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Thermocouple Testing by Comparative Evaluation with Assistance of developed Programming

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Abstract: - Thermocouples are widely used to measure temperature in industries and science. Two thermocouples respond somewhat differently under identical measurement conditions. As a result, these need to be tested and calibrated to produce interpretable measurement. This paper discusses about the experimental set-up developed to carry out the testing of thermocouples, after establishing an interface between the thermocouple test set and PC for quick and precise results. The computer software was also developed to plot comparative thermocouple performance characteristics.

Keywords: - Thermocouple, Temperature, Calibration, Computer Interface, Sensors.

I. INTRODUCTION

Temperature is the mostly measured quantity in different processes. Its wide range of applications and varied environment of operation, call for a variety of engineering adaptations of the temperature measuring system[12]. Industrially the most important temperature transducer is the thermocouple[13]. Typically thermocouples are used for temperature measurements and it is important to ensure that the thermocouples are accurate and give reliable readings[9]. When connected in pairs, thermocouples are simple and efficient sensors that output an extremely small dc voltage proportional to the temperature difference between the two junctions in a closed thermoelectric circuit. The thermoelectric thermometry is based on the fact that an EMF is generated when the junctions of two dissimilar metals are kept at different temperatures; the magnitude of the EMF depends on the temperatures of the junctions[15]. The response of a particular thermocouple depends on the exact formulation of the metals used to construct it. Measuring with two thermocouples will respond somewhat differently under identical conditions. A given thermocouple material must be calibrated over the complete range of temperatures in which it is to be used[5].

Computer assisted experimentation is an exciting and emerging field which empowers the capabilities of the conventional measurement systems and yields fascinating performance. The experimentation example can be good preparation for the design and implementation of any computer assisted physical system. The results of advancing the on-machine and post-process sensing and analysis techniques will have significant impact on research into precision and agile engineering applications. The research results can be used to identify, decouple, and then minimize confounded measurement uncertainties. The results of developing innovative measurement procedures and sampling strategies will advance the technology in extracting information that truly represents the actual dimensions and the form of measured features. Therefore, the quality and reliability of the inspection data can be improved dramatically and a more accurate and meaningful conclusion can be drawn[14].

In the present study, the efforts have been made to establish an interface by means of analog to digital converter (A/D) card between the measurement system and PC. All A/D converters accomplish their task by partitioning the full analog input range into a fixed number of digital steps. An important feature of data acquisition products is how they bring together sophisticated functions in an integrated, easy-to-use system. Given the companion software that is available, the user can take advantage of the latest technology without being intimately familiar with the internal details of the hardware[3]. This interface enables to carry out the experimentation of thermocouple testing and temperature monitoring with the help of PC and temperature sensors. The computer software has been developed in VB6 to record the data and software plots the performance characteristics for the thermocouple.

II. WORKING OF THERMOCOUPLE TEST SET (TTS)

The TTS unit comprises a potentiometer, a calibrated source and a wheat-stone bridge. The EMF of the thermocouple was measured with a potentiometer, which was capable of an accuracy of a few tenths of a micro-volt. Two suitable types of potentiometer are the Diesselhorst and the vernier[8]. A taut suspension type galvanometer is built-in. Initial standardization carried independently with the help of coarse and fine potentiometer rheostats. For testing of a thermocouple, the null point of the galvanometer for selected range of

EMF values of the thermocouple was found out. The EMF generated by thermocouple under test was tabulated (Table 1). Noltingk[9] shown that, for type-k thermocouples, the characteristic is almost linear in the range –50 °C to 400 °C.

III. CAX SETUP FOR THERMOCOUPLE TESTING

All Computers are able to suitably analyses large scale data systems that are generated in various experimental studies. Figure 1 shows the generalized block diagram of experimental set-up developed. The CAX set-up consists TTS, thermocouple (*k*-type), WB, digital thermometer, A/D PCL-812 PC interface card and the PC as shown in Figure 2. The corresponding software was developed by using a commercially available visual programming package VB6. The PCL-812 A/D converter card is a high speed, multifunction data acquisition card for IBM PC and compatible computers. The temperature & EMF values measured by CAX setup are given in Table 2.

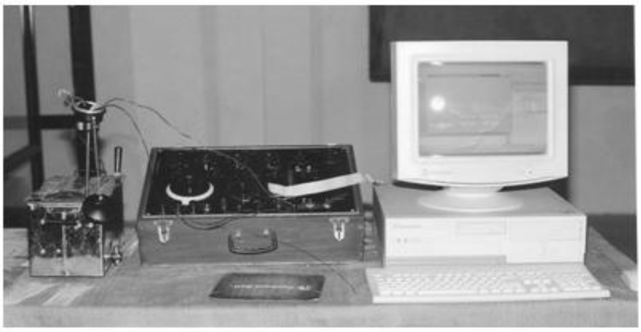

Fig 1: CAX set-up for thermocouple testing

IV. FLOWCHART, COMPUTER PROGRAMMING AND OBSERVATIONS

The steps involved in development of computer program are represented by flowchart as shown in Figure 3. The computer program generates various forms required to input, output and display of information. The standard objects available in VB6 library were used as per the requirement. The inputs can be provided through specially designed forms. The available option plots time v/s temperature characteristic for the given individual temperature sensor on time scale. The measurement option available on the form records data with the help of data acquisition card in real time.

Table 1 Temperature & EMF measured by WB & TTS

Sr. No.	WB Temperature = T_{WB} (°C)	EMF corresponding to T_{WB} = E_{WB} (mV)	EMF Readings by TTS = E_{TTS} (mV)	Total EMF, $E=E_{TTS}+E_{RM}$* (mV)	Temperature Corresponding to E = T_{TTS} (°C)
1	39	1.570	0.21	1.576	39.0
2	44	1.776	0.30	1.666	42.5
3	48	1.941	0.45	1.816	45.0
4	50	2.023	0.56	1.926	48.0
5	52	2.106	0.68	2.046	54.0
6	57	2.312	0.98	2.346	57.5
7	60	2.436	1.15	2.516	62.0
8	63	2.561	1.27	2.636	65.0
9	65	2.644	1.39	2.756	67.5
10	68	2.768	1.45	2.816	69.0
11	71	2.893	1.73	3.096	75.0
12	74	3.017	1.86	3.226	79.0
13	78	3.184	2.08	3.446	82.0
14	80	3.267	2.18	3.546	86.5
15	82	3.350	2.26	3.626	88.5
16	85	3.474	2.43	3.796	92.0
17	88	3.599	2.59	3.956	96.0
18	90	3.682	2.64	4.006	98.0
19	92	3.765	2.72	4.086	99.5
20	93	3.806	2.79	4.156	101.5

* E_{RM} = 1.366 mV at room temperature 34 °C

The digital temperature values are displayed for the adjacent test unit on the form. Further, the recorded data is stored in separate data file. This data is used by computer program to plot the characteristics. The intervals of data acquisition can be controlled automatically as per requirement. The program can be abruptly terminated, whenever required. The TTS reading corresponds to the difference in temperature between the surroundings (room) and the WB. To test the thermocouple, room temperature* had taken into consideration to get the absolute value of temperature (T_{TTS}). To make accurate temperature measurements with thermocouples, the reference junction temperature must remain constant; if it varies, suitable compensation for these variations must be provided[10]. Here, the equivalent mV (E_{RM}) value for the room temperature was selected from reference table[11]. Then the mV value was added corresponding to the room temperature, to every E_{TTS} reading (Table 1).

V. RESULT ANALYSIS

From Table 3 and Figure 3, it appears that, there is a closed association of the behavior of the graphs generated from the observed readings T_{WB}, calculated readings T_{TTS} from the generated EMF, (E) and T_{CAX}, with corresponding EMFs, (E_{WB}, E and E_{CAX}) respectively. The thermocouple characteristic plotted with reference to time by computer program is shown in Figure 4. Approximately a linear trend was observed for the recorded readings. The correlate curve of temperature vs EMF nearly runs parallel. Initially, the temperature T_{TTS} is higher and at the end it is lower than the temperature T_{CAX} because the surrounding temperature plays an important role at lower temperatures. At higher temperatures, related EMF affects very little. This ensures the quick, faster and precise performance with developed CAX setup for the desired interval of time.

Table 2 Temperature & EMF measured by CAX

Time (min)	T_{CAX} (°C)	E_{CAX} (mV)
0	33.00	1.224
2	35.00	1.327
4	43.00	1.627
6	47.00	1.781
8	51.00	1.998
10	55.00	2.192
12	59.00	2.275
14	64.00	2.524
16	70.00	2.731
18	76.00	2.923
20	83.00	3.227
22	91.00	3.622

Table 3 Regression statistics for WB, TTS & CAX readings

Regression Statistics for	E_{WB} vs T_{WB}	E vs T_{TTS}	E_{CAX} vs T_{CAX}
Multiple R	0.998	0.998	0.998
R Square	0.996	0.996	0.997
Adjusted R Square	0.996	0.996	0.997
Standard Error	1.222	1.027	0.888
Observations	20	20	12

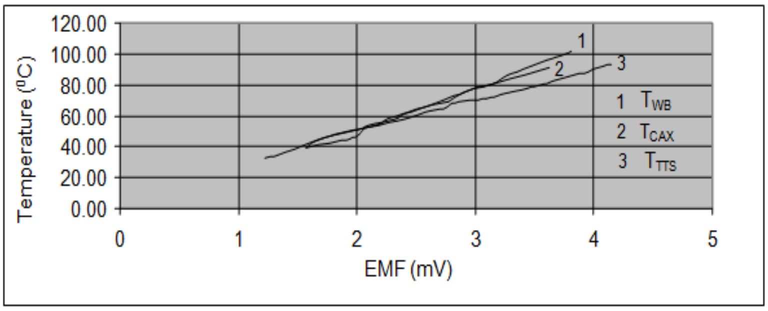

Fig 3: Characteristics of EMF vs WB, TTS and CAX temperatures respectively

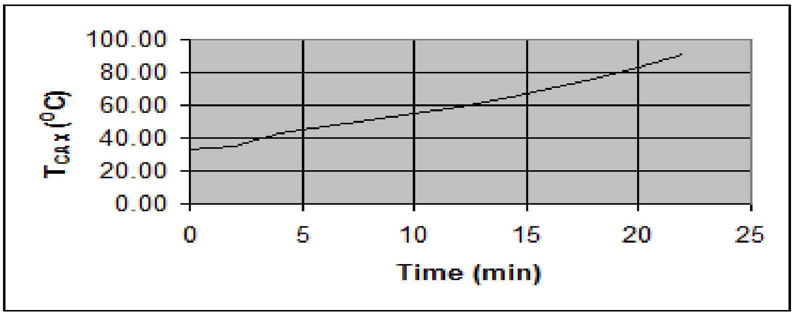

Fig 4: Thermocouple characteristics by CAX setup

VI. CONCLUSIONS

This paper has provided the consolidation of the information regarding thermocouple testing by using the developed CAX set-up. The experimentation was restricted to type-k thermocouple tested in air. The thermocouple performance was compared by three methods, i.e. WB, TTS and CAX. From the plotted characteristics, it is seen that, the performance of the thermocouple by discussed method was matching with the performance shown by the standard method.

Modern equipment is continuously being developed, but certain basic devices have proved their usefulness in broad areas. Undoubtedly, these devices shall be widely used for next many years. These devices are of great interest and unique in themselves. They serve as the vehicle for presentation and development of general techniques and principles required in the field of measurement and instrumentation in handling problems. Moreover, these general concepts can be useful in treating many devices that may be developed in future. Common advantages of such computer based systems are their flexibility and adaptability to changing situations and requirements. Future changes can be accommodated rapidly and cheaply by program modifications.

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