	16	55302	11148
	17	38170	5646
	9	60651	14746
	10	71822	19164
	11	78904	21780
	12	81293	22669
AUG	13	78904	21780
	14	71882	19095
	15	60651	14805
	16	45851	9245
	17	28224	3679
	9	49202	13272
	10	61428	18448
	11	69091	21684
	12	71701	22787
SEP	13	69091	21684
	14	61428	19106
	15	49202	13565
	16	33176	7448
	17	14423	1675

Month	Time	Global clear	Global overcast
	9	32875	9723
	10	44220	14729
	11	51320	18311
	12	53737	19766
OCT	13	51320	18211
	14	44220	14556
	15	32875	9388
	16	17981	3415
	17	1917	33
	9	21335	4373
	10	32708	8846
	11	39858	11922
	12	42295	12912
NOV	13	39858	11834
	14	32708	8846
	15	21335	4422
	16	6908	538
	9	16540	2881
	10	27793	7023
	11	34908	9915
	12	37336	10965
DEC	13	34908	9915
	14	27793	7023
	15	16540	2881
	16	3059	101

```
SOLAR5: Passive Solar Design Tool    (Released 8/86)    UCLA    1/ 1/80 23: 1
                                     Project Title:  THESIS
                                     Building Type:  OFFICE BUILDING LOWRISE
                                     Climate Data :  BOSTON
  CLIMATE DATA:


SITE CONDITIONS:  From ASHRAE Handbook and N.O.A.A. Climate Data Summary
       42.= Latitude
        6.= Winter Outdoor Design Low Temperature  Degrees F
       91.= Summer Outdoor Design High Temperature  Degrees F
     5634.= Heating Degree Days
                                 JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Temperature Average Daily Max.   37.  37.  47.  59.  68.  74.  84.  81.  73.  59.  42.  35.
Temperature Average Daily Min.   23.  23.  31.  40.  50.  59.  65.  63.  57.  47.  38.  27.



DESIGN CONDITIONS:  User Supplied Constraints for This Project
      68. = Lowest Indoor Comfort Temperature  Degrees F
      78. = Highest Indoor Comfort Temperature  Degrees F
    0.50 = Ground Reflectance  (vegetation=.25 new snow=.74)
       0. = Temperature Bias  (shifts average temperature curves up or down)
             0.=Average Curve as Input    1.=Hits Summer Design High
            -1.=Hits Winter Design Low   2.=Hits Summer High and Winter Low
```

```
SOLAR5: Passive Solar Design Tool    (Released 8/86)    UCLA    1/ 1/80 23: 2
                                      Project Title:   THESIS
                                      Building Type:   OFFICE BUILDING LOWRISE
                                      Climate Data :   BOSTON
 ENVELOPE DESIGN SUMMARY :
 Scheme 5: NON-DAYLIT MODULE

   114.00 = East-to-West Overall Dimension  FT.                          % of MAX
    93.00 = North-to-South Overall Dimension  FT.                        Envelope
   10602. = Area of the Largest Floor or Flat Roof  SQ.FT.               = 100.%
       3. = Number of Floors
   31806. = Total Floor Area  SQ.FT.                                     = 100.%
    10.50 = Floor to Floor Height  FT. (Effects Exterior Surface Areas)
     9.00 = Floor to Ceiling Height  FT.  (Effects Interior Volume)
  286254. = Total Volume of Occupied Space  CU.FT. (Interior)            = 100.%
       0. = Bearing Off True South (Clockwise is Positive)
```

```
 SURFACE AREA DESIGN SUMMARY :
 Scheme 5: NON-DAYLIT MODULE
```

	Area sq.ft.	% of Surface	Transmissivity Absorptivity	U-value	Time Lag	Decrement Factor
WINDOW SOUTH	0.SF	0.%	0.00	1.10		
WEST	0.SF	0.%	0.00	1.10		
NORTH	0.SF	0.%	0.00	1.10		
EAST	0.SF	0.%	0.00	1.10		
SKYLIGHT	0.SF	0.%	0.00	1.10		
WALLS SOUTH	0.SF	0.%	0.30	0.14	2.HRS	0.80
WEST	0.SF	0.%	0.30	0.14	2.HRS	0.80
NORTH	0.SF	0.%	0.30	0.14	2.HRS	0.80
EAST	0.SF	0.%	0.30	0.14	2.HRS	0.80
ROOF	10602.SF	100.%	0.40	0.07	2.HRS	0.70
FLOOR-RAISED	10602.SF	100.%		0.08	2.HRS	0.80
SLAB EDGES=	0.FEET	0.%		F=.34	24.HRS	0.00

Note: On 4 elevations percent of windows + walls does not equal 100%

```
SOLAR5: Passive Solar Design Tool    (Released 8/86)     UCLA    1/ 1/80 23: 3
                                       Project Title:  THESIS
                                       Building Type:  OFFICE BUILDING LOWRISE
                                       Climate Data :  BOSTON
  INTERNAL LOADS :
  Scheme 5: NON-DAYLIT MODULE


     0.2 = Infiltration Air Changes per Hour (eg. house=.5, sealed office=.1)
   318.1 = *Number of Occupants Total
   100.0 = *Floor Area for Each Occupant  SQ.FT./PERSON
    240. = BTU/HR of each Person: Sensible (eg. office work about 240.)
    160. = BTU/HR of each Person: Latent   (eg. office work about 160.)
  76334. = *Total Occupant Load  BTU/HR
      8. = HOUR When People Enter     (If They Never Leave Type 1.)
     17. = HOUR Before People Leave  (If They Never Leave Type 24.)
     2.0 = *Lighting Power Density  WATTS/SQ.FT.              ============
 216917. = *Total Lighting Load  BTU/HR  (at 3.41 BTU/WATT)    *These values
      8. = HOUR When Lights Are Turned On     (1. to 24.)      are  computed
     18. = HOUR Before Lights Are Turned Off (1. to 24.)       automatically
     0.5 = *Equipment Power Density  WATTS/SQ.FT.              but  you  may
  54229. = *Total Equipment Load  BTU/HR                       override them
      8. = HOUR When Equipment Is Turned On      (1. to 24.)   if  you  wish
     18. = HOUR Before Equipment Is Turned Off (1. to 24.)     ============
```

```
SOLAR5: Passive Solar Design Tool    (Released 8/86)     UCLA    1/ 1/80 23: 4
                                      Project Title:  THESIS
                                      Building Type:  OFFICE BUILDING LOWRISE
                                      Climate Data :  BOSTON
 HVAC SYSTEM DESIGN:
 Scheme 5: NON-DAYLIT MODULE


    3. Number of Heating-Cooling Systems: (0=Infiltration Only at Fixed Rate)
         (1=Vent Fans Only, 2=Heating+Venting, 3=Heating+Cooling+Venting)
  0.20 Infiltration Air Changes per Hour (eg. new house=.5, sealed office=.1)
 15.00 Fresh Air per Person CFM Required(eg. 30 if smoking, 15 if no smoking)
  6.00 Economizer Cooling Maximum Air Changes per Hour(eg. office=6. omit=0.)
 -5.00 Economizer Cooling Minimum Temperature Difference Required (eg.-15.F)
 65.00 Thermostat SetBACK during Occupied Nighttime Hours: 1am-6am(eg. 58.F)
 50.00 Thermostat SetBACK Temperature during Unoccupied Hours(eg. to 48.F)
 85.00 Thermostat Set-UP Temperature During Hot Unoccupied Hours(eg. 88.F)
 30.00 % Latent Load: added to Outside Air Cooling Load for Humidity(eg. 30%)
  3.10 Air Conditioner C.O.P. (good Coefficients of Performance= 2.8 to 3.3)
  0.86 Heating System  C.O.P. (usually Package Single Zone =.75, V.A.V.=.86,
                              Dual Duct =.65, Electric =1.0, Heat Pump =2.9)




 RATES FOR ELECTRICITY AND GAS:
 Scheme 5: NON-DAYLIT MODULE


1.08000 Gas Rate   $/THERM   (usually $1.08)  1 Therm = 100,000 BTU
0.05882 Electric Base Rate  $/KWHr Off-Peak (usually $.05882)  1 KWHr=3414 BTU
 560.00 Monthly Basic Charge or Connect Fee  $/MO.  (usually $560.00)
         Time-of-Use charges apply only to large buildings (over 500 KW)
         To eliminate them simply type in 0.0 for all 3 HOURS below.
     8. HOUR Mid-Peak Period Begins  (usually 8.)
    13. HOUR On-Peak  Period Begins  (usually 13.)
    18. HOUR  Off-Peak Period Begins  (usually 18.)
0.07052 Mid-Peak Rate  $/KWHr  (usually $.07052)
0.08452 On-Peak  Rate  $/KWHr  (usually $.08452)
   0.65 $/KW  Time-of-Use Mid-Peak Monthly Surcharge  (usually $0.65)
   5.05 $/KW  Time-of-Use On-Peak  Monthly Surcharge  (usually $5.05)
```

**** HOURLY SUMMARY **** SOLAR5 **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2:28

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** JANUARY ****

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	25.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-38.	0.	0.	0.	0.	-41.	-111.
2	24.83	0.	0.	0.	0.	0.	0.	0.	0.	0.	-33.	-39.	0.	0.	0.	0.	-42.	-113.
3	24.05	0.	0.	0.	0.	0.	0.	0.	0.	0.	-33.	-40.	0.	0.	0.	0.	-42.	-115.
4	23.47	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-40.	0.	0.	0.	0.	-43.	-117.
5	23.12	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-41.	0.	0.	0.	0.	-43.	-118.
6	23.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-41.	0.	0.	0.	0.	-43.	-119.
7	23.69	0.	0.	0.	0.	0.	0.	0.	0.	0.	-35.	-41.	0.	0.	0.	0.	-43.	-119.
8	25.64	0.	0.	0.	0.	0.	0.	0.	0.	0.	-38.	-45.	0.	217.	54.	76.	-223.	42.
9	28.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	-38.	-45.	0.	217.	54.	76.	-211.	55.
10	31.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-37.	-44.	0.	217.	54.	76.	-196.	70.
11	34.36	0.	0.	0.	0.	0.	0.	0.	0.	0.	-33.	-39.	0.	217.	54.	76.	-185.	91.
12	36.31	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-34.	0.	217.	54.	76.	-177.	107.
13	37.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-26.	-31.	0.	217.	54.	76.	-174.	116.
14	36.88	0.	0.	0.	0.	0.	0.	0.	0.	0.	-25.	-29.	0.	217.	54.	76.	-175.	119.
15	36.53	0.	0.	0.	0.	0.	0.	0.	0.	0.	-25.	-29.	0.	217.	54.	76.	-177.	117.
16	35.95	0.	0.	0.	0.	0.	0.	0.	0.	0.	-26.	-31.	0.	217.	54.	76.	-179.	111.
17	35.17	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-34.	0.	217.	54.	76.	-182.	103.
18	34.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	-33.	-39.	0.	217.	54.	0.	-39.	160.
19	33.12	0.	0.	0.	0.	0.	0.	0.	0.	0.	-28.	-34.	0.	0.	0.	0.	-34.	-96.
20	31.92	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-34.	0.	0.	0.	0.	-35.	-98.
21	30.65	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-35.	0.	0.	0.	0.	-36.	-100.
22	29.35	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-36.	0.	0.	0.	0.	-37.	-103.
23	28.08	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-36.	0.	0.	0.	0.	-38.	-106.
24	26.88	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-37.	0.	0.	0.	0.	-40.	-108.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	25.78		0.20	0.0		0.00	0.00	0.77	0.77		
2	24.83		0.20	0.0		0.00	0.00	0.77	0.77		
3	24.05		0.20	0.0		0.00	0.00	0.77	0.77		
4	23.47		0.20	0.0		0.00	0.00	0.77	0.77		
5	23.12		0.20	0.0		0.00	0.00	0.77	0.77		
6	23.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	23.69		0.20	0.0		0.00	0.00	0.77	0.77		
8	25.64		1.00	0.0		63.57	0.00	6.71	6.71		
9	28.44		1.00	0.0		63.57	0.00	6.71	6.71		
10	31.56		1.00	0.0		63.57	0.00	6.71	6.71		
11	34.36		1.00	0.0		63.57	0.00	6.71	6.71		
12	36.31		1.00	0.0		63.57	0.00	6.71	6.71		
13	37.00		1.00	0.0		63.57	0.00	10.12	10.12		
14	36.88		1.00	0.0		63.57	0.00	10.12	10.12		
15	36.53		1.00	0.0		63.57	0.00	10.12	10.12		
16	35.95		1.00	0.0		63.57	0.00	10.12	10.12		
17	35.17		1.00	0.0		63.57	0.00	10.12	10.12		
18	34.22		0.20	0.0		63.57	0.00	5.44	5.44		
19	33.12		0.20	0.0		0.00	0.00	0.77	0.77		
20	31.92		0.20	0.0		0.00	0.00	0.77	0.77		
21	30.65		0.20	0.0		0.00	0.00	0.77	0.77		
22	29.35		0.20	0.0		0.00	0.00	0.77	0.77		
23	28.08		0.20	0.0		0.00	0.00	0.77	0.77		
24	26.88		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2:30

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** FEBRUARY ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	25.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-39.	0.	0.	0.	0.	-41.	-112.
2	24.83	0.	0.	0.	0.	0.	0.	0.	0.	0.	-33.	-39.	0.	0.	0.	0.	-42.	-114.
3	24.05	0.	0.	0.	0.	0.	0.	0.	0.	0.	-33.	-40.	0.	0.	0.	0.	-43.	-116.
4	23.47	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-41.	0.	0.	0.	0.	-43.	-118.
5	23.12	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-41.	0.	0.	0.	0.	-43.	-118.
6	23.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-41.	0.	0.	0.	0.	-43.	-118.
7	23.69	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-41.	0.	0.	0.	0.	-41.	-117.
8	25.64	0.	0.	0.	0.	0.	0.	0.	0.	0.	-37.	-44.	0.	217.	54.	76.	-216.	50.
9	28.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	-38.	-45.	0.	217.	54.	76.	-203.	61.
10	31.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-34.	-40.	0.	217.	54.	76.	-192.	81.
11	34.36	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-35.	0.	217.	54.	76.	-183.	100.
12	36.31	0.	0.	0.	0.	0.	0.	0.	0.	0.	-26.	-31.	0.	217.	54.	76.	-177.	114.
13	37.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-27.	0.	217.	54.	76.	-175.	122.
14	36.88	0.	0.	0.	0.	0.	0.	0.	0.	0.	-22.	-26.	0.	217.	54.	76.	-176.	124.
15	36.53	0.	0.	0.	0.	0.	0.	0.	0.	0.	-22.	-26.	0.	217.	54.	76.	-178.	122.
16	35.95	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-28.	0.	217.	54.	76.	-180.	116.
17	35.17	0.	0.	0.	0.	0.	0.	0.	0.	0.	-26.	-31.	0.	217.	54.	76.	-184.	107.
18	34.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-36.	0.	217.	54.	0.	-39.	165.
19	33.12	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-35.	0.	0.	0.	0.	-34.	-99.
20	31.92	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-34.	0.	0.	0.	0.	-35.	-98.
21	30.65	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-35.	0.	0.	0.	0.	-37.	-101.
22	29.35	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-36.	0.	0.	0.	0.	-38.	-104.
23	28.08	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-37.	0.	0.	0.	0.	-39.	-107.
24	26.88	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-38.	0.	0.	0.	0.	-40.	-109.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	25.78		0.20	0.0		0.00	0.00	0.77	0.77		
2	24.83		0.20	0.0		0.00	0.00	0.77	0.77		
3	24.05		0.20	0.0		0.00	0.00	0.77	0.77		
4	23.47		0.20	0.0		0.00	0.00	0.77	0.77		
5	23.12		0.20	0.0		0.00	0.00	0.77	0.77		
6	23.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	23.69		0.20	0.0		0.00	0.00	0.77	0.77		
8	25.64		1.00	0.0		63.57	0.00	6.71	6.71		
9	28.44		1.00	0.0		63.57	0.00	6.71	6.71		
10	31.56		1.00	0.0		63.57	0.00	6.71	6.71		
11	34.36		1.00	0.0		63.57	0.00	6.71	6.71		
12	36.31		1.00	0.0		63.57	0.00	6.71	6.71		
13	37.00		1.00	0.0		63.57	0.00	10.12	10.12		
14	36.88		1.00	0.0		63.57	0.00	10.12	10.12		
15	36.53		1.00	0.0		63.57	0.00	10.12	10.12		
16	35.95		1.00	0.0		63.57	0.00	10.12	10.12		
17	35.17		1.00	0.0		63.57	0.00	10.12	10.12		
18	34.22		0.20	0.0		63.57	0.00	5.44	5.44		
19	33.12		0.20	0.0		0.00	0.00	0.77	0.77		
20	31.92		0.20	0.0		0.00	0.00	0.77	0.77		
21	30.65		0.20	0.0		0.00	0.00	0.77	0.77		
22	29.35		0.20	0.0		0.00	0.00	0.77	0.77		
23	28.08		0.20	0.0		0.00	0.00	0.77	0.77		
24	26.88		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2:32

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** MARCH ****

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	34.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-32.	0.	0.	0.	0.	-33.	-90.
2	33.34	0.	0.	0.	0.	0.	0.	0.	0.	0.	-25.	-33.	0.	0.	0.	0.	-34.	-93.
3	32.35	0.	0.	0.	0.	0.	0.	0.	0.	0.	-26.	-34.	0.	0.	0.	0.	-35.	-95.
4	31.61	0.	0.	0.	0.	0.	0.	0.	0.	0.	-26.	-35.	0.	0.	0.	0.	-36.	-97.
5	31.15	0.	0.	0.	0.	0.	0.	0.	0.	0.	-27.	-35.	0.	0.	0.	0.	-36.	-98.
6	31.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-27.	-36.	0.	0.	0.	0.	-35.	-98.
7	31.61	0.	0.	0.	0.	0.	0.	0.	0.	0.	-27.	-36.	0.	0.	0.	0.	-34.	-97.
8	33.34	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-42.	0.	217.	54.	76.	-181.	92.
9	35.94	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-38.	0.	217.	54.	76.	-170.	110.
10	39.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-25.	-33.	0.	217.	54.	76.	-159.	131.
11	42.06	0.	0.	0.	0.	0.	0.	0.	0.	0.	-21.	-27.	0.	217.	54.	76.	-148.	151.
12	44.66	0.	0.	0.	0.	0.	0.	0.	0.	0.	-17.	-23.	0.	217.	54.	76.	-139.	168.
13	46.39	0.	0.	0.	0.	0.	0.	0.	0.	0.	-14.	-19.	0.	217.	54.	76.	-133.	180.
14	47.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	-17.	0.	217.	54.	76.	-131.	186.
15	46.85	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	-17.	0.	217.	54.	76.	-132.	185.
16	46.39	0.	0.	0.	0.	0.	0.	0.	0.	0.	-14.	-19.	0.	217.	54.	76.	-134.	181.
17	45.65	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16.	-22.	0.	217.	54.	76.	-138.	172.
18	44.66	0.	0.	0.	0.	0.	0.	0.	0.	0.	-20.	-26.	0.	217.	54.	0.	-29.	195.
19	43.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	-19.	-26.	0.	0.	0.	0.	-24.	-69.
20	42.06	0.	0.	0.	0.	0.	0.	0.	0.	0.	-22.	-29.	0.	0.	0.	0.	-25.	-77.
21	40.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-21.	-28.	0.	0.	0.	0.	-27.	-76.
22	39.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-22.	-29.	0.	0.	0.	0.	-29.	-80.
23	37.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-30.	0.	0.	0.	0.	-30.	-83.
24	35.94	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-31.	0.	0.	0.	0.	-32.	-87.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	34.56		0.20	0.0		0.00	0.00	0.77	0.77		
2	33.34		0.20	0.0		0.00	0.00	0.77	0.77		
3	32.35		0.20	0.0		0.00	0.00	0.77	0.77		
4	31.61		0.20	0.0		0.00	0.00	0.77	0.77		
5	31.15		0.20	0.0		0.00	0.00	0.77	0.77		
6	31.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	31.61		0.20	0.0		0.00	0.00	0.77	0.77		
8	33.34		1.00	0.0		63.57	0.00	6.71	6.71		
9	35.94		1.00	0.0		63.57	0.00	6.71	6.71		
10	39.00		1.00	0.0		63.57	0.00	6.71	6.71		
11	42.06		1.00	0.0		63.57	0.00	6.71	6.71		
12	44.66		1.00	0.0		63.57	0.00	6.71	6.71		
13	46.39		1.00	0.0		63.57	0.00	10.12	10.12		
14	47.00		1.00	0.0		63.57	0.00	10.12	10.12		
15	46.85		1.00	0.0		63.57	0.00	10.12	10.12		
16	46.39		1.00	0.0		63.57	0.00	10.12	10.12		
17	45.65		1.00	0.0		63.57	0.00	10.12	10.12		
18	44.66		0.20	0.0		63.57	0.00	5.44	5.44		
19	43.44		0.20	0.0		0.00	0.00	0.77	0.77		
20	42.06		0.20	0.0		0.00	0.00	0.77	0.77		
21	40.56		0.20	0.0		0.00	0.00	0.77	0.77		
22	39.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	37.44		0.20	0.0		0.00	0.00	0.77	0.77		
24	35.94		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2:34

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** APRIL ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	44.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16.	-26.	0.	0.	0.	0.	-25.	-67.
2	42.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	-17.	-27.	0.	0.	0.	0.	-26.	-70.
3	41.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	-18.	-28.	0.	0.	0.	0.	-27.	-73.
4	40.72	0.	0.	0.	0.	0.	0.	0.	0.	0.	-19.	-29.	0.	0.	0.	0.	-27.	-74.
5	40.18	0.	0.	0.	0.	0.	0.	0.	0.	0.	-19.	-29.	0.	0.	0.	0.	-26.	-75.
6	40.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-19.	-29.	0.	0.	0.	0.	-25.	-74.
7	40.72	0.	0.	0.	0.	0.	0.	0.	0.	0.	-19.	-29.	0.	0.	0.	0.	-23.	-71.
8	42.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-34.	0.	217.	54.	76.	-130.	159.
9	45.86	0.	0.	0.	0.	0.	0.	0.	0.	0.	-19.	-29.	0.	217.	54.	76.	-118.	181.
10	49.50	0.	0.	0.	0.	0.	0.	0.	0.	0.	-15.	-23.	0.	217.	54.	76.	-106.	204.
11	53.14	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	-18.	0.	217.	54.	76.	-95.	224.
12	56.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-14.	0.	217.	54.	76.	-86.	241.
13	58.28	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-10.	0.	217.	54.	76.	-80.	253.
14	59.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-3.	-8.	0.	217.	54.	76.	-79.	258.
15	58.82	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2.	-8.	0.	217.	54.	76.	-80.	257.
16	58.28	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-9.	0.	217.	54.	76.	-83.	252.
17	57.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	-6.	-12.	0.	217.	54.	76.	-87.	242.
18	56.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9.	-16.	0.	217.	54.	0.	-19.	228.
19	54.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	-8.	-16.	0.	0.	0.	0.	-14.	-37.
20	53.14	0.	0.	0.	0.	0.	0.	0.	0.	0.	-12.	-21.	0.	0.	0.	0.	-16.	-48.
21	51.35	0.	0.	0.	0.	0.	0.	0.	0.	0.	-12.	-21.	0.	0.	0.	0.	-18.	-50.
22	49.50	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	-22.	0.	0.	0.	0.	-20.	-55.
23	47.65	0.	0.	0.	0.	0.	0.	0.	0.	0.	-14.	-23.	0.	0.	0.	0.	-22.	-59.
24	45.86	0.	0.	0.	0.	0.	0.	0.	0.	0.	-15.	-25.	0.	0.	0.	0.	-24.	-63.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	44.22		0.20	0.0		0.00	0.00	0.77	0.77		
2	42.78		0.20	0.0		0.00	0.00	0.77	0.77		
3	41.60		0.20	0.0		0.00	0.00	0.77	0.77		
4	40.72		0.20	0.0		0.00	0.00	0.77	0.77		
5	40.18		0.20	0.0		0.00	0.00	0.77	0.77		
6	40.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	40.72		0.20	0.0		0.00	0.00	0.77	0.77		
8	42.78		1.00	0.0		63.57	0.00	6.71	6.71		
9	45.86		1.00	0.0		63.57	0.00	6.71	6.71		
10	49.50		1.00	0.0		63.57	0.00	6.71	6.71		
11	53.14		1.00	0.0		63.57	0.00	6.71	6.71		
12	56.22		1.00	0.0		63.57	0.00	6.71	6.71		
13	58.28		1.00	0.0		63.57	0.00	10.12	10.12		
14	59.00		1.00	0.0		63.57	0.00	10.12	10.12		
15	58.82		1.00	0.0		63.57	0.00	10.12	10.12		
16	58.28		1.00	0.0		63.57	0.00	10.12	10.12		
17	57.40		1.00	0.0		63.57	0.00	10.12	10.12		
18	56.22		0.20	0.0		63.57	0.00	5.44	5.44		
19	54.78		0.20	0.0		0.00	0.00	0.77	0.77		
20	53.14		0.20	0.0		0.00	0.00	0.77	0.77		
21	51.35		0.20	0.0		0.00	0.00	0.77	0.77		
22	49.50		0.20	0.0		0.00	0.00	0.77	0.77		
23	47.65		0.20	0.0		0.00	0.00	0.77	0.77		
24	45.86		0.20	0.0		0.00	0.00	0.77	0.77		

$$$$ HOURLY SUMMARY $$$$ SOLARS $$$$ HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) $$$$ 4/ 8/87 2:37

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

$$$$ MAY $$$$

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	54.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9.	-20.	0.	0.	0.	0.	-16.	-45.
2	52.64	0.	0.	0.	0.	0.	0.	0.	0.	0.	-10.	-21.	0.	0.	0.	0.	-17.	-48.
3	51.52	0.	0.	0.	0.	0.	0.	0.	0.	0.	-10.	-22.	0.	0.	0.	0.	-17.	-49.
4	50.69	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	-22.	0.	0.	0.	0.	-17.	-50.
5	50.17	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	-22.	0.	0.	0.	0.	-16.	-49.
6	50.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	-22.	0.	0.	0.	0.	-14.	-47.
7	50.69	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	-25.	0.	0.	0.	0.	-12.	-50.
8	52.64	0.	0.	0.	0.	0.	0.	0.	0.	0.	-14.	-26.	0.	217.	54.	76.	-81.	226.
9	55.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-10.	-21.	0.	217.	54.	76.	-71.	246.
10	59.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-6.	-15.	0.	217.	54.	76.	-60.	266.
11	62.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2.	-11.	0.	217.	54.	76.	-52.	283.
12	65.36	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-7.	0.	217.	54.	76.	-45.	298.
13	67.31	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	-4.	0.	217.	54.	76.	-40.	307.
14	68.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-2.	0.	217.	54.	76.	-39.	311.
15	67.83	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-2.	0.	217.	54.	76.	-40.	311.
16	67.31	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	-3.	0.	217.	54.	76.	-44.	305.
17	66.48	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	-6.	0.	217.	54.	76.	-49.	295.
18	65.36	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9.	0.	217.	54.	0.	-10.	252.
19	64.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-8.	0.	0.	0.	0.	-6.	-13.
20	62.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	-3.	-13.	0.	0.	0.	0.	-8.	-24.
21	60.76	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-18.	0.	0.	0.	0.	-10.	-35.
22	59.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-6.	-16.	0.	0.	0.	0.	-12.	-33.
23	57.24	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-17.	0.	0.	0.	0.	-14.	-38.
24	55.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-8.	-19.	0.	0.	0.	0.	-15.	-42.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	54.00		0.20	0.0		0.00	0.00	0.77	0.77		
2	52.64		0.20	0.0		0.00	0.00	0.77	0.77		
3	51.52		0.20	0.0		0.00	0.00	0.77	0.77		
4	50.69		0.20	0.0		0.00	0.00	0.77	0.77		
5	50.17		0.20	0.0		0.00	0.00	0.77	0.77		
6	50.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	50.69		0.20	0.0		0.00	0.00	0.77	0.77		
8	52.64		1.00	0.0		63.57	0.00	6.71	6.71		
9	55.56		1.00	0.0		63.57	0.00	6.71	6.71		
10	59.00		1.00	0.0		63.57	0.00	6.71	6.71		
11	62.44		1.00	0.0		63.57	0.00	6.71	6.71		
12	65.36		1.00	0.0		63.57	0.00	6.71	6.71		
13	67.31		1.00	0.0		63.57	0.00	10.12	10.12		
14	68.00		1.00	0.0		63.57	0.00	10.12	10.12		
15	67.83		1.00	0.0		63.57	0.00	10.12	10.12		
16	67.31		1.00	0.0		63.57	0.00	10.12	10.12		
17	66.48		1.00	0.0		63.57	0.00	10.12	10.12		
18	65.36		0.20	0.0		63.57	0.00	5.44	5.44		
19	64.00		0.20	0.0		0.00	0.00	0.77	0.77		
20	62.44		0.20	0.0		0.00	0.00	0.77	0.77		
21	60.76		0.20	0.0		0.00	0.00	0.77	0.77		
22	59.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	57.24		0.20	0.0		0.00	0.00	0.77	0.77		
24	55.56		0.20	0.0		0.00	0.00	0.77	0.77		

```
****      HOURLY SUMMARY       **** SOLARS ****      HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU)      ****    4/ 8/87  2:39
                                   Project Title:    THESIS
                                   Building Type:    OFFICE BUILDING LOWRISE
                                   Climate Data :    BOSTON
```

**** JUNE ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	62.75	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2.	-14.	0.	0.	0.	0.	-8.	-24.
2	61.48	0.	0.	0.	0.	0.	0.	0.	0.	0.	-3.	-15.	0.	0.	0.	0.	-8.	-26.
3	60.43	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-16.	0.	0.	0.	0.	-9.	-28.
4	59.65	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-16.	0.	0.	0.	0.	-8.	-29.
5	59.16	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-17.	0.	0.	0.	0.	-8.	-28.
6	59.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-17.	0.	0.	0.	0.	-6.	-27.
7	59.45	0.	0.	0.	0.	0.	0.	0.	0.	0.	-6.	-19.	0.	0.	0.	0.	-5.	-30.
8	60.75	0.	0.	0.	0.	0.	0.	0.	0.	0.	-8.	-21.	0.	217.	54.	76.	-51.	267.
9	62.75	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-16.	0.	217.	54.	76.	-43.	284.
10	65.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	0.	217.	54.	76.	-35.	300.
11	67.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	-7.	0.	217.	54.	76.	-28.	316.
12	70.25	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	-3.	0.	217.	54.	76.	-22.	329.
13	72.25	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.	-1.	0.	217.	54.	76.	-17.	338.
14	73.55	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.	1.	0.	217.	54.	76.	-14.	344.
15	74.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.	1.	0.	217.	54.	76.	-12.	346.
16	73.84	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.	0.	0.	217.	54.	76.	-13.	343.
17	73.35	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.	-2.	0.	217.	54.	76.	-16.	336.
18	72.57	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-4.	0.	217.	54.	0.	-3.	269.
19	71.52	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.	-3.	0.	0.	0.	0.	2.	6.
20	70.25	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	-8.	0.	0.	0.	0.	1.	-4.
21	68.82	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-13.	0.	0.	0.	0.	-1.	-15.
22	67.28	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-11.	0.	0.	0.	0.	-3.	-13.
23	65.72	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-12.	0.	0.	0.	0.	-5.	-17.
24	64.18	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-13.	0.	0.	0.	0.	-6.	-21.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	62.75		0.20	0.0		0.00	0.00	0.77	0.77		
2	61.48		0.20	0.0		0.00	0.00	0.77	0.77		
3	60.43		0.20	0.0		0.00	0.00	0.77	0.77		
4	59.65		0.20	0.0		0.00	0.00	0.77	0.77		
5	59.16		0.20	0.0		0.00	0.00	0.77	0.77		
6	59.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	59.45		0.20	0.0		0.00	0.00	0.77	0.77		
8	60.75		1.00	0.0		63.57	0.00	6.71	6.71		
9	62.75		1.00	0.0		63.57	0.00	6.71	6.71		
10	65.20		1.00	0.0		63.57	0.00	6.71	6.71		
11	67.80		1.00	0.0		63.57	0.00	6.71	6.71		
12	70.25		1.00	0.0		63.57	0.00	6.71	6.71		
13	72.25		1.00	0.0		63.57	0.00	10.12	10.12		
14	73.55		1.00	0.0		63.57	0.00	10.12	10.12		
15	74.00		1.00	0.0		63.57	0.00	10.12	10.12		
16	73.84		1.00	0.0		63.57	0.00	10.12	10.12		
17	73.35		1.00	0.0		63.57	0.00	10.12	10.12		
18	72.57		0.20	0.0		63.57	0.00	5.44	5.44		
19	71.52		0.20	0.0		0.00	0.00	0.77	0.77		
20	70.25		0.20	0.0		0.00	0.00	0.77	0.77		
21	68.82		0.20	0.0		0.00	0.00	0.77	0.77		
22	67.28		0.20	0.0		0.00	0.00	0.77	0.77		
23	65.72		0.20	0.0		0.00	0.00	0.77	0.77		
24	64.18		0.20	0.0		0.00	0.00	0.77	0.77		

```
$$$$        HOURLY SUMMARY        $$$$ SOLARS $$$$        HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU)        $$$$        4/ 8/87  2:41
                                        Project Title:  THESIS
                                        Building Type:  OFFICE BUILDING LOWRISE
                                        Climate Data :  BOSTON
```

$$$$ JULY $$$$

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	69.75	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	-9.	0.	0.	0.	0.	-2.	-8.
2	68.14	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	-11.	0.	0.	0.	0.	-2.	-11.
3	66.81	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-12.	0.	0.	0.	0.	-3.	-13.
4	65.82	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-12.	0.	0.	0.	0.	-2.	-14.
5	65.21	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-13.	0.	0.	0.	0.	-1.	-13.
6	65.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-12.	0.	0.	0.	0.	0.	-11.
7	65.57	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2.	-15.	0.	0.	0.	0.	2.	-15.
8	67.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-18.	0.	217.	54.	76.	-16.	308.
9	69.75	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	0.	217.	54.	76.	-8.	327.
10	72.85	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	-7.	0.	217.	54.	76.	3.	347.
11	76.15	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.	-3.	0.	217.	54.	76.	12.	365.
12	79.25	0.	0.	0.	0.	0.	0.	0.	0.	0.	11.	1.	0.	217.	54.	76.	20.	380.
13	81.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	14.	4.	0.	217.	54.	76.	27.	392.
14	83.43	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	6.	0.	217.	54.	76.	31.	399.
15	84.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	6.	0.	217.	54.	76.	32.	401.
16	83.79	0.	0.	0.	0.	0.	0.	0.	0.	0.	15.	5.	0.	217.	54.	76.	31.	398.
17	83.18	0.	0.	0.	0.	0.	0.	0.	0.	0.	13.	3.	0.	217.	54.	76.	27.	390.
18	82.19	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	2.	0.	217.	54.	0.	6.	291.
19	80.86	0.	0.	0.	0.	0.	0.	0.	0.	0.	13.	3.	0.	0.	0.	0.	11.	26.
20	79.25	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.	-2.	0.	0.	0.	0.	9.	15.
21	77.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-7.	0.	0.	0.	0.	7.	5.
22	75.49	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.	-5.	0.	0.	0.	0.	4.	6.
23	73.51	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	-6.	0.	0.	0.	0.	2.	1.
24	71.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-8.	0.	0.	0.	0.	0.	-4.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	69.75		0.20	0.0		0.00	0.00	0.77	0.77		
2	68.14		0.20	0.0		0.00	0.00	0.77	0.77		
3	66.81		0.20	0.0		0.00	0.00	0.77	0.77		
4	65.82		0.20	0.0		0.00	0.00	0.77	0.77		
5	65.21		0.20	0.0		0.00	0.00	0.77	0.77		
6	65.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	65.57		0.20	0.0		0.00	0.00	0.77	0.77		
8	67.22		1.00	0.0		63.57	0.00	6.71	6.71		
9	69.75		1.00	0.0		63.57	0.00	6.71	6.71		
10	72.85		1.00	0.0		63.57	0.00	6.71	6.71		
11	76.15		1.00	0.0		63.57	0.00	6.71	6.71		
12	79.25		1.00	0.0		63.57	0.00	6.71	6.71		
13	81.78		1.00	0.0		63.57	0.00	10.12	10.12		
14	83.43		1.00	0.0		63.57	0.00	10.12	10.12		
15	84.00		1.00	0.0		63.57	0.00	10.12	10.12		
16	83.79		1.00	0.0		63.57	0.00	10.12	10.12		
17	83.18		1.00	0.0		63.57	0.00	10.12	10.12		
18	82.19		0.20	0.0		63.57	0.00	5.44	5.44		
19	80.86		0.20	0.0		0.00	0.00	0.77	0.77		
20	79.25		0.20	0.0		0.00	0.00	0.77	0.77		
21	77.44		0.20	0.0		0.00	0.00	0.77	0.77		
22	75.49		0.20	0.0		0.00	0.00	0.77	0.77		
23	73.51		0.20	0.0		0.00	0.00	0.77	0.77		
24	71.56		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2:43

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** AUGUST ****

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	67.50	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	-10.	0.	0.	0.	0.	-3.	-11.
2	65.98	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-12.	0.	0.	0.	0.	-4.	-15.
3	64.72	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	0.	0.	0.	0.	-4.	-17.
4	63.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-13.	0.	0.	0.	0.	-5.	-19.
5	63.20	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-14.	0.	0.	0.	0.	-4.	-19.
6	63.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-14.	0.	0.	0.	0.	-3.	-19.
7	63.54	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-14.	0.	0.	0.	0.	-2.	-17.
8	65.11	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-17.	0.	217.	54.	76.	-43.	283.
9	67.50	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-17.	0.	217.	54.	76.	-24.	303.
10	70.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	0.	217.	54.	76.	-13.	323.
11	73.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	-6.	0.	217.	54.	76.	-3.	342.
12	76.50	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.	-2.	0.	217.	54.	76.	6.	359.
13	78.89	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.	1.	0.	217.	54.	76.	13.	371.
14	80.46	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	3.	0.	217.	54.	76.	17.	379.
15	81.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	3.	0.	217.	54.	76.	19.	382.
16	80.80	0.	0.	0.	0.	0.	0.	0.	0.	0.	11.	2.	0.	217.	54.	76.	18.	379.
17	80.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.	0.	0.	217.	54.	76.	15.	372.
18	79.28	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.	-2.	0.	217.	54.	0.	4.	281.
19	78.02	0.	0.	0.	0.	0.	0.	0.	0.	0.	9.	-1.	0.	0.	0.	0.	9.	17.
20	76.50	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-6.	0.	0.	0.	0.	7.	6.
21	74.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	6.	-5.	0.	0.	0.	0.	5.	6.
22	72.94	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-6.	0.	0.	0.	0.	3.	2.
23	71.06	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	-8.	0.	0.	0.	0.	1.	-3.
24	69.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	-9.	0.	0.	0.	0.	-1.	-7.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	67.50		0.20	0.0		0.00	0.00	0.77	0.77		
2	65.98		0.20	0.0		0.00	0.00	0.77	0.77		
3	64.72		0.20	0.0		0.00	0.00	0.77	0.77		
4	63.78		0.20	0.0		0.00	0.00	0.77	0.77		
5	63.20		0.20	0.0		0.00	0.00	0.77	0.77		
6	63.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	63.54		0.20	0.0		0.00	0.00	0.77	0.77		
8	65.11		6.00	0.0		63.57	0.00	6.71	6.71		
9	67.50		1.00	0.0		63.57	0.00	6.71	6.71		
10	70.44		1.00	0.0		63.57	0.00	6.71	6.71		
11	73.56		1.00	0.0		63.57	0.00	6.71	6.71		
12	76.50		1.00	0.0		63.57	0.00	6.71	6.71		
13	78.89		1.00	0.0		63.57	0.00	10.12	10.12		
14	80.46		1.00	0.0		63.57	0.00	10.12	10.12		
15	81.00		1.00	0.0		63.57	0.00	10.12	10.12		
16	80.80		1.00	0.0		63.57	0.00	10.12	10.12		
17	80.22		1.00	0.0		63.57	0.00	10.12	10.12		
18	79.28		0.20	0.0		63.57	0.00	5.44	5.44		
19	78.02		0.20	0.0		0.00	0.00	0.77	0.77		
20	76.50		0.20	0.0		0.00	0.00	0.77	0.77		
21	74.78		0.20	0.0		0.00	0.00	0.77	0.77		
22	72.94		0.20	0.0		0.00	0.00	0.77	0.77		
23	71.06		0.20	0.0		0.00	0.00	0.77	0.77		
24	69.22		0.20	0.0		0.00	0.00	0.77	0.77		

```
****        HOURLY SUMMARY        **** SOLAR5 ****        HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU)        ****    4/ 8/87  2:45
                                        Project Title:   THESIS
                                        Building Type:   OFFICE BUILDING LOWRISE
                                        Climate Data :   BOSTON
```

**** SEPTEMBER ****

		WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
HR	TEMP.	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
1	60.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-15.	0.	0.	0.	0.	-8.	-28.
2	59.34	0.	0.	0.	0.	0.	0.	0.	0.	0.	-5.	-16.	0.	0.	0.	0.	-9.	-31.
3	58.35	0.	0.	0.	0.	0.	0.	0.	0.	0.	-6.	-17.	0.	0.	0.	0.	-10.	-33.
4	57.61	0.	0.	0.	0.	0.	0.	0.	0.	0.	-6.	-18.	0.	0.	0.	0.	-10.	-35.
5	57.15	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-18.	0.	0.	0.	0.	-10.	-36.
6	57.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-19.	0.	0.	0.	0.	-10.	-36.
7	57.61	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-19.	0.	0.	0.	0.	-9.	-35.
8	59.34	0.	0.	0.	0.	0.	0.	0.	0.	0.	-15.	-27.	0.	217.	54.	76.	-66.	240.
9	61.94	0.	0.	0.	0.	0.	0.	0.	0.	0.	-12.	-24.	0.	217.	54.	76.	-55.	257.
10	65.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-8.	-18.	0.	217.	54.	76.	-43.	278.
11	68.06	0.	0.	0.	0.	0.	0.	0.	0.	0.	-3.	-13.	0.	217.	54.	76.	-32.	299.
12	70.66	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9.	0.	217.	54.	76.	-24.	315.
13	72.39	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	-5.	0.	217.	54.	76.	-18.	327.
14	73.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-3.	0.	217.	54.	76.	-16.	333.
15	72.85	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	-3.	0.	217.	54.	76.	-17.	332.
16	72.39	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	-4.	0.	217.	54.	76.	-19.	328.
17	71.65	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	-7.	0.	217.	54.	76.	-22.	319.
18	70.66	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-10.	0.	217.	54.	0.	-4.	256.
19	69.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	-10.	0.	0.	0.	0.	1.	-8.
20	68.06	0.	0.	0.	0.	0.	0.	0.	0.	0.	-3.	-13.	0.	0.	0.	0.	0.	-16.
21	66.56	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1.	-11.	0.	0.	0.	0.	-2.	-14.
22	65.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2.	-12.	0.	0.	0.	0.	-4.	-18.
23	63.44	0.	0.	0.	0.	0.	0.	0.	0.	0.	-3.	-13.	0.	0.	0.	0.	-5.	-21.
24	61.94	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4.	-14.	0.	0.	0.	0.	-7.	-24.

	TEMPERATURE		AIR	OUTPUT OF		LIGHTS	COST (DOLLARS)			TOTAL ENERGY	
HOUR	OUTDOOR	INDOOR	CHANGES	HVAC SYSTEM	STORED	(KWHR)	GAS	ELECTRICITY	TOTAL	SITE	SOURCE
1	60.56		0.20	0.0		0.00	0.00	0.77	0.77		
2	59.34		0.20	0.0		0.00	0.00	0.77	0.77		
3	58.35		0.20	0.0		0.00	0.00	0.77	0.77		
4	57.61		0.20	0.0		0.00	0.00	0.77	0.77		
5	57.15		0.20	0.0		0.00	0.00	0.77	0.77		
6	57.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	57.61		0.20	0.0		0.00	0.00	0.77	0.77		
8	59.34		1.00	0.0		63.57	0.00	6.71	6.71		
9	61.94		1.00	0.0		63.57	0.00	6.71	6.71		
10	65.00		1.00	0.0		63.57	0.00	6.71	6.71		
11	68.06		1.00	0.0		63.57	0.00	6.71	6.71		
12	70.66		1.00	0.0		63.57	0.00	6.71	6.71		
13	72.39		1.00	0.0		63.57	0.00	10.12	10.12		
14	73.00		1.00	0.0		63.57	0.00	10.12	10.12		
15	72.85		1.00	0.0		63.57	0.00	10.12	10.12		
16	72.39		1.00	0.0		63.57	0.00	10.12	10.12		
17	71.65		1.00	0.0		63.57	0.00	10.12	10.12		
18	70.66		0.20	0.0		63.57	0.00	5.44	5.44		
19	69.44		0.20	0.0		0.00	0.00	0.77	0.77		
20	68.06		0.20	0.0		0.00	0.00	0.77	0.77		
21	66.56		0.20	0.0		0.00	0.00	0.77	0.77		
22	65.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	63.44		0.20	0.0		0.00	0.00	0.77	0.77		
24	61.94		0.20	0.0		0.00	0.00	0.77	0.77		

$$$$ HOURLY SUMMARY $$$$ SOLAR5 $$$$ HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) $$$$ 4/ 8/87 2:47

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

$$$$ OCTOBER $$$$

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	49.67	0.	0.	0.	0.	0.	0.	0.	0.	0.	-14.	-23.	0.	0.	0.	0.	-18.	-56.
2	48.76	0.	0.	0.	0.	0.	0.	0.	0.	0.	-15.	-24.	0.	0.	0.	0.	-19.	-58.
3	48.01	0.	0.	0.	0.	0.	0.	0.	0.	0.	-15.	-25.	0.	0.	0.	0.	-20.	-59.
4	47.46	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16.	-25.	0.	0.	0.	0.	-20.	-61.
5	47.12	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16.	-26.	0.	0.	0.	0.	-20.	-62.
6	47.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16.	-26.	0.	0.	0.	0.	-20.	-62.
7	47.46	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16.	-26.	0.	0.	0.	0.	-19.	-61.
8	48.76	0.	0.	0.	0.	0.	0.	0.	0.	0.	-21.	-31.	0.	217.	54.	76.	-115.	181.
9	50.70	0.	0.	0.	0.	0.	0.	0.	0.	0.	-22.	-32.	0.	217.	54.	76.	-106.	187.
10	53.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-18.	-28.	0.	217.	54.	76.	-97.	204.
11	55.30	0.	0.	0.	0.	0.	0.	0.	0.	0.	-14.	-23.	0.	217.	54.	76.	-89.	220.
12	57.24	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	-19.	0.	217.	54.	76.	-83.	234.
13	58.54	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9.	-16.	0.	217.	54.	76.	-79.	244.
14	59.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-14.	0.	217.	54.	76.	-77.	248.
15	58.88	0.	0.	0.	0.	0.	0.	0.	0.	0.	-7.	-14.	0.	217.	54.	76.	-78.	248.
16	58.54	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9.	-16.	0.	217.	54.	76.	-80.	243.
17	57.99	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	-19.	0.	217.	54.	76.	-82.	236.
18	57.24	0.	0.	0.	0.	0.	0.	0.	0.	0.	-14.	-22.	0.	217.	54.	0.	-17.	218.
19	56.33	0.	0.	0.	0.	0.	0.	0.	0.	0.	-12.	-21.	0.	0.	0.	0.	-11.	-44.
20	55.30	0.	0.	0.	0.	0.	0.	0.	0.	0.	-11.	-20.	0.	0.	0.	0.	-12.	-43.
21	54.17	0.	0.	0.	0.	0.	0.	0.	0.	0.	-12.	-20.	0.	0.	0.	0.	-14.	-45.
22	53.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-12.	-21.	0.	0.	0.	0.	-15.	-48.
23	51.83	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	-22.	0.	0.	0.	0.	-16.	-51.
24	50.70	0.	0.	0.	0.	0.	0.	0.	0.	0.	-13.	-23.	0.	0.	0.	0.	-17.	-53.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	49.67		0.20	0.0		0.00	0.00	0.77	0.77		
2	48.76		0.20	0.0		0.00	0.00	0.77	0.77		
3	48.01		0.20	0.0		0.00	0.00	0.77	0.77		
4	47.46		0.20	0.0		0.00	0.00	0.77	0.77		
5	47.12		0.20	0.0		0.00	0.00	0.77	0.77		
6	47.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	47.46		0.20	0.0		0.00	0.00	0.77	0.77		
8	48.76		1.00	0.0		63.57	0.00	6.71	6.71		
9	50.70		1.00	0.0		63.57	0.00	6.71	6.71		
10	53.00		1.00	0.0		63.57	0.00	6.71	6.71		
11	55.30		1.00	0.0		63.57	0.00	6.71	6.71		
12	57.24		1.00	0.0		63.57	0.00	6.71	6.71		
13	58.54		1.00	0.0		63.57	0.00	10.12	10.12		
14	59.00		1.00	0.0		63.57	0.00	10.12	10.12		
15	58.88		1.00	0.0		63.57	0.00	10.12	10.12		
16	58.54		1.00	0.0		63.57	0.00	10.12	10.12		
17	57.99		1.00	0.0		63.57	0.00	10.12	10.12		
18	57.24		0.20	0.0		63.57	0.00	5.44	5.44		
19	56.33		0.20	0.0		0.00	0.00	0.77	0.77		
20	55.30		0.20	0.0		0.00	0.00	0.77	0.77		
21	54.17		0.20	0.0		0.00	0.00	0.77	0.77		
22	53.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	51.83		0.20	0.0		0.00	0.00	0.77	0.77		
24	50.70		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2:49

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** NOVEMBER ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	38.89	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-32.	0.	0.	0.	0.	-28.	-83.
2	38.59	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-32.	0.	0.	0.	0.	-28.	-84.
3	38.34	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-32.	0.	0.	0.	0.	-28.	-84.
4	38.15	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-32.	0.	0.	0.	0.	-29.	-85.
5	38.04	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-32.	0.	0.	0.	0.	-29.	-85.
6	38.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-33.	0.	0.	0.	0.	-29.	-86.
7	38.15	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-33.	0.	0.	0.	0.	-29.	-86.
8	38.59	0.	0.	0.	0.	0.	0.	0.	0.	0.	-28.	-37.	0.	217.	54.	76.	-166.	116.
9	39.23	0.	0.	0.	0.	0.	0.	0.	0.	0.	-28.	-37.	0.	217.	54.	76.	-163.	119.
10	40.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-37.	0.	217.	54.	76.	-160.	122.
11	40.77	0.	0.	0.	0.	0.	0.	0.	0.	0.	-26.	-33.	0.	217.	54.	76.	-157.	132.
12	41.41	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-30.	0.	217.	54.	76.	-154.	140.
13	41.85	0.	0.	0.	0.	0.	0.	0.	0.	0.	-21.	-28.	0.	217.	54.	76.	-153.	145.
14	42.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-20.	-27.	0.	217.	54.	76.	-152.	148.
15	41.96	0.	0.	0.	0.	0.	0.	0.	0.	0.	-21.	-27.	0.	217.	54.	76.	-153.	147.
16	41.85	0.	0.	0.	0.	0.	0.	0.	0.	0.	-22.	-29.	0.	217.	54.	76.	-153.	144.
17	41.66	0.	0.	0.	0.	0.	0.	0.	0.	0.	-24.	-32.	0.	217.	54.	76.	-153.	139.
18	41.41	0.	0.	0.	0.	0.	0.	0.	0.	0.	-28.	-36.	0.	217.	54.	0.	-32.	175.
19	41.11	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-30.	0.	0.	0.	0.	-26.	-79.
20	40.77	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-30.	0.	0.	0.	0.	-26.	-79.
21	40.39	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-31.	0.	0.	0.	0.	-26.	-80.
22	40.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-31.	0.	0.	0.	0.	-27.	-81.
23	39.61	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-31.	0.	0.	0.	0.	-27.	-81.
24	39.23	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23.	-31.	0.	0.	0.	0.	-28.	-82.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	38.89		0.20	0.0		0.00	0.00	0.77	0.77		
2	38.59		0.20	0.0		0.00	0.00	0.77	0.77		
3	38.34		0.20	0.0		0.00	0.00	0.77	0.77		
4	38.15		0.20	0.0		0.00	0.00	0.77	0.77		
5	38.04		0.20	0.0		0.00	0.00	0.77	0.77		
6	38.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	38.15		0.20	0.0		0.00	0.00	0.77	0.77		
8	38.59		1.00	0.0		63.57	0.00	6.71	6.71		
9	39.23		1.00	0.0		63.57	0.00	6.71	6.71		
10	40.00		1.00	0.0		63.57	0.00	6.71	6.71		
11	40.77		1.00	0.0		63.57	0.00	6.71	6.71		
12	41.41		1.00	0.0		63.57	0.00	6.71	6.71		
13	41.85		1.00	0.0		63.57	0.00	10.12	10.12		
14	42.00		1.00	0.0		63.57	0.00	10.12	10.12		
15	41.96		1.00	0.0		63.57	0.00	10.12	10.12		
16	41.85		1.00	0.0		63.57	0.00	10.12	10.12		
17	41.66		1.00	0.0		63.57	0.00	10.12	10.12		
18	41.41		0.20	0.0		63.57	0.00	5.44	5.44		
19	41.11		0.20	0.0		0.00	0.00	0.77	0.77		
20	40.77		0.20	0.0		0.00	0.00	0.77	0.77		
21	40.39		0.20	0.0		0.00	0.00	0.77	0.77		
22	40.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	39.61		0.20	0.0		0.00	0.00	0.77	0.77		
24	39.23		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLAR5 **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2:52

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** DECEMBER ****

		WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
HR	TEMP.	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
1	28.59	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-38.	0.	0.	0.	0.	-38.	-106.
2	28.04	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-38.	0.	0.	0.	0.	-38.	-108.
3	27.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-38.	0.	0.	0.	0.	-39.	-109.
4	27.27	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-39.	0.	0.	0.	0.	-39.	-110.
5	27.07	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-39.	0.	0.	0.	0.	-39.	-111.
6	27.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-39.	0.	0.	0.	0.	-39.	-111.
7	27.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	-32.	-39.	0.	0.	0.	0.	-39.	-111.
8	28.51	0.	0.	0.	0.	0.	0.	0.	0.	0.	-36.	-43.	0.	217.	54.	76.	-211.	56.
9	30.11	0.	0.	0.	0.	0.	0.	0.	0.	0.	-36.	-43.	0.	217.	54.	76.	-203.	66.
10	31.89	0.	0.	0.	0.	0.	0.	0.	0.	0.	-36.	-43.	0.	217.	54.	76.	-195.	73.
11	33.49	0.	0.	0.	0.	0.	0.	0.	0.	0.	-33.	-39.	0.	217.	54.	76.	-189.	87.
12	34.60	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-36.	0.	217.	54.	76.	-184.	98.
13	35.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	-28.	-33.	0.	217.	54.	76.	-183.	104.
14	34.93	0.	0.	0.	0.	0.	0.	0.	0.	0.	-27.	-32.	0.	217.	54.	76.	-184.	106.
15	34.73	0.	0.	0.	0.	0.	0.	0.	0.	0.	-27.	-32.	0.	217.	54.	76.	-184.	104.
16	34.40	0.	0.	0.	0.	0.	0.	0.	0.	0.	-28.	-34.	0.	217.	54.	76.	-186.	100.
17	33.96	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-36.	0.	217.	54.	76.	-187.	94.
18	33.41	0.	0.	0.	0.	0.	0.	0.	0.	0.	-35.	-41.	0.	217.	54.	0.	-40.	156.
19	32.78	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-35.	0.	0.	0.	0.	-34.	-98.
20	32.09	0.	0.	0.	0.	0.	0.	0.	0.	0.	-29.	-35.	0.	0.	0.	0.	-35.	-99.
21	31.37	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-36.	0.	0.	0.	0.	-35.	-100.
22	30.63	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-36.	0.	0.	0.	0.	-36.	-102.
23	29.91	0.	0.	0.	0.	0.	0.	0.	0.	0.	-30.	-37.	0.	0.	0.	0.	-37.	-103.
24	29.22	0.	0.	0.	0.	0.	0.	0.	0.	0.	-31.	-37.	0.	0.	0.	0.	-37.	-105.

	TEMPERATURE		AIR	OUTPUT OF		LIGHTS	COST (DOLLARS)			TOTAL ENERGY	
HOUR	OUTDOOR	INDOOR	CHANGES	HVAC SYSTEM	STORED	(KWHR)	GAS	ELECTRICITY	TOTAL	SITE	SOURCE
1	28.59		0.20	0.0		0.00	0.00	0.77	0.77		
2	28.04		0.20	0.0		0.00	0.00	0.77	0.77		
3	27.60		0.20	0.0		0.00	0.00	0.77	0.77		
4	27.27		0.20	0.0		0.00	0.00	0.77	0.77		
5	27.07		0.20	0.0		0.00	0.00	0.77	0.77		
6	27.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	27.40		0.20	0.0		0.00	0.00	0.77	0.77		
8	28.51		1.00	0.0		63.57	0.00	6.71	6.71		
9	30.11		1.00	0.0		63.57	0.00	6.71	6.71		
10	31.89		1.00	0.0		63.57	0.00	6.71	6.71		
11	33.49		1.00	0.0		63.57	0.00	6.71	6.71		
12	34.60		1.00	0.0		63.57	0.00	6.71	6.71		
13	35.00		1.00	0.0		63.57	0.00	10.12	10.12		
14	34.93		1.00	0.0		63.57	0.00	10.12	10.12		
15	34.73		1.00	0.0		63.57	0.00	10.12	10.12		
16	34.40		1.00	0.0		63.57	0.00	10.12	10.12		
17	33.96		1.00	0.0		63.57	0.00	10.12	10.12		
18	33.41		0.20	0.0		63.57	0.00	5.44	5.44		
19	32.78		0.20	0.0		0.00	0.00	0.77	0.77		
20	32.09		0.20	0.0		0.00	0.00	0.77	0.77		
21	31.37		0.20	0.0		0.00	0.00	0.77	0.77		
22	30.63		0.20	0.0		0.00	0.00	0.77	0.77		
23	29.91		0.20	0.0		0.00	0.00	0.77	0.77		
24	29.22		0.20	0.0		0.00	0.00	0.77	0.77		

**** MONTHLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS **** 4/ 6/87 2:54

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
**** JANUARY ****																	Total BTU for 31 Days (Units are in THOUSAND BTU)
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23346.	-27595.	0.	0.	0.	0.	-75464.	-44077.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	53.0%	62.6%	0.0%	0.0%	0.0%	0.0%	171.2%	266.8%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	73969.	18492.	23664.	0.	33796.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	218.9%	54.7%	70.0%	0.0%	343.6%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	23346.	27595.	0.	73969.	18492.	23664.	75464.	77873.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	30.0%	35.4%	0.0%	95.0%	23.7%	30.4%	96.9%	311.4%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23346.	-27595.	0.	73969.	18492.	23664.	-75464.	-10281.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	227.1%	268.4%	0.0%	719.5%	179.9%	230.2%	734.0%	920.1%
**** FEBRUARY ****																	Total BTU for 28 Days (Units are in THOUSAND BTU)
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-20330.	-24286.	0.	0.	0.	0.	-67850.	-40081.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.7%	60.6%	0.0%	0.0%	0.0%	0.0%	169.3%	280.6%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	66810.	16703.	21374.	0.	32502.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	205.6%	51.4%	65.8%	0.0%	322.7%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	20330.	24286.	0.	66810.	16703.	21374.	67850.	72583.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	28.0%	33.5%	0.0%	92.0%	23.0%	29.4%	93.5%	299.5%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-20330.	-24286.	0.	66810.	16703.	21374.	-67850.	-7580.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	268.2%	320.4%	0.0%	881.5%	220.4%	282.0%	895.2%	1104.7%
**** MARCH ****																	Total BTU for 31 Days (Units are in THOUSAND BTU)
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16392.	-21651.	0.	0.	0.	0.	-59068.	-35311.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	46.4%	61.3%	0.0%	0.0%	0.0%	0.0%	167.3%	275.0%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	73969.	18492.	23664.	0.	54324.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	136.2%	34.0%	43.6%	0.0%	213.8%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	16392.	21651.	0.	73969.	18492.	23664.	59068.	89634.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.3%	24.2%	0.0%	82.5%	20.6%	26.4%	65.9%	237.9%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-16392.	-21651.	0.	73969.	18492.	23664.	-59068.	19013.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	86.2%	113.9%	0.0%	389.0%	97.3%	124.5%	310.7%	327.8%

**** MONTHLY SUMMARY **** SOLAR5 **** HEAT GAIN AND LOSS **** 4/ 8/87 2:55

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** APRIL **** Total BTU for 30 Days (Units are in THOUSAND BTU)

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9117.	-15140.	0.	0.	0.	0.	-37648.	-24489.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	37.2%	61.8%	0.0%	0.0%	0.0%	0.0%	153.7%	252.6%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	71583.	17896.	22900.	0.	74962.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	95.5%	23.9%	30.5%	0.0%	149.9%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	9117.	15140.	0.	71583.	17896.	22900.	37648.	99452.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.2%	15.2%	0.0%	72.0%	18.0%	23.0%	37.9%	175.2%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-9117.	-15140.	0.	71583.	17896.	22900.	-37648.	50473.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.1%	30.0%	0.0%	141.8%	35.5%	45.4%	74.6%	160.0%

**** MAY **** Total BTU for 31 Days (Units are in THOUSAND BTU)

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-4262.	-10832.	0.	0.	0.	0.	-21824.	-16196.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	26.3%	66.9%	0.0%	0.0%	0.0%	0.0%	134.7%	227.9%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	684.	0.	0.	73969.	18492.	23664.	0.	96087.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	77.0%	19.2%	24.6%	0.0%	121.6%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	4946.	10832.	0.	73969.	18492.	23664.	21824.	112284.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.4%	9.6%	0.0%	65.9%	16.5%	21.1%	19.4%	136.9%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-3577.	-10832.	0.	73969.	18492.	23664.	-21824.	79891.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.5%	13.6%	0.0%	92.6%	23.1%	29.6%	27.3%	127.1%

**** JUNE **** Total BTU for 30 Days (Units are in THOUSAND BTU)

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-1244.	-7167.	0.	0.	0.	0.	-9680.	-7860.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.8%	91.2%	0.0%	0.0%	0.0%	0.0%	123.2%	230.2%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	2042.	60.	0.	71583.	17896.	22900.	82.	104332.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.1%	0.0%	68.6%	17.2%	21.9%	0.1%	109.8%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	3286.	7227.	0.	71583.	17896.	22900.	9763.	112192.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%	6.4%	0.0%	63.8%	16.0%	20.4%	8.7%	118.2%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	798.	-7107.	0.	71583.	17896.	22900.	-9598.	96471.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	7.4%	0.0%	74.2%	18.6%	23.7%	9.9%	113.1%

$$$$ MONTHLY SUMMARY $$$$ SOLARS $$$$ HEAT GAIN AND LOSS $$$$ 4/ 8/87 2:57

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
$$$$ JULY $$$$ — Total BTU for 31 Days (Units are in THOUSAND BTU)																	
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-180.	-4752.	0.	0.	0.	0.	-1125.	-2732.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	173.9%	0.0%	0.0%	0.0%	0.0%	41.2%	221.7%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	4966.	948.	0.	73969.	18492.	23664.	6902.	125616.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	0.8%	0.0%	58.9%	14.7%	18.8%	5.5%	102.6%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	5147.	5700.	0.	73969.	18492.	23664.	8027.	128348.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	4.0%	4.4%	0.0%	57.6%	14.4%	18.4%	6.3%	105.2%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	4786.	-3803.	0.	73969.	18492.	23664.	5777.	122884.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.9%	3.1%	0.0%	60.2%	15.0%	19.3%	4.7%	100.0%
$$$$ AUGUST $$$$ — Total BTU for 31 Days (Units are in THOUSAND BTU)																	
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-397.	-5649.	0.	0.	0.	0.	-3388.	-3942.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.1%	143.3%	0.0%	0.0%	0.0%	0.0%	86.0%	239.3%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	3347.	279.	0.	73969.	18492.	23664.	3645.	117904.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.8%	0.2%	0.0%	62.7%	15.7%	20.1%	3.1%	104.7%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	3744.	5927.	0.	73969.	18492.	23664.	7033.	121846.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	4.9%	0.0%	60.7%	15.2%	19.4%	5.8%	109.0%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	2950.	-5370.	0.	73969.	18492.	23664.	257.	113962.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	4.7%	0.0%	64.9%	16.2%	20.8%	0.2%	104.2%
$$$$ SEPTEMBER $$$$ — Total BTU for 30 Days (Units are in THOUSAND BTU)																	
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2801.	-9633.	0.	0.	0.	0.	-11974.	-9997.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	28.0%	96.4%	0.0%	0.0%	0.0%	0.0%	119.8%	244.1%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	532.	0.	0.	71583.	17896.	22900.	37.	98537.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	72.6%	18.2%	23.2%	0.0%	114.6%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	3333.	9633.	0.	71583.	17896.	22900.	12011.	108534.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	8.9%	0.0%	66.0%	16.5%	21.1%	11.1%	126.6%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2269.	-9633.	0.	71583.	17896.	22900.	-11937.	88539.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.6%	10.9%	0.0%	80.8%	20.2%	25.9%	13.5%	121.8%

**** MONTHLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS **** 4/ 8/87 2:58

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
****** OCTOBER ****** Total BTU for 31 Days (Units are in THOUSAND BTU)																	
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-10044.	-16629.	0.	0.	0.	0.	-34874.	-21783.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	46.1%	76.3%	0.0%	0.0%	0.0%	0.0%	160.1%	282.5%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	73969.	18492.	23664.	0.	76360.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	96.9%	24.2%	31.0%	0.0%	152.1%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	10044.	16629.	0.	73969.	18492.	23664.	34874.	98143.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.2%	16.9%	0.0%	75.4%	18.8%	24.1%	35.5%	181.0%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-10044.	-16629.	0.	73969.	18492.	23664.	-34874.	54577.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	18.4%	30.5%	0.0%	135.5%	33.9%	43.4%	63.9%	160.9%
****** NOVEMBER ****** Total BTU for 30 Days (Units are in THOUSAND BTU)																	
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-17282.	-22877.	0.	0.	0.	0.	-58640.	-32242.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	53.6%	71.0%	0.0%	0.0%	0.0%	0.0%	181.9%	306.4%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	71583.	17896.	22900.	0.	45822.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	156.2%	39.1%	50.0%	0.0%	245.3%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	17282.	22877.	0.	71583.	17896.	22900.	58640.	78064.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.1%	29.3%	0.0%	91.7%	22.9%	29.3%	75.1%	270.5%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-17282.	-22877.	0.	71583.	17896.	22900.	-58640.	13580.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	127.3%	168.5%	0.0%	527.1%	131.8%	168.6%	431.8%	436.9%
****** DECEMBER ****** Total BTU for 31 Days (Units are in THOUSAND BTU)																	
LOSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23142.	-27801.	0.	0.	0.	0.	-75365.	-42560.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	54.4%	65.3%	0.0%	0.0%	0.0%	0.0%	177.1%	296.8%
GAIN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	73969.	18492.	23664.	0.	32377.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	228.5%	57.1%	73.1%	0.0%	358.7%
GROSS	0.	0.	0.	0.	0.	0.	0.	0.	0.	23142.	27801.	0.	73969.	18492.	23664.	75365.	74937.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	30.9%	37.1%	0.0%	98.7%	24.7%	31.6%	100.6%	323.5%
NET	0.	0.	0.	0.	0.	0.	0.	0.	0.	-23142.	-27801.	0.	73969.	18492.	23664.	-75365.	-10183.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	227.3%	273.0%	0.0%	726.4%	181.6%	232.4%	740.1%	927.9%

$$$$ ANNUAL SUMMARY $$$$ SOLAR5 $$$$ HEAT GAIN AND LOSS $$$$ 4/ 8/87 3: 0

TOTAL BTU FOR 365 DAYS (UNITS ARE IN MILLION BTU) ASHRAE HEAT LOSS= -168303.22 BTUH

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
LOSS																	
	0.	0.	0.	0.	0.	0.	0.	0.	0.	-129.	-194.	0.	0.	0.	0.	-457.	-281.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	45.7%	69.0%	0.0%	0.0%	0.0%	0.0%	162.4%	277.1%
31806.0= FLOOR AREA : KBTU PER SQ.FT.= -8.84																	
GAIN																	
	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	1.	0.	871.	218.	279.	11.	893.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.1%	0.0%	97.6%	24.4%	31.2%	1.2%	155.8%
31806.0= FLOOR AREA : KBTU PER SQ.FT.= 28.06																	
GROSS																	
	0.	0.	0.	0.	0.	0.	0.	0.	0.	140.	195.	0.	871.	218.	279.	466.	1174.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.9%	16.6%	0.0%	74.2%	18.5%	23.7%	39.8%	184.9%
31806.0= FLOOR AREA : KBTU PER SQ.FT.= 36.91																	
NET																	
	0.	0.	0.	0.	0.	0.	0.	0.	0.	-117.	-193.	0.	871.	218.	279.	-446.	611.
	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	19.1%	31.5%	0.0%	142.5%	35.6%	45.6%	73.0%	163.0%
31806.0= FLOOR AREA : KBTU PER SQ.FT.= 19.22																	

```
SOLAR5: Passive Solar Design Tool     (Released 8/86)     UCLA    4/17/87 20:19
                                        Project Title:  THESIS
                                        Building Type:  OFFICE BUILDING LOWRISE
                                        Climate Data :  BOSTON
  ENVELOPE DESIGN SUMMARY :
  Scheme 4: DAYLIT MODULE


  114.00 = East-to-West Overall Dimension  FT.                               % of MAX
   93.00 = North-to-South Overall Dimension  FT.                             Envelope
   7956. = Area of the Largest Floor or Flat Roof  SQ.FT.                    =  75.%
      4. = Number of Floors
  31824. = Total Floor Area  SQ.FT.                                          =  75.%
   10.50 = Floor to Floor Height  FT. (Effects Exterior Surface Areas)
    9.00 = Floor to Ceiling Height  FT.  (Effects Interior Volume)
 286416. = Total Volume of Occupied Space  CU.FT. (Interior)                 =  75.%
      0. = Bearing Off True South (Clockwise is Positive)

 Note: Roof area is 75.04% of the overall East-to-West x North-to-South area
 Note: Floor area is 75.04% of no. of floors x East-to-West x North-to-South
 Note: Total volume is 75.04% of floor height x East-to-West x North-to-South
```

```
  SURFACE AREA DESIGN SUMMARY :
  Scheme 4: DAYLIT MODULE
```

	Area sq.ft.	% of Surface	Transmissivity Absorptivity	U-value	Time Lag	Decrement Factor
WINDOW SOUTH	1542.SF	32.%	0.75	0.55		
WEST	1092.SF	28.%	0.75	0.55		
NORTH	1638.SF	34.%	0.75	0.55		
EAST	1092.SF	28.%	0.75	0.55		
SKYLIGHT	0.SF	0.%	0.00	1.10		
WALLS SOUTH	1104.SF	23.%	0.30	0.07	2.HRS	0.80
WEST	672.SF	17.%	0.30	0.07	2.HRS	0.80
NORTH	1008.SF	21.%	0.30	0.07	2.HRS	0.80
EAST	672.SF	17.%	0.30	0.07	2.HRS	0.80
ROOF	7956.SF	100.%	0.40	0.07	2.HRS	0.70
FLOOR-RAISED	7956.SF	100.%		0.08	2.HRS	0.80
SLAB EDGES=	210.FEET	51.%		F=.34	24.HRS	0.00

```
Note: Slab perimeter is 50.72% of 2 x (East-to-West + North-to-South)
Note: On 4 elevations percent of windows + walls does not equal 100%
```

SOLAR5: Passive Solar Design Tool (Released 8/86) UCLA 1/ 1/80 23: 8
Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

WINDOW/SUNSHADE DESIGN :
Scheme 4: DAYLIT MODULE

			HEAD	SILL	OVERHANG		LEFT FIN		RIGHT FIN	
	QUANTITY	WIDTH	HEIGHT	HEIGHT	DEEP	OFFSET	DEEP	OFFSET	DEEP	OFFSET
SOUTH	4.	63.00	7.00	2.50	1.50	0.00	42.00	0.00	42.00	0.00
	4.	63.00	9.00	7.38	0.00	0.00	42.00	0.00	42.00	0.00
WEST	4.	42.00	9.00	2.50	0.00	0.00	63.00	0.00	63.00	0.00
NORTH	4.	63.00	9.00	2.50	0.00	0.00	42.00	0.00	42.00	0.00
EAST	4.	42.00	9.00	2.50	0.00	0.00	63.00	0.00	63.00	0.00

GLAZING :
Scheme 4: DAYLIT MODULE

(	from "WINDOW" screen)			Glazing		Orientation		Shade	Movable Insulation
(	Quantity	Wide	High)	U	Trans.	Faces	Tilts	Coef.	R Values
SOUTH	4.	63.00	4.50	0.55	0.75	0.	90.	1.00	
	4.	63.00	1.62	0.55	0.75	0.	90.	1.00	
WEST	4.	42.00	6.50	0.55	0.75	90.	90.	1.00	
NORTH	4.	63.00	6.50	0.55	0.75	180.	90.	1.00	
EAST	4.	42.00	6.50	0.55	0.75	-90.	90.	1.00	

```
SOLAR5: Passive Solar Design Tool   (Released 8/86)    UCLA    1/ 1/80 23: 9
                                     Project Title:  THESIS
                                     Building Type:  OFFICE BUILDING LOWRISE
                                     Climate Data :  BOSTON
  INTERNAL LOADS :
  Scheme 4: DAYLIT MODULE


      0.2 = Infiltration Air Changes per Hour (eg. house=.5, sealed office=.1)
    318.2 = *Number of Occupants Total
    100.0 = *Floor Area for Each Occupant  SQ.FT./PERSON
     240. = BTU/HR of each Person: Sensible (eg. office work about 240.)
     160. = BTU/HR of each Person: Latent   (eg. office work about 160.)
   76378. = *Total Occupant Load  BTU/HR
       8. = HOUR When People Enter    (If They Never Leave Type 1.)
      17. = HOUR Before People Leave  (If They Never Leave Type 24.)
      1.0 = *Lighting Power Density  WATTS/SQ.FT.               =============
  108520. = *Total Lighting Load  BTU/HR  (at 3.41 BTU/WATT)     *These values
       8. = HOUR When Lights Are Turned On    (1. to 24.)        are  computed
      18. = HOUR Before Lights Are Turned Off (1. to 24.)        automatically
      0.5 = *Equipment Power Density  WATTS/SQ.FT.               but  you  may
   54260. = *Total Equipment Load  BTU/HR                        override them
       8. = HOUR When Equipment Is Turned On    (1. to 24.)      if  you  wish
      18. = HOUR Before Equipment Is Turned Off (1. to 24.)      =============
```

```
SOLAR5: Passive Solar Design Tool    (Released 8/86)    UCLA    1/ 1/80 23:10
                                      Project Title:  THESIS
                                      Building Type:  OFFICE BUILDING LOWRISE
                                      Climate Data :  BOSTON
 HVAC SYSTEM DESIGN:
 Scheme 4: DAYLIT MODULE


    3. Number of Heating-Cooling Systems: (0=Infiltration Only at Fixed Rate)
         (1=Vent Fans Only, 2=Heating+Venting, 3=Heating+Cooling+Venting)
  0.20 Infiltration Air Changes per Hour (eg. new house=.5, sealed office=.1)
 15.00 Fresh Air per Person CFM Required(eg. 30 if smoking, 15 if no smoking)
  6.00 Economizer Cooling Maximum Air Changes per Hour(eg. office=6. omit=0.)
 -5.00 Economizer Cooling Minimum Temperature Difference Required (eg.-15.F)
 65.00 Thermostat SetBACK during Occupied Nightime Hours: 1am-6am(eg. 58.F)
 50.00 Thermostat SetBACK Temperature during Unoccupied Hours(eg. to 48.F)
 85.00 Thermostat Set-UP Temperature During Hot Unoccupied Hours(eg. 88.F)
 30.00 % Latent Load: added to Outside Air Cooling Load for Humidity(eg. 30%)
  3.10 Air Conditioner C.O.P. (good Coefficients of Performance= 2.8 to 3.3)
  0.86 Heating System  C.O.P. (usually Package Single Zone =.75, V.A.V.=.86,
                              Dual Duct =.65, Electric =1.0, Heat Pump =2.9)




 RATES FOR ELECTRICITY AND GAS:
 Scheme 4: DAYLIT MODULE


1.08000 Gas Rate   $/THERM   (usually $1.08)  1 Therm = 100,000 BTU
0.05882 Electric Base Rate  $/KWHr Off-Peak (usually $.05882)  1 KWHr=3414 BTU
 560.00 Monthly Basic Charge or Connect Fee  $/MO.  (usually $560.00)
          Time-of-Use charges apply only to large buildings (over 500 KW)
          To eliminate them simply type in 0.0 for all 3 HOURS below.
    8. HOUR Mid-Peak Period Begins  (usually 8.)
   13. HOUR On-Peak  Period Begins  (usually 13.)
   18. HOUR  Off-Peak Period Begins  (usually 18.)
0.07052 Mid-Peak Rate  $/KWHr   (usually $.07052)
0.08452 On-Peak  Rate  $/KWHr   (usually $.08452)
  0.65 $/KW  Time-of-Use Mid-Peak Monthly Surcharge  (usually $0.65)
  5.05 $/KW  Time-of-Use On-Peak  Monthly Surcharge  (usually $5.05)
```

$$$$ HOURLY SUMMARY $$$$ SOLAR5 $$$$ HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) $$$$ 4/ 8/87 1:39
Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

$$$$ JANUARY $$$$

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	25.78	-33.	-23.	-35.	-23.	0.	-3.	-2.	-2.	-2.	-23.	-28.	-4.	0.	0.	0.	-40.	-217.
2	24.83	-33.	-24.	-35.	-24.	0.	-3.	-2.	-3.	-2.	-24.	-29.	-4.	0.	0.	0.	-41.	-222.
3	24.05	-34.	-24.	-36.	-24.	0.	-3.	-2.	-3.	-2.	-24.	-29.	-4.	0.	0.	0.	-41.	-226.
4	23.47	-34.	-24.	-37.	-24.	0.	-3.	-2.	-3.	-2.	-25.	-30.	-4.	0.	0.	0.	-42.	-229.
5	23.12	-35.	-25.	-37.	-25.	0.	-3.	-2.	-3.	-2.	-25.	-30.	-4.	0.	0.	0.	-42.	-231.
6	23.00	-35.	-25.	-37.	-25.	0.	-3.	-2.	-3.	-2.	-25.	-30.	-4.	0.	0.	0.	-42.	-232.
7	23.69	-34.	-24.	-36.	-24.	0.	-3.	-2.	-3.	-2.	-25.	-30.	-4.	0.	0.	0.	-42.	-230.
8	25.64	-20.	-20.	-34.	-12.	0.	-3.	-2.	-3.	-2.	-28.	-33.	-4.	109.	54.	76.	-218.	-140.
9	28.44	64.	-13.	-28.	16.	0.	-3.	-2.	-3.	-2.	-27.	-33.	-4.	109.	54.	76.	-204.	1.
10	31.56	154.	-10.	-25.	36.	0.	-3.	-2.	-3.	-2.	-28.	-33.	-4.	109.	54.	76.	-198.	120.
11	34.36	233.	-9.	-24.	49.	0.	-2.	-2.	-3.	-2.	-26.	-30.	-5.	109.	54.	76.	-193.	225.
12	36.31	292.	-8.	-23.	53.	0.	-2.	-2.	-3.	-1.	-24.	-27.	-5.	109.	54.	76.	-190.	300.
13	37.00	234.	50.	-22.	-8.	0.	-2.	-2.	-3.	-1.	-21.	-24.	-5.	109.	54.	76.	-182.	255.
14	36.88	157.	39.	-21.	-6.	0.	-1.	-2.	-2.	-2.	-19.	-22.	-5.	109.	54.	76.	-176.	178.
15	36.53	70.	21.	-22.	-9.	0.	-1.	-1.	-2.	-2.	-18.	-21.	-4.	109.	54.	76.	-169.	80.
16	35.95	-11.	-6.	-25.	-14.	0.	-1.	-1.	-2.	-1.	-18.	-21.	-4.	109.	54.	76.	-165.	-31.
17	35.17	-28.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-2.	-20.	-24.	-4.	109.	54.	76.	-169.	-82.
18	34.22	-28.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-2.	-22.	-26.	-4.	109.	54.	0.	-34.	-30.
19	33.12	-27.	-19.	-29.	-19.	0.	-2.	-1.	-2.	-1.	-21.	-25.	-4.	0.	0.	0.	-33.	-183.
20	31.92	-28.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-1.	-21.	-25.	-4.	0.	0.	0.	-34.	-189.
21	30.65	-29.	-20.	-31.	-20.	0.	-2.	-1.	-2.	-1.	-22.	-26.	-4.	0.	0.	0.	-35.	-194.
22	29.35	-30.	-21.	-32.	-21.	0.	-2.	-1.	-2.	-1.	-22.	-26.	-4.	0.	0.	0.	-36.	-200.
23	28.08	-31.	-22.	-33.	-22.	0.	-2.	-2.	-2.	-2.	-22.	-27.	-4.	0.	0.	0.	-38.	-206.
24	26.88	-32.	-23.	-34.	-23.	0.	-3.	-2.	-2.	-2.	-23.	-27.	-4.	0.	0.	0.	-39.	-212.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	25.78		0.20	0.0		0.00	0.00	0.77	0.77		
2	24.83		0.20	0.0		0.00	0.00	0.77	0.77		
3	24.05		0.20	0.0		0.00	0.00	0.77	0.77		
4	23.47		0.20	0.0		0.00	0.00	0.77	0.77		
5	23.12		0.20	0.0		0.00	0.00	0.77	0.77		
6	23.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	23.69		0.20	0.0		0.00	0.00	0.77	0.77		
8	25.64		1.00	-141.1		31.81	1.77	4.34	6.11		
9	28.44		1.00	-0.1		31.81	0.00	4.34	4.34		
10	31.56		1.00	0.0		31.81	0.00	4.34	4.34		
11	34.36		1.00	0.0		31.81	0.00	4.34	4.34		
12	36.31		1.00	0.0		31.81	0.00	4.34	4.34		
13	37.00		1.00	0.0		31.81	0.00	6.38	6.38		
14	36.88		1.00	0.0		31.81	0.00	6.38	6.38		
15	36.53		1.00	0.0		31.81	0.00	6.38	6.38		
16	35.95		1.00	-32.1		31.81	0.40	6.38	6.79		
17	35.17		1.00	-82.2		31.81	1.03	6.38	7.42		
18	34.22		0.20	0.0		31.81	0.00	3.57	3.57		
19	33.12		0.20	0.0		0.00	0.00	0.77	0.77		
20	31.92		0.20	0.0		0.00	0.00	0.77	0.77		
21	30.65		0.20	0.0		0.00	0.00	0.77	0.77		
22	29.35		0.20	0.0		0.00	0.00	0.77	0.77		
23	28.08		0.20	0.0		0.00	0.00	0.77	0.77		
24	26.88		0.20	0.0		0.00	0.00	0.77	0.77		

```
****      HOURLY SUMMARY       **** SOLAR5 ****      HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU)       ****   4/ 8/87  1:41
                                    Project Title:   THESIS
                                    Building Type:   OFFICE BUILDING LOWRISE
                                    Climate Data :   BOSTON
```

**** FEBRUARY ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	25.78	-33.	-24.	-35.	-24.	0.	-3.	-2.	-3.	-2.	-23.	-28.	-4.	0.	0.	0.	-40.	-220.
2	24.83	-34.	-24.	-36.	-24.	0.	-3.	-2.	-3.	-2.	-24.	-29.	-4.	0.	0.	0.	-41.	-225.
3	24.05	-34.	-24.	-37.	-24.	0.	-3.	-2.	-3.	-2.	-24.	-29.	-4.	0.	0.	0.	-42.	-228.
4	23.47	-35.	-25.	-37.	-25.	0.	-3.	-2.	-3.	-2.	-25.	-30.	-4.	0.	0.	0.	-42.	-231.
5	23.12	-35.	-25.	-37.	-25.	0.	-3.	-2.	-3.	-2.	-25.	-30.	-4.	0.	0.	0.	-42.	-232.
6	23.00	-34.	-24.	-37.	-24.	0.	-3.	-2.	-3.	-2.	-25.	-30.	-4.	0.	0.	0.	-42.	-230.
7	23.69	-31.	-22.	-35.	-12.	0.	-3.	-2.	-3.	-2.	-25.	-31.	-4.	0.	0.	0.	-41.	-210.
8	25.64	-4.	-14.	-29.	32.	0.	-3.	-2.	-3.	-2.	-27.	-33.	-4.	109.	54.	76.	-210.	-61.
9	28.44	61.	-10.	-25.	37.	0.	-3.	-2.	-3.	-2.	-28.	-33.	-4.	109.	54.	76.	-198.	28.
10	31.56	147.	-9.	-23.	57.	0.	-3.	-2.	-3.	-1.	-26.	-31.	-5.	109.	54.	76.	-195.	146.
11	34.36	225.	-8.	-23.	69.	0.	-2.	-2.	-3.	-1.	-23.	-27.	-5.	109.	54.	76.	-192.	247.
12	36.31	285.	-7.	-22.	73.	0.	-2.	-2.	-3.	-1.	-21.	-25.	-5.	109.	54.	76.	-190.	319.
13	37.00	226.	70.	-21.	-7.	0.	-2.	-2.	-3.	-1.	-19.	-22.	-5.	109.	54.	76.	-184.	272.
14	36.88	150.	59.	-20.	-7.	0.	-1.	-2.	-3.	-2.	-17.	-19.	-5.	109.	54.	76.	-178.	196.
15	36.53	65.	40.	-20.	-7.	0.	-1.	-1.	-2.	-2.	-16.	-19.	-4.	109.	54.	76.	-171.	101.
16	35.95	3.	36.	-22.	-10.	0.	-1.	-1.	-2.	-2.	-16.	-19.	-4.	109.	54.	76.	-169.	32.
17	35.17	-26.	-8.	-29.	-19.	0.	-2.	-1.	-2.	-1.	-18.	-22.	-4.	109.	54.	76.	-170.	-63.
18	34.22	-29.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-2.	-20.	-24.	-4.	109.	54.	0.	-35.	-27.
19	33.12	-27.	-19.	-29.	-19.	0.	-2.	-1.	-2.	-1.	-22.	-26.	-4.	0.	0.	0.	-33.	-187.
20	31.92	-28.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-1.	-21.	-25.	-4.	0.	0.	0.	-34.	-191.
21	30.65	-29.	-21.	-31.	-21.	0.	-2.	-1.	-2.	-1.	-21.	-26.	-4.	0.	0.	0.	-36.	-197.
22	29.35	-30.	-22.	-32.	-22.	0.	-2.	-2.	-2.	-2.	-22.	-26.	-4.	0.	0.	0.	-37.	-203.
23	28.08	-31.	-22.	-33.	-22.	0.	-2.	-2.	-2.	-2.	-22.	-27.	-4.	0.	0.	0.	-38.	-209.
24	26.88	-32.	-23.	-34.	-23.	0.	-3.	-2.	-2.	-2.	-23.	-28.	-4.	0.	0.	0.	-39.	-215.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	25.78		0.20	0.0		0.00	0.00	0.77	0.77		
2	24.83		0.20	0.0		0.00	0.00	0.77	0.77		
3	24.05		0.20	0.0		0.00	0.00	0.77	0.77		
4	23.47		0.20	0.0		0.00	0.00	0.77	0.77		
5	23.12		0.20	0.0		0.00	0.00	0.77	0.77		
6	23.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	23.69		0.20	0.0		0.00	0.00	0.77	0.77		
8	25.64		1.00	-61.6		31.81	0.77	4.34	5.11		
9	28.44		1.00	0.0		31.81	0.00	4.34	4.34		
10	31.56		1.00	0.0		31.81	0.00	4.34	4.34		
11	34.36		1.00	0.0		31.81	0.00	4.34	4.34		
12	36.31		1.00	0.0		31.81	0.00	4.34	4.34		
13	37.00		1.00	0.0		31.81	0.00	6.38	6.38		
14	36.88		1.00	0.0		31.81	0.00	6.38	6.38		
15	36.53		1.00	0.0		31.81	0.00	6.38	6.38		
16	35.95		1.00	0.0		31.81	0.00	6.38	6.38		
17	35.17		1.00	-63.7		31.81	0.80	6.38	7.18		
18	34.22		0.20	0.0		31.81	0.00	3.57	3.57		
19	33.12		0.20	0.0		0.00	0.00	0.77	0.77		
20	31.92		0.20	0.0		0.00	0.00	0.77	0.77		
21	30.65		0.20	0.0		0.00	0.00	0.77	0.77		
22	29.35		0.20	0.0		0.00	0.00	0.77	0.77		
23	28.08		0.20	0.0		0.00	0.00	0.77	0.77		
24	26.88		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 1:43

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** MARCH ****

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	34.56	-27.	-19.	-28.	-19.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-4.	0.	0.	0.	-32.	-177.
2	33.34	-27.	-19.	-29.	-19.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-4.	0.	0.	0.	-33.	-182.
3	32.35	-28.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-1.	-19.	-25.	-4.	0.	0.	0.	-34.	-187.
4	31.61	-29.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-1.	-19.	-26.	-4.	0.	0.	0.	-35.	-190.
5	31.15	-29.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-1.	-20.	-26.	-4.	0.	0.	0.	-35.	-191.
6	31.00	-28.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-1.	-20.	-26.	-4.	0.	0.	0.	-34.	-190.
7	31.61	-5.	-11.	-24.	104.	0.	-3.	-2.	-2.	-2.	-22.	-28.	-4.	0.	0.	0.	-36.	-33.
8	33.34	23.	-6.	-20.	112.	0.	-3.	-2.	-3.	-2.	-24.	-31.	-4.	109.	54.	76.	-179.	101.
9	35.94	49.	-3.	-17.	65.	0.	-2.	-2.	-2.	-1.	-22.	-28.	-4.	109.	54.	76.	-166.	105.
10	39.00	127.	-2.	-15.	85.	0.	-2.	-2.	-2.	-1.	-19.	-25.	-5.	109.	54.	76.	-161.	217.
11	42.06	198.	-1.	-14.	97.	0.	-2.	-2.	-2.	-1.	-17.	-22.	-5.	109.	54.	76.	-156.	314.
12	44.66	253.	0.	-13.	102.	0.	-1.	-2.	-2.	-1.	-14.	-19.	-5.	109.	54.	76.	-152.	365.
13	46.39	200.	99.	-11.	1.	0.	-1.	-1.	-2.	-1.	-12.	-16.	-5.	109.	54.	76.	-141.	349.
14	47.00	132.	88.	-10.	2.	0.	-1.	-1.	-2.	-1.	-10.	-13.	-5.	109.	54.	76.	-133.	284.
15	46.85	55.	70.	-10.	2.	0.	-1.	-1.	-2.	-1.	-9.	-12.	-5.	109.	54.	76.	-127.	199.
16	46.39	31.	118.	-12.	-1.	0.	-1.	-1.	-2.	-1.	-10.	-13.	-5.	109.	54.	76.	-130.	213.
17	45.65	3.	109.	-16.	-5.	0.	-1.	0.	-2.	-1.	-11.	-15.	-4.	109.	54.	76.	-131.	165.
18	44.66	-20.	-14.	-22.	-14.	0.	-1.	0.	-2.	-1.	-13.	-17.	-4.	109.	54.	0.	-25.	29.
19	43.44	-19.	-14.	-21.	-14.	0.	-1.	0.	-1.	-1.	-14.	-19.	-4.	0.	0.	0.	-23.	-132.
20	42.06	-20.	-14.	-22.	-14.	0.	-2.	-1.	-2.	-1.	-16.	-22.	-4.	0.	0.	0.	-25.	-143.
21	40.56	-22.	-15.	-23.	-15.	0.	-2.	-1.	-2.	-1.	-15.	-21.	-4.	0.	0.	0.	-26.	-148.
22	39.00	-23.	-16.	-25.	-16.	0.	-2.	-1.	-2.	-1.	-16.	-21.	-4.	0.	0.	0.	-28.	-155.
23	37.44	-24.	-17.	-26.	-17.	0.	-2.	-1.	-2.	-1.	-17.	-22.	-4.	0.	0.	0.	-30.	-163.
24	35.94	-26.	-18.	-27.	-18.	0.	-2.	-1.	-2.	-1.	-17.	-23.	-4.	0.	0.	0.	-31.	-170.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	34.56		0.20	0.0		0.00	0.00	0.77	0.77		
2	33.34		0.20	0.0		0.00	0.00	0.77	0.77		
3	32.35		0.20	0.0		0.00	0.00	0.77	0.77		
4	31.61		0.20	0.0		0.00	0.00	0.77	0.77		
5	31.15		0.20	0.0		0.00	0.00	0.77	0.77		
6	31.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	31.61		0.20	0.0		0.00	0.00	0.77	0.77		
8	33.34		1.00	0.0		31.81	0.00	4.34	4.34		
9	35.94		1.00	0.0		31.81	0.00	4.34	4.34		
10	39.00		1.00	0.0		31.81	0.00	4.34	4.34		
11	42.06		1.00	0.0		31.81	0.00	4.34	4.34		
12	44.66		1.00	0.0		31.81	0.00	4.34	4.34		
13	46.39		1.00	0.0		31.81	0.00	6.38	6.38		
14	47.00		1.00	0.0		31.81	0.00	6.38	6.38		
15	46.85		1.00	0.0		31.81	0.00	6.38	6.38		
16	46.39		1.00	0.0		31.81	0.00	6.38	6.38		
17	45.65		1.00	0.0		31.81	0.00	6.38	6.38		
18	44.66		0.20	0.0		31.81	0.00	3.57	3.57		
19	43.44		0.20	0.0		0.00	0.00	0.77	0.77		
20	42.06		0.20	0.0		0.00	0.00	0.77	0.77		
21	40.56		0.20	0.0		0.00	0.00	0.77	0.77		
22	39.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	37.44		0.20	0.0		0.00	0.00	0.77	0.77		
24	35.94		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 1:45

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** APRIL ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	44.22	-20.	-14.	-21.	-14.	0.	-1.	-1.	-1.	-1.	-12.	-19.	-4.	0.	0.	0.	-24.	-133.
2	42.78	-21.	-15.	-22.	-15.	0.	-1.	-1.	-1.	-1.	-12.	-20.	-4.	0.	0.	0.	-25.	-139.
3	41.60	-21.	-15.	-23.	-15.	0.	-2.	-1.	-1.	-1.	-13.	-21.	-4.	0.	0.	0.	-26.	-143.
4	40.72	-22.	-15.	-23.	-15.	0.	-2.	-1.	-2.	-1.	-14.	-21.	-4.	0.	0.	0.	-26.	-145.
5	40.18	-21.	-15.	-23.	-15.	0.	-2.	-1.	-2.	-1.	-14.	-21.	-4.	0.	0.	0.	-26.	-144.
6	40.00	-15.	-8.	-10.	61.	0.	-2.	-1.	-2.	-1.	-15.	-23.	-4.	0.	0.	0.	-26.	-46.
7	40.72	24.	1.	-11.	192.	0.	-2.	-1.	-2.	-1.	-16.	-24.	-4.	0.	0.	0.	-27.	127.
8	42.78	50.	4.	-9.	186.	0.	-2.	-1.	-2.	-1.	-18.	-26.	-5.	109.	54.	76.	-135.	280.
9	45.86	74.	8.	-5.	141.	0.	-2.	-1.	-2.	-1.	-15.	-22.	-5.	109.	54.	76.	-121.	290.
10	49.50	109.	10.	-2.	111.	0.	-2.	-1.	-2.	0.	-11.	-18.	-5.	109.	54.	76.	-108.	320.
11	53.14	164.	11.	0.	123.	0.	-1.	-1.	-2.	0.	-9.	-14.	-5.	109.	54.	76.	-102.	402.
12	56.22	206.	12.	1.	127.	0.	-1.	-1.	-2.	0.	-6.	-11.	-5.	109.	54.	76.	-96.	462.
13	58.28	166.	124.	2.	13.	0.	-1.	-1.	-1.	-1.	-4.	-8.	-5.	109.	54.	76.	-87.	437.
14	59.00	113.	114.	3.	13.	0.	0.	-1.	-1.	-1.	-2.	-6.	-5.	109.	54.	76.	-80.	386.
15	58.82	81.	146.	2.	12.	0.	0.	0.	-1.	-1.	-2.	-6.	-5.	109.	54.	76.	-81.	384.
16	58.28	59.	191.	0.	10.	0.	0.	0.	-1.	-1.	-3.	-7.	-5.	109.	54.	76.	-86.	396.
17	57.40	32.	197.	-3.	6.	0.	-1.	0.	-1.	-1.	-4.	-9.	-5.	109.	54.	76.	-89.	362.
18	56.22	-6.	66.	-2.	-2.	0.	-1.	0.	-1.	-1.	-5.	-10.	-4.	109.	54.	0.	-16.	181.
19	54.78	-11.	-8.	-12.	-8.	0.	-1.	0.	-1.	0.	-6.	-11.	-4.	0.	0.	0.	-14.	-75.
20	53.14	-13.	-9.	-13.	-9.	0.	-1.	0.	-1.	-1.	-9.	-15.	-4.	0.	0.	0.	-15.	-90.
21	51.35	-14.	-10.	-15.	-10.	0.	-1.	-1.	-1.	-1.	-9.	-15.	-4.	0.	0.	0.	-17.	-98.
22	49.50	-16.	-11.	-17.	-11.	0.	-1.	-1.	-1.	-1.	-9.	-16.	-4.	0.	0.	0.	-19.	-107.
23	47.65	-18.	-12.	-19.	-12.	0.	-1.	-1.	-1.	-1.	-10.	-17.	-4.	0.	0.	0.	-21.	-117.
24	45.86	-19.	-13.	-20.	-13.	0.	-1.	-1.	-1.	-1.	-11.	-18.	-4.	0.	0.	0.	-23.	-126.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	44.22		0.20	0.0		0.00	0.00	0.77	0.77		
2	42.78		0.20	0.0		0.00	0.00	0.77	0.77		
3	41.60		0.20	0.0		0.00	0.00	0.77	0.77		
4	40.72		0.20	0.0		0.00	0.00	0.77	0.77		
5	40.18		0.20	0.0		0.00	0.00	0.77	0.77		
6	40.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	40.72		0.20	0.0		0.00	0.00	0.77	0.77		
8	42.78		1.00	0.0		31.81	0.00	4.34	4.34		
9	45.86		1.00	0.0		31.81	0.00	4.34	4.34		
10	49.50		1.00	0.0		31.81	0.00	4.34	4.34		
11	53.14		1.00	0.0		31.81	0.00	4.34	4.34		
12	56.22		1.00	0.0		31.81	0.00	4.34	4.34		
13	58.28		1.00	0.0		31.81	0.00	6.38	6.38		
14	59.00		1.00	0.0		31.81	0.00	6.38	6.38		
15	58.82		1.00	0.0		31.81	0.00	6.38	6.38		
16	58.28		1.00	0.0		31.81	0.00	6.38	6.38		
17	57.40		1.00	0.0		31.81	0.00	6.38	6.38		
18	56.22		0.20	0.0		31.81	0.00	3.57	3.57		
19	54.78		0.20	0.0		0.00	0.00	0.77	0.77		
20	53.14		0.20	0.0		0.00	0.00	0.77	0.77		
21	51.35		0.20	0.0		0.00	0.00	0.77	0.77		
22	49.50		0.20	0.0		0.00	0.00	0.77	0.77		
23	47.65		0.20	0.0		0.00	0.00	0.77	0.77		
24	45.86		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 1:48

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** MAY ****

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	54.00	-13.	-9.	-14.	-9.	0.	-1.	0.	-1.	0.	-6.	-15.	-4.	0.	0.	0.	-16.	-89.
2	52.64	-14.	-10.	-15.	-10.	0.	-1.	0.	-1.	0.	-7.	-15.	-4.	0.	0.	0.	-17.	-93.
3	51.52	-14.	-10.	-15.	-10.	0.	-1.	-1.	-1.	-1.	-7.	-16.	-4.	0.	0.	0.	-17.	-96.
4	50.69	-14.	-10.	-14.	-10.	0.	-1.	-1.	-1.	-1.	-8.	-16.	-4.	0.	0.	0.	-17.	-95.
5	50.17	-12.	-8.	-13.	-6.	0.	-1.	-1.	-1.	-1.	-8.	-17.	-4.	0.	0.	0.	-16.	-86.
6	50.00	0.	5.	13.	95.	0.	-1.	-1.	-1.	-1.	-9.	-18.	-4.	0.	0.	0.	-16.	62.
7	50.69	6.	12.	37.	195.	0.	-1.	-1.	-1.	-1.	-12.	-22.	-4.	0.	0.	0.	-16.	192.
8	52.64	71.	14.	3.	235.	0.	-2.	-1.	-1.	0.	-12.	-21.	-5.	109.	54.	76.	-91.	430.
9	55.56	93.	17.	6.	194.	0.	-1.	-1.	-1.	0.	-8.	-16.	-5.	109.	54.	76.	-78.	439.
10	59.00	111.	20.	9.	138.	0.	-1.	-1.	-1.	0.	-5.	-12.	-5.	109.	54.	76.	-65.	428.
11	62.44	143.	21.	11.	140.	0.	-1.	-1.	-1.	0.	-2.	-9.	-5.	109.	54.	76.	-58.	478.
12	65.36	172.	22.	12.	144.	0.	0.	-1.	-1.	0.	0.	-6.	-5.	109.	54.	76.	-53.	523.
13	67.31	145.	141.	13.	23.	0.	0.	-1.	-1.	0.	2.	-3.	-5.	109.	54.	76.	-46.	507.
14	68.00	114.	140.	13.	23.	0.	0.	0.	-1.	0.	3.	-2.	-5.	109.	54.	76.	-42.	483.
15	67.83	99.	198.	12.	21.	0.	0.	0.	-1.	0.	3.	-2.	-5.	109.	54.	76.	-47.	517.
16	67.31	78.	240.	10.	19.	0.	0.	0.	-1.	0.	2.	-3.	-5.	109.	54.	76.	-51.	527.
17	66.48	11.	199.	43.	16.	0.	0.	0.	-1.	0.	1.	-5.	-5.	109.	54.	76.	-51.	448.
18	65.36	6.	99.	20.	10.	0.	0.	0.	0.	0.	1.	-6.	-5.	109.	54.	0.	-9.	279.
19	64.00	-4.	0.	-4.	-2.	0.	0.	1.	0.	0.	1.	-6.	-4.	0.	0.	0.	-6.	-25.
20	62.44	-6.	-4.	-6.	-4.	0.	0.	0.	0.	0.	-2.	-10.	-4.	0.	0.	0.	-7.	-45.
21	60.76	-8.	-5.	-8.	-5.	0.	0.	0.	0.	0.	-5.	-13.	-4.	0.	0.	0.	-9.	-60.
22	59.00	-9.	-7.	-10.	-7.	0.	0.	0.	0.	0.	-4.	-12.	-4.	0.	0.	0.	-11.	-65.
23	57.24	-11.	-8.	-12.	-8.	0.	0.	0.	0.	0.	-5.	-13.	-4.	0.	0.	0.	-13.	-74.
24	55.56	-12.	-9.	-13.	-9.	0.	-1.	0.	-1.	0.	-6.	-14.	-4.	0.	0.	0.	-15.	-82.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	54.00		0.20	0.0		0.00	0.00	0.77	0.77		
2	52.64		0.20	0.0		0.00	0.00	0.77	0.77		
3	51.52		0.20	0.0		0.00	0.00	0.77	0.77		
4	50.69		0.20	0.0		0.00	0.00	0.77	0.77		
5	50.17		0.20	0.0		0.00	0.00	0.77	0.77		
6	50.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	50.69		0.20	0.0		0.00	0.00	0.77	0.77		
8	52.64		1.00	0.0		31.81	0.00	4.34	4.34		
9	55.56		1.00	0.0		31.81	0.00	4.34	4.34		
10	59.00		1.00	0.0		31.81	0.00	4.34	4.34		
11	62.44		1.00	0.0		31.81	0.00	4.34	4.34		
12	65.36		1.00	0.0		31.81	0.00	4.34	4.34		
13	67.31		1.00	0.0		31.81	0.00	6.38	6.38		
14	68.00		1.00	0.0		31.81	0.00	6.38	6.38		
15	67.83		1.00	0.0		31.81	0.00	6.38	6.38		
16	67.31		1.00	0.0		31.81	0.00	6.38	6.38		
17	66.48		1.00	0.0		31.81	0.00	6.38	6.38		
18	65.36		0.20	0.0		31.81	0.00	3.57	3.57		
19	64.00		0.20	0.0		0.00	0.00	0.77	0.77		
20	62.44		0.20	0.0		0.00	0.00	0.77	0.77		
21	60.76		0.20	0.0		0.00	0.00	0.77	0.77		
22	59.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	57.24		0.20	0.0		0.00	0.00	0.77	0.77		
24	55.56		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 1:50

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** JUNE ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	62.75	-6.	-4.	-7.	-4.	0.	0.	0.	0.	0.	-1.	-11.	-4.	0.	0.	0.	-7.	-45.
2	61.48	-7.	-5.	-7.	-5.	0.	0.	0.	0.	0.	-2.	-11.	-4.	0.	0.	0.	-8.	-50.
3	60.43	-7.	-5.	-7.	-5.	0.	0.	0.	0.	0.	-3.	-12.	-4.	0.	0.	0.	-8.	-52.
4	59.65	-7.	-5.	-7.	-5.	0.	0.	0.	0.	0.	-3.	-12.	-4.	0.	0.	0.	-8.	-52.
5	59.16	-3.	-1.	-1.	8.	0.	0.	0.	0.	0.	-3.	-13.	-4.	0.	0.	0.	-8.	-26.
6	59.00	8.	12.	25.	100.	0.	-1.	0.	0.	0.	-4.	-14.	-4.	0.	0.	0.	-9.	112.
7	59.45	14.	18.	48.	191.	0.	-1.	0.	-1.	0.	-7.	-17.	-5.	0.	0.	0.	-9.	230.
8	60.75	81.	20.	9.	251.	0.	-1.	-1.	-1.	0.	-7.	-17.	-5.	109.	54.	76.	-62.	507.
9	62.75	102.	23.	12.	212.	0.	-1.	-1.	-1.	0.	-4.	-13.	-5.	109.	54.	76.	-52.	512.
10	65.20	118.	25.	15.	158.	0.	-1.	0.	-1.	0.	-1.	-9.	-5.	109.	54.	76.	-41.	498.
11	67.80	140.	26.	17.	146.	0.	0.	0.	-1.	0.	2.	-6.	-5.	109.	54.	76.	-34.	524.
12	70.25	160.	27.	18.	150.	0.	0.	0.	-1.	0.	4.	-3.	-5.	109.	54.	76.	-29.	559.
13	72.25	142.	148.	19.	28.	0.	0.	0.	0.	0.	5.	-1.	-5.	109.	54.	76.	-23.	552.
14	73.55	122.	161.	19.	28.	0.	0.	0.	0.	0.	6.	0.	-5.	109.	54.	76.	-19.	551.
15	74.00	107.	216.	18.	26.	0.	0.	0.	0.	0.	6.	0.	-5.	109.	54.	76.	-20.	587.
16	73.84	87.	256.	16.	24.	0.	0.	0.	0.	0.	6.	-1.	-5.	109.	54.	76.	-22.	601.
17	73.35	18.	194.	53.	22.	0.	0.	1.	0.	0.	5.	-2.	-5.	109.	54.	76.	-19.	506.
18	72.57	14.	105.	31.	16.	0.	0.	1.	0.	0.	5.	-3.	-5.	109.	54.	0.	-2.	326.
19	71.52	5.	14.	7.	5.	0.	0.	1.	1.	0.	5.	-3.	-4.	0.	0.	0.	2.	32.
20	70.25	0.	0.	0.	0.	0.	0.	1.	1.	0.	2.	-6.	-4.	0.	0.	0.	1.	-4.
21	68.82	-1.	-1.	-1.	-1.	0.	0.	0.	0.	0.	-1.	-10.	-4.	0.	0.	0.	-1.	-18.
22	67.28	-3.	-2.	-3.	-2.	0.	0.	0.	0.	0.	1.	-8.	-4.	0.	0.	0.	-3.	-23.
23	65.72	-4.	-3.	-4.	-3.	0.	0.	0.	0.	0.	0.	-9.	-4.	0.	0.	0.	-5.	-31.
24	64.18	-5.	-4.	-6.	-4.	0.	0.	0.	0.	0.	-1.	-10.	-4.	0.	0.	0.	-6.	-39.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	62.75		0.20	0.0		0.00	0.00	0.77	0.77		
2	61.48		0.20	0.0		0.00	0.00	0.77	0.77		
3	60.43		0.20	0.0		0.00	0.00	0.77	0.77		
4	59.65		0.20	0.0		0.00	0.00	0.77	0.77		
5	59.16		0.20	0.0		0.00	0.00	0.77	0.77		
6	59.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	59.45		0.20	0.0		0.00	0.00	0.77	0.77		
8	60.75		1.00	0.0		31.81	0.00	4.34	4.34		
9	62.75		1.00	0.0		31.81	0.00	4.34	4.34		
10	65.20		1.00	0.0		31.81	0.00	4.34	4.34		
11	67.80		1.00	0.0		31.81	0.00	4.34	4.34		
12	70.25		1.00	0.0		31.81	0.00	4.34	4.34		
13	72.25		1.00	0.0		31.81	0.00	6.38	6.38		
14	73.55		1.00	0.0		31.81	0.00	6.38	6.38		
15	74.00		1.00	0.0		31.81	0.00	6.38	6.38		
16	73.84		1.00	71.8		31.81	0.00	7.18	7.18		
17	73.35		1.00	0.0		31.81	0.00	6.38	6.38		
18	72.57		0.20	0.0		31.81	0.00	3.57	3.57		
19	71.52		0.20	0.0		0.00	0.00	0.77	0.77		
20	70.25		0.20	0.0		0.00	0.00	0.77	0.77		
21	68.82		0.20	0.0		0.00	0.00	0.77	0.77		
22	67.28		0.20	0.0		0.00	0.00	0.77	0.77		
23	65.72		0.20	0.0		0.00	0.00	0.77	0.77		
24	64.18		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 1:52

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** JULY ****

		WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
HR	TEMP.	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
1	69.75	-1.	-1.	-1.	-1.	0.	0.	0.	0.	0.	3.	-7.	-4.	0.	0.	0.	-2.	-13.
2	68.14	-2.	-1.	-2.	-1.	0.	0.	0.	0.	0.	2.	-8.	-4.	0.	0.	0.	-2.	-19.
3	66.81	-2.	-2.	-2.	-2.	0.	0.	0.	0.	0.	1.	-9.	-4.	0.	0.	0.	-3.	-22.
4	65.82	-2.	-1.	-2.	-1.	0.	0.	0.	0.	0.	1.	-9.	-4.	0.	0.	0.	-2.	-21.
5	65.21	-1.	0.	0.	7.	0.	0.	0.	0.	0.	1.	-9.	-4.	0.	0.	0.	-2.	-14.
6	65.00	12.	14.	26.	99.	0.	0.	0.	0.	0.	-1.	-11.	-4.	0.	0.	0.	-3.	132.
7	65.57	18.	22.	50.	198.	0.	0.	0.	0.	0.	-4.	-15.	-4.	0.	0.	0.	-3.	262.
8	67.22	86.	26.	19.	241.	0.	0.	0.	0.	0.	-2.	-12.	-5.	109.	54.	76.	-24.	571.
9	69.75	105.	27.	19.	200.	0.	0.	0.	0.	0.	-1.	-10.	-5.	109.	54.	76.	-15.	558.
10	72.85	122.	30.	22.	145.	0.	0.	0.	0.	1.	3.	-6.	-5.	109.	54.	76.	-2.	546.
11	76.15	154.	31.	24.	148.	0.	0.	0.	0.	1.	5.	-3.	-5.	109.	54.	76.	6.	601.
12	79.25	183.	33.	26.	153.	0.	1.	0.	0.	1.	8.	0.	-5.	109.	54.	76.	17.	654.
13	81.78	157.	150.	27.	33.	0.	1.	0.	0.	1.	10.	3.	-5.	109.	54.	76.	24.	640.
14	83.43	127.	149.	28.	33.	0.	1.	0.	0.	0.	11.	4.	-5.	109.	54.	76.	29.	618.
15	84.00	112.	205.	27.	32.	0.	1.	1.	0.	0.	11.	5.	-5.	109.	54.	76.	31.	660.
16	83.79	92.	245.	25.	30.	0.	1.	1.	0.	0.	11.	4.	-5.	109.	54.	76.	29.	673.
17	83.18	25.	203.	57.	26.	0.	1.	1.	0.	0.	9.	2.	-5.	109.	54.	76.	25.	584.
18	82.19	20.	105.	34.	20.	0.	1.	1.	1.	0.	9.	2.	-5.	109.	54.	0.	7.	359.
19	80.86	9.	9.	10.	7.	0.	1.	1.	1.	1.	10.	2.	-4.	0.	0.	0.	11.	57.
20	79.25	7.	5.	8.	5.	0.	1.	1.	1.	1.	7.	-2.	-4.	0.	0.	0.	9.	37.
21	77.44	5.	4.	6.	4.	0.	1.	1.	1.	1.	4.	-5.	-4.	0.	0.	0.	6.	21.
22	75.49	3.	2.	3.	2.	0.	1.	1.	1.	1.	5.	-4.	-4.	0.	0.	0.	4.	15.
23	73.51	1.	1.	2.	1.	0.	1.	0.	1.	0.	4.	-5.	-4.	0.	0.	0.	2.	4.
24	71.56	0.	0.	0.	0.	0.	1.	0.	0.	0.	3.	-6.	-4.	0.	0.	0.	0.	-5.

	TEMPERATURE		AIR	OUTPUT OF		LIGHTS	COST (DOLLARS)			TOTAL ENERGY	
HOUR	OUTDOOR	INDOOR	CHANGES	HVAC SYSTEM	STORED	(KWHR)	GAS	ELECTRICITY	TOTAL	SITE	SOURCE
1	69.75		0.20	0.0		0.00	0.00	0.77	0.77		
2	68.14		0.20	0.0		0.00	0.00	0.77	0.77		
3	66.81		0.20	0.0		0.00	0.00	0.77	0.77		
4	65.82		0.20	0.0		0.00	0.00	0.77	0.77		
5	65.21		0.20	0.0		0.00	0.00	0.77	0.77		
6	65.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	65.57		0.20	0.0		0.00	0.00	0.77	0.77		
8	67.22		6.00	0.0		31.81	0.00	4.34	4.34		
9	69.75		1.00	0.0		31.81	0.00	4.34	4.34		
10	72.85		1.00	0.0		31.81	0.00	4.34	4.34		
11	76.15		1.00	80.6		31.81	0.00	4.91	4.91		
12	79.25		1.00	136.8		31.81	0.00	5.30	5.30		
13	81.78		1.00	125.4		31.81	0.00	7.78	7.78		
14	83.43		1.00	104.0		31.81	0.00	7.54	7.54		
15	84.00		1.00	147.1		31.81	0.00	8.02	8.02		
16	83.79		1.00	159.2		31.81	0.00	8.15	8.15		
17	83.18		1.00	0.0		31.81	0.00	6.38	6.38		
18	82.19		0.20	0.0		31.81	0.00	3.57	3.57		
19	80.86		0.20	0.0		0.00	0.00	0.77	0.77		
20	79.25		0.20	0.0		0.00	0.00	0.77	0.77		
21	77.44		0.20	0.0		0.00	0.00	0.77	0.77		
22	75.49		0.20	0.0		0.00	0.00	0.77	0.77		
23	73.51		0.20	0.0		0.00	0.00	0.77	0.77		
24	71.56		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 1:54

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** AUGUST ****

HR	TEMP.	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
1	67.50	-2.	-1.	-2.	-1.	0.	0.	0.	0.	0.	1.	-8.	-4.	0.	0.	0.	-2.	-19.
2	65.98	-3.	-2.	-3.	-2.	0.	0.	0.	0.	0.	1.	-9.	-4.	0.	0.	0.	-4.	-26.
3	64.72	-4.	-3.	-4.	-3.	0.	0.	0.	0.	0.	0.	-9.	-4.	0.	0.	0.	-4.	-30.
4	63.78	-4.	-3.	-4.	-3.	0.	0.	0.	0.	0.	-1.	-10.	-4.	0.	0.	0.	-5.	-32.
5	63.20	-3.	-2.	-4.	-2.	0.	0.	0.	0.	0.	-1.	-10.	-4.	0.	0.	0.	-4.	-32.
6	63.00	3.	5.	8.	63.	0.	0.	0.	0.	0.	-2.	-12.	-4.	0.	0.	0.	-5.	57.
7	63.54	45.	17.	12.	194.	0.	0.	0.	0.	0.	-2.	-11.	-4.	0.	0.	0.	-83.	168.
8	65.11	72.	22.	15.	194.	0.	0.	0.	0.	0.	-4.	-14.	-4.	109.	54.	76.	-90.	429.
9	67.50	95.	25.	18.	154.	0.	0.	0.	0.	0.	-1.	-10.	-4.	109.	54.	76.	-37.	478.
10	70.44	125.	25.	17.	123.	0.	0.	0.	0.	0.	0.	-9.	-5.	109.	54.	76.	-16.	499.
11	73.56	177.	26.	19.	135.	0.	0.	0.	0.	0.	2.	-6.	-5.	109.	54.	76.	-11.	578.
12	76.50	219.	28.	21.	140.	0.	1.	0.	0.	0.	5.	-3.	-5.	109.	54.	76.	-1.	644.
13	78.89	180.	137.	22.	29.	0.	1.	0.	0.	0.	7.	0.	-5.	109.	54.	76.	8.	619.
14	80.46	130.	127.	23.	29.	0.	1.	0.	0.	0.	8.	2.	-5.	109.	54.	76.	15.	569.
15	81.00	99.	157.	22.	28.	0.	1.	0.	0.	0.	9.	2.	-5.	109.	54.	76.	17.	569.
16	80.80	77.	197.	20.	25.	0.	1.	1.	0.	0.	8.	1.	-5.	109.	54.	76.	15.	580.
17	80.22	50.	197.	17.	21.	0.	1.	1.	0.	0.	7.	0.	-5.	109.	54.	76.	14.	542.
18	79.28	12.	69.	18.	12.	0.	1.	1.	1.	0.	7.	0.	-5.	109.	54.	0.	6.	285.
19	78.02	7.	5.	6.	5.	0.	1.	1.	1.	1.	7.	-1.	-4.	0.	0.	0.	9.	38.
20	76.50	6.	4.	6.	4.	0.	1.	1.	1.	0.	4.	-5.	-4.	0.	0.	0.	7.	24.
21	74.78	4.	3.	4.	3.	0.	1.	0.	1.	0.	4.	-4.	-4.	0.	0.	0.	5.	16.
22	72.94	2.	2.	3.	2.	0.	1.	0.	1.	0.	4.	-5.	-4.	0.	0.	0.	3.	8.
23	71.06	1.	1.	1.	1.	0.	1.	0.	0.	0.	3.	-6.	-4.	0.	0.	0.	1.	-2.
24	69.22	-1.	-1.	-1.	-1.	0.	0.	0.	0.	0.	2.	-7.	-4.	0.	0.	0.	-1.	-11.

HOUR	TEMPERATURE OUTDOOR	TEMPERATURE INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	COST (DOLLARS) ELECTRICITY	COST (DOLLARS) TOTAL	TOTAL ENERGY SITE	TOTAL ENERGY SOURCE
1	67.50		0.20	0.0		0.00	0.00	0.77	0.77		
2	65.98		0.20	0.0		0.00	0.00	0.77	0.77		
3	64.72		0.20	0.0		0.00	0.00	0.77	0.77		
4	63.78		0.20	0.0		0.00	0.00	0.77	0.77		
5	63.20		0.20	0.0		0.00	0.00	0.77	0.77		
6	63.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	63.54		6.00	0.0		0.00	0.00	0.77	0.77		
8	65.11		6.00	0.0		31.81	0.00	4.34	4.34		
9	67.50		6.00	0.0		31.81	0.00	4.34	4.34		
10	70.44		1.00	0.0		31.81	0.00	4.34	4.34		
11	73.56		1.00	0.0		31.81	0.00	4.34	4.34		
12	76.50		1.00	121.4		31.81	0.00	5.19	5.19		
13	78.89		1.00	98.5		31.81	0.00	7.48	7.48		
14	80.46		1.00	0.0		31.81	0.00	6.38	6.38		
15	81.00		1.00	0.0		31.81	0.00	6.38	6.38		
16	80.80		1.00	0.0		31.81	0.00	6.38	6.38		
17	80.22		1.00	0.0		31.81	0.00	6.38	6.38		
18	79.28		0.20	0.0		31.81	0.00	3.57	3.57		
19	78.02		0.20	0.0		0.00	0.00	0.77	0.77		
20	76.50		0.20	0.0		0.00	0.00	0.77	0.77		
21	74.78		0.20	0.0		0.00	0.00	0.77	0.77		
22	72.94		0.20	0.0		0.00	0.00	0.77	0.77		
23	71.06		0.20	0.0		0.00	0.00	0.77	0.77		
24	69.22		0.20	0.0		0.00	0.00	0.77	0.77		

$$$$ HOURLY SUMMARY $$$$ SOLARS $$$$ HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) $$$$ 4/ 8/87 1:56

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

$$$$ SEPTEMBER $$$$

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	60.56	-6.	-5.	-7.	-5.	0.	0.	0.	0.	0.	-3.	-11.	-4.	0.	0.	0.	-8.	-49.
2	59.34	-7.	-5.	-8.	-5.	0.	0.	0.	0.	0.	-4.	-12.	-4.	0.	0.	0.	-9.	-55.
3	58.35	-8.	-6.	-8.	-6.	0.	0.	0.	0.	0.	-4.	-13.	-4.	0.	0.	0.	-10.	-59.
4	57.61	-8.	-6.	-9.	-6.	0.	0.	0.	0.	0.	-5.	-13.	-4.	0.	0.	0.	-10.	-62.
5	57.15	-8.	-6.	-9.	-6.	0.	0.	0.	0.	0.	-5.	-14.	-4.	0.	0.	0.	-10.	-64.
6	57.00	-8.	-6.	-9.	-6.	0.	0.	0.	0.	0.	-5.	-14.	-4.	0.	0.	0.	-10.	-63.
7	57.61	16.	5.	-1.	106.	0.	-1.	0.	-1.	0.	-7.	-16.	-4.	0.	0.	0.	-11.	85.
8	59.34	43.	10.	2.	120.	0.	-1.	-1.	-1.	-1.	-11.	-20.	-5.	109.	54.	76.	-63.	312.
9	61.94	68.	14.	6.	80.	0.	-1.	-1.	-1.	0.	-8.	-17.	-5.	109.	54.	76.	-51.	323.
10	65.00	143.	16.	8.	99.	0.	0.	-1.	-1.	0.	-6.	-14.	-5.	109.	54.	76.	-46.	432.
11	68.06	211.	17.	9.	111.	0.	0.	-1.	-1.	0.	-4.	-11.	-5.	109.	54.	76.	-41.	525.
12	70.66	264.	18.	11.	116.	0.	0.	0.	-1.	0.	-1.	-7.	-5.	109.	54.	76.	-36.	599.
13	72.39	213.	113.	12.	18.	0.	1.	0.	-1.	0.	1.	-5.	-5.	109.	54.	76.	-26.	561.
14	73.00	148.	102.	13.	19.	0.	1.	0.	0.	0.	3.	-3.	-5.	109.	54.	76.	-18.	498.
15	72.85	75.	84.	13.	18.	0.	1.	0.	0.	0.	4.	-2.	-5.	109.	54.	76.	-12.	416.
16	72.39	51.	126.	10.	15.	0.	1.	0.	0.	0.	3.	-3.	-5.	109.	54.	76.	-15.	424.
17	71.65	23.	110.	6.	9.	0.	1.	1.	0.	0.	2.	-5.	-5.	109.	54.	76.	-14.	367.
18	70.66	0.	0.	0.	0.	0.	1.	1.	0.	0.	2.	-5.	-4.	109.	54.	0.	0.	155.
19	69.44	1.	1.	1.	1.	0.	0.	1.	0.	0.	0.	-7.	-4.	0.	0.	0.	1.	-6.
20	68.06	0.	0.	0.	0.	0.	0.	0.	0.	0.	-2.	-10.	-4.	0.	0.	0.	0.	-16.
21	66.56	-2.	-1.	-2.	-1.	0.	0.	0.	0.	0.	-1.	-8.	-4.	0.	0.	0.	-2.	-20.
22	65.00	-3.	-2.	-3.	-2.	0.	0.	0.	0.	0.	-1.	-9.	-4.	0.	0.	0.	-3.	-28.
23	63.44	-4.	-3.	-4.	-3.	0.	0.	0.	0.	0.	-2.	-10.	-4.	0.	0.	0.	-5.	-35.
24	61.94	-5.	-4.	-6.	-4.	0.	0.	0.	0.	0.	-3.	-11.	-4.	0.	0.	0.	-6.	-43.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	60.56		0.20	0.0		0.00	0.00	0.77	0.77		
2	59.34		0.20	0.0		0.00	0.00	0.77	0.77		
3	58.35		0.20	0.0		0.00	0.00	0.77	0.77		
4	57.61		0.20	0.0		0.00	0.00	0.77	0.77		
5	57.15		0.20	0.0		0.00	0.00	0.77	0.77		
6	57.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	57.61		0.20	0.0		0.00	0.00	0.77	0.77		
8	59.34		1.00	0.0		31.81	0.00	4.34	4.34		
9	61.94		1.00	0.0		31.81	0.00	4.34	4.34		
10	65.00		1.00	0.0		31.81	0.00	4.34	4.34		
11	68.06		1.00	0.0		31.81	0.00	4.34	4.34		
12	70.66		1.18	0.0		31.81	0.00	4.34	4.34		
13	72.39		1.00	0.0		31.81	0.00	6.38	6.38		
14	73.00		1.00	0.0		31.81	0.00	6.38	6.38		
15	72.85		1.00	0.0		31.81	0.00	6.38	6.38		
16	72.39		1.00	0.0		31.81	0.00	6.38	6.38		
17	71.65		1.00	0.0		31.81	0.00	6.38	6.38		
18	70.66		0.20	0.0		31.81	0.00	3.57	3.57		
19	69.44		0.20	0.0		0.00	0.00	0.77	0.77		
20	68.06		0.20	0.0		0.00	0.00	0.77	0.77		
21	66.56		0.20	0.0		0.00	0.00	0.77	0.77		
22	65.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	63.44		0.20	0.0		0.00	0.00	0.77	0.77		
24	61.94		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 1:58

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** OCTOBER ****

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	49.67	-15.	-10.	-16.	-10.	0.	-1.	-1.	-1.	-1.	-10.	-17.	-4.	0.	0.	0.	-18.	-104.
2	48.76	-15.	-11.	-16.	-11.	0.	-1.	-1.	-1.	-1.	-11.	-18.	-4.	0.	0.	0.	-19.	-108.
3	48.01	-16.	-11.	-17.	-11.	0.	-1.	-1.	-1.	-1.	-11.	-18.	-4.	0.	0.	0.	-19.	-111.
4	47.46	-16.	-11.	-17.	-11.	0.	-1.	-1.	-1.	-1.	-11.	-19.	-4.	0.	0.	0.	-20.	-114.
5	47.12	-16.	-11.	-17.	-11.	0.	-1.	-1.	-1.	-1.	-12.	-19.	-4.	0.	0.	0.	-20.	-115.
6	47.00	-16.	-11.	-17.	-11.	0.	-1.	-1.	-1.	-1.	-12.	-19.	-4.	0.	0.	0.	-19.	-114.
7	47.46	-13.	-10.	-15.	-2.	0.	-1.	-1.	-1.	-1.	-12.	-19.	-4.	0.	0.	0.	-18.	-99.
8	48.76	13.	-1.	-10.	42.	0.	-2.	-1.	-1.	-1.	-14.	-22.	-5.	109.	54.	76.	-104.	134.
9	50.70	75.	3.	-7.	49.	0.	-2.	-1.	-2.	-1.	-16.	-24.	-5.	109.	54.	76.	-101.	209.
10	53.00	158.	5.	-5.	68.	0.	-1.	-1.	-2.	-1.	-14.	-21.	-5.	109.	54.	76.	-100.	320.
11	55.30	233.	6.	-4.	80.	0.	-1.	-1.	-2.	0.	-12.	-18.	-5.	109.	54.	76.	-98.	416.
12	57.24	290.	6.	-4.	85.	0.	0.	-1.	-2.	-1.	-10.	-16.	-5.	109.	54.	76.	-96.	486.
13	58.54	234.	82.	-2.	7.	0.	0.	-1.	-1.	-1.	-8.	-13.	-5.	109.	54.	76.	-87.	444.
14	59.00	161.	71.	-2.	7.	0.	0.	-1.	-1.	-1.	-6.	-11.	-5.	109.	54.	76.	-79.	373.
15	58.88	79.	52.	-1.	6.	0.	0.	0.	-1.	-1.	-5.	-10.	-5.	109.	54.	76.	-72.	283.
16	58.54	19.	46.	-3.	3.	0.	0.	0.	-1.	-1.	-5.	-10.	-5.	109.	54.	76.	-68.	215.
17	57.99	-9.	1.	-10.	-6.	0.	0.	0.	-1.	-1.	-6.	-12.	-5.	109.	54.	76.	-63.	128.
18	57.24	-11.	-7.	-11.	-7.	0.	0.	0.	-1.	-1.	-8.	-14.	-5.	109.	54.	0.	-13.	85.
19	56.33	-9.	-6.	-10.	-6.	0.	-1.	0.	-1.	0.	-9.	-16.	-4.	0.	0.	0.	-11.	-74.
20	55.30	-10.	-7.	-11.	-7.	0.	-1.	0.	-1.	0.	-8.	-15.	-4.	0.	0.	0.	-12.	-76.
21	54.17	-11.	-8.	-12.	-8.	0.	-1.	0.	-1.	0.	-8.	-15.	-4.	0.	0.	0.	-13.	-82.
22	53.00	-12.	-8.	-13.	-8.	0.	-1.	0.	-1.	0.	-9.	-16.	-4.	0.	0.	0.	-15.	-88.
23	51.83	-13.	-9.	-14.	-9.	0.	-1.	-1.	-1.	-1.	-9.	-16.	-4.	0.	0.	0.	-16.	-93.
24	50.70	-14.	-10.	-15.	-10.	0.	-1.	-1.	-1.	-1.	-10.	-17.	-4.	0.	0.	0.	-17.	-99.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	49.67		0.20	0.0		0.00	0.00	0.77	0.77		
2	48.76		0.20	0.0		0.00	0.00	0.77	0.77		
3	48.01		0.20	0.0		0.00	0.00	0.77	0.77		
4	47.46		0.20	0.0		0.00	0.00	0.77	0.77		
5	47.12		0.20	0.0		0.00	0.00	0.77	0.77		
6	47.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	47.46		0.20	0.0		0.00	0.00	0.77	0.77		
8	48.76		1.00	0.0		31.81	0.00	4.34	4.34		
9	50.70		1.00	0.0		31.81	0.00	4.34	4.34		
10	53.00		1.00	0.0		31.81	0.00	4.34	4.34		
11	55.30		1.00	0.0		31.81	0.00	4.34	4.34		
12	57.24		1.00	0.0		31.81	0.00	4.34	4.34		
13	58.54		1.00	0.0		31.81	0.00	6.38	6.38		
14	59.00		1.00	0.0		31.81	0.00	6.38	6.38		
15	58.88		1.00	0.0		31.81	0.00	6.38	6.38		
16	58.54		1.00	0.0		31.81	0.00	6.38	6.38		
17	57.99		1.00	0.0		31.81	0.00	6.38	6.38		
18	57.24		0.20	0.0		31.81	0.00	3.57	3.57		
19	56.33		0.20	0.0		0.00	0.00	0.77	0.77		
20	55.30		0.20	0.0		0.00	0.00	0.77	0.77		
21	54.17		0.20	0.0		0.00	0.00	0.77	0.77		
22	53.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	51.83		0.20	0.0		0.00	0.00	0.77	0.77		
24	50.70		0.20	0.0		0.00	0.00	0.77	0.77		

\$\$\$\$ HOURLY SUMMARY \$\$\$\$ SOLARS \$\$\$\$ HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) \$\$\$\$ 4/ 8/87 2: 1

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

\$\$\$\$ NOVEMBER \$\$\$\$

		WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
HR	TEMP.	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
1	38.89	-22.	-16.	-24.	-16.	0.	-2.	-1.	-2.	-1.	-17.	-23.	-5.	0.	0.	0.	-27.	-156.
2	38.59	-23.	-16.	-24.	-16.	0.	-2.	-1.	-2.	-1.	-17.	-23.	-5.	0.	0.	0.	-28.	-158.
3	38.34	-23.	-16.	-24.	-16.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-5.	0.	0.	0.	-28.	-159.
4	38.15	-23.	-16.	-24.	-16.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-5.	0.	0.	0.	-28.	-160.
5	38.04	-23.	-16.	-25.	-16.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-5.	0.	0.	0.	-28.	-161.
6	38.00	-23.	-16.	-25.	-16.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-5.	0.	0.	0.	-28.	-161.
7	38.15	-23.	-16.	-24.	-16.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-5.	0.	0.	0.	-28.	-161.
8	38.59	-9.	-12.	-22.	-4.	0.	-2.	-1.	-2.	-1.	-20.	-26.	-5.	109.	54.	76.	-152.	-17.
9	39.23	70.	-7.	-19.	22.	0.	-2.	-1.	-2.	-1.	-20.	-27.	-5.	109.	54.	76.	-156.	90.
10	40.00	156.	-5.	-18.	41.	0.	-2.	-1.	-2.	-1.	-22.	-28.	-5.	109.	54.	76.	-161.	190.
11	40.77	233.	-5.	-18.	52.	0.	-2.	-2.	-2.	-1.	-20.	-26.	-5.	109.	54.	76.	-165.	278.
12	41.41	290.	-5.	-18.	56.	0.	-1.	-2.	-2.	-1.	-19.	-24.	-5.	109.	54.	76.	-167.	341.
13	41.85	233.	53.	-17.	-4.	0.	-1.	-1.	-2.	-1.	-17.	-22.	-5.	109.	54.	76.	-160.	293.
14	42.00	158.	42.	-17.	-4.	0.	-1.	-1.	-2.	-1.	-15.	-20.	-5.	109.	54.	76.	-153.	218.
15	41.96	72.	23.	-17.	-6.	0.	-1.	-1.	-2.	-1.	-15.	-20.	-5.	109.	54.	76.	-145.	123.
16	41.85	-7.	-2.	-20.	-10.	0.	-1.	-1.	-2.	-1.	-15.	-20.	-5.	109.	54.	76.	-136.	20.
17	41.66	-22.	-16.	-24.	-16.	0.	-1.	-1.	-2.	-1.	-16.	-22.	-5.	109.	54.	76.	-136.	-22.
18	41.41	-23.	-16.	-24.	-16.	0.	-2.	-1.	-2.	-1.	-18.	-24.	-5.	109.	54.	0.	-27.	4.
19	41.11	-21.	-15.	-22.	-15.	0.	-2.	-1.	-2.	-1.	-17.	-22.	-5.	0.	0.	0.	-25.	-146.
20	40.77	-21.	-15.	-22.	-15.	0.	-2.	-1.	-2.	-1.	-17.	-22.	-5.	0.	0.	0.	-25.	-148.
21	40.39	-21.	-15.	-23.	-15.	0.	-2.	-1.	-2.	-1.	-17.	-23.	-5.	0.	0.	0.	-26.	-149.
22	40.00	-22.	-15.	-23.	-15.	0.	-2.	-1.	-2.	-1.	-17.	-23.	-5.	0.	0.	0.	-26.	-151.
23	39.61	-22.	-15.	-23.	-15.	0.	-2.	-1.	-2.	-1.	-17.	-23.	-5.	0.	0.	0.	-27.	-153.
24	39.23	-22.	-16.	-24.	-16.	0.	-2.	-1.	-2.	-1.	-17.	-23.	-5.	0.	0.	0.	-27.	-155.

	TEMPERATURE		AIR	OUTPUT OF		LIGHTS	COST (DOLLARS)			TOTAL ENERGY	
HOUR	OUTDOOR	INDOOR	CHANGES	HVAC SYSTEM	STORED	(KWHR)	GAS	ELECTRICITY	TOTAL	SITE	SOURCE
1	38.89		0.20	0.0		0.00	0.00	0.77	0.77		
2	38.59		0.20	0.0		0.00	0.00	0.77	0.77		
3	38.34		0.20	0.0		0.00	0.00	0.77	0.77		
4	38.15		0.20	0.0		0.00	0.00	0.77	0.77		
5	38.04		0.20	0.0		0.00	0.00	0.77	0.77		
6	38.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	38.15		0.20	0.0		0.00	0.00	0.77	0.77		
8	38.59		1.00	-18.1		31.81	0.23	4.34	4.56		
9	39.23		1.00	0.0		31.81	0.00	4.34	4.34		
10	40.00		1.00	0.0		31.81	0.00	4.34	4.34		
11	40.77		1.00	0.0		31.81	0.00	4.34	4.34		
12	41.41		1.00	0.0		31.81	0.00	4.34	4.34		
13	41.85		1.00	0.0		31.81	0.00	6.38	6.38		
14	42.00		1.00	0.0		31.81	0.00	6.38	6.38		
15	41.96		1.00	0.0		31.81	0.00	6.38	6.38		
16	41.85		1.00	0.0		31.81	0.00	6.38	6.38		
17	41.66		1.00	-22.3		31.81	0.28	6.38	6.66		
18	41.41		0.20	0.0		31.81	0.00	3.57	3.57		
19	41.11		0.20	0.0		0.00	0.00	0.77	0.77		
20	40.77		0.20	0.0		0.00	0.00	0.77	0.77		
21	40.39		0.20	0.0		0.00	0.00	0.77	0.77		
22	40.00		0.20	0.0		0.00	0.00	0.77	0.77		
23	39.61		0.20	0.0		0.00	0.00	0.77	0.77		
24	39.23		0.20	0.0		0.00	0.00	0.77	0.77		

**** HOURLY SUMMARY **** SOLAR5 **** HEAT GAIN AND LOSS - (UNITS ARE IN THOUSAND BTU) **** 4/ 8/87 2: 3

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** DECEMBER ****

HR	TEMP.	WINDOWS SOUTH	WEST	NORTH	EAST	SKY LIGHT	WALLS SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	EQPT.	PEOPLE	AIR INFIL.	TOTAL
1	28.59	-30.	-22.	-32.	-22.	0.	-3.	-2.	-2.	-2.	-23.	-28.	-4.	0.	0.	0.	-37.	-206.
2	28.04	-31.	-22.	-33.	-22.	0.	-3.	-2.	-2.	-2.	-23.	-28.	-4.	0.	0.	0.	-38.	-208.
3	27.60	-31.	-22.	-33.	-22.	0.	-3.	-2.	-2.	-2.	-23.	-28.	-4.	0.	0.	0.	-38.	-211.
4	27.27	-31.	-22.	-33.	-22.	0.	-3.	-2.	-2.	-2.	-23.	-28.	-4.	0.	0.	0.	-38.	-212.
5	27.07	-32.	-22.	-34.	-22.	0.	-3.	-2.	-2.	-2.	-24.	-29.	-4.	0.	0.	0.	-38.	-214.
6	27.00	-32.	-22.	-34.	-22.	0.	-3.	-2.	-2.	-2.	-24.	-29.	-4.	0.	0.	0.	-39.	-214.
7	27.40	-31.	-22.	-33.	-22.	0.	-3.	-2.	-3.	-2.	-24.	-29.	-4.	0.	0.	0.	-38.	-213.
8	28.51	-23.	-21.	-34.	-18.	0.	-3.	-2.	-3.	-2.	-26.	-31.	-5.	109.	54.	76.	-204.	-132.
9	30.11	61.	-13.	-27.	9.	0.	-3.	-2.	-3.	-2.	-26.	-31.	-5.	109.	54.	76.	-196.	3.
10	31.89	151.	-11.	-25.	28.	0.	-3.	-2.	-3.	-2.	-27.	-33.	-5.	109.	54.	76.	-196.	112.
11	33.49	229.	-10.	-25.	40.	0.	-2.	-2.	-3.	-1.	-26.	-30.	-5.	109.	54.	76.	-196.	208.
12	34.60	287.	-10.	-25.	44.	0.	-2.	-2.	-3.	-1.	-24.	-28.	-5.	109.	54.	76.	-196.	274.
13	35.00	230.	41.	-24.	-9.	0.	-2.	-2.	-3.	-2.	-22.	-26.	-5.	109.	54.	76.	-190.	227.
14	34.93	153.	30.	-23.	-10.	0.	-1.	-2.	-3.	-2.	-20.	-24.	-5.	109.	54.	76.	-184.	150.
15	34.73	64.	12.	-24.	-11.	0.	-1.	-1.	-2.	-2.	-19.	-23.	-5.	109.	54.	76.	-176.	51.
16	34.40	-18.	-14.	-28.	-17.	0.	-1.	-1.	-2.	-2.	-20.	-24.	-5.	109.	54.	76.	-173.	-67.
17	33.96	-29.	-20.	-31.	-20.	0.	-2.	-1.	-2.	-2.	-22.	-26.	-5.	109.	54.	76.	-176.	-96.
18	33.41	-29.	-20.	-31.	-20.	0.	-2.	-1.	-2.	-2.	-23.	-28.	-5.	109.	54.	0.	-35.	-36.
19	32.78	-27.	-19.	-29.	-19.	0.	-2.	-1.	-2.	-1.	-21.	-26.	-4.	0.	0.	0.	-33.	-186.
20	32.09	-28.	-20.	-29.	-20.	0.	-2.	-1.	-2.	-1.	-21.	-26.	-4.	0.	0.	0.	-34.	-189.
21	31.37	-28.	-20.	-30.	-20.	0.	-2.	-1.	-2.	-1.	-22.	-26.	-4.	0.	0.	0.	-34.	-193.
22	30.63	-29.	-20.	-31.	-20.	0.	-2.	-1.	-2.	-1.	-22.	-27.	-4.	0.	0.	0.	-35.	-196.
23	29.91	-29.	-21.	-31.	-21.	0.	-2.	-2.	-2.	-2.	-22.	-27.	-4.	0.	0.	0.	-36.	-199.
24	29.22	-30.	-21.	-32.	-21.	0.	-2.	-2.	-2.	-2.	-22.	-27.	-4.	0.	0.	0.	-36.	-203.

HOUR	TEMPERATURE OUTDOOR	INDOOR	AIR CHANGES	OUTPUT OF HVAC SYSTEM	STORED	LIGHTS (KWHR)	COST (DOLLARS) GAS	ELECTRICITY	TOTAL	TOTAL ENERGY SITE	SOURCE
1	28.59		0.20	0.0		0.00	0.00	0.77	0.77		
2	28.04		0.20	0.0		0.00	0.00	0.77	0.77		
3	27.60		0.20	0.0		0.00	0.00	0.77	0.77		
4	27.27		0.20	0.0		0.00	0.00	0.77	0.77		
5	27.07		0.20	0.0		0.00	0.00	0.77	0.77		
6	27.00		0.20	0.0		0.00	0.00	0.77	0.77		
7	27.40		0.20	0.0		0.00	0.00	0.77	0.77		
8	28.51		1.00	-132.5		31.81	1.66	4.34	6.00		
9	30.11		1.00	0.0		31.81	0.00	4.34	4.34		
10	31.89		1.00	0.0		31.81	0.00	4.34	4.34		
11	33.49		1.00	0.0		31.81	0.00	4.34	4.34		
12	34.60		1.00	0.0		31.81	0.00	4.34	4.34		
13	35.00		1.00	0.0		31.81	0.00	6.38	6.38		
14	34.93		1.00	0.0		31.81	0.00	6.38	6.38		
15	34.73		1.00	0.0		31.81	0.00	6.38	6.38		
16	34.40		1.00	-67.7		31.81	0.85	6.38	7.23		
17	33.96		1.00	-96.3		31.81	1.21	6.38	7.59		
18	33.41		0.20	0.0		31.81	0.00	3.57	3.57		
19	32.78		0.20	0.0		0.00	0.00	0.77	0.77		
20	32.09		0.20	0.0		0.00	0.00	0.77	0.77		
21	31.37		0.20	0.0		0.00	0.00	0.77	0.77		
22	30.63		0.20	0.0		0.00	0.00	0.77	0.77		
23	29.91		0.20	0.0		0.00	0.00	0.77	0.77		
24	29.22		0.20	0.0		0.00	0.00	0.77	0.77		

**** MONTHLY SUMMARY **** SOLARS **** . HEAT GAIN AND LOSS **** . 4/ 8/87 2: 5

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
**** JANUARY ****																	Total BTU for 31 Days (Units are in THOUSAND BTU)
LOSS	-15559.	-12398.	-22406.	-11891.	0.	-1743.	-1204.	-1892.	-1204.	-17155.	-20320.	-3178.	0.	0.	0.	-74508.	-94683.
	16.4%	13.1%	23.7%	12.6%	0.0%	1.8%	1.3%	2.0%	1.3%	18.1%	21.5%	3.4%	0.0%	0.0%	0.0%	78.7%	193.6%
GAIN	37343.	3392.	0.	4791.	0.	0.	0.	0.	0.	0.	0.	0.	37005.	18503.	23677.	0.	35936.
	103.9%	9.4%	0.0%	13.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	103.0%	51.5%	65.9%	0.0%	347.0%
GROSS	52902.	15790.	22406.	16682.	0.	1743.	1204.	1892.	1204.	17155.	20320.	3178.	37005.	18503.	23677.	74508.	130619.
	40.5%	12.1%	17.2%	12.8%	0.0%	1.3%	0.9%	1.4%	0.9%	13.1%	15.6%	2.4%	28.3%	14.2%	18.1%	57.0%	235.9%
NET	21784.	-9006.	-22406.	-7100.	0.	-1743.	-1204.	-1892.	-1204.	-17155.	-20320.	-3178.	37005.	18503.	23677.	-74508.	-58748.
	37.1%	15.3%	38.1%	12.1%	0.0%	3.0%	2.0%	3.2%	2.0%	29.2%	34.6%	5.4%	63.0%	31.5%	40.3%	126.8%	174.2%
**** FEBRUARY ****																	Total BTU for 28 Days (Units are in THOUSAND BTU)
LOSS	-13293.	-10402.	-19837.	-9891.	0.	-1559.	-1072.	-1716.	-1072.	-14953.	-17901.	-2877.	0.	0.	0.	-67196.	-81999.
	16.2%	12.7%	24.2%	12.1%	0.0%	1.9%	1.3%	2.1%	1.3%	18.2%	21.8%	3.5%	0.0%	0.0%	0.0%	81.9%	197.3%
GAIN	32521.	5747.	0.	7491.	0.	0.	0.	0.	0.	0.	0.	0.	33424.	16712.	21386.	0.	37511.
	86.7%	15.3%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	89.1%	44.6%	57.0%	0.0%	312.7%
GROSS	45814.	16149.	19837.	17382.	0.	1559.	1072.	1716.	1072.	14953.	17901.	2877.	33424.	16712.	21386.	67196.	119509.
	38.3%	13.5%	16.6%	14.5%	0.0%	1.3%	0.9%	1.4%	0.9%	12.5%	15.0%	2.4%	28.0%	14.0%	17.9%	56.2%	233.5%
NET	19228.	-4655.	-19837.	-2400.	0.	-1559.	-1072.	-1716.	-1072.	-14953.	-17901.	-2877.	33424.	16712.	21386.	-67196.	-44488.
	43.2%	10.5%	44.6%	5.4%	0.0%	3.5%	2.4%	3.9%	2.4%	33.6%	40.2%	6.5%	75.1%	37.6%	48.1%	151.0%	186.4%
**** MARCH ****																	Total BTU for 31 Days (Units are in THOUSAND BTU)
LOSS	-10137.	-7786.	-15672.	-7274.	0.	-1294.	-884.	-1488.	-884.	-12119.	-16054.	-3198.	0.	0.	0.	-59001.	-63917.
	15.9%	12.2%	24.5%	11.4%	0.0%	2.0%	1.4%	2.3%	1.4%	19.0%	25.1%	5.0%	0.0%	0.0%	0.0%	92.3%	212.4%
GAIN	33236.	14989.	0.	17627.	0.	0.	0.	0.	0.	0.	0.	0.	37005.	18503.	23677.	0.	73163.
	45.4%	20.5%	0.0%	24.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.6%	25.3%	32.4%	0.0%	198.2%
GROSS	43373.	22774.	15672.	24900.	0.	1294.	884.	1488.	884.	12119.	16054.	3198.	37005.	18503.	23677.	59001.	137060.
	31.6%	16.6%	11.4%	18.2%	0.0%	0.9%	0.6%	1.1%	0.6%	8.8%	11.7%	2.3%	27.0%	13.5%	17.3%	43.0%	204.9%
NET	23099.	7203.	-15672.	10353.	0.	-1294.	-884.	-1488.	-884.	-12119.	-16054.	-3198.	37005.	18503.	23677.	-59001.	9246.
	249.8%	77.9%	169.5%	112.0%	0.0%	14.0%	9.6%	16.1%	9.6%	131.1%	173.6%	34.6%	400.2%	200.1%	256.1%	638.1%	267.4%

**** MONTHLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS **** 4/ 8/87 2: 6

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** APRIL **** Total BTU for 30 Days (Units are in THOUSAND BTU)

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
LOSS	-6511.	-4388.	-7507.	-4213.	0.	-810.	-536.	-969.	-528.	-6917.	-11442.	-3104.	0.	0.	0.	-38762.	-40911.
	15.9%	10.7%	18.3%	10.3%	0.0%	2.0%	1.3%	2.4%	1.3%	16.9%	28.0%	7.6%	0.0%	0.0%	0.0%	94.7%	209.4%
GAIN	32324.	26535.	232.	29808.	0.	0.	7.	0.	0.	0.	0.	0.	35812.	17906.	22913.	0.	120763.
	26.8%	22.0%	0.2%	24.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	29.7%	14.8%	19.0%	0.0%	137.1%
GROSS	38834.	30923.	7739.	34021.	0.	810.	543.	969.	528.	6917.	11442.	3104.	35812.	17906.	22913.	38762.	161673.
	24.0%	19.1%	4.8%	21.0%	0.0%	0.5%	0.3%	0.6%	0.3%	4.3%	7.1%	1.9%	22.2%	11.1%	14.2%	24.0%	155.4%
NET	25813.	22147.	-7275.	25596.	0.	-810.	-528.	-969.	-528.	-6917.	-11442.	-3104.	35812.	17906.	22913.	-38762.	79852.
	32.3%	27.7%	9.1%	32.1%	0.0%	1.0%	0.7%	1.2%	0.7%	8.7%	14.3%	3.9%	44.8%	22.4%	28.7%	48.5%	100.0%

**** MAY **** Total BTU for 31 Days (Units are in THOUSAND BTU)

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
LOSS	-3617.	-2465.	-3818.	-2465.	0.	-427.	-303.	-537.	-248.	-3348.	-8397.	-3303.	0.	0.	0.	-23769.	-25143.
	14.4%	9.8%	15.2%	9.8%	0.0%	1.7%	1.2%	2.1%	1.0%	13.3%	33.4%	13.1%	0.0%	0.0%	0.0%	94.5%	209.6%
GAIN	32520.	34994.	6247.	38773.	0.	7.	55.	2.	0.	412.	0.	0.	37005.	18503.	23677.	0.	164640.
	19.8%	21.3%	3.8%	23.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	22.5%	11.2%	14.4%	0.0%	116.7%
GROSS	36137.	37459.	10065.	41238.	0.	434.	358.	539.	248.	3760.	8397.	3303.	37005.	18503.	23677.	23769.	189782.
	19.0%	19.7%	5.3%	21.7%	0.0%	0.2%	0.2%	0.3%	0.1%	2.0%	4.4%	1.7%	19.5%	9.7%	12.5%	12.5%	129.0%
NET	28903.	32529.	2428.	36308.	0.	-419.	-248.	-535.	-248.	-2936.	-8397.	-3303.	37005.	18503.	23677.	-23769.	139497.
	20.7%	23.3%	1.7%	26.0%	0.0%	0.3%	0.2%	0.4%	0.2%	2.1%	6.0%	2.4%	26.5%	13.3%	17.0%	17.0%	100.0%

**** JUNE **** Total BTU for 30 Days (Units are in THOUSAND BTU)

	WINDOWS SOUTH	WINDOWS WEST	WINDOWS NORTH	WINDOWS EAST	SKY LIGHT	WALLS SOUTH	WALLS WEST	WALLS NORTH	WALLS EAST	ROOF	FLOOR	SLAB	INTERNAL LOADS LIGHTS	INTERNAL LOADS EQPT.	INTERNAL LOADS PEOPLE	AIR INFIL.	TOTAL
LOSS	-1265.	-853.	-1294.	-833.	0.	-149.	-126.	-212.	-63.	-1138.	-5700.	-3319.	0.	0.	0.	-11919.	-10207.
	12.4%	8.4%	12.7%	8.2%	0.0%	1.5%	1.2%	2.1%	0.6%	11.2%	55.8%	32.5%	0.0%	0.0%	0.0%	116.8%	263.3%
GAIN	33560.	37354.	9255.	41028.	0.	99.	116.	50.	54.	1394.	1.	0.	35812.	17906.	22913.	69.	182947.
	18.3%	20.4%	5.1%	22.4%	0.0%	0.1%	0.1%	0.0%	0.0%	0.8%	0.0%	0.0%	19.6%	9.8%	12.5%	0.0%	109.1%
GROSS	34825.	38207.	10548.	41861.	0.	249.	242.	262.	117.	2533.	5700.	3319.	35812.	17906.	22913.	11988.	193154.
	18.0%	19.8%	5.5%	21.7%	0.0%	0.1%	0.1%	0.1%	0.1%	1.3%	3.0%	1.7%	18.5%	9.3%	11.9%	6.2%	117.3%
NET	32295.	36501.	7961.	40196.	0.	-50.	-9.	-163.	-9.	256.	-5699.	-3319.	35812.	17906.	22913.	-11851.	172740.
	18.7%	21.1%	4.6%	23.3%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	3.3%	1.9%	20.7%	10.4%	13.3%	6.9%	100.0%

**** MONTHLY SUMMARY **** SOLAR5 **** HEAT GAIN AND LOSS **** 4/ 8/87 2: 8

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
**** JULY ****										Total BTU for 31 Days (Units are in THOUSAND BTU)							
LOSS	-255.	-172.	-263.	-166.	0.	-26.	-22.	-28.	-5.	-226.	-3736.	-3344.	0.	0.	0.	-1758.	-2919.
	8.7%	5.9%	9.0%	5.7%	0.0%	0.9%	0.7%	1.0%	0.2%	7.8%	128.0%	114.6%	0.0%	0.0%	0.0%	60.2%	342.7%
GAIN	38406.	39066.	12771.	42782.	0.	428.	272.	245.	255.	3628.	679.	0.	37005.	18503.	23677.	6205.	216838.
	17.7%	18.0%	5.9%	19.7%	0.0%	0.2%	0.1%	0.1%	0.1%	1.7%	0.3%	0.0%	17.1%	8.5%	10.9%	2.9%	103.3%
GROSS	38660.	39238.	13035.	42949.	0.	454.	294.	273.	260.	3854.	4414.	3344.	37005.	18503.	23677.	7964.	219757.
	17.6%	17.9%	5.9%	19.5%	0.0%	0.2%	0.1%	0.1%	0.1%	1.8%	2.0%	1.5%	16.8%	8.4%	10.8%	3.6%	106.4%
NET	38151.	38893.	12508.	42616.	0.	402.	250.	217.	250.	3401.	-3057.	-3344.	37005.	18503.	23677.	4447.	213918.
	17.8%	18.2%	5.8%	19.9%	0.0%	0.2%	0.1%	0.1%	0.1%	1.6%	1.4%	1.6%	17.3%	8.6%	11.1%	2.1%	100.0%
**** AUGUST ****										Total BTU for 31 Days (Units are in THOUSAND BTU)							
LOSS	-516.	-366.	-548.	-366.	0.	-20.	-36.	-64.	-4.	-313.	-4288.	-3332.	0.	0.	0.	-8131.	-4722.
	10.9%	7.7%	11.6%	7.7%	0.0%	0.4%	0.8%	1.3%	0.1%	6.6%	90.8%	70.6%	0.0%	0.0%	0.0%	172.2%	380.8%
GAIN	40422.	32451.	7852.	35931.	0.	374.	214.	160.	182.	2438.	163.	0.	37005.	18503.	23677.	3107.	189219.
	21.4%	17.1%	4.1%	19.0%	0.0%	0.2%	0.1%	0.1%	0.1%	1.3%	0.1%	0.0%	19.6%	9.8%	12.5%	1.6%	107.0%
GROSS	40938.	32817.	8400.	36296.	0.	394.	249.	224.	186.	2751.	4451.	3332.	37005.	18503.	23677.	11238.	193942.
	21.1%	16.9%	4.3%	18.7%	0.0%	0.2%	0.1%	0.1%	0.1%	1.4%	2.3%	1.7%	19.1%	9.5%	12.2%	5.8%	113.7%
NET	39905.	32085.	7304.	35565.	0.	355.	178.	97.	178.	2125.	-4125.	-3332.	37005.	18503.	23677.	-5023.	184497.
	21.6%	17.4%	4.0%	19.3%	0.0%	0.2%	0.1%	0.1%	0.1%	1.2%	2.2%	1.8%	20.1%	10.0%	12.8%	2.7%	100.0%
**** SEPTEMBER ****										Total BTU for 30 Days (Units are in THOUSAND BTU)							
LOSS	-1816.	-1286.	-1967.	-1286.	0.	-143.	-153.	-264.	-91.	-2137.	-7195.	-3235.	0.	0.	0.	-12186.	-15014.
	12.1%	8.6%	13.1%	8.6%	0.0%	1.0%	1.0%	1.8%	0.6%	14.2%	47.9%	21.5%	0.0%	0.0%	0.0%	81.2%	211.5%
GAIN	37684.	18448.	2665.	21399.	0.	179.	86.	18.	24.	465.	0.	0.	35812.	17906.	22913.	34.	140869.
	26.7%	13.1%	1.9%	15.2%	0.0%	0.1%	0.1%	0.0%	0.0%	0.3%	0.0%	0.0%	25.4%	12.7%	16.3%	0.0%	111.9%
GROSS	39499.	19733.	4633.	22684.	0.	322.	238.	283.	115.	2601.	7195.	3235.	35812.	17906.	22913.	12220.	155903.
	25.3%	12.7%	3.0%	14.6%	0.0%	0.2%	0.2%	0.2%	0.1%	1.7%	4.6%	2.1%	23.0%	11.5%	14.7%	7.8%	121.5%
NET	35868.	17162.	698.	20113.	0.	37.	-67.	-246.	-67.	-1672.	-7195.	-3235.	35812.	17906.	22913.	-12152.	125875.
	28.5%	13.6%	0.6%	16.0%	0.0%	0.0%	0.1%	0.2%	0.1%	1.3%	5.7%	2.6%	28.5%	14.2%	18.2%	9.7%	100.0%

**** MONTHLY SUMMARY **** SOLARS **** HEAT GAIN AND LOSS **** 4/ 6/87 2: 9

Project Title: THESIS
Building Type: OFFICE BUILDING LOWRISE
Climate Data : BOSTON

**** OCTOBER **** Total BTU for 31 Days (Units are in THOUSAND BTU)

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
LOSS	-6058.	-4135.	-7702.	-4062.	0.	-563.	-464.	-806.	-463.	-7315.	-12242.	-3362.	0.	0.	0.	-34045.	-39526.
	15.3%	10.5%	19.5%	10.3%	0.0%	1.4%	1.2%	2.0%	1.2%	18.5%	31.0%	8.5%	0.0%	0.0%	0.0%	86.1%	205.5%
GAIN	39172.	8418.	0.	10779.	0.	15.	1.	0.	0.	0.	0.	0.	37005.	18503.	23677.	0.	95879.
	40.9%	8.8%	0.0%	11.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	38.6%	19.3%	24.7%	0.0%	143.5%
GROSS	45229.	12552.	7702.	14842.	0.	578.	465.	806.	463.	7315.	12242.	3362.	37005.	18503.	23677.	34045.	135406.
	33.4%	9.3%	5.7%	11.0%	0.0%	0.4%	0.3%	0.6%	0.3%	5.4%	9.0%	2.5%	27.3%	13.7%	17.5%	25.1%	161.6%
NET	33114.	4283.	-7702.	6717.	0.	-547.	-463.	-806.	-463.	-7315.	-12242.	-3362.	37005.	18503.	23677.	-34045.	56353.
	58.8%	7.6%	13.7%	11.9%	0.0%	1.0%	0.8%	1.4%	0.8%	13.0%	21.7%	6.0%	65.7%	32.8%	42.0%	60.4%	100.0%

**** NOVEMBER **** Total BTU for 30 Days (Units are in THOUSAND BTU)

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
LOSS	-10501.	-8193.	-15623.	-7963.	0.	-1182.	-854.	-1362.	-854.	-12633.	-16809.	-3376.	0.	0.	0.	-57285.	-61693.
	17.0%	13.3%	25.3%	12.9%	0.0%	1.9%	1.4%	2.2%	1.4%	20.5%	27.2%	5.5%	0.0%	0.0%	0.0%	92.9%	221.5%
GAIN	36364.	3524.	0.	5115.	0.	0.	0.	0.	0.	0.	0.	0.	35812.	17906.	22913.	0.	46691.
	77.9%	7.5%	0.0%	11.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	76.7%	38.3%	49.1%	0.0%	260.5%
GROSS	46865.	11717.	15623.	13078.	0.	1182.	854.	1362.	854.	12633.	16809.	3376.	35812.	17906.	22913.	57285.	108384.
	43.2%	10.8%	14.4%	12.1%	0.0%	1.1%	0.8%	1.3%	0.8%	11.7%	15.5%	3.1%	33.0%	16.5%	21.1%	52.9%	238.3%
NET	25863.	-4669.	-15623.	-2848.	0.	-1182.	-854.	-1362.	-854.	-12633.	-16809.	-3376.	35812.	17906.	22913.	-57285.	-15002.
	172.4%	31.1%	104.1%	19.0%	0.0%	7.9%	5.7%	9.1%	5.7%	84.2%	112.0%	22.5%	238.7%	119.4%	152.7%	381.9%	444.8%

**** DECEMBER **** Total BTU for 31 Days (Units are in THOUSAND BTU)

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
LOSS	-15189.	-12304.	-22006.	-11860.	0.	-1711.	-1180.	-1840.	-1180.	-16998.	-20469.	-3337.	0.	0.	0.	-74239.	-92175.
	16.5%	13.3%	23.9%	12.9%	0.0%	1.9%	1.3%	2.0%	1.3%	18.4%	22.2%	3.6%	0.0%	0.0%	0.0%	80.5%	197.8%
GAIN	36433.	2543.	0.	3765.	0.	0.	0.	0.	0.	0.	0.	0.	37005.	18503.	23677.	0.	31787.
	114.6%	8.0%	0.0%	11.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	116.4%	58.2%	74.5%	0.0%	383.6%
GROSS	51623.	14846.	22006.	15626.	0.	1711.	1180.	1840.	1180.	16998.	20469.	3337.	37005.	18503.	23677.	74239.	123962.
	41.6%	12.0%	17.8%	12.6%	0.0%	1.4%	1.0%	1.5%	1.0%	13.7%	16.5%	2.7%	29.9%	14.9%	19.1%	59.9%	245.4%
NET	21244.	-9761.	-22006.	-8095.	0.	-1711.	-1180.	-1840.	-1180.	-16998.	-20469.	-3337.	37005.	18503.	23677.	-74239.	-60388.
	35.2%	16.2%	36.4%	13.4%	0.0%	2.8%	2.0%	3.0%	2.0%	28.1%	33.9%	5.5%	61.3%	30.6%	39.2%	122.9%	170.4%

**** ANNUAL SUMMARY **** SOLARS **** HEAT GAIN AND LOSS **** 4/ 8/87 2:11

TOTAL BTU FOR 365 DAYS (UNITS ARE IN MILLION BTU) ASHRAE HEAT LOSS= 0.00 BTUH

	WINDOWS				SKY	WALLS							INTERNAL LOADS			AIR	
	SOUTH	WEST	NORTH	EAST	LIGHT	SOUTH	WEST	NORTH	EAST	ROOF	FLOOR	SLAB	LIGHTS	EQPT.	PEOPLE	INFIL.	TOTAL
LOSS																	
	-85.	-65.	-119.	-62.	0.	-10.	-7.	-11.	-7.	-95.	-145.	-39.	0.	0.	0.	-463.	-533.
	15.9%	12.1%	22.3%	11.7%	0.0%	1.8%	1.3%	2.1%	1.2%	17.9%	27.1%	7.3%	0.0%	0.0%	0.0%	86.8%	207.6%
	31824.0= FLOOR AREA : KBTU PER SQ.FT.= -16.75																
GAIN																	
	430.	227.	39.	259.	0.	1.	1.	0.	1.	8.	1.	0.	436.	218.	279.	9.	1336.
	32.2%	17.0%	2.9%	19.4%	0.0%	0.1%	0.1%	0.0%	0.0%	0.6%	0.1%	0.0%	32.6%	16.3%	20.9%	0.7%	142.9%
	31824.0= FLOOR AREA : KBTU PER SQ.FT.= 41.99																
GROSS																	
	515.	292.	158.	322.	0.	11.	8.	12.	7.	104.	145.	39.	436.	218.	279.	472.	1869.
	27.5%	15.6%	8.4%	17.2%	0.0%	0.6%	0.4%	0.6%	0.4%	5.5%	7.8%	2.1%	23.3%	11.7%	14.9%	25.3%	161.3%
	31824.0= FLOOR AREA : KBTU PER SQ.FT.= 58.73																
NET																	
	345.	163.	-80.	197.	0.	-9.	-6.	-11.	-6.	-87.	-144.	-39.	436.	218.	279.	-453.	803.
	43.0%	20.3%	9.9%	24.5%	0.0%	1.1%	0.8%	1.3%	0.8%	10.8%	17.9%	4.9%	54.2%	27.1%	34.7%	56.4%	100.0%
	31824.0= FLOOR AREA : KBTU PER SQ.FT.= 25.24																

Alexander, M.E.F. "No Windows". *Lancet,* March 10, 1973.

Anon. "Industrial lighting in windowless factories". *Light and Lighting 57,* no. 9, 1964.

Bryan, H.J. "Power play". *Progressive Architecture,* April 1983.

Bryan, H.J. "Seeing the light". *Progressive Architecture,* September 1982.

Bryan, H.J., Kroner W.M. and Leslie R.P. *Daylighting : A Resourcebook.* Center for Architectural Research. Troy, NY : Rensellaer Polytechnic Institute, 1981.

Calderhead, J., editor. *Hospitals for People.* London : King Edward's Hospital Fund for London, 1975.

Carpman, J.R., Grant, M.A. and Simmons, D.A. *Design That Cares : Planning Health Facilities for Patients and Visitors.* Chicago : American Hospital Publishing, Inc., 1986.

Cohen, E. and Cohen, A. *Planning the Electronic Office.* New York : McGraw-Hill, Inc., 1983.

Collins, B.L. *Windows and People : A Literature Survey.* Washington, D.C. : U.S. Government Printing Office, 1975.

Dell 'Isola, A.J. and Kirk, S.J. *Life cycle costing for design professionals.* New York : McGraw-Hill, Inc., 1981.

Dietz, A.G.H., Lam, W.M.C. and Hallenbeck R.F. *An approach to the design of the luminous environment.* Albany, NY : State University Construction Fund, 1976.

Egan, M.E. *Concepts in Architectural Lighting.* New York : McGraw-Hill, Inc., 1983.

Evans, B.H. *Daylight in Architecture.* New York : McGraw-Hill, Inc., 1971.

Harris, D.A., Palmer A.E., Lewis M.S., Murron, D.L., Meckler, G. and Gerdes, R. *Planning and Designing the Office Environment.* New York : Van Nostrand Reinhold Company, 1981.

Hawkes D. and MacCormac, R. "Office form, energy and land use". *RIBA Journal,* June 1978.

Hermann Miller Research Corporation. *Everybody's Business : A fund of retrievable ideas for humanizing life in the office.* Zeeland, MI : Hermann Miller Research Corporation, 1985.

Hollister, F.D. *Greater London Council : A report on the problems of windowless environments.* London : Hobbs the Printers Ltd., 1968.

Hopkinson, R.G., Petherbridge, P. and Longmore J. *Daylighting.* London : Heinemann, 1966.

Juillerat, E.E. "Fire hazards of windowless buildings". *National Fire Protection Association Quarterly,* July 1964.

Lam, W.M.C. *Perception and Lighting as Formgivers for Architecture.* New York : McGraw-Hill, Inc., 1977.

Lang, J., Burnette, C., Moleski, W. and Vachon, D. *Designing for Human Behavior : Architecture and the Behavioral Sciences.* Stroudsburg, PA : Dowden, Hutchinson and Ross, Inc., 1974.

Manning, P. "Windows, emvironment and people". *Interbuild/Arena,* October 1967.

Manning, P., editor. *Office design : a study of environment.* Pilkington Research Unit, Department of Building Science. Liverpool : University of Liverpool, 1965.

Martin, L. and March L., editors. *Urban space and structures.* Cambridge, UK : Cambridge University Press, 1972.

Mayo E. *The Human Problems of an Industrial Civilization.* New York : The Viking Press, 1960.

Olgyay, A. and Olgyay, V. *Solar Control and Shading Devices.* Princeton, NJ : Princeton University Press, 1976.

Olgyay, V. *Design with Climate : A Bioclimatic Approach to Architectural Regionalism.* Princeton, NJ : Princeton University Press, 1966.

Plant, C.G.H. "The light of day". *Light and Lighting 63,* 1970.

Robbins, C.L. *Daylighting Design and Analysis.* New York : Van Nostrand Reinhold Company, 1986.

Ruys, S.J. *Windowless Offices.* M.A. Thesis. Seattle, WA : University of Washington,1970.

Saxon, R. *Atrium buildings : development and design.* New York : Van Nostrand Reinhold, 1983.

Schmertz, M.F., editor. *Office Building Design : An Architectural Record Book.* New York : McGraw-Hill, Inc., 1975.

Smith, F.K. and Bertolone, F.J. *Bringing Interiors to Light : The Principles and Practices of Lighting Design.* New York : Whitney Library of Design, 1986.

SolarVision Publications Inc. *Natural Lighting.* Church Hill, NH : SolarVision Publications Inc., 1982.

Southern California Edison. *Daylighting Performance and Design.* (Booklet distributed at Second International Daylighting Conference. Long Beach, CA, 1986).

Terkel, S. *Working.* New York : Pantheon Books, 1972.

Turner, D.P. *Windows and Environment.* Pilkington Environmental Advisory Service. London: Architectural Press, 1971.

Wagner, W.F. *Energy-efficient Buildings : An Architectural Record Book.* New York : McGraw-Hill, Inc., 1980.

Wurtman, R.J. "The effects of light on the human body". *Scientific American,* July 1975.

Wurtman, R.J. "Biological considerations in the Lighting Environment". *Progressive Architecture,* September 1973.

Ulrich, R.S. "View through a window may influence recovery from surgery". *Science,* April 27, 1984.