Analysis of thermal environment at a workplace: A case study in a jewelry shop

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ABSTRACT: The current paper presents the steps and conclusions of a case study about thermal environment in the watchmaker workshop section of a jewelry store. The employee's tasks include fixing watches, changing their batteries, occasionally engraving. The main goal of this work is to perform a series of thermal environment related tests, study their results and draw conclusions about possible ways to correct the problems found. For this purpose, it is necessary to test the thermal stress, using the Wind Chill Index (WCI), and the thermal comfort, resorting to the PMV (Predicted Mean Vote)/PPD (Predicted Percentage of Dissatisfied) index. It was also applied a survey to the employee, gathering his opinion on the subject. The results showed that the workplace in study does not represent a health risk to the worker, in other words there is no thermal stress, only discomfort.

1 INTRODUCTION

Amongst the many ergonomic factors that can be considered when analyzing a workplace, there is one that is related with the existent thermal environment at workplace, which can be characterized by a set of parameters that influence the human body. In occupational terms, it is a factor that is involved directly or indirectly with workers’ health and well-being, and consequently in the tasks which they are assigned. Frota (1995) states that “man has better living conditions and health when his body can operate without being subjected to fatigue or stress, including thermal.”

Risks related to the thermal environment stem from the difficulty of the body to maintain a normal and stable temperature. According to Miguel (2001), it is known that the problem facing thermal environments is homeothermy. The study of the thermal environment is divided into two parameters: thermal stress and thermal comfort.

The first one, stress, is by definition, according to the Oxford Dictionary (2009), "a state of mental or emotional strain or tension resulting from adverse or very demanding circumstances." Thus, thermal stress can be defined as "an environmental factor can influence the productivity of the work performed by an operator, leading to the workers reduced enthusiasm and increase of the rate of incidents, which may become accidents." (Yi & Chan, 2012).

Given the biological diversity between individuals, it is impossible that all occupants of a particular room feel thermally comfortable, hence it is important to create comfort conditions for which the largest percentage can feel comfortable. The ISO 7730 (2005) defines thermal comfort as “that condition of mind which expresses satisfaction with the thermal environment.” However, the definition given by this standard implies a certain degree of subjectivity, assuming the analysis of two types of aspects: physical aspects (thermal environment) and subjective aspects (the state of mind of the individual). According to Markov (2002), to satisfy all individuals within a given thermal environment is a difficult task.

Based on the previous, the main purpose of this study is to analyze the thermal environment conditions of a watchmaker, and determine the environmental and personal indicators of thermal stress and comfort. In other words, the parameters that influence the worker’s health and well-being.

This paper starts with a Theoretical Background in which some definitions are clarified with more detail in order to achieve a better understanding of what is explained in the following topics. In Methodology the workplace is described and some parameters, techniques and instruments used in this study and their functions are specified. Additionally, all the methods and calculations are properly explained. The next section is Results and Discussion in which the results of the study are presented and interpreted. Finally, some possible solutions are pointed out and the appropriate conclusions are drawn.
2 METHODOLOGY

2.1 Workplace description

The workplace in study is in a jewelry shop, specifically in the watchmaker's workshop. It was decided to focus on this workplace, since this is a job that requires a lot of attention and care with very meticulous tasks. In addition, it was also the workplace that was suggested by the management of jewelry shop. Regarding the choice of the parameter in question, there were two aspects taken into consideration: the work is very detailed, which implies a low metabolism and in addition there were some complaints from the worker regarding thermal comfort. This employee works 5 hours per day, with a break of 10 minutes, 6 days a week. His job consists of repairing watches, changing batteries, occasionally engraving jewelry pieces and performing tests in some pieces (to verify what material they are made of).

2.2 Data collection—equipment and methods

The analysis of the station's thermal environment was split in two parts: in the first the thermal stress and in the second the thermal comfort were thoroughly analyzed.

In order for these two parameters to be analyzed, knowledge concerning measurement units and characteristics relative to the current thermal environment in the work station were needed. These units were: dry bulb temperature; humid bulb temperature; air velocity; globe temperature and relative humidity.

The use of some specific devices was required in order to determine the parameters mentioned above.

To measure the dry and humid bulb temperature, a rotational psychrometer was used, expressed in Celsius degrees (°C). This device consists of two liquid expansion thermometers: the dry bulb one and the humid bulb one, which is involved in a cotton coating that has to be previously humidified by putting distilled water in the tank. The air velocity (m/s) was measured with a digital thermal anemometer from TSI VeloCheck Model 8370. The globe temperature was measured using a globe thermometer. This device consists of a hollow metal sphere, painted matte black, of variable thickness in order to maximize the absorption in the infrared area. This temperature is measured through a mercury thermometer inserted in the globe. Its bulb must be placed in the center of the sphere and is expressed in Celsius degrees (°C).

At last, the relative humidity is obtained using the psychrometer and the corresponding hygrometric ruler that is expressed in percentage (%). This ruler presents two intervals of measurement (A and B) and it is necessary to verify if the registered temperatures are in these intervals. Next, line A or line B is placed depending of the dry and humid bulb temperatures’ interval.

Regarding the measurements, it is important to refer that these were not made in the most critical conditions, as most of them were carried out in the afternoon period and during the winter. Following the measurements, an analysis of the thermal stress rate was made. This is a defined set of indicators that allows a precise evaluation of level of thermal stress that a worker is exposed to, regarding his/her physical activity and the conditions of his/her surrounding environment. The WCI (Wind Chill Index) method, the term used to describe the rate of heat loss of the human body resulting from the combined effect of low temperature and wind, was also applied by analyzing the WCC (Wind Chill Chart) using the previously measured air velocity and air temperature.

Afterwards, the thermal comfort was analyzed using the PMV/PPD rate (Predicted Mean Vote/Predicted Percentage of Dissatisfied). According to ISO 7730 (2005), PMV is a "index that predicts the mean value of the votes of a large group of persons on the 7-point thermal sensation scale, based on the heat balance of the human body and PPD is an index that establishes a quantitative prediction of the percentage of thermally dissatisfied people who feel too cool or too warm". For the purposes of this investigation, Standard, thermally dissatisfied people are those who will vote hot, warm, cool or cold on the 7-point thermal sensation.

In order to calculate the PMV/PPD rate, the previously made measurements were used, as well as an estimate of the worker metabolism, according to ISO 8986 (2004), as well as the thermal isolation of the clothing, according to ISO 7730 (2005) and the Comfort Calculator Program (Marsh, 1999).

At last, a small survey was conducted to the employee in order to better perceive his opinion regarding his workplace to complement the results of the analysis.

3 RESULTS AND DISCUSSION

To begin the objective analysis, measurements concerning thermal environment were needed, for which it was used the aforementioned devices. The values are presented in Table 1.

3.1 Thermal stress index

For the thermal stress index, in other words, the heat risk to which the worker is exposed, the Wind Chill Index (WCI) was needed. In order to fulfill this goal, it was crucial to resort to Figure 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Devices</th>
<th>Obtained values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry-bulb temperature (°C)</td>
<td>Psychrometer</td>
<td>14.9°C</td>
</tr>
<tr>
<td>Wet-bulb temperature (°C)</td>
<td>Psychrometer</td>
<td>12.0°C</td>
</tr>
<tr>
<td>Air velocity (m/s)</td>
<td>Anemometer</td>
<td>0.60 m/s</td>
</tr>
<tr>
<td>Globe temperature</td>
<td>Globe</td>
<td>15.0°C</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>Hygrometric ruler</td>
<td>75%</td>
</tr>
</tbody>
</table>

Figure 2. Wind Chill Chart (adapted from WorkSafeBC OHS Guideline 7.33-2).

After analyzing Figure 1, we can conclude that the workplace in study does not pose a health risk for the worker, because for a low estimated wind speed, the minimum temperature in which there can exist a health risk is 30°F, or -1.1°C, and the current work station temperature is around 58.1°F (or 14.5°C).

Even though a situation of thermal stress is not present, as the task required meticulous and is performed with bare hands for more than twenty minutes, and the environment is below 16°C, there are precautions that should be taken in order to keep the worker's hands warm.

3.2 Thermal comfort index

An evaluation of the thermal sensation and discomfort level experienced by the individuals was carried out, according to the PMV/PPD (Predicted Mean Vote/Predicted Percentage of Dissatisfied) indexes. In addition to the previously obtained parameters, there was still a need to estimate a few more parameters, allowing to calculate the aforementioned index. The results obtained are the following:

- estimated Metabolism = 70 w/m² = 126W
- estimated Icl = 0.91 clo

Ultimately, the Comfort Calculator (Marsh, 1999) software was used for automatically calculating the PMV/PPD indexes, presenting the obtained results in Figure 2.

To provide a neutral thermal environment, in other words, a comfortable thermal environment, the limit values from the aforementioned indexes should be between -0.5 and +0.5 for the PMV, and below 10% for the PPD.

From Figure 2, it is confirmed that the PMV obtained was -1.6, and the PPD 56.7%. This way, a conclusion is reached that a state of cold thermal discomfort is present, existing a considerable number of dissatisfied people.

In accordance with the survey filled by the worker, it was acknowledged that he feels slightly cold, and rather uncomfortable in his workplace.

4 SOLUTIONS

After the results, a "brainstorm" session was held to find possible solutions to the problem in study.

After analyzing the results of the "brainstorming" session, these were divided into constructive, organizational and individual protection measures (Table 2).

Some of the solutions were chosen to be described in more detail, as they can be implemented in the workplace. As for constructive measures it was thought that the most appropriate, easy to implement, and most versatile one will be the air conditioning, since it contains heating, cooling and dehumidifying functions. The jewelry shop can choose between two types of air conditioners: the portable air conditioner, which installation can be performed by the buyer and it can be transported to other locations. However, it has a
few disadvantages, such as the fact that it is noisy during operation and the power consumption is slightly higher when compared to other devices of the same power. And the split air conditioners, which are quieter because it possesses two units: an internal one, which is inside the workplace, and external one, in which the refrigeration compressor, the one responsible for noise, is located. In addition, they are more discreet and efficient than the rest. However, the installation must be done by a professional, which means that the apparatus price is higher. Thus, the final decision depends on the investment that the jewelry shop management is willing to make.

Regarding organizational measures, the worker can get hot drinks as there is an appropriate place in his workplace for that effect; he just needs to acquire the habit of doing so. However, this option should be adopted with healthy hot drinks, as the ingestion of some drinks like coffee can have other side effects. For this purpose, and if the worker has a smartphone, there is a mobile app that will help him remember to have his drink. In addition, there is another mobile app that warns the worker periodically, and prompts him to perform some workplace exercises, in order to get warmer.

Finally, and not holding a high cost, the worker should wear clothing fitted for his type of work, such as thermal sweaters and boots, in order to minimize the thermal discomfort he feels since his metabolism is very low.

5 CONCLUSION

The analysis carried out in this paper regarding the thermal environment, aims to determine whether the thermal conditions at a specific workplace are appropriate to the work done by the employee. In the analysis of heat stress using the WCI method, it is concluded that the worker is not in a thermal stress environment, in which his health will be at risk. However, as the ambient temperature is below 16°C and the tasks performed are manual and detailed, the need to implement a viable solution for hand heating arises, such as hot contact plates or radiant heaters.

Since there is no risk of thermal stress, a PMV/PPD analysis was performed in order to ascertain the existence of thermal comfort. From the calculation of the aforementioned index it is concluded that there is no thermal comfort, since the value of the PMV = -1.6, and it is expected that 56.3% of individuals are dissatisfied with the current thermal conditions. To complement this analysis, a survey was filled by the employee, and the results are consistent with the aforementioned analysis, by other words, the worker feels some discomfort and cold at work.

Furthermore, it is also worth noting that the measured relative humidity is 5% above that which is adequate to obtain a neutral thermal environment.

Thus, it is necessary to implement some solutions in order to reduce the discomfort felt by the worker. Some solutions suggested in this paper are: thermal boots and sweaters, air conditioning, a cap filled with salt used to remove any localized humidity, dehumidifier, among others. It is essential to remember that these solutions have been proposed through a brainstorm based on this case. These were analyzed and divided into categories. Some were then selected for a more detailed analysis.

It is thus concluded that the accomplishment of this paper was quite beneficial in the extent that it provided the housing of the knowledge acquired during the semester in the course of ergonomic workplace analysis, especially regarding the opportunity to apply theoretical knowledge to a real context in a greater depth. With the accomplishment of this paper it was also possible to discuss different ideas among members of the group, which helped everyone increasing their respective knowledge.

REFERENCES


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