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Temperature Control Mechanism, A Panacea for Effective Fluids Storage

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Abstract - *There is of course a continuing large-scale demand for many of the traditional staple products, but with the intense competition in these areas, the producers will have to make their processes more efficient with adequate storage systems. Sources of raw materials will be more varied and market demand more uncertain, creating the need for more flexible tank storage that is capable of storing economically all the process end products. Tighter environmental constraints and tighter requirements for hygiene, health and safety on the plant means that processes must be more closely monitored. The Resistant Temperature Detector (RTD) is used in areas where high precision is needed and narrow temperature spans are required in order to accurately control a process as to ensure the stability and safety of a process product, the precise and quantitative measurement of temperature is required and this is accomplished with the aid of a temperature sensor and the signals receive from the sensor is being process by the temperature regulators.*

***Key Words*: Environment, Product, Safety, Storage, Temperature.**

1. INTRODUCTION

Temperature control is the measurement of temperature transition of an object collectively within a space and the passage of heat energy is alternated in and out of the space in other for the average temperature to be achieved. In ensuring the stability and safety of a process product there are various methods that can be applied in measurement and control of temperature of the storage systems. Stability can be referred to two main issues for fuels: stability at elevated temperature and pressure of the recirculation of fuel in an engine system and aging or long-term storage stability [1]. In petroleum products, Stability of fuel temperature at elevated fuel system is referred to as Thermal stability while Oxidative stability as the long-term storage stability.

The principles which help in identifying combustible, flammable and storage conditions in order to ensure the highest level of stability are [2]:

i. Fluids must be stored in a separate storage system away from the storage of metals like lead, rust, zinc, brass bronze, tin, copper and iron so as to reduce a high means of sedimentation and its degradation processes.

ii. With the use of a nitrogen blanket on storage tanks and storage of fuel in a well-sealed drum Oxidation of fuel which is the removal of oxygen from the fuel can be achieved and storage life can be prolonged.

iii. The increase in the unsaturation level from monounsaturated to polyunsaturated causes the stability of the fuel to exponentially decrease since the fluids oxidize most likely at a higher level of unsaturation as saturated fatty acid esters are fairly stable. The reaction of oxygen at the point of unsaturation of the fuel molecules can form peroxides which breaks down into gums, acids and sediments.

iv. Sunlight and heat can significantly facilitate these processes.

v. Antioxidants either incorporated as additives or natural can greatly increase the stability of fluids as well as its storage life.

Temperature sensors are highly essential as there are products that greatly rely on temperature control and maintenance to function appropriately such as thermostats, refrigerators and oven. The control of temperature plays an important role in control and process engineering, examples which include the maintenance of a chemical reactor at an ideal set-point temperature, monitoring the temperature to guarantee the safety of the personnel in the event of a runaway reaction and to reduce harmful environmental impact, temperature of the streams to be released into the environment should be maintained and monitoring of temperature of fluids in tank farms [3]. While temperature is generally sensed by humans as “hot”, “neutral”, or “cold”, control engineering requires precise, quantitative measurements of temperature in order to accurately control a process, this is accomplished with the aid of a temperature sensors and the signals receive from the sensors are being process by the temperature regulators. As heat is added to a system, molecular motion increases which result in the system experiencing an increase in temperature. Temperature changes as a function of the average energy of a molecular movement from a thermodynamics perspective, the measurement of the energy of a molecular movement is not an easy function as temperature sensors are mainly designed to measure the change of a property in response to temperature [4]. The calibration of the device is done using a standard in accordance to the traditional temperature scale (i.e., the boiling point of water at known pressure).

2. STORAGE SYSTEM.

Although the storage of local gases is difficult, most at times the use of caverns or salt deposit and underground mines can be used in storing these gases. Oil and gas are directly piped to a tanker terminal to be stored in an onboard storage tank on most production sites without a pipeline to be transported by a shuttle tanker. These petroleum products are stored on concrete platforms in tanks, on floating units and cells around the shafts, a separate storage tanker is used on some floaters. When oil volume differs, ballast handling is highly essential to balance its buoyancy in both cases [5]. The crude oil is stored in a fixed roof tanks while the floating roof tanks are used for condensate in an onshore platform, the use of special tank gauging systems like level radars, pressure or float in moderating the level of storage caves, cells and tanks is utilized. Depending on the tank geometry, its level measurement is converted into appropriate volume via tank strapping tables and compensated for temperature to provide standard volume. The float gauge calculates for density and as such mass can be ascertained [6].

A typical maximum capacity of different volume of tank comprises of 25 – 85 tanks in the area of 5 – 55 million barrels in a tank farm. About three weeks of oil production is usually stored in the storage tanker, one week is scheduled for a proper cycle while the other extra weeks for expected delays which can amount to millions of barrels. Documentation of accurate volume of what is received and dispatched are kept [7]. The record of stock movement and logistics operations are kept in the tank farm management system, various product and quality blending must surely be handled for installation that serve multiple production sites.

Plate 1 shows a typical process facility and storage tank of the oil refining industry.

Plate 1: Typical Process Facility and Storage Tanks [5].

2.1 Storage of Flammable Materials.

Generally, flammable materials must be kept separately from a potential ignition source in a well-ventilated storage room and these materials should not be stored anywhere close to electrical equipment's and should be kept away from exits [8]. A flammable material must be placed back into an appropriate container should it be removed from its original container.

2.2 Storage tanks and rooms.

Flammable materials used in production sites should be stored in large containers (tanks or drums), there may be an excluded storage room for these specific materials as they are mostly in large volumes as well as available in different types and sizes hence the need for a proper storage. The Alberta Fire Code outlines the specific obligation for most overhead and underground storage tanks and rooms [9]. Facilities, pipelines and well sites licensed are approved by the Alberta Energy and Utilities Board for production, processing, exploration, handling, treatment, recovery, disposal or transmission of hydrocarbons are covered by *Guide 55:*[10].

In general:

i. Compressed gases must not be stored beside flammable material containers.

ii. Flammable material storage areas are highly restricted for smokers.

iii. Storage rooms ventilation systems must be properly designed and maintained on a regular basis.

iv. Ignition sources such as open flames, sparks and heat should be located away from bulk storage containers.

v. Other chemicals are to be kept away from the flammable materials bulk storage rooms and containers.

vi. Bulk storage rooms and areas are to be equipped with spill protection having appropriate signage or placarding.

vii. The use of large containers in blocking access or being kept near exits of the flammable material storage rooms should be completely avoided.

2.3 Incompatible Materials.

Incompatibility involves the combination of two or more undesirable and unplanned chemical reactions. The occurrence of incompatibility reactions produces hazard such as: fire or explosion, violent reaction, toxic dusts, heat or pressure, mists and flammable fumes or gases [8].

Chemicals are normally grouped into five main categories; flammable/combustible, acid, alkaline or basic, oxidizer and reactive. These groups lack compatibility as such should be stored separately from each other.

Table 1 clearly shows some incompatible materials that will results in fire and/or explosive hazard when stored or mixed together.

Table 1: Incompatibility of Materials [9].

S/N	E +	N =	P
1	Acids or Bases (Corrosives)	Reactive metals such as aluminum beryllium calcium lithium potassium magnesium sodium zinc powder	Fire
2	Cyanide and Sulphur Gases	Acids	Fire
3	Solvent or Reactive organic materials such as Alcohols Aldehydes Nitrated Hydrocarbons	Acids Bases Reactive Metals	Explosion
4	Oxidizers such as Chlorates Chlorine Chlorites Chromic acid Hypochlorite's Nitrates Perchlorates Permanganates Peroxides	Flammable Liquid Flammable Solids Flammable Wastes Combustible Wastes	Explosion
5	Flammable Liquids	Acids Bases Oxidizers Poisons	Fire Explosion or Violent Reaction
6	Flammable Compressed Gases	Oxidizers	Fire Explosion or Violent Reaction

3. METHODOLOGY

Theoretical models of process control are based on conservation laws such as the conservation of mass and energy. Thus,

Rate of mass

accumulation = Rate of mass in – Rate of mass out (1)

Also,

$$E_A = E_{INC} - E_{OC} + H_{AD} + W \qquad (2)$$

Where;

E_A: Rate of energy accumulation.

E_{INC}: Rate of energy in by convection.

E_{OC}: Rate of energy out by convection.

H_{AD}: Net rate of heat addition to the system from the surroundings.

W: Net rate of work performed on the system by the surroundings.

The total energy of a thermodynamic system, E_{tot}, is the sum of its internal energy, kinetic energy and potential energy:

$$E_{tot} = E_{in} + E_{ke} + E_{pe} \qquad (3)$$

Assumptions.

i. Changes in potential energy and kinetic energy can be neglected because they are small in comparison with changes in internal energy.

ii. The net rate of work can be neglected, because it is small compared to the rates of heat transfer and convection.

From equation 2, the energy balance can be written as:

$$\frac{dE_{in}}{dt} = -\Delta\left(w\hat{H}\right) + Q \qquad (4)$$

Where;

E_{in}: The internal energy of the system.

H: The enthalpy per unit mass.

W: The mass flow rate.Q: The rate of heat transfer to the system.

The Δ operator denotes the difference between outlet conditions and inlet conditions of the liquid.

Consequently, the $-\Delta$*(wH)* term represents the enthalpy of the inlet liquid minus the enthalpy of the outlet liquid.

3.1 Resistance Temperature Detector (RTDs).

This is used in areas where high precision is needed and where narrow temperature span are required. Because the electrical resistance of a conductor changes as its temperature varies. The magnitude of the change with respect to 1°C changes in temperature is its temperature coefficient of resistance.

Platinum = 0.00392 ohm/^{0}C over a range of 0°C to 100°C. It has a linear characteristic.

Resistivity of platinum = 10 ohm – cm at 20°C

$$R_t = R_{rt}\,(1 + \alpha T) \qquad (5)$$

$$\frac{dRt}{dT} = \alpha R_{rt} \qquad (6)$$

Where;

R_t: Resistance in ohms, at temperature T.

R_{rt}: Resistance in ohms at a reference temperature (often 0°C).

α: Temperature coefficient of resistance.

To project the appropriate value of temperature greater than 1000°C or less than – 500°C.

We also calculate,

$$R = R_{rt}(1 + \alpha T + \beta T^2 + \gamma T^3 + \cdots) \qquad (7)$$

Where;

β: Imperial obtained from the manufacturer.

γ: Temperature coefficient of the metal conductor.

Conductor diameter = 0.002 (standard from literature).

Resistance value = 10 to 500 Ohms.

A piece of alloy can be connected in series or shunt connected internally to raise or lower overall resistance to standardize RTDs for interchangeability.

Figure 1 shows the Wheatstone Bridge, which can be adapted to give an indication analogous to temperature.

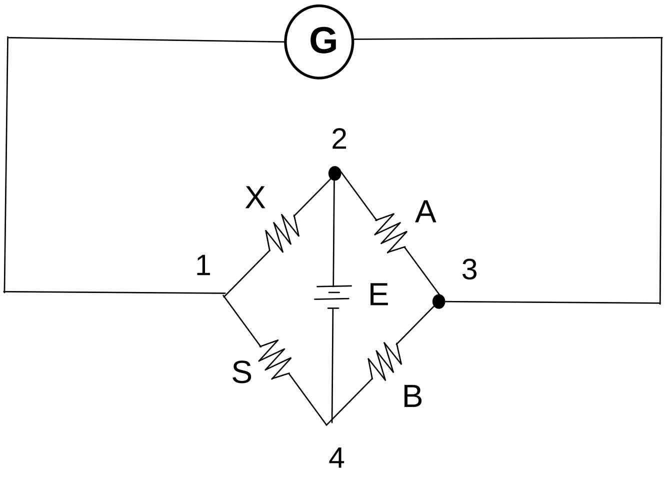

Fig. 1: Wheatstone Bridge, the basic circuit for the readout device

The resistance X represents RTD. The Galvanometer G (a sensitive DC current meter with zero center scale) can be calibrated to deflect accordingly. L which is the lead resistance as shown in figure 3.2 becomes a part of the X - terminal of the bridge circuit.

Since,

$$E = V_{21} + V_{14} = V_{23} + V_{14} \qquad (8)$$

i.e., when the voltage at node 1 equals the voltage at node 2, galvanometer G will experience null (zero) indication.

Therefore, the ratio of the bridge components.

$$A/(X + 2L) = B/S \qquad (9)$$

Or

$$X = S\left(\frac{A}{B}\right) - 2L \qquad (10)$$

Figure 2 shows a two-conductor circuit with a lead resistance.

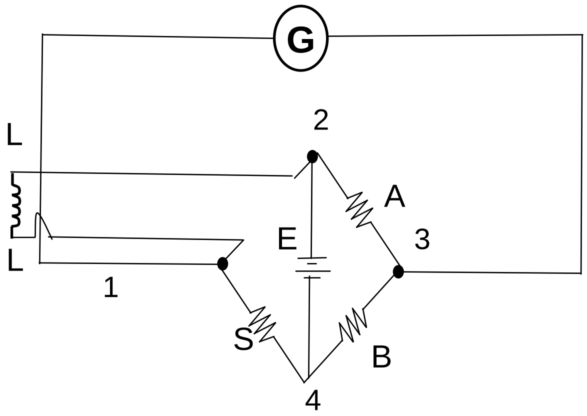

Fig. 2: Lead Resistance becomes a part of the measurement in a two-conductor circuit.

3.2 Deflection Reading.

By adding the resistance L to both terminals of the bridge circuit as shown in figure 3 for meter null, the following ratio applies.

$$\frac{A+L}{X+L} = \frac{B}{S} \tag{11}$$

Or

$$X = S\left(\frac{A+L}{B}\right) - L \tag{12}$$

Note, the addition of variable resistance C provides the adjustment of the galvanometer G to some convenient point. For the value of X, G can be calibrated to read temperature directly.

Figure 3 shows the elimination of the effect of lead resistance.

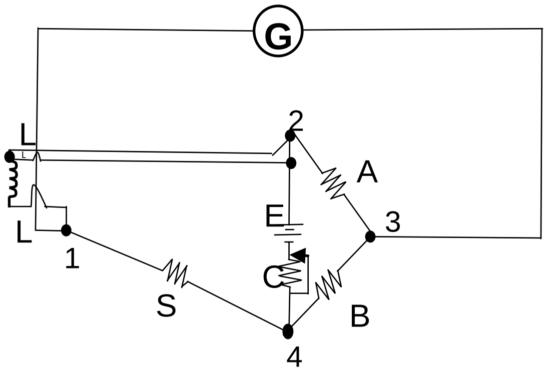

Fig 3: Eliminating the effect of Lead Resistance by adding resistance in another terminal of the bridge circuit using a three-wire system to cancel out the lead resistance.

3.3 Null Direct Reading.

Resistance A could be replaced by a highly accurate adjustable resistance which is calibrated to correspond to the temperature which X measures.

For each new reading, Galvanometer G is set to null electronically by means of resistance A as shown in figure 4.

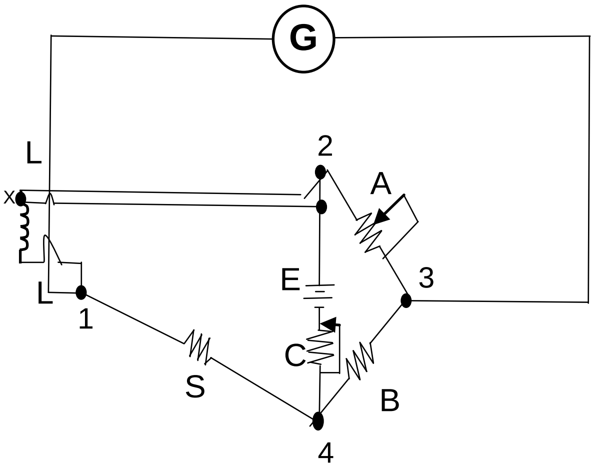

Fig. 4: Temperature made analogous to potentiometer setting which nulls the meter in a null - direct reading bridge.

Also, by placing sliding contacts in both the galvanometer and battery circuit loops as shown in figure 4, the effects of contact resistance are eliminated.

Resistances R_1 and R_2 are gauged so that percentage of span K is equal.

Therefore; with galvanometer at null, the equation becomes.

$$\frac{X}{A+KE} = \frac{S+d\ (1-K)}{B+KD+E\ (1-K)} \tag{13}$$

Or

$$X = \frac{A\ (S+D)\ +\ (ED+ES-A)K-DK^2}{(B+E)\ +\ (D-E)K} \tag{14}$$

The voltage source E can be replaced by an alternately current source (normally f - 1000 Hz) and resistance A and B can be replaced by capacitor creating an AC bridge.

Thus;

$$\frac{I_S}{Z_A} = \frac{Z_S}{Z_B} \tag{15}$$

$$\frac{X}{\frac{1}{2fCA}} = \frac{S}{\frac{1}{2fCB}} \qquad (16)$$

Or

$$X = \frac{C_B}{C_A} S \qquad (17)$$

3.4 Operation of the Resistant Temperature Detector (RTD) Sensor.

Because of the peculiar nature of petroleum products, most RTDs are made of platinum which is linear over a greater range of temperatures, resistant to corrosion and based its operation upon a linear relationship between temperature and resistance, since the resistance increases with temperature. However, in determining a resistor material the following factors such as temperature sensitivity, temperature range, durability and response time must be duly put into consideration [11]. For each of these characteristics, different types of materials have different range. The principle of the RTDs is based upon the Callendar – Van Dusen equation, which relates the electrical resistance to the temperature above 0 °C up to the melting point of aluminum which is ~660 °C. Based upon an experimental data from the specific RTD, the equation normally takes on a linear form since it is merely a generic polynomial and the coefficients of the higher - order variable is relatively small (a_2, a_3, etc.).

The RTD is made up of an outer sheath material which is composed to efficiently conduct heat to the resistor, resist degradation from heat and prevent it from the surrounding medium contaminations. The resistance sensor is mostly composed of metals, such as nickel, copper or platinum and responsible for the temperature measurement. The choice of material for the sensor strongly determines the range of temperatures wherein the RTD can be utilized. The most common type of resistor, platinum sensor has a range of approximately -200°C – 800°C. The two insulated connection leads are connected to the resistor, these leads continue to complete the resistor circuit.

Figure 5 shows the schematic diagram of the RTD sensor.

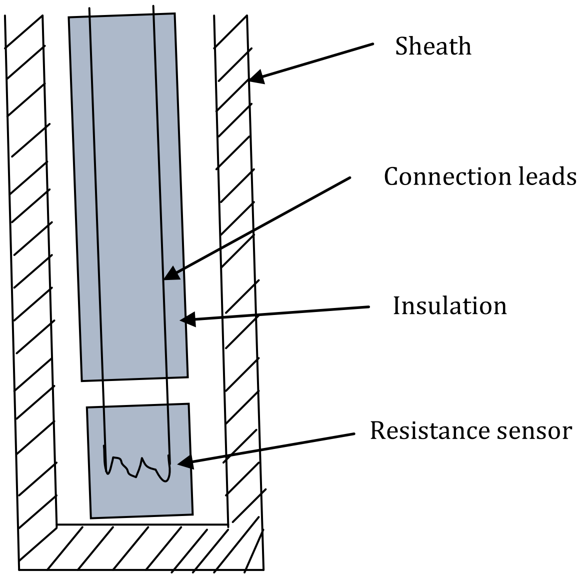

Fig. 5: Schematic diagram of Resistance Temperature Detector (RTD).

There are 4 main classes of RTD sensors, they are the wire-wound thermometers, coil elements, film thermometers and 187 carbon resistors [12].

The 187 Carbon Resistors are accurate for low temperatures, less expensive, are not affected by strain gauge effects or hysteresis, hence the most used type of RTD sensors by researchers.

Film thermometers are often made of platinum with a very thin layer of metal on a plate, on the micrometer scale this layer is very small. Based on the composition of the metal and plate, the thermometers have different strain gauge effect and the type of components used determines its stability problem,

In wire-wound thermometers the coil gives stability to the measurement. Although a larger diameter of the coil gives more stability, it also increases the amount in which the wire can expand which in turn increases strain and drift. Hence, they have very good accuracy over a large temperature range.

The coil elements have generally replaced the wire-wound thermometers in all industrial applications because of their similarity features. The coil is allowed to expand over large temperature ranges while decreasing the drift and giving support

4. RESULTS.

The results obtained on the effect of temperature error difference using the PD, PI and PID controllers are shown as follows;

Figure 6 shows the control of temperature error deviation using the PD controller.

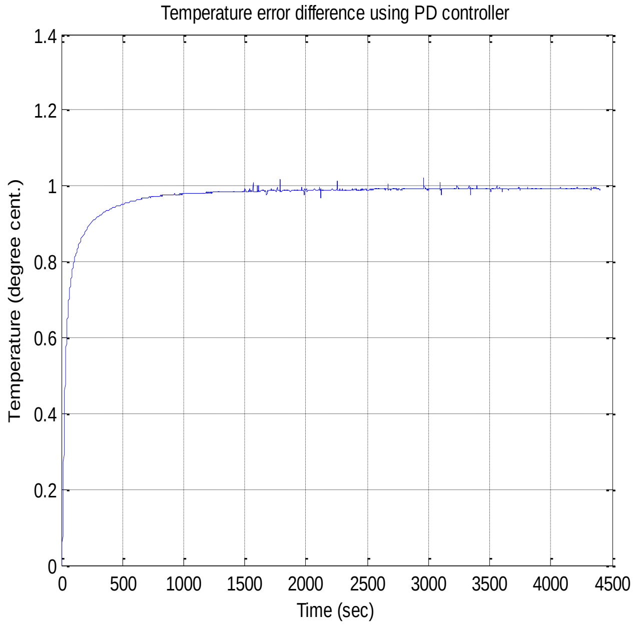

Fig. 6: Temperature Error Deviation using Proportional Derivative (PD) Controller.

Figure 7 shows the control of temperature error deviation using the PI controller.

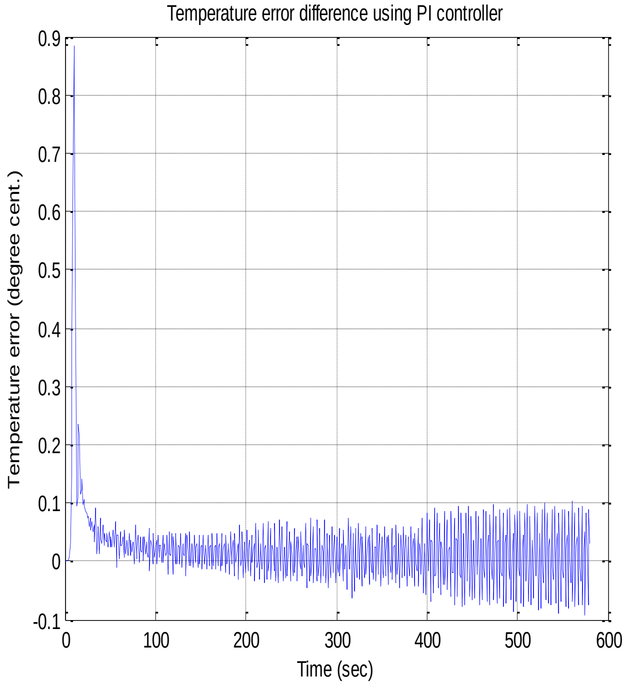

Fig. 7: Temperature Error Deviation from setpoint using Proportional Integral (PI) Controller.

Figure 8 shows the control of temperature error deviation using the PID controller.

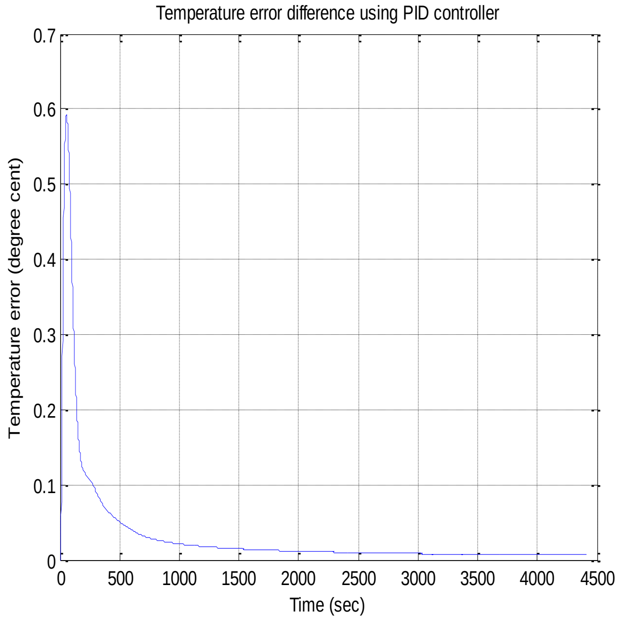

Fig. 8: Action of the PID Controller on the control of the Temperature Error Deviation from set point.

The figures, 6, 7 and 8 and tables 2, 3 and 4 shows the simulated results of temperature error deviation when PD, PI, and PID controllers were used respectively.

The oscillogram of figure 6 shows the deviation of set point when Proportional Derivative (PD) controller is being used. The essence is to actually compare the performance of the PD controller with Proportional Integral Derivative (PID) controller. Table 2 shows temperature error deviation with time.

The simulated result of figure 7 shows the control of temperature using proportional integral controller. The error is being manipulated by the controller to achieve a better result so that the temperature could be stable. It is used to compare the performance with Proportional Integral Derivative (PID) controller. Table 3 shows temperature error deviation with time.

The simulated result of figure 8 shows the control of temperature using Proportional Integral Derivative (PID) controller. The error is being manipulated by the controller to achieve the best result as to ensure that the temperature remains stable. It was discovered that PID controller gives an excellent control measure when compared with PI and PD controllers. Table 4 shows temperature error deviation with time.

Table 2: Temperature Error Deviation Control with time using PD.

TIME (SECONDS)	TEMPERATURE (°C)
500	0.95
1000	0.96
1500	0.97
2000	0.98
2500	0.99
3000	1.0
3500	1.0

Table 3: Temperature Error Deviation Control with time using PI

TIME (SECONDS)	TEMPERATURE (°C)
50	0.89
100	0.09
200	-0.91
300	-0.93
400	-0.96
500	-0.99
600	-0.1

Table 4: Temperature Error Deviation Control with time using PID

TIME (SECONDS)	TEMPERATURE (°C)
500	0.05
1000	0.04
1500	0.03
2000	0.02
2500	0.02
3000	0.02
3500	0.01

5. CONCLUSIONS

The evaluation of the temperature of a product is a sine-qua-non in a tank gauging system for input to the Standard Volume and Mass Calculation. Through the analog instruments, manual measurements were carried out which forms the development of data loggers. Regrettably these data loggers can no longer satisfy the postulated sequence of possible present events due to a function of lack of time and correctness. This type of configuration will not show a representative value of the overall product temperature, since all storage tanks will show a significant temperature gradient from top to bottom. The film thermometer resistant temperature detector is used in monitoring the rising buildup of temperature resulting from weather variation and increased pressure in the storage tank in order to guarantee the safety of the personnel and its environment.

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