Contents

1. Scope

1) This document defines the requirements for installation of temperature sensors for cryogenic purposes in applications like
   - magnet cryostats,
   - cryogenic supply systems,
   - cryogenic transport systems,
   - cryogenic current lead boxes,
   - auxiliary cryogenic systems

   within FAIR accelerators.
2) This document is NOT related to any other purpose as aforementioned.

2. Definitions

1) *Sensitive applications* in terms of this document are temperature sensor applications
   - where electromagnetic stray fields are inducing additional noise,
   - where high measurement resolutions are required.

3. Sensor Applications down to 30 K

3.1. Materials

1) Only temperature sensors as specified in [1], chapter 2 must be applied.
2) In case of sensitive applications leadwire material as specified in [2], section 3.3.1. must be applied.
3) In case of non sensitive applications material as specified in [2], section 3.3.2. must be applied.
4) For surface degreasing only uncontaminated detergents (e.g. Isopropyl Alcohol, Acetone) must be applied.
5) Approved solder and flux materials are stated in [4].
6) Capable epoxy resin and curing agent systems, formulated especially for strain gage bonding, must be applied as adhesive. The adhesive systems
   - Vishay® M-Bond 600 for oven curing process
   - Vishay® M-Bond AE-10 for room temperature curing process

   or products equivalent in composition and properties are approved for application. Shelf - and pot lifetime of the chemicals must not be exceeded.
7) Adhesive tape of the Electrical Tape - type as defined in [3], chapter 3 must be applied for electrical insulation.
8) Adhesive tape of the Aluminium - type as defined in [3], chapter 4 must be applied for thermal shielding.

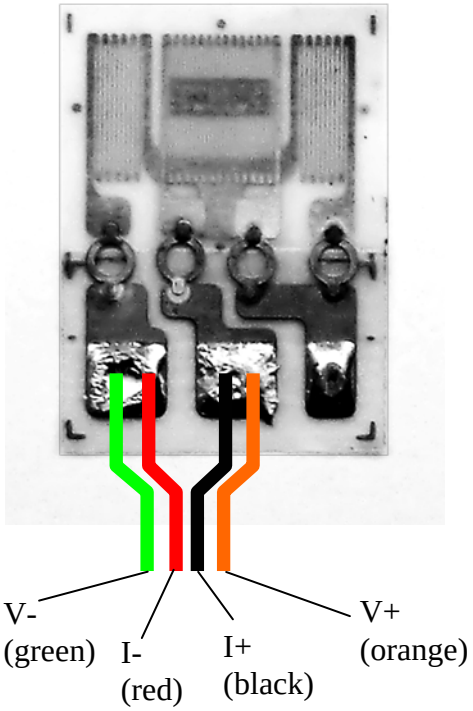

Figure 1: CLTS Sensor wiring scheme with wire configuration for non sensitive applications

3.2. Leadwires connection

1) To avoid damages at the sensors, soldering of the sensor leadwires must be performed before bonding a sensor in its final operating position.
2) In case of a non sensitive application the wire configuration as shown in Figure 1 must be applied as a four-wire RTD configuration.
3) In case of a sensitive application the colour code of the wires differs due to a different wire configuration compared to Figure 1, the connection scheme remains the same.

3.3. Application in operation position

1) The temperature sensors are of certain flexibility but must not be applied on surfaces other then smooth, plane or cylindrical surfaces with r ≥ 5 mm.
2) For application on surfaces different from the description above, additional adaptation measures need to be applied whereas a maximum thermal coupling must be realised. Necessary adaptation must be approved by the contracting entity.
3) Surface cleaning and sensor gluing must be applied as described in [5].

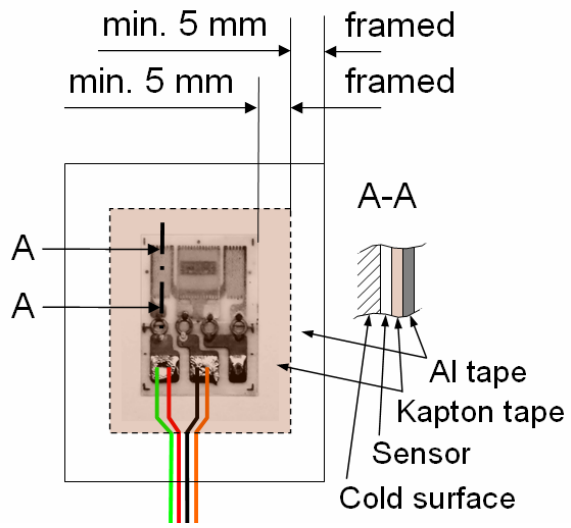

Figure 2: Sensor protection with adhesive tape

3.4. Sensor Protection and Labelling

1) After proper application in working position (see section 3.3) the sensor must be
   - electrically insulated with electrical tape
   - thermally insulated with Al – adhesive tape
   - as defined in Figure 2.
2) Any shortcut or wire grounding must be carefully avoided.
3) Sensors, applied to a plane surface or a surface with large curvature must be additionally fixed with a cover plate of 2 mm thickness (see Figure 3). The cover plate must be of the same material then the object the sensor is applied to.
4) The sensor must be unremovable labelled on the cover plate, showing the full sensor identification number as listed in the documentation.
5) For sensor applications on a tube surface, an adequate pipe clamp must be used for fixation of the cover.
6) The additional cover must not destroy any structures on the sensor.
7) Covers different then specified must be agreed with the contracting entity.

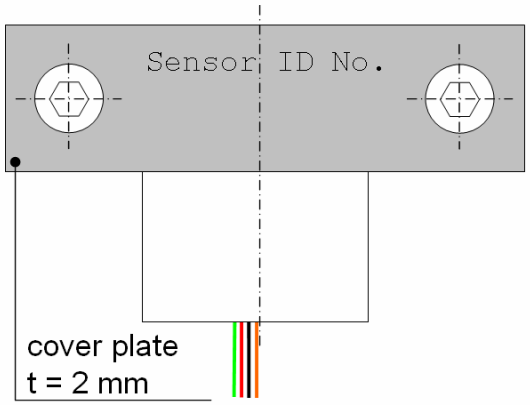

Figure 3: Bolted cover plate with sensor ID No. applied to a sensor in flat application.

4. Sensor Applications below 30 K

4.1. Materials

1) Only temperature sensors as specified in [1], chapter 3 must be applied. Other sensor types must be agreed with the contracting entity in writing.
2) In case of sensitive applications leadwire material as specified in [2], section 3.3.1. must be applied.
3) In case of non sensitive applications material as specified in [2], section 3.3.2. must be applied.
4) Adhesive tape of the Electrical Tape - type as defined in [3], chapter 3 must be applied for electrical insulation purposes.
5) Approved solder and flux materials are stated in [6].

4.2. Leadwire connection

1) To avoid damages at the sensors, soldering of the sensor leadwires must be performed before mounting a sensor in its final operating position.
2) In case of a sensitive application the sensor must be connected by applying a four-wire RTD configuration as shown in Figure 4.
3) In case of a non sensitive application the colour code of the wires differs due to a different wire configuration compared to Figure 4, the connection scheme remains the same.
4) The detailed connector to lead configuration for connection of a CERNOX® sensor is dependent of the packaging type. For details see [6].
5) The colour code of the leads must be assigned to the signal type as shown in Figure 4.

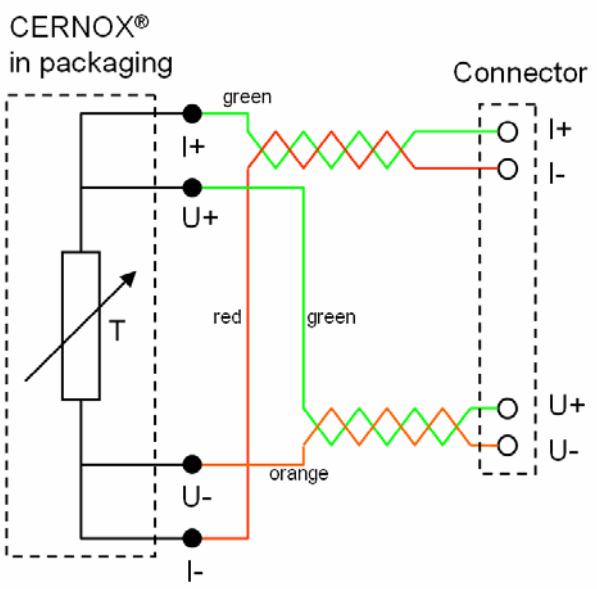

Figure 4: CERNOX® sensor wiring scheme with wire configuration for sensitive applications.

4.3. Application in operation position

1) To achieve correct measurements at low temperatures sensors need a proper thermal coupling to the surrounding being measured.
2) The applied solution must be agreed with the contracting entity in detail.

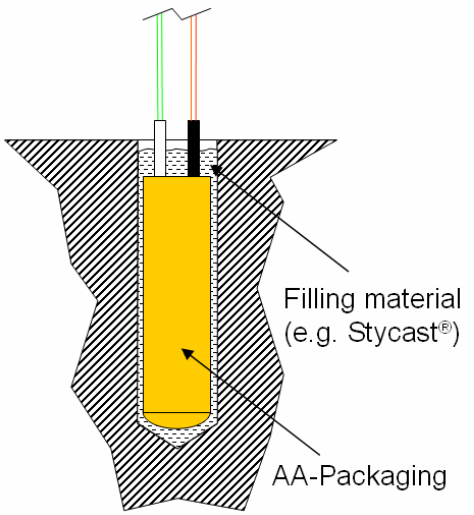

Figure 5: Sensor mounting in a rigid volume

4.3.1. Rigid body temperatures

1) For accurate measurement, the insertion of the sensor into the solid, representing the temperature surrounding, is essential. A solution as shown in Figure 5 might be applied. The use of the packaging type "AA" is recommended.
2) In case a sensor can be applied unremovable, for an optimum thermal coupling the sensor must be mounted in the hole by applying an adequate cryogenic epoxy resin like Stycast® 2850FT (for details see [6]).
3) For more detailed information on the installation process see [6].
4) In case a sensor must be applied removable, a slight amount of APIEZON"N" must be applied to the drill hole. In such a case the sensor must be secured against moving by applying an adequate lock plate on top of the hole. Leakage of APIEZON"N" by gravity influences must be avoided carefully.
5) A proper thermal shielding of the measurement position is required.
6) Virtual vacuum leaks induced by dead volumes must be avoided by applying adequate venting drill holes, respectively vacuum degassing of filling materials.
7) The shielding and application method (removable or unremovable) must be agreed with the contracting entity.

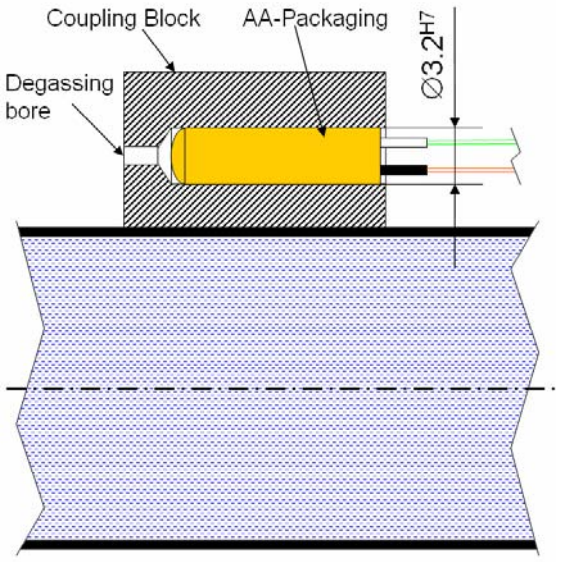

Figure 6: Sensor mounting on tubing surfaces

4.3.2. Low accuracy fluid temperatures

1) For measurements of fluid temperatures with low requirements on accuracy, the measurement at the outside of cryogenic tubing is sufficient.

2) A solution as shown in Figure 6 must be applied. The coupling block must be made from copper and being brazed to the tubing.
3) In case a sensor can be applied unremovable, for an optimum thermal coupling the sensor must be mounted in the hole by applying an adequate cryogenic epoxy resin like Stycast® 2850FT (for details see [6]).
4) For more detailed information on the installation process see [6].
5) In case a sensor must be applied removable, a small amount of APIEZON"N" must be applied to the drill hole. In such a case the sensor must be secured against moving by applying an adequate lock plate on top of the hole.
6) A proper thermal shielding of the measurement position is required.
7) The shielding and application method (removable or unremovable) must be agreed wit the contracting entity.

4.3.3. High accuracy fluid temperatures

1) For measurements of fluid temperatures with high requirements on accuracy, the sensor must be applied to the inside of cryogenic tubing within the fluid current.
2) A solution as demonstrated in Figure 7 must be applied.
3) The quill insert must be made from adequate stainless steel material showing a thin walled shaft.
4) A quill insert must be fixed He-leak tight by applying a tube fitting with cutting ring gasket (e.g. SwageLok®).
5) The construction must fulfil all requirements on pressure equipment if identified as such according to the European pressure equipment directive 97/23/EC [8].

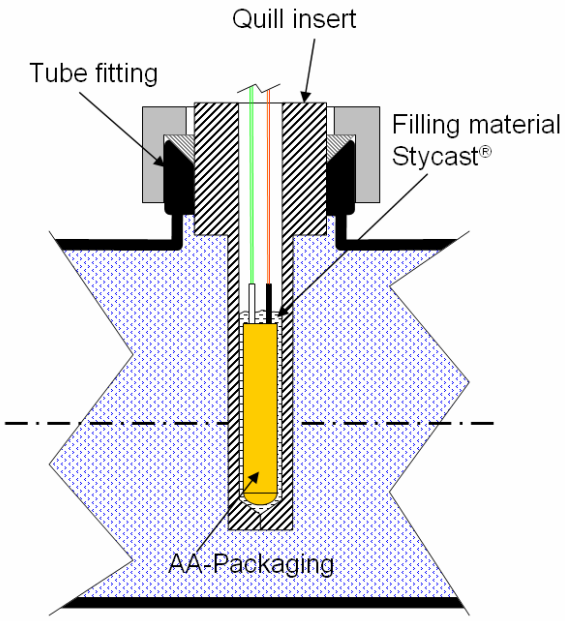

Figure 7: Sensor mounting in fluid current

6) For an optimum thermal coupling the sensor must be mounted in the quill insert by applying an adequate cryogenic epoxy resin like Stycast® 2850FT (for details see [6]).
7) Virtual vacuum leaks induced by dead volumes must be avoided by applying vacuum degassing to the epoxy resin filling.
8) When ever possible the temperature sensor must be applied in the centre of the flow.
9) For more detailed information on the installation process see [6].

4.4. Sensor Protection and Labelling

1) Any shortcut or wire grounding of lead wires must be carefully avoided.
2) The sensor must be labelled; if somehow possible in an unremovable manner; showing the full sensor identification number as listed in the documentation.

5. Wire Routing and Thermal Interception

1) All wire routing must be optimised for
   - low heat load,
   - low noise induction,
   - practical wiring paths.
2) An appropriate strain relief must be applied to the leadwire in the sensor position.
3) The leadwire must be thermally intercepted on the same temperature level as the sensor. For proper thermal interception of the lead wires see [6].
4) Before the lead wire is connected to an electrical feedthrough, it must be thermally intercepted at the temperature level of the thermal shield.
5) A free length of ≥ 300 mm in front of the electrical feed through must provide a low heat load onto the thermal shield.
6) The warm end wiring must allow an unhindered handling of the cable flange the lead wire is connected to.
7) Any solutions must be agreed with the contracting entity.

6. Sensor- and Leadwire Testing

1) To avoid installation of broken sensors or lead-wires the sensor with the leadwires installed must be tested prior to installation. The test must be performed with an adequate ohm-meter using a four-wire RTD configuration.
2) For testing, the sensor must be smoothly warmed e.g. by applying a warm air stream.
3) The test must be repeated after full installation.
4) No faulty sensors or leadwires are allowed.
5) All testing must be recorded within a dedicated protocol.

7. Connection to Feedthrough and Labelling

1) The leadwires must be connected to electrical feedthrough types specified by [7].
2) The dedicated choice of feedthrough (solder cup connection or plug connection) is dependent of the definition within the correlated detailed specification of the cryogenic system.
3) Only feedthroughs of the 4 – pin configuration must be applied. For the appropriate wire configuration see Figure 8.

4) In case of plugged connections a connector plug of the type LEMO® ERA.0S.304.CLL or equivalent in construction, performance AND quality must be applied.
5) The leadwires, connected to the feedthroughs, must be properly labelled close to the feedthrough. The labelling must show the full sensor identification number of the correlated sensor as listed in the documentation.

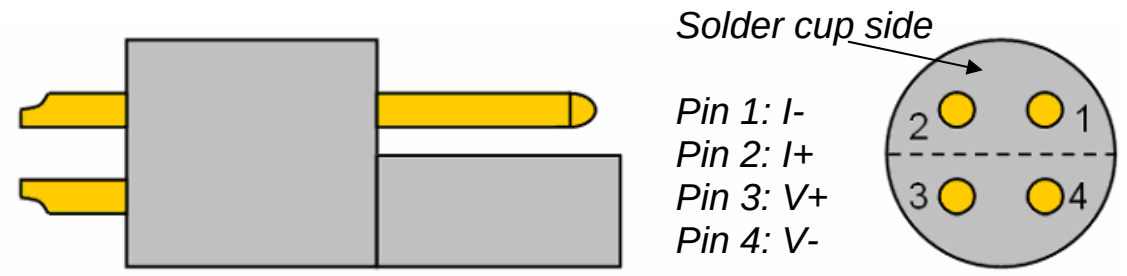

Figure 8: Leadwire configuration at the solder cups of a plug connector, respectively an electrical feedthrough with solder cups (see [7]). The figure shows the insert of the component only.

8. Documentation

1) The documentation must be completed and fully compiled latest after the sensor installation and wiring was completed and all sensors with wiring and connectors were fully tested.
2) The documentation must at least consist of:
   - sensor list,
   - calibration data and quality documentation of the sensors in use,
   - quality documentation of the wires and feedthroughs in use,
   - technical drawing of the sensor positions and wire routing,
   - testing protocols.
3) All documentation for each sensor in use must be assigned doubtless to the dedicated sensor by appropriate listing of sensors serial numbers and names used for labels and in technical drawings.

9. References

[1] Technical Guideline No. TR3.52e: Temperature Sensors for Cryogenic Purposes, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany, 2010

[2] Technical Guideline No. TR3.56e: Low Power Cabling for Cryogenic Purposes, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany, 2010

[3] Technical Guideline No. TR3.57e: Adhesive Tapes for Cryogenic Purposes, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany, 2010

[4] Strain Gage Soldering Techniques, Document Number: 11089, Revision 15-Aug-07, Vishay Intertechnology, Inc., http://www.vishay.com/docs/11089/tt609.pdf

[5] Strain Gage Installations with M-Bond 43-B, 600, and 610 Adhesive Systems, Document No.:11130, Revision 14-Apr-09, Vishay Intertechnology, Inc., http://www.vishay.com/docs/11130/b-130.pdf; 2010

[6] Appendix C, Sensor Packaging and Installation; Lake Shore Cryotronics, Inc.; http://www.lakeshore.com/pdf_files/Appendices/LSTC_appendixC_l.pdf; 2010

[7] Technical Guideline No. TR3.53e: Low Voltage Feedthroughs for Cryostat Applications, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany, 2010

[8] Directive 97/23/EC, European parliament and the council of the European Union, http://eur-lex.europa.eu, 1997