

**ELECTRICAL OPTIONS/ SPECIFICATIONS**

OUTPUT	SUPPLY
0.5 TO 4.5V RATIOMETRIC	5V
SUPPLY CURRENT 12mA TYP. 20mA MAX.	

CABLE: 0.2mm<sup>2</sup>, O/A SCREEN, PUR JACKET – SUPPLIED WITH 50cm OR REQUIRED LENGTH IN cm (15000cm MAX).  
 STANDARD 3-CORE: JACKET Ø4mm BLACK e.g. 'L50'  
 OPTIONAL 5-CORE: JACKET Ø4.6mm BLUE e.g. 'LQ50'

CABLE/CONNECTOR\* CONNECTIONS;

3 CORE	5 CORE	CONNECTOR	
RED	RED	:1	+Ve
–	ORG	:1	+SENSE (5-WIRE ONLY)
BLACK	BLACK	:3	0V
–	GRY	:3	–SENSE (5-WIRE ONLY)
WHITE	WHITE	:2	OUTPUT
SCREEN	SCREEN	:4	BODY

\*CONNECTORS; MAXIMUM CONDUCTOR CROSS SECTION 0.75mm<sup>2</sup>  
 RANGE OF DISPLACEMENT FROM 0–5mm TO 0–800mm e.g.76, IN INCREMENTS OF 1mm.

BODY MATERIAL: STAINLESS STEEL.

NOTE:– READ INSTALLATION SHEET M100–19 FOR FULL INSTRUCTIONS FOR USE.

**ATEX / IECEx APPROVED TO**

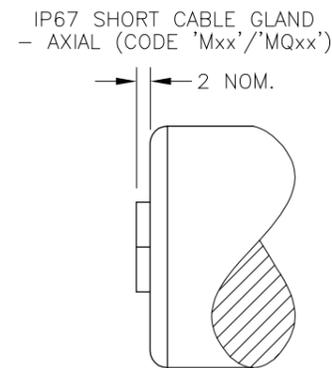
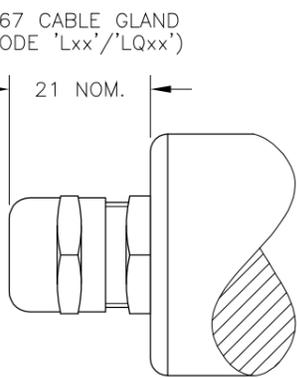
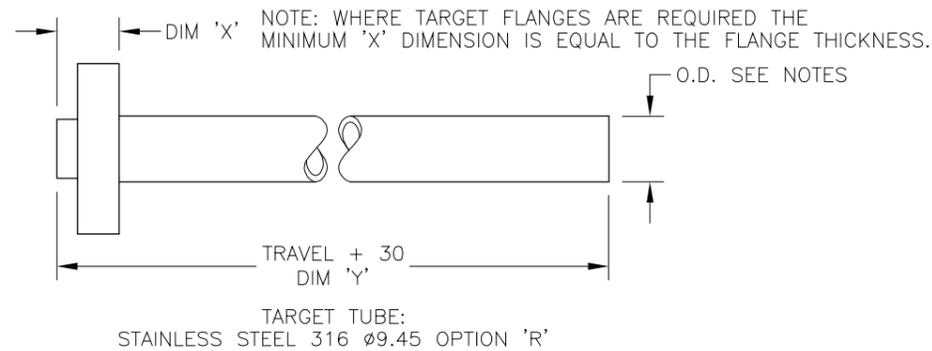
III M1/1GD

Ex ia IIC T4 Ga (Ta= -40° to +80°C)  
 Ex ia IIIC T135°C Da (Ta= -40° to +80°C)  
 Ex ia I Ma (Ta= -40° to +80°C)  
 Ui 11.4V, li 0.2A, Pi 0.51W

APPROVED FOR USE IN CONJUNCTION WITH A GALVANICALLY ISOLATED BARRIER.

NOTE: APPROVAL ONLY APPLIES AT NORMAL ATMOSPHERIC PRESSURE!

OPTION 'W' FLANGE ILLUSTRATED; SEE TG24–11 FOR DETAILS TO SPECIFY TARGET TUBES. SEE P100–12 FOR DETAILS TYPICAL TARGET TUBE MOUNTING ARRANGEMENTS



F	OPTION 'S' REMOVED - RAN1035.	PDM
G	RANGE WAS 20-600 RAN1056	RDS
H	TARGET NOTES AMENDED ~ RAN1114	PDM
J	5-CORE OPTION ADDED ~ RAN1102	PDM
K	OPTION 'M' ADDED ~ RAN1166, RANGE NOTE AMENDED ~ RAN1200	PDM
L	HEX. LENGTH 14 WAS 15 ~ RAN1160	PDM

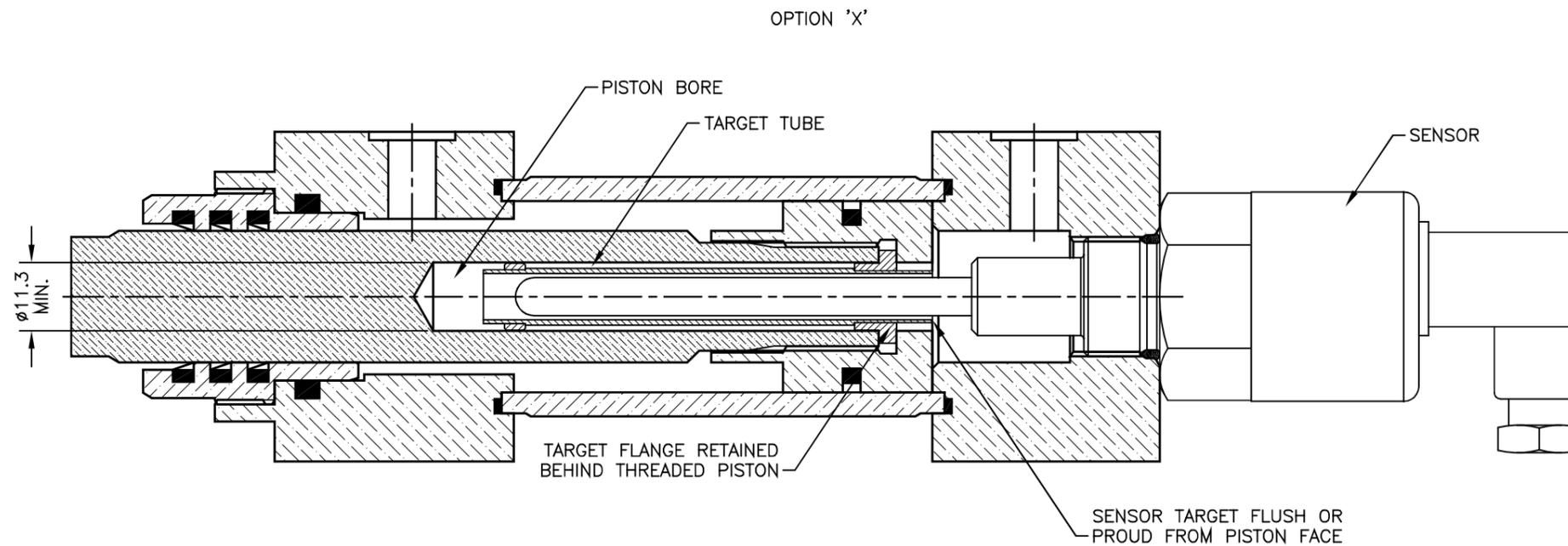
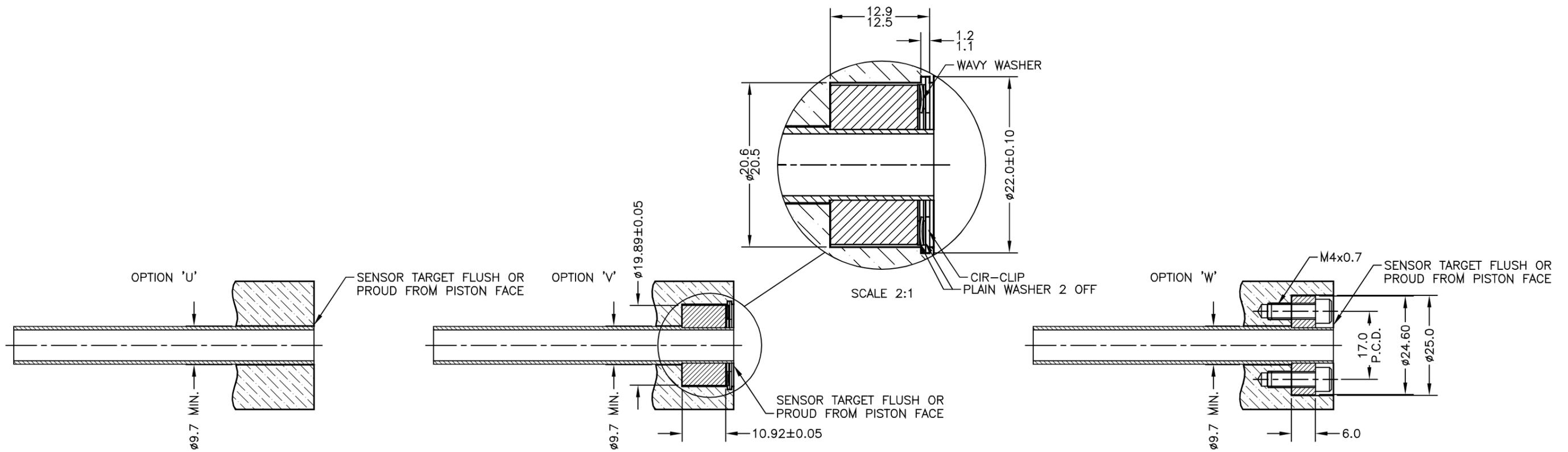


DRAWINGS NOT TO BE CHANGED WITHOUT REFERENCE TO THE CHANGE PROCEDURE. CHANGES TO PARTS USED IN INTRINSICALLY SAFE PRODUCT MUST BE APPROVED BY THE AUTHORISED PERSON  
 THIS IS AN UNCONTROLLED PRINT AND WILL NOT BE UPDATED.



F	29/06/15		CHECKED BY	X	±0.4
G	9/11/15		RDS	X.X	±0.2
H	18/10/16			X.XX	±0.1
J	05/04/17	DESCRIPTION			
K	29/08/17	M100 INTRINSICALLY SAFE			
L	11/10/17	CYLINDER LINEAR POSITION SENSOR			
SCALE 10mm		DRAWING NUMBER		M100-11	REV L
					SHEET 1 OF 1

SEE DRAWING TG24-11 FOR TARGET TUBE FLANGE OPTIONS 'V', 'W' & 'X'.



A	FIRST ISSUE.	RDS
B	REDRAWN.	PDM
C	WORDING AMMENDED	RDS

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A	28/06/95		CHECKED BY	X	±0.4
B	04/10/11		MAS	X.X	±0.2
C	26/10/17			X.XX	±0.1
DESCRIPTION					DIMS mm
TYPICAL TARGET TUBE FITTING OPTIONS					
SCALE		DRAWING NUMBER		REV	
10mm		P100-12		C	
		SHEET		OF	
		1		1	

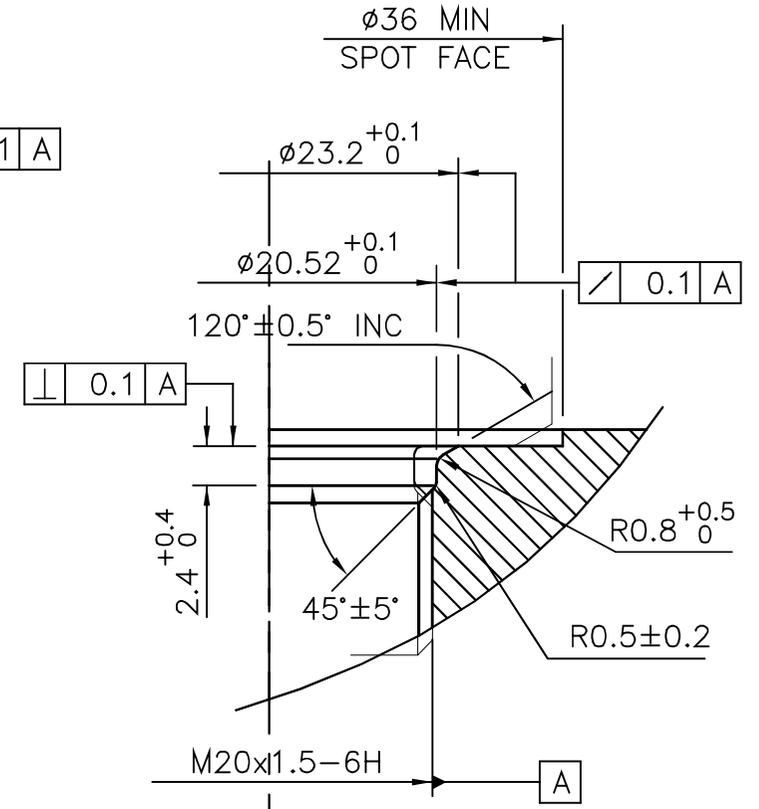
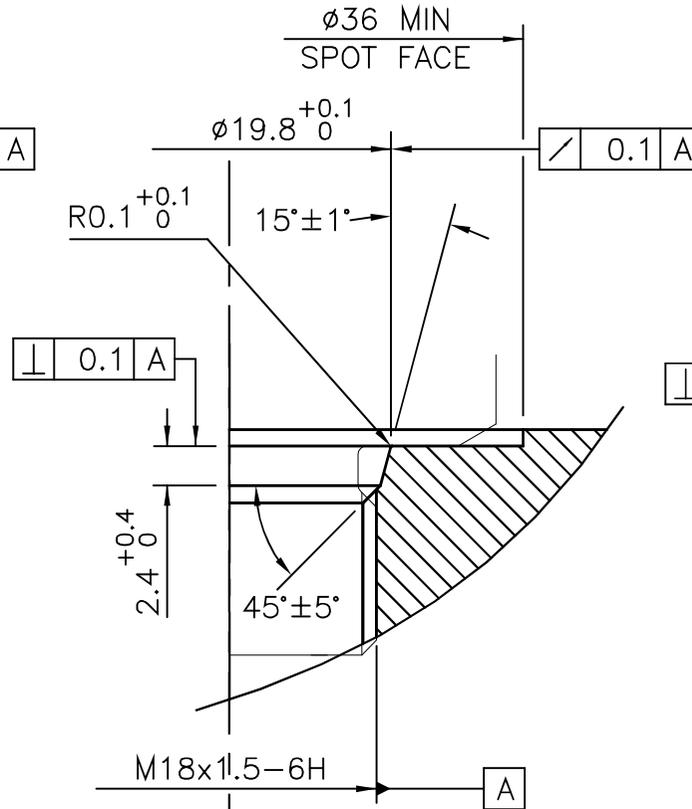
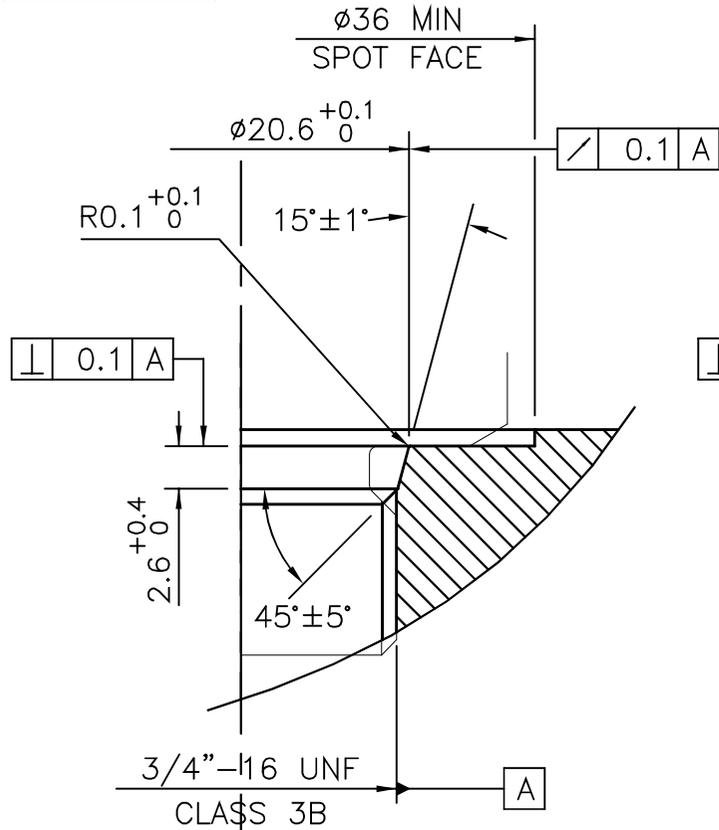
CHECKED  
AT REV.

A

RDS

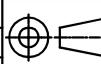
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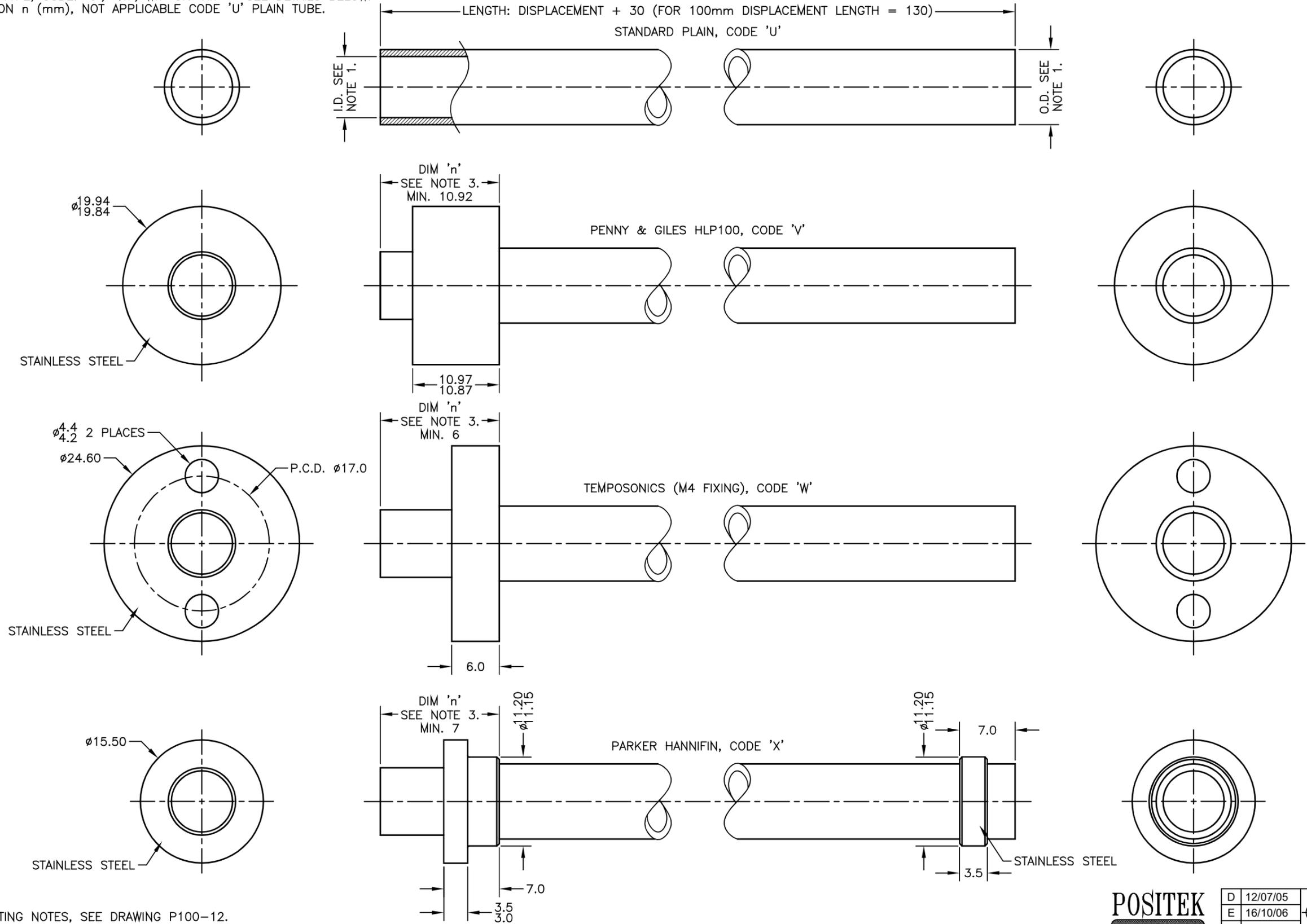
A	FIRST ISSUE	COH/DS
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A	29/01/95	 SEE NOTE 1	MATERIAL	X $\pm 0.4$ X.X $\pm 0.2$ X.XX $\pm 0.1$ ALL DIMS mm
			DESCRIPTION	INSTALLATION DETAILS MOUNTING THREADS & SEALS
		SCALE	DRAWING NUMBER	P100-15 REV A
		5mm		SHEET 1 OF 1

TARGET TUBE OPTION NOTES:-

- SPECIFY TUBE MATERIAL; CODE:-  
'R' STAINLESS STEEL 316  $\phi$ 9.45.  
'S' ALUMINIUM 6063  $\phi$ 3/8" (9.2-9.8). NOTE! ONLY AVAILABLE WITH P100 OR P106 VERSIONS.
- SPECIFY FLANGE TYPE; CODE: 'U', 'Vn', 'Wn' OR 'Xn' ~ SEE DETAILS BELOW.
- SPECIFY DIMENSION n (mm), NOT APPLICABLE CODE 'U' PLAIN TUBE.



TARGET TUBE MOUNTING NOTES, SEE DRAWING P100-12.

D	MINIMUM 'X' DIMENSIONS ADDED	PDM
E	MATERIAL OPTION REMOVED.	PDM
F	MAT'L OPTION REINSTATED RAN221.	PDM
G	X DIM FOR PH FLANGE SHOWN RAN225	RDS
H	9.45 WAS 9.5 RAN396	RDS
J	REDRAWN, PH FLANGE ROTATED RAN507.	PDM
K	NOTE 1 AMENDED ~ RAN1114.	PDM

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D	12/07/05		CHECKED BY	X	±0.4
E	16/10/06		RDS	X.X	±0.2
F	24/09/08			X.XX	±0.1
					DIMS mm
G	13/11/08	DESCRIPTION			
H	11/12/12	TARGET TUBE AND FLANGE			
J	23/07/14	OPTIONS (LIPS 100/106)			
K	30/11/16				
SCALE		DRAWING NUMBER		REV	
5mm		TG24-11		K	
		SHEET		OF	
		1		1	

# LIPS<sup>®</sup> M100 CYLINDER - LINEAR POSITION SENSOR

## INTRINSICALLY SAFE FOR HAZARDOUS MINING ENVIRONMENTS

- Intrinsically safe for Mining to:  
Ex I/II M1/GD
- Non-contacting inductive technology to eliminate wear
- Travel set to customer's requirement
- High durability and reliability
- High accuracy and stability
- Sealing to IP67



As a leading designer and manufacturer of linear, rotary, tilt and intrinsically safe position sensors, Positek<sup>®</sup> has the expertise to supply a sensor to suit a wide variety of applications.

Our intrinsically safe M100 LIPS<sup>®</sup> (Linear Inductive Position Sensor) incorporates electronics system EX07 which is ATEX / IECEx approved for use in potentially explosive gas/vapour, dust atmospheres and mining environments.

The M100 is designed for demanding hydraulic or pneumatic cylinder position feedback applications where service life, environmental resistance and cost are important and is ideal for OEMs seeking good sensor performance for arduous applications in hazardous areas.

Overall performance, repeatability and stability are outstanding over a wide temperature range. The unit is highly compact and space-efficient, being responsive along almost its entire length. Like all Positek<sup>®</sup> sensors, the M100 provides a linear output proportional to travel. Each unit is supplied with the output calibrated to the travel required by the customer, any stroke from 0-5mm to 0-800mm and with full EMC protection built in.

The sensor is very rugged, being made of stainless steel with an inert fluoropolymer-sheathed probe with a stainless steel target tube. The sensor is easy to install in cylinders and has a range of mechanical options. Environmental sealing is to IP67.

### SPECIFICATION

<b>Dimensions</b>	
Body diameter	35 mm
Body Length (to seal face)	43 mm
Probe Length (from seal face)	calibrated travel + 58 mm
Target Tube Length	calibrated travel + 30 mm
For full mechanical details see drawing M100-11	
<b>Power Supply</b>	+5V dc nom. ± 0.5V, 10mA typ 20mA max
<b>Output Signal</b>	0.5-4.5V dc ratiometric, Load: 5kΩ min.
<b>Independent Linearity</b>	≤ ± 0.25% FSO @ 20°C - up to 450 mm ≤ ± 0.5% FSO @ 20°C - over 450 mm ≤ ± 0.1% FSO @ 20°C* available upon request.
*Sensors with calibrated travel from 10 mm up to 400 mm.	
<b>Temperature Coefficients</b>	< ± 0.01%/°C Gain & < ± 0.01%FS/°C Offset
<b>Frequency Response</b>	> 10 kHz (-3dB)
<b>Resolution</b>	Infinite
<b>Noise</b>	< 0.02% FSO
<b>Intrinsic Safety</b>	Ex I/II M1/GD Ex ia IIC T4 Ga (Ta= -40°C to 80°C) Ex ia IIIC T135°C Da (Ta= -40°C to 80°C) Ex ia I Ma (Ta= -40°C to 80°C)
Approval only applies to the specified ambient temperature range and atmospheric conditions in the range 0.80 to 1.10 Bar, oxygen ≤ 21%	
<b>Sensor Input Parameters</b>	Ui: 11.4V, Ii: 0.20A, Pi: 0.51W.
(connector option/s)	Ci: 1.16µF, Li: 50µH
(cable option/s)	Ci: 1.36µF, Li: 860µH with 1km max. cable
<b>Environmental Temperature Limits</b>	
Operating	-40°C to +80°C
Storage	-40°C to +125°C
<b>Sealing</b>	IP67
<b>Hydraulic Pressure</b>	350Bar
<b>EMC Performance</b>	EN 61000-6-2, EN 61000-6-3
<b>Vibration</b>	IEC 68-2-6: 10 g
<b>Shock</b>	IEC 68-2-29: 40 g
<b>MTBF</b>	350,000 hrs 40°C Gf
<b>Drawing List</b>	
M100-11	Sensor Outline
P100-12	Typical Target Installation details
P100-15	Mounting Thread details
TG24-11	Optional Target Tube Flange details
Drawings, in AutoCAD <sup>®</sup> dwg or dxf format, available on request.	

Do you need a position sensor made to order to suit a particular installation requirement or specification? We'll be happy to modify any of our designs to suit your needs - please contact us with your requirements.

# LIPS<sup>®</sup> M100 CYLINDER - LINEAR POSITION SENSOR INTRINSICALLY SAFE FOR HAZARDOUS MINING ENVIRONMENTS

Intrinsically safe equipment is defined as "equipment which is incapable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmosphere mixture in its most easily ignited concentration."

ATEX / IECEx approved to;

- Ex I/II M1/GD
- Ex ia IIC T4 Ga (Ta= -40°C to 80°C)
- Ex ia IIIC T135°C Da (Ta= -40°C to 80°C)
- Ex ia I Ma (Ta=-40°C to 80°C)

Designates the sensor as belonging to; Groups I and II: suitable for all areas (including mining), Category M1/1 GD: can be used in areas with continuous, long or frequent periods of exposure to hazardous gas (Zones 2 to 0) and dust (Zone 20), equipment remains energised.

Gas:

Protection class ia, denotes intrinsically safe for all zones Apparatus group IIC: suitable for IIA, IIB and IIC explosive gases.

Temperature class T4: maximum surface temperature under fault conditions 135°C.

Dust:

T135°C: maximum surface temperature under fault conditions 135°C.

Ambient temperature range extended to -40°C to +80°C.

It is imperative Positek<sup>®</sup> intrinsically safe sensors be used in conjunction with a galvanic barrier to meet the requirements of the product certification. The Positek X005 Galvanic Isolation Amplifier is purpose made for Positek IS sensors making it the perfect choice. Refer to the X005 datasheet for product specification and output configuration options.

#### Safety Parameters:-

- Ui: 11.4V, Ii: 0.20A, Pi: 0.51W
- Ci = 1.36µF\*      Li = 860µH\* (cable option/s)
- Ci = 1.16µF      Li = 50µH (connector option/s)

\*Figures for 1km cable where: Ci = 200pF/m & Li = 810nH/m

Sensors can be installed with a maximum of 1000m of cable.

Cable characteristics must not exceed:-

- Capacitance: ≤ 200 pF/m for max. total of: 200 nF.
- Inductance: ≤ 810 nH/m for max. total of: 810 µH

For cable lengths exceeding 10 metres a five wire connection is recommended to eliminate errors introduced by cable resistance and associated temperature coefficients.

ATEX / IECEx approved sensors suitable for gas (X series) and dust (E series) applications, are also available from Positek.

## TABLE OF OPTIONS

**CALIBRATED TRAVEL:** Factory set to any length from 0-5mm to 0-800mm (e.g. 254mm)

### ELECTRICAL INTERFACE OPTIONS

The Positek<sup>®</sup> X005 Galvanic Isolation Amplifier is available with the following output options;

- Standard: 0.5 - 9.5V or 4 - 20mA.
- Reverse: 9.5 - 0.5V or 20 - 4mA.

### CONNECTOR/CABLE OPTIONS

- Connector - Binder 713 series IP67
- Cable<sup>†</sup> with Pg 9 gland or short gland IP67

<sup>†</sup>Three core (black jacket) or five core (blue jacket) cable options available.

Cable length >50 cm – please specify length in cm up to 15000 cm max.

We recommend all customers refer to the 3 or 5-Wire Mode Connection page.

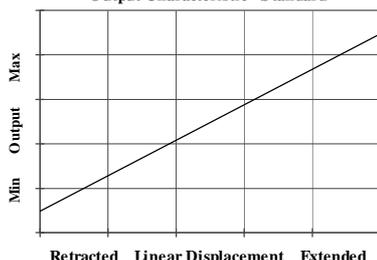
### MOUNTING THREAD OPTIONS

- M18, M20, ¾ UNF 30 mm hex A/F, Ø30 mm seal face.
- Supplied with O-ring seal.

### FLANGE OPTIONS

Penny & Giles HLP100, Temposonics (M4 fixing) and Parker Hannifin cylinders versions available.

Output Characteristic - Standard



For further information please contact:

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Positek Ltd, Andoversford Industrial Estate, Cheltenham GL54 4LB U.K.



M100-17p

# Three or Five-Wire Mode Connection FOR INTRINSICALLY SAFE SENSORS IN HAZARDOUS ATMOSPHERES

The aim of this document is to help readers who do not understand what is meant by three or five wire modes of connection between the galvanic isolation amplifier and sensor, and the factors behind them. It is by no means an in-depth technical analysis of the subject.

Whether opting for a pre-wired Positek® Intrinsically Safe sensor or one with a connector, choosing the right mode of connection and cable to suit the application requires careful consideration.

Interconnecting cables are not perfect conductors and offer resistance to current flow, the magnitude of resistance<sup>†</sup> depends on conductors resistivity, which changes with temperature, cross sectional area<sup>‡</sup> and length. If the voltage were to be measured at both ends of a length of wire it would be found they are different, this is known as volts drop. Volts drop changes with current flow and can be calculated using Ohm's law, it should be noted that volts drop occurs in both positive and negative conductors. The effects of volts drop can be reduced by increasing the conductors cross sectional area, this does not however eliminate the effects due to temperature variation. There are instances where large cross-section cables are not practical; for example most standard industrial connectors of the type used for sensors have a maximum conductor capacity of 0.75mm<sup>2</sup>, copper prices and ease of installation are other considerations.

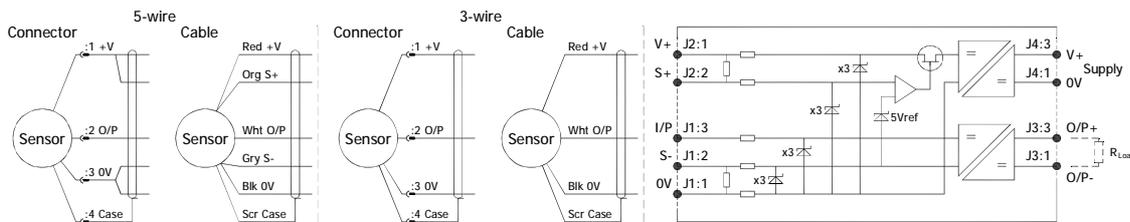
This is important because the effects of volts drop can significantly alter the perceived accuracy of the sensor which is ratiometric i.e. the output signal is directly affected by the voltage across the sensor. Changes in temperature will also be seen as gain variation in the sensor output.

**Three wire mode** connections are common and are suitable in most cases with short or moderate cable runs. Applications that do not require a high degree of accuracy but have cable runs, say in excess of 10m, volts drop can be reduced by introducing a terminal box close to the sensor and using a larger cross-section cable for a majority of the cable run. Sensors supplied with three core cable are calibrated with the cable fitted which largely eliminates errors due to conductor resistance at room temperature however, as mentioned above, small gain errors due to temperature fluctuations should be expected.

**Five wire mode** connections have significant benefits as losses in the positive and negative conductors are compensated for by the galvanic isolation amplifier which can 'sense' the voltage across the sensor and dynamically adjust the output voltage so that the voltage across the sensor is correct. The effects of cable resistance and associated temperature coefficients are eliminated allowing for smaller conductors than a three wire connection for the same cable run. The amplifier can compensate for up to 15Ω per conductor with a current flow of 15mA, which is more than adequate for 150m of 0.25 mm<sup>2</sup> cable, longer lengths will require larger conductors.

For this reason Positek® recommends five wire connections for cable lengths exceeding 10 metres in 0.25 mm<sup>2</sup> cable to preserve the full accuracy of the sensor.

See illustrations below for examples of connecting a sensor to the galvanic isolation amplifier.



Cable Length (metres)	Up to 150	150 - 300	300 - 450	450 - 600	600 - 900	900 - 1000
Cross Section (mm <sup>2</sup> )	0.25	0.5	0.75	1.0	1.5	2.0

The table above shows recommended conductor sizes with respect to cable length for both three and five wire connections, based on copper conductors. Three wire connections will introduce a gain reduction of 5% and a ±1% temperature dependence of gain over the range -40°C to +80°C for the cable temperature. (i.e. about -150 ppm/°C for the maximum lengths shown and less pro rata for shorter lengths.)

It should be noted that the maximum cable length, as specified in the sensor certification, takes precedence and must not be exceeded.

Positek® sensors are supplied with three core 0.25 mm<sup>2</sup> cable as standard, however five core 0.25 mm<sup>2</sup> cable can be supplied on request. The galvanic isolation amplifier is available as;

- G005-\*\*\* for 'G' and 'H' prefix sensors
- X005-\*\*\* for 'E', 'M' and 'X' prefix sensors

<sup>†</sup>  $R = \rho L/A$   $\rho$  is the resistivity of the conductor ( $\Omega m$ )  $L$  is the length of conductor (m)  $A$  is the conductor cross-sectional area (m<sup>2</sup>).

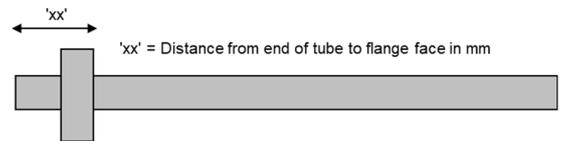
<sup>‡</sup> It is presumed that direct current flow is uniform across the cross-section of the wire, the galvanic isolation amplifier and sensor are a dc system.

# Intrinsically Safe - Dust Atmospheres

## LIPS® SERIES H100 Cylinder – Linear Position Sensor

a	b	c	d	e	f	g	h
H100	Displacement	A	Y	Connections	Option	R	Option Z-code

a Displacement (mm)		Value
Displacement in mm	e.g. 0 - 254 mm	254
b Output		
Supply V dc V <sub>s</sub> (tolerance)	Output	Code
+5V (4.5 - 5.5V)	0.5 - 4.5V (ratiometric with supply)	A
c Calibration Adjustments		Code
Sealed		Y
d Connections Cable* or Connector		Code
Connector	IP67 M12 IEC 60947-5-2	J
Cable Gland	IP67 M12 - 3-core cable	Lxx
Cable Gland	IP67 M12 - 5-core cable	LQxx
Cable Gland	IP67 Short - 3-core cable	Mxx
Cable Gland	IP67 Short - 5-core cable	MQxx
*Supplied with 50 cm as standard, specify required cable length specified in cm. e.g. L2000 specifies cable gland with 20 metres of cable. Nb: restricted cable pull strength.		
e Mounting Thread		Code
M20 x 1.5	Hex. 30 mm A/F, Ø 30 mm seal face.	N
3/4 16 UNF	Supplied with O-ring seal.	P
M18 x 1.5		T
See P100-15 Drawing for Mating Thread Details.		
f Target Tube		Code
Stainless Steel 316	OD: 9.45 mm	R
See P100-12 Drawing for Typical Target Installation details.		
g Target Tube Mounting Flange		Code
None		U
Penny & Giles HLP100	Please specify flange position in mm.	Vxx
Temposonics (M4 fixing)	eg. W17.5 specifies a Tempo style flange fitted 17.5 mm from the front face	Wxx
Parker Hannifin		Xxx
See TG24-11 Drawing for Target Details.		
h Z-code		Code
Calibration to suit G005 - Default		Z000
≤ ± 0.1% @20°C Independent Linearity displacement between 10mm & 400mm only!		Z650
Connector with cable option 'J' or 'JQ' with length required in cm i.e. J100 specifies connector with 100cm of cable.		Z999



### Note!

All Intrinsically Safe (IS) sensors must have a Z-code suffix.  
IS sensors must be used in conjunction with a Galvanic Isolation Amplifier - See G005 for Output options.

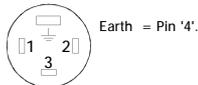
# Generic Installation Information

## H SERIES SENSORS

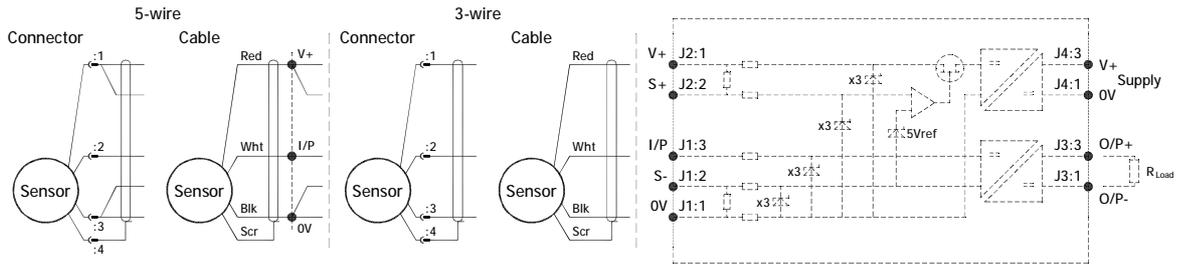
### INTRINSICALLY SAFE FOR HAZARDOUS GAS/VAPOUR & DUST ATMOSPHERES

CSA Qualified Intrinsically Safe Device Certificate number 13.2588225		Class I, Zone 0 Ex ia IIC T4 (Ta = -40°C to +80°C) AEx ia IIC T4 / Ex ia IIC T4 (Ta = -40°C to +80°C) AEx ia D IIC T93°C (Ta = -40°C to +80°C)	
Electronics Option	Output Description:	Supply Voltage: V <sub>s</sub> (tolerance)	Load resistance:
A	0.5 - 4.5V (ratiometric with supply)	+5V (4.5 - 5.5V)	5kΩ min

**Connector Pin Layout:**  
DIN 43650 C



IEC 60947-5-2



**Putting Into Service:**

The sensor must be used with a galvanic isolation barrier designed to supply the sensor with a nominal 5V and to transmit the sensor output to a safe area. The barrier parameters must not exceed:-

$U_i = 11.4V$	$I_i = 0.20A$	$P_i = 0.51W$
$C_i = 1.36\mu F^*$	$L_i = 710\mu H^*$	(with maximum length integral cable)
$C_i = 1.16\mu F$	$L_i = 50\mu H$	(without integral cable)

\*Figures for 1km cable where:  $C_i = 200pF/m$  &  $L_i = 660nH/m$

The sensor is certified to be used with up to 1000m of cable, cable characteristics must not exceed:-

Capacitance:  $\leq 200 pF/m$  for max. total of: 200 nF  
 Inductance:  $\leq 660 nH/m$  for max. total of: 660  $\mu H$

**Use:**

The sensor is designed to measure Linear or rotary displacement and provide an analogue output signal.

**Assembly and Dismantling:**

The unit is not to be serviced or dismantled and re-assembled by the user.

**WARNING:** Substitution of components may impair intrinsic safety  
**AVERTISSEMENT:** La substitution de composants peut altérer la sécurité intrinsèque

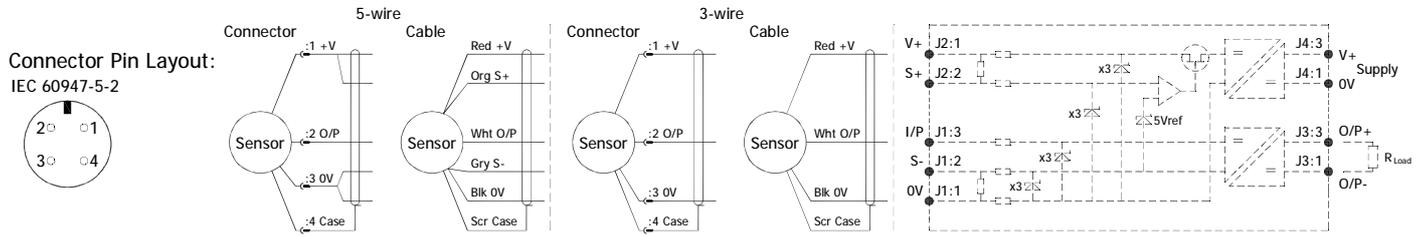
**Maintenance:**

Accumulated dust layer must not exceed a depth of 50mm.



# Installation Information

## LIPS<sup>®</sup> H100 CYLINDER - LINEAR POSITION SENSOR INTRINSICALLY SAFE FOR HAZARDOUS DUST ATMOSPHERES



Approval only applies to specified ambient temperature range and atmospheric conditions in the range: 0.80 to 1.10 Bar, oxygen ≤ 21%.

**The H100 is available with the following connections:-**

- IP67 IEC 60947-5-2 Connector Option 'J'
- IP67 Cable gland with cable Options 'Lxx', 'LQxx', 'Mxx' or 'LQxx'

The performance of the sensor may be affected by voltage drops associated with long cable lengths; For cable lengths exceeding 10 metres a five wire connection is recommended to eliminate errors introduced by cable resistance and associated temperature coefficients.

Cable Up to 150m of 0.2 mm<sup>2</sup>, screened, PUR jacket; 3 core cable 4 mm dia. black, 5 core cable 4.6 mm dia. Blue.

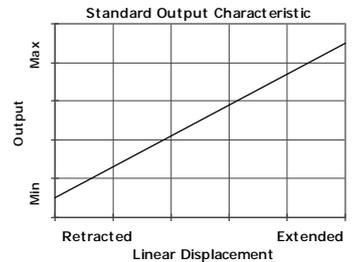
N.b. sensors supplied with cable, the free end must be appropriately terminated.

**Warning** - The M12 IEC 60947 connector may be rotated for purposes of convenient orientation of the connector and cable, however rotating the connector more than one complete revolution is not recommended.

**Repeated rotation of the connector will damage the internal wiring!**

**Mechanical Mounting:** Via mounting thread, maximum tightening torque: 100Nm. See drawing P100-15, Installation Details Mounting Threads & Seals. An O ring seal is provided, size BS908 for M20 & 3/4 UNF thread or 14.3 x 2.4 for M18 thread. Install the target tube using the flange provided or fix directly into the piston rod using adhesive for instance, the end of the target tube can be proud or flush with the piston end face as required.

**Output Characteristic:** Target position at start of normal travel is 36.0 mm from seal face. The output increases as the target is moved away from the sensor body, the calibrated stroke is between 5 mm and 800 mm.



**Incorrect Connection Protection levels: Not protected** – the sensor is not protected against either reverse polarity or over-voltage. The risk of damage should be minimal where the supply current is limited to less than 50mA.