 Input paper: [[1]](#footnote-1) ENG4-10.21

Input paper for the following Committee(s): check as appropriate Purpose of paper:

**□** ARM • ENG **□** PAP • Input

**□** ENAV **□** VTS **□** Information

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Technical Domain / Task Number 2 Develop guidance on AtoN design & maintenance for hot climates / 2.3.1

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Impact of hot climates on human performance and task maintenance of aids to navigation

# Summary

The purpose of this document is to identify the adverse effects generated by the combination of high temperature and relative humidity recorded during certain times of the year in some regions, analyse the different labor conditions associated to each specific task, define preventive actions necessary for a safe labour environment and determine the impact and gradual degradation on the equipment of aids to navigation.

## Purpose of the document

To expand on the problems caused by the effect of hot climate on human resources, equipment of aids to navigation and associated risks to the maintenance of the signaling system on board.

## Related documents

ENG 1 Input Paper - Provision of AtoNs in extremely Hot Climatic Conditions

# Background

ENG 1 Input Paper - Provision of AtoNs in extremely Hot Climatic Conditions

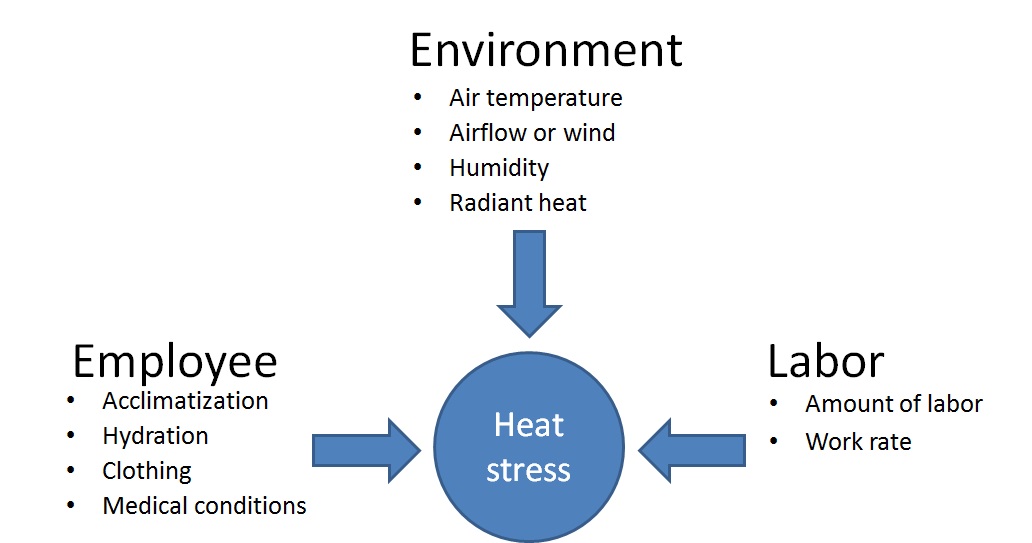
# EFFECTS OF HOT CLIMATE ON HUMAN BODY

The human body needs to maintain a constant body temperature and for that end it has physiological mechanisms that help keep it at 37 Celsius degrees.

Physical activity generates heat, but the body also absorbs it from the environment. When the physical activity is strenuous and the environment is hot, prolonged exposure to hot climate can become aggressive to the organism. The impact of this aggression would depend on time of exposure and the body's ability to dissipate heat, which depends on the metabolism of each worker.

The effects of the heat become apparent when the body cannot adapt to the high temperatures and this situation is extended for several days. These effects are enhanced in humid and windless climatic conditions, as can be the case for the tasks maintenance of the signaling system during summer in certain regions.

This heat load that the workers receive and accumulate in their bodies, resulting from the interaction of the workplace environmental conditions, the physical activity they do and the clothes they wear, is called thermal Heat stress.



1. Variables of the thermal stress cycle

## Consequences

It should also be considered the time exposure (length of work). Even when the thermal stress is not very high, the accumulated load heat, added to other factors such as obesity, age, health condition, prescribed medicine or lack of acclimatization to heat, among others, can become dangerous for the worker.

Excess of body heat can:

* Increase the probability of work accidents.
* Worsen previous health problems (cardiovascular, respiratory, kidney and skin diseases or diabetes, among others.
* Produce heat-related illnesses, such as :
  + - Sunstroke
    - Cramps
    - Dehydration / Exhaustion by heat
    - Heat stroke

**Sunstroke:**

* It is produced after a prolonged and direct exposure to the sun. Sunstroke can manifest in the form of violent headaches, drowsiness, sickness, loss of consciousness, high temperature, and in some occasions, skin burns. To face these health problems it is very important to cool the person off with air or water.

**Cramps by heat:**

* Muscle cramps usually come with excessive sweating. It is necessary to stop all activities, drink water and lie down for several hours in a cool environment. If the symptoms continue for more than one hour, it is necessary to contact health services.

**Exhaustion /Dehydration by heat:**

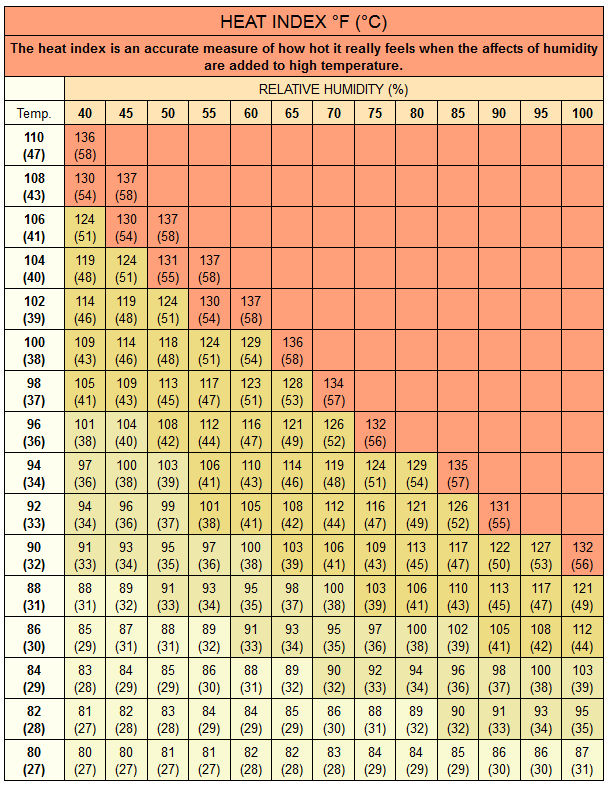
* They result from long hot journeys and profound sweating. They manifest in the form of fainting, weaknesses and weariness, sleeplessness and night anxiety. In these cases, it is necessary that the workers affected rest in a cool environment, drink water and consider the possibility of contacting health services if these symptoms worsen or continue.

**Heatstroke:**

* It results from the lack of control of body temperature, which rises drastically. It manifests in the form of hot reddish and dry skin, sickness and intense thirst, sleepiness and/or unusual aggressiveness, loss of consciousness and convulsions. In the presence of a crew member with a heatstroke it is necessary to get medical assistance urgently. Until assistance arrives and the vessel is docked, the affected person should be kept in a cool environment, with cold air and water, by means of a shower or wetting his garments.

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

There are heat alert procedures mainly based on heat index values. 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. Therefore, the National Weather Forecast set the procedures for alerts when the heat index is expected to be above 105-110 ºF (equivalent to 41 a 43 ºC), depending on the local climate conditions of at least two running days.



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

# HEAT EFFECS ON MAINTENANCE TASKS

Maintenance of aids to navigation systems implies widely differentiated work situations, though exposed to the same risk of thermal stress. This stems from the nature of the tasks to be carried out. A 100% are usually outdoor activities, as for the case of in situ maintenance of aids to navigation systems and to a lesser extent for the case of the personnel in charge of the maintenance of signaling at the workshops due to its volume and refrigeration difficulties.

This document has analyzed the potential risks of thermal stress in certain regions where the climatic conditions for the summer season create work environments with high temperatures and relative humidity. These uncomfortable and high risk situations in terms of workers’ health cause degradation of the aids to navigation equipment throughout time.

## Impact on personnel of buoy tender deck

Outdoor activities carried out during the maintenance of the aids to navigation together with sun reflection on water enhance the risks of thermal stress for workers since it is almost unfeasible to provide coverage or protection from the incidence of UV rays.

In the daily tasks of the maintenance of a signaling system there are practically no tasks that can be protected from the incidence of solar radiation due to the fact that the activities are carried out outdoor, with high volume elements and normally with the help of a crane.

* Withdrawal and relocation or re-installation of a floating or fixed signal.
* Replacement or reinstatement of photovoltaic or lighting equipment
* Replacement or reinstatement of moorings system or any other constitutive element of the signal.
* Maintenance of accessory elements of the signal, racon, among others.
* Maintenance of electrical equipment installed , such as AIS, weather station,
* Cleaning of signal and its components



1. Images of typical situations of the maintenance of aids to navigation system.

These diverse tasks that have been arranged together require different effort and solar radiation exposition periods of workers. This is why it becomes necessary to analyze the real workload of the maintenance work plan, thus preventing pressing or pushing the working conditions on board to the limits, situation that can be not alerted by the scheduling and monitoring personnel since they are not exposed to the same working conditions.

## Impact on the maintenance personnel in the workshops

The tasks of repair and maintenance of the signaling system in the workshops are also affected by hot climate and relative humidity since most of the workplaces of high volume elements, such as hulls, towers, structure reparations, surface treatments and painting are installations hard to refrigerate or to a great extent with outdoor work surfaces.

To the above mentioned, it must be added the protection that the worker should have to carry out the tasks safely, regardless of the PPE, such as special protection for surface treatments and welding.



1. Examples of personnel performing surface treatments tasks

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1. Examples of personnel performing welding tasks

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1. Examples of personnel performing painting tasks

### Climatization alternatives

At present, and considering the maintenance tasks to be carried out in the workshops, the implementation of forced humidified ventilation can be an option since it allows to modify the parameters of temperature and relative humidity.



1. Portable and fixed climatizer in operation

## Interferences in the use of Personnel Protection Elements - PPE

During the maintenance tasks of aids to navigation system the personnel involved should comply with specific safety requirements that compel them to wear Personnel Protection Elements (PPE), which under extreme weather conditions, such as the combination of hot climate and relative humidity they can interfere in the safety, convenience/ comfort, and health of the worker.

During maintenance of aids to navigation system in operation, a worker should wear:

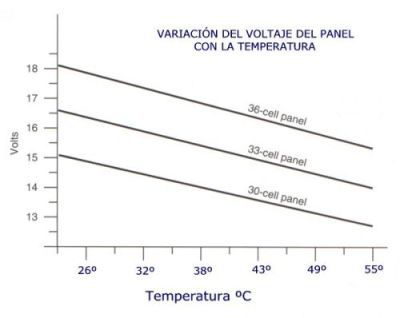
* Eye and facial protection during the normal performance of the tasks considering that the worker will be exposed to the projection of solid and/or liquid particles, or damaging radiations such as welding, among others.
* Head protection when there is risk of being injured by objects that may fall down or hit the worker, or if the work is carried out near exposed electrical conductors that can touch their heads.
* Adequate hand protection when the worker is exposed to danger such as the absorption of harmful substances, cuts, severe grazes, perforations, thermal and chemical burns on the grounds that hands and arms are more frequently injured that any other part of the body.
* Feet protection when the workers are exposed to heavy elements that may fall down or to cutting objects, leaks, cables, exposed electrical connections or the manipulation of chemical products or hydrocarbons.
* Ear protection when the workers are exposed to disturbing, irradiating or harmful noises considering that the loss of auditory sense is a common injury at work, which is usually disregarded as it manifests gradually.

This natural interference between the compulsory use of PPE and environmental working conditions may lead to a fall in safety standards due to the fact that wearing PPE in work places affected by high real feel temperatures usually produce discomfort.

# IMPACT OF hot climate ON EQUIPEMENT

## Solar panels

As the temperature increases, the solar cells decrease the voltage efficacy. It is not unusual then that a solar panel reaches temperatures above 50º C in summer, representing a voltage reduction of 15%.



1. Variation of voltage panel with change in temperature

The output theoretical power of the solar unit is the term usually used to refer to the panel size or capacity, which hardly ever operates under normal conditions because this value has been measured under standard test conditions (STC): 1.000 W/m2 irradiation, and 25ºC ambient temperature, which rarely happens in a day.

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.

**Example: :** in a clear andsunny day, the solar cell temperature will range from 25° to 30° C above ambient temperature. So, if ambient temperature is 20° C, the temperature of the cell can be 50° C (depending on the amount of time that the unit has been under the sun)

### Thermal characteristic of a solar panel:

The efficiency of a solar panel is affected by its thermal characteristics, which help predict the operation of the solar panel.

* Nominal Operating Cell Temperatura (NOCT):

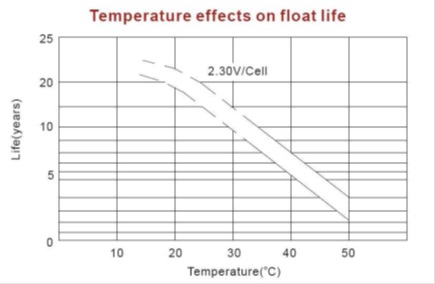
It has a direct relation with the temperature reached by the cells at a certain ambient temperature; the lower the temperature of the unit, the better it will work and the more power it will generate, as such, the NOCT should be as low as possible.

* Power temperature coefficient :

It shows the percentage loss of power output of the panel for every degree above 25ºC that the solar cells heated up; then it shall be as low as possible.

## Batteries

Batteries are designed to work within a wide range of temperature: from - 15ºC to 45ºC. The continuous use of the batteries at temperatures around 40ºC, even when the charge voltage for this temperature is corrected, enhances the risk of thermal runnaway and dry-out. This is due to the fact that according to the “Arrhenius law” the corrosion index doubles for every 10º C of positive increase of the operating temperature.



1. Battery aging curve with change of temperature

Hot climate with batteries in operation will produce an increase of cell temperature.

• Aging acceleration

• Spontaneous sulfation

• Dissolution of active matter

Other effects of high temperatures on batteries are voltage and float current variation, decrease of lifecycles and consideration for storage.

### Voltage and float current

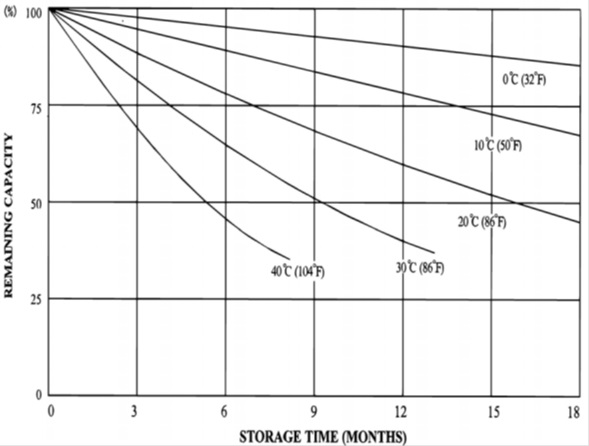
Float charge voltage for a temperature in operation above 25ºC should be adjusted due to the variation of the temperature range in excess in voltage production for every element in the battery.

### Life cycles

The batteries life cycles are highly affected by the battery temperature while in operation. Operation temperatures above constant 35ºC will reduce drastically the life cycles.

### Battery storage

Batteries should be stored in protected places, dust-free, dry and cold, and avoiding storage temperatures above 25 °C. Higher temperatures together with long periods of storage time can lead to the sulfation of the plates, resulting in a diminished residual capacity, and shorter lifecycles.



1. Discharge curve with change in time and temperature

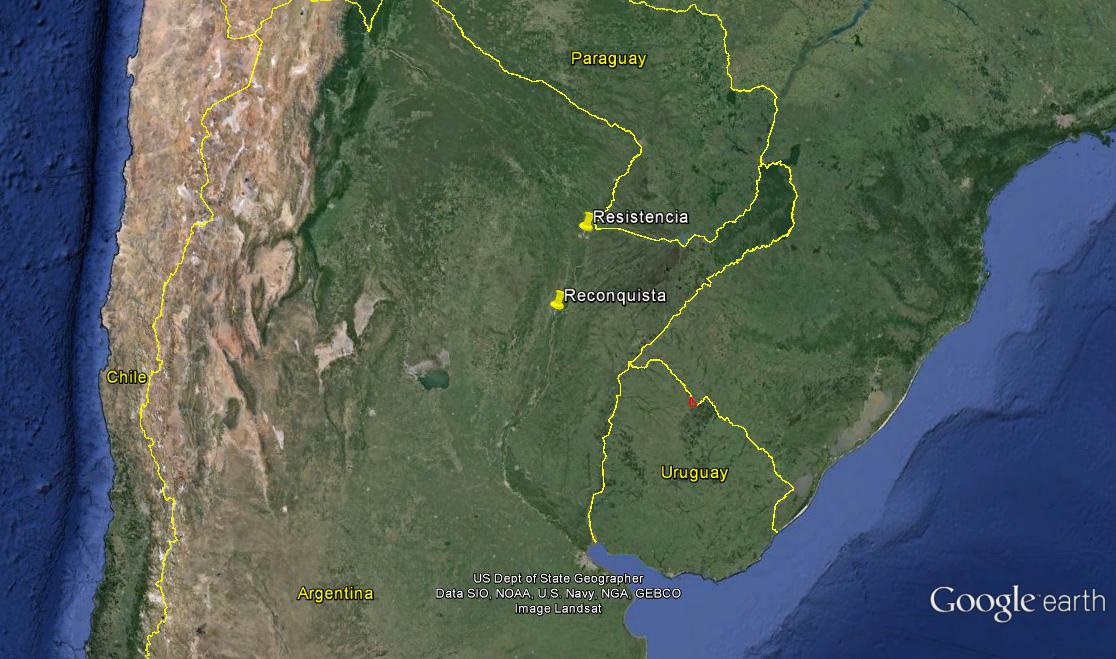
## Surface temperature measures

The effect of high ambient temperature is also reflected in the efficiency and accelerated degradation of the aids to navigation, be this the equipment or the conditions of the surface.

### In-situ temperature measures

This document has shown temperature measures of the lighting and photovoltaic system of the aids to navigation installed in Paraguay - Paraná waterway between the Argentine cities of Reconquista (province of Santa Fe) and Resistencia (province of Chaco).

* Reconquista: Latitude: 29º 14´03” ; Longitude: 59º 34´45”
* Resistencia: Latitude: 27º 29´24” ; Longitude: 58º 55´35”



1. Geographical Zone Analysis – Google Earth.

Surface measures of the devices installed in the navigation aids, such as the diopter of the torch, the battery, the exterior of the battery box and the solar panel evidence that they operate at temperatures higher than the specified nominals.



1. Temperature measures on the exterior of the battery box and on the battery



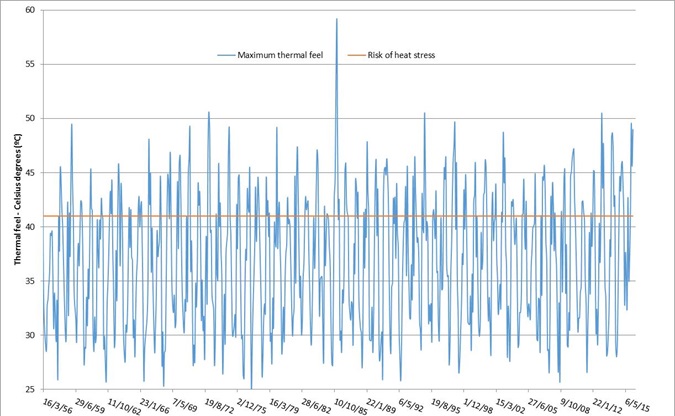
1. Temperature measure on the dioptric of the lantern and solar panel.

|  |  |
| --- | --- |
| Date | 19-02-2016 |
| Time | 09:55 AM |
| Ambient temperature | 41º |
| Port hand buoy km | 1096 |
| Latitude | 28º 09´37” |
| Longitude | 59º 05´14” |
|  | **Temperature** |
| Battery box | 39º |
| Solar panel | 43º |
| Battery | 51º |
| Lantern | 37º |
| Buoy surface | 35º |
| Buoy tender's deck | 37º |

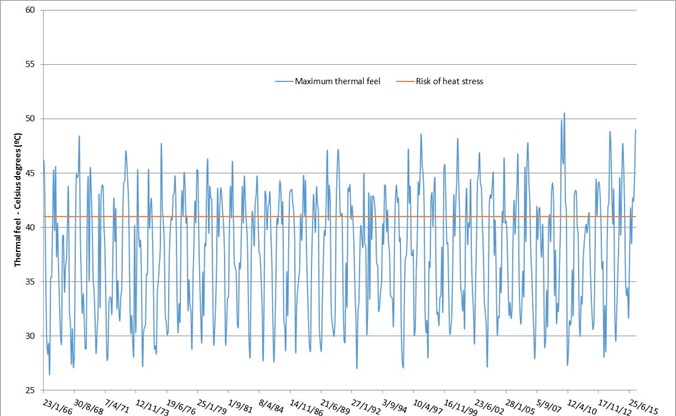
### Real feel record

The analysis of the real feel historical records of a sub-tropical region shows that the resulting weather condition in summer enhance the risks of thermal stress.

These high ambient temperatures and relative humidity usually last for periods longer than 2 days (the shortest period globally agreed before launching alert procedures). They do not even decrease at night which negatively impacts on the workers quality sleep.



1. Real feel record in Reconquista – 60-year period (1956-2016) - SMN National Meteorological Service.



1. Real feel record in Reconquista Resistencia – 50 year period (1966- 2016)- SMN National Meteorological Service.

# implementation of preventive measures

There are several ways to reduce thermal stress. All of them are based on simple principles but specific for every activity. It is then necessary to carry out a study of the work environment and activities performed before implementation.

As for this case study, that is, maintenance tasks of aids to navigation, the possibility to apply a protocol to prevent risk induced by thermal stress, is evident only in the form of general tips but applied to an integral context, they produce an efficient control framework to combat heat effects on human body.

* Avoid hard physical work on peak heat hours (workshop personnel + technician on board).
* Distribute the work in off-peak heat hours (morning/evening) and where possible for the workshop personnel, divide or reduce the work day.
* Be on the alert for weather forecast. Be aware of the variables that impact on thermal stress.
* Facilitate acclimatization to heat. This situation -usually disregarded- is crucial in places where the crew members are foreign, come from different latitudes or live far from the workplace. Acclimatization is not immediate; it is a gradual process that takes between 7-14 days during which the crew members should gradually increase their working hours (% of the normal working day) until reaching the 100% working day. There are also requirements for the use of Personnel Protection Elements.
* In the cases where it is not possible to air-condition the workplaces because the work is carried out outdoor or in big workshops, it is suggested to provide workplaces in the shade.
* Wear light clothes (cotton, for example), light colors and head protection. This type of clothing would allow the thin air layer trapped between the skin and clothes to protect the skin from direct contact with the environment air when it is hotter that the skin temperature, which is usually 35°C. It is best to wear loose clothes to help maintain this protective air layer. This is the reason why in hot desert climates people are covered from head to toe.
* Breaks can be a good opportunity to shower and cool down the body temperature. This can also be achieved by wetting the clothes.
* Drink large quantities of liquids (water, juices, even when not thirsty). Do not drink alcohol. Sweating is the natural mechanism for the cooling of the human body; for example, a 70kg person can have a sweating rate between 1.5 and 2 liters per hour. Water loss would prevent the worker from recovery during the working hours. Drinking water to quench thirst cannot be enough to be hydrated since thirst is usually perceived after a 1-2 liters of body water loss. It is for this reason that workers should be formed and informed about the benefits of a good hydration and the importance of a good hydration. Drink great quantities of liquid before exposure to heat stress.
* Design the installations, processes and equipment at work considering the environment temperatures; such is the case for the personnel of vessel machinery, hull or big workshops.
* Evaluate the need for job rotation due to heat risk.

Similar to the application of an Environmental Management Plan (EMP), there should be a preventive plan with specific measures to control the risk of overexposure to hot environments when it can be avoided, such as the activities of hull workers or machines of buoy tenders.

All the complaints must be considered and all work posts should be individually observed since even if temperatures may not be relevant, the heat conditions, there can be problems in the thermal balance of people or cases of special sensitivity.

# References

1. ENG 1 Input Paper - Provision of AtoNs in extremely Hot Climatic Conditions
2. Work in hot environments, Impact of high temperature in the workplace and Environmental factors in the workplace – ILO International Labour Organization and Spain / Argentine labour organizations.
3. Heat Index – NOAA National Oceanic and Atmospheric Administration and SMN National Meteorological Service.

# Action requested of the Committee

Consider this paper when developing guidance on AtoN design & maintenance for hot climates

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)