THERMOCOUPLE GENERAL INFORMATION

Thermocouples consist of two dissimilar metals and provide a means of sensing temperature in a variety of processes. Temperature is the most widely measured process variable and its measurement is critical in many manufacturing processes. We at JMS manufacture temperature probes of exceptional quality to assure this measurement is accurate.

Thermocouples can be constructed in a variety of ways from flexible wires smaller than a human hair to rugged sheath one half inch in diameter. They can measure temperatures from -454°F to 4200°F.

Thermocouples are low-impedance devices that work by producing electro-motive forces and these EMF's are correlated to a temperature based on a curve specified for that particular thermocouple calibration. The EMF produced occurs due to temperature gradients along the wire and not at the junction. This phenomenon can be explained in three scientific theories called the Seebeck effect, the Peltier effect, and the Thompson effect.

Three laws of thermoelectric circuits that explain thermocouple behavior are **The Law of Intermediate Metals** which explains that a circuit's EMFs are algebraically additive unless the circuit is at a uniform temperature, **The Law of Homogeneous Metals** which indicates an EMF cannot be created unless another type of metal exists in the circuit and a temperature gradient exists.

The third law is the **The Law of Intermediate Temperatures.** If two dissimilar homogeneous metals produce a thermal EMF of X; it will remain at that number if a third material is introduced into the circuit, if both ends of that third material are at the same temperature.

The millivolt signal produced by the thermocouple is a <u>very, very, very</u> low level signal. Thus, transmitting this signal over a long distance may be difficult if any extraneous "noise" is introduced into the system. This noise may cause errors in the EMF signal. Shielded lead wire should be used in areas with excessive "noise" to help eliminate the problem.

The lead wire that extends from the thermocouple must match the calibration of the thermocouple. This lead wire continues to transmit the signal from the thermocouple to the instrument, and as long as it is one homogeneous metal, it does not produce an EMF along that length even if it does experience temperature gradients.

The output of a thermocouple depends on the magnitude of the temperature difference between the measuring junction and the reference junction. The reference junction is the cold end to which the thermocouple is connected. While the hot measuring junction is stable at a given temperature, the output of the point at which the reference junction is made must be compensated for in the instrumentation. This is accomplished through "cold junction Compensation." The temperature of the cold junction is measured and calculated into the overall EMF signal to obtain the accurate hot junction temperature, or the temperature of the process.[2]

[2]Benedict, R.P. Fundamentals of Temperature, Pressure and flow Measurement, Second Edition, Wiley, New York (1977).

THERMOCOUPLE POINTS

1. A thermocouple produces an EMF based on the composition of the two dissimilar metals only, irregardless of the dimension or length of the conductors.

2. No voltage is produced at the thermocouple junction, only in those portions of the sensor that are in a temperature gradient.

THERMOCOUPLE CALIBRATION INFORMATION

(J)–Iron vs Constantan (Most Common)

May be used in vacuum, oxidizing, reducing, and inert atmospheres. Heavier gauge wire is recommended for long term life above 1000°F since the iron element oxidizes rapidly at these temperatures.

(T)–Copper vs Constantan (Most Common Cold)

May be used in vacuum, oxidizing, reducing, and inert atmospheres. It is resistant to corrosion in most atmospheres. High stability at sub-zero temperatures and its limits of error are guaranteed at cryogenic temperatures.

(K)–Chromel vs Alumel (Most Common Real Hot)

Recommended for continuous use in oxidizing or inert atmospheres up to 2300°F (1260°C), especially above 1000°F. Cycling above and below 1800°F (1000°C), is not recommended due to EMF alteration from hysteresis effects. Should not be used in sulfurous or alternating reducing and oxidizing atmospheres unless protected with protection tubes. Fairly reliable and accurate at high temperatures.

(E)–Chromel vs Constantan

May be used in oxidizing or inert atmospheres, but not recommended for alternating oxidizing or inert atmospheres. Not subject to corrosion under most atmospheric conditions. Has the highest EMF produced per degree than any other standard thermocouple and must be protected from sulfurous atmospheres.

(S,R)–Platinum vs Platinum Rhodium (Most Common Real, Real Hot)

Recommended for use in oxidizing or inert atmospheres. Reducing atmospheres may cause excessive grain growth and drifts in calibration.

(N)–Nicrosil vs Nisil (New ... Better Than “K”)

May be used in oxidizing, dry reducing, or inert atmospheres. Must be protected in sulfurous atmospheres. Very reliable and accurate at high temperatures. Can replace Type K thermocouples in many application.

(W)–Tungsten vs Rhenium

Recommended for use in vacuum, high purity hydrogen, or pure inert atmospheres. May be used at very high temperatures (2316°C), however, is inherently brittle.

THERMOCOUPLE CALIBRATION INFORMATION

	ANSI T/C CALIBRATION	NAMES	CONDUCTOR IDENTIFICATION	COLOR CODING	MAGNETIC
	J	Iron Constantan	+ -	white red	yes no
	T	Copper Constantan	+ -	blue red	no no
	K	Chromel Alumel	+ -	yellow red	no yes
	E	Chromel Constantan	+ -	purple red	no no
Not ANSI	P	Platinel	N/A	N/A	N/A
	S	Platinum 10% Rhodium Pure platinum	+ -	black red	no no
	R	Platinum 13% Rhodium Pure platinum	+ -	green red	no no
	B	Platinum 30% Rhodium Platinum 6% Rhodium	+ -	grey red	no no
	N	Nicrosil Nisil	+ -	orange red	no no
Not ANSI	W	Tungsten Tungsten 26% Rhenium	+ -	white red	no no
Not ANSI	C	Tungsten 5% Rhenium Tungsten 26% Rhenium	+ -	white red	no no

ANSI THERMOCOUPLE CALIBRATION	TEMP. RANGE (°F)	LIMITS OF ERROR STANDARD	SPECIAL	EMF(mV) OVER TEMP. RANGE
J	32 to 5300 5300 to 1400	±4°F ±3/4%	±2°F ±3/8%	0 to 15.032 15.032 to 42.922
T	-300 to -75 -150 to -75 -75 to +200 200 to 700	±2% ±2% ±1 1/2°F ±3/4%	±1% ±1% ±3/4°F ±3/8%	-5.341 to -2.134 -3.410 to -2.134 3.9967 to 19.095
K	-300 to 32 32 to 530 530 to 2300	±2% ±4°F ±3/4%	N/A ±2°F ±3/8%	 0 to 11.243 11.243 to 50.990
E	-300 to 600 600 to 1600	±3°F ±1/2%	N/A N/A	0 to 22.248 22.248 to 66.559
S	32 to 1000 1000 to 2700	±2.5°F ±1/4%	N/A N/A	0 to 4.609 22.348 to 15.362
R	32 to 1000 1000 to 2700	±2.5° ±1/4%	N/A N/A	0 to 12.426
N	32 to 2300	±4°F ±3/4%	±3/8%	0 to 33.9802
W	32 to 4208	±1%		0 to 37.066

Note: To determine the limits of error in degrees C, multiply the limits of error in degrees F x 5/9.

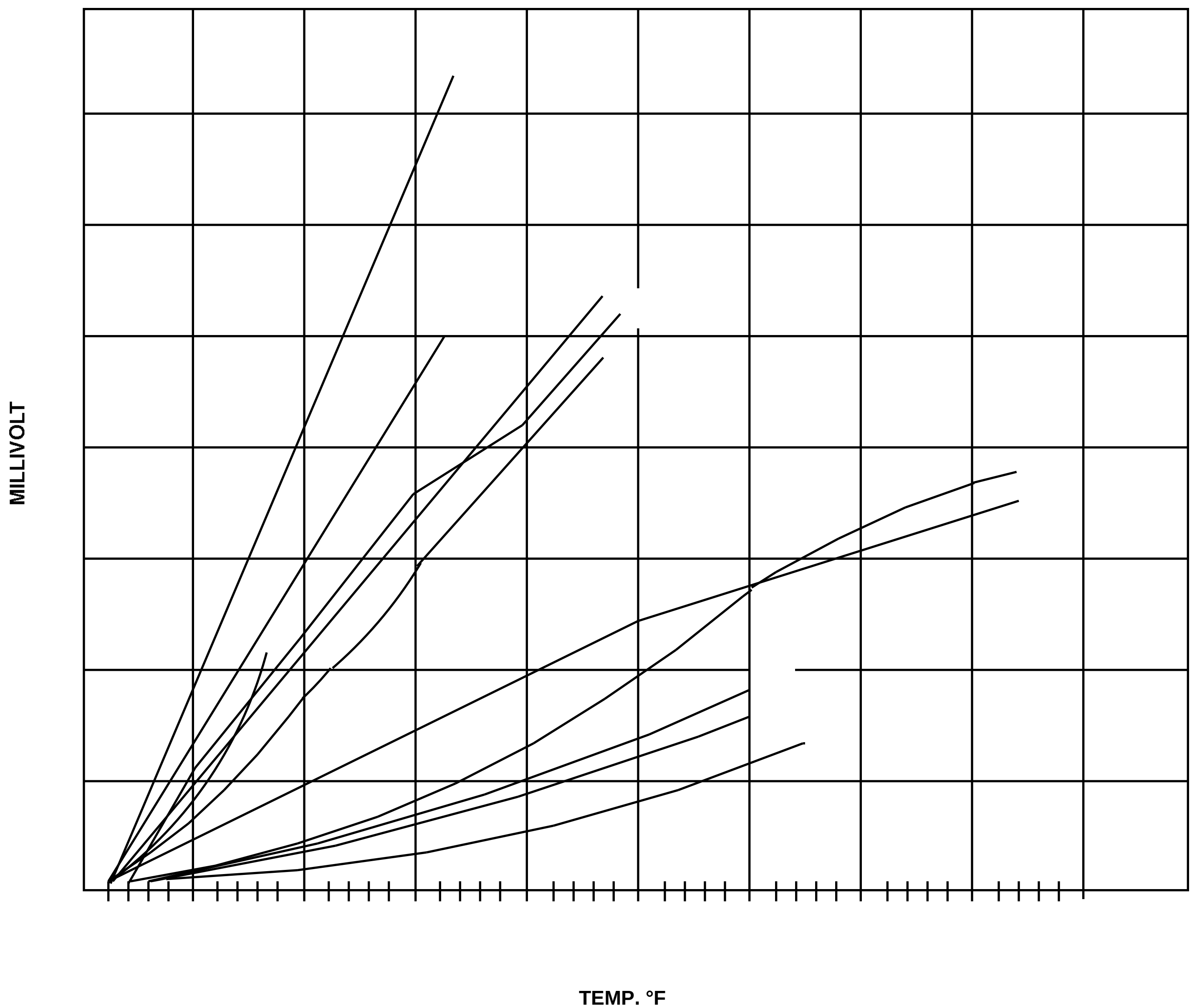
THERMOCOUPLE-MILLIVOLT GRAPH

T=Copper vs. Constantan
E=Chromel vs. Constantan
J=Iron vs. Constantan
K=Chromel vs. Alumel
W=Tungsten vs. Tungsten 26% Rhenium (also known as Type G)
C=Tungsten 5% Rhenium vs. Tungsten 26% Rhenium (also known as Type W5)
R=Platinum vs. Platinum 13% Rhodium
S=Platinum vs. Platinum 10% Rhodium
B=Platinum 6% Rhodium vs. Platinum 30% Rhodium
N=Nicrosil vs. Nisil
P=Platinel

Selection of the optimum type of thermocouple and auxiliary components for a pyrometric system is necessarily based on a number of variables or factors of the application. The temperature range, EMF output, accuracy required, resistance to atmospheric conditions, pressure and shock are typical thermocouple systems for a given application.

The following technical information is intended to serve only as a guide for thermocouple selection. Any recommendation stated is based on past practices and experience, and no guarantees, implied or otherwise, are made as to optimum operation conditions.

Although some of these materials will operate at higher temperatures than shown on the chart, they represent what is generally conceded as the maximum reliable operating temperature.



ELEMENT CONSTRUCTION

SUGGESTED UPPER LIMIT FOR OUTSIDE DIAMETER						
CALIBRATION	**1/25”**	**1/16”**	**1/8” & 3/16”**	**1/4”**	**5/16”**	**7/16”**
J	900°F	1100°F	1200°F	1200°F	1200°F	1200°F
T	300°F	400°F	700°F	700°F	700°F	700°F
K	1400°F	1800°F	2000°F	2000°F	2000°F	2100°F
E	1000°F	1200°F	1200°F	1800°F	1800°F	1800°F
Hoskins 2300-K	1800°F	2200°F	2300°F	2300°F	2300°F	2300°F

TEMPERATURE INFORMATION FOR SHEATH MATERIAL				
MATERIAL SYMBOL	**SHEATH MATERIAL**	**MELTING POINT (°F)**	**MAX. TEMP. IN AIR (°F)**	**ATMOSPHERE***
H	304SS	2550	1650	ORNV
J	310SS	2550	2100	ORNV
L	316LSS	2550	1650	ORNV
O	446SS	2700	2100	ORNV
M	Inconel 600	2500	2100	ONV
P	Inconel 702	2620	1500	ONV
Q	Platinum	3216	3000	ON
R	Molybdenum	4750	1000	VNR
S	Tantalum	5440	750	V
T	Titanium	3300	600	V
U	HOSKINS 2300	2550	2300	ORNV
V	NICROBELL C	2585	2280	ORV

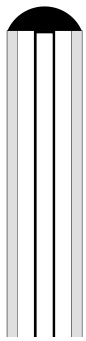
*KEY
O=Oxidizing R=Reducing N=Neutral V=Vacuum

For high temperature applications 1000°F to 2300°F, new proprietary materials have been developed to perform better than the alloys used in the past.

U = HOSKINS 2300 : “...maintains special limits accuracy by up to 10 times longer than probes made from other cable.”

V = NICROBELL : “Sheathed Type N can be used to replace Platinum / Rhodium sensors up to a maximum continuous temperature of 2280°F...”

MEASURING JUNCTION



GROUNDED JUNCTION

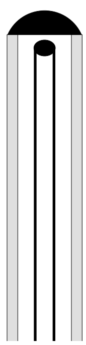
The **grounded** thermocouple junction is an integral part of the thermocouple sheath tip.

Advantages:

- fast response time in relation to ungrounded and isolated junctions.
- protects the wires from environmental chemicals and corrosives.
- prolongs the operational life of the thermocouple. Longer lifespan than the exposed junction thermocouple.
- it is recommended for high pressure applications.
- it is the least expensive construction.

Disadvantages:

- thermal expansion of sheath material may differ from element to cause mechanical stress and work hardening of metals.
- ground loops may cause interference with instruments.
- faults in insulation are more difficult to detect.



UNGROUNDED JUNCTION

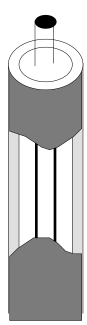
The **ungrounded** thermocouple junction is electrically insulated and electrically isolated from the outer sheath material. In a dual ungrounded thermocouple, one common junction is electrically insulated from the outside sheath.

Advantages:

- the thermocouple junction is isolated from the ground.
- defects in the MgO insulation can be detected by measuring resistance from loop to sheath.
- long term drift under cycling conditions is minimized.

Disadvantages:

- response time is usually slower than grounded thermocouples.
- more expensive than grounded thermocouples.



EXPOSED JUNCTION

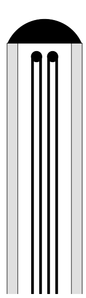
The **exposed** thermocouple junction extends beyond the protective metallic sheath.

Advantages:

- recommended for measurement of noncorrosive static gas, or air.
- very fast response time, faster than grounded junction.

Disadvantages:

- cannot be used in an environment with a high percentage of solids, high pressure, or flowing material since the junction is exposed to this environment.



ISOLATED JUNCTION

Isolated thermocouple junctions are used in a dual or triple thermocouple when the junctions are isolated from the outer sheath material as well as from each other.

Advantages:

- the elements are insulated from ground.
- performs better than ungrounded or grounded junctions in a thermal cycling environment.

Disadvantages:

- slower response time than a grounded dual thermocouple.

*For tip sensitivity information, see page 3-8.

THERMOCOUPLE OPERATION AND INSTALLATION INSTRUCTIONS

Thermocouples are installed by means of compression fittings, welded 1/2" x 1/2" NPT fittings, or bayonet fittings.

Follow these instructions for installation of a thermocouple with a 1/2" x 1/2" NPT fitting:

(1) Insert thermocouple into process hole
(2) Tighten probe into place by turning probe into threaded connection.

When installing a spring-loaded sensor, the wires should be disconnected from the terminal block to prevent twisting and shorting during installation.

INSTALLATION:

Place thermocouple in area not too close to heating element or direct flame.

When measuring very high temperatures, install thermocouple vertically, if possible, to avoid protection tube element sagging.

Always use thermocouple extension wire to correlate with calibration of thermocouple and instrumentation being used.

Install thermocouple away from AC power lines, preferably more than one foot away.

Do not run thermocouple wires in the same conduit with other electrical wires.

ELECTRICAL:

Make sure the extension wire is clean so a good electrical connection will result at the terminal block. Connect the positive extension wire to the positive thermocouple wire and the negative extension wire to the negative thermocouple wire. Wires are color coded for identification as follows, notice that the negative leg is always red.

	THERMOCOUPLE TYPE			EXTENSION WIRES		
	POS.	NEG.	OUTER JACKET	POS.	NEG*	OUTER JACKET
E	purple	red	brown	purple	red	purple
J	white	red	brown	white	red	black
K	yellow	red	brown	yellow (KX)	red	yellow
R	N/A	N/A	N/A	green	red	green
S	N/A	N/A	N/A	black	red	green
T	blue	red	brown	blue	red	blue
N	orange	red	brown	orange	red	orange

*A tracer having the color corresponding to the positive extension may be used on the negative wire code. Occasionally, it is necessary to determine thermocouple polarity in the field. The above characteristics are helpful, along with the information on the following page.

TYPE E-The negative wire has lower resistance in ohms per foot than the positive element for the same size wire.

TYPE J-The positive element is frequently rusty and is magnetic. It has a lower resistance in ohms per foot for the same size wire.

TYPE K-The negative element is slightly magnetic. It has a lower resistance in ohms per foot for the same size positive wire.

TYPE R or S-The negative wire is softer. The positive wire has a lower resistance in ohms per foot for the same size wire.

TYPE T-The negative wire is silver in appearance. The positive wire has a lower resistance in ohms per foot for the same size wire, and is usually copper colored.

TYPE N-The positive leg has a higher resistance in ohms per foot for the same size wire.

Note: When in doubt, twist the wire together, and connect opposite ends to a volt meter. Heat the twisted end with a cigarette lighter. If the volts go up - polarity is correct ...

OPERATION:

The temperature of the connection head should be kept as near room temperature as possible to avoid errors due to the extension wires. The maximum recommended temperature at the terminal block is 400°F.

MAINTENANCE:

The quality and frequency of calibration checks must be determined for each individual application by noting the decalibration rate of each thermocouple at individual installations. Thermocouples will deteriorate due to contamination from their environments. Calibration is usually made by comparison with a working standard. The thermocouple may be removed from its installation and checked in an electric furnace with the working standard; however, check the thermocouple in its installed position and location if possible. See page VI.

Return thermocouples that were removed for tests to the same location and immersion depth for reliable and repeatable readings.

Do not use a thermocouple to measure a very low temperature if it has been used to measure a very high temperature previously.

Make sure protection tubes and thermowells are in good condition when protecting thermocouples with them.

Do not run a single thermocouple to two different instruments. This can result in instrument imbalance. A dual isolated thermocouple should be used instead.

STORAGE:

Store in a clean dry place. Avoid stacking probes in areas of excessive moisture or humidity (ie: dripping, condensation). Special packing with desiccant can be specified. (See page II)

TYPE N THERMOCOUPLE VERSUS TYPE K THERMOCOUPLE IN A BRICK MANUFACTURING FACILITY

The following paper was presented by Barbara Hudson, former General Manager of JMS Southeast, Inc., at the Brick Plant Forum Convention at Clemson University in Clemson, South Carolina.

ABSTRACT:

The brick industry historically has had the option of a Type K thermocouple, which is inaccurate yet inexpensive, versus Type R and S thermocouples which are very expensive yet accurate. This article investigates the Type N thermocouple which has been developed as a substitute for the Type K thermocouple in the 32°F to 2300°F temperature range.

TYPE K VERSUS TYPE R OR S THERMOCOUPLE

Through the years, many changes have occurred in the firing of structural clays including gas, oil, and sawdust combustion. Yet, the temperature measuring methods has remained the same as far as thermocouple configurations are concerned. Throughout history, a Type K thermocouple has been used in an area which was thought of as being "non-critical". The Type R or S thermocouples (platinum-rhodium) have been used in the past in "control" areas. The reasons for these uses include: Type K thermocouples, but are also less stable and less accurate. Type K thermocouples are easily attainable, however, and widely accepted in all industries.

The reasons for the instability in Type K thermocouples are due to some inherent properties in the chromel/alumel material. One problem that occurs with this thermocouple is an effect called short-range ordering. It occurs in a temperature range of about 500°F to 1020°F when nickel and chromium atoms in the chromel leg tend to form an ordered crystalline structure. The ordering produces a different metallurgical structure and if a temperature gradient exists, an erroneous EMF is produced.

Another shortcoming of Type K thermocouples is the hysteresis effect that occurs when a Type K thermocouple is cycled up and down in temperatures above and below 1800°F. The re-ordering of the crystalline structure changes with each cycle. After the first pass above this temperature, the Type K temperature indication will probably be accurate. However, with each additional cycle after this one, the error will increase more and more. The Type K thermocouple also experiences a cumulative drift after a period of time at temperatures above 1650°F. Finally, this thermocouple experiences a physical defect called "green rot" which is caused due to preferential oxidation of the chromel leg.

Even with these problems of instability and lack of longevity in Type K thermocouples, they are widely used and accepted in the brick industry as well as other industries. This is due to the fact that they are inexpensive and the choices have been limited in the past to a thermocouple that could replace Type K at a comparable price.

The platinum-rhodium thermocouples (Type R and S) on the other hand have been used as control thermocouples in the past. They are much more stable than the Type K thermocouples, but much more expensive also. They can be ten times the expense of a Type K thermocouple. Type R or S thermocouples do, however, after a period of time at elevated temperatures, experience a drift due to platinum migration.

In essence, for temperature measurement in a brick kiln, we have a fairly accurate option at a high cost versus an unstable and "short life" option at a reasonable cost. A compromise was needed!

TYPE N THERMOCOUPLES

Noel Burley, from Australia, began extensive research on a type N thermocouple (nisil/nicrosil). The composition of this thermocouple is the following: Nicrosil-NI-14.2%, Cr-1.4%, Si and Nisil-Ni-4.4%, Si-.1%, Mg. Noel Burley's research showed that the Type N thermocouple exhibited thermal stability above 1650°F, while Type K thermocouples showed a gradual and cumulative drift. He also showed the Type N thermocouple showed no short-term change due to crystal restructuring that occurred with the Type K thermocouple. Also, the Type N had superior resistance to oxidation (no “green rot”) and could replace the Type K throughout its entire range of 32°F-2300°F. Its cost is about the cost of a Type J thermocouple. Due to this information, we decided to experiment with the Type N thermocouple in a brick manufacturing environment.

EXPERIMENTATION:

Frank Todd and Frank Todd, Jr., at Fletcher Brick were kind enough to allow us to do some experimentation in their facility. We were restricted to a short time frame, so we needed accelerated life data on comparisons between a Type K and Type N thermocouple. In communication with Fletcher Brick, a top to bottom and side to side temperature gradient was suspected in their tunnel kiln. They desired better monitoring to attain better control, thus better brick. If they were to go to platinum/rhodium thermocouples as side port monitoring sensors, the thermocouples alone would have cost in excess of $6,000 not including the data logger needed for data collection. Due to accelerated life data needed, we used 20 gauge thermocouples realizing they would deteriorate quickly. Stage 1 of our experimentation included manufacturing 10 dual thermocouples which consisted of one 20 gauge Type K and one 20 gauge Type N thermocouple in each sensor. These were installed in side ports of the kiln and ran for 30 days. The Type R thermocouples existed in the top center of the kiln as control thermocouples. All monitoring thermocouples were connected to a 40 channel data logger which printed the temperature of all sensors every six hours. This data was converted to actual temperatures for the Type N thermocouples and was compared to the control Type R sensors for kiln changes. After all the data was compiled, the drift was plotted for four Type K thermocouples. The drift of the Type K thermocouple was difficult to predict. All four sensors drifted in non-repeatable and inconsistent patterns.

The Type N readings were graphed and they also failed within the 30 day period as was predicted since 20 gauge wire was used. The drift, however, was more predictable. This was only a preliminary stage of our experimentation. We will continue our work with the 14 gauge Type N versus Type K thermocouples.

CONCLUSION:

In conclusion, Type N thermocouples can be used in all areas of the brick; i.e. traveling thermocouples, air conditioning vents, kiln control, monitoring sensors, and drying sensors.

Research has shown Type N thermocouples have better thermal stability than Type K in the temperature range of 1200°F-1400°F, which is the pre-heat zone where carbon burn-out occurs.

Also better control can be obtained with a Type N thermocouple at the quartz inversion point of 1050°F.

Two or three different types of thermocouples used in a single plant within the Type N temperature range of 32°F-2300°F can be replaced by the Type N thermocouple. This would standardize the plant with one type of thermocouple enabling the use of one type of controller, one type of data logger, etc.

This thermocouple is also ASTM certified. It has been given a color code of orange/red. It is listed in most thermocouple manufacturers catalog. We at JMS Southeast, Inc., will continue doing research with the Type N thermocouple in structural clay firing applications.

REFERENCES:

1. Brick Association of North Carolina (Marion Cochran).
2. The Nicrosil versus Nisil Thermocouple: Properties and Thermoelectric reference Data - NBS Monograph 161.
3. Temperature Sensors Product Information Bulletin (TS-02) by R. Kampion of Leeds and Northrup.

TYPE N THERMOCOUPLE GENERAL INFORMATION

COMPOSITION: Nisil/Nicrosil

Nisil		Nicrosil	
Nisil:	Ni-4.4 wt%	Nicrosil:	Ni-14.2 wt%
	Si-0.1 wt%		Cr-1.4 wt%
	Mg		Si

	Color Code	Magnetic
Nisil: (N)	Red	No
Nicrosil:(P)	Orange	No

ACCURACY:

32°F to 2300°, ± 4° or .75% of temperature reading. Can replace Type "K" thermocouples throughout entire range.

Type "N" is available in beaded assemblies or sheath material. Extension wire and other temperature accessories such as meters, controllers, transmitters, etc., are also available.

ADVANTAGES:

1. Superior thermal stability at temperatures over 1650°F, while other thermocouples such as Type "K" exhibit much greater cumulative drift.

2. Superior thermal stability in that no short term change occurs due to the crystal restructuring.

3. Superior resistance to oxidation. (No green rot.)

4. Does not exhibit hysteresis effect as the Type "K" thermocouple does.

DECIMAL EQUIVALENT CHART

INCH FRACTION	DECIMAL EQUIV.	INCH FRACTION	DECIMAL EQUIV.	INCH FRACTION	DECIMAL EQUIV.
1/64	.0156	23/64	.3594	45/64	.7031
1/32	.0312	3/8	.375	23/32	.7187
3/64	.0469	24/64	.3906	47/64	.7344
1/16	.0625	13/32	.4062	3/4	.75
5/64	.0781	27/64	.4219	49/64	.7656
3/32	.0937	7/16	.4375	25/32	.7812
7/64	.1094	39/64	.4531	51/64	.7969
1/8	.125	15/32	.4687	13/16	.8125
9/64	.1406	31/64	.4844	53/64	.8281
5/32	.1562	1/2	.5	27/32	.8437
11/64	.1719	33/64	.5156	55/64	.8594
3/16	.1875	17/32	.5312	7/8	.875
13/16	.2031	35/64	.5469	57/64	.8906
7/32	.2187	9/16	.5625	29/32	.9062
15/64	.2344	37/64	.5781	59/64	.9219
1/4	.25	19/32	.5937	15/16	.9357
17/64	.2656	39/64	.6094	61/64	.9531
9/32	.2812	5/8	.625	31/32	.9687
19/64	.2969	41/64	.6406	63/64	.9544
5/16	.3125	21/32	.6562	1	1.00
21/64	.3281	43/64	.6719		
11/32	.3437	11/16	.6875		

THERMOCOUPLE TEMPERATURE LIMITS

	Material	Couple Condition	AWG					
			8	14	16	20	24	30
S R	Platinum and Platinum-Rhodium	Bare Protected	- -	- -	- -	- 2800 F	- 2700 F	- 2400 F
T	Copper and Constantan	Bare Protected	- -	600°F 700°F	500°F 600°F	400°F 500°F	400°F 400°F	400°F 400°F
J	Iron and Constantan	Bare Protected	1200°F 1400°F	900°F 1100°F	900°F 1100°F	800°F 900°F	650°F 700°F	600°F 700°F
K	Chromel and Alumel	Bare Protected	2000°F 2300°F	1700°F 2000°F	1700°F 2000°F	1600°F 1800°F	1400°F 1600°F	1300°F 1500°F
E	Chromel and Constantan	Bare Protected	1400°F 1600°F	1100°F 1200°F	1100°F 1200°F	900°F 1000°F	700°F 800°F	700°F 800°F

NOMINAL PHYSICAL PROPERTIES OF ELEMENT

	Thermoelement Material									
	Positive (+) Conductors							**Negative (-) Conductors**		
Property	**J**	**T**	**K,E**	**N+**	**R**	**S**	**J,T,E**	**K**	**R,S**	**N-**
Melting Point (°C)	1535	1083	1430	1410	1870	1850	1210	1400	1773	1400
Electrical Resistivity Ohms/CMF @ 20°C	60.14	10.37	425	.560			294	177	63.80	.220
Thermal Conductivity Watts/cm/°C @ 100°C	.662	3.88	.192	.031			.212	.297	.695	.055
Specific Heat Cal./GM/°C @ 20°C	.1065	.0921	.107	.011			.094	.125	.0324	.012
Density-lb/In^3	.2840	.3233	.3154				.322	.3107	.7750	
Tensile Strength Annealed-PSI	50,000	35,000	95,000	110,00			60,000	85,000		95,000
Magnetic Strength @ 20°C	Strong	None	None	None	None	None	None	None	Strong	None
Specific Gravity	7.86	8.92	8.73	.852			8.9	8.60	21.45	.870

TABLE 1. Characteristics Compositions of Thermoelement Alloys.

	CHEMICAL composition (weight %)									
Alloy	Cr	Si	Mg	Mn	Al	Fe	Co	C	Cu	Ni
nicrosil	14.2	1.4	-	-	-	0.1	-	.03	-	bal.
nisil	-	4.4	0.1	-	-	0.1	-	-	-	bal.
type (or EP)	9.3	0.5	-	0.5	-	0.5	0.5	-	-	bal.
type KN	-	1.1	-	2.8	1.9	0.5	0.5	-	0.5	bal.
type JP	-	-	-	.25	-	bal.	-	-	.12	-
type JN	-	-	-	.75	-	0.3	0.3	-	bal.	44.5
type TP	-	-	-	-	-	-	-	-	99.95	-
type TN (or EN)	-	-	-	0.1	-	0.1	-	-	bal.	45