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Implementation of Workshop Air Pollution Monitoring System Based On Wireless Sensor Network

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Abstract *- Workshop contamination can lead to changes in the characteristics of the air. Welding process for example inside the workshop will generate different pollutants just like fume and gases. These gases may threat the environment. Also the direct exposure of these gases by people inside the workshop may be considered as a risk on their health. For all reasons mentioned above air pollution monitoring system is important issue to decrease the risk of low level of health. This paper introduces the implementation of wireless sensor network to monitor a workshop air pollution.*

The proposed system prototype contains a set of gas sensors (CO, H2, NH3, Butane, Propane, Ethanol and NO2) which are deployed on stack and infrastructure of Wireless sensor Network. These sensors are calibrated using appropriate calibration technologies. They are controlled by ARDUINO based microcontroller. Also there is the main server which Installed on raspberry pi 3 and contains the main database of the system which supports real time management strategies by using the web interface to monitor the air pollution in form of numbers and charts.

Sensors which controlled by ARDUINO platform are connected to the server using the wireless technology (Wi-Fi) and the communication is done by using Message Queuing Telemetry Transport protocol (MQTT).When the level of Carbon Monoxide gas is above the threshold the system will send an alert email to the department of the civil defense.

The system is checked and tested in the training workshops of University of Technology to measure the levels of harmful gases which may harm the people in the workshops.

Index Terms*-- Wireless sensor Network (WSN), Gas Sensors, Air pollution monitoring system (APMS), Message Queuing Telemetry Transport protocol (MQTT).*

I. INTRODUCTION

Air pollution is very important issue for the human beings also it has a direct effects on the human health. Gases just like CO, LPG, NO2, Propane, Butane and O3 may increase the impacts of the health of the over-all public [1].

Air pollution maybe caused by car emissions, trucks, factories and environment. When people breathe contaminated air they could be exposed to health risks just like cancer, children disorder growing, premature death, coughing and cardiovascular system weakness [2].

Hence to reduce the impacts of the air pollution, governments have used air pollution monitoring systems which are highly reliable, accurate and capable of measuring wide range of pollution situations using specified instruments. The main draw backs of these monitoring stations are their large size, weight and expensive cost. For these reasons, the researchers were looking for Wireless Sensor Network (WSN) which are low cost and the information of them can be reorganized in a minute or even in seconds [3].

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WSN has the ability of adaption to any network topology and the self-configuration. WSN can be monitored remotely. Also it has high adaption for the mobility [4].

In this paper an Air pollution monitoring system (APMS) is implemented based on WSN to monitor the pollution inside the workshop.

The prototype type of the system consists of sensors node which are controlled by microcontroller and the data of sensors nodes are published via Wi-Fi to the raspberry pi which contains the main database and this data may be retrieved using web applications and the whole system can be monitored in real time by the system administrator.

II. REALATED WORK:

Air pollution monitoring system based on WSN has become a crucial part of researches in recent years, especially under the recent enormous increase of trucks, factories and environmental pollution due to the population increase.

Somphop Chanthakit and Choopan Rattanapoka, (2018) [4] presented the implementation of MQTT system to monitor the air quality measurements. The system is simple, efficient and could contain an alerting messages for user after the increasing of harmful gases concentration.

Ch.V.Saikumar et al., (2017) [5] used very simple and low cost sensors with central web server implementing the system in form of (IOT) which is widely used now a days. One weak point is that the system does not support urban area measurements.

Avinash Rai et al., (2017) [6] presented zigbee based air pollution monitoring and control using WSN to measure the values of CO, CO2, humidity and temperature the results of simulation were very satisfied and considered the low power consumption.

V.S.Revathy et al., (2016) [7] adopted a type of air pollution monitoring using WSN with both software (simulation) and hardware (practical implemented) system. The proposed system was very clear and easy to implement. One point to be considered is the output of the readings of CO and CO2 sensors which did not contain PPM (part per millions) units but only the analog readings of sensors output.

Kalaimani G and Prof Dr.S.Sakthivel (2015) [8] the author proposed an air quality monitoring system to monitor pollution in industrial areas. The work considered the power consumption and used air pollution clustering protocol. The only point to be mentioned is that the system was using multiple base stations and thus will increase the communication and may affect the power consumption.

Sherin Abraham and Xinrong Li (2014) [9] presented a WSN for indoor air pollution monitoring system and it was based on a zigbee module. In fact the author only focused on the calibration process of the sensors.

III. THE PROPOSED SYSTEM:

A case study has been taken in this paper at the University of Technology in Baghdad specifically in the training workshops in order to measure the concentration of air pollution. Visits have been made to the casting division of the main workshop and it was noticed that the Aluminum has smelted. They also smelt Nickel and Chrome.

After few searches and investigations it is found that the Chlorine and Sulfur gases are produced from the smelted Aluminum, while the arsenic is produced from the smelted Nickel.

Another part that was visited is the welding division of the work shop and it was noticed that the working machines there would produce Ozone gas which cause a suffocation.

The last part was the metal works division and the machines were old CNC machines which produce NO, Butane and CO gases.

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Any interaction between the Oxygen and Nitrogen will produce Nitrogen Oxides which will in turn form the harmful Ozone.

Air pollution monitor system (APMS) is a basic system to detect the pollution in the air just like CO, No2 gases which can affect the human health.

Normally to measure the concentration of pollutants, a Part per Million (ppm) unit is used. It represents the units of mass of gas per one million units of the over-all mass [10].

The proposed system contains two main parts, the first is the receiving unit which collects data via sensor and controlled by the microcontrollers. The second part is the web server which accepts the data by Wi-Fi and store it in the central database.

As shown in figure 1 the system contains:

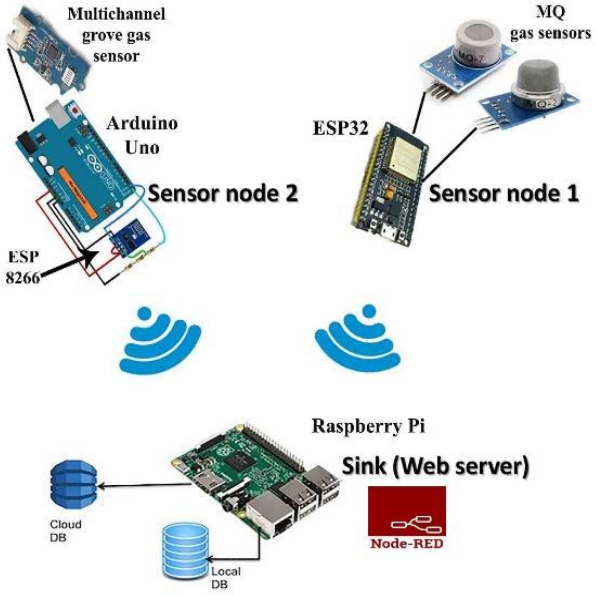

FIG. 1: THE OVERALL SYSTEM HARDWARE COMPONENTS

A. MQ-7 Gas Sensor:

This sensor has two important things which are the easy of usage and the effective cost. It is usually used to measure the concentration of Carbon Monoxide (CO) gas in the range of (20-2000) ppm. To get the best measurement, a sensor must be preheated for minutes before starting of work [11].

FIG. 2: MQ-7 GAS SENSOR

B. MQ-2 gas sensor:

MQ-2 gas sensor is used to detect the leakages of gases like (Liquid Petroleum Gas) LPG, Propane and Alcohol. Due to the sensitivity and high response time of this sensor, its measurement can be taken as soon as possible [11].

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FIG. 3: MQ-2 GAS SENSOR

C. Multichannel Grove Gas Sensor:

This sensor is environmental gas sensor. This multichannel sensor can detect unhealthful gases simultaneously so it can monitor the concentration of more than one gas. The gases are Carbon monoxide CO (from 1 to1000) ppm, Nitrogen dioxide NO2 (from 0.05 to 10) ppm, Ethanol C2H6OH (from 10 to 500) ppm, Hydrogen H2 (from 1 to 1000) ppm, Ammonia NH3 (from 1 to 500) ppm, Methane CH4 (more than 1000) ppm, Propane C3H8 (more than 1000) ppm and Butane C4H10 (more than 1000) ppm [12].

FIG. 4: MULTICHANNEL GROVE GAS SENSOR

The overall working process of sensor processing is illustrated in the flowchart figure 5.

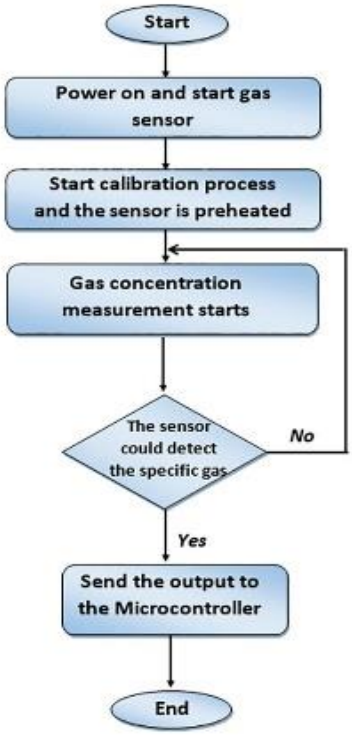

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FIG. 5: SENSOR FLOW CHART

D. Arduino Uno:

It is considered as a microcontroller board which is based on the ATmega328P. It contains fourteen digital input/output pins (such that six can be used as Pulse Width Modulation outputs), six analog inputs, a sixteen. It includes all needed things to be considered as a microcontroller. In order to connect UNO to the computer, a USB cable could be used. Arduino UNO does not include a Wi-Fi connection and to supply it an ESP8266 is attached [13].

FIG. 6: ARDUINO UNO MICROCONTROLLER

E. ESP8266:

ESP8266 is Wi-Fi system on chip (SoC) module developed by Espressif system. This module is widely used in Internet of things applications. ESP8266 module is developed to be used as a wireless transceiver for end points (Internet of things). An AT commands are used to communicate with ESP8266 module. ESP8266 support TCP/IP connection [14].

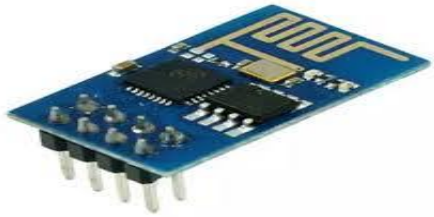

FIG. 7: ESP8266 MODULE

F. ESP32:

ESP32 is a system on chip microcontroller with low cost, low power and Wi-Fi service and also it contains dual mode Bluetooth service. It is considered as the successor to the ESP-8266 microcontroller.

ESP32 was designed for Internet of things applications, mobile devices, and electronics applications. With different types of software proprietary, Esp32 could achieve low power consumption [15].

FIG. 8: ESP32 MICROCONTROLLER

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G. Raspberry Pi 3:

It is a small and affordable computer with 1.4GHz 64-bit quad-core processor, dual-band wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and Power-over-Ethernet support (with separate PoE HAT).

FIG. 9: RASPBERRY PI

Micro SD card is used in order to store the operating system of pi device. Raspberry pi may have one to four USB ports.
Raspberry pi model B has an 8P8C Ethernet ports with Wi-Fi (802.11 n) and Bluetooth service [11].

H. WSN (Wireless Sensor Network):

A wireless sensor network (WSN) refers to spatially scattered and devoted sensors which are used to observe the physical conditions in the environmental location. A WSN relies on wireless connectivity such that the data of sensors can be delivered wirelessly. A WSN system may contain the opening which delivers the connectivity to the wireless nodes. The selection of the wireless procedure depends on the necessities. Nowadays the most famous selection is the 2.4 GHz radio such that it supports IEEE 802.15.4 (Zigbee) or IEEE 802.11 (Wi-Fi) standards [16].

I. MQTT:

It is a Message Queuing Telemetry Transport, actually it is built in the top of TCP/IP protocol. It uses (publish-subscribe) topics, It is considered as a light weight messaging protocol used with high latency low bandwidth or unreliable networks.

The design of this protocol is used to reduce the number of resources and the bandwidth of the network to ensure the reliability and the correct message arrival. For all reasons mentioned above the MQTT protocol can be used for machine to machine and Internet of Things communication where the bandwidth and power consumption is the crucial part to be considered [17].

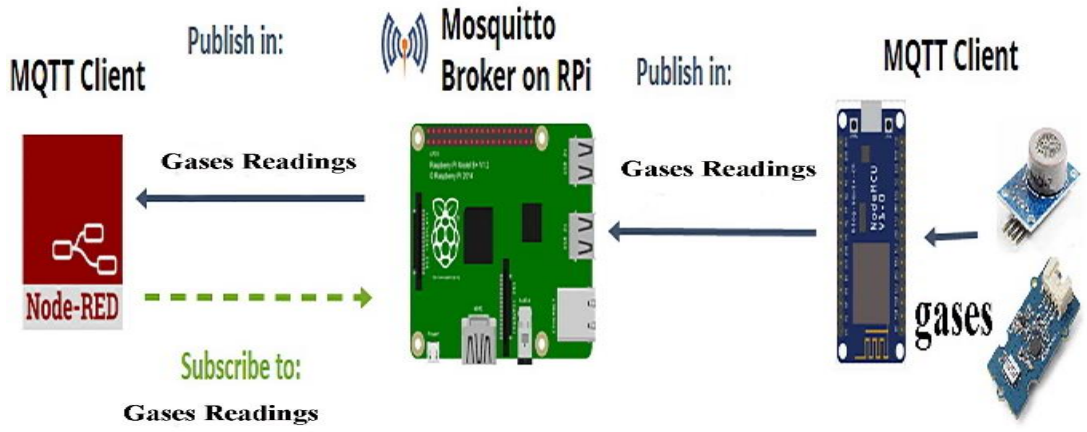

FIG. 10: MQTT PROTOCOL

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J. Node Red:

It is a visual programming tool development tool created by IBM for wiring hardware together basically with IOT and different applications. It is based on Node.js (a server-side java script platform). The flows of node red are stored using JSON which can be easily imported and exported.
Node red can be run on the local server:
http://localhost:1880, also to access the live data dashboard http://localhost:1880/ui can be used [18].

After receiving the sensor readings in the raspberry pi the data will be transferred to the SQL database and then it can be visually retrieved in order to be monitor.

Figure (11) illustrates the actual prototype of the project.

In the figure (12) the flow chart of overall system is shown which clarifies the working principles of the proposed system.

It is obvious that the sensors will collect data after the codes are loaded to the microcontroller, these sensors values will be transferred to the main server (raspberry pi) by Wi-Fi connection using MQTT protocol.

FIG. 11: SYSTEM HARDWARE

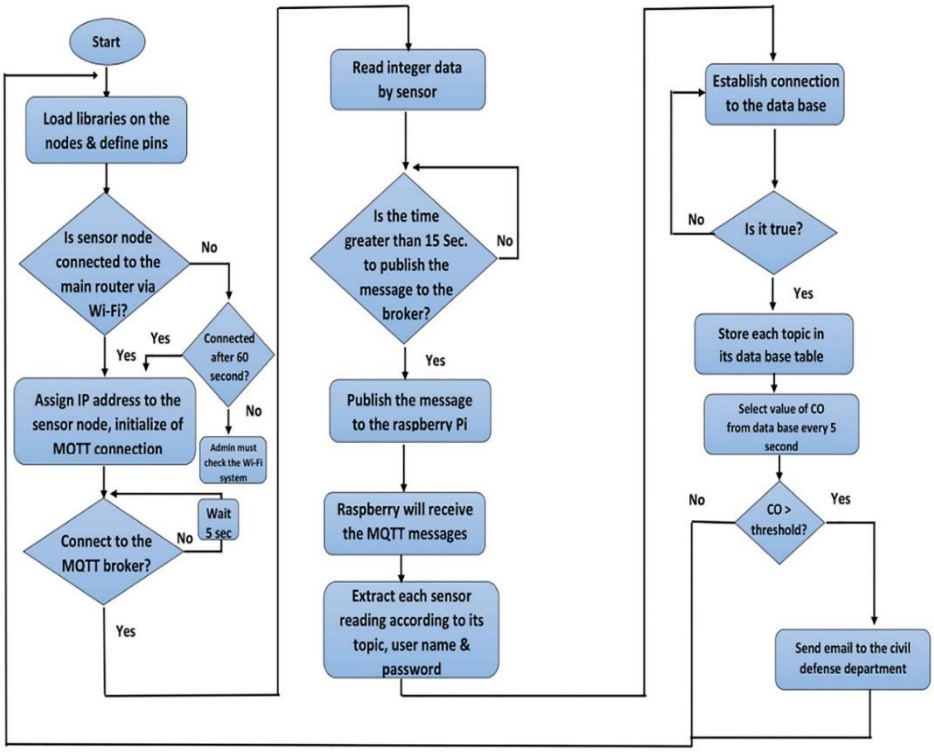

FIG. 12: SYSTEM FLOWCHART

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IV. THE RESULTS AND CONCLUSION:

This paper proposed implementation of air pollution monitoring system using WSN by using central web server. The main data base is shown below

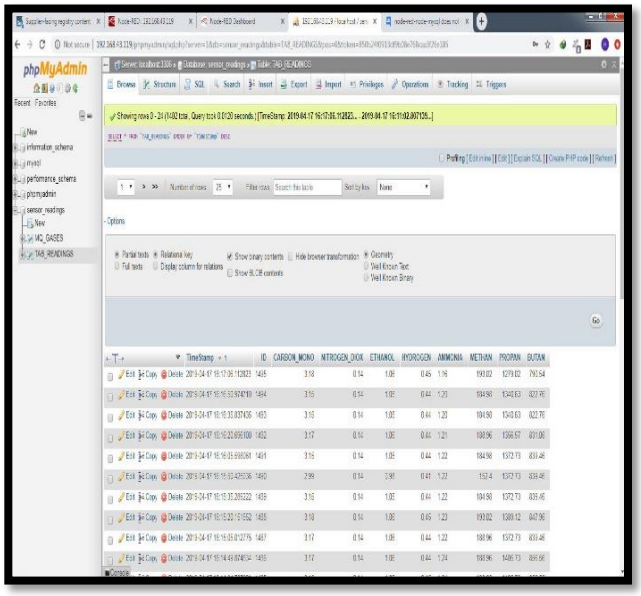

FIG. 13: THE MAIN DATA BASE SYSTEM

The prototype is tested in the casting division of the University of Technology.

The following results are considered first in the normal conditions and when the furnace was turned on, the levels of gases readings are increased.

The charts of the system indicate the concentration of gases in PPM(Y axis) while the (x axis) represents the time.

Figure (14) shows the normal levels of gases concentrations (CO, LPG, NH3, H2 and Ethanol). These readings are collected from two sensor nodes and it is measured the level of gases before turning the furnace on of the casting workshop.

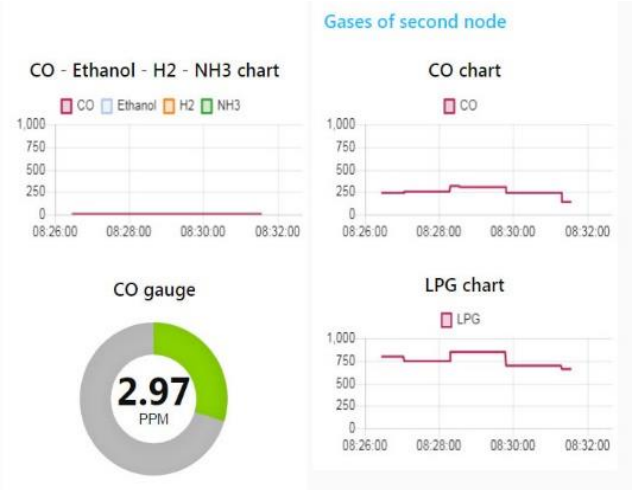

FIG. 14: NORMAL GASES LEVELS OF CASTING WORKSHOP

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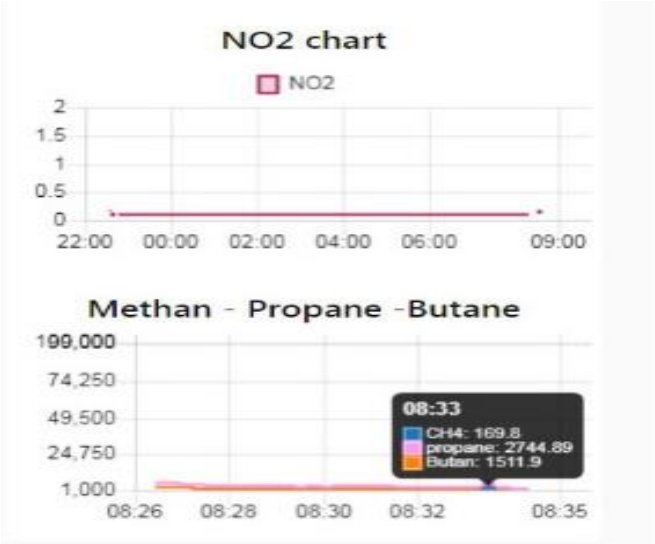

FIG. 15: NORMAL GASES LEVELS (NO2, METHANE, PROPANE, BUTANE) OF CASTING WORKSHOP

Figure (16) and figure (17) show the levels of gases after turning on the furnace in the casting division of University of Technology.

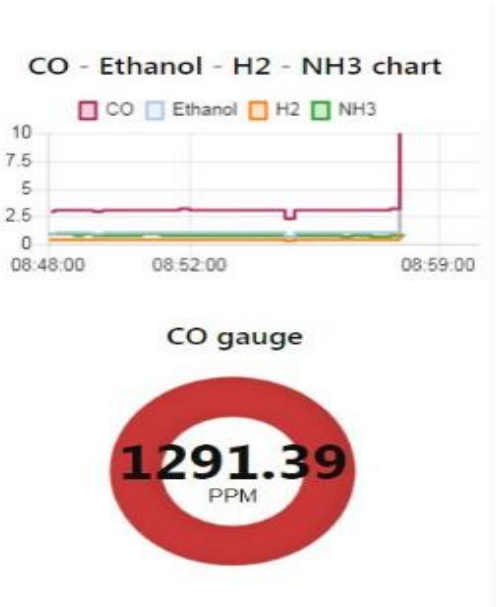

FIG. 16: HIGH LEVEL CONCENTRATION OF CO GAS IN THE CASTING WORKSHOP

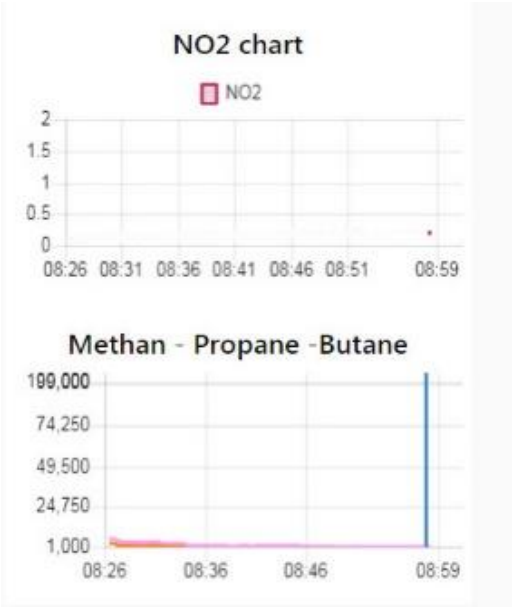

FIG. 17: HIGH LEVEL CONCENTRATION OF METHANE GAS IN THE CASTING WORKSHOP

Levels of Co and methane gas are only increased and affected while the other gases are remained stable in that time

The implemented system is easy to use and not so expensive as compared to the different air monitoring system devices. It also collects the data in real time which makes it reliable.

The following figure (18) shows the email sent from the broker (Raspberry pi) to alert the civil defense or administrator about the increment in CO gas level.

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FIG. 18: ALARMING EMAIL OF CO HIGH LEVEL

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