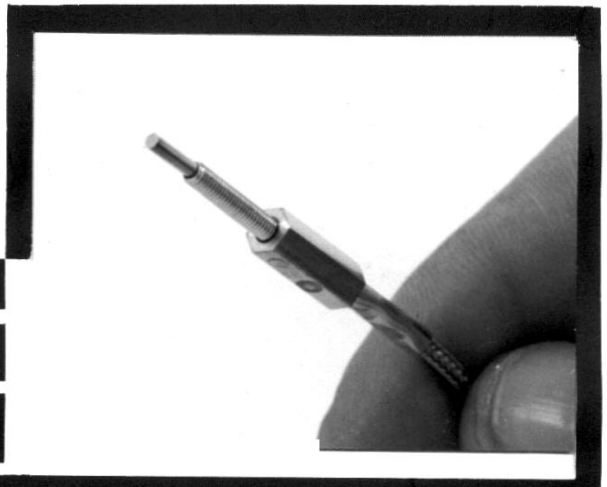
Bulletin 500
10/00

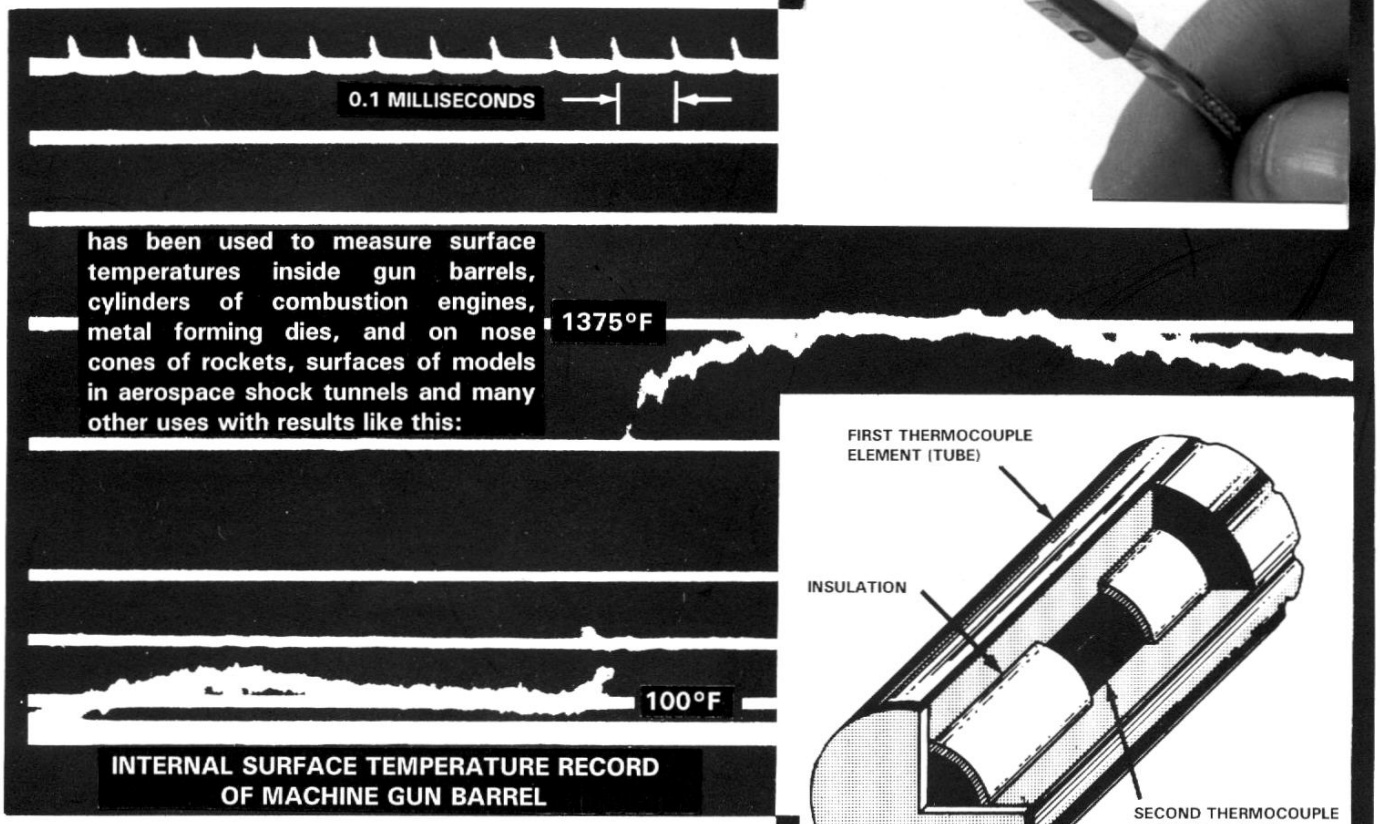
MEASURE SURFACE TEMPERATURE

WITH A RESPONSE TIME AS LITTLE AS

1 MICROSECOND

A small MEDTHERM Coaxial surface temperature probe like this:





has been used to measure surface temperatures inside gun barrels, cylinders of combustion engines, metal forming dies, and on nose cones of rockets, surfaces of models in aerospace shock tunnels and many other uses with results like this:

INTERNAL SURFACE TEMPERATURE RECORD OF MACHINE GUN BARREL

One thermocouple element (a tube) is swaged over the second element (a wire) with 0.0005" thick insulation between the elements. The thermocouple junction is formed by a vacuum deposited metallic plating across the sensing end of the assembly. (Artist's rendering shows thickness of insulation and metallic plating exaggerated in size.)

because of this unique construction:

MEDTHERM
CORPORATION
POST OFFICE BOX 412 / HUNTSVILLE, ALABAMA 35804

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CORPORATION

COAXIAL SURFACE THERMOCOUPLE PROBES

FEATURES

- MICROSECOND RESPONSE TO METAL WALL SURFACE TEMPERATURE CHANGES
- ALLOWS VERY SHORT DURATION TESTING
- AVAILABLE PROBE DIAMETERS FROM .015 INCH
- PRECISE LOCATION OF THERMOCOUPLE
- RUGGED RENEWABLE JUNCTIONS
- WITHSTAND HIGH PRESSURE AND HEAT FLUX

APPLICATIONS

- WIND TUNNEL MODEL SURFACE TEMPERATURE AND HEAT FLUX MEASUREMENT
- INSIDE SURFACE TEMPERATURES OF: ENGINE CYLINDERS · AIR COMPRESSORS · GUN BARRELS · BEARINGS · DIE CASTING DIES
- BLAST EFFECTS ON STRUCTURES
- LASER TARGET SURFACE TEMPERATURES

HISTORY

MEDTHERM Corporation has manufactured thousands of coaxial thermocouples since 1970 which have been successfully used for microsecond response time surface temperature measurements of metal walls in the above applications and many others. The coaxial metal wall surface thermocouple was first documented in 1941 by P. Hackemann in Germany. Further development was carried out and documented by D. Bendersky at the Midwest Research Institute (MRI, 1953) and C.E. Moeller at MRI (1954 to 1966). The coaxial thermocouples were manufactured commercially to the Moeller design by the Motech Co. and Mo-Re Inc. from 1954 to 1966. Production and development was continued by Heat Technology Laboratory from 1966 to 1970 and by MEDTHERM from 1970 forward to today.

DESCRIPTION

MEDTHERM Co-Ax thermocouple probes are coaxial thermocouples consisting of a small wire of one thermocouple material coated with a .0005" thickness of a special ceramic insulation of high dielectric strength swaged securely in a tube of a second thermocouple material. The insulation resistance between the wire and the tube is effective to more than 1500°C at steady state (over 1700°C for transient temperatures). The thermocouple junction is formed by vacuum depositing a metallic coating of one to two microns thickness over the sensing end of the probe, forming a metallurgical bond. A variety of mounting configurations and transition pieces for lead wire connections may be installed on the coaxial probe assembly.

FAST RESPONSE METAL WALL SURFACE TEMPERATURE MEASUREMENTS

MEDTHERM Co-Ax surface thermocouple probes offer microsecond response times in the measurement of rapidly varying metal wall surface temperatures such as encountered inside combustion chambers, gun barrels, bearings, die casting dies, and apparatus for heat transfer studies. The through-the-wall mounting technique for the Co-Ax thermocouples lends itself to measurement of wall surface temperatures where it is important not to disturb the surface geometry, such as rocket nose cones, cannon projectiles, or wind tunnel models. The wall temperatures measured in this way are often used to compute pulses of heat flux absorbed by the surface, such as aerospace models installed in shock tunnels. The probes may also be used for measurement of internal wall temperatures where the location of the sensing element must be precisely known, such as in conduction heat transfer studies.

The Co-Ax surface thermocouple is ideal for the applications described above because the thermal junction is formed within a one or two micron thickness at the end of the probe, thus allowing positioning of the junction within one or two microns. The probe can be installed through an accurately drilled hole in the test surface such that the junction forms a continuous part of the test surface, or it can be installed in a "blind" hole in the test wall to measure internal temperature at a precisely known location.

FAST RESPONSE SURFACE HEAT FLUX MEASUREMENTS

Surface heat flux is computed from the continuous or time sampled measurement of the true metal wall surface temperature versus time using computation methods reported by a number of authors since the 1950's, several of which are described by Beck, Blackwell, and St. Clair in Inverse Heat Conduction, Wiley Interscience, New York, 1985. The fast response capability, along with the subminiature probe diameters, allow the measurement of heat transfer rates at many points on a very small metal model in just a few milliseconds of test time. This approach can make substantial cost savings in hypersonic tunnel heat transfer research programs.

AVAILABLE MOUNTING CONFIGURATIONS AND MATERIALS

Since each coaxial thermocouple should be suited in configuration and in material properties to its application, a wide variety of configurations is offered. You may specify mounting configuration by "designing your own" thermocouple probe as described on the facing page. You may specify one of the standard configurations on the back page of this brochure, select from the hundreds of standard configurations available in the MEDTHERM catalog and other publications, or you may send a sketch of your desired configuration to the factory for prompt quotation. The most common of the available thermocouple materials are listed below.

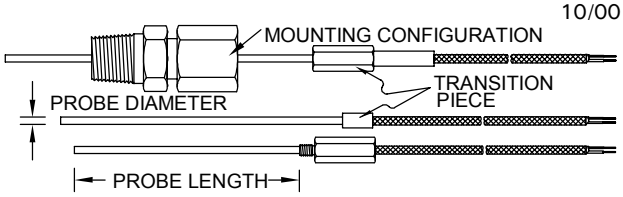
COAXIAL THERMOCOUPLE ELEMENT DESCRIPTIONS

ISA Calibration Code	Outer Tube	Center Wire	Recommended Temperature Range
T	Copper	Constantan	- 270 to + 400°C(1000°C†)
J	Iron	Constantan	- 210 to + 1200°C
E	Chromel P*	Constantan	- 270 to + 1000°C
K	Chromel P*	Alumel*	- 270 to + 1372°C
S	Platinum - 10% Rhodium	Platinum	+ 200 to + 1700°C (1768°C†)

*Hoskins Mfg. Co.

†Short duration.

DESIGN YOUR OWN MEDTHERM CO-AX METAL WALL SURFACE TEMPERATURE PROBE



1

SELECT PROBE DIAMETER, PROBE MATERIAL (ISA CALIBRATION), AND PROBE LENGTH. Start all surface temperature probe model numbers with TCS, then add the code for probe diameter, and the ISA Calibration symbol, and add the probe length in inches (tolerance on probe length is ±.010"). If a .061 diameter "K" (chromel/alumel) probe, 1.00" long is desired, start the model designation as TCS-061-K-1.00

*Price for additional length is determined by the length to the nearest 1/2".

ISA Calibration	LENGTH Inches	Basic price for 0-1" probe length	Price for each Additional inch
.015" ± .001" Probe Dia. (Code 015)			
E	0-6		
K	0-6		
S	0-6		
.031" ± .001" Probe Dia. (Code 031)			
T	0-6		
J	0-6		
E	0-6		
K	0-6		
S	0-6		
.061" ± .001" Probe Dia. (Code 061)			
T	0-6		
J	0-6		
E	0-6		
K	0-6		

ISA Calibration	LENGTH Inches	Basic price for 0-1" probe length	Price for each Additional inch
.099" ± .001" Probe Dia. (Code 099)			
T	0-6		
J	0-6		
E	0-6		
K	0-6		
#3-56 Thread Full Length of Probe (Code 099T)			
T	0-1		
J	0-1		
E	0-1		
K	0-1		

2

SELECT JUNCTION PLATING MATERIAL. Recommended platings are shown in table at extreme right. Add the plating code to the model number. If chromium plating is desired, add - CR to the model number; TCS-061-K-1.00-CR.

Available Plating Materials

Material	Order Code	Price
None	0	
Chromium	CR	
Nickel	NI	
Platinum	PT	
Copper	CU	

Recommended Plating Materials

ISA Calibration Code	Plating Material
T	CR
J	CR
E	CR
K	CR
S	PT

3

SELECT LEAD WIRE INSULATION AND LENGTH OF LEADS. Add the insulation code to the model number. All lead wires are 28 or 30 AWG (factory selects the largest lead possible with each probe). Standard lead wire length is one foot and is included in the basic price of the probe. If more than one foot lead length is desired, add the number of whole feet to the insulation code. If fiberglass primary and fiberglass secondary insulation, metallic braided shielding and two feet of lead wire are desired, add GGS2 to the model number; TCS-061-K-1.00-CR-GGS2.
(Teflon usable to 220ºC, Fiberglass usable to 500ºC, one time to 700ºC.)

Primary	Secondary	Order Code	Price for each foot over the one ft. std.
Fiberglass	Fiberglass	GG	
Teflon	Fiberglass	TG	
*Fiberglass	Fiberglass	GGS	
*Teflon	Fiberglass	TGS	

*Metallic braided shielding overall.

4

SELECT TRANSITION PIECE. Add the transition piece code to the model number. Example: If a 1/4" hex filled with ceramic and a strain relief tube are desired, add B2CSR to model number; TCS-061-K-1.00-CR-GGS2-B2CSR.

Description		Code	Price
Cylindrical Transition, Stainless Steel, Epoxy filled (175ºC)	.187" dia. x 3/4" lg	A1	
	.125" dia. x 1/4" lg	A2	
	.093" dia. x 1/4" lg	A3	
Hex Transition, Stainless Steel, Epoxy filled(175ºC)	3/16"Hex x 1/2" lg.	B1	
	1/4"Hex x 1/2" lg.	B2	
	3/8"Hex x 3/4" lg.	B3	
	1/4"Hex x 3/8" lg.	B4	

Optional Features

Description	Add to Code	Add to Price
Ceramic Filled, (With fiberglass wire only, useful to 700ºC,see wire temp. limits)	C	
Strain Relief Tube (Available on "B" hex transitions only)	SR	

5

SELECT MOUNTING CONFIGURATION. Add code to model number (if mounting provisions not required, use order code "0"). If a variable immersion type with 1/8" NPT mountingthread is desired, add - BB to model number; TCS-061-K-1.00-CR-GGS2-B2CSR-BB.

Threaded Section on Front of Transition Piece. (Use with B1, B2, B3, or B4 Hex Transition only)

Hex Size	Thread	Thread Length	Code	Price
3/16"	#3-56UNF	1/8"	AA	
1/4"	#3-56UNF	1/2"	AB	
3/8"	1/4-28UNF	1"	AC	
1/4"	#8-32UNC	1/4"	AD	

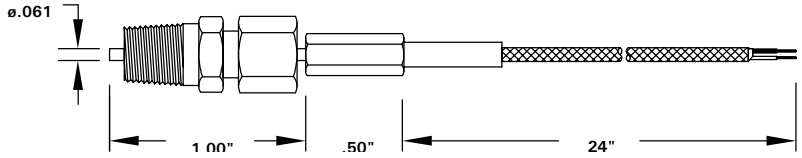
SST Variable Immersion Fitting with Lava Gland * (1/8-NPT to 7500 psi and 1/16-NPT to 5000 psi.)

Probe Code	NPT	Hex	Max. Length	Code	Price
015 or 031	1/16"	11/32"	0.90"	BAA	
061	1/16"	11/32"	0.90"	BA	
015 or 031	1/8"	1/2"	1.25"	BBA	
061	1/8"	1/2"	1.25"	BB	
099	1/8"	1/2"	1.25"	BC	

* To specify Teflon gland (220ºC max), add "T" to Code.

EXAMPLE

Suppose that a chromel-alumel probe with chromium plating is desired; the probe diameter is to be .061", the probe length is to be 1.00", the lead wire is to have fiberglass on each wire and fiberglass overall with a metallic braid shielding, a 1/4" hexagonal transition piece will house the junction of the lead wire to the probe, with ceramic potting, strain relief tube, and a 1/16" NPT variable immersion type fitting is to be installed on the probe (same as example used in steps 1 through 5, above).
The probe and its Model Number designation are shown below:



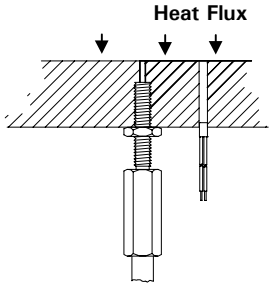
Model Code	1 Probe Diameter Code	1 ISA Calibration Code	1 Probe Length Code	2 JunctionPlating Material Code	3 Insulation Code	3 Lead Length Code	4 Transition Piece Code	4 Ceramic Code	4 Strain Relief Code	5 Mounting Configuration Code
TCS	061	K	1.00	CR	GGS	2	B2	C	SR	BA

Model TCS-061-K-1.00-CR-GGS2-B2CSR-BA:

SURFACE TEMPERATURE AND HEAT FLUX APPLICATIONS

In order to obtain the most accurate measurements of rapidly changing surface temperatures, it is necessary that the presence of the sensor have negligible effect on the temperature of the surface of interest. To meet such a condition when the surface is exposed to convective heating or cooling, it is also necessary that the probe not disturb the surface continuity so that the convective heat transfer rate will not be altered. These conditions are met with the Co-Ax probe when installed in a wall so that the thermocouple junction is flush with the wall surface. When so installed, the sensor will accurately indicate the surface temperature of the probe itself. In order for the probe surface temperature to be at nearly the undisturbed wall surface temperature, the probe material should be selected to have values of the thermal diffusivity, α, and the thermal conductivity, k, that match the corresponding wall material value of $\sqrt{k\rho c}$ (or $k/\sqrt{\alpha}$) as nearly as possible, and the probe diameter should be small compared to wall thickness. Approximate values at 212 °F are:

Material	k Btu/ft hr °F	α ft²/hr	$\sqrt{k\rho c}$ Btu/ft² $\sqrt{sec}$ °F
Copper	219	4.3	1.76
Aluminum	119	3.3	1.09
Platinum	42	0.98	0.69
Iron	33	0.63	0.69
Carbon Steel (C1020)	27	0.53	0.62
Alumel	17	0.26	0.56
Type 410 Stainless Steel	14	0.27	0.45
Constantan	13	0.23	0.45
Chromel P	11	0.19	0.42
Type 302 Stainless Steel	9.4	0.16	0.39



Two Typical Model TCS Coaxial Probes Mounted Flush in a Metal Wall Surface

Probes installed as shown above may also be used to measure surface temperature in sliding contact areas such as bearing faces. In many such abrading applications, the thermal junction at the end of the probe continuously re-establishes itself due to the action of the facing surface in forming new "slivered" junctions of the thermocouple material across the small insulation gap. This sliver junction technique is often used to establish junctions on contoured model installations and to renew those junctions when necessary, while the probes are in place in the test article. Complete instructions for completing these junctions are available from the factory. The advantages of the probe when installed as shown are:

TIME CONSTANT: The small thickness and mass of the thermocouple junction allows a nominal time constant of 1 microsecond for the vapor deposited junction. The time constant is the theoretical time to reach 63.2% of a step change in surface temperature for a 2 micron thick junction. The observed time constant for sliver junctions is usually less than 10 microseconds.

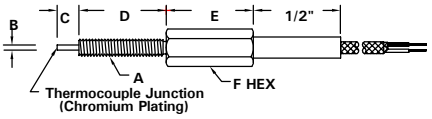
ACCURACY: ISA Standard Limits of Error materials are used. Conduction losses are similar to the undisturbed wall because the thermocouple materials become part of the wall.

NO SURFACE PROTUBERANCE: Convective flow over the surface is undisturbed.

FOUR TYPICAL STANDARD MODELS

Over the years, four standard configurations have been found to cover a wide variety of applications. The dimensions are shown below:

Model No.	Mounting Thread A	Probe Diameter B	Probe Length C	Thread Length D	Transition Length E	Transition Hex F	Total Length
TCS-101	#2-56UNC	0.061	0.062	0.12	0.25	1/4 HEX	0.44
TCS-102	#3-56UNF	0.031	0.125	0.50	0.50	3/16 HEX	1.12
TCS-103	1/4-28UNF	0.061	0.250	1.50	0.75	3/8 HEX	2.5
TCS-104	#4-48UNF	0.031	1.00	0.50	0.50	1/4 HEX	2.0



Lead wires are 30 gauge, 12 inches long with fiberglass insulation with wire overbraid. Other configurations are available.

ORDERING INFORMATION

Order "design your own" probes from the inside page and the above standard models by the number as shown above. To designate the thermoelectric materials, add the ISA material designation code as - "M" at the end of the model number. For example, a model TCS-103 probe with a constantan inner thermoelement and iron outer thermoelement is designated model TCS-103-J, a model often used in die casting dies. The platinum 10% rhodium vs. platinum is not available in 0.061 diameter.

SPECIAL CO-AX SURFACE THERMOCOUPLE PROBES

The Co-Ax surface probes can be routinely customized in many ways. In addition to the shapes presented here, many units are available to install from the outside surface of a model. The sensitive end of the probe may be shaped at installation to fit the contour of virtually any metal surface. Special mounting provisions, probe sizes, and high temperature MgO insulated sheathed lead wire is available. Thermocouples can be provided to fit existing mounting holes for quartz crystal pressure transducers and spark plugs. Models with back side thermocouples are available for steady state heat flux measurements. Special materials may be used with appropriate calibration of their thermoelectric properties. Many customers have MEDTHERM install the probes in their test articles at our manufacturing plant. Triaxial thermocouples are available which offer good thermal connection but provide electrical isolation of the thermocouple junction from its surroundings (ungrounded junction). For quotations or other information, contact our local representative or contact the factory.

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