AN INTRODUCTION TO DIGITAL ADDRESSABLE LIGHTING INTERFACE (DALI) SYSTEMS & STUDY OF A DALI DAYLIGHTING APPLICATION

by

LISA MEYER

B.S., Kansas State University, 2007

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Architectural Engineering and Construction Science College of Engineering

KANSAS STATE UNIVERSITY Manhattan, Kansas

2007

Approved by:

Major Professor Raphael A. Yunk

Abstract

The DALI (Digital Addressable Lighting Interface) protocol has set forth the requirements for a digital fluorescent ballast that out performs its predecessors with respect to flexibility and functionality. The advantages of a DALI lighting control system range from advanced dimming capabilities and daylight sensing to saving money in energy and maintenance costs. A DALI lighting control system can also be beneficial to designers when trying to meet the requirements of code or recommended practices.

The information in this report will help designers decide when to consider using a DALI lighting control system. This report covers topics such as the advantages of digitally addressable lighting, the equipment required to make a DALI system work, the limitations and drawbacks of DALI, cost information on installing and using a DALI system, and how DALI can help meet code and recommended practices, and concludes with a case study demonstrating how a DALI system has the potential to save money in energy costs.

Table of Contents

List of Figures
List of Tables
CHAPTER 1 - Introduction
CHAPTER 2 - Background
Definitions
0-10V System
Address
AGI-32
Control Unit
DALI Loop
DALI Message
Daylight Harvesting
Differential Manchester Encoding
IEC, International Electrotechnical Commission
Preset
Router
Introduction to DALI Systems
History of the DALI Protocol
CHAPTER 3 - Advantages of DALI
Dimming
Daylight Sensing7
Save Energy7
Space Use Flexibility
Ease of Modification
Lower Maintenance Costs
Individual Control9
Integration with a Building Management System9
Emergency Lighting Testing 10

Installation/Design	
Ability to Work with Retrofit Designs	
CHAPTER 4 - DALI Equipment	
Requirements for a Basic DALI System	
DALI Ballasts	
DALI Control Units	
DALI Power Supply	
Low Voltage Wires	
Optional DALI Equipment	
Occupancy Sensors	
Photosensors	
Closed-Loop Photosensors	
Open-Loop Photosensors	
Fixtures with Integral Photosensors	
Routers	
Additional Control Units	
Touch Button Wall Devices	
Wall Touch Screens	
DALI Software	
CHAPTER 5 - Limitations and Drawbacks	
Limitations	
Loop Current	
Distance/Voltage Drop	
Number of Ballasts, Groups, and Presets on a DALI Loop	
Drawbacks	
Programming	
Ballast Replacement	
Ballast Energy Consumption in Off Mode	
CHAPTER 6 - Cost Information	
CHAPTER 7 - Installing, Programming, and Using the System	
Wiring/Communication	

Appendix D - Case Study Daylighting Study Results	. 50
Appendix E - Case Study Calculations	. 67
Appendix F - Case Study AGI-32 Screen Shots	. 69
Appendix G - Permissions	. 72

List of Figures

Figure 3-1 Ballast Wiring Configurations for DALI	11
Figure 4-1 Watt Stopper EZ Dali Control Unit	13
Figure 4-2 Tridonic Control Unit	13
Figure 4-3 Starfield Control Unit	13
Figure 4-4 Starfield Router	16
Figure 7-1 Low Voltage Wiring Diagram – Sensors Connected to the Control Unit	24
Figure 7-2 Low Voltage Wiring Diagram – Sensors Connected to the Ballast Loop	25
Figure 7-3 Sample System Wiring Diagram	25

List of Tables

CHAPTER 1 - Introduction

Any new technology is expected to be better than its predecessor in that it should be more flexible and have greater functionality. Digitally Addressable Lighting Controls have been making their way into lighting designs providing increased flexibility and functionality compared to any other dimming system on the market. As an alternative to other dimming systems such as 0-10V systems and DSI (Digital Serial Interface) control systems, they have many advantages that will be discussed in detail in this report.

The purpose of this report is to create a basic understanding for entry-level and experienced engineers of digitally addressable lighting for fluorescent lamps that meets the requirements of the DALI protocol. After reading this report, the engineer should have a good idea of when it would and would not be appropriate to choose a DALI system design. This report covers what DALI is, how it works, the required components, and the advantages and disadvantages of using a DALI system. This report does not cover manufacturer specific products, but does describe some of the products available to consumers. It is assumed that an engineer would consult a manufacturer's representative for specific product options once the decision to design a DALI lighting control system is made. This report also does not go into great depth on how products are designed or specifically how they work since that information is not essential for designing a system. This type of information may be useful for those wishing to create their own products but is beyond the scope of this report.

CHAPTER 2 - Background

DALI is an acronym for Digital Addressable Lighting Interface. The term interface refers to a ballast. This chapter includes a definitions section, an introduction to what DALI systems are, and the history of DALI.

Definitions

This section is intended to explain some of the terminology that is used throughout the paper. The first occurrence of each term defined in this section will be shown in bold as a reference to this section.

0-10V System

A 0-10V system is an analog low voltage lighting control system that uses analog dimming ballasts connected in parallel and controlled simultaneously by changing the voltage from 0V up to 10V with a dimming control unit. The ballasts are not addressable and can not be controlled individually. Hard wiring determines which analog ballasts will be controlled as a group (Ribarich).

Address

An address, when referring to a DALI system, is a series of eight data bits that is unique to each ballast in a DALI loop (Zhang). The address is used to identify a particular ballast when messages are sent from the control unit.

AGI-32

AGI-32 is a lighting calculation software created by Lighting Analysts, Inc. Lighting Analysts, Inc. describes the software as "comprehensive calculations, ease of modeling, and fast, high-quality rendering for any interior or exterior environment, considering electric and/or daylighting sources" (What).

2

Control Unit

A control unit is the "brain" of a DALI system because it is responsible for telling the ballasts which functions to perform. It can also request information from the ballasts related to ballast/lamp performance. The control unit also creates, stores, and recalls presets when told to do so by the user via a touch button, touch screen signal, or computer software.

DALI Loop

A DALI loop is a group of up to 64 DALI ballasts connected to a control unit or router with low voltage communication wires. A DALI loop can act individually as a system when connected to a control unit, or can be connected to other DALI loops with routers to create a larger DALI network.

DALI Message

A DALI message is a command from a control unit or a response from a ballast. A message command is made up of one start bit, the eight-bit address, an eight-bit command, and two stop bits. A response message consists of one start bit, eight data bits, and two stop bits. Refer to the definition of **Differential Manchester Encoding** for more information on bits.

Daylight Harvesting

Daylight harvesting refers to integrating natural daylight with artificial light to illuminate a space. It is done using lighting controls that sense light levels and respond by dimming or turning off lights to maintain a specified light level.

Differential Manchester Encoding

Differential Manchester encoding is a type of electronic communication using a series of zeros and ones to signify the presence or absence of transitions to indicate logical value (Data). These values make up the bits used in an address and a DALI message.

IEC, International Electrotechnical Commission

The IEC is an international standards organization that sets standards for electrical technology. The standards are based on safety, performance, the environment, and energy efficiency. The American National Standards Institute (ANSI) is a member of the IEC (www.iec.ch).

Preset

A preset may also be referred to as a scene. A preset is a lighting scenario that is stored in the control unit that can be recalled at any time. The preset lighting scenario can be comprised of any combination of ballasts or groups of ballasts, each of which can be set to a different desired dimming level to meet the needs of the space.

Router

A router is used to connect DALI loops to an Ethernet network. This allows more than one DALI loop to be controlled as one system.

Introduction to DALI Systems

A DALI system is a method of controlling light fixtures in a space ranging from single rooms to multiple buildings. Ballasts are connected with the typical hot, neutral, and ground wires to provide power as well as two low-voltage wires. The low-voltage wires act as a means of communication with the **control unit**. The control unit assigns what is referred to as an **address** to each ballast. The address allows the DALI control unit to call on each ballast individually with a **DALI message** and assign it a specific task or receive information from it. The control unit can send/receive ballast information ranging from turn on/off, dim, ballast malfunction, and lamp burn out. Ballasts can also be assigned to groups defined by the user via the control unit. This allows the control unit to send out a group message. Each ballast knows, based on the information. The difference between a DALI lighting control system and other lighting control systems with preset functions is that in a DALI system a ballast can be assigned to any group at any time regardless of how the power circuits are wired. Other lighting control systems require groups to be determined during the design phase because they are defined by hard-wired groups.

History of the DALI Protocol

In 1990, European ballast manufacturers such as Philips, Osram, Tridonic, Huco, Trilux, and Vossloh-Schwabe began researching new ballasts that could communicate individually with a control unit. The reason for this research was to explore the possibilities of a lighting control system with greater flexibility than a **0-10V dimming system**. The **IEC** created standard 60929,

4

Annex E: Control Interface for Controllable Ballasts which is known less formally as the DALI protocol, to establish the requirements for the new DALI ballasts. The importance of a standard is that it sets a minimum set of requirements so that components are interchangeable. Many manufacturers have been able to create DALI products since the technology is not patented. Development of commercial DALI products began in 1998. For a ballast to be labeled as a DALI ballast, it must meet the requirements of the DALI protocol. Other DALI equipment such as control units are not defined by the DALI protocol and are labeled as DALI simply because they have the capability of communicating with DALI ballasts. Because the DALI ballasts operate using the same protocol, those manufactured by different companies have the ability to work together. This allows consumers to find more competitive pricing among products. This is also important because ballast replacement does not depend on any one manufacturer's status as far as discontinued products are concerned. Note that because the DALI protocol only defines the requirements for DALI ballasts, other DALI products such as control units may not be compatible with products from competing manufacturers, but all DALI ballasts will work with any DALI control unit (Technical).

CHAPTER 3 - Advantages of DALI

A DALI lighting control system has the capability of performing a wide variety of tasks beyond those of a typical switch or dimming system. The system can incorporate dimming, daylight sensing, and occupancy sensing, and save energy. This chapter will discuss each of these advantages of DALI systems.

Dimming

The ability to dim lights is essential for many buildings since various daily tasks require dimming. Conference rooms, auditoriums, and classrooms can all benefit from the ability to dim lights. A DALI system makes this task simple. DALI ballasts are capable of dimming down to 1% for linear fluorescent lamps and 3% for compact fluorescent lamps (DaliPro). **Presets** on the control units can be set to tell a certain DALI group to dim to a pre-assigned level. Once the preset is defined within the control unit, only the touch of a button is required to achieve a desired level of dimming. This can save time and allow flexibility for a user. Prior to a meeting or class, users can define presets or use presets already created that meet their needs for specific tasks, such as showing multimedia displays while occupants are taking notes. Owners may also desire various light levels to create different moods for different events such as low light level evening dinners or higher light level conferences. Dimming presets allow the changes to be made instantly at the touch of a button.

According to the DALI protocol, DALI ballasts shall be capable of providing 256 levels of brightness that follow a logarithmic dimming curve. Logarithmic dimming allows for larger increments in brightness at high light levels and smaller increments of brightness at the lower light levels. The result is dimming that appears linear to the human eye (Ribarich).

As it relates to dimming, a DALI lighting control system is different from any other dimming control system because it can be addressed individually and meet the needs of an occupant more flexibly, and the logarithmic dimming capability increases occupant comfort.

Note that some manufacturers are starting to make DALI ballasts that do not have the capability to dim, so it is important to make sure a non-dimming DALI ballast is not specified

when dimming is required. Non-dimming DALI ballasts are beneficial because they are more cost effective in areas that do not require dimming such as some restrooms and corridors (Lighting).

Daylight Sensing

Often an owner wants to incorporate daylight into a space for color rendering purposes, to make occupants feel less like they are cooped up indoors, or to save money in energy costs. A DALI system is one of the best ways to integrate daylight with artificial light while maintaining a fairly uniform footcandle level on the workplane. The only time the light level may not remain uniform is when daylight provides a higher footcandle level than that for which the space was designed. In this case, installing blinds or shades on the windows may be beneficial. Since each ballast can be controlled separately in a DALI system, the control unit, after receiving readings from a photosensor, can send individual messages to each ballast about how much they need to dim to keep light levels fairly constant. Refer to Chapter 4 for more information on photosensors, including open-loop versus closed-loop systems. In a typical 0-10V system, where ballasts are grouped based on wiring, the entire group must be dimmed the same amount. This setup requires a careful analysis of daylight levels during the design phase to make sure fixtures are grouped so that dimming requirements are the same for each fixture in a group to allow for a uniform footcandle level on the workplane. In a DALI system, fixtures do not need to be grouped prior to installation, or at all if an open loop photosensor is used. This makes the system easier to design; however, depending on the level of precision desired by the owner, more time will be required for programming. The advantage of a DALI system would be the guarantee of having the capability to provide adequate light levels.

Save Energy

The article "Emerging Trends in Building Lighting Control Systems" by Craig DiLouie states that according to the California Energy Commission (CEC) significant amounts of energy can be saved by controlling lighting. The CEC claims an energy savings of 5-10% can be achieved by automatically shutting off a building's lights at the end of a workday. Shutting off a portion of a building's lighting during peak demand loads can save 5-15%. Scheduled dimming of large lighting loads can generate a 2-10% savings (DiLouis, Emerging Trends). A DALI

7

system has the capability to perform each of these functions. It can be programmed to turn lights on/off based on a programmed time schedule, scenes can be set in which some of the fixtures are turned off at a set time of day, and it can dim lights to a desired level. Utilizing a **daylight harvesting** setup has the potential to reduce energy consumption by 30-60% (Advance). See Chapter 9, Daylighting Case Study for an example of how DALI can save energy.

Space Use Flexibility

A DALI control unit has the capability of storing up to 16 preset scenes. A scene refers to a group of ballasts that are told to perform a certain task at the touch of the button on the control panel. Tasks range from turning on/off to dimming to a specified light level. A DALI lighting system creates a space that is flexible for many uses. Presets can be programmed before an event that requires many different light levels or atmospheres. Simply touching the specific preset button on the control panel will change the lighting to the desired scene. One application for which this feature is especially useful is a conference. Part of the day a meeting or classroom light level may be desired for taking notes and later a lower light level may be desired for a dinner function. It is also particularly useful when a stage/speaking area is not clearly defined in a space because it allows the owner to change the lighting to highlight any stage location. The lighting presets can be changed to accommodate any arrangement of furniture or occupants as long as a fixture exists in the desired location. It would still be rather simple to add an additional fixture to a **DALI loop**, provided space is available on the loop. Refer to Chapter 5 for space limitations. The advantage of using a DALI lighting control system in place of another lighting control system with preset capabilities is that DALI groups can be defined/redefined at any time and other system's groups must be determined during the design phase so that they may be hard wired by groups during construction.

Ease of Modification

On occasion the function or layout of a space requires modification. Whether this is a change in furniture layout, new tenant requirements, or simply new task requirements, a DALI lighting system provides the flexibility to adapt the lighting controls to any new space. Because the wiring of the ballasts plays no part in how the fixtures are grouped or controlled, changes can be made whenever the need arises. Fixtures can easily be regrouped and groups can be

reprogrammed to fit the needs of the space. Because modification of a DALI system is so simple, it avoids the costly changes associated with a hard-wired system.

Lower Maintenance Costs

Maintenance is often a principal concern for building owners. A DALI system, when used with a computer interface and DALI software, has the ability to provide feedback from the ballasts back to the program. Signals are sent that, for example, report information about failed lamps and ballasts. This information allows maintenance staff to be notified immediately and tells them the exact location where the malfunction has taken place, provided ballast location has been inputted into the computer software. This can reduce the time it takes staff to maintain lamps and allows them to focus on other building issues. This function of a DALI system would be especially beneficial in a large system, maybe even as large as an entire campus because attention can be immediately focused where there is a problem, instead of waiting for a problem to be identified and located.

Individual Control

A DALI system allows occupants individual control of the lighting in their workspace. In an open-office scenario, one employee may desire a higher light level than another. Because each of the ballasts are controlled separately, each fixture can be set to dim to any level desired. One drawback of this feature is that it would be time consuming to change just one fixture in a large loop of fixtures, especially if it were located toward the end of a 64-ballast loop. Programming also requires that all lights are turned off being so that the one fixture specified to be changed can be identified by having that particular ballast turned on, which may be a problem during business hours.

Integration with a Building Management System

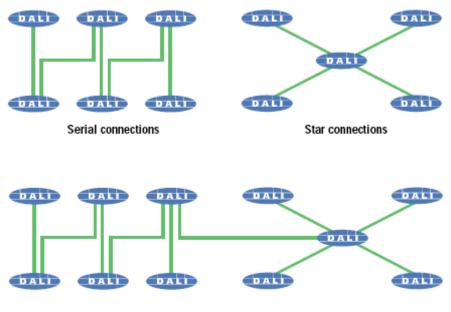
A DALI system can be integrated with a building management system (BMS) that controls other systems in a building such as HVAC. This enables an owner to view and change lighting conditions from a computer. From a maintenance perspective, using DALI with a BMS works the same as using DALI with computer software as described in the previous section on maintenance costs. Note that without a DALI system, the ballasts connected to the BMS would not be individually addressable (Advance).

Emergency Lighting Testing

When building standards require each emergency fixture to be tested for its performance and battery condition on a regular basis, time can be saved if a DALI lighting control system in combination with computer software is utilized. Software such as EM winPRO from Tridonic can test the performance of emergency lighting as it relates to lamp and ballast faults and battery status and report their performance back to a computer. The fixtures can be set to be tested periodically or continuously. Because the testing procedure is performed by a computer, testing can be done during off hours without requiring the presence of maintenance staff. After-hours testing is important when productivity issues and potential distractions are a concern to an owner (Hayes).

Installation/Design

A DALI lighting control system is advantageous to any other lighting system requiring dimming or presets in the design phase and installation. Because DALI is individually addressable, the power conductors and low voltage control wires can be installed in any configuration. Other lighting control systems require wiring based on the expected needs of the space at the design phase. DALI offers flexibility in that groups can be assigned at any time regardless of how the fixtures are wired. For example, 0-10V dimming systems require ballasts to be installed in parallel and controlled simultaneously by a single control unit (Ribarich). DALI systems can be installed in series, in a star configuration, or in a combination of the two with the potential of reducing the amount of wiring needed or reducing the maximum distance (Advance). Figure 3-1 (Advance), below, shows the various wiring configurations. See Chapter 5 for more information on distance restrictions.



Combined installation

Figure 3-1 Ballast Wiring Configurations for DALI

Ability to Work with Retrofit Designs

A DALI lighting control system can work with a retrofit lighting design. An old control system can be updated by replacing the ballasts in the fixtures with DALI ballasts and providing control wiring to a control unit. If the original system is a 0-10V dimming system, the original control wires can still be used for the new DALI system.

CHAPTER 4 - DALI Equipment

This chapter covers the equipment required to make a DALI lighting control system work. In addition, it covers optional equipment that will upgrade a DALI system to the next level.

Requirements for a Basic DALI System

The most basic DALI system, the system used in a simple single room application, requires light fixtures equipped with DALI ballasts, a DALI control unit, a DALI power supply, and low voltage wires connecting the devices. Even as a basic system, it can still perform essential tasks such as dimming and creating presets. More complex systems, such as those controlling multiple rooms or buildings, require the additional equipment discussed in the Optional DALI Equipment section of this chapter.

DALI Ballasts

When specifying ballasts for a DALI system, designers must make sure the ballasts follow the correct protocol. That protocol, as mentioned earlier, is IEC Standard 60929 which dictates all of the requirements for the ballast so that it will be compatible in any DALI system.

Each ballast within the DALI system is individually addressable. When the system is programmed, each ballast is assigned a unique code, its address, which is used by the control unit to call upon it to perform specific tasks. The ballasts are capable of communicating with the control unit using Differential Manchester encoding.

DALI Control Units

Control units are required in a DALI system to act as the brain of the system. The control unit is responsible for communicating with the ballasts and storing and recalling presets. Because control units are not defined within the requirements of the IEC Standard 60929, control devices from different manufacturers may not work together. They should, however, be able to communicate with any manufacturer's DALI ballast. A designer would need to check with a manufacturer's representative to see if two control devices could work together. In a basic DALI

system, only one control unit is required, so compatibility is not an issue. Figures 4-1, 4-2, and 4-3 show examples of some DALI control units.

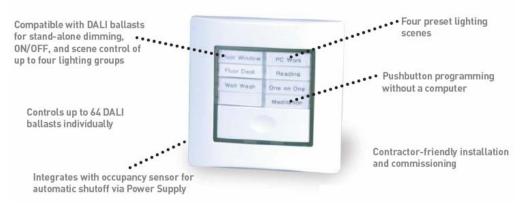


Figure 4-1 Watt Stopper EZ Dali Control Unit



Figure 4-2 Tridonic Control Unit



Figure 4-3 Starfield Control Unit

DALI Power Supply

Because DALI is a low voltage system, a low voltage power supply is required for the system to operate. A DALI power supply steps down a line voltage to the required voltage of 24V DC (An Introduction). The power supply unit has connections to a 120V power supply. The output of the unit is the low voltage wiring that allows for communication between the control unit and each ballast.

Low Voltage Wires

Low voltage wires run between the control unit, power supply, and ballasts. Standard building wire can be used for the low voltage wiring. The low voltage wires can be run in the same conduit as the power conductors as long as local codes allow. The layout of the wires does not affect the performance of the system. They can be designed in a series layout, a star connection, or a combination of the two (Advance).

Optional DALI Equipment

Many options exist for adding equipment to a DALI lighting control system. The additional equipment allows the system to outperform the most basic system's ability to dim lights and set presets. Some other equipment that can be used with a DALI system include occupancy sensors, photosensors, a computer interface, and a Building Management System. Note that this is not an all-inclusive list and that each manufacturer may have its own special DALI equipment.

Occupancy Sensors

Just as with any other application, an occupancy sensor detects occupants in a space and sends the occupancy message to another device that will decide whether the lights need to be turned on or off. An occupancy sensor in a DALI application must be able to communicate the DALI language of Differential Manchester Encoding in order to communicate with the rest of the DALI components. In a DALI system, the control unit can be set to wait a certain period of time once receiving occupancy information from the occupancy sensor before turning the lights

14

on or off. It can also be set to dim the lights for a period of time before they are turned completely off.

Photosensors

Photosensors can be used in a DALI system to sense light and relay the light level message to the control unit, which can then send a message to ballasts to dim. Two types of photosensors will work in a DALI system: a closed-loop photosensor and an open-loop photosensor. Each will perform daylighting functions, but in each case the system will operate a little differently. Another option for sensing daylight is to use light fixtures that have integral photosensors. It is up to designers to choose the best option for a photosensor for a project based on their engineering judgment.

Closed-Loop Photosensors

Closed-loop photosensors are typically mounted on the ceiling within a space. They sense light on the workplane (daylight and lamp light) and report the levels to a control device that can dim fixtures to adjust the light level to a user-defined level. Each sensor controls one zone or, in the case of DALI, one fixture. If it is desired that each DALI equipped fixture is dimmed separately from another, a separate closed-loop photosensor would be required for each. Otherwise, the photosensor would control a group of fixtures that would all have to be dimmed the same amount. Having a separate photosensor for each DALI fixture would be possible, but that would not be a very cost effective solution (Kohnen).

Open-Loop Photosensors

Open-loop photosensors are positioned to only see daylight and no artificial light. They can then report daylight levels and ballasts can be dimmed to a relative percentage based on the sensor reading. As long as a group of fixtures sees the same source of daylight, they can all be connected to one photosensor. One photosensor can be used for an entire façade of a building as long as there are not any other objects, such as other buildings or trees, blocking the sunlight. In a DALI system, each of the ballasts can be set to be dimmed to a different relative percentage based on the photosensor reading (Kohnen).

Fixtures with Integral Photosensors

Another option for daylighting is to use light fixtures with integral photosensors. This eliminates the need to decide whether to use an open-loop or closed-loop photosensor. Because the photosensors are integral, each fixture can be dimmed separately, based on the light level at the nearby workplane.

Routers

Routers are used when more than 64 ballasts are desired on one DALI system. A router connects two DALI loops making it possible to have 128 ballasts controlled by one control unit. If more than 128 ballasts are desired on one DALI system, multiple routers can be connected to an Ethernet network. Figure 4-4 shows an example of a router made by Starfield.



Figure 4-4 Starfield Router

Additional Control Units

By adding control devices, a DALI lighting control system can perform additional functions that the basic DALI system cannot perform by itself. This section covers these additional types of control units and what each can do. Keep in mind that multiple control units can be used in one DALI system, but because control units are not defined within the DALI protocol, different manufacturer's control units may not be able to communicate with another manufacturer's control units.

Touch Button Wall Devices

Touch-button wall control units are the most common type of control device for use in a single DALI loop when 64 or less ballasts are required. The buttons on the unit can create presets, define groups, and recall presets.

Remote touch-button devices are also available. They are typically used as a second switching location and have the ability to recall presets, but not necessarily define them. They are generally used when control is desired in more than one location within a space.

Wall Touch Screens

Another option for individual room control is a wall touch screen. The main difference between a wall touch screen control device and a touch button control device is that touch screen can be used with software to provide the user with additional information. The software allows the user to see digitally what the control device is doing, such as which ballasts are assigned to which groups and what the dimming levels are for each preset. The only way one can tell what the presets are when using the touch-button control device is to actually call up the preset and see if it is desirable.

DALI Software

Computers installed with DALI software can also be used to control DALI systems. This option is generally used when a large space or multiple spaces are being controlled from one location. Many manufacturers of DALI products create software that can be used with a personal computer. When routers are connected to a computer with DALI software, all connected DALI loops can be controlled from one location.

Software is available that is controlled via the internet. This means owners can have access to their system from anywhere in the world with an internet connection. The lighting system can be monitored remotely for light levels, ballast performance, and emergency lighting testing (Lighting).

Personal Digital Assistants (PDA's) can also be used to control a DALI system. They work much like a personal computer since they are simply small computers. The control capabilities are accessed via the internet.

DALI software can also incorporate a DALI system into a building management system. DALI can be integrated with a building management system to any extent desired. The DALI system can act as a stand-alone system by simply reporting to the building management system information such as ballast status and failures. Another option would be to have the DALI system fully integrated with the building management system. In this application, the building management system would be able to control all DALI loops connected to the interface via a

17

translator that would translate the language from the building management system into differential Manchester encoding so that it could be understood by the DALI system. The building management system would be able to send commands to ballasts, change light levels throughout the system, define presets, and query information about ballast or lamp status/failure (Advance).

CHAPTER 5 - Limitations and Drawbacks

As with any new technology, DALI systems do have limitations with respect to the maximum amount of current on a loop, distance and voltage drop, the number of ballasts and groups on a loop, commissioning costs, ballast replacement issues, and energy consumption in off mode. This section will discuss these issues.

Limitations

Loop Current

One limitation on a DALI system is the current allowed to run through each loop. This limit is 250mA with a maximum consumption of 2mA per ballast connected to the loop. This means that the simplest system consisting of one ballast and one control unit can consume a maximum of 2mA. Exceeding the current limitation may result in a reduced signal reliability causing lack of communication or response between the DALI devices. Therefore, designers must keep track of how much power each device requires so that the current limitation is not exceeded (Technical).

Distance/Voltage Drop

As with any wiring project, the voltage drop on a run of wire must be considered as it may affect the performance of the equipment. The maximum voltage drop allowed for a DALI loop to keep a clear message all the way to the end of the loop is 2V. As a rule of thumb for typical wiring and installation, the maximum distance between any devices on the loop should not exceed 984 feet (300m) (Advance; Technical).

Number of Ballasts, Groups, and Presets on a DALI Loop

The maximum number of ballasts allowed on one DALI loop is 64. If the devices chosen draw more power than others, it is possible to have a maximum number of ballasts allowed be less than 64. It is important to check current limitations when ballast quantities are calculated. In most cases, however, 64 ballasts can be used. The maximum number of groups on one DALI

loop is 16. One ballast has the ability to belong to each of the 16 groups or as little as no groups. Up to 16 preset scenes can be stored within the control unit on a single DALI loop (Advance).

Drawbacks

Programming

A major issue when a DALI control system is chosen is the time required for programming the system. After the system is installed, ballasts are assigned addresses that are stored in a database with information such as physical locations and which control device operates them. The amount of time required for programming depends on the complexity of the system. It makes sense that a system contained to one small conference room would require much less time for programming than a large exhibition hall. The desired functions and number of presets are also a key factor deciding how much time programming will require. Also keep in mind that future changes in space layout may require re-programming the system. Ballasts may need to be assigned to different groups and presets may need to be re-defined. One way to reduce future costs is to train an in-house staff member during the programming process so that future changes can be made by the in-house staff (DALI Explained).

Ballast Replacement

As the system ages, ballasts may require replacement. In a DSI or 0-10V system, ballast replacement is relatively simple since the ballasts are not individually addressable. Because DALI ballasts are addressable and each has a unique address, replacing a ballast may be challenging. The replacement ballast must be set with the same address as the old ballast. Currently, DALI ballasts can only have their addresses defined and viewed with the use of special equipment. This requires that maintenance staff determine the address of the failed ballast and set the new ballast with the same address. Another option would be to use the default address already stored in the new ballast and program the new ballast to the groups and preset dimming levels of the old ballast (An Introduction).

Ballast Energy Consumption in Off Mode

Another drawback to a DALI system is that the control electronics within the ballasts continue to use energy even when the lamps are off. This is because there is no switch that

20

disconnects power to the devices. They simply receive a message from the control unit telling them to turn off. However, the power consumption is significantly reduced to about one watt per ballast during "off" times as compared to times when the lamps are on (An Introduction). Depending on the system size, one watt per ballast may be significant. One way to address this would be to control the power circuits with a contactor by having the contactor switched to the off position during times when lighting is not required (Koffler).

CHAPTER 6 - Cost Information

An important issue during the design phase of any space is cost. Often owners have specific budgets and must keep spending limits in mind when deciding on a system. The cost of a DALI system really depends on the complexity of the system desired. Systems consisting of only DALI ballasts and a control unit would naturally cost much less than those with DALI ballasts, multiple control units, routers, and occupancy sensors. To gain a more accurate estimate of how much a DALI system will cost, a designer should check with a manufacturer's representative. Having more accurate cost information would allow a designer to perform costbenefit analyses on various dimming control systems including DALI. Some argue that DALI systems cost less than dimming systems such as 0-10V systems and others say the two systems cost about the same in the end.

When cost-benefit analyses are performed one key issue is the time required for programming each system. Programming times also depend on the level of complexity desired. A DALI system installed in a conference room with only 20 light fixtures would require much less time for programming than a system installed in a large multi-purpose event space with 500 light fixtures.

According to the article "DALI Explained" published in *Buildings Magazine*, Stuart Berjansky from Advance Transformer claims, "if you take a traditional 0-10V system and a DALI system, the installed cost for both will be about the same. Your ballast is going to cost you more, but you'll save in labor because of the lack of lighting circuit requirements. You have less homeruns going back to your electric panels, you have less electric panels" (DALI Explained). Another article, "DALI Takes the Lighting Industry Back to School," discusses the DALI system installed in the lighting lab at Penn State University under the direction of Dr. Martin Moeck. At one point Moeck states, "I was surprised to find out the cost of a conventional 0-10V DC analog fluorescent dimming ballast system was \$45,500. The DALI system cost \$29,100 to install" (Knisley). This is an installation savings of about 35%. Keep in mind the amount of time required to program a DALI system depends on its complexity. If a staff member can be trained to program the system, that may be more cost effective than hiring a technician to do the programming.

CHAPTER 7 - Installing, Programming, and Using the System

This chapter covers basic information regarding how DALI systems are installed as far as wiring and programming are concerned. It also gives a basic idea about assigning addresses to the ballasts and assigning groups and presets.

Wiring/Communication

The wiring in a DALI lighting control system is rather simple. As mentioned previously, ballasts can be connected to any available unswitched power supply without the need to group fixtures in any way. All components in the system including, but not limited to, ballasts, sensors (occupancy and photocell), switches, and control units can be wired in any way as long as the distance requirements that are listed in Chapter 5: Limitations and Drawbacks are met. Sensors and switches can be connected directly to the control unit or to the wires running between the ballasts; see figures 7-1 (Advance) and 7-2 (Advance). There is no difference in performance for either configuration. As mentioned in Chapter 3, wiring can be installed in series, in a star configuration, or in a combination of the two (Advance). Figure 7-3, on the next page is a sample wiring diagram for a DALI system. Note that each manufacturer will have information specific to wiring and should be consulted in regards to this information, especially when products such as routers and Ethernet connections are used.

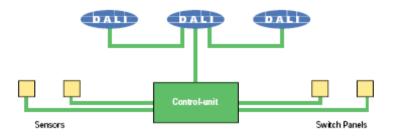


Figure 7-1 Low Voltage Wiring Diagram – Sensors Connected to the Control Unit

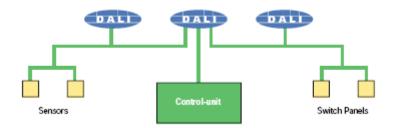


Figure 7-2 Low Voltage Wiring Diagram – Sensors Connected to the Ballast Loop

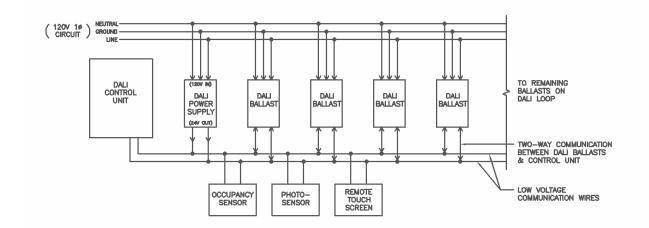


Figure 7-3 Sample System Wiring Diagram

The purpose of the low-voltage control wiring is to allow components in the system to communicate with one another. DALI uses **differential Manchester encoding** to communicate. A DALI message structure is made up of an address and a command. The address corresponds to one of the ballasts in the loop, and the command tells that particular ballast what to do. If a ballast is assigned to a group, it and the other ballasts defined in the group can receive group commands based on a group address stored within the ballast memory (DALI-Lighting). This allows one message to be sent to an entire group of fixtures rather than individual messages being sent to each individual ballast needing to perform a desired function. The method of sending out a group message can be more beneficial than sending out many individual messages because it can prevent what is known as the "Mexican Wave". The "Mexican Wave" occurs when a large number of ballasts receive individual messages, but not all at exactly the same time. It may become noticeable that a ballast on one end of the room received its message before a

ballast on the opposite side of the room when they didn't turn on simultaneously (An Introduction).

Assigning Addresses

The address stored in a DALI ballast can either be programmed before installation or afterwards. Programming addresses prior to installation ensures that each ballast will already have a unique method of identification. When an address is programmed after the installation of the system, the control device can register addresses assigned by the manufacturer into its database. If any addresses are found not to be unique, new addresses are assigned to the ballasts. Each ballast must have its own unique address so that messages from the control unit can be sent to the correct ballast.

Assigning Groups and Presets

This section explains how to use a DALI lighting control system for assigning groups, creating presets, and making changes. Specifics on programming may vary depending on manufacturer; therefore, the manufacturer or manufacturer's representative should be consulted for specifics regarding programming.

Each ballast can be assigned to any number of up to sixteen groups within its loop. The purpose of assigning groups is for ease of creating presets and sending out messages. As mentioned in the wiring/communication section of this chapter, it is more desirable to send out a group message than several messages to several different ballasts.

Once groups are defined, presets can be stored within the control unit. Presets can contain any number of DALI groups. For example, each group within a preset can be set to different dimming levels or fade rates, as desired. The purpose of assigning presets is to recall quickly a lighting scene as required by the event occurring in a space. With presets, a space such as a conference room can be changed quickly from a low light level required for media presentations to a higher light level required for a general meeting.

As the function of a space changes, because of a new tenant or different events for example, changing the system is simple. Groups and presets can be redefined in the same manner they were originally programmed.

Ballast Memory

Ballasts, like control units, have the capability of storing information within their memory. Ballasts store information such as light levels, if their power is on; system failure; fade time and rate; their addresses; and groups to which they are assigned. This function allows for two-way communication between the ballasts and control unit in which the ballasts can send messages back to the control unit or software (Advance).

CHAPTER 8 - Meeting Code/Recommended Practice Requirements

As a result of the nation's concern about energy resources, codes and recommended practice guidelines are requiring greater controllability of lighting in commercial applications. This section discusses how some code requirements and recommended practices can be achieved by utilizing a DALI lighting control system. This section covers topics from the International Energy Conservation Code - 2003 (IECC), ASHRAE/IESNA Standard 90.1-2004, California Title 24, and the Leadership in Energy and Environmental Design (LEED) Rating System. Note that this is not intended to be an all inclusive list of codes/recommended practices to which DALI is applicable. Also keep in mind the importance of checking with the local authority having jurisdiction when applicable codes are determined. This chapter is divided in sections based on various code/recommended practice. Within each section, a code reference will be given, followed by an explanation of how DALI can help meet the requirements. Also, note that this chapter assumes applications with a fluorescent lighting system.

IECC

805.2.2.1 Light Reduction Controls

Each area that is required to have a manual control shall also allow the occupant to reduce the connected lighting load in a reasonably uniform illumination pattern by at least 50 percent. Lighting reduction shall be achieved by one of the following or other approved method:

- 1. Controlling all lamps or luminaires;
- 2. Dual switching of alternate rows of luminaires, alternate luminaires or alternate lamps;
- 3. Switching the middle lamp luminaires independently of the outer lamps; or
- *4. Switching each luminaire or each lamp.*

A DALI lighting control system can be used to meet this requirement of the IECC with its capability of dimming fluorescent fixtures. If the building's lighting design contains lamp types other than fluorescent types, technology similar to DALI may still be used, but a DALI control system would work best for a building with a fluorescent design. A building-wide DALI system connected to a BMS or computer software can control all fixtures in the building from one location. If dual switching is desired, it can be set up by creating presets. Switching some lamps in a fixture while leaving others on would be possible if they are controlled by separate ballasts; however, since dimming is available, switching alternate lamps in fixtures would not be necessary.

805.2.2.2 Automatic Lighting Shutoff

Buildings larger than 5,000 square feet $(465m^2)$ shall be equipped with an automatic control device to shut off lighting in those areas. This automatic control device shall function on either.

- A scheduled basis, using time-of-day, with an independent program schedule that controls the interior lighting in areas that do not exceed 25,000 square feet (2323 m²) and are not more than one floor; or
- 2. An unscheduled basis by occupant intervention.

A DALI lighting control system has the capability of setting times for lights to turn on and off. Occupancy sensors can also be used as a method of turning off the lights when they are not needed.

ASHRAE/IESNA Standard 90.1

9.4.1.1 Automatic Lighting Shutoff

Interior lighting in buildings larger than 5000 ft² shall be controlled with an automatic control device to shut off building lighting in all spaces. This automatic control device shall function on either

a. a scheduled basis using a time-of-day operated control device that turns lighting off at specific programmed times—an independent program schedule shall be provided for areas of no more than 25,000 ft² but not more than one floor—or

- b. an occupant sensor that shall turn lighting off within 30 minutes of an occupant leaving a space—or
- *c. a signal from another control or alarm system that indicates the area is unoccupied.*

The requirements of this section, much like those in IECC section 805.2.2.2, can also be achieved with a DALI lighting control system.

9.4.1.2 Space Control

Each space enclosed by ceiling height partitions shall have at least one control device to independently control the general lighting within the space. Each manual device shall be readily accessible and located so the occupants can see the controlled lighting.

- a. A control device shall be installed that automatically turns lighting off within 30 minutes of all occupants leaving a space, except spaces with multi-scene control, in: 1. Classrooms (not including shop classrooms, laboratory classrooms, and preschool through 12th grade classrooms), 2.
 Conference/meeting rooms, 3. Employee lunch and break rooms. These spaces are not required to be connected to other automatic lighting shutoff controls.
- b. For all other spaces, each control device shall be activated either manually by an occupant or automatically by sensing an occupant. Each control device shall control a maximum of 2500 ft² area for a space 10,000 ft² or less and a maximum of 10,000 ft² area for a space greater than 10,000 ft² and be capable of overriding any time-of-day scheduled shutoff control for no more than four hours.

This space control requirement is feasible with a DALI system. Even if an entire building is controlled by one single DALI system, smaller wall control units can be placed throughout the building for occupant control of individual spaces. The control units in combination with occupancy sensors can be set to turn off lights within 30 minutes of occupants leaving a space.

California Title 24

Section 131 (b) Multi-Level Lighting Controls

The general lighting of any enclosed space 100 square feet or larger in which the connected lighting load exceeds 0.8 watts per square foot, and that has more than one light source (luminaire), shall have multi-level lighting controls. A multi-level lighting control is a lighting control that reduces lighting power by either continuous dimming, stepped dimming, or stepped switching while maintaining a reasonably uniform level of illuminance throughout the area controlled. Multi-level controls shall have at least one control step that is between 50% and 70% of design lighting power and at least one step of minimum light output operating at less than 35% of full rated lighting system power.

DALI's dimming capability will meet this requirement. Presets can be assigned in which light levels can be changed instantly to accommodate the need to save energy in cases such as a brownout or just to help minimize peak loads.

Section 131 (c)(1) Daylit Areas

Daylit areas greater than 250 square feet in any enclosed space shall have at least one lighting control that:

а.	Controls at least 50% of the power in the daylit areas separately from other
	lighting in the enclosed space; and
b.	Controls luminaires in vertically daylit areas separately from horizontally
	daylit areas.
с.	Maintains a reasonably uniform level of illuminance in the daylit area using

DALI's daylighting capabilities would be especially useful in this case. Uniform light levels could be maintained by dimming each fixture the amount required in each specific location. The only reason ambient design levels would not be maintained would be if the daylight contribution was greater than the design light level. The daylighting capability can be overridden, if necessary, in cases where reducing energy use is a greater priority.

one of the methods specified in section 131 (b) items 1 or 2.

Section 131 (d) Shut-off Controls

For every floor, all indoor lighting systems shall be equipped with a separate automatic control to shut off the lighting. This automatic control shall meet the requirements of Section 119 and may be an occupant sensor, automatic time switch, or other device capable of automatically shutting off the lighting.

A DALI lighting control system can use occupant sensors, timed on/off settings, and manual switching to achieve the requirements for shut-off controls.

LEED

Energy & Atmosphere Credit 1: Optimize Energy Performance

The intent of this credit is "to achieve increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use." To obtain this credit a design must demonstrate a percentage of improvement in building energy performance compared to a baseline of ASHRAE/IESNA Standard 90.1-2004. Energy can be saved by utilizing a DALI lighting control system. Energy can be saved by utilizing DALI's daylighting capabilities. See Chapter 9 – Daylighting Case Study for an example of how this can be done.

Indoor Environmental Quality Credit 6.1: Controllability of Systems: Lighting

This credit is intended to "provide a high level of lighting system control by individual occupants or by specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort, and well-being of building occupants." To obtain the credit, a design must provide individual lighting controls for a minimum of 90% of the building's occupants and controllability for all shared multi-occupant spaces that allow adjustments to meet the needs and preferences of the group.

A DALI lighting control system would be one way to achieve this credit. While it may be easiest to provide individuals with task lighting to fulfill the individual lighting control portion of the credit, DALI can also be used. To provide individual control with a DALI system, there would either need to be individual control units controlling the fixtures in each occupant's space or there could potentially be groups created for occupants' light fixtures in which they

could specify their own desired dimming levels/ambient light levels from a more central location. The other half of the credit, controllability of multi-occupant spaces in areas such as a conference room, can be met with a DALI control unit in the specific room being controlled. Occupants would have the option of setting any desired groups and presets to meet their needs.

CHAPTER 9 - Daylighting Case Study

The following case study was performed to show how a DALI lighting control system can save money in energy costs by utilizing daylight sensing in combination with DALI's dimming capabilities. The study was performed using Lighting Analyst's **AGI-32** software.

About the Space

The space chosen for this study is one floor of a multi-story office building located in Littleton, Colorado. The space measures about 23,000 square feet. The space consists primarily of open office space with a core consisting of conference rooms, elevators, restrooms, and mechanical rooms. The core of the building is not included in this daylight case study since that the area does not see significant levels of daylight. The exterior surface consists primarily of floor-to-ceiling diffuse glass windows. For exact locations see the floor plan in Appendix A. Since the building is not neighbored too closely to any other tall buildings, a significant amount of sunlight reaches the working plane throughout the day making it perfect for considering the use of daylight and dimming light fixtures to save money. A DALI lighting control system was chosen to do just that.

AGI-32 Software Calculation

The following sections explain the models that were created to perform the daylighting study. One model was used to calculate the amount of daylight that reaches the workplane at various times of day on various days of the year. Another model was created that does not allow daylight to enter the space, but rather determines the required number of artificial light fixtures to achieve the desired average ambient light level of 50fc on the workplane to simulate times of the day when no daylight is present. AGI-32, created by Lighting Analysts Inc. was chosen for this case study because of its ability to perform daylight studies. The daylighting study function can calculate the footcandle level at any desired point at any specified geographical location based on latitude and longitude. Once the footcandle levels were determined by the program, it was possible to calculate manually what dimming levels were required by each light fixture. This

information was used to calculate energy savings compared to a baseline model where all lamps are on 100% during business hours.

Creating the Daylighting Model

The first step of performing the AGI-32 calculation was to build a model that would best match the actual conditions of the space. Since information on reflectances and construction materials were unknown, assumptions were made based on engineering judgment. For example, the average footcandle level was based on IES recommendations and reflectances were chosen based on prior experiences in class and industry. A floor plan of the office was imported from an AutoCAD file as a template for constructing the walls, columns, and cubicles. The outer footprint of the building was constructed as a room with default reflectances of 80/50/20 for ceiling, walls, and floor respectively. Interior walls were constructed as rooms within the outer footprint with similar reflectances. Round floor-to-ceiling columns with a 50% reflectance were constructed since they would play into how much daylight and lamp light would reach the work plane. Cubicle walls were constructed at heights of 5'-0" with a 20% reflectance. The floor-toceiling windows were created by modifying the wall type to that of a daylight transition diffuse glass window (surface number 21) with a transparency of 19%. See Appendix F for screen shots of values inputted into AGI-32. The fixtures were not placed in this model since they were not needed for the daylight calculations. Calculation points were placed at the level of the work plane (2'-6" A.F.F.).

Creating the Artificial Daylighting Model

Another model was created for the purpose of determining the number of light fixtures required to provide an average ambient light level of 50fc when no daylight is present. This model was constructed in the same way as the daylighting model, only the daylighting capabilities were disabled. Light fixtures were placed in this model using IES files found on the manufacturer's website.

The light fixtures were suspended indirect/direct fixtures mounted at 9'-0" above finished floor with a ceiling height of 11'-0". The fixture was Finelite's Series 14 (see Appendix B for fixture cut sheet). The low profile fixture measured 8" wide by 4' long with a thickness of 2". Two T8 lamps, a white cross blade, and standard anodized aluminum reflectors were chosen.

The fixtures were mounted in a linear pattern end to end at approximately 12'-0" on center between rows. This arrangement provided an average footcandle level of 50 FC on the work plane (2'-6" above finished floor), assuming no daylight was present. Each fixture was equipped with a two-lamp DALI ballast. The ballasts were all connected to a 120V power supply. As mentioned previously, the arrangement of circuits is irrelevant when a DALI control system is used. The ballasts also had two low voltage control wires running to them allowing communication between the ballasts and the DALI control unit. Since there were more than 64 ballasts in this space and control of the space as a whole was desired, routers were used to connect DALI loops. Refer to Chapter 5 for ballast quantity limitations.

Running the Daylighting Model

The next step in AGI-32 was to set up and run a daylight study. Using the Daylight Study Wizard, the following parameters were set. The site location was set as Littleton, Colorado with a latitude of 39.617 degrees North and a longitude of 105.017 degrees West. Sky conditions were set as clear sky. Dates and times were chosen to provide the best data to approximate year-round savings. The dates January 1st, April 1st, July 1st, and October 1st were chosen because they have approximately the same number of days between them. To obtain a good average, it was important to pick dates and times with equal spacing between them. The study was set to calculate light levels at 7:00 am, 10:00 am, 1:00 pm, 4:00 pm, and 7:00 pm on each date chosen. These times were selected because they fell during typical office hours of 7:00 am to 7:00 pm and had the possibility of daylight. January 1st at 7:00 am and 7:00 pm, April 1st at 7:00 pm, and October 1st at 7:00 pm were not calculated in this part of the study since no daylight was present at these times. They were, however, factored into the total average of the study as times when 100% artificial light was required. After setting parameters, the daylight study was set to calculate. AGI-32 calculated footcandle levels for each calculation point for each date and time specified based on the given parameters, reflectances, and construction. Due to the level of detail within the program, each calculation took approximately 45 minutes to complete.

Results of the Daylight Study

The results of the daylight study were then analyzed. Depending on how much daylight could reach a particular area of the work plane, some fixtures could be dimmed. Each fixture

was highlighted on the plan according to the level it could be dimmed. Table 9-1 shows how dimming levels were assigned and the corresponding highlighted color. Appendix D contains these data sheets showing highlighted colors corresponding to dimming levels. A table showing the number of fixtures at each dimming level for each time analyzed can be found in Appendix E. These quantities were then used to calculate energy usage as described in the next section.

Light Level from Daylight (FC)	% Lamps Could be Dimmed to	Light Level from Lamps (FC)	Total Light on the Work Plane	Highlighted Color
≥ 40	0	0	40 +	blue
30-40	25	12	42-52	green
20-30	50	25	45-55	pink
20-Oct	75	37	47-57	orange
≤ 10	100	50	50-60	yellow

Table 9-1 Case Study Dimming Levels

Calculations

The quantities from the daylight study were used to calculate the amount of energy consumed at each time on each date chosen for the study. All calculations can be found in Appendix E. The average cost per day utilizing the daylight harvesting capabilities of a DALI system came to \$3.27 and a yearly cost of \$1,192. For comparison, a baseline calculation was performed in which lights were assumed to be at 100% output for the entire workday (7:00am to 7:00pm). The yearly cost of energy for this scenario came to \$2,257. This resulted in a savings of \$1,065 for using the daylight harvesting capabilities of a DALI system, compared to not using daylight harvesting. This is a 47% savings.

Keep in mind that several variables in this case study could be different from any other space. The location of the building could have a huge impact on energy savings because of the building's orientation, sunlight availability, and typical sky conditions in the area. Another issue to keep in mind is the difference in energy costs relative to different parts of the country. For example, energy in California costs more than energy in Colorado.

Case Study Conclusion

This case study showed how energy can be saved by utilizing a DALI system's daylight harvesting capabilities. Similar techniques can be used to estimate an energy cost savings for

any project and may be beneficial when a cost-benefit analysis like the one mentioned in Chapter 6 is performed.

CHAPTER 10 - Conclusion

In conclusion, DALI lighting control systems have many advantages as well as some disadvantages. A designer should carefully evaluate a project as far as what the owner is looking to obtain from the lighting control system, the budget for the project, and the required functions of the space before considering designing a DALI system. Such spaces as a multi-use convention center or a conference/presentation room may be a good candidates for a DALI system since they often require a wide variety of light levels and lighting atmospheres. As shown for one application with a high level of daylight available, a DALI lighting control system has the potential to save money in energy costs by utilizing daylight harvesting. For some owners, the added flexibility of a DALI system may outweigh added costs of the system over a non-dimming system. For example, a convention hall may be able to book more events if clients know they will be able to get the type of light levels they desire for their function. A nondimming system only allows for a limited number of options such as turning off every other fixture, which depends on how the system was wired. A 0-10V system can offer dimming options, but fixture grouping also depends on circuiting arrangements. A DALI system can provide the flexibility to control the lighting for any occasion provided fixtures have been designed and installed to accommodate the range of desired results

References

<<u>www.iec.ch</u>>.

2003 International Energy Conservation Code., 2003.

Advance Transformer Co. "The ABC's of DALI." 2003.

ANSI/ASHRAE/IESNA Standard 90.1-2004., 2004.

"DALI - Lighting with Intelligence." <<u>www.dali-ag.org/b_mzlz0.htm</u>>.

"DALI Explained." Buildings Magazine: March 2007.

<<u>www.buildings.com/functions/print_article.aspx?contentID=1463</u>>.

"DALI Technic." <<u>www.osram.com</u>>.

"DaliPro Digital Dimming Technical Product Information." 2006. <<u>www.unvlt.com</u>>.

"Data Encoding Techniques." <<u>www.rhyshaden.com/encoding.htm</u>>.

DiLouis, Craig. "Emerging Trends in Building Lighting Control Systems." <u>Electrical Construction &</u> <u>Maintenance</u>: January 2007. .

----. "States Incorporate Energy Standard in Lighting Design Requirements." <u>Electrical Construction &</u> <u>Maintenance</u>: January 2007. .

"EMAIL INTERVIEW Stuart Berjansky & Ken Sinclair." September 2002 <<u>www.automatedbuildings.com/news/sep02/interviews/dali.htm</u>>.

- Hayes, Stephen. "Make Your Emergency Lighting Burden Less Testing." <u>Electrical Engineering</u> (2006): 32-3.
- Hein, P. F. "DALI A Digital Addressable Lighting Interface for Lighting Electronics." <u>Industry</u> <u>Applications Conference, 2001. Thirty-Sixth IAS Annual Meeting. Conference Record of the 2001</u> IEEE 2: 901.

"An Introduction to DALI." <<u>www.dynalite-online.com/content/dali.htm</u>>.

Knisley, Joe. "DALI Takes the Lighting Industry Back to School." <u>Electrical Construction &</u> <u>Maintenance</u>: January 2007. .

Koffler, John. Personal Interview. October 1, 2007.

Kohnen, Dan. E-mail. September 17, 2007.

"LIF Technical Statement No. 31." <<u>www.lif.co.uk</u>>.

"Lighting Controls." <<u>www.luxonic.co.uk/pdfFiles/pdfFile87.pdf</u>>.

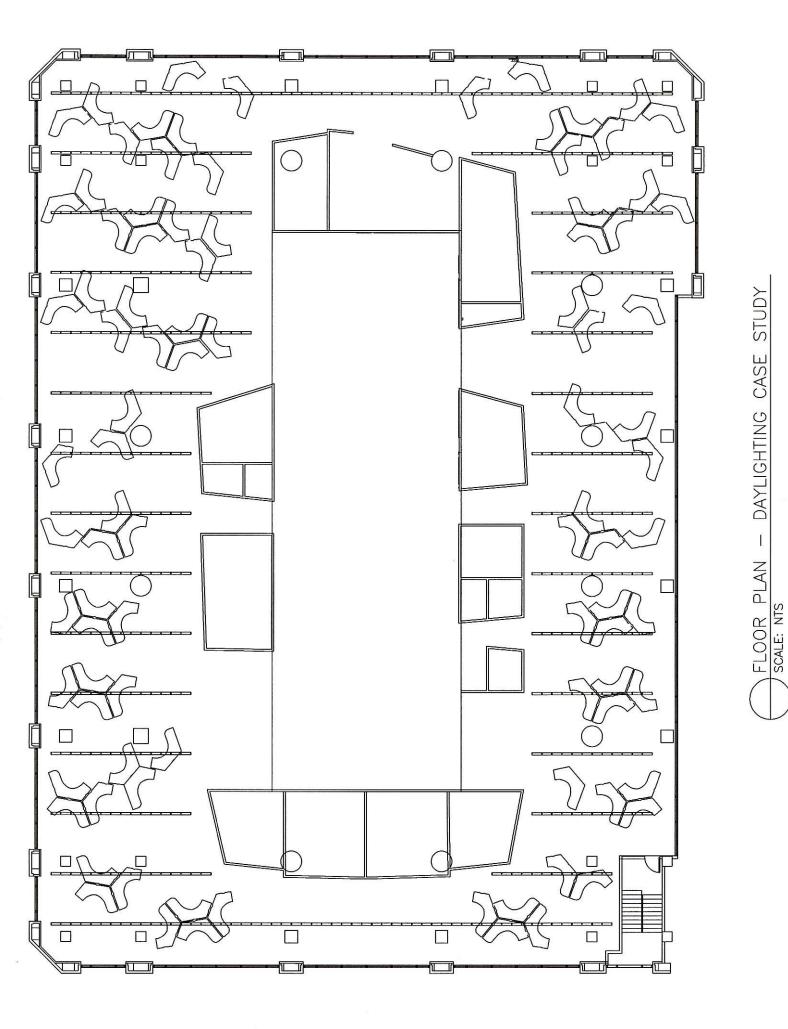
Ribarich, Thomas J., and Cecilia Contenti. "Analog and Digital Fluorescent Lighting Dimming Systems." <u>International Rectifier</u>.

"System Description." May 1, 2003 2003. <<u>www.dali-ag.org</u>>.

"A Universal Advance in Digital Lighting." <u>The Electrical Review</u> 238.2 (2005): 14-6.

"What is AGI32?" <<u>http://www.agi32.com/Products/AGI32/agi32.htm</u>>.

Zhang, Yuejun, Ping Zhou, and Mingguang Wu. "Research on DALI and Development of Master-Slave Module." <u>Networking, Sensing and Control, 2006. ICNSC '06. Proceedings of the 2006 IEEE</u> <u>International Conference</u>. Appendix A - Case Study Floor Plan

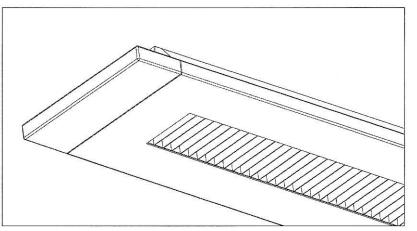


Appendix B - Case Study Light Fixture Cut Sheet

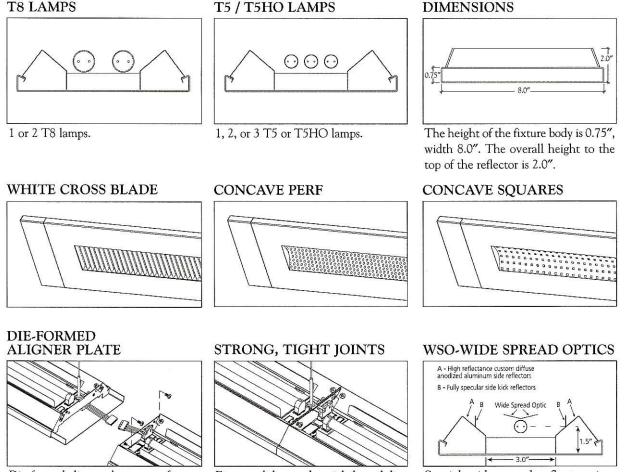
FINELITE

Finelite Series 14 brings new definition to pendant luminaires with a stunning ultra sleek profile. Available in 1 or 2 T8, or 1, 2 or 3 lamp T5 or T5HO cross sections, Series 14 comes in 4' and 8' lengths.

Clean, contemporary, standard signal white finish compliments the modern design and brings new elegance to today's contemporary architecture.



The ultra thin profile of Series 14 adds design and style to any application.

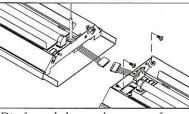


Special wide spread reflector gives extended distribution and is especially effective in low ceiling areas.

Finelite, Inc. 30500 Whipple Road Union City, CA 94587-1530 510 / 441-1100 FAX: 510 / 441-1510 www.finelite.com

@ 2006 FINELITE, INC. ALL RIGHTS RESERVED · Form CTK0022 . 05/06

T8 LAMPS

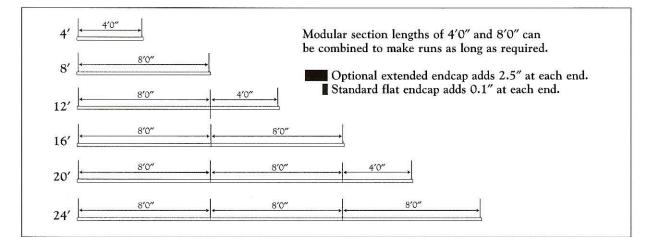


Die-formed aligner plate comes factory installed for smooth joints. Plugtogether wiring ensures electrical connections are right every time.

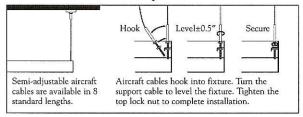
Fixtures slide together tightly and dieformed internal aligner plate ensures strong joints with no light leaks.

FINELITE

Series 14 - Technical Sheet



STANDARD SEMI-ADJUSTABLE SUPPORT



SPECIFICATIONS

CONSTRUCTION: 18 gauge die-formed steel body. All components hard tooled to tolerances of 0.005".

DOWNLIGHT SHIELDING OPTIONS: WCB White cross blade baffles.

- CS Concave shield, square perforations.
- CP Concave shield, round perforations.

ENDCAPS: (FE) Flat Endcap standard *add* 0.1" *at each end*. Optional: (EE) Extended Endcap, aluminum die-cast endcap, adds 2.5"at each end. No exposed fasteners, holes or knockouts.

REFLECTORS: (AA) Standard—Anodized Aluminum diffuse high reflectance reflectors. Optional: (EP) Fully specular side reflectors, (WSO) Wide spread optic system for 1 T5HO. NOTE: EP and WSO reflectors NOT AVAIL-ABLE with emergency battery packs, 347 volt, or dimming ballasts. Consult factory. ELECTRICAL: 120 or 277 volt prewired. Fixture and electrical components UL/C-UL listed and fixture will bear UL/ C-UL labels. Optional Adders: 347 volt prewired, dual circuit, emergency circuits, emergency battery packs.

LAMPING: 1 or 2 T8 or 1, 2 or 3 lamp T5 or T5HO cross sections. 1 T8 lamp is on angle. UV stabilized lamp diffuser standard for T5HO lamps - 0.100 acrylic. Also available without diffuser (open).

BALLAST: Electronic low profile instant start ballasts <20%THD standard. Optional Adders: Rapid Start, Dimming ballasts (controls by others). Emergency battery packs, 347 volt, and dimming ballasts require special reflector. Consult factory.

the state of the

OPTIONAL ADJUSTABLE SUPPORT

Fully adjustable aircraft cable simplifies installations on variable ceiling heights. Cable length can vary from 6" to 150".

Depress the head of the fitting to allow continuous adjustment of the cable length.

MOUNTING OPTIONS: Semi-adjustable aircraft cable, $(AC) \pm 0.5''$ in lengths of 12", 15", 18", 21", 24", 27", 30", 36". Order length, e.g. AC 18". Optional Adders: Fully adjustable aircraft cable (FA) in lengths up to 150".

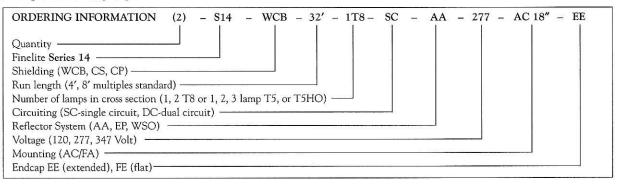
SUPPORT CABLES: Stainless steel with plated hardware.

FEED: 18 gauge straight cord. 14 gauge feed cord used when fixture current exceeds 6 amps. Optional Adders: Coil Cord Feed.

FINISHES: Finelite signal white standard. 185 colors available from Tiger Drylac's RAL color chart for a nominal adder.

LENGTHS: 4' and 8' section lengths can be combined to make longer runs.

WEIGHT: Fixture weight = 2.0 lb/ft.



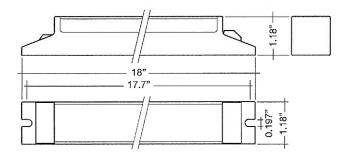
Finelite, Inc. 30500 Whipple Road Union City, CA 94587-1530 510 / 441-1100 FAX: 510 / 441-1510 www.finelite.com

Appendix C - Case Study Ballast Cut Sheet



Electronic digital ballast for dimming 100% to 1% Fluorescent lamps T8

PCA EXCEL one4all models for 32 W 120-277 V 50/60 Hz, digital dimmable



Features

- Continuous, flicker free dimming from 1 % – 100 %
- Digital bi-directional communication
- Disturbance free precise control with a digital signal (DSI), switchDIM or DALI
 - DALI Digital Addressable Lighting Interface
 64 addresses, 16 groups, 16 light scenes, adjustable fading time
 - DSI Digital Serial Interface
- Return status feedback signal and programmable parameter in DALI and DSI mode
- · Polarity free control wiring
- Conventional wire type can be used for control wiring
- Control wiring can be run in same conduits as power wires
- Universal voltage input (UVI) 120–277V
- Slim profile design 1.18" H x 1.18" W

Models for 1- and 2-lamp application

78

- Quick connectors for wire size
 16 18 AWG
- End-of-lamp-life protection and inrush current limiting circuitry
- Microcontroller and ASIC (Application Specific Integrated Circuit) technology for optimum dimming performance
- 3 years warranty
- Standby mode

	Ballast	Lamp I	Lamp Information			allast Operating Performance							
Order #	Description	No. of Lamps	Lamp Type (Linear only)	Watts (W)	Voltage max. Line Current 50/60Hz (A) rms				Ballast Factor	tc Point *	min. Start Temperature	min. Dimm Temperature	
					(V)	120V	277 V	120V	277V	1	(F / °C)	(F / °C)	(F / °C)
24033592	PCA 1/32 T8 EXCEL one4all	1	T8 32W / 48"	32	120-277	0.31 A	0.13 A	37 W	36 W	1	158/70	0/-18	50/10
24033603	PCA 2/32 T8 EXCEL one4all	2	T8 32W / 48"	32	120-277	0.61 A	0.26 A	73 W	70 W	1	167 / 75	0/-18	50/10
												* temperature	calibration point

Applications

PCA EXCEL one4all digital dimming ballasts are ideal for executive space applications that require programmable architectural-grade dimming performance or building-wide load control applications that require monitoring and real-time control of lighting loads.

The low profile 1.18" x 1.18" cross section makes these ballasts ideal for architectural fixtures or any application that requires a limited cross sectional area.

Executive Space Applications

- Offices
- Board Rooms
- Conference Rooms
- Training Rooms

Building-Wide Applications

- Open Office Areas
- Private Offices
- Meeting Rooms
- Public Spaces
- · Classrooms
- Warehouses

Data sheet 01/04-26-9 We reserve the right to make technical changes without prior notice.

TRIDONIC.ATCO

Description

Tridonic's PCA EXCEL one4all T8 digital control dimming ballast sets a new standard for electronic fluorescent dimming. Combining digitalDIM control technology with true 100 % - 1 % continuous dimming, the PCA EXCEL one4all ballast provides a new level of system performance and flexibility that easily changes to meet present and future lighting needs. Designed with a ballast factor of 1.0, PCA EXCEL one4all ballasts provide full rated lumen output to achieve

maximum lamp performance and dimming range capabilities. Digital control enables true two-way ballast/control communication that is immune to noise and power disturbances. Control wiring is polarity free and can be run in the same conduits as the power wires. The PCA EXCEL one4all universal voltage input capabilities provide added on-site installation flexibility by eliminating the need for multiple single voltage ballast types and also eliminates order errors.

Standards

PCA EXCEL one4all complies with

- UL Listed #935
- Suitable for Class I or Class II (control) installations
- Meets ANSI C82.11 Ballast Standard
- Meets FCC 47CFR Part 18 EMI/RFI emission requirements for Class A (non-consumer) equipment
- Meets ANSI C62.41 Category A surge protection standards
- · Manufactured in ISO 9001 and 9002-certified facility
- CELMA Energy Classification EEI = A1

Dimming

Dimming range 1 % to 100 % Eye sensitivity optimized dimming curve. Digital control with:

- DSI signal: 8 bit Code Max. fading time 1 % to 100 % 1.4 s Status feedback
- · DALI signal: 16 bit Code Max. fading time 1 % to 100 % 0.5 s Individually addressable Programmable parameters:
 - minimum dimming level
 - maximum dimming level
 - individual ballast status feedback
 - 64 addresses
 - 16 groups
 - 16 scenes
 - fading time etc.

Recommendation

Lamp burn in of 100 hrs. is recommended before dimming!

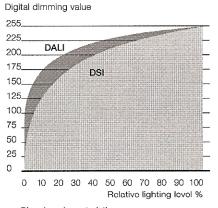
Performance

Dimming Range	1 % - 100 %
Ballast Factor	1.0
Power Factor	> 0.98
THD	< 10%
3rd Harmonic	< 8%
Inrush Current Peak	< 7 Amps
Lamp Operating Frequency	> 40 kHz
Lamp Current Crest Factor	< 1.7
EMI / RFI	FCC Part 18
Max. Housing Temperature	167°F/75°C
Max. Output Voltage	< 600 rms
Power consumption in	
sleep mode	< 1 W (120 V)
	< 2 W (277 V)

Temperature range

Dimming range 1 % to 100 % from 50 °F / 10 °C to maximum permissible ambient temperature.

Dimming characteristics PCA EXCEL



Dimming characteristics as seen by the human eye

Control input (DA/purple)

Digital signal can be wired on the ballast terminals DA/purple. These connections are used to use the ballast in DSI or in DALI control mode.



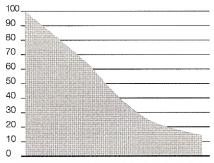
The control input is polarity free and protected against accidental connection with mains voltage. Control wires should be installed in accordance to the national and local electrical codes. Control functions differ depending on capabilities of connected control module.

Lamp starting characteristics

Programmed rapid start Starting time 1.0 s Start at any dimming level, without initial flash to higher level.

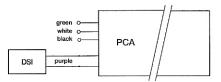
Energy Savings PCA EXCEL

Mains power in %

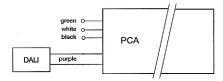


100 90 80 70 60 50 40 30 20 15 10 5 4 3 2 1 Dimming level in %









DALI PCA EXCEL one4all

AC operation

Mains voltage 120-277 V 50/60 Hz



SHEET	DATE	TIME
N/A	JANUARY 1	7:00 AM
S1	JANUARY 1	10:00 AM
S2	JANUARY 1	1:00 PM
S3	JANUARY 1	4:00 PM
N/A	JANUARY 1	7:00 PM
S4	APRIL 1	7:00 AM
S5	APRIL 1	10:00 AM
S6	APRIL 1	1:00 PM
S7	APRIL 1	4:00 PM
N/A	APRIL 1	7:00 PM
S8	JULY 1	7:00 AM
S9	JULY 1	10:00 AM
S10	JULY 1	1:00 PM
S11	JULY 1	4:00 PM
S12	JULY 1	7:00 PM
S13	OCTOBER 1	7:00 AM
S14	OCTOBER 1	10:00 AM
S15	OCTOBER 1	1:00 PM
S16	OCTOBER 1	4:00 PM
N/A	OCTOBER 1	7:00 PM

Appendix D - Case Study Daylighting Study Results

But Aus 55.3 Br.d. Br.2 4.4.3 55.3 Br.d. Br.2 4.4.3 96.5 V.3.8 B9.6 Ta.3 V.3.1 51.4 56.0 V.3.2 4.4.3 96.5 Pa.3 B.1.1 51.4 56.0 V.3.2 4.4.3 76.0 165 5.4.7 Pa.3 B.1.4 56.0 V.3.2 4.5.4 36.1 110 165 5.4.7 Pa.3 12.0 Pa.5 Sa.2 4.0.9 Sz.6 110 192 5.48 Pa.3 12.0 Pa.5 Sa.2 24.0.4 Sr.1 102 192 Pa.4 17.3 Pa.6 V.3.3 102 192 192 Pa.3 16.6 Y.3.3 10.9 Y.3.5 192 Pa.3 16.6 Y.3.3 10.9 Y.3.5 10.9 Pa.4 17.9 20.0 9.1 1.4.1 1.5.3 1.4.1 Pa.5 18.6 Y.3.3 10.9 4.65 2.4.6 Pa.5 18.5 7.3.3 10.9 9.65 2.4.6 Pa.5 18.5 7.3.3 10.9 9.65 2.4.6 Pa.5 19.2 <	104 139 202 330 144 147 27 247 144 147 27 241 144 147 247 245 144 247 245 144 247 245 145 247 245 145 247 245 145 247 345 145 247 355 146 249 245 146 249 255 146 249 249 255 146 249 249 255 146 249 249 249 255 146 249 249 249 249 249 249 249 249 249 249	112 144 148 148 148 148 148 148 148 148 148
1 5.0 5.1 <th5.1< th=""> <th5.1< th=""> <th5.1< th=""></th5.1<></th5.1<></th5.1<>		21.0 22.8 23.7 241 27.0 31.1 31.5 249 36.5 32.1 47.8 57.9 52.9 44.3 32.0 43.4 43.5 32.0 36.5 37.1 46.5 52.9 57.7 59.3 30.2 44.0 40.5 50.0 26.9 719 145 132 50.3 12.1 33.0 29.9 58.5 50.5 26.1 175 0.5 132 50.3 12.1 35.0 20.9 10.5 10.5 27.1 36.6 10.9 10.1 17.5 0.2 0.6 11.7 74.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.7 74.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.9 10.1 17.5 0.2 0.6 11.5 10.5 25.5 21.1 36.6 10.0 10.5 10.5 10.5 10.5 10.5 10.5 10.5
Nov Tase And Avr.1 Apo Mood Sada Avr.1 Apo Mood Sada S		17.1 17.1 17.1 17.1 17.1 17.1 17.1 17.1 17.1 17.1 23.3 24.9 18.2 15.1.3 49.6 26.5 25.5 19.2 51.3 49.6 76.5 15.5 19.4 10.2 10.5 25.7 47.3 15.1 19.5 10.4 26.3 35.5 35.1 16.2 17.3 10.5 35.5 11.1 160 150 71.6 17.3 10.5 35.6 12.5 35.7 11.6 89.4 17.3 10.5 20.4 260 261 150 17.6 17.3 10.5 20.5 260 261 14.0 150 10.6 20.2 25.9 200 261 43.0 43.0 10.7 16.2 25.4 150 260 261 43.0 43.4
57.5 45.6 11.8 42.2 47.7 31.4 35.2 35.1 95.6 85.0 35.8 14.2 26.4 32.0 28.3 19.0 28.4 39.8 70.0 39.4 21.9 11.0 7.7 21.6 21.0 20.0 39.4 34.4 21.9 11.0 7.7 21.6 21.0 20.8 39.7 39.8 70.0 21.9 11.0 7.7 21.6 21.0 20.8 39.1 49.1 34.4 31.5 13.4 70.3 33.5 18.1 16.6 3.1 40.0 31.1 16.6 3.1 14.1 19.2 3.4 70.0 35.5 36.7 31.1 16.6 3.3 14.1 19.2 3.4 70.0 35.2 36.7 31.1 16.6 3.3 3.4 3.5 3.5 3.7 3.6 35.2 31.1 11.1 10.5 3.4 3.5 3.5 3.7 3.6 36.2 31.1 15.5 3.5 3.5 3.5 3.7 3.6 37.2 31.1 15.5 3.5 3.5 3.5 3.6 4.5 <		20.1 21.3 21.7 19.3 28.1 28.4 29.2 27.3 28.1 28.4 29.2 27.3 33.0 56.2 36.5 39.4 59.7 59.1 55.8 30.0 56.2 36.5 39.4 59.3 59.1 59.1 10 44.5 30.0 39.7 59.4 59.4 59.8 59.1 49.3 11 55.8 30.6 59.4 59.4 59.8 59.8 59.1 49.3 11 55.8 30.6 59.4 59.8 59.8 39.1 49.3 11 55.9 39.6 59.4 59.8 59.8 49.3 59.3 11 55.4 55.7 25.7 25.7 25.7 25.7 25.7 12 59.3 59.8 10.5 10.5 25.2 25.7 25.7 13 12.7 55.7 25.7 25.7 25.7 25.7 25.7 13 25.4 55.7 57.7 57.7 57.4 57.
18.8 31.4 36.0 41.3 43.0 57.5 32.3 38.7 38.7 38.4 36.0 41.3 43.0 57.5 81.9 38.1 38.7 38.2 31.4 36.0 41.3 43.0 57.5 81.9 38.1 38.2 38.2 38.1 12.3 56.9 55.7 56.8 13.5 56.4 15.5 55.8 28.1 38.2 38.3 13.5 14.1 12.4 11.1 71.6 91.9 35.3 96.4 14.1 12.4 11.1 71.6 91.9 35.3 96.4 14.1 12.4 11.1 71.6 91.3 91.3 91.3 91.3 91.3 75.8 28.0 91.5 31.3 13.3 11.6 74.6 34.5 29.0 31.3 13.2 14.1 70.0 34.5 29.0 31.3 12.2 14.1 70.0 34.5 30.5 31.3 13.2 31.3 70.0 34.5 30.5 31.3 13.2 31.3 70.0 34.5 30.5 31.3 13.2 31.3 70.0 34.5 2	bit 361 365 267 20.0 36.9 26.0 26.7 21.6 26.7 21.6 96.7 24.4 26.7 21.6 76.1 54.5 36.0 22.1 76.1 54.6 36.0 22.1 76.1 54.6 36.0 22.1 76.1 54.6 36.2 22.4 76.1 54.6 32.2 22.4 76.1 54.6 32.7 32.9 96.6 30.6 32.7 32.9 57.8 30.6 32.3 46.8	1 1 <th1< th=""> <th1< th=""> <th1< th=""> <th1< th=""></th1<></th1<></th1<></th1<>

- DAYLIGHTING CASE STUDY SCALE: NTS

JANUARY 1, 10:00 AM

Lin bas	N: Dia Dia <thdia< th=""> Dia <thdia< th=""> <thdia< th=""> <thdia< th=""></thdia<></thdia<></thdia<></thdia<>	21.4 22.5 22.2 19.2	22.8 29.8 41.7 57.6 26.9 51.8 025 51. 25.8 55.2 52.2 52.0 36.7 90.3 90.9	29.1 *2.1 83.2 *3.5 20.3 *2.3 13.2 *3.2 20.7 *0.2 80.5 *0.8 26.0 *52 82.8 *2.0 *2.7 0.5 53 *5.4	25.6 20.6 40.2 51.9 36.3 39.6 53.9 46.0 82.1 55.6 46.2 85.0	25.4 40.5 01.2 70.4 10.2 25.8 51.2 70.4 10.8 22 35.0 20.1 70.9 75.7 25.1 12.5 75.0 103 75.7 25.1 12.6 75.5 26.1 1.3 3 29.6 75.7 149 96.1 59.6 75.7 149 96.1
7 bet hos bat 412	41.6 43.4 50.9 5.7 29.3 27.4 26.4 27.9 84.2 96.3 9.5 25.2 76.5 76.3 84.2 9.6 9.6 9.6 75.7 3.6 9.2 7.2.5 9.1 8.4 5.7 3.6 9.2 7.2.5 9.2 12.7 5.7 3.6 5.0 5.0 5.1 5.4 5.7 3.6 5.0 5.0 5.1 5.4 5.7 5.6 5.0 5.1 5.4 5.4	4.3 b.5 b.3 b.1 f5.1 3 3.8 b.5 4.2 3.1 f5.6 3 3.8 b.5 4.2 3.1 f5.6 3 3.7 b.0 7.7 10.8 f5.6 3 3.7 5.0 7.7 10.8 f5.8 3 3.7 5.9 b.3 70.8 f5.8	0			420 355 044 374 303 128 541 354 551 747 505 513 729 554 551 741 705 515 566 785 113 137 148 145 250 254 573 146 157 193 218 434 597 550 259 257 b62 b65 560 512 468 112
730 B5.1 40.3 2355 54.6 27.7	47.4 43.1 44.6 bo 53.0 41.6 bos 27.7 9.1 1.3.7 22.0 26.4 20.8 18.9 12.7 14.8 17.7 78.5 b2 2.6 5.7 5.2 12.3 7.3 4.5 5.3 2.1 6.8 5.7 4.5 5.3 2.1 6.8 5.7	2.8 2.8 3.9 3.5 4.4 3.5 1.6 2.2 3.5 3.9 1.6 2.8 3.1 3.1 3.7 3.9 3.6 2.6 4.1 4.0 4.3 4.5 4.7 5.0			22 22 12 12 12 12 12 12 12 12 12 12 12 1	ez. 513 471 459 444 420 bos 166 465 463 483 531 541 bos 166 563 233 665 723 bos 166 563 733 665 723 bos 166 564 138 219 209 541 460 560 216 257 290 541 460 560 216 257 290 bs 740 266 254 138 26 291 bs 740 266 254 56 257 200
1,1,2,0 5,1,1 1	bes 23.1 36.3 46.1 48.3 4 b(4 22.8 26.5 26.8 31.2 3 14.4 0.8 18.3 20.1 20.7 3 14.4 0.8 18.3 20.1 20.7 3 2 0.8 18.3 20.1 20.7 3 2 0.8 18.3 20.1 20.7 3 2 0.8 18.3 20.1 20.7 3 2 0.8 12.7 4.4 3.57 3 3 3 5 3 5 <td>b b c c c c c c c c c c</td> <td></td> <td></td> <td>24.2 28.1 51.9 56.5 46.9 50.0</td> <td>61.3 35.1 30.5 57.8 58.9 Ya.5 '50.9 '3.30 '57.1 '101 ' 107 '34.5 '139 '166 '162 ' 108 24.5 '210 236 '242 ' 188 24.5 '210 236 '242 ' 251 '234 '315 '355 '555 '555 ' 152 '2555 '442 '555 '555 '555 '555 ' 159 '144 '560 'b25 '539 '</td>	b b c c c c c c c c c c			24.2 28.1 51.9 56.5 46.9 50.0	61.3 35.1 30.5 57.8 58.9 Ya.5 '50.9 '3.30 '57.1 '101 ' 107 '34.5 '139 '166 '162 ' 108 24.5 '210 236 '242 ' 188 24.5 '210 236 '242 ' 251 '234 '315 '355 '555 '555 ' 152 '2555 '442 '555 '555 '555 '555 ' 159 '144 '560 'b25 '539 '
0 56.0 45.8 b7.2 59.6 54.4	5 25.2 33.2 43.7 41.3 56.8 1 13.6 20 27.7 27.1 24.7 1 3.5 11.7 18.1 18.1 16.8 1 3.5 11.7 18.1 18.1 16.8 1 1.1 5.4 2.8 7.5 11.7 5.8 5.4 5.7 5.9 7.8 5.4 5.2 5.0 5.2 5.4	b.7 b.6 b.5 b.0 b.5 8.7 5.9 5.5 5.5 5.6 5.5 5.3 5.5 5.5 5.5 5.5 5.5 5.3 5.5			20.3 29.9 28.3 27.1 42.7 241	5 56.2 56.1 52.4 56.8 51.3 6.3.0 56.4 48.5 71.7 58.8 1.6. 2.2.6 48.5 71.7 58.8 1.6. 2.2.6 16.4 58.8 13.8 1.6. 2.2.6 16.4 52.5 20.6 2.6.4 15.2 52.5 20.6 3.57 4.64 15.3 51.1 4.22 5.76 3.2.0 3.81 15.26 4.60
1 75.1 \$70 54.2 243 \$44	T ₁ 17 %6.6 22.1 36.7 %0.6 70.5 80.6 70.5 80.6 70.6 70.6 70.6 <	6 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1				70.3 71.6 86.2 81.4 80.8 85.3 74.7 13.6 94.6 81.4 80.8 85.3 74.7 21.7 220 250 91.4 80.8 26.2 103 266 34.8 81.4 80.6 26.9 268 54.8 26.4 12.9 26.9 263 54.8 0.8 24.0 422 433 263 54.8 0.8 24.0 422 433
51.8 by 4.8 130 %	404 44.9 22.1 26.9 46.0 27.1 26.2 25.3 22.6 11.1,6 17.2 20.4 20.4 3.3 82.8 10 11.3 5.4 3.5 3.5 8.5 8.6 11.3 5.4 5.5 2.5 8.5 8.6 10.8 4.3 2.2 7.0 7.6	14.9 10.7 7.4 8.6 8.5 8.6 8.6 8.8 8.7 8.0 5.7 5.7 5.1 5.1 5.1 8.5 8.4 5.8 5.3 5.2 5.6 5.5 5.5 5.5 8.5 9.4 5.8 5.3 5.2 5.6 5.5			28.2 27.3 24.0 35.5 56.0 53.3 45.0 47.5 46.9	51.3 57.6 51.7 10.3 66.0 40.1 75.6 72.4 70.7 72.2 12.4 106 50.1 75.0 70.1 13.9 225 21.9 150 3.19 225 319 259 150 4.59 4.59 392 394 546 599 4.69 391 561 245
1	Met Met <td>46:1 36.3 27.0 22.0 30:6 23:0 30:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:7 20:7 20:7 20:7 20:7 20:7 20:7 20:7 2</td> <td>8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9</td> <td></td> <td>251 251 251 251 251 251 251 251 251 251</td> <td>3 565 720 565 823 55.7 8 524 562 560 736 562 9 242 103 121 109 562 9 220 158 171 150 721 8 320 158 171 150 721 2 427 466 456 559 5 45 559 514 820 833</td>	46:1 36.3 27.0 22.0 30:6 23:0 30:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:6 23:0 40:7 20:7 20:7 20:7 20:7 20:7 20:7 20:7 2	8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9		251 251 251 251 251 251 251 251 251 251	3 565 720 565 823 55.7 8 524 562 560 736 562 9 242 103 121 109 562 9 220 158 171 150 721 8 320 158 171 150 721 2 427 466 456 559 5 45 559 514 820 833
404 34 25 871	111 100 84.2 41.3 224 132 86.6 54.0 220 130 81.3 25.2 126 60.9 70.5 51.2 197 53.5 76.7 51.8 273 53.0 29.4 51.7	286 189 59.2 52.7 290 170 162 29.5 285 181 11 74.9 285 181 110 76.8	214 138 39.1 75.5 214 138 39.0 77.7 253 156 106 77.6 251 164 119 81.0	289 193 126 25.9 289 193 126 25.0 280 194 120 21.1 280 194 120 21.1 7.7 7.7		2013 100 2015 100 2000 20

SCALE: NTS – DAYLIGHTING CASE STUDY

JANUARY 1, 1:00 PM

		11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
11:8 11:8		7,7, 1,3,7 1,6,6,1 1,6,6,1 1,6,6,1 1,6,5,7 1,6,5,7 1,1,6,5 1,1,6,5 1,1,6,5 1,1,6,5 1,1,6,5 1,1,6,5 1,1,6,5 1,1,6,5 1,1,6,5 1,1,5,5 1,5,5,5 1,5,5,5,5
2 2 2 1 1 2 2 2 1 1 2 2 2 1 2 2 2 2 1 2 2 2 2 2 1 2		11:1 11:1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	\int	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
		1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
		12 12 12 12 12 12 12 12 12 12 12 12 12 1
7 30.1 9.2 9.2 9.2 9.2 9.2 1.2 1.2 1.2 1.2 1.2 1.2 1.2 1		2 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
24.7 50.7 15.0 18.8 5.6 5.4 5.6 5.3 5.6 5.3 5.6 5.3 1.4 1.6 1.4 1.6 1.6 1.6 1.6 1.6 1.6 1.6 1.6 1.6 1.6		10.7 10.2 12.6 12.9 15.6 17.1 15.6 17.1 15.6 27.1 15.6 27.4 11.4 15.4 11.4 15.4
		2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
33.9 33.1 33.9 33.1 21.5 21.5 21.5 21.5 21.5 21.5 21.5 21		b.3 b.3 b.3 b.3 b.1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 3 1 4 1 3 5 1 4 1 5 5 1 4 1 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
202 2 2 2 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	1	1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.
25 55 88 88 7. 1. 2. 2. 2. 589		11:00 1000 1000 1000 1000 1000 1000 100
		44 13.0 44 13.0 44 14 14 13.0 44 14 14 14 14 14 14 14 14 14 14 14 14 1
	=	14.6 14.6 14.6 14.6 14.6 14.6 14.6 14.6
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	2	25 13 15 19 19 19 19 19 19 19 19 19 19 19 19 19
220 224 224 224 224 224		55.2 55.3 55.8 55.8 55.8 55.8 55.8 55.8 55.8
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	1	1.3.6 1.3.5 1.3.6 1.3.5 1.3.6 1.3.5 1.3.6 1.3.5 1.3.6 1.3.5 1.3.6 1.3.5 1.3.6 1.3.5 1.3.6 1.3.5 1.3.6 1.3.5 1.5.5
24.7 25. 5.5 3.3 5.5 5.3 5.6 2.5 5.6 2.5 5.7 2.5 5.5 5.7 2.5 5.7		14.5 1.1 24.0 10 25.5 4.4 71.8 56 102 95 102 95 102 95
12 23 24 20 20 25 23 29 25 25 25 25 25 25 25 25 25 25 25 25 25		13.5 16.7 13.5 16.7 14.6 16.7 14.6 16.7 14.6 16.7 14.6 16.7 14.6 16.7 14.6 16.7 14.6 16.7 14.6 16.7 14.6 16.7 14.7 16.7 14.7 16.7 14.7 16.7 14.7 16.7 16.7 16.7 16.7 16.7 16.7 16.7 16
54.5 218 21.0 102 13.1 5.0 2.4 4 5.5 2.6 2.4 4 1.3 5.2 1.8 2.5 2.6 2.8 2.8 2.8 2.8 1.5 2.8 2.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1		
μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ μ		17.2 17.3 17.2 17.3 51.8 54.0 50.5 53.7 53.8 127 201 200
	4	103 103 103 103 103 103 103 103 103 103
5 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		B. B. B. B. B. B. B. B. B. C. 1.2.1 B. B. B. C. 1.2.1 B. B. B. B. B. B. B. B. B. C. 1.2.1 B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B. B.
22 25 25 25 25 25 25 25 25 25 25 25 25 2		10.0 5.2 3.6 7.3 5.8 5.8 0.1 3.0.7 3.0.0 3.2 3.8 7.3 3.8 0.1 3.0.7 3.0.1 10.7 10.0 3.7 3.8 0.1 3.0.7 3.0.1 12.4 12.4 12.5 12.5 0.1 3.0.1 3.0.2 13.3 19.4 18.4 17.8 0.1 3.4.5 20.3 12.9 13.3 19.4 18.4 17.8 0.1 3.4.5 20.3 12.9 23.7 25.1 14.8 12.6 0.1 3.4.5 20.3 7.2.9 23.7 25.1 14.8 16.0 25.4 3.1.3 4.1.5 35.7 25.1 14.0 16.0 14.0 11.4 72.5 25.7 15.1 15.6 14.8 16.0 11.4 72.5 25.4 15.6 15.6 14.8 16.6 11.6 10.0 14.6
		5 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
1, 10, 10, 10, 10, 10, 10, 10, 10, 10, 1		23.5 18.0 23.5 18.0 20.3 12.9 26.7 18.1 26.7 18.1 26.7 18.1 26.7 18.1
		2 23.6 2 20.3 2 20.3 2 20.3 2 20.3 2 20.3 2 20.3 2 20.3 2 20.3 2 2 20.3 2 2 20.3 2 2 20.3 2 2 2 2 2 2 2 2
		50.7 50.4 25.5 50.4 27.9 50.1 54.5 51.4 52.5 51.4 72.5 101 118 162 190
51.0 52.7 51.0 52.7 55.0 52.2 55.1 51.5 55.1 24.4 55.1 2	84.2 83.36 84.0 85.4 101 88.2 107 70.5 107 70.5 107 70.5 89.5 84.4 81.5 83.5	2017 2017 2017 2017 2017 2017 2017 2017
	183 - 135 -	

SHEET S3 – DAYLIGHTING CASE STUDY scale: NTS

JANUARY 1, 4:00 PM

/		<u>الا</u> ۲. ۴. ۴.		5/1 565	ž ž	526 585	501 501	527		573 568 23	12 15 4 23	ž ž	*589 *470	
þ	86.3 Las	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		122 214 202 122 314	185 <u>2</u> 70 195 <u>4</u> 2	215 528 243 381	258 400 259 400	245 581 212 329	163 4.7	¹ 81 187 216 520 223 327	211 285			37.0 75.4
	1 96.0	50.3 40/8 51.8 121 528 112	101	98.1 144 98.2 140 C	137		167 '	150	904 9140 9	4 * * *	141 100		61.0 92.8 92.8	92.6
			22.5	18.0 153.8 57.8	\bigcirc				Ŏŗ	101	51.5 13.5			
	42.5 53.8 37.9 15.6	26.9 31.8 26.9 31.8 22.3 28.8	~	23.3 17.3 26.8 40.3 29.6 40.5		2					31.0 38.8 57.4 37.9		18.9 45.8 29.2 47.1 64.0 23.7	78.4 86.5
	80.8 80.2 39.9 41.9	1 (1 -	X 1 / 1	15.4 20.0							20.4 24.4	()	1	102
Ē	50.0 32.4	19.6 19.6 16.7		10.7							17.8	17.9	51.9 40.8 55.2	
	32.0 200	2 8 4 10 F		5.9 5.6 7.3 8.9 8.8 10.7					=		13.0 15.7 13.0 13.0		30.2 25.8 34.6 27.8 26.0 39.2	
	58.2 52.1 58.2 52.1 58.2 35.0		1.8 1.8 1. 5.59 5.6 5.5 5.5 5.5 5.5 5.5 5.5 5.5 5.5 5.5	5.1 5.9 4.1						85 7:8 84 95 84 85 95 84 85 95 84 85 95 95 85 95 95 85 95 95 8	10.3 10.4	25.6 23.6	57.8 53.8 56.0 47.2 78.5 84.6	ĺ
	ງ 18.8 18.8 18.8	17.3 17.3 17.3 8,2	1/~	94 54 96 64 77 89						ະ ຊີ່ຊີ່ຊີ່ ຊີ່ຊີ່	10.1 9.2 P		40.6 40.4 4	(
	50.8 31.9	15.5 15.5 10.7		4.4	-					5.1 5.6 7.2	7.5 8.3 8.4 7,8	/ /m m	37.6 52.8 83.6	(
	145 - 56.5 21.3 - 19.1	20 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.7 0.	4.6 4.4								0.4 8.3 11.3 8.3	()	33.4 29.2 43.4 30.9 212 10.6	(
	46.0 26.8 32.7 28.2 5.5 5.4		** 8* 5* 10 10 10 10		=					<u> </u>	8.3 B.5		46.5 41.8 70.8 57.6 115 21.0	
	5 51.8 5 33.9	r ¥ 5 5		51 53 34 51 59 54						8. 24 80 8. 7. 4. 9. 8. 24 80	2×	20.9 20.9	47.2 72.7 109	
	1	5. 5.0 5.5 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0		ମ୍ <mark>ୟୁ</mark> ମ୍ୟୁ ମ୍ୟୁ ମ୍ୟୁ ମ୍ୟୁ							8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8		50.4 81.4	
ſ	\$1.6 \$1.23.8		5.9 4.2 5.8 5.8		-						8.7 8.7 8.4 0.7		33.7 43.3 59.5 81.8 28.7 34.7	
	35,9 %9.0		4.9 4.4								0.9 7.6 0.0 ⁷ 7.1	1.4 50 2007	57.1 97.8 0.1 87.7 119 910	(
	7 57.0 34.5											20.5	48.2 77.0 122	
	27 SE			3.0 3.1 2.4 2.5 2.2 2.2							8.5 10.1	8.6 21.0	17.5 57.2 77.5 52.4 120 122	(
	41 2 16.4 3J.5 24.7 16.6 16.7	1.5 1.4 5 4.4 1.4 1.5 1.4 1.4 1.5 1.4 1.4 1.5 1.4 1.4 1.5 1.4 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5		2.7 2.8 2.4 2.4 2.3 2.2						*.4 *.0 5.5 5.2 7.0 7.0		8.5 10.6	44.9 56.3 56.3 27.2 56.8 96.2	(
				γ ¹ γ ¹ γ 4 γ γ						"4" "ດ" ເບັ່4" ຄື	8.5 10 0		45.0 45.8 44.9 64.5 82.1 55.3 84.7 947 96.8	
	23.0		^م ن ^م ر ش	54 54 54 54 54	<u> </u>						,		⁴ 8.0	
	50.0 59.7 31.1 20.8	13.2 10.6 9.0		l							10.9 8.7	17.5 24.4 24.4	70.5 84.5 115 87.7	
	\$7.4 23.7	1.5 1.0 1.6 1.40 9 8 10.0	10.5 9.2 10.3 8.7 1							de la	11.7	15.0		
	43.9 48.0 35.5 52.0 25.3 20.3	41 14	11.5	21.6 15.0 10	19.3 14.9 ⁻ 19.1 15.2	.4 15.1 .8 15.7	-1 16.2	22.8 15.6 20.3 14.9	18.5 14.7	0.1 \$.3	10.7	2 4 B		
Ð						48.2 305 20.4 53.4 352 22.8	54.8 36.9 24.1 54.8 36.3 24.1	53.2 35.0 22.8 47.9 30.5 20.3	ال ا م	27.5 - 170 34.0 0.0 3.4				
1			\$52.7 \$55.2	8.85 24.7 51.8	مل % % ¶∎	48.2 53.4	54.8 54.8 54.8	\$53.2 \$7.9		55.2 55.2 55.2			┉┉	

SCALE: NTS SCALE: NTS

APRIL 1, 7:00 AM

210 F 10 F		
	196 2855 2856 578 227 547 257 403 2574 422 2574 422 422 422 477 285 547 117 285	
125 40 12 12 12 12 12 12 12 12 12 12 12 12 12	م 1 45 1 72 1 59 1 72 1 59 1 52 1 52 1 52	5 5 12 12 15 12 12 12 12 12 12 12 12 12 12 12 12 12
bra beso bra beso bra beso bra beso bra beso bra beso bra beso bra beso		111 111 111 111 111 111 111 111
71.4 97.6 832 27.4 97.6 832 25.4 94.0 55.8 15.0 44.2 54.8 15.0 44.2 54.8 15.0 44.2 54.8 15.0 44.2 54.8 25.4 34.8 37.5 25.4 34.8 37.5 25.4 34.8 37.5 25.4 34.8 37.5 25.4 34.8 37.5 25.4 34.8 37.5 25.4 30.8 25.5.5 25.1 25.1 27.3 25.2 19.8 39.8 26.2 19.8 39.3 26.2 19.3 31.3		46.3 58.6 42.9 56.7 75.3 56.1 75.3 56.1 75.3 56.1 75.5 56.1 25.4 57.4 25.4 57.4
103 103 103 103 103 103 103 103 103 103		401 222 222 222 221
94.8 '104 55.5 '66.4 55.5 '86.4 55.6 '55. 15.6 '15.4 12.2 '11.4 12.2 '11.4 12.5 '17.3 '12.5 '17.3 '12.6 '19.4		42.7 4.5.2 47.5 49.8 54.7 56.1 150 150 150 150 150 150 150 150 150 150 150
		57.6 5.1 5 57.6 5.1 5 57.6 5.1 5 57.6 5.1 5 57.6 5
841 500 828 504 828 504 828 504 844 900 7,0 904 7,1 85 844 900 7,1 85 7,1 85 845 900 7,1 85 7,1 185 7,1 85 7,1 185 7,1		221 221 222 221 222 222 222 222 222 222
107 105 70.0 188.3 44.5 74.8 50.6 12.6 5.4 2.6 5.4 2.6 5.4 2.6 5.4 2.6 5.5 5.8		21.2 22.4 28.0 28.9 57.4 56.7 51.1 4.70 72.7 59.5 72.7 59.5 11.4 24.3 11.4 24.3 59.5 59.5 59.5 59.5 59.5 59.5 50.584
86.9 81.5 81.5 81.5 81.5 81.5 81.5 81.5 81.5	1	24.4 24.4 24.4 24.4 24.4 24.1 168 2551 2551 2551 2551 2551 2551
22.2 2.2 2.2 2.2 2.2 2.2 2.2 2.2 2.2 2.		40.7 57.1 40.7 57.1 150 98.8 25 150 98.8 515 150 549
	_	84.5.7 45.2 84.6 57.9 89.5 77.1 89.5 77.1 81.6 71.5 205 203 205 203 205 203
999 99 99 99 99 99 99 99 99 99 99 99 99		22 22 25 26 26 26 27 27 27 27 27 27 27 27 27 27 27 27 27
65.1 95.2 65.1 95.2 85.8 5 12.1 95.8 5 12.1 19.3 5 15.9 10.4 14.1 10.4		15.4 15.4
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		200 40 40 40 40 40 40 40 40 40 40 40 40 4
bec bo4 bec bo4 be bis bis bis bis bis bis bis bis bis bis		41.0 200 400 100 100 100 100 100 100 100 100 1
105 16.7 16.7 16.7 16.7 16.7	_	821 821 821 821
		21.1 See 50.2 1.1 Sec. 1 Sec.
4 11.3 1 2 2 10.7 2 4 11.3 1 2 4 10.7 2 4		240 18.4 19.7 19.4 17.3 24.0 25.0 25.4 25.1 25.6 24.0 20.0 35.0 25.4 25.1 25.6 24.0 20.0 35.0 24.2 24.1 56.2 25.4 40.5 7.3 33.6 25.3 37.9 38.2 30.0 35.3 37.9 35.6 24.1 50.1 25.3 37.9 38.2 30.0 38.2 35.0 35.3 51.7 50.8 25.3 37.9 38.2 30.0 38.2 35.0 35.9 35.0 35.9 15.8 71.1 12.1 10.7 38.5 14.3 148 37.0 36.8 15.8 11.1 12.1 10.7 35.5 25.4 25.4 25.4 25.4 25.4 30.0 35.0 35.6 35.0 37.7 36.8 36.2 30.1 56.0 50.2 4.33 36.0 36.2 30.1 56.8 44.6 50.2 4.33 36.2
		18.4 19.7 19.4 17.3 28.4 25.1 25.6 24.0 28.3 31.8 35.8 35.6 28.4 40.5 4.3 35.8 35.6 28.4 40.5 4.3 51.7 50.8 28.9 51.4 53.0 19.8 28.0 23.4 23.0 19.8 28.0 23.4 23.0 19.8 29.0 23.4 23.0 19.8 20.0 21.7 26.3 13.8 20.0 21.7 26.3 13.8 14.8 15.8 15.8 15.8 15.8 15.8 15.8 15.8 15
19.1 19.2 4 55.2 19.3 19.4 19.4 19.4 19.5 19.5 19.5 19.5 19.5 19.5 19.5 19.5		18.4 23.4 23.4 25.4 20.0 38.3 25.0 50.0 38.5 25.0 10.7 38.5 14.5 10.7 38.5 14.5 10.7 38.5 14.5 14.6 50.2 4.53
13.17 13.17 13.17 13.17 13.17 13.18 13.17 13.18 13.18 13.18 13.18 13.18 13.18 13.18 13.18 13.18 13.18 13.18 13.18 14.18		**************************************
86. 88. 88. 88. 88. 88. 88. 88. 88. 88.		22 22 25 25 25 25 25 25 25 25 25 25 25 2
N + + 0 D D - 0 0 -	7 41.2 7 41.1 7 41.1 7 44.0 5 49.2 5 49.2 5 49.5 5 49.4 5 44.4 6 0.9 9 10.9	
350 1 4 1 4 1 4 1 4 1 4 1 4 1 4 1 4 1 4 1	87.4 55 86.0 1 1.15 74 1.15 74 1.15 74 1.16 74 1.1	

SHEET S5 – DAYLIGHTING CASE STUDY scale: NTS

APRIL 1, 10:00 AM

12 22 25 25 25 25 25 25 25 25 25 25 25 25	
	*2.7 1 *2.7 1
100 2 20 2 20 2 20 2 20 2 20 2 20 2 20	32.6 *2.2 35.1 *5.5 35.1 *5.5 35.1 *5.5 55.5 *0.5 55.6 *0.5 *0.5 *0.5 <t< td=""></t<>
15.0 State	
80.2 11.2 12.4 24.8 17.2 24.2 17.2 15.0 15.3 19.0 15.3 11.6 15.4 10.8 24 10.8 24 10.8 24 10.8 24 11.4	21.5 54.8 26.6 51.5 54.8 26.6 51.5 56.6 26.6 51.5 56.6 26.6 51.5 56.6 26.6 56.6 56.6 26.6 56.6 56.6 56.6 56.6 56.6 56.6 56.6
104 102 102 102 102 102 102 102 102 102 102	256.7 51.7 61.8 26.7 51.7 758.8 34.67 55.5 56.7 51.7 758.8 34.67 55.5 56.7 55.5 56.7 55.5 56.7 56.5 56.7 57.5 56.7 56.5 56.7 5
100 100 100 100 100 100 100 100 100 100	41 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 -
1 1 <th1< th=""> <th1< th=""> <th1< th=""> <th1< th=""></th1<></th1<></th1<></th1<>	
11:12 80.7 12:25 80.1 12:26 82.5 12:26 82.5 12:27 82.5 12:28	22.5 240 55.5 54.0 55.5 55.6 25.2 55.6 55.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6 15.6
110 113 70.7 73.9 45.7 24.0 51.0 51.7 51.0 51.7 71.5 51.0 7.5 51.6 7.5 5.5 5.4 5.4	27.1 51.0 27.1 51.0 38.7 42.3 48.1 55.2 139 735 139 735 139 735 139 705 139 705 139 705
87.7 80.3 20.8 20.8 4.9 7,5 7,5	171 42 42 42 42 42 42 42 42 42 42 42 42 42
	13 - 13 - 13 - 13 - 13 - 13 - 13 - 13 -
91.2 528 84.1 55.0 27.8 24.1 1.3 17.7 1.3 17.7 3.8 24.1 5.8 24.1 2 2 4.1 2 2 4.1 2 4	1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
5 6 5 7 3 103 5 6 5 6 5 6 5 6 5 6 5 6 5 6 5 6 5 6 5 6	
	1 1
	86.2 \$52.2 \$2.2 \$5.2 \$5.2 \$5.2 \$5.2 \$5.2 \$
115 68.7 115 88.8 11.2 11.2 11.2 11.2 11.2 11.2 11.5	
	12 24 24 24 24 24 24 24 24 24 24 24 24 24
96 4.5 56.0 111 96 4.5 56.0 111 92.7 54.9 58.8 95.1 92.7 54.9 58.8 95.1 92.7 54.9 58.8 95.1 92.7 50.0 9.7 50.8 95.3 90.7 50.0 9.7 50.8 95.3 91.7 10.0 12.5 91.2 91.1 92.7 50.0 9.3 5.1 9.4 90.1 10.1 11.1 11.1 11.1 91.7 50.0 5.3 5.8 5.8 50.0 50.3 5.1 5.4 5.8 51.8 5.8 5.8 5.8 5.8 52.8 5.8 5.1 5.8 5.8	25.4 24.2 21.3 51.4 51.3 28.9 50.5 53.3 51.8 65.0 82.1 80.3 86. 9.3 10.3 18. 9.3 18. 9.3 18. 9.3 18. 9.3 18. 9.3 18. 9.3 18. 9.3 18. 9.3 18. 9.4 18. 9.3 18. 9.4 18. 9.4 18. 9.4 18. 9.4 19.7 56. 16.1 57.4
782 888 907 308 81:1 827 349 807 994 383 407 994 383 14.0 83 301 11:7 90 83 11:1 98 7.8	
108 17.9 15.6 15.5 15.5 15.5 15.5 15.5 15.5 15.5	
bis bis 100 bis bis 100 bis bis 100 bis bis 100 bis 10	20 20 20 20 20 20 20 20 20 20
127 127 128 128 128 128 128 128 108 100	101 102 102 102 102 102 102 102 102 102

SCALE: NTS – DAYLIGHTING CASE STUDY

APRIL 1, 1:00 PM

71.1 Mar. 56.6 50.4 de.3 27.0 de.8 20.4 46.4 42.2 5.6.8 50.4 de.3 27.0 de.8 21.5 26.4 42.2 5.8 50.7 28.2 24.5 51.5 50.0 36.9 26.3 14.2 5.8 50.7 28.2 72.4 21.5 50.0 36.9 36.3 12.0 71.6 18.5 18.9 7.47 78.5 40.3 56.9 36.3 12.0 71.6 5.8.5 19.3 17.6 28.5 56.3 56.9 36.3 14.3 17.6 28.7 28.4 50.3 56.9 56.5 36.3 14.3 17.6 28.7 28.7 57.6 56.8 56.8 36.3 14.3 17.6 28.7 57.4 57.5 56.8 56.8 36.3 14.8 14.0 9.1 16.2 74.4 50.6 44.2 36.4 5.1 5.8 4.1 20.4 50.5 46.1 76.4 37.3 5.8 7.4 50.0 27.2 28.3 28.3 56.4 37.3 5.8 7.10 17.0 <	200 261 577 50 60 22.1 277 053 458 727 22.2 30.5 45.8 727 24.4 550 85.6 82.8 24.6 36.5 85.5 85.7 25.6 30.5 45.8 55.6 25.6 30.5 45.8 55.6 55.6	24.5 24.5 24.5 24.5 24.5 24.5 24.5 24.5
90.2 80.5 77.3 79.5 70.4 80.0 93.4 35.4 89.4 72.5 25.1 12.2 80.6 51.8 50.8 80.8 51.7 50.5 50.5 25.1 12.2 80.6 51.8 50.8 80.8 71.7 50.5 50.5 26.1 72.2 22.7 20.8 50.8 50.7 51.7 52.2 50.7 30.3 33.6 4.6 4.17 30.8 50.6 51.7 52.2 50.3 73.5 75.8 70.7 30.3 33.6 4.6 51.7 22.2 22.7 20.3 51.7 50.5 70.7 30.3 33.6 4.6 51.7 22.2 22.7 20.3 51.7 52.5 70.0 31.3 51.5 52.7 50.8 50.6 51.4 50.7 51.7 70.7 31.5 53.5 54.7 51.6 54.4 52.7 50.7 50.7 50.7 51.5 53.5 54.7 54.6 54.4 57.7 50.7 54.6 54.4 54.6 55.7 50.7 54.7 54.7 55.7 55.7 55.7		No.0 Yo.0 Yo.0 <th< td=""></th<>
Yor Bar Bar <td></td> <td>b.4 b.4 b.4 b.4 b.2.4 b.2.4 b.2.4 b.4 b.2.5 b.2.4 b.2.4 b.2.4 b.5.5 b.6.6 b.4.6 b.3.5 b.3.5 b.6.6 b.4.6 b.3.5 b.3.5 b.3.5 b.6.7 b.3.5 b.3.6 b.4.3 b.3.5 b.6.8 b.3.7 b.3.6 b.3.7 b.3.3 b.6.9 b.3.6 b.5.7 b.3.5 b.3.5 b.6.9 b.5.7 b.5.7 b.3.5 b.3.5 b.6.9 b.5.7 b.5.7 b.5.7 b.5.7 b.6.9 b.5.7 b.5.7 b.5.7 b.5.7 b.6.9 b.5.7 b.5.7 b.5.7 b.5.7 b.6.9 b.5.3 b.5.7 b.5.7 b.5.8 b.6.9 b.5.3 b.5.7 b.5.7 b.5.8 b.6.9 b.5.3 b.5.7 b.5.7 b.5.8 b.6.9 b.5.3 b.5.7 b.5.8 b.5.8 b.6.9 b.5.7 b.5.9 b.5.7 b.5.8 b.6.9 b.5.7 b.5.9 b.5.9 b.5.8 b.6.9 b.5.7 b.5.9 b.5.9 b.5.8 b.6.9<</td>		b.4 b.4 b.4 b.4 b.2.4 b.2.4 b.2.4 b.4 b.2.5 b.2.4 b.2.4 b.2.4 b.5.5 b.6.6 b.4.6 b.3.5 b.3.5 b.6.6 b.4.6 b.3.5 b.3.5 b.3.5 b.6.7 b.3.5 b.3.6 b.4.3 b.3.5 b.6.8 b.3.7 b.3.6 b.3.7 b.3.3 b.6.9 b.3.6 b.5.7 b.3.5 b.3.5 b.6.9 b.5.7 b.5.7 b.3.5 b.3.5 b.6.9 b.5.7 b.5.7 b.5.7 b.5.7 b.6.9 b.5.7 b.5.7 b.5.7 b.5.7 b.6.9 b.5.7 b.5.7 b.5.7 b.5.7 b.6.9 b.5.3 b.5.7 b.5.7 b.5.8 b.6.9 b.5.3 b.5.7 b.5.7 b.5.8 b.6.9 b.5.3 b.5.7 b.5.7 b.5.8 b.6.9 b.5.3 b.5.7 b.5.8 b.5.8 b.6.9 b.5.7 b.5.9 b.5.7 b.5.8 b.6.9 b.5.7 b.5.9 b.5.9 b.5.8 b.6.9 b.5.7 b.5.9 b.5.9 b.5.8 b.6.9<
769 19.1 91.8 19.2 90.0 90.1 99.9 91.4 92.3 51.5		22.0 18.8 16.4 13.9 23.8 20.4 18.7 19.6 28.1 24.5 28.8 19.6 28.1 24.5 28.3 21.1 29.2 50.3 45.9 35.3 31.1 29.2 50.3 45.9 36.3 31.1 29.2 50.3 45.8 36.3 31.1 29.4 40.7 30.4 30.3 56.5 30.4 40.3 76.3 51.1 29.3 30.4 45.9 76.3 51.1 29.3 30.4 12.6 76.3 51.1 29.3 30.4 12.6 76.3 56.3 51.0 30.4 12.6 12.5 56.5 21.0 30.7 13.6 50.1 51.0 20.4 30.7 25.5 25.4 35.1 35.8
124 136 148 151 110 117 151 75 304 220 120 148 151 110 117 151 152 304 220 20 20 20 145 152 152 152 151 15 150 25 250 217 145 151 152 151 150 15 34 20 20 21 100 141 121 122 150 14 50 20 20 14 753 741 121 122 152 150 14 150 26 21 31 20 145 122 152 150 15 151 253 250 14 508 21 31 20 145 122 152 150 15 158 26 26 21 26 15 508 21 26 26 14	1 2 <th2< th=""> <th2< th=""> <th2< th=""> <th2< th=""></th2<></th2<></th2<></th2<>	300 310 262 100 753 315 513 113 113 815 513 120 152 113 113 815 513 120 152 124 183.5 154 905 324 223 120 132 183.5 154 907 324 223 128 120 133.7 154 907 324 223 128 134 153.7 154 907 324 223 128 123 133.8 133.9 907 324 223 128 133.9 133.9 133.9 907 344 150 130 152.8 133.9 133.9 907 164 160 130 161.7 127.7 134.9 918 164 166 130 161.7 127.7 134.9 918 164 166 130 161.7 127.7 134.9 918 164 166 130 162.8 134.9 154.9 918 164 166 196 196.9 196.9

SCALE: NTS – DAYLIGHTING CASE STUDY

APRIL 1, 4:00 PM

STUDY	
CASE 3	
DAYLIGHTING	
l	
S8	ITS
SHEET	SCALE: NT
$\left(\right)$	

222 222 222 222 222 222 222 222 222 22		
120 120 120 120 120 120 120 120 120 120	163 247 560 450 168 249 560 450 560 450 560 450 560 450 550 550 550 550 550 550 550 550 55	241 12 12 12 12 12 12 12 12 12 12 12 12 12
125 125 125 125 125 125 125 125 125 125		112 123 123 123 123 123 123 123 123 123
100 1/30 1/20 120 1/14 1/20 121 1/14 1/42 1/14 121 1/42 1/12 1/14 121 1/42 1/12 1/14 121 1/14 1/42 1/16 121 1/14 1/42 1/16 121 1/14 1/42 1/16 121 1/14 1/42 1/16 121 1/14 1/16 121 1/16 1		50.7 30.3 50.8 28.1 34.9 44.9 34.1 34.4 24.4 30.4 44.7 28.6 16.4 50.1 51.1 33.2 50.6 16.4 20.6 16.4 20.6 16.4 20.6 16.4 20.6 16.4 20.6 16.4 20.6
155 '190 ", 96.2 '120 ", 85.7 '20.1 "5 84.3 "57.1 "5 15.1 "26.3 "9 19.4 '18.3 "5 19.4 '18.3 "5 19.5 '18.3 "5 '18.5 '18.3 "5 '18.5 '18.5 "5 '18.5 '18.5 "5 '18.5 '18.		21.3 24.8 20.6 24.5 19.8 18.3 25.2 18.8 27.3 50.5 27.3 50.5 27.5 56.6 27.5 56.6
100 100 100 100 100 100 100 100 100 100		15.5 15.6 15.5 15.6 15.5 15.6 15.5 15.6 15.5 15.6 15.5 15.6 15.5 15.6 15.5 15.6 15.5 15.6 15.5 15.5
200 '197 178 "31 '129 118 "35. 57.5 57.5 57.5 57.5 57.5 57.5 57.5 5		1.1 5.6 1.1 5.3 5.6 1.1 10.9 11.3 12.2 10.9 11.3 12.2 10.3 12.2 5.9 10.4 25.3 23.5 26.1 25.3 23.5 58.6 56.4 49.5 58.4 56.4 49.5 58.4 56.4 49.5
172 194 2 108 126 1 108 126 1 100 2 100 2 100 2 100 2 100 2 100 2 100 2 100 2 100 2 100 3 100		6.2 7.9 7.8 6.6 8.3 7.7 7.5.0 17.7 7.5.0 17.7 8.3 87.7 81.2 87.7 81.2 87.7
		2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
100 100 200 227 118 113 77.0 74.9 75.5 77.3 49.4 79.9 75.3 14.5 14.8 14.2 14.5 14.8 14.2 14.5 14.8 14.2 14.5 14.8 5.7 5.5 5.5 5.5		4.1 4.4 4.7 5.4 5.7 5.4 6.5 7.2 5.7 6.5 5.5 7.2 5.7 16.7 9.6 14.7 5.5 5.5 25.1 52.1 54.5 55.4 4.3.6 51.7 56.4 16.6
140 123 140 123 140 123 140 123 140 123 140 123 140 123 140 140 140 140 140 140 140 140 140 140		5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5
2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1		2 2 2 4 5 1 200
198 125 170 120 583 837 31.1 21.8 1771 22.5 19.6 17.2 16.7 15.6 13.8 12.8 12.5 11.4		8.4 7.8 7.3 10.7 8.0 7.8 10.7 8.0 7.8 10.7 8.0 7.8 15.2 15.1 15.1 15.1 15.1
182 200 506 552 505 2521 14.4 47.1 158 17.0 158 17.0 12.7 22.1 15.8 17.0 12.7 22.1 5.8 5.8 5.8 5.8		7.4 10.4 80 10.4 15,4 14.3 15,4 22.4 15,4 22.4 12,7 27.3 88.5 30.5 88.5 30.5
14 128 1972 1928 1991 1992 1992 1992 1992 1992 199		4.3 4.1 5.9 4.7 4.7 4.6 6.5 5.7 5.8 6.9 7.2 5.8 8.5 5.1 7.8 8.5 2.1 7.8 2.5 2.5 2.0 2.5 2.0 2.6 2.5 2.0 2.6 2.5 2.0 2.6 2.5 2.0 2.6 2.5 2.0 2.6 2.5 2.0 2.6 2.0 4.0 8 2.0 0 4.0 4.0 2.9 2.0 2.6 2.0 4.0 2.0 2.6 2.6 2.0 2.6 2.6 2.0 2.6 2.6 2.6 2.0 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6 2.6
85.0 84.0 84.0 85.0 85.0 85.0 85.0 85.0 85.0 85.0 85		4.5 4.5 5.5 5.5 5.5 1.2 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
171 135 1611-158 1611-158 1614-158 1614-158 1614-1614 1614-1614-		10.9 b.3 11.2 b.5 19.0 16.6 52.5 46.0 55.6 66.2
22 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		
73 140 155 73 140 155 73 150 155 73 150 155 73 150 155 75 14,5 75 14,5 75 15,5 75 15,5	10.1 20.2 22.2 10.1 20.2 22.8 10.1 20.2 22.8 10.1 20.2 22.4 10.1 20.2 23.1 10.1 20.3 23.1 10.1 20.3 23.1 10.1 20.3 23.1 10.1 20.3 23.1 10.1 20.3 23.1 10.1 20.3 23.1 10.1 20.3 21.5 10.1 20.3 21.5 10.1 20.3 21.5 10.1 20.3 21.5	
	1003 100 100	

JULY 1, 7:00 AM

\$ 1 2 124 480 466 239 585 618 579 539 599 615 615 450 589 584 232 536 484 497 Tage 3 299 539 B 800 322 35 623 588 96 18 28 225 140 87 2 33 221 43 EZ 12 10 165 63.1 265 189 ¹149 ²224 183 55.0 153 126 190 200 249 266 250 218 112 220 195 681 129 167 176 184 219 224 145 200 220 681 231 179 171 152 148 141 145 166 155 114 154 172 173 122 146 143 967 104 148 122 141 154 183 62.5 50,7 36 117 72.2 121 131 95.9 0.0 33.3 102 101 104 107 101 3 8.03 \$ 124 210 8 99.2 E. 98.2 40.8 3.9 B0.0 48.0 58.8 51.2 75.3 58.2 57.6 \$0.5 **1**1.8 95.3 209 72.8 36.3 38.3 26.3 27.1 20.0 919.9 42.3 56.1 5.5 \$7.8 \$2.4 58.2 47.4 57.1 85.9 28.9 170 39.2 48.0 31.6 42.6 223 19.2 102 0.53 2.8 33.0 5.8 6.0 28.7 2.8 4.2 1.2 8.5 31.6 4.7 8.6 209 21.6 19.4 18.1 20.8 18.3 23.8 32.4 25.3 85,1 9123 186 283 82.3 54.3 11:07 33.5 122 37.4 4.9 57.9 16.9 31.4 34.8 35.9 ^{42.8} 88.3 124 9178 52.0 18.7 78.6 7.2 47.2 12.5 10 14 280 124 20 1.6 12.5 35.5 39.5 13.2 6.13 3.4 15.5 29.7 32.0 22:0 117 210 0.5 56.3 5 ٩ ١ 11.3 2.84 THE 28.0 11.8 0.4 10.7 12.4 11.3 12.8 28.5 27.5 1 7.87 24.3 29.4 0:0 6.7 12.0 9.5 24.3 10.9 26.4 19.4 110 42 10.1 9.8 10.9 103 73.0 8.5 <u>.</u> 25.1 22.0 128 118 80.3 52.5 (B.D 8.3 61 292 1.7 6 1. 18.1 14.7 22.3 28.4 35.2 90.3 58.6 39.3 15.5 25.4 95.3 142 216 17.8 15.2 5.2 R 136 n' 8.4 8.7 ja a 13.5 26.2 17.1 42.5 65.8 97.8 10.3 22.4 30.3 147 92.7 59.9 39.8 8.3 224 16 6.9 5.7 8.0 341 14.9 4.5 2.2 20.9 5.9 9.95 9.1 25.2 24.4 \$ 38.4 5.0 6.7 218 133 36.9 4.6 337 2.8 19.2 22.0 56.5 85.6 213 213 115 72.8 49.8 35.0 bje 24.5 129 180 311 °. 9.2 7.1 43.2 8.4 42.2 14.5 93.7 \$8.6 24.0 25.5 103 8.5 2 1.2 5.1 5.5 1.8 5 20 E 65.3 172 47.1 43.5 13.1 20.5 11.7 °13.1 26.7 37.0 85.5 126 59.6 62.3 31.8 31.8 29.8 10.1 2.9 28.3 56.4 29.8 1.9 91.8 72.4 9.9 22.0 23.9 138 14 209 103 338 5.8 18.1 1 12,6 9.6 6.7. 80.4 9.5 9.6 8.2 °.5 6.9 5.6 5.0 23.5 0.67 68.6 20.7 9.01 23.5 18.4 186 12.1 9,2 9.8 127 431 8.0 2.3 5.2 54. 4.8 11.2 17.5 23.5 28.1 32.4 9.6 94 317 96.1 8.3 57.2 10.4 180 92.6 20.9 30.8 126 12.0 35.1 275 2.9.5 8.8 31.5 2.9.2 8.4 98.2 14.2 912 0.7 172 12.4 32.4 18.2 ő.5 24.7 27.1 TEL 1 5 13.0 11.5 110 82.6 20.1 25.5 28.7 24,6 52.4 196 10.6 9.5 317 00 8.3 6 0.6 11.3 20.1 31.0 14.8 7.3 48.0 39.9 14 223 127 361 8.8 10.8 71.4 13.5 76.4 13.0 94.6 28.5 B8.3 ⁹18.8 38.8 30.3 8.8 38.7 55.6 108 238 129 363 5.5 6.9 4.8 6.9 33 8.8 9.6 8.03 8.6 24 24 8.4 342 8.6 6.6 <u>ب</u> 4.9 9,9 ¹4.2 24.9 74.9 41.9 36.8 16.3 12.8 19.5 29.0 30.6 10.8 B0.3 9.4 4 9.6 6.2 5.5 5.0 279 11.8 15.1 19.7 25.5 7.92 37.2 .1 40.7 .6 32.4 15 7.4 130 160 6.7 <u>6</u> 5.4 5.2 12.2 14.5 15.0 8 17.6 98.7 6.0 5.9 5,5 5,5 11.8 42.3 27.1 18.4 21.4 B4.3 18.7 8.6 5.0 81.1 187 83.7 5.5 5.3 ġ. 130 14.8 11.1 15,0 6.2 92.4 15.2 71.8 20.0 22.5 8.4 9.5 23.4 24.1 18.8 0'11'0 42.5 29.9 20.8 49.9 112 8.93 6.93 122 204 R 25.6 22.8 25.2 21.7 31.0 42.6 39.3 84.0 24.6 20.6 28.B 64.7 53.4 40.2 6.3 31.8 25.9 23.1 101 174 283 8 L 1.8 3.7 5 27.7 16.2 36.3 23.3 26.8 16.8 31.1 23.5 40.6 34.2 33.7 27.9 52.0 36.9 36.8 44.2 34.7 28.7 46.9 36.0 45.3 35.9 108 56.9 36.6 38.0 58.8 39.2 35.6 37.8 49.5 36.2 0.2 58.8 39. 43.5 46.6 49.8 55.6 43/7 99.4 14.5 \$2.7 50.3 20.8 40.8 20.4 36.0 15.4 30.6 134 89.9 63.8 130 855 35.6 49 127 B. 130 bs. 917 34 B7.8 62 127 61 85.FT 52 112 7 134 87 222 85.4 3 134 58.8 114 3 118 135 100 85.0 128 8 121 136 75.3 F Π T J T T

SHEET S9 – DAYLIGHTING CASE STUDY scale: NTS

JULY 1, 10:00 AM

SHEET S10	1	DAYLIGHTING	CASE	STUDY	
SCALE: NTS					

8 11. 84.8 76.8 96.0 75.5 9 81.1 84.8 76.8 96.0 75.5 9 14.5 26.1 15.4 48.4 75.6 9 14.5 26.1 15.4 48.4 75.4 9 14.5 26.1 15.4 48.4 15.6 16.0 15.4 48.4 15.5 37.8 25.8 15.8 12.1 25.5 25.6 96.3 86.1 12.4 15.8 12.1 15.2 25.3 35.2 35.3 35.2 15.3 10.7 8.3 11.2 35.0 46.7 95.3 35.3 15.3 10.7 8.3 11.2 35.1 55.4 54.4 90.3 56.8 15.3 10.7 8.3 15.1 35.4 54.4 50.3 56.3 16.1 11.2 35.1 35.4 56.3 56.3 56.8 16.1 11.2 35.1 35.4 56.3 56.3 56.3 16.1 11.2 35.1 35.4 56.3 56.3 56.3 17.4 19.2 29.2 36.6 31.1 74.2 56	3555 7659 9576 110 3580 9580 9585 110 3580 9580 9585 110 3581 9545 9524 131 451.3 9553 100 150 451.4 951.7 9553 100 150 351.4 951.7 9553 146 351.6 951.7 9553 146 351.6 951.7 952 141	21.1 20.5 59.6 49.8 51.4 21.1 21.0 59.8 49.8 51.4 21.1 21.2 20.5 50.5 50.5 21.2 51.4 5.3 20.5 51.2 51.5 18.7 51.4 5.3 20.0 51.2 46.5 51.8 18.7 51.4 5.3 20.0 51.2 46.5 51.8 14.0 55.8 55.0 52.6 51.2 46.5 51.3 14.0 55.8 55.0 51.2 46.5 51.5 25.4 74.1 10.2 50.0 51.2 46.5 25.1 12.0 10.1 51.3 50.5 50.5 25.1 14.0 51.7 10.5 12.6 12.6 25.1 12.7 10.5 12.7 10.5 12.6 25.1 12.7 10.5 12.7 12.7 12.8 25.7 25.8 21.4 19.1 53.3 12.8
114 133 131 117 72.0 80.3 121 119 70.8 82.3 85.1 77.5 82.2 00.0 95.3 74.7 78.0 48.2 55.4 55.3 50.1 13.0 74.3 52.1 59.5 76.5 76.5 33.6 56.6 57.4 57.3 54.3 50.1 13.0 24.6 50.5 56.3 74.5 74.9 33.6 56.6 57.4 57.3 54.3 23.3 25.3 52.2 22.7 25.1 55.3 55.3 55.3 55.3 55.3 55.3 55.3 55.3 25.1 55.1 55.3 55.3 55.4 55.3 55.3 55.3 55.3 25.4 55.3 55.3 55.4 55.3 55.3 55.3 55.3 55.3 25.1 55.3 55.3 55.3 55.3 55.3 55.3 55.3 55.3 25.1 55.3 55.3 55.3 55.3 55.3 55.3 55.3 35.3 55.3 55.3 55.3 55.3 55.3 55.3 55.3 35.3 55.3 55.3 55.3 <t< td=""><td></td><td>*12.9 *13.9 *4.2 *14.4 *16.6 *15.9 *16.9 *17.9 *26.7 *25.5 *24.6 *22.5 *24.8</td></t<>		*12.9 *13.9 *4.2 *14.4 *16.6 *15.9 *16.9 *17.9 *26.7 *25.5 *24.6 *22.5 *24.8
115 200 201 100 102.1 100 102.1 100 102.1 100 102.1 100 102.1 100 100 102.1 100 100 100 100 100 100 100 100 100 1		11.1 10.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 20.6 15.7 35.6 15.7 35.6 15.7 35.6 15.7 35.6 15.7 35.6 15.7 35.6 15.7 35.6 15.8 36.2 15.9 36.2 15.9 36.2 15.1 25.1 15.1 36.2 15.1 36.2 15.1 36.2 15.1 36.2 15.1 36.2 15.1 36.2 15.1 36.2 15.1 36.2 15.1 37.3 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.1 15.1 37.2 <t< td=""></t<>
Boos Total Total <tht< td=""><td></td><td>13.3 18.2 25.1 25.1 25.0 35.0</td></tht<>		13.3 18.2 25.1 25.1 25.0 35.0
71.4 700 7.33 7.41 104 57.7 7.26 100 25.6 151 112 112 123 741 104 57.7 7.26 100 25.6 151 112 112 123 781 10.5 56.0 56.4 82.8 27.4 204 103 113 40.5 56.4 84.8 81.8 36.5 21.4 205 171 1126 103 56.4 44.8 71.8 84.8 26.2 205 205 34.6 15.3 30.5 54.8 35.2 21.4 205 205 34.6 15.3 30.3 35.1 28.2 21.4 205 205 34.6 15.3 30.5 35.4 28.0 21.2 205 205 34.8 35.3 35.4 28.2 21.4 20.4 205 205 34.8 34.8 35.4 28.2 21.4 205 202 34.8 35.4 35.4 28.0 21.2 205 202 34.8 35.4 35.4 20.4 20.7 205 202 34.8 35.2 35.4	285 10 132 100 132 215 13 132 100 94 357 212 141 102 358 200 160 110 358 200 158 100 358 200 158 100 358 200 100 358 200 100 359 128 100 350 200 100 350 200 100	1 1.52 5.52 5.5 2 1 5.54 5.54 2 5 5.54 5.54 3 5 5.55 5.52 1 1 5.54 5.54 1 1 5.54 5.54 5.54 1 1 1 5.54 5.54 5.55 1 1 1 5.55 5.54 5.55 5.55 1 1 1 1 5.55 <td< td=""></td<>

JULY 1, 1:00 PM

Base base hoe '111 '100 Bris 'Bari '801 '800 'Base by 1 '701 '808 'By 1 '706 '700 '818 '813 '820 '825 '826 '813 '871 '808 '813 '871 '803 '818 '813 '820 '803 '818 '817 '808 '818 '813 '820 '818 '813 '820 '818 '813 '820 '818 '813 '820 '818 '813 '811 '818 '820 '803 '818 '813 '821 '828 '818 '818 '818 '818 '818 '818	24.3 320 46.3 74.6 26.5 33.7 50 46.3 74.6 26.5 33.7 50 56.0 80.3 26.5 33.7 50 56.0 80.3 26.5 31.0 50.0 80.3 26.1 80.0 102 26.2 44.3 80.0 102 26.2 44.3 80.0 102 26.2 44.3 80.0 102 26.2 44.3 80.0 102 26.4 55.0 55.0 80.0 80.1 26.0 102 26.0 100 26.0 100000000000000000000000000000000000	24.8 31.8 22.8 25.4 37.6 55.1 25.4 37.8 55.1 25.6 36.1 55.9 56.8 35.7 35.5 55.0 31.7 35.5 55.0 31.7 35.5 55.0 24.1 37.5 25.6 45.0 24.1 37.5 26.6 47.3 40.5 26.6 47.3 40.5
15 114 T14 T74 Tra Tra <td></td> <td>13.4 10.3 13.4 10.3 15.0</td>		13.4 10.3 13.4 10.3 15.0
1.31 1.12 1.12 1.22 1.23 10.2 1.23 10.3 24.3 26.2 26.7 11.1 518 2.81 1.92 1.92 1.92 1.92 1.92 1.92 1.92 26.0 10.1 518 2.82 1.84 1.72 1.81 1.72 1.84 1.75 28.1 1.81 27.6 4.00 87.6 846 2.82 1.74 1.82 88.4 70.3 88.4 1.72 28.6 9.83 7.14 9.84 17.3 1.41 846 2.82 1.74 1.81 47.1 57.0 42.2 28.6 9.83 7.14 1.00 10.6 846 52.0 1.81 72.7 1.51 52.5 55.0 48.0 56.1 1.73 1.42 846 54.0 1.55 57.7 57.0 52.6 17.6 57.7 5.03 1.73 1.13 846 54.0 1.55 55.0 17.0 56.1 17.2 58.1 17.2 58.1 17.2 846 54.0 1.25 55.0 55.0 56.0 56.0 17.2 57.0 56.1 17.2 56.1	100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 100 1	14 17.5 14 17.5 14 15.7 14.8 15.7 17.6 17.6 17.8 15.7 17.9 15.7 17.6 15.7 16.6 22.0 16.6 22.0 16.6 22.0 16.1 57.9 16.5 22.0 16.6 20.2 16.7 51.3 16.8 20.4 16.8 20.4 16.8 20.4 16.8 20.4 17.4 50.9 17.4 50.9 10.9 10.2 10.9 12.2 10.9 12.4 10.9 12.4 10.9 12.4

SHEET S11 – DAYLIGHTING CASE STUDY scale: NTS

JULY 1, 4:00 PM

1 1 1 1 2	7.8 "10.2 "10.2 "10.2 "10.1 8.4 "10.6 "10.2 "17.3 "27.6 9.0 "10.2 "17.3 "27.6 "10.2 "17.1 9.0 "10.2 "17.3 "27.6 "10.2 "17.1 9.0 "10.2 "17.3 "27.6 "10.2 "17.1 9.0 "10.2 "17.3 "27.6 "10.2 "17.1 9.0 "10.2 "17.3 "27.6 "10.2 "17.1 9.0 "10.2 "17.2 "10.2 "10.3 "10.2 9.0 "10.2 "10.2 "10.3 "10.3 "10.3 9.0 "10.2 "10.2 "10.3 "10.3 "10.3 9.1 "10.3 "10.3 "10.3 "10.3 "10.3 9.1 "10.3 "10.3 "10.3 "10.3 "10.3 9.1 "10.3 "10.3 "10.3 "10.3 "10.3	13 14 15 <	26 23 10 23 34 24 26 23 23 23 24 26 24 24 26 24 24 26 24 24 26 24 24 26 24 24 26 26 24 26 24 26 26 24 26 26 24 26 <td< th=""></td<>
47.9 72.6 81.9 80.9 50.6 50.7 50.6 50.6 50.6 50.6 50.6 50.6 50.6 50.6 50.6 50.6 50.6 50.6 50.7 50.6 50.7 50.7 50.7 50.7 50.7 50.7 50.7 50.7 50.7 50.7 50.7 50.7			35 54 4.1 4.2 5.5 3.0 2.8 5.1 3.3 3.1 5.3 5.1 5.3 5.7 3.9 7.5 5.6 8.2 8.8 7.3 5.6 7.3 7.9 9.0 4.7 10.0 12.8 10.0 4.8 7.8 10.4 9.0 4.7 10.0 12.8 10.0 4.8 11.5 7.7 20.7 22.1 20.8 50.0 7.8.1 10.4 75.6 3.7 32.1 20.8 50.0 7.8.1 10.4
75.6 96.1 55.3 96.5 75.4 54.0 90.0 52.2 47.9 38.5 36.5 36.5 36.5 75.4 54.0 90.0 52.2 47.9 38.5 35.5 36.5 36.6 14.4 35.6 31.9 56.2 24.3 27.1 38.5 35.5 36.6 14.4 35.6 31.9 56.2 24.3 27.1 34.1 25.3 56.3 95.3 95.7 95.7 95.7 95.8 95.7 34.1 25.3 95.9 95.0 95.0 95.7 95.1 25.4 95.8 34.1 25.3 95.9 95.0 95.8 95.7 95.8 95.2 35.1 25.3 95.9 95.0 95.8 95.7 95.2 95.2 35.2 25.0 95.8 95.9 95.9 95.9 95.2 95.2 35.1 25.9 95.9 95.9 95.9 95.9 95.2 95.2 35.1 25.9 95.9 95.9 95.9 95.9 95.9 95.2 35.1 25.9 35.9 35.9 35.9 35.9 35.9 35.1	96.5 95.2 25.0 25.0 25.0 25.0 25.0 25.0 25.0 2	243 243 243 243 243 243 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 258 255 255	302 Bit 35 32 75 55 35 45 3
312 311 100 1000 1000 1000 1000 1000 100	100 2012 50.7 7 120 2012 50.3 7 120 2013 53.7 7 140 37.5 13.6 7 146 37.5 13.6 7 142 35.1 10 1 2 142 37.5 13.6 7 142 37.5 13.6 7 142 37.5 13.6 13	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	

SHEET S12 – DAYLIGHTING CASE STUDY scale: NTS

JULY 1, 7:00 PM

(SHEET	S13		DAYLIGHTING	CASE	STUDY
	OOALT. N	Ú F				

**************************************	115 155 255 2 125 153 25 125 153 25 125 153 25 140 217 3 140 2 150 3 150 3	BALZ TAN TAN<
Tr.4 Bang H200 51.2 50.7 55.6 *3.1 bang H200 51.2 50.7 55.6 *3.1 bang 12.2 33.6 55.3 51.9 bang 12.1 24.3 116.4 77.4 17.3 1000 bang 13.1 116.4 77.4 17.3 1000 bang bang 14.0 53.8 46.6 22.6 bang bang bang bang 14.4 14.3 bang bang bang bang 1000 bang bang bang 1000 1000		10 1.15 1.15 1.17 1.81 2.24 2.78 36.6 11.8 1.1.5 1.4.4 18.3 2.0.5 20.9 24.7 36.3 10 1.1.5 1.4.4 18.3 2.0.5 20.9 24.7 35.3 20.6 5.0 2.4.4 18.3 2.0.5 2.0.7 35.3 20.6 5.0 2.4.4 18.3 2.0.5 2.4.7 35.3 20.6 5.0 2.4.4 18.2 1.2.1 2.1.3 37.8 20.6 5.0 2.4.4 18.2 1.2.1 2.4.3 36.8 21.5 3.5.0 35.4 37.2 35.1.3 36.8 27.5 3.1.5 35.1.5 35.1.7 36.8 30.8 27.6 3.1.7 35.1.5 35.1.7 36.8 30.4 37.6 31.1.7 35.8 31.1 36.8 31.4 37.6 31.7 35.8 31.9 31.4 30.6 37.6 31.7 31.8 31.4 30.6 34.4 37.6 31.7 31.9 31.9 34.1 30.6 37.6 31.7 31.8 31.4 30.6 34.4
225 122 122 007 422 403 405 405 400 439 237 122 707 422 403 405 405 406 430 439 153 144 95 15 12 12 12 12 12 1 113 101 158 131 142 148 145 134 7,8 16 15 10 158 131 142 148 145 134 7,9 15 151 142 148 154 154 152 159 51 4,1 158 150 59 15 2,3 1,0 5,7 4,1 148 4,3 1,6 10 2,4 4,4 15 15 10 15 10 15 10 15 10 5,7 4,1 148 4,3 1,6 10 15 10 5,7 4,1 148 4,3 10 15 10 5,7 4,1 148		1 1 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 5 1 5 5 5 5 5 5 1 5
4 14 24 24 25 25 25 25 25 25 25 25 25 25 25 25 25		*1. *2. *2. *2. *2. *2. *2. *2. *2. *2. *2. *4.
by Jus Jus <td></td> <td>5.8 5.7 5.1 7.2 7.3 5.9 9.0 5.5 5.5 9.0 5.5 5.5 9.1 9.2 7.3 9.0 5.5 5.5 9.1 9.2 7.3 9.0 14.3 14.4 9.0 14.4 9.4 9.0 14.3 14.4 9.0 11.8 14.8 9.0 11.8 14.8 13.0 14.4 9.6 9.4 5.3 10.0 14.4 5.70 2.6 15.6 13.8 2.70 15.7 9.53 10.6 15.2 7.1.8 5.4 15.7 9.53 10.6 15.7 15.6 4.66</td>		5.8 5.7 5.1 7.2 7.3 5.9 9.0 5.5 5.5 9.0 5.5 5.5 9.1 9.2 7.3 9.0 5.5 5.5 9.1 9.2 7.3 9.0 14.3 14.4 9.0 14.4 9.4 9.0 14.3 14.4 9.0 11.8 14.8 9.0 11.8 14.8 13.0 14.4 9.6 9.4 5.3 10.0 14.4 5.70 2.6 15.6 13.8 2.70 15.7 9.53 10.6 15.2 7.1.8 5.4 15.7 9.53 10.6 15.7 15.6 4.66
132 165 37.4 40.8 bb2 31.7 42.3 13.6 132 165 37.4 40.8 bb2 31.7 42.3 13.6 21.7 268 27.5 21.4 17.3 20.1 26.4 25.2 41.4 269 16.1 12.6 10.4 15.1 15.0 72 24. 190 16.1 12.6 16.9 26.9 11.2 13.7 24. 190 16.1 12.5 16.9 26.9 7.8 15.1 15.7 25.2 17.9 16.1 12.5 16.9 26.9 7.8 15.1 15.7 26.1 26.5 13.5 10.3 15.3 15.1 7.1 15.3 15.8 15.8 15.8 15.8 15.8 15.8 15.8 15.8		56.3 25.4 96.5 95.5 13.2 13.2 13.2 13.2 13.2 13.2 13.5 55.5

OCTOBER 1, 7:00 AM

SCALE: NTS

85.4 boo 7a.2 85.7 39.8 70.5 ab bra 97.7 76.2 56.4 86.7 75.3 %5.2 70.6 ab bra 24.2 39.8 %4.9 80.5 52.3 73.8 251 %22 24.2 39.5 %4.1 53.8 %3.2 %50 241 %22 23.3 51.0 33.2 51.3 108 %51 123 240 23.3 51.0 33.2 51.3 108 %59 152 %69 23.3 77.6 97.5 82.2 13.8 %70 256 %51 23.3 77.6 97.5 82.5 %34 203 302 551 23.1 39.0 54.9 87.4 %11 %15 253 556 23.1 39.0 54.9 87.4 %11 %15 253 566 24.1 37.4 82.4 %11 %15 253 566 24.1 37.4 %23 302 %51 25.1 39.0 54.9 87.4 %11 %15 253 566		242 242 242 242 242 242 242 242 242 242
38.2 36.6 55.3 3.4 77.7 36.4 54.2 1 34.3 53.7 46.5 53.8 3.4 77.7 36.4 54.2 1 34.1 34.2 57.7 46.5 50.0 48.8 50.7 53.8 1 34.1 34.1 34.5 7.5.6 21.5 34.3 40.3 42.2 1 38.1 25.7 56.8 22.8 22.8 27.3 26.5 26.1 1 38.1 25.7 56.8 22.8 22.8 27.3 36.5 26.1 1 38.1 27.7 54.8 54.8 56.0 44.0 13.4 9.3 1 7.2 24 5.0 56.0 50.0 55.0 44.0 70.3 56.9 1 2.9 3.6 3.6 3.6 3.6 3.6 3.6 3.6 1 2.9 3.2 3.2 3.2 3.2 3.2 3.2 3.2 1 2.9 3.6 3.6 3.6 3.6 3.6 3.6 1 2.9 3.2 3.2 3.2 3.2 3.2 3.6 1 3.6		23.6 24.8 24.6 31.8 32.5 305 42.8 31.7 36.8 46.0 36.5 44.2 46.0 36.5 44.2 46.0 36.5 44.2 46.0 36.5 44.2 133 50.6 123 34.1 133 50.6 123 34.1 199 183 1776 50.7 199 183 178 50.2 199 183 178 50.2 289 284 132 78.6 289 284 132 78.6 289 284 132 28.6 289 284 132 28.6 289 284 132 28.6 289 280 210 27.8 289 286 28.6 28.6 289 28.6 28.6 28.5 289 28.6 28.6 28.5
730 588 97.8 77.9 481 24.6 90.8 94.4 85.4 335 52.0 57.2 54.8 47.2 55.5 55		17.5 17.5 17.5 17.5 17.5 17.5 17.5 17.5 17.5 17.7 27.7 26.0 24.0 24.3 36.1 50.1 50.1 50.0 46.8 42.6 46.6 35.8 37.8 35.1 35.1 50.1 50.7 37.3 47.4 35.8 37.8 35.1 50.1 50.7 37.3 47.4 35.8 37.6 12.9 37.5 11.6 136 35.0 11.0 12.8 37.5 11.5 135 35.0 11.0 11.8 18.8 17.5 155 31.5 35.0 11.0 11.8 18.8 37.5 155 31.5 25.0 26.0 26.0 26.0 26.0 26.0 26.0 26.0 36.0 36.1 36.3 26.9 26.0 26.0 26.0 36.0 36.4 56.3 37.4 136 26.5 26.0 36.0 36.4 37.4 36.6 36.9
11 1 </td <td></td> <td>22.4 "22.1 "13.8 28.7 "29.3 "27.4 28.5 "28.6 "34.6 "53.8 "58.2 "59.7 "55.2 "51.3 "49.6 "49.8 28.5 "28.6 "24.8 "53.8 "58.3 "55.0 "22.8 28.1 "15.9 "13.9 "58.4 "50.9 "52.8 "53.3 "49.6 "49.8 28.1 "15.9 "28.4 "50.9 "57.8 "50.9 "24.6 "45.1 "15 28.3 "15.8 "15.9 "15.1 "15.0 "25.8 "17.1 "15.8 "25.9 "25.8 "175 28.4 "15.9 "15.9 "15.1 "15.0 "25.8 "25.0 "25.8 "55.0 "25.8 "25.8 "25.8 "25.8 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.9 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.</td>		22.4 "22.1 "13.8 28.7 "29.3 "27.4 28.5 "28.6 "34.6 "53.8 "58.2 "59.7 "55.2 "51.3 "49.6 "49.8 28.5 "28.6 "24.8 "53.8 "58.3 "55.0 "22.8 28.1 "15.9 "13.9 "58.4 "50.9 "52.8 "53.3 "49.6 "49.8 28.1 "15.9 "28.4 "50.9 "57.8 "50.9 "24.6 "45.1 "15 28.3 "15.8 "15.9 "15.1 "15.0 "25.8 "17.1 "15.8 "25.9 "25.8 "175 28.4 "15.9 "15.9 "15.1 "15.0 "25.8 "25.0 "25.8 "55.0 "25.8 "25.8 "25.8 "25.8 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.9 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.8 "25.9 "25.9 "25.8 "25.9 "25.
b1_2 b4.3 b5.7 b8.1 77.6 b3.9 55.5 b1.4 55.7 b8.1 77.6 b3.9 55.5 30.8 55.5 b1.1 59.3 49.1 21.4 30.8 32.5 15.8 15.8 32.2 20.2 24.5 23.3 10.1 15.4 20.7 16.0 17.6 19.8 14.4 5.6 15.8 20.0 18.4 1.2.2 3.3 1.0 20.1 16.8 1.1 1.2.2 3.1 5.9 20.1 16.8 1.4.1 1.2.2 3.1 5.9	11:1 12:2 13:2 13:3 13:3 13:3 13:3 13:3	26.6 21.1 34.0 20.1 20.1 20.1 20.1 20.1 20.1 20.1 20
281 281 768 815 281 281 753 753 756 416 81.4 281 753 755 416 81.4 281 262 27.5 781 382 351 273 106 282 71.9 111 750 168 258 133 112 288 258 133 201 116 281 258 133 201 118 288 258 133 201 108 281 258 258 258	1 1	

SHEET S14 – DAYLIGHTING CASE STUDY scale: NTS

OCTOBER 1, 10:00 AM

(SHEET S15	ĺ	DAYLIGHTING	CASE	STUDY
	/ SCALE: NTS				

b1.2 b2.1 T2.3 b5.1 b0.0 56.4 b0.5 26.1 50.6 b4.1 57.3 34.0 57.3 32.6 26.1 50.6 b1.1 22.3 23.0 57.6 50.5 40.5 20.6 15.4 21.7 24.5 53.2 71.6 45.6 20.0 12.5 17.1 25.3 19.6 57.4 57.8 56.2 20.0 12.5 17.1 15.3 17.3 25.5 57.4 57.8 56.2 20.0 12.5 17.1 15.3 17.3 25.5 57.4 57.8 56.2 30.0 12.5 13.5 12.3 25.7 57.4 57.8 56.2 35.7 10.6 13.5 12.3 25.3 57.0 41.6 76.3 35.7 14.4 26.6 10.4 56.8 50.7 55.5 41.7 35.7 56.7 56.8 26.3 74.3 56.5 71.4 35.7 56.8 50.7 56.8 41.1 72.4 50.7 56.5 26.3 26.3 56.5 11.4 50.7 56.5 70.4 24.9 <t< th=""><th>"20.5 "30.4 "44.1 "52.9 "41.1 "10.9 "52.9 "41.1 "10.9 "53.1 "54.4 "57.3 "54.3 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.4 "52.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1</th><th>21.4 3.0.1 25.3 37.6 45.3 123 25.0 38.6 54.1 75.0 123 35.0 35.2 30.5 37.6 45.8 47.3 123 35.1 35.0 36.2 30.5 12.8 38.6 79.2 123 35.0 28.1 34.4 7.6 20.7 30.1 32.1 79.2 121 34.4 88.8 54.6 55.7 131.3 34.11 26.7 79.8 100 35.8 88.8 54.6 55.8 15.8 11.6 78.8 11.1 74.1 778 108 126 137 135 11.6 78.8 11.1 74.1 25.9 62.8 138 14.6 173 11.1 74.8 79.2 14.9 25.9 62.8 138 14.6 173 14.1 74.8 79.2 14.9 25.9 62.8 138 14.8 173 14.1 26.7 79.4 14.1 74.1 26.9 56.7 24.1 21.8 26.8 50.9 14.5 24.5 14.9 26.0 36.2 54.7 24.1 21.8 26.5 50.9 14.5 24.5 14.9 26.0 36.7 24.1 21.8 25.8 53.0 51.0 22.4 14.1</th></t<>	"20.5 "30.4 "44.1 "52.9 "41.1 "10.9 "52.9 "41.1 "10.9 "53.1 "54.4 "57.3 "54.3 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.3 "52.2 "54.1 "54.4 "52.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.2 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1 "54.6 "56.0 "54.1	21.4 3.0.1 25.3 37.6 45.3 123 25.0 38.6 54.1 75.0 123 35.0 35.2 30.5 37.6 45.8 47.3 123 35.1 35.0 36.2 30.5 12.8 38.6 79.2 123 35.0 28.1 34.4 7.6 20.7 30.1 32.1 79.2 121 34.4 88.8 54.6 55.7 131.3 34.11 26.7 79.8 100 35.8 88.8 54.6 55.8 15.8 11.6 78.8 11.1 74.1 778 108 126 137 135 11.6 78.8 11.1 74.1 25.9 62.8 138 14.6 173 11.1 74.8 79.2 14.9 25.9 62.8 138 14.6 173 14.1 74.8 79.2 14.9 25.9 62.8 138 14.8 173 14.1 26.7 79.4 14.1 74.1 26.9 56.7 24.1 21.8 26.8 50.9 14.5 24.5 14.9 26.0 36.2 54.7 24.1 21.8 26.5 50.9 14.5 24.5 14.9 26.0 36.7 24.1 21.8 25.8 53.0 51.0 22.4 14.1
27 28.8 102 100 101 56.4 56.4 16.6 14.9 32.3 27.7 28.6 40.3 58.2 56.0 19.2 19.1 19.1 18.4 56.4 14.5 37.1 26.7 32.0 58.2 56.0 19.2 19.1 19.1 19.1 19.2 57.1 26.9 51.8 32.8 42.9 42.1 38.1 12.8 10.0 36.2 36 31.8 52.7 28.8 41.2 31.8 11.2 36.0 77.3 20.1 26.3 37 34.9 54.8 21.7 28.8 31.2 34.8 37.2 36.1 34.4 31.1 36 34.9 54.7 38.8 31.2 34.4 36.1 36.1 36.1 37 54.7 54.8 34.4 51.1 54.7 54.8 54.1 36 54.7 54.8 54.8 54.8 54.8 54.8 54.8 36 54.7 54.8 54.8 54.8 54.8 54.8 36 54.7 54.8 54.8 54.8 54.8 36 54.7 54.8 54.8		26.3 25.4 24.3 24.5 24.5 26.4 26.5 25.4 26.3 25.4 26.1 20.5 35.4 35.2 26.0 26.1 20.5 36.2 25.7 35.3 35.6 26.1 30.5 36.2 25.7 37.3 36.6 27.5 36.7 37.3 37.3 36.6 27.5 36.7 37.3 36.6 36.0 27.5 36.1 36.7 34.3 36.6 97.2 37.4 96.7 41.9 36.0 97.2 37.4 96.7 10.7 86.6 97.4 191 215 22.0 21.7 20.6 97.4 191 215 22.0 21.7 20.6 25.5 26.7 52.0 21.7 20.6 20.7 25.5 26.5 56.7 57.2 24.4 36.6 14.4 36.7 56.2 24.4 36.6 26.4 26.5 76.3 76.3 56.2 24.4 36.6 26.5 76.5 76.3 56.2 24.4 36.6 26.6 76.3 76.2 76.3 76.2
Hule Base Rand Hull Para Para <th< td=""><td></td><td>13.0 13.0 13.0 13.8 13.0 13.0 13.8 13.8 14.0 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.2 15.1 15.1 15.1 15.1 15.1 15.1 15.2 15.5 15.1 14.0 14.0 15.7 15.1 15.1 15.5 15.5 15.1 10.0 17.4 12.7 16.1 15.0 25.0 26.0 17.1 15.0 27.5 4.6 16.1 17.0 25.0 7.1 17.1 17.5 4.46</td></th<>		13.0 13.0 13.0 13.8 13.0 13.0 13.8 13.8 14.0 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.1 15.2 15.1 15.1 15.1 15.1 15.1 15.1 15.2 15.5 15.1 14.0 14.0 15.7 15.1 15.1 15.5 15.5 15.1 10.0 17.4 12.7 16.1 15.0 25.0 26.0 17.1 15.0 27.5 4.6 16.1 17.0 25.0 7.1 17.1 17.5 4.46
Bos Too Too Too Too Too Doo Too Too <td></td> <td>27.2 27.4 26.2 23.0 33.4 33.8 33.5 51.1 33.4 33.8 53.5 51.1 40.5 32.6 44.5 53.7 86.1 53.7 49.0 70.4 57.7 95.6 40.1 70.4 57.7 56.0 86.5 72.8 35.6 40.1 70.4 57.7 56.0 86.5 10.3 35.6 40.1 70.4 57.1 56.3 56.3 10.3 35.6 40.1 10.4 57.1 56.3 56.4 14.0 71.2 97.6 35.1 79.7 98.5 14.0 71.2 91.6 30.0 31.4 31.7 15.0 21.1 87.7 350.3 31.4 31.7 18.0 85.4 29.0 21.7 49.8 53.1 19.0 31.0 31.1 40.1 35.8 31.7 19.0 31.0 31.1 40.1 31.7 49.8 19.0 31.0 31.8 31.7 49.8 53.1 10.6 31.0 31.0 31.7 49.8 53.1 10.6 31.0 31.0</td>		27.2 27.4 26.2 23.0 33.4 33.8 33.5 51.1 33.4 33.8 53.5 51.1 40.5 32.6 44.5 53.7 86.1 53.7 49.0 70.4 57.7 95.6 40.1 70.4 57.7 56.0 86.5 72.8 35.6 40.1 70.4 57.7 56.0 86.5 10.3 35.6 40.1 70.4 57.1 56.3 56.3 10.3 35.6 40.1 10.4 57.1 56.3 56.4 14.0 71.2 97.6 35.1 79.7 98.5 14.0 71.2 91.6 30.0 31.4 31.7 15.0 21.1 87.7 350.3 31.4 31.7 18.0 85.4 29.0 21.7 49.8 53.1 19.0 31.0 31.1 40.1 35.8 31.7 19.0 31.0 31.1 40.1 31.7 49.8 19.0 31.0 31.8 31.7 49.8 53.1 10.6 31.0 31.0 31.7 49.8 53.1 10.6 31.0 31.0
72.4 72.4 72.4 71.7 72.8 90.3 79.9 101 162 151 121 72.6 151 54.0 57.3 258 161 126 70.6 55.3 50.1 57.3 258 161 126 70.6 55.3 50.1 57.3 258 161 126 70.6 55.3 50.1 57.3 260 131 112 70.5 55.4 50.6 56.3 260 131 132 70.5 55.6 51.3 50.3 260 131 132 70.5 55.6 51.3 50.3 260 131 75.7 55.6 51.2 50.3 260 112 53.2 53.2 53.2 54.3 26.6 112 43.2 55.6 51.2 58.0 26.6 112 43.2 54.2 54.3 54.3 26.8 101 71.2 54.2 54.3 54.3 26.8 101 71.2 54.2 54.3 54.3 26.8 101 102 102 105 54.3 26.8 101 101 102 </td <td>142 142 145 145 145 145 145 145 145 145</td> <td>300 101 730 101 101 101 241 241 241 0.5 10.5 10.5 422 241 10.5 10.5 10.5 10.5 422 241 10.5 10.1 10.5 10.5 256 71.4 10.5 10.1 10.5 10.5 256 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.5 71.3 20.4 10.5 10.5 268 71.5 71.5 71.5 71.5 10.5 27 10.5 10.5 10.5 10.5</td>	142 142 145 145 145 145 145 145 145 145	300 101 730 101 101 101 241 241 241 0.5 10.5 10.5 422 241 10.5 10.5 10.5 10.5 422 241 10.5 10.1 10.5 10.5 256 71.4 10.5 10.1 10.5 10.5 256 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.2 71.3 20.4 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.4 10.5 10.5 10.5 10.5 268 71.5 71.3 20.4 10.5 10.5 268 71.5 71.5 71.5 71.5 10.5 27 10.5 10.5 10.5 10.5

OCTOBER 1, 1:00 PM

	16.2 21.1 20.1 46.6 16.0 22.4 0.3 36.6 16.0 22.4 0.3 36.6 16.0 22.4 0.3 36.6 27.8 0.2 26.6 0.4 26 0.4 26 0.5 20.0 26.6 0.4 2 0.4 0.6 0.5 16.5 24.8 0.7 0 26.6 0.4 0.5 16.5 24.8 0.7 0 26.6 0.4 0.5 16.5 24.8 0.7 0 26.7 16.5 24.8 0.7 0 26.8 16.5 24.8 0.7 0 26.8 0 26.8 16.5 24.8 0.7 0 26.8 0	142 122 123 144 144 144 144 144 144 144 144 144 14
bis 550 341 244 467 565 551 443 200 564 252 50 283 757 357 357 357 258 255 51 120 183 255 253 751 377 160 108 122 156 185 255 25 371 160 108 128 156 165 255 25 56 25 55 55 56 56 55 55 75 24 25 55 56 56 56 55 54 45 27 25 25 50 32 54 56 25 45 27 25 25 35 36 32 54 56 25 45 27 25 25 35 35 35 26 25 54 55 45		10.3 315 13.8 1.34 13.8 1.34 13.0 1.72 13.0 1.72 13.1 1.7.6 14.1 1.6.4 16.3 1.7.6 17.2 1.7.8 16.3 1.7.2 17.2 1.7.8 16.3 1.7.2 17.2 1.7.8 16.4 1.4.3 17.2 1.7.8 17.2 1.7.8 17.2 1.7.8 17.2 1.7.8 18.0 82.5 19.1 12.6 15.1 12.6 15.1 12.1 15.1 12.5 15.2 10.6 10.7 10.5 20.6 14.0 10.7 10.6 10.7 10.5 20.6 24.7 10.3 1.8.2 10.3 1.8.2 10.3 1.8.2 10.3 1.8.2
969 50.5 *29.3 %3.8 %0.7 53.8 %0.8 %2.5 97.1 35.5 50.5 \$2.8 %0.7 53.8 %0.8 %0.8 23.3 23.3 73.8 %0.7 53.8 %0.8 %0.8 23.3 23.5 52.8 %0.7 53.8 %0.8 %0.8 15.4 %0.8 %1.4 %0.8 %0.8 %0.8 %1.5 15.5 %1.4 %0.8 %1.6 %1.5 %1.6 15.6 %0.8 %1.7 %1.5 %1.5 15.7 %0.8 %1.7 %1.5 %1.5 15.7 %0.8 %1.7 %1.5 %1.5 15.7 %0.8 %1.7 %1.5 %1.5 15.8 %1.8 %2.8 %1.8 %1.5 15.8 %1.8 %2.8 %1.8 %1.5 15.7 %1.8 %2.8 %1.8 %1.5 15.7 %1.8 %2.8 %1.8 %1.5 15.8 %1.8 %2.8 %2.8 %1.6 15.8 %1.8 %2.8 %2.8 %3.0 15.7 %1.8 %2.8 %3.0 15.7 %2.8		Ba 84 9.5 9.02 11.8 9.5 12.3 13.6 16.8 9.45 17.5 15.7 Bo.1 21.6 23.4 23.1 20.8 9.90 17.8 26.9 33.2 28.7 22.4 9.65 21.2 57.1 26.9 33.2 28.7 22.4 9.65 26.7 57.1 26.5 51.0 39.6 9.7.3 80.7 59.7 57.1 26.5 51.0 39.6 9.7.3 80.7 59.7 57.1 26.5 51.0 39.6 9.7.3 80.0 50.4 51.1 35.1 71.4 89.8 2.6 77.3 80.7 50.4 51.1 35.1 36.5 9.5 9.7.3 97.0 70.4 51.2 12.6 11.9 35.2 95.0 15.7 20.4 51.3 13.6 11.9 35.2 95.0 19.7 20.4 51.3 13.6 13.6 13.7 20.5 10.7 52.9 50.6 50.1 53.2 20.5 50.0 51.0
B4.8 40.6 55.5 44.1 47.7 30.8 39.7 10.5 34.8 9.1 27.7 30.8 25.0 21.4 10.2 34.8 9.1 26.2 25.0 15.6 4.7 30.6 14.7 14.7 3.4.7 30.8 15.6 4.7 30.6 14.7 14.7 3.4.7 9.0.1 11.8 8.7 7.2 0.3 10.4 8.2 8.4 9.5 8.7 7.9 9.1 14.7 3.4.7 9.0.1 11.8 8.7 7.2 0.3 10.4 8.2 8.5 9.5 8.5 7.7 9.8 8.1 8.2 5.8 9.1 5.7 7.9 8.1 8.2 5.8 7.1 5.7 5.0 5.1 5.8 7.1 5.7 5.0 5.1 5.8 7.1 5.7 5.0 5.1 5.8		Table
B2.1 15.3 49.2 94.3 44.3 39.5 95.5 91.5 32.2 40.3 35.5 95.4 34.3 35.5 95.7 90.4 91.5 32.2 40.3 35.5 35.5 35.5 35.5 35.5 36.5 95.8 2.4 35.5 35.5 25.1 35.5 35.1 35.5 95.8 2.6.7 21.6 25.4 35.6 95.1 35.5 95.8 2.6.7 31.6 35.1 35.6 35.7 35.6 95.8 2.6.7 31.6 35.1 35.2 35.6 35.7 95.3 2.6.1 31.6 32.7 31.6 35.7 35.6 95.3 2.6.1 31.3 32.3 35.6 35.7 35.6 94.1.6 2.6.1 31.3 3.3 35.8 35.7 36.6 44.4 30.1 20.6 34.3 35.3 35.9 37.1 36.6 44.4 30.1 30.5 34.3 35.3 37.9 37.1 36.6 44.4 30.1 30.6 36.6 37.3 37.3 37.9 36.7 14.4.3 9.0.6 36.6 <td></td> <td>'19.8 '17.2 '15.0 '12.8 '19.8 '17.4 '15.6 '21.6 '19.9 '17.4 '15.6 '24.0 '22.8 '22.3 '21.0 '21.6 '24.0 '22.8 '22.3 '21.0 '21.0 '24.0 '22.8 '22.3 '21.0 '21.0 '24.0 '22.8 '22.8 '23.4 '23.7 '25.5 '27.9 '23.8 '23.8 '23.7 '25.5 '25.4 '25.8 '23.8 '20.7 '17.5 '42.8 '3.6 '33.8 '55.5 '17.5 '42.9 '14.6 '53.8 '20.4 '17.5 '12.7 '14.6 '53.8 '20.4 '17.6 '25.4 '12.9 '14.6 '53.8 '17.7 '25.6 '57.8 '20.4 '21.1 '25.6 '51.1 '22.8 '22.8 '22.8 '31.4</td>		'19.8 '17.2 '15.0 '12.8 '19.8 '17.4 '15.6 '21.6 '19.9 '17.4 '15.6 '24.0 '22.8 '22.3 '21.0 '21.6 '24.0 '22.8 '22.3 '21.0 '21.0 '24.0 '22.8 '22.3 '21.0 '21.0 '24.0 '22.8 '22.8 '23.4 '23.7 '25.5 '27.9 '23.8 '23.8 '23.7 '25.5 '25.4 '25.8 '23.8 '20.7 '17.5 '42.8 '3.6 '33.8 '55.5 '17.5 '42.9 '14.6 '53.8 '20.4 '17.5 '12.7 '14.6 '53.8 '20.4 '17.6 '25.4 '12.9 '14.6 '53.8 '17.7 '25.6 '57.8 '20.4 '21.1 '25.6 '51.1 '22.8 '22.8 '22.8 '31.4
100 221 223 223 125 815 80.9 58.8 260 224 961 52.3 51.6 50.9 58.8 222 30 985 94.2 161 52.3 51.9 50.9 58.8 252 30 985 94.2 161 54.6 20.3 27.9 266 91.0 168 94.2 161 54.6 20.3 27.9 266 91.0 161 94.4 107 73.9 50.0 260 91.0 35.3 124 105 75.7 59.0 260 24.0 35.3 124 105 75.7 59.0 260 24.0 256 97.9 105 75.7 59.0 265 24.0 256 173 121 104 75.8 57.5 265 24.0 256 173 121 104 75.8 57.5 265 24.0 256 173 121 104 75.8 57.5 265 24.0 256 123 105 75.0 105 75.0 105 75.8	252 253 253 254 255 253 254 255 255 255 255 255 255 255 255 255	102 142 102 144 102 144 102 144 102 144 102 145 102 145 103 155 158 103 155 158 103 157 103 157 103 157 104 105 105 157 106 1657 107 1772 108 164 108 164 10

SHEET S16 – DAYLIGHTING CASE STUDY scale: NTS

OCTOBER 1, 4:00 PM

E

COST PER DAY ******		3.27																				
AVERAGE ENERGY USE PER DAY*****			88.88																			
COCT DED	COST PER DAY****			\$4.12					\$3.10				\$2.65				\$3.20					
AVERAGE	_			10.57				7.95				6.80				8.21						
ES DIMMED TO VATTS CONSUMED AT % LUMEN KWh USED AT	SPECIFIED	TIME***	15.87	6.07	5.26	9.77	15.87	8.98	4.20	4.22	6.50	15.87	6.31	4.77	4.63	6.77	11.53	8.92	4.50	4.61	7.16	15.87
JMEN		100%	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
AT % LI	**	75%	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
TS CONSUMED	OUTPUT**	50%	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
		25%	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
WAT		%0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
ED TO	PUT	100%	248	37	38	20	248	57	23	32	46	248	22	19	25	42	108	52	28	35	48	248
S DIMM	IEN OUTPUT	75%	0	26	19	72	0	39	13	15	26	0	43	20	18	41	59	62	10	15	24	0
IXTURE		50%	0	26	21	22	0	50	33	13	26	0	27	34	22	21	26	32	32	12	35	0
NUMBER OF FIXTURI	SPECIFIED % LUIV	25%	0	34	22	16	0	35	10	17	29	0	44	26	29	28	12	29	17	26	39	0
NUMB	SPE	%0	0	125	148	68	0	67	169	171	121	0	112	149	154	116	43	73	161	160	102	0
	TIME		7:00 AM	10:00 AM	1:00 PM	4:00 PM	7:00 PM	7:00 AM	10:00 AM	1:00 PM	4:00 PM	7:00 PM	7:00 AM	10:00 AM	1:00 PM	4:00 PM	7:00 PM	7:00 AM	10:00 AM	1:00 PM	4:00 PM	7:00 PM
	DATE			JANUARY 1	JANUARY 1	JANUARY 1	JANUARY 1	APRIL 1	APRIL 1	APRIL 1	APRIL 1	APRIL 1	JULY 1	JULY 1	JULY 1	JULY 1	JULY 1	OCTOBER 1	OCTOBER 1	OCTOBER 1	OCTOBER 1	OCTOBER 1
	SHEET*		N/A	S1	S2	S3	N/A	S4	S5	S6	S7	N/A	S8 S8	S9	S10	S11	S12	S13	S14	S15	S16	N/A

DAYLIGHT STUDY CALCULATIONS

NOTES:

* Sheet/Date/Time correspond with sheets in Appendix E

** Values come from "Energy Savings' graph on ballast cutsheet (see Appendix C). Percent power usage at each dimming level was multiplied by (2 lamps) at 32VV each divided by the ballast factor (1.00)

*** Average kWh consumed at a particular time of the day was found by multiplying (# of fixtures at % lumen output) by the corresponding (watts consumed at % lumen output). This value was divided by 1000 to change VM to kWh. **** Average kWh consumed at any time of the day for each date was found by averaging the kWh at each of the five time of the day for each date.

***** Energy cost per day for each date was calculated by multiplying the average energy use for that day by 12 hours of building occupancy times the energy rate of \$0.03246. See calculations on next page for to see how energy rate was calculated.

***** Average kWh consumed per day for any day of the year was calculated by averaging the kWh consumed for each date.

****** The average energy cost per day for any day of the year was calculated by multiplying the average kWh consumed for any day of the year by 12 hours of building occupancy times the energy rate of \$0.03246

Appendix E - Case Study Calculations

CASE STUDY CALCULATIONS

CALCULATING COLORADO ENERGY RATE

The following energy rates for Colorado were found on www.xcelenergy.com Rate for Summer Season (June 1st-September 30): \$0.03497 Rate for Winter Season (October 1-May 31): \$0.03120 A weighted average based on number of days was used to calculate an average energy rate that could be applied to the whole year = \$0.03246

ENERGY COSTS

ESTIMATED COST PER YEAR FOR USING DIMMING: (COST PER DAY FOR ALL DATES (\$3.27))x(365 DAYS) \$1,191.93

BASELINE CALCULATION:

ESTIMATED COST PER YEAR USING 100% LUMEN OUTPUT AT ALL TIMES OF OCCUPANCY: (248 BALLASTS)x((64 W/BALLAST)/1000)x(12 HOURS)x(\$0.03246/kWh)x(365 DAYS) \$2,256.60

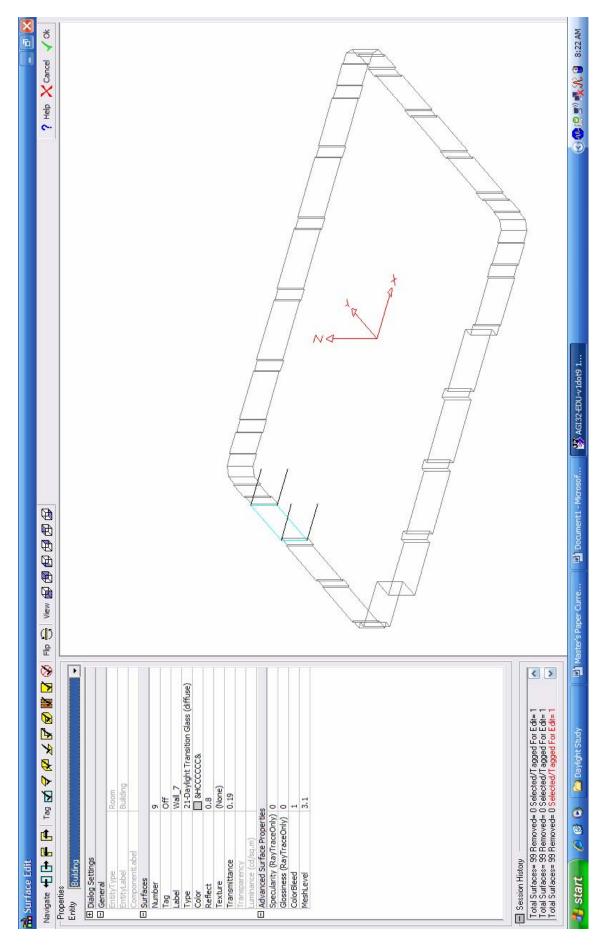
ENERGY COST SAVINGS FROM DIMMING: (BASELINE COST) - (COST USING DIMMING) \$1,064.67

PERCENT SAVINGS: (\$1,065/\$2,257)x100 47.19%

Appendix F - Case Study AGI-32 Screen Shots

	Set Parameters	Set Dates and Times	Ok
General Study Name [[Daylight Study		Cancel
Image Type		Label Images	Help
RGB Only	C Pseudo Only C RGB And Pseudo	🔽 Study Name 🔽 Compass North	
Generate In	nages for All Defined Viewpoints	🔽 Site Name 🔽 Sky Conditions	Start
🔲 Ray Tracing) Images	✓ Latitude/Longitude ✓ Date/Time	Start
🔽 Save Rei	erated AGI32 Job Files ndered Environment Files (Radiosity Solutio	n Files)	
🔽 Save Rei		n Files)	
 ✓ Save Report ✓ Create Tab D Daylight 	ndered Environment Files (Radiosity Solutio		
 ✓ Save Rei ✓ Create Tab D Daylight Site Location 	ndered Environment Files (Radiosity Solutio elimited Text File For Each Sample		
✓ Save Rei ✓ Create Tab D Daylight	ndered Environment Files (Radiosity Solutio elimited Text File For Each Sample LAI World Headquarters - Littleton, Colo		

Set Paramet	ers	ľ	Set Dates and Times				
ate And Time Sample							
Date	Time		Daylight Savings			Cancel	
1/1/2007	10:00:00 AM		O True 💿 False	Ø		11-1-	
1/1/2007	1:00:00 PM		C True 💿 False	8		Help	
1/1/2007	4:00:00 PM		C True 💿 False				
4/1/2007		C True 💿 False					
4/1/2007	10:00:00 AM		C True			Start	
4/1/2007	1:00:00 PM		O True ⊙ False	2			
4/1/2007	4:00:00 PM		C True 💿 False	8 I I I I I I I I I I I I I I I I I I I			
7/1/2007	7:00:00 AM		O True ⊙ False	8			
7/1/2007	10:00:00 AM		O True ⊙ False	8			
7/1/2007	7/1/2007 1:00:00 PM						
7/1/2007	4:00:00 PM		O True				
7/1/2007	7:00:00 PM		O True				
10/1/2007	7-00-00 AM		O True				
	Load	Save	Delete All	Add			
ky Conditions - Select One Or	More	Elec	tric Lighting - Select One	e Or Both			
🖊 Clear Sky			Dn 🔲 Off				
Partly Cloudy							
🗌 Overcast		Num	nber Of Samples	7.6	_		
🗌 General Sky - Type 1		#	<date and="" sample<="" td="" time=""><td>es> 16</td><td></td><td></td></date>	es> 16			
🗌 General Sky - Type 2							
🗌 General Sky - Type 3			x # <sky condition<="" td=""><td>ns> 1</td><td></td><td></td></sky>	ns> 1			
🗌 General Sky - Type 4		💌 🛛 🗴 ±	KElectric Lighting Option	ns> 1	_		
Absolute Zenith Luminance Fa	178112 - 1862 - 187						



Appendix G - Permissions

All images not created by the author are used with permission from the original source.

Figure 4-1

Used with permission from Watt Stopper

You have our permission to use the product photo for your school report. Joy Null Director of Public Relations Watt Stopper/Legrand Tel: 408-486-7503

Figures 3-1, 7-1, & 7-2

Used with permission from Advance Transformer

You can utilize the figures in our ABC's of DALI brochure. Please provide appropriate credit. Stuart Berjansky Senior Product Manager, Dimming and Controls Advance Tel: 847-390-5334

Figures 4-3 & 4-4

Used with permission from Starfield Controls

You may use our images as long as there is full credit given as Starfield Controls components Greg Dreith Starfield Controls Tel: 303-427-1661

Figure 4-2

Used with permission from Tridonic John Koffler VP Sales & Marketing, Tridonic.USA Tel: 770-717-0556