Relamping Hotel Guestrooms to Decrease Operating Costs

by

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(ABSTRACT)

The purpose of this study was to determine if the hotel industry could reduce a portion of its operating costs used for unnecessary lighting expenses. The study was conducted at the Donaldson Brown Center in Blacksburg, Virginia with 32 hotel guests participating. Data was collected to determine light fixture usage during periods of guestroom inactivity (inactive is defined as periods after the guest had checked-in but was out of the guestroom). Two treatment rooms and two control rooms were monitored to determine inactivity of the room, usage of light fixtures, and usage of daylight. Light levels and wattage readings were taken to determine consistency in light levels of the lamps and energy used by the different fixture/lamp combinations in each of the four rooms. One treatment room and one control room were on the east side of the building and the other treatment and control room were on the west side. The test rooms were evaluated to insure that all interior variables (i.e., structural configuration, size, materials and finishes, furnishings, light fixtures, and HVAC system) were controlled. The only features changed in the guestrooms were lamps housed in the fixtures of the two treatment rooms where the ceiling fixtures were relamped with two 16 watt compact fluorescent lamps (CFLs) and portable fixtures were relamped with one 18 watt CFL. Standard incandescent lamps were used in the control rooms. It was found that the time lights are left on in inactive rooms can amount to a considerable portion of a hotel's operating costs for energy usage. Results show a 64-71% reduction in energy consumed by CFLs compared to incandescent lamps. Fixtures housed with incandescent lamps cost an average of $.008 per hour to run compared to those lamped with CFLs which cost $.003 per hour to run. Through total or strategic relamping of fixtures, operating costs for electric lighting can be cut by more than 50% and energy resources would be saved. Implemented environmental strategies could then be used as a marketing tool to attract environmentally conscious consumers.
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Table of Contents

Abstract .............................................................................................................. ii
Acknowledgments .......................................................................................... iii

Chapter 1

Introduction ..................................................................................................... 1
  Purpose ......................................................................................................... 4
  Research Questions ...................................................................................... 5
  Theoretical Foundation ............................................................................... 5
  Research Hypotheses ................................................................................ 9
  Justification ................................................................................................ 9
  Limitations .................................................................................................. 10
  Operational Definitions .............................................................................. 10

Chapter 2

Literature Review .......................................................................................... 13
  Development of Hotel Industry .................................................................. 13
  Guestroom Design .................................................................................... 14
  Guestroom Lighting .................................................................................. 17
  General Characteristics of Incandescent and Compact Fluorescent Lamps ... 18
  Selection of Light Sources ....................................................................... 19
  Improvements in Energy Efficient Lighting ............................................ 20
  Energy Consumption ................................................................................ 20
    Energy Usage and Demands .................................................................. 20
    Effects of Energy Consumption on Lighting ...................................... 21
  Summary .................................................................................................. 23

Chapter 3

Methodology .................................................................................................. 24
Conclusions ........................................................................................................... 57
Implications ......................................................................................................... 58
Recommendations for Further Research ......................................................... 58

References .......................................................................................................... 60

Appendices ......................................................................................................... 63

Appendix A: Eleven Broad Categories and Descriptions of Hotel Facilities
Currently on the U.S. Market ......................................................................... 63
Appendix B: Guestroom Furnishings and Fixtures Dimensions ...................... 65
Appendix C: Photo Representations of Finishes and Materials Used Throughout
the Guestroom ................................................................................................. 66
Appendix D: Reflectance Values of Room Finishes .............................................. 67
Appendix E: Script for the Registration Desk at the Donaldson Brown Center .... 68
Appendix F: Information Statement .................................................................. 69

Vita ...................................................................................................................... 70
List of Tables

Table 1. Specification data for the EH18-L, Philips (75W), EFT16LE, and Philips (60W) .......................................................... 34

Table 2. Amount of Fixture Usage when Guestrooms were Inactive ........................................... 43

Table 3. High, Medium, and Low Usage Ranges for Inactive Rooms with at Least One Fixture On, General Illumination Fixtures, and Task Illumination Fixtures ........... 44

Table 4. Two-Way Analysis of Variance of General and Task Fixture Usage when the Guestroom is Inactive ................................................................................. 45

Table 5. High, Medium, and Low Usage Ranges for Individual Fixtures ..................................... 46

Table 6. Two-Way Analysis of Variance of Individual Fixture Usage when the Guestroom is Inactive ................................................................................. 46

Table 7. Comparison of High and Low Usage Groups for the Dresser/Credenza Fixture when the Guestroom is Inactive ................................................................. 47

Table 8. Comparison of High and Low Usage Groups for the Night Stand Fixture when the Guestroom is Inactive ................................................................................. 47

Table 9. Light Levels Measured in Footcandles for Individual Fixtures and Fixture Combinations in the Guestroom ................................................................................. 49

Table 10. Wattage Readings of Ceiling, Dresser/Credenza, and Night Stand Fixtures with Incandescent and Compact Fluorescent Lamps ................................................. 49

Table 11. Per Hour Cost to Run Each Fixture .................................................................................. 49

Table 12. One-Way Analysis of Variance of the Amount of Daylight Present in the Guestroom When it Becomes Inactive ................................................................................. 51

Table 13. Comparison of Average Daily costs Between Incandescent and Compact Fluorescent Lamps When Left on in Inactive Guestrooms ................................................... 54

Table 14. Comparison of Lost Annual Electrical Expenditures from Inactive Rooms for a 1,000 Guestroom Hotel at 80% Occupancy ................................................................. 58
List of Figures

Figure 1. General Systems Theory model as it relates to a guestroom environment. .......... 6
Figure 2. General Systems Theory as it relates to human interaction and hotel guestroom lighting system framework use to determine how much energy is consumed due to light fixtures being left on when the room is inactive. ......................... 8
Figure 3. Three basic guestroom layouts. ........................................................................... 16
Figure 4. Position of the test rooms relative to the other guestrooms on the third floor . . . . . 25
Figure 5. Plan view of a single guestroom. ......................................................................... 27
Figure 6. Ceiling fixture (positioned in the entrance of the guestroom). .......................... 29
Figure 7. Table lamp (portable fixture) with shade in place. ............................................. 30
Figure 8. ProLight compact fluorescent horizontal lamp system (EH18-L) with a non-integrated ballast and lamp. ................................................................. 32
Figure 9. Abco/Panasonic compact fluorescent lamp (EFT16LE) with an integrated ballast. ............................................................................................................. 33
Chapter 1

INTRODUCTION

As early as 500 B.C. boarding houses, resorts, and small inns existed to accommodate travelers. Since then the hotel industry has had a long-running history of worldwide development and change due to economic development, improvements in national infra-structures, and international commerce and travel (Rutes & Penner, 1985). In the United States, the hotel industry has experienced three boom periods during the 1900s which have coincided with economic peaks in the 1920s, 1950s, and early-1980s (Rutes & Penner). These boom periods have helped spur the development of new facilities, a rise in travel by the general public, and the integration of new technologies into these commercial spaces—spanning from skyscraper construction in the 1920s to virtual technologies in the 1990s (Rutes & Penner). However, since the recession of the mid- and late-1980s, the hotel industry has suffered from overdevelopment (Watson, 1993) despite its ability to stay abreast of innovations and new technologies.

The economic downturn of the 1980s not only affected development in the hotel industry, it also affected consumer attitudes and behaviors toward travel and lodging accommodations. Shulman (1991) has identified nine changes in consumers’ leisure habits to predict why they travel, where they travel to, and what they expect from the hotel industry. He predicts that consumers in the 1990s will differ in their leisure habits from the 1980s due to (a) changed spending patterns; (b) more travel to see family and friends; (c) a heightened awareness of the environmental impact of travel; (d) less acceptance of self-indulgence; (e) a rise in demand for romance, fantasy, excitement, color, and adventure; (f) demand for a more streamlined and simplified travel industry; (g) less demand for newness of destinations; (h) an increase in routine health regimens; and (i) a change in demographic trends. Because of so much variation in travel interests existing among consumers and the hospitality industry fighting for market share in a tightened economy, there has been an increase in marketing techniques used to attract customers (Evens & Murmann, 1989). Recent trends in marketing for the lodging industry have included offering amenities, discounts, and campaigns promoting ecotourism.
One of the most popular marketing tools has been personal care amenities, which are a courtesy or pleasantry offered by the hotel. Examples of amenities include shampoo, toothpaste, bathrobe, fully-stocked refrigerator, or an in-room coffee maker with coffee (Evans & Murrrmann, 1989; Wagner & Watkins, 1994). Discounts include lowered room rates, complimentary meals and lounge discounts, and travel packages. Ecotourism is a relatively new term used to define ecologically responsible tourism (West, 1995), which in the lodging industry, translates into environmentally-aware managed facilities, also known as green environments. The term green environment is used to define management policies for facilities that incorporate environmentally friendly strategies through recycling, water conservation, and energy conservation. Conservation strategies, whether voluntarily implemented by the facilities planners and management or prescribed by governmental regulation, can affect all areas of a hotel’s external and internal environments.

A hotel’s internal environments are divided into three types, the service areas (e.g., housekeeping, maintenance, and kitchen), common areas (e.g., dining, entertaining, meeting, conferencing, and indoor recreation facilities), and private areas or guestrooms. Although the service and common areas are critical for the successful functioning of the hotel and the social activities occurring in the hotel, the “guestroom establishes the private comfort level of the overnight guest” (Penner, 1991, p. 168).

In order to establish a comfort level for the guest, the guestroom has to accommodate many activities such as sleeping, bathing, dressing, relaxing, eating, entertaining, and working. And, the guestroom’s internal environment (i.e., sleeping space, living space, and bathroom), as opposed to the common areas of the hotel, needs to be a primary consideration when designing hospitality spaces (Nusbaum, 1989). The guestroom’s internal environment is composed of attributes, or characteristics, that include furnishings, heating and air conditioning, light, water, humidity, air quality, and background sound and noise.

Attributes such as utilities that consume natural resources have been found to be wasteful (West, 1995), and travelers surveyed by Wagner and Watkins (1994) and Wolff (1990) gave negative ratings to or complained about many guestroom attributes. Complaints included uncomfortable bedding, poor water pressure (Wagner & Watkins), inadequate lighting, HVAC
systems with ineffective controls, and noise and vibration from the HVAC, plumbing, corridor, and adjacent rooms (Wolff).

A successful guestroom design meets basic physical and psychological needs that relate to life and daily activities such as shelter, safety, privacy, and comfort (Nusbaum, 1989). These activities are affected by the guestroom’s internal environment, and the attributes used to modify, change, or define the environment such as furnishings, finishes, or light. Specifically, lighting influences an individual’s physical orientation, security, relaxation, time orientation, contact with nature and people, and the definition of personal territory (Nusbaum).

End (1978) points out that guestroom lighting is important to give the guest a sense of well-being and to provide comfortable levels of illumination for reading, working, and grooming. However, guestroom lighting does not appear to always meet people’s needs. Wolff (1990) found that people are dissatisfied with the lighting in the bathroom for basic hygiene, and in the bedroom/living area for processing paper work and reading tasks. Poor lighting could be the result of low luminance levels, missing light bulbs, poor fixture placement, and glare, all of which can lead to discomfort from eye strain. Lighting not only affects guests’ well-being and comfort levels, but is also a sizable operating expense for the hotel due to the cost of installation, maintenance, and energy consumption.

The economic boom of the early-1980s created a false sense of security concerning the amount of natural resources available. For example, in 1982 “electric utilities consumed 34% of the nation’s (U.S.) fuel and produced only 10% of the usable energy. . . . An annual increase in electric demand of 3.5% will require almost a 50% increase in the nation’s generating capacity in the next 10 years” (Aulbach & Conrade, 1984, pp. 16-17). Consumers are once again becoming more environmentally aware of how energy is used in residential and commercial spaces. Because of this renewed awareness, the trend for travelers is to seek out and patronize facilities that incorporate some sort of conservation measures (Shulman, 1991).

The use of energy, and its cost, is becoming a more important issue in the hotel industry since costs have accelerated in recent years (Rutes & Penner, 1985). Of a hotel’s total operating expenses, the amount of energy consumed by the mechanical and electrical systems is estimated to be between 19% and 25% (Aulbach & Conrade, 1984). Lighting alone is estimated to be 40% of
the total energy consumed by a property (Brown, 1994), and West (1995) states that “...$114 of electricity per room per year is used by standard guestroom lights” (p. 26).

Energy consumed by guestroom lighting can be curbed using a number of methods which include, but are not exclusive to, (a) the installation of light sensors that turn light fixtures off when the room is inactive (West, 1995), (b) the installation of compact fluorescent lamps as opposed to incandescent lamps (Brown, 1994; West), and (c) the promotion of the use of daylight as a supplementary light source to electric light (Johannesen, 1991). West recommends the installation and use of light sensors to turn light fixtures off when the room is inactive. However, he found that the sensors did not always operate properly and would turn the lights off even when the rooms were occupied.

Brown (1994), Johannesen (1991), and West (1995) all recommend the use of compact fluorescent lamps in the guestroom. Studies by West and Brown indicate a 63 to 70% savings, respectively, in energy consumption if rooms are relamped with fluorescent lighting. However, none of the studies state why hoteliers have not taken advantage of these savings on a large-scale. Johannesen also recommends using daylight to illuminate a guestroom. However, when designing for non-commercial-like spaces, such as a hotel guestroom, daylighting is difficult to monitor and control due to personal preferences of the guest.

The total amount of energy used by guestrooms and the proportion of that energy that is typically consumed by guestroom lighting has been determined (Brown, 1994; West, 1995); however, the investigations did not examine what proportion of energy costs were due to guestroom lights left on in unoccupied rooms after guests have checked-in. If it can be shown that lights are left on when not needed, and if this is a significant factor in the amount of energy consumed by lighting, the hospitality industry could focus on conservation measures specific to this problem.

Purpose

The purpose of this study was to determine if hotel guests unnecessarily waste energy by leaving lights on in their guestrooms when they are unoccupied (defined as an inactive room for the purposes of this study); to determine which fixtures in hotel rooms are left on most often; to determine the amount of time fixtures are left on, and to verify findings concerning the energy
efficiency of incandescent and compact fluorescent lamps when used in guestrooms. Findings from this study could then be used to explore ways to reduce guestroom operating costs.

Research Questions

1. Do hotel guests leave the lights on in their guestroom when the room is inactive?
2. When the lights are left on in an inactive guestroom, are certain fixtures left on more often than other fixtures (i.e., ceiling fixtures as opposed to portable fixtures).
3. What is the difference in the amount of energy consumed by fixtures with incandescent lamps compared to compact fluorescent lamps?
4. Does the amount of daylight present affect whether or not lights are left on in an inactive room?

Theoretical Foundation

An adapted version of the General Systems Theory was adapted for this study to evaluate human interaction with a hotel guestroom lighting system to determine the usage of light fixtures when the guestroom is inactive and to calculate how much energy is being unnecessarily consumed. The General Systems Theory utilizes the relationship between the three broad concepts of (a) systems, (b) objects, and (c) attributes which are used to define an environment (Hall & Fagen, 1956). The relationship developed from the theory can then be translated into a linear framework of inputs, throughputs, and outputs.

According to Hall and Fagen (1956) a system is the relationship between (a) the boundaries that delineate a unit, (b) the objects within the boundaries, and (c) the objects’ attributes. The relationships within the boundaries of the system then interface to achieve a goal, purpose, or result (Goldsmith, 1996). For the purpose of this study, the system is a single guestroom that is delineated by its interior and exterior walls and fenestration.

There are two tiers of sub-systems within the boundaries that delineate the larger system, which could in turn become systems of their own if separated from the total environment (Figure 1). The first tier is the division of the whole guestroom into two sub-systems, the living/bedroom area and the bathroom. Because the bathroom is not being evaluated in this study this sub-system is not addressed. The living/bedroom area contains the second tier of sub-systems within the total
Figure 1. General Systems Theory model as it relates to a guestroom environment.
guestroom system. These sub-systems include the HVAC, lighting, electrical access, telephone, and television.

Once the system is defined, the objects within it can be identified. The objects are a system's parts, components, or resources (Hall & Fagen, 1956). Parts and components are the physical elements of systems while resources are a system's assets or what is available to use in order to attain or satisfy something (Goldsmith, 1996). Hall and Fagen explain that there are two kinds of objects: (a) physical objects that are tangible components such as furniture, light fixtures, and finishes; and (b) abstract objects that are intangible resources such as energy or daylight. Goldsmith agrees with Hall and Fagen, but adds a third object type: human resources, which are "the skills, talents, and abilities that people possess" (p. 75). Only the objects of the lighting sub-system will be examined in this study, the light fixtures, lamp types, and people (or human resources).

Objects are then defined by their attributes, which are also referred to as properties or characteristics (Hall & Fagen, 1956). Depending on the objects being described or specified, attributes can be anything from a point-of-view to a physical appearance. Attributes of the objects in this study include, but are not exclusive to, the type of light fixtures (general or task), the type of lamps used within the fixtures (incandescent or compact fluorescent), and human resources (their use of the guestroom lighting).

Once the system has been defined by its objects and attributes, it can then be translated into a linear framework of inputs, throughputs, and outputs which, in turn, define interactions or transformations within the space. The inputs are the independent variables, which are taken from the defined system. Throughputs are the processes that take place in utilizing the system. And, the outputs are the dependent variables or outcomes from the manipulation and utilization of the inputs (Figure 2).

The independent variables for this study are the objects defined for the system. They are (a) lamp type (compact fluorescent and incandescent), (b) light source (general illumination fixture and task illumination fixture), and (c) human resources (guests staying in the test rooms).

The processes used in the throughput are:
(a) the characteristics of the light process (how often the lamp is used or not used, and efficacy of the lamp),
Figure 2. General Systems Theory as it relates to human interaction and hotel guestroom lighting system framework use to determine how much energy is consumed due to light fixtures being left on when the room is inactive.
(b) fixture usage, which is divided into two categories

1. the number of fixtures used at one time and what they are (only task, only general, or a combination task and general); and
2. the amount of time a lamp is used which is divided into three categories (high, medium, and low);

(c) daylight (divided into three levels of high, medium, and low); and

(d) guest behavior (the amount of time spent out of the guestroom and their habits in utilizing the lighting system).

The dependent variables are the length of time lamps are operated when the guestroom is inactive and energy consumption.

Research Hypotheses

1. There is a difference in the amount of time lights are left on between task illumination fixtures and general illumination fixtures when the room is inactive.
2. There is a difference in the amount of time each fixture is being used when the room is inactive.
3. The amount of time lights are left on will not differ in inactive rooms when daylight is present.

Justification

Results have been published concerning the amount of energy savings compact fluorescent lamps produce compared to incandescent lamps when used in hotel guestrooms. However, investigations into how much time is spent in and out of the guestroom by the guest, whether or not they leave light fixtures on when they are away, and how much energy is unnecessarily consumed by lights being left on was unknown prior to this study.

This study investigated (a) what fixtures were left on when a guestroom was inactive; (b) how much energy was consumed, and therefore wasted, by lights left on when the guestroom was inactive; (c) the amount of energy savings that can be realized by using compact fluorescent lamps as opposed to incandescent lamps, and (d) whether or not the presence of daylight affects lamp usage. These results were then used to calculate lost revenue for a hotel due to unnecessary energy
consumption from lighting, and for the development of strategies to curb light fixture usage when guestrooms are inactive.

The conclusions and recommendations drawn from the results of this study will help the hotel industry conserve natural resources by suggesting conservation strategies concerning light usage when guestrooms are inactive. Hotels will also be able to reduce operating costs by conserving energy. The implementation of conservation strategies can then be used by the hotel as a marketing tool to attract consumers.

Limitations

Steps were taken to insure that each of the guestroom environments used as test rooms were identical. However, there were factors that could have influenced the results of this study: the number of guests registered per room, the time of year the study took place, and the electrical rate. First, the employees at the registration desk were requested to register only one person parties. However, to try to insure that all of the test rooms were full at the same time, parties of more than one were sometimes registered in the rooms. Second, if the study were duplicated during another season, such as summer when the days are longer, the results may differ because of the increased amount of daylight hours that can be used to light the room. Third, the national average KWH rate was used to calculate the per hour cost to run the different fixture/lamp combinations. However, fluctuations in actual costs may occur because peak demand rates were not taken into consideration in the per hour cost calculations.

Operational Definitions

The following are definitions relevant to this study:

1. Active room data is defined as the guest having checked-in for their room at the hotel’s registration desk.

2. Inactive room data is defined as the guest having left the guestroom during an active room data period.

3. Lamp refers to the bulb, base, and internal elements of a light source.

4. Luminaire refers to a light fixture or a full lighting device which may include the lamp, reflectors, lenses, wiring, and sockets (Nuckolls, 1976).
5. Light is the term applied to the visible energy emitted from a source which is either absorbed, reflected, or transmitted upon striking a surface and is measured in lumens or candlepower (Philips, 1993a).

6. Lumen (lm) is the unit that represents the total quantity of light given off by a lamp regardless of the direction the light is moving (Philips, 1993a).

7. Efficacy is the ability of a lamp to convert electrical power (watts) into light (lumens), and is expressed as lumens per watt (lm/w) (Philips, 1993a).

8. Lamp life is the rated life, in burning hours, of a lamp. This is based upon the median life of large representative groups of lamps that are tested in the laboratory under controlled conditions (Philips, 1993a).

9. Lumen maintenance is the ability of a lamp to sustain its lumen output over a period of time (usually rated at 70% of the lamp life). Depreciation can be caused by a gradual deterioration of the phosphors and the blackening of the inside of the tube or bulb (Philips, 1993b).

10. Spectral energy distribution is the exact colors that a lamp emits which, in turn, affects a lamp’s color rendering abilities. A spectral energy distribution chart (or profile) is a graphic depiction of the specific wavelengths emitted and the relative intensity or strength of each wavelength (Smith & Bertolone, 1986).

11. Color temperature is a concept used to define the overall color of light emitted from a lamp and is based on the Kelvin temperature scale. However, it is not a measurement of actual temperature, therefore, it is expressed in Kelvin (K) only (no degrees; Philips, 1993a). Two examples are: (a) lamps that have an illuminated appearance of bright white to blue-white have a high color temperature (4000 K and above); and (b) lamps that have an illuminated appearance of yellow-white to red-white have a low color temperature (3000 K and below).

12. Color rendering index (CRI) is an evaluation method to determine how colors appear under a given lamp type. It is measured on an index from 0-100, with D-50 fluorescence (the laboratory equivalent to daylight) and incandescent lighting both equal to 100 and the standards for comparison. Light from lamps with a 70-80 CRI are considered to have good color rendering properties, and lamps with a 80+ CRI are considered to have
excellent color rendering properties. Objects illuminated under a higher CRI commonly appear to be more vibrant, brilliant, or bright (Phillips, 1993b). However, CRI is not an indication of what colors will actually be rendered since this is an effect of the spectral energy distribution of the lamp and not CRI.
Chapter 2

LITERATURE REVIEW

Development of the Hotel Industry

The hotel market in the United States has developed and been transformed due to economic changes, technological advances, and demographic trends since the Industrial Revolution. A chronology of the lodging industry illustrates how hotels have changed and incorporated technological innovations along with fantasy and play to appeal to and attract customers.

The first hotel boom was generated by economic prosperity in the 1920s. However, the depression of the 1930s forced many U.S. hotels into receivership. A slowed economy during the 1940s, due to World War II, virtually stopped all new construction and innovation (Rutes & Penner, 1985).

A second boom occurred during the mid-1950s after independent operators formed associations that spurred lodging development (Penner, 1977). Another contributing factor to the hotel boom was mass travel by the middle class due to greater financial affluence and paid-vacation time. Because of these circumstances vacation villages, casino hotels, and resorts were developed and became vacation get-aways for many people.

The 1960s saw 23,000 hotels, 40,000 motels, and 170 chains operated in the United States. Contemporary urban hotels, conference centers used extensively by businesses, and major hotel/mixed-use complexes were developed. During the 1970s the airlines became active in hotel development by investing in and building facilities near airports, and luxury condominiums, suite hotels, and timesharing at resorts became the trend (Rutes & Penner, 1985).

The third hotel boom, in the early 1980s, was generated by innovative marketing and the development of specialized hotel types. Large-scale complexes and condo hotels were developed in conjunction with the rapid expansion of airport hotels, conference centers, suite hotels, vacation villages, health spas, marina hotels, ski lodges, timesharing, and condo resorts. The bed and breakfast and country inn also increased in popularity during this period; but, the newest development in the hotel industry happened in Orlando, Florida with the opening of mega-hotels as
part of the Disney complex (Rutes & Penner, 1985). The 1980s also saw a shift in the United State’s hospitality industry due to a shift in the economic climate. The recession of the mid-1980s left many hotels floundering financially due to overdevelopment in the industry as a whole (Watson, 1993).

Today, because of the changes that have occurred in the lodging industry, 11 broad categories of hotels, motels, resorts, and other business and pleasure destinations have evolved that try to attract and satisfy a large diversity of travelers. They include downtown hotels, suburban hotels and motels, resorts, convention hotels, conference centers, residential and condominium hotels, suite hotels, super-luxury hotels, mega-hotels, mixed-use developments, and casino hotels (see Appendix A for descriptions).

There are also specialty facilities that target specific consumer groups that are subcategories within the 11 broad categories. For the purpose of simplification, all lodging types will be referred to as hotels throughout this report. The greatest difference between the many categories of hotels are the services and common area facilities they provide. However, the one space within all lodging types that varies the least, yet guests depend upon to provide a sense of comfort, is the guestroom (End, 1978).

Guestrooms usually represent the largest amount of space in a hotel. Depending on the type of hotel, guestrooms can consume anywhere from 35 to 80 percent of the total floor area. Guestroom environments range from a basic rectangular space of approximately 230 square feet that houses a minimum amount of furniture and sparse bathroom facilities, to luxurious suites with 450 square feet or more that offer apartment-like living facilities, spacious rooms, top-of-the-line furnishings, and lavish bathroom facilities (Penner, 1991).

Guestroom Design

A hotel’s physical attributes are influenced by the hotelier and the design team (e.g., architects, interior designers, engineers, landscape architects, and consultants) used to develop and implement the hotel's interior and exterior environments. The design team is responsible for all aspects of the building, from the beginning to the end, to insure a successful project. However, Penner (1991) states that “although many hotel operators believe that guestroom design offers a
valuable opportunity for influencing guest satisfaction and creating a positive experience, few operators or designers have given it careful enough thought” (p. 162). This could be attributed to three factors: (a) recommended guestroom dimensions are based on common solutions (Penner), (b) the perception of allied design professionals that there is a lack of accessible information that will help them solve problems related to interior environments (Dickson & White, 1993), and/or (c) there is a perceptual difference between what the design experts develop and what the end user expects from a design (Scott, 1993). Scott attributes this perceptual difference to a lack of research that identifies preferred environmental attributes that meet the end users' needs in order to function in an environment.

The configuration of the guestroom block in a hotel is usually based on two parallel rows of bedrooms served by a central corridor (double-loaded corridor), and the size and configuration of the guestroom is dictated by the placement of the bathroom (Erdi, Doswell, Copp, Beavis, Campbell-Smith & Lawson, 1970). Three basic guestroom layouts are (a) an arrangement with the bathrooms on the external walls of the hotel; (b) an arrangement with bathrooms between the bedrooms, resulting in one bathroom on an external wall and one bathroom on an internal (corridor) wall; and (c) an arrangement with the bathrooms positioned on the internal walls (Figure 3).

The most common arrangement is the layout with the bathrooms positioned on the internal walls (Erdi et al., 1970). This guestroom requires an entrance area that can house a dressing area, closet space, or furnishings (e.g., chairs, luggage rack, or table). The most common guestroom sizes range between 300 to 350 square feet with dimensions of 12 to 14 feet wide and 16 to 20 feet deep, excluding the bathroom, closet, and entrance area (End, 1978; Penner, 1991). Typical furniture and equipment housed within a basic guestroom includes:

(a) bed(s);
(b) fitted or nonportable furniture (e.g., closet space, shelves or drawers, dressing table with a mirror above—which can double as a writing desk—bedside tables, and lights over beds, near mirrors, and in the entrance area); and
(c) loose or portable furniture (e.g., occasional chairs, easy chairs, table, desk, table lamps, luggage rack, and a television).
Figure 3. Three basic guestroom layouts: (a) a plan arrangement with the bedrooms on the external walls; (b) a plan arrangement with the bathrooms between the bedrooms, resulting in one external and one internal bathroom; and (c) a plan arrangement with internal bathrooms (Erdi et al., 1970).
As an element in the above furnishings lists, lights/luminaires appear as both fitted and loose furniture. For future reference, fitted luminaires such as ceiling mounted or wall mounted fixtures will also be referred to as permanent fixtures, and loose luminaires such as table or floor lamps will also be referred to as portable fixtures.

Guestroom Lighting

Lighting is an important element in the design of a guestroom. The primary goal of guestroom lighting is to achieve a balance between lighting results and lighting costs (Era, 1994). A lighting system needs to provide an adequate amount of illumination to perform tasks (amount of light falling on a surface), produce a good quality of light (perceived brightness and color of light), and be economically feasible for the intended application (initial cost, maintenance, and efficacy).

An example of not achieving a balance between lighting results and lighting costs is a ceiling fixture positioned in the middle of a guestroom to be used as the sole source of illumination. It may be economically desirable because a number of different types of standard-size lamps can be used with it, but it usually will not provide an overall adequate amount of light, nor will it provide an overall good quality of light for all tasks. However, ceiling fixtures do have their place in guestroom design and should not be excluded as a lighting option. Erdi and colleagues (1970) state that in the entrance area of the guestroom a ceiling fixture may be the best solution because all that is needed is a source of general illumination. However, table fixtures or wall mounted fixtures are needed next to the bed, dressing table/credenza unit, and writing table/work surface to insure an adequate amount of light for specific tasks performed at these sites. Rea (1994) supports this design advice by stating that general illumination provides a background for task lighting because it decreases contrast ratios between the foreground and background lessening eye fatigue; and, that task lighting should be used in areas where reading, desk work, television viewing, and grooming take place.

The Illuminating Engineering Society of North America recommends illumination levels for a hotel guestroom to be between 10 and 20 footcandles (fc) for general illumination and 20 to 50 fc for grooming or reading. These levels are based upon the visual characteristics of a task (e.g., orientation, reading, and grooming), age of the people using the space, importance of
accuracy of visual performance, and the reflectance level of the background material(s) that are being viewed (Rea, 1994).

Erdi and colleagues (1970) are more specific and recommend levels of 10 fc for general illumination and 20 fc where specific tasks are performed (e.g., reading and grooming). They also state that an even level of 20 fc throughout a guestroom is undesirable and that lighting should be adjustable, in direction and intensity, to suit individual needs of the guest.

General Characteristics of Incandescent and Compact Fluorescent Lamps

The challenge for designers is to provide quantity as well as quality illumination to the end user so they are able to see and easily perform tasks. Traditional systems tend to use the standard incandescent lamp in hospitality installations. Incandescent lamps are commonly referred to as a general service lamp which is defined as an incandescent bulb with a medium Edison-type screw-in base that operates on a circuit of 30 volts (V) or higher. These lamps range from 10 to 1500 watts (W), come in a variety of sizes and shapes, can have a clear or frosted interior finish, and have a common lumen output range of 200 to 2500 (Rea, 1994), which is approximately 15 lumens per watt overall (Mills, 1993).

Incandescent lamps produce light by heating a filament within the bulb, most commonly constructed of tungsten wire, to produce light. These lamps render yellow and red hues very well.

A more energy efficient product compared to the standard incandescent lamp has been on the market for approximately 10 years. The compact fluorescent lamp (CFL) is a relatively new lighting product designed to be an energy-saving alternative to the standard incandescent lamp (Rea, 1994; Serres, 1994; Tucker, 1987). Many of the new all-purpose CFLs are integrated units. Serres defines an integrated CFL as a unit comprised of a ballast (or controller) and a discharge tube (bulb) made into one unit where the connections between the controller and discharge tube are not accessible. Therefore, when the discharge tube no longer functions and needs to be replaced, the ballast is also disposed of.

Other CFL design variations include a separate ballast system to be used with lamps that have a special pin-type base and are often designed for a particular use or wattage (Rea, 1994). With these lamp systems, the discharge tube can be replaced without having to replace the ballast.
Literature on these types of lamp systems include separate specifications for the lamp life and ballast life.

The compact fluorescent lamp, like the incandescent lamp, is available in a variety of shapes and sizes. CFLs range from 5 to 42 W, with smaller wattages interchangeable with conventional incandescent lamps that range from 25 to 100 W, and have a common lumen output range of 250 to 3200 (Rea, 1994), which is approximately 60 lumens per watt overall (Mills, 1993).

Compact fluorescent lamps, like other fluorescent lamps, produce light through a discharge tube due to an ionization of mercury gas between two electrodes, which in turn activates a blend of phosphors (Rea, 1994). The blend of rare-earth phosphors produces spectral emission peaks in the short-, middle-, and long-wavelength regions of the visible spectrum and is also referred to as a triphosphor system. The advantage of a triphosphor system compared to a non-triphosphor CFL system or a traditional fluorescent tube lamp is its color rendering ability. A non-triphosphor CFL system and traditional fluorescent tube lamp only have spectral emission peaks in two of the three wavelength regions. The range of spectral illuminance that can be produced by CFLs that utilize the triphosphor system enhances brightness, produces a high efficacy, and has good lumen maintenance (Rea).

Selection of Light Sources

Hotels have traditionally used general service lamps for illuminating guestrooms because they can accommodate most general lighting needs. For a hotel installation, Rea (1994) recommends that public spaces use incandescent and rare-earth fluorescent lamps in conjunction with each other. He states that the advantages of incandescent lighting are low initial costs and good color rendering properties. Disadvantages are a short life, low efficacy, and high energy usage. The advantages of fluorescent lighting are high efficacy, low energy usage, and a long life. Disadvantages are poorer color rendering ability than incandescent lamps, external temperature effects upon a lamp, and a lamp’s start-up time. However, when specifically addressing guestroom light, Rea does not specify a particular lamp type, but suggests that lamps be selected by appropriateness of their physical properties of rated color temperature and color rendering ability.
Improvements in Energy Efficient Lighting

Energy efficient lighting systems, especially commercial fluorescent lighting systems, in the past have been used to wash an environment with a sea of illuminance, striping an interior of it’s three-dimensional form and often color. Even though there have been problems in the past with designs using fluorescent lamps, they have become a constant in the built environment due to their energy efficiency (Boray, Gifford & Rosenblood, 1989).

Past deficiencies in fluorescent lamp design include the inability to easily relamp fixtures with standard Edison-type sockets since most fluorescent lamp systems utilize a pin-base socket, the expense of replacing or relamping an existing system with a new one, and the poor appearance of objects under fluorescent light. However, innovations in fluorescence and the physical structure of lamps has improved fluorescent lighting so that it is easier to use them as replacement lamps for standard incandescent lamps (Stashik, 1985). Fluorescent lamps now have ballasts with an Edison-type screw base. The lamps have been designed to fit into the harps of table and floor fixtures. Lower wattages have been developed to equate those of standard incandescent lamps. And, by using rare-earth phosphors as part of the fluorescence a better quality of light is created.

Energy Consumption

Energy Usage and Demands

The use of energy is a chief concern in the hospitality industry because it can be as much as 25% of a hotel’s total undistributed operating expenses. A hotel’s total undistributed operating expenses are costs that cannot be identified or matched to a specific revenue source (e.g., guestrooms, food and beverage, gift shop) on the income statement (Aulbach & Conrade, 1984). Energy conservation practices are being adopted by all types of commercial spaces because of the limitation of natural resources and the small-scale use of renewable resources. Shanklin (1993) states that the U.S. alone “consumes slightly more than one fourth of the world’s annual oil and natural gas production and nearly one fourth of its coal” (p. 222). This quantity is not related to population density, but to American’s life-styles and lack of energy conservation practices. Shanklin and others often refer to the economic impact of the oil embargo of the 1970s and how current energy usage may impact future business.
Stashik (1985) describes a “high-energy-demand-future,” and that by the year 2025 experts are predicting that to meet demands “two additional Saudi Arabias would be needed to supply enough oil, coal production would be tripled, three times as many rivers would be impounded behind hydroelectric dams, and several hundred large nuclear power plants would be built” (p. 577). Tucker (1987) agrees with Stashik and both state that lighting energy management is one way to affect rising energy consumption and costs.

Nadel (1993) states “that improved lighting efficiency offers significant and accessible energy savings in the commercial, residential, and industrial sectors” (p. 145). Currently, 20% of energy consumption in the U.S. is due to lighting (Mills & Piette, 1993), and of the three sectors commercial consumption is 57% (Nadel). Hotels fall into the commercial category. It is estimated that U.S. consumers spend “approximately $9 billion on lighting equipment each year and $38 billion for the associated electricity” (Mills & Piette, 1993, p. 75). Mills and Piette also state that the amount of energy used can be significantly reduced by using energy efficient light sources. They predict that approximately 57% of electricity consumed by lighting could be saved by the year 2010 if cost-effective strategies using energy efficient lighting systems were applied to new and existing buildings.

Nadel (1993) agrees with Mills and Piette (1993), but also argues that greater savings may be possible as technologies advance and are combined with building and energy policies that require minimum efficiency standards for lighting equipment (e.g., the Energy Policy and Conservation Act). Currently, standards are being used at the local level, while national standards specific to lighting are still being developed. However, government programs that are voluntary (e.g., U.S. Environmental Protection Agency’s Green Lights program and the Federal Energy Management Program) have been established (Mills, 1993).

**Effect of Energy Consumption on Lighting**

A way for hoteliers to save energy, and money, is to retrofit or design hotels to use less energy. Busch, du Pont, and Chirarattonanon (1993) state that initial costs for energy efficient lighting systems may be more than for traditional systems, but that the expense can be justified because of the reduction in electricity costs. Their study, conducted in Thailand, showed that lights
consume 25% of all electricity in a hotel environment. However, U.S. commercial buildings commonly have a significantly higher rate of electrical consumption for lighting than commercial spaces in other countries (Nilsson & Aronsson, 1993). Therefore, the percentage of lighting energy consumption by hotels in the U.S. is probably higher than the 25% in Thailand.

Advances in lighting technology have provided more energy efficient lamps with improved performance. However, other than manufacturer’s specifications, very little is known about the performance of these relatively new lamps beyond laboratory testing. An investigation by Brown (1994) found that 40% of a hotel's energy costs are due to lighting. He suggests that compact fluorescent lamps be used in place of the commonly prescribed incandescent lamps will improve energy savings and light quantity. The study found that when four fixtures lamped with compact fluorescents are placed in the sleeping area of a guestroom, the CFLs provided a 39.5% higher light output than incandescent lamps, and energy consumption was reduced by 70%. In the study, new 26 W CFLs were compared to (a) 100 W long-life rated incandescent lamps that had been used in the room for an unknown period of time, and (b) 90 W energy-saver incandescent lamps that had never been used before. Brown was primarily interested in footcandle readings to evaluate the amount of luminance within the space at various locations in the guestrooms, and did not investigate the customer’s use of light within the space.

A more current study by West (1995) gathered data at nine Florida hotel properties, from February 28 through July 17, 1995. He compared one EnviroRoom installation to one standard room in each facility to study the benefits of lighting, water service, and air conditioning energy management systems. For lighting, he replaced fluorescent T12 40 W lamps and magnetic ballasts with fluorescent T8 32 W lamps and electronic ballasts above the vanity area that were attached to an occupancy sensor light switch. He also replaced incandescent lamps with the ProLight EH27L compact fluorescent bases which were fitted with Panasonic FDL27LE lamps for the living/bedroom area.

Results indicate that the compact fluorescents “provide a simple annual rate of return of 56.6%, and a payback in 1.8 years on average” (West, 1995, p. 26). He also reported an annual savings of 63% for hotel guestrooms retrofitted with EnviroRoom lighting equipment (fluorescent tube lamps in the bathroom, compact fluorescent lamps in the living/bedroom area, and an
occupancy sensor light switch). The study did not investigate fixture usage in the EnviroRooms compared to the standard rooms (M. K. West, personal communication, September 29, 1995). However, 40 customer complaints or comments were filed with the hotels for the combined 802 guest nights. The complaints included comments about water service, lighting, and air conditioning. Complaints about the lighting were directed toward the occupancy sensor light switches and not toward the quantity or quality of light that the CFLs or T8 lamps produced.

Daylighting is another major source of energy efficient light. It can be used to reduce the energy consumption of buildings by using mechanical devices to monitor and control the amount of light being let into a space (Stashik, 1985). Kristensen (1994) states that electricity used for lighting can be reduced 50-75% when using electric light in combination with daylighting techniques. These techniques include sidelighting (vertical windows with a shading system), light shelves (redirect daylight to reflect off of the ceiling plane), reflective blinds, rooflights (clerestory windows that extend above the roofline), and atria. The systems that Kristensen proposes are primarily for commercial spaces and may not work effectively in a hotel guestroom environment. However, when designing for non-commercial-like spaces, such as a hotel guestroom, daylighting is difficult to monitor and control due to personal preferences of the guests.

Summary

Results have been published concerning the amount of energy used by guestroom systems, and that the estimated lighting costs can be as much as 40% of the expenditures for energy consumed by these systems (Brown, 1994). Compact fluorescent lamps compared to incandescent lamps can save energy and therefore revenue when used in hotel guestrooms. However, guest behaviors such as how much time is spent in and out of the guestroom by the guest, whether or not they leave light fixtures on when they are away, and how much energy is unnecessarily being consumed by lights being left on is unknown at this time. In an attempt to determine if hotels can reduce operating expenses through conservation measures, this study investigated the amount of time lights were left on unnecessarily, compared the efficiency of incandescent and fluorescent lamps, and the effect of daylight on lighting usage.
Chapter 3

METHODOLOGY

This study investigated how much time light fixtures were left on in inactive hotel guestrooms in order to calculate how much energy is unnecessarily being consumed. Differences in the amount of time between fixture usage (general and task) was determined along with how much energy these lighting systems consume when equipped with incandescent and compact fluorescent lamps. With this information, the amount of lost income due to inefficient lighting and lights being left on when the guestroom was inactive was also calculated.

Location of Study

The setting for the study was the Donaldson Brown Conference and Continuing Education Center (which will be referred to as the Donaldson Brown Center) located on the campus of Virginia Polytechnic Institute and State University. Four guestrooms were selected for the tests, two were the treatment environments (rooms 303 and 315) that were relamped with compact fluorescent lamps, and two were the control environments (rooms 304 and 316) that were relamped with new incandescent lamps. One treatment and control room were located on the east side of the building and the other treatment and control room were located on the west side. Figure 4 shows the position of the test rooms in relation to the other rooms on the third floor. The test rooms were evaluated to insure that all aspects of the environments were identical in structural configuration and size. Materials used for wall, floor, and furniture finishes, and bedspread and window treatments were identical, as well as the furnishings, light fixtures, and type of heating, ventilation, and air conditioning systems (HVAC).

Participants

The study was conducted from Tuesday, December 5, 1995 to Thursday, December 21, 1995, and 39 people participated in it. A power analysis (factor of .85) was used to determine the number of participants needed for the study because the number of subjects in the literature cited ranges between three and 800. The power analysis aided in determining that 30 to 40 participants were needed for the
Figure 4. Position of the test rooms relative to the other rooms on the third floor.
for the study. Only 32 of the 39 guest night stays were used for data analysis. The fewest number of guest night stays collected for one room was eight (room 303). For purposes of analyses, eight guest night stays were then used to determine the number of guest night stays used for each room to create a balance in the amount of data. The first eight guest night stays were used for guestrooms that had more than eight guest night stays. Participants were guests registered at the Donaldson Brown Center who were asked if they would be willing to participate in a study. Guests were notified at the time of registration that they would be staying in a test room, and if they agreed to participate, they were registered to a vacant test room. The registration staff tried to insure that the test rooms were all active at the same time by registering guests to rooms 303, 304, 315, and 316 before offering other rooms. Guests were assigned to the test rooms on a first-come-first-serve basis. Check-in and check-out times were monitored, but not controlled, to determine the length of each stay at the Donaldson Brown Center.

Room Description

Each room contained a total of 284.375 square feet. This includes the entrance (41.25 square feet), living/bedroom area (190.625 square feet), and bathroom (52.5 square feet). Appendix B lists furnishings and fixtures that were contained in each room. Figure 5 is the floor plan of an individual room.

The wall finish in the entrance was a multi-hued wallpaper printed with a random-looking brushed pattern in tones of rose, pink, and beige. It was used on the walls that house the entrance door, bathroom door, and closet. The closet is constructed of birch with a light stain.

The living/bedroom area wallpaper was identical to the entrance finish and used on all of the walls. Wood furniture was finished with a mahogany veneer and a dark stain. The bedspread had a hunter green and burgundy stripe pattern. A combination valance and opaque drapery was used as a window treatment. The valance had a dark paisley pattern in deep green and burgundy hues and the drapery was an opaque blackout beige color fabric. Side chair upholstery was a multi-hued striped pattern, which, when viewed at more than one foot away, looked like a dark green and burgundy striped pattern. Reflectance values for different finishes that covered large areas in the guestrooms ranged
from 9.7 footcandles for the bedspread to 58.4 footcandles for the wallpaper. Appendix C illustrates each of these elements and Appendix D lists their respective reflectance values.

The material descriptions and reflectance values are given because of their impact on how much light is reflected throughout the room. Hence, their reflectance values would have some influence on the perceived brightness or dimness of the rooms and therefore to the extent that supplemental light may have been thought necessary. This, in turn, may have influenced the amount of time light fixtures were used and how many were used. Because the objects and their finishes were the same in every room, interior variables were controlled so as not to confound the data collected.

**Luminaire Descriptions**

There were two ceiling fixtures in each room. One was located in the entrance and the other in the center of the living/bedroom area. The fixtures had a cake-pan style metal base that was mounted directly to the ceiling. Each held two lamps within a bowl-like frosted lens (Figure 6) and were controlled by a single switch next to the door.

There were two portable fixtures (table lamps) in each room. One was located on the night stand between the beds and the other was on the dresser/credenza. The lamps were fashioned in a traditional style with a brass base and stem with a translucent beige shade (Figure 7).

**Lamp Descriptions**

For the purpose of this study, lamps housed in the ceiling fixtures in the entrance and living/bedroom areas and portable fixtures in the living/bedroom areas of the two treatment rooms were changed. The bathroom lamps, which were not part of this study, remained the same in all rooms and were not evaluated.

The control rooms were lamped with 60 W incandescent lamps in the ceiling fixtures and 75 W incandescent lamps in the portable fixtures. The treatment rooms were lamped with 16 W compact fluorescent lamps (CFLs) in the ceiling fixtures and 18 W compact fluorescent lamps in the portable fixtures. The 60 W incandescent lamp is equal to an 16 W compact fluorescent lamp, and the 75 W incandescent lamp is equal to the 18 W compact fluorescent lamp in perceived brightness, however, the CFL is promoted as conserving on the amount of energy that is consumed to produce the same amount
Figure 6. Ceiling fixture (positioned in the entrance of the guestroom).
Figure 7. Table lamp (portable fixture) with shade in place.
of light as an incandescent lamp. All lamps were new; however, the compact fluorescent lamps were burned for 100 hours prior to installation to stabilize the lamps for color rendering quality, lumen output, and to eliminate any flicker that may occur due to a lamp burning-off excess chemicals (Rea, 1993).

Lamps used for the control rooms were Philips industrial service incandescent lamps. Model 60A/35/TF, which is a 60 W standard incandescent lamp with a silicone coating applied to the bulb to prevent shattering, were used in the ceiling fixtures. A model 75A/RS/TF, which is a 75 W standard incandescent lamp with a silicone coating applied to the bulb to prevent shattering, was used in the portable fixtures. These lamp types are used regularly in the guestrooms at the Donaldson Brown Center.

Lamps used in the treatment rooms were ProLight compact fluorescent horizontal lamp systems (EH18-L) that utilized a Panasonic FCL18LE quad-tube lamp with a ProLight EH18-L 18 watt ballasts, and the Abco/Panasonic compact fluorescent lamps (EFL16LE) (Figures 8 and 9). The EH18-L systems were installed in the portable fixtures and the EFL16LE was installed in the ceiling fixtures.

Both compact fluorescent lamp types had instant start ballasts with an Edison-type screw base for easy adaptation to an incandescent socket. However, the EH18-L system used in the portable fixtures was a non-integrated unit (the ballast and lamp are two separate units) so when the lamp burns out, the lamp can be replaced without having to replace the ballast. The EFL16LE used in the ceiling fixtures, on the other hand, was an integrated unit (the ballast and the lamp are contained as one unit), so when the lamp burns out the whole unit needs to be replaced. The EFL16LE integrated unit was used in the ceiling fixtures because of its more compact size compared to the EH18-L non-integrated unit, therefore making it easier to relamp the ceiling fixture. The ballast of the nonintegrated unit may consume more energy and has its own power rating or ballast factor. Having the ballast separate from the lamp can increase how much energy the whole unit (ballast and lamp) consumes making it less economical than the integrated unit.

The ballast life of the two compact fluorescent lamps was different because the EH18-L is a nonintegrated unit and the EFL16LE is an integrated unit. In a nonintegrated unit, the ballast life is a separate factor from the lamp life since the lamp can be replaced once it stops operating, whereas an
Figure 8. ProLight compact fluorescent horizontal lamp system (EH18-L) with a non-integrated ballast and lamp (ProLight, 1994).
Figure 9. Abco/Panasonic compact fluorescent lamp (EFT16LE) with an integrated ballast (Abco/Panasonic, 1995).
integrated unit does not have a ballast life because once the lamp stops operating the whole unit needs to be replaced. The EH18-L system used in the portable fixtures also included an anti-theft (ratcheting) device as part of the ballast section and the EFT16LE did not. Theft of the lamps is less likely an issue for ceiling fixtures than for the more accessible portable fixtures. Therefore, ballasts with the anti-theft device were not used in the ceiling fixtures.

The EH18-L system is designed to be used in place of a standard 75 W incandescent lamp. The EH model has been compared to a number of incandescent lamps and, according to manufacturer data, performs as well or better than incandescent lamps made by Abco, General Electric, Philips, and Sylvania (ProLight, 1994).

Other important information when comparing lamps is the rated lamp life, rated ballast life, lamp color temperature, color rendering index (CRI), and lumens per watt. In general, the compact fluorescent lamps have a much higher rated lamp life and more efficient lumens per watt output than a standard incandescent. The incandescent lamps have a better color rendering index than the compact fluorescents; however, this is primarily due to the fact that the incandescent lamp is the standard by which all other lamp types are compared to when gathering CRI data. The lamp color temperature for both lamps was very close, and unless the lamps were to be compared side-by-side it would be very difficult to distinguish the difference (Abco/Panasonic, 1995). Table 1 compares specification information for all lamp types used in this study.

Table 1
Specification Data for the EH18-L, Philips (75W), EFT16LE, and Philips (60W)

<table>
<thead>
<tr>
<th>Lamps Used in Portable Fixtures</th>
<th>Lamps Used in Ceiling Fixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent</td>
<td>Incandescent</td>
</tr>
<tr>
<td><strong>EH18-L system</strong></td>
<td><strong>75A/RH/TH</strong></td>
</tr>
<tr>
<td>Rated Lamp Life (hours)</td>
<td>10,000</td>
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<tr>
<td>Rated Ballast Life (hours)</td>
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<tr>
<td>Color Rendering Index</td>
<td>82</td>
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<tr>
<td>Lumens/Watt</td>
<td>59</td>
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</table>
Monitoring Systems

Following are descriptions of equipment that were used to monitor guests’ usage of electric light, their usage of daylight, as well as monitoring the amount of time the room was active and inactive.

Wattmeter

Wattage readings were taken for the different fixture and lamp combinations in the guestrooms. Light fixtures were measured, using a wattmeter, for actual energy consumption. This information was then compared to manufacturer’s specifications and prior findings in the Brown (1994) and West (1995) studies to reevaluate and confirm actual energy consumption for both the compact fluorescent lamps and incandescent lamps. A Fluke 87 True RMS Multimeter was used to measure the watts used by each fixture/lamp combination. Data were collected on the same day for each fixture by reading the digital display of the Fluke 87 True RMS Multimeter and manually recording the figure onto a record sheet.

Light Meter

Prior to the beginning of the study, light level readings were taken in the guestrooms using a Philips Digital Light Meter Model DL2001. The readings were taken to insure there were no differences in the amount of light, measured in footcandles, being given off by fixtures lamped with incandescent lamps compared to those lamped with compact fluorescent lamps. Readings were taken directly under the entrance ceiling fixture and the living/bedroom ceiling fixture. Readings were also taken on top of the round table and on top of bed pillows located adjacent to the night stand fixtures since these are areas where reading and work is typically done in the guestroom. The light levels were taken at 24 inches above the floor because much of the floor space is covered by furnishings with surfaces at approximately this height (two beds, one night stand, one dresser/credenza, two chairs, and one round table). Data were collected on the same day for all rooms, with the drapes closed to control for daylight entering the room, by reading the digital display of the Philips Digital Light Meter and manually recording the figure onto a record sheet.
Thermocouples

A thermocouple is a temperature measuring device that utilizes an interface between two different materials which for the purpose of this study were the two wires that constitute a type J thermocouple wire. Individual thermocouple wires were attached to the surface of one bulb of a lamp housed in the ceiling fixtures and one to each bulb of the lamp housed in the portable fixtures. It acted as a sensor by monitoring the change in temperature that resulted from the heat being given off by a lamp when it was in use. This temperature change was monitored and saved in a datalogger. It was then used to determine when each fixture was turned on and off.

Occupyance Sensor

A GEM System® Guestroom Management System was used to monitor guestroom activity. The GEM System consisted of four basic components: (a) a sensor/controller, (b) a door switch, (c) an HVAC relay assembly, and (d) a transformer.

The sensor/controller determined the activity of a guestroom by detecting changes in infrared energy due to the presence or absence of guests. It did not monitor motion, thus, it was not affected by moving inanimate objects, such as a window treatment moving due to a breeze, stationary heat sources such as the HVAC unit, or images caused by light changes from a television. The door switch was mounted in the door frame and connected to the sensor/controller which detected when the guestroom door had been opened and closed. This in turn triggered the sensor/controller to monitor for changes in infrared energy to detect whether or not there was someone in the guestroom. The transformer was a low voltage power source for the whole system.

The GEM System is usually used to monitor activity to automatically regulate the room temperature when the room is inactive. It was used in this study only to monitor activity. The GEM system was connected to the datalogger by a twisted pair 22-guage PVC insulated wire that carried a voltage signal which was used as an indicator of room activity. When the HVAC relay assembly received a message that there was activity in the room from the sensor/controller, a rise in the voltage was created and transmitted to the datalogger indicating that the room was active (>1 V reading). The opposite happened to indicate that the room was inactive (0 V reading).
Photosensitive Transducers

Transducers are electromechanical devices that convert one form of energy into another. Photosensitive transducers were used to measure light levels (in footcandles) and then convert the light levels into voltage levels. This data was used to determine whether or not daylight was an influence in the amount of electric light being used in the guestroom.

One photosensitive transducer was placed above the window within the window framing in each room (on the room-side of the window draperies). Voltage levels were monitored and saved in a datalogger. The voltage levels saved in the datalogger were in direct correlation with light levels measured in footcandles for each room on any given day at any given time. Information from the voltage levels was used to determine how much daylight was coming into the room when the room became inactive.

Dataloggers

One digital datalogger per room was used to record thermocouple, occupancy sensor, and transducer input. The dataloggers used were one Electronic Controls Design, Inc. model 5200 and three Campbell Scientific Inc. model 21X Micrologger. Each system was capable of monitoring up to 10 input channels to read and record temperature changes, voltage changes, and time/date information.

Thermocouple inputs were temperature readings. Input from the occupancy sensor and photosensitive transducer were voltage readings. The occupancy sensor cued the datalogger when the occupancy sensor detected an occupant (>1 V) or did not detect an occupant (0 V). Whereas the transducer was a reading of light level converted into a voltage signal which enabled the datalogger to read a range of voltage inputs. Time/date changes were also monitored for all of the systems. Data from the dataloggers was transferred onto a computer once every day during housekeeping hours.

A test was performed in each room prior to data collection for the study to insure that all of the monitoring equipment was in accurate working order.

Data Collection

Participants were guests staying at the Donaldson Brown Center who had agreed to participate in this research project; however, they were not informed about the purpose of the study. When a guest
registered for a room, they were asked if they would be willing to participate in an energy audit of the components in the guestrooms and if they would be willing to stay in one of the rooms being used for the evaluation. If the guest agreed to participate, consent was confirmed over the telephone (Appendix E). Upon check-out, guests were given a written statement about the project they had participated in (Appendix F).

Inspection of the test rooms and transferring of information from the dataloggers was done daily. The investigator called the Donaldson Brown Center to find out if the test rooms were vacant to transfer the dataloggers information. This happened during the period after one guest had checked out and before another guest checked in for the day, which was typically between 12:00 p.m. and 2:00 p.m.

Data Analysis

To analyze data gathered from the study, the Statistical Package for the Social Sciences (SPSS; 1995) was used to perform descriptive statistics, t-tests, one-way analysis of variance (ANOVA), and two-way ANOVA to determine significance between variables. Descriptive statistics were used to organize and classify the data. This was accomplished by using means, medians, standard deviations, percentiles, and ranking in order to explain central tendency, range of distribution, and to compare relationships between factors.

The ANOVAs were tested at an alpha level of .05. These tests were used to identify significant differences between variables in order to more fully describe relationships among the variables. The research question, research hypothesis, statistical hypothesis, and data analysis schematic for the research questions are identified below.

**Research Question 1**

Do hotel guests leave lights on in their guestroom when the room is inactive?

**Data analysis.** Descriptive statistics to examine activity and light usage.
Research Question 2

When lights are left on in an inactive guestroom, are certain fixtures left on more often than other fixtures (i.e., ceiling lights, portable fixture on the dresser/credenza, and portable fixture on the night stand).

Research hypothesis 2.1. There is a difference in the amount of time lights are left on between task illumination fixtures and general illumination fixtures when the guestroom is inactive.

Statistical hypothesis 2.1. There is no difference in the amount of time lights are left on between task illumination fixtures and general illumination fixtures when the guestroom is inactive.

Data analysis 2.1. A two-way ANOVA was performed to compare general illumination fixtures and task illumination fixtures to the amount of time they were used (high, medium, and low) when the guestroom was inactive. Fixture usage was divided into high, medium, and low ranges by using a statistical ranking technique to synthesize the data. The ranking, performed by SPSS (1995), divided the data into three groups based on natural breaks in the data.

<table>
<thead>
<tr>
<th>AMOUNT OF TIME USED</th>
<th>FIXTURE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Task</td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>

Research hypothesis 2.2. There is a difference in the amount of time each fixture is being used when the room is inactive.

Statistical hypothesis 2.2. There is no difference in the amount of time each fixture is being used when the room is inactive.

Data analysis 2.2. A two-way ANOVA was performed to compare individual fixtures (ceiling, dresser/credenza, and night stand) to the amount of time they are used (high, medium, and low) when
the room was inactive. When significance was found using the two-way ANOVA, t-tests were used as post hoc tests to determine if there was significance within the variable.

<table>
<thead>
<tr>
<th>FIXTURE</th>
<th>AMOUNT OF TIME USED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Ceiling</td>
<td></td>
</tr>
<tr>
<td>Dresser/Credenza</td>
<td></td>
</tr>
<tr>
<td>Night Stand</td>
<td></td>
</tr>
</tbody>
</table>

Research Question 3

What is the difference in the amount of energy consumed by fixtures with incandescent lamps compared to compact fluorescent lamps?

Data analysis. Descriptive statistics, energy equation, and cost equation calculations were performed to compare incandescent lamps with compact fluorescent lamps for the amount of energy they consume. The data were then examined to determine the cost of lost energy for each lamp type in inactive rooms.

Research Question 4

Does the amount of daylight present affect whether or not lights are left on in an inactive room?

Research hypothesis. The amount of time lights are left on will differ in inactive rooms when daylight is present.

Statistical hypothesis. There is no difference in the amount of time lights are being left on in inactive rooms when daylight is present.

Data Analysis. A one-way ANOVA was performed to compare daylight levels (high, medium, and low) when the guestroom became inactive.

<table>
<thead>
<tr>
<th>INACTIVE ROOM</th>
<th>DAYLIGHT LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 4

RESULTS

The purpose of this study was to determine if the hotel industry could reduce the proportion of operating costs going toward unnecessary lighting expenses. The focus of this research was to investigate how much energy is used, and therefore wasted, when light fixtures were left on in guestrooms that are inactive. Data were collected which recorded the amount of time light fixtures were left on in inactive guestrooms. Four guestrooms at the Donaldson Brown Center were monitored for time of activity and inactivity, fixture usage, and daylight levels. This chapter presents the findings that address four research questions.

Descriptive statistics were used to explore whether or not guests leave the lights on in their guestroom when it is inactive. Three hypotheses, tested at $\alpha = .05$, utilized the data gathered to determine whether or not there are differences between general illumination fixture usage and task illumination fixture usage; whether or not there are differences between individual fixture usage (ceiling, dresser/credenza, and night stand); and if the presence of daylight in the room is related to whether or not lights are left on when the room becomes inactive.

Description of the Data

The raw data collected for the study consisted of thermocouple temperature readings of lamps and voltage readings of an occupancy sensor and a photosensitive transducer. All raw data readings were recorded every six minutes by a datalogger placed in each of the four guestrooms. Active room data periods spanned from 12:00 p.m. to 11:54 a.m. for all of the test rooms throughout the test period. A guestroom became active once the guest checked-in at the registration desk and then was considered inactive when the guest left the guestroom during their active room data period. Only inactive room data were used in the analysis to accept or reject hypotheses and address the research questions.

Once the data was separated and synthesized, total amounts of time were calculated for:

1. total activity of the guestroom;
2. total inactivity of the guestroom;
3. total inactivity of the guestroom with at least one light fixture left on—ceiling, dresser/credenza, and/or night stand;
4. usage of general illumination fixtures and task illumination fixtures when the room was inactive;
5. usage of each fixture (ceiling, dresser/credenza, and night stand) when the room was inactive;
6. light levels and wattage readings from different fixture/lamp combinations; and
7. daylight levels entering into the guestroom when the room became inactive.

Using SPSS (1995), the totals for amounts of time and levels of daylight of each case—a case being data for each room on each day—were then ranked into groups of high, medium, and low. Levels of high, medium, and low were determined based on a sequential ranking of unique values. This method of ranking evaluates each case and then assigns a sequential numeric value to the cases—identical values receive the same sequential numeric value. The measures of daylight in footcandles were also ranked into high, medium, and low levels of light entering the room through the window when the guestroom became inactive.

Inactive Guestrooms and Fixture Usage

In order to determine if hotel guests leave the lights on in their guestroom when the room is inactive, fixture usage and room activity was investigated using descriptive statistics. The data shows that lights were left on 90.6% of the time guestrooms were inactive, meaning that when guests leave their room they nearly always leave one or more lights on.

Guest night stays (active hours) ranged from 8½ hours to just under 24 hours. Of this time, the range of inactivity times in the rooms was 0 minutes to 15 hours 54 minutes, which means that some guests never left the room until they checked-out. Guest check-in times ranged from 12:00 p.m. to 12:36 a.m. and check-out times ranged from 7:24 a.m. to 11:54 a.m. Central tendency for light usage when guestrooms were inactive is best represented by using the median of how much time guests left at least one fixture on when the room was inactive (Table 2). The median, instead of the mean, was used because the range of inactive time for the 32 guest night
stays examined spanned 15 hours and 54 minutes to 0 minutes. The median time that at least one fixture was left on when the room was inactive was 2 hours and 24 minutes. There were only three (9%) cases in which the fixtures were not left on. The total amount of usage of individual fixtures while the rooms were inactive was as follows:

1. 81% of the guests used the ceiling fixture during inactive periods with a range of usage spanning 0 minutes to 7 hours 30 minutes;
2. 38% of the guests used the dresser/credenza fixture during inactive periods with a range of usage spanning 0 minutes to 9 hours 6 minutes; and
3. 56% of the guests used the night stand fixture during inactive periods with a range of usage spanning 0 minutes to 15 hours 54 minutes.

Table 2

<table>
<thead>
<tr>
<th>Fixture Usage</th>
<th>Number of Rooms</th>
<th>Percentage of Rooms</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Lights Left On</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>At Least One Light Left On</td>
<td>29</td>
<td>91</td>
</tr>
<tr>
<td>Ceiling Fixture Left On</td>
<td>26</td>
<td>81</td>
</tr>
<tr>
<td>Dresser/Credenza Fixture Left On</td>
<td>12</td>
<td>38</td>
</tr>
<tr>
<td>Night Stand Fixture Left On</td>
<td>18</td>
<td>56</td>
</tr>
</tbody>
</table>

Note. n = 32

Fixture Usage

To determine if certain fixtures are left on more often than other fixtures, two hypotheses were tested. The first hypothesis was a comparison of the amount of fixture usage between general illumination fixtures and task illumination fixtures. The second hypothesis was more specific and compared the amount of fixture usage between each type of fixture (ceiling, dresser/credenza, and night stand).

General versus Task Fixture Usage

A two-way ANOVA was performed to determine if there were significant differences in the amount of time general illumination fixtures and task illumination fixtures were used when the room was inactive. The dependent variable used in the test was the inactive room with at least one
light fixture being left on. The independent variables used in the test were (a) the amount of usage of general illumination fixtures and (b) the amount of usage of task illumination fixtures. Time had been ranked into levels of high, medium, and low for both the dependent and independent variables using a sequential ranking of unique values (SPSS, 1995). Ranges for high, medium, and low amounts of time for inactive rooms with at least one fixture on, usage of general illumination fixtures, and usage of task illumination fixtures were determined.

The amounts of time for inactive rooms with at least one fixture on and usage of general illumination fixtures were divided into the three ranges; however, the task illumination fixtures did not have enough variation in the scores to create a medium range, therefore the data was only categorized into two levels of usage labeled high and low (Table 3). The total amount of time for inactive rooms with at least one fixture on spanned 6 minutes to 15 hours 54 minutes. The total amount of time general illumination fixtures were in use when the room was inactive spanned 0 minutes to 7 hours 30 minutes. The total amount of time task illumination fixtures were in use when the room was inactive spanned 0 minutes to 15 hours 54 minutes.

Table 3

<table>
<thead>
<tr>
<th>Inactive Rooms with at Least One Fixture On</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 hrs 42 min to 15 hr 54 min</td>
<td>1 hr 24 min to 8 hrs 36 min</td>
<td>6 min to 1 hr 18 min</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General Illumination Fixtures</th>
<th>5 hrs 42 min to 7 hrs 30 min</th>
<th>1 hr 0 min to 5 hrs 18 min</th>
<th>0 min to 54 min</th>
</tr>
</thead>
</table>

| Task Illumination Fixtures                  | 8 hrs 42 min to 15 hrs 54 min | *                           | 0 min to 7 hrs 48 min |

*Note. * not enough variation in the scores to create a medium range.

Statistical significance was identified for the task illumination fixture main effect ($F_{1,27} = 4.032, p = .017$). However, there was no significant difference for the general illumination fixture main effect (Table 4). These results can be interpreted to mean that the task illumination fixtures are left on for a greater amount of time than the general illumination fixtures when the guestroom is
inactive. A post hoc evaluation was not executed because individual fixture usage is examined in the next research question.

Table 4

Two-Way Analysis of Variance of General and Task Fixture Usage when the Guestroom is Inactive

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum-Squares</th>
<th>Mean Square</th>
<th>F-Ratio</th>
<th>Prob&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Effects</td>
<td>3</td>
<td>5.387</td>
<td>1.796</td>
<td>4.032</td>
<td>.017*</td>
</tr>
<tr>
<td>General Fixtures</td>
<td>2</td>
<td>2.218</td>
<td>1.109</td>
<td>2.490</td>
<td>.102</td>
</tr>
<tr>
<td>Task Fixtures</td>
<td>1</td>
<td>3.663</td>
<td>3.663</td>
<td>8.225</td>
<td>.008*</td>
</tr>
<tr>
<td>Variance</td>
<td>4</td>
<td>5.444</td>
<td>1.361</td>
<td>3.056</td>
<td>.034</td>
</tr>
<tr>
<td>Error</td>
<td>27</td>
<td>12.024</td>
<td>.445</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>17.469</td>
<td>.564</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. *p<.05

Individual Fixture Usage

A two-way ANOVA was performed to analyze individual fixture usage when the guestroom was inactive. The dependent variable used in the test was the inactive room with at least one light fixture being left on. The independent variables used in the test were the amount of time individual fixtures (ceiling, dresser/credenza, and night stand) were used which had been ranked as levels of high, medium, and low.

The amounts of time for the ceiling fixtures were divided into the three ranges; however, the dresser/credenza and night stand fixtures did not have enough variation in the scores to create a medium range, therefore the data was only categorized into two levels of usage labeled high and low (Table 5). The total amount of time for the ceiling fixtures spanned 0 minutes to 7 hours 30 minutes, the dresser/credenza fixture spanned 0 minutes to 9 hours 6 minutes, and the night stand fixture spanned 0 minutes to 15 hours 54 minutes.

Statistical significance was identified for the dresser/credenza fixtures main effect (F$_{1,27} = 7.977, p = .009$) and the night stand fixtures main effect (F$_{1,27} = 21.638, p = .000$) for when the guestrooms were inactive. There was no significant difference for the ceiling fixture main effect for when the guestroom was inactive (Table 6), therefore it can be inferred that this fixture was
used the least amount of time when rooms were inactive. When examining the mean of the fixtures that were significantly different, it appears that the night stand fixture (1.25) is left on more often when the guestroom is inactive than the dresser/credenza fixture (1.06).

Table 5

<table>
<thead>
<tr>
<th>High, Medium, and Low Usage Ranges for Individual Fixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling Fixtures</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td>5 hrs 42 min to</td>
</tr>
<tr>
<td>7 hrs 30 min</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>1 hr to</td>
</tr>
<tr>
<td>5 hrs 18 min</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>0 min to</td>
</tr>
<tr>
<td>48 min</td>
</tr>
<tr>
<td>Dresser/Credenza Fixture</td>
</tr>
<tr>
<td>8 hrs 54 min to</td>
</tr>
<tr>
<td>9 hrs 6 min</td>
</tr>
<tr>
<td>•</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>0 min to</td>
</tr>
<tr>
<td>7 hrs 6 min</td>
</tr>
<tr>
<td>Night Stand Fixture</td>
</tr>
<tr>
<td>4 hrs 54 min to</td>
</tr>
<tr>
<td>15 hrs 54 min</td>
</tr>
<tr>
<td>•</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>0 min to</td>
</tr>
<tr>
<td>3 hrs 24 min</td>
</tr>
</tbody>
</table>

Note. * not enough variation in the scores to create a medium range.

Table 6

<table>
<thead>
<tr>
<th>Two-Way Analysis of Variance of Individual Fixture Usage when the Guestroom is Inactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
</tr>
<tr>
<td>Main Effects</td>
</tr>
<tr>
<td>Ceiling Fixture</td>
</tr>
<tr>
<td>Dresser/Credenza Fixture</td>
</tr>
<tr>
<td>Night Stand Fixture</td>
</tr>
<tr>
<td>Variance</td>
</tr>
<tr>
<td>Error</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Note. *p<.05

T-tests were then performed as a post hoc evaluation of the dresser/credenza fixture and the night stand fixture to determine if there was a significant difference between groups (high and low usage) within the variables. The first t-test compared the means of the high and low usage groups for the dresser/credenza fixture. It was found that there is a significant difference between the high and low usage groups (\( t = 24.44, df = 31, p<.05 \); Table 7). A comparison of the means for each of the usage groups indicates credenza/dresser fixture usage falls into the high usage group (3.000) more often than the low usage group (1.7000). From these findings, we can infer
that the dresser/credenza fixture is most often used for approximately 9 hours when the guestroom was inactive.

Table 7
Comparison of High and Low Usage Groups for the Dresser/Credenza Fixture when the Guestroom is Inactive

<table>
<thead>
<tr>
<th>Usage Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>3.0000</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1.7000</td>
<td>.7022</td>
<td>24.44*</td>
</tr>
</tbody>
</table>

Note. *p<.05 using a critical value of 1.694 with df 30

The second t-test compared the means of the high and low usage groups for the night stand fixture. Once again as in the dresser/credenza fixture, it was found that there is a significant difference between the high and low usage groups (t = 16.07, df = 31, p < .05; Table 8). A comparison of the means for each of the usage groups indicates night stand fixture usage falls into the high usage group (2.6250) more often than the low usage group (1.5000). From these findings, we can infer that the night stand fixture is most often used between 5 and 16 hours when the guestroom was inactive.

Table 8
Comparison of High and Low Usage Groups for the Night Stand Fixture when the Guestroom is Inactive

<table>
<thead>
<tr>
<th>Usage Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>2.6250</td>
<td>.5175</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1.5000</td>
<td>.5898</td>
<td>16.07*</td>
</tr>
</tbody>
</table>

Note. *p<.05 using a critical value of 1.694 with df 30

Based on the findings from the statistical tests, the research hypothesis was supported because statistical significance was found for the usage of the dresser/credenza and night stand
fixtures when the guestroom was inactive. Therefore, the dresser/credenza fixture and the night stand fixture were the two lights guests most often chose to leave on when they were not in their rooms. It was also found that the night stand fixture is left on more often than the dresser/credenza fixture.

T-tests performed on each of the portable fixtures revealed that the high usage level was the most common usage range for both fixture types. When the fixtures were left on in an inactive guestroom, guests left the dresser/credenza fixture on for approximately 9 hours and the night stand fixture was left on between 5 and 16 hours.

Light Levels and Energy Consumption

Light level readings were taken to compare and insure sameness of fixture/lamp combinations within all of the guestrooms and to compare with recommended levels for guestroom spaces. Readings for each measurement point, with different lamp combinations, were almost identical for every room. Footcandle measurements only differed by ±2 fc from the mean of each reading location and fixture/lamp combination (Table 9). The largest difference in footcandle measurements between rooms were found in the entrance with only the ceiling fixture on and readings ranged from 6 fc to 9 fc.

Wattage readings were also taken for the different fixture/lamp combinations. These readings were used in energy and cost equations to determine how much energy is actually consumed by both compact fluorescent and incandescent lamp types and how much it cost to run the different fixture/lamp combinations (Table 10).

An energy equation (KWH = Watts x Hours/1000) was used to determine the number of kilowatt hours (KWH) or energy each fixture/lamp combination consumed. Once energy totals were calculated, a cost equation was applied (Cost = KWH x Rate) to determine the amount of money spent for electricity to run each fixture/lamp combination for a one hour period (Table 11). The national average KWH rate of $0.083 was used in the cost equation to determine the per hour cost to run each fixture/lamp combination.
Table 9
Light Levels Measured in Footcandles for Individual Fixtures and Fixture Combinations in the Guestroom

<table>
<thead>
<tr>
<th>Light Level Reading Location</th>
<th>Fixture(s) Measured</th>
<th>304</th>
<th>316</th>
<th>303</th>
<th>315</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Incld</td>
<td>Incld</td>
<td>CFL</td>
<td>CFL</td>
</tr>
<tr>
<td>Under entrance fixture</td>
<td>ceiling</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Under living/bedroom fixture</td>
<td>ceiling</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>ceiling and credenza</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>ceiling and night stand</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>ceiling, credenza, &amp; night stand</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>credenza and night stand</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>credenza</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>night stand</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>On top of table</td>
<td>ceiling, credenza, &amp; night stand</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>On top of pillow</td>
<td>ceiling, credenza, &amp; night stand</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Note:
CFL = compact fluorescent lamps used in the fixtures for the specified room.
Incld = incandescent lamps used in the fixtures for the specified room.

Table 10
Wattage Readings of Ceiling, Dresser/Credenza, and Night Stand Fixtures with Incandescent and Compact Fluorescent Lamps

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Fixture Type</th>
<th>Ceiling</th>
<th>Dresser/Credenza</th>
<th>Night Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td></td>
<td>240*</td>
<td>71.6</td>
<td>70.5</td>
</tr>
<tr>
<td>Compact Fluorescent</td>
<td></td>
<td>70*</td>
<td>25.1</td>
<td>25.1</td>
</tr>
</tbody>
</table>

Note. *two lamps in fixture

Table 11
Per Hour Cost to Run Each Fixture

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Fixture Type</th>
<th>Ceiling</th>
<th>Dresser/Credenza</th>
<th>Night Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td></td>
<td>$.020*</td>
<td>$.006</td>
<td>$.006</td>
</tr>
<tr>
<td>Compact Fluorescent</td>
<td></td>
<td>$.006*</td>
<td>$.002</td>
<td>$.002</td>
</tr>
</tbody>
</table>

Note. *two lamps in fixture
Wattage readings from Table 8 were used to calculate the differences in the percentage of energy the lamps consume. The ceiling fixtures that housed two incandescent lamps consumed 71% more energy than those housing two compact fluorescent lamps. The dresser/credenza fixtures that housed an incandescent lamp consumed 65% more than those that housed a compact fluorescent lamp. And, the night stand fixtures that housed an incandescent lamp consumed 64% more than those that housed a compact fluorescent lamp.

The fixture/lamp combinations that consumed the most amount of energy and cost the most to run were those that housed incandescent lamps. Ceiling fixtures that housed incandescent lamps cost 70% more to run than ceiling fixtures that housed compact fluorescent lamps. Portable fixtures that housed incandescent lamps cost 67% more to run than portable fixtures that housed compact fluorescent lamps.

Findings for both light levels and energy consumption are not surprising because the compact fluorescent lamps are designed to produce the same amount of light yet use fewer watts to produce the light. The findings for light levels support manufacturer's specifications, that when correctly matched, the compact fluorescent lamps produce an equal amount of light as the incandescent lamps. However, light levels for the guestrooms are far below the 10 to 20 footcandle levels recommended by both Rea (1994) and Erdi et al. (1970). The findings for energy consumption also support manufacturer's specifications that a 70% reduction in energy consumption can result in the use of compact fluorescent lamps as opposed to incandescent lamps. These results also support findings of a 70% energy savings reported by Brown (1994) and a 63% energy savings reported by West (1995).

Influence of Daylight

A one-way ANOVA was used to determine if the amount of daylight present in the guestroom when it becomes inactive affects whether or not lights are left on. The statistical hypothesis, there is no difference in the amount of time lights are left on in inactive rooms when daylight is present was tested. Significant differences were not found for the presence of daylight in the guestroom, as measured at the window, when lights were left on in inactive rooms (Table 12).
Table 12
One-Way Analysis of Variance of the Amount of Daylight Present in the Guestroom When it Becomes Inactive

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum-Squares</th>
<th>Mean Square</th>
<th>F-Ratio</th>
<th>Prob&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2</td>
<td>.8911</td>
<td>.4455</td>
<td>.7662</td>
<td>.4754</td>
</tr>
<tr>
<td>Within Groups</td>
<td>25</td>
<td>14.5375</td>
<td>.5815</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>15.4286</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. *p<.05

Although statistical significance was not found, 23 of the 32 rooms (72%) had daylight entering into them at some point after the room became active. Twenty-one of the 23 rooms (91%) had daylight entering them when the room became inactive. Light levels ranged from 172 fc to 546 fc for high, from 33 fc to 167 fc for medium, and from 0 fc to 29 fc for low. The data shows that daylight was used more often in the mornings. Twenty of the 23 guests (87%) had daylight entering their window in the morning. Seventeen (74%) of the guests had daylight entering their window in the afternoon or early evening. These percentages indicate that guests do use daylight in their guestrooms even though it may not influence their usage of fixtures when the room becomes inactive.

Discussion

The results indicate guests do leave light fixtures on when their guestroom is inactive. The fixture being left on the most often when the guestroom is inactive was located on the night stand and was typically left on for approximately 5 hours. Mean usage of the night stand fixture was 4 hours 20 minutes with some cases leaving it on for up to 16 hours. The reason that this fixture is left on more often when the room is inactive than the ceiling and dresser/credenza fixtures could, in part, be the result of its placement in the room. The night stand fixture is the farthest away from the door making it the least accessible and most inconvenient fixture to turn off before leaving. Guests might also choose to leave this fixture on knowing that it would be the last one turned off for the night. The telephone and clock are also placed on the night stand making it an area in the guestroom to do work and therefore need light.
The fixture that is left on the second most often was located on the dresser/credenza and when left on it was typically used for 9 hours. Sixty-three percent of the inactive guestrooms did not use the dresser/credenza fixture during the course of this study; however, when the fixture was used, it was typically left on for long periods of time. The reason that this fixture was turned off more often than the night stand fixture may be due to its placement in the room. The dresser/credenza fixture is more accessible and not as inconvenient as the night stand fixture, when comparing their placements in relation to the door. This would make the dresser/credenza fixture the more likely of the two to be turned off prior to the room becoming inactive. However, its limited usage (only 37% of the rooms) may also have been the result of it being adjacent to the television and mirror where it could create problems with glare.

The ceiling fixture is left on the least often, with usage ranging from 71/2 hours to no usage at all when the guestroom was inactive. Mean usage of the ceiling fixture, when it was left on, was 3 hours 10 minutes. The ceiling fixture was most often left on for short periods of time (30 minutes to 1 hour) right after the guest checked-in and just prior to check-out. The reason that this fixture was left on the least may have been because of the convenient placement of the switch being located adjacent to the door. This would make it easier for the guest to turn the light on when they entered the room and then shut the light off when leaving the room. The light produced from the ceiling fixture also flattens the features and dulls the aesthetics of the guestroom creating a more sterile, institutional look than the light produced by the portable fixtures.

The amount of energy consumed varied between fixture and lamp combinations. According to manufacturer's specifications, the 18 W compact fluorescent lamps (CFL) used in the dresser/credenza and night stand fixtures of the two treatment rooms should have consumed 76% fewer watts than the 75 W incandescent lamps used in the same type of fixtures in the two control rooms. The 16 W CFL used in the ceiling fixtures of the treatment rooms should have consumed 73% fewer watts than the 60 W incandescent lamp used in the ceiling fixtures of the control rooms.

Results from this study show actual wattages consumed by these lamps showed that:
1. the 16 W CFLs housed in the ceiling fixture consumed 71% fewer watts than the 60 W incandescent lamps housed in the ceiling fixtures;
2. the 18 W CFLs housed in the dresser/credenza fixtures consumed 65% fewer watts than the 75 W lamps housed in the dresser/credenza fixtures; and
3. the 18 W CFLs housed in the night stand fixtures consumed 64% fewer watts than the 75 W lamps housed in the night stand fixtures.

Even though the fixtures were all relamped with compact fluorescent lamps, differences in the amount of energy that they consumed could have varied because of variations in electrical current to the fixture, the efficiency of the fixture to carry electricity, the connection between the fixture and the lamp, the differences in the amount of energy to run the different types of ballasts, and/or the ability of the lamp to convert the electricity into visible light.

The amount of energy savings that can be realized by using compact fluorescent lamps as opposed to incandescent lamps can range from 64% to 71%. These results support the 70% savings in energy that Brown (1994) reported and the 63% savings in energy that West (1995) reported. However, unlike Brown’s findings, the CFLs used in this test did not produce a 39.5% higher light output than the incandescent lamps. In fact, because of having controlled for differences in the light levels, by using CFLs that were comparable to the incandescent lamps being used at the Donaldson Brown Center, there was only a ±2 fc mean difference in the amount of light emitted by the different lamp types.

When calculating the dollar amount for the cost of electricity for the different lamp types, the portable fixtures that housed the CFLs cost $.002 per hour and the ceiling fixtures that housed two CFLs cost $.006 per hour to run. The portable fixtures that housed the incandescent lamps cost $.006 per hour and the ceiling fixtures that housed two incandescent lamps cost $.020 per hour. These figures were calculated using the national average KWH rate of $.083.

Cost equation figures indicate 67% to 70% loses of income for the hotel due to the use of inefficient lamps. These figures translate to a average daily loss from an inactive guestroom that is lamped with incandescent lamps of $.06 when the ceiling fixture is left on, $.03 when the dresser/credenza fixture is left on, and $.03 when the night stand fixture is left on. The average daily loss for an active guestroom that is lamped with compact fluorescent lamps of $.02 when the ceiling fixture is left on, $.01 when the dresser/credenza fixture is left on, and $.01 when the night stand fixture is left on (Table 13).
Table 13

Comparison of Average Daily Costs Between Incandescent and Compact Fluorescent Lamps When Left on in Inactive Guestrooms

<table>
<thead>
<tr>
<th>Ceiling Fixture</th>
<th>Mean Daily Usage</th>
<th>Incandescent</th>
<th>Compact Fluorescent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dresser/Credenza Fixture</td>
<td>5 hrs 9 min</td>
<td>$.03</td>
<td>$.01</td>
</tr>
<tr>
<td>Night Stand Fixture</td>
<td>4 hrs 20 min</td>
<td>$.03</td>
<td>$.01</td>
</tr>
</tbody>
</table>

This study found that the presence of daylight did not influence lights being left on when the guestroom became inactive, meaning that lights were just as likely to be left on regardless of how much daylight was present in the guestroom. This may have been the influenced by limited daylight hours because of the winter season in which the study took place, the location of the hotel, the type of hotel, and/or the check-in and check-out times of the guests.
Chapter 5

SUMMARY AND CONCLUSIONS

Summary

The goal of guestroom lighting is to achieve a balance between lighting results and lighting costs (Era, 1994). These goals can be aided by the use of an efficient lighting system that incorporates elements such as compact fluorescent lamps (Brown, 1994; West, 1995), light sensors (West), and the use of daylight (Johannesen, 1991). Human consumption such as how many fixtures are used and how long fixtures are used by the guest also influence lighting efficiency and economy.

The total amount of energy used by guestrooms and the proportion of that energy that is typically consumed by guestroom lighting have been reported in the literature by Brown (1994) and West (1995); however, their investigations did not examine what proportion of energy costs were due to guestroom lights being left on by the guest when the room was unoccupied. If results indicate that lights are left on when not needed, and if this is a significant factor in the amount of energy consumed by lighting, the hospitality industry could focus on conservation measures specific to this problem.

The purpose of this study was to determine if hotel guests waste energy unnecessarily by leaving lights on in their guestrooms when the room is inactive. Factors such as room inactivity, fixture usage, and daylight levels were used to investigate how much time light fixtures were left on and therefore unnecessarily lost energy. The participants in this study were guests staying at the Donaldson Brown Center in Blacksburg, Virginia. The 32 guest night stays used for data analysis included information about guestroom activity and inactivity, what light fixtures were used, when light fixtures were used, whether or not daylight entered the guestroom, light levels in the room, and the amount of wattage different fixture/lamp combinations consumed.

The data were used to address four research questions and three hypotheses that were tested at $\alpha = .05$. Data were analyzed using descriptive statistics to describe the range of time for a guest night stay, guestroom inactivity, and fixture usage. A two-way analysis of variance
ANOVA) was performed to analyze differences between general illumination fixtures and task illumination fixtures. A two-way ANOVA was used to analyze differences between individual fixture usage of the ceiling, dresser/credenza, and night stand fixtures. T-tests were used as a post hoc evaluation to analyze the simple effects by comparing the means of dresser/credenza and night stand fixture usage. A one-way ANOVA was used to analyze if the presence of daylight influenced fixture usage when the guestroom became inactive.

The results indicated that hotel guests do leave the lights on in their guestrooms when the rooms are inactive. Statistical significance was found when comparing the usage of general illumination fixtures and task illumination fixtures when guestrooms were inactive. The results showed that task illumination fixtures are left on more often than general illumination fixtures when the guestroom is inactive. Further analysis of individual fixture usage data also found statistically significant results. Individual fixtures that were most commonly left on included the night stand and dresser/credenza fixtures for an average of 5 hours and 4½ hours, respectively, during an inactive room period. Statistical significance was not found for the levels of daylight entering the guestroom when the room became inactive.

Lighting efficiency and economy issues concerning light levels, energy consumption, and cost of electricity to run the different fixture/lamp combinations were also investigated. The results indicate that light levels between compact fluorescent lamps (CFLs) and incandescent lamps are comparable (within ±2 fc level means) when properly matched according to manufacturer’s specifications. Energy consumed by fixtures that housed CFLs was 64% to 71% less than fixtures that housed incandescent lamps. When electrical costs are calculated using the national average KWH rate, the fixtures housing the compact fluorescent lamps cost $.008 less to run on average per hour than the fixtures housing the incandescent lamps. When multiplied by the number of fixtures used in a guestroom, this figure could range from $.008 per hour for the usage of one fixture to $.032 per hour for the usage of four fixtures, such as in the guestrooms at the Donaldson Brown Center.
Conclusions

Findings from the study support the literature in that fixtures lanced with compact fluorescent lamps will save energy and money. Savings can be realized by either relamping every fixture in the guestroom or strategically relamping those fixtures that are used most often. In the case of this study, the night stand and dresser/credenza fixtures were most commonly left on when the guestroom was inactive. Relamping every fixture in the guestroom could result in a 67% to 70% savings in lighting expenditures per room without jeopardizing the quantity of light within guestrooms. If strategic relamping of fixtures that are left on most often is preferred to total relamping, expenditures for electricity can range from $.002 per hour to run a single fixture housing a compact fluorescent lamp to $.006 per hour to run a single fixture housing an incandescent lamp.

Depending on the size of the hotel considerable savings could be realized. For example, assuming that a large 1,000 guestroom hotel had an annual occupancy rate of 80%, and guestrooms averaged 5 hours a day in lost energy to unnecessary lighting. It would cost the hotel $.006 per hour per room for electricity to run a single light fixture housing one incandescent lamp, where as, it would cost $.002 per hour per room for electricity to run a single light fixture housing one compact fluorescent lamp when no one is in the room.

At an 80% annual occupancy rate (800 of the guestrooms are active throughout the year), these electrical costs for a 5 hour period of time when fixtures are used without anyone in the guestroom would translate to be $8,760 for guestrooms lanced with incandescent lamps and $2,920 for guestrooms lanced with compact fluorescent lamp.

These electrical cost estimates drastically increase when using the upper limits of 16 hours for the usage of a single fixture in an inactive room. Annual electrical expenditures at an 80% occupancy rate for a single fixture at upper limits would equal $28,032 for guestrooms lanced with incandescent lamps or $9,344 for guestrooms lanced with compact fluorescent lamps (Table 14).
Table 14
Comparison of Lost Annual Electrical Expenditures from Inactive Rooms for a 1,000 Guestroom Hotel at 80% Occupancy

<table>
<thead>
<tr>
<th>Amount of Time One Fixture is Left On</th>
<th>Incandescent Lamp ($0.006 per hour)</th>
<th>Compact Fluorescent Lamp ($0.002 per hour)</th>
<th>Difference in Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Hours</td>
<td>$8,760</td>
<td>$2,920</td>
<td>$5,840</td>
</tr>
<tr>
<td>16 Hours</td>
<td>$28,032</td>
<td>$9,344</td>
<td>$18,688</td>
</tr>
</tbody>
</table>

Implications

By total or strategic relamping with compact fluorescent lamps, operating costs for electricity in the guestrooms would be dramatically cut by more than 50%. These savings could then be passed onto the consumer through reduced rates for rooms or as room discounts, especially during high vacancy periods. These reductions in electrical expenditures, no matter how small, could also help increase profit margins of a facility.

Relamping would also save precious energy resources. With a decrease in electrical demand, there would be a decrease in natural resources such as oil and coal used to generate electricity. Also, if the demand for fluorescent lamps increases costs for the lamps would decrease. Hence, manufacturing costs would decrease making it more economically feasible for increased commercial use of these lamps. Other strategies such as asking guests to turn off the lights prior to leaving the guestroom, or installing a low voltage security light in each guestroom could also be implemented by the management of the facility to reduce electrical consumption. Strategies for relamping could then be used as a marketing tool to attract both economic and energy conscious consumers.

Recommendations for Further Research

Further research needs to be done with larger sample sizes over a longer period of time to better understand the use of light in hotel guestrooms to support the results found in this study. Also, carrying out this study in different types of hotel facilities (e.g., resorts, multi-use complexes, suite hotels) would give greater generalizability to findings involving the usage of light.
Studies that include bathroom lighting and its usage compared to other spaces of the guestroom would provide additional information into light usage. And, investigations that explore the usage of all electrical fixtures (e.g., television, lights, clock) within a guestroom environment would give a more complete view of how consumers use electricity. This study was limited to the use of light fixtures in the living/bedroom area. With a combination of all lighting and other electrical fixtures determinations into whether or not people use their television as a source of light, especially at night prior to going to bed, or if the bathroom fixtures are left on more often than the living/bedroom fixtures when the guestroom is unoccupied could be made.

More research could also be done on the use of occupancy sensors that are hooked-up to light fixtures and their impact on energy consumption and conservation. Within this realm, investigations into how the installation of a low-voltage security light in each guestroom as part of energy conservation efforts by hotel facilities could be explored to identify its impact on fixture usage when rooms are inactive.

Research also needs to be done to determine the perception of the quality of light being emitted by compact fluorescent lamps, especially if they are mixed with an incandescent light source. This study did not cover the perceptual factors of lighting, other than recording light levels in footcandles to control lighting variables within the rooms. If compact fluorescent lamps are used in conjunction with incandescent sources, perceptual differences in the amount of light or color of light may influence which fixtures are used the most in the guestroom environment.
REFERENCES


Appendix A

Eleven Broad Categories and Descriptions of Hotel Facilities Currently on the U.S. Market
(Rutes & Penner, 1985)

1. Downtown Hotels. The downtown hotel provides accommodations for business travelers during the week and vacationers during the weekend. They feature the following facilities: meeting rooms, small conference rooms, restaurant and lounge, retail space, and indoor recreation facilities.

2. Suburban Hotels and Motels. This type of accommodation most commonly appears near business or corporate office parks, universities, medical centers, airports, entertainment centers, and shopping centers that are away from a city’s downtown area. They may include retail space, health clubs for hotel guests and the surrounding population, and private restaurants and lounges.

3. Resorts. Resorts are most easily distinguished by their location. The local environment and topography determine how large the resort will be and what kind of amenities it delivers. Some of the more common amenities include golf courses, tennis courts, beachfront, skiing, boating, and sight-seeing. These facilities try to invoke a sense of personal ownership in the guest by providing a residential setting in a vacation paradise.

4. Convention Hotels. The convention hotel is specifically designed and equipped to serve large groups (500 to 5,000 people). They feature meeting spaces, exhibit halls for trade shows, registration and administrative areas, and banquet rooms.

5. Conference Centers. The conference center provides facilities similar to a convention center but on a smaller scale, catering to small- and medium-sized groups (10 to 400 people).

6. Residential and Condominium Hotels. These hotels are commonly located in high-rise residential areas adjacent to central business districts and offer apartment-like accommodations in their guestroom design for prolonged stays. They feature arrangements that include separate bedroom(s), living room, dining, and kitchenette areas. Residential and condominium hotels
provide the benefits of a full-service hotel except for a restaurant, lounge, and banquet facilities on the premises.

7. Suite Hotels. The suite hotel consists of units that have a separate bedroom, bathroom, and living/dining room. These accommodations also provide a wet bar which includes a counter sink, cabinet, mini-refrigerator, and coffee maker. The suite hotel also furnishes a full range of services for guests and commonly has meeting and banquet areas.

8. Super-Luxury Hotels. These hotels are noted for their pampering service, privacy, and elegant character. Elegant residential characteristics in all of their facilities from the lobby to the guestroom are featured. Standard offerings include a gourmet restaurant and bar with a vintage wine cellar, full balconies, landscaped terraces, courtyards, outdoor roof gardens, and saunas and whirlpools.

9. Mega-Hotels. The mega-hotel encompasses all of the services and facilities of tourist and convention centers, family resorts, and sports resorts at one location. They most often have innovations such as local transit systems (i.e., built-in monorail, tour boats, buses, etc.), ideal locations for sight-seeing, sight-seeing features (i.e., theme parks, wild animal displays, and nature preserves), convention facilities, and are near airports.

10. Mixed-Use Developments. Mixed-use developments are similar to suburban hotels and motels except that they are built in areas of heavy traffic and are very near or part of shopping malls or civic centers.

11. Casino Hotel. The noted feature of these hotels are their gaming, entertainment, and conference facilities.
Appendix B

Guestroom Furnishings and Fixtures Dimensions

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Furnishing</th>
<th>Length or Diameter</th>
<th>Width</th>
<th>Height</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>open-faced closet</td>
<td></td>
<td>69</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>circular table</td>
<td>32 diameter</td>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>1</td>
<td>dresser/credenza unit</td>
<td>72</td>
<td></td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>1</td>
<td>mirror (overall)</td>
<td></td>
<td>26</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mirror (glass)</td>
<td></td>
<td>21</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>television</td>
<td></td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>side chair</td>
<td></td>
<td>20</td>
<td>35</td>
<td>24</td>
</tr>
<tr>
<td>2</td>
<td>double-size bed</td>
<td>82</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>night stand</td>
<td></td>
<td>22</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>adjacent double-hung windows</td>
<td></td>
<td>56</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>ceiling fixture</td>
<td>13 diameter</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>ceiling fixture</td>
<td>10\text{\pi} diameter</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>table lamp</td>
<td></td>
<td></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>1</td>
<td>table lamp</td>
<td></td>
<td></td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>lamp shades</td>
<td>15 diameter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>pictures</td>
<td></td>
<td>33</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Note. All measurements are reported in inches.
Appendix C

Photo Representations of Finishes and Materials Used Throughout the Guestroom

Wallpaper
Side Chair Fabric
Bedspread Fabric

Window Treatments
Appendix D

Reflectance Values of Room Finishes

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Reflectance Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>wallpaper</td>
<td>multi-hued random-looking brushed pattern</td>
<td>58.4</td>
</tr>
<tr>
<td>closet</td>
<td>light stained birch</td>
<td>30</td>
</tr>
<tr>
<td>wood furniture</td>
<td>mahogany veneer with dark stain</td>
<td>4</td>
</tr>
<tr>
<td>bedspread</td>
<td>striped pattern</td>
<td>9.7</td>
</tr>
<tr>
<td>window valance</td>
<td>dark paisley pattern</td>
<td>20.8</td>
</tr>
<tr>
<td>window curtain</td>
<td>opaque beige speckled pattern</td>
<td>66.7</td>
</tr>
<tr>
<td>side chairs</td>
<td>striped upholstery</td>
<td>6.5</td>
</tr>
<tr>
<td>pictures</td>
<td>outdoor scene</td>
<td>21.8</td>
</tr>
<tr>
<td>HVAC unit</td>
<td>matte beige paint</td>
<td>66</td>
</tr>
<tr>
<td>carpet</td>
<td>dark cut-pile</td>
<td>6.3</td>
</tr>
<tr>
<td>ceiling</td>
<td>off-white textured stucco</td>
<td>61.5</td>
</tr>
</tbody>
</table>
Appendix E

Script for the Registration Desk at the
Donaldson Brown Continuing Education and Conference Center

DBCEC: Usual welcome (e.g., Hello, Donaldson Brown Continuing Education and Conference Center registration desk, how may I help you?)

Guest: Requests a room.

DBCEC: We are working with the interior design program on campus to identify electrical components of the room that could be improved for better energy performance.

In order to do this we are asking guests staying in room (303/304/315/316) if they would be willing to stay in a room that is being monitored for energy consumption.

Would you be interested in helping us with this?

Guest: No. (Offer the guest another room).

Yes. (Continue)

DBCEC: Okay, I'll book you in this room and note that you are willing to participate in this project.

Usual close.
Appendix I

Information Statement

We would like to assure you that there were no personal monitoring devices in this room (audio or video). Part of the equipment in the guestroom was used to regulate the heating, ventilation, and air conditioning when guests are out of their rooms to conserve energy. The other equipment was used to evaluate how often each light fixture was used and the amount of daylight coming into the room.

This research has been approved by the Institutional Review Board of Virginia Tech. All individual room data will be kept confidential. The energy information will only be identified by the room number and what day it was collected.

If you have any questions about this research, please contact Cheryl Kieliszewski, 248 Wallace Hall, Department of Housing, Interior Design, and Resource Management, Virginia Tech, phone: 231-6832, e-mail: <cher@vt.edu>; Jeanette Bowker, , Department of Housing, Interior Design, and Resource Management, Virginia Tech, phone: 231-6163; or Howard Feiertag, Donaldson Brown Center, Virginia Tech, phone: 231-9459.

Thank you for your willingness to participate in this study.
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EDUCATION

Doctor of Philosophy, January 1996 (start date)  
Virginia Polytechnic Institute and State University, Blacksburg, Virginia  
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Bachelor of Science, December 1989  
University of Wisconsin - Stevens Point, Stevens Point, Wisconsin  
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Major: Interior Design

EMPLOYMENT

Ownership

Lighting Design Specialists, Blacksburg, Virginia  
Lighting Design Consulting Services  
January 1996 to Present

Professional Experience

Radford University, Radford, Virginia  
Adjunct Faculty  
Team taught junior and senior level professional practices class and research topics class  
January 1996 to May 1996

Virginia Polytechnic Institute and State University, Blacksburg, Virginia  
Graduate Teaching Assistant  
August 1995 to May 1996  
August 1993 to May 1994

Department of Housing, Interior Design, and Resource Management  
Assist in lecture and design studio sessions, maintain resource room, and assist in departmental functions.
North Dakota State University, Fargo, North Dakota
Lecturer December 1990 to May 1993
Department of Apparel, Textiles, and Interior Design
Adjunct faculty position for interior design. Responsible for course development of lecture and studio sessions. Team-teaching experience in lecture and studio courses.

Design Consultant September 1991 to May 1993
Residential space planning. Office space planning and furnishing in conjunction with North Dakota State University physical plant.

Work Experience

Virginia Polytechnic Institute and State University, Blacksburg, Virginia

Editorial Assistant Journal of Extension February 1994 to May 1996
Receive and prepare manuscripts for electronic publication. Duties include: reformatting manuscripts to comply with APA style format; assign, disseminate, and track peer reviews; assist in editing proof copies; prepare manuscripts for final publication; and communicate with authors regarding the status of manuscripts.

North Dakota State University, Fargo, North Dakota
Administrative Secretary February 1990 to August 1993
Office of Graduate Studies and Research
Assistant to the Dean of Graduate Studies and Research.

Sentry Insurance Company, Inc., Stevens Point, Wisconsin
Word Processing Operator January 1988 to January 1990

Personal Lines Property Rater May 1986 to January 1988

Document Service Clerk May 1985 to May 1986

Hohensee Financial Services, Stevens Point, Wisconsin
Office Assistant April 1988 to May 1989

PROJECTS AND ACTIVITIES

Poster Session

- 1995 Graduate Research Symposium, poster presentation, sponsored by Graduate Student Assembly, Virginia Polytechnic Institute and State University, March 1995
Presentations

- Learning Session Co-lecturer, *COLOR—Science or Art*, Expanding Your Horizons North Dakota State University Science and Math Conference, April 1993

Manuscripts


Design Competition

- 7th Annual Healthcare Design Competition, product design—adjustable control panel, sponsored by The Center for Health Design, Inc., October 1994

Undergraduate Projects

- Field Experience, space planning, Stevens Point City Treasurer Office, County-City Building, Stevens Point, Wisconsin, April 1989
- Internship, Assistant Designer, Facilities Department, University of Wisconsin - Stevens Point, Summer 1988

PROFESSIONAL ACTIVITIES

Professional and Student Organizations

- Kappa Omicron Nu: Member, April 1995 to Present; Editor, July 1995 to June 1996
- Illuminating Engineering Society of North America, Student Member, September 1994 to Present
- Graduate Student Assembly Representative for Housing, Interior Design and Resource Management Department, Virginia Polytechnic Institute and State University, August 1994 to August 1995
- American Society of Interior Design, Student Chapter, University of Wisconsin-Stevens Point, 1988 to 1989

Committee Involvement

- Curriculum Development Committee for Interior Design, North Dakota State University, March 1992 to June 1992
- Futures Conference, (Co-advisor), North Dakota State University, March 1992