

# Comfort Temperature and Lighting Intensity: Ergonomics of Laboratory Room Machine Tools

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**Abstract:** Laboratories that meet ergonomic standards will support the learning process, both academically and technically, to facilitate the growth and development of skills. This study aims to uncover and provide an overview and information about laboratory ergonomics standards which include thermal comfort (temperature), workspace laboratory lighting. This study uses a quantitative approach with a survey method carried out in the Machine Tool Unit Laboratory of the Department of Mechanical Engineering Education with a population of 60 students who are carrying out practicum. Techniques using direct observation and measurement. Lux Meter to measure lighting and then Digital Thermometer which functions to measure temperature at the observation point in the laboratory. Data collection starting at 07.00 until 12.00 and in the afternoon starting from 13.00 to 16.00, which is the time to do work activities. Measurements made at ten observation points the results showed that; (1) thermal comfort (temperature) with a value of 30.44 degrees Celsius, while the ideal practical standard ranges from 24 – 27 degrees Celsius; (2) Lighting with a value of 422.14 Lux while the ideal practice standard ranges from 500 – 1000 Lux. These results indicate that there is a tendency for temperature and lighting in laboratory rooms under conditions that are less than the standard set. To increase work productivity, these factors can cause less concentration and stress at work.

**Keywords:** Human Thermal, Productivity, Physical Condition, Workplace Design, Work Environment.

## 1. Introduction

Every day humans are involved in a different work environment condition where the different conditions significantly affect human ability [1]. Humans will be able to carry out their activities well and achieve optimal results if the work environment is supportive. Humans will be able to carry out their work well if supported by a pleasant work environment. A working environment condition said to be the right work environment if humans can carry out their activities optimally with a healthy, safe, and safe [2].

Irregularities in the work environment be a result for a long time. Furthermore, adverse environmental conditions can require more energy and time, which certainly does not support obtaining an efficient and productive work system design [3]. Workers need a comfortable work environment to be able to work

optimally and productively; therefore the work environment must handle and designed so that it is conducive for workers to carry out activities in a safe and comfortable atmosphere [4].

The environmental evaluation carried out by measuring workplace conditions and knowing workers' responses to exposure to the work environment [5]. The planning and design of work systems need to consider factors that can affect working environment conditions such as noise, lighting, temperature, and others. A working environment said to be good if, under certain conditions, humans can carry out their activities optimally [6]. Incompatibility of the work environment with humans who work in the environment can see its impact within a specified period. Work environment factors, tools, and methods significantly affect productivity. To get high

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productivity, these factors must be compatible with the abilities, abilities, and limits of human workers [7].

Adams and Berlin [8], stated that the decrease in work productivity in workers is mainly due to the existence of work fatigue. International Labor Organization [9], states that the factors that influence the occurrence of work fatigue are the existence of work monotony; the disproportionate intensity and duration of mental and physical work; work environment, weather and noise factors; mental factors such as responsibility, tension and the presence of conflicts; and the presence of diseases, illness and inadequate nutrition [10].

The facts in the field show that laboratory conditions that are not comfortable can cause difficulties and often there are inconsistencies in carrying out the work or in data analysis so that it can cause negligence that results in work accidents. The occurrence of errors in work processes that can trigger the occurrence of accidents shows that the occurrence of work errors mostly caused by an error in the design because several work equipment designed not following the physical condition of the operator. In this regard, one thing that needs to consider in supporting the learning of machine tool practicum is the aspect of structuring the work environment by paying attention to ergonomic aspects, so students feel comfortable and easy to adjust to the level of the work process, and can be skilled and independent in completing practical work. Once the workspace or practicum must design in such a way as to create a work climate that is conducive and comfortable [11].

Feeling comfortable is very important biologically because it will affect the performance of human organs while working. Deviations from the comfort threshold will cause functional changes that will ultimately affect the physical and mental health of workers [12]. Humans will be able to carry out their activities well and achieve optimal results if the work environment is supportive. Right environmental quality conditions will provide a sense of comfort and health that supports human performance and productivity. The quality of a pleasant work environment and by human conditions as workers will support the work performance and productivity produced. Control and handling of work environment factors such as noise, temperature, vibration, and lighting are problems that must deal with seriously and continuously. Noise, hot temperatures, vibrations, and poor lighting in the workplace are among the sources that cause work pressure and decrease work productivity [13].

The ergonomics approach has caused the human mindset about designing technology (products) to change [11]. In other words, now humans no longer must adjust to the technology they operate, but rather the technology designed by first considering the strengths and limitations of humans who operate it [14]. Ergonomics is an interdisciplinary scientific approach from the application of the principles of human behavior to the design of human

systems with machines directed at adjusting to machines and auxiliary equipment, to improve performance with conditions that are safe, comfortable, efficient, healthy and safe at work [15]. The purpose of applying ergonomics is to (1) Improve work performance (increase work speed, accuracy, work safety and reduce excessive work energy and reduce fatigue); (2) Reducing time wasted and minimizing equipment damage caused by "human error," and (3) Improving human comfort at work. The results of this study will contribute in the form of recommendations on ergonomic standards for the physical environment in the development of the Laboratory.

## 2. Research Methods

### 2.1. Study Approach

Referring to the description of the formulation of the problems that have raised, the design of this study uses a quantitative approach with a survey method, in which the researcher describes quantitatively, trends, behaviors or opinions of a population by examining the population sample [16]. This design aims to analyze the ergonomics of the existing work environment in the machine tool unit laboratory in terms of thermal comfort (temperature) and room lighting.

### 2.2. Location and Respondents

The study conducted at the Laboratory of machine tool units at Universitas Negeri Makassar. The reason for choosing the location is because of the availability of supporting facilities and infrastructure such as laboratories, workshops, and complete workshops.

The participants who were directly involved in data collection activities were students who were carrying out the practicum. The number of students who are carrying out a practicum machine tool practicum consists of two classes with 30 students each. The time of the activity adjusted to the practicum schedule of the students of the machining engineering expertise program which held on Monday and Tuesday in August – October 2018.

### 2.3. Data Collection

In research, data collection on environmental aspects uses the help of some equipment, namely Lux Meter to measure lighting and then Digital Thermometer, which functions to measure the temperature at the observation point in the laboratory. Data in the form of questionnaires and discussions also applied in this study to obtain responses from workers about the work environment namely lighting, room temperature.

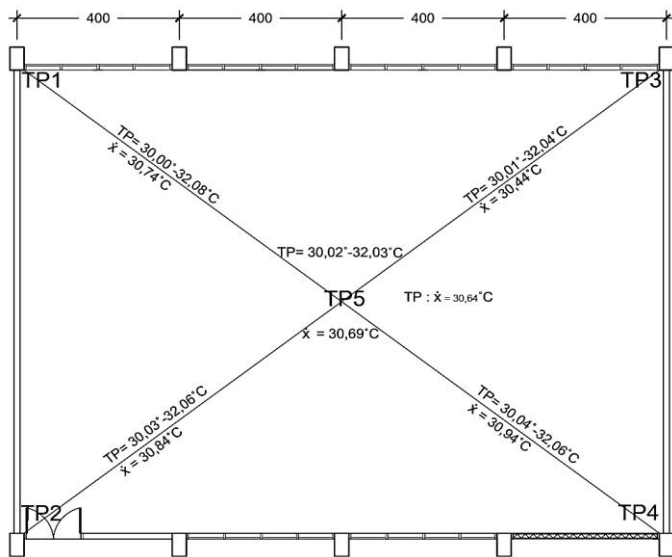
Data collection for temperature and lighting carried out in the morning starting from 07.00 until 12.00 and in the afternoon starting from 13.00 to 16.00, which is the time to do work activities. To maintain the accuracy of the

data, measurements made at ten observation points in the machine laboratory room.

### 3. Result and Discussions

#### 3.1. Thermal

Thermal is one of the essential aspects of ergonomics in the work environment both physically and non-physically, which can have an impact on employee performance or productivity [17]. The observation points for temperature measurements that have obtained can be presented in the figure as follows.



**Figure 1.** Temperature Measurement Observation Points at the Machine Laboratory.

Thermal comfort must meet so that students who are doing activities in the environment can be more productive [18]. The results of temperature measurements that have obtained can be presented in the following table.

**Table 1.** Results of Temperature Measurement at the Laboratory of Machines.

| No. | Observation Point | Observation Point (° C) |       |       |       |       |
|-----|-------------------|-------------------------|-------|-------|-------|-------|
|     |                   | TP1                     | TP2   | TP3   | TP4   | TP5   |
| TT  | 07.30-08.00       | 30.00                   | 30.01 | 30.02 | 30.01 | 30.02 |
| TT  | 08.00-08.30       | 30.01                   | 30.01 | 30.01 | 30.01 | 30.01 |
| T1  | 08.30-09.00       | 30.00                   | 30.00 | 30.00 | 30.00 | 30.00 |
| T1  | 09.00-09.30       | 30.01                   | 30.02 | 30.02 | 30.01 | 30.02 |
| T2  | 09.30-10.00       | 31.02                   | 31.01 | 31.02 | 31.02 | 31.02 |
| T2  | 10.00-10.30       | 31.01                   | 31.02 | 31.01 | 31.03 | 30.02 |
| T3  | 10.30-11.00       | 31.04                   | 31.03 | 30.02 | 31.04 | 31.03 |
| T3  | 11.00-11.30       | 32.08                   | 32.08 | 30.05 | 32.06 | 32.03 |
| T4  | 11.30-12.00       | 32.04                   | 32.03 | 32.04 | 32.03 | 32.02 |
| T4  | 12.00-12.30       | 30.08                   | 30.07 | 30.08 | 30.04 | 30.05 |

Based on the results of measurements and tests, it is known that the average temperature of the work environment is 30.64 degrees Celsius. If referring to the

standard or recommendation regarding the room temperature threshold value that is allowed in workspace in the industry in accordance with the Regulation of the Indonesian Minister of Health on the standards and requirements for industrial work environment health, then for turning work with an allocation of work and rest time of 50 – 70 percent, with the mild category having a threshold value of 31.0 degrees Celsius, students who do practicums can be categorized as potentially experiencing physiological effects (heat strain) [19].

Indonesia generally acclimatized to a tropical climate with temperatures around 29 – 30 degrees Celsius with humidity of 85 – 95 percent. Acclimatization of heat means an adjustment process that occurs to a person during the first week at work. After the first week of being in a hot place, labor able to work without the influence of heat stress; this depends on the acclimatization of everyone as seen from the workload so that work variations needed.

Geographically, Indonesia is on the equator and has a tropical climate. Tropical regions according to temperature measurements are tropical regions with average temperatures above 20 degrees Celsius, Indonesian regions have average temperatures that can generally reach 35 degrees Celsius. Furthermore, Indonesian territory has a high humidity level, which can reach 85 percent. This situation occurs among others due to the position of Indonesia, which is at the meeting of two extreme climates (due to the position between two continents and two oceans). This condition makes Indonesia less profitable for students in doing work activities because student work productivity tends to decrease or low if it is in a working environment that is too cold or too hot. Comfortable thermal temperatures for Indonesians are in the temperature range of 22.8 – 25.8 degrees Celsius with humidity of 70 percent.

SNI (Indonesian National Standard) [20], states that a comfortable temperature for conducting activities is in the range of 22.80 – 25.80 degrees Celsius. With the measurement results obtained, it is quite far from the permissible comfort limit. It is due to an increase in temperature the more the day, the higher. At this temperature, mental activity and responsiveness begin to decrease and tend to make mistakes in work so that it can cause physical fatigue. The heat of the workspace caused by the heat of the production machine and the lack of air ventilation. Incoming sunlight, besides useful as lighting can also increase the room temperature. Too hot temperatures reduce agility, extend reaction time and decision-making time, interfere with the work of the brain, disrupt the coordination of sensory and motor nerves, and make it easier to stimulate.

Conditions of the work environment with inappropriate temperatures can influence performance degradation, but it also influences human psychology in their work [21]. The ways that can do to reduce the condition of hot air, including by improving ventilation and

open space designed so that it feels quite comfortable, and workers get enough fresh air. It also can be by installing a fan or exhaust fan so that it can help the room's ventilation system to reduce the humidity in the workspace.

Hot workplace temperatures will affect work performance. Work productivity will reach the highest level if the worker works at a temperature of 24 – 26 degrees Celsius. Besides, hot working temperatures also quickly lead to fatigue, so workers easily lose concentration resulting in accidents quickly. Humans obtain thermal balance with the environment in a relatively narrow range ( $37 \pm 1$  degrees Celsius). To survive, the acceptable limit for the inner core body temperature is between 35.5 to 39.5 degrees Celsius. The skin can tolerate a more extensive temperature range with a limit between -0.6 degrees Celsius (frozen skin) and 45 degrees Celsius (skin starts burning). Thermal balance occurs when body heat generated according to the level of heat loss through physiological processes. The body produces heat through metabolism and muscle activity not related to external work, and heat exchange with the environment through several processes [22], [23].

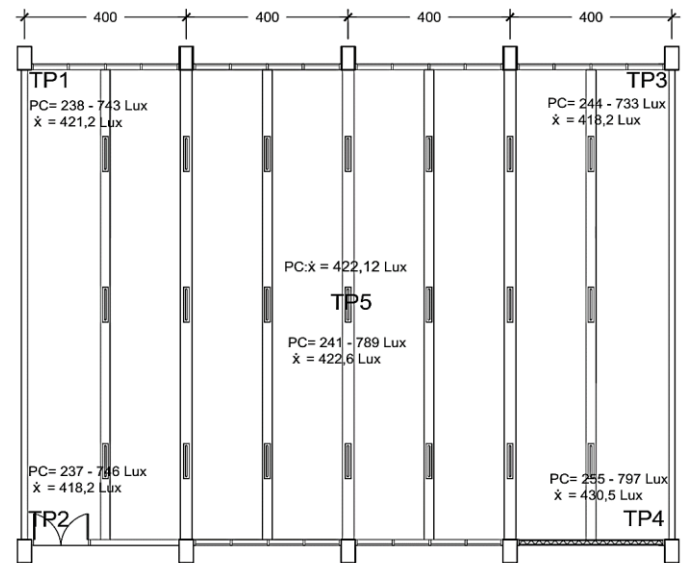
Another fundamental factor of indoor environmental quality is the temperature in the room. This has a significant impact on human psychology, and physical conditions, as a result, can affect behavior and productivity at work [24], [25]. For example, a meta-analysis of temperature and productivity works found that temperatures between 21 – 22 degrees Celsius will increase productivity, and when temperatures rise between 23 – 24 degrees Celsius productivity starts to decrease relatively. When temperatures reach 30 degrees Celsius, only 91.1 percent of the relative productivity observed. Therefore, this would suggest that the optimal temperature for relative productivity reached between 21 – 24 degrees centigrade [26].

In research about the relationship between a decrease in room temperature and productivity in work which includes the type of routine work done in the office and physical and mental work done in laboratories. From the results of the study, it found that the influence of temperature seen to be more dominant in affecting the physical and mental work performed in a laboratory room compared to routine work performed in an office space. The visible effect of comfort in working room temperature can be seen from the decrease in motivation at work [27]–[31].

### 3.2. Lighting

Humans need lighting to visually recognize an object where the organs of the body that affect vision are the eyes, nerves, and nerve center of vision in the brain. In many industries, lighting or lighting influences product quality. High, low, or blindingly strong lighting effects both eye fatigue and nervous tension of workers whose workplace lighting is inadequate or not up to standard. In other words,

it can explain that the main function of workplace lighting is to illuminate the work object so that it is visible, easy to do quickly, and productivity can increase. Lighting both high, low, and dazzling affect eye fatigue and nervous tension. To obtain optimal lighting quality [32], [33].



**Figure 2.** Lighting Measurement Observation Points at the Machine Laboratory

Proper lighting allows workers to see the objects they work, quickly, and without unnecessary efforts. More than that, adequate lighting gives the impression of a better view and a refreshing environment [34]. The lighting level factor to support the visual aspect; humans need an illumination to recognize an object. The lighting observations or measurements that have obtained can be presented in the following Table 2.

**Table 2.** Results of Lighting Measurement at the Laboratory of Machines.

| No. | Observation Point | Observation Point (Lux) |     |     |     |     |
|-----|-------------------|-------------------------|-----|-----|-----|-----|
|     |                   | TP1                     | TP2 | TP3 | TP4 | TP5 |
| TT  | 07.30-08.00       | 238                     | 253 | 244 | 255 | 242 |
| TT  | 08.00-08.30       | 245                     | 237 | 245 | 257 | 241 |
| T1  | 08.30-09.00       | 297                     | 291 | 294 | 296 | 245 |
| T1  | 09.00-09.30       | 367                     | 366 | 368 | 369 | 367 |
| T2  | 09.30-10.00       | 425                     | 435 | 453 | 465 | 483 |
| T2  | 10.00-10.30       | 442                     | 421 | 437 | 446 | 434 |
| T3  | 10.30-11.00       | 425                     | 415 | 414 | 411 | 414 |
| T3  | 11.00-11.30       | 396                     | 386 | 379 | 374 | 366 |
| T4  | 11.30-12.00       | 743                     | 746 | 733 | 797 | 789 |
| T4  | 12.00-12.30       | 634                     | 632 | 615 | 635 | 645 |

Based on the results of measurements and analysis, it is known that the average lighting, if measured from the light intensity of the room in the workshop, is 422.14 Lux which is below the standard threshold value. Based on the work environment quality standard, the lighting for the



space used to do work that requires accuracy is 500 – 1000 lux [20]. It is shown that lighting at work can be said to be wrong. Bad lighting directly will not cause damage to the eyes, but often cause fatigue and discomfort while lighting that is too high/strong is also undesirable because this situation can cause glare in the eyes. Hopkinson and Collinns [35], states that lighting problems include the ability of humans to see things, the characteristics of the sense of sight, efforts made to see objects better and the effect of lighting on the environment.

Parts of the body that affect vision, namely, eyes, nerves, and nerve center of vision in the brain. High illumination strength, low, and blinding effect on eye fatigue and nervous tension. If a study room has a level of lighting that is less or excessive, it will affect the physical state of students or users of the room, which impacts quality and productivity. In contrast to research conducted by Seppanen [36], that in the workspace after replacing fluorescent lamps with LEDs the subjective feeling in typing difficulties reduced but there is no noticeable improvement in performance. This phenomenon is consistent with previous findings that satisfaction is not related to cognitive task performance [37], [38].

Lighting for workshops should be designed with enough lighting levels to work with various levels of accuracy, especially in machining jobs which usually require a relatively high level of precision. It is in line with Loe [39], which states that the design of lighting installations for educational spaces adjusted to the needs of room use such as for libraries, laboratories, workshops or lecture halls. Each room has different lighting intensity needs. The quality of lighting, noise, psychology is an essential factor in the work environment in improving employee morale which can ultimately affect worker productivity [40]–[42]. Lighting at work significantly affects work productivity, where good lighting allows workers to see objects that do clearly and quickly, in addition to adequate lighting gives the impression of a better view and a refreshing environment, to reduce work fatigue and increase work productivity [43], [44].

According to Grandjean [45], lighting that not well designed will cause visual disturbance or fatigue during work. Influence and lighting that does not meet the requirements will have an impact, namely: 1) Eye fatigue so that the reduced power and work efficiency; 2) Mental fatigue; 3) Complaints of aches in the eye area and headaches around the eyes; 4) Damage to the senses of the eye and others. Furthermore Armstrong [46], states that the low intensity of lighting can cause visibility and eye strain disturbances. Conversely the intensity of excessive lighting can also cause glare, reflections, excessive shadows, visibility, and eye strain. The more beautiful the work and the inspection and quality control, or more elegant the details and the less contrast, the higher the illumination needed, between 500 lux to 100 lux.

## 4. Conclusions

Productivity at work can be improved by adjusting the size of the workplace to human capabilities and limitations. Workplaces that are adapted to humans include improving the accuracy of using the body, the work environment, in this case, is the temperature and lighting of the room then the other aspects are the work position and nutrition of food intake consumed. If the ability to work (ability) can increase, then the work delay can reduce or the time needed to do something in one unit can be shortened so that productivity can increase.

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