A new control engine room thermal comfort control system

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Abstract: - This paper proposes a new air conditioning control system based on general thermal comfort levels under real conditions aimed at reducing control engine room work risk. The results of this study showed an unsatisfactory environment in the control engine room and showed that the final environment will present a higher mean temperature, near the upper limit of thermal comfort and, consequently, a lower thermal shock could be expected.

Key-Words: - HVAC, control system, engine room, environment, risk, comfort.

1 Introduction
Some datasheets [1] list the hazards that a marine engineer is exposed to during his normal work activity. Of the hazards he encounters in his daily routine, the most important that he has to contend with is the sharp difference in temperature between the control engine room and his own engine room. As we can see from these datasheets what is of concern is not only the degree of heat or cold that a marine engineer is exposed, but also the duration of exposure and the relative change between environments. To reduce this workplace risk, it is proposed to change the limit values of the thermal comfort conditions in the control engine room and, therefore, a new thermal comfort control system must be designed. This new control system must take into consideration the difference between the thermal environments in the control engine room and the own engine room in the working conditions at all latitudes the ship may traverse.

Once the thermal parameters to prevent a work risk are identified, a comfort-based control [2] can be designed. Furthermore, with the air conditioning (HVAC) operating in that temperature range it is essential that the lowest possible operating cost of the HVAC installation is achieved [3]; likewise, modelling the heat dynamics of a ship could be a useful tool to predict its maintenance requirements and ensure adequate work risk prevention, by selecting insulation materials, analysing control strategies or designing a suitable heating system [4]. These techniques could be combined into neuronal networks, adaptive models, and regression models.

Consequent to this finding, the Department of Energy and Marine Propulsion of the University of A Coruña developed a new control system for indoor ambiences that is self controlled and reduces the thermal shock between two different ambiences, like the engine and control engine room of a ship and, thus can prevent workplace risk. This procedure is described here and was developed in this study with the aim of presenting a new tool for workplace risk prevention for future use in international shipping worldwide.

2 Materials and Methods
2.1 Indoor and outdoor conditions
The measuring apparatus used were a heat stress module and data loggers. Tinytag Plus 2 dual channel data-loggers with thermistor- and capacitive sensors were also installed to record temperature- and relative humidity values with accuracies of ± 0.2ºC and ± 3% RH, respectively. These data loggers sampled the temperature and relative humidity at sampling frequencies ranging from five- to ten minutes. The global temperature was sampled with a heat stress data logger AVM-40 (Kestrel 4000) of sampling range -29 to +70 °C and accuracy of +0.1ºC. Finally, the heat stress and the general thermal comfort indices were obtained in accordance with standard procedures and Fanger’s [5] index.

2.2 Software resources
Control system simulation, in accordance with real sample data, was done with Matlab Simulink.
This software is an environment for multidomain simulation and Model-Based Design for dynamic and embedded systems [6]. Therefore, its characteristics simulate the control system adequately.

2.3 Thermal comfort model
In this study, the methodology employed to define the thermal comfort model and sampling indoor comfort conditions conformed to ISO 7730 [7]. Once the comfort conditions were obtained they were utilized to develop a model for HVAC control system. In this context, the Institute for Environmental Research at Kansas State University, under contract with ASHRAE, has conducted extensive research on the subject of thermal comfort in sedentary regimes. The purpose of this investigation was to develop a simplified model to express the PMV in terms of parameters easily sampled in an environment. The subjects of study undertook sedentary metabolic activity dressed in normal clothes of thermal resistance approximately 0.6 clo. Their exposure to the indoor ambience was for three hours.

In accordance with ASHRAE, the PMV model can be adjusted to a 3-D model by applying Eq. 5.

\[ PMV = a \cdot t + b \cdot p_v - c \]  

To relate this model with indoor parameters like temperature and partial vapour pressure a curve fitting was done. The obtained model was then installed in the HVAC control system of Simulink Ham Tools to simulate real conditions. Finally, this procedure was compared with the adaptive- and fixed set point methods.

2.4 Matlab Simulink control system
Once we defined the thermal comfort model for the control engine room we could design a control system that allowed raising the indoor ambience to the highest limit of thermal comfort. Thus, the risk of thermal shock was reduced whenever a marine engineer from the engine room entered the required cold environment in the control engine room. The diagram of the typical control system is of the model developed for the air conditioning system. In this arrangement, variables used for control of indoor air are measured and compared with those in the desired reference. Using the resulting difference, the controller regulates the air-handling unit (AHU) and reduces the difference between the actual indoor air conditions and those proposed by the authors of the above quoted reference.

In our case study, two different HVAC systems were proposed and simulated under real conditions. Fig. 1 shows the blocks for a fixed temperature set point based on the typical set point values employed in the control engine room of ships.

![Fig. 1. PMV thermal comfort set point.](image)

Fig. 1 shows the variable set points of the HVAC control system. In this last system we can see that each proposed set point temperature depends clearly on the indoor temperature, relative humidity, and each of the model’s constants for heating- and cooling periods. The indoor temperature and relative humidity sampled in the control engine room are referred to as indoor T and indoor RH, respectively. With these values, the PMV index was derived from the calculated value of partial vapour pressure of the indoor ambience. Once we know the thermal comfort conditions of the control engine room we can change the indoor ambience towards its hottest extreme within the comfort limits of PMV=+0.5. In other words, we can attain a higher temperature. Finally, to simulate indoor conditions with respect to time and define our control system behaviour with Matlab Simulink, temperature and relative humidity of the indoor control engine room were fitted to a curve and adjusted to a sinusoidal shape.

3 Results and Discussion
It is commonly known that an air conditioning control system in the control engine room tends to lower the temperature to 20ºC. Despite this, marine engineers will want these values corrected for each different indoor situation of the voyage to reduce workplace risk of thermal shock and heat stress in contrast to that in the engine room where the typical values of temperature are in the region of 38ºC. Nevertheless, in practice this set point is almost never changed and, consequently, we find engineers suffer from headache and muscular pain.

As noted in datasheets the indoor temperatures in the engine room range from 28ºC to 38 ºC and represent the principal heat gain for the control engine room for Mediterranean sea voyage.
On account of this influence and in accordance with the typical indoor ambience obtained by the fixed temperature set point control system, the control engine room indoor temperature and relative humidity were close to 20°C and 40%, respectively. This low temperature could result in a physical hazard.

As a possible solution to this extreme environment, a self adjustment control system that took into consideration the indoor temperature and the relative humidity was proposed and the hottest set point temperature within the thermal comfort limits of P. O Fanger suggested was (PMV=+0.5). Matlab Simulink simulated this control system, the indoor temperature and relative humidity at the control engine room were sampled and curve fitted to enable easy simulation in the software, as shown in Fig. 2.

Once the control system was designed, it was used to simulate the sampled conditions representing the thermal comfort range within which we could work in the control engine room and compared them with actual data generated by the samples. This range is indirectly represented by the temperature and relative humidity curves of PMV=+0.5 in Fig. 2. This figure reveal that the new control system suggested a temperature of about 28°C and a relative humidity of 28% for a PMV of 0.5 and a value of 20°C. In our study, it was useful to set the control system in a PMV value of 0.5 because it would reduce the operator’s thermal shock when he came from work in the engine room and released the accumulated heat in the control engine room. Besides, this set point adjustment would prevent only physical hazards. This adjustment could be expected to reduce the working hours of the HVAC system and thereby extend the average life of equipment.

While these are the advantages, it was observed that this high temperature would reduce the environment’s relative humidity to very low values, and despite this being beneficial for the electrical environment human occupants could be expected to suffer dehydration.

A solution attempted for this last problem was to reduce the adjusted PMV to a lower value like 0.4, which would in turn reduce the indoor temperature set point and, consequently, raise the indoor relative humidity. Another possible solution was to increase the number of air changes per hour in the control engine room. In particular, using outdoor air would be especially advantageous because of its low values of temperature and high values of relative humidity. Finally, future research work is necessary to understand workplace risk and improve the work environment of marine engineers. Furthermore, a complete analysis of the hull engine room and control engine room must be done to design a better control system.

4. Conclusions
In the present study, indoor conditions of the engine room and the control engine room of a merchant ship were investigated during a sea voyage. Our findings were as follows: the low indoor temperature conditions observed in the control engine room were a definite source of physical hazards for marine engineers who came in from the hot environment of the engine room. To reduce this workplace risk, a new control system based on the general thermal comfort level was developed and the conditions simulated. This simulation, based on real data generated by the sample, showed the new expected environment that could be obtained. For example, indoor temperatures of 28°C were proposed whereby a reduced thermal shock could be expected. Besides this, these modifications could be expected to reduce the working hours of the HVAC system and thereby extend the average life of equipment.

Finally, for development of a suitable design to equip ships further research work that is carried out should analyse the hull engine room and control engine room completely.

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References:


