



# Thermocouple Cables Write-up

This is a comprehensive write-up prepared for customer information which covers the following topics

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## Introduction

One of the biggest problems in the nascent days of the cable manufacturing sector was availability of quality specialized cables. Indian suppliers of such cables were scarce and could not supply the desired quality. Alternatively, importing these cables was possible but they were too expensive with high delivery periods. In order to solve this problem Udey Pyrocables was founded back in 1976. We pioneered the manufacturing of Thermocouple Extension Cables, Instrumentation Signal cable & Pneumatic Multi-tube bundle in India.

Even today we follow the same ideology and try to bridge the gap by **supplying excellent quality, affordable prices and reasonable delivery schedules of scarcely available products domestically**. Some of the newer products that we're supplying with this objective are VFD cables, Bus cables, Solar Cables, VDE standard control cable & Polyurethane Cables.

We **specialize in providing tailor made service** for each of our client's requirements and would love to work in association with you to develop better experience with regards to the cable design, cable quality & purchasing experience.

Udey Pyrocables manufactures a wide range of cables on the latest modernized machines to produce quality cables. We have an in-house testing laboratory which meets the requirements of International Standards and can conduct Physical, Routine, Acceptance, Type Tests, FRLS, Halogen free tests etc. all the Instruments are **NABL calibrated**. **Our Plant is located at Lonavala with a total area of 10 acres (100 KMs from Mumbai and 60 KMs from Pune in Maharashtra).**

Our company is **ISO 9001:2015 registered, ISI & CE certified** having approvals with eminent consultants & contractors. Safety and quality are of prime importance to us and in order to ensure the same testing is conducted at every stage of production so that every cable leaving our plant is perfect. We have worked with and delivered outstanding service and products to some of the biggest companies in India & beyond (exporting to 15 countries including the US, Japan, Singapore, Egypt, Middle East etc)

We have complete professional Management with an experienced team of engineers, we take care from our offer to the order placement where cable is designed as per your site requirements and conditions, job cards are made and QA Plan is submitted to you where eve stage our QC department ensures complete checks on every process to full stage of readiness, to shipment.



# Thermocouple Cables Write-up

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## Product Range

### Power & Control Cables

Standard: IS 7098 & IS 1554  
Conductor: Al., Cu., ATC  
Size: 1.5 - 400 sq.mm.  
XLPE/ PVC insulated  
Armoured/ Unarmoured  
Extruded/ Taped  
Range - Upto 1.1 kV & 1.9/ 3.3 kV

### Flexibles & Housing wiring

Standard: IS 694  
Conductor: Cu., ATC  
Size: 0.5 - 400 sq.mm.  
PVC/ ZHLS/ FRLS

### Instrumentation, Signal & RTD cable

Standard: BS 5308, BS EN 50288-7, IEC 189, EIL 6-52-46, EIL 6-52-51, IEC 60092-375, 376, BS EN 50288 PART-7, VDE 0815, VG 95218, NEK 606  
Conductor: Cu., ATC  
Size: 0.5 - 2.5 sq.mm.  
Shielding: Al-Mylar + drain/ ATC braid  
Individual-Overall/ Overall  
Armoured/ Unarmoured  
PVC/ FR/ FRLS/ ZHLS/ Silicon Rubber/ PTFE/ Fiberglass/ Kapton

### Thermocouple Cable

Standards: ANSI 96.1, IEC 584-3, BS 1843, IS 8784, DIN 43714, EIL 6-52-46  
Conductor: J, K, E, T, R, S, B, N  
Size: 0.5 - 2.5 sq.mm.  
Shielding: Al-Mylar + drain/ ATC braid  
Individual-Overall/ Overall  
Armoured/ Unarmoured  
PVC/ FR/ FRLS/ ZHLS/ Silicon Rubber/ PTFE/ Fiberglass/ Kapton

### Fire Resistant Cable (FS Cable)

Standards: BS 7846  
Conductor: ATC, ABC  
Size: 1.5 - 400 sq.mm.  
Fire Barrier Tape: Mica Glass Tape  
Armoured/ Unarmoured  
XLPE/ Silicon - ZHLS

### Communication Cables

Profibus Cable  
Profinet Cable  
Foundation Fieldbus Cable



# Thermocouple Cables Write-up

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	Modbus Cable DeviceNet Cable Can Bus Cable Optical Fiber Cable Cat 5e, 6 & 7
<b>Control Cables As per VDE</b>	VDE 0207 LiYY LiYCY LiYCY PUR LiYCY-TP Li2YCY Pimf YY Cable CY Shielded Control cable SY Cable
<b>VFD Cable</b>	Conductor: Cu., ATC, Al. Size: 1.5 - 400 sq.mm. Ground Conductors - 1 or 3 Insulation: XLPE/ PVC Shielding: Al foil + ATC braid/ Copper Tape Individual-Overall/ Overall PVC/ FRLS/ ZHLS
<b>Uninyvin Cable</b>	Conductor: ATC HR PVC, Glass Fiber, Nylon Fiber, Nylon Lacquer
<b>Heat resistant Cable</b>	Based on the peak temperature and operating temperature these cables are designed. Material options - Silicon Rubber/ PTFE/ PFA/ FEP/ PEEK/ Kapton/ Fiber Glass etc
<b>Solar Cables</b>	Standards: 2pfg 1169 Conductor: ATC Size: 2.5 - 400 sq.mm.
<b>Robotic Cables</b>	Conductor: Class 5 or Class 6 ABC Insulation: PE, TPE, EPR Sheathing: PU Shielding: ATC braid (Optional)



# Thermocouple Cables Write-up

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## Introduction to Thermocouple Cables

### The Principle

The principle on which the modern Thermocouple operates is derived from Seebeck's discovery. The discovery being, if a circuit is formed using two dissimilar metal conductors with one junction at a temperature higher than the other, a current will flow in the circuit. The EMF is proportional to the temperature difference between the junctions.

### What is a thermocouple cable ?

Thermocouple cable is a cable that is connected between a thermocouple Sensor and a thermometer for measuring the temperature.

Thermocouple: A thermocouple is two dissimilar thermo elements so joined as to produce a thermal EMF when the measuring and reference junctions are at a different temperature.

- \* Measuring Junction: The measuring junction is that junction of a thermocouple which is subjected to the temperature or which is automatically compensated for its temperature.
- \* Reference junction: The reference junction is that junction of a thermocouple which is at a known temperature.

### What is the difference between Extension & Compensating cable ?

Cable manufactured using the original materials are known as the thermocouple extension cable.

Whereas the cable manufactured using alloying which give similar readings as the thermocouple original material is known as Compensating cable

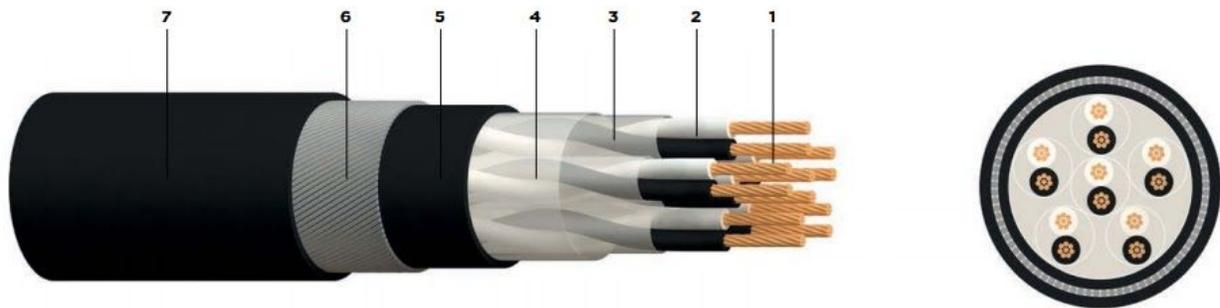
Wire used to pass the signal from the sensor to the reading instrument is known as the extension grade wire

# Thermocouple Cables Write-up

## Cable Construction

### Pair Cable (Individual & Overall Shielded)

- |                  |                |                          |                       |
|------------------|----------------|--------------------------|-----------------------|
| 1 - Conductor    | 2 - Insulation | 3 - Individual Shielding | 4 - Overall Shielding |
| 5 - Inner Sheath | 6 - Armour     | 7 - Outer Sheath         |                       |



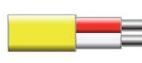
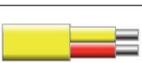
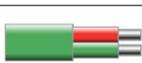
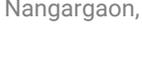
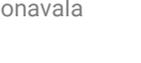
\* Please note the color code is just for representation. Color code is dependent on the applicable standard and type of Thermocouple conductor.



# Thermocouple Cables Write-up

## Applicable standard

IS 8784 IS 2056 IS 2957 IS 2054 IS 2055	Indian Standard Institute For Thermocouple / Compensating cable For Copper / Constantan For Iron / Constantan For Chromel / Alumel Platinum / Platinum Rhodium
ASTM E 230	American Society for Testing & Material
ANSI MC 96.1	American National Standard Institute
IEC 584-1/2/3	International ElectroTechnical Commision
DIN - EN 60584-1/2	Deutsche Industrie Normen
BS - 4938-1041	British Standard
JIS-C-1602/1610	Japanese Industrial Standard

Thermocouple Extension Type		 ANSI	 BS	 DIN	 NFC	 JIS	 IEC
JX	Iron +						
	Constantan® -						
KX	Chromel® +						
	Alumel® -						
TX	Copper +						
	Constantan® -						
EX	Chromel® +						
	Constantan® -						
NX	Nicrosil® +						
	Nisil® -						
SX	Copper +						
	Alloy II -						



# Thermocouple Cables Write-up

## Electrical Properties

	0.5 Sq.mm.		0.75 Sq.mm.		1.0 Sq.mm.		1.5 Sq.mm.		2.5 Sq.mm.	
	Bare	Tinned	Bare	Tinned	Bare	Tinned	Bare	Tinned	Bare	Tinned
<b>Insulation Resistance</b>										
XLPE (MΩ/km)	1000									
PVC (MΩ/km)	5									
<b>Capacitance</b>	<b>Core to Core @ 1000 Hz</b>									
XLPE (nF/km)	< 150									
PVC (nF/km)	< 250									
<b>Capacitance</b>	<b>Core to Screen @ 1000 Hz</b>									
XLPE (nF/km)	< 400									
PVC (nF/km)	< 400									
<b>Test Voltage</b>										
Core to Core (kV)	2000 V AC for 1 min.									
Core to Screen (kV)	1000 V AC for 1 min.									
Rated Voltage (V)	300/500									

\* Please note electrical parameters mentioned above are for class 2 conductor

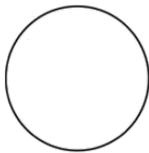
# Thermocouple Cables Write-up

## Conductor

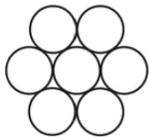
### Conductor Material

Conductors are generally solid, stranded or flexible in compliance with ANSI MC 96.1 and as shown in the Table

### Conductor Design



- Solid (Class 1)



- Stranded (Class 2)



- Multi-stranded/ Flexible (Class 5)

### Conductor Construction Details

Nominal Size (In sq.mm.)	Solid (Class 1) (No of strands x size of each strand)	Stranded (Class 2) (No of strands x size of each strand)	Flexible (Class 5) (No of strands x size of each strand)
0.5 (20 AWG)	1 x 0.8 mm	7 x 0.3 mm	16 x 0.2 mm
0.8 (18 AWG)	1 x 1.02 mm	7 x 0.38 mm	24 x 0.2 mm
1.0	1 x 1.13 mm	7 x 0.73 mm	32 x 0.2 mm
1.3 (16 AWG)	1 x 1.29 mm	7 x 0.49 mm	19 x 0.3 mm
1.5	1 x 1.37 mm	7 x 0.53 mm	30 x 0.25 mm



# Thermocouple Cables Write-up

## Loop Resistance of Thermocouple Conductor (Solid conductor)

Type of Thermocouple	KX (Ω/ kM)	KXA (Ω/ kM)	TX (Ω/ kM)	JX (Ω/ kM)	EX (Ω/ kM)	SX/ RX (Ω/ kM)
0.5 (20 AWG)	1910	980	980	1214	2312	280
0.8 (18 AWG)	1212	624	624	778	1470	175
1.3 (16 AWG)	746	385	385	475	905	110

## Types of Thermocouple Conductor

Thermocouple Type	+ve Conductor	-ve Conductor	Temperature Range	Limits of Error
K - extension	Chromel	Alumel	0 - 1100°C	+/- 2.2°C
K - compensating	Copper	Constantan	0 - 1100°C	+/- 2.2°C
T - Extension	Copper	Constantan	-185 - 300°C	+/- 1.0°C
J - Extension	Iron	Constantan	20 - 700°C	+/- 2.2°C
E - Extension	Chromel	Constantan	0 - 800°C	+/- 1.7°C
R/S Compensating	Copper	Constantan	0 - 1500°C	+/- 5.0°C
B Compensating	Copper	Constantan	0 - 1500°C	--



# Thermocouple Cables Write-up

## Insulation

### Insulation Material

The insulation of cable conductors normally consists of polyethylene, cross-linked polyethylene, cross linked HFFR/ZHFR, HFFR/ZHFR, PVC (polyvinyl chloride). Special materials, for example high temperature resistance Elastomer, fluoropolymers or non-halogenic flame retardant materials, may be used for special application.

### Insulation Material Selection Criteria

The choice of insulating material is primarily determined by the following requirements:

- \* Electrical transmission properties
- \* Minimum and/or maximum operating temperatures
- \* Flammability properties
- \* Resistance to radiation
- \* Resistance to oil and chemicals

### Properties of generally used insulating materials

Properties	PVC	XLPE
Electrical Properties		
Dielectric Constant	4-7	2.3
Specific Volume Resistivity @ 20°C	10 <sup>14</sup> Ω.cm	10 <sup>15</sup> - 10 <sup>16</sup> Ω.cm
Specific Volume Resistivity @ 70°C	10 <sup>10</sup> - 10 <sup>11</sup> Ω.cm	10 <sup>12</sup> Ω.cm
Thermal Properties		
Max Operating Temperature	70°C	90°C
Low Temperature Properties	Tends to come brittle	Good

## Cabling Elements & Laying

### Cabling Element

Thermocouple cables come in pairs. e.g 1 Pair, 2 Pair or 12 Pair etc

For twisting insulated wires to form a pair the preferred lay length is between 80-100mm for conductor size upto 1.5 sq.mm. and 150 for conductor size 2.5 sq.mm.

The cable assembly consists of all the cabling elements in cable, including the wrapping over the cabling elements.

To keep the interference of cabling elements (pairs) negligible, the length of twist of adjacent elements must be different. This provides for a more complicated standing technique during manufacture. When using individually screened pairs, it is not necessary to vary the length of twist between those cabling elements.

The cable elements are twisted in concentric layers. In the case of multilayer cables the direction of lay changes from a layer to layer. This last measure also contributes to mutual decoupling in the case of unscreened pair, triple or quad elements.





# Thermocouple Cables Write-up

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## Screening

Screening is provided to reduce or prevent the possible external interference in cables such as

- \* Cross-talk from adjacent line circuits in the cable itself
- \* Externally induced interference from sources outside the cable e.g. electrical equipment, machine or plants running on HF energy

### Screening against internal interference

Only the capacitance unbalance between the cabling elements is of significance to internal interference. The magnetic interference can be injected.

Internal interference can be reduced by:

- \* different lay lengths for the cable elements (Done in case of CAT 6 cables)
- \* providing individual screening of cable elements

Individual screening normally consists of a helically lapped plastic – laminated aluminium foil which, together with a drain wire, endures a continuous electrical connection. The foil is applied with a 25% overlap so as to guarantee a 100% covering to the cable element in bends. Braids or layers of lapped copper wires may also be used, though for cost reasons they are less popular.

### Screening against external interference

Looking at the external interference the influence of magnetic interference can no longer be neglected; one must differentiate between LF and HF electric and magnetic fields and choose a suitable screening solution. The material and design of a screen has to be adapted to the kind of interference.

\* Screening against electrical interference - Material with good electrical conductivity has to be used as screening against electric interference. The degree of screening which can be achieved depends on the frequency, especially when using braids. Copper braids or lapped plastic-coated aluminium or copper tapes can be provided as an alternative in the LF range. **Longitudinally welded copper tapes are a suitable screening in the HF range.**

\* Screening against magnetic interference - Iron tapes are recommended as screening against magnetic interference, though if particularly high screening levels are required, highly-permeable materials such as tapes of Mu-Metal or amorphous metals should be used.

\* Screening in the LF range - At frequencies of up to 10 KHz, the influences of both electrical and magnetic interference can be regarded separately. Interference from electric fields can be almost completely avoided by the use of conductive screens; however, care must be taken to ensure a high degree of coverage since otherwise the electric field may affect the cable assembly. Screening against LF magnetic interference requires those measures specified above; since conductive screens may be penetrated by magnetic interference and are thus useless, An eddy current, which weakens the magnetic interference only sets in with these screenings at frequencies above 10 KHz.



# Thermocouple Cables Write-up

\* Screening in the HF range - Screening in the HF range is based on losses (i.e withdrawal of energy) in the electromagnetic interference by absorption and reflection in or on the screening material. Thus the magnetic field component is weakened by absorption (opposing field by eddy currents) whereas the electric field component is attenuated by reflection.

## Types of Screening assembly

- \* Individual & Overall Screening
- \* Overall Screening
- \* Unscreened

## Types of Screening materials

	Aluminium / Mylar tape with tinned copper drain wire
	Copper tape with tinned copper drain wire (Optional)
	Bare Copper braid for EMI shielding
	Tinned Copper braid for EMI shielding in corrosive atmosphere

# Thermocouple Cables Write-up

## Armouring

The primary purpose of armour is to protect the cable against mechanical damage during installation and operation. **Apart from this mechanical protection, armour can also fulfill various electrical functions, eg. earth conductor, screen or inductive protection.**

### Armouring Selection Criteria

Unless otherwise specified in different specifications, the mechanical and electrical requirements for installation and operation determine the design of the armour. The following are of prime importance :

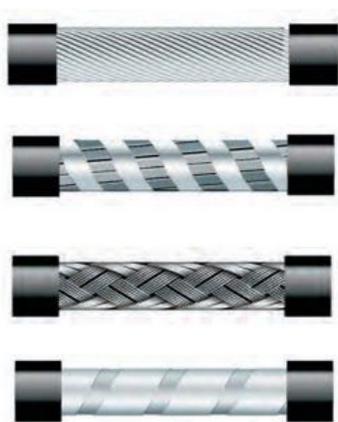
Mechanical requirements:

- \* Max. expected tensile loads
- \* Max. expected pressure and impact loads after laying
- \* Protection against rodents
- \* Type of connections
- \* Min. required bending radius

Electrical requirements :

- \* Minimum cross-section if used as earth conductor
- \* Size of reduction factor depending on the induced EMF

### Types of Armour



Aluminium / Mylar tape with tinned copper drain wire

Copper tape with tinned copper drain wire (Optional)

Bare Copper braid for EMI shielding

Tinned Copper braid for EMI shielding in corrosive atmosphere



# Thermocouple Cables Write-up

## Sheathing

The bedding and overall sheaths of instrument cables are most commonly made of polyvinyl- chloride (PVC) and sometimes polyethylene (PE). HFFR Non-halogenic (zero halogen), flame retardant materials, high temperature resistant fluoropolymers or polyamides are much used in special applications.

## Bedding

Bedding must be provided if supplementary elements such as armour are applied. In such cases they mainly serve to protect the cable assembly against humidity and mechanical loads. Commonly PVC , FR PVC , FRLS PVC, and HFFR are used.

## Outer Sheathing Selection Criteria

Outer sheathing is provided over the armouring in case of Armoured cables or above laid up cable in case of unarmoured cable. Transportation, storage, installation and operation determine the choice of material and specification. The following must be considered while selecting the appropriate material

- \* Type of installation, ie. indoor, outdoor installation, on ramps, in earth or water.
- \* Type and extent of mechanical loads during and after installation
- \* Possible environmental influences of : humidity, oil, chemicals & solar radiation etc
- \* Max. and min. temperatures during installation and operation
- \* Desired Fire properties

## Temperature Rating of High Temperature Materials

Material	Peak Temperature
Silicon Rubber	150°C
FEP	200°C
PFA	260°C
PTFE	260°C
PEEK	300°C
Fiberglass	300°C
Kapton	400°C
Silicon Fiber	1000°C
Ceramic Fiber	1200°C



# Thermocouple Cables Write-up

## Fire Performance in Cables

Test	Specification	General PVC	FRLS PVC	LSZH
Oxygen Index	ASTM D 2683	> 23%	> 29%	> 31%
Temperature Index	ASTM D 2683	120°C	250°C	300°C
Smoke Density	ASTM D 2643/77	<80%	<60%	<40%
Acid Generation	IEC 754-1	<26%	<20%	<2%
Flammability Test	IEEE 383	Complete length of 850mm is burnt	Un-Burnt portion greater than 300mm	Un-Burnt portion greater than 300mm

# Thermocouple Cables Write-up

## Different Thermocouple Cable Constructions

Configuration	Sample Image
Tx - PVC - PVC	
Tx - PVC - ATC Braid - PVC	
Tx - Silicon - Silicon	
Tx - Silicon - Silicon - SS wire braid	
Tx - Silicon - Fiber Glass	
Tx - Silicon - ATC Braid - Silicon	
Tx - Fiber Glass - Fiber Glass	
Tx - Fiber Glass - Fiber Glass - SS wire braid	
Tx - FEP - FEP	
Tx - PFA - PFA	

\* Tx - Any thermocouple conductor