A Comparative Study about Accuracy Levels of Resistance Temperature Detectors RTDs Composed of Platinum, Copper, and Nickel

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Paper History:

Received: 10th Dec. 2023

Revised: 19th Feb. 2023

Accepted: 24th March 2023

Abstract:

Platinum, copper, and nickel were founded the best metals used in resistance temperature detectors RTDs. They commonly used in laboratory and industrial applications because they provide accurate and reliable measurements in a wide temperature range from (- 200 to 850 °C). They have high conductivity, sensitivity, and hardness to resist strain shock, pressure, and vibration.

The accuracy level of them depends on reliability, stability, repeatability, linearity, and response to time. This study aims to determine and compare the accuracy of these three metals in regarding to their features which include stability, repeatability, and response time. The study has gathered and analyzed the data of these suitable and precise metals and compared with each other.

The results showed that platinum is widely needed for RTDs due to its precision, stability, higher accuracy, and linearity output, while copper and nickel are not stable or repeatable as platinum. It was indicated that temperature coefficient of resistance TCR for nickel is bigger and for copper is medium, but for platinum is lower.

Keywords: Platinum, Copper, Nickel, RTD, Accuracy, Temperature Measurement.

دراسة مقارنة حول مستويات دقة أجهزة RTD المكونة من البلاتين والنحاس والنيكل

سالم عزيز كاكو

الخلاصة:

وجدت بان البلاتين والنحاس والنيكل هي من أفضل المعادن المستخدمة في تركيب المتحسسات المقاومة الحرارية لقياس درجات الحرارة الناتجة مابين (- ٢٠٠ لغاية ٨٥٠ درجة مئوية) . هذه المعادن تمتلك صلادة موصلية وحساسية عالية امام صدمة الاجهاد والضغط ومقاومة الاهتزاز والتأثيرات البيئية. ان لهذه المعادن معامل مقاومة ملائمة والاستقرارية و التكرارية التي تمكن من تحسين مستوى الدقة والخطية ، ولكنها تختلف من حيث مستوى الدقة استنادا الى خصائص كل معدن كالاستقراية والتكرارية ووقت الاستجابة التي لها تأثير على مستوى دقة نتائج المتحسسات المقاومة الحرارية والتي هي تعتبروظيفة تشغيلية مهمة لهذه المتحسسات المستخدمة في كثير من التطبيقات الصناعية والاجهزة الحساسة.

هذه الدراسة قد حددت ثم قارنت دقة هذه المعادن الثلاثة الى جانب الاستقرارية والتكرارية ووقت الاستجابة لها ، ثم حددت ٩ خصائص رئيسية . وانها قامت بجمع وتحليل البيانات المتعلقة بهذه المعادن التي تكون الاكثر ملائمة وضبطا عند مقارنتها بمعادن اخرى.

هذه الدراسة بينت بان البلاتين هو معدن ملائم و ومطلوب بكثرة للمتحسسات المقاومة الحرارية لانها اكثر ضبطا واستقرارا ، ويمنح دقة عالية ومخرجات خطية ، ولكن النحاس والنيكل ليسا بمستوى الاستقرارية او التكرارية مثل البلاتين بالرغم من انهما اقل كلفة . ايضا ان النتائج اظهرت من ان معامل المقاومة الحرارية للنيكل هي الاعلى ولكن للنحاس والبلانين هي متوسطة واقل على التوالي.

1. Introduction:

Resistance Temperature Detector RTD is considered as reliable and accurate device for measuring temperature. It is regarded as sensing element that operates on principle of the measurement of all electrical changes in the metals , the value of resistance depends on the temperature [1]. RTD is dedicated to convert temperature into the electrical signal. RTDs are used for many appliances such as power plants, cell phones, laboratories, engine automotive, communication devices, electronic devices, medical equipment, aerospace, and others [2].

Also, the RTDs are the most widely used temperature sensors in industrial measurement [3]. They are commonly utilized for measuring the range of temperature and metrology with high precision such as chips, computer disk, micro electromechanical systems, and medical tests, in addition, they can offer benefits in a wide range operating temperature of (- 200 to 850 °C).

Sensitivity, repeatability, and stability are features that related to RTDs accuracy. They should be highly accepted because they promote the accuracy level. RTDs will result a better linearity, they will be reliable, easy to install, and suitable to calibrate, however. they are stable and have better situation when compared with other technologies of temperature measurement [4].

Platinum, copper, and nickel are three metals which are widely contribute of RTDs construction, because they have extremely reproducible electrical properties. They hold purity which is an effective factor that has an impact on the levels of features of stability and repeatability. Both features are connected with accuracy level. It should be mentioned that the purer and cleaner metal has the best electrical conduction for RTDs which their resistance value be affected by any change of temperature. The electrical voltage conduction (resistance coefficient) will maximize the accuracy in their outcomes.

These metals are different in some results, platinum is wider applied in RTDs more than copper and nickel in industry sector, platinum will make up the most accurate RTDs while copper and nickel make RTDs that are lower cost, but copper and nickel metals are not as stable or repeatable as platinum. The platinum RTDs can give a highly accurate linear output across (- 200 to 600 °C), and platinum RTDs are more expensive than copper or nickel RTDs [5].

These three metals have low sensitivity and high conductivity; therefore, they are used as sensor's resistance and they give acceptable results, but in most cases the electrical conductivity of metals is affected by existence of oxidation.

The relationship between resistance vs. temperature is vital character because it shows feature variations of metals and indicates the stability, because any RTD as a sensor changes its resistance as its temperature changes [6].

The resistance can be expressed as thermal resistance which is a heat property and a measurement of a temperature difference by which a material resists a heat flow [7]. Figure 1 shows the relationship between resistance vs. temperature for platinum, copper, and nickel used in RTDs [8] where the temperature is the x-axis. The normalized resistance is the y-axis concerning resistance at 0 °C. The tolerance to platinum changes by 0.4Ω per degree centigrade of the temperature, has also the highest time stability.

Temperature coefficient of resistance TCR will change depending on the metals which is expressed as a percentage per degree of temperature [9]. To keep accuracy of RTDs during operation, the correct calibration of RTD can give the same and exact readings due to the resistance of used metal will remain at the same value [10].

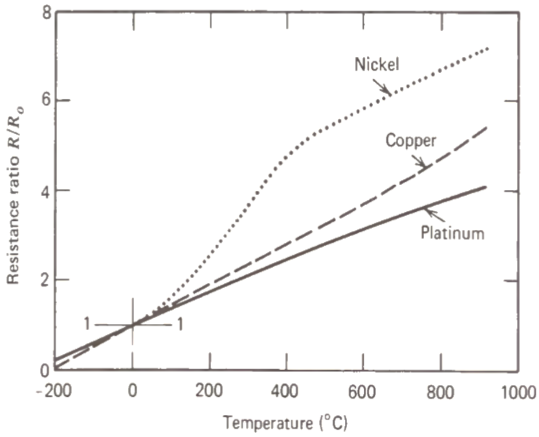

Figure 1: Shows the resistance-temperature relationship for platinum, copper, and nickel [8].

2. Literature Review:

The results and data were collected from the previous works of the researchers, and then the results were analyzed. Shantanu [11] has investigated about has investigated about a system for measuring multiple temperature points using two wire configuration RTD for temperature range (- 100 °C to 100 °C) which composed of micro controller unit (MCU) and analog- digital convertor, voltage source, and the resistance values of the RTDs are calculated based on the voltage measured across the RTDs and the current sensing resistor. The results of the test have showed that the accuracy of temperature measurement device can reach to ±0.02 °C., however, the challenge with the RTD measurement circuit has showed the limitation of measuring current. This was because of each of self-heating effect, in-circuit resistance, and lead-wire resistance. The errors in individual components related to tolerance, temperature coefficient, linearity, etc. The study has suggested to add three reference resistors for the constructed system to gain maximum value which calculated by Monte-Carlo analysis. The proposed method for RTD resistance from 600 Ω to 1400 Ω with a step size of 100 Ω which were showed in a given table.

Sang-Yoon et al. [12] have studied about copper metal used in printed circuit board PCB based on RTD. The research was done by making a PCB which has a lower unit cost than some other materials. It has affirmed that PCB based polymerase chain reaction PCR chip will require temperature sensors to accurately measures the temperature at each step. It proved also, that the error rate of copper pattern should be small. The investigation of the research appeared that the resistance of copper will be changed due to oxidation phenomena's effect, but it remains linear over a wide range of temperature. The research has analyzed the error rate of the measured temperatures. In addition of these results, it showed that the type of 2-point system will be suitable and give high accuracy level, and the error rate less than 0.52 °C has been registered. The results also showed that the copper is easy to design in a pattern on a PCB. Yuliana et al. [13] have searched on models in a sensitive element of RTD considering the temperature effect of heat physical characteristics of the sensor's metal. The purposes were doing a model of process of heat transfer in the RTD, then presenting a comparison of results on integrated characteristics by considering the physical properties of materials. The study has showed a table on limits of allowable errors of RTD types of platinum, copper, and nickel which were 0.6 + 0.008, 0.5 + 0.0065, and 0.3 + 0.008 respectively, but they were within three ranges of temperature (- 100 to 300 °C), (- 200 to 200 °C), and (0 to 180 °C). The results under constant values of heat physical characteristics of RTD used materials have been shown as a table on thermal conductivity λ Watts per meter- Celsius (W/m°C) which refers to ability of materials to conduct heat which have different values according to metal types. Here, the values were for platinum (70), for copper (390), and for nickel (92). But the result about deviations of RTDs were found that for copper are from 11,7% to 14,8%, for platinum are from 7,3 % to 14,3 %, and for nickel are from 10,5 % to 11,4 % .

Apinai et al. [14] has declared the importance of RTD in the industrial applications, and type RTD constructed from platinum wire provides distinctives behaviors of high accuracy, high linearity, high stability, and a low hysteresis effect. The study has presented the problems of errors of temperature measurement in the industrial process and lead-wire resistance of RTD. It has showed the change in the ambient temperature causes the variation in the lead-wire resistance due to thermal property of the metals used for the lead-wire, and how it causes the error in quantity of measured temperature. The study has proposed a procedure and techniques to determine the accuracy level and error of RTD, and to compensate lead-wire resistance of RTD using two diodes. The proposed techniques were based on use of a three-step current signal to excite the RTD. Also, they used microcontroller to exhibits high accuracy, simple configuration, and low cost in a harsh environment operating. The study has declared that the techniques can be used in mechanical, engineering, civil engineering, automobile, scientific and medical equipment, and used to measure the quantity of each of gas, humidity, airflow, force, pressure, and strain. The study has set tables of measured results for RTD (Pt100 and Pt 1000) with different lead-wire resistance using 2 analog input/output (AIO) board and 2 microcontroller board. It has presented figures of errors of temperature measurement for (Pt100 and Pt1000) using 1 analog input/ output (AIO) board and 2 microcontroller board. The study has mentioned three factors of errors happening that cause an inaccuracy of calculated resistances and diode voltage in the proposed procedure. The experimental results showed: (1) the maximum error of the temperature measurement from the Pt100 RTD of about 0.27 °C was observed when the lead wire was placed in various temperatures of the environment, from 30 °C to 70 °C. , (2) the maximum errors of about 0.25 °C and 0.21 ◦C for the Pt100 and Pt1000, respectively, were achieved of the measured temperature for the variation of the RTD temperature varied from 0 °C to 300 °C.

Surankumar et al. [15] has achieved an experimental study about the number of problems that can affect the response time of RTDs such as dynamic response time. The objective was to study and analysis of the settling time and time constant of different RTD types such as Pt100 bare, Pt500 thermowell, and Pt1000 sheath. The purposes of the study were: (1) to demonstrate dynamic behavior of RTD, (2) to find out model of RTD using System Identification Toolbox, and (3) to understanding the different parameter that affect the dynamic response of RTD. The study has named three important characteristics to achieve the experiment such as: reliability, good calibration, and fast dynamic response time. It has emphasized that the temperature should be accurate and RTD platinum is widely used because of accuracy and linearity over the wide range. The study has used the plunge test method and self-heating test method which are two widely experimental method for measuring the dynamic response and for analysis dynamic behavior of temperature sensors. The experiments are carried out in the heating chamber and the range was from -50°C to 800C with allowable safe limit of 300°C. Also, the Remote Trigger Temperature Setup is used in this experiment which consist of three K-type thermocouples were with bare, sheath, and thermowell. A number of experiments have been performed and the response time was monitored. The data were used to derive the mathematical model, also, the toolbox of a Matlab-based software was used for taking accurate data.

The results have showed the setting time and time constant were as follows:

(1) for Pt100 bare, (Settling time = 4.24 sec & Time constant = 1.09 sec).

(2) for Pt500, (Settling time = 38.9 sec & Time constant = 9.89 sec).

(3) for Pt1000 sheath, (Settling time = 10.4 sec & Time constant = 2.64 sec).

They are susceptible to a range of potential problems, affecting both their accuracy and their response time.

Research [16] has conducted about the problem of conversion speed of the Analog-to-digital converters (ADCs) decreases with increasing resolution, those converters are essential blocks in modern measurement systems. Due to this problem, it is impossible to measure fast and noisy signals very accurately, also, this problem cannot be alleviated either by repeating or averaging the measurement results, this will lead to error. Therefore, the study has proposed a method and device for on-line temperature measurement with Pt-100 sensor operating in a nonlinear mode. The study proposed a method and device for on-line temperature measurement with Pt-100 sensor operating in a nonlinear mode, the sensor measures the temperature in range of 00C to 2000C, whereas the measured data are processed by applying a two-bit stochastic digital measurement method (SDMM) of Pt-100 sensor, also, in order to achieve greater accuracy, the calibration curve for the sensor is approximated by the calibration polynomial (CP).

It was showed, at a sampling frequency of 1 MHz, the maximum accuracy is reached in 17.5 sec. and is equal to 0.015% of full scale. On the other hand, when the measurement time interval is 0.1 sec. (the shortest measurement interval), the accuracy is equal to 0.1% of full scale, therefore, the proposed device can be used for both calibration and measurement purposes.

Also, it has showed that for accuracy, it is completely independent of resolution, and in the case when the offset value is equal to 5 mV, the accuracy of measurement of sensor is below 10 ppm which its resistance changes with temperature. In addition, the relative full-scale error of the Pt-100 sensor is 0.015 %, the maximum accuracy is reached after 700 seconds (if the instrument were operating at a frequency of 1 MHz, the maximum accuracy would be reached after 17.5 seconds). The research has declared that the proposed method and device can be used for very accurate temperature measurements from 0C to 200°C.

3. Aims of the study:

- Comparing between accuracy of RTDs composed by each of platinum, copper, and nickel.
- Designate the importance and influences of accuracies of three metals
- Present and compare the features which are related to accuracy level of RTDs that composed with each metal individually.
- Determine and compare the basic characteristics which are related to operating accuracy of RDs.
- Indicating factors which are regarded as important requirements which are regarding to measurement accuracy in RTDs instrumentation channels.

4. Importance of the study:

Importance of the study are as follows:

- Indicating the accuracy levels lead to more control and perfect results of temperature measurement particularly in locations that need a very precision result.
- To know the impact of each of platinum, copper, and nickel on accuracy, sensitivity, resistance, stability, repeatability, and response time, these can lead to more specific measurement outputs.
- Indicating the features and basic characteristics will allow manufacturers to construct pure RTDs that will be suitable for each specific location being measured.

5. Materials and Methods:

5.1. RTD

RTDs are temperature sensors composed of metallic elements that their resistance will change through the temperature measurement process. The sensors are used to measure temperatures by comparing the resistance of RTDs with place of which the temperature being measured, a small current is passed through pure electrical wire and voltage which is proportional to resistance. It is measured and converted to units of temperature.

RTDs are manufactured or made from various types of metals including platinum, copper, or nickel, or alloys of various metals [17]. The range of temperature measurement of RTDs thin film is (- 50 to 500 °C), but for wire wound is between (- 200 to 850 °C). RTDs thin film are reliable and offer higher level of accuracy compared with other measuring instruments. The error in temperature reading depends on some factors, but a regular absolute error is less than 0.02°C for the range -100°C to +100°C for RTDs resistance from 600 Ω to 1400 Ω . This is according to Callendar-Van Dusen equation [11]. RTD temperature sensor should be manufactured with suitable metals to meet the demand of accuracy level and to maintain stability, but it should be known that other features such as stability, repeatability, response time are vital features which improve the accuracy [18].

Platinum, copper, and nickel have many advantages. They have good level of accuracy and they have small error limits [19]. These metals have specific features such as ruggedness which means that they are sensitive to strain shock and any other pressure encountered them. .In addition to these features they can give accuracy and linearity over a wide range of temperature, and the errors can be controlled, but cannot be eliminated completely [20].

5.2. Platinum

In more details about features related to the accuracy level. The platinum (Pt) is a metal that is vastly demanded to be used in many industries. It owns a physical and chemical properties which make it to be an essential element in RTDs operation. This metal is widely used because it has highest temperature coefficient of resistance TCR [16]. Platinum holds many features such as high malleability, high corrosion resistance, high ductility, stable electric properties, chemical stability, and it has negligible reactivity with surrounding factors [21]. These features increase the accuracy level and it can be used in high temperature RTDs sensors.

Platinum has high melting point of 1770°C, and according to standard (EN IEC 60751:2022) it operates in the range of -200 °C to + 850 °C [22].

Platinum can offer suitable physical and chemical stability; therefore, it will increase the accuracy of RTDs and it holds really high temperature tolerance. Accuracy of RTDs will remain high because platinum gives slight reactivity and stability against certain conditions such as mechanical vibrations, shocks, external loads, and temperature fluctuations [23].

Accuracy of RTDs will be more because the platinum contributes to the precision and stability of temperature measurement in the RTDs [24]. Types of Pt 100, Pt 500, and Pt 1000 have wide temperature range, high stability, and repeatability [25].

5.3. Copper

In more details about features related to the accuracy level. The copper (Cu) is a metal that it owns several excellent features that make it to be at suitable situation of application. The best power point of this metal is its low cost.

Copper has the best resistance to temperature linearity over the three RTDs types, but it oxidizes at higher temperature. It is a low-cost material and cheaper than platinum and nickel, It used in limited range of temperature measurement of (- 200 – 260 °C) due to its resistance changes with the change of temperature. It has good linear and lower TCR compared to platinum [16].

The accuracy level facing vulnerability, because it performs at poorly level in an oxidizing atmosphere. Therefore, it has a small output, and it has an inability to achieve its processes within the narrow spans of measuring.

5.4. Nickel

In more details about features related to the accuracy level. The nickel (Ni) is a metal that it sets between platinum and copper. It holds a good compromise between both metals [25]. Nickel is cheaper than platinum and it has limited range of temperature measurement (-60 °C to +260 °C) and the disability of manufacturing it in a high range of purity. It is a nonlinear above 300 °C but has a good resistance of corrosion. It has a very limited accuracy and losses it at higher temperature.It has lower purity and reacts easily with any chemical changes such as oxidation and corrosion [27].

5.5. RDTs Accuracy

Accuracy of RTDs is a quality of being correct and precise state. It is an error free, and the accuracy level refers to minimum rate of error during RTDs functions. Accuracy of an RTD sensor is referring also to the deviation of the temperature, or tolerance grade in some reference temperature. The tolerance and accuracy limits are defined by some International Standards such as such as ASTM-E1137: 2008 and EN IEC 60751:2022 [28, 29] which have presents tables of temperature/resistance and including accuracy of metals in RTDs. In regards with accuracy grade, the typical accuracies are as follows:

For platinum 100 Ω, the accuracy is 0.35 (class A), but it is 0.8 (class B) for 100 °C temperature. For platinum 500 Ω, the accuracy is 1.15 (class A), but it is 2.8 (class B) for 500 °C temperature.

For copper 9.035 Ω, the tolerance is 2.83 for (-73 °C), but it is 7.78 for 260 °C.

For nickel 120 Ω, the tolerance is 1.25 for (-73°C) temperature, and it is 4.28 for 260 °C.

For platinum, class A, TCR is 0.00392 Ω/ Ω/°C, but for class B it is 0.003850 Ω/ Ω/°C.

For copper, the temperature coefficient of resistance TCR is 0.004274 Ω/ Ω/°C.

For nickel, TCR is 0.006720 Ω/ Ω/°C.

the sensor resistance changes per temperature degree at 0°C (32°F) will be 0.39 Ω, 0.78 Ω, 1.56 Ω, 1.95 Ω, and 3.90 Ω for Platinum 100 Ω, 200 Ω, 400 Ω, 500 Ω, and 1000 Ω respectively. Likewise does in the copper type at 0°C (32°F) will be 0.039 Ω and 0.39 Ω for copper 10 Ω and 100 Ω respectively. Also, the sensor resistance will be 0.72 Ω for nickel 120 Ω.

Temperature coefficient resistance TCR is defined as resistance change per ohm per degree °C. It is determined by the purity of the winding wire used in manufacturing of the sensor element.

It should be mentioned that there are some factors affecting on accuracy in RTDs, such factors include lead wire resistance effect, self-heating effect, electromagnetic force error, non-linearity, corrosion, radiation, and insulation loss [30].

The accuracy is usually denoted by its initial element accuracy that measured at one point of 0 °C (32 °F). The level of this accuracy differs with temperature range, here, the effective tolerance of an RTD sensor is really a combination of base resistance tolerance and TCR. For most RTDs, the calibration temperature be at 0 °C, but any temperature above or below this exact temperature will gain a wider tolerance band and lower accuracy level.

The acceptance of accuracy is correlated with accuracy level. The RTD correlation can predict the accepted temperature with acceptable accuracy [31]. In many applications, the necessity of accuracy comes with the focus on each of repeatability and stability of the sensor, therefore, the features of stability and repeatability are often confused with the accuracy level, but the important thing is to understand the difference between them in order to choose type of metal to application purpose in designated location.

5.6. Features of accuracy

There are several features of accuracy of RTDs take a role in their operating and results. As declared in sections 5.2., 5.3., 5.4., and 5.5. The features are: repeatability, stability, response time, linearity, signal output, overall system costs, temperature range, corrosion, and purity. They have different roles in determining accuracy, but repeatability, stability, and response time are three features that have wider effects and have higher roles[32].

5.6.1. Repeatability

Repeatability is the ability of the sensor to give the same output value or to give the same reading but under repeated identical conditions. This feature is dealing with the ability of repeated same output value within a spanned temperature range, however, the RTDs typically repeatable to ± 1.4 °C or 0.5%, whichever is greater. The same temperature profile was used to qualify the accuracy, repeatability, and long-term reliability of the RTD device [23]. RTDs have to be developed and used to detect repeating frequency and temperature due to its linearity, measurement repeatability and stability [32].

5.6.2. Stability

Stability is the quality of being unchanging and it will be free from any change or variation. Therefore, the stability is the state of being fixed and not likely to change. In regards with RTDs, the stability is quality of stable temperature measuring. Also, stability is the ability to cope with changes which occurs in operational conditions. The stability is regarded as ability of sensor to maintain at its specified accuracy level for an extended period of time, usually it will be one year but in case of properly used RTDs. Accuracy of measurement and stability of long-term monitoring are the key factors which affecting on the system working conditions. Different suppliers provide different temperature measurement solutions with different degrees of accuracy, long-term stability, and reliability [33].

The features are the ability of sensors to maintain a consistent output when a constant input is applied, but the physical or chemical changes can cause deviation, therefore, the drift rates conservatively specified by manufacturers are typically 0.05°C/year. To meet a 0.1 °F (-17.7222 °C) temperature error requirement, the combined current source accuracy and stability should be within + - 0.02 % of current set point [10].

5.6.3. Response time

Response time is the ability of sensor to react to any change in temperature level. This is depending on thermal mass ability of the sensor which is the ability of a material to absorb and store heat energy. It depends on material being measured but it varies according to the application type. The sensors can have high stability and linearity. They can operate at a wide range of temperature but may give slow response time. Thin film types of RTDs are now replacing the wire type because of their small dimensions and short response time [2].

Specifically, response time is described in terms of a time constant which is the time necessary for a temperature sensor to respond to a 63.2% step change in temperature [34].

6. Analysis of data:

6.1. Features

The analysis from [16, 20- 26] in above sub-sections (5.2., 5.3., and 5.4.) will summarized as in table 1 is showing the comparison between some features of three metals which have effects on the accuracy level of RTDs. The features have different values.

Table 1: Comparison between features of platinum, copper, and nickel which have effects on accuracy level of RTDs.

Features	Pt	Cu	Ni
Rang of Temp.	-200°C to +850 °C	-200°C to +260 °C	-60°C to +260°C
Oxidation	None	Easily oxides	Relatively oxides
Corrosion	None	Easily subjected to corrosion	Subjected to corrosion
Purity	High degree of purity	Lowest degree of purity	Lower degree of purity
Stability	Highest degree	Lowest	lower
Repeatability	Highest degree	Lowest	Lower
Res. &Temp. relationship	linear	Linear	nonlinear

6.2. Basic Characteristics

The analysis from [16- 34] in above section (5. Methods and materials) will summarized as in table 2. It is showing the basic characteristics, TCR, and range of temperatures of three metals.

Table 2: Three metals and basic characteristics and their TCR with temperature range [35]

Temperature range, TCR, and basic characteristics of metals
Platinum (Pt) at Temperature range (°C) = $(-200\sim+850)$. TCR (Ω · Ω−1 · °C−1) = 0.00385. Basic characteristics: High malleability, high corrosion resistance, high ductility, best stability of electric properties, good linearity, a wide range of temperatures, negligible reactivity with surrounding factors, high temperature tolerance, high melting point, and suitable physical and chemical stability.
Copper (Cu) at Temperature Range (°C) = $(-200\sim+260)$. TCR (Ω · Ω−1 · °C−1) = 0.00472. Basic characteristics: Affordable prices or low cost, cheaper than Pt and Ni, best resistance to temperature, oxidizes at higher temperature, resistance changes with the change of temperature, limited range of temperature measurement, good linearity, lower TCR compared to Pt.
Nickel (Ni) at Temperature Range (°C) = $-60\sim+260$). TCR (Ω · Ω−1 · °C−1) = 0.00672. Basic characteristics: Reasonable prices, cheaper than Pt., low cost, high sensitivity, limited range of temperature measurement, good compromise between Pt and Cu, nonlinear above 300 °C., good resistance to corrosion.

7. Results and Discussion:

It was noted that the accuracy of three metals were as following ranges:

- ✓ Accuracies of Pt are between 0.35, 0,8, 2,8, and 1.15 for 100 Ω and 500 Ω of class A and B.
- ✓ Tolerances of Cu are 2.83 and 7.78 between (- 73 C to 260 °C).

Tolerances of Ni are 1.25 and 2.28 between (- 73 °C to 260 °C) as showed in figure(2) .

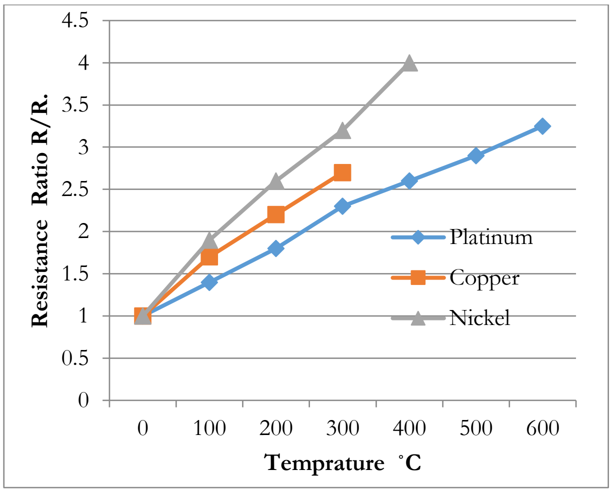

Figure (2): The accuracy of Pt, Cu, and Ni at different temperatures

While, the TCR values of them as follows:

- ✓ Pt is between (0.00392 Ω/ Ω/C and 0.003850 Ω/ Ω/°C).
- ✓ Cu is 0.004274 Ω/ Ω/°C.
- ✓ Ni is 0.006720 Ω/ Ω/°C. as showed in the figure (3).

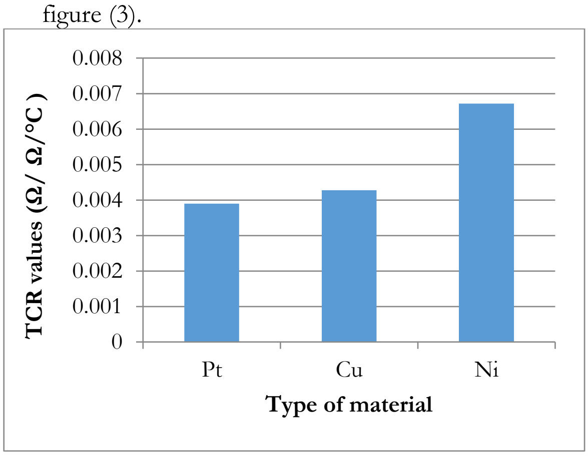

Figure (3): The temperature coefficient resistance of Pt, Cu, and Ni.

The research has recorded that there are 9 features of metals composed RTDs that affecting on accuracy level. They are including repeatability, stability, response time, linearity, signal output, overall system costs, temperature range, corrosion, and purity as showed in figure (4).

Also, the research has noted that repeatability, stability, and response time are 3 features that are most important in determining of accuracy levels of RTDs because they are dealing with the repeated output value within a spanned temperature range. Also, they have ability to react to any change of temperature level within a spanned temperature range. Also, they have ability to react to any change of temperature level as shown in figure (5).

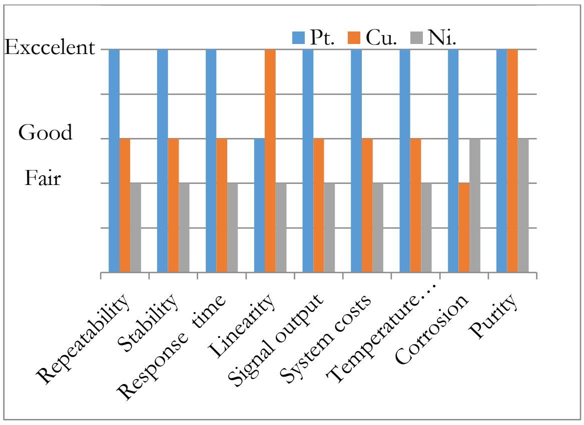

Figure (4) Nine features that are important in determining of accuracy levels of RTDs

It was noted that repeatability, stability, and response time are 3 features that are most important in determining of accuracy levels of RTDs because they are dealing with the repeated output value within a spanned temperature range. Also, they have ability to react to any change of temperature level as showed in figure (5).

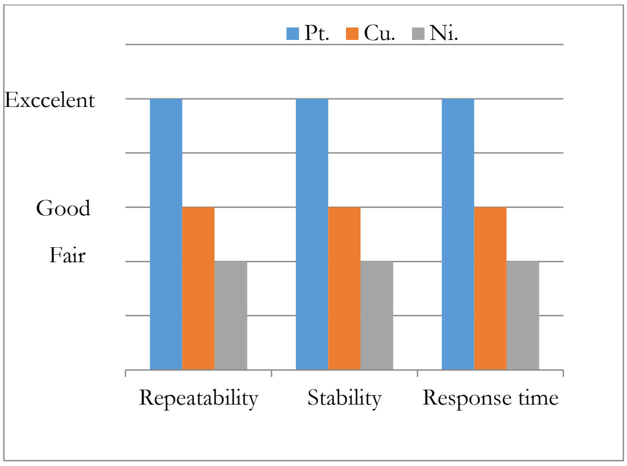

Figure (5) shows 3 features that are most important in determining of accuracy levels of RTDs

It was noted that there will be 9 basic characteristics related to three metals that can increase or decrease the accuracy and enforce the features of them. They include strong accuracy, best stability, good linearity, high sensitivity, ductility, resistance to corrosion, purity, reasonable prices, high melting point, high sensitivity, and negligible reactivity with surrounding factors as showed in figure (6).

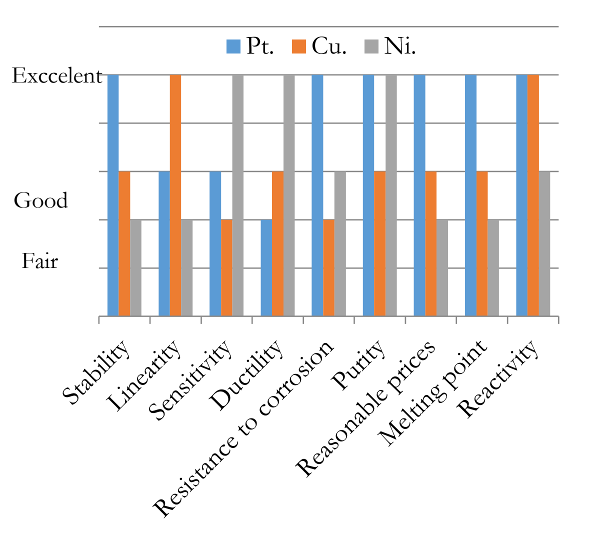

Figure (6) Nine features of metals composed RTDs that affecting on accuracy level.

About the metals Pt., Cu., and Ni., the research has founded that:

- ✓ The accuracy of platinum RTDs will remain high because platinum gives slight reactivity and stability against certain conditions such as mechanical vibrations, shocks, external loads, and temperature fluctuations. Also, Pt will increase the accuracy of RTDs due to malleability, high corrosion resistance, high ductility, high melting point, and stable electric properties. In addition, it offers suitable physical and chemical stability, it holds really high temperature tolerance as well. Moreover, platinum increases the accuracy of RTDs because it contributes to precision and stability of temperature measurement.
- ✓ The accuracy level of copper RTDs facing vulnerability because it will be oxidized at higher temperature in spite of this, it has the best resistance to temperature linearity. Also, the output is small and its resistance changes with the changing of temperature.
- ✓ The accuracy of nickel RTDs has a limited level because at high temperature has low purity and it react easily with any chemical changes such as oxidation and corrosion.

About the accuracy with relation to internal composition of RTDs, the results have showed that:

- ✓ It was noted that some factors are affecting on accuracy of RTDs.These factors involve lead wire resistance effect, self-heating effect, electromagnetic force error, non-linearity, corrosion, radiation, and insulation loss.
- ✓ The accuracy is generally expressed by its initial element accuracy that calculated at 0°C (32 °F).The level of this accuracy differs with temperature range, here, the effective tolerance of an RTD sensor is actually a blend of base resistance tolerance and TCR .

8. Conclusions:

RTDs are most reliable and accurate devices in temperature measurement composed of platinum, copper, or nickel metals. Their resistance will change in process of temperature measurement. This research has defined and presented accuracy of them, and compared them according to their related features and basic characteristics.

Platinum is widely demanded metal for RTDs construction. It contributes to the precision and stability of temperature measurement in RTDs. Copper has some excellent features that make it suitable for RTDs manufacturing. It has lower cost than platinum and nickel and has good resistance to temperature linearity, but it oxidizes in atmosphere and has small output. While Nickel is between platinum and copper. It is cheaper than platinum, nonlinear above 300 °C, and it has higher output and good resistance to corrosion.

ASTM E1137 and DIN 43760 are two standards which are issued about the resistance of metals and RTDs.

The analysis of data indicated that the accuracy level of platinum, copper, and nickel has showed different values of accuracies, and showed 9 features with11 basic characteristics related to three metals composed RTDs which are connected to accuracy levels. They are between superior, best, and medium states.

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