PROJECT FINAL REPORT

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Clean Sky

ACTIPPTSENS

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4.1. Final publishable summary report.-

A. Executive Summary.-

Turboshaft noise and toxic gas emission reduction require monitoring technologies for fuel consumption and power transmission optimization that can accurately measure pressure, position and temperature with the view of advancing in the a new turboshaft concept for a new green and silenthelicopter family. The overall objective of the ActivePPTSens consortium is to develop a demonstrator in the field of new sensors technologies for pressure, temperature and position with the main aim of providing improved technologies for safety, reliability and reduced environment impact of air-engines.

In order to achieve this goal, the project´s approach has been to identify and define first the specifications, for the sensors to be developed for turboshaft engines, for the measurement of temperature and pressure of air, fuel and oil and of shaft speed based on inputs from the Topic Manager and provide an in-depth analysis of the several existing technologies found on the market for the adopted sensors in the frame of the project. This analysis included the state of the art of the commercial products, analysis of the commercial products with respect to the specifications, discussion of the main criteria of selection, elaboration of a final comparative matrix and recommendations.After a preliminary cost analysis of the project prototypes, R&D work is carried out to develop a contactless torque sensor to measure the torque and the rotation speed of either a stationary axle or a rotating shaft without contact using stationary electronic components and a piezoelectric MEMS pressure sensor based on the completely new development using electrospun piezoelectric nanofibers to obtain a higher pressure sensibility, easy integration under structural elements and complex geometrical shape capability and incorporation of a Pt100 thermocouple under IDE electrodes for measuring the operating temperature.

A new contactless torque sensor demonstrator has been developed providing an improved overall sensing performance. Its maininnovative features are that torque is measured without contact with the shaft, usesan innovative torque sensing technology based on a deformation mechanical converter to amplify the small angular displacement and its placement in the shaft is non-intrusive and weight in line with other commercial products. However, the price is, nowadays, not competitive due mainly to the low scale product. Regarding the overall goal of developing a pressure sensor with the active element would be entirely new and made from piezoelectric nanofibers has been achieved with the the correct microstructure, has been accomplished and is a significant step in going beyond the state of the art.

B. Description of the main S&T Results.-

B.1.-PROJECT CONTEXT AND OBJECTIVES

Turboshaft noise and toxic gas emission reduction require monitoring technologies for fuel consumption and power transmission optimization that can accurately measure pressure, position and temperature with the view of advancing in the a new Turboshaft concept for a new green and silent helicopter family.

The overall objective of the ActivePPTSens consortium is to develop a demonstrator in the field of new sensors technologies for pressure, temperature and position with the main aim of providing improved technologies for safety, reliability and reduced environment impact of air-engines, based on the specification of TURBOMECA, leader of the SAGE5 demonstrator of the Clean Sky JU.More specifically, the concrete objectives of the project are:

- O1: Identification and definition of specifications for the sensors to be developed for turboshaft engines, for the measurement of temperature and pressure of air, fuel and oil and of shaft speed.

- O2: Provide an in-depth analysis of the several existing technologies found on the market for the adopted sensors in the frame of the ActiPPTSens project. This should include, for the different sensors:
  - ✓ O2.1: State of the art of the commercial products.
  - ✓ O2.2: Analyse the different commercial products with respect to the findings of O1 and consultations with distributors or manufacturers.
  - ✓ O2.3: Discussion around the main performances and criteria of selection.
  - ✓ O2.4: Elaboration of the final comparative matrix.

- O3: Carry out a preliminary cost analysis of the prototypes to be developed in the project:
  - ✓ O3.1: Contactless torque sensor CTS.
  - ✓ O3.2: Piezoelectric MEMS pressure and temperature sensors.

- O4: Develop sensor devices and prototypes:
  - ✓ O4.1: Contactless Torque Sensor CTS starting from the one developed and patented by CEDRAT TECHNOLOGIES as technology for PSA cars but to fulfil the needs of O1. It should measure the torque and the rotation speed of either a stationary axle or a rotating shaft without contact using stationary electronic components.
  - ✓ O4.2: Piezoelectric MEMS pressure sensor based on the completely new development of using electrospun PZT nanofibers to obtain a higher pressure sensibility easy integration under structural elements and complex geometrical shape capability. The sensor to integrate a Pt100 thermocouple under IDE electrodes for measuring the operating temperature.

- O5: Carry out the diffusion activities of the project as well as to perform a market analysis to assess the potentialities of the different sensors proposed in the frame of ActiPPTSens.

As we will see in section B.2, objectives have been achieved except O4.2 where only a partial fulfilment of the objective has been obtained but its main challenge, fabrication of a piezoelectric nanofiber mesh with the correct microstructure, has been accomplished and is a significant step in going beyond the state of the art. Also, a suitable route to solve this has also been identified.

B.2.-MAIN S&T RESULTS

In order to achieve the objectives stated for the project, work was subdivided into 6 workpackages (WPs): WP1: Management; WP2: Turboshaft Concept Analysis and Sensors Specification; WP3: Technologies analysis and selection; WP4: Development plan; WP5: Sensors and prototype development and WP6: Communication: Dissemination and Exploitation. The results obtained in each are summarised in the following sections.

WP2.-Turboshaft concept analysis and sensors specification.

The main objective of this WP was the identification and definition of specifications for the sensors to be developed for turboshaft engines, for the measurement of temperature and pressure of air, fuel and oil and of shaft speed.

In order to achieve this objective, the methodology followed was to use the requirements of the project topic manager TURBOMECA as guidelines, study the new concepts and developments about turboshaft engines in projects NEWAC, DREAM, VITAL and TEENI as references and also relevant experts of TURBOMECA were invited to one day workshop to help the consortium for the open questions.

The consortium studied the requirements of project topic manager TURBOMECA that were provided in their three documents: CLEANSKY – Pressure, position and temperature sensor requirements, CLEANSKY – Contactless torque sensor requirements and General Specifications for Accessories.

A one day workshop was organized, and many considerations for the sensor specification were clarified. In general, the sensors are expected to function reliably and with high precision. Priority was given to minimise any fuel leakage and/or damage to the turboshaft engine during failure/accident. In addition, in case of engine failure/accident the sensors must be able to continue working for at least 5 minutes so that the engine condition can be monitored. The durability, weight, and cost of sensor packaging are also important factors to be considered. A trade off among different solutions would be made by taking into account the development cost, the design analysis, and the steps in manufacturing and tests. The specification related to aeronautics standards may not be fully taken into account in terms of qualification, though the technical choices should be made in the direction to the standards, because the Technology Readiness Level of the developed sensors corresponds to the validation of technology in laboratory conditions at the end of the project.

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The main considerations for the position sensor are rotation speed, torque, temperature, concentricity, radial displacement of shaft versus engine casing, axial displacement of shaft, and surrounding environment of shaft. Based on some specific and practical points, a compliance matrix of understanding the requirements and the difficulties in the sensor development was generated. Then, a Specification table was elaborated to meet the functional requirements for the position sensor.

For the temperature and pressure sensors, the first consideration was to avoid the fire environment by changing the location of the sensors, which is the situation at present. Other considerations include reduction of wiring, reduction of the quantity of temperature sensors, accuracy, drift control, mechanical design, life span, cost, accessibility, and elimination of recalibration. Some of these considerations have desirable values:

- ✓ Calibration: The electronics must not need to be recalibrated if the sensor is substituted with another one.
- ✓ Drift: The new sensors should have a better drift behavior, so it was expected that their accuracy does not get out of the range in 10 years.
- ✓ Life-span: At present these sensors are required to function properly during the life-span of the engine established at 150.000 hours.
- ✓ Accessibility: Sensor replacing/changing needs to be completed in 15 minutes so that they can be changed in the field.

These requirements were complex. To work effectively, a requirement matrix was generated that bridges the requirements with solutions and/or difficulties. The requirement items were classified as critical and desirable. Based on the clarified requirements, the sensor specifications were defined.

The deliverable for this WP is the*Specification Review*. The deliverable reported the work carried out by the consortium including clarification of the requirements for the sensor development and the identified specification for each type of the sensors. The core of the deliverable is the sensor specification that was presented in tables, including:

- ✓ Specification of air temperature sensors
- ✓ Specification of oil temperature sensors
- ✓ Specification of fuel temperature sensors
- ✓ Specification of air pressure sensors
- ✓ Specification of oil pressure sensors
- ✓ Specification of fuel pressure sensors
- ✓ Specification of position (speed) / torque sensors

This work package has been accomplished as described in the proposal. It was the beginning of the project, involving many different considerations. The specifications defined in this WP were used in the following ones, though some were left open for deciding in the following WPs.

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WP3.-Technologies analysis and selection

The main objective of this WP was to provide an in-depth analysis of the several existing technologies found on the market for the adopted sensors in the frame of the ActiPPTSens project.

The work was broken in four phases for the different sensors:

1. State of the art of the commercial products.
2. Analyse of the different commercial products with respect to results of WP2 and consultations with distributors or manufacturers.
3. Discussion around the main performances and criteria of selection.
4. Elaboration of the final comparative matrix.

In this context, the market for the two kinds of sensor was studied and potential commercial solutions were investigated.

PRESSURE AND TEMPERATURE SENSORS:

Concerning pressure and temperature sensors, the different technologies were investigated in regards of the specification issued during the WP2. Several technologies are available actually on the market but only few are really applicable in an aeronautic program. The initial performances for sensors are reviewed (resolution, accuracy, stability, bandwidth…) coupled with the extra performances for this specific project (temperature range, reliability, packaging, volume,…)

From this stage, the main technologies were identified respectively for the pressure sensors and for temperature sensors:

- Piezo resistive technology.
- Capacitive technology.
- Piezoelectric technology.
- Surface Wave velocity (SAW) based emerging technology.

for pressure sensors and

- NTC or PTC sensors.
- SAW.

for temperaturesensors.

TORQUE AND SPEED SENSORS:

Concerning the torquemeter, the work was very similar and the main technologies were identified to cover the torque measurement and the speed measurement aspect.

- Strain gage as plugged solution.

- SAW transducer as plugged solution.
- Magnetostrictive technology.
- 2 Optical discs based solution.
- Differential Magnetic transformer.
- 2 Phonic wheels using variable reluctance sensor based solution (the initial Topic Manager solution).

for torquetransducers and

- Variable reluctance technology
- Hall effect technology
- Optical sensor

for speedtransducers.

As already mentioned for the other kind of sensor, the criteria of selection were not only based on the initial performances but also on the severe environment and some maintenance criteria. Even if many commercial products,with good performances, are available in the market, only a few reliable products are possible to be used for the turboshaft torque measurement.

A lot of work was done to select the technologies and the associated commercial products by meeting the different manufacturers, by analysing a large number of datasheets and by studying the proposed solutions in regard to the initial specification from WP2.

Finally, a final comparison matrix, with several criteria, was established for these sensors to highlight potential technologies proposed in the frame of ActiPPTSens and to select potential back-up solutions in case development work to be carried out in WP5 showed some problems versus the initial requirements.

In order to rationalize the very extensive amount of data gathered, three categories were identified to filter the different products: As a consequence, the specification requirements weresummarized in three categories:

CAT1: Critical specifications

CAT2: Desirable specifications

CAT3: All specifications

For the temperature and pressure sensors, from more than 750 potential candidates, less than 11 were identified as final potential solutions by comparing their advantages and drawbacks.For the torque and speed sensors, only 4 potential candidates were identified with more or less potential for an aeronautic application.

From these inputs, the partners proposed to the topic manager two back-up solutions for the pressure and temperature solutions and for the torque and speed meter. These were:

1. The OEM series from Keller and more specifically, the series 10 which is already used in the aeronautic sector.
2. Kullite sensor ETL/T-312 (P&T). It satisfies everything and measures both pressure and temperature.

For pressure & temperature sensors and

3. The 4000 series from NCDE GmbH with an emergent technology but with a very high potential Torque range and its accuracy, Temperature range and the maintenance phase.
4. The powerlignserie from Kop Flex but this is a similar solution used initially by TM.

for torque sensors.

The Topic Manager selected the OEM series from Keller for the Pressure and Temperature sensors and the 4000 series from NCDE GmbH with magnetostrictive technology based for the torque and speed sensors.

From this selection, the partners used these data for their in depth analysis and as a road map to develop their own solutions: Performances of the commercial market versus performances of the proposed solutions were investigated in the next WPs.

WP4.-Development plan.

The objective of this WP is to carry out a preliminary cost analysis of the prototypes to be developed on WP5 looking at such things as the cost of materials and electronic components, fabrication process, man power costs etc. so that the consortium has an idea of the cost figures for the different Technologies to be used on WP5. Work on each sensor technology was carried out by the same partners that would be doing their development in WP5; CEDRAT TECHNOLOGIES for the torque and speed sensors and TECNALIA and ICV-CSIC for the pressure & temperature sensors.

TORQUE AND SPEED SENSORS:

The elaboration of this simple cost analysis was directly linked to the proposed solutions.This cost analysis included at least the cost analysis of materials and electronic components as well as the cost analysis of the fabrication process of the sensors.

This work was very preliminary because some results were not achieved. Nevertheless, from the baseline issued from WP5, CEDRAT TECHNOLOGIES worked on a preliminary MAIT integration able to fix a rough cost figure which is based on very similar product that the company has that mix electronic and mechanical parts to have a full mechatronic system; see Figure 1.

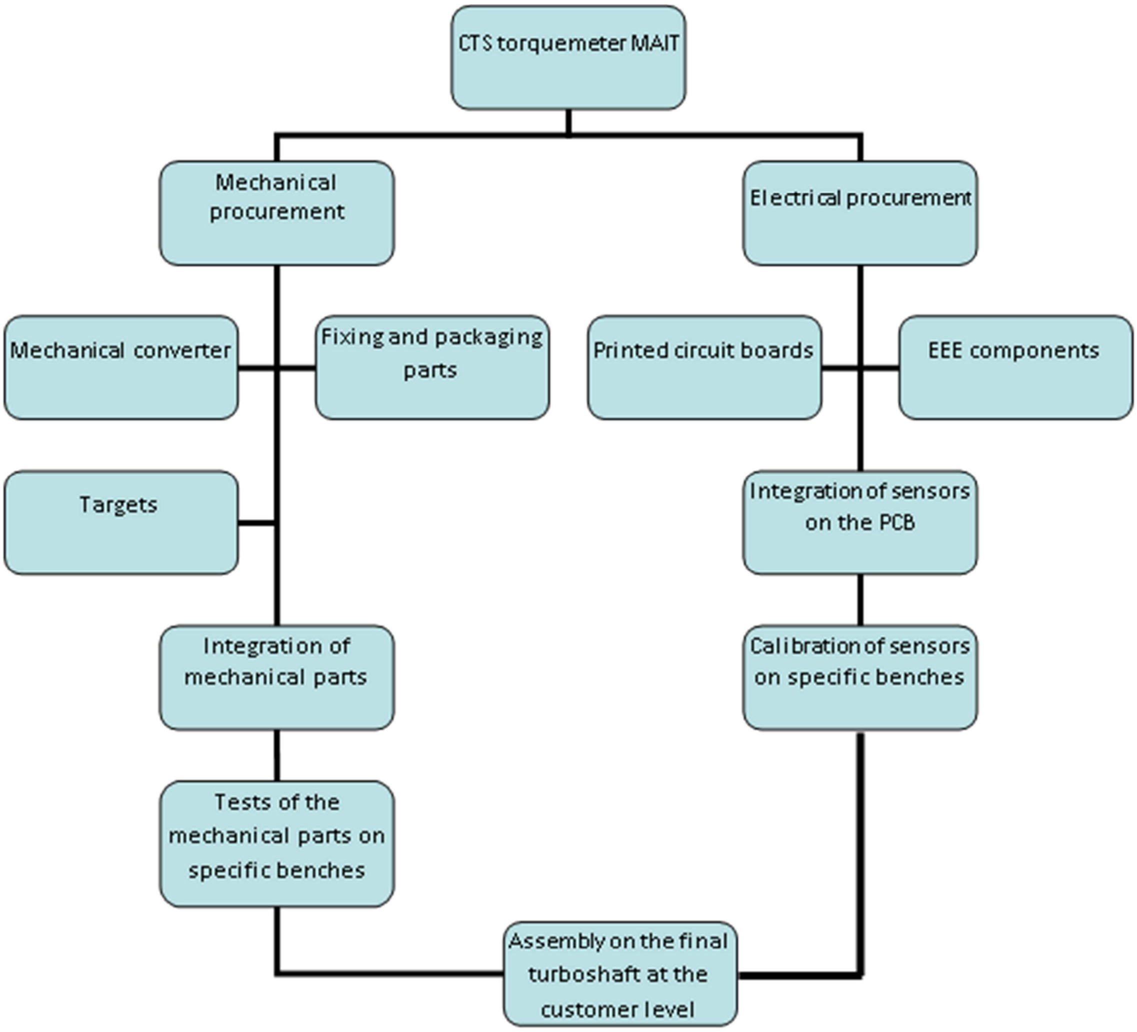

Figure 1 Preliminary flowchart of the torquemeter

The preliminary figures obtained are summarised in Table 1 for the main mechanical parts and electrical parts and in Table 2 the costs for the assembly integration and test of the mechanical parts and electrical parts.

Parts in Units	1 Unit	10 Units	100Units
Mechanical converter	1.250	600	400
Targets	300	150	100
Fixing and packaging parts	600	400	300
PCBs	500	350	275
EEE components	100	50	35
TOTAL	**2.750**	**1.550**	**1.075**

Table 1 Cost figure of themain mechanical parts and electrical parts.

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Assembly in Units	1 Unit	10 Units	100Units
Mechanical converter + targets → 1	200	100	50
1 + fixing and packaging parts	200	100	50
Tests of the mechanical sub-function	100	75	50
PCB + EEE components on the shaft side	100	50	25
PCB+ EEE components for the conditioning	300	150	75
Calibration Tests of the electrical sub-function	300	150	75
TOTAL	**1.200**	**625**	**325**

Table 2 Cost figure of the Assembly integration and tests phases.

This very preliminary cost figure issued before the WP5 results was based on the large volume production. With the cost figure issued from WP5, the price for one unit is more in the 10k€ range principally due to the high cost of the parts and due to a non-appropriate production bench.

PRESSURE AND TEMPERATURE SENSORS:

In contrast to the torque and speed sensors discussed previously, in this case, the objective was to develop, in collaboration with ICV-CSIC, a very novel nanofiber-based PZT sensor and fully characterize it functionally so that with these inputs (performed in WP5) it would have been possible to have some very crude estimate of its development plan. It should be pointed out, nevertheless, that such a plan would have been, at best, very approximate and with many uncertainties given that we would have been dealing with a sensor that had just “come out” of the prototype stage and, also, because TECNALIA nor ICV-CSIC are not industrial companies so that such evaluations are not within their usual activity.

As is fully explained in the next section, this was not possible even though a very considerable effort was made (given the important novelty of this development). The basic reason is that it was not possible to obtain a clear piezoelectric response from any of the various prototypes produced for poling and characterization.As a consequence and in agreement with the proposal, it was decided to use a commercial “back-up” solution. Since the sensors are commercial, data regarding the development plan is not applicable for such commercial products.

WP5.-Sensors and prototype development.

The objective of this WP is the development of sensors devices and prototypes with the three selected functionalities of Pressure, Position (Speed) and Temperature. The technologies considered as potential candidates for the prototype fabrication are:

- ✓ Contactless Torque SensorCTS. Developed and patented by CEDRAT TECHNOLOGIES as technology for PSA cars. The CTS Contactless Torque Sensor measures the torque and the rotation speed of either a stationary axle or a rotating shaft without contact using stationary electronic components. This unique compact structure measures torque by means of a low-cost standard eddy current sensor. This technology can be cost effective given its automotive industry heritage.

- ✓ Piezoelectric MEMS sensors. Currently under development by TECNALIA and ICV-CSIC. Piezoelectric sensors based on electrospun PZT nanofibers show higher pressure sensibility, longer life cycle, easy integration under structural elements and complex geometrical shape capability. The sensor design adds a Pt100 thermocouple under IDE electrodes for measuring the operating temperature. The sensor data is managed by a microcontroller with CAN bus communication.

<u>TORQUE AND SPEED SENSORS:</u>

From the WP2 inputs, CEDRAT TECHNOLOGIES was involved in the design and the manufacturing of a torquemeter prototype. The proposed solution, as identified in the beginning of the project,is based on a mechanical converter able to transform a torque to a linear position. We will call this mechanical part the mechanical converter. To explain the role of the converter in a few words, the shaft’s torsion is transmitted to the converter which creates deformation of one half of the converter’s arches in one direction, and the other half in the opposite direction. Thus the goal is reached, the converter transforms angular shift into significant axial shift and it is only necessary to mount two targets on the converter. Now to measure the torque one simply needs to measure the linear displacement of the two targets as shown in Figure 2.

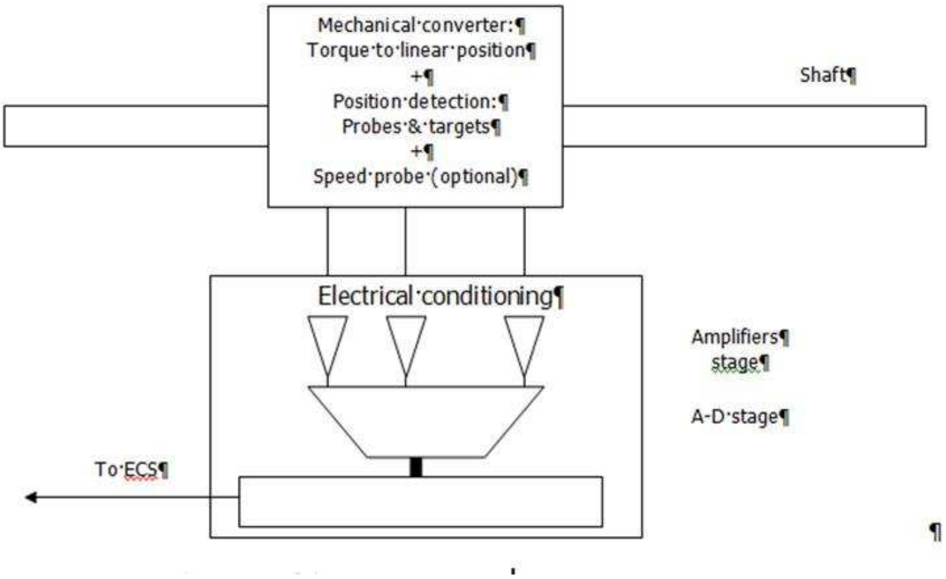

Figure 2 Main architecture of the CTS torquemeter.

To sense the linear stroke, two targets are used and a contactless differential eddy current based position sensor is integrated. This function allows a non-contact torquemeter and so could be used in infinite rotation torquemeter. To complete the sensing function, an additional speed sensor was integrated based on a hall effect. All these parts are located near the shaft.A second important part was the conditioning of the sensors. A design based on electronic components was used to transform the variation of the Resistance and inductance of the Eddy current sensor to electrical signal and to send towards the ECU to be analyzed and corrected if necessary.

As this system is the combination of mechanical and electrical performances, a basic work breakdown structure was initiated covering the entire development phases:

- A-Modelling.
- B-Design.
- C-Procurement and manufacturing.
- D-Testing.

<u>A – Modelling:</u>

Modelling of the mechanical and electrical behaviour as well as the gain of the main performances was carried out. From this stage, a mechanical feasibility was established: The mechanical geometry was established and the mechanical performances were computed.

Two solutions were investigated to be compact with respect to the allocated volume near the shaft. A less compact solution was chosen but with better performance.Mechanical sensitivity, stress and thermal analysis, centrifugal effects and modal analysis were the main criteria studied during this mechanical modelling phase.

The results of the Von Mises analysis are shown in Figure 3.

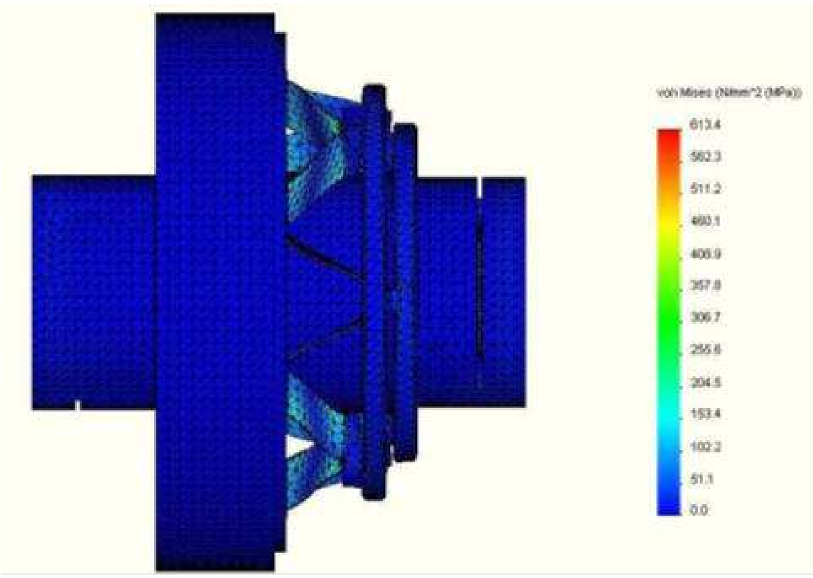

Figure 3 Von Mises stress analysis calculation.

The main results of this this phase were:

- The mechanical sensitivity of the inner target was about: 0.373 µm/Nm at 1000 Nm.
- At 10000 rpm, the outer target mean displacement was around -10µm and the inner target mean displacement was around -13µm.
- The first mode of vibration occurs at 1037Hz.
- The thermal senstivity at the displacement level gave an outer target displacement of 106 µm and an inner target displacement of 130 µm for 125 °C.

It should be kept in mind that a stroke variation is the picture of the torque measurement.From this stage, an electrical feasibility was established for the torque and for the speed sensing function.

For the torque sensor, as already mentioned, the structure developed by CTEC is employed. It consists in a torque to displacement “transformer” on the rotor. This displacement should be sensed. In the project the proposal is to sense the displacement using Eddy Current Sensors (ECS) on the stator, as those are contactless sensors. These probes are PCB probes, especially compact and robust for the application, are integrated on a PCB ring that targets the rotor to measure the displacement. This PCB is integrated close to the shaft, so the temperature sensor is also integrated on this PCB. The temperature sensor is a PT100, which is a thermal varying resistance. The resistance varies linearly with the temperature, which makes it easier to process. This torque sensor PCB has 6 electrical interfaces, 2 for each CS probe, and 2 for the temperature sensor.

This PCB is connected to the front-end board where there are two conditioning stages for ECS probes. These conditioning stages are based on the ECSµ10 core, but with no gain and offset setting through potentiometers, in order to reduce the volume required. The outputs of the ECS stages are sampled on the front end, as they are critical signals. Sampling was performed using a 16bits ADC.

For the speed sensor, the proposed development consisted in building a simple encoder dealing only with one rotation direction (which is the case here). The proposed principle was to have a known number of discrete elements on the rotor (tooth or magnets), and a simple sensor is used to detect those elements. The angular position is known by counting the elements, and the speed is known by measuring the time difference between two elements.An ECS can be used to detect the presence / absence of conducting teeth on the rotor.

This solution presented the main advantage that it did not require to add elements on the rotor; it is only required to machine the teeth in the rotor structure. The structure was made of aluminium, perfectly fitted for an Eddy current application. For the integration, the idea would be to place this probe directly on the front-end board, and to target the rotor on its outer diameter in a tangential fashion through a small "window" as shown in Figure 4.

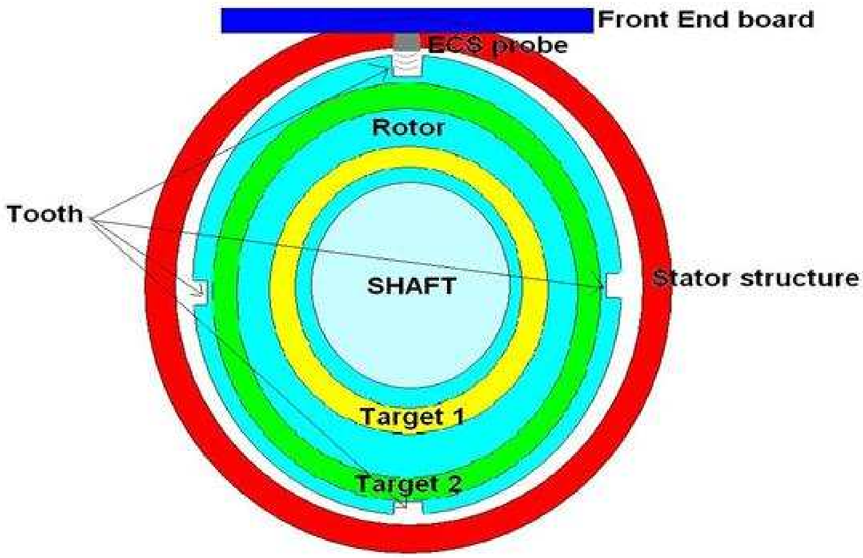

Figure 4 Speed sensor with ECS and 4 teeth.

For the conditioning stage, an additional ECS conditioner core was used, with the comparator stage, so that a binary "digital" output was obtained, depending on the presence or absence of a tooth. In rotation, there is a rising and a falling edge for each beginning or end of the tooth.The value of the speed is only known when a new tooth appears. In order to guarantee a 50Hz refresh rate of the speed measurements for a rotation at 300rpm (5Hz), it was required to use a minimum of 10 teeth equally distributed around the circumference of the rotor, which means that there are 10 known positions per rotation; see Figure 5.

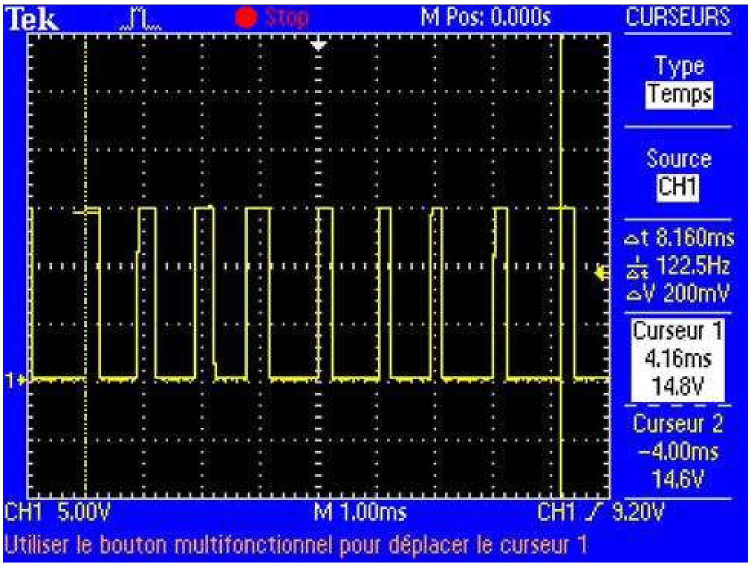

Figure 5 Output of the comparator for 8 teeth at 7300rpm.

Concerning the processing, it was chosen an embedded µ-controller to have an autonomous solution even if this solution is not entirely well appropriate concerning the aeronautics standards. This µ controller manages successively:

- The look-up tables for the positions sensors.
- The treatment between the measured stroke and the torque output.
- The counter of pulse for the speed measurement.
- The final DACs to obtain two analog outputs, one for the torque and one for the speed.

This processing could be in the future integrated into the ICU.

With the work described in this phase, *all the technological bricks have been analysed and ready to be implemented during the design phases.*

B – Design:

The final design of the torquemeter was investigated and including the mechanical design of the mechanical converter and the packaging as well as the electrical design of the signal conditioning and associated processing.

Several views of the proposed torquemeter are shown in Figure 6.

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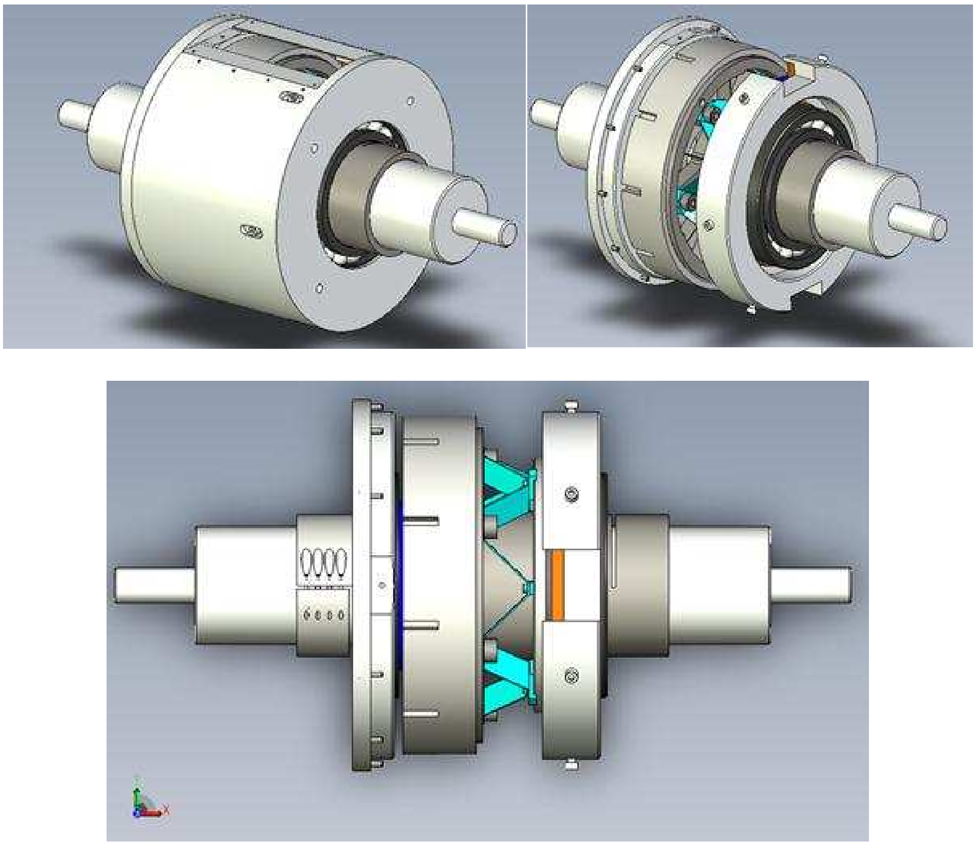
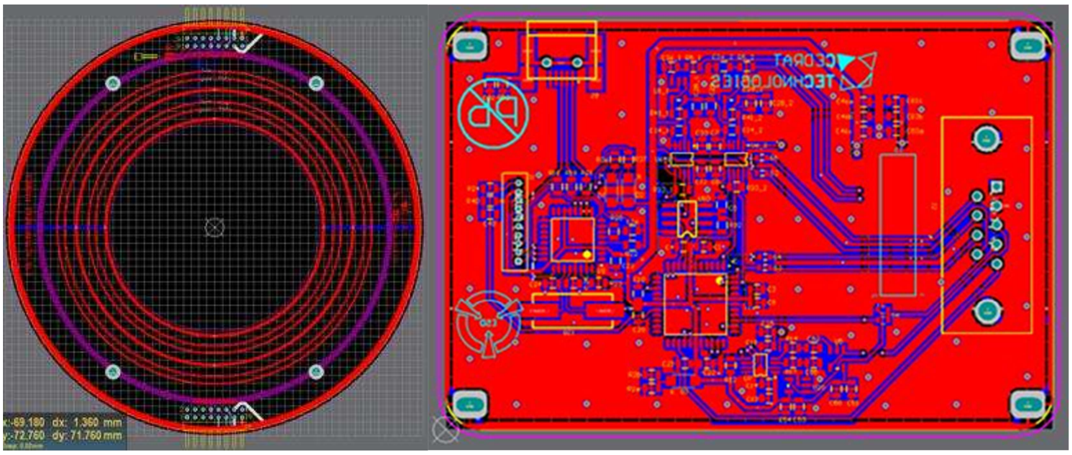
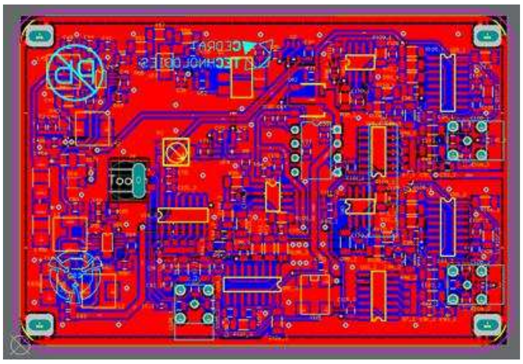


Figure 6 Several views of the CT2S in small torque configuration.

The PCB for the probes has 8 layers, with a total thickness of 800µm.It is shown, together with the PCB for the for the front end conditioner, in Figure 7.



(a) **(b)**



(c)
Figure 7PCB for the torque probes(a)& (b) and PCB for the front end conditioner (c).

The main design features of the contactless torque sensor are summarised inTable 3.

Feature	Value
Mechanical torque sensing technology	Contactless angular to linear converter
Electrical sensing Technology	Eddy current sensors in differential
Maximal Torque	+/-1000Nm
Accuracy @ ambient	+/-1.5%
Sensitivity	2.57 mV/N with 2.5V offset as 0Nm
Modulation error	<0.5%
Output	Analogue 0-10V
Speed sensing technology	10 teeth sensed w/ electrical sensor (see under)
Electrical sensing technology	Eddy current sensor
Speed range	0-10000rpm
Sensitivity	2000rpm/V
Output	Analogue 0-5V
Embedded electronic	Yes
Dimensions (without shaft)	Diameter: 170mm x Length: 161mm
Approximate Weight	4.5 kg
Shaft diameter	50mm

Table 3 Main design features of the contactless torque sensor.

C – Procurement and Manufacturing:

During this phase, all the subsystems were procured, manufactured (PCB and EEE mounting) and integrated at CEDRAT TECHNOLOGIES.Figure 8 shows the assembled torquemeter and its test bench.

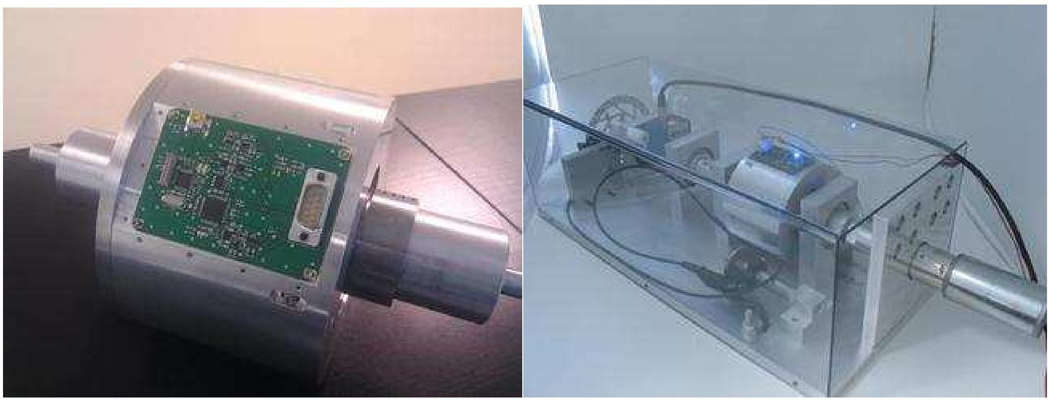


Figure 8 Torquemeter assembled and ready to be tested in its test bench.

D – Testing:

Since CEDRAT TECHNOLOGIES was not able to provide the couple torque and speed in the same time, a specific test plan was elaborated to take into account this aspect; see Figure 9. Coupled with specific tests done by TM in their facilities, the torquemeter was fully tested and the performances were checked.

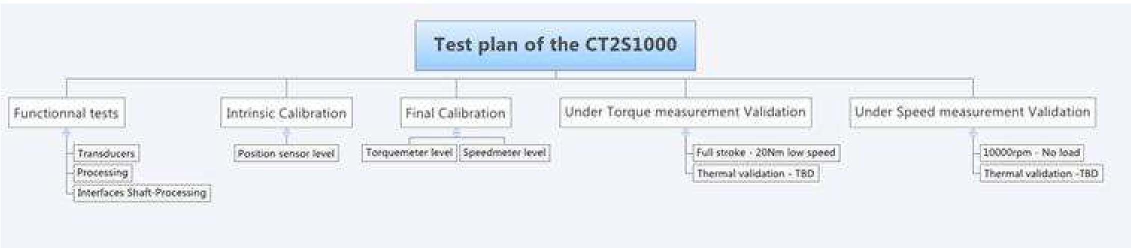


Figure 9 Test plan.

To carry out this test plan, a dedicated test bench was designed and is shown in Figure 10.

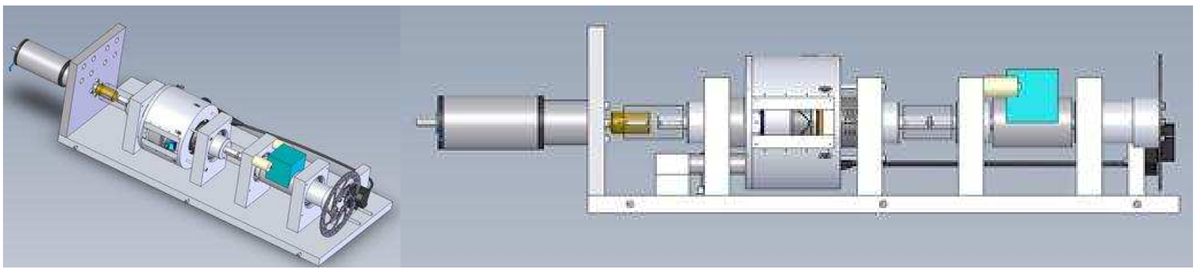


Figure 10 Test bench at CEDRAT TECHNOLOGIES.

It consists of a shaft equipped with a torque and speed sensor used as reference. Basically it is built around a motor able to provide enough speed to check the behaviour versus speed.As the sensing principle is based on the linear stroke measurement of the differential probes, the test bench uses a shaft more compliant able to simulate the maximum stroke under 20Nm instead of 1000Nm. This allows using a motor with less power.To apply a torque on the shaft, a brake using a bicycle brake will block the shaft in the +/-20Nm range. The reference sensor is a NCTE Gmh torque sensor. The range is +/-50Nm/10000rpm and the accuracy class is 0.1%. It has a sensitivity of 80mV/Nm and is mounted in line with the proposed torquemeter.

As explained before, the torque measurement is based on the stroke measurement of the two Eddy current sensors. As first step, a calibration is required to linearize the output of the ECS so that the torque output will be linear. The torque output is computed as the difference between the two linearized ECS outputs. This allows to increase the gain, and to compensate the thermo-mechanical behavior.The second step was to validate the functional performance. In static conditions, the CTS shows a linearity of approximately ±2% on its nominal range of ±14.5N.m (±1000Nm), and its gain is approximately 177mV/Nm.

The torquemeter was measured in low/medium speed to validate the accuracy during rotation. An averaging processing using 10 measurements was implemented: When no averaging wasused, the modulation error has amplitudesmaller than 50mVpp, i.e. less than 1% of the measurement range. When averaging is used, the system becomes almost insensitive to the modulation error. This was tested up to 3000rpm.The speed output is refreshed ten times per rotation, and it has a sensitivity of 0.5mV/rpm (or 2000rpm/V).

PRESSURE AND TEMPERATURE SENSORS:

The objective was to develop, in collaboration with ICV-CSIC, a very novel nanofiber-based PZT sensor, not available in the market or at a prototype level, and fully characterize it functionally. Such a development requires the following work to be carried out: development of the sol-gel (ICV-CSIC), development of the electrospinning solution, electrospinning of the solution to deposit the nanofibers on the appropriate electrode, thermal treatment of the nanofibers to transform the nanofibers into the adequate PZT nanofibers, encapsulation of the PZT nanofibers, poling of the nanofibers and sensor design and testing(TECNALIA, ICV-CSIC). All these constitute the partial objectives that need to be achieved sequentially and will be briefly discussed below.

DEVELOPMENT OF THE SOL-GELs:

The nanoparticle dispersion technique is essentially a two-step process where ceramic nanoparticles are synthesized and then incorporated into a chosen polymer matrix that is mainly necessary to maintain the necessary viscosity and surface tension required to produce fibers by electrospinning. The critical processing step in this technique is controlling the dispersion of the nanoparticles in the polymer before the electrospinning process, which is the main reason why the sol-gel technique was used to introduce the ceramic nanoparticles inside the polymeric nanofiber backbone.

In the sol–gel process, a solution of metal compounds or a suspension of very fine particles in a liquid (referred to as a sol) is converted into a highly viscous mass (the gel). In general, the soluble sol–gel precursors are combined with a solvent and polymer and are then electrospun. A main concern with this method is the miscibility of such chemicals and their reaction kinetics. The latter concerns have not been studied in the published literature for electrospun ceramic fibers.

A further complexity introduced in this work was to use dopants in the original formulation to enhance the PZT performance as a piezoelectric sensor. Donor dopants doants (i.e., Nb replacing Ti or Zr lattice sites) were used in the new formulations studied since they are expected to influence the coercive electric field, piezoelectric coupling factor and aging which would result in an enhancement of electromechanical coupling so that the PZT sensor will also improve its sensibility giving a higher electric signal with the same mechanical stress that undoped PZT. From all the possible dopants, Nb was chosen as the best candidate to achieve an improved PZT sensor.Two different sols were developed:

Sol A: Compositions of PZTN, ($Pb(Zr_{0.53}Ti_{0.455}Nb_{0.015})O_3$) + 3 %wtPbO, were processed using metal-alkoxide sol–gel chemistry. Excess lead was used to compensate lead loss during sintering. The preparation route is shown inFigure 11.

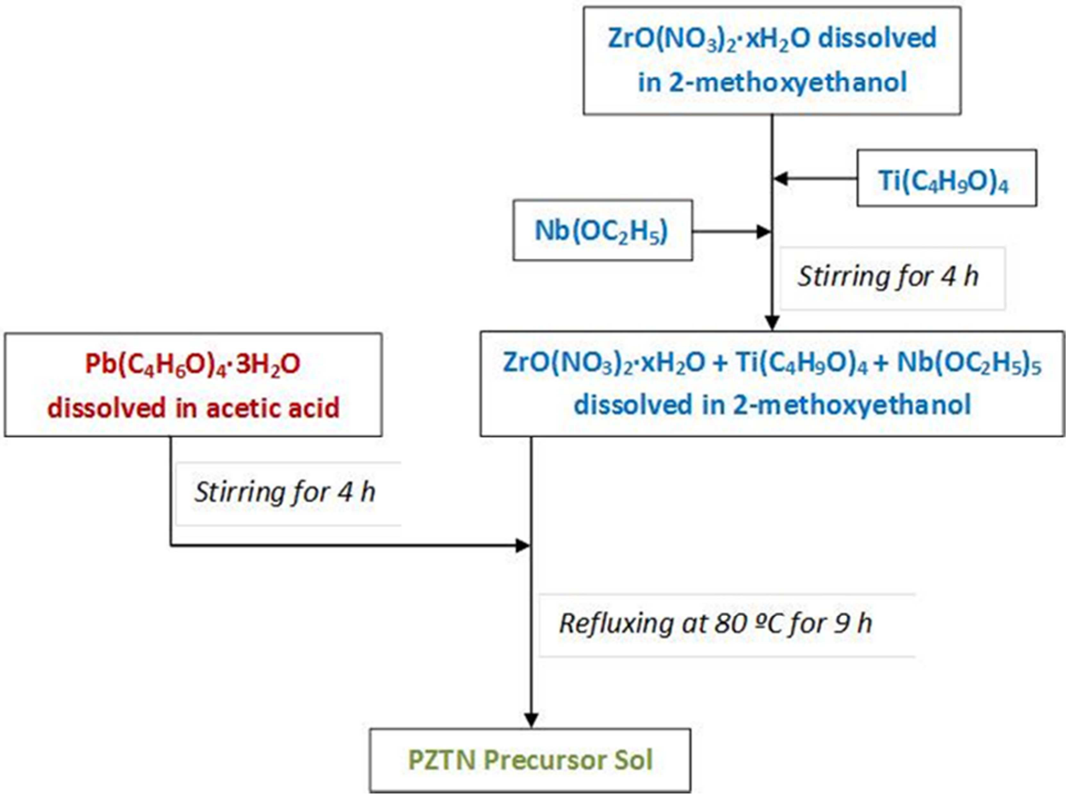


Figure 11 Schematic view of the preparation of the PZTNb precursor sol A.

Different concentrations of the PZTN in the sol solution were prepared and checked ranging between 0.3 and 1 M. After the pyrolysis and calcination of samples, they were characterized by differential thermal analysis (DTA) and thermo gravimetric analysis (TGA) in order to optimize the heating schedule and by X-ray diffraction, see Figure 12. Well-defined perovskite peaks with higher intensity are obtained, showing a PZTNb is rhombohedral structure, which actually agrees with the formulated stoichiometry. Some traces of PbO can be still detected (attributed to the starting excess) but no secondary phases were ever observed. The main problem encountered was that the total weight losses are quite high, around 65 %, which could generate cracks and defects in the PZT nanofibers during the thermal treatments.

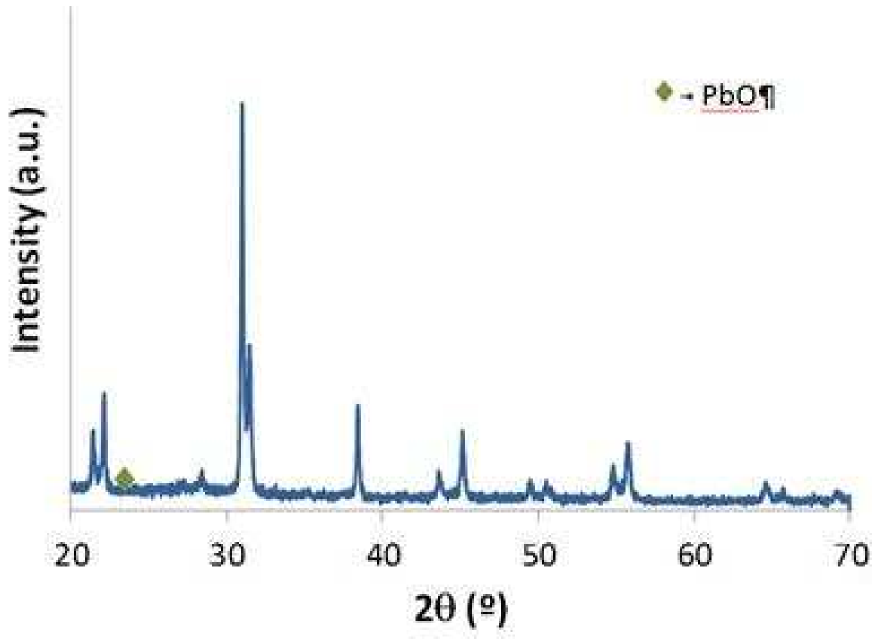


Figure 12X-ray diffractogram of the gel powder A calcined at 800 ºC.

Sol B: The preparation route is shown inFigure 13. The reason for developing sol B is to diminish the nanofiber shrinkage attributed to the high weight losses observed during calcination.

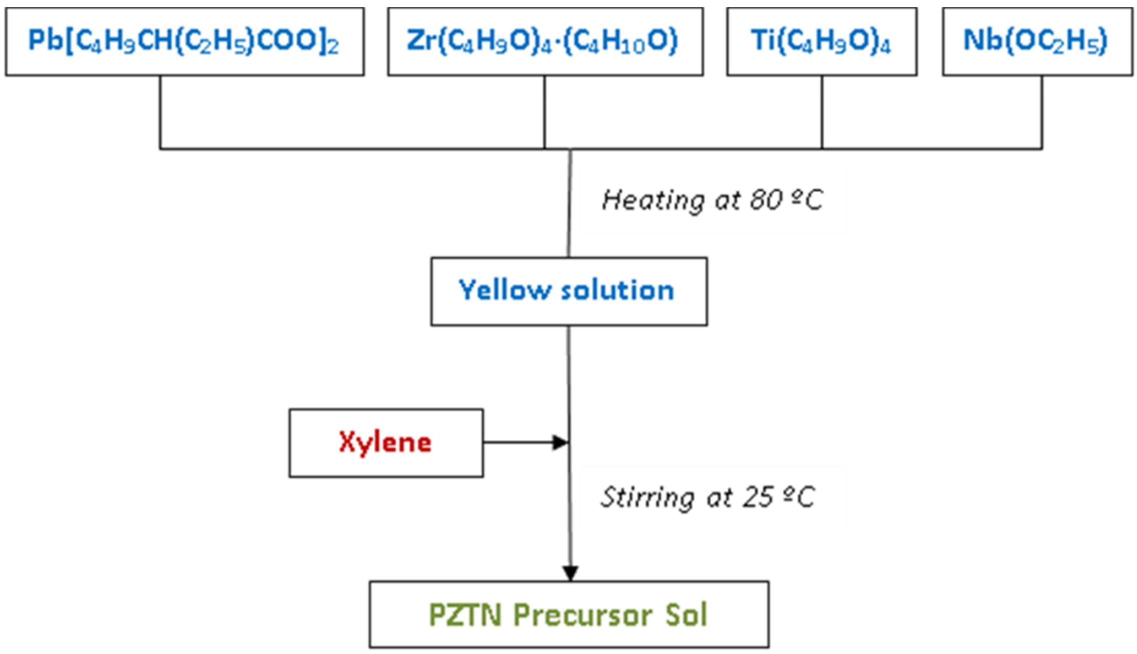


Figure 13 Schematic view of the preparation of the PZTNb precursor sol B.

In this case, the X ray plot of the gel powder treated at 800 ºC, Figure 14, evidences a single-phase perovskite. Actually, the peaks correspond to a mixture of rhombohedral and tetragonal perovskite structures which is usual in a PZTN composition at the morphotropic phase boundary. No secondary phases were detected at this temperature. Total weight losses, around 55 %, are lower in this case than in the sol A.

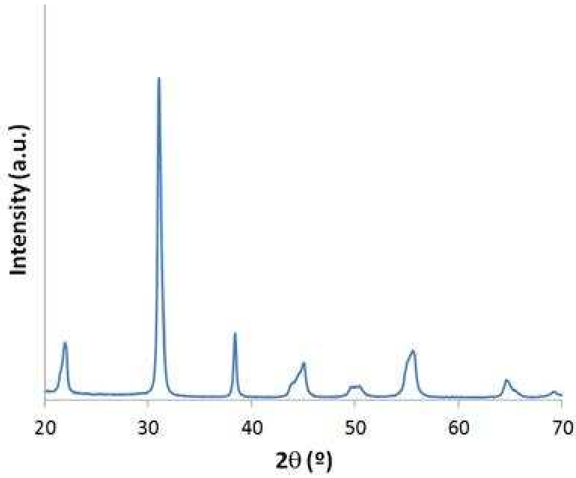


Figure 14X-ray difractogram of the gel powder B calcined at 800 ºC

Back-up Sol: As was seen when nanofibers were thermally treated, even sol B gave rise to large shrinkages and breakage of nanofibers so a search for commercially available PZT sol-gel material was carried out and sufficient amounts bought to develop the electrospinning precursor solution.

ELECTROSPINNING

The electrospinning process begins when the preparation of the solution which requires, at least, three different ingredients: the sol-gel a polymer that will be used as a binder and a suitable solvent or solvents. These have to be mixed together in adequate proportions so that it has the correct properties for its electrospinning and conversion into nanofibers; mainly polarity and viscosity. The nanofibers are produced once the solution is subjected to a high electrostatic field between the needle tip and the collector (which is the name given to the device or place where the nanofibers will be deposited). The solvents that have been added to the solution are eliminated, by evaporation, during the stage when the jet has been ejected from the needle but has not yet arrived to the collector. The polymer will be eliminated in a subsequent thermal treatment.

***Electrospinning with the developed sol-gel A*:** The first step was to develop the electrospinning solution.After several trials and consultation with the specialized literature, the following procedure, and ingredients, was used to produce the electrospinning solution. Materials: sol-gel A, distilled water, PVAc (Mw ≈ 500,000), 96% cosmetic grade ethylic alcohol and methanol.

The two sol-gel components were to mix in a reflux flask, during 3 hours at 80 ºC. After this, 100 ml of distilled water are added and the reflux process was carried out again for 6 more hours at the same temperature. Once this hydrolysis stage is finished, the PZTNb sol-gel was filtered out.In parallel to the previous procedure, a second solution is prepared that will be used as binder so that it can be electrospun. This solution (after several trials) consists of 18% weight of PVAc dissolved in ethanol/methanol (in relation 20/80). The next stage is the condensation one. In it both solutions are mixed together, binder solution and the filtered PZTNb sol-gel, in a ratio 0.8 to 1 (weight) giving rise to the electrospinning solution (Figure 15) which, as mentioned before, is the starting point for the electrospinning process.

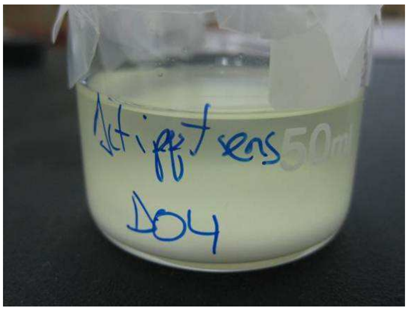


Figure 15 Electrospinning solution ref D04.

Several solutions were prepared varying the time of stirring during the condensation phase and the amount of acetic acid added in the acidification stage to optimize and understand their effect on the morphology of the nanofibers.

After carrying out an extensive electrospinning parameter test matrix that included two different types of collectors (C1: paper + metallic plate covered with aluminum foil and C2: metallic grid), the flow rate, V and distance from needle tip to collector distance, the samples obtained, see Figure 16 and Table 4 for the main samples, were characterized.

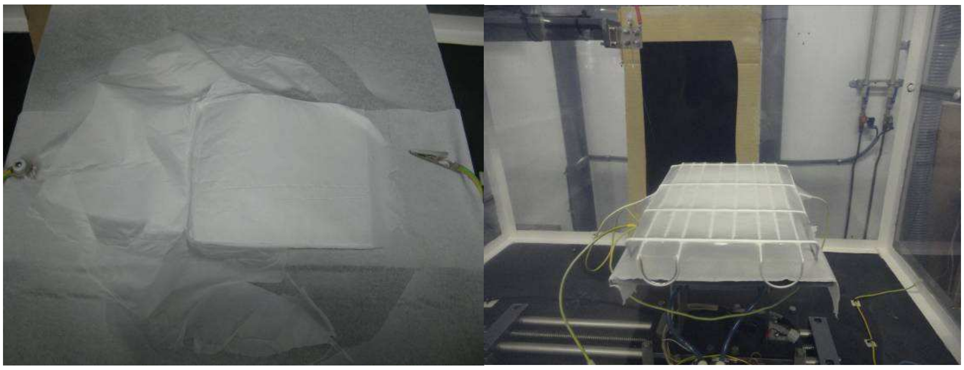


Figure 16PZTNb/PVAc nanofibers deposited on C1 (left) and C2 (right) collector.

Sample Ref.	Collector	Flow Rate (ml/h)	d_{ac} (mm)	V (kV)
D02E01	Grid	0.8	200	15
D03E02	Grid	0.5	200	14
D03E03	Paper + plate	0.5	200	15
D06E04	Paper + plate	0.5	200	14

Table 4 Test matrix for sol-gel A.

At this stage of the development, characterization of the nanofibers was carried out by means of optical microscopy since it is sufficient for determining if there are any obvious defects present such as excess solvent or beads and for knowing the distribution and diameter range of the nanofibers obtained. Some defects were observed in some of them as a very initial stage of excess solvent which was corrected.

Figure 17shows a view of the as-electrospun PZTNb/PVAc nanofibers using a metallic-grid collector.

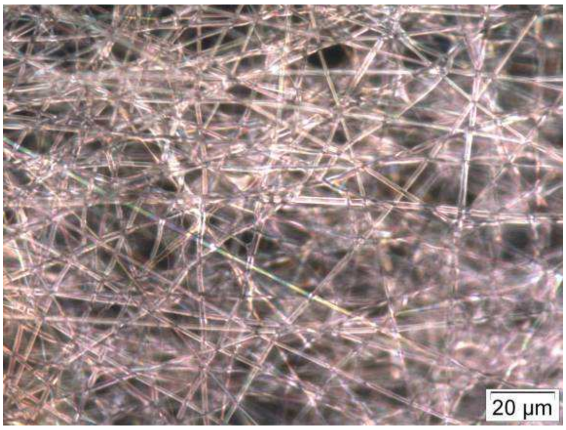


Figure 17 Optical micrograph of the as-electrospun PZTNb/PVAc nanofibers using a metallic grid collector (sample D03E02).

The diameters are quite homogeneous ranging between 1.5 to 2.0 µm. There are no beads present and, in this sample, no excess solvent.

***Electrospinning with the developed sol-gel B*: T**he electrospinning solution was prepared in a similar way as before with different additions of xylene (to control the viscosity) and mixed at room temperature in a close flask for 24 hours. Two different mixes were prepared with 5% and 2.5% weight of xylene.

As before, an extensive electrospinning parameter test matrix that included three different types of collectors (C3: aluminum foil, C4: aluminum foil + Teflon plate and C5: Interdigitated alumina electrode[1]), the flow rate, voltage, distance from needle tip to collector distance, relative humidity and deposition time was carried out. These samples, Table 5 and Figure 18, were characterized.

Sample Ref.	Collector	Flow Rate (ml/h)	d_{ac} (mm)	V (kV)	HR (%)	Time (min)
D07E05	C4 (Al foil+Teflon)	0.5	200	14	30-35	300
D07E06	C3 (Al foil)	0.1	200	14	30-35	180
D08E07	C5 (Interdigitated electrode)	0.1	300	15	65	20
D08E08	C5 (Interdigitated electrode)	0.1	300	15	65	20
D08.01E09	C5 (Interdigitated electrode)	0.1	300	15	60	20
D08.01E010	C5 (Interdigitated electrode)	0.1	300	14	55	20

Table 5 Test matrix for sol-gel B.

[1]*Supplied by Electronics Design Center.*

Figure 18 Samples fabricated with collector C3 (left; D07E05) and C5 (right; D08E07).

As before, some excess solvent was observed in the samples which was corrected. Figure 19 shows two examples. With sol-gel B and collector C3, the nanofiber diameter distribution is less homogeneous than before; diameters ranging between 1 and 5 µm. Beads were not a problem either since only in rare cases could one be seen. With collector C5, several aspects were improved such as the homogeneity of the nanofiber diameter distribution which now ranges between 1 and 2 µm, beads were not seen and no excess solvent detected. It can also be seen that the nanofibers are aligned in the perpendicular direction the fingers of the interdigitated electrode which should also favor the polarization of the nanofibers.

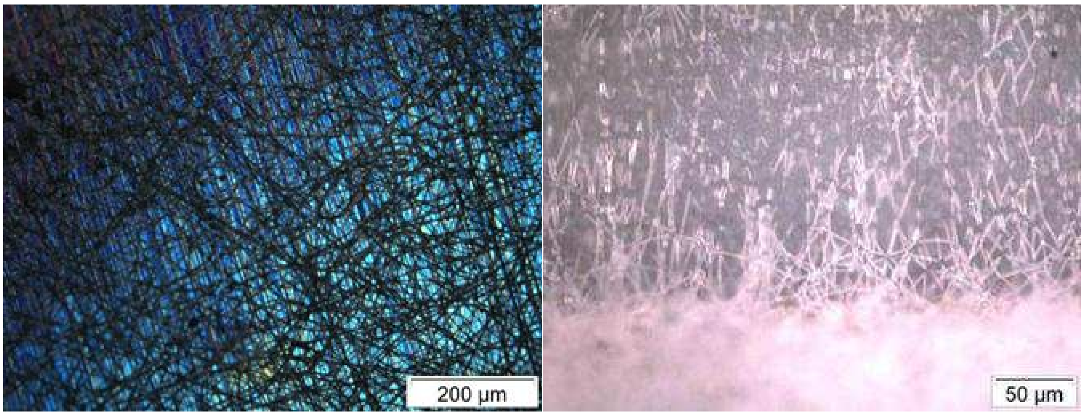


Figure 19 Optical micrographs of the as-electrospun PZTNb/PVAc nanofibers using C3 (left) and C5 (right) collectors.

Electrospinning with the back-up sol-gel: In order to keep development to a minimum during this stage, the binding polymer selected was the same as before (PVAc) and a combination of ethanol and methanol (1:4 ratio by weight) as a solvent. These solvents are then combined with the binding polymer in ratios very similar to the previous cases (around 16% to 18% weight of polymer).Table 6 summarizes the parameters changed during the tests.

Range of Process Parameters	
Voltage (V)	10-16 kV
Needle tip to collector (d_{ac})	100-150 mm
Feed rate (F_r)	0.05-0.5 ml/h
Relative Humidity	40%

Table 6 Range of process parameters used for electrospinning the back-up sol-gel.

Besides, several processing times were considered with the objective of obtaining a sufficient thickness of nanofiber mesh deposited on the interdigitated electrode given the considerable loss of material (binding polymer) during thermal processing which adds up to the usual shrinkage that accompanies any sintering process causing a quite considerable change in the nanofiber mesh which can yield a final product (PZT nanofibers) without the needed consistency for the sensor needs; see Figure 20.

(a) *(b)* *(c)*

Figure 20 Electrodes with back-up PZT nanofibers deposited on them prior to thermal treatment using different deposition times: 2 minutes (a), 10 minutes (b) and 20 minutes (c).

A similar characterization as before revealed absence of defects and uniform nanofiber diameter distribution (diameters ranging between 1 and 1.5 µm.) as shown in Figure 21. It is clear from the figure that the nanofibers are deposited in a reasonably uniform way throughout the electrode (platinum fingers and alumna spacing between them). Also the nanofiber diameter distribution is very similar to the one obtained when an aluminum foil was used as collector.

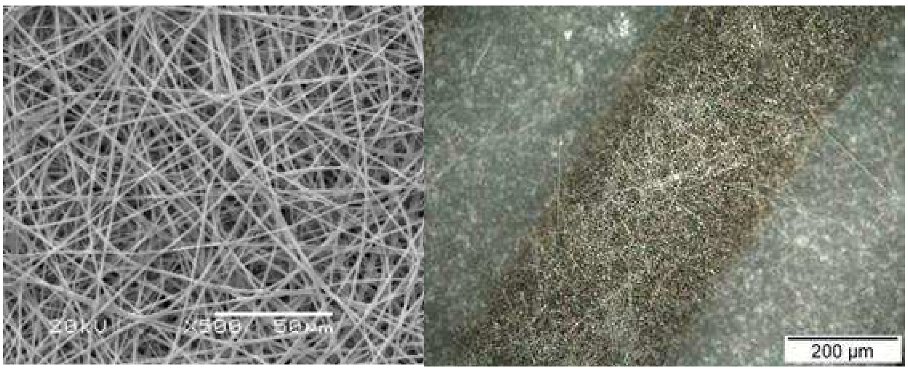


Figure 21SEM micrograph of the as-electrospun PZTNb/PVAc nanofibers using C3 (left) and optical one using the interdigitated electrode collectorC5 (right).

THERMAL TREATMENT OF THE ELECTROSPUN NANOFIBERS

The nanofibers obtained via electrospinning, which have been discussed in the previous section, are not yet in a form useful for sensing. We need first to subject the obtained nanofibers to a thermal processing stage (calcination and annealing) which is necessary to achieve various things: eliminate the binding polymer and organics, form the ceramic PZT material with the correct crystallographic phase and composition, and obtain the above material correctly sintered forming continuous nanofibers. This process is delicate and many problems can appear. The main one is shrinkage due to dissolution of organic materials, the crystallization during the high temperature steps and sintering, often results in a disintegrated or cracked structure of the fiber. Thermal treatments were carried out for each sol-gel, the aim of these tests have been to identify the relevant processing parameters such as the sintering temperature and crystallographic phase formation (in the range 500 to 800 ºC), heating rate profile (in the range below 10 ºC/min), cooling rates as well as time at sintering temperature (in the range 15 to 45 minutes) or the support system for the nanofibers.

Several tests with ***sol-gel A*** were carried out but,in all of them, it was already apparent the main problem which is the very large contractions obtained, around 75-80%, as is clearly shown in Figure 22. The other main problem was that the thermally processed material did not remain in a plane and since it is very fragile (ceramic nanofibers), this difficults very much its subsequent processing.

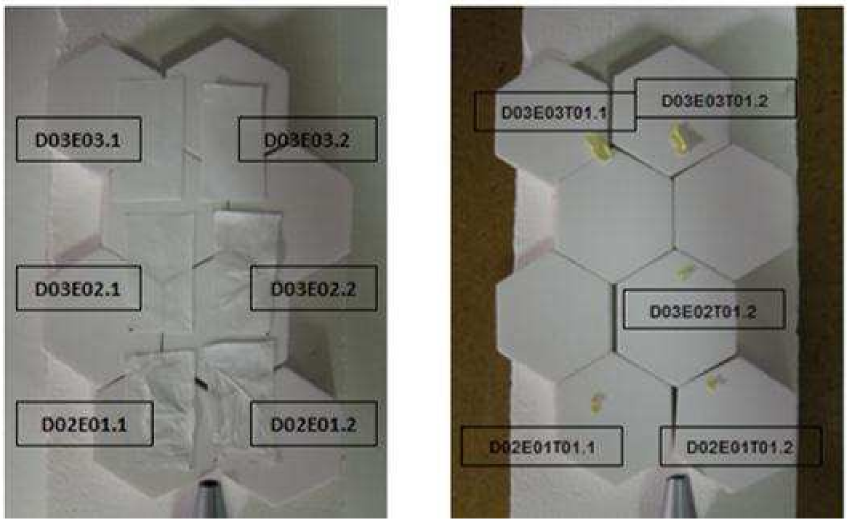


Figure 22 View of the PZTNb/PVAc nanofiber samples before (left) and after (right) thermal processing with cycle T01.

A similar procedure was followed with ***sol-gel B***. In this case, tests with the interdigitated electrode were also performed. Although the contraction problem was improved, it was not sufficient to guarantee electrical connection between the fingers of the interdigitated electrode; see Figure 23.

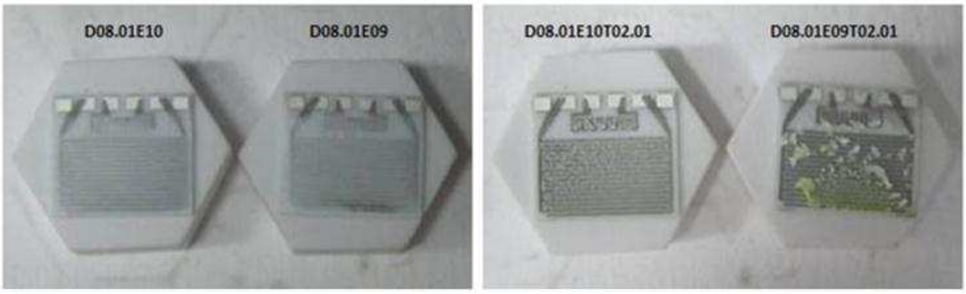


Figure 23*View* of a PZTNb/PVAc nanofiber samples D08.01E09 and D08.01E10 before (left) and after (right) thermal processing with cycle T02.01.

This procedure was redone once more with the ***back-up sol-gel***. As can be seen from Figure 24, the results are much better: shrinking has now been reduced to 40% and samples deposited on alumina foil remained flat and without cracks. On the other hand, samples on interdigitated alumina electrodes were broken into smaller parts in a similar manner to what was obtained before with the developed PZTNb material.

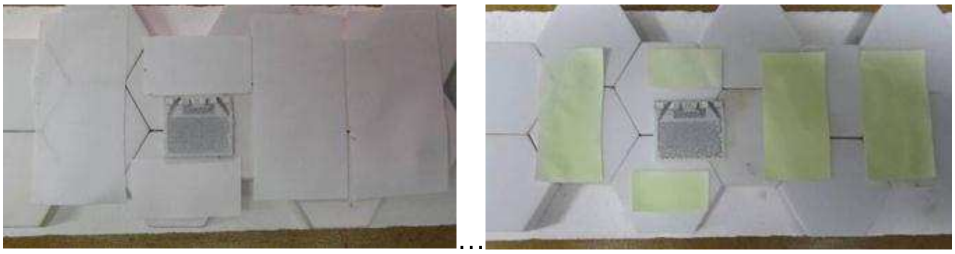


Figure 24 View of back-up PZT/PVAc nanofiber samples D09.01E12 and D09.02E13 deposited on the electrode before (top) and after (bottom) thermal processing with cycle T02.03.

Given the poor results obtained with sol-gel A, no further characterization was carried out with these samples. Results with sol-gel B on the interdigitated electrode showed that there is no homogeneous layer of PZTNb nanofiber mesh over the electrode; it is broken into small patches. In Figure 25 (left) we see that the patches lie basically only on the platinum tracks (appear as dark lines in the image) whereas this situation is improved with the samples shown in the image on the right since now the patches are distributed reasonably uniformly over all the electrode surface. Nevertheless, electrical continuity is very small if at all.

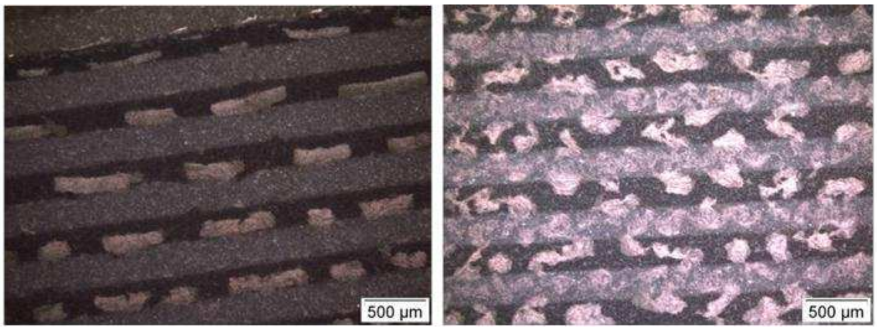


Figure 25 Low magnification micrograph of the as-sintered samples D08E07T02 (left) and D08.01E10T02.01 (right) on an interdigitated electrode.

REPORT

Results with the back-up sol-gel improved again. The PZT nanofiber mesh is continuous without broken nanofibers for the C3 collector; Figure 26 (left) nanofiber diameters averaging around 900 nm. The improvement is also clear when looking at results with the interdigitated electrode since although the original mesh is broken into pieces, these are larger and there are areas with PZT nanofiber continuity across the platinum electrode fingers; Figure 26 (right).

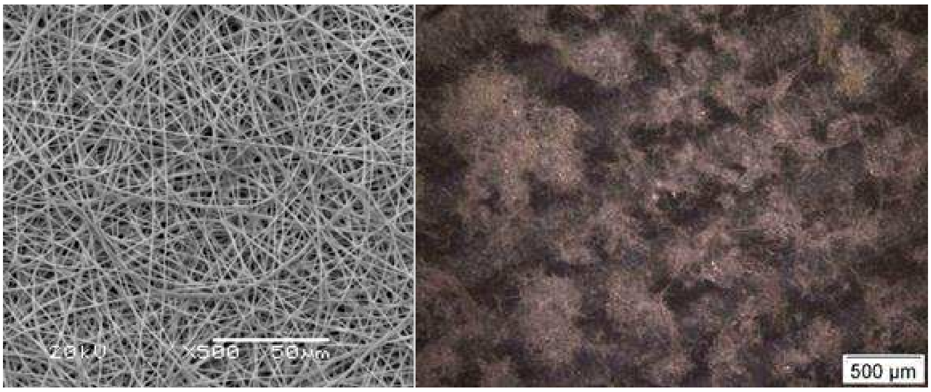


Figure 26SEM micrograph of the thermally treated PZT nanofibers using an aluminum foil collector (C3, left) and an optical one with aninterdigitated electrode collector (C5, right).

Figure 27shows an X-ray difractogram of the PZT material made from the back-up sol-gel showing, the expected mixture of the rhombohedral and tetragonal phases.

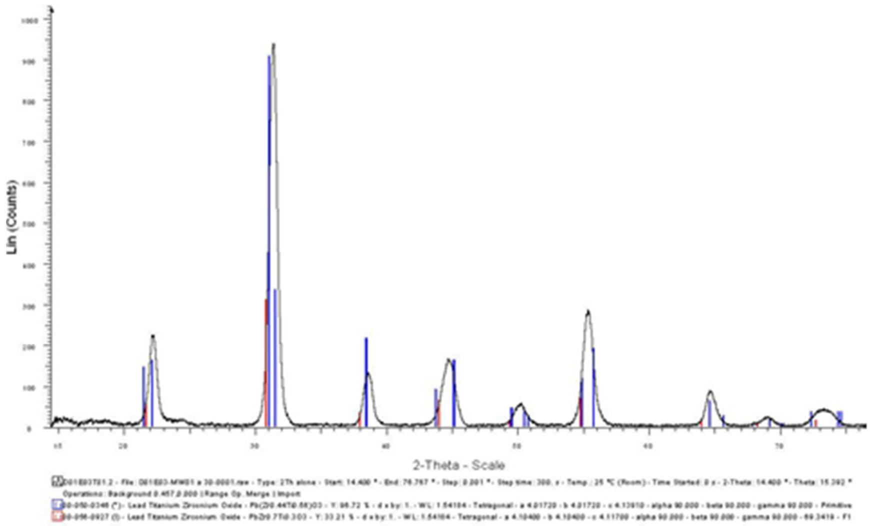


Figure 27X-ray difractogram of the PZT material made from the back-up sol-gel.

REPORT

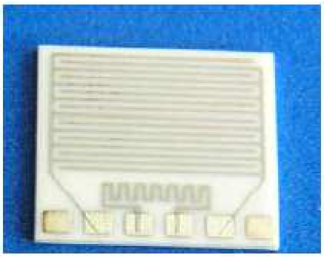
SENSOR DESIGN FABRICATION AND CHARACTERISATION

The first part of the work consisted in fabricating and characterizing the subsystem that will make the actual pressure and temperature measurements since this is where all the development and novelty lies. This involves selecting and appropriate sensor with a T probe, fabricating the PZTNb nanofibers, placing them on the electrode, encapsulating the ensemble, poling the nanofibers and characterizing the response of this subsystem. Based on the results of this work, the rest of the system (electronics and connections) would be built and characterized.

In the previous sections we learnt how to fabricate the active element of the sensor system (i.e. PZT nanofibers). The interdigitated electrode used as a collector in some of the tests was selected carefully from available commercial sources and based on a predetermined set of considerations. From the various possibilities available, two candidates were identified as suitable for our purposes. In both cases, the substrate is alumina with interdigitated electrodes given their good sensibility:

- Model 103 from CWRU. Electronics Design Center. The distance between the fingers of the interdigitated electrode are 250 µm and poses a pT100 temperature measurement element underneath.

- Synkera Technologies Inc. Similar to the previous one but the distance between the fingers of the interdigitated electrode is 15 µm.



The first model was chosen for the initial prototypes given its availability in low quantities. Its dimensions are 13 x 15 mm and are suitable for the purpose. Once good results are obtained, this electrode would be substituted by the Synkera one which is much smaller: 2 x 3 mm.

Encapsulation**:** There are two reasons for this process step. The first one is to protect piezoelectric nanofibers during the poling stage where they are going to be immersed in an oil bath at high temperatures and the second is to improve the capacity to manipulate the nanofibers since ceramic nanofibers are very difficult to handle until they are encapsulated. After studying various options, thebicomponent silicone elastomer Sylgard 184 from Dow Corning was selected.

Many techniques were studied, and samples fabricated, during this phase. The most relevant ones were:

- Encapsulation of PZT and PZTNb nanofibers on alumina interdigitated electrode by:
  - Direct immersion of the electrode in the silicone elastomer followed by curing in air; Figure 28 (left).
  - Direct application of the elastomer on the electrode which has been previously been boxed, Figure 28 (right).

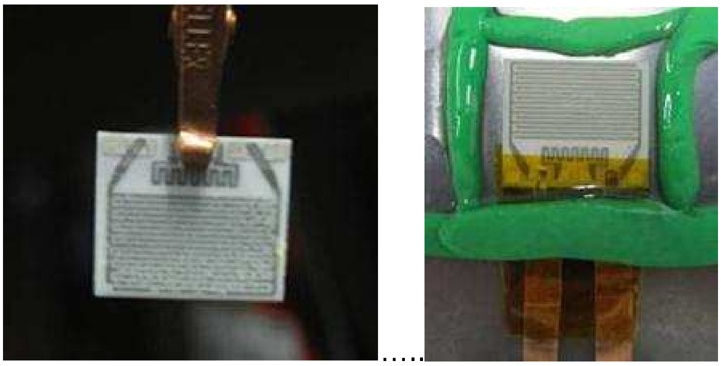


Figure 28 Encapsulated electrode with PZT nanofibers made from back-up solution, ref D09.02E13T02.03, by immersion in the elastomer (left) and PZTNb nanofibers made from sol-gel B, ref D08E08T02, by direct application of the elastomer on the electrode (right).

- Encapsulation of PZT nanomesh. The difference with the encapsulation described above is that now the nanomesh made from PZT nanofibers will be encapsulated and the interdigitated electrodes fabricated in the same process. Threemain routes were followed:
  - Interdigitated electrode on flexible support + encapsulation;Figure 29.

Figure 29 Encapsulated interdigitated electrode on flexible support.

The main problem encountered was trying to avoid getting silicone between the nanomesh and the electrode to avoid a defective electric contact between the electrode and the nanomesh. Several trials were carried out but a way to avoid this was not found.

  - Ink jet printing of an interdigitated electrode the PZT nanomesh + encapsulation; Figure 30. In principle this is a good option since it guarantees that there is always a good connection between the interdigitated electrode and the PZT nanomesh.

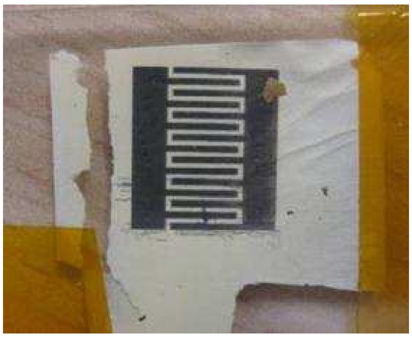


Figure 30 As printed electrode on PZT nanomesh.

Nevertheless, it is very difficult to do since the PZT nanofiber mesh is very fragile so the printing of the electrode is difficult to carry out without damaging it. Also, the electrical connections are also difficult to make (made from silver tincture) without breaking the nanomesh since, now, the electrode forms part of it so any manipulation is very delicate and resulted in breakage of the nanomesh.

- Electrospray of silver electrodes on both sides of the PZT nanomesh + encapsulation using silver tincture; Figure 31.

Figure 31 Intermediate stage in the fabrication of the electro-sprayed electrode.

The main problems encountered were difficulties in handling the system during turning for electro-spraying the second side (mainly rupture) which could be eventually handled and failure in making a good contact between the electrode and the copper wire. This was confirmed during the poling stage.

***Poling*:** The purpose of poling is to order in some specified direction the dipole moments of the PZT. This is accomplished by subjecting the material to an electric field; see Figure 32. After reviewing the relevant literature, the conditions chosen are to apply a potential difference between the electrodes of 4V/µm during 24 hours while, at the same time, the material is immersed in an oil bath that was maintained at a temperature in the range 120 ºC to 150 ºC. Its purpose is to favor the dipole orientation process and to avoid thermal gradients in the material as a consequence of the current that flows during the poling process.

Figure 32 Poling of a PZT sample.

Characterization: The electrical response of the sensor was measured using a commercial impedance measuring apparatus Agilent E4980A Precision LCR Meter. As the most convenient way of representing the electrical response of the sensor samples, the measurement of the impedance angle (phase) to detect the signal change in the sensor as a consequence of the poling process. These measurements were carried out as a function of the frequency sweeping the range between 20 Hz and 100 kHz.

In general, the response was negative and can be attributed to a bad electrical connection between the nanomesh and the electrode as discussed previously or, for samples deposited directly over an alumina interdigitated electrode, to nanofibers breaking as a consequence of the contractions encountered during thermal treatment In one case, though, in two cases some very weak signal was obtained suggesting that some small degree of success in the poling of the sample had been achieved. An example of this is shownFigure 33.

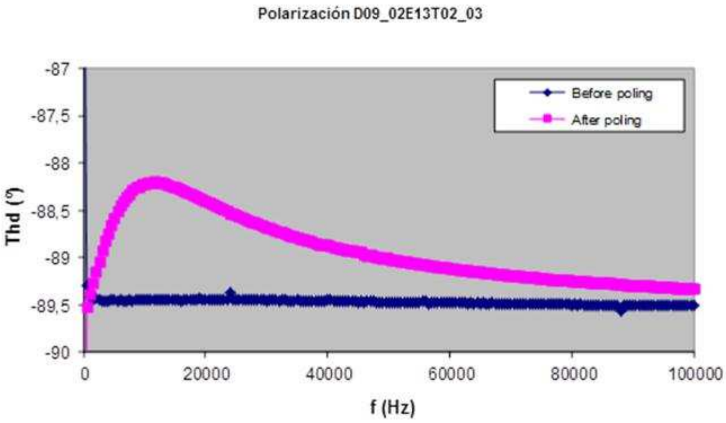


Figure 33 Impedance measurements results obtained with sample ref. D09_02E13T02_03.

<u>BACK-UP SOLUTION</u>

The goal was to develop a pressure sensor whose active element would be entirely new and made from piezoelectric nanofibers. Thus the work had two different stages, the first one was be to develop the active element made from piezoelectric nanofibers (including encapsulation, electrode and basic electrical connections) and the second one would be devoted to including the rest of the of the required elements and electronics to obtain a prototype for testing. Since all the novelty, as well as the risks, are included in stage one (no such nanofiber-based active element exists), work was initially been targeted to completing stage one first.

It is clear from the results discussed in this document that the degree of success encountered in developing the new active element has not met with the required degree of success even though a very considerable effort has been made. Nevertheless, we would like to point out that the main challenge, fabrication of a piezoelectric nanofiber mesh with the correct microstructure, has been accomplished and is a significant step in going beyond the state of the art.

As a consequence and in agreement with the proposal, it was decided to use a commercial “back-up” solution. In order to do so, the Topic Manager was asked to choose the one he thought most appropriate based on the extensive document, delivered in WP3, which included a full study of the available option in the market, based on the requirements and discussions with the TM, and where the most suitable options were summarized and evaluated its merits in an arbitrary scale with the recommendations made by the consortium. The Topic Manager selected the second best option, sensor OEM Series 10 from KELLER with conditioning electronics. After discussions, prior to acquiring and delivering it to the Topic Manager, it was found out that the supplier would not assure a good functioning between -40 ºC and -55ºC (lowest temperature range required) in D3.1. After communications with the Topic Manager about this, it was stated that TECNALIA had no resources (and, at any rate, such work is not included in the scope of the project) to do a characterization of the sensor´s behavior up to -55ºC, the Topic Manager could not do it either and no other option was selected. Since the supplier, mentioned that it was possible that they would look at this problem themselves (but without a definite date), it was decided to keep in touch with them at regular intervals to find out if they would modify the sensor to comply with the temperature requirement. This was a very slow process, but eventually such a sensor was produced and two samples, ref. PA-9FLC with A-100 oil from KELLER, were acquired and delivered to the Topic Manager. According to information from the supplier, the new sensor was modified by changing the oil inside it. Besides these two sensors, another set of two sensors (third best option in D3.1) were acquired and delivered to the Topic Manager (ref. Series 3101 from GEMS Sensors & Controls).

CONCLUSIONS& MAIN RESULTS:

Regarding the torquemeterproposed and realised in the frame of ActiPPTSens has reached a TRL4-5 for the developed demonstrator. The main performances were measured and compared with commercial products. Efforts to be compatible with the aeronautic sector were made to be more compact and reliable. The main conclusions and innovative features are:

- ✓ The proposed torquemeter uses a different technology to sense the torque on a shaft without contact.
- ✓ Compared with the other technologies currently used in the torquemeter, the CTS uses an innovative torque sensing technology based on a deformation mechanical converter to amplify the small angular displacement (resulting of the applied torque on the shaft) in a linear displacement with more sensitivity. This is improved the overall sensing performance.
- ✓ Compared with the other commercial contactless sensor, the developed technology does not age. In other commercial products, sensing elements are usually strain gage based which are very accurate but are not very stable with time since the gluing process is not stable with the life time impacting directly the long term stability. The eddy current sensors are magnetic sensors without this kind of problem.
- ✓ Compared with presently used torquemeters for the turboshaft, the developed technology is able to measure static behaviour. The bandwidth range is from 0 rpm to 10000 rpm. The actual technology with phonic wheel is not able to provide torque under 300rpm.
- ✓ Compared with the other commercial contactless sensor, the developed technology doesn't need to cut the shaft to insert the torquemeter or to implement sensor on the shaft. The innovative technology is non-intrusive and only two external rings are necessary to plug the torque sensor on the shaft. The applied torque is not applied on the sensing element.
- ✓ Compared with the expected overall dimensions and weight, the developed technology is in the range of the other commercial products (mainly due to the shaft diameter).

- ✓ Regarding the pressure and temperature sensor, the main conclusions are:
- ✓ The overall goal of developing a pressure sensor with the necessary requirements and whose active element would be entirely new and made from piezoelectric nanofibers has not been fully achieved.
- ✓ It should be pointed out that the main challenge, fabrication of a piezoelectric nanofiber mesh with the correct microstructure, has been accomplished and is a significant step in going beyond the state of the art.The main hurdle (fragility of the ceramic nanofibers and the need of a very good electrical contact between the electrode and the nanofibers) encountered is related to a production type problem and not really to a new development
- ✓ A suitable route to success has also been identified but constraints in the project scheduling and costs have not made it possible to complete it, even though a project extension has been applied for given the obvious interest in solving this final issue. In short, the identified route would be to produce the nanofiber mesh, cut it into pieces of the required size, thermally treat them (all this steps are solved), then find a way to “encapsulate” only one face of the PZT nanomesh taking good care that the encapsulating material does not permeate to the other face (and this, though straightforward, is a rather difficult step to accomplish) so as to impart to the nanomesh sufficient “ductility” to assure the required degree of handling necessary to print the electrode, by ink jet printing, on the free face (this step has been addressed in a satisfactory manner) assuring a perfect electrical contact with the nanomesh. The final step would then be to encapsulate the rest of the nanomesh and printed electrode which be straightforward to achieve.

- ✓ According to the project results and the plan detailed in the proposal, the commercial back-up solution has been adopted and the following sensors delivered:
    - ***Two (2) sensors, ref. PA-9FLC with AS-100 oil from KELLER***. These correspond to the choice made by the Topic Manager from the options that were described in deliverable D3.1 except that these sensors are an evolution that allows them to work up to -55ºC as required by The Topic Manager’s specification.

- ✓ An extra set of sensorswa also delivered corresponding to the third best option identified in D3.1.:
    - ***Two (2) sensors, ref. 3101 (Series 3100) from GEMS Sensors & Controls***.

REPORT

WP6.- Communication: dissemination and exploitation.

The main objective of this WP is to perform the diffusion activities of the project as well as to perform a market analysis to assess the potentialities of the different sensors proposed in the frame of ActiPPTSens.

The special characteristics of ActiPPTSens project involving the dissemination of sensitive information made the consortium to take special care on both the diffusion and dissemination activities, and the exploitation activities. To accurately perform them, the consortium decided, during the kick-off meeting, to establish a Steering Committee (SC) whose mission would be the approval of the proposals related to public diffusion of any information about ActiPPTSens developments. Also, the leader of WP6 was nominated as Exploitation Manager, being in this case, responsible for the coordination of the dissemination activities from the inputs given by the consortium. The work carried out was:

- Graphic image (D6.1): elements (logo and templates) were developed by TECNALIA following the visual image presented in ActiPPTSens proposal presented to Clean Sky.
- Website (D6.1): *actipptsens.eu* web site was build up with the agreement of the whole consortium. The SC decided to not include the “restricted area” link in this website. Information about the partners of the consortium, a brief description of the objectives of ActiPPTSens project as well as of Clean Sky initiative was included. The approval of the project Topic Manager was also requested. ActiPPTSens website was located at CSIC server.
- “Restricted area” for the use of the members of the consortium was located at TECNALIA server. User access and passwords were provided by TECNALIA partner.
- Market opportunities (D6.2): Bibliographic revision to identify of market opportunities both on torque and pressure sensors was made. The main and most useful documents were employed and data about both the market growth in the next years and the main applications were identified.
- Description of the Torque sensor (D6.2): A new contactless torquemeter using a different technology is proposed. This sensor provides an improved overall sensing performance:
    - Torque is measured without contact with the shaft.
    - Sensitivity is improved through the use of an innovative torque sensing technology.
    - High stability with time through the use of eddy current sensors are magnetic sensors.
    - Can measure static behaviour. Actual technology is not able to provide torque under 300rpm.
    - Its placement in the shaft is very simple and non-intrusive with overall dimensions and weight in line with other commercial products.
    - However, the price is, nowadays, not competitive due mainly to the low scale product.

- Description of the Pressure & Temperature sensor (D6.2): As explained before, the commercial back-up solution has been adopted in this case (their specification sheets are included in the Annex).
- Exploitation (D6.3): Consortium commitment was achieved in order to make an appropriate use of the exploitation of the developments made by each partner in the frame of the ActiPPTSens project. A patent policy was established and the property of the different prototypes was settled to the partner which developed each of them. A reduced grant for the use of those prototypes

inside the consortium was decided with an extended duration to two years after completion of the project.

- Torque sensors will be mainly used in automotive and industrial uses. However, it is expected that torque sensors will be the most important sensor used where rotational force/ movement needs to be measured, as occurred in some applications in the aerospace industry. More specifically:
    - Fiat, Liebherr Aerospace and CETIM have been contacted regarding the torquemeter and have shown interest in the proposed technology, developed in the frame of ActiPPTSens, and condider it interesting for future applications.
    - These potential contacts show the interests in the proposed technology but at this moment, the technology is not developed sufficiently to access a potential commercial activity. CEDRAT TECHNOLOGIES is making a considerable effort to find applications based on the features and advantages that such a new system has.
    - In parallel to these contacts, CEDRAT TECHNOLOGIES is answering to the call with the French pole (‘pole pegase’ - http://innover.pole-pegase.com) for the next version of helicopter (helicoptère du future - aerospace cluster) with similar targets. This opportunity will help CEDRAT TECHNOLOGIES to develop more in depth its own technology of torquemeter in regards of its robustness versus the environment.

- Piezoelectric, MEMS pressure sensors will experience a rapid growth in the next years because piezoelectric pressure sensors dominate the market and the conventional sensors will be substituted by MEMS due to the numerous advantages they offer. These piezoelectric pressure sensors will find countless uses including various applications in aerospace industry.

In conclusion, the proposed deliverables, as described in the proposal, have been accomplished to the level that the development results, described in WP5, have allowed.

C. Potential Impact.-

The overall objective of the ActivePPTSens consortium was to develop a demonstrator in the field of new sensors technologies for pressure, temperature and position with the main aim of providing improved technologies for safety, reliability and reduced environment impact of air-engines. The technologies that the ActivePPTSens has worked on are:

✓ Contactless Torque Sensor CTS that measures the torque and the rotation speed of either a stationary axle or a rotating shaft without contact using stationary electronic components.

✓ MEMS Pressure & Temperature Piezoelectric sensor based on electrospun PZT nanofibers with large potential for higher pressure sensibility, longer life cycle, easy integration under structural elements and complex geometrical shape capability.

TORQUE SENSORS:

Torque sensors market is considered as a growth market because the number of applications is increasing year after year. Automotive market has exhibited the largest growth in the last years, but it is also estimated that industrial and measurement torque sensors markets are likely to show large growths with new applications. Torque sensors are used in diverse applications, from a basic engine crank and electric power steering in automotive industry to highly sophisticated prosthetic applications in medical orthopedic end uses. Within industrial applications, reaction and rotary torque types are offered to satisfy many applications, including electric motor testing, dynamometers, hydraulic pump testing, fan testing, and torsion test machines. Shaft, flange, and spline-mount configurations, as well as rotary transformer and digital telemetry signal transmission technologies, are used in many applications.

The torque market is expected to grow from $650 million in 2010 to $1065 billion in 2016. The introduction of wireless torque sensors has resulted in faster penetration of a number of markets. Therefore, there are a large number market participants competing in world industrial torque sensors market.In 2010, revenues from automotive torque sensors contributed 55.8% while revenues from torque sensors in the aerospace industry contributed 1.1%. On the other hand, revenues from industrial end users in 2010 contributed 23.3% of the total torque sensor revenues and this is estimated to increase to 24.1% in 2017. It is expected that torque sensors will be the most important sensor used where rotational force/ movement needs to be measured accurately.

As it is well known in ActiPPTSens, in the aerospace industry, torque sensors have very critical applications in helicopters or aircraft. During the ActiPPTSens project, CEDRAT TECHNOLOGIES has developed a torquemeter compatible with the main characteristics of aeronautics application.

Given its main characteristics, as a consequence of the new technology employed in the development of the prototype, it possess some important characteristics that put it above its potential competitors: contactless, non-intrusive technology, improved sensitivity, high stability and capacity to measure static behaviour. This is important also to extend its use to other domains which requires a non intrusive solution to measure torque and speed on a shaft. Aerospace and industrial sectors are good candidates for this use and the proposed solution is not limited in term of range due to a simple mechanical conversion for the torque transducer. For example, in the past, CEDRAT TECHNOLOGIEShas used this technology in robotics to measure torque at the end of a gearbox.

As explained before, several commercial contacts have already been made (Fiat, Liebherr Aerospace, CETIM) but at this moment, the technology is not developed sufficiently to access a potential commercial activity.What is required as next step to attain the full impact that this development can have in the market is to validate a simpler and cheaper process to realise the core of the torquemeter to address commercial markets with more competitiveness because a lot of intrusive solutions exist.

In order to take this step, CEDRAT TECHNOLOGIES is already answering to the call with the French pole (‘pole pegase’ - http://innover.pole-pegase.com) for the next version of helicopter (helicoptère du future - aerospace cluster) with similar targets, so that CEDRAT TECHNOLOGIES can develop more in depth its own torquemeter technology with two main targets in mind:

- Its robustness versus the environment.
- Improve the production process to reduce the manufacturing prices.

MEMS PRESSURE AND TEMPERATURE SENSORS:

Piezoelectric, MEMS pressure sensors will experience a rapid growth in the next years because piezoelectric pressure sensors dominate the market and the conventional sensors will be substituted by MEMS due to the numerous advantages they offer. These piezoelectric pressure sensors will find countless uses including various applications in aerospace industry.

Market for Smart Pressure Sensors in Asia-Pacific is expected to grow at a CAGR of 6.9% up to 2015. Demand for sensors will also grow in line with electronics demand. In this way, global revenue from motion sensor technology in smartphones and tablets will expand to $2.1 billion in 2015, up from $1.1 billion in 2011. The motion sensor category consists of a range of products, including microelectromechanical system (MEMS) accelerometers, MEMS gyroscopes and MEMS pressure sensors. MEMS are also increasingly being used for an increased number of applications in diverse industries. This market is considered key for future growth by sensors manufacturers.

Among the three main MEMS-based sensors, pressure sensors dominate the market revenues with a large revenue share of 48.2 percent in 2009. A sizable share of the revenues comes from the automotive segment, however, pressure sensors also find wide use in the medical industry, the defense market and in the aerospace industry. Growth in the long term is expected to be driven by the demand for pressure sensors from emerging economies and large automotive markets such as India and China. The growth will be even stronger if the European Union and other countries pass legislations similar to that of the National Highway Traffic Safety Administration (NHTSA - U.S. Department of Transportation). Growth is also expected to be driven by the aerospace and defense segment, where MEMS pressure sensors are finding use because of the numerous advantages they offer over conventional pressure sensors.

As explained before, it is not possible to state the potential impact of the prototype developed within the project since the overall goal of developing a pressure sensor with the necessary requirements and whose active element would be entirely new and made from piezoelectric nanofibers has not been fully achieved. As a consequence, no real performance data has been gathered that can be compared to existing solutions so assess its potential impact.

It should be pointed out, nevertheless, that the main challenge, fabrication of a piezoelectric nanofiber mesh with the correct microstructure, has been accomplished and is a significant step in going beyond the state of the art and that the difficulties still remaining are related to a production type problem and not really to a new development with a suitable route to solving them having been identified within the project.

D. Address of the project public website and relevant contact details.-

The ActiPPTSens website: www.actipptsens.eu
Project coordinator:

TECNALIA

Dr. Nieves Murillo

Pº Mikeletegi, 2. Parque Tecnológico

E-20009 Donostia-San Sebastian

Tel.: (+34) 902 760 002

International Calls: (+34) 943 105 115

Mobile: (+34) 667116099

Fax: 901 706 009

nieves.murillo@tecnalia.com

4.2. Use and dissemination of foreground

A plan for use and dissemination of foreground (including socio-economic impact and target groups for the results of the research) shall be established at the end of the project. It should, where appropriate, be an update of the initial plan in Annex I for use and dissemination of foreground and be consistent with the report on societal implications on the use and dissemination of foreground (section 4.3 – H).

The plan should consist of:

- Section A .- s section should describe the dissemination measures, including any scientific publications relating to foreground. Its content will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

- Section B.- s section should specify the exploitable foreground and provide the plans for exploitation. All these data can be public or confidential; the report must clearly mark non-publishable (confidential) parts that will be treated as such by the Commission. Information under Section B that is not marked as confidential will be made available in the public domain thus demonstrating the added-value and positive impact of the project on the European Union.

A. Section A (public)

- A2: List of all dissemination activities (publications, conferences, workshops, web sites/applications, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters).

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES

No.	Type of activities[2]	Main leader	Title	Date/Period	Place	Type of audience[3]	Size of audience	Countries addressed
1	Website	ICV-CSIC-CSIC	ActiPPTSens	01.03.2011-1.08.2012	www.actipptsens.eu	Scientific community, Industry, civil society, policy makers	-	-
2	Conference	ICV-CSIC-CSIC	Electroceramics XII	June 13-16 2010	Trondheim, Norway	Scientific community, industry.		
3	Conference	CU	CIRP ICME 2010	23-25 June 2010	Italy	Scientific community, industry.		
4	Conference	CU	IESM 2011	25-27 May 2011	France	Scientific community, industry.		
5	Conference	CU	Manufacture 2011	24-25 October 2011	Poland	Scientific community, industry.		
6	Conference	CU	WAC2012	24-28 June 2012	Mexico	Scientific community, industry.		
		TECNALIA						

[2] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.
[3] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

B. Part B1 (Confidential[4] or public)

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[5]:	Confidential Click on YES/NO	Foreseen embargo datedd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	NO		FR 2909760	Dispositif de mesure d'un couple de torsion	Peugeot PSA

C. Part B2

Type of Exploitable Foreground[6]	Descriptionof exploitable foreground	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Commercial exploitation of R&D results	Torquemeter design for industrial application + its associated elecronics.	NO		Contactless torquemeter	C29.3.1 - Manufacture of electrical and electronic equipment for motor vehicles.	TRL5 after ActiPPTSens. Some adaptations to push on the market.	FR 2909760	CEDRAT TECHNOLOGIE STechnologies

In addition to the table, please provide a text to explain the exploitable foreground, in particular:Its purpose

- *How the foreground might be exploited, when and by whom*
- *IPR exploitable measures taken or intended*

[4]Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.
[5]A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.
[19] A drop down list allows choosing the type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.
[7] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

- *Further research necessary, if any*
- *Potential/expected impact (quantify where possible)*

In order to exploit it, a further step is necessary. CEDRAT TECHNOLOGIES is already answering to the call with the French pole ('pole pegase' - http://innover.pole-pegase.com) for the next version of helicopter (helicoptère du future - aerospace cluster) with similar targets, so that CEDRAT TECHNOLOGIES can develop more in depth its own torquemeter technology with two main targets in mind:

- Its robustness versus the environment.
- Improve the production process to reduce the manufacturing prices.

With this, CEDRAT TECHNOLOGIES will develop the last generation of this transducer.

4.3. Report on societal implications.-

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

A **General Information** *(completed automatically when **Grant Agreement number** is entered.*	
Grant Agreement Number:	255909
Title of Project:	Active Pressure, Position & Temperature sensors for turboshaft
Name and Title of Coordinator:	Dr. Nieves Murillo - TECNALIA
B **Ethics**	
1. Did your project undergo an Ethics Review (and/or Screening)? • If Yes: have you described the progress of compliance with the relevant Ethics Review/Screening Requirements in the frame of the periodic/final project reports? Special Reminder: the progress of compliance with the Ethics Review/Screening Requirements should be described in the Period/Final Project Reports under the Section 3.2.2 *'Work Progress and Achievements'*	***NO***
2. Please indicate whether your project involved any of the following issues (tick box) :	***NO***
RESEARCH ON HUMANS	
• Did the project involve children?	
• Did the project involve patients?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	

• Did the project involve Human data collection?	
RESEARCH ON HUMAN EMBRYO/FOETUS	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
• Did the project on human Embryonic Stem Cells involve cells in culture?	
• Did the project on human Embryonic Stem Cells involve the derivation of cells from Embryos?	
PRIVACY	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
RESEARCH ON ANIMALS	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
RESEARCH INVOLVING DEVELOPING COUNTRIES	
• Did the project involve the use of local resources (genetic, animal, plant etc)?	
• Was the project of benefit to local community (capacity building, access to healthcare, education etc)?	
DUAL USE	
• Research having direct military use	0 Yes 0 No
• Research having the potential for terrorist abuse	

C Workforce Statistics		
3 Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).		
Type of Position	**Number of Women**	**Number of Men**
Scientific Coordinator	1	
Work package leaders	2	4
Experienced researchers (i.e. PhD holders)	1	3
PhD Students		
Other	3	8

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	**1**
Of which, indicate the number of men:	1

D Gender Aspects			
5. Did you carry out specific Gender Equality Actions under the project?	○ ⊗	Yes No	
6. Which of the following actions did you carry out and how effective were they?			
	Not at all effective		**Very effective**
❑ Design and implement an equal opportunity policy	○ ○ ○ ○ ○		
❑ Set targets to achieve a gender balance in the workforce	○ ○ ○ ○ ○		
❑ Organise conferences and workshops on gender	○ ○ ○ ○ ○		
❑ Actions to improve work-life balance	○ ○ ○ ○ ○		
○ Other:			
7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?			
○ Yes- please specify			
⊗ No			
E Synergies with Science Education			
8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?			
○ Yes- please specify			
⊗ No			
9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?			
○ Yes- please specify			
⊗ No			
F Interdisciplinarity			

10. Which disciplines (see list below) are involved in your project?

⊗ Main discipline[8]: 2.3 (aeronautical, materials)

⊗	Associated discipline8: 2.2 (electronic)	○	Associated discipline8:⊗

G Engaging with Civil society and policy makers

11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	○ ⊗	Yes No

11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)?

○ No

○ Yes- in determining what research should be performed

○ Yes - in implementing the research

○ Yes, in communicating /disseminating / using the results of the project

11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ ○	Yes No

12. Did you engage with government / public bodies or policy makers (including international organisations)

○ No

○ Yes- in framing the research agenda

○ Yes - in implementing the research agenda

○ Yes, in communicating /disseminating / using the results of the project

13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers?

○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible)

○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible)

○ No

13b If Yes, in which fields?

[8] Insert number from list below (Frascati Manual).

REPORT

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs DevelopmentEconomic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

13c If Yes, at which level? ○ Local / regional levels ○ National level ○ European level ○ International level			
H Use and dissemination			
14. How many Articles were published/accepted for publication in peer-reviewed journals?			**0**
To how many of these is open access[9] provided?			
How many of these are published in open access journals?			
How many of these are published in open repositories?			
To how many of these is open access not provided?			
Please check all applicable reasons for not providing open access:			
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑other[10]: ……………			
15. How many new patent applications ('priority filings') have been made? *("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).*			**1**
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box).	Trademark		**0**
	Registered design		
	Other		
17. How many spin-off companies were created / are planned as a direct result of the project?			**0**

[9] Open Access is defined as free of charge access for anyone via Internet.
[10] For instance: classification for security project.

Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:

❑	Increase in employment, or	❑	In small & medium-sized enterprises
☑	Safeguard employment, or	☑	In large companies
❑	Decrease in employment,	❑	None of the above / not relevant to the project
❑	Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	*Indicate figure:*
Difficult to estimate / not possible to quantify	☑
Note: Cu estimates a total of 5.44 PMs employment. For the rest of the partners, the answer is as in the ticked box choice.	

I	Media and Communication to the general public		
20. As part of the project, were any of the beneficiaries professionals in communication or media relations?			
○ Yes		⊗ No	
21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?			
○ Yes		⊗ No	
22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?			
❑	Press Release	❑	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
❑	Brochures /posters / flyers	☑	Website for the general public / internet
❑	DVD /Film /Multimedia	☑	Event targeting general public (festival, conference, exhibition, science café)
23 In which languages are the information products for the general public produced?			
❑	Language of the coordinator	☑	English
❑	Other language(s)		

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002):

FIELDS OF SCIENCE AND TECHNOLOGY

1. NATURAL SCIENCES

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 ENGINEERING AND TECHNOLOGY

REPORT

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)
3. MEDICAL SCIENCES
3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)
4. AGRICULTURAL SCIENCES
4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
4.2 Veterinary medicine
5. SOCIAL SCIENCES
5.1 Psychology
5.2 Economics
5.3 Educational sciences (education and training and other allied subjects)
5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].
6. HUMANITIES
6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
6.2 Languages and literature (ancient and modern)
6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]

4.4. FINAL REPORT ON THE DISTRIBUTION OF THE European Union FINANCIAL CONTRIBUTION.-

1. Explanation of the use of the resources.-

I. TECNALIA.-

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR COST ITEMS FOR BENEFICIARY TECNALIA FOR THE OVERALL PROYECT PERIOD

Concept	Amount in € with 2 decimals	Explanations
Personnel direct costs	*169,560.84€*	Salaries of researchers. (26,78 PM). RTD
	7,085.16€	Salaries of researchers. (6 PM). MGM
Subcontracting	-	
Direct cost	*11,118.53€*	
Travels	*1,958.54€*	TRAVELING: .KoM of the project Attending. (22-23/10/10) All consortium members and the Topic Manger.
		Workshop of Specifications at TURBOMECA facilities in Bordes, Fr. (29/10/10).
		Travel to Madrid Bilateral Meeting (22/03/11)
		Travel to Madrid Bilateral Meeting (10-11/04/11)
		AIRTEC 2011-Space World Conference Frankfurt, Alemania (02-04/11/11)
CONSUMABLES	*9,159.99€*	-Administrative Document sending. -Amplificator for Piezoelectric sensoR.

		-Electrodes for the sensors manufacture. -Encapsulating material. -Gas for samples treatment. -Material for the laboratory. -Materials for sample preparation. -Modification of the electrospinning. -Piezoelectric sensor. -Solvent.

II. CEDRAT.-

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR COST ITEMS FOR BENEFICIARY CEDRAT FOR THE OVERALL PROYECT PERIOD

Concept	Amount in € with 2 decimals	Explanations
Personnel direct costs	*175,457.99.€*	Salaries of 17 persons for 35,95 pm person months
Subcontracting	-	
Direct cost	*30,559.05€*	
TRAVELING: Participation of Olivier Sosnicki to partners meeting at Toulouse 28-29.10.2010	2,205.85€	Attending Project meeting.
Participation of Olivier Sosnicki to partners meeting at Bilbao 09-10.03.2011		Attending Project meeting.
CONSUMABLES	*28,353.20€*	Purchase for the contatcless torque sensor 1000 conception (bearings, etc.) Conditioning electronics for the CTS: 10,109.52 EUR Electromechanical parts of the CTS: 15,923.21 EUR Test bench parts: 2,320.47 EUR

III. CU.-

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR COST ITEMS FOR BENEFICIARY CU FOR THE OVERALL PROYECT PERIOD		
Concept	Amount in € with 2 decimals	Explanations
Personnel direct costs	*35649.75.€*	Salaries of Dr Ji 5.44 person months and Dr M Packianther for 0.69 person months
Subcontracting	-	
Direct cost	*3621.57€*	
Travel to Bilbao 22-23.07.10 M Packianther.	*279.98€*	Attending Project meeting.
Travel to France 27-30/10/10 M Packianther	*627.32.€*	Attending Project meeting.
Travel to Spain 09-12/03/11 M Packianther	*613.65€*	Attending Project meeting.
Travel to Farnborough Sensory show Dr Ji	*61.29 €*	Attending a sensor event looking for newest development, including pressure and temperature sensors.
Consumables	*717.35€*	These were required by CU team to undertake the allocated technical work.
Hospitality Dr Ji 22/08/11	*113.75€*	The hospitality was provided during the meeting which took place to discuss ActiPPTSens project with the research team from Wuhan University of Technology, China who is working on novel FBG sensor based monitoring system for high speed rotary machines.
Equipment – DTP – IT solutions	*1208.23€*	These were required by the CU team to undertake the allocated technical work.

IV.ICV-CSIC.-

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR COST ITEMS FOR BENEFICIARY ICV-CSIC FOR THE OVERALL PROYECT PERIOD		
Concept	Amount in € with 2 decimals	Explanations

REPORT

Personnel direct costs	*23695.87€*	2.22 Person/Month from Scientific Researcher Amador Caballero (301*48.91=17721.91€) 1.51 Person/Month from Scientific Researcher Marina Villegas (204*43.99=8973.96€) Total: 3.73 Person/Month
Subcontracting	*1011.89*	Certificate on the financial statements
Direct cost	*37529.38 €**	
Travel to San Sebastian of Dr. Marina Villegas Travel to San Sebastian of Dr. Amador Caballero Travel to San Sebastian of Dr. Marina Villegas Travel to San Sebastian of Dr. Amador Caballero	*594.88 €* *479.68 €* *564.42 €* *611.72 €*	Project meeting from 09/03/11 to 10/03/11 Project meeting from 09/03/11 to 10/03/11 Project meeting from 22/07/11 to 23/07/11 Project meeting from 22/07/11 to 23/07/11
Syringe Pump	*3899.01€*	Equipment for WP5. Pilot-lab tests for facility in obtaining fibers from prepared sols. First runs to study the role of viscosity in both the gel stability and the viability of fiber shaping.
Software IC-control	*5929.00€*	Equipment for WP5. Automation of laboratory reactor to improve the reliability of sols preparation
Lithium acetate, Erbium acetate	*138.20€*	Material for the laboratory WP5. Chemical reagents for preparing doped PZT sols
Platinized Si wafers	*980.00€*	Material for the laboratory WP5. Electroded substrates for the study of the interface green fiber-substrate and its role in fiber shaping
Glass beaker	*19.54€*	Material for the laboratory WP5. Laboratory glass material for synthesis
Silicon paste tube	*66.00€*	Material for the laboratory WP5. Silicon paste for sealing purposes in the reactor
Glass beaker	*14.70€*	Material for the laboratory WP5. Laboratory glass material for synthesis
Pipettes, plugs	416.80€	Material for the laboratory WP5. Laboratory material for synthesis
Automatic pipette	258.47€	Material for the laboratory WP5. Laboratory material for synthesis
Teflon centrifugal blade	70.80€	Material for the laboratory WP5. Mixing accessory for reactor used for the preparation of sols
Kapton flexible heating	149.40€	Material for the laboratory WP5. Flat polymide film heater to check the thermal resistance of pilot-lab fibers and the role of the heat

		transfer from the substrate in the fiber shrinkage
Diamond cutting disc	240.43€	Material for the laboratory WP5. Cutting tool for the preparation of substrates
Ethanol	94.83€	Material for the laboratory WP5. Chemical reagent for preparing PZT sols
SiC substract, ceramic fiber plug	330.00€	Material for the laboratory WP5. Substrates. Laboratory material for furnaces
PZT stacks	4810.00€	Material for the laboratory WP5. Commercial piezoelectric for the analysis of the relationship microstructure-properties in the best possible case
Microspatula, spatula, tongs	176.52€	Material for the laboratory WP5. Laboratory material for synthesis
Zirconyl nitrate hydrate	91.60€	Material for the laboratory WP5. Chemical reagents for preparing doped and undoped PZT sols
2-Methoxyethanol, anhydrous	209.70	Material for the laboratory WP5. Chemical reagents for preparing doped and undoped PZT sols
Sensors PPP-NCH-50	1527.00€	Material for the laboratory WP5. Level sensors to implement the reactor capabilities
Piezoelectric disc	245.00€	Material for the laboratory WP5. Commercial piezoelectric for the analysis of the relationship microstructure-properties
Piezoelectric disc	98.00€	Material for the laboratory WP5. Commercial piezoelectric for the analysis of the relationship microstructure-properties
PZT stacks	4480.00€	Material for the laboratory WP5. Commercial piezoelectric for the analysis of the compatibility electrode vs ceramic parts. Analysis of the metal-ceramic multilayer structure to achieve the best known response
Registration 4th International Congress on EPD	1318.07€	Diffusion WP6. Participation of Scientific Researcher Amador Caballero in the 4th International Congress on EPD. This meeting is focused in electrically driven shaping films and coatings from sols and gels.
Registration 4th International Congress on EPD	1318.07€	Diffusion WP6. Participation of Scientific Researcher Marina Villegas in the 4th International Congress on EPD. This meeting is focused in electrically driven shaping films and coatings from sols and gels.
Registration MRS Spring Meeting	459.46€	Diffusion WP6. Participation of Scientific Researcher Marina Villegas in the MRS Spring Meeting. Sessions covering sol-gel process issues are well recognised and is a state of the art meeting of the topic.
Registration MRS Spring Meeting	459.46€	Diffusion WP6. Participation of Scientific Researcher Amador Caballero in the MRS Spring Meeting. Sessions covering sol-gel process issues are well recognised and is a state of the art meeting

		of the topic.
Diamond Tip Scribe	69.40€	Material for the laboratory WP5. Tool for testing green fibers integrity in order to manipulate the green devices before sintering
Glass Flask	112.14€	Material for the laboratory WP5. Laboratory material for synthesis
SIDI Analysis	137.82€	Characterization WP5. Characterization tests of prepared doped and undoped PZT sols before and after thermal treatments. XRD for structural characterizationand RMN for cuantitative measure of organic components
SIDI Analysis	143.92€	Characterization WP5. Characterization tests of prepared doped and undoped PZT sols before and after thermal treatments. XRD for structural characterization
SIDI Analysis	138.84€	Characterization WP5. Characterization tests of prepared doped and undoped PZT sols before and after thermal treatments XRD for structural characterization and mass spectrometry for composition characterization
Fine Pt powder	3250.00€	Material for the laboratory WP5. Component of conductive electrode paste to prepare lab-scale green Pt-coated green PZT fibers for the analysis of cosintering difficulties
Steel jar, Steel bar	2707.42€	Material for the laboratory WP5. High-energy milling components to adapt the particle size of prepared powders to the requirements of colloidal gels
Making of the image of the website	276.00€	Web page design WP6. First payment of the ActiPPTSens webpage
Making of the image of the website	644.00€	Web page design WP6. Final payment of the ActiPPTSens webpage

2. Financial statements – Form C and Summary financial report.-

FP7 - Grant Agreement - Annex V - Article 171 of the Treaty

Summary Financial Report - Article 171 of the Treaty

Project acronym	ActiPPTSens	Project nr.	255909	Reporting period from	01/04/2010	to	31/08/2012	Page	1/1

Funding scheme	171

				Type of activity								Total (A)+(B)+(C)+(D)			
Beneficiary nr.	If 3rd Party, linked to beneficiary	Adjustment (Yes/No)	Organization Short Name	RTD (A)		Demonstration (B)		Management (C)		Other (D)					
				Total	Max JU Contribution	Total	Max JU Contribution	Total	Max JU Contribution	Total	Max JU Contribution	Total	Max JU Contribution	Receipts	Interest
1		No	TECNALIA	303,346.49	227,509.87	0.00	0.00	64,094.64	48,070.98	0.00	0.00	367,441.13	275,580.85	0.00	0.00
2		No	CEDRAT	388,194.14	291,145.61	0.00	0.00	0.00	0.00	0.00	0.00	388,194.14	291,145.61	0.00	0.00
3		No	CU	47,135.29	35,351.47	0.00	0.00	251.52	188.64	0.00	0.00	47,386.81	35,540.11	0.00	0.00
4		No	ICV-CSIC	88,002.50	66,001.88	0.00	0.00	1,011.89	758.92	0.00	0.00	89,014.39	66,760.80	0.00	0.00
TOTAL				826,678.42	620,008.83	0.00	0.00	65,358.05	49,018.54	0.00	0.00	892,036.47	669,027.37	0.00	0.00

Requested JU contribution for the reporting period (in €)	592,339.96

4.5. ANNEX

KELLER

PIEZORESISTIVE OEM PRESSURE TRANSMITTERS — SERIES 4 LC…9 LC

-40…150 °C, WITH EMBEDDED SIGNAL CONDITIONING

The Series 4 LC…9 LC family of miniature OEM pressure transmitters combines a piezoresistive pressure sensor with -40…150 °C-capable signal conditioning in one compact, easy-to-integrate package.

Technology

The "LC" line of miniature pressure transmitters leverages Keller's extensive background in high-stability piezoresistive pressure sensors and innovative digital signal processing. Now, both pressure sensor and signal processor are integrated into a miniature, hermetically-sealed housing no larger than was once required for the sensor only!

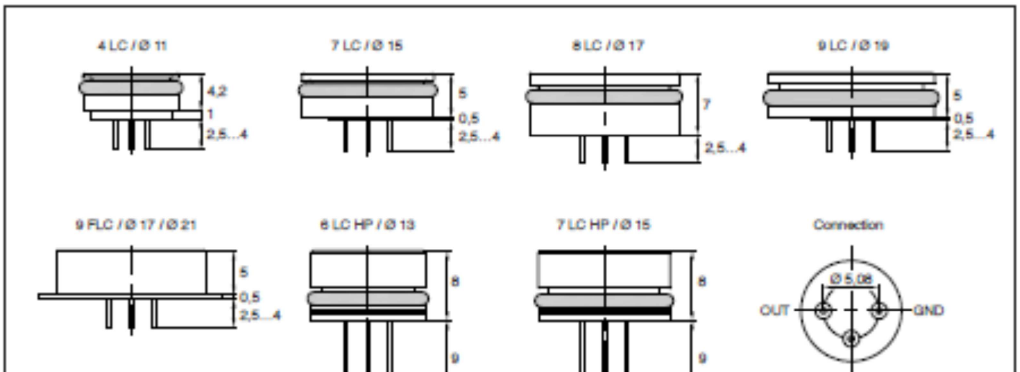
The name given to this new technology is Chip-In-Oil (CIO). CIO means not only that the entire pressure transmitter is embedded within a hermetically-sealed, oil-filled housing, but that this transmitter can then be seamlessly integrated into the OEM product, achieving cost savings and system performance not possible with other, conventional technologies.

Interfaces

The ratiometric analog output simplifies the integrators task by providing a signal output wherein the output is ratiometric to the supply, thereby eliminating the need to incorporate an expensive, absolute reference. Providing an 0,5…4,5 VDC output from a 5 VDC supply, the LC-transmitter is inherently protected against overvoltage and reverse polarity up to ±33 VDC and provides noise immunity by a factor of 10X relative to the latest standards regarding emitted and conducted EMI.

Performance features

- Hermetically protected sensor electronics - extremely resistant to environmental influences
- Operating temperature up to 150 °C
- Ultra-compact, robust housing made from stainless steel (optionally Hastelloy C-276)
- No external electronics for compensation or signal processing
- Extremely accurate, outstanding long-term stability, no hysteresis
- Pressure ranges of 1 bar to 1000 bar
- Extremely easy to integrate in overall systems
- Two-chip solution with pressure sensor and signal processing separation provides a high degree of flexibility



Generally applies:
No force must be applied to the pins!

Subject to alterations 02/2011

KELLER AG für Druckmesstechnik — St. Gallerstrasse 119 — CH-8404 Winterthur — Tel. +41 (0)52 - 235 25 25 — Fax +41 (0)52 - 235 25 00
KELLER Ges. für Druckmesstechnik mbH — Schwarzwaldstrasse 17 — D-79798 Jestetten — Tel. +49 (0)7745 - 9214 - 0 — Fax +49 (0)7745 - 9214 - 50

Companies approved to ISO 9001 www.keller-druck.com

REPORT

KELLER

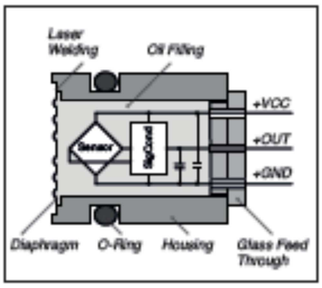
Specifications

Accuracy*	max. +/- 0,25 %FS * Linearity best straight line @ RT, hysteresis, repeatability
Overpressure	2,5 x pressure range, max. 300 bar resp. 1200 bar (6 LC HP, 7 LC HP)
Stability	max. +/- 0,3 %FS

Type/ Version	Dimensions [mm]	Pressure Range	Storage Temperature	Operating Temperature	TEB [1] [%FS]
4 LC	ø 11 x 4,2	3...200 bar abs.[2]	-10...+80 °C	0...50 °C	± 1,0 %FS
7 LC	ø 15 x 5	2...200 bar abs. 2...30 bar rel. [3]	-40...+125 °C	-10...80 °C -40...+125 °C	± 1,0 %FS ± 2,0 %FS
8 LC	ø 17 x 7	1...200 bar abs.	-40...+150 °C	-10...80 °C	± 0,8 %FS
9 LC	ø 19 x 5	1...30 bar rel.		-40...+125 °C	± 1,5 %FS
9 FLC	ø 17 x 5,5 Flange ø 21	1...50 bar abs. 1...30 bar rel.		-40...+150 °C (only > 3 bar)	± 2,5 %FS
6 LC HP	ø 13 x 8	200...1000 bar	-40...+150 °C	-10...80 °C	± 0,8 %FS
7 LC HP	ø 15 x 8			-40...+150 °C	± 2,0 %FS

(1) TEB (Total Error Band): Maximum deviation within specified pressure and operating temperature range
(2) abs: Absolute Pressure Measurement (PAA: Absolute. Zero at vacuum PA: Sealed Gauge. Zero at 1,0 bar abs.)
(3) rel: Referential version (PR: Vented Gauge. Zero at atmospheric pressure)

The integration of the transmitter electronics means that even extremely small designs can be properly supported, and there is a considerable amount of freedom for connection variants. Furthermore, there is no need to protect the nonexistent downstream electronics against moisture and condensation.



Type	3-wire
Signal Output	0,1...0,9 V/V (0,5...4,5 V ratiometric)
Supply	5,0 VDC ± 0,5 V
Reverse Polarity and Overvoltage Protection	± 33 VDC (permanently on all leads)
Power Consumption	max. 8 mA
Load Resistance	> 5 kΩ
Sampling Rate / Bandwidth	2 kHz / 800 Hz
Rise Time T_{99}	1 ms
Response Time (Supply ON)	< 5 ms (0...99%)
Isolation	> 100 MΩ @ 500 VDC
EMC-Industry	EN 61000-6-2 / EN 61000-6-3 / EN 61326-2-3 / BCI 200mA @ 1...250MHz
DO-160F RF Susceptibility (radiated)	Cat. R: 150 V/m @ 400 MHz...8 GHz PM / 30 V/m @ 100 MHz...400 MHz CW & SW,
DO-160F RF Susceptibility (conducted)	Cat.R: 30 mA @ 10 kHz...40 MHz / 3 mA @ 40 MHz...400 MHz
Material in Contact with Media	Stainless Steel AISI 316L (DIN 1.4404 / 1.4435) / optionally Hastelloy C-276 Exception: 6 LC HP / 7 LC HP optionally and @ > 600 bar and > 100 °C: Inconel 718 O-Rings: Viton® 70 Shore A @ 6 LC HP / 7 LC HP: Viton® 90 Shore A Support Ring @ 6 LC HP / 7 LC HP: PTFE
Pressure Endurance	0...100% FS @ 25°C: > 10 mio. pressure cycles with appropriate installation (see install. requirements)
Vibration Endurance	20 g, 5...2000 Hz, X/Y/Z-axis
Shock	75 g sine 11 ms
Oil Filling	Silicone oil, others on request
Electrical Connection	- Glass feed through pins D = 0,45 mm, L = 2,5...4 mm, Positioning: See scale drawing. Attention: It's important not to load forces to the pins! - Silicone wires 0,09 mm² @ the glass feed through pin - Plug JST 1,5 mm, 3-pole. Type: B3B-ZR-SM4-TF. Only for -20...85 °C and not for 4 LC & 6 LC As counterpart: IDC-socket with 1,27 mm flat band. Type: 03ZR-8M-P As counterpart: Crimp-socket with wires AWG 28. Type: ZHR-3, Crimp-contact: SZH-003-P0.5
Options	Other pressure and temperature ranges, other accuracies.

Serie 21 C

Applications requiring a mechanical package with certain pressure and electrical connections can be accommodated. Almost any combination of connections is possible with our Series 21C product line. CIO is optionally available with the 2-wire I2C digital interface, enabling bus-capability in the system design.

Subject to alterations 02/2011

KELLER AG für Druckmesstechnik	St. Gallerstrasse 119	CH-8404 Winterthur	Tel. +41 (0)52 - 235 25 25	Fax +41 (0)52 - 235 25 00
KELLER Ges. für Druckmesstechnik mbH	Schwarzwaldstrasse 17	D-79798 Jestetten	Tel. +49 (0)7745 - 9214 - 0	Fax +49 (0)7745 - 9214 - 60

Companies approved to ISO 9001 www.keller-druck.com

Gems Sensors & Controls

3100 Series and 3200 Heavy Duty Series

Compact OEM Pressure Transmitters

- 0–50 psi to 0-30,000 psi ranges (0-3.5 bar to 0-2,200 bar)
- High Proof Pressures
- Broad Choice of Outputs
- RoHS Compliant

For OEMs that need consistent high levels of performance, reliability and stability the 3100 and 3200 Series sputtered thin film units offer unbeatable price performance ratio in a small package size. They feature all-stainless steel wetted parts, a broad selection of electrical and pressure connections, and wide choice of electrical outputs to allow stock configurations suitable for most applications without modification. At the heart of both these series is a sputter element that also provides exceptional temperature specifications. Plus, our manufacturing process for the 3100 and 3200 Series include the latest automated equipment, producing the most consistent and best price to performance sensor on the market today.

Additionally, 3200 Series transmitters feature thicker diaphragms and a pressure restrictor to withstand the rigors of cavitations or extreme pressure spikes, delivering years of reliable and stable performance in pulsating applications.

The compact construction of both these series makes them ideal for installation where space is at a premium. And they are fully RoHS compliant.

Specifications

Performance	
Long Term Drift	0.2% FS/YR (non-cumulative)
Accuracy	
3100	0.25% FS
3200	0.5% FS for <1000 psi (60 bar)
Thermal Error	
3100	0.83% FS/100°F (1.5% FS/100°C)
3200	2% FS/100°C for <1000 psi (60 bar)
Compensated Temperatures	-40°F to +257°F (-40°C to +125°C)
Operating Temperatures	-40°F to +257°F (-40°C to +125°C)
Zero Tolerance	
3100	0.5% of span
3200	1% FS for <1000 psi (60 bar)
Span Tolerance	
3100	0.5% of span
3200	1% FS for <1000 psi (60 bar)
Response Time	1 ms
Fatigue Life	Designed for more than 100 M cycles
Mechanical Configuration	
Pressure Port	See under "How to Order," last page
Wetted Parts	17-4 PH Stainless Steel
Electrical Connection	See under "How to Order," last page
Enclosure	IP67 (IP65 for electrical code A)
Vibration	40G peak to peak sinusoidal, (Random Vibration: 20 to 1000 Hz @ approx. 40G peak per MIL-STD-810E)
Shock	Withstands free fall to IEC 68-2-32 procedure 1
EMC (Radiated Immunity)	100 V/m
Approvals	CE, conforms to European Pressure Directive, Fully RoHS compliant, UL recognized files # E219842 & E174228
Weight	35 grams

ALAVA INGENIEROS

Individual Specifications

Voltage	
Output (3-wire)	0 V min. to 10 V max. See under "How to Order," last page
Supply Voltage	2 Volts above full scale to 30 Vdc max @ 4.5 mA (6.5 mA on dual output version)
Source and Sinks	2 mA
Current	
Output (2-wire)	4-20 mA
Supply Voltage	8-30 Vdc
Maximum Loop Resistance	(Supply Voltage-8) x 50 ohms
Ratiometric	
Output	0.5 to 4.5 Vdc @ 4 mA (6.5 mA on dual output version)
Supply Voltage	5 Vdc ±10%

PRESSURE TRANSDUCERS

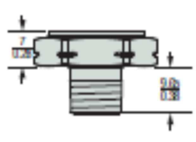
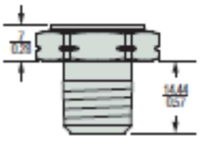
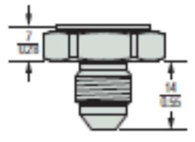
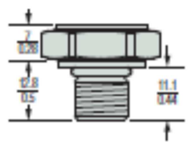
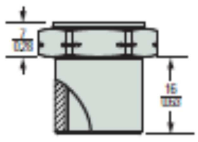
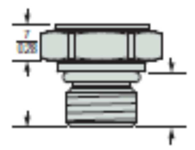
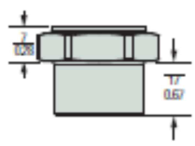
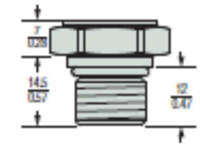
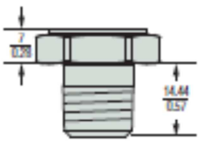
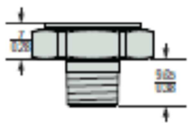
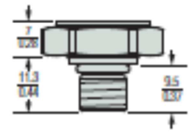
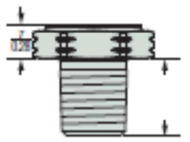
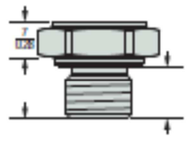
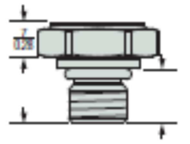
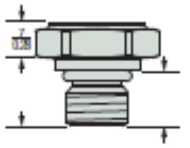
Visit www.GemsSensors.com for most current information.

SPUTTERED THIN FILM

Pressure Capability

Pressure Range PSI (Bar)	Proof Pressure (x Full Scale)		Burst Pressure (x Full Scale)	
	3100	3200	3100	3200
50-300 (3.5-25)	3.00 x FS		40 x FS	
500-1,500 (40-100)			20 x FS	
2,000-6,000 (160-400)		3.00 x FS	10 x FS	
7,500-9,000 (600)	2.00 x FS			10 x FS
10,000 (700)			4 x FS	
15,000 (1,000)		2.50 x FS		>60,000 PSI (4,000 bar)
25,000 (1,800)	1.40 x FS		1.8 x FS	
30,000 (2,200)		—	1.5 x FS	—

Pressure Ports

				
Fitting Code	**08** – 1/8"-27 NPT	**02** – 1/4"-18 NPT	**04** – 7/16"-20 UNF with 37° Flare	**1J** – 7/16"-20 UNF with O-Ring
Torque	2-3 TFFT*	2-3 TFFT*	15-16 NM	18-20 NM
				
Fitting Code	**0E** – 1/4"-18 NPT Internal	**0K** – M14 x 1.5	**1G** – SAE 4 Female 7/16" Schrader	**1P** – 9/16-18 "Heavy Duty"
Torque	2-3 TFFT*	2-3 TFFT*	18-20 NM	18-20 NM
				
Fitting Code	**4C** – 1/4"-18 NPTF Dryseal	**4D** – 1/8"-27 NPTF Dryseal	**4N** – SAE J1926/2 3/8-24	**01** – G1/4" External
Torque	2-3 TFFT*	2-3 TFFT*	18-20 NM	30-35 NM
				
Fitting Code	**05** – G1/4" A Integral Face Seal	**0L** – M12 x 1.5	**2T** – M12x1.5 HP Metal Washer Seal	
Torque	30-35 NM	18-20 NM	30-35 NM	

Notes:
The diameter of all cans is 19 mm (0.748")
Hex is 22 mm (0.866") Across Flats (A/F) for deep socket mounting
*NPT Threads 2-3 turns from finger tight, then wrench tighten 2-3 turns.

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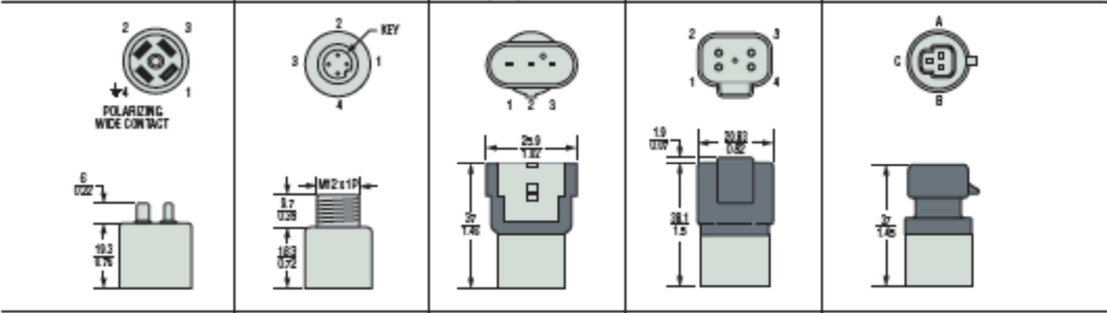
PRESSURE TRANSDUCERS

Gems Sensors & Controls

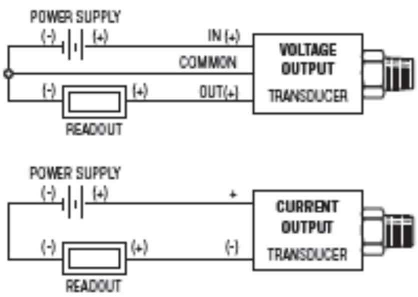
Electrical Connector



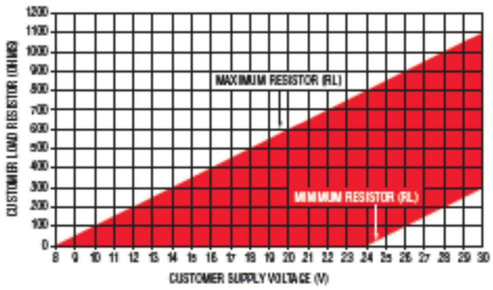
Pin #	DIN 9.4 mm, Code B: Voltage Mode	DIN 9.4 mm, Code B: Current Mode	M12 x 1P, Code E: Voltage Mode	M12 x 1P, Code E: Current Mode	Amp Superseal 1.5, Code 6: Voltage Mode	Amp Superseal 1.5, Code 6: Current Mode	Deutsch DT04-4P, Code 8: Voltage Mode	Deutsch DT04-4P, Code 8: Current Mode	Packard MetriPack, Code 9: Pin ID	Packard MetriPack, Code 9: Voltage Mode	Packard MetriPack, Code 9: Current Mode
1	V_{out}1 (pressure)	No Connect	V_{supply}	Supply	V_{out}1 (pressure)	No Connect	Ground	Return	C	V_{out}1 (pressure)	No Connect
2	V_{supply}	Supply	V_{out}1 (pressure)	No Connect	Ground	Return	V_{supply}	Supply	A	Ground	Return
3	V_{out}2 (temp)	No Connect	Ground	Return	V_{supply}	Supply	V_{out}2 (temp)	No Connect	B	V_{supply}	Supply
4	Ground	Return	V_{out}2 (temp)	No Connect	—	—	V_{out}1 (pressure)	No Connect	—	—	—

PRESSURE TRANSDUCERS

Wiring Diagram



Current Output Mode (Load Resistor Range)

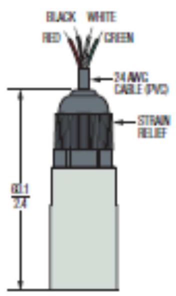


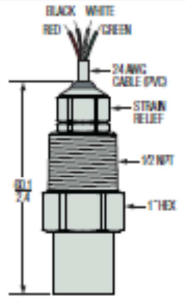
Minimum Resistor Value = 50 • (+V − 24) for +V > 24V
Maximum Resistor Value = 50 • (+V − 8) for +V > 8V

ALAVA INGENIEROS

SPUTTERED THIN FILM

Cable-Out Types





	Strain Relief Gland		1/2" Conduit Connection	
Wire Color	**Voltage Mode**	**Current Mode**	**Voltage Mode**	**Current Mode**
Red	Supply	Supply	Supply	Supply
Black	Ground	Return	Ground	Return
White	$V_{out}1$ (pressure)	No Connect	$V_{out}1$ (pressure)	No Connect
Green	$V_{out}2$ (temp)	No Connect	$V_{out}2$ (temp)	No Connect

Mating Connectors

Part Number	Description	For Use on Elect. Code #
557230	MINI DIN Connector, Strain Relief	B
557703-01M0	M12 Cord Set – 1 Meter (Red 1, Green 2, Blue 3, Yellow 4)	E
557703-03M0	M12 Cord Set – 3 Meters (Red 1, Green 2, Blue 3, Yellow 4)	E
557703-04M0	M12 Cord Set – 4 Meters (Red 1, Green 2, Blue 3, Yellow 4)	E
557703-05M0	M12 Cord Set – 5 Meters (Red 1, Green 2, Blue 3, Yellow 4)	E
	Recommended Mating Parts (AMP p/n: Housing 282087-1; Contacts 3X 183025-1; Seal 281934-1; Boot 880811-2)	6
557701	AMP Superseal Mate Kit	6
210729	AMP 3.5" Cable Cord Set – Clear Pos 1, Black Pos 2, Red Pos 3	6
210730	AMP 12" Flying Leads Cord Set – White Pos 1, Black, Red Pos 3	6
	Recommended Mating Parts (AMP p/n: Socket Conn 1-967325-1. Consult AMP for Contacts, Wire Seal and Strain Relief options)	7
557702	DIN 72585 Twist Lock Mate Kit	7
	Recommended Mating Parts (Deutsch p/n: Housing Plug DT064S-P012; Wedge W4S-P012; Sockets 4X 0462-201-1631)	8
224153	Deutsch Cord Set 3" Long (18 AWG PVC Cable – Black 1, Red 2, Green 3, White 4)	8
	Recommended Mating Parts (Delphi Packard MetriPack p/n: Body 12065286; Seal 12052893. Consult Delphi for Contacts)	9
218760	Packard Mate Kit	9
223974	Packard Cord Set 3" Long (24 AWG PVC Cable – White 1, Black 2, Red 3)	9
223975	Packard Cord Set 6" Long (24 AWG PVC Cable – White 1, Black 2, Red 3)	9
220492	Packard Mate - 12" Flying Leads – 3 Conductor PVC 18 AWG	9
222976	Packard Mate - 18" Flying Leads – 3 Conductor PVC 18 AWG	9
220797	Packard Mate - 24" Flying Leads – 3 Conductor PVC 18 AWG	9

PRESSURE TRANSDUCERS

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REPORT

How to Order

Use the bold characters from the chart below to construct a product code

3100 B 200PG 02 B R 001

Series
- **3100 / 3200** - Pressure Transducer – Combination Pressure and Temperature[1]
- **3101 / 3201** - Temp. Output Range -40°C to 125°C
- **3102 / 3202** - Temp. Output Range 0°C to 100°C
- **3103 / 3203** - Temp. Output Range 0°C to 80°C

Output
- **B** - 4-20 mA
- **C** - 1-6 V
- **H** - 1-5 V
- **N** - 0.5-4.5 V
- **R** - 0-5 V
- **S** - 0-10 V
- **T** - 0.5-4.5 V Ratiometric

Pressure Range – psi

050PG - 0-50 psiG[5]	**10CPG** - 0-1,000 psiG	**10KPS** - 0-10,000 psiS
075PG - 0-75 psiG	**15CPG** - 0-1,500 psiG	**15KPS** - 0-15,000 psiS[2]
100PG - 0-100 psiG	**20CPS** - 0-2,000 psiS	**20KPS** - 0-20,000 psiS[2]
150PG - 0-150 psiG	**25CPS** - 0-2,500 psiS	**25KPS** - 0-25,000 psiS[2]
200PG - 0-200 psiG	**30CPS** - 0-3,000 psiS	
300PG - 0-300 psiG	**35CPS** - 0-3,500 psiS	
500PG - 0-500 psiG	**40CPS** - 0-4,000 psiS	
600PG - 0-600 psiG	**50CPS** - 0-5,000 psiS	
750PG - 0-750 psiG	**60CPS** - 0-6,000 psiS	
	75CPS - 0-7,500 psiS	

Pressure Range - bar

0004G - 0-4 barG[5]	**0160S** - 0-160 barS	**1000S** - 1,000 barS[2]
0005G - 0-5 barG	**0250S** - 0-250 barS	**1600S** - 1,600 barS[2]
0010G - 0-10 barG	**0400S** - 0-400 barS	
0016G - 0-16 barG	**0600S** - 0-600 barS	
0025G - 0-25 barG		
0040G - 0-40 barG		
0060G - 0-60 barG		
0100G - 0-100 barG		

Cable Length
- **001** - 1 meter
- **002** - 2 meters
- **003** - 3 meters
- **004** - 4 meters
- **005** - 5 meters

Optional Restrictor (3200 only)
- **R** - Restrictor
- **0** - No Restrictor

Electrical Connection
- **B** - Industrial DIN (mating connector not supplied)
- **E** - M12 x 1P (4-Pin)
- **F** - Cable version
- **3** - 3-1/2" NPT Male Conduit
- **8** - Deutsch DT04-4P
- **9** - Packard MetriPack

Pressure Port[4]
- **08** - 1/8-27 NPT External
- **02** - 1/4-18 NPT External
- **04** - 7/16-20 External (SAE #4, J514)
- **1J** - 7/16-20 External (SAE #4, J1926-2)
- **0E** - 1/4"-18 NPT Internal
- **0K** - M14 x 1.5 Straight
- **1G** - Schrader SAE #4, 7/16" Internal
- **1P** - SAE 6 (9/16"-18 UNF 2A)
- **4C** - 1/4-18 NPTF External (Dryseal)
- **4D** - 1/8-27 NPTF External (Dryseal)
- **4N** - SAE 3 3/8-24 UNF External

European Threads
- **01** - G1/4 External
- **05** - G1/4 External Soft Seal
- **0L** - M12 x 1.5 (<1,000 bar, 15,000 psi)
- **2T** - M12 x 1.5 (6g) (≥1,000 bar, 15,000 psi)

Notes:
1. Temperature outputs are for voltage output pressure sensors only (applies to codes -C, -H, -N, and -T only) and limited to connections that have 4 pins (Electrical codes -B, -E, -7, and -8). Accuracy is 3.5% of temperature span. Requires additional 2mA of power.
2. Ranges 15,000 psi (1,000 bar) and above available with -2T pressure port only.
3. For use with pull-up or pull-down resistors, contact factory.
4. Pressure ports 0E and 1G are NOT available with the Restrictor option.
5. 0-50 PSI (4 bar) – **NOT** available with 4-20 mA or 0-10 Vdc outputs.

PRESSURE TRANSDUCERS

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