USER MANUAL

ICT

Integrating Current Transformer

Rev. 5.0

www.bergoz.com

bergoz INSTRUMENTATION

More than 40 years of experience recognized in the world of particle accelerators

Record of updates

Version	Date	Updates performed
4.0	01/2018	Review of the full manual. Obsoletes all previous versions
4.1	12/2019	Modification of the cover page and creation of the distributors' page
4.2	04/2021	Addition of the CAW_50 option and the BK200C option Update of the drawing in the "Installation over a vacuum chamber" chapter
5.0	07/2024	Manual template update

DISTRIBUTORS

U.S.A.

GMW Associates
www.gmw.com
sales@gmw.com

Japan

Hayashi-Repic Co., Ltd.
www.h-repic.co.jp
sales@h-repic.co.jp

India

GEEBEE International
www.geebeeinternational.com
info@geebeeinternational.com

China

Beijing Conveyi Limited
www.conveyi.com
sales@conveyi.com

South Korea

Seyoung Co., Ltd
www.seyoungsys.com
apark@seyoungsys.com

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INITIAL INSPECTION

It is recommended that the shipment be inspected immediately upon delivery. If it is damaged in any way, contact Bergoz Instrumentation or your local distributor. The content of the shipment should be compared to the items listed on the invoice. Any discrepancy should be notified to Bergoz Instrumentation or its local distributor immediately. Unless promptly notified, Bergoz Instrumentation will not be responsible for such discrepancies.

WARRANTY

Bergoz Instrumentation warrants its beam current monitors to operate within specifications under normal use for a period of 12 months from the date of shipment. Spares, repairs and replacement parts are warranted for 90 days. In exercising this warranty, Bergoz Instrumentation will repair, or at its option, replace any product returned to Bergoz Instrumentation or its local distributor within the warranty period, provided that the warrantor's examination discloses that the product is defective due to workmanship or materials and that the defect has not been caused by misuse, disassembly, neglect, use of faulty part, accident or abnormal conditions, repair made by the customer, or operations. Damages caused by ionizing radiations are specifically excluded from the warranty. Bergoz Instrumentation and its local distributors shall not be responsible for any consequential, incidental or special damages.

ASSISTANCE

Assistance in installation, use or calibration of Bergoz Instrumentation beam current monitors is available from Bergoz Instrumentation, 01630 Saint Genis Pouilly, France. It is recommended to send a detailed description of the problem by email to info@bergoz.com.

SERVICE PROCEDURE

Products requiring maintenance should be returned to Bergoz Instrumentation or its local distributor: The purchaser/customer must ask for a RMA (Return Material Authorization) number to Bergoz Instrumentation or its local distributor before return of goods. Bergoz Instrumentation will repair or replace any product under warranty at no charge.

For products in need of repair after the warranty period, Bergoz Instrumentation will assess the technical issue and send a quote to the purchaser/customer. The purchaser/customer must provide a purchase order before repairs can be initiated. Bergoz Instrumentation can issue fixed price quotations for most repairs.

RETURN PROCEDURE

All products returned for repair should include a detailed description of the defect or failure as well as name, phone number and email of a contact person to allow further inquiry. Contact Bergoz Instrumentation or your local distributor to determine where to return the product. Returns must be notified by email prior to shipment.

The shipment of a product under warranty or out of warranty back to the factory is paid by the user/customer, including the customs fees. The return of this repaired product under warranty back to the customer is paid by Bergoz Instrumentation.

Return of product out of warranty should be made prepaid or will be invoiced. Bergoz Instrumentation will not accept freight-collect shipments. Shipments should be made via UPS, FedEx or DHL. Within Europe, the transportation services offered by the national Post Offices can be used. The delivery charges or customs clearance charges arising from the use of other carriers will be charged to the customer.

SAFETY INSTRUCTIONS

The Toroid sensor contains materials such as cobalt and iron. Those materials may become radioactive when exposed to high energy particle beams. Follow applicable radiation-safety procedures when the Toroid sensor must be handled.

GENERAL DESCRIPTION

ICT Integrating Current Transformer is a passive current transformer designed to measure charges of very short pulses with high accuracy. By combining a fast capacitively shorted transformer and a slow read out transformer in a common magnetic circuit, an output signal of well-defined shape is created. Depending on requirements, output signal length can range from a few nanoseconds up to 70ns full length.

Integrating the ICT output signal results a value proportional to beam pulse charge with negligible beam pulse length and position dependence.

The ICT magnetic cores and associated transformer windings form an essentially noise free current source. The measurement noise and consequently the measurement resolution are only determined by the signal processing. Hence, the ICT can be used in a wide variety of accelerators with very different beams.

Bergoz Instrumentation BCM-IHR-E electronics may be used with the ICT to obtain an accurately calibrated turn-key solution for pulse charge measurements.

In-flange models

In-flange models are current transformers whose cores are embedded in a pair of vacuum flanges. Flanges are Conflat with usual inner diameters.
These current transformers are UHV compatible at least to 1e-9 mbar. Soap or alcohol cleaning before installation is however recommended. To reach pressure down to 1e-11 mbar, adequate pumping and prior cleaning, e.g. plasma, are required.

Current transformer temperature should never exceed 100°C (212°F) at any time during bake out or operation unless the current transformer is made from a selection of higher temperature alloys and materials:

- Option BK150C allows bake out at 150°C (300°F)
- Option BK185C allows bake out at 185°C (365°F)
- Option BK200C allows bake out at 200°C (392°F)

Current transformer wall current break ("gap") is a ceramic ring (Al_2O_3 99.7%) brazed onto two Kovar transition sleeves.
Standard models are made from AISI 304 steel, AISI 316LN is available on option.

In-flange ICT part numbers follow below syntax:

In-flange ICT	
-CFx"-	x" is the CF flanges OD [inch]
-xx.x-	xx.x is the sensor ID [mm]
-xx-	xx is the sensor axial length [mm]
-UHV-	UHV: Sensor UHV compatible with brazed ceramic wall current break; - As delivered down to 1e-9 mbar - After adequate cleaning down to 1e-11 mbar
-xxx-	Output pulse full length duration, standard is -070- [ns]
-xx.x	xx.x is the sensitivity of the sensor [V/A]
Example: ICT-CF6"-60.4-40-UHV-070-5.0	
Options for In-flange ICT	
-ARBxx-	In-flange ICT sensor with special arbitrary aperture
-316LN-	In-flange ICT sensor in AISI316LN instead of 304
-BK150C-	In-flange ICT sensor bakeable at 150°C (300°F)
-BK185C-	In-flange ICT sensor bakeable at 185°C (365°F)
-BK200C-	In-flange ICT sensor bakeable at 200°C (392°F)
-LD-	Low Droop sensor option
-H	Radiation-tolerant sensor option, all components R.I.>6
-CAW1_50	1-turn calibration winding, loaded 50Ω (0.25W), insulated SMA connector

In-air models

In-air models are current transformers whose cores are potted in a toroidal copper casing. In-air ICTs are typically installed over a vacuum chamber whose wall current flow is interrupted by a user-installed break ("gap") protected from stress by bellows. The wall current is diverted by a user-installed wall current bypass. A user-installed shield prevents RF fields radiating out of the gap.

In-air ICT should not be heated above 100°C (212°F) at any time.
In-air ICT should not be placed in vacuum, they might burst.
Specially degassed In-air ICT can be placed in low vacuum (1e-4 mbar).

In-air ICT part numbers follow below syntax:

In-air ICT	
-xxx-	xxx is the sensor ID [mm]
-xxx-	Output pulse full length duration, standard is -070- [ns]
-xx.x	xx.x is the sensitivity of the sensor [V/A]
Example: ICT-055-070-5.0	
Options for In-air ICT	
-VAC-	In-air ICT sensor degassed. Warning: excessive degassing if placed in vacuum <1e-4 mbar
-LD-	Low Droop sensor option
-H	Radiation-tolerant sensor option, all components R.I.>6
-CAW1_50	1-turn calibration winding, loaded 50Ω (0.25W), insulated SMA connector

BCM-IHR-E

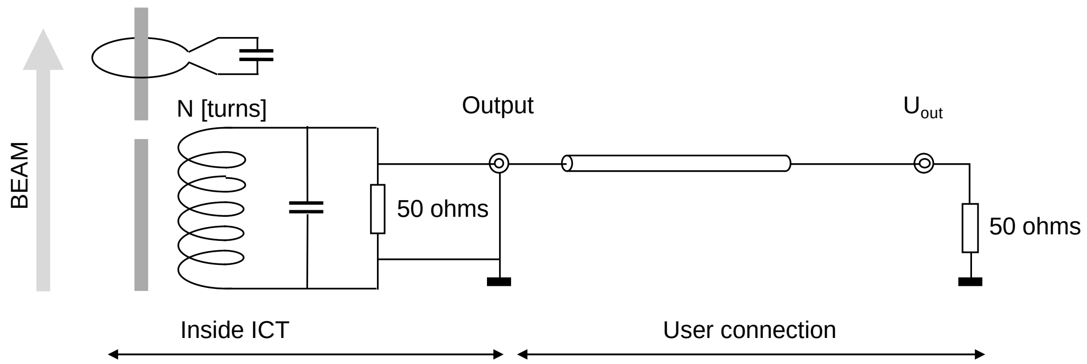
You may have received BCM-IHR-E electronics with the ICT. The ICT & BCM-IHR-E usually system includes:

Description		Order code
1	Integrating Current Transformer	e.g. ICT-CF4"1/2-34.9-40-UHV-5.0
2	BCM-IHR-E electronics module	BCM-IHR-E
3	19" RF-shielded chassis for BCM-E modules of all versions with power supply and spare power supply	BCM-RFC/XX XX: number of wired BCM stations
4	ICT to BCM-RFC chassis interconnect coaxial cable	BCM-C/xxx or BCM-RHC/xxx xxx: cable length in meters

Please refer to the BCM-IHR-E manual for more information.

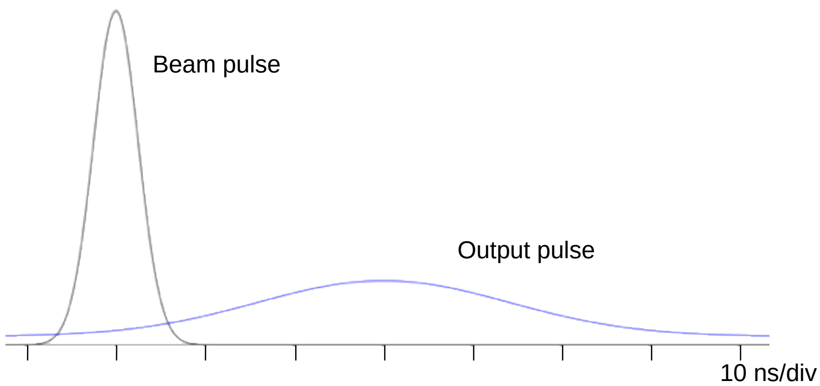
OPERATING PRINCIPLE

The Integrating Current Transformer (ICT) is a passive transformer designed to measure charges of very fast pulses with high accuracy. Beam pulses may have any length shorter than the ICT output pulse.



The ICT is a fast capacitively shorted transformer coupled to a slow readout transformer in a common magnetic circuit[1].

It delivers a pulse with typically 20 ns rise time irrespective of the beam pulse rise time. The ICT output pulse charge is in exact proportion to the beam pulse charge.



The sensitivity of the Integrating Current Transformer is also called transfer impedance.
It depends on the ICT model. It is expressed in terms of the integral of the output pulse voltage as a function of the input pulse charge, therefore in Vs/C, or Ω.

[1] Measuring Bunch Intensity, Beam Loss and Bunch Lifetime in LEP, K.B.Unser, Proceedings of the 2nd European Particle Accelerator Conference, 1990, Vol.1, p.786

SPECIFICATIONS

Sensitivity (nominal)	0.5	1.25	2.5	5.0	10.0	Vs/C
Turns ratio (old reference)	50:1	20:1	10:1	5:1	2x 5:1	
Output pulse (full length)	70	0.23	0.30	0.39	0.39	ns
Droop	< 3	< 6	< 10	< 32	< 157	%/µs
Droop with Low Droop option	< 0.2	< 1	< 3	< 8	< 32	%/µs
Max. charge/pulse	2000	324	81	20	5	µC
Max. rms current (f >10kHz)	2.7	2.7	2.7	2.7	2.7	A
Max. peak current (pulses = 1ns)	0.4	0.2	0.1	0.1	0.1	kA

Please contact Bergoz Instrumentation for 10.0 V/A sensitivity specifications.

ELECTRICAL CONNECTIONS

In-flange and In-air ICTs are equipped with SMA jack connectors with PTFE dielectric.

ICTs ordered with radiation tolerant option -H are equipped with SMA jack connectors with PEEK dielectric.

BNC or N-type connectors are available on request.

OUTPUT SIGNAL POLARITY

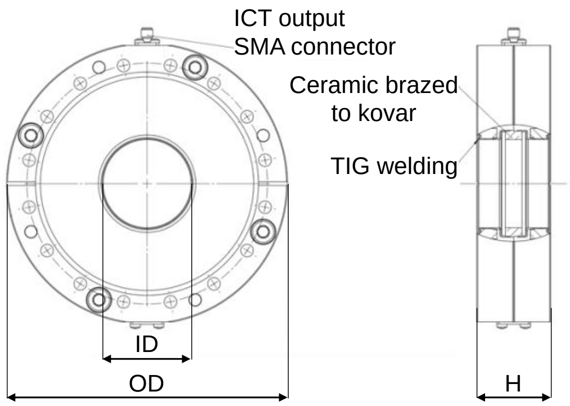
The Integrating Current Transformer is bipolar.
Arrows are printed on the outer surface of the toroid.
Charges (positive) crossing the aperture in the direction of the arrow give positive outputs.
For example, an electron beam (= negative charge) passing in the direction of the arrow yields a negative output.

CABLE CONNECTION

Most 50Ω coaxial cable types are appropriate to connect the ICT to its measuring instrument, for example an oscilloscope. However, the longer the cable and the lower the charge to be measured, the higher are demands on coaxial cable performance.
To measure charges below 500 pC, depending on the environmental background noise, consider using double-shielded cables or cables with a solid shield.
Depending on length and type, coaxial cables deform and attenuate pulsed signals. When the ICT signal is integrated, integration may be affected by such cable induced pulse attenuation and deformation. It is therefore recommended to use large diameter, low-loss cables for longer distances.

MECHANICAL DIMENSIONS AND DRAWINGS

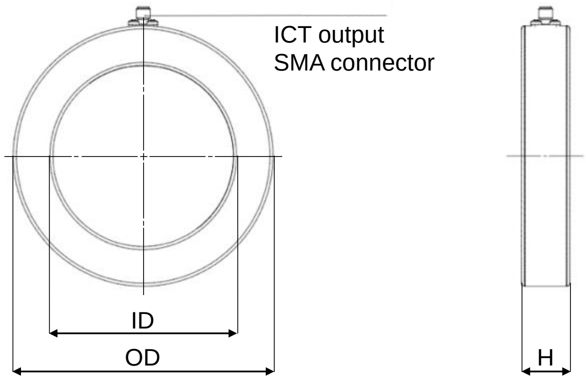
In-flange models



In-flange ICT sensor order code	Flange OD (inch)	Pipe OD (inch)	Mating flange	ID (mm)	H (mm)
ICT-CF3"3/8-22.2-40-UHV-070-xx	3.375”	1"	DN/NW50CF	22.2	
ICT-CF4"1/2-34.9-40-UHV-070-xx	4.5”	1.5"	DN/NW63CF	34.9	
ICT-CF4"1/2-38.0-40-UHV-070-xx	4.5”	40 mm	DN/NW63CF	38.0	
ICT-CF6"-47.7-40-UHV-070-xx	6”	2"	DN/NW100CF	47.7	
ICT-CF6"-60.4-40-UHV-070-xx	6”	2.5"	DN/NW100CF	60.4	
ICT-CF6"3/4-96.0-40-UHV-070-xx or ICT-CF8"-96.0-40-UHV-070-xx	6.75” 8”	4"	DN/NW130CF DN160/NW150CF	96.0	
ICT-CF10"-147.6-40-UHV-070-xx	10”	6"	DN/NW200CF	147.6	
ICT-CF12"-198.4-40-UHV-070-xx	12”	8"	DN/NW250CF	198.4	
ICT-CFXX"-XXX-XX-UHV-070-5.0 Vs/C and lower sensitivity					40.0

Please ask Bergoz Instrumentation for ICT-CFXX"-XXX-XX-UHV-070-10.0 Vs/C dimensions.

In-air models



In-air ICT sensor order code	ID min (mm)	OD max (mm)	H max (mm)
ICT-016-070-xx	16	42	
ICT-028-070-xx	28	64	
ICT-055-070-xx	55	91	
ICT-082-070-xx	82	118	
ICT-122-070-xx	122	156	
ICT-178-070-xx	178	226	
ICT-XXX-070-2.5 Vs/C and lower sensitivity			32
ICT-XXX-070-5.0 Vs/C			45

Please ask Bergoz Instrumentation for ICT-XXX-070-10.0 Vs/C dimensions.

Drawings

Drawings in .pdf can be found on our website:
www.bergoz.com :: ICT & BCM-IHR :: Downloads :: Technical drawings
Dimensions missing on the website can be obtained by contacting info@bergoz.com

INSTALLATION

In-flange models

In-flange model mechanical parts are in direct electrical contact with the vacuum chamber. Its output connector body and, hence, the coaxial cable shield are also in direct electrical contact with the vacuum chamber. It is therefore important to equip every segment of the coaxial cable with common mode filters to mitigate ground loops. A cable segment is any section of cable between two grounded connectors or bulkheads, for example through a grounded patch panel.

In-flange ICT bolts must be tightened at the recommended torque according to the flange type, but not beyond.

In-air models

In-air ICT must be installed over the vacuum chamber, not too far away from the wall current gap. It is recommended to install bellows to avoid stress on the gap, wall current bypass and RF overall shield.

The output connector body is in direct electrical contact with the In-air ICT copper shell. Therefore, to prevent ground loops, it is recommended that the In-air ICT shell is electrically isolated from the vacuum chamber.

Common mode filters

To improve EMI rejection common mode filters should be installed at both ends of each cable segment. Each filter shall comprise a MnZn ferrite core for high frequency >500 MHz rejection, and an iron-based nanocrystalline core with soft B-H loop for low frequency rejection.

INSTALLATION OVER A VACUUM CHAMBER

The installation of an In-air ICT on the outside of a vacuum chamber requires some precautions.

a) The electrical conductivity of the vacuum chamber must be interrupted in the vicinity of the ICT, otherwise beam and beam-induced wall current will flow through the ICT aperture and cancel each other. This vacuum chamber electrical break should be designed to be high impedance over the entire ICT bandwidth, but low impedance at higher frequencies. The higher harmonics of the beam induced fields should be prevented from escaping the vacuum chamber, because:
   a. they are not "seen" by the ICT therefore unnecessary
   b. they heat the ICT and any other conductive materials inside wall current bypass and RF shield
   c. they cause various ringing modes inside wall current bypass and RF shield.

b) Wall current DC and very low frequency components must be diverted around the ICT through a low impedance path.

c) A fully enclosing RF shield must be installed over wall current bypass, ICT and vacuum chamber electrical break to avoid emission of RF radiation.

d) The enclosing shield forms a cavity. Cavity ringing at any of the beam harmonics must be avoided.

e) The ICT must be protected from being heated beyond 100°C (212°F) during vacuum chamber bake-out.

Wall current break or “gap”

When installing an In-air ICT over a vacuum chamber, an electrical break or “gap” must be installed in order to stop the wall current induced by the beam.

If vacuum pressure is 1e-7 mbar or above, a polymer gasket O-ring can be used between two flanges to assure the desired electrical isolation.

For vacuum pressures below 1e-7 mbar, a ceramic ring brazed to the vacuum chamber is indicated.

Thermal protection of the In-air ICT

The ICT must not be heated beyond 100°C (212°F). If the vacuum chamber requires bake out, a thermal shield must be installed between the vacuum chamber (or the heating sleeves) and the ICT.

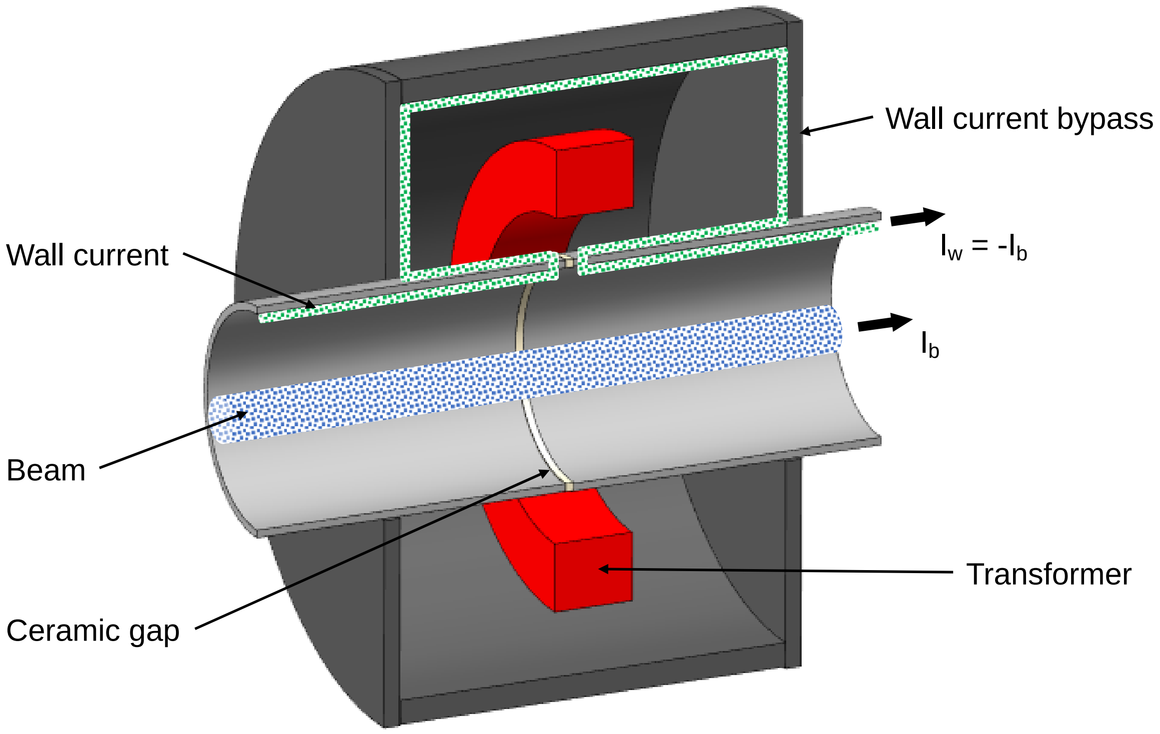
The thermal shield can be a simple copper cylinder cooled by water circulating in a copper tube brazed onto the cylinder.

The water circuit must not pass through the ICT aperture. It must enter and leave on the same side of the ICT, otherwise it may create an electrical short around the ICT toroid.

Keeping high harmonics of the beam out of the In-air ICT cavity

Wall current break, wall current bypass and RF shield form a cavity. The ICT is placed inside this cavity.

The beam current flows through the vacuum chamber. Its electromagnetic fields induce a wall current in the conductive vacuum chamber walls. The flow of this wall current is interrupted by the wall current break. Depending on gap capacitance, high frequency components see a low impendence and continue to flow over the gap. DC and lower frequency components see a high impedance and are diverted over the wall current bypass. Depending on cavity geometry also some high frequency resonances may be present inside the cavity.



The transformer “sees” all currents passing through its aperture, i.e. beam current I_b and high frequency components of wall current I_w. Since these two currents cancel each other, only the beam current components whose corresponding wall current is diverted over the wall current bypass and the high frequency resonances are visible to the transformer. Only these currents induce a magnetic flux in its core.

By increasing the gap capacitance all unnecessary frequencies can be kept out the cavity. By reducing the size of the cavity high frequency resonances can be avoided.

Note that always the full charge of the beam current pulse is visible to the transformer, irrespective of the value of the gap capacitance.

ICT RADIATION RESISTANCE

ICTs contain materials which may be damaged by ionizing radiations. They are listed hereafter.

Organic and radiation-sensitive materials used in the "Standard" sensor[2]:

The "Standard" sensor is supplied when the "Rad-Tolerant" option is not ordered.

Component	*Material*	*Radiation resistance*
Wiring insulation	Polyester 1350 tape	10^6 Gy
	Fiber glass	> 10^8 Gy
	with rubber adhesive	> 10^6 Gy
Stress absorbent	Silicon rubber tape SIR	5 x 10^5 Gy
	Silicon rubber SIR	2 x 10^5 Gy
Connector dielectric	PTFE "Teflon"	< 10^3 Gy

Organic and radiation-sensitive materials used in the "Rad-Hard" sensor[2]:

The "Rad-Tolerant" sensor is supplied when the "Rad-Tolerant" option is ordered. The ordering code and model number are then terminated by -H.

Component	*Material*	*Radiation resistance*
Wiring insulation	Polyester 1350 tape	10^6 Gy
	Fiber glass	> 10^8 Gy
	with rubber adhesive	> 10^6 Gy
Stress absorbent	Polyurethane foam PU	5 x 10^6 Gy
	Polyurethane rubber PUR	5 x 10^6 Gy
Connector dielectric	Poly-ether-ether-ketone PEEK	6 x 10^7 Gy

The above radiation resistance values are indicative only. They do not imply any guarantee of whatever nature from the manufacturer. The manufacturer specifically declines any responsibility for any damage, direct or consequential, caused by ionizing radiations.

[2] *Source: Compilation of Radiation Damage Test Data, H.Schönbacher et al.,*
CERN 79-04: http://cds.cern.ch/record/133188/files/CERN-HS-RP-038-YR-PARTI.pdf?version=1
CERN 79-08: http://cds.cern.ch/record/141784/files/CERN-HS-RP-093.pdf?version=1
CERN 82-10: http://cds.cern.ch/record/141784/files/CERN-HS-RP-093.pdf?version=1
CERN 89-12: http://cds.cern.ch/record/205520/files/CERN-89-12.pdf?version=1

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www.bergoz.com

If you have any questions, feel free to contact us by e-mail

info@bergoz.com

Bergoz Instrumentation – 156, rue du Mont Rond – Espace Allondon Ouest – 01630 SAINT GENIS POUILLY – France
Tél. : +33 (0) 459 42 66 42 Fax : +33 (0) 450 42 66 43 – bergoz@bergoz.com

www.bergoz.com
S.A.S. capital 152K€ - APE 2651B – TVA-VAT-IVA-USt. N° FR88414997130 – Siren 414 997 130 R.C.S. Bourg-en-Bresse