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IMPROVING INDOOR AIR QUALITY USING LOCAL EXHAUST VENTILATION (LEV)

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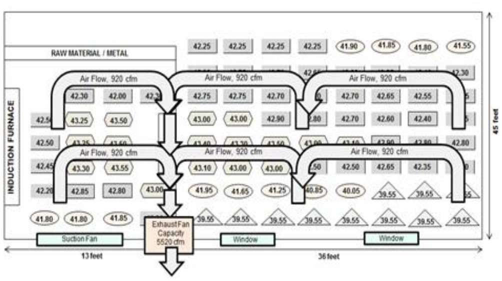
Graphical abstract



Abstract

Ventilation is used to control indoor air quality for maintaining the health and performance of human and ensuring healthy environment. It is known that the environmental criteria are dictated by temperature, humidity, and contamination. In a case study at XY company, questionnaires were distributed to the workers and interviews were conducted to find out the level of satisfaction on working conditions in certain areas. 70% respondents reported feeling uncomfortable because of heat, dust and hot environment. An analysis of indoor air quality was carried out to measure the temperature at pouring area. Based on the analysis, the range of temperatures is from 35°C to 43°C. A local exhaust ventilation (LEV) system was design for improve indoor air quality and reduce extreme heat. The LEV system was proposed for the pouring area to capture then discharged heat or contaminants through a series of strategically placed overhead ducts.

Keywords: Indoor air quality (IAQ), indoor air quality monitor, local exhaust ventilation (LEV), extreme heat, temperature, pouring

1.0 INTRODUCTION

The foundry indoor air can be completely polluted with hazard gases, depending on the kind of occurred activities, emissions sources and type of equipment used. One of the important environmental issues associated with the foundry especially in metal casting industry is Hazardous Air Pollutants (HAPS). It includes gases, which are generated when molds containing carbon materials are subjected to high temperatures as happens in the pouring of cast metals. Of all the hazardous air pollutants released from poured castings, benzene is the largest. Emissions from the pouring process depend on the metal temperature. Hot metal will produce larger hazardous gas emission which will cause indirect indoor air pollution [1].

A person working in extremely hot environment such as in foundry industry where he needs to work near furnaces and extremely hot or molten metal is at a greater risk of heat-related disorders and safety problems. The heat-related disorders such as heat cramps, heat exhaustion and heat stroke are due to heat imbalance in the human body. It was reported that the body core temperature, heart rate and sweating are increased while working in hot environment [2, 3]. Thus, drawing up protection when in such condition is one of important tasks of all employers and employees in foundry industry.

2.0 METHODOLOGY

2.1 Indoor Air Quality Improvement

The objective of control of environmental exposure to a substance or condition is to reduce the risk or hazard to health. Hazard may be defined as a risk at a specific site, as modified by a person, place, and time. There are two principal methods to improve air quality that have been utilized in the foundry industry such as (i) dilution ventilation, and (ii) local exhaust ventilation (LEV) [4]. LEV is more appropriate than dilution ventilation because it can be implemented in the area of melting, metal casting and pouring which produce extremely hot and highly toxic contaminants [4,5,7]. LEV is more effective to remove heat, fume, silica dust and less costly in an air cleaning operation and installation [4,5,7]. LEV can be considered as one of alternative methods to control environmental hazards caused by indoor pollutants [5]. LEV may be supplemented with a local air moving device such as fan to provide better mixing, reduce stratification, or produce local air motion to control heat stress.

LEV requires lower air volumes than are required for dilution ventilation [7]. The volume of air required is determined by the size of the space to be ventilated and the number of times per hour that the air in the space is to be changed. Generally, recommended rate of air changes rate for foundry industry is 20 Ac/hr [6]. There are a few requirements to setup the ventilating equipment such as local codes or regulations that need to be involved and considered into. Some of the codes are based on a specified amount of air per person and on the air required per square foot of the floor area. For this study, the reading air changes rate are taken as 10Ac/hr because the design of LEV is more focus for pouring area only.

This study is conducted on XY Company, a small and medium (SM) manufacturing company of foundry parts, with a total number of thirty male and three female workers. Out of these numbers, only twenty workers are well-trained and able to do pouring process. The company uses conventional open pouring operation with no modern facilities. The conventional open pouring operation means that the pouring process was done in open furnace with open air environment. Indirectly, all of the workers are exposed to hazards. In addition, environment inside the building provide unsatisfactory conditions for the workers' health due to extreme heat, dust and fumes emitted during pouring process. Based on the eye observation and survey, the circulation of air flow inside the building is not adequate and safe for health because the window and suction fan are provided is limited. Therefore, the main objective of this study is to reduce the extreme heat in the pouring area of XY Company. The second objective is to design and propose local exhaust ventilation (LEV) system for its foundry area in order to improve the indoor air quality.

Four methods are used to identify the safety and health hazards in XY Company. First, a set of questionnaire are distributed to the workers working in pouring. Second step, a series of interviews were conducted amongst the workers and management. Third step, eye observations during pouring process was done for three hours. Step four, relevant information regarding health and safety of workers. Preliminary investigation is directed to monitoring the heat and temperature generated from pouring process. Local Exhaust Ventilation System (LEV) technique is then introduced to circulate the air in the foundry area as a way of controlling and reducing workers exposure to extremely hot working condition. Subsequently this can improve the company's indoor air quality and its workers health.

2.2 Analysis of Indoor Air Quality Monitor

Indoor air quality equipment (IAQ) is used to monitor indoor air temperature in the pouring area. Data from IAQ monitor is summarized as in Figure 1. The layout of pouring area with range of temperature and was classified into four different colours; red for hot temperature above 43°C, green for temperature above 42°C, blue for temperature above 41°C, and purple for temperature above 40°C. The results show purple colour of which indicates low temperature at less than 40°C because closes with window and fan.

2.3 Calculation and Design Analysis

All calculation of the LEV based on Air Duct Calculator (Ductulator), English and SI Metric Units. The Ductulator is an accurate, easy-to-use chart that aids in the design layout of air handling systems, sizing of ducts and reviewing the existing duct systems. Table 1 shows the factors and indicators retrieved from Ductulator in order to calculate required air volume in cubic feet per minute (CFM) unit.

Table 1 Factors in ductulator

Factors	Indicator
Friction in inches of water per 100' of duct	Inner blue band
Desired velocity in feet/minute (FPM) in round duct	Inner red band
Round duct diameter	Window

Procedure: With the friction per 100-feet of duct known, set this friction (inner blue band) opposite required CFM (outer blue band). The resulting velocity in round duct (inner red band) coincides with established CFM in outer band. Round duct diameter is indicated in window by arrow. Various equivalent rectangular duct sizes are read from green bands.

Based on the factors retrieved from Ductulator as shown in Table 1, the calculation for LEV is depending on the volume of pouring area which is 45ft x 49ft x 15ft. The air change rate of 10Ac/hr is taken considering the factors of factory, process and heat. The calculation of the overall ventilation air comes to *5512.5 ft³/min*. Therefore, in order to design the required LEV, six inlets are required. Each inlet has airflow of *920cfm*. The inlet should be located very close to the source of contaminants for effective ventilation.

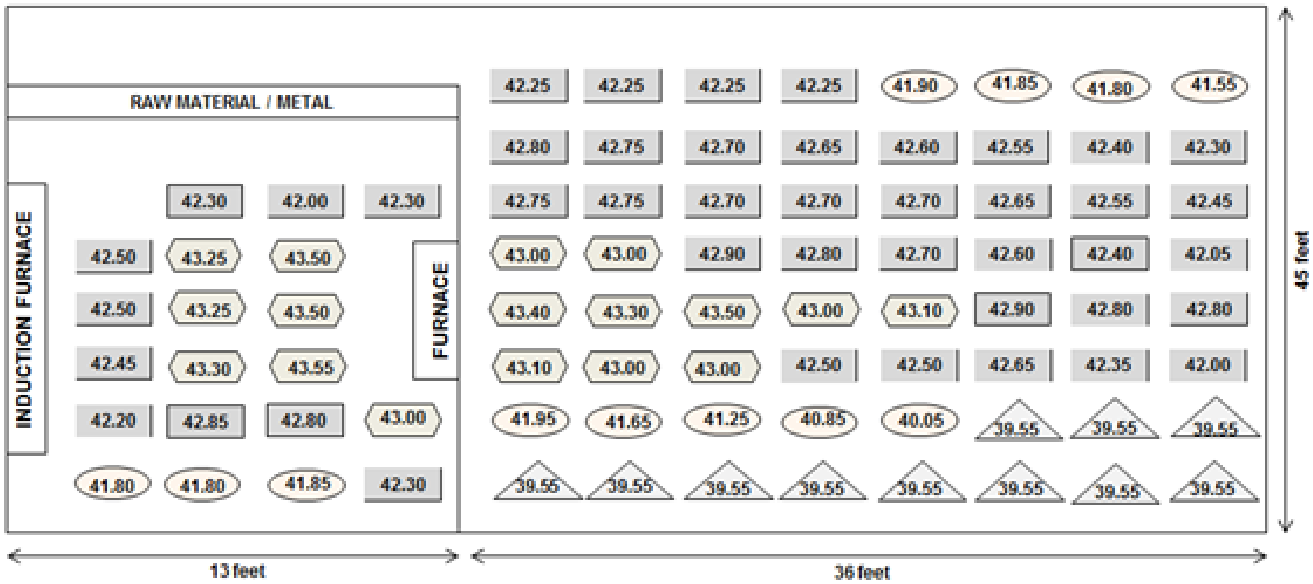


Figure 1 Layout of pouring area with temperature

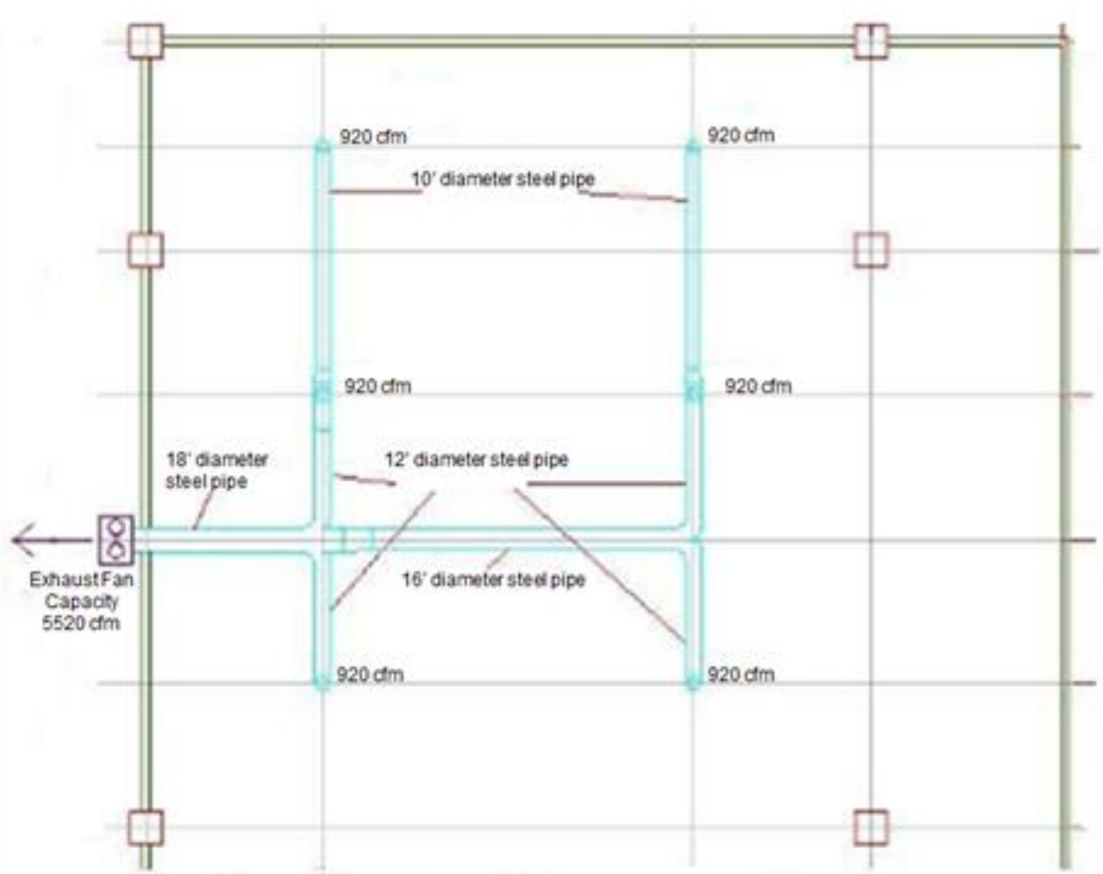


Figure 2 Plan view of LEV ducting design

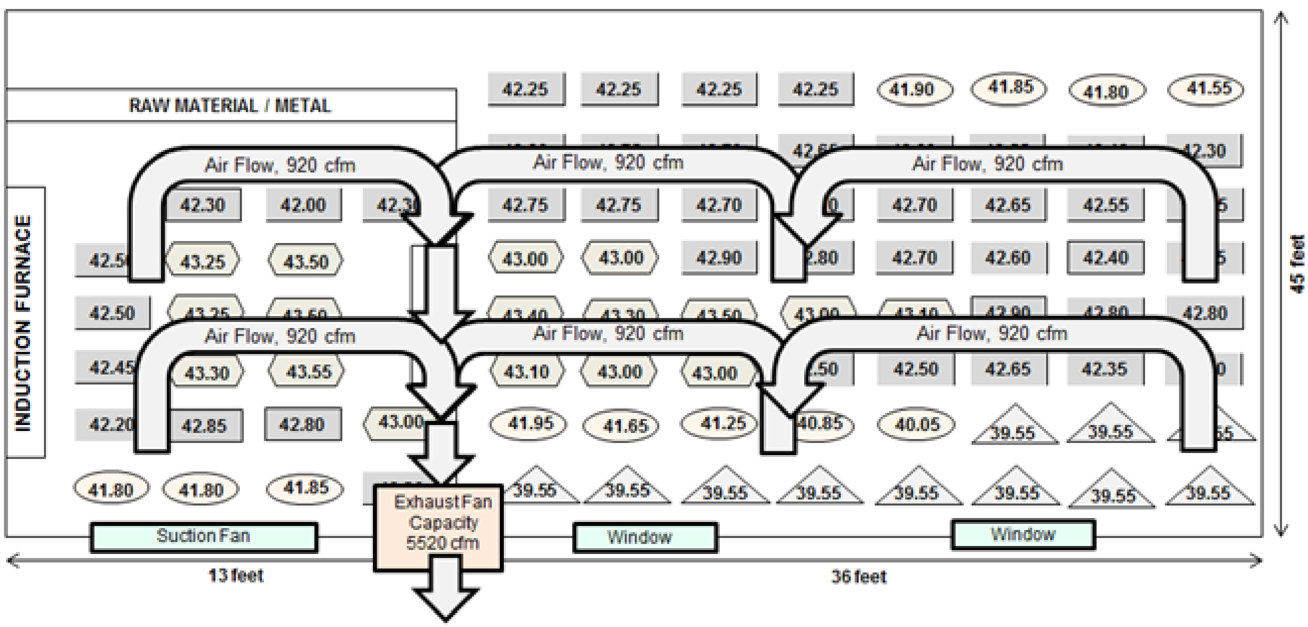


Figure 3 Location of LEV with respect to ambient temperature

3.0 RESULTS AND DISCUSSION

3.1 LEV Ducting Design

According to calculation improvement and design analysis, LEV must be designed with six inlets of 920cfm/each. The system is designed using AutoCAD 2002. The LEV system is required to remove odors, fumes, dust and heat from an enclosed occupied space. Such exhaust may be of the natural variety or may be mechanical by means of roof or wall exhaust fans or mechanical exhaust systems. Figure 2 shows the plan view of local exhaust ventilation system within the dimension. Each inlet will flow out air at 920cfm. Initially, two inlets will flow out air of 920cfm each through 10-inch diameter size steel pipe duct. The air from initial stage will then merge at the second inlet and total air flow will become 1840cfm. Duct size of 12-inch diameter steel pipe are used at this stage. Bigger ducts are used to accommodate increasing air flow volume. The third stage, which is at the furnace area, have ducts of size 12-inch diameter. The air flow from furnace area (920cfm) will merge with air flow from pouring area (1840cfm) and passing through duct of size 16-inch diameter and 18-inch diameter to an exhaust fan of capacity 5520cfm.

3.2 Air Flow Layout

The location of LEV is based on the collected data and its analysis. Figure 3 shows the implementation of LEV air flow at the pouring area. The six inlets of LEV are proposed to be located at hot temperature areas between 40 and 43 degree Celsius. The temperature indicators are as shown in Figure 1.

4.0 CONCLUSION

Investigation from this study showed that several working areas in this company have exceeded the normal working conditions and can be considered hazardous for human. Thus, the implementation of LEV is highly recommended for XY Company. LEV implementation could benefit workers, processes, equipment, place and time. However, for this particular case study, the design of LEV system is solely based on temperature only. For future study, more operational parameters such as humidity, fumes and gas emission can be included for the design of LEV purposes.

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