Using of Deming cycle to evaluate climatic conditions at workplace

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Abstract: Classic Deming Cycle is a method of gradual improvement of quality of products, services, processes, applications and data running through repeated practice of four basic operations. The article is based on model adapted for use in ergonomics, which was extended to five actions, by which it is possible to create such climatic conditions, in which operator will work in comfort. Design of work environment is currently hot topic because of hygiene limits in Czech enterprises. There is no simple tool usable for persons in production, which would simply evaluate optimal working conditions including safety restrictions. Enterprises must focus in future on worker understanding as an element standing in the middle of system. User centred system approach is future trend of businesses around the world. Working environment is influenced by physical factors. Most discussed factors are climatic conditions in workplace. By microclimatic conditions we mean air temperature, humidity and air velocity in workplace. The aim of this article is to show how by using Deming Cycle creates optimal microclimatic conditions in operator workplace. Deming cycle adapted for ergonomics has been tested in a company with a focus on automotive industry, dominated with assembly plants. This aim of the article is by using Deming Cycle, modified for application in ergonomic, assess workplace microclimate and to propose appropriate measures to improve working environment for humans.

Key-Words: Deming Cycle, Humidity, Microclimate, Temperature, UCD concept, Work Environment

1 Introduction
Perfect working environment is one, in which all components of work culture are in line with level of technology. In terms of aesthetics and ergonomics, the workplace must be well resolved if it has to have a positive impact on both productivity and human labour quality, as well as on social development and cultivation of human abilities and characteristics.

Work activities take place in real working environment that inflicts on people. Among most important factors of work environment, that negatively affects of worker are: microclimatic conditions, colour design, dust, excessive stress, noise and vibration. In particular microclimatic conditions are currently topical issue of most manufacturing companies in Czech Republic.

The issues regarding working environment design is often underestimated by employers and employees. Managers should have an overview of how to design, create, upgrade and modify workplace.

The importance of workplace assessing in terms of ergonomics is illustrated by words of MUDr. Jana Hlávková from a national reference physiology and work psychophysiology institute, which says: "Introduction of new methods for the evaluation of ergonomic risks is necessary because of methodological assessment of individual work factors unification with other EU states [2].

We assume that using Deming cycle modified for use in ergonomics can workplace microclimate be assessed and to propose appropriate measures to adapt workplace, in accordance with the prescribed limits and hygiene standards for production companies in Czech Republic.

2 Problem formulation
The first study dealing with people safety and work environments carried out in the late 1890s. The study was performed by the Frederick W. Taylor. Taylor had begun to take a keen interest in the best way to do a job in order to ensure the workers’ productivity [6], [13], [21].

Why is it important to deal with workers environment? According to i.dnes website (the most famous news portal on Czech internet), number of patients due to occupations is increasing. Workers are mainly destroyed by unilateral effort. While once clearly dominated miners with lung problems,
they are now replaced by workers with health problems from monotonous work on assembly lines [9].

Looking to the future, there is a growing awareness of the importance of considering the human factor in system and product development and operation. There is discussion about requiring all products for human use to have passed certain tests and be certified by Human Factors specialists before release into market.

Future of production and enterprise competitiveness is in access to workers, what is confirmed by four paradigms after EFFRA (European Factories of the Future Research Association):

**Factory and Nature - green / sustainable**
- Lowest resource consumption / energy – lean, clean, green
- Closed loops for products / production and scarce resources
- Sustainability in material, production processes / workers

**Factory as a good neighbour - close to the customer**
- Manufacturing close to people (in cities / metropolitan areas)
- Factory integrated and accepted in the living environment
- Event-oriented production / integration of customers

**Factories in the value chain - collaborative**
- Strive for highly competitive products (flexible, responsive, high speed of change)
- European Production System: design oriented products, mass customized products
- Integration of the product and process engineering - agile and demand driven
- Mastering the collaboration from simple to sophisticated products in the value chain

**Factory and Humans - human centred**
- Human oriented interfaces for workers: process-oriented simulation and visualization
- Products and work for different type of skilled labour, education and training with IT-Support
- Regional balance: work conditions in line with the way of life, flexible time- and wage- systems [1].

### 2.1 UCD concept

Central to the Human Factors approach is the concept that is designed for the human. It is adopted as a „user-centred design“ (UCD) approach [18]. In the UCD approach, the operators’ roles and responsibility are viewed as fundamental to ensuring the success of the operation and given priority in the design process. This approach is embedded in the concept of usability – a term defined by the International Organisation for Standardisation [3].

The usability of a product is defined as the degree to which specific users can achieve specific goals within a particular environment, effectively, efficiently, comfortably, and in an acceptable manner [15]. Usability is an important topic in design and in Human Factors. This is mentioned in the number of publications [4], [5], [7], [14]. There are many ways of measuring liability but it is generally recognised that liability encompasses the easy in which the system can be used. Its effectiveness in allowing the user to achieve his or her goals and its likeability are important [17], [19], [20].

### 2.2 Working environment

The work is performed in certain physical environment. Physical factors affect man and his behaviour and work performance. In physical terms, most authors focus primarily on microclimate of working environment (temperature, humidity and workplace air flow), workplace lighting, noise and vibration, interior colour and air pollution [15].

The effect of environmental factors affecting human may have negative, neutral or positive impact [8]. In this context individual priority goals were designed: microclimate in the workplace. Optimal microclimate combination of temperature and humidity in the workplace shows Fig.1.

![Fig. 1: Perception humidity depending on the room temperature](image-url)
2.3 Microclimate in the workplace
Generally is microclimate categorized into hot, neutral and cold. Neutral represents moderate conditions. It is recognised that six primary factors affect how individuals respond to thermal environments. There are air temperature, air velocity, radiant temperature, humidity, clothing worn and the intensity and level of the activities of the humans in the environment [16]. We are able to measure of how satisfied we are with our thermal environment.

To assess workplace adjustments, checklists are, used, which assess the overall state of system changes. Checklist includes adjustment of working environment in its effects on human. Questions are uniformly formulated so that the answer "no" refers to working conditions that can be improved.

Most highly processed regulation for area of indoor environmental quality of buildings is government regulation No. 361/2007, which sets conditions for health protection at work. Thermal comfort in indoor environment of buildings corresponds to optimal conditions, given by range of temperature so that individual susceptibility of environment thermal state is respected. The optimal thermal conditions correspond to 10% of dissatisfied people with thermal state of a given environment.

Other methods and means:
- ČSN ISO 9886: Rating of heatload under physiological measurements
- ČSN ISO 9886: Ergonomics - Determination of organism heat production
- ČSN EN 7993: Hot environments [12]

Temperature, humidity and air velocity are measured according to approved methodology (methodology presented in Journal of Ministry of Health No. 2/2009). Heatload is evaluated according to the government regulation No. 361/2007 [12].

Tools used in area of physical factors include temperature sensors for short-term measuring, for longer measurement thermographs with writing during these temperatures are used. Additionally spherical thermometer, radiometer, contact thermometers can be used. Used instruments for measuring humidity are psychrometers, capacitive hygrometers. Air velocity in area is to be measured by methods that allow determine (with sufficient precision) low flow velocities from 0.05 to 0.5 m s⁻¹ [12].

To measure air velocity most commonly omnidirectional sensors, e.g. anemometer with heated ball, thermostat anemometer, laser Doppler anemometer, ultrasonic anemometer are used. Furthermore, directional sensors such as vane anemometers and anemometers with filament are used.

2.4 Deming cycle
PDCA cycle (Deming cycle) was designed by professor of economics W.E. Deming. It was originally designed primarily for efficient solutions and improving of production activities, processes and systems, but today is also used in work safety [11]. To evaluate workplace microclimate we use Deming cycle modified for use in ergonomics (Fig. 2).

![Deming cycle](image)

Fig. 2: Deming cycle for Ergonomics [11].

The cycle starts with finding the current status and setting priority. Then ergonomic analysis follows. In next phase, actions are determined. Fourth step is to design a suitable working environment. In last phase, measures are in place and effectiveness is proven. Once process goes through all steps, new cycle begins. By constant repetition level of safety and health at work is gradually increasing.

With regard to above-described cycle in creation of an optimal working environment with a suitable microclimate we will proceed in following steps:

2.4.1 Current status establishment and prioritization
It is of course necessary to have enough information about actual workplace; it means nature and type of work, classification into work class, standards and regulations, etc. If a problem is known (problem with physical factors at work), we fix our attention in this direction. Information is obtained from employers; further information is required from
employees in form of their evaluation aspects of current work environment, job satisfaction levels, etc. Various forms of questionnaires, tests, interviews, group discussions are offered to use. Overall, it is beneficial to use appropriate form of observing events on jobsite. Final source of data are valid standards and limits.

2.4.2 Ergonomics analysis processing
Measurement is made, on which basis we can certainly set source of physical factors.

2.4.3 Determination of measures
At this stage data are processed and evaluated and compared with limits standards.

2.4.4 Proposed work environment solution
Based on processed data it is better to outline more options. We deal with suggestions, how to eliminate sources of physical factors making workplace modifications, use of personal protective equipment. Graphs, tables, etc. are used for description.

2.4.5 Selection and implementation of solutions
Selection is of course fully within the competence of responsible representative. He makes a choice of solutions. Consequently that step is realized and entire process is now complete.

3 Problem Solution
Deming cycle was certified in the company producing parts for the automotive industry. We focused on the hall, dominated by assembly plants. Elevated temperature, air flow and humidity were carried out in the summer months during the afternoon, night and morning shifts.

3.1 Current status establishment and prioritization
Description of workplace:

- Type of work: assembly plants arranged in a U-cells
- Length of work: 8 hours work shift
- Type of work: work standing, involvement of both upper limbs
- Machine: operator occasionally works with machines

- Walking: up to 2 m movement in workplace
- Departments are included in Class IIIa work, whose brief description of the NV No. 68/2010 The description in [12] is followed:
  It is the job standing with permanent involvement of both hands, sometimes bent, walking - maintenance of machines, semi-automatic machine operators, assembly work on assembly lines in the automotive industry.
- For working class IIIa no inside workplaces are below permissible values:
  - Temperature (t): 10°C - 30°C
  - Air velocity (v_a): 0,05 – 0,3 m.s^1
  - Humidity (Rh): 30 – 70%
- Measurements were provided from 12:39 one day till 15:19 next day. We chose this period because of outside weather which was extremely warm in these days. This period should be longer than one day (24 hours). Temperature and humidity are changed during morning, afternoon and night.

3.2 Ergonomics analysis processing
Temperature and air velocity were measured by the Heavy Duty Hot Wire ThermoAnemometer: 407123: Airflow meter with telescoping probe designed to fit into small openings. Humidity was measured by RH520A: Humidity and Temperature Chart Recorder with Detachable Probe: Graphical data logger for Humidity/Temperature measurements and Dew Point calculation.

The above described measuring devices are used to determine approximate values of microclimatic conditions. They cannot be compared with specialized devices used in control by health authorities. Due to its availability they can be used as preventive tool in manufacturing companies.

3.3 Determination of measures
Results are described below:

**Temperature**

- max.: 30°C, min.: 20°C
Temperature in workplace ranged in standards according to NV No. 68/2010. At one point, temperature reached 30°C – peak temperature. High temperatures cause excessive fatigue and lack of concentration leading up to serious accidents. During prolonged high temperatures signs of acute health disorders from heat such as nausea or even vomiting can be observed.

### Air velocity
- max.: 1.2 m.s\(^{-1}\), min.: 0 m.s\(^{-1}\)

Values of air flow were beyond prescribed limits. Generally, air flow may cause a feeling of discomfort. Higher flow rates usually improve thermal comfort at higher temperatures; however, they can also lead to health problems. If body surface due to air flow cools excessively rapidly by evaporation of sweat, it may cause organism chilling. Air draft should be solved at the workplace.

### Humidity
- max.: 39%, min.: 17%

Humidity at workplace dropped well below permitted values. Healthy individuals may experience more intense drying of upper respiratory tract mucous membranes, decrease of their protective function and increase of possibility of penetration of certain harmful substances to lower respiratory tract.

### 3.4 Proposed work environment solution

In this step ways of reducing risk of microclimatic effects on operators were proposed. High temperature at workplace can be solved by serving protective drinks to operators. It was recommended serve protection drinks. They must be harmless to health, must have suitable temperature and must not contain more than 6.5 weight percent of sugar. The amount of alcohol in them must not exceed 1 weight percent, drinks for minors must not contain alcohol at all. Another way, how protect the operator against high temperatures on workplace is to secure suitable work rotation and rest.

By allowing rest possibility to operator, problems caused by high air flow can be solved. If it is not possible to remove uneven flow, it is necessary to ensure possibility of relaxing in living room with another way of ventilation or by change of workplace. To protect workers from flowing cold air it was recommended to install door air curtains or build a vestibule. Then indoor climatic conditions no longer depend on frequency and time of opening of front door.

### 3.5 Selection and implementation of solutions

Production Manager agreed with our recommendation. Changes in design of workplaces were carried out in recent times. At present, the other options discussed above optimization working environment. The company is interested in the application of Deming cycle on other physical factors. Results of the changes and benefits will not be known for a long time. Diseases of the impact of physical factors are measured after a longer time horizon.

### 4 Conclusion

We believe that this example Deming cycle use for assessment of microclimatic conditions on workplace will be basis for further research in evaluation of other physical factors, whose risks are needed to solve in Czech companies. Simple and comprehensible tool for workplace design assessment was described and applied. It will be
usable both in workplace design for designers, as well as during manufacturing process for workers. In Deming cycle adapted to ergonomics were included requirements for hygienic limits for microclimatic conditions in workplace.

The tool is usable primarily for manufacturing companies, on which are greatest demands in terms of safety and health at work. Main advantage of tool is its clarity. If enterprises use extended Deming cycle, they will be able to affect risk resulting from negative impact of physical factors on operators. By using tools optimal and comfortable environment for workers will be created.

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References: