3. Technical Requirements

3.1 General technical requirements
3.2 Material requirements
3.3 Cleaning requirements
3.4 Recommendation for storage
3.5 Recommendation for gluing procedures
3.6 Recommendations during cutting and machining operations
3.7 Recommendation for cleanness
3.8 Recommendation for cleaning
3.9 Packing and transportation
3.10 Volume production steps
3.11 Read out panel production steps

4.1 Fabrication and control plan
4.2 Inspection, test and quality control plan
4.3 List of certificate and document required

3.1 General technical requirements:

The accuracy on the distance between the bakelite plate assures the performance of the chambers. This distance is maintained internally by spacers called buttons and by a frame that is glued around the bakelite edges. The tolerances on these spacer elements are specified on the attachment drawing (2.000±0.015). The accuracy of the button and frames is not sufficient to guarantee an uniformity of the gas gap distance. A permanent sag between spacers can occurs if during the glue operation excessive pressure is applied or a not correct restrain system is used. This effect can be measured using a local reference plane defined by button position and measuring the local deviations of the plane inside the button area.
Another important requirement is related to **the gas tightness** that is assured by a proper gluing and sealing of the edge frame and tube inlet and outlet.
The cleanness of the internal module surface is also very important, especially this condition must be assured before closing the chamber. In fact when the gas volume is formed there is no easy way to remove dirt inside modules which is connected with outside through a small tube. The cleanness and the absence of scratches on the inside surface is essential to guarantee the absence of discharge during the operating condition (8 Kvolt is applied between the bakelite plate).
A cleanness of the gas volume surfaces is also necessary for the **glue operation.** A proper cleaning method and surface preparation and is essential. A contamination from dust, oil and other materials must be avoided.
The graphite plane must be uniform and his resistively need to be in a specify range.
An insulating foil is glued to the graphite plane, this foil must not have wrinkles on his surface and no air must be trapped inside the foil.
Other important elements are the **high voltage connection** with the high graphite plane, this need to be reliable during working and handling conditions.
The inner surface of bakelite varnishing with linseed oil leads to obtain a low noise chamber, this is a critical operation because is done after the chamber volume is formed. The gas volume is not accessible easily any more and any inspection is very difficult. A good method for this operation must be chosen to obtain the best uniformity and polymerization and stability of the oil. The oil stability can be achieved using a proper linseed of and polymerization method.
The **read-out strips** are glued on a foam supports and no wrinkle on the surface must be present after this operation. A good planarity of the foam plus strip need to achieved when this are lying on a reference horizontal plane.
The connection between the chamber and the strip plane is another operation that require a good alignment with the chamber envelope and a good contact must be assure in all conditions with the graphite plane.
The **cable soldering** to the strips must be carried-out in a proper clean condition and with proper material and process.
A **final assembled chamber** must stay in a specify envelope and his planarity measure in a horizontal reference must be in a tolerance.

3.2 Material requirements:

The RPC construction is carried out using a number of basic materials or components that have to be certified and tested for acceptance. This section described the technical parameters and the acceptance test, whenever needed, of all unit components.

Material for the gas volumes

1. **bakelite plates.**

Names:	Celfen 2
Produced by:	PanPla – Italy
Maximum size:	1.6x3.2 m^2
Thickness:	2.00±0.17 mm
Max Roughness:	0.2 μm
Resistivity range:	2-7x10^{11} +/- 30% Ωcm
Resistivity measurement:	For each plate the resistivity is measured at the production site.

Using a special tool, the plate is pressed between two small metal electrodes which are connected to a voltage generator ranging 10 to 1000 V. The measured current gives the material resistivity.
The measurement is carried out at room temperature (20 ^{0}C), with a relative humidity bellow 50%.
Plates outside the indicated range are discarded.

2. **Graphite paint**

Name.	DAG 305 solved in MIBK
Produced by:	Akenson
Drying time:	1 hour

3. **Insulating films**

Material specification:	Polyetilenterephatale	
Name:	DIEPOL	
Produced by:	Effegidi S.P.A.	
Thickness:	190 μm	
Dielectric rigidity (@25 ^{0}C-50 Hz)	150 KV/mm	(ASTM D149)
Dielectric constant (@25 ^{0}C-50 Hz)	3.3	(ASTM D150)
Volume resistivity (@25 ^{0}C-DC)	10^{18} Ω	(ASTM D257)
Surface resistivity (@25 ^{0}C-50 Hz)	10^{14} Ω	(ASTM D257)
Isolation class:	B	(DIN 57 530)
Melting temperature:	260 ^{0}C	

4. **Hot melt adhesive**

Name:	TERMOMELT PS 856
Produced by:	LEUENBERGER & c S.P.A.
Working temperature:	150-170 ^{0}C

5. **Spacer edge frame and buttons:**

Material name:	Polycarbonate
Production method:	Injection molding
Spacer thickness and button:	2.000+/-0.015 mm

6. **Epoxy adhesive for spacers**

Name:	Scotch Weld DP 460
Produced by:	3M
Work life (@ 23 ^{0}C):	60-90 min
Min. polymerization time (@ 23 ^{0}C):	4-6 hours
Max shear stress with polycarbonate:	2.8-3.4 Mpa (after 24 hours)
	10% (after 5 hours)
	25% (after 6 hours)
	90% (after 7 hours)

7. **Conductive adhesive for copper pads**

Name:	E-Solder n^0 3025
Produced by:	Conductive Adhesive

Material for Strip Panels

1. Copper-PET composite film ????

Name:
Produced by:
Material specification: Copper/Polyetilenterephtalate
Gluing strength: >2.5 N/ 15 mm
Copper thickness: 40 +/- 3 μm
PET thickness: 190 +/- 5 μm
Total thickness: 233 +/- 13 μm

2. **Rigid plastic foam**

Name: Styrofoam
Produced by: Dow Chemical Company
Density: 30 Kg/m^3
Compression elastic module: 10-20 Mpa
Compr. Strength @ 10% deformation: 12-20 Kpa
Thickness: **????** 2.6+/- 0.3 mm

3. **Hot melt adhesive**

Name: TERMOMELT PS 856
Produced by: LEUENBERGER & c S.p.A.
Working temperature: 150-170 ^0C

3.3 Cleaning requirements:

The recommendations that guarantee the cleaning conditions are reported in §§ 3.4, 3.6 and § 3.7.
The Contractor has to supply his own plan to guarantee the final cleaning conditions of the components.

3.4 Recommendations for storage

The builder needs to have an efficient system for storage and tracking of the raw materials and the finished parts, in order to avoid damage and contamination of the surface in the parts and mixed-up in the raw materials. It is important to avoid that the bakelite plates, modules and chambers are subject to a bending moment due to the gravity, this occurs maintaining the structures horizontally. This must be avoided especially for a long period of time, because can procure a permanent deformation on the bakelite plate, modules and chamber.

3.5 Gluing procedure

Gluing procedures and glue material have to be approved by INFN.
Before the gluing the following procedures have to be carried-out:
-Identify the backelite.
-Examination of surface.
-Dimensional check.
-Degreasing of all pieces before gluing; this is considered one of the most important operation.
- All gluing must take place at room temperature with relative humidity below the 50%.
Excessive level of humidity will end up in no glue curing, and the glue will not became hard any more.

3.6. Recommendations during cutting and machining:

During all cutting and machining process a superficial protection layer is removed. For this reason a contamination of the material can occur with coolant and lubricating fluids used for cutting and machining. The method used dry or wet have to be approved by INFN.
The roughness indicated in the drawings must be verified, and cracks in the parts or holes and craters are not allowed.

3.7. Recommendations for cleanness.

All area in which the assembly and gluing takes place must be maintained on overpressure. A filtering system must maintain the air clean with the class n. 100 000 and the relative humidity needs to be less than 50%. All the operator need to wear gloves, hat and clean dress to avoid dusk, finger prints and hair on the material. Especially this must be respected in the area in which the surface of bakelite plate are exposed. We consider this strictly necessary in the processing and assembly the gas volume to avoid the contamination of the inside surface of modules.

3.8. Recommendation for cleaning.

The cleaning of components must be reduced at the minimum using a proper handling, storage methods during the fabrication process. The are where this operations takes place has to conform with the recommendation reported in the § 3.7. However where is necessary to clean components, it is important to avoid starch and the surface and cleaning agents that are not approved by INFN. We recommend using special clean soft cloth and isopropilic alcohol. **????**

3.9. Recommendations for packing and transportation:

All parts must be packed in a plastic bag and grouped in wood crates that can be piled up. The wooden crates have to be large enough to later contain completely assembled chambers.

The storage is going to be done in a protected area.

The transportation with covered trucks has to protect the wood crates from exposure to rain.

3.10. Volume Production steps.

Step 1 – Graphite coating

The graphite paint, DAG305 solved in Methyl-Isobutyl-Khetone is prepared and sprayed on a single bakelite plate for testing the surface resistivity.The bakelite plates to be painted are masked with paper tape along the edges. The width of the region to be masked is 9 mm.
The paint is sprayed by means of high pressure airless spraying system working in closed volume under a hood. The masked are placed, in horizontal position, under graphite jets produced by a set of nozzles moving at constant speed along the plate. At the end of the spraying procedure the plate is kept still a few minutes under the hood, in a air stream, until the solvent has fully evaporated. The graphite layer is thickened, along the plate with a further coat of paint applied with a brush. The masking tape finally is removed.

Resistivity test of the graphite coat.

The resistivity of each plate is measured according the scheme indicated in figure. The resistance measured across the four point of figure must be within fixed values according to the plate dimensions. For instance, for 1000 x 2000 mm^2 $R_{12}=R_{34}=120$ KΩ +/-30 %.

P1-P2 Resistance	$V_1 < R_{12} < V_2$
P3-P4 Resistance	$V_1 < R_{34} < V_2$
P1-P4 Resistance	$V_3 < R_{14} < V_4$
P2-P3 Resistance	$V_3 < R_{23} < V_4$

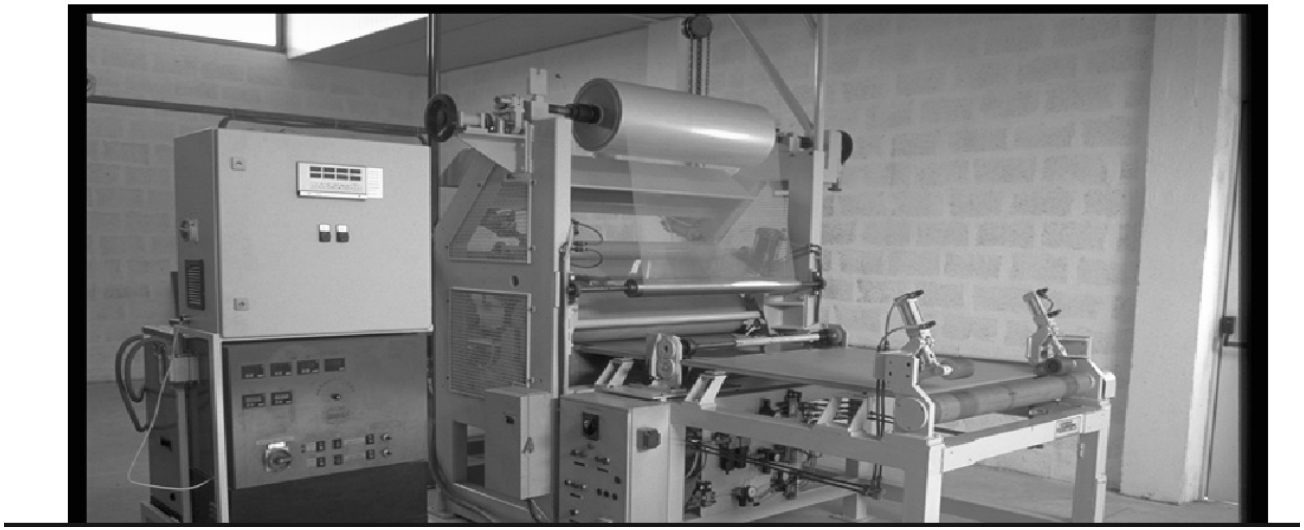
Step 2-Gluing of the copper electrode

A 70 μm tin-coated copper pad is glued on the graphite paint using a silver-epoxy adhesive. The curing time is 8 hours.

Step 3-Gluing the PET isolating film

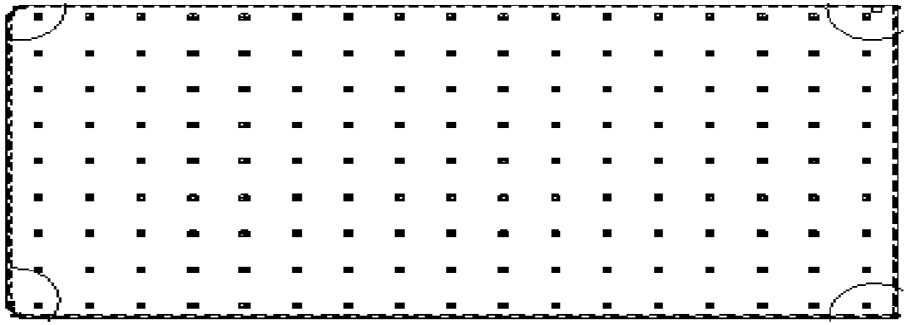
The graphite electrode is isolated from the external readout panels with a PET film, 190 μm thick, which is glued on the graphite with a “hot melt” type adhesive, that is applied using the facility shown in the following figure. The adhesive used is Thermomelt PS 856, produced by Leuenberger & C. The adhesive is heated above the melting point and then pumped from the melting point up to an extrusion head which is kept at constant, well-controlled temperature. The PET film is rolled at constant velocity by a rubber coated rotating iron cylinder, which keeps it in contact with the extrusion head so that an uniform layer of hot adhesive (50-70 mm thickness) is deposited on its surface. A few second later, the film is pressed by the same cylinder against the bakelite plate. The plates are introduced one by one in the gluing facility with a 10 cm free gap between them to facilitate their separation.

3 min·man /2m plate
3 - 4 persons



Step 4-Gluing of the spacer edge frames

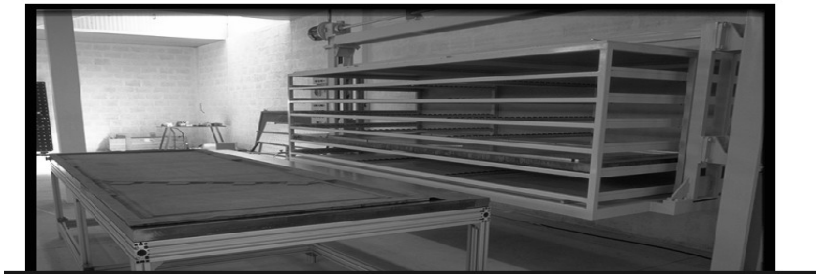
Two panels prepared as described in step 3 are glued together using polycarbonate spacer and edge frames to form a Gas volume.
The pattern of the spacers and the edge frame is shown in figure.
An epoxy adhesive (Scotch Weld DP 460 produced by 3M) is used.
A special facility is used for this operation. The glue dispensers, spaced 100 mm apart, are mounted on a rigid bar as long as the maximum width of the plates. The bar translates long the maximum width of the plates.
The bar translates along the plate in steps of 100 mm so that the glue can be dispensed over all spacer positions.



Spacers pattern (100 mm side square) in a Gas Volume

At each step, the following operation are performed in parallel for all spacers positions of the column:
deposition of drops of adhesive
deposition of spacers
A third operation, deposition of a second drops of adhesive on top of the deposed spacers, is accomplished in a second working cycle for all spacers in the plate.
The edge frame is glued with the same procedure. A thin bead of glue is applied (by hand) all along the edge. The frame segments are put in position one in each side of the plate, and a second string of glue is put on top of the frame.
The second panel is then overlapped to the first one.

During the curing time the Gas volume is kept under a rubber cloth at the relative pressure of –200 mbar and at constant temperature of 35 ^{0}C.



The two components of the adhesive are mixed together only inside the dispensers, i.e. very short time before the application.
Relevant parameters for this step:
Glue workable time after components are mixing: 60 min
Typical time between components mixing and pressure application: 20 min
Time during which the gas Volume is held under pressure: 4 hours

Spacer gluing test

Every five gas volume (about 1000 spacers) a spacer is glued on a small test plate and cured during the 8 hours under standard conditions. After that time, the spacer is gradually stressed for 10 min under controlled conditions up the breaking point. The test is successful if the breaking occurs with a normal stressing force of over 8 Kg. In case of successful test, the last 5 Gas volume assembled before test are discharged.

Step 5-Gas inlet and outlet mounting

The gas inlets are mounted on the Gas volume according to the following procedure.
Two holes are drilled on each short side of the frame, near the corners. The drill positions for the two holes are fixed by a jig. Chips produced by drilling are continuously removed by an aspirator system. The gas inlets are then glued in the provided holes.

Step 6-HV and ground connections

To allow connection of the graphite electrodes to the high voltage supply, a small hole of 1.5 mm diameter is made on the PET film in the position corresponding bto the center of the two copper pads glued on both graphite coating. The HV pole connection is made during final assembly of the Unit. For the ground pole connection an enamel-insulated wire of 0.4 mm diameter is used. One end of the wire is soldered on the corresponding copper pad and the other end is fixed close to the HV connection position. The wire runs along the edge of the gas volume and in embodied in it as explained in the next section. The soldering is protected with a HV insulating tape 40 μm thick.

Relevant parameter for this step:

Enameled wire isolation:	2 kV
Tape isolation:	6 kV
Check:	Visual inspection

Step 7-Edge sealing

The edges sealing of the bakelite plates are isolated using a melt which fills the two channels section 2x3 mm that remain around the edges of the frame. The hot melt is injected inside these two channels with a hand moved proper tool with the gas volume lying on a working table. This operation is also needed to embody in the gas volume structure the enamel insulated wire mentioned in the previous section. The excess of melt is cut out after it has cooled down to room temperature.

Relevant parameter for this step is:

Working time:	15 min
Cooling time:	2 hours
Check:	visual inspection

Table for edge sealing with hot melt

Step 8-Outer spacers

Self-adhesive paper label, 0.2 mm thick, are glued on both faces of the gas volume at the position of each inner spacer to avoid, under the pressure applied by the support frame, any contact with the neighbor elements except the spacer positions. This eliminates any stress that could deform the gap inside the gas volume.

Step 9-Inner surface varnishing

A batch of 20 modules, sandwich between two rigid panels, is placed in vertical position with the long side inclined at about 100 mrad with respect the horizontal plane. The gas inlets are connected with a plastic flexible pipes, as shown in the photo, to a steel cylinder, containing the varnish, which can be moved along the vertical direction.

The surface of the liquid inside the cylinder lies initially below the lower gas inlets. The cylinder is then lifted at constant speed so the varnish level visible through the transparent pipes. The varnish circuit is sealed and, during the filling, the pressure inside the gas volume is kept negative with respect to the atmosphere to compensate the varnish static pressure. The cylinder is subsequently lowered at very low speed up the complete emptying of the gas volume. One hour later the gas volumes are connected to airflow for 36 hours up to complete polymerization of the varnish.

Relevant parameters for this step:

Varnish composition:	linseed oil/eptane = 40/60
Depletion rate:	3 cm/min
Time of coating cycle:	2 hours
Air flow:	30-40 vol/hour
Total time including varnish polymerization:	48 hours

3.11 Read-out panel production steps

Step 1-Strip milling

A composite film made of 40 μm copper film glued on 190 μm thick PET support is machined with a number of end mills mounted on the same revolving shaft. The position of the mills can be adjusted along the shaft. The pattern has wide strips alterned with tiny strips. The machined film is winded in coils of arbitrary length.

Relevant parameters for this step are:

Maximum workable width:	1.3 m
Strips position tolerance:	+/-1 mm
Working speed:	10 m/hour

Check the strips position (QC)

During the strip milling, the strip position is checked every 20 meter. The film is pressed against a plexiglas bar which has a reference mask for the position of all strips. The test fails is found outside the correct position by more than 1 mm. In this case the last 40-meter of strips produced before the failure are cut out and discarded.

Step 2 Strip panel gluing

Assembly of the **longitudinal** strip panels is done in the following steps:

1. A composite film of 40 mm cooper on 60 mm PET supported is glued on the rigid foam plate 2.7 mm thick with the cooper surface outside. The facility used is the same described in step 3 of the gas volume production. The adhesive is also the same.
2. With the same procedure the strips film is glued on the other face of the foam with the aluminum strips outside.

Assembly of the transverse strip panels requires one additional operation. Indeed, since the transverse strip panel

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4.1 Fabrication and control plan

The Contractor, after the adjudication, has to provide

-Fabrication and control plan.
This has to be approved by INFN (Pisa) and has to include the time schedule for the construction, test and shipment. INFN and the Contractor will decide at which stages INFN representatives have to check the fabrication of the components. This will be notified in advance to the firm by mail or fax.

-Technical specifications for the manufacturing process (cutting, machining, gluing, etc). All the manufacturing processes must be described by the Contractor and approved by INFN. The description has to include the area in which the work is going to be done and the identification of any subcontractors.

-The Contractor has to supply a plan to assure the cleanliness during the manufacturing process.

-Non conformities should be notified and approved by INFN representatives.

-Repairs should be notified and approved by INFN.

-The Contractor has to demonstrate to have a quality control plan that assures the control for all manufacturing processes.

4.2 Inspections, test and quality control plan.

The inspections occur in different phases of the manufacturing process to assure the proper quality. The supplier must have his own quality assurance plan that will be approved by INFN.

We can identify the phases in which the inspections must take place.

a) Raw material procurements.
b) Graphite coating.
c) Gluing of the PET isolating foil
d) Preparation of the button and frames.
e) Gluing the bakelite plates together.
f) Modules inner surface varnishing
g) Preparation of strips and gluing on a foam.
h) Soldering cable to the strips
I) Chamber assembly

Some of the inspections will be done in collaboration with INFN experts.
The supplier has to collect in a book the results of the inspections.
We require a mechanical inspections on build module opening it to verify the internal surface quality.

4.3 List of certificates and documentation required

The Contractor have to supply to INFN the quality control plan and book.
The quality control book must contain:
-A complete certificate set of the materials used

-records of the inspection and test at the factory (including surface finishing and dimensional checks)

-A protocol of the gluing procedure.

-Report of visual inspection of surface in term of cleanness and present of scratch.

-Report of dimensional check.

-Report of the inner surface varnishing

-Report of the mechanical tests.