

IALA GUIDELINE

1038

METHODS AND AMBIENT LIGHT LEVELS FOR THE ACTIVATION OF AtoN LIGHTS

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DOCUMENT REVISION

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May 2009	Section 6 revised.	Measurement and calibration methods added.
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1. INTRODUCTION

The most important aspect of a primary or secondary battery powered system design is the calculation of the daily energy load [4]. In order to conserve energy, AtoN lights which are only required during hours of darkness are switched off during daylight hours. For lighted aids to navigation that only operate at night, the switch-on / switch-off times can be regulated by either time switches, GNSS synchronisation, a real time clock or photo-sensitive devices that are calibrated to correspond to a nominated illuminance level, and external systems. Photo-sensitive devices are still the dominant technology for triggering daytime or night time operation for AtoN.

In other applications, high power day time lights must be switched to lower intensity at night time in order to avoid glare, or lights may be switched on or intensity increased during periods of poor visibility in fog.

Time switch control switches the light on and off at pre-set times and requires a knowledge of the optimum switching time in morning and evening. In addition, the time switch must have a solar dial facility, so that the set times are automatically adjusted as seasons and length of day vary. Time switches cannot be used to switch the light on during periods of poor visibility. A manual switch or remote system may be used in overriding the light on and off during these times of poor visibility.

Photosensitive devices do not suffer from these limitations. Since operation is dependent on ambient light level, photosensitive switches automatically adjust to varying seasons and weather conditions. They therefore provide the Mariner with the optimum AtoN service with minimum energy consumption.

There are however conflicting requirements when using photosensitive daylight switches. If the selected ambient light level at which the light switches on is too high, the navigational light will be on for a long time. Energy resources will be wasted and the operational life of lanterns will be shortened. If the switching level is too low, the navigational light will not switch on until sometime later and will be turned off earlier, thereby reducing the effectiveness of the navigation mark in its aid-to-navigation function and increasing the hazard to vessels and the risk of collision. In extreme cases bright moonlight may cause the light to switch off during the night if the switching level is set incorrectly. The problem of later switching on is that heavy overcast may cause the light to switch on during daylight.

1.1. SCOPE

This guideline has been developed to assist aids to navigation authorities when selecting methods for activation of AtoN lights, and measuring the ambient light levels at which AtoN lights should switch on and off.

2. AMBIENT LIGHT LEVELS

The ambient light levels at which AtoN lights should switch on and off should be chosen so that the AtoN light switches on while the ambient light level is sufficiently high to allow safe navigation, while not switching on during overcast conditions when the AtoN is not necessary for safe navigation. A number of studies have been carried out to assist this determination.

2.1. TYPICAL AMBIENT LIGHT LEVELS

Typical ambient light levels for different conditions are shown in 0.

Table 1 *Typical ambient light levels*

Conditions	Ambient light levels (lux)
Sunlight Direct Illumination	$1 \times 10^5 \sim 1.3 \times 10^5$
Sunny Days in the Daytime	$1 \times 10^4 \sim 2 \times 10^4$
Cloudy Day	10^3
Wholly Cloudy Day	10^2
Civil Twilight Shadow	10
Dark Twilight Shadow	1
Full Moon	10^{-1}
The Moon at the First Quarter (or The Moon at the Third Quarter)	10^{-2}
Bright Sky Without Moon	10^{-3}
Cloudy Sky Without Moon	10^{-4}

2.2. TIMING OF ASTRONOMICAL EVENTS

The astronomical events that define the transitions from day to night are shown in Table 2¹.

Table 2 *Timing of Astronomical Events.*

Event	Condition	Typical Illumination (lux)	Comment (Assuming the absence of moonlight, artificial lighting or adverse atmospheric conditions)
Sunset/Sunrise	Upper edge of the sun's disc is coincident with the horizon.	600	
Civil Twilight (beginning / ending)	Centre of the sun is at a depression angle of six (6) degrees below the horizon.	6	Illumination is sufficient for large objects to be seen but no detail is discernible. The brightest stars and planets can be seen. For navigation at sea, the sea horizon is clearly defined.
Nautical Twilight (beginning / ending)	Centre of the sun is at a depression angle of twelve (12) degrees below the horizon.	0.06	It is dark for normal practical purposes. For navigation at sea, the sea horizon is not normally visible.
Astronomical Twilight (beginning / ending)	Centre of the sun is at a depression angle of eighteen (18) degrees below the horizon.	0.0006	Illumination due to scattered light from the sun is less than that from starlight and other natural light sources in the sky.

¹ The timing of astronomical events can also be applied to calculations (computer programs) for sizing solar power supplies [1].

2.3. EFFECT OF SUN ELEVATION ON AMBIENT LIGHT LEVEL

Table 3 shows the effect of sun elevation on ambient light level in clear weather.

Table 3 *Effect of suns elevation on ambient light level in fine weather.*

Elevation of the Sun (°)	Ambient light level (lux)	Remarks
−18°	6.51×10^{-4} lx	Astronomical twilight (beginning/ending)
−12°	8.31×10^{-3} lx	Nautical twilight (beginning/ending)
−6°	3.4 lx	Civil twilight (beginning/ending)
−5°	10.8 lx	
−0.8°	453 lx	
−0.25°	600 lx	Sunrise / Sunset (Upper edge of the sun' disc is coincident with the horizon)
0°	732 lx	
5°	4760 lx	
10°	1.09×10^4 lx	
15°	1.86×10^4 lx	
20°	2.73×10^4 lx	
25°	3.67×10^4 lx	
30°	4.70×10^4 lx	
40°	6.67×10^4 lx	
50°	8.50×10^4 lx	
60°	10.2×10^4 lx	
70°	11.3×10^4 lx	
80°	12.0×10^4 lx	
90°	12.4×10^4 lx	

2.4. ORIENTATION OF DAYLIGHT SWITCH

Tests carried out in China in 2004 [2] indicate that measured ambient light levels are significantly affected by the orientation of the measuring instrument. This means that the orientation of a daylight switch for AtoN light control must be chosen carefully.

At any given moment, ambient light level may be measured towards the sun horizontally, away from the sun horizontally, or towards zenith. These three values vary with time and weather conditions. Table 4 and Table 5 show measured values of ambient light level for different weather conditions. Generally speaking, the tested ambient light level towards zenith comes closest to the ambient light level on the ground at that time.

Table 4 *Effect of measuring instrument orientation on measured light level*

(overcast weather, 38 degrees north latitude and 118 degrees east longitude)

Time UTC 14 Feb	Ambient light level for different orientations (lux)			Time difference for ambient light level of different orientations to reach the same value of ambient light					
	I Towards the sunrise	II Towards zenith	III Away from the sunrise	III is later than I (minute)		I is later than II (minute)		III is later than II (minute)	
6:56	50	83	48						
6:57	57	90	48	1	48				48
6:58	67	116	50	2	50				50
6:59	80	133	61	2	61	3	80		61
7:00	90	149	72	2	72	3	90		72
7:01	106	170	79	2	79	3	106	6	79
7:02	120	191	84	3	84	4~5	120	6	84
7:03	127	215	90	3	90	4~5	127	6	90
7:04	142	242	107	3	107	4~5	142	7	107
7:05	160	275	112	4	112	4~5	160	7	112
7:06	181	311	122	3	122	4~5	181	7~8	122
7:07	202	347	144	3	144	4~5	202	7	144
7:08	238	378	180	2	180	4~5	238	7	180
7:09	259	421	219	2	219	4~5	259	6	219
7:10	273	476	238	2	238	4~5	273	6	238
7:11	310	532	249	3	249	4~5	310	7	249
7:12	338	591	274	2	274	5	338	7	274
7:13	371	651	315	1	335	5	371	7	335
7:14	438	736	347	2	347	4~5	438	7	347
7:15	483	821	386	2	386	5~6	483	7	386
7:16	528	925	417	2	417	5~6	528	8	417
7:17	589	1000	486	2	486	5	589	7	486
7:18	702	1090	465	3	465	4~5	702	8	465
7:19	770	1148	531	3	531	4~5	770	8	531
7:20	830	1216	622	3	622	5	830	7	622

Table 5 *Effect of measuring instrument orientation on measured light level*

(fine weather, 38 degrees north latitude and 118 degrees east longitude)

time 9 Feb UTC	Ambient light level of different orientations (lux)			Time difference for ambient light level of different orientations to reach the same value of ambient light					
	I Towards the sunset	II Towards zenith	III Away from the sunset	III is earlier than I (minute)		I is earlier than II (minute)		III is earlier than II (minute)	
17:30	680	660	418	5	418	<1	680	5	418
17:31	650	630	380	5	380	<1	650	4	380
17:32	590	574	340	5	340	<1	590	4	340
17:33	530	516	318	4	318	<1	530	4	318
17:34	470	457	280	4	280	<1	470	4	280
17:35	410	401	250	4	250	<1	410	4	250
17:36	370	355	228	4	228	<1	370	4	228
17:37	310	314	210	3	210	<1	310	3	210
17:38	265	284	185	3	185	<1	265	3	185
17:39	232	245	150	3	150	<1	232	3	150
17:40	206	215	125	4	125	<1	206	4	125
17:41	188	189	110	4	110	<1	188	4	110
17:42	160	168	98	3	98	<1	160	3	98
17:43	143	140	79	3	79	<1	143	3	79
17:44	123	122	68	3	68	<1	123	3	68
17:45	101	103	58	3	58	<1	101	3	58
17:46	78	82	43	3	43	<1	78	3	43
17:47	69	68	36	3	36	<1	69	3	36
17:48	55	56	28	3	28	<1	55	3	28
17:49	45	45	22	4	22	<1	45	4	22
17:50	35	36	19			<1	36		
17:51	28	29	17			<1	29		
17:52	26	26	16			<1	26		
17:54	25	22	14						
17:55		18							
17:56		14							
17:57		11							
17:58		8							
17:59		6							
18:00		4							
18:01		2							
18:02		1							
18:03		0							

In Table 4 (overcast), at any given time, the ambient light level away from the sunrise is 80% of that towards the sunrise and the ambient light level towards the sunrise is 60% of that towards zenith. The time difference is 1 to 3 minutes to reach the same ambient light level when measuring towards the sun and away from the sun (III is later than I). The time difference is 6 to 7 minutes when measuring away from the sun and towards zenith.

In Table 5 (fine weather), at any given time, the ambient light level measured away from the sun is 60% of that measured towards the sun. The ambient light level towards the sunset is roughly the same as that towards zenith. There is a time difference of 3-5 minutes to reach the same ambient light level towards the sun and away from the sun.

In clear conditions, a large bright moon directly in front of the daylight switch may be sufficiently bright to cause the AtoN light to be switched off if the switching level is set too low. Increasing the switching threshold overcomes this problem.

In many applications, pointing the daylight switch away from the noontime sun (north in northern hemisphere) provides satisfactory performance. It is important to make sure that light from other sources or reflections does not affect at daylight switch (sensor). For floating aids to navigation, pointing the daylight switch vertically at zenith often provides a compromise, although it is found that fitting the daylight switch within the lantern lens provides satisfactory performance on buoys in many applications.

2.5. EFFECT OF LATITUDE

The higher the latitude, the longer the time difference to reach the same ambient light level at various orientations.

Consider the civil twilight (horizontal altitude of the sun -6 degrees ~ 0 degree) in Table 6. The time difference between Civil Twilight and Sunrise is the shortest near the equator at about 21 minutes all the year. At 40 degrees this increases to 30 minutes all year around. High latitudes regions change fast with variations of seasons and longitudes.

Table 6 *Period between Twilight Civil and Sunrise (elevation of the sun from -6°~ 0°)*

	2001-06-21 Midsummer			2001-09-22 the autumnal equinox			2001-12-21 midwinter		
Lat.	Twilight Civil	Sunrise	Period	Twilight Civil	Sunrise	Period	Twilight Civil	Sunrise	Period
°	h m	h m	m	h m	h m		h m	h m	m
N70°	□	□		0442	0540	58	■	■	
N66°	□	□		04 54	05 43	49	0854	1035	101
N64°	■	01 31		04 58	05 43	45	0834	0952	78
N60°	00 49	02 36	107	05 05	05 44	39	0805	0902	57
N50°	03 06	03 51	45	05 15	05 46	31	0718	0756	38
N40°	03 59	04 31	32	05 21	05 47	26	0648	0718	30
N30°	04 32	04 59	27	05 23	05 48	25	0626	0652	26
N20°	04 57	05 21	24	05 27	05 49	22	0607	0630	23
N10°	05 18	05 40	22	05 28	05 49	21	0550	0612	22
0°	05 36	05 58	22	05 28	05 49	21	0532	0554	22
S10°	05 53	06 16	23	05 28	05 50	22	0514	0537	23
S20°	06 10	06 34	24	05 27	05 50	23	0454	0518	24
S30°	06 29	06 55	26	05 24	05 50	26	0429	0456	27
S40°	06 52	07 22	30	05 21	05 49	28	0355	0428	33
S50°	07 21	08 00	39	05 15	05 49	34	0303	0347	44
S56°	07 46	08 33	47	05 09	05 48	39	0207	0309	62
□ the sun continuously above the horizon ■ the sun continuously below the horizon ■ the sun continuously twilight									

2.6. METEOROLOGICAL EFFECTS

The effect of clouds on ambient light levels is considered in section 2.2.

The ambient light levels in fog conditions can vary, ranging from very bright in shallow sea fog conditions to quite dark in heavy fog conditions. However, the danger to safe navigation due to restricted visibility is much the same for all fog conditions. Snow conditions also frequently give rise to restricted visibility with relatively high ambient light levels. Therefore, it can be difficult to use photosensitive switches effectively to detect poor visibility conditions.

3. LOCAL ENVIRONMENTAL FACTORS

Local conditions can have a significant impact on the ambient light level and the light level at which an AtoN should switch.

3.1. BRIGHT ARTIFICIAL LIGHT

In harbours and confined waters where there is background lighting, consideration should be given to the possible need for AtoN lights to switch on earlier than the background lights. Typical switch on levels for streetlights is 200 lux.

3.2. HYDROGRAPHY AND METEOROLOGY

Local hydrographical or meteorological conditions may give rise to frequent fog, snow, ice or shadow conditions that affect the local ambient light levels. The effects of these are discussed in section 2.6.

Weather reports may be used to switch AtoN's locally, either by remote telemetry or by manual override. Visibility detectors are also used in determining meteorological conditions. Information can be obtained from third party meteorological observations as well as sources such as AIS (message 8, broadcasted to a base station for interpretation and forwarded to relevant applications).

4. APPLICATION EXAMPLES

4.1. RIVER LIGHTS, CHANNELS, PIERS

In rivers where multiple lights are used to mark a channel, it is desirable, and sometimes necessary, to ensure that all lights switch on and off at the same time. Where there are dark riverbanks on part of the channel, it may be found that the lights in this part of the channel switch on and off earlier and later than those in more open section of the channel. This could be a typical application where one of the low power alternative system (see section 7) could be used. GNSS or RTC are good options to force an entire buoy channel to turn ON/OFF at the same time on a master/slave system, avoiding the problem of having lights turning ON/OFF at different times on a channel. This principle could be applicable to passing traffic by large ships in narrow channels, a terminal, bridge or pier where several lights need to be switched at the same time.

4.2. MAJOR LIGHTHOUSE SYSTEMS

In a lighthouse or beacon where shadows, vegetation, obstruction, or environmental variations occur, the use of a secondary switching system is recommended. One solution is using an external, secondary photo-sensitive device directed outside the lighthouse, unaffected by variations. Further solutions include using an alternative system, see section 7.

5. SENSORS

5.1. HUMAN PERCEPTION OF LIGHT

The unit of illuminance, the lux (lumen/m^2), is photometric and is therefore based on the spectral response of the human eye in bright light (photopic response $V(\lambda)$).

Photometric devices such as luxmeters are corrected, usually by the use of filters, to this photopic response. However, photoreceptors (LDR and PD) used in light level switching usually are not corrected to $V(\lambda)$. Therefore, there will be errors between the levels recorded or switched by the two devices when illuminated by light sources of different spectral distribution.

If true lux level switching is desired, it would be necessary to employ photopic correction in the photoreceptor. However, most devices currently in service worldwide would fall outside any such specification.

One exception to this is photoreceptors employing selenium. Such devices have a spectral response close to $V(\lambda)$. Unfortunately, they suffer from degradation with age and use, just like real eyes.

When selecting a photometric sensor, consideration may be given to the spectral response in relation to $V(\lambda)$.

5.2. SPECTRAL RESPONSE

Ideally, the spectral response of the light detector carrying out the switching should be corrected to the human eye response. If such devices were corrected to $V(\lambda)$, the calibrating light source would not need to be daylight because the luxmeter and the switching device would have a similar spectral response.

Unfortunately, devices currently in use are usually not corrected, and this causes problems with their calibration. Using a standard light source (such as illuminant A) for calibrating switching devices requires a correction to be carried out. The information required for such a correction are:

- 1 Spectral response of standard lamp (this changes when the lamp voltage is reduced to simulate falling light levels).
- 2 Spectral response of measuring instrument (luxmeter).
- 3 Spectral response of switching device.
- 4 CIE $V(\lambda)$.

There is a CIE formula that gives a correction factor from the above spectral data.

Irrespective of the type of sensor used, it is essential that the sensor should not have any significant sensitivity outside the spectrum of the human eye response, so that the sensor does not respond to radiation to which the human eye is not sensitive.

However, in practice, spectral correction using test lamps is difficult and expensive.

Figure 1 shows the spectral distribution for visible light during daytime and at sunrise and sunset.

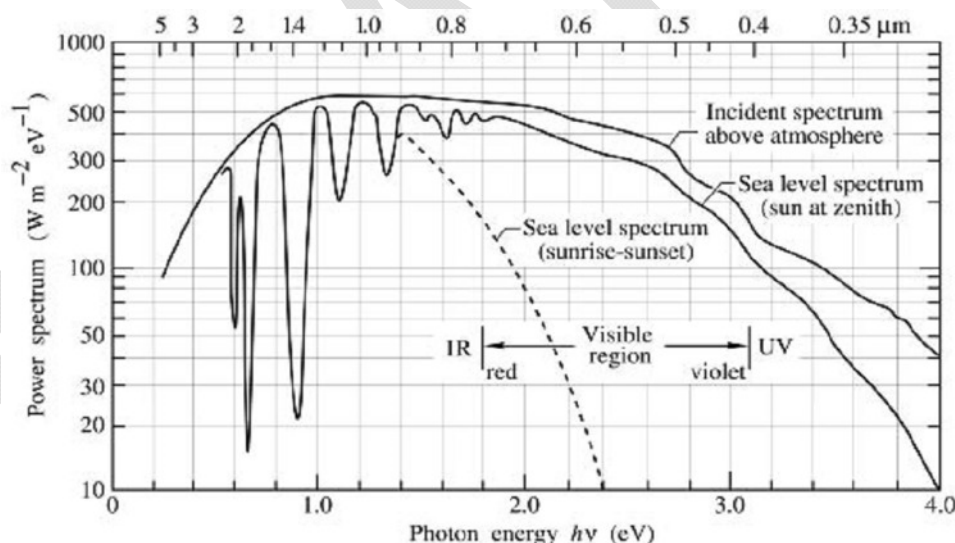


Figure 1 *Power spectrum of solar radiation versus photon energy and wavelength for different conditions (adopted from Jackson, 1975)*

5.3. LIGHT DEPENDENT RESISTOR (LDR)

The most common daylight switch sensors are the light dependent resistor (LDR), as they are cheap and simple to use. The resistance of the LDR varies with illumination, with LDR resistance decreasing as illuminance increases. This change in resistance is used to trigger the switching action.

In case of LDR, we can typically choose between 520, 540, 560, 570, 620 and 630 nanometres of peak sensitivity wavelength. Manufacturers state that these sensors are non-polar resistive elements with spectral response characteristics close to the human eye but do not supply the spectral response curve. The manufacturer's resistance values for adjustment are measured for tungsten filament lamps operating at a colour temperature of

2856 K, and then changes are necessary for the adjustment of the daylight levels. It is important to know the spectrum of light in sunset or sunrise is near to this lamp (see Figure 1). The accuracy between 100 and 10 lux depending of the model is about 85% or 90%.

5.4. SEMICONDUCTOR PHOTODIODE

Some photovoltaic applications use the output of the solar array as a daylight sensor. The output from one solar panel is connected to a comparator where voltage is compared with an adjustable reference voltage. The change in solar cell voltage is used to trigger switching action. Additionally, separate semiconductor photodiode sensors are also available.

When using the solar array, the spectral response of the may be considered. The spectral response of a silicon solar array is good in blues or near ultraviolet zones but is not good in the red zones. In GaAs arrays, the spectral response is better in the red zones of the spectrum.

6. RECOMMENDED SWITCHING LEVELS

The selection of the ambient light at which AtoN lights switch on or off must meet the following criteria:

- the navigational requirements must be met, i.e. the navigation light must be switched on when the light is required as an AtoN;
- where multiple lights are used as AtoN such as to form a channel using buoys, all lights should switch on and off almost simultaneously to avoid gaps in the channel mark at lighting up and light off time;
- switching levels should not be set too high, to avoid excessive daily energy consumption, or too low, to avoid interference from bright moonlight;
- however, where there is a conflict between energy consumption and provision of the AtoN function, priority should be given to the AtoN function;
- the recommended switching levels should be based on the basic characteristics of human perception.

Ideally, the AtoN should switch on at an ambient light level when the AtoN becomes unusable as a daymark.

6.1. HYSTERESIS IN SWITCHING LEVELS

In order to ensure that the on and off switching levels are clearly defined, it is necessary to ensure adequate hysteresis between the on and off levels.

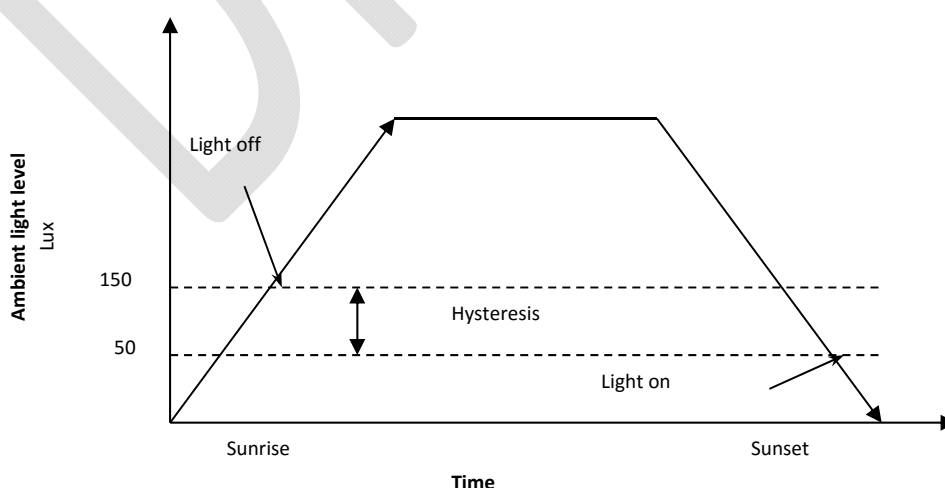


Figure 2 *Hysteresis in AtoN light switching*

In Figure 2, a difference of 100 lux between the light off level as ambient light level increases and the light on level as ambient light decreases ensures that the light does not switch on and off at the switching threshold point. Typical hysteresis of 50 to 100 lux provides satisfactory performance. It is also considered to include a time delay of a few minutes in the hysteresis system to limit the bandwidth of the switching element.

6.2. IALA SURVEY OF SWITCHING LEVELS USED BY MEMBERS

In 2003, IALA carried out a survey through a questionnaire on ambient Light Levels at which AtoN lights should be switched on and off [3]. A total of 8 responses were received, from Finland, France, Germany, Sweden, Denmark, Holland, England and Hong Kong. The responses are summarised in **Erreur ! Source du renvoi introuvable.**

The following observations were made:

- 1 Most of the respondents have established formal policies defining the ambient light level at which their AtoN's turn on and off.
- 2 One respondent (Germany) has no ambient light sensors at their lighthouses, but controls ON and OFF switching on the basis of the time of sunset – 1 hour and sunrise + 1 hour at a reference location. This method seems to discard any effects from varying meteorological conditions.
- 3 The ON switching level for lighthouses varies in the range 20-100 lux.
- 4 The ON switching level for buoys varies in the range 15-200 lux.
- 5 The OFF switching level for lighthouses varies in the range 40-200 lux.
- 6 The OFF switching level for buoys varies in the range 40-200 lux.
- 7 According to one respondent, it is important to ensure that a system of AtoN turn ON and OFF at approximately the same time, in particular, on leading lines where lights preferably should switch simultaneously.
- 8 Most of the respondents have a switching time delay (hysteresis) to avoid switching oscillation but the switching delay time varies in the range 15-600 seconds.
- 9 In many cases the switching level can be adjusted, both in the workshop and in the field.
- 10 Both light dependent resistor (LDR) and semiconductor photodiode type sensors are used.
- 11 At lighthouses, most respondents face the sensors away from the sun.
- 12 During manufacturing process, switching levels may or may not have been tested against ambient light.
- 13 In many cases lighthouse switching levels are tested during commissioning and in some cases monitored afterwards.
- 14 Buoy lanterns are generally not tested during commissioning, but in some cases monitored afterwards.
- 15 The switching level adjustments may either be done by flasher programming or by mechanical means including adjustable optical filters.

6.3. AMBIENT LIGHT SWITCHING LEVELS

A useful guide to the ambient light levels at which AtoN lights should switch on and off is as follows:

- switch on at 50 – 100 lux;
- switch off at 150 – 200 lux;
- hysteresis of 50 - 100 lux;
- if hysteresis has time delay, typical value of 0.5 to 8 minutes.

In certain conditions of local visibility switching at higher lux levels, up to 300 lux, may be appropriate dependent on location.

7. TESTING AND ADJUSTMENT OF NAVIGATION LIGHT SWITCHING LEVELS

This procedure is designed to set an aid-to-navigation light to turn on and off corresponding to a desired ambient light level. The procedure assumes that the light sensitive device used to turn on and off the AtoN light, called the daylight switch, is adjustable. The procedure contains two parts; the first part describes the construction of a light source simulator used for the calibration. The second part describes the actual procedure.

Because of the difference in spectral characteristics between artificial light and sunlight, it is difficult to devise effective workshop methods of setting up daylight switches using artificial light. Standards such as (CIE) D65, D55 and D75 simulate daylight at different times of the day but are expensive.

The spectral characteristics of the light meter used for the measurement is also important.

7.1. LIGHT SOURCE SIMULATOR

An enclosed booth can be used to control the level of illumination of the daylight switch to configure the switch on and off levels. The booth's interior is painted white and ideally spherical to ensure integrated distribution of light. The booth is designed to allow access to measuring location with minimum outside lighting interference. The size of the booth should be sufficiently large to accommodate the test lantern and provide even illumination within the booth.

The light source used for calibrating a 'daylight switch' should have a similar spectral distribution to the sun (or daylight). However, the spectral response of most light detectors is not perfectly corrected to the human eye response (CIE $V(\lambda)$). This will give an error when calibrating the daylight switch.

7.1.1. TUNGSTEN FILAMENT LAMP

Using a tungsten filament lamp for calibration the error may be significant, because of the low colour temperature and the infrared light. Therefore, a calibration factor should be applied to account for spectral differences.

The spectrum of the lamp can be improved by the use of an infrared blocking filter and a conversion filter to achieve artificial light in compliance with standard D55 or D65.

The tungsten filament lamp can be a typical 100 W, inside frosted, incandescent light bulb that is normally used in the residential lighting. When used without filter it is rated at about 90 cd and burns at approximately 2900 K. The preferred lamp is a halogen lamp with a higher colour temperature of approximately 3100 K.

The light source may be connected to a variable power supply to vary the intensity slightly. To avoid a large change in spectral output, the lamp should be driven near the nominal voltage and current.

7.1.2. SHORT-ARC XENON LAMP

A short-arc xenon lamp provides a better spectral distribution, but it has a high infrared content and should be used with an infrared blocking filter. The output of the lamp is also difficult to control.

7.1.3. WHITE LED

A white LED source may provide a sufficient spectral distribution for the calibration process. The intensity can be controlled over a large range without changing the spectral output.

7.1.4. DAYLIGHT

Where daylight is available, it may be used to illuminate the interior of the box through an adjustable opening. This method is only suitable where the level of daylight remains constant during the period of calibration and variations do not occur due to shadows from moving clouds or passing traffic. The light level within the booth is adjusted by varying the size of the daylight aperture.

7.2. MEASURING EQUIPMENT

In order to measure the ambient or illuminating light level, a calibrated luxmeter will be required. The luxmeter should be capable of measuring illuminance in the range required, e.g. 1 to 5000 lux and have sufficient resolution over that range, e.g. 3 significant figures. The luxmeter should have a spectral response close to $V(\lambda)$ with an $f1'$ figure of 2% or better (see IALA Recommendation E-200-3 on Marine Signal Lights - Measurement.).

One problem with introducing a measuring instrument into a light booth is that the instrument itself tends to cast shadows, thereby compromising the evenness of illuminance in the booth. In order to keep this shadowing to a minimum, a luxmeter with a separate, and preferably small, measurement head is preferred. The head can be placed in the booth and the main body of the instrument can be placed outside the booth. More than one measurement head may be used at different positions within the booth to check the evenness and level of illumination.

7.3. CALIBRATION AND ADJUSTMENT OF DAYLIGHT SWITCH

7.3.1. CALIBRATION PROCEDURE USING THE LIGHT BOOTH

This method is used for indoor calibration of daylight switches and is mainly for use with small lanterns such as used on buoys.

To determine the switching levels of a lantern:

- at the light booth, turn on the light source slowly until full brilliance is achieved. Wait for 5 minutes before proceed to next step;
- place the lantern and luxmeter inside the light simulator booth at location of uniform light (direct incidence of the light on either sensor must be avoided to ensure a proper measurement);
- dim light source slowly until the lantern light comes on. Record this light level as the simulated ON light level;
- increase the light level until the lantern light turns off. Record the light level as the simulated OFF light level;
- apply any corrections necessary for the type of light source employed.

To program a lantern with specific switching levels:

- set the threshold of the ON level to the minimum value and the OFF level to the maximum value;
- place the lantern with daylight switch located at the measuring location of the light booth;
- turn on the light source to the specified ON level, waiting for a few minutes until the light level stabilizes;
- adjust the lantern light ON level until the light switches on;
- increase the light source level to the specified OFF light level;
- adjust the lantern light OFF level until the light switches off.

7.3.2. OUTDOOR MEASUREMENT

This procedure is applied to external daylight switch configuration where the daylight switch is exposed to direct sunlight such as in large lighthouses.

- use an external daylight switch as normally installed in a lantern that can be controlled to turn on and off through software of the flasher/lampchanger, or via an adjustable hardware such as potentiometers;
- place a portable luxmeter beside the daylight switch so these two components are aligned at the same plane and in close proximity; other sensor placement may be used where necessary to obtain actual ambient light level measurement. The daylight switch is normally oriented either north or south (avoid east or west direction) to avoid problems with rising and setting sun;

- monitor the luxmeter readings around dusk in the evening;
- at the desired daylight switch setting level per section 5.3, adjust the lantern light to turn on;
- repeat this step in the next morning around dawn. Adjust the lantern light to turn off at desired ambient light level.

8. ALTERNATIVE SWITCHING METHODS AND POWER CONSIDERATIONS

8.1. REAL-TIME CLOCK (RTC)

An RTC option is available for switching the light on and off based on a set schedule. This option is generally included on current light technology, so will not require any additional considerations for power consumption. RTC option generally does not account for seasonal change, but is used as a secondary method in conjunction with a light dependent resistor.

8.2. GNSS / CELLULAR / RADIO / SATELLITE

A GNSS receiver determines day and night configuration using an available input for control and override for the default sensor.

GNSS option with an AtoN that is already being used for synchronisation will not have additional power consumption for switching on and off. However, adding GNSS for input control and override will increase power consumption, depending on manufacturer and model, ranging approximately 1-4 Wh per day.

Cellular messages may be used for switching, data reporting and alarm transmission. Energy consumption varies dependent on frequency of switching, reporting schedule, and alarm reporting. Generally, power consumption will be 2 or more Wh per day.

Radio and satellite links are also an option, but typically have a significant increase in power consumption. This would require adding additional solar panels, batteries, or other power sources depending on the design and application of the AtoN. This option is not recommended on buoys or locations with a limited surface area for expansion.

8.3. VISIBILITY DETECTOR

A sampling method is used, measuring the atmospheric visibility over a particular sample area; if the sample value is under the visibility detectors value, a switch for the lights to be overridden will become active. Depending on the method used for the visibility detector, power consumption is approximately 5 to 10 Wh per day. Visibility detectors are typically used for switching fog signals, but can also be applied to other AtoNs.

8.4. AtoN ON DEMAND (AoD)

An AoD is practical at locations where use of occasional lights is substantiated due to limited traffic densities and restricted availability of energy. AoD can also be implemented as a complementary solution to enable increasing of luminous intensity of regular AtoN lights in severe weather conditions like fog or heavy rain.

AoD is an AtoN light equipped with a subsystem that enables remote activation of the navigational light signal based on the needs of the mariners overriding normal operation. An AoD must be equipped with remote control equipment that corresponds to the activation method and communication protocol.

When deployment of an AoD is considered and general navigational risk assessment allows it, decisions regarding the following aspects must be made:

- 1 Intended group of users – all mariners, limited groups of mariners or vessels (local ferries), all vessels carrying AIS, etc.
- 2 Activation method – direct (requested by a mariner), or indirect (automated, based on AIS traffic data or other relevant information available over the communications network).

3 Selection of activation technology suitable for targeted user groups and selected methods.

8.4.1. AOD ACTIVATION METHODS

Activation methods selected for AoD depend on targeted group of users and access limitations. Risks associated with the vulnerabilities and availability must be considered before deploying an AoD. It should also be decided whether the AtoN light signal remains on until deactivated, or shuts down after a time period.

8.4.2. MANUAL AOD ACTIVATION

8.4.2.1. VHF Signal

Multiple successive activation instances of the 'Transmit' (Push to Talk) button on a marine VHF radio channel are used to activate the light for a pre-determined time period.

This technology is suitable for unlimited user group but does not provide any means for user authentication as well as no feedback information on state of the light.

8.4.2.2. Cellular Short Message Service (SMS)

Short Message Service (SMS) messages of the cellular phone system are used to activate the light for a pre-determined time period.

This technology is suitable for unlimited user group as well as selected groups of phone numbers. It does provide basic means for user authentication and even feedback information, but cannot be considered 100% reliable: while up to 5% of all SMS messages may be lost in transmission or significantly delayed. Additionally, it also requires the user to have cellular reception.

8.4.2.3. Network Solution

Network solutions based on dedicated network servers and/or standard web browsers are used for the activation and deactivation of the light. App based solutions using a dedicated client application software utilising network server technology may replace the use of a web browser.

This technology is suitable for unlimited user group as well as limited groups with access based on user names and passwords. Due to global access potential, unlimited anonymous public access is not recommended. It provides wide range of means for user authentication, provision of feedback information, posting warnings and logging of all related events at the server side. Since users have no direct access to the AtoN, such systems provide higher degree of protection against unauthorized activations and remote system disruptions.

8.4.3. AUTOMATED AOD ACTIVATION

8.4.3.1. AIS

AIS receiver may be used as a proximity alert, for signalling a light to turn on for a period of time, or to change the light intensity. By analysing the traffic of AIS-equipped vessels, it is possible to switch on or change intensity of either AtoN lights or indirect lighting based on the speed and direction of vessels. To achieve optimum power consumption, such systems can be built to power the light source only in sectors corresponding the direction necessary.

Systems are available to detect both class A and B AIS transceivers. AIS receivers are sufficient for discovering relevant vessels, helping to reduce power consumption. A typical AIS AtoN type 1 requires less than 10 Wh per day, depending on message scheduling. Additional software development could be necessary to turn on the AIS receiver during particular times, minimizing power consumption. An example provided in ENG4-9.20 [5] shows that such systems can be implemented with a power consumption of approximately 2.5 Wh per day, including the computational module.

9. ACRONYMS

AIS	Automatic Identification System
AoD	AtoN on demand
AtoN	Aid(s) to Navigation
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination)
DIP	Dual in-line (switch)
GaAs	Gallium Arsenide
GNSS	Global Navigation Satellite System
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities – AISM
IR	Infrared
LDR	Light dependent resistors
LED	Light-Emitting Diode
LMT	Lichtmesstechnik GmbH Berlin
MHz	Megahertz
nm	nanometre
PD	Photo diode
RTC	Real-time clock
SMA	Swedish Maritime Administration
SMS	Short Message Service
UTC	Co-ordinated Universal Time (Universal Time Co-ordinated)
UV	Ultra Violet (light) (10 – 380 nm)
VHF	Very High Frequency (30 MHz to 300 MHz)
$V(\lambda)$	photopic response
Wh	watt hour

10. REFERENCES

- [1] IALA, IALA Aids to Navigation Guide (NAVGUIDE) 7th Edition, Chapter 3, Page 64, Table 11, Timing of Astronomical Events, IALA Aids to Navigation Guide (NAVGUIDE) 7th Edition.
- [2] IALA Engineering Environment and Preservation of Historic Lighthouses Committee, EEP4 Input Comment on ambient Light level at which the Lights should switch on and off, Maritime Safety Administration of Peoples Republic of China, 2004. [Available on IALA Wiki]
- [3] IALA Engineering Environment and Preservation of Historic Lighthouses Committee, IALA EEP3 Input Summary of Responses to IALA ambient Light Level Questionnaire, Royal Danish Administration of Navigation and Hydrography, 6 September 2003.
- [4] IALA Guidelines on a standard Method for Defining and Calculating the Load Profile of Aids to Navigation, December 1999.
- [5] 'AIS detection for visual AtoN'. IALA ENG Committee input document ENG4-9.20 by Sigge Gustafsson / SMA.[Available on IALA Wiki]

ANNEX A SUMMARY OF RESPONSES TO AMBIENT LIGHT LEVEL QUESTIONNAIRE 2003

	Question	Comments (Lighthouse)	Comments (Buoy)
1	Does your organisation have standards/policy for switching of light levels of AtoN's?	NO = 1, YES = 4 'ON switching level is set' 'We depend upon the lantern supplier's standard for their equipment and is normally one hour before dark and one hour after dawn' 'There are no switching sensors in lighthouses'	NO = 1, YES = 5 'ON switching level is set' 'as supplied by lantern manufacturer' 'We depend upon the lantern supplier's standard for their equipment and is normally one hour before dark and one hour after dawn'
2	ON switching level (lux)?	20, 50, 100, 100, 50-100 'Depends on the sunset. Light switches ON one hour before sunset in the city of Cuxhaven.'	15, 20, 50-00, 100, 100, 100, 200
3	OFF switching level (lux)?	40, 100, close to 100, 150, 200 'Depends on the sunset. Light switches ON one hour before sunset in the city of Cuxhaven.'	40, 60, 100, 100-150, 150, 200, 200
4	Acceptable tolerance levels?	+30 and -0, ON 10-40 and OFF 10-60, Varies from 70-350 'Switching levels are field adjusted according to the amount of trees and other obstructions around AtoN to have AtoN switch on and off times approximately equal between AtoN. Adjustment is especially important and difficult on leading lines because lights should switch on and off simultaneously.'	±20 10% ON 10-40 and OFF 10-60 Varies from 70-350 Not defined
5	Is there a switching time delay?	NO = 2 YES = 4	NO = 2 YES = 6
6.1	Switching delay time?	60, 15-60, 15-240, 600 seconds	15-60, 15-240, 30, 60, 60, 600 seconds
6.2	Can the switching level be adjusted?	NO = 2 YES = 4	NO = 1 YES = 5 'Only in some lanterns'
7	What is the adjustment range of switching level	2 lux 10-1000 lux ±50%	2 lux 15-60 lux, 10-1000 lux ±50%

	Question	Comments (Lighthouse)	Comments (Buoy)
8	Can the switching level adjustment be factory or field set?	YES = 2 'Factory and field' 'Field set' 'Factory setting is usually 100 lux'	YES = 2 'Factory and field' 'Field set', 'Field' 'Factory setting is usually 100 lux' 'Only factory/workshop set'
9	What type of light switching sensor is used?	LDR = 3 'Cadmium Sulphate Photocell' 'Photodiode' 'Photoconductive cell'	LDR = 3 'Cadmium Sulphate Photocell' 'Photodiode', 'Photoconductive cell' 'Phototransistor BP 103/4'
10	Which direction does the sensor face (vertical, facing the sun or away from the sun)?	'Facing North', 'Vertical facing North' 'Vertical away from the sun' 'Away from the sun' 'To the most open direction and away from the forest' 'Fitted in base of a light tube which collects light all around (360 degrees)'	'Typically horizontal' 'Vertical, sensor is facing the sun'
11.1	Are switching levels tested against ambient light levels during manufacture?	YES = 2 NO = 3	YES = 3 NO = 2
11.2	Are switching levels tested against ambient light during commissioning (user)?	YES = 3 NO = 2 'On and Off times are monitored after commissioning'	YES = 1 NO = 4 'On and Off times are monitored after commissioning'
11.3	Please provide details of switching level adjustment procedures.	'With old flashers adjustment is made by rotation optical filter. With new programmable flashers adjustment can be made either by filter or programming' 'Mechanical Adjustment' 'to cover switching resistor' 'Resistor value'	'DIP Switch setting according to manual' 'Programmable flasher' 'LMT lux measurements lamp + daylight.' 'to cover switching resistor'