OCS Study
BOEM 2016-002

Development of Guidance for Lighting of Offshore Wind Turbines Beyond 12 Nautical Miles

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Development of Guidance for Lighting of Offshore Wind Turbines Beyond 12 Nautical Miles

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ABOUT THE COVER

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EXECUTIVE SUMMARY

In fulfilling its jurisdictional responsibilities under the Energy Policy Act of 2005, the Outer Continental Shelf Lands Act, and the National Environmental Policy Act, the Department of the Interior's Bureau of Ocean Energy Management (BOEM) is actively involved in evaluating potential environmental impacts related to the development and operation of offshore renewable energy. The lighting of offshore wind facilities is a primary concern for avian resources, important for aviation and navigational safety, and also of concern for visual impacts to onshore areas adjacent to renewable energy development.

The Federal Aviation Administration (FAA) has jurisdiction over how wind turbines should be marked and lit in order to maintain safe airspace for pilots out to the 12 Nautical Mile (NM) limit of the territorial sea. BOEM has jurisdiction for the development of lease areas in federal waters and responsibility for determining marking and lighting of proposed wind turbine structures beyond 12 NM. Since no wind turbines are currently installed beyond 12 NM on the Outer Continental Shelf (OCS), BOEM presently has the opportunity to evaluate whether to adopt the FAA Advisory Circular AC-70/7460-1L and the Obstruction Marking and Lighting (December 2015) guidance for installations beyond 12 NM, or to develop alternative guidance that could reduce or avoid impacts to birds and/or to visual onshore receptors while still maintaining aviation safety.

ESS Group, Inc. (ESS) evaluated the FAA guidance for marking and lighting wind turbines and conducted additional research on other available lighting guidance, offshore lighting impacts to birds, visual impacts, and technical capabilities of various lighting and control technologies in order to help inform the preparation of alternative guidance for BOEM to consider.

Building off of the previous work of the OCS Study BOEM Report 2013-0116, *Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments*, a review of international guidelines was conducted in order to identify any relevant updates for the International Civil Aviation Organization (ICAO) guidelines and rules and regulations from select jurisdictions that represent some of the largest offshore wind markets in Europe. The review found that there have been no changes to ICAO guidelines, or those of Belgium, Germany, or the United Kingdom that affect the lighting of offshore wind turbines. Changes made in Denmark and Canada were informative in preparing the alternative guidance. Appendix B provides the full report on the international guidelines review. ESS also conducted additional literature review of any relevant studies concerning impacts to birds that have been completed since 2013. The review indicates that in those instances where obstruction lighting is required, there is general agreement amongst avian specialists that the use of flashing, red lights of the lowest intensity practicable is the preferred arrangement for limiting impacts on avifauna.

Aviation obstruction lighting associated with offshore wind farms has been documented to have visibility beyond 25 miles, thus raising visual impact concerns. A number of factors – some of which can be controlled and others that cannot – that influence visibility and visual impact related to obstruction lighting for offshore wind turbines were evaluated in order to inform the alternative guidance with the goal towards minimizing visual impacts to shore.

A full review of available technology for lighting and control of obstruction lights was conducted. In addition to review of existing literature, the ESS team conducted outreach to academics, regulators, and vendors. Information is presented on lighting technology (incandescent, fluorescent, Light Emitting Diodes (LED), and Infrared), and control technology (visibility controlled variable intensity, and demand oriented lighting).

In cooperation with BOEM's efforts to evaluate offshore wind turbine lighting beyond the FAA's own jurisdictional limit of 12 NM, the FAA provided BOEM with a pre-approval draft version of a revised FAA Advisory Circular AC-70/7460-1L Obstruction Marking and Lighting. These new draft FAA guidelines included, in part, new guidance on the marking and lighting of wind turbines of heights of 499 ft. and above (Chapter 13), as well as new guidance on Aircraft Detection Systems (Chapter 14). The draft Advisory Circular AC-70/7460-1L was issued as a final document by the FAA on December 4, 2015. As a means of assisting BOEM in determining whether to adopt the new draft FAA guidelines for use beyond 12 NM, or to consider alternative guidelines that may be more applicable for the offshore environment, the ESS team has utilized Chapter 13 of the FAA guidance and revised it to reflect alternative guidance based on the information presented above. This alternative guidance is presented in Appendix A.

After evaluating the new draft FAA guidance for marking and lighting wind turbines and conducting additional research on other available lighting guidance, offshore lighting impacts to birds, visual impacts and technical capabilities of various lighting and control technologies, the ESS team has prepared alternative guidance for obstruction lighting of offshore wind turbines beyond 12 NM for BOEM's consideration. The proposed alternative guidance presented in Appendix A is, in some respects, more prescriptive in nature than the FAA's guidelines (i.e. specifying the use of LED lighting fixtures with LEDs that emit infrared energy between 675 and 900 nanometers), yet also introduces the use of technology that is not currently part of the FAA's guidance (i.e. visibility controlled variable intensity lighting). The alternative guidance, due to its prescriptive nature, provides clarity, direction, and standardization to the offshore wind industry. If implemented, the alternative guidance is expected to significantly reduce any visual impacts to onshore observers (beyond 12 NM), minimize any impacts to birds, address concerns over night vision goggles (NVG) compatibility and maintain the same level of conspicuity and airspace safety as the FAA's guidance within 12 NM.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ADS	Aircraft Detection System
ADLS	Aircraft Detection Lighting System
BMP	Best Management Practices
BOEM	Bureau of Ocean Energy Management
cd	Candela
DNV GL	Garrad Hassan America Inc.
ESS	ESS Group Inc.
FAA	Federal Aviation Administration
fpm	Flashes per Minute
ICAO	International Civil Aviation Organization
IR	Infrared
LED	Light Emitting Diode
MW	Megawatts
NM	Nautical Mile
NVG	Night Vision Goggles
NVIS	Night Vision Imaging System
OCS	Outer Continental Shelf
USCG	US Coast Guard

1.0 INTRODUCTION

In fulfilling its jurisdictional responsibilities under the Energy Policy Act of 2005 (EPAct), the Outer Continental Shelf Lands Act and the National Environmental Policy Act, the Department of the Interior's Bureau of Ocean Energy Management (BOEM) is actively involved in evaluating environmental impacts related to the development and operation of offshore renewable energy. BOEM continues to develop best management practices (BMPs) and guidelines for monitoring and mitigation of conflicts and impacts related to construction and operations of renewable energy development on the Outer Continental Shelf (OCS). The lighting of offshore wind facilities is a primary concern for avian resources, important for aviation and navigational safety, and also of concern for visual impacts to onshore areas adjacent to renewable energy development. Earlier research on many of the issues pertaining to offshore lighting was initiated by BOEM in 2012 and resulted in the OCS Study BOEM Report 2013-0116 *Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environment* (OCS Study 2013-0116).

While the Federal Aviation Administration (FAA) has jurisdiction over how wind turbines should be marked and lit in order to maintain safe airspace for pilots, their jurisdiction applies only out to the 12 Nautical Mile (NM) limit of the territorial sea. BOEM has issued a number of commercial leases for renewable energy development for submerged lands on the OCS that extend beyond 12 NM from shore, and has jurisdiction for the development of those areas, including the marking and lighting of proposed wind turbine structures located beyond 12 NM from shore. With no wind turbines currently installed beyond 12 NM, BOEM at this time has the opportunity to evaluate whether to adopt the FAA Guidance (Advisory Circular 70/7460-1L) for installations beyond 12 NM, or to develop their own alternative guidance that could reduce or avoid impacts to birds and/or to visual onshore receptors while still maintaining pilot safety in an area with significantly less low-level aviation activity then areas closer to shore.

In their efforts to provide clarity, direction, and standardization to the offshore wind industry in advance of the first turbines being installed beyond 12 NM, BOEM has contracted with ESS Group Inc. (ESS) to evaluate the adoption of FAA guidance beyond 12 NM, and to propose alternative guidance that would address aviation safety and environmental concerns including effects on birds and visual impacts to shoreline users. ESS, supported by teaming partner Garrad Hassan America (DNV GL), evaluated the FAA guidance for marking and lighting wind turbines and conducted additional research on other available lighting guidance, offshore lighting impacts to birds, visual impacts, and technical capabilities of various lighting and control technologies in order to help inform the preparation of alternative guidance. The draft alternative guidance is presented as Appendix A of this report. This report will provide an overview of the research conducted and the findings used to justify the alternative guidance presented in Appendix A.

2.0 REVIEW OF INTERNATIONAL GUIDELINES

In helping to prepare OCS Study 2013-0116, DNV GL researched international guidelines, as well as rules and regulations from civil aviation authorities from numerous jurisdictions in North America, Europe, and Asia, with the findings presented as Appendix B (Guidelines, Rules and Regulations) of that report. In order to supply supporting information to the proposed guidance for 12 NM and beyond, DNV GL performed a review of key international guidelines to determine if any significant changes may have taken place since 2013 that would help inform this effort.

A review was conducted of relevant updates for the International Civil Aviation Organization (ICAO) guidelines and rules and regulations from select jurisdictions that represent some of the largest offshore wind markets in Europe. These included Belgium, Denmark, Germany, and the United Kingdom, as well as Canada. The review found that there have been no changes to ICAO guidelines, or those in Belgium, Germany, or the United Kingdom that affect the lighting of offshore wind turbines. Where changes have occurred, several were considered informative for the development of lighting guidance beyond 12 NM. These include:

- Denmark now requires that there must be a regulator for the light intensity and a measurement of the visibility, so that the intensity of the obstruction lights may be adjusted according to the meteorological visibility. Turbines are to be lit day as well as night. Additionally, each offshore wind turbine must be lit with two red lamps, and depending upon the location within the array, the intensity and characteristic will vary with 2000 candela (cd) flashing lights specified for turbines at corners or sharp bends along the periphery of an array and 10 cd steady burning lights specified for turbines along the periphery and inside the perimeter turbines. Turbines with heights greater than 150 m (492 ft.) should also be equipped with a red solid light with an intensity of 32 cd at an intermediate height midway between the sea surface and the nacelle.

- Canada is preparing draft guidelines for onshore wind turbines that would require two medium intensity flashing red lights to be located on the nacelle, one light operating at all times and a second light serving as backup in case of failure of the first operating light. Additional low intensity red lights would also be required at intermediate levels and synchronized to flash with the top lights. The draft guideline also adds provisions for the use of aircraft detection systems (ADS) on a case-by-case basis, along with the basic specifications to be met if such a radar activated obstruction lighting system is to be used.

DNV GL's full report is included as Appendix B.

3.0 REVIEW OF ENVIRONMENTAL IMPACTS

In evaluating any lighting schemes for offshore wind turbines, BOEM shares the common goal with the FAA of maintaining conspicuity to pilots and ultimately aviation safety, however BOEM is also mandated with minimizing or avoiding environmental impacts related to offshore renewable energy production including those that might occur from the marking and lighting of wind turbine structures. While the earlier report (OCS Study 2013-0116) found that impacts from offshore lighting have minimal if any effect on marine mammals, sea turtles, and fish, BOEM maintains its objective of minimizing any impacts to birds as well as any visual impacts to onshore receptors.

3.1 Avifauna

An extensive review of scientific literature concerning the impacts to birds from offshore lighting was presented in OCS Study 2013-0116. Many of the studies reviewed agreed on a few general principles regarding mitigation of impacts to avian resources from offshore lighting. These are the following.

1) Fewer lights are preferable to more lights

2) Lower intensity lights are preferable to higher intensity lights

3) White lights are the least favorable choice for lighting structures

4) Strobing or flashing lights are preferable to steady burning lights

These principles are consistent with FAA guidance (AC-70/7460-1L) for wind turbines, which calls for the use of flashing red lights for obstruction lighting. ESS conducted an additional literature search and reviewed any relevant studies that have been completed since 2013. With the exception of a small amount of research that has been conducted on the use of green lighting, the preponderance of the information reviewed continues to support the implementation of the general principles as stated above. In those instances where obstruction lighting is required, there is general agreement amongst avian specialists that the use of flashing, red lights of the lowest intensity practicable is the preferred arrangement for limiting impacts on avifauna.

3.2 Visual Impacts

Aviation obstruction lighting associated with offshore windfarms has been documented to have visibility beyond 25 miles, thus raising visual impact concerns. The visibility of these lights is of particular concern in offshore windfarms because the undeveloped coastal landscape and ocean are typically perceived as high-value aesthetic and natural resources of preservation quality. There are a number of factors – some of which can be controlled and others that cannot – that influence visibility and visual impact related to obstruction lighting for offshore wind turbines as shown in Table 1.

Table 1. Factors that Influence Visibility

Adjustable Control Factors	Limited Control Factors	Uncontrolled Factors
Light Intensity	Distance from the Viewer	Height of the Light Source
Physical Dimension of the Light Source	Flash Rate	Height of the Viewer
Color of the Light Source		Viewing Angle
Light Source Technology		Atmospheric Conditions

Light Intensity:

The greater the luminous intensity of a signal light, the more likely it will be detected in a field of view (Bullough, 2011), and as intensity increases, detection probability increases in a curvilinear manner. FAA guidance (AC 70/7460-1L) require a medium intensity red flashing light with a minimum resulting intensity of 2000 cd, referred to by the FAA as an L-864 fixture. While the light intensity must be sufficient for pilots to have enough reaction time (distance) in order to avoid the obstruction, this distance depends on the altitude and speed of the aircraft, as well as the purpose of the flight, but generally FAA guidance suggests that the L-864 fixture has a meteorological visibility of three miles, which is deemed sufficient avoidance time. As mentioned previously, in Europe, aviation signals (similar in intensity to the L-864) have been observed approximately 25 miles away (Sullivan, 2013). This light source assumes highly variable offshore meteorological conditions, thus on clear nights, the light can be seen many miles beyond the intended observer. While the L-864 at 2000 cd has been shown to be visible approximately 25 miles away, FAA researchers conducting flight evaluations of tower based obstruction lighting to reduce avian fatalities (Patterson, 2012) observed that L-810 obstruction lights (with an intensity of only 32 cd) were not visible until approximately 10 miles away.

Physical Dimension of the Light Source:

The physical dimension or size of the light source can have an influence on visibility distance (Douglas, 1977). Essentially, if the source of the light is within the viewer's line of sight, the physical dimension of the fixture will have an impact on the visibility distance (Douglas, 1977). By increasing the size of a light source, the distance it is visible will increase more so than an increase in intensity (Douglas, 1977). However, without specific application research, the actual correlation for the L-864 fixture size over visibility distance is not known.

Color of the Light Source:

There is likely little difference in visibility distance when using white verses colored lights. However, shorter wavelength colors (violet, blue, and green) and white lights tend to create more discomfort or annoyance from glare than longer wavelength colors such as orange and red (Bullough, 2011).

Light Source Technology:

Obstruction lighting typically includes incandescent bulbs or Light Emitting Diodes (LED), both of which are described in more detail in Section 4.0 below. In terms of visibility, LED lights have a narrower spectral power distribution and produce more saturated colors, which can lead to the perception of increased brightness for fixtures of the same luminance (Bullough, 2014). However, these differences in perceived intensity were determined insignificant for red-color signals. The flash characteristics of LED versus incandescent lights are different in that incandescent have a smooth off-to-on transition and LED have immediate onset and offset times, thus producing higher noticeability (Bullough, 2014).

Height of Light Source:

FAA guidance recommends that the obstruction light be placed "as high as possible on the turbine nacelle so they are visible from 360 degrees." As larger output turbines are produced, they tend to have larger rotor diameters thus requiring taller towers and generators/nacelles. This results in a higher aviation obstruction light position. Since turbine generation output is one of the single biggest factors in the economic viability of a wind project and larger and larger machines are under development, there is little that can be done to reduce the height of the obstruction lighting, and in fact height can be expected to increase for projects beyond 12 NM.

Distance from the Viewer:

The distance of the light source from the viewer is likely to be one of the best mitigating factors in nighttime visibility. Light will dissipate over distances. Additionally, there are physical factors such as curvature of the earth and atmospheric conditions, which can completely diminish the visibility of obstruction lighting. The effects of curvature of the earth are expressed in Figure 1 and Table 2. Essentially, it is physically possible (assuming clear daytime conditions and excellent acuity on the part of the viewer) for the tops of the nacelles of wind turbines of tower heights ranging from 100 to 150 m to be seen from approximately 44-53 km (23.5-27.8 NM) over water before they fall below the physical horizon (adjusted for refraction). This does not address visibility at night when the lamps are lit but shows that under normal viewing conditions, at those distances, the obstruction light fixture will not be visible to an observer at beach level. This distance is increased proportionally if the height of the viewer increases.

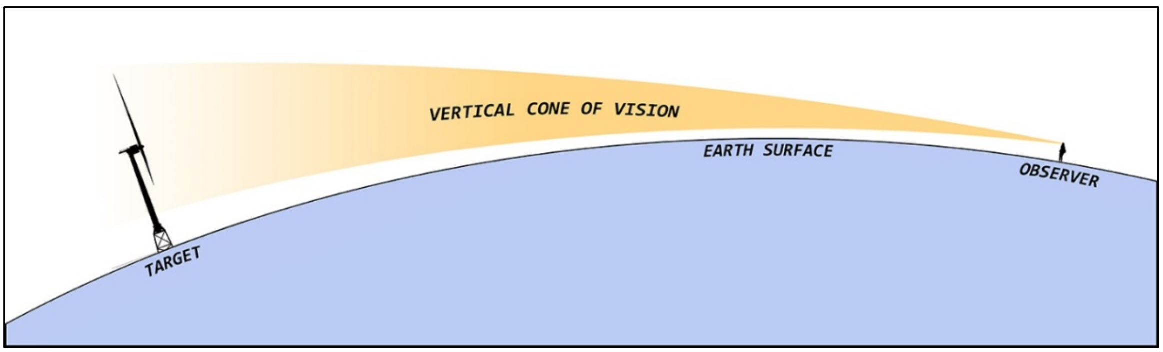
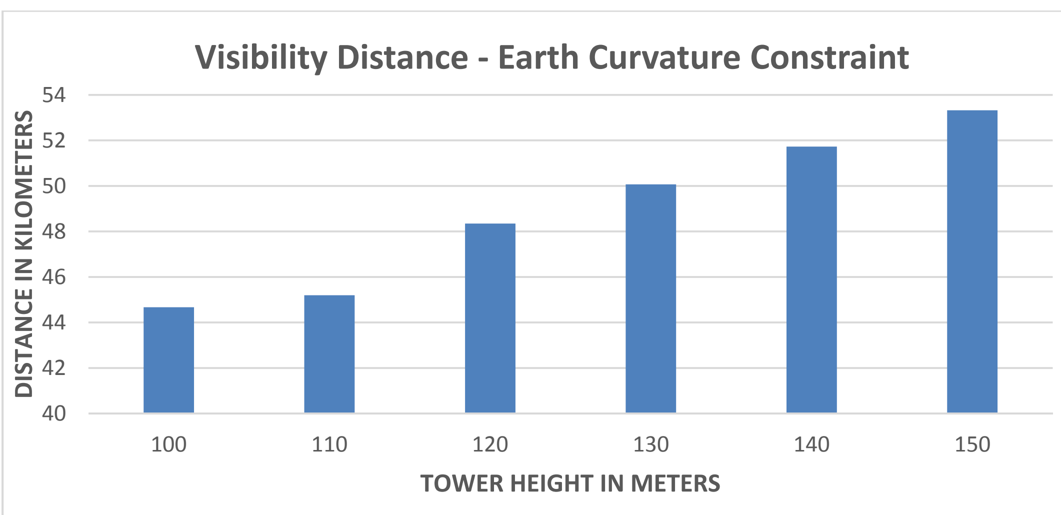


Figure 1. Effect of Earth Curvature on Visibility

Table 2. Visibility Distance for Selected Tower Heights



Flash Rate:

According to FAA guidance, the recommended flash rate of 20-40 flashes per minute (fpm) is required for the L-864 medium intensity light. This equates to one flash every 3 to 1.5 seconds respectively. The FAA further determined during its evaluation of new obstruction lighting techniques that this reduces avian fatalities (Patterson, 2012) and that a flash rate of 30 +/- 3 fpm provided the optimum presentation to pilots. LED lights have been found to have greater perceived intensity and detectability resulting from the color saturation produced by the light and the immediate onset and offset times when flashing (Bullough, 2014). Therefore, it is likely that slower flash rates may be less conspicuous from shoreline locations.

Height of the Viewer:

The height of the viewer has a similar linear effect as increasing the height of the tower. However, it is possible that in variable terrain, the height of the viewer can have a more profound effect on visibility. For example, if a coastal view was blocked by a feature close to the viewer, elevating the viewer would have more influence on visibility than raising the tower height at equal increments.

Viewing Angle:

If the signal acts as a point source of light, the visibility distance may be increased. As the physical dimension of the source increases, so does the effective intensity at the eye. Therefore, if the direct source of the light can be directed or shielded, the visibility distance may be reduced.

Atmospheric Conditions:

The distance within which obstruction lighting of any intensity will be visible will vary according to atmospheric conditions such as sea haze, fog, low cloud ceiling. Clear sky conditions with the highest level of meteorological visibility will result in lights being visible over greater distances than during times of low meteorological visibility.

4.0 TECHNOLOGY REVIEW

In order to best inform any alternative guidance that may be proposed for lighting of offshore wind turbines, a full review of available technology for lighting and control of obstruction lights was conducted. In addition to review of existing literature, the ESS team conducted outreach to academics, regulators, and vendors. Information is presented on various types of lighting and controls, with emphasis on how each may or may not help to minimize or eliminate impacts to birds, and/or onshore visual impacts while still maintaining pilot conspicuity and safety.

4.1 Lighting Technologies

Incandescent and Fluorescent:

Historically, obstruction lighting has primarily utilized incandescent light technology, which generates light through the heating of a filament until it glows. Incandescent lights have been significantly less expensive than fluorescent and LED lights but the bulbs are significantly less durable; the 2,000-hour life span of incandescent lights is a fraction of the life span of LED lights. The life span of incandescent lights is further reduced by on/off cycles, which also appears to have a more direct effect on avian fatalities as best described by FAA researchers:

> "Incandescent lamps have a tendency to be slow in turning on and off due to the time it takes for the filament inside the light fixture to either warm up when turned on or cool down when it is turned off. This slow warming and cooling time gives the appearance of a lazy flash pattern. In some situations, where an incandescent light fixture is being flashed at a faster flash rate (between 35 and 40 fpm), the filament of the light fixture cannot cool completely before it is energized again to complete the next flash cycle. Essentially, the light never completely turns off. Wildlife biologists believe that migratory birds will still fixate on these lights even if they change intensity during the flash cycle. As long as there is some light available, the birds will focus on it for navigation. For this reason, it is very important that the lights used on obstructions go completely off during a flash cycle." (Patterson, 2012).

Incandescent lights consume much more energy than LED lights for the same illumination (as much of the energy is lost as heat). They are also slightly sensitive to low temperatures and humidity. Due to developments in fluorescent and LED technology and cost reductions, incandescent lights are less competitive, particularly when considering the lifecycle cost.

The 8,000-hour life span, durability, and lighting efficiency offered by fluorescent lights is a noticeable improvement compared to incandescent lights but remain well below LED technology. In addition, fluorescent lights contain mercury, which complicates their disposal, and are sensitive to low temperature and humidity. Furthermore, they have a lag time when turning on, and on/off cycles drastically reduce their life span. For these reasons, fluorescent lights are mostly used in constant burn situations.

While some manufacturers continue to offer incandescent lighting systems, these are mainly limited to low-intensity lights. Fluorescent lighting systems can also be obtained but their drawbacks do not make them a good choice for wind farms. Both incandescent and fluorescent lights are now rarely used in wind turbine obstruction lighting systems due to the numerous advantages of LED lighting.

Light Emitting Diodes (LED):

LEDs are small, rugged, durable, and extremely energy efficient and long lasting. The life span of LED lights can reach up to 60,000 hours, meaning that after such time, their light output has dropped to 70% of the original output. LEDs consume 90% less energy than traditional incandescent lights and 50% less than fluorescent lights for the same illumination. LEDs can also sustain moderate power surges without experiencing failure. Additionally, LEDs contain no toxic materials, are recyclable, are not sensitive to low temperature or humidity, and on/off cycles do not affect durability.

The reduction in cost of LED technology over recent years coupled with the lower maintenance requirements (in both time and cost) has resulted in LED technology becoming the predominant technology for wind turbine obstruction lighting. The initial investment required for LED technology is higher than incandescent or fluorescent lights, but this margin is continuously narrowing. Many manufacturers offer Type L-864 and L-810 LED lights, as well as Infrared (IR) lights in LED.

Unlike incandescent bulbs, LEDs have an instant on-and-off capability, which according to the FAA, offers improved conspicuity over traditional incandescent (Patterson, 2012). As noted earlier, LEDs yield a different spectral output and a different intensity profile as compared to incandescent lighting. Thus, the question has arisen, could a lower LED intensity requirement be as effective as a higher incandescent requirement? Current research indicates that for certain colors, LED lights are judged by observers as brighter than comparable incandescent versions. However, this does not generally apply to red and yellow lights, which appear comparable to incandescent versions. Furthermore, fog tends to reduce the perceived intensity differences between LED and incandescent lights (Bullough, 2014).

Infrared:

Infrared (IR) lighting utilizes a region of the electromagnetic spectrum that has slightly longer wavelengths than visible light, but is not visible to the naked human eye. IR provides night visibility for pilots using night vision goggles (NVG) and night vision imaging systems (NVIS).

An issue that has been raised by both the Department of Defense and the US Coast Guard (USCG) is that LEDs without IR emit a single wavelength of colored light that is outside the range of NVG and NVIS (and also do not produce a significant thermal signature), making the obstruction lights virtually invisible to military and/or USCG search and rescue pilots conducting low-level activities when operating with NVG or NVIS. Manufacturers are now making L-864 and L-810 obstruction lights in LED versions, which include IR LEDs, making them visible to the human eye as well as NVG and NVIS.

Aviation IR aircraft warning lights have been approved for use at on-shore wind farms in the United Kingdom. Compliance with regulations has resulted in safe and consistent detection ranges when using NVG. At this time the FAA has not published any guidance related to infrared lighting for wind power applications.

4.2 Control Technologies

Visibility Controlled Variable Intensity Lighting:

Light intensity dimming consists of lowering the intensity of the obstruction lighting in conditions of good meteorological visibility, and returning it to full intensity during periods of low visibility. The purpose is to dim the lights under clear conditions while maintaining a level of visibility that is sufficient for aviation safety. Light intensity dimming reduces energy use, light pollution, bird attractants, and other negative impacts of traditional systems.

While dimming technologies are not currently approved by the FAA, some jurisdictions require or allow the dimming of nighttime obstruction lighting in cases of high meteorological visibility as a means of reducing visual impacts. Belgian, Danish and German regulations allow light intensity from aviation obstruction lighting to be lowered to 30% when visibility is more than 5 km and to 10% when visibility is more than 10 km. Canada has also indicated that they intend to test the applicability and safety of variable intensity lighting. Several manufacturers currently produce visibility sensors capable of controlling the intensity of obstruction lighting.

Demand Oriented Lighting:

On-demand lighting of wind turbines reduces energy use, light pollution, bird attractants, and other negative impacts of traditional systems. On-demand Aircraft Detection Systems (ADS) are designed to sense an approaching aircraft and initiate the project’s aviation and obstruction lighting. Thus, when no aircrafts are in the area, the project the lighting is either completely off or operated at a reduced light output. Marine navigation lighting would operate independently of the ADS system and therefore these systems would not affect marine navigation.

Current demand-oriented systems available on the market use radars to monitor the perimeter of a wind farm. Currently, these systems have only been installed and tested in onshore scenarios. The radars, the number of which depends on the size of the wind farm, communicate aircraft position information to a central controller, which in turn make commands to the obstruction light controllers (mounted with the lights).

Few manufacturers currently offer such systems, although ADS technology has been demonstrated as effective and reliable at an onshore wind farm (Patterson, 2015). The draft FAA guidance (AC 70/7460-1L) included a new chapter on ADS that details the requirements for any proposed ADS installation, and specifies that proposed systems will be evaluated by the FAA on a case-by-case basis.

Centralized Control:

The European experience has shown that offshore wind farms are designed and constructed to be operated, and monitored from onshore centralized locations utilizing highly computerized Supervisory Control and Data Acquisition systems. With all obstruction lighting linked through external network based controllers, lights can be individually or collectively monitored remotely. Monitoring and control of FLASH / FAIL alarms, synchronization, flash rates, etc. are all accomplished remotely from the central onshore control center.

5.0 RECOMMENDATIONS FOR BOEM LIGHTING GUIDANCE

In cooperation with BOEM’s efforts to evaluate offshore wind turbine lighting beyond the FAA’s jurisdictional limit of 12 NM while still maintaining conspicuity to pilots and ultimately aviation safety, the FAA provided BOEM with a pre-approval draft version of a revised FAA Advisory Circular AC 70/7460-1L Obstruction Marking and Lighting (December 2014). These new draft FAA guidelines included, in part, new guidance on the marking and lighting of wind turbines of heights of 499 ft. and above (Chapter 13), as well as new guidance on Aircraft Detection Systems (Chapter 14). The final Advisory Circular AC 70/7460-1L was issued on December 4, 2015 and uses the term Aircraft Detection Lighting Systems (ADLS) in Chapter 14.

As a means of assisting BOEM in determining whether to adopt the new draft FAA guidelines for use beyond 12 NM, or to consider alternative guidelines that may be more applicable for the offshore environment, the ESS team has utilized Chapter 13 of the new draft FAA guidance and revised it to reflect alternative guidance based on the information presented above. This alternative guidance is presented in Appendix A.

Much of the new FAA guidance continues to be appropriate and applicable to implement beyond 12 NM, however where alternative guidance has been presented in Appendix A, this section will discuss the justification and reasoning behind the change. Acknowledging that the airspace beyond 12 NM from shore experiences considerably less low-level air traffic than the airspace closer to shore, these alternative guidelines, while similar, differ in some instances from the new FAA guidance (within 12 NM) in order to minimize environmental impacts when possible, without diminishing pilot safety.

Where significant changes have been proposed, such changes are discussed below by section numbers which correspond both to the new FAA guidance document and to the proposed alternative (Appendix A).

Section 13.4 - Marking Standards:

There are no proposed changes to painting for daytime conspicuity, however details have been added specific to offshore siting and structures. Clarification has been made that lattice towers, which require painting of alternate bands of orange and white, are different than offshore foundations that are relatively close to the water but may involve some amount of open framework and would be painted yellow in accordance with US Coast Guard marine navigation requirements. Section 13.4.3 concerning contrast against snow is no longer applicable for offshore conditions and would be deleted in the alternative guidance.

Section 13.5 –Lighting Standards:

The fundamental change in 13.5.1 is to require the use of a more prescriptive lighting fixture. While the red, flashing, medium intensity (L-864) is common to both sets of guidance, the proposed change for use beyond 12 NM specifies the fixture to be LED and incorporate LEDs that emit infrared energy between 675 and 900 nanometers. As described above, LEDs have become the standard in the industry primarily for reasons of economy, maintenance, power consumption, and lesser impacts to birds due to the sharp on/off cycling. The inclusion of IR LEDs emitting energy within a specific range is a direct result of input provided by, and requests made from, the Department of Defense and the USCG to ensure compatibility with their NVG equipment.

The FAA guidance in Section 13.5 is focused on marking and lighting of wind turbines of heights below 499 ft., which is more applicable to smaller land-based wind turbines, and may not be appropriate for offshore installations, which tend to include turbines higher than 499 ft. It is highly unlikely that developers will install wind turbines offshore that are less than 499 ft. tall. A typical 5 MW wind turbine discussed in the NREL Technical Report (500-38060 February 2009 is 502 ft. tall and the Deepwater Wind Block Island project, which represents the first commercial offshore wind project in the US, is utilizing 6 MW wind turbines at 589 ft. The economics and efficiencies of working this far offshore will ensure that developers will utilize the fewest and largest wind turbines possible in order to generate the required amount of electricity. In the rare instance that a developer should propose a smaller machine beyond 12 NM, the FAA guidelines would appear to be adequate. For this reason, a number of the sections in the new FAA guidance are marked for deletion in the alternative guidance.

In the case of a proposed project that involves wind turbines configured in an array that straddles the 12 NM jurisdictional boundary, it is important that the array be lit in a consistent manner as to be identifiable as a single entity and avoid confusion to pilots. In this case, it is recommended that the FAA guidance that would be in effect for those turbines within 12 NM, be utilized for those turbines beyond 12 NM unless agreement is made otherwise between the two agencies.

In order to minimize visual impacts, the alternative guidance for BOEM proposes that visibility controlled light intensity technology be required on all medium intensity (2000 cd L-864) fixtures. This is proven technology, which will significantly reduce the intensity of the fixtures that have the potential to be seen from shore (the lower intensity L-810 having been shown by the FAA to only be visible within 10 miles and therefore not visible beyond the 12 NM limit).

The use of ADS technology has not been mandated, as the use of the visibility controlled light intensity technology will reduce visible impacts to shore significantly, and the relatively high cost and additional complexity of a relatively new technology may not be justified. It has been left open as an option for developers who may choose to add the technology to the existing suite of required controls. If ADS is proposed by the developer, the FAA's new guidance at Chapter 14 would be followed.

Section 13.6 - Wind Turbines above 499 ft.:

With the FAA's minimum safe altitude for flight established at 500 ft., and all structures above that having been determined to be obstructions to aviation and are required to be lit, the FAA then differentiates between the lighting for wind turbines between 499-699 ft. and those 699 ft. and higher. While BOEM leased areas that are sited 12NM and beyond and will not be in close proximity to onshore airports or likely to have any effect on Instrument Flight Rule pathways (which operate at higher altitudes), it has to be taken into consideration that, although less than that taking place nearer to shore, some amount of low altitude flying (down to the minimum of 500 ft.) may take place due to:

- Military training exercises
- Commercial Fish spotters
- Biological aerial survey flights (avian / marine mammal)
- Visual Flight Rule flights (between airports/during low-ceiling events etc.)

In order to ensure that the continual airspace from 500 ft. and above is as safe as possible for all forms of aviation, and in light of the taller wind turbines expected further offshore, it is suggested that BOEM should also require that each wind turbine beyond 12 NM be lit in agreement with the FAA's new guidance.

While both the FAA guidance and the proposed alternative guidance are in agreement that each wind turbine above 499 ft. should have two L-864 flashing red obstruction lights on the top of the nacelle, the proposed guidance for beyond 12 NM specifies that only one of the two fixtures is required to be lit at any one time, with the second unit available as a backup. This change is consistent with Canadian guidelines and the apparent intent of the FAA guidelines in Section 13.6.3, which indicates that no notification is required if one light fails, only that it be repaired as soon as possible (leaving one light to provide adequate conspicuity for some period of time). This change, in effect, reduces any visual impacts from offshore wind turbines under BOEM's jurisdiction by 50%.

Section 13.7 – Wind Turbines at or Above 699 ft. (213 m):

Both the FAA guidance and the proposed alternative guidance are in agreement that each wind turbine above 699 ft. should have additional intermediate lighting on the tower utilizing low intensity red flashing (L-810) obstruction lighting. The proposed alternative guidance is more prescriptive and requires that the obstruction lighting fixture be an LED, which should incorporate LEDs that emit infrared energy between 675 and 900 nanometers for the reasons previously described above.

6.0 CONCLUSION

After evaluating the new draft FAA guidance for marking and lighting wind turbines and conducting additional research on other available lighting guidance, offshore lighting impacts to birds, visual impacts and technical capabilities of various lighting and control technologies, the ESS team has prepared alternative guidance for obstruction lighting of offshore wind turbines beyond 12 NM for BOEM's consideration. The proposed alternative guidance presented in Appendix A is, in some respects, more prescriptive in nature than the FAA's guidelines (i.e. specifying the use of LED lighting fixtures with LEDs that emit infrared energy between 675 and 900 nanometers), yet also introduces the use of technology that is not currently part of the FAA's guidance (i.e. visibility controlled variable intensity lighting). The alternative guidance, due to its prescriptive nature, provides clarity, direction, and standardization to the offshore wind industry. If implemented, the alternative guidance is expected to significantly reduce potential visual impacts to onshore observers (beyond 12 NM), minimize any impacts to birds, address concerns over NVG compatibility, and maintain the same level of conspicuity and airspace safety as the FAA's guidance within 12 NM.

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Appendix A

Alternative Guidance

CHAPTER 13. MARKING AND LIGHTING OFFSHORE WIND TURBINES (BEYOND 12 NM)

Note: This section is presented in the format of FAA Advisory Circular AC-70/7460-1L, Obstruction Marking and Lighting (December 2015)

13.1 Purpose.

This chapter provides guidelines for the marking and lighting of offshore wind turbine installations beyond the 12 NM territorial sea on the Outer Continental Shelf (OCS). These guidelines are applicable to single wind turbines and wind turbine farms. For the purpose of this alternate guidance document, wind turbine farms are defined as a wind turbine development that contains more than three (3) turbines. The recommended marking and lighting of these structures is primarily intended to provide day and night conspicuity and to assist pilots in identifying and avoiding these obstacles, while secondarily minimizing any associated environmental impacts.

13.2 General Standards.

The development of offshore wind turbine farms is a very dynamic process, which is dependent on the wind resource, bathymetry, seabed conditions and environmental resources within the area.

Offshore wind turbines that are sited relatively close to shore (within 12 NM) are under the jurisdiction of the FAA and are evaluated by an FAA Obstruction Evaluation (OE) Specialist who determines a lighting scheme that provides safety for air traffic. Proximity to airports and Visual Flight Rule routes, and local flight activity are considered when making the recommendation.

Offshore wind turbines that are sited beyond 12 NM, are not under the jurisdiction of the FAA and are the responsibility of the US Department of the Interior through the Bureau of Ocean Energy Management (BOEM). While BOEM shares the common goal with the FAA of maintaining conspicuity to pilots and ultimately aviation safety, BOEM is also mandated with minimizing or avoiding environmental impacts related to offshore energy production including those that might occur from the marking and lighting of wind turbine structures. Acknowledging that the airspace beyond 12 NM from shore experiences considerably less low-level air traffic than the airspace closer to shore, these guidelines, while similar, differ in some instances from FAA guidance (within 12 NM) in order to minimize environmental impacts when possible without diminishing pilot safety. The following guidelines are recommended for wind turbines sited 12 NM or further offshore on the OCS.

13.3 Wind Turbine Configurations.

Prior to marking and lighting the offshore wind turbine farm, the configuration should be determined. While not as critical as in the marking and lighting of an upland wind turbine farm, understanding the configuration will help to ensure adequate delineation of the overall installation. The following is a description of the most common configurations.

1. Linear—wind turbine farms in a direct, consecutive configuration. The line may be ragged in shape or be periodically broken, and may vary in size from just a few turbines to many turbines forming a line that is several miles long.
2. Cluster—wind turbine farms arranged in circular configuration. A cluster is typically characterized by having a pronounced perimeter, with various turbines placed inside the circle at various, erratic distances throughout the center of the circle.
3. Grid—wind turbine farms arranged in a geographical shape, such as a square or a rectangle, in which the turbines are placed a consistent distance from each other in rows, giving the appearance that they are part of a square pattern.

13.4 Marking Standards.

13.4.1 Wind turbines must be painted white or light grey, as these colors have been shown to be the most effective method for providing daytime conspicuity. Most wind turbines currently produced are painted light grey, RAL 7035, which is the darkest acceptable off-white paint allowed. The preferred white paint color is pure white, RAL 9010, or an equivalent. Any shade of white between these two RAL specifications is allowable. See Table 13-1.

Table 13-1. Wind Turbine Paint Standard Colors

Color	RAL Number
Pure White	9010
Light Grey (Darkest Acceptable)	7035

13.4.2 Painting blade tips and/or using various paint colors to camouflage wind turbines with the surrounding water surface or horizon is not permitted.

13.4.3 Reserved

13.4.4 For turbines that are constructed with lattice-type masts, the mast structure shall be painted with alternating bands of aviation orange and white, in accordance with Chapter 3. This requirement for alternating bands of aviation orange and white does not apply to jacketed or framework type foundations which may be used to support the mast from the seabed to an elevation above the design wave height (not likely to exceed 60-70 feet above the water surface). For turbines constructed with monopole (or solid) masts, painting shall be done according to Section 13.4.1 above and alternating bands are not required. The turbine's nacelle and blades shall remain solid white or off white per 13.4.1.

13.5 Lighting Standards.

13.5.1 Nighttime offshore wind turbine obstruction lighting shall consist of medium intensity aviation red flashing, strobe, or pulsed LED obstruction lights meeting the minimum standards of the FAA L-864 fixture. Studies have shown that red lights provide the most conspicuity to pilots while also minimizing impacts to birds when flashed. To ensure compatibility with night vision goggles (NVG) the lights should incorporate LEDs that emit infrared energy between 675 and 900 nanometers.

13.5.2 Those commercial wind turbines expected to be installed beyond 12 NM are anticipated to be of a size and scale that will be significantly greater than 499 feet above mean sea level in overall height. As such, each wind turbine shall be lit in order to ensure that any obstructions are clearly marked and lighted in the airspace above 499 feet.

In rare cases, not all wind turbine units within a wind turbine farm may need to be lighted. Such cases may include offshore wind farms which utilize smaller machines with overall heights of 499' or less, or which straddle the 12 NM jurisdictional boundary between FAA and BOEM, in which case the consistent lighting of the entire wind farm as one complete entity would take precedent. The decision to adopt one lighting standard or another would be determine on a case by case basis in consultation with FAA.

13.5.3 All aviation obstruction lighting should be automatically controlled utilizing GPS or other acceptable technology in order to be synchronized to flash simultaneously (within ±1/20 second (0.05 second) of each other). Controls shall include dry contact alarms for FLASH / FAIL monitoring and flash synchronization adjustability.

The light intensity of all L-864 LED fixtures shall be automatically reduced (dimmed) based on meteorological visibility (i.e. clear sky conditions) in order to minimize visual impacts while maintaining adequate conspicuity to pilots. Visibility sensors and controls shall be installed which will allow light intensity to be lowered to 30% when visibility is more than 5 km (3.1 miles) and to 10% when visibility is more than 10 km (6.2 miles). In no instances shall the intensity be reduced to less than 200 candela.

The additional use of Aircraft Detection Lighting Systems (ADLS) to automatically activate the obstruction lights when approaching aircraft are detected until such time as they are no longer needed by the aircraft, is acceptable but not mandated. Any ADLS will need to conform with FAA guidance (see Chapter 14 of AC 70/7460-1L).

13.5.4 Should any lighting fixture or the lighting system synchronization fail, a lighting outage report should be prepared and submitted to the Bureau of Safety and Environmental Enforcement (BSEE).

13.5.5 Light fixtures should be placed as high as possible on the turbine nacelle so they are visible to pilots from 360 degrees. (See Figure A-23 in Appendix A of AC 70/7460-1L)

13.5.6 Daytime lighting of wind turbines is not required. See paragraph 13.4 for daytime marking requirements.

13.6 Wind Turbines Above 499 Feet.

13.6.1 For wind turbines with a rotor tip height, while at top dead center, greater than 499 feet (153 m) Above Mean Sea Level (AMSL), but less than 699 feet AMSL, the turbines shall be lighted in accordance with paragraph 13.5. In addition to these requirements, the top of the turbine's nacelle shall be equipped with a second L-864 LED flashing red light. One of the two L-864 fixtures must be operating each night, with the second fixture serving as a backup in case the first experiences operational failure.

13.6.2 The two obstruction lights should be arranged horizontally, positioned on opposite sides of the nacelle, both be visible from 360 degrees, and have the same flash characteristic. (See Figure A-23 in Appendix A of AC 70/7460-1L) This lighting configuration ensures the turbines in this size category are always lighted.

13.6.3 In the event one of the two obstruction lights fails, no light failure notification is required; however, the light should be restored to service as soon as possible.

13.6.4 All turbines within this size category should be illuminated, regardless of their location within a wind turbine farm, and should be configured to flash simultaneously with the other turbines in the same farm. This requirement ensures the pilots operating at 500 feet AMSL have sufficient warning that a wind turbine obstruction may be within their flight path.

13.7 Wind Turbines at or Above 699 Feet (213 m).

13.7.1 For wind turbines with a rotor tip height, while at top dead center, at or above 699 feet (213 m) AMSL, additional lighting is required.

13.7.2 In addition to the lighting identified in paragraph 13.6, an additional level of lights is required at a point midway between the top of the nacelle and the water surface. The location of the additional lights may be adjusted as necessary to allow mounting at a seam within the turbine's mast.

13.7.2.1 The additional level of lights shall consist of a minimum of three (3) low intensity, aviation red flashing, strobe, or pulsed LED obstruction lights meeting the minimum standards of the FAA L-810 fixture, configured to flash in unison with each of the two L-864 red flashing lights located at the top of the nacelle. To ensure compatibility with night vision goggles (NVG) the lights should incorporate LEDs that emit infrared energy between 675 and 900 nanometers. The L-810s should be spaced at equal distances around the mast. The lights should be installed to ensure a pilot approaching from any direction has an unobstructed view of at least two of the lights. (See Figure A-23 in Appendix A of AC 70/7460-1L)

13.7.2.2 For wind turbine structures with a mast diameter greater than 20 feet (6 m), four L-810 red lights shall be used.

13.7.2.3 All turbines within this size category should be illuminated, regardless of their location within a turbine farm, and should be configured to flash simultaneously with the other turbines in the same farm. This requirement ensures the pilots operating at 500 feet AMSL have sufficient warning that a wind turbine obstruction may be within their flight path.

13.8 Lighting of Wind Turbines During Construction Phase.

To ensure proper conspicuity of turbines at night during construction, all turbines should be lighted with temporary lighting once they reach a height of 200 feet (61 m) or greater until the permanent lighting configuration is turned on. As the structure's height continues to increase, the temporary lighting should be relocated to the structure's uppermost height. The temporary lighting may be turned off for short periods if they interfere with construction personnel. If practical, permanent obstruction lights should be installed and operated at each level as construction progresses. An L-810 steady-burning red light shall be used to light the structure during the construction phase, if the permanent L-864 flashing-red lights are not in place. If power is not available, turbines shall be lighted with a self-contained, solar-powered, LED, steady-burning red light that meets the photometric requirements of an FAA L-810 lighting system. The lights should be positioned to ensure a pilot has an unobstructed view of at least one light at each level.

Appendix B

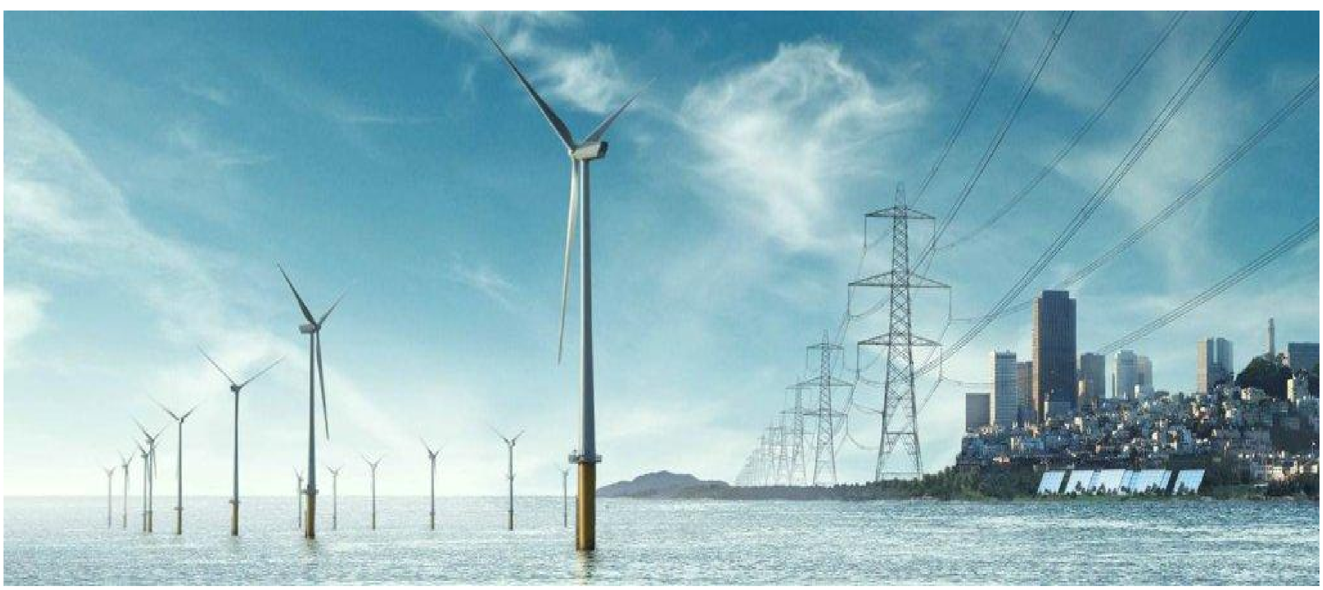
International Guidelines and Technology Review Report

BOEM OFFSHORE WIND LIGHTING GUIDANCE

Evaluation of Aviation Lighting Schemes for Offshore Wind Projects

ESS Group, Inc.

Document No.: 703403-USSD-T-01-A
Date: 27 11 January 2016



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1.0 INTRODUCTION

ESS Group Inc. (ESS) was contracted by the Bureau of Ocean Energy Management (BOEM) under BOEM Task Order M15PX00035 to support BOEM with the development of guidance for aviation obstruction lighting for offshore wind turbines located beyond 12 nautical miles (nm) from shore. Garrad Hassan America, Inc. (DNV GL) was retained by ESS as a subcontractor to research international guidelines for applicable information pertaining to lighting of offshore wind turbines and to gather information on the latest available lighting technologies and control systems for marine use. This Technical Note summarizes DNV GL's work and is intended to contribute to work that ESS is conducting to develop guidance for BOEM.

1.1 Background

DNV GL previously supported ESS as a subcontractor to research guidelines, rules, and regulations for lighting schemes for offshore wind facilities under BOEM Contract M12-PD-00007. Under that subcontract DNV GL researched international guidelines as well as rules and regulations from civil aviation authorities (CAAs) from numerous jurisdictions in North America, Europe, and Asia. DNV GL's work under that previous contract culminated in a Technical Note titled "BOEM - Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments – Task 2 (Guidelines, Rules and Regulations)" (the "DNV GL Guidance Report") [1].

The US Department of Transportation Federal Aviation Administration (FAA) develops and maintains guidance documentation for marking and lighting obstructions that have been deemed to be a hazard to navigable airspace. The FAA's guidance is applicable to obstructions located up to 12 nm from shore. The overall goal of the current research effort is to provide BOEM with information such that BOEM can develop guidance for offshore wind turbines located beyond 12 nm. It is expected that such guidance will be either the adoption of the key principles of the FAA guidelines or an alternative lighting scheme that may minimize impacts while still maintaining the same level of safety represented by the FAA guidelines.

1.2 Approach

In order to supply supporting information to ESS and BOEM, DNV GL performed a review of key international guidelines (in effect updating the DNV GL Guidance Report), researched lighting technology currently available in the market, and communicated with lighting technology representatives regarding the capabilities and limitations of various products.

2.0 INTERNATIONAL GUIDELINES

The DNV GL Guidance Report presents a detailed description of guidelines, rules, and regulations from numerous international jurisdictions as well as the International Civil Aviation Organization (ICAO). The following sections present relevant updates for ICAO guidelines and rules and regulations from select jurisdictions that represent some of the largest offshore wind markets in Europe. This section is not intended to provide a comprehensive summary of changes to international guidelines, rather it is intended to summarize changes that may address key challenges that the offshore wind industry has faced and changes that may impact the deployment of advanced obstruction lighting technology.

2.1 ICAO Guidance

Since the time of writing the DNV GL Guidance Report, an amendment to Annex 14, “Aerodromes – Aerodrome Design and Operations” (Annex 14, Volume I to the Convention on International Civil Aviation) was published by the ICAO Council [2]. After review of this document, DNV GL confirms that there are no changes to the requirements described in the DNV GL Guidance Report.

2.1.1 Belgium

As detailed in the DNV GL Guidance Report, the applicable regulations in Belgium regarding aviation lighting for offshore wind turbines are: the Circulaire ‘CIR-GDF-03’ [3] (published June 2006) and the IALA O-139 published in December 2008. An updated version of the IALA O-139 second edition was published in December 2013 [4]. After review of these documents, DNV GL confirms that there are no changes to the requirements described in the DNV GL Guidance Report.

2.1.2 Canada

Transport Canada’s (TC) Canadian Aviation Regulations CAR-621 [5] provides guidance for aviation obstruction lighting and were published in June 2012. Canada does not have aviation lighting guidance specific for offshore wind turbines. An updated version of the CAR-621 is currently in preparation, but the date of publication is unknown [6]. This draft guideline adds provisions for onshore wind turbines of 150 m to 315 m in overall height including:

- Two CL-864 lights should be located on the nacelle, one light operating at all times and a second light serving as backup in case of failure of the first operating light.
- At least 3 CL-810 lights should be installed at an intermediate level at half the nacelle height and configured to flash at the same rate as the light on the nacelle.

For wind turbines of more than 315 m of overall height, additional marking and lighting may be required.

This draft guideline also adds provisions for the use of aircraft detection systems [6]. These sensor-based systems would automatically activate the obstruction lights when approaching aircraft are detected until such time as they are no longer needed by the aircraft. The purpose is to reduce energy consumption, and minimize cause for complaint from local residents. According to the draft guidelines, wind farms installing an obstruction lighting system with ADS capabilities, will be required to comply with the following:

- Turn on the obstacle lights and to emit an audio signal when an aircraft is detected within a specified minimum flight time to the impact boundary (three-dimensional boundary around the wind farm) for both a heading directly towards the impact boundary as well as a potential maneuver towards the impact boundary.
- Once the lighting is activated, full intensity must be achieved within two seconds of activation and the lighting must be maintained for a period of at least 60 seconds.
- The audio signal must comply with provisions set out in the guidelines as well as Industry Canada guidelines and permit requirements.
- The lighting for use with ADS is of a design such that it will provide:
    - Fail safes for sensor or communications failure and obstruction lights failure.
    - Self-test capability.
    - Case-by-case ADS application review process and acceptance.

Also, TC intends to test light intensity dimming technology on selected wind farms in Canada**.**

2.1.3 Denmark

Since the time of writing the DNV GL Guidance Report, the Danish Transport Authority (Trafikstyrelsen) has published the BL 3-11 'Provisions on aviation marking of wind turbines' second edition [7] (published in February 2014), effective as of 28 March 2014. This regulation states that for all offshore wind farms in Denmark:

- There must be a regulator for the light intensity and a measurement of the visibility so that the light can be adjusted according to the visibility;
- The lights shall be visible from every direction around the nacelle, which requires two lanterns to be installed on each nacelle; Furthermore, the regulation indicates that for offshore turbines with a total height of 100 to 150 m:
- Turbines located in the corner and at sharp bends along the periphery of the wind farm must be marked with medium intensity flashing red light, 2,000 candelas.
- Turbines along the periphery and inside the wind farm area shall be lit with fixed red light of low intensity (10 candelas as a minimum) during the day and night.
- If the distance between the turbines marked with medium intensity lights exceeds 900 m then the final requirements for the aviation marking must be agreed with the Danish Transport Authority.

In addition to the requirements listed above, all turbines with a total height above 150 m, should also be equipped with a red solid light with an intensity of 32 candelas on an intermediate level (halfway between nacelle and mean sea level). Since lights are required to be visible from all directions, this will likely require 3 fixed lights (with a spacing of 120 degrees) at each turbine.

2.1.4 Germany

As detailed in the DNV GL Guidance Report, the applicable regulations in Germany regarding aviation lighting for offshore wind turbines is the General Administrative Regulation AVV Kennzeichnung [8] (published May 2009). DNV GL confirms that there have been no updates to this document.

As noted in DNV GL Guidance Report, Germany's General Administrative Regulation AVV Kennzeichnung provides for the use of Automatic Detection Systems (ADS). DNV GL was informed by a vendor of ADS technology that wind farm operators are notified by the military when training operations will be occurring near a specific wind farm. The operator is then required to override the ADS and turn the lights on during such operations. This pragmatic approach avoids the potential issues associated with ADS systems not performing as intended in the presence of high speed, evasive aircraft. DNV GL is still working to verify this.

2.1.5 United Kingdom

In the UK, requirements for lighting of wind farms are regulated by the Maritime Coastguard Agency (MCA), the Ministry of Defence (MOD) and the Civil Aviation Authority (CAA). DNV GL has previously investigated these requirements as detailed in the DNV GL Guidance Report. Since DNV GL's Guidance Report, the following regulations or guidelines have been updated:

- CAP 393 – "Air Navigation: The Order and Regulations" Fourth Edition Amendment [9], published in April 2015.
- CAP 764 – "CAA Policy and Guidelines on Wind Turbines" Fifth Edition [10] published in June 2015.
- IALA O-139 "On the Marking of Man-Made Offshore Structures" Second Edition [4], published in December 2013.
- MOD Obstruction Lighting Guidance [11], Published in 21 November 2014.

After review of these documents, DNV GL did not find any changes on the aviation lighting requirements for offshore wind farms since DNV GL Guidance Report. However, the DNV GL Guidance Report did not include the following requirements found in Article 220 of the 'Air Navigation Order 2009':

- All aviation lights fitted to the turbines must be displayed at night. If any light fails, the light should be repaired or replaced as soon as reasonably practicable. In some cases, the CAA may direct that the WTGs are fitted with additional lights in specific positions and display them at specific times.

In November 2012, the CAA published the Policy Statement: 'The Lighting And Marking Of Wind Turbine Generators And Meteorological Masts In United Kingdom Territorial Waters' [12], which indicates that in some cases, the aviation lights are proving to cause difficulties to the maritime community; therefore, the CAA is working on the development of an aviation warning lighting standard (not available as of the date of this Technical Note) and that where this issue is evident, developers can make a case to use a flashing red Morse code letter ‘W’ to resolve potential issues. The CAA has made it clear that there are no intentions to change the lighting specifications set out in Article 220 and that these remain the default lighting requirements. The consideration of the flashing Morse code ‘W’ requirement is already under consideration for certain projects such as Burbo Banks Extension and Neart-Na-Gaoithe.

Furthermore, the MOD Obstruction Lighting Guidance [11] provides the following standard:

- The MOD minimum standard for offshore developments is a 200 candela flashing red light on wind turbines as well as infrared (IR) lighting set to flash Morse Code W over a continuous six second cycle and synchronized over the whole wind farm. However, in the majority of the cases, these MOD requirements are exceeded by the CAA, MCA and Trinity House statutory requirements and therefore, these are only stated as the preferred solution and not as a stipulated requirement.

3 AVIATION OBSTRUCTION LIGHTING TECHNOLOGY

The installation of aviation obstruction lighting on wind turbines is intended to maintain a safe environment for airplanes to fly and eliminate the risk of airplane strike. Appropriate lighting requirements can vary depending on terrain, weather patterns, geographic location, number of turbines and overall layout.

Obstruction lighting can also have secondary negative impacts, which should be minimized if at all possible. Negative aspects could include visual disruption/distraction of neighboring parties, confusion with navigational aids used in shipping activities, and impacts to wildlife.

The current technologies available in the market are aimed at improving and/or maintaining adequate safety levels while considering negative impacts, reliability and costs.

3.1 FAA and other requirements

3.1.1 FAA requirements

The FAA Advisory Circular AC 70/7460 - *Obstruction Marking and Lighting* requires that wind farms be lighted during the night but does not require daytime lighting [13].

The AC 70/7460 requires that wind turbine obstruction lighting consist of FAA Type L-864 red flashing, strobe, or pulsed lights. Arrays of flashing, strobe, or pulsed lights should be synchronized to flash simultaneously (within 0.05 second of each other), be positioned on top of the nacelle and be visible from 360°.

The FAA guidelines imply that wind turbines with a total tip height above 499 feet (153 m) are a greater safety risk. Wind turbines with a total tip height above 499 feet (153 m) should be equipped with a second L-864 flashing red light on top of the nacelle. Additionally, all turbines with a total tip height above 499 feet (153 m) should be lighted, whereas a project with a total tip height below 499 feet (153 m) does not need to light every turbine. Wind turbines with a total tip height above 699 feet (213 m) should, in addition to being equipped with a second L-864 flashing red light on top of the nacelle, be equipped with a minimum of three L-810 red flashing lights set at mid-level on the tower and configured to flash in unison with the top lights. DNV GL notes that type L-810 lights are currently not necessary for lighting wind turbines as wind turbines of more than 699 feet in height are not commonly being installed.

Current FAA guidelines do not have any provisions regarding infrared lighting. According to the FAA, an updated version of Advisory Circular AC 70/7460 is currently in preparation, but the date of publication is unknown. DNV GL is unaware if infrared lighting will be included in the revised guidelines but notes that the available draft of the revised guidelines does not include infrared lighting [14]. DNV GL has learned during discussions with providers that the development of infrared lighting systems is progressing slowly because specifications remain to be established by the FAA and the Department of Defense.

The lighting equipment used for aviation obstruction lighting must comply with FAA requirements set out in Advisory Circular 150/5345-43G - *Specifications for Obstruction Lighting Equipment* [15]. Basic characteristics of the L-864 and L-810 lighting systems are as follows:

Table 2 Basic characteristics of the L-864 and L-810 lighting systems

Characteristic	**L-864**	**L-810**
Vertical Beam Center	0°	4° and 20°
Peak intensity	2,000 ± 25% candela at 0°	Minimum of 32.5 candela
Vertical beam spread	3°	10° minimum
Beam restriction	Heavy restriction of light allowed past 10° below horizontal	

Furthermore, lighting systems must comply with all technical requirements outlined in AC 150/5345-43G, including automatic reporting capacity in case of lighting fixture failures, as well as qualification requirements.

FAA specifications for Intensity Step Changing require that red obstruction lights turn on when the ambient light decreases to not less than 35 foot-candles (367.7 lux) and turn off when the ambient light increases to not more than 60 foot-candles (645.8 lux).

The FAA requires a rigorous testing program for lighting systems to prove compliant with FAA guidelines. There is one independent testing body which the FAA has accepted to complete such programs, Intertek Testing Services, formerly known as ETL Testing Laboratories. After testing and certification from Intertek Testing Services, a lighting system is considered FAA approved.

The draft revised AC 70/7460-1L guideline also provides performance standards for Aircraft Detection Systems (ADS) [14]. These sensor-based systems would automatically activate the obstruction lights when approaching aircraft are detected until such time as they are no longer needed by the aircraft. This technology intends to reduce the impact of night-time lighting on nearby communities and migratory birds and extends the life expectancy of obstruction lights. Marine navigation lighting would operate independently of the ADS system and therefore these systems would not impact marine navigation.According to the draft guidelines, wind farms installing an obstruction lighting system with ADS capabilities, will be required to comply with the following:

- Horizontal detection coverage: Activation and illumination of obstruction lighting prior to aircraft penetrating the perimeter of the volume, which is a minimum of 3 nm (5.5 km) away from the obstruction or the perimeter of a group of obstructions.
- Vertical detection coverage: Activation and illumination of obstruction lighting prior to aircraft penetrating the volume, which extends from the ground up to 1,000 feet (304 m) above the highest part of the obstruction or group of obstructions, for all areas within the 3 nm (5.5 km) perimeter.
- Fail safes for aircraft detection loss, ADS component or system failures, daily system checks.

- Option for voice/audio warnings over an aviation frequency licensed by the FCC in the MULTICOM/UNICOM frequency band and in accordance with appropriate FAA and FCC regulations.
- Case-by-case ADS application review process and acceptance.

3.1.2 Other requirements

DNV GL considers operational requirements of obstruction lighting systems for offshore wind farms should include:

- Be rugged enough to endure harsh environmental conditions, such as salt, humidity, cold and ice;
- High efficiency to reduce energy use and increase life;
- Use sustainable materials and advanced technology;
- Be compact enough for the limited space available on a wind turbine nacelle; and
- Be flexible enough to meet the needs and individual requirements of different customers.

The lighting system must also consider the power source. Cabling each light to achieve synchronous flashing is not practical due to distance and cost. One alternative is to use the timing signals derived from a Global Positioning System capable of achieving a quick and reliable satellite fix under varying environmental conditions.

Beyond the regulatory and technical requirements aimed at ensuring aviation safety in the most efficient and cost-friendly way, obstruction lighting systems should consider other potential impacts caused by the presence of lights in the environment. Addressing light-related potential impacts such as nuisance and wildlife attractants can promote social acceptance of wind farms. The International Energy Agency (IEA) provides recommendations with regards to the lighting of wind farms in order to increase social acceptance, including:

- Abandoning xenon white lights;
- Using synchronized flashing, strobe, or pulsed lights;
- Applying light intensity adjustment using visibility measurements; and
- Allowing and using demand-oriented obstruction lights.

3.2 Lighting technologies

3.2.1 Incandescent and Fluorescent

Historically, obstruction lighting has primarily utilized incandescent light technology. Incandescent lights have been significantly less expensive than fluorescent and light emitting diode (LED) lights but the bulbs are significantly less durable; the 2,000-hour life span of incandescent lights is a fraction of the life span of LED lights. The life span of incandescent lights is further reduced by on/off cycles. Incandescent lights consume much more energy than LED lights for the same illumination (as much of the energy is lost as heat). They are also slightly sensitive to low temperatures and humidity. Due to developments in fluorescent and LED technology and cost reductions, incandescent lights are less competitive, particularly when considering the lifecycle cost.

The 8,000-hour life span, durability and lighting efficiency offered by fluorescent lights is a noticeable improvement compared to incandescent lights but remain well below LED technology. In addition, fluorescent lights contain mercury which complicates their disposal, and are sensitive to low temperature and humidity. Furthermore, they have a lag time when turning on, and on/off cycles drastically reduce their life span. For these reasons, fluorescent lights are mostly used in constant burn situations.

While some manufacturers continue to offer incandescent lighting systems, these are mainly limited to low-intensity lights. Fluorescent lighting systems can also be obtained but their drawbacks do not make them a good choice for wind farms. Both incandescent and fluorescent lights are now rarely used in wind turbine obstruction lighting systems due to the numerous advantages of LED lighting.

3.2.2 LED

Light emitting diodes are small, rugged, durable and extremely energy efficient and long lasting. The life span of LED lights can reach up to 60,000 hours, meaning that after such time their light output has dropped to 70% of the original output. LEDs consume 90% less energy than traditional incandescent lights and 50% less than fluorescent lights for the same illumination. LEDs can also sustain moderate power surges without experiencing failure. Additionally, LEDs contain no toxic materials, are recyclable, are not sensitive to low temperature or humidity, and on/off cycles do not affect durability. The reduction in cost of LED technology over recent years coupled with the lower maintenance requirements (in both time and cost) has resulted in LED technology becoming the predominant technology for wind turbine obstruction lighting.

However, LEDs are generally designed to disperse light over an area as wide as 120 degrees. Manufacturers of lighting systems must therefore design secondary optics to restrict the light into a tight beam. The technology of choice generally consists of molded optical-grade polymethyl methacrylate (PMMA), also known as acrylic.

The initial investment required for LED technology is higher than incandescent or fluorescent lights, but this margin is continuously narrowing. Many manufacturers offer Type L-864 and L-810 LED lights, as well as IR lights. However, LED quality can vary between manufacturers and not all manufacturers offer all types of lights.

State of the art Type L-864 lights use an integrated controller with wireless GPS synchronization and meet the intensity and radiation requirements of the FAA. The controller allows for dry contact alarms fail safe operation, and flash rate adjustability. These Type L-864 lights are sophisticated and several manufacturers currently supply FAA approved models to the wind industry.

Type L-810 lights are less sophisticated. These lights are commonly called “markers” and often are designed for “steady burn” during dark hours, although some manufacturers offer optional flashing. In wind turbine applications, Type L-810 lights are commonly installed in groups of three at an intermediate height on the tower structure. Most Type L-810 lights do not have a controller as standard hardware, but can be included in a larger system incorporating a single controller to operate both the L-810 marker lights and L-864 nacelle lighting (in order to synchronize flashing and provide alarming for the entire system). Several manufacturers currently supply FAA approved models to the wind industry.

It should be noted that LEDs yield a different spectral output and a different intensity profile as compared to incandescent lighting. Thus, the question has arisen, could a lower LED intensity requirement be as effective as a higher incandescent requirement? Current research indicates that for certain colors, LED lights are judged by observers as brighter than comparable incandescent versions. However, this does not generally apply to red and yellow lights, which appear comparable to incandescent versions. Furthermore, fog tends to reduce the perceived intensity differences between LED and incandescent lights [16].

3.2.3 Infrared Lighting

Infrared lighting provides night visibility for pilots using night vision goggles (NVG) and night vision imaging systems (NVIS).

LEDs emit a single wavelength of colored light that is outside the range of NVG and NVIS. LEDs also do not produce a significant thermal signature and are, therefore, invisible to NVG and NVIS. In some cases, wind turbine lighting may require the use of double obstruction lights with a red visible head and an IR head (referred to herein as "IR+RED") making the light visible with or without NVG or NVIS. IR+RED lighting capable of switching between IR only and IR+RED modes has been developed for military applications. These lights can be switched to IR only, and are then invisible without NVG.

Aviation IR aircraft warning lights have been approved for use at on-shore wind farms in the United Kingdom. Compliance with MOD regulations has resulted in safe and consistent detection ranges when using NVG. DNV GL notes that the FAA has not published any guidance related to infrared lighting for wind power applications.

3.2.4 Demand oriented lighting

On-demand lighting of wind turbines reduces energy use, light pollution, bird attractants, and other negative impacts of traditional systems. On-demand systems are designed to sense approaching aircraft (Aircraft Detection Systems) and initiate the project's obstruction lighting. Thus, when no aircraft are in the area of the project the lighting is either completely off or operated at a reduced light output.

Current demand-oriented systems available on the market use radars to monitor the perimeter of a wind farm. The radars, the number of which depend on the size of the wind farm, communicate aircraft position information to a central controller, which in turn make commands to the obstruction light controllers (mounted with the lights).

Few manufacturers offer such systems. Laufer Wind's Aircraft Detection System is a radar-based demand-oriented system that has been demonstrated as effective and reliable. The Laufer Wind system has been tested for onshore wind farms but to date has not been deployed offshore. DeTect offers their HARRIER Visual Warning System which is also radar-based. Although DeTect has not deployed the HARRIER system for aviation obstruction lighting at an offshore wind farm, DeTect's

MERLIN system, which is essentially the same hardware set up as the HARRIER system, has been deployed at offshore wind farms in Europe for avian monitoring.

3.2.5 Visibility controlled variable intensity lighting

Light intensity dimming consists of lowering light intensity in conditions of good visibility. The purpose is to dim the lights under clear conditions while maintaining a level of visibility that is sufficient for aviation safety. Light intensity dimming reduces energy use, light pollution, bird attractants, and other negative impacts of traditional systems.

While dimming technologies are not currently approved by the FAA, some jurisdictions require or allow the dimming of night time obstruction lighting in cases of high meteorological visibility. As mentioned above, Belgian, Danish and German regulations allow light intensity to be lowered to 30% when visibility is more than 5 km and to 10% when visibility is more than 10 km. Transport Canada intends to test the applicability and safety of variable intensity lighting. Few manufacturers offer such systems. The LIDS™ (Light Intensity Dimming Solution) technology is offered by Technostrobe. According to the supplier, this is an optical analysis system that has been demonstrated as effective and reliable. When conditions are clear, the LIDS system reduces the intensity of the obstruction lights by up to 90%.

4 CONCLUSIONS AND RECOMMENDATIONS

DNV GL considers that aviation obstruction lighting of offshore wind farms should be harmonized as much as possible with the requirements currently applied by the FAA for onshore wind farms. Also, situational and environmental elements specific to offshore wind farms should be harmonized as much as possible with the requirements currently applied by the ICAO, as these international guidelines remain the benchmark for the development of aviation safety regulations.

General DNV GL recommendations for aviation obstruction lighting of offshore wind farms installed on the OCS beyond 12 nm from shore include:

- The lighting pattern of the wind farm should comply with the specifications set forth in FAA Advisory Circulars.
- Given the remoteness of an offshore project, all turbines used in offshore applications beyond 12 nm should be outfitted with two type L-864 nacelle mounted lights. Only one of the two fixtures is required to be lit at any one time, with the second unit available as a backup that comes on in the event of a failure in the primary light. All L-864 lights for a project should be synchronized to flash simultaneously. This is consistent with the FAA guidance for onshore turbines with a total tip height above 499 feet (153 m), and ensures all turbines remain lighted even in the event of a light failure.
- For turbines with a total tip height above 699 feet (233 m), in addition to being equipped with L-864 flashing red lights on top of the nacelle, three type L-810 lights should be positioned at equal distance around, and mid-way up, the tower. These secondary lights could be lit continuously during the night or could be synchronized to flash with the main type L-864 lights.
- Flash synchronization for nacelle-mounted L-864 lights and tower-mounted L-810 lights (if required) should be implemented through wireless GPS or equivalent.
- Lighting systems should be equipped with fail safes to reduce risks related to systems failures. The fail-safes should include all the following:
    - Dry contacts for alarm monitoring/status: Photocell alarm, light alarms, operation mode (day/night), etc.
    - Signal or warning to the operations center in case of failure; such signal or warning should indicate location of such failure.
    - Self-test button.
- Lighting systems used in offshore applications beyond 12 nm should be tested and certified prior to installation by Intertek Testing Services or a similar, qualified third party testing organization to specifications in Advisory Circular 150/5345-43G.
- Demand oriented lighting technologies designed to reduce the use of obstruction lighting should be strongly encouraged, and possibly required, to reduce the impacts on neighboring communities and wildlife and to reduce energy consumption.

- Automatic light intensity dimming technology is currently used in other jurisdictions and many systems have been shown to be effective and reliable. This technology is less expensive than aircraft detection systems.
- Provisions for the use of aircraft detection systems are included in a draft revised FAA Advisory Circular. Radar technology is considered effective; however, there exist only a small number of projects which have used radars for wind farm lighting applications. This technology is more expensive than light dimming technologies.

- BOEM guidelines should include provisions for testing and certification of demand oriented lighting systems. Whereas lighting systems are approved by the FAA according to a standardized third party testing process accepted by the industry, there is no approval process yet standardized for demand oriented lighting systems.
- Industry expect that IR lighting of offshore turbines will eventually be considered essential by the Department of Defense for wind farms located near sensitive military aviation areas. Any IR lighting requirements will therefore have to comply with the Department of Defense requirements. While some IR lighting systems are currently available, DOD input will be essential to define BOEM guidelines for IR systems. BOEM should coordinate with the DOD on any guidelines related to IR technology.

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Appendix C

Federal Aviation Administration - Advisory Circular
Obstruction Marking and Lighting, AC No: 70/7460-1L
December 4, 2015

U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Obstruction Marking and Lighting

Date: 12/04/15
Initiated By: AJV-15

AC No: 70/7460-1L

1. **Purpose.**
This Advisory Circular (AC) sets forth standards for marking and lighting obstructions that have been deemed to be a hazard to navigable airspace.

2. Advisory Circular 70/7460-1L is effective immediately. However, flashing L-810 lighting has a delayed effective date and becomes mandatory on September 15, 2016.

3. **Cancellation.**
Advisory Circular 70/7460-1K, Obstruction Lighting and Marking, dated February 1, 2007, is cancelled.

4. **Principal Changes.**
The principal changes in this AC are:

    1. The height of a structure identified as an obstruction has been lowered from 500 feet above ground level (AGL) to 499 feet above ground level, by amendment to Title 14 Code of Federal Regulations (14 CFR) Part 77, *Safe, Efficient Use, and Preservation of the Navigable Airspace* (75 Federal Register 42303, July 21, 2010). Accordingly, all structures that are above 499 feet AGL are considered obstructions and the Federal Aviation Administration (FAA) will study them to determine their effect on the navigable airspace. This will ensure that all usable airspace at and above 500 feet AGL is addressed during an aeronautical study and that this airspace is protected from obstructions that may create a hazard to air navigation.

    2. Standards for voluntary marking of meteorological evaluation towers (METs), less than 200 feet above ground level (AGL), has been added to provide recommendations towards increasing conspicuity of these structures, particularly

for low-level agricultural flight operations. These standards include those for lighting and marking of the tower and associated guy wires.

3. A new Chapter 14, Aircraft Detection Lighting Systems, has been added to provide performance standards for these types of systems.

4. New lighting and marking standards are provided to reduce impact on migratory bird populations.

5. Medium-intensity white and medium-intensity dual obstruction light are now authorized on towers up to and including 700 feet AGL.

6. Editorial changes have been made.

5. Related Reading Material.

1. Advisory Circular 150/5345-43, Specification of Obstruction Marking and Lighting.

2. 14 CFR Part 77, Safe, Efficient Use and Preservation of the Navigable Airspace.

6. Application.

The FAA recommends the guidelines and standards in this AC for determining the proper way to light and mark obstructions affecting navigable airspace. This AC does not constitute a regulation and, in general, is not mandatory. However, a sponsor proposing any type of construction or alteration of a structure that may affect the National Airspace System (NAS) is required under the provisions of Title 14 Code of Federal Regulations to notify the FAA by completing the Notice of Proposed Construction or Alteration form (FAA Form 7460-1). These guidelines may become mandatory as part of the FAA's determination and should be followed on a case-by-case basis, as required.

7. Comments or Suggestions.

Direct comments or suggestions regarding this AC to:

Manager, Obstruction Evaluation Group
Federal Aviation Administration
ATTN: AJV-15
800 Independence Avenue, S.W.
Washington, DC 20591

Jodi S. McCarthy
Director, Airspace Services

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CHAPTER 1. ADMINISTRATIVE AND GENERAL PROCEDURES

1.1 Reporting Requirements.

A sponsor proposing any type of construction or alteration of a structure that may affect the NAS as required under the provisions of Title 14 Code of Federal Regulations (CFR) Part 77, Construction or alteration requiring notice, is to notify the Federal Aviation Administration (FAA) by completing the Notice of Proposed Construction or Alteration form (FAA Form 7460-1). This form should be filed electronically at http://oeaaa.faa.gov.

1.2 Preconstruction Notice.

The notice must be submitted:

1. At least 45 days prior to the date of proposed construction or alteration is to begin.
2. On or before the date an application for a construction permit is filed with the Federal Communications Commission (FCC). (The FCC advises its applicants to file with the FAA well in advance of the 45-day period to expedite FCC processing.)

1.3 FAA Acknowledgement.

The FAA will acknowledge, in writing, each FAA Form 7460-1 notice received.

1.4 Supplemental Notice Requirement.

1. If required, the FAA will include a statement requiring the filing of FAA Form 7460-2, Notice of Actual Construction or Alteration, on the determination. All FAA Forms 7460-2 should be filed electronically at http://oeaaa.faa.gov.
2. FAA Form 7460-2 Part 1 is to be completed and sent to the FAA at least 10 days prior to starting the actual construction or alteration of a structure. Part 2 shall be submitted within 5 days after the structure has reached its greatest height. The form should be filed electronically at http://oeaaa.faa.gov.
3. In addition, a supplemental notice shall be submitted upon abandonment of construction.
4. Letters are acceptable in cases where the construction/alteration is temporary or a proposal is abandoned. This notification process gives the FAA the necessary time to change effected procedures and/or minimum flight altitudes and to otherwise alert airmen of the structure’s presence.

   Note: Notification, as required in the determination, is critical to aviation safety.

1.5 Modifications and Deviations.

Requests for modification or deviation from the standards outlined in this AC must be submitted to the FAA Obstruction Evaluation Group (OEG). The sponsor is responsible for adhering to approved marking and/or lighting limitations, and/or recommendations given, and should notify the FAA and FCC (for those structures regulated by the FCC) prior to removal of marking and/or lighting. A request received after a determination is issued may require a new study and could result in a new determination.

1. Modification Examples. Modifications will be based on whether they impact aviation safety. Examples of modifications are as follows:

   a. Marking and/or Lighting Only a Portion of an Object. The object may be located with respect to other objects or terrain that only a portion of it needs to be marked or lighted.

   b. No Marking and/or Lighting. The object may be located with respect to other objects or terrain, removed from the general flow of air traffic, or may be so conspicuous by its shape, size or color that marking or lighting would serve no useful purpose.

   c. Voluntary Marking and/or Lighting. The object may be located with respect to other objects or terrain that the sponsor feels increased conspicuity would better serve aviation safety. Sponsors who desire to voluntarily mark and/or light their structure should do so in accordance with this AC.

   d. Marking or Lighting an Object in Accordance with the Standards for an Object of Greater Height or Size. The object may present such an extraordinary hazard potential that higher standards may be recommended for increased conspicuity to ensure aviation safety.

2. Deviations. The assigned Obstruction Evaluation Specialist will conduct an aeronautical study of the proposed deviation(s) and forward their recommendation to FAA Headquarters, OEG Manager, in Washington, DC, for final approval. Examples of deviations that may be considered:

   a. Colors of objects.

   b. Dimensions of color bands or rectangles.

   c. Colors/types of lights.

   d. Basic signals and intensity of lighting.

   e. Night/day lighting combinations.

   f. Flash rate.

3. The FAA strongly recommends that owners become familiar with the different types of lighting systems and to specifically request the type of lighting system desired when submitting FAA Form 7460-1. Information on these systems is given in Table A-1 in Appendix A. While the FAA will make every effort to accommodate the structure sponsor's request, sponsors should also request

information from system manufacturers to determine which system best meets their needs based on purpose, installation, and maintenance costs.

1.6 Additional Notification.

Any change to the submitted information on which the FAA has based its determination, including modification, deviation, or optional upgrade to white lighting on structures, may require notice to the FCC prior to making the change for proper authorization and annotations of obstruction marking and lighting. These structures may be subject to inspection and enforcement of marking and lighting requirements by the FCC. FCC Forms and Bulletins can be obtained from the FCC's National Call Center at 1-888-CALL-FCC (1-888-225-5322) or online at http://www.fcc.gov/forms. Upon completion of the actual change, complete the "Add Supplemental Notice (7460-2 Form)" at the http://oeaaa.faa.gov website. You may also mail the FAA Form 7460-2 to:

FAA Aeronautical Information Services

1305 E W Hwy
Silver Spring, MD 20910
1-800-626-3677

CHAPTER 2. GENERAL

2.1 Structures to be Marked and Lighted.

Any temporary or permanent structure, including all appurtenances, that exceeds an overall height of 200 feet (61 m) above ground level (AGL) or exceeds any obstruction standard contained in 14 CFR Part 77 should be marked and/or lighted. However, an FAA aeronautical study may reveal that the absence of marking and/or lighting will not impair aviation safety. Conversely, the object may present such an extraordinary hazard potential that higher standards may be recommended for increased conspicuity to ensure aviation safety. In general, commercial outside lighting should not be used in lieu of FAA-recommended marking and/or lighting. Recommendations on marking and/or lighting structures can vary, depending on terrain features, weather patterns, geographic location, and in the case of wind turbines, the number of structures and overall design layout. The FAA may also recommend marking and/or lighting a structure that does not exceed 200 (61 m) feet AGL or 14 CFR Part 77 standards because of its particular location. The marking and lighting configurations are illustrated in Appendix A, Figures A-1 through A-27.

2.2 Guyed Structures.

The guys of a 2,000-foot (610-m) skeletal tower are anchored between 1,600 feet (488 m) and 2,000 feet (610 m) from the base of the structure. This places a portion of the guys 1,500 feet (458 m) from the tower at a height of between 125 feet (38 m) and 500 feet (153 m) AGL. Title 14 CFR Part 91, Section 119, requires pilots, when operating over other than congested areas, to remain at least 500 feet (153 m) from man-made structures. Therefore, the tower must be cleared by 2,000 feet (610 m) horizontally to avoid all guy wires. Properly maintained marking and lighting are important for increased conspicuity because the guys of a structure are difficult to see until the aircraft is dangerously close.

2.3 Marking and Lighting Equipment.

Considerable effort and research was expended to determine the minimum marking and lighting systems or quality of materials that will produce an acceptable level of aviation safety. The FAA will recommend only those marking and lighting systems that meet established technical standards. While additional lights may be desirable to identify an obstruction to air navigation and may, on occasion, be recommended, the FAA will recommend minimum standards in the interest of safety, economy, and related concerns. Therefore, to provide an adequate level of safety, obstruction lighting systems should be installed, operated, and maintained in accordance with the recommended standards herein. Table A-1 in Appendix A contains descriptions of each FAA-approved obstruction lighting fixture that is referred to in this AC.

2.4 Light Failure Notification.

2.4.1 Sponsors should consider that conspicuity is achieved only when all recommended lights are working. Partial equipment outages decrease the margin of safety. Any outage should be corrected as soon as possible. Failure of steady-burning side or intermediate lights should be corrected as soon as possible, but notification is not required.

2.4.2 Any failure or malfunction that lasts more than thirty (30) minutes and affects a top light or flashing obstruction light, regardless of its position, should be reported immediately by calling Outage Reporting and Notice to Airmen (NOTAM) 877-487-6867, or for Alaska 800-478-3576, so a NOTAM can be issued. Lights that are voluntary (not required by an FAA determination) do not require a NOTAM. For structures that are regulated by the FCC, the FCC advises that noncompliance with notification procedures could subject the sponsor to penalties or monetary forfeitures.

2.4.3 The following information should be specified for outage reporting:

1. Name of persons or organizations reporting the light failures, including any title, address, and telephone number.
2. The type of structure.
3. Location of structure (including latitude and longitude, if known, prominent structures, landmarks, etc.).
4. Height of structure AGL/above mean sea level (AMSL) if known.
5. A return to service date.
6. FCC Antenna Structure Registration Number (for structures that are regulated by the FCC).

Note 1: When the primary lamp in a double obstruction light fails, and the secondary lamp comes on, no report is required.

Note 2: After 15 days, the NOTAM is automatically deleted from the system. The sponsor is responsible for calling outage reporting to extend the outage date or to report a return to service date.

2.5 Notification of Restoration.

As soon as normal operation is restored, notify outage reporting. For structures that are regulated by the FCC, the FCC advises that noncompliance with notification procedures could subject the sponsor to penalties or monetary forfeitures.

2.6 Federal Communications Commission (FCC) Requirement.

The use of a high-intensity flashing white lighting system on structures located in residential neighborhoods (as defined by applicable zoning laws) trigger requirements for FCC licenses and an environmental assessment.

2.7 Voluntary Marking of Meteorological Evaluation Towers (METs) Less Than 200 Feet (61 m) AGL.

2.7.1 Recommendation.

The FAA recommends voluntary marking of METs less than 200 feet (61 m) AGL in accordance with marking guidance contained in this advisory circular (AC). Historically, this guidance has not been applied. However, the FAA recognizes the need to address safety impacts to low-level agricultural flight operations, and it believes that voluntarily marking METs less than 200 feet (61 m) AGL in remote and rural areas enhance the conspicuity of these structures.

2.7.2 Painting.

METs should be painted in accordance to the criteria contained in Chapter 3, paragraphs 3.1 through 3.4, specifically, with alternate bands of aviation orange and white paint. In addition, paragraph 3.5 states that all markings should be replaced when faded or otherwise deteriorated.

2.7.3 High-Visibility Sleeves.

It is recommended that several high-visibility sleeves be installed on the MET's outer guy wires. One high-visibility sleeve should be installed on each guy wire, as close to the anchor point as possible, but at a, height well above the crop or vegetation canopy. A second sleeve should be installed on the same outer guy wires midway between the location of the lower sleeve and the upper attachment point of the guy wire to the MET.

2.7.4 Spherical Markers.

It is also recommended that high-visibility aviation orange spherical marker (or cable) balls be attached to the guy wires. Spherical markers should be installed and displayed in accordance to Chapter 3, paragraph 3.5. The FAA, however, recognizes various weather conditions and manufacturing placement standards may affect the placement and use of high-visibility sleeves and/or spherical markers. Thus, some flexibility is allowed when determining sleeve length and marker placement on METs.

2.8 Obstruction Height Definition Changed to 499 Feet AGL.

Because of changes made to 14 CFR Part 77, *Safe, Efficient Use, and Preservation of the Navigable Airspace*, on July 21, 2010, the height of a structure (identified as an obstruction) was lowered to 499 feet AGL from 500 feet AGL. Consequently, all structures that are above 499 feet AGL will be designated as obstructions. The FAA will conduct an aeronautical study to determine the effect on navigable airspace. This will ensure all usable airspace at and above 500 feet AGL is addressed during the study and the airspace is safe for air navigation.

CHAPTER 3. MARKING GUIDELINES

3.1 Purpose.

This chapter provides recommended guidelines to make certain structures conspicuous to pilots during daylight hours. One way to achieve this conspicuity is to paint and/or mark these structures. Recommendations on marking structures can vary, depending on terrain features, weather patterns, geographic location, and the number of structures. Specific marking guidelines for wind turbines are contained in Chapter 13.

3.2 Paint Colors.

Alternate sections of aviation orange and white paint should be used as the contrast in colors provides maximum visibility of an obstruction. Specific paint standards are contained in Chapter 12.

3.3 Paint Standards.

To be effective, the paint used should meet specific color requirements when freshly applied to a structure. Because all outdoor paints deteriorate with time, and it is not practical to give a maintenance schedule for all climates, surfaces should be repainted when the color changes noticeably or its effectiveness is reduced by scaling, oxidation, chipping, or layers of contamination. The subsequent standards should be followed.

3.3.1 Materials and Application.

The FAA recommends that quality paint and materials be selected to maximize years of service. The paint should be appropriate for the surfaces to be painted, including any previous coatings, and suitable for the environmental conditions. Surface preparation and paint application should follow the manufacturer’s recommendations.

> **Note:** In-Service Aviation Orange Color Tolerance Charts are available from private suppliers for determining when repainting is required. The color should be sampled on the upper half of the structure, since weathering is greater there.

3.3.2 Surfaces not Requiring Paint.

Ladders, decks, and walkways of steel towers and similar structures do not need to be painted if a smooth surface presents a potential hazard to maintenance personnel. Painting may also be omitted from precision or critical surfaces if the paint would have an adverse effect on the transmission or radiation characteristics of a signal. However, the structure’s overall marking effect should not be reduced.

3.3.3 Skeletal Structures.

Complete all marking/painting prior to or immediately upon completion of construction. This applies to catenary support structures, radio and television towers, and similar skeletal structures. To be effective, paint should be applied to all inner and outer surfaces of the framework.

3.4 Paint Patterns.

Various types of paint patterns are used to mark structures. The pattern is determined by the size and shape of the structure. The following patterns are recommended.

3.4.1 Solid Pattern.

Obstacles should be painted aviation orange if the structure's horizontal and vertical dimensions do not exceed 10.5 feet (3.2 m).

3.4.2 Checkerboard Pattern.

Alternating rectangles of aviation orange and white are normally displayed on the following structures:

1. Water, gas, and grain storage tanks.
2. Buildings, as required.
3. Large structures exceeding 10.5 feet (3.2 m) across, having a horizontal dimension that is equal to or greater than the vertical dimension.

3.4.3 Size of Patterns.

The sides of the checkerboard pattern should measure not less than 5 feet (1.5 m) or more than 20 feet (6 m) and should be as nearly square as possible. However, if it is impractical because of the size or shape of a structure, the sides of the patterns may be less than 5 feet (1.5 m). When possible, the corner surfaces should be painted aviation orange. (See Figures A-15 and A-16 in Appendix A.)

3.4.4 Alternate Bands.

Alternate bands of aviation orange and white are normally displayed on the following structures:

1. Communication towers and catenary support structures.
2. Poles.
3. Smokestacks.
4. Skeletal framework of storage tanks and similar structures.
5. Structures that appear narrow from a side view are 10.5 feet (3.2 m) or more across, and the horizontal dimension is less than the vertical dimension.
6. Coaxial cable, conduits, and other cables attached to the face of a tower.

3.4.5 Color Band Characteristics.

Bands for structures of any height should be:

1. Equal in width, provided each band is not less than 1 1/2 feet (0.5 m) or more than 100 feet (31 m) wide.

2. Perpendicular to the vertical axis with the bands at the top and bottom painted orange.
3. An odd number of bands on the structure.
4. Approximately one-seventh the height, if the structure is equal to or less than 700 feet (214 m) AGL. For each additional 200 feet (61 m) or fraction thereof, add one (1) additional orange and one (1) additional white band. Table 3-1 shows the required band widths based on the height of the structure.
5. Equal and in proportion to the structure's AGL height.

Table 3-1. Structure Height to Bandwidth Ratio

Example: If a structure is:		
Greater Than	**Equal to or Less Than**	**Band Width**
10.5 feet (3.2 m)	700 feet (214 m)	1/7 of height
700 feet (214 m)	900 feet (275 m)	1/9 of height
900 feet (275 m)	1,100 feet (336 m)	1/11of height
1,100 feet (336 m)	1,300 feet (397 m)	1/13 of height

3.4.6 Structures With a Cover or Roof.

If the structure has a cover or roof, the highest orange band should be continued to cover the entire top of the structure. (See Figures A-15 and A-16 in Appendix A.)

3.4.7 Skeletal Structures Atop Buildings.

If a flagpole, skeletal structure, or similar object is erected on top of a building, the combined height of the object and building will determine whether marking is recommended. However, only the height of the object filed with the FAA determines the width of the color bands.

3.4.8 Partial Marking.

If marking is recommended for only a portion of a structure because the structure is shielded by other objects or terrain, the width of the bands should be determined by the overall height of the structure. A minimum of three bands should be displayed on the upper portion of the structure.

3.4.9 Teardrop Pattern.

Spherical water storage tanks with a single, circular standpipe support may be marked in a teardrop-striped pattern. The tank should show alternate stripes of aviation orange and white. The stripes should extend from the top center of the tank to its supporting standpipe. The width of the stripes should be equal, and the width of each stripe at the greatest girth of the tank should not be less than 5 feet (1.5 m) nor more than 15 feet (4.6 m). (See Figure A-17 in Appendix A.)

3.4.10 Community Names.

If it is desirable to paint the name of the community on the side of a tank, the stripe pattern may be broken to serve this purpose. This open area should have a maximum height of 3 feet (0.9 m). (See Figure A-17 in Appendix A.)

3.4.11 Exceptions.

Structural designs not conducive to standard markings may be marked as follows:

1. If it is not practical to paint the roof of a structure in a checkerboard pattern, it may be painted solid orange.
2. If a spherical structure is not suitable for an exact checkerboard pattern, the shape of the rectangles may be modified to fit the shape of the surface.
3. Storage tanks not suitable for a checkerboard pattern may have alternating bands of aviation orange and white or a limited checkerboard pattern applied to the upper one-third of the structure.
4. The skeletal framework of certain water, gas, and grain storage tanks may be excluded from the checkerboard pattern.

3.5 Unlighted Markers.

Unlighted markers are used to identify structures and to make them more conspicuous when it is impractical to paint them. Unlighted markers may also be used in addition to aviation orange and white paint when additional conspicuity is necessary for aviation safety. Unlighted markers should be displayed in conspicuous positions on or adjacent to the structures so as to retain the general definition of the structure. They should be recognizable in clear, daytime visibility from a distance of at least 4,000 feet (1,219 m) and in all directions from which aircraft are likely to approach. Unlighted markers should be distinctively shaped, i.e., spherical or cylindrical, so that they are not mistaken for items that are used to convey other information. They should be replaced when faded or otherwise deteriorated.

3.5.1 Spherical Markers.

Spherical markers are used to identify overhead wires and catenary transmission lines that are less than 69 kV. Markers may be of another shape, i.e., cylindrical, provided the projected area of such markers is not less than that presented by a spherical marker.

1. Size and Color.

   The diameter of the markers used on extensive catenary wires (catenary wires that cross canyons, lakes, rivers, etc.) should not be less than 36 inches (91 cm). Smaller 20-inch (51-cm) spheres are permitted on less extensive catenary wires or on power lines below 50 feet (15 m) AGL and within 1,500 feet (458 m) of an airport runway end. Each marker should be a solid color, specifically aviation orange, white, or yellow.

2. Installations.

   a. Spacing. Unlighted markers should be spaced equally along the wire at approximately 200-foot (61-m) intervals, or fraction thereof. There should be less space between markers in critical areas near runway ends [i.e., 30 feet to 50 feet (10 m to 15 m)]. They should be displayed on the highest wire or by another means at the same height as the highest wire. Where there is more than one wire at the highest point, the markers may be installed alternately along each wire if the distance between adjacent markers meets the spacing standard of 200 feet or less. This method distributes the weight and wind-loading factors. (See Figure A-1 in Appendix A.)

   b. Pattern. An alternating color scheme provides the most conspicuity against all backgrounds. Unlighted markers should be installed by alternating solid-colored markers of aviation orange, white, and yellow. Normally, an orange marker is placed at each end of a line and the spacing is adjusted [not to exceed 200 feet (61 m)] to accommodate the rest of the markers. When less than four markers are used, they should all be aviation orange. (See Figure A-1 in Appendix A.)

   c. Wire Sag. Wire Sag, or droop, will occur due to temperature, wire weight, wind, etc. Twenty-five (25) feet (7.62 m) is the maximum allowable distance between the highest wire installed with marker balls and the highest wire without marker balls, and shall not violate the sag requirements of the transmission line design.

   d. Adjacent Lines. Catenary crossings with multiple transmission lines require appropriate markers when the adjacent catenary structure's outside lines are greater than 200 feet (61 m) away from the center of the primary structure. (See Figure A-2 in Appendix A.) If the outside lines of the adjacent catenary structure are within 200 feet (61 m) or less from the center of the primary structure, markers are not required on the adjacent lines. (See Figure A-3 in Appendix A.)

3.5.2 Flag Markers.

Flags are used to mark certain structures or objects when it is technically impractical to use spherical markers or paint. Some examples are temporary construction equipment, cranes, derricks, oil and other drilling rigs. Catenaries should use spherical markers.

1. Minimum Size. Each side of the flag marker should be at least 2 feet (0.6 m) in length.

2. Color Patterns. Flags should be colored as follows:

   a. Solid. Aviation orange.

   b. Orange and White. Arrange two triangular sections, one aviation orange and the other white to form a rectangle.

c. Checkerboard. Flags 3 feet (0.9 m) or larger should be a checkerboard pattern of aviation orange and white squares, each 1 foot (0.3 m) plus or minus 10 percent.

3. Shape. Flags should be rectangular in shape and have stiffeners to keep them from drooping in calm wind.

4. Display. Flag markers should be displayed around, on top, or along the highest edge of the obstruction. When flags are used to mark extensive or closely grouped obstructions, they should be displayed approximately 50 feet (15 m) apart. The flag stakes should be strong enough to support the flags and be higher than the surrounding ground, structures, and/or objects of natural growth.

3.6 Unusual Complexities.

The FAA may also recommend appropriate marking in an area in which grouped obstructions present a common obstruction to air navigation.

3.7 Omission or Alternatives to Marking.

The alternatives listed below require FAA review and concurrence.

3.7.1 High-Intensity Flashing White Lighting Systems.

High-intensity flashing white lighting systems are more effective than aviation orange and white paint and therefore can be recommended instead of paint marking. This is particularly true under certain ambient light conditions involving the position of the sun relative to the direction of flight. When high-intensity lighting systems are operated during daytime and twilight, other methods of marking may be omitted. When operated 24 hours a day, other methods of marking and lighting may be omitted.

3.7.2 Medium-Intensity Flashing White Lighting Systems.

When medium-intensity flashing white lighting systems are operated during daytime and twilight on structures 700 feet (213 m) AGL or less, other methods of marking may be omitted.

Note: Sponsors must ensure that alternatives to marking are coordinated with the FCC for structures under its jurisdiction prior to making the change.

CHAPTER 4. LIGHTING GUIDELINE

4.1 Purpose.

This chapter describes the various obstruction lighting systems used to identify structures that have been determined to require added conspicuity. The lighting standards in this AC are the minimum necessary for aviation safety. Recommendations on lighting structures can vary, depending on terrain features, weather patterns, geographic location, and number of structures. Specific lighting guidelines for wind turbines are contained in Chapter 13.

4.2 Standards.

The standards outlined in this AC are based on using light units that meet specified intensities, beam patterns, color, and flash rates as stated in AC 150/5345-43, *Specification for Obstruction Lighting Equipment*. These standards may be obtained from: www.faa.gov/airports/resources/advisory_circulars/

4.3 Lighting Systems.

Obstruction lighting may be displayed on structures as follows:

1. <u>Aviation Red Obstruction Lights</u>. Use flashing lights and/or steady-burning lights during nighttime. Tower structures are typically marked with flashing red lights. Buildings and smaller obstructions located near airports should be marked with steady-burning red lights. (See Chapter 5).
2. <u>Medium-Intensity Flashing White Obstruction Lights</u>. Medium-intensity flashing white obstruction lights may be used during daytime and twilight with automatically selected reduced intensity for nighttime operation. When this system is used on structures 700 feet (213 m) AGL or less, other methods of marking and lighting the structure may be omitted. Aviation orange and white paint is always required for daytime marking on structures exceeding 700 feet (213 m) AGL. This system is not normally recommended on structures 200 feet (61 m) AGL or less.
3. <u>High-Intensity Flashing White Obstruction Lights</u>. High-intensity flashing white obstruction lights may be used during daytime with automatically selected reduced intensities for twilight and nighttime operations. When this system is used, other methods of marking and lighting the structure may be omitted. This system should not be used on structures 700 feet (213 m) AGL or less, unless an FAA aeronautical study shows otherwise.

   Note: All flashing lights on a structure should flash simultaneously except for catenary support structures, which have a distinct flashing sequence between the levels of lights (see paragraph 4.4).
4. <u>Dual Lighting</u>. This system consists of red lights for nighttime and high- or medium-intensity flashing white obstruction lights for daytime and twilight. When a dual lighting system incorporates medium-intensity flashing white lights on

structures 700 feet (213 m) AGL or less or high-intensity flashing white lights on structures greater than 700 feet (213 m) AGL, other methods of marking the structure may be omitted.

5. Obstruction Lights During Construction. As the height of the structure exceeds each level at which permanent obstruction lights would be recommended, two or more lights of the type specified in the determination should be installed at that level. Temporary high or medium-intensity flashing white lights, as recommended in the determination, should be operated 24 hours a day until all permanent lights are in operation. In either case, two or more lights should be installed on the uppermost part of the structure any time it exceeds the height of the temporary construction equipment. They may be turned off for periods when they could interfere with construction personnel. If practical, permanent obstruction lights should be installed and operated at each level as construction progresses. The lights should be positioned to ensure that a pilot has an unobstructed view of at least one light at each level.

6. Obstruction Lights in Urban Areas. When a structure is located in an urban area where there are numerous other white lights (e.g., streetlights) red obstruction lights with painting or a medium-intensity dual system is recommended. Medium-intensity lighting is not normally recommended on structures less than 200 feet (61 m).

7. Temporary Construction Equipment Lighting. Since there is such a variance in construction cranes, derricks and other drilling rigs, each case should be considered individually. Lights should be installed according to the standards given in Chapters 5, 6, 7, or 8, as they would apply to permanent structures.

4.4 Lighted Spherical Markers.

4.4.1 Lighted markers are available for increased night conspicuity of high-voltage (69 kV or greater) transmission line catenary wires. These markers should be used on transmission line catenary wires near airports, heliports, across rivers, canyons, lakes, etc. The lighted markers should be manufacturer-certified as recognizable from a minimum distance of 4,000 feet (1,219 m) under nighttime conditions, minimum Visual Flight Rule (VFR) conditions or having a minimum intensity of at least 32.5 candelas. The lighting unit should emit a steady-burning, red light.

4.4.2 Lighted markers should be installed on the highest energized line. If the lighted markers are installed on a line other than the highest catenary, then markers specified in Chapter 3 paragraph 3.5 should be used in addition to the lighted markers. The maximum distance between the line energizing the lighted markers and the highest catenary above the lighted marker should be no more than 25 feet (7.62 m) and shall not violate the sag requirements of the transmission line design.

4.4.3 Lighted markers should be distinctively shaped, (i.e., spherical or cylindrical) so they are not mistaken for items that are used to convey other information. They should be visible in all directions from which aircraft are likely to approach. The area in the immediate vicinity of the supporting structure's base should be clear of all items and/or objects of natural growth that could interfere with the line-of-sight between a pilot and the structure's lights. (See Figure A-4 in Appendix A.) When a catenary wire crossing requires three or more supporting structures, the inner structures should be equipped with enough light units per level to provide full coverage from which aircraft are likely to approach.

4.5 Inspection, Repair, and Maintenance.

To ensure the proper candela output for fixtures with incandescent lamps, the voltage provided to the lamp filament should not vary more than plus or minus three percent of the lamp's rated voltage. The input voltage should be measured at the closest disconnecting means to the lamp fixture with the lamp operating during the hours of normal operation. (For strobes, the input voltage of the power supplies should be within 10 percent of rated voltage.) Lamps should be replaced after being in operation for approximately 75 percent of their rated life or immediately upon failure. Flashtubes in a light unit should be replaced immediately upon failure, when the peak effective intensity falls below specification limits or when the fixture begins skipping flashes, or at the manufacturer's recommended intervals. Due to the effects of harsh environments, light fixture lenses should be visually inspected every 24 months, or when the light fixture fails, for ultraviolet (UV) damage, cracks, crazing, dirt buildup, etc., to ensure the certified light output has not deteriorated. (See Chapter 2 paragraph 2.4 for reporting requirements in case of failure.) Lenses that have cracks, UV damage, crazing, or excessive dirt buildup should be cleaned or replaced.

4.6 Nonstandard Lights.

Moored balloons, chimneys, church steeples, and similar obstructions may be floodlighted by fixed search light projectors installed at three or more equidistant points around the base of each obstruction. The searchlight projectors should provide an average illumination of at least 15 foot-candles (161.45 lux) over the top one-third of the obstruction.

4.7 Placement Factors.

The height of the structure AGL determines the number of light levels. The light levels may be adjusted slightly, but not to exceed 10 feet (3 m) when necessary to accommodate guy wires and personnel who replace or repair light fixtures. Except for catenary wire support structures, the following factors should be considered when determining the placement of obstruction lights on a structure.

1. Red Obstruction Lighting Systems. The structure's overall height, including all appurtenances, such as rods, antennas, and obstruction lights, determines the number of light levels.
2. Medium-Intensity Flashing White Obstruction Lighting Systems. The structure's overall height, including all appurtenances such as rods, antennas, and obstruction lights, determines the number of light levels.

3. High-Intensity Flashing White Obstruction Lighting Systems. The main structure's overall height, excluding all appurtenances, such as rods, antennas, and obstruction lights, determines the number of light levels.

4. Dual Obstruction Lighting Systems. The structure's overall height, including all appurtenances, such as rods, antennas, and obstruction lights, is used to determine the number of light levels for a medium-intensity white obstruction light/red obstruction dual lighting system. The structure's overall height, excluding all appurtenances, is used to determine the number of light levels for a high-intensity white obstruction light/red obstruction dual lighting system.

5. Adjacent Structures. The elevation of the tops of adjacent buildings in congested areas may be used as the equivalent of ground level to determine the correct number of light levels required.

6. Shielded Lights. If an adjacent structure or object blocks the visibility of an obstruction light, the light's horizontal placement should be adjusted or additional lights should be mounted on that object to retain or contribute to the definition of the obstruction.

7. Nesting of Lights. Care should be taken to ensure that obstruction lights do not become blocked or "nested" as new antennas, hardware, or appurtenances are added to the top of a structure. If new equipment is added that blocks the obstruction light's visibility, the light fixtures must be relocated and/or raised so that it is not blocked by the new equipment. For example, when new larger cellular antenna panels are fitted to older towers, the obstruction light will need to be raised so that it is not blocked by the larger antenna panels. The widest structure, appurtenance, lightning rod, or antenna that can be placed in front of an obstruction light (excluding the L-810 light) without significantly blocking the obstruction light's visibility should be no wider than 7/8 of an inch. Due to their smaller size, L-810 lights should not be blocked by any structure.

4.8 Monitoring Obstruction Lights.

Obstruction lighting systems should be closely monitored by visual or automatic means. It is extremely important to visually inspect obstruction lighting in all operating intensities at least once every 24 hours on systems without automatic monitoring. In the event a structure is not readily accessible for visual observation, a properly maintained automatic monitor should be used. This monitor should be designed to register the malfunction of any light on the obstruction regardless of its position or color. When using remote monitoring devices, the system's communication and operational status should be confirmed at least once every 24 hours. The monitor (aural or visual) should be located in an area generally occupied by the responsible personnel. In some cases, this may require a remote monitor in an attended location. For each structure, a log should be maintained in which the lighting system's daily operations status is recorded. Light fixture lenses should be replaced if serious cracks, hazing, dirt buildup, etc., has occurred.

4.9 Ice Shields.

Where icing is likely to occur, metal grates or similar protective ice shields should be installed directly over each light unit to prevent falling ice or accumulation from damaging the light units. The light should be mounted in a manner to ensure an unobstructed view of at least one light by a pilot approaching from any direction.

4.10 Light Shields.

In general, light shields are not permitted because of the adverse effects they have on the obstruction light fixture's photometrics. In addition, these shields can promote undesired snow accumulation, bird nesting, and wind loading.

4.11 Distraction.

When obstruction lights are in proximity to a navigable waterway, they may distract vessel operators. To avoid interference with marine navigation, coordinate with the Commander of the District Office, United States (U.S.) Coast Guard before installing the lighting system. The contact information for the U.S. Coast Guard is:

Commandant (CG-5531)
U.S. Coast Guard
2100 2nd St SW, Stop 7580
Washington, DC 20593-7580
202-372-1561

CHAPTER 5. RED OBSTRUCTION LIGHT SYSTEM

5.1 Purpose.

Red obstruction lights are used to increase conspicuity during nighttime. Daytime and twilight marking is required. Recommendations on lighting structures can vary, depending on terrain features, weather patterns, geographic location, and number of structures. Specific lighting guidelines for wind turbines are contained in Chapter 13.

5.2 Standards.

The red obstruction light system is composed of flashing omnidirectional lights (L-864) and/or steady-burning or flashing (L-810) lights. When one or more levels are comprised of flashing lights, the lights should flash simultaneously. The number of light levels needed is shown in Figure A-6 in Appendix A.

1. Single Obstruction Light. A single red obstruction light (L-810) may be used when more than one obstruction light is required either vertically or horizontally, or when maintenance is needed, and can be installed within a reasonable time.
    a. Top Level. A single steady-burning light (L-810) may be used to identify low structures, such as airport instrument landing system buildings, as well as long horizontal structures, such as perimeter fences and building roof outlines.
    b. Intermediate Level. Single flashing or steady-burning lights (as appropriate for size and type of structure) may be used on skeletal and solid structures when more than one level of lights is installed, and there are two or more single lights per level.
2. Double Obstruction Light. A double steady-burning (L-810) light should be installed when used as a top light, at each end of a row of single obstruction lights, and in areas or locations where the failure of a single unit could cause an obstruction to be totally unlighted.
    a. Top Level. Structures 150 feet (46 m) AGL or less should have one or more double steady-burning lights installed at the highest point and operating simultaneously.
    b. Intermediate Level. Double flashing or steady-burning lights (as appropriate for size and type of structure) should be installed at intermediate levels when a malfunction of a single light could create an unsafe condition and in remote areas where maintenance cannot be performed within a reasonable time. Both units may operate simultaneously, or a transfer relay may be used to switch to a spare unit should the active system fail.
    c. Lowest Level. The lowest level of light units may be installed at a higher elevation than normal on a structure if the surrounding terrain, trees, or adjacent building(s) would obscure the lights. In certain instances, as determined by the FAA, the lowest level of lights may be eliminated.

5.3 Control Device.

Red obstruction lights should be operated by an acceptable control device (e.g., photocell, timer, etc.) adjusted so the lights will be turned on when the northern sky illuminance reaching a vertical surface falls below a level of 60 foot-candles (645.8 lux) but before reaching a level of 35 foot-candles (376.7 lux). The control device should turn the lights off when the northern sky illuminance rises to a level of not more than 60 foot-candles (645.8 lux). The lights may also remain on continuously. The sensing device should, if practical, face the northern sky in the Northern Hemisphere. (See AC 150/5345-43.)

5.4 Poles, Towers, and Similar Skeletal Structures.

The following standards apply to radio and television towers, supporting structures for overhead transmission lines, and similar structures.

1. Top-Mounted Obstruction Light.
   a. Structures 150 Feet (46 m) AGL or Less. Two or more steady-burning red (L-810) lights should be installed in a manner to ensure an unobstructed view of one or more lights by a pilot.
   b. Structures Exceeding 150 Feet (46 m) AGL. At least one red flashing (L-864) light should be installed in a manner to ensure an unobstructed view of one or more lights by a pilot.
   c. Appurtenances 40 Feet (12 m) or Less. If a rod, antenna, or other appurtenance 40 feet (12 m) or less in height is incapable of supporting a red flashing light, then it may be placed at the base of the appurtenance. If the mounting location does not allow an unobstructed view of the light by a pilot, then additional lights should be added.
   d. Appurtenances Exceeding 40 Feet (12 m). If a rod, antenna, or other appurtenance exceeding 40 feet (12 m) in height is incapable of supporting a red flashing light, a supporting mast with one or more lights should be installed adjacent to the appurtenance. Adjacent installations should not exceed the appurtenance’s height and be within 40 feet (12 m) of the tip to allow the pilot an unobstructed view of at least one light. If the rod, antenna, or other appurtenance is 7/8 inch wide or more, at least two lights must be installed on the supporting mast to provide the necessary unobstructed view.
2. Mounting Intermediate Levels. The number of light levels is determined by the height of the structure, including all appurtenances, as shown in Figure A-6 in Appendix A. The number of lights on each level is determined by the shape and height of the structure. These lights should be mounted to ensure an unobstructed view of at least one light by a pilot.
   a. Steady-Burning Lights (L-810).
      i. Structures 150 Feet (46 m) AGL or Less. Two or more steady-burning (L-810) lights should be installed diagonally or on diametrically opposite positions.

ii. Structures Exceeding 150 Feet (46 m) AGL. These structures do not require steady-burning (L-810) lights.

b. Flashing Lights (L-810). For structures exceeding 151 feet (46 m) but not more than 350 feet (107 m) at intermediate levels, two or more flashing (L-810) lights should be mounted outside at diagonally opposite positions of intermediate levels. These lights should be configured to flash simultaneously with the L-864 flashing light on the top of the structure at a rate of 30 flashes per minute (fpm) (± 3 fpm).

c. Flashing Lights (L-864).

i. Structures 350 Feet (107 m) AGL or Less. These structures do not require flashing (L-864) lights at intermediate levels.

ii. Structures Exceeding 350 Feet (107 m) AGL. At intermediate levels, as shown in Figure A-6 in Appendix A, two (L-864) lights should be mounted outside at diagonally opposite positions.

5.5 Chimneys, Flare Stacks, and Similar Solid Structures.

5.5.1 Number of Light Units.

The number of units recommended depends on the diameter of the structure at the top. The number of lights recommended below is the minimum.

1. Structures 20 Feet (6 m) or Less in Diameter. Three light units per level (see Figure A-20 in Appendix A).
2. Structures Exceeding 20 Feet (6 m) but not More Than 100 Feet (31 m) in Diameter. Four light units per level (see Figure A-20 in Appendix A).
3. Structures Exceeding 100 Feet (31 m) but not More Than 200 Feet (61 m) in Diameter. Six light units per level (see Figure A-21 in Appendix A).
4. Structures Exceeding 200 Feet (61 m) in Diameter. Eight light units per level.

5.5.2 Top-Mounted Obstruction Lights.

1. Structures 150 Feet (46 m) AGL or Less. L-810 lights should be installed horizontally at regular intervals at or near the top.
2. Structures Exceeding 150 Feet (46 m) AGL. At least three L-864 lights should be installed.
3. Chimneys, Cooling Towers, and Flare Stacks. Lights may be displayed as low as 20 feet (6-m) below the top (see Figure A-13 in Appendix A) to avoid the obscuring effect of deposits and heat generally emitted by this type of structure. It is important that these lights are readily accessible for cleaning and lamp replacement. It is understood that with flare stacks, as well as any other structures associated with the petrol-chemical industry, normal lighting requirements may not be necessary. This could be due to the location of the flare stack/structure within a large, well-lighted,

petrol-chemical plant, or the fact that the flare, or working lights surrounding the flare stack/structure, is as conspicuous as obstruction lights.

5.5.3 Mounting Intermediate Levels.

The number of light levels is determined by the height of the structure including all appurtenances. For cooling towers 600 feet (183 m) AGL or less, intermediate light levels are not necessary. Structures between 150 feet and 350 feet AGL or less should have a second level of steady-burning red light units installed approximately at the midpoint of the structure and in a vertical line with the top level of lights. Structures exceeding 350 feet (107 m) AGL should have a second level of flashing light units.

1. Steady-Burning (L-810) Lights. The recommended number of light levels is shown in Figure A-15 in Appendix A. At least three lights should be installed on each level.
2. Flashing (L-864) Lights. The recommended number of light levels is shown in Figure A-6 in Appendix A. At least three lights should be installed on each level.
    a. Structures 350 Feet (107 m) AGL or Less. These structures do not need intermediate levels of flashing lights.
    b. Structures Exceeding 350 Feet (107 m) AGL. At least three flashing (L-864) lights should be installed on each level in a manner, allowing an unobstructed view of at least one light.

5.6 Group of Obstructions.

When individual objects, except wind turbines, within a group of obstructions are not the same height and are spaced a maximum of 150 feet (46 m) apart, the prominent objects within the group should be lighted in accordance with the standards for individual obstructions of a corresponding height. If the outer structure is shorter than the prominent object, the outer structure should be lighted in accordance with the standards for individual obstructions of a corresponding height. Light units should be placed to ensure that the light is visible to a pilot approaching from any direction. In addition, at least one flashing light should be installed at the top of a prominent center obstruction or on a special tower located near the center of the group. For the purpose of marking and lighting obstructions other than wind turbines, a group of obstructions is considered to be three (3) or more structures.

5.7 Alternate Method of Displaying Obstruction Lights.

The FAA may recommend that lights be placed on poles equal to the height of the obstruction and installed on or adjacent to the structure instead of installing lights on the obstruction.

5.8 Prominent Buildings, Bridges, and Similar Extensive Obstructions.

When objects within a group of obstructions are approximately the same overall height above the surface and are located a maximum of 150 feet (46 m) apart, the group of obstructions may be considered an extensive obstruction. Light units should be installed on the same horizontal plane at the highest portion, or edge, of the prominent obstructions. Light units should be placed to ensure the light is visible to a pilot approaching from any direction. If the structure is a bridge and is over navigable water, the sponsor must obtain prior approval of the lighting installation from the Commander of the District Office of the U.S. Coast Guard to avoid interference with marine navigation. Steady-burning lights should be displayed to indicate the extent of the obstruction, as follows:

1. Structures 150 Feet (46 m) or Less in Any Horizontal Direction. If the structure/bridge/extensive obstruction is 150 feet (46 m) or less horizontally, at least one steady-burning light (L-810) should be displayed on the highest point at each end of the obstruction's major axis. If this is impractical because of the overall shape, display a double obstruction light in the center of the highest point.
2. Structures Exceeding 150 Feet (46 m) in at Least One Horizontal Direction. If the structure/bridge/extensive obstruction exceeds 150 feet (46 m) horizontally, at least one steady-burning light should be displayed for each 150 feet (46 m), or fraction thereof, of the overall length of the major axis. At least one of these lights should be displayed on the highest point at each end of the obstruction. Additional lights should be displayed at approximately equal intervals, not to exceed 150 feet (46 m) on the highest points along the edge between the end lights. If an obstruction is located near a landing area and two or more edges are the same height, the edge nearest the landing area should be lighted.
3. Structures Exceeding 150 Feet (46 m) AGL. Steady-burning red obstruction lights should be installed on the highest point at each end. At intermediate levels, steady-burning red lights should be displayed for each 150 feet (46 m), or fraction thereof. The vertical position of these lights should be equidistant between the top lights and the ground level, as the shape and type of obstruction will permit. A steady-burning red light should be displayed at each outside corner on each level with the remaining lights evenly spaced between the corner lights.
4. Exceptions. Flashing red lights (L-864) may be used instead of steady-burning lights if early or special warning is necessary. These lights should be displayed on the highest points of an extensive obstruction at intervals not exceeding 3,000 feet (915 m). At least three lights should be displayed on one side of the extensive obstruction to indicate a line of lights. (See Figure A-22 in Appendix A.)
5. Ice Shields. See paragraph 4.9.

CHAPTER 6. MEDIUM-INTENSITY FLASHING WHITE OBSTRUCTION LIGHT SYSTEMS

6.1 Purpose.

Medium-intensity flashing white (L-865) obstruction lights may provide conspicuity both day and night. Recommendations on lighting structures can vary, depending on terrain features, weather patterns, geographic location, and number of structures.

6.2 Standards.

6.2.1 The medium-intensity flashing white light system is normally composed of flashing omnidirectional lights. Medium-intensity flashing white obstruction lights may be used during daytime and twilight with automatically selected, reduced intensity for nighttime operation. When this system is used on structures 700 feet (213 m) AGL or less, other methods of marking and lighting the structure may be omitted. (Aviation orange and white paint is always required for daytime marking on structures exceeding 700 feet (213 m) AGL. This system is not normally recommended on structures 200 feet (61 m) AGL or less. The number of light levels needed is shown in Figure A-7 in Appendix A.

6.2.2 Using a 24-hour, medium-intensity, flashing white light system in urban/populated areas is not normally recommended due to their tendency to blend with the background lighting in these areas at night. This makes it extremely difficult for some types of aviation operations, i.e., medical-evacuation (medevac) and police helicopters to see these structures. Using this type of system in urban and rural areas often results in complaints. In addition, this system is not recommended on structures within 3 nautical miles (NM) of an airport.

6.3 Radio and Television Towers and Similar Skeletal Structures.

6.3.1 Mounting Lights.

The number of levels recommended depends on the height of the structure, including antennas and similar appurtenances.

1. Top Levels. One or more lights should be installed at the highest point to provide 360-degree coverage, ensuring an unobstructed view by a pilot approaching from any direction.
2. Appurtenances 40 Feet (12 m) or Less. If a rod, antenna, or other appurtenance 40 feet (12 m) or less in height is incapable of supporting the medium-intensity flashing white light, then it may be placed at the base of the appurtenance. If the mounting location does not allow an unobstructed view of the medium-intensity flashing white light by a pilot approaching from any direction, then additional lights should be added.
3. Appurtenances Exceeding 40 Feet (12 m). If a rod, antenna, or other appurtenance exceeds 40 feet (12 m) above the tip of the main structure, a medium-intensity flashing white light should be placed within 40 feet (12 m) from the top of the

appurtenance. If the appurtenance (such as a whip antenna) is incapable of supporting the light, one or more lights should be mounted on a pole adjacent to the appurtenance. Adjacent installations should not exceed the height of the appurtenance and be within 40 feet (12 m) of the tip to allow the pilot an unobstructed view of at least one light. If the rod, antenna, or other appurtenance is 7/8 of an inch wide or more, at least two lights must be installed on the supporting mast to provide the necessary unobstructed view.

6.3.2 Intermediate Levels.

At intermediate levels, two or more lights (L-865) should be mounted outside at diagonally or diametrically opposite positions of intermediate levels. The lowest light level should not be less than 200 feet (61 m) AGL.

6.3.3 Lowest Levels.

The lowest level of light units may be installed at a higher elevation than normal on a structure if the surrounding terrain, trees, or adjacent building(s) would obscure the lights. In certain instances, as determined by the FAA, the lowest level of lights may be eliminated.

6.3.4 Structures 700 Feet (213 m) AGL or Less.

When medium-intensity flashing white lights are used during nighttime and twilight only, marking is required for daytime. When operated 24 hours a day, other methods of marking and lighting are not required.

6.3.5 Structures Exceeding 700 Feet (213 m) AGL.

The lights should be used during nighttime and twilight and may be used 24 hours a day. Marking is always required for daytime.

6.3.6 Ice Shields.

See paragraph 4.9.

6.4 Control Device.

The light intensity is controlled by a device (photocell) that changes the light's intensity when the ambient light changes. The system should automatically change intensity steps when, in the Northern Hemisphere, the northern sky illumination reaching a north-facing vertical surface is as follows:

1. Twilight-to-Night. This should not occur before the illumination drops below 5 foot-candles (53.8 lux) but should occur before it drops below 2 foot-candles (21.5 lux).
2. Night-to-Day. The intensity changes listed in subparagraph 6.4 1 above should be reversed when changing from the night-to-day mode.

6.5 Chimneys, Flare Stacks, and Similar Solid Structures.

The number of light units recommended depends on the diameter of the structure at the top. Normally, the top level is on the highest point of a structure. However, the top level of chimney lights may be installed as low as 20 feet (6 m) below the top to minimize deposit build-up due to emissions. (See Figure A-13 in Appendix A.) The number of lights recommended below is the minimum, as shown in Figure A-20 in Appendix A.

1. Structures 20 Feet (6 m) or Less in Diameter. Three light units per level. (See Figure A-20 in Appendix A.)
2. Structures Exceeding 20 Feet (6 m) but not More Than 100 Feet (31 m) in Diameter. Four light units per level. (See Figure A-20 in Appendix A.)
3. Structures Exceeding 100 Feet (31 m) but not More Than 200 Feet (61 m) in Diameter. Six light units per level. (See Figure A-21 in Appendix A.)
4. Structures Exceeding 200 Feet (61 m) in Diameter. Eight light units per level.

6.6 Group of Obstructions.

When individual objects within a group of obstructions are not the same height and are spaced a maximum of 150 feet (46 m) apart, the prominent objects within the group should be lighted in accordance with the standards for individual obstructions of a corresponding height. If the outer structure is shorter than the prominent object, the outer structure should be lighted in accordance with the standards for individual obstructions of a corresponding height. Light units should be placed to ensure that the light is visible to a pilot approaching from any direction. In addition, at least one medium-intensity flashing white light should be installed at the top of a prominent center obstruction or on a special tower located near the center of the group.

6.7 Special Cases.

When lighting systems are installed on structures located near highways, waterways, airport approach areas, etc., caution should be exercised to ensure that the lights do not distract or otherwise cause a hazard to motorists, vessel operators, or pilots on an approach to an airport. In these cases, shielding may be necessary. This shielding should not derogate the lighting system’s intended purpose.

6.8 Prominent Buildings and Similar Extensive Obstructions.

When objects within a group of obstructions are approximately the same overall height above the surface and are located a maximum of 150 feet (46 m) apart, the group of obstructions may be considered an extensive obstruction. Light units should be installed on the same horizontal plane at the highest portion, or edge, of the prominent obstructions. Light units should be placed to ensure that the light is visible to a pilot approaching from any direction. Lights should be displayed to indicate the extent of the obstruction as follows:

1. Structures 150 Feet (46 m) or Less in Any Horizontal Direction. If the structure/extensive obstruction is 150 feet (46 m) or less horizontally, at least one light should be displayed on the highest point at each end of the obstruction's major axis. If this is impractical because of the overall shape, display a double obstruction light in the center of the highest point.
2. Structures Exceeding 150 Feet (46 m) in at Least One Horizontal Direction. If the structure/extensive obstruction exceeds 150 feet (46 m) horizontally, at least one light should be displayed for each 150 feet (46 m), or fraction thereof, of the overall length of the major axis. At least one of these lights should be displayed on the highest point at each end of the obstruction. Additional lights should be displayed at approximately equal intervals not to exceed 150 feet (46 m) on the highest points along the edge between the end lights. If an obstruction is located near a landing area and two or more edges are the same height, the edge nearest the landing area should be lighted.
3. Structures Exceeding 150 Feet (46 m) AGL. Lights should be installed on the highest point at each end. At intermediate levels, lights should be displayed for each 150 feet (46 m), or fraction thereof. The vertical position of these lights should be equidistant between the top lights and the ground level as the shape and type of obstruction will permit. One such light should be displayed at each outside corner on each level with the remaining lights evenly spaced between the corner lights.

CHAPTER 7. HIGH-INTENSITY FLASHING WHITE OBSTRUCTION LIGHT SYSTEMS

7.1 Purpose.

High-intensity (L-856) flashing white obstruction lights provides the highest degree of conspicuity both day and night. Recommendations on lighting structures can vary, depending on terrain features, weather patterns, geographic location, and number of structures.

7.2 Standards.

High-intensity flashing white obstruction lights should be used during daytime with automatically selected, reduced intensities for twilight and nighttime operations. When high-intensity white obstruction lights are operated 24 hours a day, other methods of marking and lighting may be omitted. This system should not be recommended on structures 700 feet (213 m) AGL or less unless an FAA aeronautical study shows otherwise. The number of light levels needed is shown in Figures A-8 and A-9 in Appendix A.

7.3 Control Device.

7.3.1 Light intensity is controlled by a device (photocell) that changes the light's intensity when the ambient light changes. Using a 24-hour, high-intensity flashing white light system in urban/populated areas is not normally recommended due to their tendency to merge with background lighting in these areas at night. This makes it extremely difficult for some types of aviation operations (i.e., medevac) and police helicopters to see these structures. Using this type of system in urban and rural areas often results in complaints.

7.3.2 The system should automatically change intensity steps when, in the Northern Hemisphere, the northern sky illuminance reaching a north-facing vertical surface is as follows:

1. Day-to-Twilight. This should not occur before the illumination drops to 60 foot-candles (645.8 lux) but should occur before it drops below 35 foot-candles (376.7 lux). The illuminance-sensing device should, if practical, face the northern sky in the Northern Hemisphere.
2. Twilight-to-Night. This should not occur before the illumination drops below 5 foot-candles (53.8 lux) but should occur before it drops below 2 foot-candles (21.5 lux).
3. Night-to-Day. The intensity changes listed in subparagraphs 7.3.2 1 and 7.3.2.2 above should be reversed when changing from the night-to-day mode.

7.4 Units per Level.

One or more light units are needed to obtain the desired horizontal coverage. The number of light units recommended per level (except for the supporting structures of catenary wires and buildings) depends upon the average outside diameter of the specific structure and the horizontal beam width of the light fixture. Light units should be installed to ensure an unobstructed view of the system by a pilot approaching from **any** direction. The number of lights recommended below is the minimum.

1. <u>Structures 20 Feet (6 m) or Less in Diameter</u>. Three light units per level.
2. <u>Structures Exceeding 20 Feet (6 m) but not More Than 100 Feet (31 m) in Diameter</u>. Four light units per level.
3. <u>Structures Exceeding 100 Feet (31 m) in Diameter</u>. Six light units per level.

7.5 Installation Guidance.

On most obstruction high-intensity light fixtures, the effective peak intensity of the light beam can be adjusted from 0 to 8 degrees above the horizon. Standard installation should place the top light at 0 degrees to the horizontal and all other light units installed in accordance with Table 7-1.

Table 7-1. Light Unit Elevation Above the Horizontal

Height of Light Unit Above Terrain	Degrees of Elevation Above the Horizontal
Exceeding 500 feet AGL	0
Above 400 feet to 500 feet AGL	1
Above 300 feet to 400 feet AGL	2
300 feet AGL or less	3

1. <u>Vertical Aiming</u>. When terrain, nearby residential areas, or other situations dictate, the light beam may be further elevated above the horizontal. The main beam of light at the lowest level should not strike the ground closer than 3 statute miles (5 km) from the structure. If additional adjustments are necessary, the lights may be individually adjusted upward, in 1-degree increments, starting at the bottom. Excessive elevation may reduce its conspicuity by raising the beam above a collision course flight path.
2. <u>Special Cases</u>. When lighting systems are installed on structures located near highways, waterways, airport approach areas, etc., caution should be exercised to ensure that the lights do not distract or otherwise cause a hazard to motorists, vessel operators, or pilots on an approach to an airport. In these cases, shielding or adjusting the aim of the vertical or horizontal light may be necessary. This adjustment should not derogate the lighting system's intended purpose. Such

adjustments may require an additional review, as described in Chapter 1 paragraph 1.5.

3. Relocation or Omission of Light Units. Light units should not be installed in such a manner that the light pattern/output is disrupted by the structure.

   a. Lowest Level. The lowest level of light units may be installed at a higher elevation than normal on a structure if the surrounding terrain, trees, or adjacent building(s) would obscure the lights. In certain instances, as determined by the FAA, the lowest level of lights may be eliminated.

   b. Two Adjacent Structures. When two structures are within 500 feet (153 m) of each other and the light units are installed at the same levels, the sides of the structures facing each other do not need be lighted. (See Figures A-18 and A-19.) However, all lights on both structures must flash simultaneously, except for adjacent catenary support structures. Vertical placement of the lights should be adjusted to either or both structures' intermediate levels to place the lights on the same horizontal plane. If one structure is higher than the other, a complete level(s) of lights should be installed on the higher structure that extends above the top of the lower structure. If the structures are of such heights that the levels of lights cannot be placed in identical horizontal planes, then the light units should be placed so that the center of the horizontal beam patterns do not face toward the adjacent structure. For example, structures situated north and south of each other should have the light units on both structures installed on a northwest/southeast and northeast/southwest orientation.

   c. Three or More Adjacent Structures. The treatment of a cluster of structures as an individual or a complex of structures will be determined by the FAA, taking into consideration the location, heights, and spacing of other structures.

7.6 Antenna or Similar Appurtenance Light.

When a structure lighted by a high-intensity, flashing white light system is topped with an antenna or similar appurtenance exceeding 40 feet (12 m) in height, a medium-intensity flashing white light (L-865) should be placed within 40 feet (12 m) from the tip of the appurtenance. This light should operate 24 hours a day and flash simultaneously with the rest of the lighting system. The location of the appurtenance light is shown in Figure A-9 in Appendix A. Structures with an appurtenance 40 feet (12 m) or less in height should be lit in accordance with Figure A-8.

7.7 Chimneys, Flare Stacks, and Similar Solid Structures.

The number of light levels depends on the height of the structure, excluding appurtenances. Three or more lights should be installed on each level to ensure an unobstructed view by the pilot. Normally, the top level is on the highest point of a structure. However, the top level of chimney lights may be installed as low as 20 feet (6 m) below the top to minimize deposit buildup due to emissions.

7.8 Radio and Television Towers and Similar Skeletal Structures.

1. Mounting Lights. The number of levels recommended depends on the height of the structure, including antennas and similar appurtenances. At least three lights should be installed on each level and mounted to ensure that the effective intensity of the full horizontal beam coverage is not impaired by the structural members.
2. Top Level. One level of lights should be installed at the highest point of the structure. If the highest point is a rod or antenna incapable of supporting a lighting system, then the top level of lights should be installed at the highest portion of the main skeletal structure. If guy wires come together at the top, it may be necessary to install this level of lights as low as 10 feet (3 m) below the top. If the rod or antenna exceeds 40 feet (12 m) above the main structure, a medium-intensity, flashing white light (L-865) should be mounted on the highest point. (See Figure A-9 in Appendix A.) If the appurtenance (such as a whip antenna) is incapable of supporting a medium-intensity light, one or more lights should be installed on a pole adjacent to the appurtenance. The adjacent installation should not exceed the height of the appurtenance and be within 40 feet (12 m) of the top, allowing a pilot an unobstructed view of at least one light. If the rod, antenna, or other appurtenance is 7/8 of an inch wide or more, at least two lights must be installed on the supporting mast to provide the necessary unobstructed view.
3. Ice Shields. See paragraph 4.9.

7.9 Hyperbolic Cooling Towers.

Light units should be installed to ensure an unobstructed view of at least two lights by a pilot approaching from any direction.

1. Number of Light Units. The number of units recommended depends on the diameter of the structure at the top, as shown in Figure A-21 in Appendix A. The number of lights recommended below is the minimum.
    a. Structures 20 Feet (6 m) or Less in Diameter. Three light units per level.
    b. Structures Exceeding 20 Feet (6 m) but not More Than 100 Feet (31 m) in Diameter. Four light units per level.
    c. Structures Exceeding 100 Feet (31 m) but not More Than 200 Feet (61 m) Diameter. Six light units per level.
    d. Structures Exceeding 200 Feet (61 m) in Diameter. Eight light units per level.
2. Structures Exceeding 600 Feet (183 m) AGL. Structures exceeding 600 feet (183 m) AGL should have a second level of light units installed approximately at the midpoint of the structure and in a vertical line with the top level of lights.

7.10 Prominent Buildings and Similar Extensive Obstructions.

When objects within a group of obstructions are approximately the same overall height above the surface and are located not more than 150 feet (46 m) apart, the group of obstructions may be considered an extensive obstruction. Light units should be installed on the same horizontal plane at the highest portion, or edge, of the prominent obstructions. Light units should be placed to ensure that the light is visible to a pilot approaching from **any** direction. These lights may require shielding, such as louvers, to ensure minimum adverse impact on local communities. Use extreme caution when using high-intensity flashing white lights.

1. If the obstruction is 200 feet (61 m) or less in either horizontal dimension, three or more light units should be installed at the highest portion of the structure to ensure that at least one light is visible to a pilot approaching from any direction. Light units may be mounted on a single pedestal at or near the center of the obstruction. If the light units are placed more than 10 feet (3 m) from the center point of the structure, use a minimum of four light units.
2. If the obstruction exceeds 200 feet (61 m) in one horizontal dimension, but is 200 feet (61 m) or less in the other, two light units should be placed on each of the shorter sides. These light units may be installed either adjacent to each other at the midpoint of the obstruction’s edge or at (near) each corner, with the light unit aimed to provide 180 degrees of coverage at each edge. One or more light units should be installed along the overall length of the major axis. These lights should be installed at approximately equal intervals, not to exceed a distance of 100 feet (31 m) from the corners or from each other.
3. If the obstruction exceeds 200 feet (61 m) in both horizontal dimensions, the light units should be equally spaced along the overall perimeter of the obstruction at intervals of 100 feet (31 m), or fraction thereof.

CHAPTER 8. DUAL LIGHTING WITH RED/MEDIUM-INTENSITY FLASHING WHITE LIGHT SYSTEMS

8.1 Purpose.

This dual lighting system includes red lights (L-864) for nighttime and medium-intensity, flashing white lights (L-865) for daytime and twilight use. This lighting system may be used in lieu of operating a medium-intensity flashing white lighting system at night. There may be some populated areas where nighttime use of medium-intensity light systems may cause significant environmental concerns. Using the dual lighting system should reduce/mitigate those concerns. Recommendations on lighting structures can vary, depending on terrain features, weather patterns, geographic location, and number of structures.

8.2 Installation.

The light units should be installed as specified in Chapters 4, 5, and 6. The number of light levels needed is dependent on the height of the obstruction, as shown in Figure A-10 in Appendix A.

8.3 Operation.

Light systems should be operated as specified in Chapter 3. Both systems should not be operated at the same time; however, there should be no more than a 2-second delay when changing from one system to the other. Outage of the uppermost red light shall cause the white obstruction light system to activate and operate in its specified “night” step intensity.

8.4 Control Device.

The light system is controlled by a device (photocell) that changes the light’s intensity when the ambient light changes. The system should automatically change steps when, in the Northern Hemisphere, the northern sky illuminance reaching a north-facing vertical surface is as follows:

1. <u>Twilight-to-Night</u>. This should not occur before the illumination drops below 5 foot-candles (53.8 lux) but should occur before it drops below 2 foot-candles (21.5 lux).
2. <u>Night-to-Day</u>. The intensity changes listed in subparagraph 8.4 1 above should be reversed when changing from the night-to-day mode.

8.5 Antenna or Similar Appurtenance Light.

When a structure equipped with a dual lighting system is topped with an antenna or similar appurtenance exceeding 40 feet (12 m) in height, a medium-intensity flashing white (L-865) and a flashing red light (L-864) should be placed within 40 feet (12 m) from the tip of the appurtenance. The white light should operate during daytime and twilight and the red light during nighttime. These lights should flash simultaneously with the rest of the lighting system.

8.6 Omission of Marking.

When medium-intensity white obstruction lights are operated on structures 700 feet (213 m) AGL or less during daytime and twilight, other methods of marking may be omitted.

CHAPTER 9. DUAL LIGHTING WITH RED/HIGH-INTENSITY FLASHING WHITE LIGHT SYSTEMS

9.1 Purpose.

This dual lighting system includes red lights (L-864) for nighttime and high-intensity flashing white lights (L-856) for daytime and twilight use. This lighting system may be used in lieu of operating a flashing white lighting system at night. There may be some populated areas where nighttime use of high-intensity lights may cause significant environmental concerns and complaints. Using the dual lighting system should reduce/mitigate those concerns. Recommendations on lighting structures can vary, depending on terrain features, weather patterns, geographic location, and number of structures.

9.2 Installation.

The light units should be installed as specified in Chapters 4, 5, and 7. The number of light levels needed is shown in Figures A-11 and A-12 in Appendix A.

9.3 Operation.

Lighting systems should be operated as specified in Chapters 4, 5, and 7. These systems should not be operated at simultaneously; however, there should be no more than a 2-second delay when changing from one system to the other. Outage of the uppermost red light shall cause the white obstruction lighting system to activate and operate in its specified “night” step intensity.

9.4 Control Device.

9.4.1 The light intensity is controlled by a device (photocell) that changes the light intensity when the ambient light changes.

9.4.2 The system should automatically change intensity steps when, in the Northern Hemisphere, the northern sky illuminance reaching a north-facing vertical surface is as follows:

1. Day-to-Twilight. This should not occur before the illumination drops to 60 foot-candles (645.8 lux) but should occur before it drops below 35 foot-candles (376.7 lux). The illuminance-sensing device should, if practical, face the northern sky in the Northern Hemisphere.
2. Twilight-to-Night. This should not occur before the illumination drops below 5 foot-candles (53.8 lux) but should occur before it drops below 2 foot-candles (21.5 lux).
3. Night-to-Day. The intensity changes listed in subparagraph 9.4.2 1 and 9.4.2.2 above should be reversed when changing from the night to day mode.

9.5 Antenna or Similar Appurtenance Light.

When a structure using this dual lighting system is topped with an antenna or similar appurtenance exceeding 40 feet (12 m) in height, a medium-intensity flashing white light (L-865) and a red flashing light (L-864) should be placed within 40 feet (12 m) from the tip of the appurtenance. (See Figure A-11 in Appendix A.) The white light should operate during daytime and twilight and the red light during nighttime. Structures with an appurtenance 40 feet (12 m) or less in height should be lit in accordance with Figure A-12 in Appendix A.

9.6 Omission of Marking.

When high-intensity white obstruction lights are operated during daytime and twilight, other methods of marking may be omitted.

CHAPTER 10. MARKING AND LIGHTING OF CATENARY AND CATENARY SUPPORT STRUCTURES

10.1 Purpose.

This chapter provides guidelines for marking and lighting catenary and catenary support structures. For the purpose of marking and lighting, catenary is defined as suspended wires (or lines) kept at a defined mechanical tension by supporting structures. These wires may be either energized or non-energized and are used for transmission, distribution, or for other purposes, as defined. The recommended marking and lighting of both the structures and wires provides day and night conspicuity and assists pilots in identifying and avoiding catenary wires and associated support structures.

10.2 Catenary Marking Standards.

Catenary wires should be marked with lighted or unlighted marker balls to make the wires more visible to pilots approaching the hazard. High-voltage (69 kV or greater) transmission lines are typically mounted on large catenary support structures and should be fitted with lighted markers to provide sufficient conspicuity in both day and nighttime conditions. Transmission lines that are less than 69 kV are typically mounted on smaller catenary support structures and should be fitted with unlighted markers that provide daytime conspicuity.

10.2.1 Catenary Markers.

Lighted markers provide increased nighttime conspicuity of high-voltage (69 kV or greater) transmission line catenary wires. However, since lighted markers require a minimum line load to operate, it should be noted that the lights may not be operational under certain transmission system conditions, such as power outages or line maintenance. These lighted markers should be used on transmission line catenary wires near airports, heliports, across rivers, canyons, lakes, areas of known risk to aviation, etc. The lighted markers should be manufacturer-certified as (1) recognizable from a minimum distance of 4,000 feet (1,219 m) under nighttime conditions, (2) minimum VFR conditions, or (3) have a minimum intensity of at least 32.5 candelas. The lighting unit should emit a steady-burning red light. Lighted markers should be used on the highest energized line. If the lighted markers are installed on a line other than the highest catenary wire, then the unlighted markers specified in Chapter 3 paragraph 3.5 should be used in addition to the lighted markers. The maximum sag distance between the line energizing the lighted markers and the highest catenary wire above the lighted markers should be no more than 25 feet (7.6 m), and it should not violate the sag requirements of the transmission line design. (See Figure A-5 in Appendix A.) Markers should be distinctively shaped, i.e., spherical or cylindrical, so that they are not mistaken for items used to convey other information. They should be visible to a pilot approaching from any direction. The area in the immediate vicinity of the supporting structure's base should be clear of all items and/or objects of natural growth that could interfere with the line-of-sight between a pilot and the structure's markers.

10.2.1.1 Size and Color.

The diameter of the markers (lighted and unlighted) used on extensive catenary wires that cross canyons, lakes, rivers, etc., should not be less than 36 inches (91 cm). Preferred 20-inch (51-cm) markers, or smaller 12-inch (30.48-cm) markers, are permitted on less extensive catenary wires or on power lines below 50 feet (15 m) above the ground and within 1,500 feet (458 m) of an airport runway end. Each lighted marker should be a solid color; specifically aviation orange, white, or yellow. For transmission lines that are configured in a "double-bundled" arrangement and would typically require the larger 36-inch markers, the next smaller size marker may be used to prevent the marker from rubbing against the parallel transmission line.

10.2.1.2 Installation.

1. Spacing. Lighted markers should be spaced equally along the wire at intervals of approximately 200 feet (61 m), or a fraction thereof. Intervals between markers should be less in critical areas near runway ends, i.e., 30 feet to 50 feet (10 m to 15 m). If the lighted markers are installed on a line other than the highest catenary wire, then unlighted markers specified in Chapter 3 paragraph 3.5 should be used in addition to the lighted markers. The maximum distance between the line energizing the lighted markers and the highest catenary wire above the line with the lighted markers can be no more than 25 feet (7.62 m), so long as the requirement does not violate the transmission line design's droop requirement. The lighted markers may be installed alternately along each wire if the distance between adjacent markers meets the 200-foot (61m) spacing standard. This method allows the weight and wind loading factors to be distributed. (See Figure A-5 in Appendix A.)
2. Pattern. An alternating color scheme provides the most conspicuity against all backgrounds. Lighted and unlighted markers should be installed by alternating solid-colored markers of aviation orange, white, and yellow. Normally, an orange marker is placed at each end of a line and the spacing is adjusted [not to exceed 200 feet (61 m)] to accommodate the rest of the markers. When less than four markers are used, they should all be aviation orange. (See Figure A-5 in Appendix A).
3. Wire Sag. Wire sag or droop will occur due to temperature, wire weight, wind, etc. Twenty-five (25) feet (7.62 m) is the maximum allowable distance between the highest wire installed with marker balls and the highest wire without marker balls, and it should not violate the transmission line design's sag requirements. (See Figure A-5 in Appendix A.)
4. Adjacent Lines. Catenary crossings with multiple transmission lines require appropriate markers when the adjacent catenary structure's

outside lines are greater than 200 ft (61 m) away from the center of the primary structure. (See Figure A-2 in Appendix A.) If the outside lines of the adjacent catenary structure are within 200 ft (61m) or less from the center of the primary structure, markers are not required on the adjacent lines. (See Figure A-3 in Appendix A.)

10.3 Catenary Lighting Standards.

When using medium-intensity flashing white (L-866), high-intensity flashing white (L-857), dual medium-intensity (L-866/L-885), or dual high-intensity (L-857/L-885) lighting systems operated 24 hours a day, other marking of the support structure is not necessary.

1. Levels. A system of three levels of sequentially flashing light units should be installed on each supporting structure or adjacent terrain. One level should be installed at the top of the structure, one at the height of the lowest point in the catenary wire, and one level approximately midway between the other two light levels. In general, the middle level should be at least 50 feet (15 m) from the other two levels. The middle light unit may be omitted when the distance between the top and the bottom light levels is less than 100 feet (30 m).

   a. Top Levels. One or more lights should be installed at the top of the structure to provide 360-degree coverage, ensuring an unobstructed view. If the installation presents a potential danger to maintenance personnel or inhibits lightning protection, the top level of lights may be mounted as low as 20 feet (6 m) below the highest point of the structure.

   b. Horizontal Coverage. The light units at the middle and bottom levels should be installed to provide a minimum of 180-degree coverage, centered perpendicularly to the flyway. When a catenary crossing is situated near a bend in a river, canyon, etc., or is not perpendicular to the flyway, the horizontal beam should be directed to provide the most effective light coverage to warn pilots approaching from either direction of the catenary wires.

   c. Variation. The vertical and horizontal arrangements of the lights may be subject to the structural limits of the towers and/or adjacent terrain. A tolerance of 20 percent from uniform spacing of the bottom and middle light is allowed. If the base of the supporting structure(s) is higher than the lowest point in the catenary, such as a canyon crossing, one or more lights should be installed on the adjacent terrain at the level of the lowest point in the span. These lights should be installed on the structure or terrain at the height of the lowest point in the catenary. (See Figure A-4 in Appendix A).

2. Flash Sequence and Duration. The flash sequence for catenary wire support structures should be middle, top, and bottom with all lights on the same level flashing simultaneously. This pattern of flashes is designed to present a unique signal that pilots should interpret as a warning that catenary wires are in the vicinity of the lights. The time intervals for the sequence and duration of the flash pattern are outlined in FAA AC 150/5345-43, Specification for Obstruction Lighting

Equipment. If Light-Emitting Diode (LED) obstruction light fixtures are used to light catenary wires, a slower flash rate of 40 fpm is allowed to enable each light fixture to make a well-defined flash so that the middle-top-bottom flash pattern will be easily recognized. Field experience has shown that LED fixtures flashing at 60 fpm, as specified in AC 150/5345-43, do not have enough time to turn off in between flash cycles, and appear as if they are steady-burning. Slowing the flash rate to 40 fpm promotes a cleaner, crisper presentation for the pilot to recognize. In the event there are only two levels of lights, the lights should simply alternate at the same flash rate/duration as if there were three lights.

3. Synchronization. Although not required, it is preferred that the corresponding light levels on associated supporting towers of a catenary crossing flash simultaneously.
4. Structures 700 feet (213 m) AGL or Less. When medium-intensity white lights (L-866) are operated 24 hours a day or when a dual red/medium-intensity light system (L-866 daytime and twilight/L-885 nighttime) is used, marking can be omitted. When using a medium-intensity white light (L-866) or a flashing red light (L-885) during twilight or nighttime only, paint should be used for daytime marking.
5. Structures Exceeding 700 Feet (213 m) AGL. When high-intensity white lights (L-857) are operated 24 hours a day or when a dual red/high-intensity system (L-857 daytime and twilight/L-885 nighttime) is used, marking can be omitted. This system should not be used on structures 700 feet (153 m) or less unless an FAA aeronautical study shows otherwise. When a flashing red obstruction light (L-885), a medium-intensity (L-866) flashing white lighting system, or a high-intensity white lighting system (L-857) is used for nighttime and twilight only, paint should be used for daytime marking.

10.4 Control Device.

The light intensity is controlled by a device (photocell) that changes the intensity when the ambient light changes. The lighting system should automatically change intensity steps when, in the Northern Hemisphere, the northern sky illuminance reaching a north-facing vertical surface is as follows:

1. Day-to-Twilight (L-857 System). This should not occur before the illumination drops to 60 foot-candles (645.8 lux) but should occur before it drops below 35 foot-candles (376.7 lux). The illuminance-sensing device should, if practical, face the northern sky in the Northern Hemisphere.
2. Twilight-to-Night (L-857 System). This should not occur before the illumination drops below 5 foot-candles (53.8 lux) but should occur before it drops below 2 foot-candles (21.5 lux).
3. Night-to-Day. The intensity changes listed in subparagraph 10.4.1 and 10.4.2 above should be reversed when changing from the night-to-day mode.

4. Day-to-Night (L-866 or L-885/L-866). This should not occur before the illumination drops below 5 foot-candles (563.8 lux) but should occur before it drops below 2 foot-candles (21.5 lux).
5. Night-to-Day. The intensity changes listed in subparagraph10.4.4 above should be reversed when changing from the night-to-day mode.
6. Red Obstruction (L-885). The red lights should not turn on until the illumination drops below 60 foot-candles (645.8 lux) but should occur before reaching a level of 35 foot-candles (367.7 lux). Lights should not turn off before the illumination rises above 35 foot-candles (367.7 lux) but should occur before reaching 60 foot-candles (645.8 lux).

10.5 Area Surrounding Catenary Wire Support Structures.

The area in the immediate vicinity of the supporting structure's base should be clear of all items and/or objects of natural growth that could interfere with the line-of-sight between a pilot and the structure's lights.

10.6 Three or More Catenary Wire Support Structures.

Where a catenary wire crossing requires three or more supporting structures, the inner structures should be equipped with enough light units per level to provide full 360-degree coverage across rivers, canyons, lakes, areas of known risk to aviation, etc.

10.7 Adjacent Catenary Structures.

Where an adjacent catenary wire crossing requires three or more supporting structures, the inner structures should be equipped with enough light units per level to provide full 360-degree coverage across rivers, canyons, lakes, areas of known risk to aviation, etc.

CHAPTER 11. MARKING AND LIGHTING MOORED BALLOONS AND KITES

11.1 Purpose.

The purpose of marking and lighting moored balloons, kites, and their cables or mooring lines is to indicate the presence and general definition of these objects to pilots when approaching from **any** direction.

11.2 Standards.

These marking and lighting standards pertain to all moored balloons and kites that require marking and lighting under 14 CFR Part 101.

11.3 Marking.

Flag markers should be used on mooring lines to warn pilots of their presence during daylight hours.

1. Display. Markers should be displayed at no more than 50-foot (15-m) intervals and should be visible for at least 1 statute mile.
2. Shape. Markers should be rectangular in shape and not less than 2 feet (0.6 m) on a side. Stiffeners should be used in the borders to expose a large area and to prevent drooping in calm wind or wrapping around the cable.
3. Color Patterns. One of the following color patterns should be used:
   a. Solid Color. Aviation orange.
   b. Orange and White. Two triangular sections, one of aviation orange and the other white, combined to form a rectangle.
   c. Refer to paragraph 12.2 Paint Standard.

11.4 Purpose.

Flashing obstruction lights should be used on moored balloons or kites and their mooring lines to warn pilots of their presence during the hours between sunset and sunrise and during periods of reduced visibility. These lights may be operated 24 hours a day.

1. Systems. Flashing red (L-864) or white lights (L-865) may be used to light moored balloons or kites. High-intensity lights (L-856) are not recommended.
2. Display. Flashing lights should be displayed on the top, nose section, tail section, and on the tether cable approximately 15 feet (4.6 m) below the craft to define the extremes of size and shape. Additional lights should be equally spaced along the cable's overall length for each 350 feet (107 m), or fraction thereof.
3. Exceptions. When the requirements of this paragraph cannot be met, floodlights may be used.

11.5 Operational Characteristics.

The light intensity is controlled by a device (photocell) that changes the intensity when the ambient light changes. The system should automatically turn the lights on and change intensities as ambient light conditions change. The reverse order should apply in changing from nighttime-to-daytime operation. The lights should flash simultaneously.

CHAPTER 12. MARKING AND LIGHTING EQUIPMENT AND INFORMATION

12.1 Purpose.

This chapter lists documents relating to obstruction marking and lighting systems and where they may be obtained.

12.2 Paint Standard.

12.2.1 Paint and aviation colors/gloss, referred to in this AC, with the exception of wind turbines, should conform to Federal Standard FED-STD-595. Wind turbines shall meet the standards in Chapter 13 paragraph 13.4 of this AC.

12.2.2 Approved colors shall be formulated without using lead, zinc chromate, or other heavy metals to match international aviation orange, white, and yellow, as listed in Table 12-1. All coatings shall be manufactured and labeled to meet Federal Environmental Protection Act Volatile Organic Compound(s) guidelines, including the National Volatile Organic Compound Emission Standards for architectural coatings.

1. Exterior Acrylic Waterborne Paint. Coatings should be ready-mixed, 100 percent acrylic, exterior latex formulated for application directly to galvanized surfaces. Ferrous iron and steel or nongalvanized surfaces shall be primed with a manufacturer-recommended primer compatible with the finish coat.
2. Exterior Solvent-Borne Alkyd-Based Paint. Coatings should be ready-mixed, alkyd-based, exterior enamel for application directly to nongalvanized surfaces, such as ferrous iron and steel. Galvanized surfaces shall be primed with a manufacturer-recommended primer compatible with the finish coat.

Table 12-1. Federal Standard FED-STD-595

Color	Number
Orange	12197
White	17875
Yellow	13538

12.3 Availability of Specifications.

Federal specifications describing the technical characteristics of various paints and their application techniques may be obtained from:

GSA - Specification Branch
301 7th Street NW
Room 6109
Washington, DC 20407
Telephone: (202) 619-8925

URL:
https://gsafas.secure.force.com/fedspecs?CFID=4925496&CFTOKEN=a7069f081ddb8f75-F75D2F5A-5056-8700-5912C733830A0C3

12.4 Lights and Associated Equipment.

The lighting equipment referred to in this AC should conform to the latest edition of one of the following specifications, as applicable:

1. Obstruction Lighting Equipment.
   a. AC 150/5345-43, *FAA Specification for Obstruction Lighting Equipment*.
   b. Military Specifications MIL-L-6273, *Light, Navigational, Beacon, Obstacle or Code, Type G-1*.
   c. Military Specifications MIL-L-7830, *Light Assembly, Markers, Aircraft Obstruction*.
2. Certified Equipment.
   a. AC 150/5345-53, *Airport Lighting Certification Program*, lists the manufacturers that have demonstrated compliance with the specification requirements of AC 150/5345-43.
   b. Other manufacturers' equipment may be used provided the equipment meets the specification requirements of AC 150/5345-43.
3. Airport Lighting Installation and Maintenance.

   AC 150/5340-30, *Design and Installation Details for Airport Visual Aids*.
4. Vehicles.
   a. AC 150/5210-5, *Painting, Marking, and Lighting of Vehicles Used on an Airport*, contains provisions for marking vehicles principally used on airports.
   b. FAA Facilities**.** Obstruction marking for FAA facilities shall conform to FAA Drawing Number D-5480, referenced in FAA Standard FAA-STD-003, *Paint Systems for Structures*.

12.5 **Availability.**

The standards and specifications listed above may be obtained from:

1. Military Specifications: Copies of Military standards and specification may be obtained from:

   DAP/DODSSP
   Building 4, Section D.
   700 Robbins Ave.
   Philadelphia, PA 19111-5094
   Tel; (215)697-2179
   FAX: (215)697-1460
   URL: https://acc.dau.mil/dodssp

2. FAA Advisory Circulars: Copies of FAA ACs may be obtained online at:

   http://www.faa.gov/airports/resources/advisory_circulars/

CHAPTER 13. MARKING AND LIGHTING WIND TURBINES

13.1 Purpose.

This chapter provides guidelines for the marking and lighting of wind turbine farms. These guidelines are applicable to single wind turbines and wind turbine farms. For the purpose of this AC, wind turbine farms are defined as a wind turbine development that contains more than three turbines. The recommended marking and lighting of these structures is intended to provide day and night conspicuity and to assist pilots in identifying and avoiding these obstacles.

13.2 General Standards.

The development of wind turbine farms is a very dynamic process, which changes based on the terrain. Each wind turbine farm is unique. Therefore, it is important that a lighting plan be developed that provides sufficient safety for air traffic. Proximity to airports and VFR routes, extreme terrain where heights may vary widely, and local flight activity should be considered when developing a lighting plan. The following guidelines are recommended for wind turbines.

13.3 Wind Turbine Configurations.

Prior to marking and lighting the wind turbine farm, the configuration and the terrain of the wind turbine farm should be determined. The following is a description of the most common configurations.

1. Linear—wind turbine farms in a direct, consecutive configuration, often located along a ridge line, the face of a mountain, or along borders of a mesa or field. The line may be ragged in shape or be periodically broken, and may vary in size from just a few turbines to many turbines forming a line that is several miles long.
2. Cluster—wind turbine farms arranged in circular configuration. A cluster is typically characterized by having a pronounced perimeter, with various turbines placed inside the circle at various, erratic distances throughout the center of the circle.
3. Grid—wind turbine farms arranged in a geographical shape, such as a square or a rectangle, in which the turbines are placed a consistent distance from each other in rows, giving the appearance that they are part of a square pattern.

13.4 Marking Standards.

13.4.1 Wind turbines should be painted white or light grey, as these colors have been shown to be the most effective method for providing daytime conspicuity. Wind turbine manufacturers typically use a European color-matching system that is referred to as the RAL Color Standard. Unlike the Federal Specification 595, the RAL system used a four-digit code to identify a specific color of paint. For example, an RAL 9xxx code would represent a color in the white/black range, and an RAL 6xxx code would be in the grey range. Most wind turbines currently produced are painted light grey, RAL 7035, which is the darkest acceptable off-white paint allowed. The preferred white paint color is pure white, RAL 9010, or an equivalent. Any shade of white between these two RAL specifications is strongly recommended. See Table 13-1.

Table 13-1. Wind Turbine Paint Standard Colors

Color	RAL Number
Pure White	9010
Light Grey (Darkest Acceptable)	7035

13.4.2 In geographic areas that experience lengthy periods of snow cover (i.e., Alaska), and where it is deemed necessary, the mast of the turbine may be painted alternating bands of aviation orange and white to provide additional contrast against the snow. The nacelle and blades of the turbine shall remain solid white or light grey. (See Figure A-24 in Appendix A.)

13.4.3 Blades or blade tips shall not be painted or manufactured in colors to camouflage wind turbines with the surrounding terrain. (See Figure A-25 in Appendix A.)

13.4.4 For turbines that are constructed with lattice-type masts, the mast structure shall be painted with alternating bands of aviation orange and white, in accordance with Chapter 3. The turbine's nacelle and blades shall remain solid white or light grey.

13.5 Lighting Standards.

13.5.1 Nighttime wind turbine obstruction lighting should consist of FAA L-864 aviation red flashing, strobe, or pulsed obstruction lights. Studies have shown that red lights provide the most conspicuity to pilots.

13.5.2 In most cases, not all wind turbine units within a wind turbine farm need to be lighted. Obstruction lights should be placed along the perimeter of the wind turbine farm so that there are no unlit separations or gaps more than 1/2 statute mile (sm) (804 m). Wind turbines within a grid or cluster should not have an unlighted separation or gap of more than 1 sm (1.6 km) across the interior of a grid or cluster of turbines. (See Figure A-26 in Appendix A.)

13.5.3 Any array of flashing, strobe, or pulsed obstruction lighting should be synchronized to flash simultaneously (within ±1/20 second (0.05 second) of each other).

13.5.4 Should any lighting fixture or the lighting system synchronization fail, a lighting outage report should be prepared in accordance with Chapter 2 paragraph 2.4.

13.5.5 Light fixtures should be placed as high as possible on the turbine nacelle so they are visible by a pilot approaching from **any** direction. (See Figure A-23 in Appendix A.)

13.5.6 Daytime lighting of wind turbines is not required. See paragraph 13.4 for daytime marking requirements.

13.5.7 When developing lighting plans for wind turbine farms, it is best to use an aerial-view map or diagram of the turbine farm to plan the location of the required lighting. This way, a certain degree of strategy plan can be applied, which, in many instances, results in a minimal number of lights.

13.5.8 For linear turbine configurations, lights should be placed on the turbine positioned at each end of a line or string of turbines. Lights should also be placed along the line of turbines so that there is no more than a 1/2-sm (2,640-foot (805-m)) gap between the lighted turbines. In the event the gap between lights on the last segment of turbines is significantly short, it may be appropriate to move the lights on the turbine string back toward the starting point to present a well-balanced string of lights. High concentrations of lights should be avoided. (See Figure A-26 in Appendix A.)

13.5.9 For cluster turbine configurations, a turbine should be selected as a starting point along the outer perimeter of the cluster. The turbine should be lighted, and a light should be placed on the next turbine along the perimeter of the cluster (clockwise or counterclockwise) so that no more than a 1/2-sm (2,640-foot (805-m)) gap exists. This pattern should be continued around the perimeter of the cluster until the starting point is reached. In the event that the gap between the lights on the last segment of turbines is significantly short, it may be appropriate to move the lights along the perimeter of the cluster back toward the starting point to present a well-balanced perimeter of lights. If the distance across the cluster is greater than 1 sm, additional lights should be placed on other turbines throughout the center of the cluster so that there are no unlighted gaps across the cluster. (See Figure A-26 in Appendix A.) (Example: If the distance across a wind turbine farm is 1.8 sm (2.9 km), a light should be placed on a turbine at approximately every 0.9 sm (1.4 km).

13.5.10 For grid turbine configurations, turbines on the corners of the farm should be lit, and then use the same concept for selecting which turbines should be lit as outlined in paragraph 13.5.9.

13.5.11 Special Considerations.

13.5.11.1 Occasionally, some wind turbines may be located apart from the main group of turbines. If one or two wind turbines protrude from the general limits of the turbine farm, these turbines should be lighted in addition to those identified in the main group.

13.5.11.2 Additional lighting may be necessary on wind turbines located on the interior of a cluster or grid configuration whose height is 100 feet (30 m) or higher than the other wind turbines located within the farm.

13.6 Wind Turbines Above 499 Feet.

13.6.1 For wind turbines with a rotor tip height, while at top dead center, greater than 499 feet (153 m) AGL, but less than 699 feet AGL, the turbines should be lighted in accordance with paragraph 13.5. In addition to these requirements, the top of the turbine's nacelle should be equipped with a second L-864 flashing red light. (See Figure A-23 in Appendix A.)

13.6.2 The two obstruction lights should be arranged horizontally, positioned on opposite sides of the nacelle, visible to a pilot approaching from **any** direction, and flash simultaneously. (See Figure A-23 in Appendix A.) This lighting configuration ensures the turbines in this size category are always lighted.

13.6.3 In the event one of the two obstruction lights fails, no light failure notification is required; however, the light should be restored to service as soon as possible.

13.6.4 All turbines within this size category should be illuminated, regardless of their location within a wind turbine farm, and should be configured to flash simultaneously with the other turbines in the same farm. This requirement ensures the pilots operating at 500 feet AGL have sufficient warning that a wind turbine obstruction may be within their flight path.

13.7 Wind Turbines at or Above 699 Feet (213 m).

13.7.1 For wind turbines with a rotor tip height, while at top dead center, at or above 699 feet (213 m) AGL, additional lighting is required. All wind turbines of this size, regardless of number or configuration should be lighted.

13.7.2 In addition to the lighting identified in paragraph 13.6, an additional level of lights is required at a point midway between the top of the nacelle and ground level. The location of the additional lights may be adjusted as necessary to allow mounting at a seam within the turbine's mast.

13.7.2.1 The additional level of lights should consist of a minimum of three L-810 flashing red lights configured to flash in unison with the two L-864 red flashing lights located at the top of the nacelle at a rate of 30 fpm (± 3 fpm). The L-810s should be spaced at equal distances around the mast. The light should be installed to ensure a pilot approaching from **any** direction has an unobstructed view of at least two of the lights. (See Figure A-23 in Appendix A.)

13.7.2.2 For wind turbine structures with a mast diameter greater than 20 feet (6 m), four L-810 red lights should be used.

13.7.2.3 All turbines within this size category should be illuminated, regardless of their location within a turbine farm, and should be configured to flash simultaneously with the other turbines in the same farm. This requirement ensures the pilots operating at 500 feet AGL have sufficient warning that a wind turbine obstruction may be within their flight path.

13.8 Lighting of Wind Turbines During Construction Phase.

To ensure proper conspicuity of turbines at night during construction, all turbines should be lighted with temporary lighting once they reach a height of 200 feet (61 m) or greater until the permanent lighting configuration is turned on. As the structure's height continues to increase, the temporary lighting should be relocated to the structure's uppermost height. The temporary lighting may be turned off for short periods if they interfere with construction personnel. If practical, permanent obstruction lights should be installed and operated at each level as construction progresses. An L-810 steady-burning red light shall be used to light the structure during the construction phase, if the permanent L-864 flashing-red lights are not in place. If power is not available, turbines should be lighted with a self-contained, solar-powered, LED, steady-burning red light that meets the photometric requirements of an FAA L-810 lighting system. The lights should be positioned to ensure a pilot has an unobstructed view of at least one light at each level. Using a NOTAM (D) to justify not lighting the turbines until the entire project is completed is prohibited.

13.9 Lighting and Marking of Airborne Wind Turbines.

The FAA is currently conducting research to develop special lighting and marking standards for Airborne Wind Turbines. Sponsors should consult with their respective FAA OE Specialists for updated information.

13.10 Lighting and Marking of Offshore Wind Turbines.

FAA lighting and marking recommendations apply to structures out to 12 NM from the coast of the United States, which is the extent of the territorial seas. The Bureau of Ocean Energy Management (BOEM), which maintains jurisdiction of land leases beyond the 12 NM, may also require compliance with the marking and/or lighting recommendations identified in this AC.

CHAPTER 14. AIRCRAFT DETECTION LIGHTING SYSTEMS

14.1 Purpose.

Aircraft Detection Lighting Systems (ADLS) are sensor-based systems designed to detect aircraft as they approach an obstruction or group of obstructions; these systems automatically activate the appropriate obstruction lights until they are no longer needed by the aircraft. This technology reduces the impact of nighttime lighting on nearby communities and migratory birds and extends the life expectancy of obstruction lights.

14.2 General Standards.

14.2.1 The system should be designed with sufficient sensors to provide complete detection coverage for aircraft that enter a three-dimensional volume of airspace, or coverage area, around the obstruction(s) (see Figure A-27 in Appendix A), as follows:

1. Horizontal detection coverage should provide for obstruction lighting to be activated and illuminated prior to aircraft penetrating the perimeter of the volume, which is a minimum of 3 NM (5.5 km) away from the obstruction or the perimeter of a group of obstructions.
2. Vertical detection coverage should provide for obstruction lighting to be activated and illuminated prior to aircraft penetrating the volume, which extends from the ground up to 1,000 feet (304 m) above the highest part of the obstruction or group of obstructions, for all areas within the 3 NM (5.5 km) perimeter defined in subparagraph 14.2.1 1 above.
3. In some circumstances, it may not be possible to meet the volume area defined above because the terrain may mask the detection signal from acquiring an aircraft target within the 3 NM (5.5 km) perimeter. In these cases, the sponsor should identify these areas in their application to the FAA for further evaluation.
4. In some situations, lighting not controlled by the ADLS may be required when the 3 NM (5.5 km) perimeter is not achievable to ensure pilots have sufficient warning before approaching the obstructions.

14.2.2 The ADLS should activate the obstruction lighting system in sufficient time to allow the lights to illuminate and synchronize to flash simultaneously prior to an aircraft penetrating the volume defined above. The lights should remain on for a specific time period, as follows:

1. For ADLSs capable of continuously monitoring aircraft while they are within the 3 NM/1,000 foot (5.5 km/304 m) volume, the obstruction lights should stay on until the aircraft exits the volume. In the event detection of the aircraft is lost while being continuously monitored within the 3 NM/1,000 foot (5.5 km/304 m) volume, the ADLS should initiate a 30-minute timer and keep the obstruction lights on until the timer expires. This should provide the untracked aircraft sufficient time to exit the area and give the ADLS time to reset.

2. For ADLSs without the capability of monitoring aircraft targets in the 3 nm/1,000 foot (5.5 km/304 m) volume, the obstruction lights should stay on for a preset amount of time, calculated as follows:

   a. For single obstructions: 7 minutes.

   b. For groups of obstructions: (the widest dimension in nautical miles + 6) x 90 seconds equals the number of seconds the light(s) should remain on.

14.2.3 Acceptance of ADLS applications will be on a case-by-case basis and may be modified, adjusted, or denied based on proximity of the obstruction or group of obstructions to airports, low-altitude flight routes, military training areas, or other areas of frequent flight activity. It may be appropriate to keep certain obstructions closest to these known activity areas illuminated during the nighttime hours, while the remainder of the group's obstruction lighting is controlled by the ADLS.

14.2.4 Project sponsors requesting ADLS use should include in their application maps or diagrams indicating the location of the proposed sensors, the range of each sensor, and a visual indication showing how each sensor's detection arc provides the full horizontal and vertical coverage, as required under paragraph 14.2.1. In the event that detection coverage is not 100 percent due to terrain masking, project sponsors should provide multiple maps or diagrams that indicate coverage at the affected altitudes. A sample diagram is shown in Figure A-27 in Appendix A.

14.2.5 <u>Types of ADLS Component or System Failure Events</u>.

1. In the event of an ADLS component or system failure, the ADLS should automatically turn on all the obstruction lighting and operate in accordance with this AC as if it was not controlled by an ADLS. The obstruction lighting must remain in this state until the ADLS and its components are restored.

2. In the event that an ADLS component failure occurs and an individual obstruction light cannot be controlled by the ADLS, but the rest of the ADLS is functional, that particular obstruction light should automatically turn on and operate in accordance with this AC as if it was not controlled by an ADLS, and the remaining obstruction lights can continue to be controlled by the ADLS. The obstruction lighting will remain in this state until the ADLS and its components are restored.

3. Complete light failure should be addressed in accordance with Chapter 2 paragraph 2.4.

14.2.6 The ADLS's communication and operational status shall be checked at least once every 24 hours to ensure both are operational.

14.2.7 The ADLS should be able to detect an aircraft with a cross-sectional area of 1 square meter or more within the volume, as required in subparagraphs 14.2.1 1 and 14.2.1 2.

14.2.8 Each ADLS installation should maintain a log of activity data for a period of no less than the previous 15 days. This data should include, but not be limited to, the date, time, duration of all system activations/deactivations, track of aircraft activity, maintenance issues, system errors, communication and operational issues, lighting outages/issues, etc.

14.2.9 Operational Frequencies.

1. Unlicensed devices (including FCC Part 15) devices cannot be used for this type of system.
2. Any frequency used for the operation of ADLS must be individually licensed through the FCC.

14.3 **Voice/Audio Option.**

14.3.1 ADLS may include an optional voice/audio feature that transmits a low-power, audible warning message to provide pilots additional information on the obstruction they are approaching.

14.3.2 The audible transmission should be in accordance with appropriate FAA and FCC regulations.

14.3.3 The audible transmission should be over an aviation frequency licensed by the FCC and authorized under the Code of Federal Regulations Title 47- Part 87.483 (excluding 121.5 MHz).

Note: Using air traffic control frequencies in the 117.975-MHz to 137-MHz frequency band is prohibited for this operation.

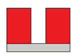
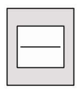
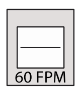
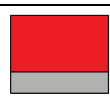
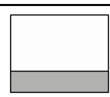
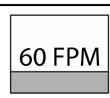
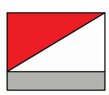
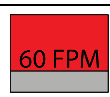
14.3.4 The audible message should consist of three quick tones, followed by a verbal message that describes the type of obstruction the system is protecting. Appropriate terms to be used include tower(s), wind turbine(s), or power line(s).

14.3.5 The audible message should be repeated three times or until the system determines the aircraft is no longer within the audible warning area defined in the following paragraph.

14.3.6 The audible message should be considered as a secondary, final warning and should be activated when an aircraft is within 1/2 NM (926 m) horizontally and 500 feet (152 m) vertically of the obstruction. The use of, or variation to, the audible warning zone may occur, depending on site-specific conditions or obstruction types.

APPENDIX A. SPECIFICATIONS FOR OBSTRUCTION LIGHTING EQUIPMENT CLASSIFICATION

Table A-1. FAA-Approved Obstruction Lighting Fixtures

Type	Symbol	Description
L-810		Steady-Burning - RED Single Obstruction Light
L-810		Steady-Burning – RED Double Obstruction Light
L-856		High-Intensity Flashing – WHITE Obstruction Light (40 FPM)
L-857		High-Intensity Flashing – WHITE Catenary Light (60 FPM)
L-864		Medium-Intensity Flashing – RED Obstruction Light (20-40 FPM)
L-865		Medium-Intensity Flashing – WHITE Obstruction Light (40-FPM)
L-866		Medium-Intensity Flashing - WHITE Catenary Light (60-FPM)
L-864/L-865		Medium-Intensity Flashing Dual – RED / WHITE Obstruction Light (20-40 FPM) Obstruction Light (40 FPM)
L-885		Low-Intensity Flashing - RED Red Catenary Light (60 FPM)
FPM = Flashes Per Minute		

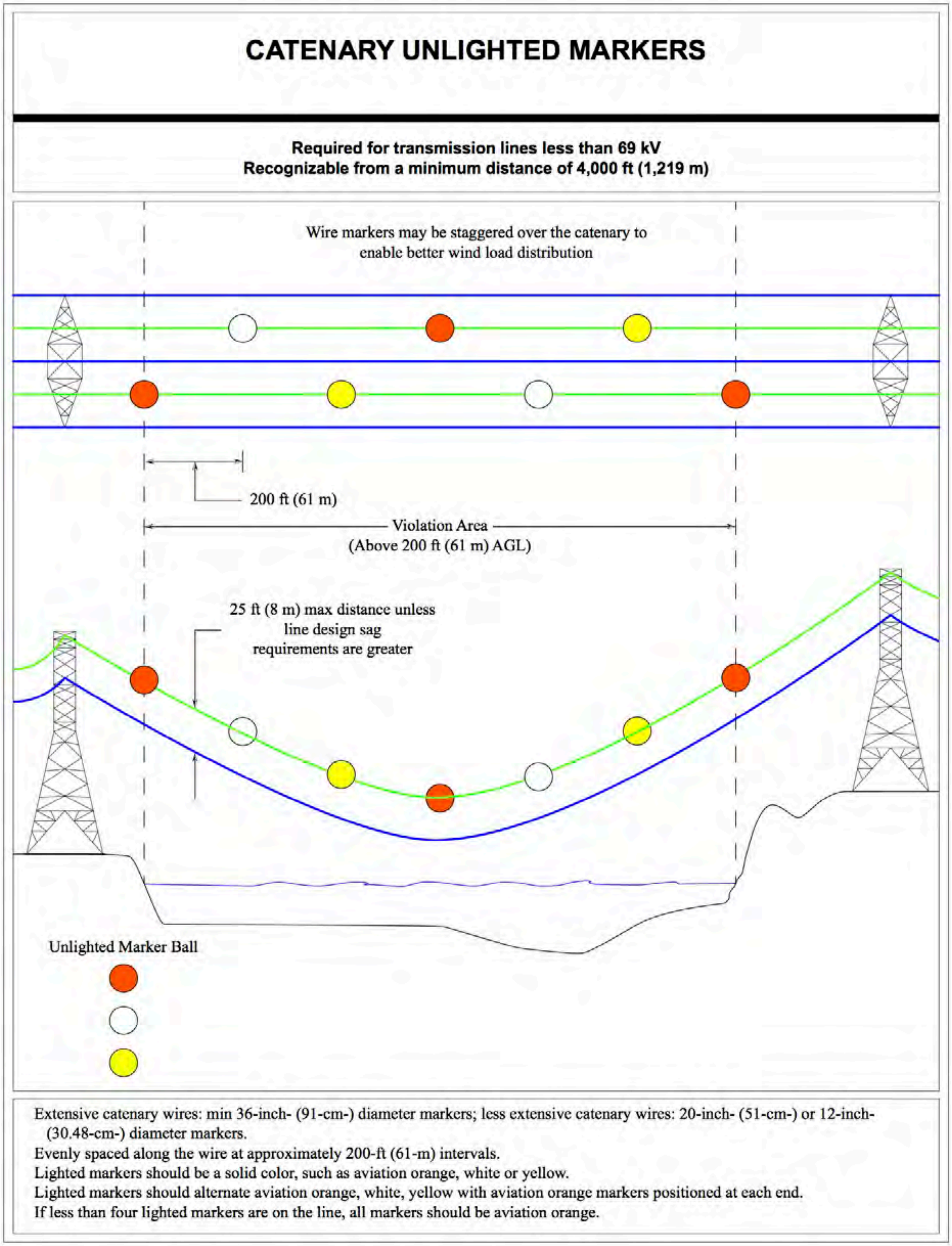


Figure A-1. Catenary Unlighted Markers

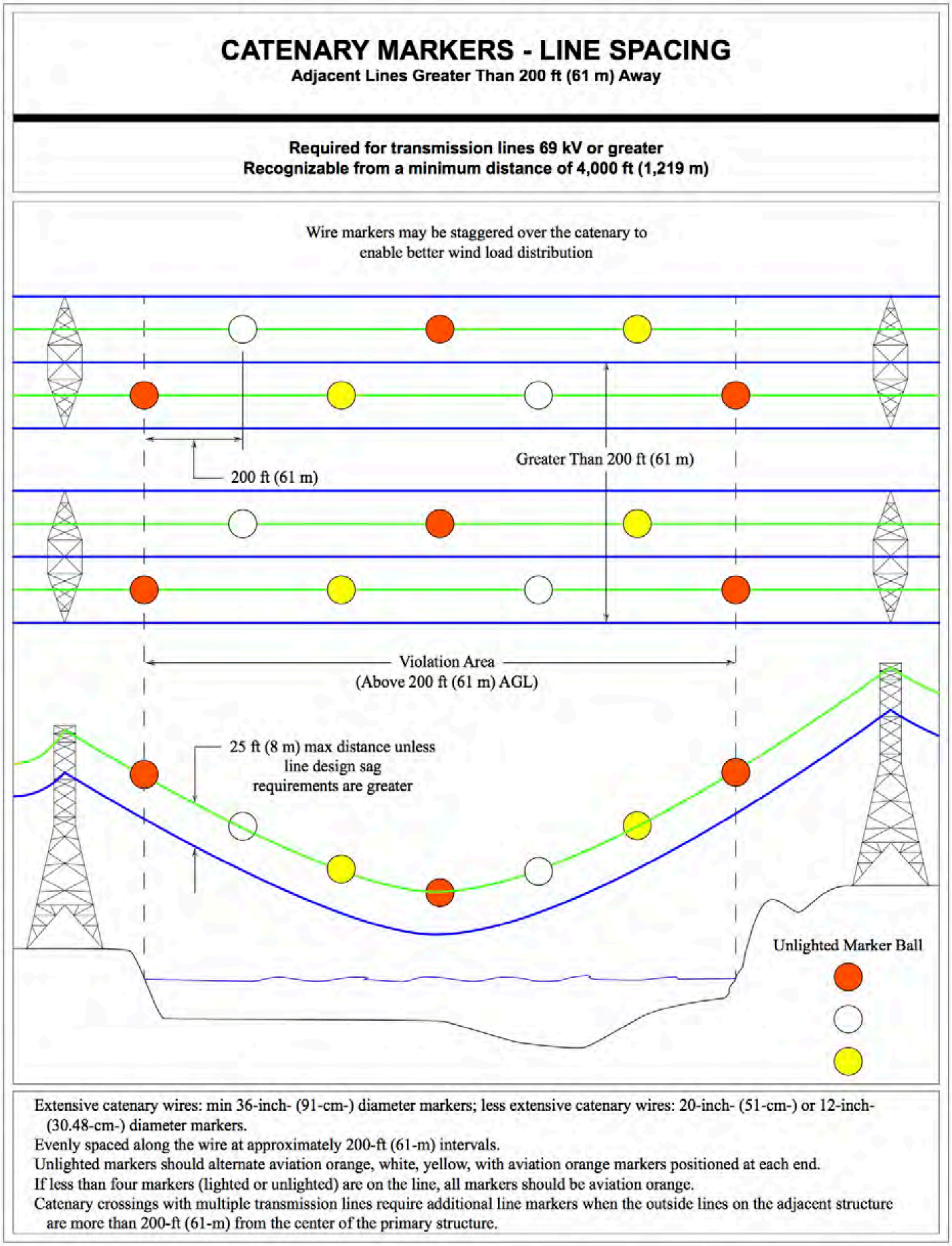


Figure A-2. Catenary Markers - Line Spacing (Adjacent Lines Greater Than 200 ft (61 m) Away)

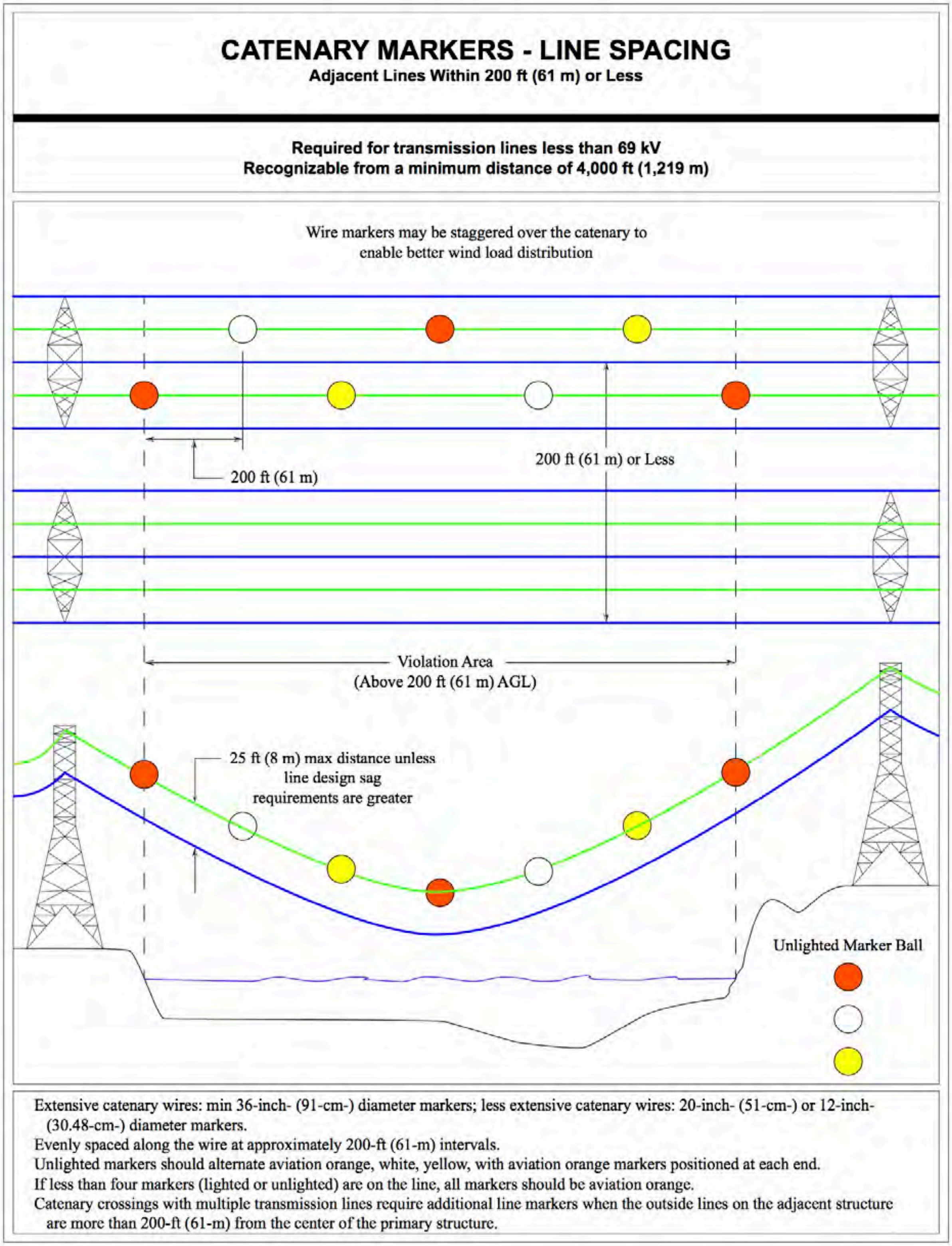


Figure A-3. Catenary Markers – Line Spacing (Adjacent Lines Within 200 ft (61 m) or Less

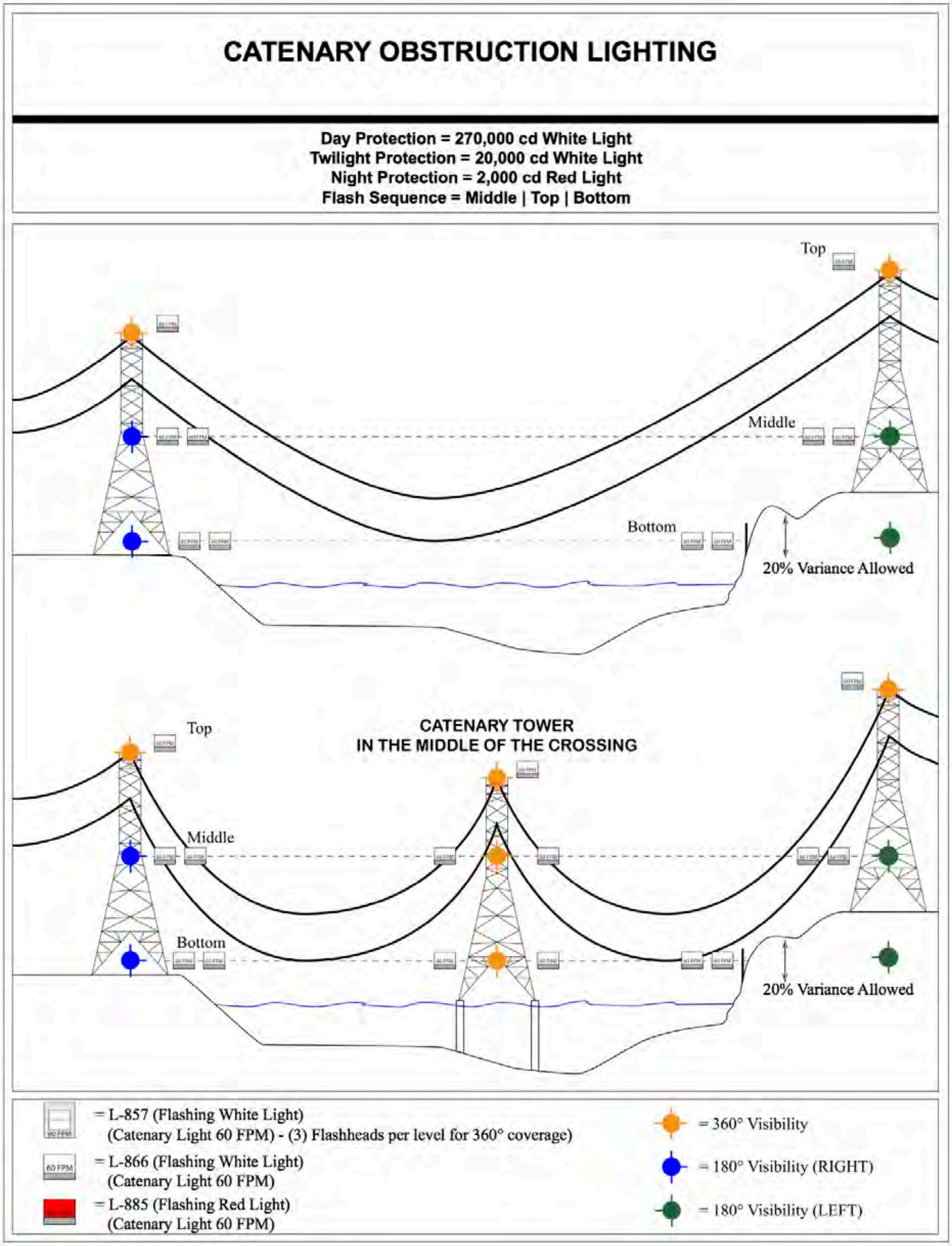


Figure A-4. Catenary Obstruction Lighting

Figure A-5. Catenary Lighted Markers **Figure A-5. Catenary Lighted Markers**

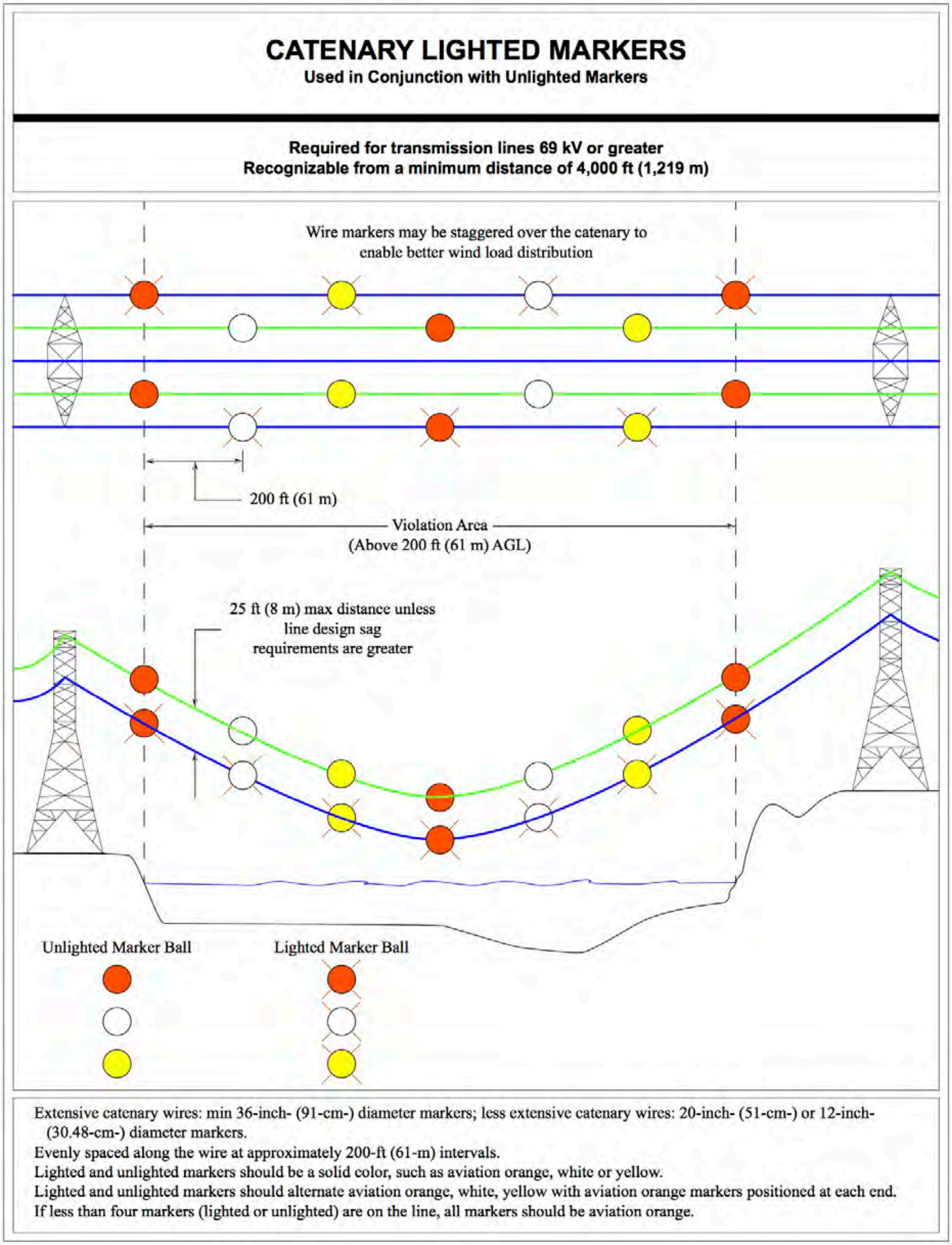


Figure A-5. Catenary Lighted Markers

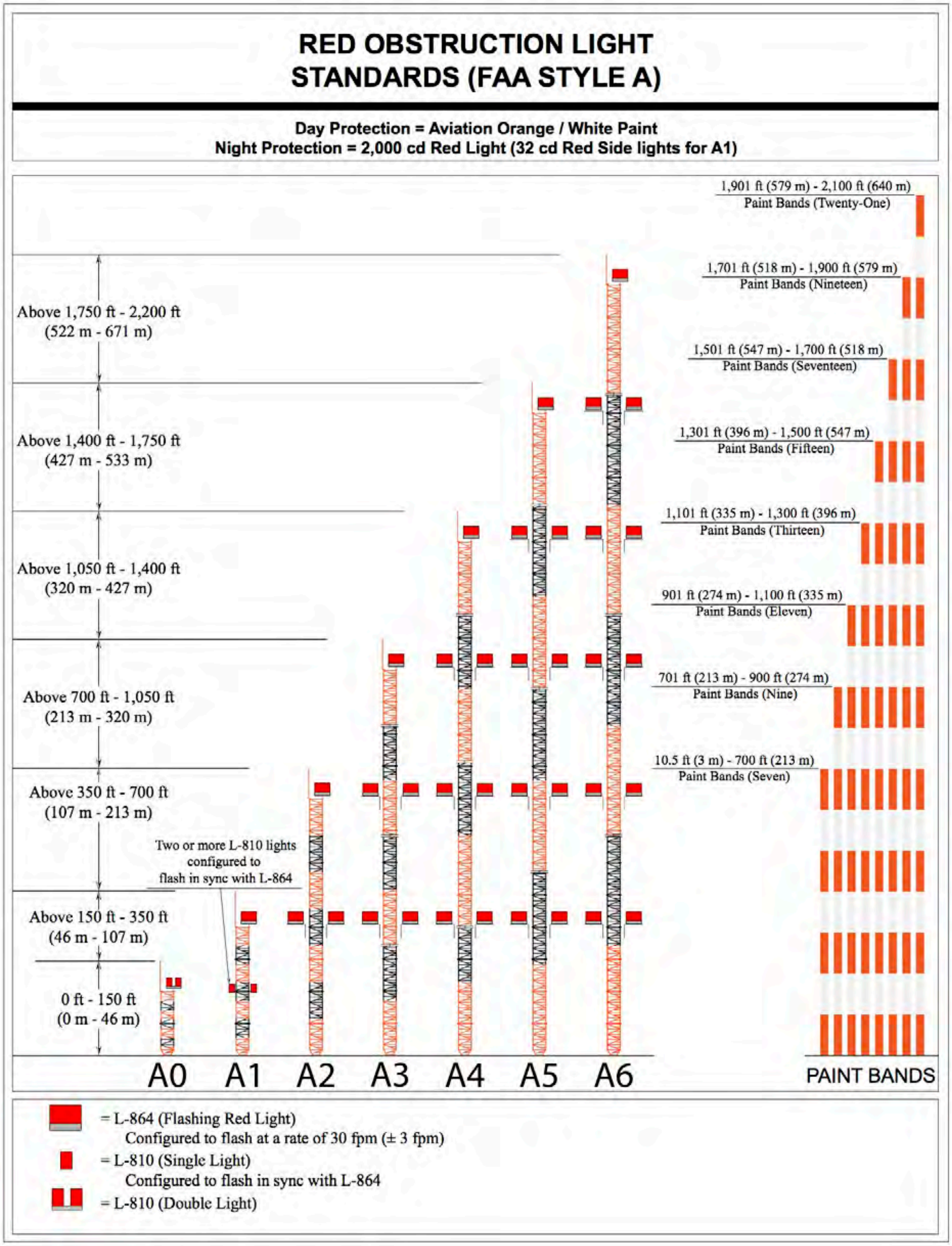


Figure A-6. Red Obstruction Light Standards

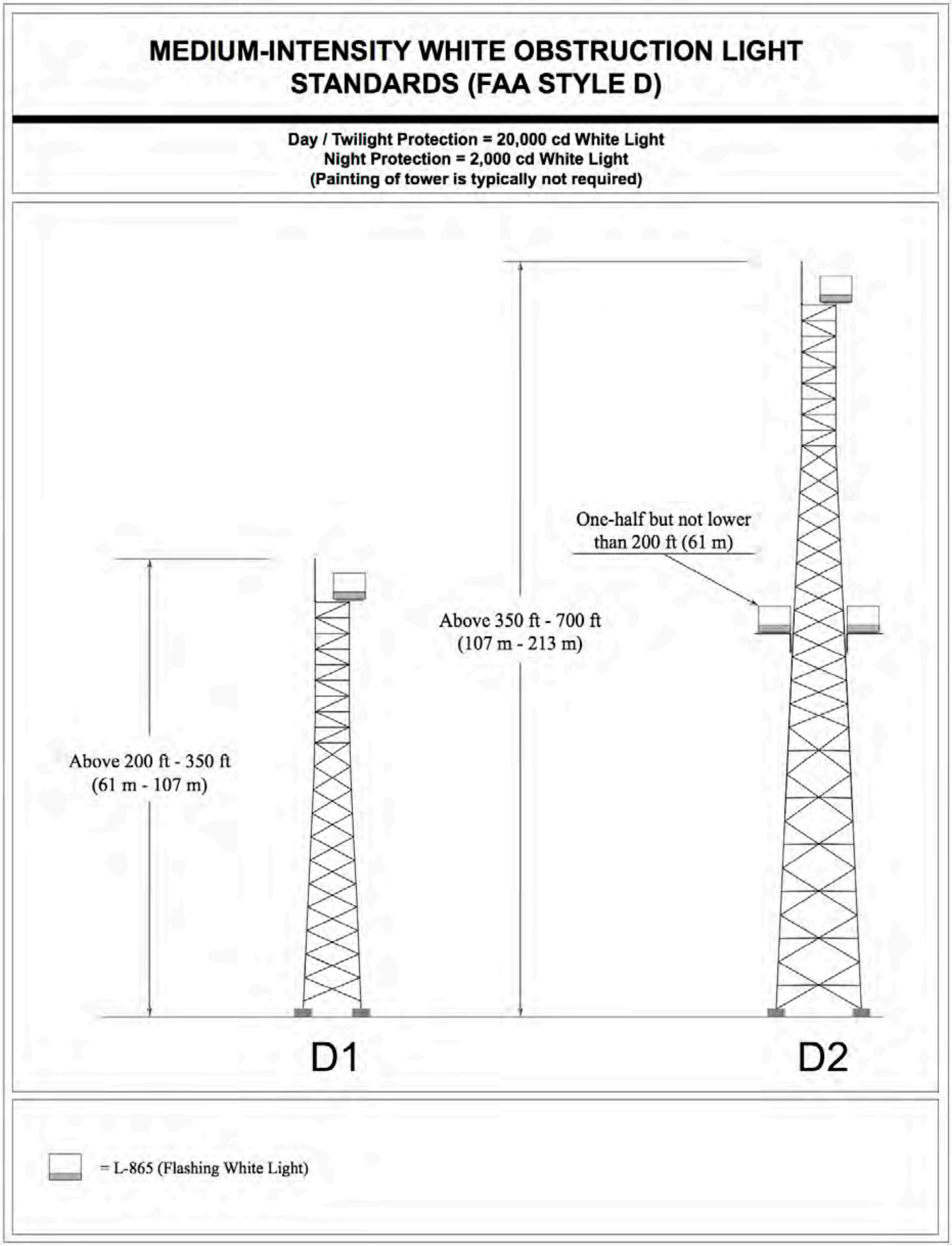


Figure A-7. Medium-Intensity White Obstruction Light Standards

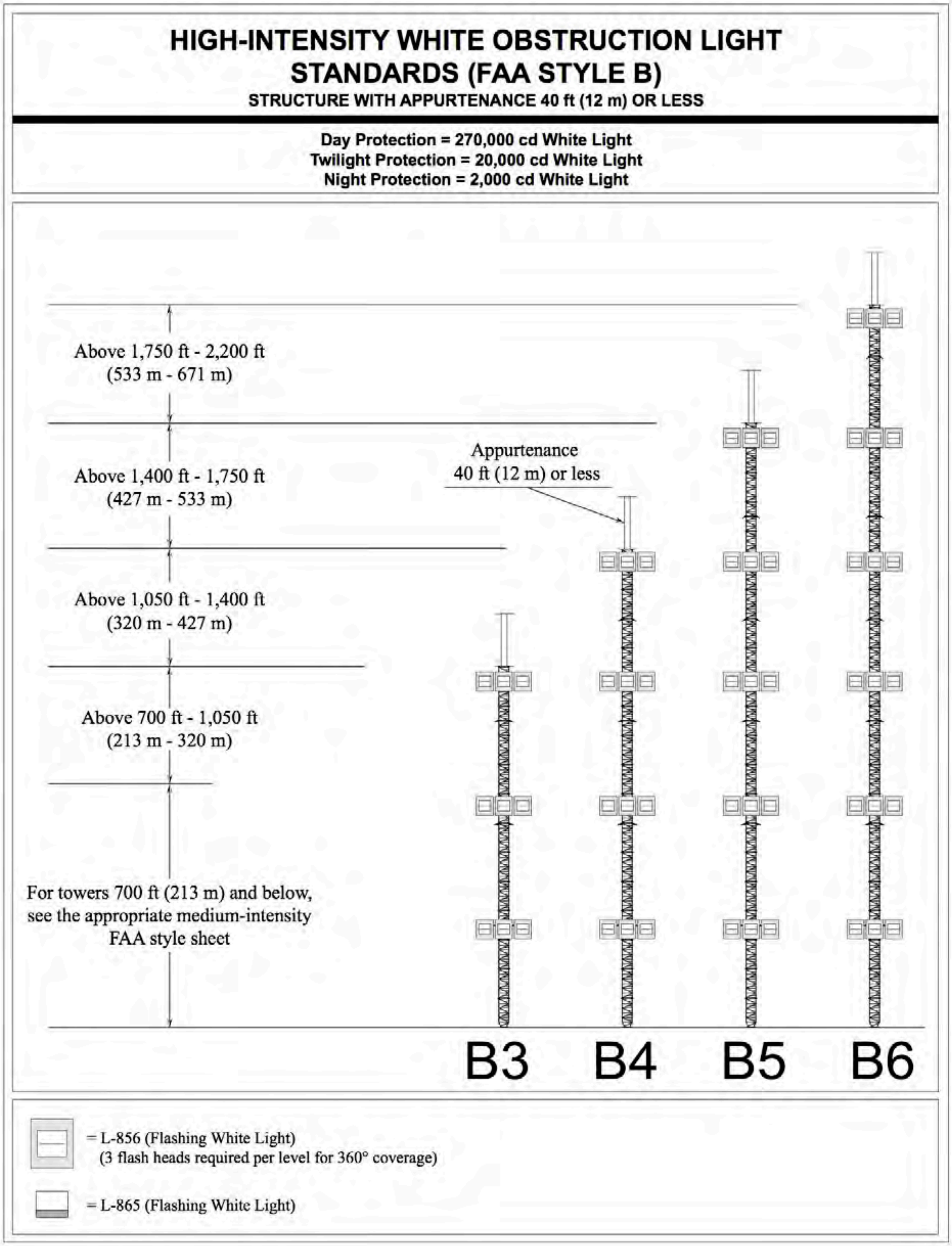


Figure A-8. High-Intensity White Obstruction Light Standards—Structures With Appurtenance 40 Feet or Less

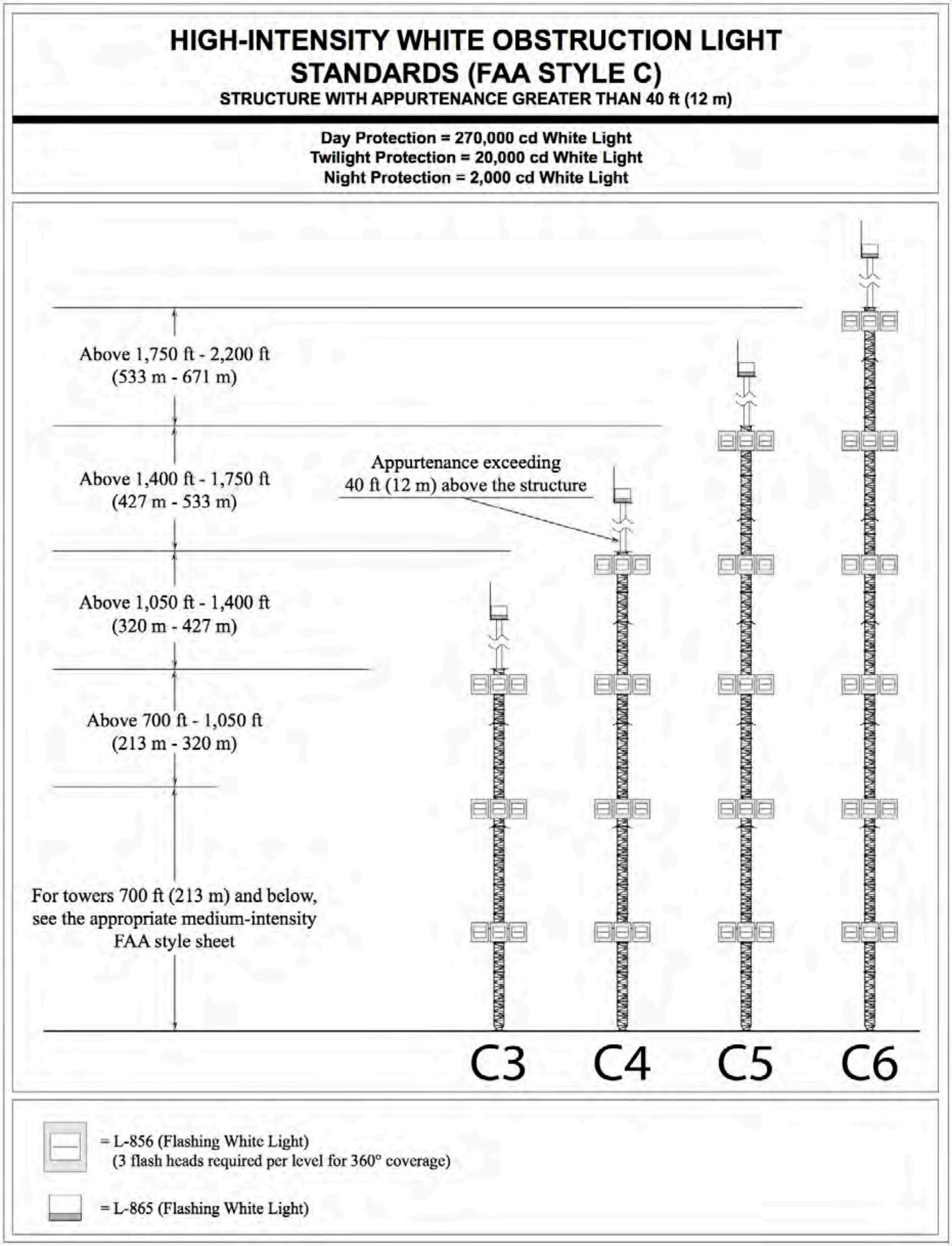


Figure A-9. High-Intensity Obstruction Lighting Standards—Structures With Appurtenance Over 40 Feet High

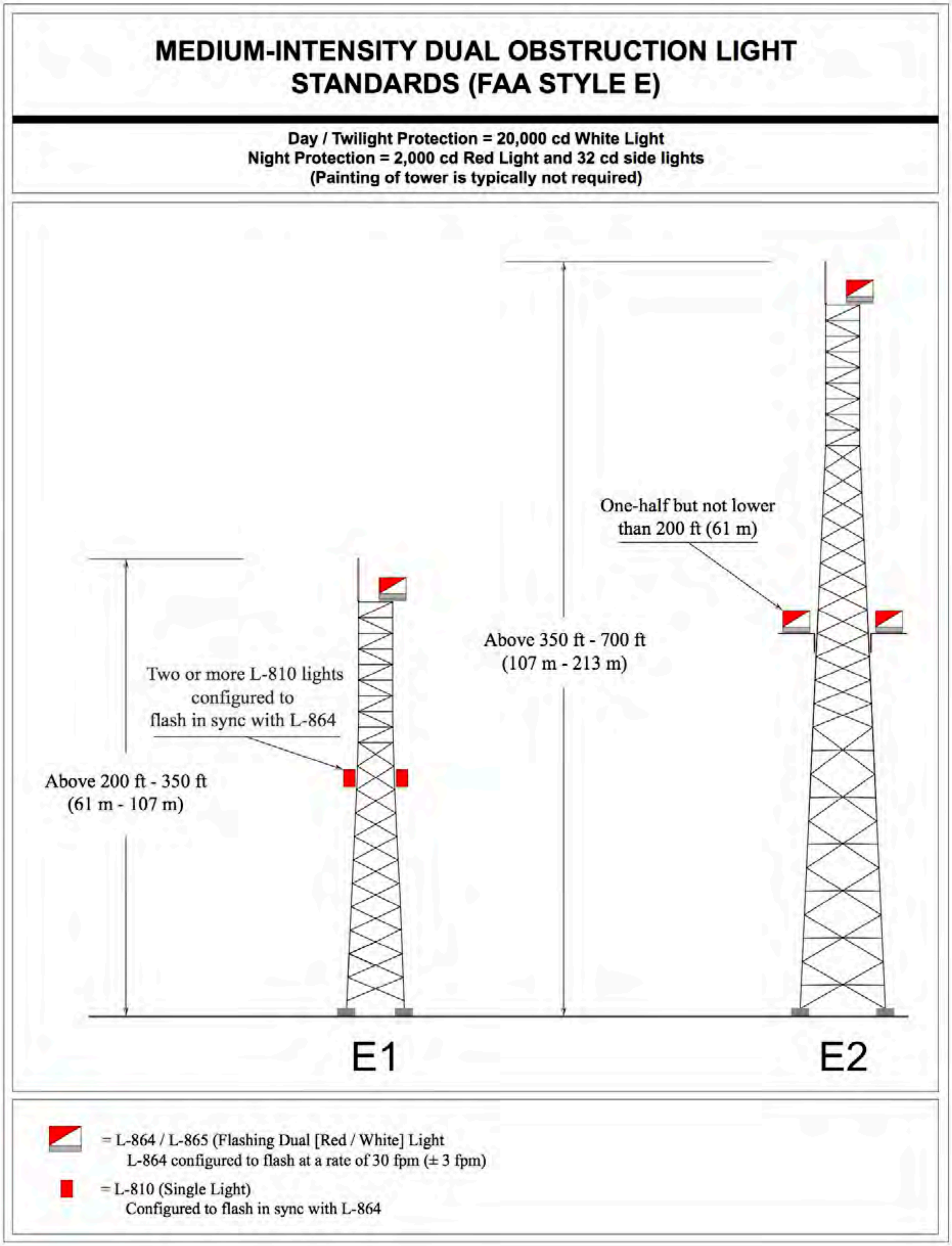


Figure A-10. Medium-Intensity Dual Obstruction Lighting Standards

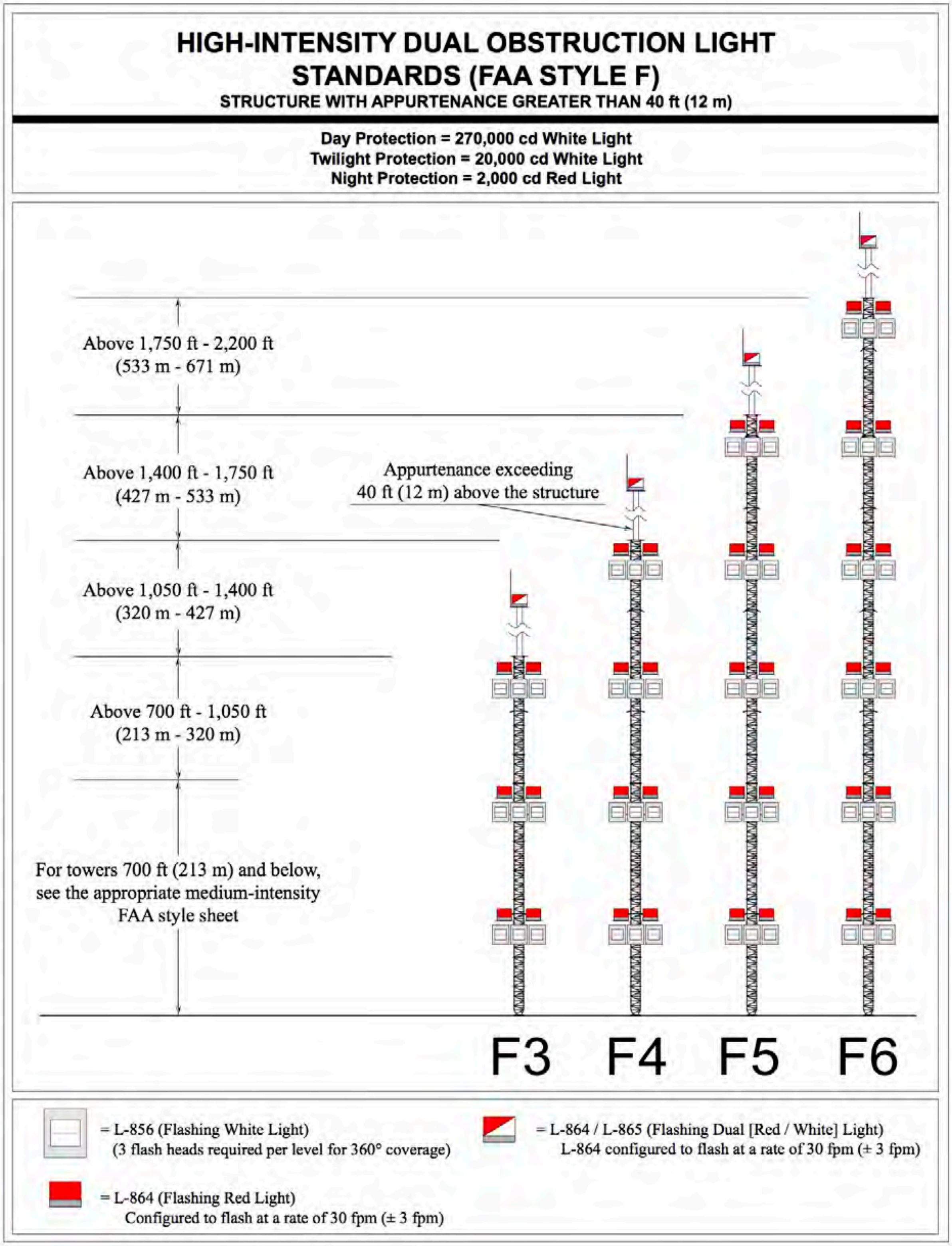


Figure A-11. High-Intensity Dual Obstruction Lighting Standards—Structures With Appurtenance Over 40 Feet High

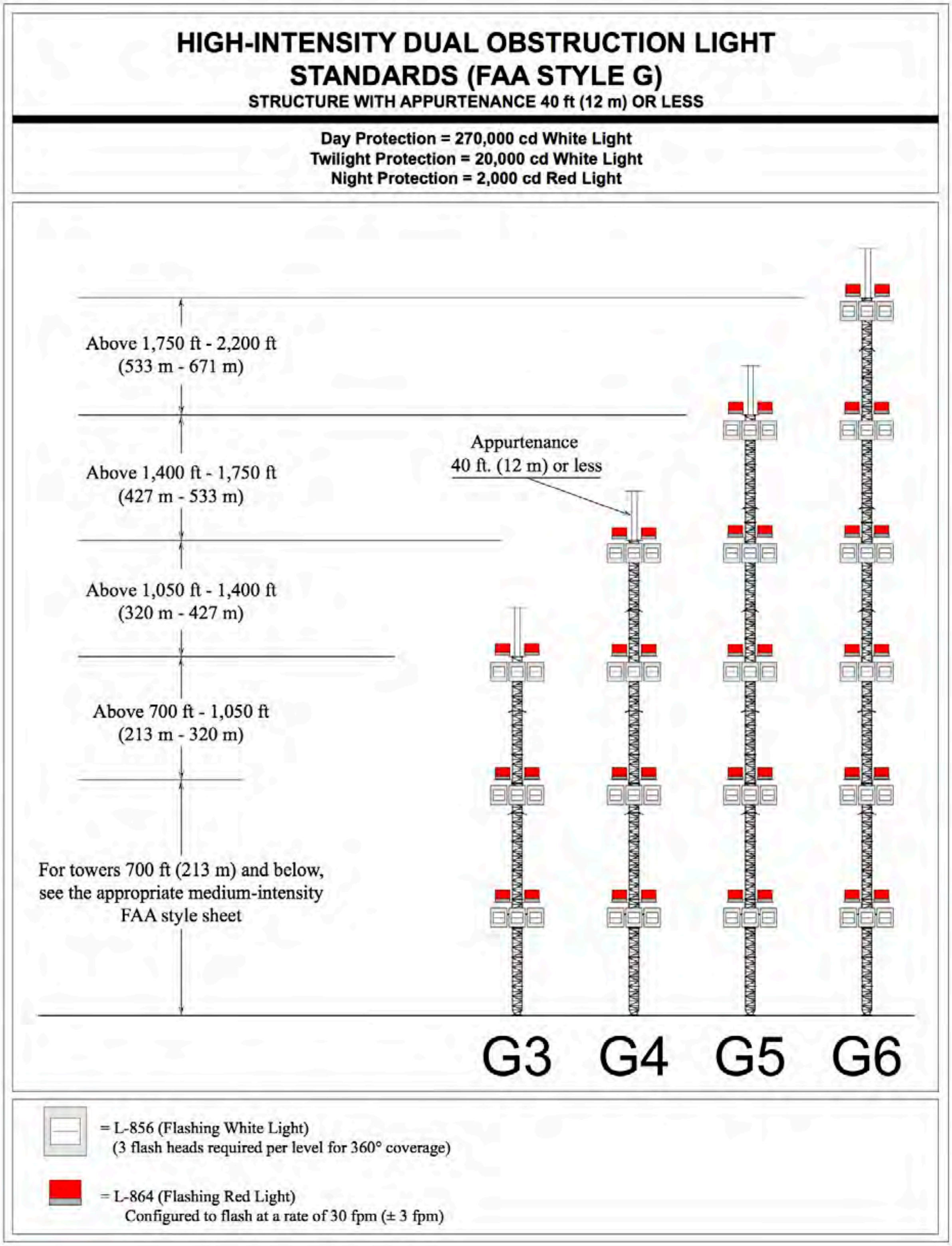


Figure A-12. High-Intensity Dual Obstruction Lighting Standards—Structures With Appurtenance 40 Feet or Less

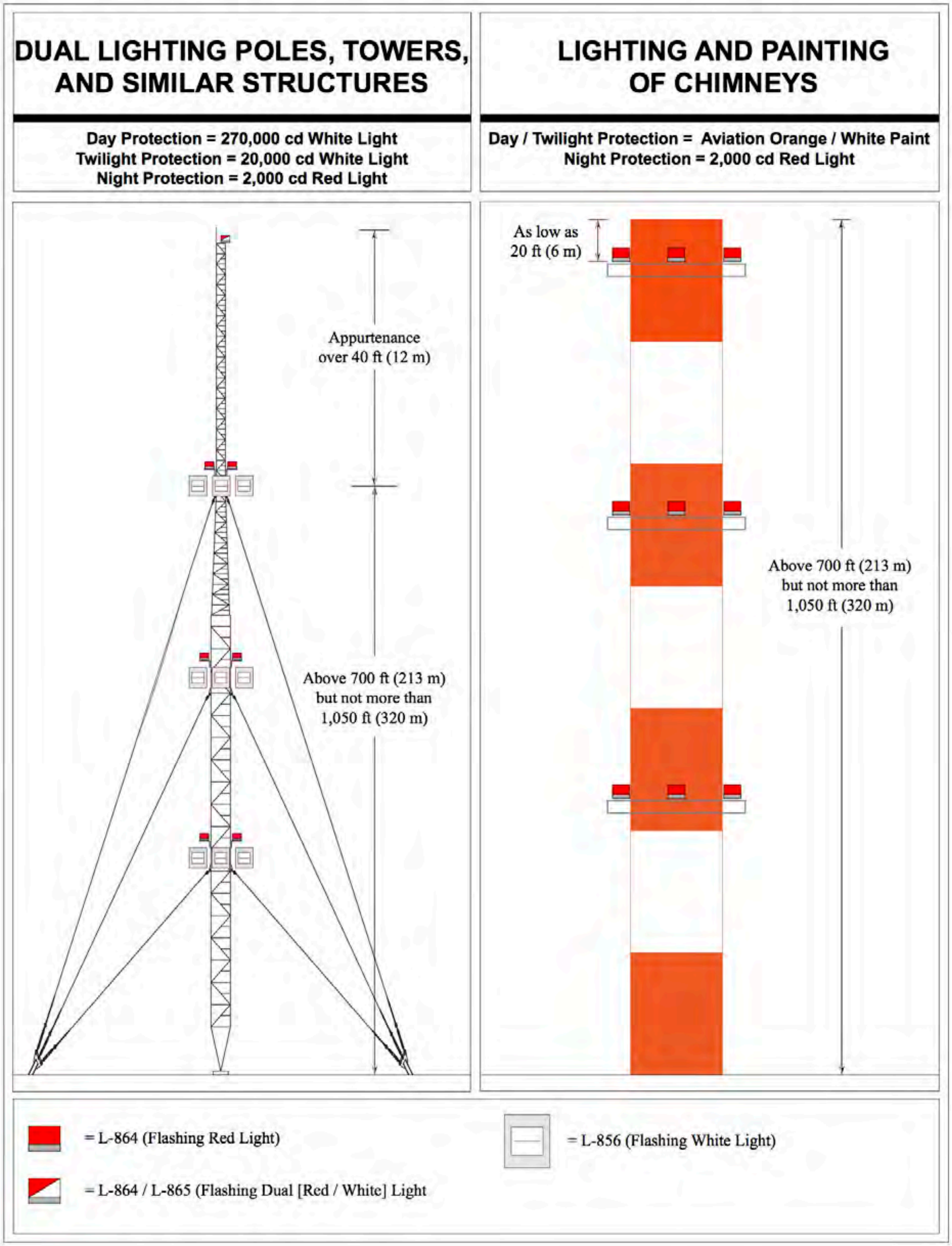


Figure A-13. Painting and/or Dual Lighting of Chimneys, Poles, Towers, and Similar Structures

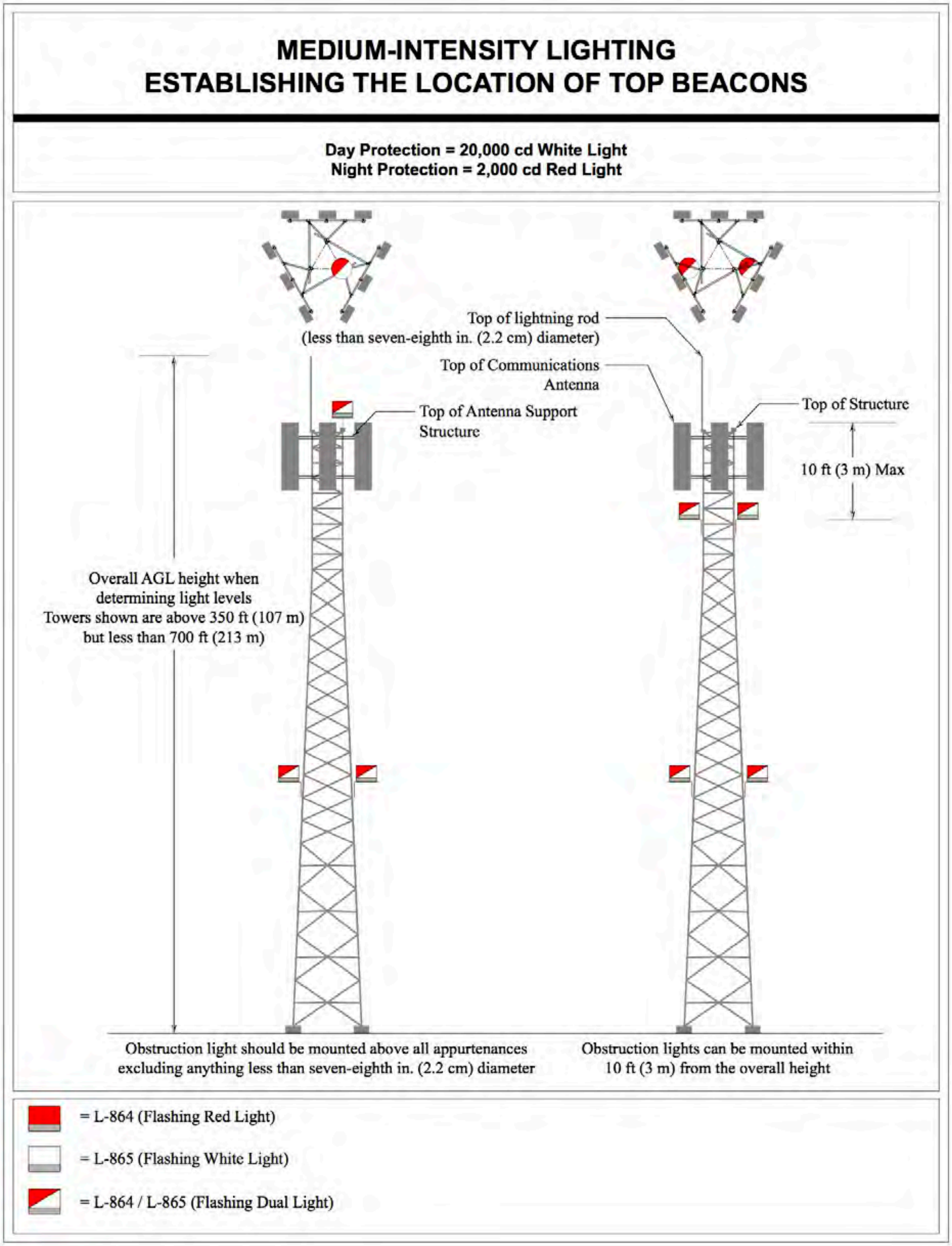


Figure A-14. Medium-Intensity Lighting—Establishing the Location of Top Beacons

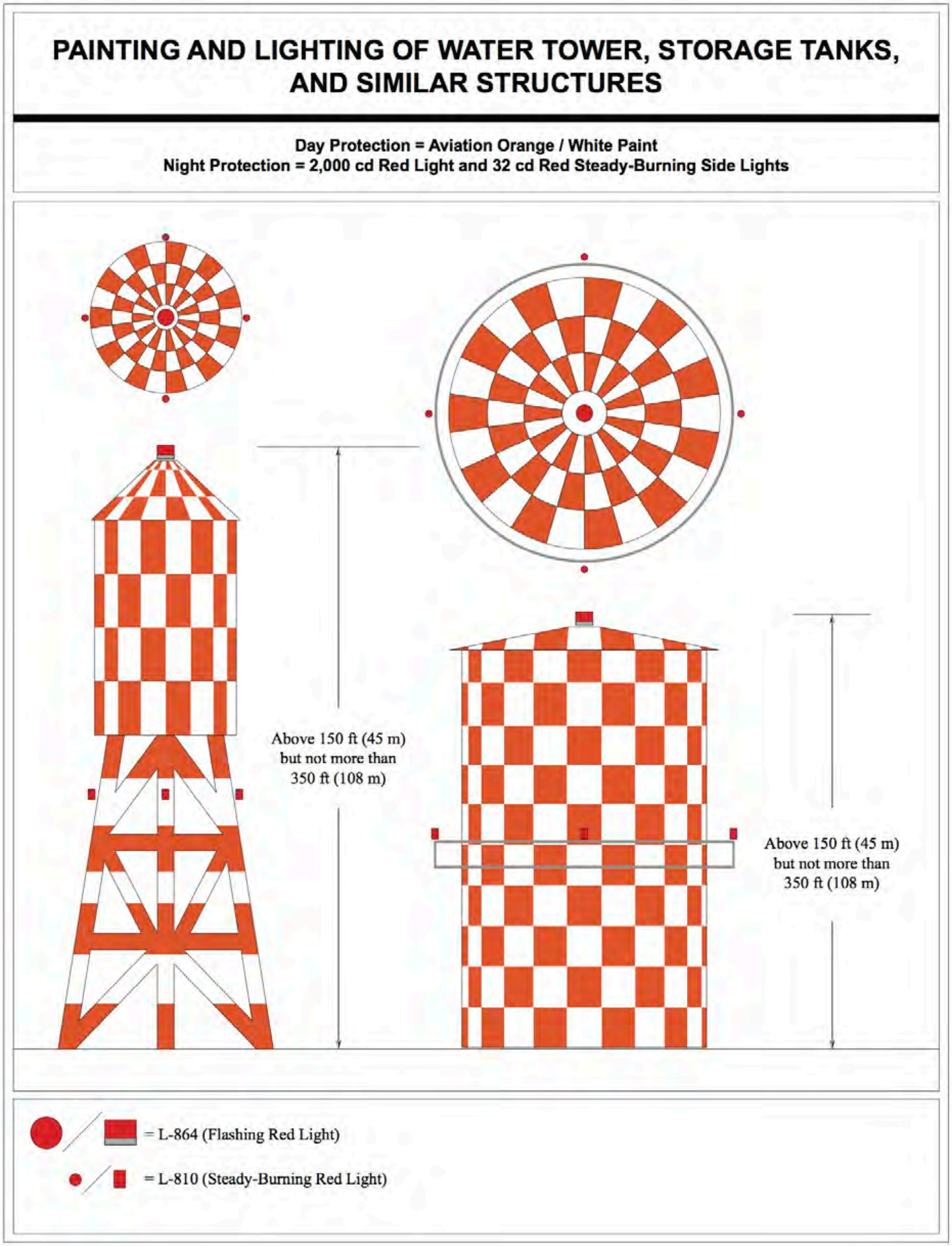


Figure A-15. Painting and Lighting of Water Towers, Storage Tanks, and Similar Structures

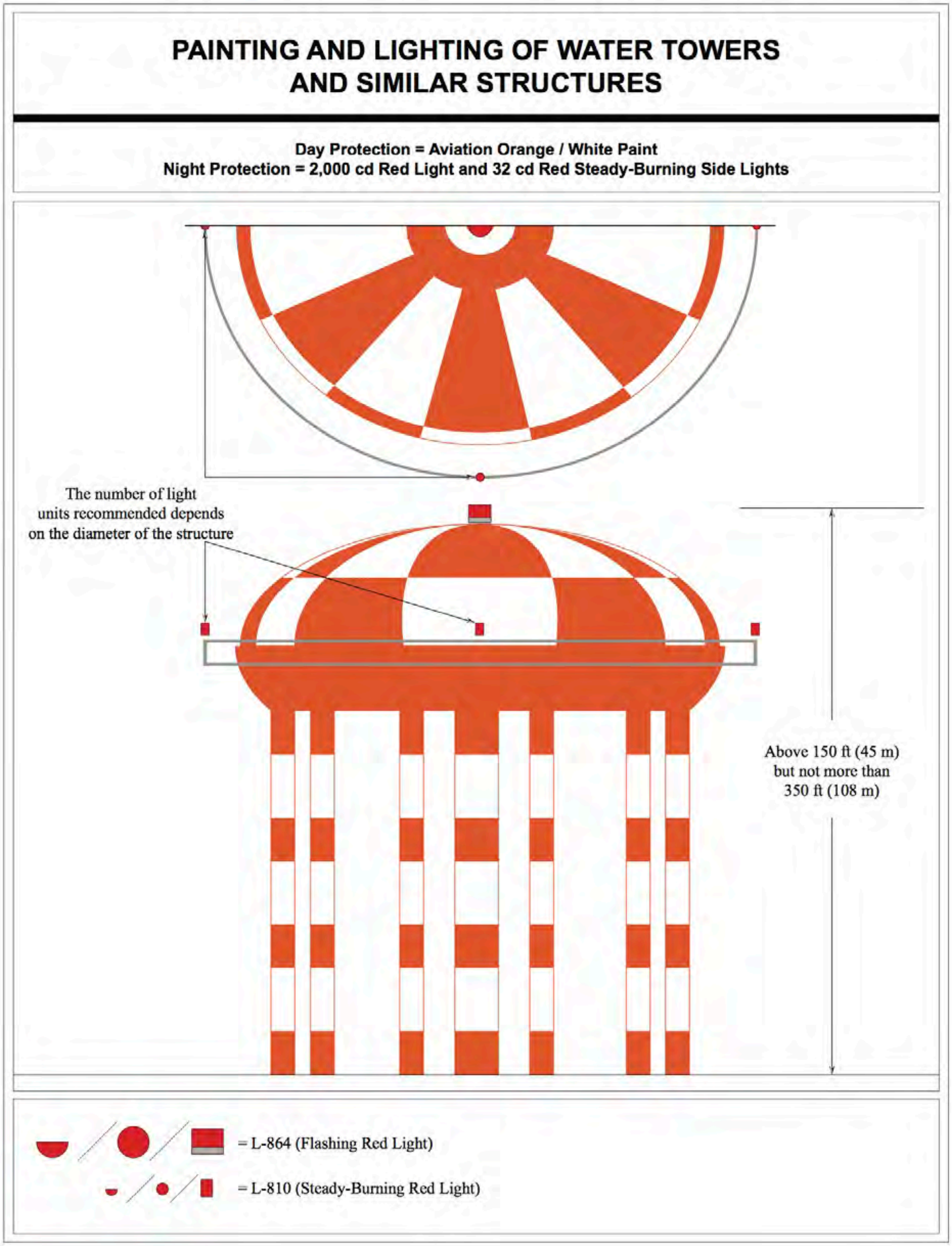


Figure A-16. Painting and Lighting of Water Towers and Similar Structures

Figure A-17. Painting a Single Pedestal Water Tower Using the Teardrop Pattern

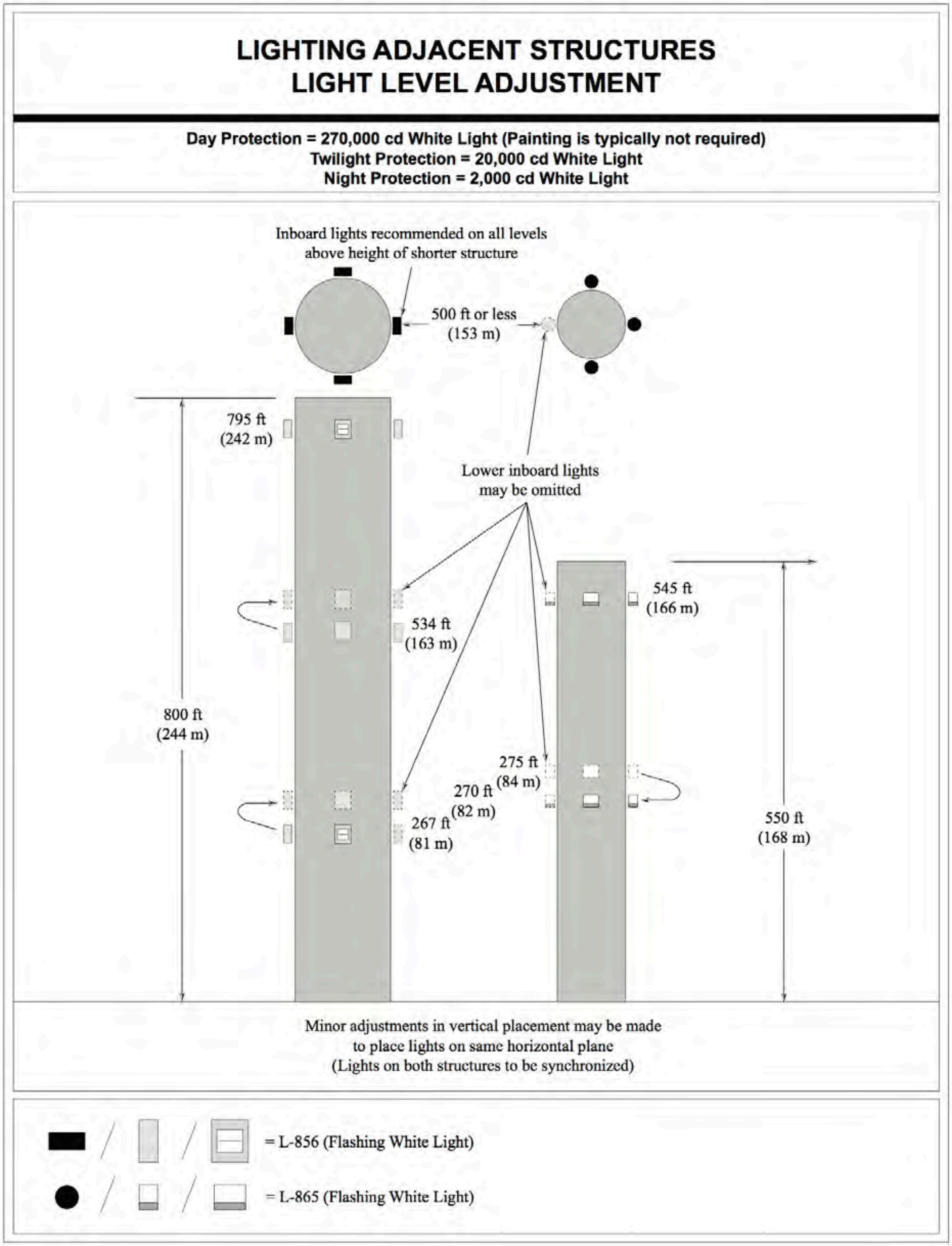


Figure A-18. Lighting Adjacent Structures—Light Level Adjustment

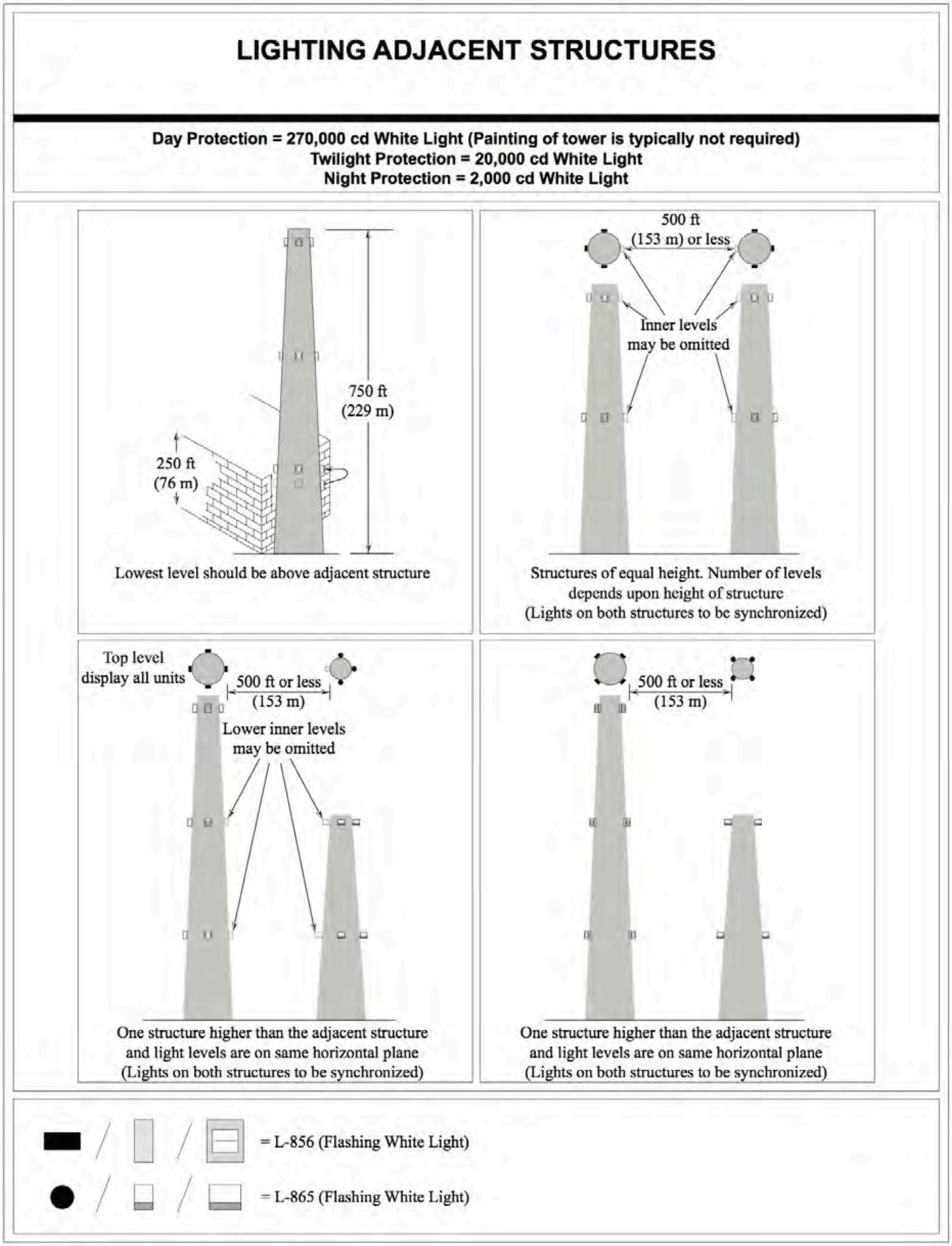


Figure A-19. Lighting Adjacent Structures

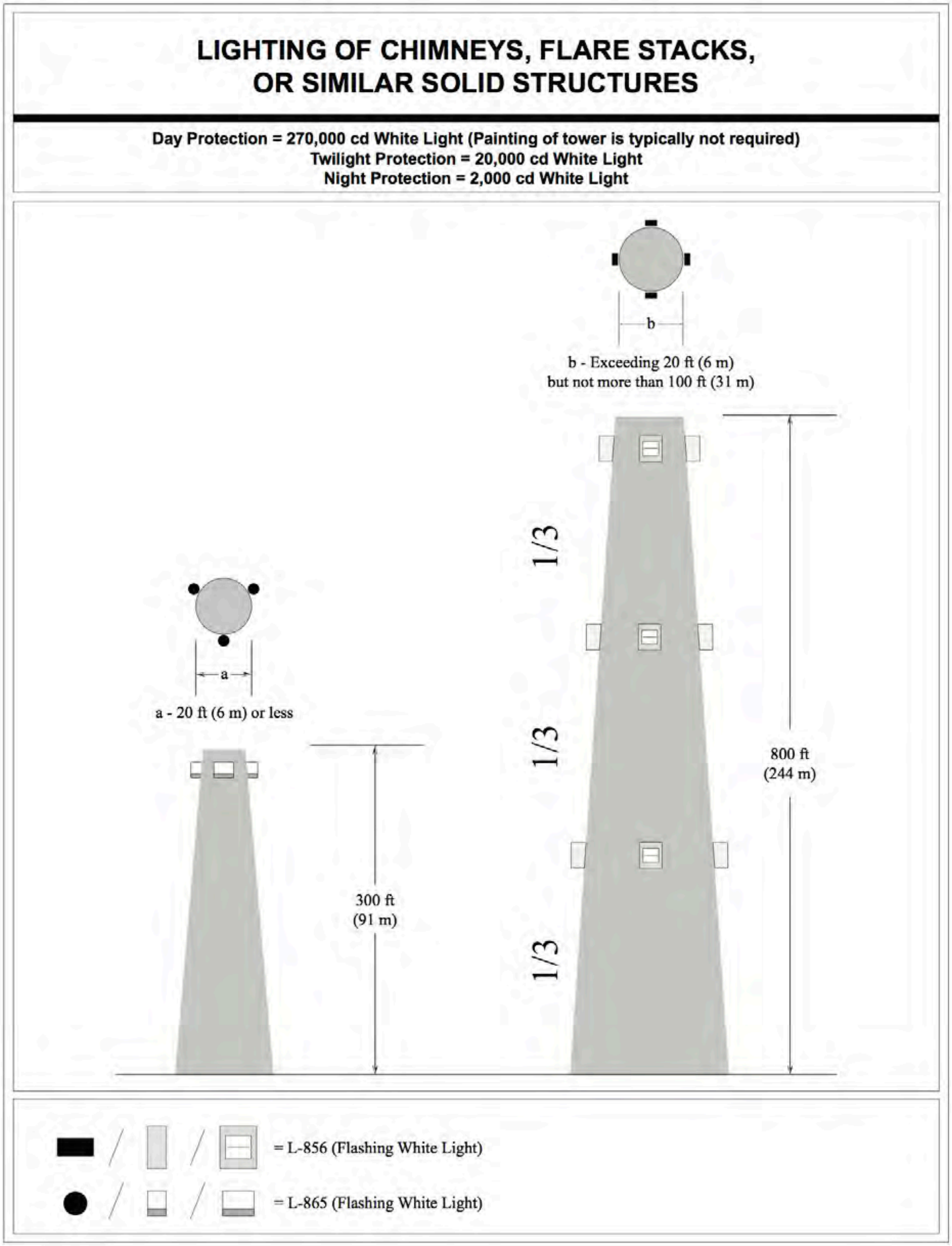


Figure A-20. Lighting of Chimneys, Flare Stacks, or Similar Solid Structures

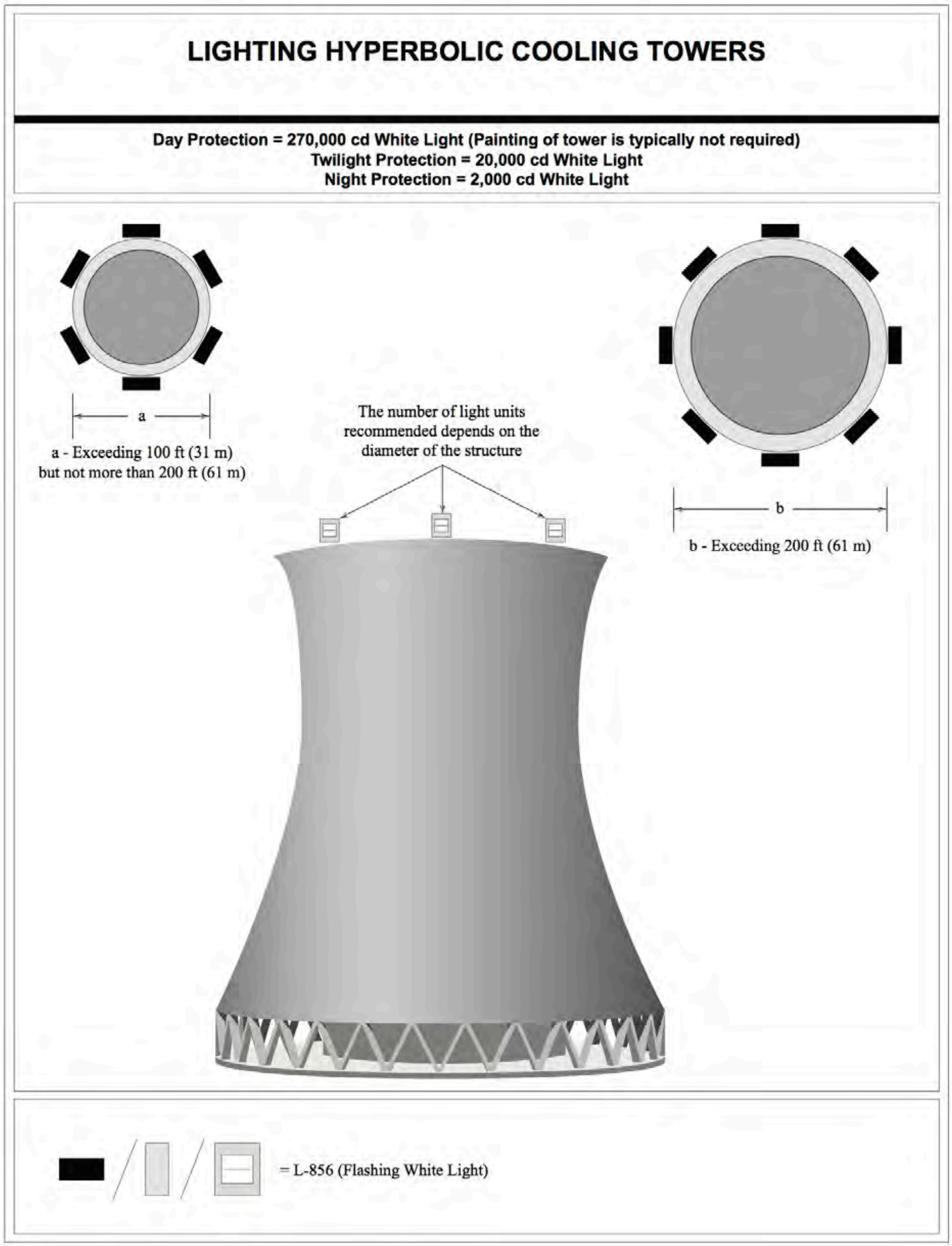


Figure A-21. Hyperbolic Cooling Tower

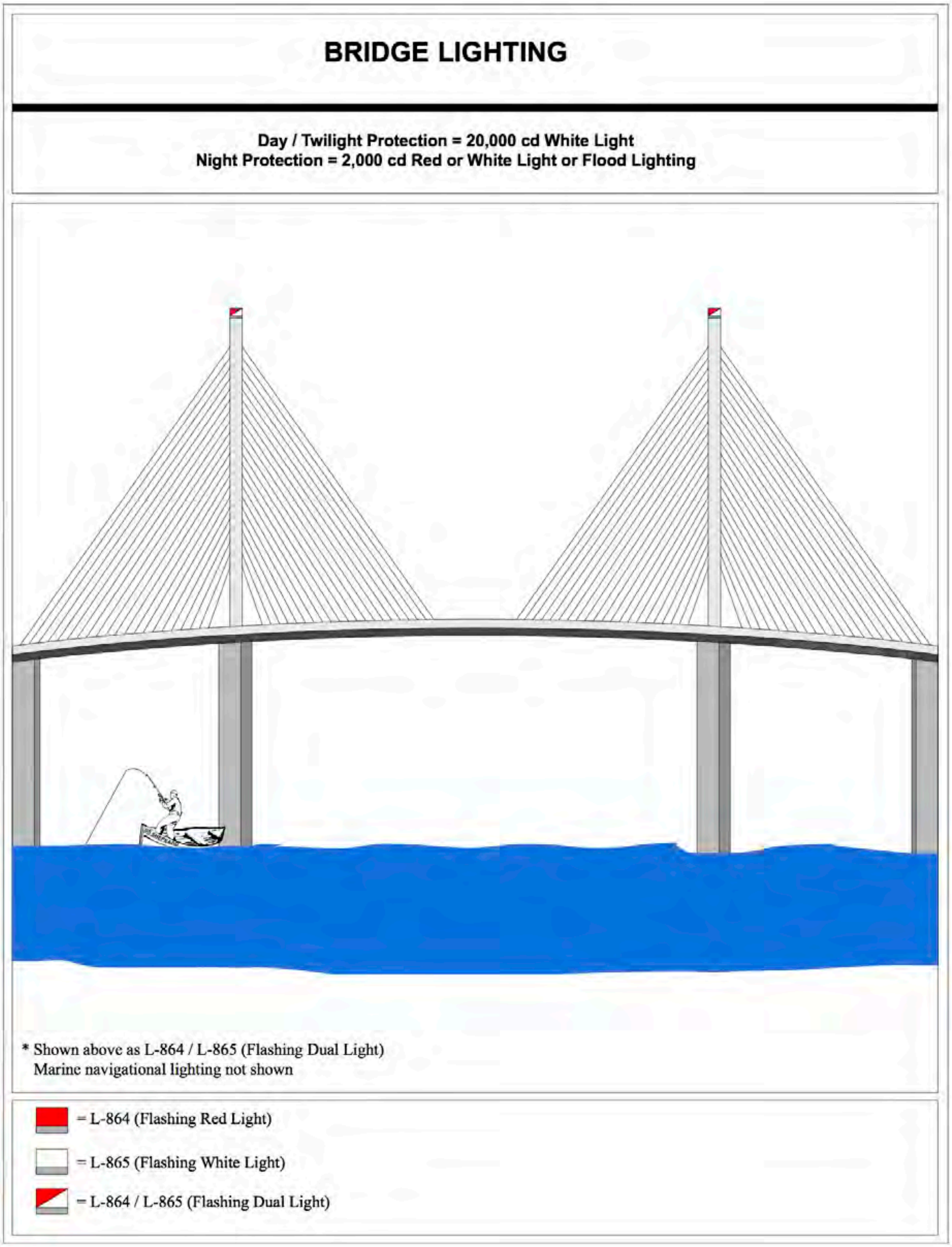


Figure A-22. Bridge Lighting

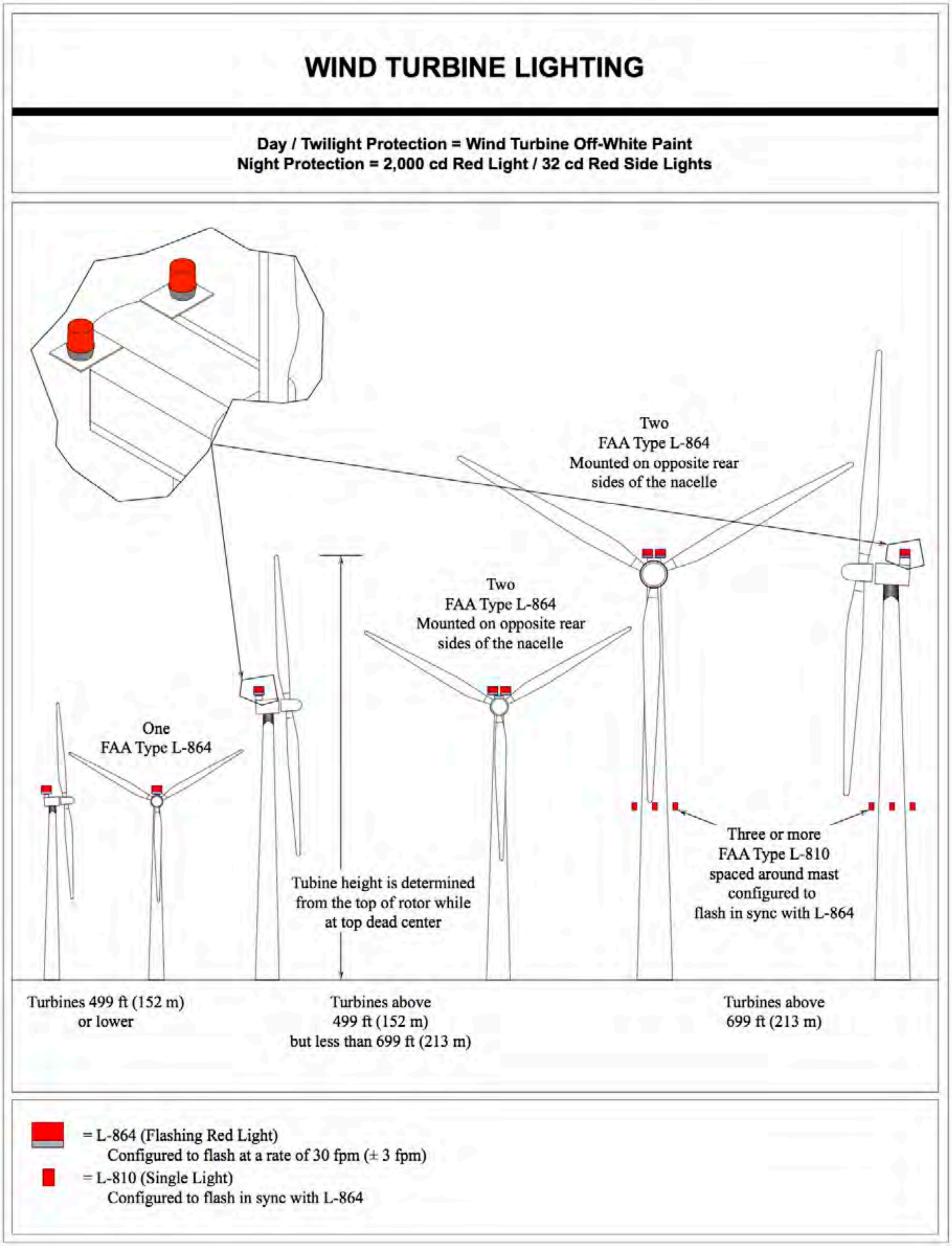


Figure A-23. Wind Turbine Lighting

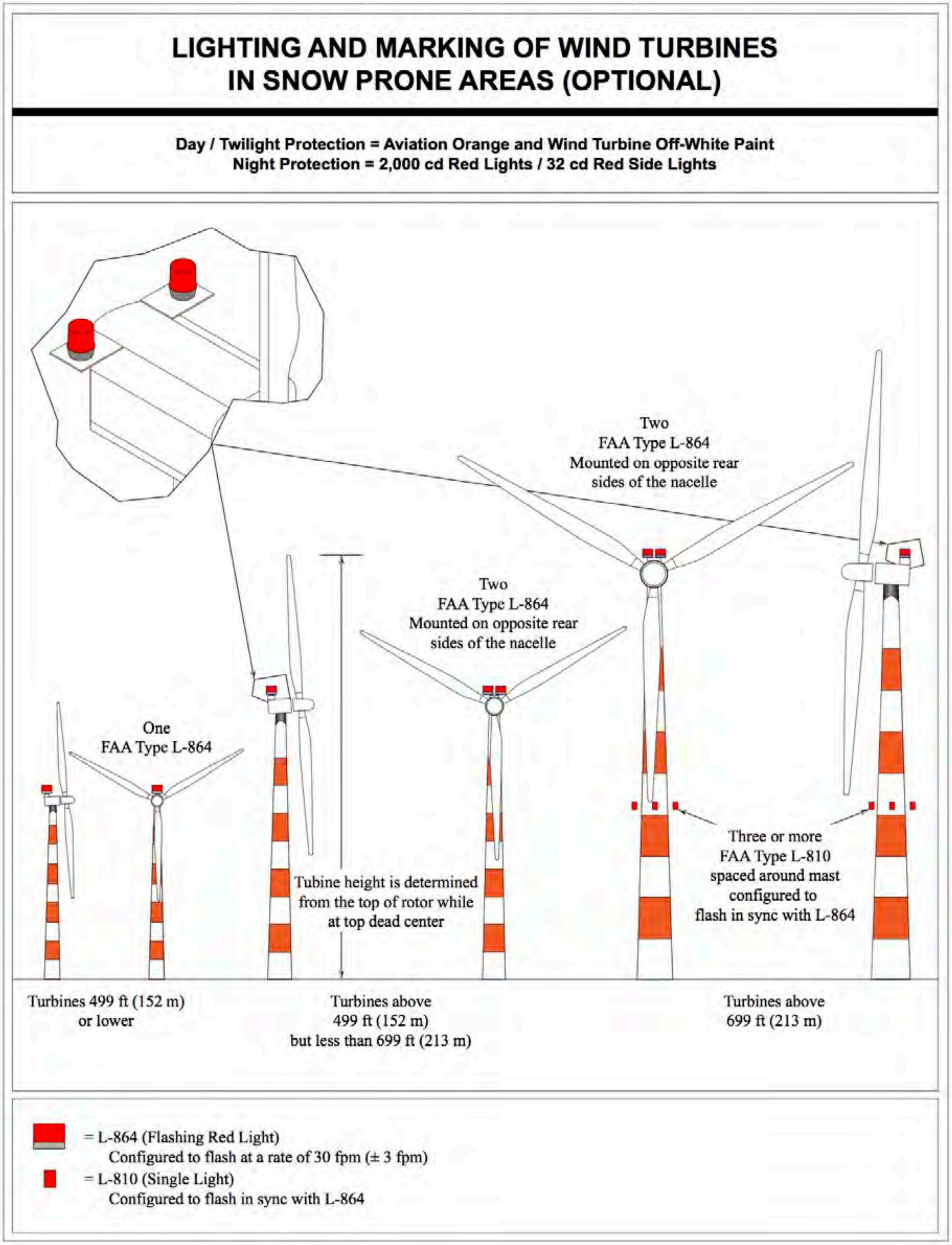


Figure A-24. Wind Turbine Lighting and Marking in Snow Prone Areas (Optional)

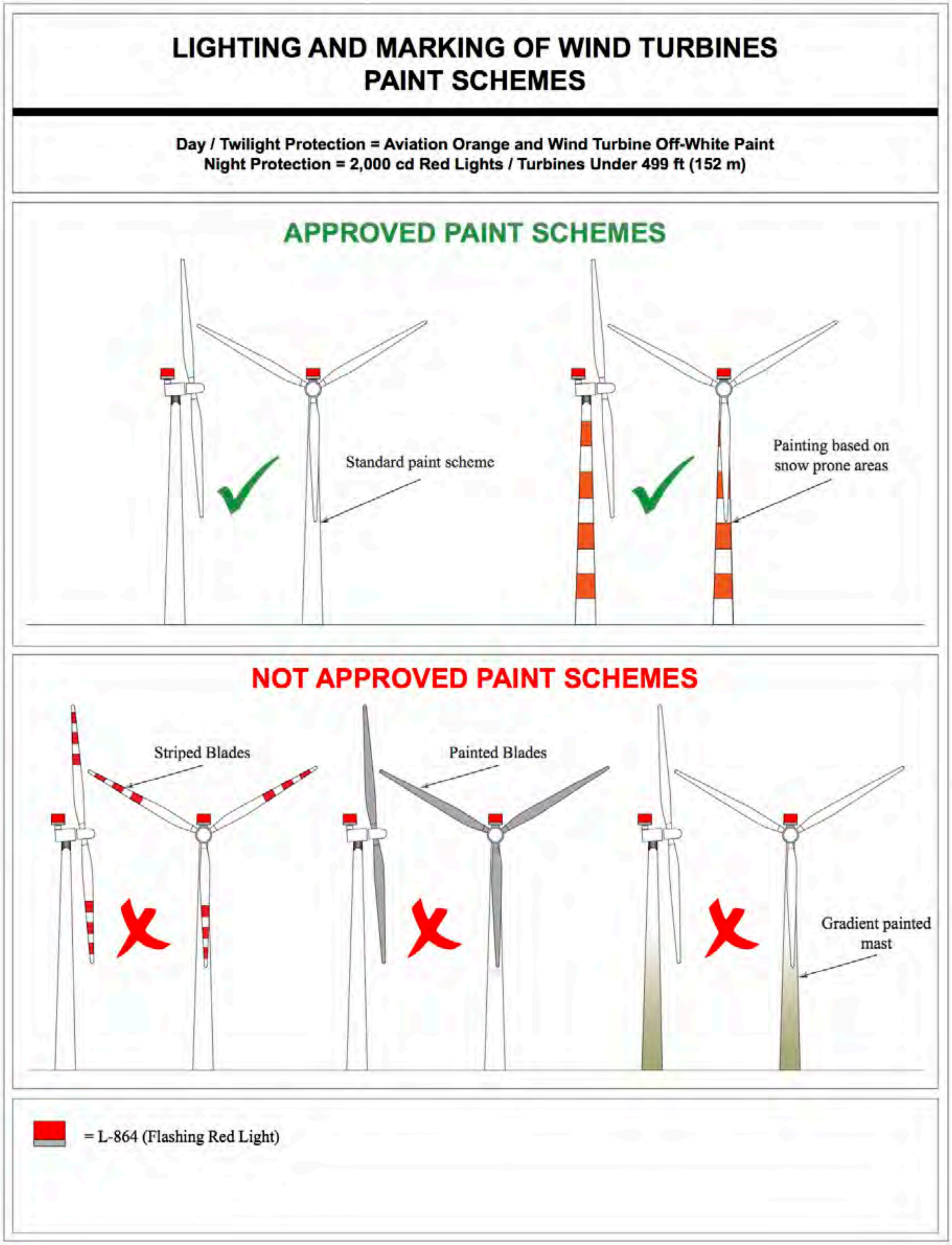


Figure A-25. Lighting and Marking of Wind Turbines – Paint Schemes

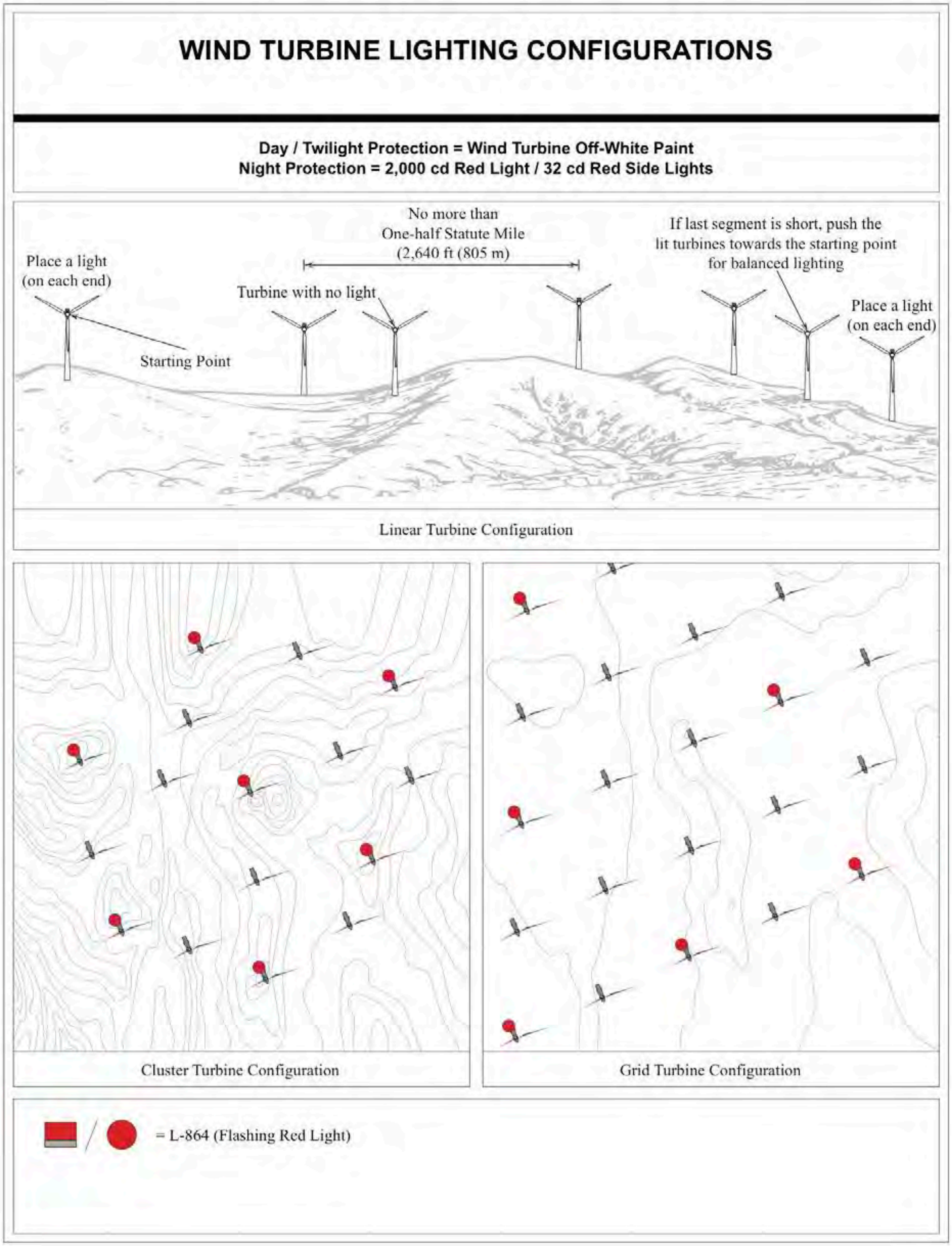


Figure A-26. Wind Turbine Lighting Configurations

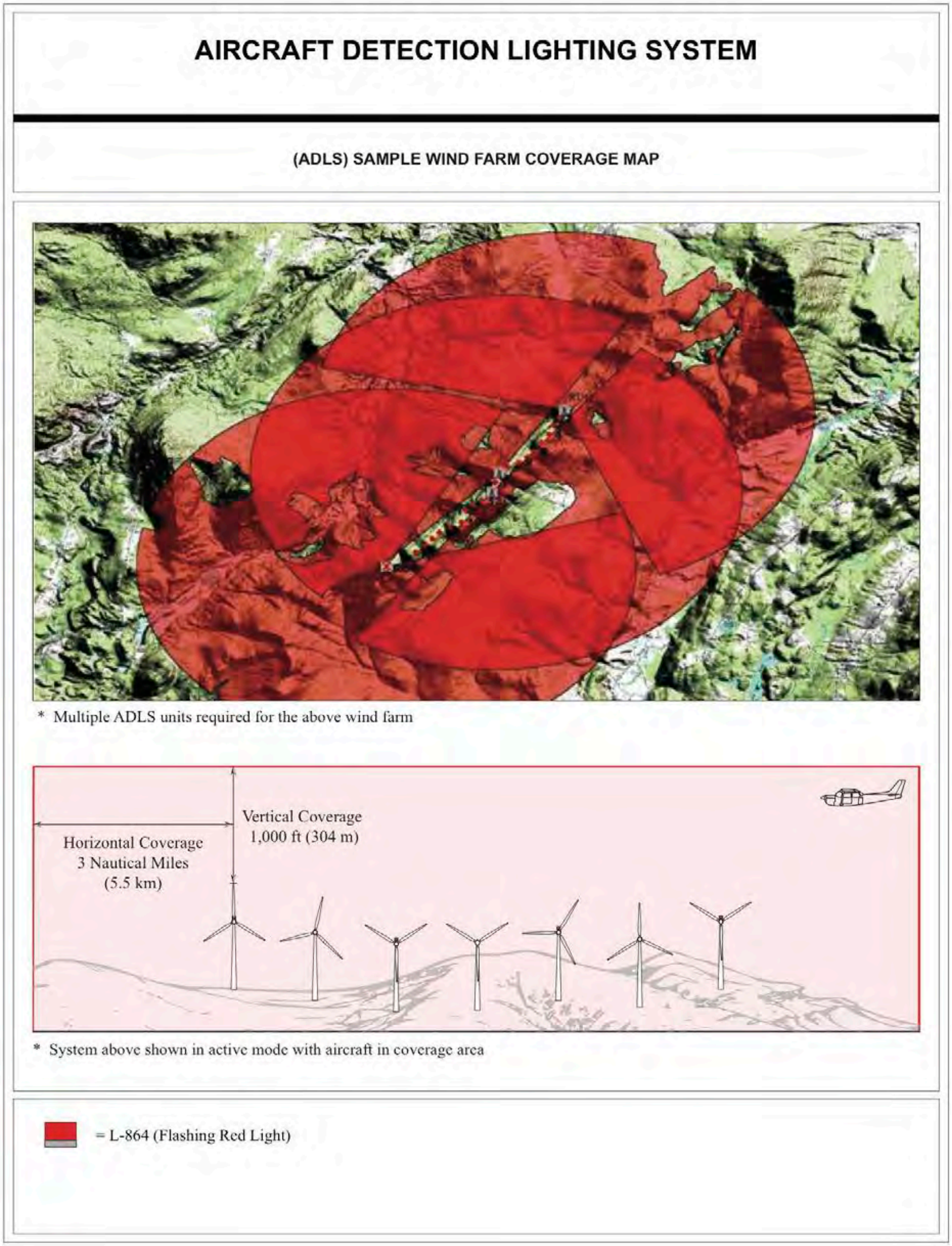


Figure A-27. Sample of Aircraft Detection Lighting System Coverage Map

APPENDIX B. MISCELLANEOUS

B-1 **Rationale for Obstruction Light Intensities**.

Sections 91.117, 91.119 and 91.155 of 14 CFR Part 91, *General Operating and Flight Rules*, prescribe aircraft speed restrictions, minimum safe altitudes, and basic visual flight rules (VFR) weather minimums for governing the operation of aircraft, including helicopters, within the United States.

B-2 **Distance Versus Intensities**.

Table B-1 shows the distance the various intensities are visible under 1 and 3 statute miles meteorological visibilities:

Table B-1. Distance and Intensity

Time Period	**Meteorological**		
Night		2.9 (4.7 km)	1,500 (±25%)
	3 (4.8 km)	3.1 (4.9 km)	2,000 (±25%)
		1.4 (2.2 km)	32
Day		1.5 (2.4 km)	200,000
	1 (1.6 km)	1.4 (2.2 km)	100,000
		1.0 (1.6 km)	20,000 (±25%)
Day		3.0 (4.8 km)	200,000
	3 (4.8 km)	2.7 (4.3 km)	100,000
		1.8 (2.9 km)	20,000 (±25%)
Twilight	1 (1.6 km)	1.0 (1.6 km) to 1.5 (2.4 km)	20,000 (±25%)
Twilight	3 (4.8 km)	1.8 (2.9 km) to 4.2 (6.7 km)	20,000 (±25%)

Note: Distance calculated for north sky illuminance.

B-3 **Conclusion**.

Aircraft pilots travelling at 165 kt (190 mph/306 kph) or less should be able to see obstruction lights in sufficient time to avoid the structure by at least 2,000 feet (610 m) horizontally under all conditions of operation, provided the pilot is operating in accordance with 14 CFR Part 91. Pilots operating 250 kt (288 mph/463 kph) aircraft should be able to see the obstruction lights unless the weather deteriorates to 1 statute mile (1.6 km) visibility at night, during which time period 2,000 candelas enables the light to be seen at 1.2 statute miles (1.9 km). To provide an acquisition distance of 1.5 statute miles, a higher intensity of 20,000 candelas would be required. This light, with 3-statute mile visibility at night, could generate a residential annoyance factor. In addition, aircraft at these speeds can normally be expected to operate under instrument flight rules (IFR) at night when the visibility is 1 statute mile (1.6 km).

Note: The 2,000-foot avoidance distance comes from the guy wires of a 2,000-foot structure. The guy wires at a 45-degree angle would be at a distance of 1,500 feet from the structure at a 500-foot elevation. Since the aircraft is to be 500 feet clear of obstacles (the guy wire), the distance of avoidance from the structure is 1,500 + 500 = 2,000 feet. (See Figure B-1.)

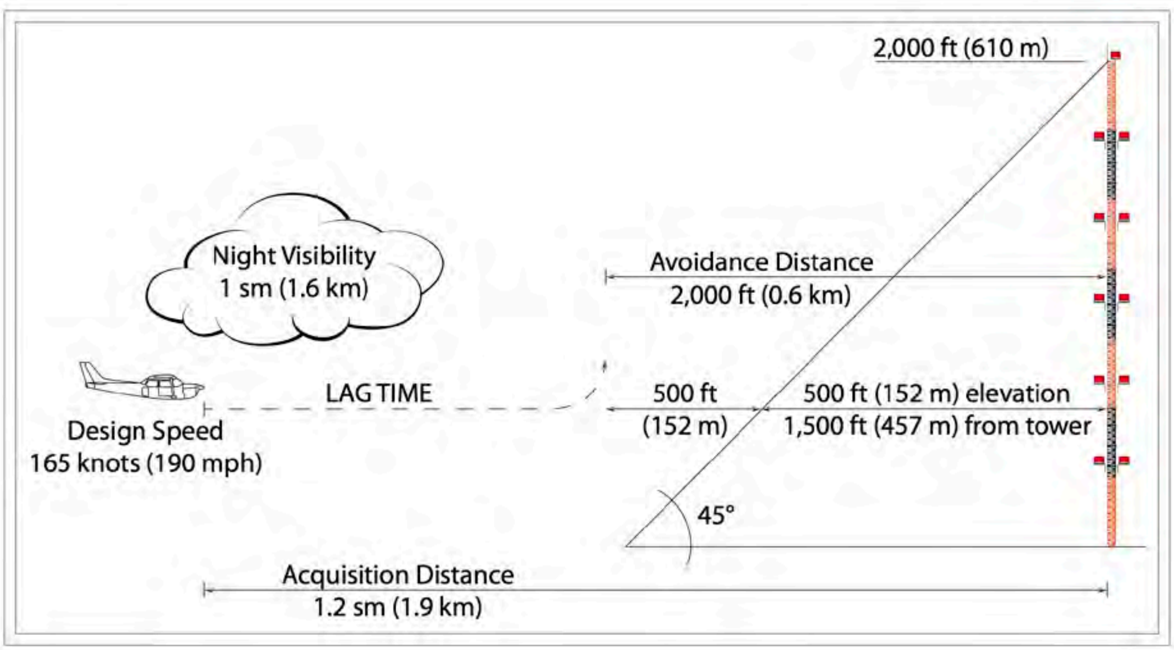


Figure B-1. Illustration of Acquisition Distance Calculation

B-4 **Definitions**.

B-4.1 Flight Visibility.

The average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night.

Reference: *Airman's Information Manual Pilot/Controller Glossary*.

B-4.2 Meteorological Visibility.

A term that denotes the greatest distance, expressed in statute miles, that selected objects (visibility markers) or lights of moderate intensity (25 candelas) can be seen and identified under specified conditions of observation.

B-5 **Lighting System Configuration**.

1. Configuration A . Red Obstruction Lighting System.
2. Configuration B. High-Intensity White Obstruction Lights for structures with appurtenance 40 feet or less.
3. Configuration C. High-Intensity White Obstruction Lights for structures with appurtenance greater than 40 feet.
4. Configuration D. Medium-Intensity White Obstruction Lights.
5. Configuration E. Medium-Intensity Dual White and Red Obstruction Lights.
6. Configuration F. High-Intensity Dual Obstruction Lights for structures with appurtenance greater than 40 feet.
7. Configuration G. High-Intensity Dual Obstruction Lights for structures with appurtenance 40 feet or less.

Example: "Configuration B 3" denotes a high-intensity lighting system with three levels of light.