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

**□** ARM • ENG **□** PAP • Input

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

Agenda item [[2]](#footnote-2) 10.6

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

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Some considerations of the impact of temperature and relative humidity on Aids to Navigation in the Tropic

# Summary

The purpose of this document is to identify the adverse effects generated by the high temperature on the corrosion rate, solar panel performance and plastics properties and concrescences on 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 equipment’s of aids to navigation.

## Related documents

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

ENG 4 Input Paper - Impact of hot climates on human research and task maintenance of aids to navigation.

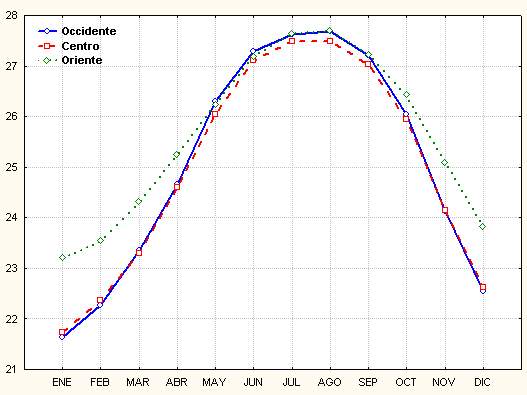
# Background

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

ENG 4 Input Paper - Impact of hot climates on human research and task maintenance of aids to navigation.

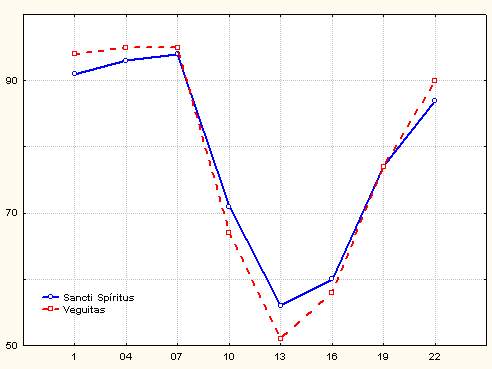
# EFFECTS OF temperature

Due to its geographical position, Cuba is located in really next latitude to the Tropic of Cancer, and temperatures are usually high. The average temperature ranges from 22 ºC to 28 ºC (Celsius degrees) and it may be higher in the eastern coast. The maximum average temperature registered ranges from 27 ºC to 32 ºC (Celsius degrees) and the minimum average temperature, from 17 ºC to 23 ºC (Celsius degrees).



1. Annual values of average temperature in three regions of Cuba for the 1981-2010 period

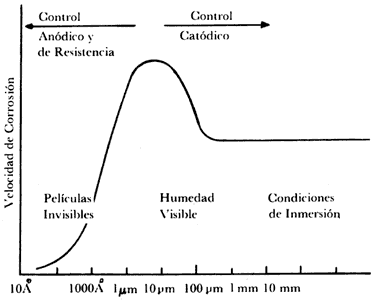
The average relative humidity stays very high, often around 80%. The daily highs are usually above 90%, and they occur at sunrise, while the minimum drops to 50-60% in the interior of the island, at noon. Rainfall is heavier in western and central areas and main mountain ranges.



1. Behavior of relative humidity during a day in two seasons of central and eastern Cuba

For more than half the year, the average temperatures are above 25 ºC (Celsius degrees) and the average relative humidity, around 80%. Due to its configuration and geographical location, the influence of seaspray extends to the whole national territory and it has become the main air contaminant, together with SO2, in areas with refineries or other oil processing plants.

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1. Corrosion rate for different humidity conditions

## Influence of temperature on the corrosion rate

It is well known that temperature increase is a factor to be taken into account in the analysis of the corrosion rate of metallic elements, either sheltered or outdoor. On the one hand, even when the corrosion rate is not directly proportional to the increase of temperature given that when the temperature is above a certain value, water evaporation and crystal conversion of diluted contaminants decrease the probability of corrosion, it cannot be denied the direct influence of temperature on the kinetics of the oxidation process of the metals exposed to solar radiation. On the other hand, in the whole national territory, it can be observed high moistening times with temperatures above 25 ºC (Celsius degrees) during the early morning hours, concurrent with relative humidity values around 90%. Under these circumstances, corrosion expands rapidly.

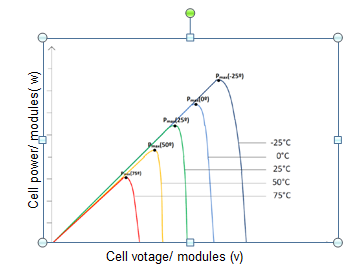
These conditions noticeably favor the decay of metallic structures, specially affected in areas of high and extreme corrosion aggressivity due to the influence of wind, which causes the expansion of sea spray. The costs to be considered to lessen the effects of corrosion are related to:

* Element substitution costs
* Designing costs
* Systematic maintenance costs
* Accident costs

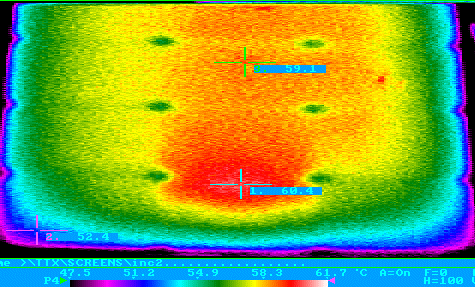
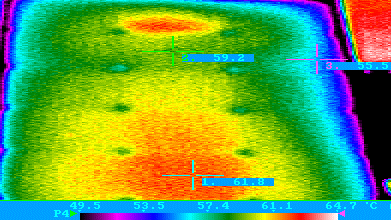
In industrialized countries, the cost of corrosion ranges from 4% to 5% of GIP (Gross Internal Product); for a country with limited economic resources, uncontrolled corrosion would lead to a dangerous reduction of the level of the services.

A geographical study of the operation zones and the characterization of the quality of the surrounding atmosphere is the action to be taken to determine what solutions could be adopted. The use of primary barriers based on hot galvanization has shown good results with affordable costs. In addition, at present there are primers available that -as secondary barriers- substantially improve the useful life of exposed metallic structures. Although the use of metals with low levels of corrosion is more costly, it can be the choice variable for more complex cases of industrial contamination in coastal environments.

## Influence of temperature on solar panel performance

At certain times of the day, an object exposed to sunlight in Cuba can reach temperatures around 70 º C (Celsius degrees). We shall consider, for example this value in the photovoltaic modules.

1. Impact of temperature in the power of a solar module



1. Thermal image of the two photovoltaic modules

As observed, the color is not uniform in all the useful area of the module, caused by the border effect and coating factor.

As it can be observed in the pictures above, increase in temperature can lead to an important power decrease. Considering that manufacturers 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 twice as high or even more. This may imply overdesign of the installations with its consequent additional cost.

## Influence of Solar radiation on plastic properties

Solar radiation includes ultraviolet rays (UV), visible radiation and infrared radiation. Plastic materials are synthetic materials obtained through a polymerization process or the multiplication of carbon atoms in long molecular chains of organic composites, by-products of oil and other natural substances. The mobility of these long chains depends basically on background temperature and, as expected, it directly affects the plastic properties.

Ultraviolet radiation is the most harmful; it leads to plastic decomposition and eventually to a degradation process even with the incorporation of protective agents. Temperature is an important factor in plastic degradation. In broad terms, the rate of chemical reactions increases with temperature, and plastics are not exception. On average, the rate of reaction doubles for every 10°C rise in temperature. As observed, temperature increase accelerates the plastic degradation process. For the case of plastics, due to their low thermal conductivity, surface temperature exposed to the sun can be above the ambient temperature and it can reach surface temperatures at around 100 ºC in August. In practice, some flaws in the torches used in aids to navigation are caused by temperature. As such, plastics get deformed, they soften up, the joints get mechanical failures, and sealings get affected allowing for salt penetration and eventual electronic failure.

To sum up, in the Tropic it would be impossible to build a system disregarding the impact of ambient temperature. Hot climate poses special demands on the design. The impact of temperature requires the use of high-quality and energetically efficient elements, which increases considerably implementation and maintenance costs.

# References

# Action requested of the Committee

Develop 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)