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Evaluation of thermal overload in boiler operators

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Abstract. The Brazilians educational institutions need a large energy demand for the operation of laundries, restaurants and accommodation of students. Much of that energy comes from steam generated in boilers with wood fuel. The laboral activity in boiler may present problems for the operator's health due to exposure to excessive heat, and its operation has a high degree of risk. This paper describes an analysis made the conditions of thermal environment in the operation of a B category boiler, located at a Higher Education Institution, located in the Zona da Mata Mineira The equipments used to collect data were Meter WBGT of the Heat Index; Meter of Wet Bulb Index and Globe Thermometer (WBGT); Politeste Instruments, an anemometer and an Infrared Thermometer. By the application of questionnaires, the second phase consisted of collecting data on environmental factors (temperature natural environment, globe temperature, relative humidity and air velocity). The study concluded that during the period evaluated, the activity had thermal overload.

Keywords: thermal comfort, occupational disease, boiler

1. Introduction

1.1. Energia renovável

New technologies for the conversion of wood into liquid fuels, solid and gaseous high-value, have currently great interest worldwide they and receive a great amount of resources for their research and development. Direct combustion or burning is the most traditional form of energy use of wood, but there are also thermochemical processes of gasification and pyrolysis [11].

Biomass may be a complement cleaner and safer, once it uses sources such as wood and their waste, bagasse, black liquor (in pulp and paper industries), elephant grass, the energy forests and biogas for generation of thermal and thermal-eletric energy. (Figure 1) [1]. The energy from traditional biomass currently represents approximately 6.5% of the energy matrix (equivalent to 7.9 million kW produced), but it may represent 14% by 2020. With the worsening of environmental pollution by the extraction and conversion of fossil fuels, coupled with the risk of shortages and frequent increases in oil prices, several alternative sources of energy have been proposed as options for reducing environmental impact and dependence on derivatives oil [9].

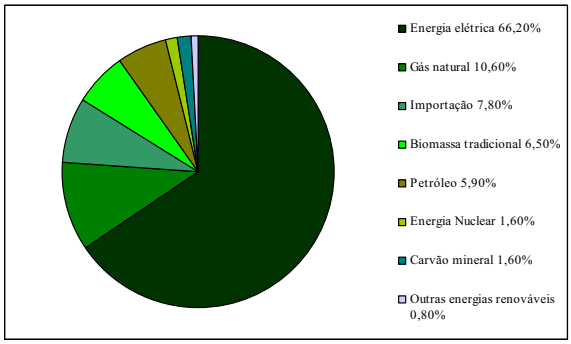

Fig. 1 Energy sources [1]

The wood represents only 4.5% of bioenergy used in Brazil. (Figura 2) [1]. However, due to physical and climatic attributes of Brazil, energy forests have the potential to contribute more substantially in the production of bioenergy.

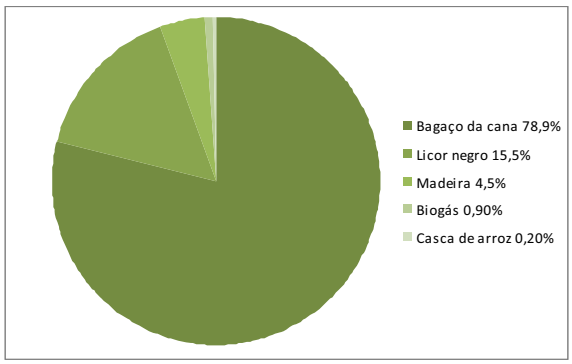

Fig. 2 Main sources of renewable energies used in Brazil [1]

About 40% of the wood produced in Brazil is transformed into charcoal. The residential sector is the most fuel-consumer (29%), after the charcoal. Usually it is for cooking food in rural areas. The industrial sector comes next with about 23% of consumption. The main industrial consumers of wood in the country are industries of food and beverage, pulp and paper and ceramics. Firewood is also intended for use in furnaces for heating air for drying agricultural products, and production of thermal energy in steam generators for industrial processes and electric power production [1].

1.2. Combustão

Combustion is the phenomenon of oxidation of a body held in a short time, a chemical combination of exothermic character [5]

When moist wood is introduced into a blazing furnace, there are three steps defined by heating zones: drying or evaporation of water contained in the material, takes longer in larger chunks, distillation and burning of volatiles contained in the material, fixed carbon burning, which occurs at temperatures of 400 ° C to 550 º C with the flame at lower temperatures [5].

1.3.Thermal confort

Thermal comfort in a particular environment can be defined as a sense of well-being experienced by a person as a result of satisfactory combination in this environment, the mean radiant temperature (MRT), humidity (RH), ambient temperature (ta) and relative air speed (VR) with the activity developed and clothing used by people. [6]

The well-being of man is a broad concept that ranges from factors necessary to maintaining their physical health, responsible for his feeling of satisfaction. When it comes to satisfaction with thermal conditions of an environment, then it´s thermal comfort [6].

The thermal comfort is closely related to the thermal equilibrium of the human body and this balance is influenced by environmental and personal factors. Thus, there are environments where conditions are favorable to thermal equilibrium of the human body and the man feels well prepared and there are others where the conditions are unfavorable, they cause discomfort, decrease of work efficiency and increase of the possibility of accidents [6].

1.4. Mechanisms of heat exchange

The exchanges between the human body and the environment can, in simplified form, be represented by the following equation:

$$Cmet + Cconv + Crad – Cev = \pm Q \quad (1)$$

Where:

Cmet - Portion of metabolic energy transformed into heat (W/m²).

Cconv - Heat transfer by convection (W/m²).

Crad - Heat transfer by radiation (W/m²).

Cev – evaporation of sweat (W/m²).

Q – Total heat changed by the body (W/m²).

When the value of Q in equation (1) is zero, the body is in thermal equilibrium, this is the first condition for obtaining the thermal comfort. [6].

1.5. Factors influencing thermal overload

When the air temperature is lower than the skin temperature, removing heat by convection will be greater the lower the air temperature. If the air is at a temperature higher than teh skin temperature, it will shall give up body heat by convection. As for evaporation, the influence of air temperature will depend on the relative humidity and air velocity.

Relative humidity (RH)

The relative humidity varies with air temperature. So, if it´s necessary lower relative humidity than the normal environment, it must reduce the amount of

water vapor in the air or increase the ambient air temperature.

The relative humidity has great influence on heat removal by evaporation, to the extent that the low humidity allows the relatively dry air to absorb moisture from the skin quickly, and thereby also promote quickly removing heat from the body.

Ventilation

It necessary to know the temperature and relative humidity, to analyze the contribution of ventilation to remove heat from the human body. For the condition of unsaturated air and cooler than the skin, it can be said that when ventilation increases the evaporation process increases, because the moisture is removed from the body more quickly, and the process of convection increases, because the speed of exchange of air surrounding the body is larger, the same way, when ventilation decreases the processes of convection and evaporation also decrease [6].

1.6. Boiler operation

Boilers, pressure vessels and furnaces are devices that work in a high degree of energy and if it is released inappropriately present a potential for catastrophic accidents. Therefore these devices require special attention in terms of reliability. In this work, the boiler is a flamotubular type, which the combustion gases (smoke) pass by inside the boiler tubes that are surrounded by water, giving heat to it [2].

Thus, when evaluating the thermal overload in boiler operators, it is intended to minimize the risks caused by thermal exposure and propose measures to improve working lives of those involved in the operation.

1.7. Assessment of work environment

In the operations necessary in a boiler, the work is performed under several adverse conditions to the welfare, safety and health of human beings. Throughout the working day the worker may find themselves subject to temperature variations, and high noise levels and inadequate illumination.

The work in adverse labor conditions produces fatigue, physical and nervous exhaustion, decrease in production and increased risk of errors and accidents at work, in addition to exposing the body to various diseases [3].

The thermal comfort zone is bounded by temperatures between 20 and 24 ° C, relative humidity 40 to 60% and moderate air velocity of about 0.7 m s-1. The temperature differences present in the same environment should not exceed 4 ° C, and above 30 ° C it increases the risk of damage to the health of the operator, the breaks become larger and more frequent, the degree of concentration decreases and the frequency of errors and accidents tend to increase significantly [8].

The assessment of exposure to excessive temperatures is of great importance so that we can ensure the thermal comfort of the worker. There are several indices for assessment of exposure to heat, however this study will be used the Wet Bulb Globe Thermometer (WBGT).

The WBGT index is an indicator that encompasses the main factors causing the thermal overload (high temperature, radiant heat and high humidity) and also the main factors attenuators of the same (room ventilation, low relative humidity and low temperature) providing a range of working time and rest time for the situation [4].

The WBGT index is defined by the equations described below, considering the indoor or outdoor, with or without load solar [10].

a) Indoors or outdoors without solar incidence:

$WBGT = 0,7\ tbn + 0,3\ tg$

b) Outdoors with solar incidence

$IBUTG = 0,7\ tbn + 0,1\ tbs + 0,2\ tg$

where:

tbn - natural wet bulb temperature, ºC

tg – globe temperature, ºC

tbs – dry bulb temperature, ºC

The tolerable limits for exposure to heat were established according with tables 1, 2 and 3 of Annex 3 of the NR15 [10].

Analyzing the WBGT index average of the values found in different environments at the home of coldeiras was made for the interpretation of work and rest time, based on the tables in Annex 3 of the Standard referred above. Thus, for the conditions in the boiler house is considered heavy work (metabolism 550 kcal h^{-1} and continuous. The WBGT average maximum is 30.0 º C for heavy work, also presented in this standard. Therefore, the tolerance limit was exceeded, characterizing a situation in which the body is gaining a certain amount of heat due to metabolism and adverse environmental conditions, sweat is necessary to lose this heat thereby defined by thermal overload. Thus, for each hour of work under current conditions, they can operate the boiler for a maximum of 15 min rest and 45 min. To get around this, can be adopted a system of rotation of work among operators.

2. Method

2.1.Descrição do ambiente de trabalho

This paper describes an analysis carried out the conditions of thermal environment in the operation of a boiler located in a B category Higher Education Institution, located in the Zona da Mata Mineira. The study was done during the three shifts and two phases. In the first phase was used questionnaires and the second phase consisted of the collection of data on environmental factors (temperature natural environment, globe temperature, relative humidity and air velocity). This phase refers to the moment of greatest thermal radiation exposure of operators. The equipment used for data collection were the WBGT Index Meter Heat, model ITWTG2000, Meter Index and Wet Bulb Globe Thermometer (WBGT index), Politest Instruments, MPG 01, the Text anemometer , 405 V1 model Infrared Thermometer , INSTRUTERM, digital model TI-890. To obtain the parameters determined were used NR 13 - Boilers and Pressure Vessels and NR15 - Unhealthy Activities and Operations by the Ministry of Labor and Employment (Ordinance 3214, 6/8/1978), as well as the Hygiene Standards Occupational 06 - Assessment of occupational exposure to heat-FUNDACENTRO [7], [10].

3. Results and discussion

3.1 Observations "in situ"

To assess the boiler adequacy to the Regulatory Standards mentioned above, there was a checklist of compliance.

The boiler assessed is B category, built in 1988 and is currently in operation despite not pass by inspections. The boiler has safety valves, instruments indicating the pressure of the accumulated value, feeders, water drainage system, referral system to control the water level to avoid overheating by poor water supply (including the siren alert).

It was told by operators that the mechanical engineer has the documents with the boiler project and the maintenance reports are stored in a closet. The alleged documents are poorly maintained and had no organization (Figure 3).

Fig. 3 Documents closet

However, operators did not confirm the existence of the documents, which implies non-compliance with paragraph 13.1.6 of NR 13 [10]. This same rule emphasizes that documents the boiler must be always available for consultation by operators, maintenance personnel, and inspection of Representatives of the Internal Commission for Accident Prevention (ICAP).

De acordo com as informações obtidas na entrevista não houve treinamento para exercer a função, embora a contratação do profissional tenha sido feita com exigência de experiência prévia na atividade. Os operadores iniciaram suas atividades após a contratação e não fizeram o estagio prático de sessenta horas conforme recomendado no subitem b do item 13.3.9. Foi informado também que não há reciclagem de operadores (13.3.11).

According to information obtained in interviews there wasn´t training to perform the function, although the hiring of professionals has been made with the requirement of prior experience in the activity. The operators started their activities after the contracting It was also informed that there is no recycling operators.

Treatment of water for the boiler is made with the addition of chemical to prevent corrosion and fouling residue. Air pollutants formed during combustion of wood is released through a chimney and there is no system for collecting particulate matter control and gases. It was found that the operators are unaware of an operation manual of the boiler. The instruments and controls of the boilers have reasonable state of repair. The inspection is done annually by the supplier of boilers and the reports of this procedure are retained with them. The inspection of the safety valve is done manually by the operator in random situations to check for problems. This conduct is not according with the rules which states that it should happen at least once a month for this type of boiler.

It was observed that there were wood and ash blocking the main exit. All wood is stored in the courtyard, outdoor haphazardly, until ready to use. This is inadequate and may cause risk of accidents, and provide shelter for venomous animals. It was observed that the transport of logs to the boiler causes severe physical effort, and the risk of accidents. (Fig. 4).

Fig. 4 Suspensão da tora de madeira.

Another mistake is due to the use of PPE (NR 6) [10]. During the visit, it was observed that in just a few moments, the glove and scrape of steel-toed boots are used.

The place is not properly vented. According to NR 13 [10], the place must have permanent ventilation with air intakes that can not be blocked.

3.2. Avaliação da carga térmica de trabalho

After observation of the workplace, it was marked four main points, using as reference the port boiler: 0.30 m, 1.0 m, 2.0 m and place of rest, for three shifts and rated the WBGT index, air velocity and relative humidity.

The results of the WBGT index can be found in Table 1. It is noteworthy that the air velocity didn´t changed, from 0.2 ms-1 for all points assessed. It was found through infrared digital thermometer, the internal temperature of the boiler, 750 ° C due to its interna-lrefractory walls.

Table 1
Medium IBUTG

		Measuring place	Morning	Afternoon	Night
Distance between operator and boiler door	30cm	Opened	35,57	44,47	24,27
		Closed	28,57	36,58	34,13
	1m	Opened	30,93	42,48	33,40
		Closed	28,17	28,95	32,20
	2m	Opened	28,17	34,52	30,60
		Closed	26,73	27,22	29,53
	Rest place	-	21,27	25,75	24,67

It is observed that under these conditions the results of work in three shifts, only on the rest place there is no thermal overload, regardless the operation is being carried out of the gutter with the door open (for the feed) or closed (WBGT <25 ° C) (Fig. 5 and 6).

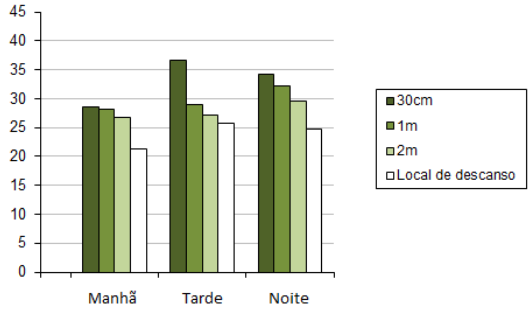

Fig. 5 Medium WBGT with the boiler door closed

It can be seen in Figure 5 that even when the activity is performed with the boiler door closed , the WBGT average exposure was found higher than the ceiling established by law and the worst condition was found in the afternoon to 0, 30 meters away.

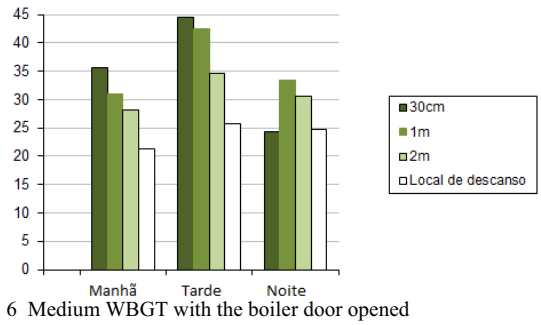

Fig. 6 Medium WBGT with the boiler door opened

A similar situation is found in the afternoon with the boiler door opened , the distance with more thermal overload was 0.3 m during the feeding the boiler, in the afternoon (Fig. 6).

In table 2 you can check the relative humidity found in the evaluated point. Observe the relative humidity was found superior to the values stipulated by the comfort zone, it must be emphasized that the wood are not previously dried, then release too much water during the carbonization process, which may contribute to increased relative humidity the air surrounding the boiler.

Table 2

Medium Relative Humidity

Relative Humidity (%)				
	Measuring place	Morning	Afternoon	Night
30cm	Opened	98,30	90,70	86,37
	Closed	66,60	70,93	82,77
1m	Opened	61,27	89,50	90,13
	Closed	91,20	88,97	72,17
2m	Opened	57,67	91,70	88,40
	Closed	92,37	79,03	79,00
	Rest place	79,70	73,30	77,20

4. Conclusions

The study concluded that during the period evaluated, the activity had thermal overload and may cause dehydration, fatigue and chronic diseases, such as skin cancer.

It must educate operators about the importance of breaks and the correct use of PPE. There is also a need to implement a new way of feeding the boiler, which there is no thermal overload and the maximum thermal radiation received by the operator must be in the limits that do not cause thermal discomfort, established by law.

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