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Comparative Analysis between Automated Industrial Oven Firing and Manual Firing for Continuous Colour Coating Line. A Case Study of Kolorkote Nigeria Limited, Ota

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Abstract

Automation of industrial oven has made firing and controlling of temperature to be easy and save. In the recent year, industrial oven has always been fired manually and this has cause a lot of accident to personal, equipment, materials in the industry. The performance and the operational problem of manual firing were investigated in order to determine its shortcoming. To achieve this, firing procedure, gas regulation, flame regulation, efficiency and effectiveness of heat distribution, occurrence of fault, troubleshooting and rectification and shutdown procedure were investigated and compared to automatic operation of industrial oven. It was discovered that manual oven has problem of firing, temperature regulation, time wastage, gas wastage but all these problems were overcome to about 98 % by automatic oven due to the introduction of programmable Logic Controller and SCADA. The advantages of industrial automated oven include easy firing, high degree of safety, high efficiency, faults are easily detected and rectified.

Keywords: Automation; continuous; firing; heat distribution; industry; performance; controller.

1. Introduction

Oven is a thermally insulated chamber used for the heating, baking and drying of a substance [1]. It is a compartment that is well lagged and can accommodate a higher temperature of about 1000 degree Celsius.

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The Kolorkote Nigeria Limited is a company involving in baking a paint applied to aluminum, Aluzinc or Galvanized iron metal as they pass through the oven. The oven has three zones of about twenty (24) meters and four (4) meters wide and eight (8) meters for each zone. The oven has one burner on each zone making it three zones all together. The type of oven used in Kolorkote is gas fired oven. It comprises a combination of mechanical and electrical parts for the regulation of the flow of gas and air into the burners and controls temperature to the required values [2]. Both the mechanical and electrical components work together in order to achieve desire result. The first chamber is called curing state which is designed to cause a chemical reaction in a substance once a specific temperature is attained. The second chamber is called drying state and is designed to remove moisture typically used in pre-treating and painting with higher temperature than curing state while the third chamber combined the function of curing and drying in order to have a well baked finished product. Automated oven has made industrial heating an interesting one due to its ability to achieve set point in a very short time with good quality product and easy to maintain. Fault detection and rectification are very easy compare to manual oven.

2. Components of Automated Oven

2.1 Gas Train

Gas train is a combination of electrical components in a gas line pipe that regulates, controls the flow of gas into the burner of the oven. This comprises many components such as pressure switches, gas regulators, filters, solenoid valves etc. all these components work together to regulate oven temperature and provide safety. Figure 1 shows the component of gas train.

Figure 1: Gas train

2.2 Some Components on the Gas Train

2.2.1 Pressure Switch

This is a type of switch that recognizes the incoming gas and compares it with the set pressure. It may be low or high pressure controlled. If the set point pressure exceeds or below value, it operates either from normally open (NO) to normally close (NC). The electrical rating may be 5 Amps at 250 V and having a range pressure of about 0.5 to 600 mbar etc.

2.2.2 Gas Regulators

This is a part of gas train that ensures the exact gas pressure get into the burning chamber. It acts as a step down of pressure gas. For example 4 bars to 100 mbar as shown in figure 1.

This can be regulated in the ratio that is required for a good flame to be achieved.

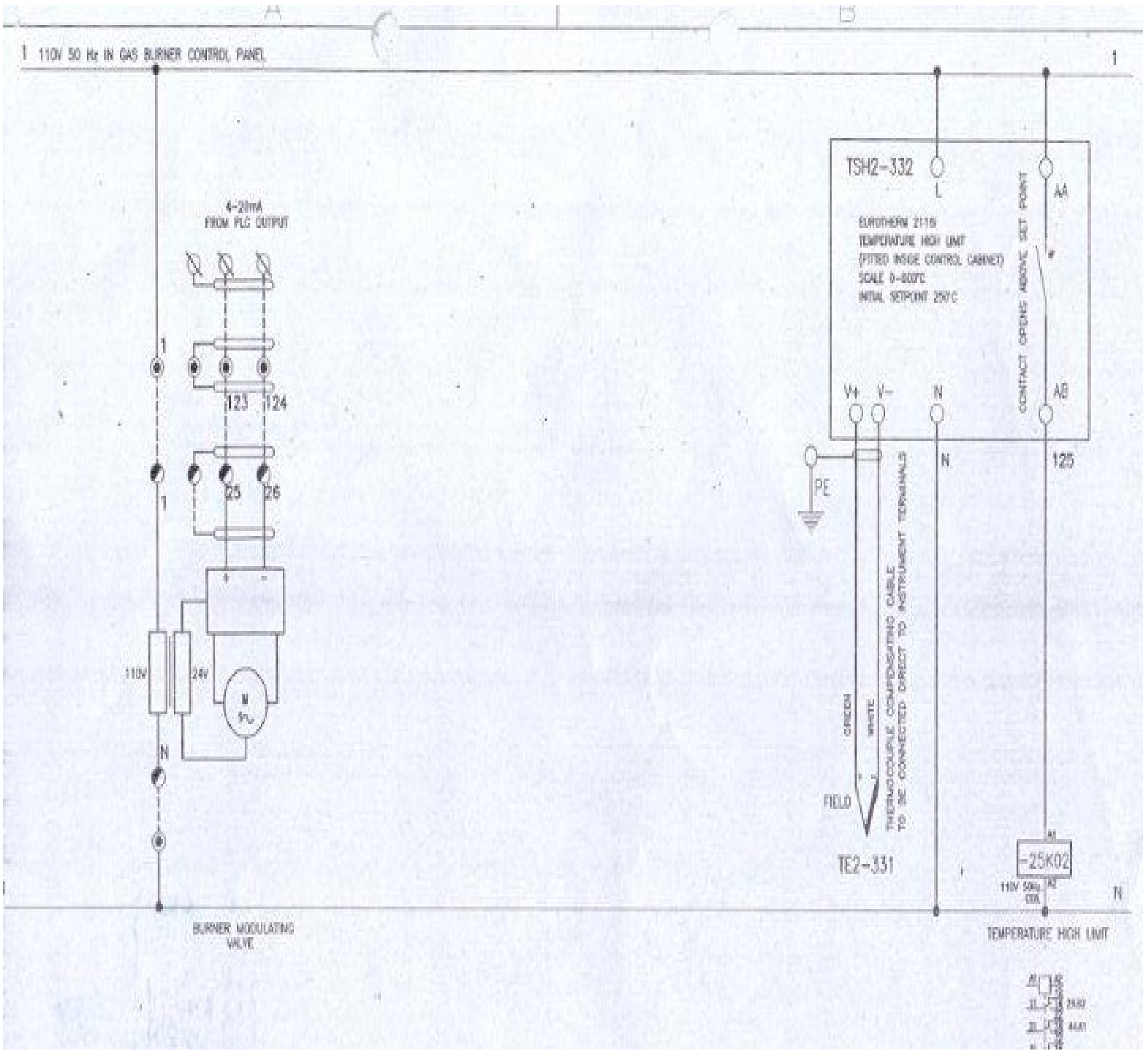

Figure 2: Schematic diagram of a burner modulation

2.3 Solenoid Valve

This is an electrical controlled valve, which has an inlet and outlet for the gas flow. The solenoid controls the plunger that when actuates opens and allows the flow of gas through its outlet. It may be rated 220Vac or 110Vac, and flow rated adjustable. The solenoid valve provides safety. The valves are mounted on the pilot gas train and main gas train to ensure proper safety. It enables the pressure switch to detect air flow.

2.4 Burner Modulation

This is otherwise known as servomotor. It regulates the inflow of air/gas into the system when it gets a signal 4 – 20 mA from either temperature controller or programmable logic controller (PLC). The burner gets its command from temperature controller which shows the set point value temperature and process variable value temperature. The temperature controller compares the two values of temperature and sends a signal to servomotor either to close or open to allow flow of gas/air which in turn increases the temperature or reduces the temperature. Figure 2 shows the wiring connection of the servomotor to temperature controller. This motor can rotate in both directions and have a stroke of 90^0 or 180^0. It can be set to desired stroke. It has a protected shaft at both sides that can be attached to a butterfly valve, which allows for the inflow of air or gas into the chamber.

2.5 Flame Ionization Detector

This is the type of sensor that responses to the ultra violet light of a flame. Therefore, it does not react to the daylight, light from filament lamps and infra-red radiation from hot work plates. The ionization detector is positioned very close to spark plug at an angle so that it can sense the flame produces by spark plug. The ionization detector operates on 220Vac voltage. With incident ultra violet light, the alternating current flows through the detector cell, which is converted by rectifier into a direct current signal. The flame signal amplifier reacts to the current.

2.6 Ignition Transformer

This is a step up transformer that step-up from 220V to 7.5KV with low amperage. The spark plug is connected to the

ignition transformer to effect the spark. The spark plug is installed to generate a spark on the pilot train. Its position in such that is generates a spark along the pilot line and when gas is opened on the pilot, it catches a flame.

2.7 Sequence Controller

This performs all the operations in a sequential manner to establish the firing of the oven. The sequence controller energies the pilot valve and ignition transformer at the same time, when there is a flame the ionization detector senses the flame and send signal to main valve to energize. When all this fails, it lock-out and start the sequence all over again. The sequence controller also gives the feedback to the system, by given a signal to show when there is ‘FLAME ON, EXCESS TEMPERATURE AND LOCK-OUT’. And also, a fault experience on the gas train will be detected on the sequence controller and it will only locks out on the faulty equipment. Figure 3: Shows electrical wiring diagram of a sequence controller. This contains the spark plug, ionization detector, air solenoid valve, ignition transformer, pilot gas valve and main gas valve.

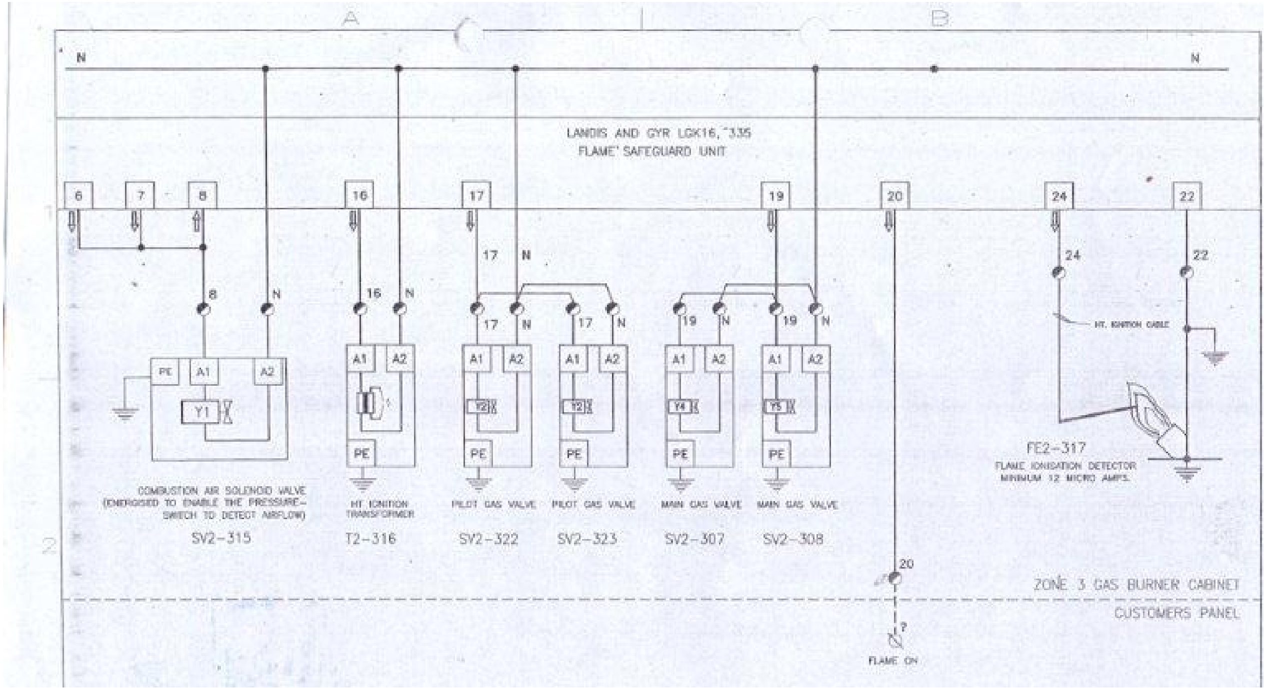

Figure 3: Electrical wiring of sequence controller

2.8 Temperature Controller

Automation of oven is essentially for safety and temperature controlling. This temperature controlling is the main factor so that the material to be baked can be maintained at the set temperature. Without automation, it has been seen to be very difficult to achieve the set temperature and this achieve by a temperature controller and servomotor. A temperature controller is an electronic system that has ability to give the details of temperature that is being sensed by a thermocouple, and send a signal in millivolts or milliamps to the servomotor to respond accordingly. There are two values display on the screen of the temperature controller, the set value and the process value. The set value is the preset value enters into the system as a reference point while the process value is the value that is achieved from the thermocouple sensor which is sent to through the transmitter into the SCADA. The temperature controller compares the process value with the set valve and if there is different it then sends a signal to a servomotor, either to open or close depending on the state of the signal sent. Other components associated with the operation of temperature controller are thermocouple and transmitter.

2.9 Thermocouple

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. Thermocouples are widely used type of temperature sensor for measurement and control. And can also be used to convert heat into electric power. Any junction of dissimilar metals will produce an electric potential related to temperature. Thermocouples for practical measurement of temperature are junctions of specific alloys which have a predictable and repeatable relationship between temperature and voltage. Different alloys are used for different temperature ranges. Properties such as resistance to corrosion may also be important when choosing a type of thermocouple. Where the measurement point is far from the measuring instrument, the intermediate connection can be made by extension wires which are less costly than the materials used to make the sensor. Thermocouples are usually standardized against a reference temperature of 0 degrees Celsius; practical instruments use electronic methods of cold-junction compensation to adjust for varying temperature at the instrument terminals. Electronic instruments can also compensate for the varying characteristics of the thermocouple, and so improve the precision and accuracy of measurements. It is a sensor of different types, for example type K, E or J.

2.10 Transmitter

This is an electronic device that transmit the converted heat energy signal by thermocouple in the form of electrical signal to a Supervisory Control and Data Acquisition (SCADA) where it can easily be controlled or visualized by an electrical personnel or trained operator.

3. Control and Interlocks of Oven

The control and interlock of automated industrial oven is a system that ensures the safety of personnel and oven components. This is done so that whenever there is failure of any component the oven will quickly trip within a set time and this is shown on the supervisory control data acquisition (SCADA). The interlock involves the following equipments: Combustion motor, recirculation motor, temperature controller, sequence controller, gas switches.

3.1Combustion Fan Motor or Blower

This is a fan that provides air to the burner. In the Kolorkote oven, this fan motor is rated 1.27kW, 415V which is connected to a fan that rotates to provide air for combustion to take place in the oven. Air and gas are mixed in certain proportion to give a good flame. This proportion is achieved by a regulator. As the air enters the regulator, it gives way to the proportional value of gas to pass through the combustion chamber. An interlock is provided to the motor control and the gas solenoid value at the mini-gas station. This means whenever the motor is ON, it is then the solenoid could be ON. The control of this motor is incorporated to the main control of the system, to achieve the indication interlock ok.

3.2 Recirculation Fan Motor

This is another important part in the oven to achieve evenly distributed temperature in all chambers of the oven. The motor is rated 18.5 kW/24.8HP, 415V, which is connected to a fan that rotates to ensure that the temperature generated is evenly distributed within the oven zones

An interlock is provided to the motor control system in each zone to the main control system automatically so that when one recirculation motor is not ON “interlock OK” is not achieves, so firing could not be achieved.

4. Principle of Firing and Operation

The method used in the staring up of automated oven in Kolorkote Nigeria Limited follows the principle of sequence controller. In order to minimize risk, the sequence controller initiates the firing process by checking all the basic components needed for the oven to fire. After checking the initial requirements such as interlocking of all the combustion fans, recirculation fans, servo, transmitter, thermocouple etc. Programmable Logic Controller (PLC) is configured to aid the completion of the process with the help of Supervisory Control Data Acquisition (SCADA).

All these control systems comprise PLC-I/O that interface to a PC with appropriate software, or a PLC paired with data collection software. This also benefit from the use of an operator interface referred to as Human Machine interface (HMI) which enable the operator to make changes to set point values, process time, flow rate etc. [3]. After ascertain the initial requirements, the ignition transformer steps up the 220 V to about 7.5 kV to effect the operation of spark plug and at the same type the pilot gas switch is energized to allow initial combustion to take place. This process continues as the flame generated is expanded by flame ionization detector and this allows the main gas to come in for complete combustion as electrically shown in figure 3 [4]

5. Advantages of automatic oven over manual firing

The following are the major advantages of automatic oven firing over manual firing.

- Faster processing time
- High degree of safety
- Easy troubleshooting of fault
- Efficient distribution of generated heat
- Efficient process control
- Easy coordination and communication
- Proven performance
- Economic operation
- Reduces wastage of materials that could result from excess heat.
- Cost reduction in the area of gas usage.

6. Limitation to Automatic Oven Firing

- It requires skill personnel to operative effectively and efficiency
- It is capital intensive which makes it impossible for many small companies to use
- There can be several unpredictable costs that may exceed the actual cost saved by the automation itself.
- System error may make troubleshooting cumbersome.

7. Troubleshooting and Fault Finding Guide of Automated Oven in Industries

Table 1

SYMPTOM	**CAUSES**	**SOLUTION**
Burner light up sequence does not start	No electrical supply	Check electrical supply at local isolator. Check the control fuse.
	Burner electrical control circuits are not in start-up condition.	Check controls and switches in control circuit. Check all pressure switches and micro switches.
	Airflow pressure switch not made	Check setting on switch, if this is correct check the airflow.
	Low gas pressure switch not made	Check setting on switch, if this is correct check gas pressure.
Start cycle begins but burner locks out or shuts down before initiating the ignition sequence	Low combustion air pressure differential	Reset burner pressure switch. If pressure switch is set correctly open the air damper on the combustion air fan. Check that the combustion air fan motor is rotating in the correct direction. Check that the combustion air fan is running, if not check the overload or circuit breakers.
SYMPTOM	CAUSES	SOLUTION

Main flame does not light and burner locks out at the end of the pilot phase.	Faulty main shut off valves	Check electrical supply to valve. Check condition of the valve, if faulty, replace.
	No main gas	Check manual valve open. Check the adjustment of the gas control valve Ensure gas is available at burner
	Not enough main gas	Check main gas flow adjuster and gas regulator
Main flame lights but shuts down after a short period of time.	Pilot gas rate too high	Adjust pilot gas rate
	Control circuit operating	Check control circuit, over temperature limits etc.
	Burner gas or air ports blocked	Check and clean. Identify source of blockage and rectify.
	Flame sensor not detecting the flame	Over firing and flame is "lifting off", reset main flame firing rate. Check flame sensor installation and position Check the main gas pressure governor
SYMPTOM	CAUSES	SOLUTION
Pilot does not light	No spark	Check electrical supply to ignition transformer. Check electrical connection to spark plug.

		Check operation of ignition transformer. Check the condition of spark plug and clean, reset or replace.
	No pilot gas	Check manual valve open. Check that pilot solenoid valve opens. Ensure gas is available at burner.
	Not enough pilot gas	Check pilot gas flow adjuster and pilot gas regulator.
	Pilot blown out	Reduce process air flow if possible. Increase pilot gas rate.
Pilot lights but locks out when ignition de-energized	Pilot gas too low	Adjust pilot gas.
Pilot lights but the burner locks out before the main valves are energized	Flame sensor not detecting the flame	Check sensor for damage or moisture. Clean flame sensor. Check flame installation and position.
	Faulty sensor	Replace sensor
SYMPTOM	CAUSE	SOLUTION
Flame failure (lockout) during normal main flame operation	Faulty main shut off valve.	Check electrical supply to valve. Check condition of the valve if faulty, replace
	No main gas	Check manual valve open. Check the adjustment of the gas control valve Ensure gas is available at burner
	Not enough main gas	Check main gas flow adjuster and gas regulator
	Control circuit operating	Check control circuit, over temperature limits etc.

	Burner gas or air ports blocked	Check and clean. Identify source of blockage and rectify.
	Flame sensor not detecting the flame	Over firing and flame is "lifting off", reset main flame firing rate. Check flame sensor installation and position Check the main gas pressure governor
	Combustion air failure	Inspect combustion air fan for damage. Check fan overload. Check air filter (if fitted) and clean if necessary.

8. Conclusion

- This study has shown that automatic firing of industrial oven is better than manual firing. It is clearly shown that through automatic regulation of gas and air into the oven burner, the heat require in normal operation is achieved and this is impossible with manual firing.
- The degree of safety is very high and reliable in automatic firing which gives it an edge over manual firing.
- The use of Programmable Logic Controller in the automation of industrial oven has made automatic firing of oven in industrial more desirable in area of troubleshooting and resolution of fault without a waste of time.

9. Recommendation

This paper has shown the importance of automatic oven firing with respect to performance. To overcome the limitations to the use of automatic firing of oven in industries the manufacturers should design low cost industrial oven so that small industries would benefit from the system. Also, training of personnel to enhance individual performance and be conscious of maintenance and safety procedure.

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