

# Performance of the Prototype Furnace Evaporator with PLC Control

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**Keywords:** Furnace, Evaporator, Heater, Programmable Logic Controlled (PLC).

**Abstract:** Furnace Evaporator (FE) is an instrument that has two (2) functions as a furnace and evaporation, in an effort to increase the capacity of the material both activities are needed. The Furnace Evaporator was first patented by Pierce, James Louis, in 1917, using an energy source from gas, used for processing natural materials. This Furnace Evaporator (FE) is designed to use a heat energy source (heater) from electricity, to later become a prototype FE with a working temperature of 50°C-900°C, and heat control based on Programmable Logic Control (PLC). The FE prototype has two horizontal and vertical doors, with a combustion chamber area of about 36 cm<sup>3</sup>. Prototype has accuracy in generating heat, the temperature value on the HMI monitor screen when compared to a measuring instrument has a chi square (R<sup>2</sup>) value of 0.995. Operational testing was carried out in three (3) conditions, namely when the prototype hood was closed (C1), half closed (C2) and open (C3), the results had different temperature resolution responses, namely, 2.14 V/s, 1.25 V/s and 0.83 V/s. If the three parameters are combined, they have a non-linear relationship with a chi square (R<sup>2</sup>) value of 0.9939, which means that they are significantly related.

## 1 INTRODUCTION

*Furnace* is an instrument that has the function of heating materials / materials with a *heater*. Furnace can be used in sintering and calcining processes. Sintering process is a process of heating the material not to exceed the melting point in order to improve the structure and quality of the material. Calcination is the process of heating solids in the absence or with very little supply of air or oxygen to carry out thermal decomposition.

Evaporator is an instrument that functions to change part or all of a solvent from a solution from a liquid to a vapor. Evaporators have two basic principles, to exchange heat and to separate the vapor formed from the liquid. Furnace Evaporator (EF) is an instrument that has two (2) functions as a material furnace and chemical evaporation. This tool was first patented by Pierce, James Louis, in 1917 with Patent No. 1,228,240, 1917. This prototype Furnace Evaporator (FE) is gas-fueled, fuel is injected into the chamber at the top to form a vortex fire inside. This Furnace Evaporator (FE) is designed to use a heat energy source (*heater*) from AC electricity. *heater* used has a capacity of 300°C-1200°C. This tool is used as a support in the design of Gas sensors with

Si<sub>(1-x)</sub>Al<sub>(x)</sub>O<sub>3</sub> substrates, this tool functions as a furnace for the calcination process (furnace) and an evaporator when the chemical liquid process is evaporated to the sensor cover.. The prototype of the sensor design in question can be shown in Figure 1,

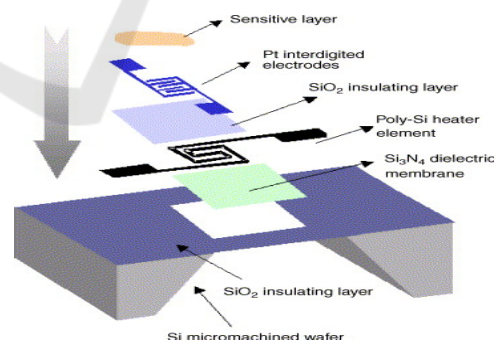


Figure 1: Sensor prototype.

Sensitive layer is a chemical material as a sensor cover that functions to respond to the gas to be detected. The evaporation temperature for chemical liquids ranges from about 90<sup>0</sup> C to 200<sup>0</sup> C, depending on the melting point.

The higher the heating temperature with the longer coating time, the thicker the layer thickness on the sensitive layer (cover sensor). The coating

thickness setting can be adjusted based on the rotation time and speed if the material is placed on a swivel stand. The results of the study [2] with SnO material as the sample showed that at a heating temperature of 100 °C - 200 °C, the thickness of the coating attached to the substrate ranged from 83.8 to 80.9 nm. The higher the annealing temperature, the lower the refractive index of the thin film, that is, at a heating temperature of 100°C, the refractive index is higher.

The three (3) dimensional shape of the prototype Furnace Evaporator (FE) that has been designed can be shown in Figure 2. There is a hole above it which is intended to regulate the air in the combustion chamber inside. The condition of C1 when the hole is closed, so that the combustion chamber does not come into contact with the outside air.

The condition of C2 when only a small gap is given, so that the combustion chamber is in contact with the air and in the condition of C3, the hole is not closed, it means that the combustion chamber is in contact with the outside air.

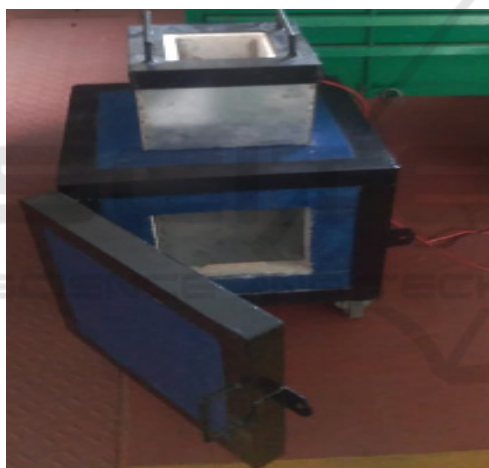


Figure 2: Photo Furnace Evaporator (FE).

Figure 2 shows a photo Furnace Evaporator (FE), frame made of steel with walls made of calcite, refractory brick. Above it is a hole intended to regulate air when operated or also needed when cooling. Physical dimensions of 41 cm x 41 cm x 75 cm with a volume of space is 36 cm<sup>3</sup> (30 cm x 30 cm x 40 cm), the overall weight is about 12.5 Kg.

This tool has several electrical components, including, Table 1.

Table 1.

Name of Tool	Specifications
PLC Modicon TM221CE16R	16 digital I/O, 2 analog inputs 1 Serial port, 1 Ethernet port 220-250 VAC power supply, 24 VDC out
Heater	1500 WATT
Solid State Relay	5A
MCB	16 A
Transmitter Thermocouple	0-16 V Temperature range -100–1000 C
NYAF CABLE	2.5 mm, 0.75 mm

## 2 PLC Modicon TM221CE16R

Programmable Logic Controlled (PLC) used in this tool is Modicon M221 is one of the products that issued by Schneider Electric. This M221 PLC can be programmed using *software* provided for free by Schneider Electric, namely *SoMachine Basic*. PLC M221 has 16 Digital I/O ie 9 inputs and 7 outputs and also 2 Analog inputs, with a power supply of 100-240 Vac, with an ethernet port and also some LED indicators. Figure 3 below shows the physical form of the TM221CE16R PLC.

This PLC uses *SoMachine Basic* software, which is PLC software that is used to configure, communicate all devices connected to these devices, including the Human Machine Interface (HMI) system and networks related to automation functions.



Figure 3: PLC TM221CE16R.

### 2.1 HMI and SCADA

*Vijeo Citect* is one of the *software* used in the creation, programming, and application *software*

SCADA Vijeo Citect can be applied to handle various cases in industries such as wastewater treatment, food and beverage production, mining, automobile assembly, *metal casting*, transportation, *aerospace*, defense systems, security, etc.

*software* consists of four main applications, namely *Vijeo Citect Explorer*, *Vijeo Citect Project Editor*, *Vijeo Citect Graphic Builder*, and *Vijeo Citect Runtime*.

- 1) *Vijeo City Explorer* is an application that is at the top level of Vijeo Citect applications that functions in programming and system configuration. In figure 2.4 is the view of *Vijeo City Explorer* which used for:
  - a) Starting and stopping the Citit Project Editor and the Citit Graphics Builder.
  - b) Selecting and managing Projects
  - c) Create projects, delete, *backup* and *restore* projects
  - d) Run other applications, such as Cicode Editor.
  - e) Explore and access the components of the *software* being worked on.
- 2) Configuring *Software* Vijeo Citect

Before creating a layout in the *software*, it is necessary to set up or initialize the project to be created. The things that must be set are clusters and servers, communication parameters, variable tags, trend tags, IO devices, alarms, roles and users. All these settings are done using the Vijeo City Project Editor software. However, for Vijeo Citect Version 7.5, the only parameter that must be configured is the IO Device. The other parameters are already configured (default from Citit). However, if you use a client and server network system, it needs to be reconfigured.

### 3 METHODOLOGY

This applied research uses experimental methods, designs and builds to produce a prototype. The level of Technology Readiness is at levels 5 and 6, namely. The validation, Prototype and or a collection of Prototype in the relevant environment and Demonstration of System/Subsystem Models or Prototypes in the relevant environment.

Planning and design is carried out at the Electrical Engineering Laboratory of the Politeknik Negeri Jakarta and some mechanical work is carried out in a private mechanic workshop around Depok.

Some of the materials needed are as follows;

- a) Input Prototype; Thermocouple Sensors and Transmitters,
- b) the Output Prototype; Heater and some Relay Contacts Multiple Indicator Lights.
- c) Control Prototype, PLC Modicon TM221CE16R With specifications of 16 digital I/O, 2 analog inputs 1 Serial port, 1 Ethernet port 220-250 VAC power supply, 24 VDC out

### 4 RESULTS AND DISCUSSION

Results Thermocouple sensor readings from the FE combustion chamber are sent to the transmitter to be amplified voltage as input from PLC (Programmable Logic Controlled). Furthermore, this data will be changed by the PLC into BCD and processed by the PLC program to control the Actuator (Heater), through Solid State Relay (SSR).

The control and monitoring system uses HMI/SCADA with the Vijeo City Project Editor software. The connection from the FE Module to the Laptop as a monitor uses from a PLC using TCP/IP communication, which is connected by an Ethernet cable. Some of the tests carried out were

- a) Measurement of the EF prototype Thermocouple and Display in Monitor.

To take measurements, it is necessary to prepare this thermocouple which has been added a meter to measure temperature, in the EF Prototype combustion chamber. Then the results are compared with the readings on the HMI, which are displayed on the laptop/PC.

The results can be shown in the diagram shown in Figure 4, below.

From the picture, the readings on the HMI / Scada are almost the same as the readings with a temperature meter using a thermocouple in Figure 4.

From the picture, the readings on the HMI / Scada are almost the same as the readings with a temperature meter using a thermocouple.

Notation R2 is useful for testing the relationship or effect of two nominal variables and measuring the strength of the relationship between one variable and another nominal variable ( $C =$  Coefficient of contingency). From the explanation and the  $R^2$  ; 0.9995 , it shows that the generated by this EF Prototype can be stated as accurate and reliable.

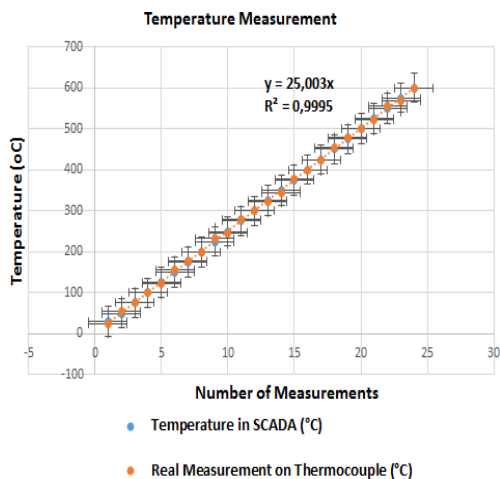


Figure 4: Temperature measurement.

b) EF Prototype Responsive Testing.

There are three (3) patterns in this test, namely;

The first test when the hood of the EF prototype is closed. This test is intended so that the combustion chamber does not come into contact with air, in this condition the EF Prototype is used as a Furnace for Calcination activities. The second and third conditions are when the hood is half opened and fully opened.

The temperature on the EF set at a lower temperature of 345°C and an upper temperature limit of 360°C. The Prototype's Temperature Response will work between these temperatures. Then in the observed conditions the response of temperature to the increase in time (in second) is  $\Delta t$ , when the hood is closed, half opened and opened. Figure 5, shows the EF performance for the three conditions.

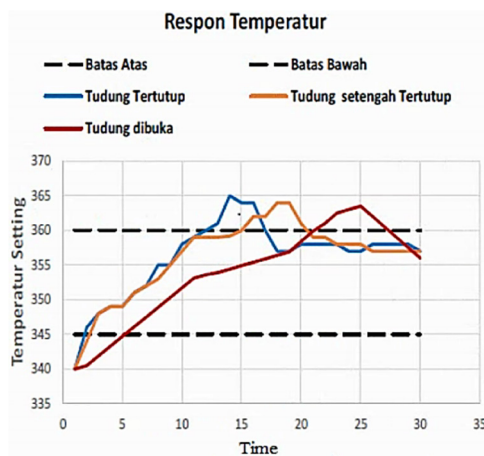


Figure 5: EF Temperature Response for the three conditions.

The diagram above shows a comparison of performance responses when the hood is closed (C1), half closed (C2) and open (C3).

EF Temperature Response when the hood is closed (C1), thus the combustion chamber is not in contact with outside air,

S or Resolution can be stated (R1)

$$R1 = \frac{V}{t} = \frac{15}{7} = 2.14 \text{ V/s} \quad (1)$$

Then for Temperature Response when the hood is opened halfway (C2) has a resolution or temperature response (R2) of;

$$R2 = \frac{V}{t} = \frac{15}{12} = 1.25 \text{ V/s} \quad (2)$$

Then for the Temperature Response when the hood is fully opened (C3) has a resolution or temperature response (R3) of:

$$R3 = \frac{V}{t} = \frac{15}{18} = 0.83 \text{ V/s} \quad (3)$$

Figure 6 shows a diagram of the Temperature Resolution value for the three conditions, if the three conditions are connected to each other then it has a non-linear relationship with the chi square value ( $R^2$  of 0.9939).

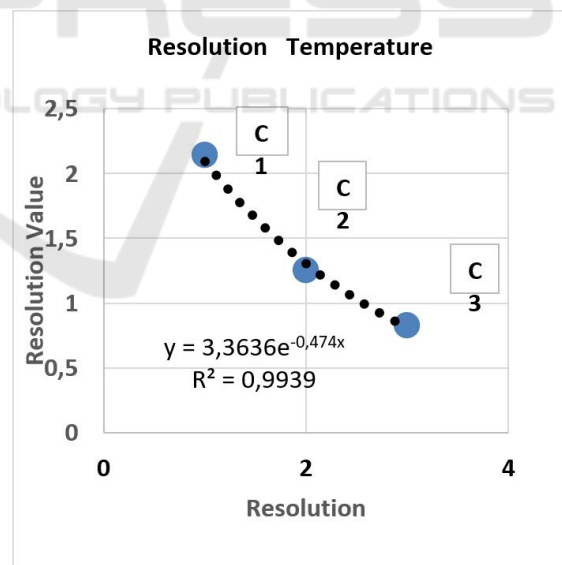


Figure 6: Temperature Resolution.

## 5 CONCLUSION

From the results of the discussion it can be concluded that;



The prototype Furnace Evaporator (FE) which is designed to have an accuracy in generating heat, displays the temperature value on the HMI monitor screen (laftpo) when compared to a measuring instrument with a Thermocouple meter with a *chi square value (R<sup>2</sup>)* of 0.995. The test was carried out under three (3) conditions, namely when the prototype hood was closed (C1), half closed (C2) and open (C3). The three have different temperature resolution responses, namely, 2.14 V/s, 1.25 V/s and 0.83 V/s. If the three parameters of the Temperature Resolution Response are connected, all three have a non-linear relationship with the *chi square value (R<sup>2</sup>)* 0.9939 which means it has a significant relationship.

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