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CONSTRUCTION OF IRON-CONSTANTAN THERMOCOUPLE FROM LOCALLY AVAILABLE RAW MATERIALS

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ABSTRACT

Measuring of temperature in furnaces has been a problem in many research institutes and universities. The objective of this research is to produce a device capable of measuring temperatures in the range of 400 to 1000°C. This research is on the design of a type J or iron-constantan thermocouple. Constantan is an alloy having a composition of 60% copper and 40% nickel. A type J thermocouple was made by twisting iron lead wire and constantan lead wire. A performance evaluation carried out showed that the measurements were reliable at 95% confidence level for temperatures up to 1000°C.

***Keywords**: Seebeck Effect, Peltier Effect, Thomson Effect, Iron-Constantan*

INTRODUCTION

Measuremaent of mechanical, thermal, electrical, and chemical quantities are made by devices called sensors and transducers. The sensor is responsive to changes in the quantity to be measured e..g. temperature, position, systolic blood pressure or chemical concentration. The transducer converts such measurement into electrical signals, which usually amplified can be fed into instruments for the readout, recording or control of the measured quantities. Sensors and transducers can operate at locations remote from the observer and in environment unsuitable or impractical for humans.It has been stated that by virtue of thermocouple operation of transducing thermal energy into electrical, it is used widely in temperature measurement and control [Baker et al., 1953]Knowledge of operating temperature is so essential in industries and small scale laboratories. This explains the relevance of temperatuare measuring devices of which thermocouple enjoys the widest application. This is because of its small size lightweight, long life, reliability and its relatively large range of usefulness. In industries, a close monitoring of temperatures of operations or reactions is required, often times leading to control action. In the home, the thermocouple finds application in the heating/cooling system. On the sea, the thermocouple can prove very useful in sensing equipment temperatuares. Thermoelectric effects result from energy conversion from one form to the other. According to turner a transducer is a device which converts energy from one form to the other [Bradley et al., 1988]. He classified tranducers into two categories viz, output tranducers and input tranducers. Output tranducers or actuators convert electrical, pneumatic or hydraulic energy into mechanical force. Input tranducers or sensors convert state parameters such as temperature, pressure, force, magnetic field strength etc, into (usually) electrical energy, since this is generally the most cônvinient form for measurement or signal processing. Thermocouple is an example of an input tranducer. The objective of this study is to design and construct a thermocouple capable of measuring higher temperataures normally encountered in research furnaces. Standards have been defined for some special base metal thermocouples. The letter designations were originally used by the instrument society of america and have now gained world wide acceptance [Dally, et al., 1984]. Table 1 highlights the eight standard base metal thermcouple types and their composition.

Table1: Letter designation and composition for standardized thermocouples

Thermocouple type designation	Thermocouple materials	
	Positive wire	Negative wire
B	Platinum with 30% Rhodium	Platinum with 6% Rhodium
J	Iron	Copper-Nickel alloy (alumel)
K	Nickel-chromium alloy (chromel)	Nickel-aluminium alloy (alumel)
E	Nickel-chromium alloy (alumel)	Copper-nickel alloy (constantan)
N	Nicrosil	Nisil
R	Platinum with 13% Rhodium	Platinum
S	Platinum with 10% Rhodium	Platinum
T	Copper	Copper-nickel alloy (constantan)

Iron-Constantan characteristics

Constantan is an alloy having a composition of 60% copper and 40% nickel. It is extensively used for making standard electrical resistors. It has an electrical ressistivity of 48 x 10^{-6} ohm-cm units at 0°C. Its temperature coefficient of resistance is very low varying between ±0.000004°C at room temperature. Its specific gravity is 8.9 [Avner, 1974]. The thermoelectric power of iron as compared to other metals is usefully exploited in temperature measurement [Turner, 1980].

Materials and methods.

The materials used for the production were iron lead wire, constantan lead wire, insulators for lead wires protective tube or wall and welding element. A base metal thermocouple is any of the metals found at the lower part of the electrochemical series, such as copper, lead, zinc and tin. They are the direct opposite of the noble metals such as gold and silver [Pollock, 1991] Suitable lengths of the two wires were cut. The ends were carefully twisted together for about three turns and welded together (see Plate 1). The two wires were insulated such that only the junction is heated.

Plate 1: Iron-constantan thermocouple

Tests

The tests were conducted at reference temperatures of 0°, 29° and 31°C. 0°C was obtained by immersing the cold junction in a jar of ice while reference temperatures of 29°C and 31°C were obtained over an extended period. A standard thermocouple was connected to the digital "Eurotherm" controller of the oven. The controller was set to a cutout temperature of 1000°C. The constructed thermocouple was inserted into the oven and the readings were taken over intervals of 50°C.

Table 2: Resultant reading and expected reading at 0° reference

Temperature °C	Resultant reading mV	Expected reading (mV)
0	0	0
50	2.532	2.585
100	5.159	5.268
150	8.118	8.008
200	10.421	10.777
250	13.386	13.553
300	16.325	16.325
350	18.978	19.089
400	21.956	21.846
450	24.662	24.607
500	27.444	27.388
550	30.096	30.21
600	32.979	33.096
650	35.945	36.066
700	39.006	39.132
750	42.347	42.283
800	45.625	45.498
850	48.844	48.716
900	52.061	51.875
950	55.734	54.948
1000	58.12	57.942

Table 3: Resultant reading and expected reading at 29°C reference temperature

Temperature °C	Resultant reading mV	Expected reading (mV)
29	1.484	1.484
50	2.532	2.585
100	5.159	5.268
150	7.843	8.008
200	10.610	10.777
250	13.422	13.553
300	16.214	16.325
350	18.813	19.089
400	21.625	21.846
450	24.441	24.607
500	27.276	27.388
550	30.210	30.210
600	33.272	33.096
650	36.307	36.066
700	39.389	39.132
750	42.538	42.283
800	45.692	45.498
850	48.972	48.716
900	52.061	51.875
950	55.312	54.948
1000	58.297	57.942

Table 4: Resultant reading and expected reading at 31°C reference temperature

Temperature °C	Resultant reading mV	Expected reading (mV)
31	1.588	1.588
50	2.479	2.585
100	5.169	5.268
150	8.008	8.008
200	10.421	10.777
250	13.442	13.553
300	16.214	16.325
350	18.923	19.089
400	21.625	21.846
450	24.496	24.607
500	27.276	27.388
550	30.153	30.210
600	33.272	33.096
650	36.307	36.066
700	39.317	39.132
750	42.538	42.283
800	45.692	45.498
850	48.908	48.716
900	51.999	51.875
950	55.191	54.948
1000	58.179	57.942

Statistical test

Analysis of variance ANOVA tool in Microsoft Excel was used for this analysis. The test results for the three reference temperatures were analysed and the resuslts are shown in the table 5 below.

Table 5.1: ANOVA Test at 0°C

[1]	[2]	[3]	[4]	[5]	[6]	[7]
Summary						
Groups	Count	Sum	Average	Variance		
RESULTANT READING (mV)	21	589.738	28.0876	327.8732		
Expected Reading(mV)	21	589.212	28.05771	323.45		
ANOVA						
	SS	df	MS	F	P-value	F-crit
Between Groups	0.006558	1	0.006588	2.02E-05	0.996434	4.08474
Within Groups	13026.46	40	325.6616			
Total	13026.47	41				

Table 5.2: ANOVA Test at 29°C

[1]	[2]	[3]	[4]	[5]	[6]	[7]
Summary						
Groups	Count	Sum	Average	Variance		
RESULTANT READING (mV)	21	591.479	28.16567	325.4391		
Expected Reading(mV)	21	590.696	28.12838	319.3911		
ANOVA						
	SS	df	MS	F	P-value	F-crit
Between Groups	0.014597	1	0.014597	4.53E-05	0.994665	4.08474
Within Groups	12896.6	40	322.4151			
Total	12896.62	41				

Table 5.3: ANOVA Test at 31°C

[1]	[2]	[3]	[4]	[5]	[6]	[7]
Summary						
Groups	Count	Sum	Average	Variance		
RESULTANT READING (mV)	21	591.187	28.15176	324.1307		
Expected Reading(mV)	21	590.6	28.12381	319.6274		
ANOVA						
	SS	df	MS	F	P-value	F-crit
Between Groups	.008204	1	0.008204	2.55E-05	0.995997	4.08474
Within Groups	12875.16	40	321.879			
Total	12875.17	41				

Table 5.4: Summary

Reference Temperature	F_{cri}	$F_{calculated}$	$F_{cal} < F_{cri}$?	Probability	Comment
0°C	4.08474	2.02E-05	YES	0.996434	No significant difference
29°C	4.08474	4.53E-05	YES	0.994665	No significant difference
31°C	4.08474	2.55E-05	YES	0.995997	No significant difference

RESULTS AND DISCUSSION

Performance evaluation showed that the constructed thermocouple functions as expected within a reasonable limit of error. The basis for comparison is the standard for type J thermocouple of the International Practical Temperature Scale of 1968 (IPTS 68).

CONCLUSION

A thermocouple has been constructed using locally available raw materials. Its design is robust and the performance depends only on choice of material. From the tests, we conclude that the performance conforms to standard. It is faithful and maintenance free. The J type thermocouple so described may be produced in research facilities to enhance the meausring of temperature accurately up to 1000°C.

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