SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Task 31: Daylighting Buildings in the 21st Century

Daylight Control Systems
CALIBRATION & COMMISSIONING GUIDE

IEA Solar Heating & Cooling Programme
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DAYLIGHT CONTROL SYSTEMS
CALIBRATION AND COMMISSIONING GUIDE

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CALIBRATION & COMMISSIONING GUIDE

EXECUTIVE SUMMARY

If a lighting control system is not calibrated and commissioned correctly, it is unlikely that the design intent – occupant satisfaction and significant energy savings – will be achieved.

Failure to commission control systems has been noted as one of the single greatest reasons for the failure of daylighting systems to save energy. Furthermore Lighting controls in a number of applications are not properly commissioned and many operational problems are there from start-up.

The range of control systems in the marketplace and diverse range of projects means that specific advice needs to be sought from the system provider when preparing a procedure for calibration and commissioning each project. It is not intended that reliance can therefore be placed on this guide alone when formulating such a procedure.

It remains the case however that there is little by way of generic information devoted to the topic. So the intention of this guide is to list matters to consider as a prompt to preparing a project specific Calibration & Commissioning Procedure.

A series of checklists are provided which it is expected will provide a starting basis. The Calibration & Commissioning Guide steps through several sections comprising Pre-Commissioning, Commissioning, Handover and Post Occupancy

It also recognises that Daylighting Controls in practice more commonly occur as part of a raft of lighting control strategies.
These may include Occupancy Sensing, Time Based Scheduling, Tuning and others.

It is therefore expected that Daylighting Controls Commissioning will be consolidated into a more general lighting controls commissioning document. This is acknowledged and aided at specific points.

Beyond the scope of this guide are the important areas of Commissioning Shading Controls, Advanced Daylighting systems and Advanced Daylighting Control Systems using complex algorithms such as Adaptive Control. Invariably such systems require specialist guidance when commissioning.

This guide provides some further background in 2 keys areas where there are noted dependencies for effective control systems performance.

These are in the area of *Barriers to effective calibration and commissioning* (Appendix A) and *Photosensor design and placement* (Appendix B).

A list of references is contained as section 4 to this guide.

CALIBRATION & COMMISSIONING GUIDE

1. INTRODUCTION

1.1 Scope of Guide

There are a wide variety of lighting control systems with corresponding variations in the calibration and commissioning requirements.

No single document can hope to encompass the range of control systems in the marketplace and diverse range of projects. Always specific advice should be sought from the system provider when preparing a procedure for calibration and commissioning a particular project.

It remains the case however that there is little by way of generic information devoted to the topic. So the intention of this guide is to list matters that may be included when preparing a Calibration & Commissioning Procedure specific to the project at hand.

This Guide considers Daylight Controls Systems only. However it is recognized that Daylighting Controls in practice more commonly occur as part of a raft of lighting control strategies. These may include Occupancy Sensing, Time Based Scheduling, Tuning and others. It is therefore expected that application will most probably seek to consolidate Daylighting Controls Commissioning into a more general lighting controls commissioning document. This is acknowledged and aided at specific points in the text.

Commissioning of Shading Controls and / or Advanced Daylighting systems is important but is beyond the scope addressed here. Similarly Advanced Daylighting Controls systems using complex algorithms such as Adaptive Control will invariably require specialist guidance.

The topic of calibration was introduced in the IEA SHC Task 21. Subsequently several publications have reviewed the field performance of Daylight Control Systems including a significant research study on photosensor products published in 2000 by Bierman & Conway in the United States which reported “We found no standard performance or technical specification, no standard test procedure or technical specification, no standard commissioning procedure, and no detailed guidelines for commercial building illumination applications.” The study went on to comment “.A generic commissioning guide would be very useful to field personnel and to energy service companies or others who must verify correct operation and deliver guaranteed energy savings.” Efforts along these lines have occurred. For example The Seattle City Light ‘Standard Commissioning Procedure for Daylighting Controls’ has provided a useful style and content reference

This Document seeks to make a further step in this direction by compiling various commentary and recommendations. A List of References is enclosed from which material has been drawn and in many cases quoted.

Ultimately however the Process and Checklists provided here are with the intent to prompt not prescribe.

They are simply one reference for those preparing a commissioning procedure which must invariably be specific to each project and the systems used

1.2 Calibration & Commissioning - Definitions

Commissioning

"…a systematic process that ensures that all elements of the daylighting system perform an interactively and continuously according to documented design intent and the needs of the building owner." The Illuminating Engineering Society of North America (IESNA) Handbook

Calibration is defined as

That subset of activities that relates directly to the proper functioning of an electrical or mechanical sensor. It refers to an electrical or mechanical adjustment to a sensor to obtain the desired output from the sensor given the actual range of the input (a physical parameter such as light).'

1.3 The Importance of Calibration & Commissioning

If a Daylight Control system does not operate in accordance with occupant expectations the risk is run that occupants will defeat the system. The consequence is that rather than be energy efficient the system will conversely end up in a state which causes maximum energy consumption. This is primarily because failure modes result in maximum light output for safety reasons.

If a lighting control system is not calibrated and commissioned correctly, it is unlikely that the design intent – occupant satisfaction and significant energy savings – will be achieved. It is important to consider that Calibration and Commissioning will not correct a Daylight Control System design that is flawed to begin with.

Failure to commission control systems has been noted as one of the single greatest reasons for the failure of daylighting systems to save energy. Furthermore Lighting controls in a number of applications are not properly commissioned and many operational problems are there from start-up. Successful commissioning eliminates these problems before occupants arrive and gets the building off on the right track.

1.4 Recommissioning

When standardised maintenance and energy management procedures fail to fix chronic building problems, recommissioning provides s systematic approach for discovering and solving them.

Recommissioning entails the examination of actual building equipment systems operation and maintenance procedures for comparison to intended or design operation and maintenance procedures. Hence the need to well document the original procedures in the first place.

2. FORMAT

The Guide is divided in several sections which comprise, Pre-Commissioning, Commissioning, Handover and Post Occupancy.

2.1 Pre-Commissioning

In this phase the following tasks are carried out:

1 Confirming Commissioning Budget & Resources
1 Compiling a List of the reference documentation:
1 Agreeing the functional description for the control system
1 Obtaining Involvement of the Key Players
1 Draft Commissioning Manual Preparation
1 Agree Commissioning Timing & Format
1 Pre-Commissioning Inspection

2.2 Commissioning

This phase involves

1 Daylight Zone Schedule compilation
1 Photosensor Installation Visual Inspections
1 Calibration of Photosensors (refer also Generic Calibration Procedure and Calibration Fault Diagnostic Chart)
4 Daylight Control System Installed Characteristics Inspection
5 Nameplate Data Verification
6 Performance Verification
7 Networked Controls Verification (where applicable)

2.3 Handover Checks

Handover includes:

1 Documentation updated from Draft to Final
2 Training provisions for Occupants and Operations & Maintenance Personnel
3 Consideration of Specilaist Maintenance Contracts
4 Recommissioning Procedure Performance Verification

2.4 Post-Occupancy Checks

Post Occupancy Checks include

1 Occupant Comfort Check to verify satisfaction with system
2 Resource check to verify availability of calibration and commissioning equipment
3 Verification of maintenance procedures
4 Identification of further improvement opportunities,

3. CALIBRATION & COMMISSIONING BASIC GUIDE - DAYLIGHTING CONTROLS

*BUILDING NAME:*____

*BUILDING ADDRESS*_____________________________________

PROJECT TYPE (New/Retrofit/Recommission) __________________

*NAME & FIRM OF TEST PERSON*_____________________________

*DATE OF TEST(S)*____

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FOREWORD

Consult manufacturers of systems first to determine recommended calibration and commissioning procedures relevant for inclusion.
It is expected this will result in checklists edited to the specific installation.

It is also expected the Commissioning Agent will wish to add sections dealing with other forms of Lighting Controls. In this instance it is expected that Sections A, C, D and E may then become common sections to an overall Lighting Controls Commissioning Procedure.

Prevailing occupational health and safety standards and fire and life safety regulations may also indicate further items for consideration.

Section A	Pre-Commissioning Checks Expect to suffice as a common lighting controls front end section.	
Section B	Commissioning Checks	
	Section B1	Daylighting Controls Commissioning Checks
	+ Possible	
	(Section B2)	Occupancy Controls
	(Section B3)	Time Based Scheduling
	(Section B4-B'x')	(additional sections determined in consultation)
Section C	Networked Controls Commissioning Checks Expected to form a common section for all lighting controls. Elaborated to suit specific network architectural design and regard to project circumstances eg other system interfaces.	
Section D	Handover Checks Expand section as required to cover other Lighting Controls	
Section E	Post Occupancy Checks Expand section as required to cover other Lighting Controls	
Section F	Glossary of Terms Expand section as required to cover other Lighting Controls Terminologies	

A. Pre-Commissioning Example Checklist (Common Provision for all Lighting Controls)

Plan to Succeed – Pre-Commissioning Planning

Many of the barriers to effective calibrating and commissioning (refer Appendix A) are surmountable with basic planning.
Several, such as Ergonomics, Sensitivity and Application Data need to be addressed at the initial design stage.
Others such as Control System expertise, and Logistical barriers can be addressed through proper planning at the Pre-Commissioning Stage. Logistical issues require early consideration and contingency planning.

Suitable conditions for calibration and commissioning need to be obtained. Consider whether it is better to defer calibration and commissioning until occupancy has occurred even if this means allowing the Lighting Control System to operate lighting at full output rather than invite occupants to become disaffected and reject a system that has been inadequately commissioned.

Table 1 –PRE-COMMISSIONING EXAMPLE CHECKLIST

Installation Condition		Status (Typically 'Yes' expected sought - use footnotes for extra space eg 'No' answers)	Note
	BUDGET & RESOURCES		
1	Commissioning Agent Appointed	Yes □ No □	
	REFERENCE DOCUMENTATION		
2	Reference Documents eg Lighting Controls Specifications and Drawings issued for Construction and Functional specification obtained and included in Procedure? (Refer list below)	Yes □ No □	
3	Lighting Control System Supplier & Installation Contractor submittals obtained and included in this Procedure ?	Yes □ No □	
4	Written Calibration Instructions for Sensors obtained from suppliers and vendors?	Yes □ No □	
5	List of Known Defects from Independent Examination and / or Interview with Building Operations and Maintenance Representative (s) included in this Procedure	Yes □ No □	Recommission Projects Only.
	FUNCTIONAL DESCRIPTION		
6	Plain Language Description of the Functional Description included in Procedure.	Yes □ No □	
7	Functional Description agreed with Building Operator ?	Yes □ No □	
	KEY PLAYERS		
8	Commissioning participation confirmed for the following:		
	- commissioning agent	Yes □ No □	
	- building management operations	Yes □ No □	
	- building maintenance personnel	Yes □ No □	
	- designers representative	Yes □ No □	
	- system installer	Yes □ No □	
	- component suppliers eg for calibration instruction	Yes □ No □	
	- allied trades eg building automation	Yes □ No □	
	DRAFT COMMISSIONING PROCEDURE		
9	Calibration Procedures Agreed and importance understood?	Yes □ No □	

10	Commissioning Procedure made Project Specific	Yes □ No □	
11	Contingency Plan Formulated for Post Occupancy Commissioning	Yes □ No □	
12	Draft Commissioning Procedure Compiled	Yes □ No □	
	PRE-COMMISSIONING INSPECTION		
13	Inspection Time Scheduled	Yes □ No □	

B1. Daylighting Controls Commissioning Example Checklist

To be formulated at time of Pre-Commissioning with regard to equipment used and specific recommendations of system equipment vendor.

B1.1 NAMEPLATE DATA – EXAMPLE CHECKLIST

Table 2 Nameplate Data (Expand as required to suit actual Project Controls Components. Consider including other Lighting Controls components eg Occupancy Sensors)
s

Equipment Type	Manufacture	Model No	Daylight Zones Applied	Comments (use footnotes for responses requiring additional space)
Photosensor				
Lighting Controller				
Controlled Ballasts				

Footnotes:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

For additional footnotes refer attached pages ____________ (Insert)

B1.2 DAYLIGHT ZONE SCHEDULE – EXAMPLE CHECKLIST

Table 3 - DAYLIGHT ZONE SCHEDULE (Adapt as required)

Zone No	Location Description	Switchboard	Control Zone Ref	Comments (Note additional & repetitive comments as footnotes)
1				
2				
3				
4				

Footnotes:

a. ____

b. ____

c. ____

d. ____

e. ____

For additional footnotes refer attached pages ____________ (Insert)

B1.3 DAYLIGHTING CONTROL SYSTEM, INSTALLED CHARACTERISTICS - EXAMPLE CHECKLIST

Table 4 – SYSTEM INSTALLED CHARACTERISTICS

	Characteristic	Response (Typically Yes / No but use footnotes for responses requiring additional space)
	EACH PROJECT INSTALLATION	
1	Special Daylight System features eg skylights, light shelves, sloped ceilings, special glazings, daylight redirecting systems- Are they installed and operational? (Note1)	
2	Skylights & other daylight glazings - Are they clean?. (Note2)	
3	Interior finishes and work space locations – Are they consistent with efficient use of daylight? (Note 3)	
4	Electric Lighting - Is it fully Functional, clean and fitted with lamps burned -in.? (Note4)	
5	Daylight zoning vs Daylight Availability in a space – Do they correlate ? (Note 5)	
6	Perimeter Lighting Zones – at least one control zone per each perimeter exposure on each floor?	
7	Perimeter v Interior Zoning- Is there separate control of luminaries close to and far from the windows?	
7	Setup - Do all lamps in lighting zone dim to approx. the same level?	
8	Local Manual Controls - Are they functional as designed ?	
9	Other Interference Factors - Anything that interferes with design intent of system eg blinds closed all the time, external obstructions, localised high reflectance areas below sensors?	
10	Device labelling – Is it consistent with the reference documents? (Note 6).	

Footnotes:

1. Describe each such system and where installed.
2. Daylight Performance impaired without clean daylight glazings.
3. Obstructions to daylight transfer may be readily addressed to improve daylighting.
4. Burn-in period per lamp manufacturer's recommendations needs to be allowed eg typically 100 hrs with T8 fluorescent lamps.
5. Poor zoning can result in poor controllability and user complaint.
6. Update as required the reference documents in the Draft Commissioning Manual to reflect 'as-constructed condition' as any inconsistencies should be picked up at this point to aid future Operations and Maintenance or else correct the documented condition.

B1.4 PHOTOSENSOR CHARACTERISTICS – EXAMPLE CHECKLIST

Table 5 – PHOTOSENSOR INSTALLED CHARACTERISTICS

	Characteristic	Response (Typically Yes / No but use footnotes for responses requiring additional space)
	EACH PROJECT INSTALLATION	
1	Photosensor Response – Is response to Daylight vs Electric Lighting distinguished.?	
2	Spatial Characteristic of Photosensor - is it defined and is orientation correct?	
3	Indirect Lighting-where used are photosensors mounted at lower plane of fixture to avoid direct viewing of lamp flux and, facing down.?	
4	Spectral Distribution of Photosensor – Is it known and corresponds to human eye V-λ correction.?	
5	Spectrally selective glazings – Any special considerations for photosensor response?	
6	External Obstructions–Is zoning resolved sufficiently to respond to daylight differences ?	
7	Controls calibration- Were they calibrated ?(If not do not proceed until calibration is complete–Note1)	
8	Calibration – Was it done with finishes & furniture in place and after lamp burn in?	
9	Calibration - Was it done with window treatments & shading systems in place & correctly adjusted?	
10	Calibration adjustments- Located ergonomically and compliant with occupational health & safety?	

	Characteristic	Response (Typically Yes / No but use footnotes for responses requiring additional space - note 2)			
	EACH SENSOR	# A	# B	# C	#D
11	ID Reference– Is the Sensor labelled for Identification and cross reference by Building Management?				
12	Photosensor mounting – Is Mounting in proper location, per manufacturer's directions to accurately control work plane illuminance?				
13	Shielding – Are Sensors shielded to meet prescribed view / non-view of daylight glazings ?				
14	Direct Sunlight and reflected sunlight onto photosensors - Avoided by positioning and / or shielding?				
15	Task Reflectance - Is Task Reflectance within Sensor Operating Recommendations ?				

Footnotes:

1. Calibration is required generally because it is not known what range of input values eg illuminance levels, may be encountered by a sensor in any particular building application. Obtain and / or agree the Manufacturer's calibration instructions.
2. # A to # D denotes sensor references. Adapt to suit particular project references and quantities.
3. Refer also to Appendix B for Photosensor Design & Placement Considerations

B1.5 PERFORMANCE VERIFICATION

A basis for performance verification / response to the specific design specifications of the Project should be jointly developed and agreed between designer and control system provider.

Operation of data loggers over a period of several days to document operation is recommended for verification purposes. Visual inspection can however be acceptable under certain circumstances by mutual consent.

Logger data and graphs where provided should be annotated so it is clear what is being proven.

As-built drawings should show the location of test areas and locations subject to performance verification as an aid to any future recommissioning.

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C. Networked Controls Commissioning Example Checklist

Many lighting control system now employ networking of lighting controls in either hard wired or wireless format.
The development of a commissioning procedure for networked lighting controls should be developed specific to each project and made specific to the system being commissioned.
It should be developed during Pre-Commissioning Stage.
Standardising Communication Protocol between Lighting Control Devices has been identified as pivotal to encouraging Lighting Controls Components to work well together for more complex lighting control strategies

Table 6 –EXAMPLE COMMISSIONING CHECKS

Installation Condition		Status	Notes (For additional space use footnotes)
1	Network hardware and software – Is it provided and functional per the Design Schematics and Network Topology approved Submittals?	Yes □ No □	
2	Networked Digital Ballasts - where installed is the protocol and addressing fully functional?	Yes □ No □	
3.	Network Reserve - Does the Number of connected devices allow at least 15% spare capacity for additional devices are part of future installation / fitout ?	Yes □ No □	
4	New Equipment additions - Does the 'lookup and discovery' process for self-identification operates as required?	Yes □ No □	
5	Loss of Service System Performance- Does the network adapt and perform as required when service comes and goes eg physically disconnection and reconnection of each device type such as luminaire ballast, photosensor, network device, power supply unit and cable interconnection.?	Yes □ No □	
6	System Safeguards Are preventative components in place to avoid inadvertent control action in one zone affecting adjacent zone(s)?	Yes □ No □	
7	Interfaces to other Building Technology Systems. Are these in place and functional? eg energy metering, building automation systems	Yes □ No □	
8	Interface stability. Do systems remain stable under disconnection and reconnection of the system interface?	Yes □ No □	
9	Software Functionality. Does operation comply with the functional description of the lighting control system?	Yes □ No □	

Footnotes:
a.____

b.____

c.____

For additional footnotes refer attached pages ____________ (Insert)

D. Handover Example Checklist

Table 7 –HANDOVER VERIFICATION

Installation Condition		Status	Notes (For additional space use footnotes)
	DOCUMENTATION		
1	Draft Commissioning Manual updated to Final Form?	Yes □ No □	
2	Final Commissioning Manual submitted to Operations and Maintenance (O+M)?	Yes □ No □	
	TRAINING		
3	Have the O & M Personnel been involved in the Commissioning Phase?	Yes □ No □	
4	Has the Commissioning Manual been explained to O & M ?	Yes □ No □	
5	Have the O & M Personnel received specific instruction on the location of Manual Overrides?	Yes □ No □	
	MAINTAIINING FUTURE PERFORMANCE		
6	Has a specialist Maintenance Contract for the maintenance of the daylighting controls system been considered and / or adequate provisions been put in place for specialist help?	Yes □ No □	
7	Has a process for the recalibration and recommissioning of daylighting controls been considered and put in place?	Yes □ No □	

Footnotes:

a.____

b.____

c.____

For additional footnotes refer attached pages ____________ (Insert)

E. Post Occupancy Example Checklist

Post Occupancy Checks should be conducted by agreement between the Building Owner and the Commissioning Agent. The following lists example checks. Amend to suit the specific project.

Table 8 – POST OCCUPANCY

Installation Condition		Status	Notes (For additional space use footnotes)
	OCCUPANT COMFORT		
1	Have occupants had the control system intent and operation explained to them? ■	Yes □ No □	
2	Has it been confirmed shortly after occupancy and commissioning that occupants are satisfied with the lighting controls?	Yes □ No □	
3	Have matters discovered which require user education been reported for action by O + M	Yes □ No □	
	CALIBRATION RESOURCES		
4	Are tools to aid calibration and commissioning on site eg torch, illuminance meter and procedure	Yes □ No □	
	MAINTENANCE		
5	Are the O + M Documents up to date?	Yes □ No □	
6	Is a schedule for cleaning luminaries and daylight glazing in place?	Yes □ No □	
7	Is a procedure for bulk lamp replacement in place?	Yes □ No □	
8	Are correct replacement lamp types recorded?	Yes □ No □	
9	Is there a process for incorporating recalibration of photosensors when fitout changes occur? eg partition changes	Yes □ No □	
10	Is there a visual inspection procedure to verify occupants are not disabling control devices eg photosensors?	Yes □ No □	
11	Energy review process – in place to check lighting energy savings are not being eroded by underlying problems requiring redress?	Yes □ No □	
12	Is there a process in place for periodic review of maintenance procedures	Yes □ No □	
	OPTIMISATION		
13	Is there a review process in place for energy efficient technologies and incentive programs aimed at encouraging sustainable lighting initiatives?	Yes □ No □	
14	Is there a process set up to monitor for further energy saving opportunities building on feedback and actual usage patterns of the building in occupancy versus that supposed at design?	Yes □ No □	

Footnotes:

a.____________________

b.____________________

c.____________________

For additional footnotes refer attached pages ____________ (Insert)

F. Glossary of Terms

A Glossary of Terms may prove useful. Examples to add to may include:

Algorithm
A decision making process that determines the output of a system in response to one or more inputs.

Daylight Zone
One or more luminaries that are controlled by a single daylighting single output unusually in response to a single photosensor.

Photosensor
Light sensitive device that includes a photocell, input optics and a mechanical housing, along with any necessary electronics, that is part of a lighting control system

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APPENDIX A – BARRIERS TO EFFECTIVE CALIBRATION & COMMISSIONING

A1 General

A number of barriers have been cited to effective calibration and commissioning.

Matters such as those listed below are best addressed at Design Stage and through Planning the Commissioning Process.

A2 Performance & Application Data

Information regarding the technical performance and application of the products provided by product manufacturers has been noted as requiring substantial improvement. Provision of manufacturer's instructions on the performance and calibration of sensors is often not detailed.

The procedure setting out how to best commission an overall system has also been noted as not clearly documented in a number of project instances.

A3 Control System Expertise

Installation practice for lighting controls varies and it is not uncommon to find that lighting controls are installed by Electrical Contractors. Such Personnel can often be inexperienced in the calibration and commissioning procedures required for Lighting Controls generally and Daylighting Controls in particular. There ane also few published guidelines to which general reference can be made to help this.

This situation has been contrasted with Mechanical Controls where the subcontractors installing the HVAC system in a building are also traditionally responsible for the operational commissioning.

The building of a body of knowledge and expertise in correct commissioning practice is seen as one way to address this problem.

A4 Logistics

Practically speaking it can be inconvenient, time-consuming and quite possibly both to properly calibrate or commission a Daylight Control System.

Timing of Commissioning is recommended to occur as soon after the building is occupied as possible.

All major room furnishings, obstructions and window treatments should be installed to assure that the lighting control system is commissioned under typical lighting conditions. The situation is complicated however in the case of tenancy works or staged occupancy when a control system installed as part of a base building design becomes divorced in time from actual occupancy

For new installations commissioning is inevitably an end of construction phase process often when the building is rushing to completion. This frequently means that internal conditions are incomplete eg blinds, finishes, furniture not as final occupied condition.

It can also mean there is a tendency to push commissioning aside in the last minute rush to move in. Activities can be performed poorly and in some cases not at all.

Recommendations have been made to recalibrate after changes in a space but this does not commonly occur once the initial commissioning round has occurred. Photosensors for example are supposed to be recalibrated when room paint, carpet, wall art or furniture is modified. Instead calibration is mistakenly avoided altogether with many photosensors are left to operate “out of the box”” uncalibrated.

To this add the logistics of conducting calibration at recommended times when External Daylight conditions are conducive for calibrating sensors properly.

Such requirements define limited windows of opportunity which in turn can lead to a tendency to apply less rigour and take short cuts.
The need to carry out night and daytime calibrations for certain systems also requires special co-ordination by the commissioning agent. This includes scheduling of personnel after normal working hours as well as security access arrangements in many instances.

During mid-summer, under daylight saving conditions, dusk may not occur for a night calibration until late of evening.

Recommendations to Co-ordinate lighting commissioning with other subsystem commissioning activities eg mechanical systems means co-ordination ahead of time to reduce time overheads for all parties.

A5 Sensitivity

The restricted range of some sensors appears to limit the ability of these sensors to adapt to a variety of space conditions and also maximise energy savings.

It has also been observed that marked variations between the same device type can occur due to broad tolerances on components.

A6 Ergonomics

There are logistical difficulties in calibrating certain types of daylight responsive systems that use ceiling-mounted light sensors.
For example the situation is best avoided that requires standing on a ladder adjusting a very small, hard to find, potentiometer in the sensor housing some 3 metres off the floor.

Configuration such as this means the commissioning agent cannot help but influence the readings of the photocell when making adjustments. Also to use a ladder is itself a deterrent to proper setup. Moreso for adjustments that may need to take place after occupancy where occupant productivity may be impacted.

Thus there is a need for ergonomically designed adjustment devices for photosensor controlled products.

A7 Time & Cost to Commission

Many existing devices provide considerable deterrent to proper commissioning with the time and attention required more considerable than other building controls.

APPENDIX B – PHOTOSENSOR DESIGN & PLACEMENT

Review of problems encountered in the application of Daylight Controls Systems, consistently point to the dependency on the Control algorithm and photosensor for successful operation. This section is included to provide further background into key considerations likely to effect performance.

B1 General

1. Consider that automatic control is dependent on the quality of information received. The Photosensor is a critical element. Review the Sensor Design & Placement basis with the Control System Designer prior to attempting commissioning to confirm understanding and assumptions for:
   - Control Algorithm
   - Sensor Spatial Distribution
   - Sensor Spectral Sensitivity
   - Luminaire Design Configuration (Ceiling/Suspended, Direct/Indirect)
   - Room size and Characteristics (colour/reflectance's)
   - Presence of Advanced Daylighting Systems
   - Window Treatments (Blinds and Shades)
   - External Obstructions to Daylight
   - Expected Calibration Procedure

B2 Control Algorithm

1. The control algorithm is the most important element to improve because it has the biggest impact on the maintained lighting level
2. An important aspect is whether the algorithm differentiates between the sensor response to electric light vs daylight. Commercial Sensors respond differently to each and as such this aspect is critical to avoid under or over dimming. This in turn means confirmation as to whether the sensors used will automatically differentiate the 2 lighting components without requiring a separate nightime and daytime adjustment.
3. The following are examples of algorithms applied for Daylight Control:

A) SIMPLE ALGORITHMS

The following descriptions appear in several literature publications.

i) Open Loop

Sensors by definition are intended not to view Electric Lighting
A Daytime Calibration is required.
(Note: Commonly specified Algorithm for Open Loop Skylighting Applications)

i) Closed Loop Integral Reset (also often called Constant Setpoint)

Sensors are intended to view both the electric lighting and the daylighting
This is the simplest control algorithm.
The Lighting Control system seeks to adjust the dimming level so that the photosensor signal is kept at a constant reference level.
The reference level is determined through a calibration at night. The reference level is set to obtain the desired task illuminance from the electric light only.
During the day as daylight increases the controller reduces the electric light level to restore the photosensor signal to its preset reference level.
In theory only a night calibration is required.

(Note: This algorithm is the most commonly applied yet has not been recommended for Daylighting Control. The widespread use is expected to be due to the fact that this type of control strategy is commonly applied in many building automation applications eg temperature, fan speed control)

iii) Closed Loop Proportional (also often called Sliding Setpoint)

The key difference between this algorithm and the 'Integral Reset' algorithm is that the photosensor signal is not kept constant.

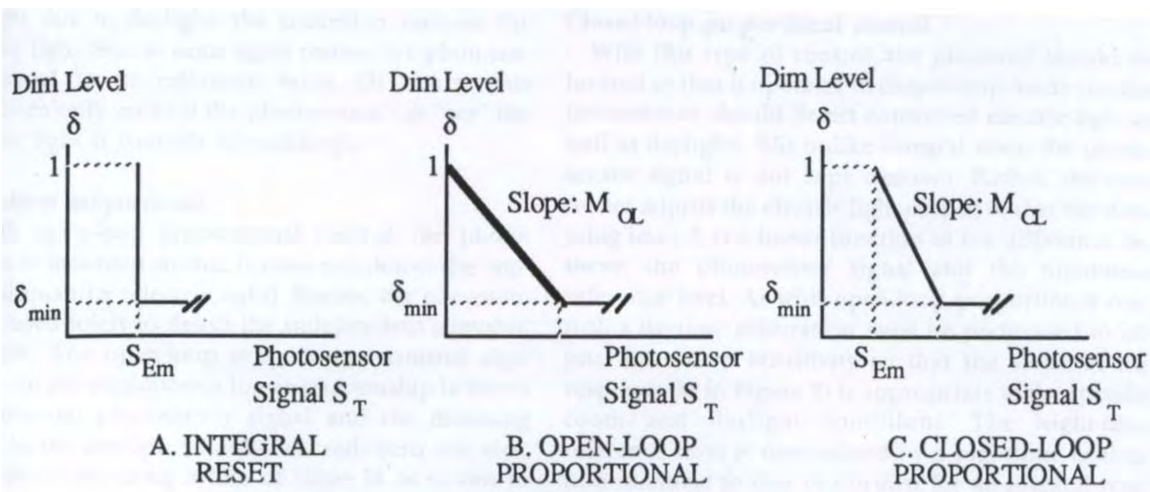
The controller adjusts the electric light output so that the dimming level occurs in proportion to the difference between the photosensor signal and the night time calibration reference level

A Daytime and Nighttime Calibration is required.
Note: This is a commonly recommended Algorithm for Closed Loop Window Sidelighting Applications

Figure 1 below illustrates the differences between the 3 algorithms

Figure 1 - Simple Algorithms

Plots showing relationship (transfer function) between the total photosensor signal S_T and fractional dimming level, ð for the 3 classical algorithms. Note the fractional dimming level can vary between $ð_{min}$ and 1 (full output)



(Source: Figure 2 of Rubinstein, Ward and Verderber (11))

B) COMPLEX ALGORITHMS

Adaptive Control

Adaptive control systems can adapt the system control parameters to respond to changes in occupant preference on how the system control should work and also to changes in the building internal space daylight characteristics.

Adaptive algorithms may apply in 2 parts; in response to user wishes and in response to environmental conditions

The key benefits of adaptive control are indicated to be those of self-commissioning and capacity to minimise user rejection of the daylighting control system. Specialist guidance will be required to commission such systems and obtain advice concerning photosensor type and placements.

B3 Sensor Spatial Distribution

1. Request and Obtain the Manufacturers Specification Sheet showing the sensor Spatial Distribution and the recommended mounting instructions.

1. Symmetrical 60 deg cone of view has been commonly specified for closed loop systems. Asymmetric Distributions may be preferred close to windows. Open loop systems are likely to require smaller cones of view. Verify suitability for algorithm employed.

1. Several studies have noted problems with Sensors directly viewing the window glazing or direct beam sunlight / reflected beam sunlight eg from outside parked cars or mirror reflective surfaces inside and outside the office. Consider sensor locations and / or partial shielding as a solution.

1. Verify Closed Loop sensors are not directly viewing the electric lighting. Reposition or fit partial shields to avoid direct / specular indirect light onto sensors affected in this way.

1. Verify Mounting Height with respect to cone of view. Lower mounting heights eg suspended luminaries, for sensors viewing down, make sensors more sensitive to changes in reflectance immediately below the sensor. Obtain wider cones of view as needed.

1. Check closed loop sensors are not fully shielded. Full shields (360 deg) are not generally recommended except to obtain a narrow sensor view angle for open loop algorithm systems.

B4 Sensor Spectral Sensitivity

1. Photosensor response to Daylight is distinctly different to Electric Light. Many photosensor products assume the response to be the same and do not differentiate between Daylight and Electric Light. The result is that as the sensitivity is decreased to obtain good daylighting performance, the less accurate the control will be for electric lighting changes resulting in a 'middle of the road' gain adjustment that achieves dimming while minimising control system errors.

1. Request and Obtain the Manufacturers Specification Sheet showing the sensor Spectral Sensitivity Response and consider if it includes filtering to approximate the sensitivity curve of the human eye (V-lambda correction filter).

1. Check that response with respect to spectrally selective glazings has been considered where such glazings have been installed into the project.

B5 Luminaire Design Configuration

1. There have been reports that indirect lighting systems are more difficult to accurately control and direct recessed lighting the easiest. Direct / Indirect being in between.

1. Photocell placement becomes more critical when an indirect lighting component is present.

B6 Room Size and Characteristics (colour / reflectances)

1. Verify reflectances in field of view at time of calibration correspond with those representative of the office eg no localised issues such as white paper filling the field of view directly below a sensor.

1. General design assumptions are for typical reflectance values from task surfaces in the range 20-40%.

1. There is conflicting advice concerning the relative importance of surface reflectance on the operation of photosensor controls. It is clear however that photosensors with a narrow field of view (les than 30 degrees) in which the task surface makes up a substantial component of the view have the capacity to cause significant changes in the photosensor response when a dark surface becomes more reflective eg white paperwork or when personnel prop beneath the sensor.

1. Research supports the idea that many of the commissioning aspects for small rooms relate to larger rooms also.

B7 Internal Horizontal 'Venetian' Blinds

1. Several studies have provided guidance on calibration and commissioning of installations with horizontal blinds installed (reference 21). These studies and the specific recommendations of the system supplier should be sought when formulating the commissioning procedure.

B8 Shading Controls

1. Shading controls where included, will need to be separately commissioned and the scope is excluded from this guide. Consideration should however be given to the shading controls when commissioning the daylight controls system to include such matters as:

a) For adjustable louvres, that they have been set at the correct seasonal angle to eliminate direct sun penetration
b) For operable louvres, that preset angles have been adjusted to the correct season.
c) For shades or blinds that occupants are intended to operate that all control devices are accessible and functional.
d) For automatic shading controls, that commissioning in accordance with the specific instructions of the manufacturer has been conducted.

B9 Presence of Advanced Daylighting Systems

1. Limited studies are available to provide guidance for the calibration procedures when daylight control systems work in conjunction with advanced glazing systems. One study (reference 19) considered Clear Glass, Venetian Blinds, Prismatic Film and an Internal Light Shelf.

1. Advanced Daylighting Systems which act to redirect beam sunlight further into a room lead to unusual luminance distributions eg compared within standard sidelighting window conditions. Attendant with this approach is the increased potential for sunlight to be redirected onto the photo-sensor indicating closer consideration of shielding requirements is necessary.

B10 External Obstructions to Daylight

1. Sections of the façade prone to obstruction will require additional sensors and zoning

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA Solar Heating and Cooling Programme

The International Energy Agency (IEA) was established in 1974 as an autonomous agency within the framework of the Economic Cooperation and Development (OECD) to carry out a comprehensive program of energy cooperation among its 25 member countries and the Commission of the European Communities.

An important part of the Agency's program involves collaboration in the research, development and demonstration of new energy technologies to reduce excessive reliance on imported oil, increase long-term energy security and reduce greenhouse gas emissions. The IEA's R&D activities are headed by the Committee on Energy Research and Technology (CERT) and supported by a small Secretariat staff, headquartered in Paris. In addition, three Working Parties are charged with monitoring the various collaborative energy agreements, identifying new areas for cooperation and advising the CERT on policy matters.

Collaborative programs in the various energy technology areas are conducted under Implementing Agreements, which are signed by contracting parties (government agencies or entities designated by them). There are currently 42 Implementing Agreements covering fossil fuel technologies, renewable energy technologies, efficient energy end-use technologies, nuclear fusion science and technology, and energy technology information centers.

The Solar Heating and Cooling Programme was one of the first IEA Implementing Agreements to be established. Since 1977, its 20 members have been collaborating to advance active solar, passive solar and photovoltaic technologies and their application in buildings.

Australia	Finland	Portugal
Austria	France	Spain
Belgium	Italy	Sweden
Canada	Mexico	Switzerland
Denmark	Netherlands	United Kingdom
European Commission	New Zealand	United States
Germany	Norway	

A total of 35 Tasks have been initiated, 25 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition, a number of special ad hoc activities—working groups, conferences and workshops—have been organized.

The Tasks of the IEA Solar Heating and Cooling Programme, both completed and current, are as follows:

Completed Tasks:

Task 1	*Investigation of the Performance of Solar Heating and Cooling Systems*
Task 2	*Coordination of Solar Heating and Cooling R&D*
Task 3	*Performance Testing of Solar Collectors*
Task 4	*Development of an Insolation Handbook and Instrument Package*
Task 5	*Use of Existing Meteorological Information for Solar Energy Application*
Task 6	*Performance of Solar Systems Using Evacuated Collectors*
Task 7	*Central Solar Heating Plants with Seasonal Storage*
Task 8	*Passive and Hybrid Solar Low Energy Buildings*
Task 9	*Solar Radiation and Pyranometry Studies*
Task 10	*Solar Materials R&D*
Task 11	*Passive and Hybrid Solar Commercial Buildings*
Task 12	*Building Energy Analysis and Design Tools for Solar Applications*
Task 13	*Advance Solar Low Energy Buildings*
Task 14	*Advance Active Solar Energy Systems*
Task 16	*Photovoltaics in Buildings*
Task 17	*Measuring and Modeling Spectral Radiation*
Task 18	*Advanced Glazing and Associated Materials for Solar and Building Applications*
Task 19	*Solar Air Systems*
Task 20	*Solar Energy in Building Renovation*
Task 21	*Daylight in Buildings*
Task 23	*Optimization of Solar Energy Use in Large Buildings*
Task 22	*Building Energy Analysis Tools*
Task 24	*Solar Procurement*
Task 25	*Solar Assisted Air Conditioning of Buildings*
Task 26	*Solar Combisystems*

Completed Working Groups:

CSHPSS — *ISOLDE*

Materials in Solar Thermal Collectors — *Evaluation of Task 13 Houses*

Current Tasks:

Task 27	*Performance of Solar Facade Components*
Task 28/	*Solar Sustainable Housing* ECBCS Annex 38
Task 29	*Solar Crop Drying*
Task 31	*Daylighting Buildings in the 21st Century*
Task 32	*Advanced Storage Concepts for Solar and Low Energy Buildings*
Task 33	*Solar Heat for Industrial Processes*
Task 34/	*Testing and Validation of Building Energy Simulation Tools* ECBCS Annex 43
Task 35	*PV/Thermal Systems*

Task Defintion Phase:

Solar Resource Knowledge Management

To find `more IEA Solar Heating and Cooling Programme publications or learn about the Programme visit our Internet site at **www.iea-shc.org** or contact the SHC Executive Secretary, Pamela Murphy, e-mail: pmurphy@MorseAssociatesInc.com.