IALA

GUIDELINE

G1136

PROVIDING AtoN SERVICES IN EXTREMELY HOT AND HUMID CLIMATES

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Association Internationale de Signalisation Maritime

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1. INTRODUCTION

In view of the volume of shipping and the unique challenges of working in hot climates, it is clear there is a need to provide guidance on the special challenges of providing Marine Aids to Navigation (AtoN) services in areas of extremely hot and humid climates. This guideline addresses specific challenges associated with these climates, covering both technical and managerial aspects.

2. BACKGROUND

There are several international regions where temperatures and humidity can rise to levels that may have a significant impact on AtoN equipment and human aspects of the provision of AtoN services. This presents significant challenges for the authorities and service providers that are responsible for the delivery of AtoN services, be they national organisations, competent authorities, private companies, port authorities, military bases or private harbours and marinas.

2.1. THE REQUIREMENT FOR AtoN IN EXTREMELY HOT AND HUMID REGIONS

The regulatory requirement for national Competent Authorities to provide such aids to navigation as the volume of traffic justifies and the degree of risk requires should not be diminished just because the climatic and environmental conditions makes the provision of such aids difficult.

Traffic densities in extremely hot regions are often high and the cargoes carried e.g. LNG, Crude Oil are often dangerous. Maritime routes are often geographically constrained in such regions, which increases the requirement for the provision of appropriate AtoN. There is also a growth in cruise liner traffic in these often very beautiful regions. These maritime traffic situations increase the importance that AtoN in these regions must be engineered and managed to meet the challenges posed by extreme climatic conditions, so that the mariner can rely confidently on them.

2.2. CHARACTERISTICS OF EXTREMELY HOT AND HUMID ENVIRONMENTS

Extreme temperatures and humidity can generate a number of climatic conditions that must be addressed to ensure that AtoN services are effective, reliable and delivered to full international standards.

Some of these climatic conditions are described below.

2.2.1. VISIBILITY

Seasonal rain, high humidity, sand storms and sand / dust laden air, associated with extremely hot and humid climates all have a negative impact on visual navigation and need to be considered when providing AtoN services in these regions.

In regions of heavy rain, high humidity, fog and sand storms, visibility can be significantly reduced. These climatic conditions may temporarily or more permanently affect atmospheric transmissivity and these should be considered when determining minimum ranges for lit or unlit AtoN.

2.2.2. TEMPERATURE

Extremely high temperatures can negatively affect the performance of AtoN equipment, including power supplies, lanterns, fittings and other electronics.

Steel buoys, towers, other structures and the installed equipment can reach temperatures that make access and handling very dangerous.

Installing, maintaining or working on AtoN in extreme heat and humidity can also significantly increase the safety and health risks to AtoN technical staff.

2.2.3. HUMIDITY

High humidity environments present issues to both AtoN equipment and personnel. Water ingress and the effect of humidity and the build-up of condensation in AtoN equipment can cause electronic failure, thereby negatively impacting availability, reducing reliability and impacting service life.

Increased humidity can also have a negative effect on the worksite, worker comfort and output efficiency, thereby increasing the risk of incidents and impacting quality.

2.2.4. EXTREME WEATHER EVENTS

Extremely hot and humid environments can generate extreme weather events particular to that area. This may include but is not limited to tropical storms, fog, monsoons, cyclones, sand/dust storms, seasonal winds and an increased chance of lightning activity.

These weather events present significant engineering and operational challenges and there may be design and installation requirements required in these areas that are not required elsewhere.

An example is shown in Figures 1 & 2, where extreme weather causes wave impact and damage to solar panels.

Figure 1 Entrance of Pasajes Port - Special bracket arrangement to protect the solar panel from wave force impact

Figure 2 *Northwest of Spain – Galicia coast – Structure and solar panels damages*

2.2.5. HIGH ULTRA-VIOLET LEVELS

High UV light levels in prolonged periods of strong sunlight can cause degradation of material properties including colour retention, plastic lenses, steel and plastic buoys, structures, coating systems and electrical/electronic equipment and fixtures.

UV exposure can also be a significant risk to workers and requires careful management and specific mitigation controls.

2.2.6. MARINE GROWTH

Very warm seawater, associated with extremely hot and humid climates, can cause the rapid growth of dense and sometimes destructive marine organisms on both buoy moorings and the foundations of fixed structures. This can increase the frequency and cost of maintenance, can adversely impact buoyancy and accelerate corrosion.

2.2.7. DUST

Dust is an issue in certain extremely hot environments and can cause a number of issues.

Dust can cover lanterns and day marks, severely impacting the range, can cover solar panels thereby reducing the ability to charge batteries and its abrasive nature can accelerate deterioration of AtoN components.

Dust can be of different physical properties, both industrial and natural, can cause different issues and require different controls and cleaning methods.

Excessive dust also poses health and safety related risks to AtoN personnel.

2.2.8. WATER TEMPERATURE AND QUALITY

High water temperature in these environments can cause a number of issues. It can accelerate corrosion and result in an increased rate of marine growth. This is further complicated in environments where the water has high salinity.

High water temperatures also create additional risks for workers, mainly those involved in underwater works. It can cause discomfort and reduces the amount of time that can be safely spent underwater. Warmer water environments also generally have a higher presence of marine organisms that can cause skin irritation or stings.

2.2.9. FLORA AND FAUNA

Some hot and humid climates promote high vegetation cover and growth. The need to constantly control and clear excessive vegetation so that does it not obstruct the operation of an AtoN can be an issue in these regions.

The presence of dangerous fauna in hot and humid regions, such as marine stingers, snakes, scorpions, spiders, venomous insects, crocodiles and sharks can present serious risks to workers and the ability to safely access, operate and maintain AtoN.

2.2.10. BIRD FOULING

Bird fouling is an issue affecting all AtoN, causing accelerated corrosion and deterioration of surface colour in all types of materials, but in extremely hot and humid environments the combination of heat and UV can harden it and make it particularly difficult to clean and remove.

3. ATON MANAGEMENT IN EXTREMELY HOT AND HUMID REGIONS

Due to the challenging conditions in these environments, AtoN management requires specific processes and solutions to ensure the services are delivered to the appropriate standards.

This inevitably impacts cost and delivery time and must be factored into planning and budgeting.

Failure to consider this in all stages of the AtoN process, including but not limited to design, specification, installation and maintenance will result in a reduced in-service life, poor AtoN delivery standards and in general, a negative impact on service delivery and availability.

Some of the main considerations are following.

3.1. SPECIAL REQUIREMENTS OF AtoN IN EXTREMELY HOT REGIONS

Given the climatic and environmental challenges posed in extremely hot and humid regions, AtoN have to be designed, installed and maintained to meet these challenges. This may result in a degree of specialized engineering; redundancy and innovative management solutions to ensure these AtoN meet their availability criteria and reliably provide appropriate information to the mariner.

Due the extent of some of these challenges, and the need for ‘above standard’ solutions, there may be an incentive to identify and standardise regions with extreme ambient conditions, in order to enable authorities and manufacturers to agree on relevant operating specifications and standards for AtoN.

The impact of extremely hot and humid climatic conditions on personnel employed directly by AtoN service providers and their contractors should not be under-estimated and may require specifically tailored controls that mitigate the risk of working under those conditions.

3.2. MANAGEMENT POLICIES AND PROCEDURES

Issues and risks specific to extreme heat and humidity need to be managed and mitigated by appropriate policies and procedures and be clearly communicated to all stakeholders. These policies should address specific issues, provide specific guidance and cover all aspects relevant to the area or region, including design, specification, procurement, maintenance, environmental management and workplace health and safety.

3.3. PERFORMANCE, RELIABILITY AND REDUNDANCY CONSIDERATIONS

To achieve adequate reliability and to mitigate issues associated with extreme heat and humidity, system redundancy may need to be considered. Redundancy will come at an increased up-front cost but helps avoid the costly repercussions of AtoN system failures and repairs. It also ensures that availability is achieved and maintained despite the environmental pressures.

The minimum standards for the performance of AtoN, AIS, remote monitoring and other electronic AtoN should be established with consideration to seasonal extremes of heat and humidity, which can cause significant effects on performance.

Data and information on failures, reliability and other operational issues can prove critical to a competent authorities' future purchasing decisions and changes to procedures and methods of working.

3.4. QUALITY CONTROL

A robust quality control system is critical in hot and humid climates where conventional standards may not have taken into consideration the extreme conditions in which the AtoN are installed and operated.

There are a number of considerations.

- The impact of human comfort and its effect on their performance, can compromise the quality of their work. This is a major factor in these climates. Preparation of equipment and installations in controlled environments, to minimize working on site under difficult conditions, can help mitigate this issue. Controlled conditions allow predictable quality, increased comfort for workers, and an overall cost efficiency.
- In the event it is not possible to undertake substantial preparation off-site, it may be possible to control the on-site work space as much as practical in order to provide a more tolerant, stable and comfortable environment. This can be done by temporary encapsulation, forms of ventilation, shading and temperature control.
- Equipment ratings on 3rd party products should be scrutinized and verified before entrusted into the field. The specific extreme conditions in these environments may not have been factored into tests and some level of trialling is encouraged before a more extensive use in the field. The level of testing, and the conditions under which equipment is tested, must be relevant to the environment in which it is installed.
- Communication and feedback between manufacturer / suppliers, Competent Authorities / Service Providers and stakeholders / end-users) is important in rectifying issues with equipment performance in these regions.

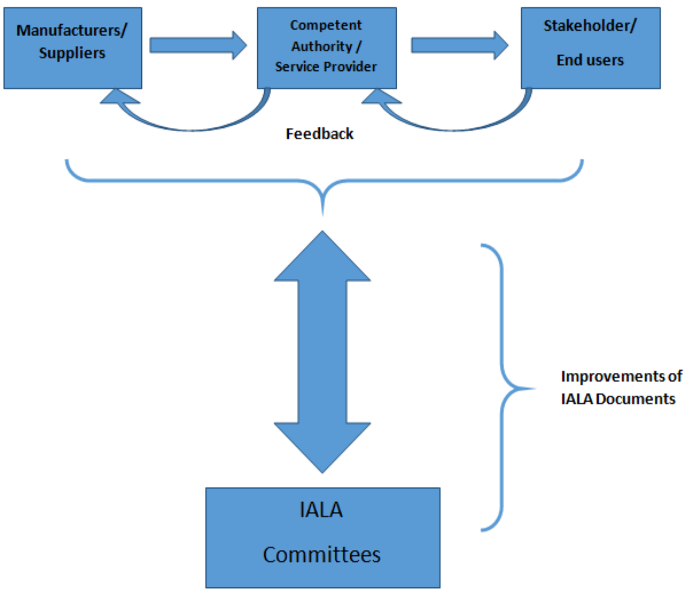


Figure 3 Communication and feedback between (Manufacturer/suppliers), (Competent Authority/ Service Provider) & (Stakeholders/End-users)

3.5. PRE-DEPLOYMENT, TRANSPORTATION & STORAGE MANAGEMENT

There is a period of AtoN ageing prior to installation and also during any intermediate maintenance or retrieval and storage periods. Correct maintenance and storage procedures appropriate to the extreme conditions and the technology and materials should be followed to maintain life-expectancy and specification and thus to protect the investment and the equipment.

In extremely hot and humid climates, this can be challenging and may require specific engineering or additional means of controlling the areas in which equipment is stored and the manner in which it is transported.

Handling and storage on site is also important. For example, during a scheduled maintenance visit to a site, spare batteries stored at less than 30 ° C and under shade ensures a minimum self-discharge of voltage.

3.5.1. APPROPRIATE BATTERY & SELF-CONTAINED LANTERNS MAINTENANCE & STORAGE

Batteries suffer from ageing effects. Minimisation of these effects requires appropriate storage and maintenance methods, with specific details dependent on the particular battery technology and the location. Similarly, self-contained lanterns should be provided the same considerations. In such AtoN, provision of easy battery charging and measurement is likely to be necessary. In some cases the battery or self-contained lanterns warranty could be voided if the manufacturer's recommended storage and maintenance procedures are not complied with.

When in storage, adequate initial and final battery charge levels are potentially critical to maintaining battery or self-contained lanterns lifetime and specification. The effects of heat and humidity on battery charge levels should be investigated. Examples are following;

Example 1: Lead-acid GEL batteries retain maximum capacity during storage if maintained at or below the typical specification temperature of 25°C and if recharged at appropriate intervals. The required recharge interval dramatically reduces with a modest increase in ambient temperature.

Example 2: When storing self-contained lanterns, care is required to ensure that these are deactivated and therefore not discharging the internal battery. This is especially important in hot or humid climates, where the temperature may require more regular checks and charging of batteries.

3.5.2. CHAIN AND SHACKLE CORROSION MANAGEMENT IN STORAGE AND TRANSPORTATION

Steel components such as chains and shackles need to be protected from corrosion in extreme environments. It is also necessary to protect these items during transportation, especially considering that they could be more exposed to corrosion at such times than during the storage period. Preventative methods such as painting, galvanising or bitumen-coating) are applicable, and storage in dry, low-humidity environment might also be necessary. Consideration should also be given to isolating components from surfaces that could support the possibility of moisture seepage or catchment.

3.5.3. STORAGE OF PAINT

Paint and other coating systems are also often affected by extreme temperature and humidity, which can shorten lifetime and alter the properties and performance of paint, particularly mixed two-pot/two-part paints. The impact or deterioration is often not noticed until the time of application.

4. AtoN MAINTENANCE IN EXTREMELY HOT AND HUMID ENVIRONMENTS

4.1. MAINTENANCE AND WORK SCHEDULES

Maintenance and work intervals should be established by the responsible parties to suit their requirements or according to their asset strategy. Scheduling of these intervals should be managed to avoid extreme conditions wherever possible.

In some regions, summer temperatures may be so extreme it is unsafe for workers to work on site in exposed conditions for long periods of time and it is therefore more appropriate to schedule site visits for more suitable seasons.

Likewise with seasonal wind or weather patterns, monsoons, cyclones or strong winds may cause dangerous sea states and conditions that make it unsafe to work on site. In these instances, work should be scheduled for seasons when sea conditions promote the safest working conditions.

Alternative means of access, such as helicopter access, may be considered for these situations.

Heavy seasonal rains in some areas may make it impossible to work safely and efficiently on an AtoN site. Wet seasons often have an accompanying dry season, which could be utilized instead.

The impact of these environments on AtoN equipment may necessitate higher site visit frequencies than would normally be expected elsewhere in the world. Accelerated corrosion, lens degradation, higher rates of marine growth, dust coverage, the effect of heat on electronics, etc. are all issues that might require shortened site visit intervals. This obviously has cost implications, related to both frequency of visits and equipment replacement. The cost benefits need to be explored by the responsible parties.

4.2. PERIODIC CHANGE OUT OF EQUIPMENT

Service periods for AtoN equipment may need to be reduced due to the effects of extreme heat and humidity. This could be due to a number of reasons, including but not limited to lens degradation (either by UV or sand/dust abrasion), water ingress and condensation in electronics. The issues may vary according to a region’s climate, or even macro-climate, and the service and change out periods should be adjusted to suit. (Annex A)

Wherever possible, selection of appropriate equipment should be used to reduce the maintenance required, which will reduce the costs associated with more frequent site visits. Upfront costs could be offset by reduced maintenance effort.

4.3. BUOYS

The water temperature in these environments can facilitate a high rate of marine growth, which may require regular removal and cleaning.

Working conditions on buoys need to be considered with buoy selection, to reduce the impact of working in extreme heat on workers.

Methods and procedures for work underwater need to take into account the impacts that very warm water may have on divers and technicians.

4.4. MOORINGS

Mooring systems in extremely hot and humid environments can be affected by the high sand / sediment load in the water. This may necessitate more regular replacement of the mooring system or at least more regular inspections. Type of mooring selection should take this factor into consideration. An alternative mooring in these locations may reduce the corrosion, subsequent maintenance and increase the lifespan. This may include heavier moorings, different material types (steel grades, synthetic etc.) and should be chosen to suit the site. This is an important factor in early design stages and a good understanding of environmental conditions is a key to successful design.

4.5. PAINT SYSTEMS

Extreme heat and humidity have a number of impacts on the application, maintenance and overall lifespan of paint systems.

All efforts should be made to apply paint systems in controlled conditions, such as workshops. However, when this cannot be achieved and on-site painting is required, a number of factors must be considered.

Paint systems should be chosen with the environmental conditions in mind. The supplier, types, application methods and temperature ranges should all be considered as they affect the service life and ongoing future costs associated with the AtoN.

Surface preparation and the condition of the surface at the time of paint application is critical. A hot surface may cause painting systems to cure irregularly, affecting finish and performance. Wet or moist surfaces, due to rain or condensation, will also cause issues with the paint system. The application of paint systems should be scheduled and optimized so that heat and humidity do not cause these issues.

The temperature of paint products also plays an important part in how the system performs, especially in two pack applications. The heat of the product at the time of mixing may cause premature curing, especially when combined with the heat produced by the chemical reactions created during the mixing process. Again, this can cause issues with curing, finishing and long-term effectiveness of the system.

For major painting works in extreme heat and humidity, a controlled environment may be required on site. This could be achieved by replicating suitable conditions on site for paint application and cure. Acceptable environmental practices should be considered to ensure there is no adverse impact on the natural environment. Encapsulation, shading, ventilation and dehumidification are possible methods.

4.6. MOULD

Mould can be an issue experienced in high humidity environments. Mould can affect conspicuity of structures and daymarks, can cause deterioration of equipment and can cause slippery and unsafe conditions for workers.

Mould can be combated by the use of high-gloss paint systems. In some cases the only suitable control measure is more regular cleaning. Adequate air flow and ventilation can also help reduce mould.

4.7. POWER SUPPLIES

Accessibility of power supplies to technicians should be a consideration in these environments. This includes the size, location and storage method. Difficulties with climbing, manual handling and access in general can be magnified when working in extreme heat and humidity.

Testing and handling protocols and procedures in hot and humid climates may require specific testing methods and precautions. High humidity and sweat can increase the risk of electrocution.

Isolation of battery bases, the use of appropriately rated, water resistant and UV protected cables and the protection of terminals may reduce this risk also.

4.8. BIRD FOULING

Consideration with bird fouling in hot climates is that it can be baked on due to the extreme heat, making it very difficult and time consuming to remove. Intensive cleaning can create dust which poses inhalation related health and safety risks to workers. Bird deterrents should be used wherever possible to prevent this problem.

Some ways used to prevent this effect:

- Install the most appropriate bird deterrent for the location and bird species. - These action prevent the bird fouling
- Paint over the surface colour with a special ant graffiti product. - These action not prevent the bird fouling but ensure an easily remove with water pressure.

4.9. MERCURY HANDLING

Handling mercury in hot conditions is very hazardous due to the evaporation of mercury vapour at the elevated temperatures. To reduce risk to the health of personnel the following must be considered as well as the standard controls to mitigate mercury risks.

- Air circulation must be adequate.
- Limit the working time during periods of intense heat.
- Where humidity is an issue, be careful of any slippery conditions which may cause slipping or mishandling of mercury.

4.10. STORAGE / STRUCTURES

There are a number of factors that affect the suitability and issues of AtoN structures in extremely hot and humid environments.

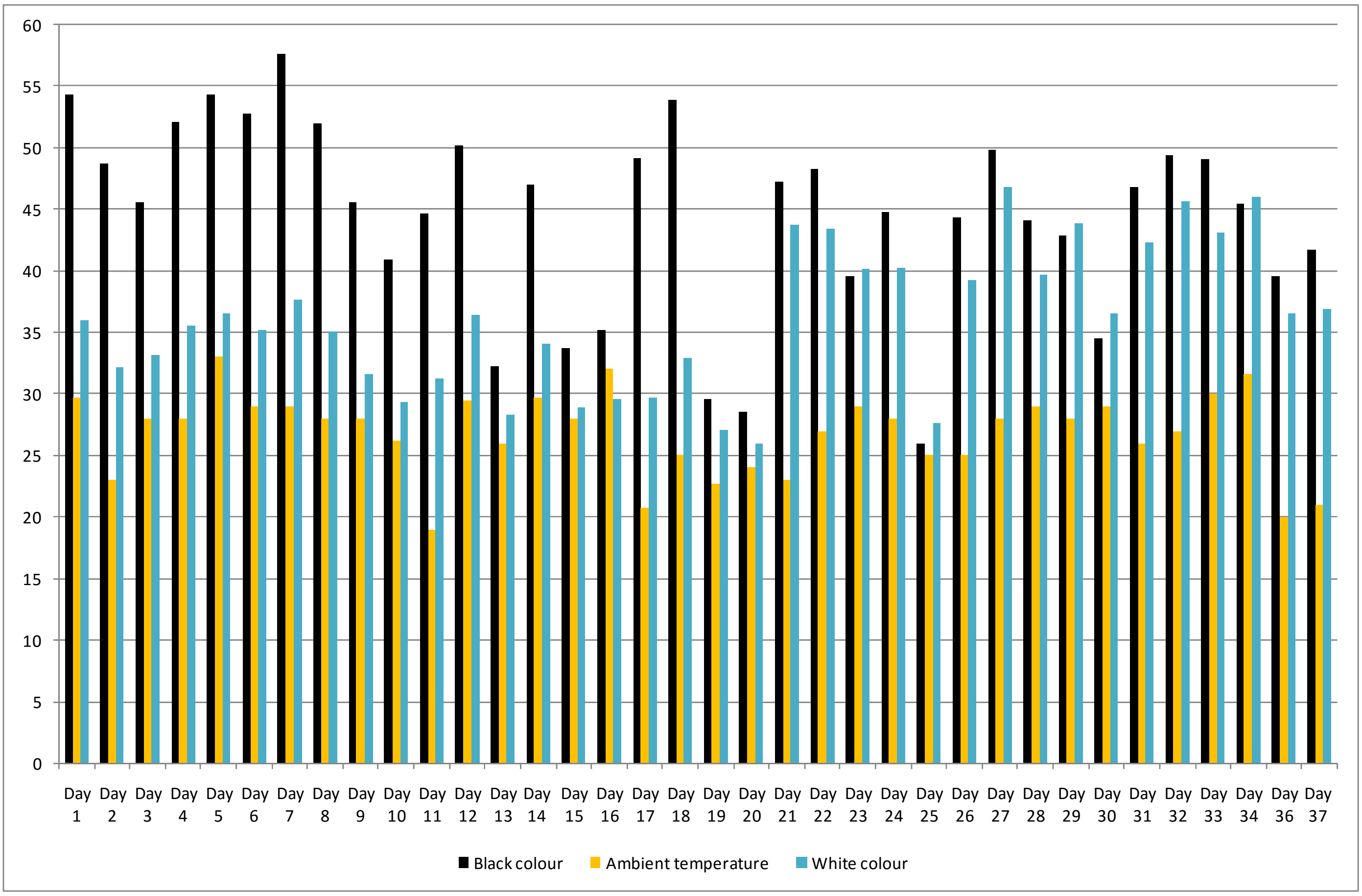
Battery ventilation is very important in hot climates, to avoid generation of heat, to allow air flow and to allow heat dissipation. This is generally applicable to most electrical equipment in these environments. Some protection from heat and humidity is critical.

A poorly ventilated structure in a hot climate may also contribute to equipment failure, due to poor heat distribution or the build-up of moisture and condensation.

In some applications, air conditioning may be possible and is an effective way of regulating internal temperatures.

The colour of the structure is also important, as certain colours (such as white) will allow better thermal protection. Darker colours should be avoided for an AtoN structures and equipment enclosures as these promote heat absorption.

An example of colour selection and effects on temperature can be seen in Figure 4, which shows results of recorded temperatures in white and black battery boxes.



Battery box colour	Black	Amb. Temp	White
Temperature sample (Celsius degree)	57.9	33	40.6
Percent of influence	175%	100%	123%

Figure 4 Measurement of Temperature vs. different surface colors

5. DESIGN AND ENGINEERING CONSIDERATIONS

5.1. GENERAL CONSIDERATIONS

Manufacturers, Competent Authorities and other service providers are encouraged to offer AtoN specifications by region (e.g. per STANAG 2895) to ensure the end user is better informed regarding their suitability and reliability for particular applications. Specifications may include the following considerations:

- Mechanical
- Electrical/electronic
- Light wave propagation
- Radio wave propagation (Obtain more data from Tropospheric Ducting Forecast)
- UV effects on optic materials & components
- Sand-blasting & similar effects on optic materials
- Moisture ingress and condensation
- Albedo (colours)
- Choice of materials, finishes, colouring methods for UV resistance
- Extreme thermal changes: daily cycle and wave-strike-induced shock.

5.1.1. MECHANICAL CONSIDERATIONS

The following considerations should be taken into account during the design, specification or procurement of AtoN equipment for use within hot or humid regions: -

- Differential expansion of dissimilar materials due to heat which may allow ingress of insects, dust or moisture into AtoN equipment.
- Rapid expansion and contraction of materials due to extreme changes in temperature may cause a permanent change in dimension, either totally or selectively.
- Packing, gaskets, seals, etc. may become distorted, bind, and fail when subject to extreme heat or humidity, causing mechanical or integrity failures. Gaskets may display a permanent set and seals may deteriorate more rapidly than would be reasonably expected.
- Moving parts may deteriorate or fail due to the effects of heat, humidity or dust.

To overcome the above factors some of the following can be considered:-

- Use like materials more suitable to the temperature and humidity ranges.
- Provide air gaps in the form of additional external housings.
- The use of 'Neoprene', for gaskets and seals; while not suited to colder climates is useful in hot climates due to its chemical inertness and resistance to heat and water.
- When was possible to use stationary lights must be implement than rotation beacons, to prevent future failures on moving parts.

Additionally, discoloration, cracking or crazing of plastic materials can be caused by the higher UV exposure.

To reduce this effect, manufacturers and authorities should ask suppliers of plastics AtoN for documentation on UV stabilisers and its rating. A product with the appropriate suitability should be chosen.

Moulders generally assess the long-term performance of their Polyethylene (PE) by referring to the raw material suppliers Technical Data Sheet (TDS). Most suppliers will include a statement on the materials UV characteristics in the TDS. The rotomoulding industry typically applies a UV rating system to measure performance. The most quoted UV rating offered around the world has been UV 8. UV ratings are critical, even when a TDS states the PE contains UV stabilisers. The use of products without a UV rating should be carefully considered, as the lack of a UV rating offers no guarantee against colour fade or severe UV degradation, which is a key issue in climates of extreme heat with long periods of strong sunlight.

An example of severe UV degradation can be seen in Figure 5.

A simple summary of the options typically offered to industry: -

- UV0 (no UV protection)
- UV4 (short term UV protection)
- UV8 (long term UV protection)
- UV16 ('longer' term protection)
- UV24 (exceptional protection)

Figure 5 Plastic buoys in Abu Dhabi/UAE–The effect of extreme sun light (UV) on the materials

5.1.2. BATTERY TECHNOLOGY AND CAPACITY

Extreme conditions should be considered when selecting battery technology (or battery technology supplied with an AtoN). For example, high temperatures can have significant effects on battery performance, with the degree dependent on the technology.

Some battery technologies exhibit significant changes in capacity, cell voltage, life cycle or charging restrictions, etc under extreme conditions and these should be taken into account when designing installations and prescribing capacity requirements (including solar capacity requirements).

When battery capacity is reduced by the effects of extreme temperature, the cyclic depth of discharge experienced by the battery could be significant, thereby reducing the lifetime of the battery. Consequently, in extremely hot climates, consideration should be given to increasing the battery capacity so as to reduce the cyclic depth of discharge and increase lifetime.

5.1.3. SOLAR PANEL PERFORMANCE

The effects of the direct sun light (UV) and the high heat damages solar cells thus reducing performance. The life span of a standard solar panel is around 15 years with an average output of at least 70% to 80%. However in reality, in hot climate regions an average of 40-50% over is achieved over a 10 year cycle. The reduction in output of the solar panel means that the charging current is insufficient, thereby reducing the battery life cycle. Units need to be replaced more frequently. The general AtoN performance and availability will be affected and operational costs may increase dramatically.

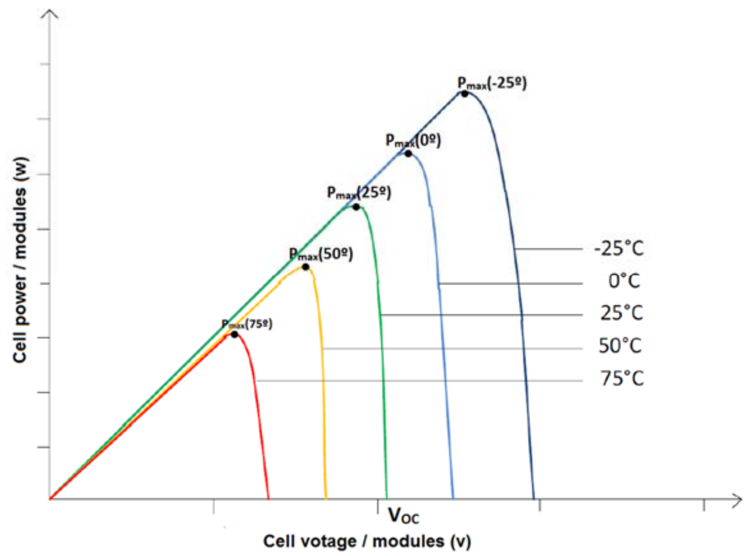


Figure 6 Impact of temperature in the power of a solar panel

As can be seen in Figure 6, increases in temperature can result decrease in power. Considering that manufacturers generally set maximum voltage values and photovoltaic module power for temperatures at around 25 ºC (Celsius degrees), it is necessary to take into account its energetic deficit for temperatures that may be up to twice as high. It may require over compensation in the design phase, which has it's a consequential increase in cost.

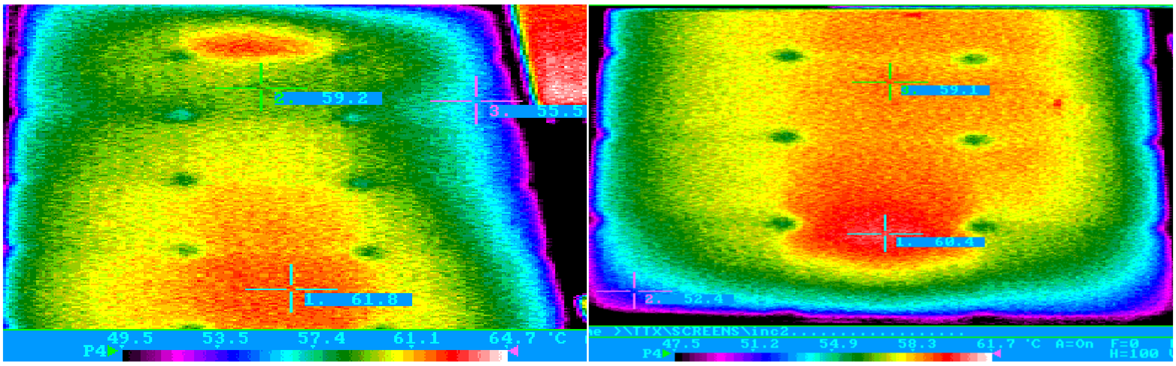


Figure 7 Thermal image of two photovoltaic modules being used in an extreme heat environment.

As observed above, the temperatures are not uniform across the entire module, caused by the border effect and a coating factor.

The output theoretical power of the solar unit is the term usually used to refer to the panel size or capacity, which does not always represent normal conditions because this value has been measured under Standard Test Conditions (STC): 1.000 W/m2 irradiation, and 25° C ambient temperature. These conditions are rarely experience in extremely hot environments.

It is established as global standard that for every 1° C above 25° C (77° F) - temperature set by manufacture for the technical operations-the unit will show a 5% fall in voltage.

The effects of the direct sunlight (UV) and the high heat damages solar cells thus reducing performance. The life span of a standard solar panel is generally 14 to 16 years with an average output of at least 70 % to 80 %. However in reality that achieved in extremely hot regions may be an average of 40-50 % over 10 years.

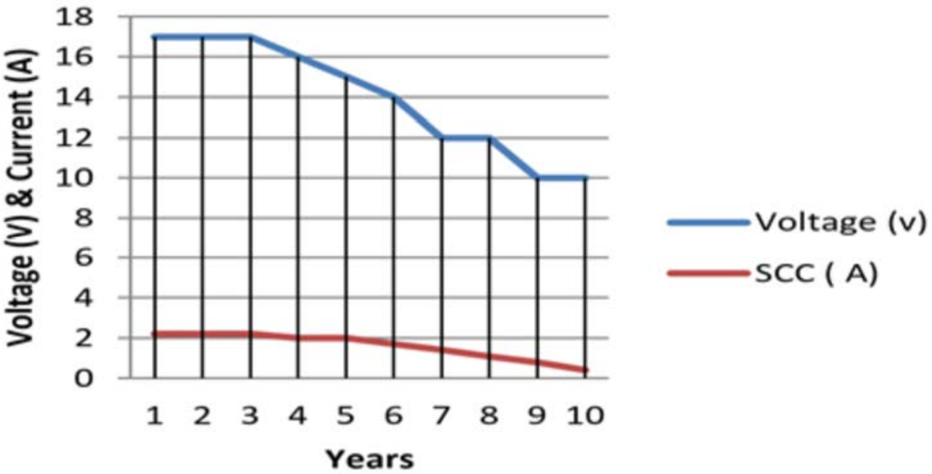


Figure 8 Power reduction over time of a solar panel deployed in an extreme heat environment

Consequently, solar panels could need derating for instantaneous performance under extremely hot conditions and additionally for the effects of long-term degradation in order to meet system requirements and to reduce negative effects on battery lifetime.

Competent authorities and service providers are recommended to implement a solar panel performance-check plan as part of their regular maintenance cycle.

5.1.4. CHOICE OF MATERIALS RELATING TO UV AND SAND-BLASTING EFFECTS

Ultra-violet radiation can affect the properties of both external and internal materials of an AtoN. The effects can result in a reduction in performance and/or lifetime of an AtoN.

Appropriate product selection and addition of redundancy might both need to be considered where the effects of UV radiation or surface abrasion by sand-storms could be significant. UV radiation could affect AtoN properties such as surface colour or optic transmissivity and might also degrade internal components of the optic head. Sand-storm abrasion could damage surfaces, such as those of optic elements, also leading to reduced optic transmissivity.

5.1.5. ATON EFFECTIVE INTENSITY PERFORMANCE AND LED PERFORMANCE

An AtoN maximum effective intensity is limited by the thermal parameters of the design as well as the ambient temperature and insolation (solar burden). Similarly, an AtoN maximum peak intensity might also be limited by environmental thermal parameters (typically to a lesser extent then the effective intensity). When an AtoN is required to operate in extreme temperatures (including the effects of insolation), the AtoN maximum performance specifications are likely to require derating. It could also be possible that the AtoN specified maximum operating temperature could be exceeded in which case it will either protect itself by reducing output intensity (or turning off), or it might be damaged if it does not include active protection.

Possible approaches to achieving the desired AtoN intensity performance and LED lifetime in extremely hot conditions include:

- Selecting a lantern with a higher maximum intensity specification than required so that the programmed required intensity is significantly below the AtoN maximum performance. (Assuming that the AtoN performance is specified at a temperature below that of the extreme conditions). This approach relies on the selected AtoN improved thermal design being able to offset the effects of the extremely high temperature environment.
- Selecting a lantern with a maximum intensity specified at or near the required extremely hot ambient operating conditions.
- Use of equipment that is rated or specific to operate in extreme heat and humidity. This may require development or a new AtoN product or enhancement of an existing AtoN product.
- Measurement during maintenance cycles of an AtoN performance over its lifetime can provide valuable information concerning the necessity for applying redundancy or compensatory adjustment to its intensity. Either or both of two strategies could be employed: applying an initial redundancy factor to the lantern's intensity, or; incrementally adjusting the intensity over time. Note that both procedures can put additional strain on both the beacon (in terms of raised internal temperatures) and on the battery (in terms of increased power consumption) and should be taken into account in the long-term specification of an AtoN installation.

As the maximum light intensity specification of an AtoN will always be affected by ambient temperature, optic transmissivity and insolation (solar burden) by a highly variable degree, especially so in hot and humid climates

Currently, AtoN specifications are based on ambient operating temperature ranges that generally exclude the requirements of extremely hot climates. Additionally, it is uncommon for manufacturers to offer sufficient specification information for AtoN that could be capable of operating in extreme climates. Thus, authorities/Service provider responsible for AtoN in extreme climates could have difficulty making informed choices in regard to both ATON selection and in planning for AtoN installation and maintenance.

Therefore, manufacturers and authorities/Service provider are encouraged to agree on a common set of operating requirements that reflect the critical parameters of an extreme climate. Perhaps, under IALA's aegis, an agreed set of regional requirements ('regions') could be developed and used as a foundation of AtoN specification and selection between manufacturers and authorities/Service provider. Under such a system, an authority might identify a regional requirement as a basis for identifying and selecting suitable AtoN product. Manufacturers could choose to offer AtoN performance specifications for selected regional requirements.

A light maximum intensity specification is a critical selection parameter that manufacturers could offer by region. For example, if regional requirements were classified by Maximum Combined Ambient Temperature and insolation then manufacturers could issue intensity performance derating information for AtoN using this classification system.

The following figures show the derating information for the same exemplary beacon based on a maximum combined ambient operating temperature. The exemplary beacon has a reference specification defined at 60°C and alternative specifications also provided for 40°C and 75°C. The alternative specifications could be provided in either absolute or relative performance units. In these equivalent examples it can be seen that the AtoN maximum performance depends on factors under user control (i.e. effective intensity and flash character) as well as on proprietary details of the manufacturer's design and the environmental operating conditions. Therefore, an AtoN manufacturer would need to provide a data set or formula to describe a range of parametric conditions for each defined operating temperature. A linear approximation of maximum AtoN performance would probably be adequate.

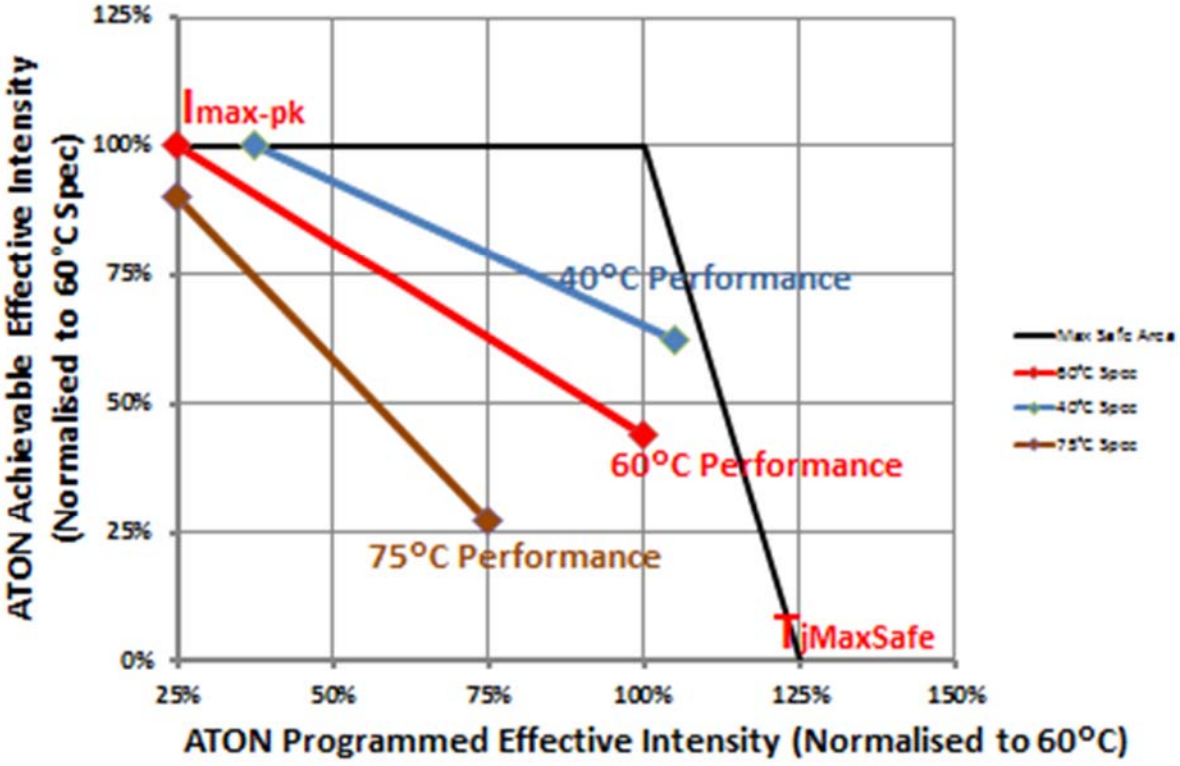


Figure 9 AtoN performance limits vs combined ambient temperature

5.1.5.1. AtoN LED Lumen Maintenance and Thermal Management

LED Lumen maintenance describes how much luminous flux an LED outputs after a certain operating time compared with its initial luminous flux. LED lifetime is a prediction of the operating time required before an LED's luminous flux output falls to 70% of its initial value. Both parameters include only the active operating time of any duty cycle experienced by an LED.

AtoN LED lumen maintenance and lifetime are strongly dependent on both the temperature of an LED's semiconductor junction and also on the simultaneous current in that junction. The maximum combined ambient temperature experienced by an AtoN has an influence on the LED junction temperature and in extreme climates it is entirely probably that the ambient temperature conditions have a significant to overwhelming effect on an LED's junction temperature. The other contributor to an LED's temperature is its own power dissipation which depends on its current and hence the intensity setting of the AtoN. Therefore, the hotter and brighter an AtoN, the shorter its lifetime is likely to be.

In principle, this parameter is designed to maintain a constant LED junction temperature across all regional specifications that are supported by an AtoN. Therefore, if an AtoN manufacturer supports this system of specification, only a single AtoN LED lifetime figure need be specified across all supported regions.

5.1.5.2. AtoN Over-Temperature Protection

In extremely hot climates, an AtoN could experience conditions that exceed its specified operating temperature range or even its safe operating temperature range. If its specified operating range is in danger of being exceeded then an AtoN could reasonably be expected to reduce its instantaneous effective intensity to protect itself from potential degradation or eventual damage. Typically, an AtoN operating according to the example described in 6.1.2.1 would actively reduce its LED current to maintain the LED junction temperature so that the designed LED lifetime is maintained.

If an AtoN is unable to maintain its LED junction temperature within design limits then LED degradation could occur and reduced intensity and/or shortened LED lifetime could be the outcome. Authorities/Service provider need to be aware of this fact and be prepared to enquire of manufacturers whether an AtoN supports active protection and how it functions.

An AtoN might experience sufficiently extreme conditions that a manufacturer considers it necessary to design it to shut down completely in such an event to avoid possible immediate, irreversible damage. An understanding of such full shutdown and recovery conditions are expected to be of critical concern to an authority.

Some of the consequences of AtoN over-temperature conditions that would likely concern an authority could include:

- An AtoN designed with over-temperature protection that is marginal for the extreme conditions could result in the AtoN spending a proportion of its deployed time disabled or performing at a lesser intensity than required by an authority.
- An AtoN designed with an over-temperature shutdown setting that is consistently exceeded during deployment will rarely or never work in the field but could likely operate correctly on the bench.
- An AtoN not including over-temperature protection that is deployed in extreme conditions could suffer permanent performance degradation and consequently a reduction in its usable lifetime.
- An AtoN that does not include over-temperature shutdown could suffer permanent performance degradation or damage upon, or shortly after deployment.
- Fixed-resistance resistors change in values.
- Electronic circuit stability varies with differences in temperature gradients and differential expansion of dissimilar materials.
- Operating/release margins of relays and magnetic or thermally activated device.
- Shortened operating lifetime.

5.1.6. Water Ingress

AtoN operating in extremely hot climates are susceptible to moisture and water ingress due to a number of factors. These include poor sealant design, inappropriate material selection, mishandling of AtoN or poor assembly procedures.

- Poor Sealant design: Consideration should be given to the differential thermal expansion rates of the various materials used in order to ensure good sealing integrity to reduce any moisture ingress. Thought should also be given to the protection of the electrical or electronic circuitry by the possible use of conformal coatings, resin gel together with the use of water resistant connectors and glands. In the case of navigation lights, self-contained or stand-alone it is recommended that a minimum IP rating of IP 67 (Annex A) is requested from the supplier.
- Material and component Selection: When selecting materials to be used, consideration should be given to the maximum operating temperatures on site, the UV protection rating of the synthetic materials used, the coating or paint to be applied and the IP (Annex A) rating of the cabling glands.

It should be a consideration that during final assembly the atmosphere within the manufacturer's production facility be as dry and controlled as possible in order to reduce the trapping of humid, moist air inside the navigation equipment. Any on site assembly needs to carefully consider the cabling route in and out of the AtoN to ensure the manufacturers IP (Annex A) rating is maintained. This will reduce the incidence of water ingress via cable entry (Support with IP (Annex A) rating index and pictures/pressure relief).

5.1.7. fixed AtoN

If specifying a fixed AtoN, consideration may be given to the following factors: colour contrast of support structure which will include colour retention and background lighting, bird fouling, and coatings. Reliability which will include but not limited to, appropriate material selection, correct positioning of hardware taking into consideration the local environmental conditions and landscape.

- Colour Contrast: Whichever raw material is selected for the fixed AtoN, the designer may consider using a material or paint system with the highest UV protection rating commercially available in order to reduce the cost of ownership.
- Fixing considerations: When attaching a fixed AtoN to a foundation, careful consideration must be given to the method of fixing. The use of chemical anchors should be used with caution as the operating temperatures may be lower than the ambient temperatures on site thus rendering them unreliable.

5.1.8. FLOATING ATON

When designing a floating AtoN, consideration may be given to the following factors: minimum colour contrast which includes colour retention, bird fouling, marine growth and coatings. Reliability which also includes, material integrity, appropriate material selection, correct mooring sizing in accordance with IALA Guideline N° 1066 whilst taking into consideration the local environmental conditions.

- **Visible Colour Contrast**: Whichever base material is selected for the floating AtoN, the designer may consider using a material or paint system with the highest UV protection rating commercially available, ideally UV 16 or higher is recommended. Written confirmation of protection performance may be requested and should be readily available from the supplier or manufacturer. As part of the contrast verification a measurement of the colour variation could be compared to IALA recommendation E-108 for confirmation of colour fade.
- **Coatings**: An appropriate coating and protection system should be applied in accordance with highest International standards to ensure long term material integrity and colour stability.
- **Reliability**: In order to maximise efficiency and reliability and reduce the cost of ownership of the floating AtoN, serious consideration should be applied to the operating environmental conditions and the quality of the components to be used. Particular emphasis should be placed on proposed site conditions in order for correct product selection. If a synthetic AtoN is selected, close scrutiny needs to be placed on the UV protection rating of the raw material. If material proposed has a protection rating lower than UV16 then the occurrence of mechanical failure is over a shorter period of time is highly likely.

5.1.9. ENERGY SOURCES AND STORAGE CAPACITY

In the majority of applications, and due to the remote or isolated nature of AtoN some form of energy storage system, usually in the form of a battery, is required. In these cases and particularly in the case of AtoN in extreme heat or humid conditions great care should be exercised in the selection of the battery. The following section highlights some of the considerations that authorities / service provider or manufacturers should take into account. For more details, refer Guideline N° 1067

There are a number of different battery technologies including:-

- Lead Acid (various technologies)
- Nickel Cadmium
- Nickel Metal Hydride
- Lithium Ion
- Developing technologies

Each technology has its advantages and disadvantages. Some technologies will be less suitable to operation in extreme climates. Some technologies could have safety issues under extremely hot conditions.

Lead-acid battery technologies are typically used for AtoN energy storage because of their low cost, adequate energy density and general suitability for solar charging applications (in terms of the random energy supply from solar panels).

Any battery technology will require compensation factors to be applied according to its predicted performance in an extremely hot climate. For example, lead-acid technologies display significant reduction in capacity at temperatures above 25°C and a compensation factor for this characteristic will likely be necessary.

Authorities/Service provider might need to take into account the method of battery autonomy calculation used in their or manufacturers' calculators. For example, a calculator's battery capacity prediction that is based on average maximum temperatures might need to be adjusted for long-term average maximum temperature trends if these are significant, or for peak temperatures if these latter conditions occur frequently. Guideline N° 1039 develop the calculators photovoltaic system, take into account the consumption and geographical location.

6. HUMAN FACTORS

6.1. GENERAL CONSIDERATIONS

Human factors in extremely hot and humid climates are one of the most critical aspects of AtoN delivery in these regions.

Human performance is severely affected in uncomfortable working environments and must be attended to in order to ensure safe and reliable delivery.

AtoN work is undertaken in a variety of different site environments. This may include working on structures or equipment directly under the sunlight or inside structures and lantern houses where temperatures and humidity may be higher than ambient conditions. Conditions will vary according to the location and this wide range of conditions must be considered.

Existing legislation pertaining to workplace safety should always form the basis for safety management and worker welfare; however the conditions associated with these extreme environments do exacerbate risks and therefore require additional appropriate controls.

In some parts of the world, the impacts of religious and cultural restrictions that may impact workers in extremely hot and humid environments need to be taken into account.

Guideline G1092 provides guidance on Safety Management concepts.

6.2. THE WORK ENVIRONMENT

It is important that workers understand the risks specific to working in extremely hot and humid environments.

The combination of heat and humidity can be hazardous for works that require a strenuous and prolonged physical activity outdoors.

Heat index values may be a useful guide to managing work activities in these environments. The heat index value, also known as real feel, either in Celsius (ºC) or Fahrenheit (ºF) according to the country, measures the real feel when the relative humidity combines with the real air temperature.

In some countries, this heat index (or real feel) can be used to set work alerts when temperatures and humidity exceed certain levels. These alerts should be set according to any existing legislation or where that is not available, according to internally set thresholds.

For example, the National Oceanic and Atmospheric Administration (NOAA) set the procedures for alerts when the heat index is expected to be above 121-128 ºF (equivalent to 49 a 54 ºC), dependent on these conditions being experienced for at least two consecutive days.

HEAT INDEX °F (°C)													
The heat index is an accurate measure of how hot it really feels when the affects of humidity are added to high temperature.													
	RELATIVE HUMIDITY (%)												
Temp.	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
110 (47)	136 (58)												
108 (43)	130 (54)	137 (58)											
106 (41)	124 (51)	130 (54)	137 (58)										
104 (40)	119 (48)	124 (51)	131 (55)	137 (58)									
102 (39)	114 (46)	119 (48)	124 (51)	130 (54)	137 (58)								
100 (38)	109 (43)	114 (46)	118 (48)	124 (51)	129 (54)	136 (58)							
98 (37)	105 (41)	109 (43)	113 (45)	117 (47)	123 (51)	128 (53)	134 (57)						
96 (36)	101 (38)	104 (40)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	132 (56)					
94 (34)	97 (36)	100 (38)	103 (39)	106 (41)	110 (43)	114 (46)	119 (48)	124 (51)	129 (54)	135 (57)			
92 (33)	94 (34)	96 (36)	99 (37)	101 (38)	105 (41)	108 (42)	112 (44)	116 (47)	121 (49)	126 (52)	131 (55)		
90 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	103 (39)	106 (41)	109 (43)	113 (45)	117 (47)	122 (50)	127 (53)	132 (56)
88 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	98 (37)	100 (38)	103 (39)	106 (41)	110 (43)	113 (45)	117 (47)	121 (49)
86 (30)	85 (29)	87 (31)	88 (31)	89 (32)	91 (33)	93 (34)	95 (35)	97 (36)	100 (38)	102 (39)	105 (41)	108 (42)	112 (44)
84 (29)	83 (28)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	92 (33)	94 (34)	96 (36)	98 (37)	100 (38)	103 (39)
82 (28)	81 (27)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	88 (31)	89 (32)	90 (32)	91 (33)	93 (34)	95 (35)
80 (27)	80 (27)	80 (27)	81 (27)	81 (27)	82 (28)	82 (28)	83 (28)	84 (29)	84 (29)	85 (29)	86 (30)	86 (30)	87 (31)

Figure 10 Heat Index value (Real Feel) Table. ºF - ºC Equivalence Vs Relative Humidity - NOAA National Oceanic and Atmospheric Administration

6.3. FATIGUE MANAGEMENT

Hot and humid environments can accelerate and increase the risk of worker fatigue.

Supervisors and team members should be able to identify and treat fatigue and there should be procedures in place to do so.

Fatigue may be magnified by heatstroke or sunstroke. This can cause violent headaches, drowsiness, sickness, loss of consciousness, high temperature and sunburn in extreme cases this can be fatal.

Fatigue management may be controlled by the following;

1. Regular hydration. This may include water, oral rehydration salts or other means.
2. Defined work and rest periods.
3. Distribution of work during suitable hours and shift management.
4. Rotation of staff.
5. Awareness and communication on the risks associated with fatigue.
6. Sun protection and allocation of shade or other means of cooling.

7. Provision of rest areas.

6.4. TRAINING FOR WORKING IN HOT AND HUMID CLIMATES

All workers should be familiarized through training, induction and awareness programs, of the risks that hot and humid work environments present to themselves and their co-workers.

There is some training available that contains components specific to working in these environments and this could be utilized where available, as an additional control.

Personnel nominated to work in these environments should be able to cope with the conditions and this may require acclimatization, especially if workers come from different locations.

Appropriate supervision and medical support (first aid kits, first aid officers) should be available on all work sites where extreme heat and humidity is an issue. These environments pose particular health risks and medical support should be appropriately equipped and trained.

6.5. PERSONAL PROTECTIVE EQUIPMENT (PPE)

PPE is a requirement on any worksite, regardless of conditions, however there are some special considerations in extremely hot and humid environments.

PPE that may be conventional in other work environments may not be suitable for work places affected by high real feel temperatures as they may increase worker discomfort.

Considerations should be made in regards to sun protection, material weight, material colour, design and breathability. Cold pack suits and other PPE cooling systems can also be utilized to increase worker comfort and avoid thermal stress.

Tool and equipment selection and storage is also an important consideration. Electrical tools may behave differently in extreme heat and humidity. Hand tools may become too hot to use. Appropriate selection and storage may avoid these issues.

7. ENVIRONMENTAL MANAGEMENT

Extremely hot and humid environments are often characterized by specific environmental profiles and AtoN can be located in places of ecological importance. This should be taken into account when working in these environments. The Guideline N° 1036 on Environmental Management provides guidance on how to manage environmental impact.

The increased maintenance needs of these environments does result in a higher frequency of visits and interactions with local habitats and therefore a higher level of impact. This can be considered during the design phase and when assessing risks and developing controls.

8. ACRONYMS

AIS	Automatic Identification System
AtoN	Aid(s) to Navigation
IMO	International Maritime Organization (Acronym style)
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
NOAA	National Oceanic and Atmospheric Administration
SCC	Solar Charge Current
STC	Standard Test Conditions
UV	Ultra-violet

9. REFERENCES

[1] Specific standards for hot climates regions– e.g. STANAG 2895

ANNEX A IP CODE, INGRESS PROTECTION RATING

The IP Code, Ingress Protection Rating, sometimes also interpreted as International Protection Rating, classifies and rates the degree of protection provided against the intrusion of solid objects (including body parts like hands and fingers), dust, accidental contact, and water in mechanical casings and with electrical enclosures.

The standard aims to provide users more detailed information than vague marketing terms such as waterproof. However, no edition of the standard is openly published for unlicensed readers.

The digits (characteristic numerals) indicate conformity with the conditions summarized in the tables below. Where there is no protection rating with regard to one of the criteria, the digit is replaced with the letter X.

For example, an electrical socket rated IP22 is protected against insertion of fingers and will not be damaged or become unsafe during a specified test in which it is exposed to vertically or nearly vertically dripping water. IP22 or 2X are typical minimum requirements for the design of electrical accessories for indoor use.

A 1. CODE BREAKDOWN

Table 1 Code Breakdown

IP indication	Solid particle protection	Liquid ingress protection	Mechanical impact resistance	Other protections
IP	Single numeral: 0-6	Single numeral: 0-8	Single numeral: 0-9	Single letter
Mandatory	Mandatory	Mandatory	No longer used	Optional

A 2. SOLID PARTICLE PROTECTION

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.

Table 2 Solid particle protection

Level	Object size protected against	Effective against
0	—	No protection against contact and ingress of objects
1	>50 mm	Any large surface of the body, such as the back of a hand, but no protection against deliberate contact with a body part
2	>12.5 mm	Fingers or similar objects
3	>2.5 mm	Tools, thick wires, etc.
4	>1 mm	Most wires, screws, etc.
5	Dust protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact
6	Dust tight	No ingress of dust; complete protection against contact

A 3. LIQUID INGRESS PROTECTION

The second digit indicates the level of protection that the enclosure provides against harmful ingress of water.

Table 3 Liquid ingress protection

Level	Protected against	Testing for	Details
0	Not protected	—	—
1	Dripping water	Dripping water (vertically falling drops) shall have no harmful effect.	Test duration: 10 minutes Water equivalent to 1 mm rainfall per minute
2	Dripping water when tilted up to 15°	Vertically dripping water shall have no harmful effect when the enclosure is tilted at an angle up to 15° from its normal position.	Test duration: 10 minutes Water equivalent to 3 mm rainfall per minute
3	Spraying water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.	Test duration: 5 minutes Water volume: 0.7 litres per minute Pressure: 80–100 kPa
4	Splashing water	Water splashing against the enclosure from any direction shall have no harmful effect.	Test duration: 5 minutes Water volume: 10 litres per minute Pressure: 80–100 kPa
5	Water jets	Water projected by a nozzle (6.3 mm) against enclosure from any direction shall have no harmful effects.	Test duration: at least 3 minutes Water volume: 12.5 litres per minute Pressure: 30 kPa at distance of 3 m
6	Powerful water jets	Water projected in powerful jets (12.5 mm nozzle) against the enclosure from any direction shall have no harmful effects.	Test duration: at least 3 minutes Water volume: 100 litres per minute Pressure: 100 kPa at distance of 3 m
7	Immersion up to 1 m	Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).	Test duration: 30 minutes Immersion at depth of at least 1 m measured at bottom of device, and at least 15 cm measured at top of device

Level	Protected against	Testing for	Details
8	Immersion beyond 1 m	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer. Normally, this will mean that the equipment is hermetically sealed. However, with certain types of equipment, it can mean that water can enter but only in such a manner that it produces no harmful effects.	Test duration: continuous immersion in water Depth specified by manufacturer

A 4. ADDITIONAL LETTERS

The standard defines additional letters that can be appended to classify only the level of protection against access to hazardous parts by persons:

Table 4 Additional letters

Level	Protected against access to hazardous parts with
A	Back of hand
B	Finger
C	Tool
D	Wire