ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

Some emission control techniques in glass processing plant

Gurjeet Sarao and Nitaigour Mahalik
Department of Industrial Technology, California State University Fresno, USA

Abstract*— Environmental protection is one of the major concerns these days because pollution is getting worse and worse and it has adverse effects on living organisms and humans. The contribution to environmental pollution due to glass manufacturing processes has not been studied intensively. In this paper we have presented work on dealing with emission in glass manufacturing plant by developing some useful techniques. We have provided information on the features of furnaces, the composition of raw materials, environmental indices and standards. In particular, we have focused on NOx, SOx and opacity control methods. The study reviews relevant variables that can be effectively controlled so as to reduce the emission by 10-20% in the glass manufacturing process.

Index Terms—**Emission control techniques, glass manufacturing, automation and control, NOx, Sox, PM.**

I. BACKGROUND AND INTRODUCTION

Emission control is one of major concern in glass manufacturing industry [1]. The environment is getting polluted every day more and more while the EPA (Environmental Protection Agency) has set up standards for industrial operations. Some of the selected pollutants categories are particle, ozone, carbon monoxide, nitrogen dioxide (NOx), and sulfur dioxide (SOx) [2-3]. In this study we have focused on particulate matter, nitrogen dioxide (NOx), and sulfur dioxide (SOx). Silica is primarily composed of SiO2 and its melting point is over 29000 F. Above this temperature, it is difficult to operate the process in normal way because the refractory cannot hold these temperatures continuously. To simply its processing with normal operating zone, other materials such as Sodium Carbonate (Na2CO3), Soda Ash, Calcium Oxide (CaO), Magnesium Oxide (MgO), Aluminum Oxide (Al2O3),). Boron, etc. are added into its batch composition such as glass ingredients. These materials are used as flux that cause to lower down the melting temperature, providing a better workability condition with improved chemical durability or interaction. However, the drawback is that the flux-added compound composition when cooked produces pollutants including NOx, SOx etc. due to high temperatures even at 18000 F, usual glass melting temperature (i.e., furnace temperature). Bearing in mind that production or formation of NOx or SOx is temperature dependent, this study is conducted to control temperature in order to control the oxide formation. Nitrogen oxides are very important family of air polluting chemical compounds. In some regions reduction of 10-15% of NOx emission from the baseline is mandatory. Similarly, the company limiting value of SOx is 50 ppm for an average of 24 hours and 0.75 lbs. per ton generation, and PM10 (Particulate Matter) limit for opacity is less than 20%. Higher the opacity higher will be the impact on the environment. In this study, we have reviewed various methodologies in order to reduce the emissions from glass furnaces. There is opportunity for improvement in this process including new raw material innovation, appropriate material grading, and process control automation methods. Fig.1 shows the schematic diagram of a glass manufacturing plant showing Scrubber System, Electrostatic precipitator, and Exhaust System.

II. CAUSE AND EFFECT OF POLLUTION: REVIEW

A. NOx

NOx includes nitrogen monoxide, nitrogen dioxide (NO2), nitrous oxide (N2O), nitrogen tetroxide (N2O4) and nitrogen pentoxide (N2O5). When temperature goes high they start reacting to form Nitric Oxides [4]. Within the process primarily three different kinds of NOx formation occurs – thermal NOx formation, fuel NOx formation, and prompt NOx formation [5]. NOx control is critical as it affects human health because it reacts in the presence of ammonia. NOx reacts in air to form acids which comes to earth in terms of rain and snow. In the presence of sun light NOx reacts with other chemicals to form toxic materials such as nitrate-radicals, nitrous-amines, to name a few. Nitrous oxide is a member of greenhouse gas group. NOx destroys O3 (Ozone) layer in by absorbing ultraviolet light. NO2 and other nitrates create situational problem, depending upon the environmental condition (temperature and humidity), of traffic because they reduce the visibility causing accidents and sometimes deaths. As the quantity of nitrogen increases, nutrients balance will also get upset. NOx reacts in air, NH3, H2O and other materials to form acids and other related compounds which create lot of problems with breathing and respiratory problems.

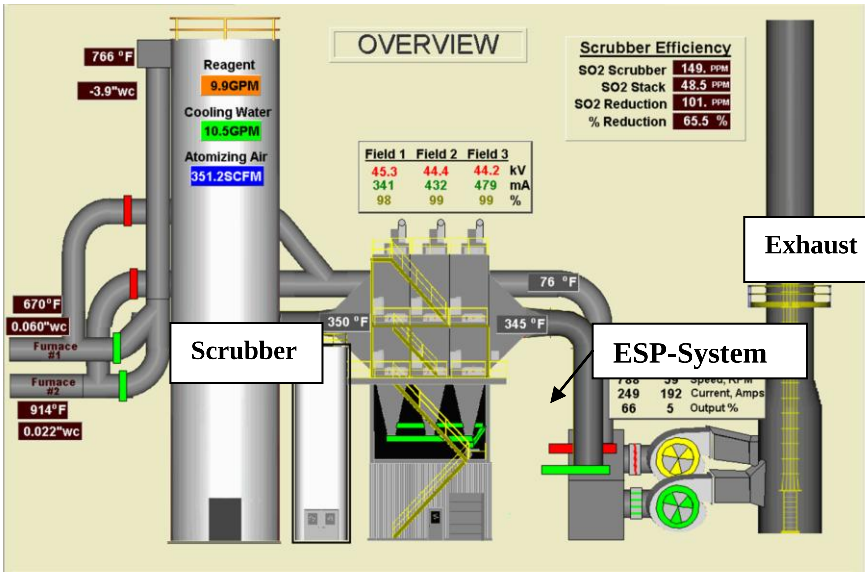

Fig.1: Glass manufacturing plant showing units and components (Scrubber System, Electrostatic precipitator, and Exhaust System (Adapted from Gurjeet Sarao MS Project and [11]; Courtesy: Saint Gobain Containers Industry.)

B. SOx

SOx is formed via combustion through a reaction between oxygen and sulfur. The presence of sulfur is can be in the fuel, raw materials and any other fining agent or ingredients [6]. The sulfur oxides are considered to be one of the highly reactive gases. SO2 produces SO3, which is very dangerous as it develops respiratory problems. Even a small quality of it such as order of one ppm can create breathing issues. When it dissolves with water, it forms sulfuric acid that can damage any metal or plants.

C. Particulate Matter

Most particles, whether solid or liquid, fewer than 10 microns are considered as microscopic particles. Particulate matter emission that causes pollution comes under airborne particles. They vary in size from 2.5 microns to less than 10 microns. These particles create serious health problems when the concentration in the air exceeds the limit set. It is denoted as PM2.5 or PM4.0, respectively. The number is the dynamic diameter of the particulate matter. The particulate matter contains base, acids, chemicals, liquids, solids, metal dust and gas particles. Due to their small size they can go deeply into lungs, heart through blood etc. They also create problems in growth in the plants and crops, developing skin disease and irritations.

III. EMISSION CONTROL TECHNIQUES

The emission of NOx, SOx, and PM can be controlled at two ends such as input end and output end. At the input end, it is at the process control stage and at the output end it is all about technology and equipment for treating exhaust. The latter method is referred to as post combustion control. Process inputs means what are added into the system for processing. This includes addition or involvement of appropriate level of raw materials, fuel, electricity, design and firing controls set up. Post-combustion control techniques are those in which existing process operations are replaced with modified strategy through augmented implementation after the emission is generated from furnace but before their release to environment. Commonly, post control techniques are always expensive and demands high maintenance [7]. Best idea is to control the inputs as much as possible. The key factors in NOx formation in glass manufacturing are (i) Flame and Operational Furnace Temperatures (FOT), (ii) Raw Materials and Batch Mix, (iii) Burner Design and Furnace Structure, (iv) Process Control System, and (iv) Excess Oxygen (Furnace Insulation). The experiments were conducted under each factor. In each case we measured the emission

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

indices using sophisticated measuring devices and then controlled these through newly applied emission controlled techniques. In each case the emission in controlled scenarios are lower than the reference values.

The rate of NOx formation increases with flame temperature (Fig.2a) [8]. In order to control the NOx we controlled the FOT through (i) burner ratio set-up, (ii) boosting, and (iii) controlling the purity of the oxygen. Note that FOT should be optimum so that we can get appropriate combustion and at the same time a good glass melting zone. Burner ratio set up was achieved by controlling the percentage of natural gas that requires mixing with the air. The normal ratio is 1:10, but depending upon the temperature, the ratios differ. Boosting is simply inserting the electrodes into the combustion zone. Electrodes made of molybdenum material having sizes from 1-5 inches depending upon the requirements, were placed. We achieved boosting that was capable of melting 4.0 – 5.0 mmbtu per ton of glass. Oxygen purity is also a critical aspect in order to get enrichment in combustion. We tested two versions such as 90% and 96% of oxygen (not shown in the figure) and found that the purity has a role in emission formation. Fig.2(b-d) shows how the emission is affected by the above mentioned controlled techniques. In fact, presence of appropriate burner ratio, electricity, and oxygen cause NOx to decrease.

To improve the work ability alumina sand that helps to lower the temperature was added. Further, we replaced Sodium Nitrite by salt cake. The important consideration in mixing salt cake is that it should be optimal. Choosing the raw material and emission control is very critical. Under this technique, the emission can be controlled by optimally utilizing the percentage of recycled glass. The range is 20-40%. Further, we re-designed the burner that can facilitate blowing of primary and secondary air. Our goal was to lower the oxygen content in primary burner stream in order to lower the peak temperature of burner flame. It was found that if the angles of burners are not set up properly the efficiency of combustion was not higher. So, controlling the angle was important. We set up various angles and measure the emission rate correspondingly.

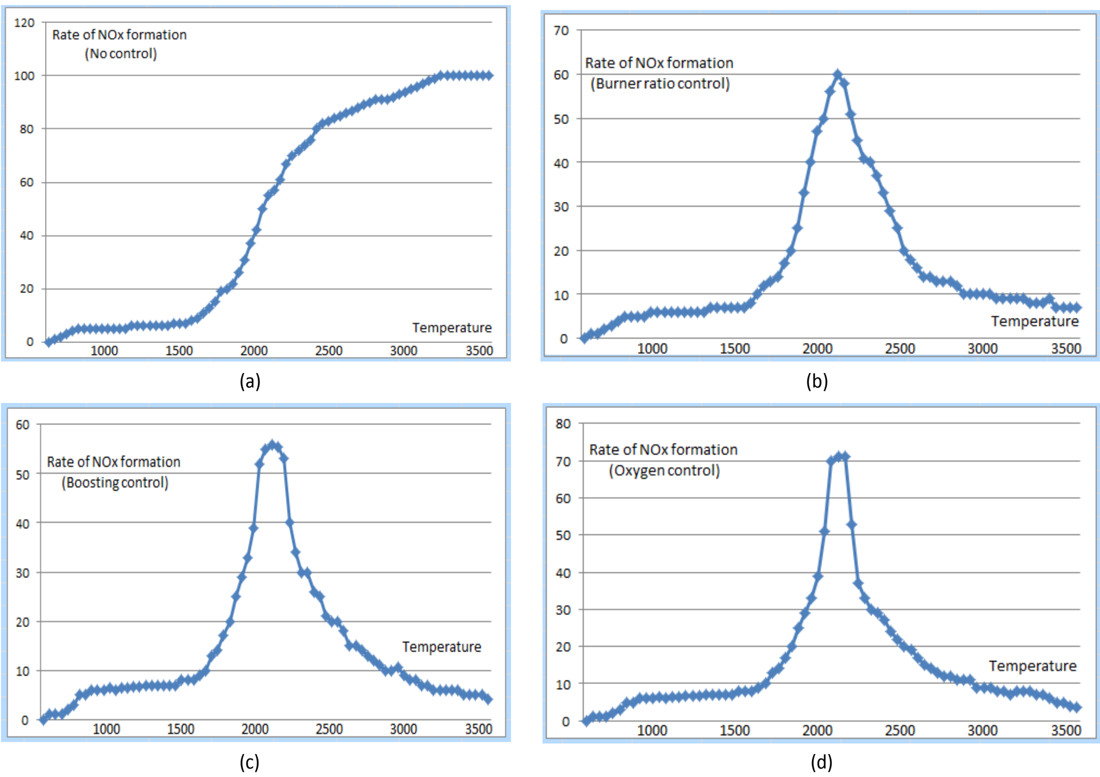

Fig.2: (a) Rate of NO_x formation without any control; (b) with ratio control, (c) with boosting control, (d) with Oxygen control.

The newly designed adjustment screw is capable of changing the burner angle. In regard to flame geometry, we made adjustments in threading to see the changes in velocity in order to adjust the geometry. Flame geometry plays vital role in various combustion requirements. The bright fire burners form eclipse was used. Note that normal NOx

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

rate was around 3.95 lbs/ton, after we made the changes in process control algorithm to control the process. As seen, the NOx dropped more than 20%. Thus, we achieved excellent results from this implementation. Fig.3 shows that overall NOx value start dropping under controlled conditions. The measurements were taken for 10 weeks period – about 6.5 weeks under un-controlled condition and 3.5 week under controlled condition. Through the experiment, it was also found that rapidly NOx changes during operation means the furnace is sucking lot of air from outside source and it is not well sealed or insulated. So, prior to conducting the experiment we had to insulate the furnace. Insulation is critical for testing of emission. We insulated the furnace with mortar material 150-patch.

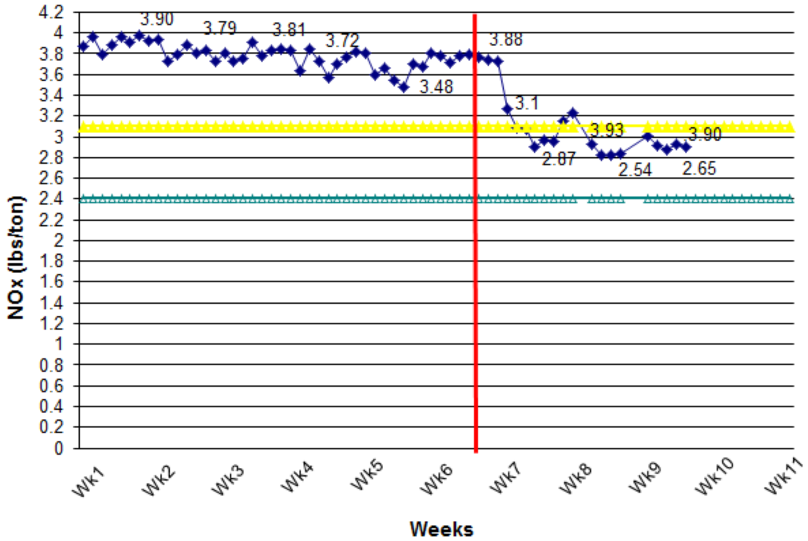

Fig.3: Reduction of emission by means of (i) Raw Materials and Batch Mix, (ii) Burner Design and Furnace Structure, and (iii) PID based Process Control

The furnace requires different types of cyclic cooling such as wind cooling, crown cooling, bottom cooling and throat cooling in an order to protect furnace refractory and avoid major disastrous like glass leaks. This requires a precise monitoring and control. Most of the glass manufacturing process control systems are however, manually operated. That is no automated process control techniques are available. We implemented PID (Proportional Integral and Derivative) control systems in the combustion system for regenerative and oxy-fuel type furnaces. We did technical analysis and developed a fieldbus based distributed control architecture in order to implement precise PID control system. The measurements were taken several times during in 24-hour time slot. Fig.4 shows one of the measurements in 32 hours.

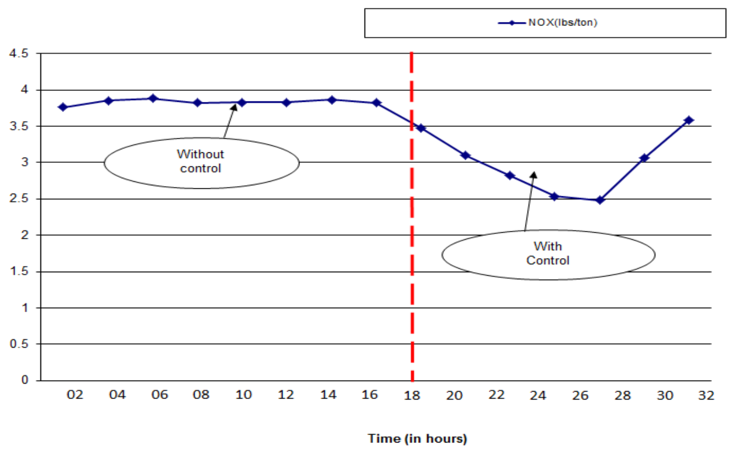

Fig.4: Controlling NO_x using process control technique (PID control)

The emission control techniques for SOx was implemented and validated. Within the glass-making process, we considered two sources [9] of SOx. One natural gas in combustion system and second is raw materials used in batch mixing. In natural gas, the quantity of sulfur can be negligible. SOx formation occurs from a reaction between sulfur and oxygen. We use salt cake as a refining agent due to its availability and cost. Post control techniques were

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014
implemented for SOx control. For understanding of a glass manufacturing system refer Fig.1. Scrubbing system was used. The design and size of scrubber depends upon the application. Scrubber devices control the pollution by absorbing and removing aerosols and acidic gaseous pollutants from the air stream. Factors affecting scrubber operation are (i) static inlet pressure drop, (ii) scrubber liquids, and (iii) resident time. The static pressure was maintained between -3.4 to -3.9 of water column. In order to neutralize the acidic gases with reagent flow rate of 9 GPM with cooling water of 10.05 GPM was used. The resident times were 6 and 9 minutes, respectively. Based on trial and error method, and considering all these three factors, we successfully controlled the scrubber operation within an optimal zone. Fig.4 shows that SOx was reduced by about 10% from the original emission, which is the best performance in our setting. The experiments were conducted over a period of 90 days (trial and error). Fig.5 shows the final results in which measurements were carried out for 30 days period.

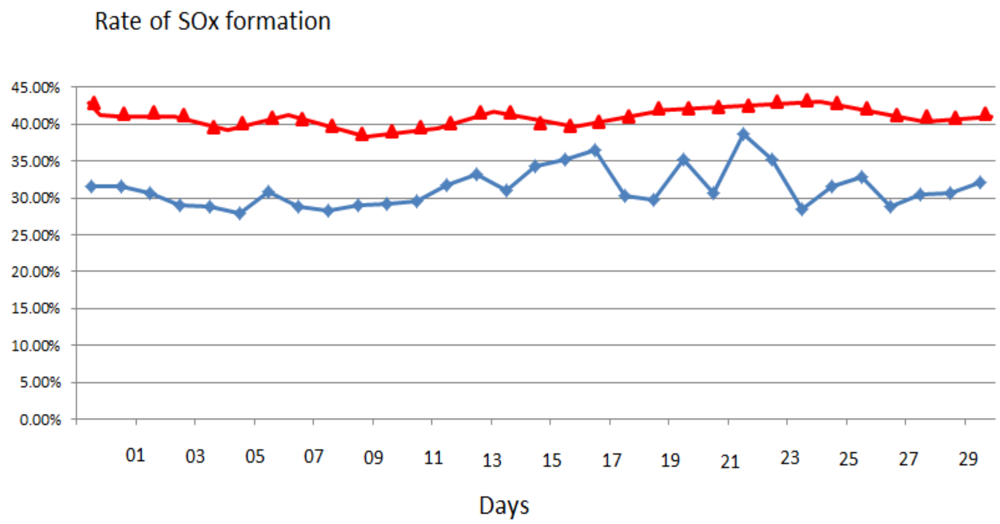

Fig.5: Reduction of SO_x by optimally selecting the three factors such as (i) static inlet pressure drop, (ii) scrubber liquids, and (iii) resident time at the scrubber efficiency of 50%.

IV. PARTICULATE MATTER EMISSION CONTROL TECHNIQUES

Typical exhaust air flow in the furnace varies in the order of 30-35 thousand standard cubic feet per minute. Because of high flow particulate maters of higher order dimension get fly into the exhaust system [10]. As a result opacity control was important in order to tackle this problem. Traditionally, the preferred grain size was employed based on three factors such as available materials, capability of the furnace, and the type of combustion system. It was identified that optimal grain size play important role in controlling particulate matter. In this study we confirmed that opacity can be controlled by optimally choosing the grain size. The opacity control was achieved in indirect and direct methods. Indirect method includes grain sizes. We did experiment by employing different sizes of mixing materials. Seven sizes of grains were cooked at different times and observation was made. The size number 5 was most preferred for low possible opacity. The direct method includes choosing of low melting point materials and mixing times variations. Note that silica has about 3% - 5% material loss compared to soda ash which has 8%-12%. Lower is better.

This study also implemented a step forward to combustion particulate control (CPC) technique. The traditional method for controlling or reducing the particulate matter has been the use of filters and electrostatic precipitator. This is called combustion particulate control (CPC). After the combustion process, the dust particles flow through electrostatic precipitator system. It works based on corona effect on the electrodes which are provided with extremely high voltage. The particulate matters get deposited on the oppositely charged precipitator plates and regularly cleaned. However, as time proceeds, the plates become heavier and the efficiency of deposition of particulate matter is not same as that when the plate was empty. As of now, there was no control of electrode voltage with respect to time. It was confirmed in this study that by controlling the magnetic field (corona discharge) which can be controlled by the electrode voltage (Fig.6), the efficiency of deposition of particulate matters on the plate can be maintained or increased.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

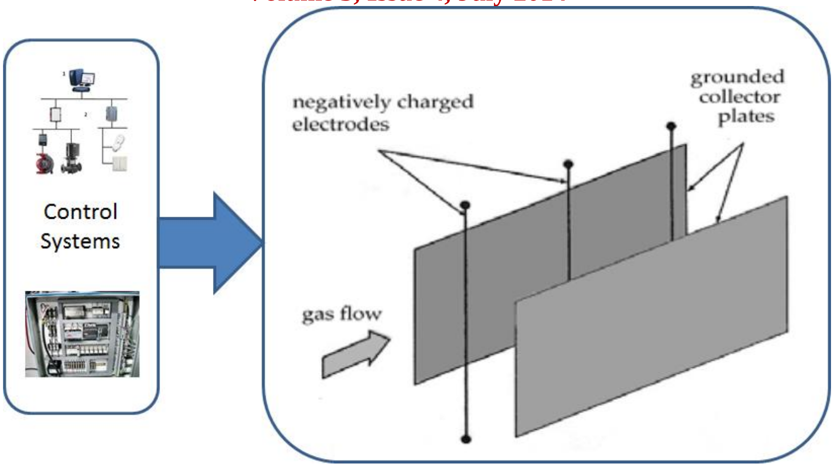

Fig.6: Electrostatic Precipitator and its control Box (Fieldbus Technology was used)

The allowable opacity limit for particulate matter is usually <20%. In this study we achieved this value via direct and indirect method as well as through CPC.

V. CONCLUSIONS

Emission control is a critical aspect of environmental pollution control. At the outset, it was necessary to review the environmental regulations, health effects due to emission, oxy-fuel regenerative process control systems, flame geometry, furnace geometry, and implementation of alternative techniques while conducting this research which is reduction of emission from the baseline. In this research study, we have demonstrated that 10-20% of emission can be reduced by employing various control techniques. In particular, we met 20% of NOx reduction by making adjustments in burner setups, air-staging and implementing PID based process control systems. For future work, there is always a chance to improve, more study work needs to be done to develop a robust control system for combustion control system for glass manufacturing combustion system that will meet all the environmental compliance permit conditions. Secondly, more research needed to lower down the temperature of mixed batch raw materials in order to lower down the emissions as well as energy usage.

ACKNOWLEDGMENT

The work is supported by through the JCAST Release Time for continued research the Department of Industrial Technology, Jordan College or Agricultural Sciences and Technology and California State University Fresno, California, USA.

REFERENCES

[1] Antonio C. Caputoa and Pacifico M. Pelagaggea (2011). Economic Comparison of Emission Control Systems for Glass Manufacturing Furnaces with Heat, Journal of the Air & Waste Management Association, Volume 51, Issue 7, PP 1009-1020, 27 Dec 2011.

[2] Jozef Pacyna (1987). Atmospheric Emissions of Arsenic, Cadmium, Lead and Mercury from High Temperature Processes in Power Generation and Industry. (Eds). T. C. Hutchinson and K. M. Meema (1987). SCOP, John Wiley & Sons Ltd.

[3] Marshall Sittig (1975). Pollution Control in Asbestos, Cement, Glass, and Allied Mineral Industries, Noyes Data Corporation, London.

[4] Fay V Tooley (1953). The Handbook of Glass Manufacture: A Book of Reference for the Plant Executive, Technologist and Engineer, Ogden Pub. Co. (Original from the University of Michigan).

[5] Alexis G, Pinucus. Melting Furnace Design in the Glass Industry (Processing in the Glass Industry Series)

[6] Barrie Jenkins, Peter Mullingar. Industrial and Process Furnaces: Principles, Design and Operation

[7] National Pollutant Inventory (1998). Emissions Estimation Technique Manual for Glass and Glass Fibre Manufacturing

[8] O. Auchet, C. Iung, O. Mallasse, and P. Riedinger (2004). Glass furnace, simplified modeling for control and real time simulation, IEEE International Symposium on Industrial Electronics, May 4-7, 2004, pp 657-661, vol. 1.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 3, Issue 4, July 2014

[9] http://www.miga.org/documents/GlassManufacturing.pdf

[10] J. Kukkonen1, L. Bozó2, F. Palmgren3, R.S. Sokhi (2003). (Ed. N. Moussioloulos) Particulate Matter in Urban Air, Springer, ISBN: 978-3-540-00842-2, Berlin.

[11] Gurjeet Sarao, N. P. Mahalik and Tony Au (2012). Air-pollution control techniques in a glass manufacturing process, Proceedings of the 33rd Annual Central California Research Symposium, April 13, Fresno State, California.

AUTHOR BIOGRAPHY

Gurjeet Sarao received MS in Industrial Technology in the Department of Industrial Technology, Jordan College of Agricultural Sciences and Technology, California State University, Fresno, USA. Mr. Sarao has 10 years of experience working in industry. He has published more than 10 papers at the seminar, conferences and symposiums. .

Nitaigour Premchand Mahalik is working as a faculty member in the Department of Industrial Technology, Jordan College of Agricultural Sciences and Technology, California State University, Fresno, USA. He has expertise in the field of Distributed Control Systems (DCS). He applies DCS in Processing and Packaging areas. His research work includes smart sensors and actuators, applications of soft-computing to FDI, Life-Cycle Data Acquisition, sensor network, and DCS simulation software. He teaches Industrial Process Control, Automated Systems, Electricity and Electronics, Signal Processing, and Research Methodology. He has authored and edited 5 Books and 12 Book Chapters. Dr. Mahalik is the co-editor of the International Journal of Automation and Control (IJAAC). He was the recipient of National Overseas and Brain Korea-21 Fellowships for Ph.D. and Postdoctoral research abroad, respectively. Dr. Mahalik has visited labs and research centers in various universities around the world. He was a member of several professional societies including ATMAE, ISA, ASABE, IAE, and ISTE.