

TITLE : Specifications for a cryostat with a 3-axes translation cold holder for wafer electrical cryo-prober					
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1. Purpose

1.1. Presentation of the DOPT Division

The optics and photonics division (DOPT) - one of the six divisions of LETI / CEA (the French Alternative Energies and Atomic Commission) - develops micro-technologies in the field of optics and optoelectronics based on its unique expertise in alternative materials such as non-silicon semiconductors; the researches are focused in four main fields of technologies:

- Imaging technologies development from visible to THz spectral range,
- Led lighting,
- Displays based on OLED technologies,
- Photonics on silicon.

2. Description of the general framework

The aim of this purchase is the electrical characterization of infrared (IR) bandgap semiconductors wafers at different cryogenic temperature, under vacuum. The sample holder will be surrounded by a cooled thermal shield inside the cryostat. Photodiodes will be electrically characterized on a wafer level scale, with an automatic X,Y motion to place the wafer electrical contact under the tip and a Z motion of the wafer to reach an electrical probe that will be fixed on a dedicated aperture on a cold shield. The top cold shield lid that will be placed on this aperture will be designed by CEA-Leti.

To perform this characterization, the DOPT Division plans to purchase a cryostat, having a moving cold holder, with the following specifications:

- 3 axes, XYZ translation, in order to move the cold sample holder (stick-slip/piezo motors with remote control). Two Z motors will be placed on this equipment, one provided by the cryostat manufacturer and one designed by CEA-Leti, as described in section 3.1.
- Independent cooling of the sample holder and cold shield in order to minimize the residual thermal radiation impinging wafer under test, with an opening in the cooled shield sized to accommodate a top shield lid made by CEA-Leti. For efficient protection of the sample under test by the thermal radiation, the covered area by the cold shield must be as high as possible.
- External optical access to the center of the cryostat (main lid opening for visual access).
- Electrical feed-troughs for instrumentation purposes (signal inputs and outputs).

The specific requirement for the different parts of the cryostat are presented below.

3. Implantation and internal architecture of the cryostat

3.1. Geometric, translation, vacuum and temperature specifications

The volume of the cryostat has to include the XYZ translation system, the heat exchanger for the sample holder and a cold shield. The top of the cold shield must be placed at a vertical distance of 80mm (at the reference position of the Z stage, see section 3.1.1) above the sample plane and 40mm below the cryostat top cover.

Compatible for mounting on an optical breadboard with a grid of 25mm-20 (M6) tapped holes.

A sample holder with custom bore pattern. A number of tapped holes (following a custom bore pattern with minimum 6 tapped holes that can be placed anywhere) on the sample holder will allow sample mounting. Our wafers under test are stucked on a wafer holder that will be screwed on the sample holder. The main sample holder must be designed to accommodate a 7-inch plate (wafer holder), upon which a 6-inch wafer will be mounted. This main sample holder contains the wafer under test, see in Figure 1

(a) below. This main sample holder must allow to screw on it our existing 4" diameter wafer holder, that allows 3" diameter wafer mounting, as shown Figure 1 (b) below.
The cooled sample holder must be flat (without any rebound at the sample holder edges).

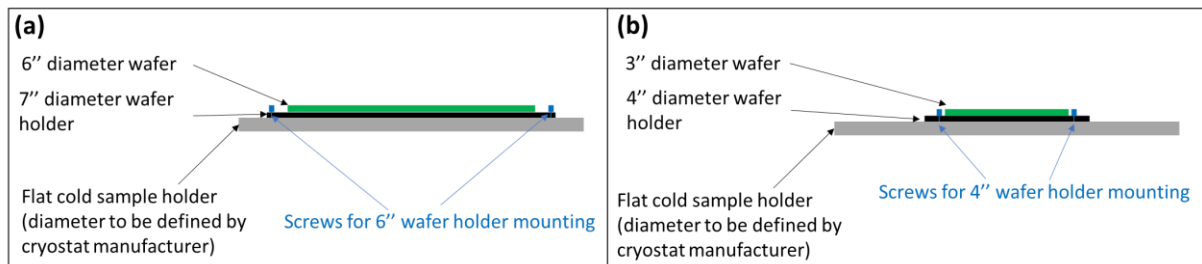


Figure 1 – Cross section view of sample holder stack. Screws are not to scale and only presented for illustration purposes. **(a)** For a 6" wafer diameter mounted. **(b)** For a 3" diameter wafer mounted.

An inhouse Z motor stage will be added by ourselves. A minimum 7cm thick removable spacer must be inserted between the top of the vertical Z stage and the bottom of the wafer chuck which should be removable by ourselves to interpose inhouse small range Z stage on top of the manufacturer provided Z stage. Therefore, the wafer chuck :

- Should be completely removable by ourselves from the cooling system (without technical support) for maintenance (connected to the cooling system with Swagelock fittings or equivalent)
- Or must be at least removable from the XYZ translation system by ourselves

in order to interpose our inhouse small range Z stage on top of the manufacturer provided Z stage.

This cold shield must be removable by ourselves (without technical support) for maintenance (connected to the cooling system with Swagelock fittings or equivalent).

Every cold part must be made of highly conductive material (e.g. Ni-plated copper). The rest can be made of aluminum, including the cryostat main lid.

The wafer holder must be located at the center of the cryostat (or at least at the center of the cold shield opening) in the horizontal (X,Y) plane at the reference position of the XY translation stages.

The top of the cold screen should contain one aperture that would allow to host the top shield lid made by CEA-Leti mentioned in section 2. The diameter of this aperture (inner diameter of the cold shield) must be 45cm minimum and 50cm maximum. This aperture will allow easy wafer dismounting at the XY motor extreme position. Around this aperture, a dedicated shoulder must be provided to serve as a supporting surface for the top shield lid. This shoulder should include an appropriate number of threaded holes and screws for lid fixation and to ensure good thermal contact. Its dimensions and number of holes are to be defined by the cryostat manufacturer and then discussed.

This shoulder, and the dimensions mentioned in sections 3.1 and 3.1.1 are represented on Figure 2 below :

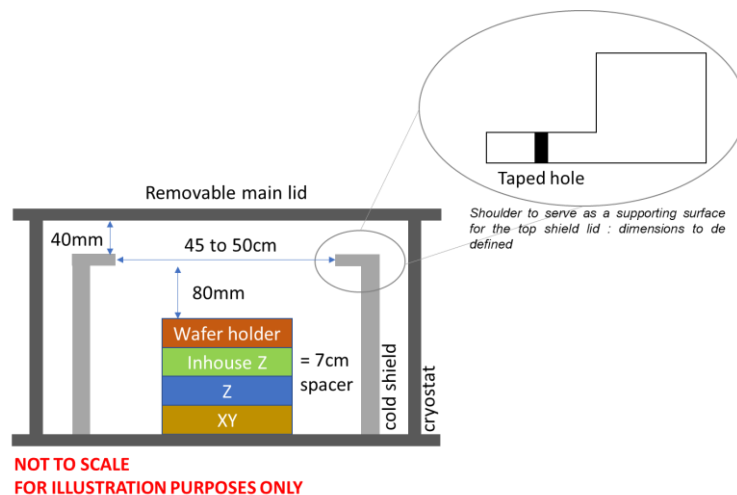


Figure 2 – Cross section of the cryostat proposal. X,Y,Z translation stages are represented at their reference position. Figure is not to scale and dedicated to illustration purposes only.

3.1.1. Mechanical specifications

- Minimum travel range in the horizontal plan for the orthogonal X and Y directions: 120 mm minimum.
- X,Y scanning resolution : 50nm (closed loop).
- Minimum horizontal (X,Y) maximum charge load : 30N
- Maximum vertical travel range in the Z direction: 20 mm
- Minimum vertical maximum charge load: 10N.
- **Drivers and software should be included to program the scanning path from a PC and ensure the security of the system (end stops)**; this part must be precisely described in the supplier proposal, and an API (Application Programming Interface) should exist to facilitate Python remote control of every device.
- The wafer holder must be located at the center of the cryostat (or at least at the center of the cold shield opening) in the horizontal (X,Y) plane at the reference position of the XY translation stages.

3.1.2. Vacuum specifications

The cryostat must be required to :

- Maximum leak rate of 10^{-8} mbar.l.s⁻¹ (a vacuum leakage test must be done with an He leakage detector, after the cryostat fabrication).
- The flange dedicated to the pumping system must be DN63 ISO K **or equivalent output diameter (DN 63 ISO K is preferred because directly compatible with our pumping system). The supplier shall price the pumping system as an optional item.**
- A vacuum of 10^{-5} mbar inside the cryostat should be achieved with our vacuum pump (nominal pumping speed for N₂: 67 l.s⁻¹) in a pumping time lower than 2h.
 - **The manufacturer can propose a design that will optimize pumping time. By instance, by having the pumping system below the cryostat (not necessarily centered below the cryostat), compatible with support mounting and adapted to prevent part or debris that may fall inside the cryostat to fall in the pumping system.**

3.1.3. Temperature and cryogenic specifications

The cryostat must be required to in the following specifications described in Table 1 below:

Table 1 – Temperature and cryogenic specifications.

Parameter	Specification
The sample holder	<ul style="list-style-type: none"> - must be connected to flexible cryocooled pipes that allow XYZ motion to enable its movement. - must be compatible with liquid Nitrogen and liquid Helium
The sample holder temperature	should be controlled from 4 to 325 K ; on a routine basis the sample will be cooled with liquid nitrogen and controlled at a temperature about 130 K .
The cold shield	<ul style="list-style-type: none"> - must be cooled by pipes welded externally along an optimized spiral trajectory in terms of diameter and pitch to minimize the cooling time - should be set at a temperature of 78 K whatever the temperature of the rest of the system is and it should be equipped with a temperature sensor

The temperature control includes the temperature sensor, the heater and a temperature controller to reach temperature to the used need, with PID to be defined.

The temperature controller API (Application Programming Interface) should exist to facilitate Python remote control.

The thermal isolation between the translation stage and the sample stage must be maximized to remain in the normal temperature range of the motor stage. As an option, a reading of the temperature on that motor stage closest to the sample stage can be proposed.

3.1.4. Main lid specifications

An optical window with a clear aperture diameter of 60mm in the cryostat lid with a high transmission of visible light, in order to see the inside of the chamber and the wafer under test through a microscope.

No connectors must be placed on the lid so it can be removed easily. The lid must have handles and be as light as possible to be easily removed to access to the inside of the cryostat.

3.1.5. Electrical specifications

The supplier shall price the following proposition has an optional item:

The sample holder surface must be electrically connected to the “force” (or also called “sense”, at the center of the cable) of a vacuum compatible electrical triaxial cable, connected to a dedicated feedthrough located at the bottom of the cryostat equipped with a female triaxial connector (see section 3.1.6). The electrical resistance between the sample holder surface and the “force” of the triaxial connector located on the feedthrough must be lower than 1 Ohm. This signal must be electrically highly isolated from the rest of the cryostat.

3.1.6. Feedthrough specifications

A good cable management is required to ensure a good reliability of the equipment.

The supplier will propose a feedthrough repartition and cable management that matches our specifications. This proposition will then be discussed, modified if needed and validated.

These feedthroughs must be located at different heights to improve cable management. Some must be located at the bottom of the cryostat (so the cables can easily go under the cooled thermal shield) and some others close to the top of cryostat, at the level of the top cooled shield lid.

The needed feedthroughs are gathered in Table 2 below:

Table 2 – Feedthroughs specifications.

Feedthroughs needed	Specification	Commentary
Connectors for heaters and temperature sensors		as many as needed, located in order to reduce the cable length inside the cryostat and optimize cable management by avoiding cable crossing.
Electrical connections for XYZ motors	located at the bottom of the cryostat.	
A 32-pins connector for instrumentation purposes	<p>This feedthrough must be located at the level of the top of the shield lid.</p> <p>As an option, this 32-pins connectors can be connected to a movable ribbon cable inside the chamber</p>	Regarding the ribbon cable : its length must be optimal: long enough to accommodate the whole top cold shield, but as short as possible for small electronic signal to go through. It must not induce vibrations or shadowing. Proper thermal anchors of the ribbon cable must be proposed to limit thermal exchange between the inside and the outside of the chamber. The supplier will propose its own cable with plugs; it must be possible to change the cable and to replace it by an in-house cable.
An 8 pins connector for electrical connection to our own Z motor		<p>(see section 3.1).</p> <p>This connector must allow us to make an electrical connection to wires inside the cryostat dedicated to our own Z motor by ourselves. This connector will be located at the bottom of the cryostat.</p>
5 blind flanged flanges (allowing later add-on),	with 3 located at the bottom of the cryostat and 2 located at the top of the cryostat.	The output diameter of such feedthrough should be around 68mm (for instance a DN 50KF flange).

a dedicated feedthrough for the female triaxial connector	with its sense connected to the wafer holder surface, see section 3.1.5	This is described as an option in section 3.1.5 This feedthrough must be located at the bottom of the cryostat and close to an around 68mm diameter blind flanged flange.
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As a guide, we propose this feedthroughs disposition along the cryostat perimeter on Figure 3 below:

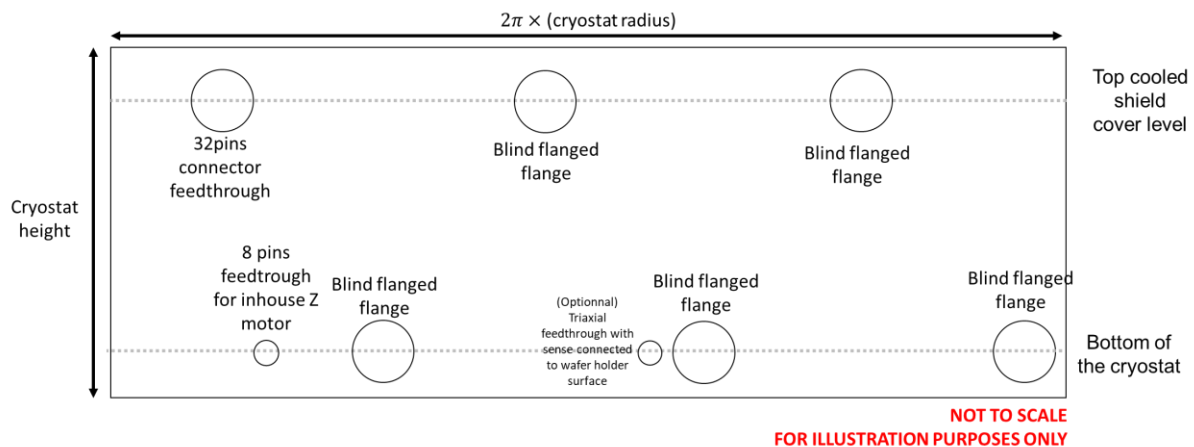


Figure 3 – Feedthroughs disposition proposal along the cryostat perimeter, for illustration purposes only. This figure is not to scale.

WARNING: Note that Figure 3 is not to scale and is only a “visual” guide for illustration purposes only. Feedthroughs does not need to be linearly spaced, but must be located all around the cryostat. The connectors for heaters and temperature sensors and for XYZ motors are not represented, as well as the flange dedicated to the pumping system.

3.1.7. Optional specifications

Optional specifications are gathered in Table 3 below.

Specifications have different rating:

- **F1** = Mandatory type of option;
- **F2** = Non-Mandatory type of option.

Note:

Mandatory type of Option: F1 The supplier must obligatorily include an offer with the specified option, otherwise the offer will be considered irregular and eliminated. The CEA reserves the right to decide whether to exercise this option or not, but the price of the option must be clearly stated in the offer. The price of mandatory options will be included in the overall budget for the comparison of offers.

Non-Mandatory type of Option: F2 The supplier has the discretion to propose or not propose the specified option. If the option is not proposed, the supplier will not necessarily be disqualified. The CEA reserves the right to decide whether to exercise the option or not.

Table 3 – Optional specifications summary.

Specifications	Rating
The cold shield could be individually controlled at least in the range of 78K to 300K, whatever is the temperature of the rest of the system.	F2
Adapted liquid nitrogen dewars and transfer lines shall be priced by the manufacturer.	F2
Pumping system (see section 3.1.2).	F2
Temperature reading of the motor stage closest to the sample stage (see section 3.1.3).	F2
Design of a ribbon cable connected to the 32 pins connector (see section 3.1.6).	F2
Electrically isolated triaxial cable connected to the sample holder and the sense of a female triaxial connector located on a dedicated feedthrough (see sections 3.1.5 and 3.1.6).	F2

4. Safety and working conditions, manuals

4.1. EC conformity

The supplied equipment shall meet the regulations in force in France.

Said regulations include the European directives converted into French Law.

In particular, the following directives shall apply, as required:

- **“Machinery” directive 2006/42/EC**
See Appendix A: Specifications for delivering work equipment (Compliance with European machinery directive 2006/42/EC).
- **“Electromagnetic compatibility” directive 2004/108/EC**
- **“Low voltage” directive 2006/95/EC**
- **EXAT directive 94/9/EC**
- **“Pressure” directive 97/23/EC**

The equipment shall be EC certified, a “CE marking” shall be affixed thereon and it shall be accompanied by an EC declaration of conformity

The various risks (mechanical, electrical, thermal, cryogenic liquid and gas) shall be clearly mentioned by Equipment Manufacturer in its proposal and handled in accordance with the instructions of the applicable directives

4.2. Electrical features in the DOPT facilities

Power supply voltages available:

- Single-phase: 1 phase + neutral + earth
Phase/Neutral voltage: 230 V +/- 10 %
Main frequency: 50 Hz

4.3. Manuals

The supplier shall deliver an instructions manual, including the general description of the equipment, drawings, installation and connection instructions and the operating instructions (descriptions and explanations necessary for the use). Instructions on the protective measures to be taken by the users, including, where appropriate, the personal protective equipment to be provided shall also be included in the manual.

Language

"All machinery must be accompanied by instructions in French.

The instructions manual accompanying the machinery must be either an original instruction manual or a translation of the original manual in which case, the translation must be accompanied by the original instruction manual." **(Transposition of 2006/42 1.7.4)**

"The instruction manual is drafted in French and may be in one or more official Community languages. The word original instruction manual must appear on the language version(s) verified by the manufacturer. Where no original instruction manual exists in French, a translation into this language must be provided by the manufacturer or by the person bringing the machinery into France. This translation must bear the words translation of the original instruction manual." **(Transposition of 2006/42 1.7.4.1)**

Consequently, the following will be provided:

- The instruction manual in its original version drafted in one of the EC languages, in any case
- The instruction manual translated in French (if the original version was drafted in another language than French) in the case where this obligation is incumbent upon the supplier.

5. Warranty

5.1. Warranty terms

The warranty will begin on the date the equipment is accepted and will remain in effect for **one year**. The warranty will cover corrective maintenance and all related costs, including labor, parts, travel, shipping, etc.

5.2. Warranty support

During the warranty period, the Contractor agrees to provide support within a maximum of **3 weeks** after receiving an email or phone call from CEA-LETI
Support must be available for service from 8:00 a.m. to 5:00 p.m. on weekdays.

In the event of repairs at the Contractor's premises, the Contractor shall be responsible for the safekeeping and use of the Equipment, which is the property of the CEA, from the time it is taken into custody at the CEA site and after the signing of a report issued by the CEA and signed by both Parties. Risk shall revert to the CEA upon the mutual signing by the Parties of the report confirming the return of the Equipment to the Grenoble site.

The Contractor is responsible for all costs associated with the transportation of the Equipment (round trip).

6. Environmental Clause

The supplier to implement all the provisions described in its environmental proposal, which forms an integral part of the contract.

In this context, and in accordance with these commitments, the Contractor shall implement all or part of the following environmental provisions during the performance of the contract:

- to design equipment that incorporates durable materials with a long service life;
- to provide equipment that can be scaled up or adapted (for example, by adding frames);
- ensure that the equipment's components are easily removable and repairable;
- provide training on the use of the equipment in accordance with the terms of the clause

The supplier remains free to propose any other alternative solution that falls within the scope of this clause.

The supplier agrees to provide recommendations to extend the service life of the Equipment during the term of the contract.

7. Checks and tests

The tests and compliance checks for the equipment covered by these specifications are divided into five categories:

- ✓ Full delivery of the equipment
- ✓ The end of the installation and commissioning operations
- ✓ The qualification checks and tests successfully passed
- ✓ Lifting of all reservations issued at the various stages
- ✓ Delivery of the equipment documentation and manuals

7.1. Checks and tests at the factory (Factory acceptance)

Factory acceptance shall be performed on the supplier's site based on the specifications defined in paragraph 3 and in this section. **Factory tests shall be performed by the supplier** and factory acceptance shall be pronounced upon submission by the supplier of test and check report transmitted to CEA.

The check and tests at the factory are summarized in the Table 4 below:

Table 4 – Check and tests at the factory.

Test	Criterion
Leak rate measurement	Maximum leak rate of 10^{-8} mbar.l.s ⁻¹ (a vacuum leakage test must be done with an He leakage detector, after the cryostat fabrication). See section 3.1.2.
Pumping speed and vacuum level	A vacuum level of 10^{-5} mbar must be reachable in a pumping time <2h, using the dedicated pumping flange (see section 3.1.2).

Cooling time	For the sample holder and the thermal shield : a 77K temperature can be reached with liquid nitrogen within working day
X,Y,Z complete motion	The complete stroke of the X,Y and Z must be performed (with the sample holder inside the cryostat)

Supplier shall not be authorised to ship the equipment without pronouncement of factory acceptance and lifting of imperative reserve before shipment.

A CEA employee will participate the factory acceptance on the supplier's site.

7.2. Checks and tests at the CEA facilities

CEA-LETI experts will require the tests of the specifications mentioned in paragraph 3, in order to pronounce the acceptance. Specifications measurements will be done at CEA facilities.

The Contractor shall submit the packaging procedure to CEA-LETI for approval. The packaging procedure must, at a minimum, specify the distribution of packages, their dimensions, and the associated instrumentation (e.g., accelerometer sensors).

The Contractor shall ensure that this procedure is carried out properly. If delivery takes place in the presence of the Contractor (or its representative), the Contractor shall verify the integrity of the various packages, inspect the associated instrumentation, and prepare a "delivery" report (based on its own documentation). Otherwise, the delivery note countersigned by CEA-LETI shall serve as an acknowledgment of receipt.

The check and tests at the factory are summarized in Table 5 below:

Table 5 – Check and tests at CEA-Leti.

Test	Criterion
Pumping speed and vacuum level	A vacuum level of 10^{-5} mbar must be reachable in a pumping time <2h, using the dedicated pumping flange (see section 3.1.2) with our vacuum pump (nominal pumping speed for N ₂ : 67 l.s ⁻¹)
Cooling time	For the sample holder and the thermal shield : a 77K temperature can be reached with liquid nitrogen within working day
X,Y,Z complete motion	The complete stroke of the X,Y and Z must be performed (with the sample holder inside the cryostat)

8. Acceptance

It certifies the acceptance of the equipment's compliance and the transfer of ownership. The equipment's warranty period begins upon issuance of the acceptance certificate.

- Acceptance is granted after:
- Full delivery of the equipment
- Completion of installation and commissioning operations
- Successful completion of qualification inspections and tests
- EC conformity approval issued by the body accredited by CEA-LETI.
- Approval by the site manager at the host facility,
- Delivery of the equipment documentation.

A certificate of acceptance without reservations (*) will be signed by CEA-LETI and the Contractor.

(*) In certain cases, an exception may be granted for reservations that are addressed in a detailed, scheduled action plan to restore compliance with the specifications set forth in this document. In such cases, acceptance will be granted “with reservations.”

Note: Only the test report prepared in accordance with CEA-LETI standards will be considered valid for the purposes of enforcing the regulations associated with this stage and initiating the warranty period. The acceptance recognises conformity of the equipment and transfer of ownership.

9. End of warranty

The warranty expires at the end of the warranty period under the following conditions:

- ✓ All reservations raised at the time of acceptance have been fully resolved.
- ✓ No anomalies detected
- ✓ Compliance with specifications during this period.

In the event of a defect, the Contractor shall be responsible for bringing the equipment into compliance. In the event of unsatisfactory performance, the warranty period shall be automatically extended for the duration specified in the contract.

10. APPENDIX

APPENDIX 1:

Purpose: The aim of this document is to recall the application conditions of this directive as well as certain important technical points

1/ Reminder of the applicable regulation

The “machinery” directive is a European text transposed into the French law.

2/ Definition of a machine

A machine is “an assembly fitted with or intended to be fitted with a drive system other than directly applied human or animal effort consisting of linked parts or components, at least one of which move and which are joined together for a specific application...”

Consequently:

Any equipment complying with the definition will be designed and built in application with the “machinery” directive 2006/42

A machine is considered as “placed on the market for the first time”, “new” or “in the new condition” if it has not been used in a member state of the European Economic Community (EEC).

Consequently:

A second-hand machine from a non-EC country will be considered as new upon its entry into the EC.

The applicable regulation will be that in force at its date of entry.

3/ Reference standards

The presumption of conformity with regulatory requirements is provided by compliance with the provisions described in the harmonised standards mentioned above and circulated by AFNOR Tour de l'Europe 92049 Paris Cedex 7, France:

- specific standards to machinery
- general safety standards,
- standards pertaining to electrical equipment of machinery NF EN 60-204

Note: Compliance with standard 61010-1 does not give a presumption of compliance to the machinery directive

4/ Documents to be provided with the equipment subject to directive 2006/42

➤ EC declaration of conformity

2006/42 annex II:

"EC DECLARATION OF CONFORMITY OF THE MACHINERY

The declaration and translation thereof must be drawn up under the same conditions as the instructions [See Annexe I, Section 1.7.4.1, points a) and b)] and must be typewritten or else handwritten in capitals.

This declaration relates exclusively to the machinery in the state in which it was placed on the market and excludes components which are added and/or operations carried out subsequently by the final user.

The EC declaration of conformity must contain the following particulars:

- 1) business name and full address of the manufacturer and, where appropriate, its authorised representative;
- 2) the name and address of the person authorised to compile the technical file, who must be established in the community;
- 3) description and identification of the machinery, including generic denomination, function, model, type, serial number and commercial name;
- 4) a sentence expressly declaring that the machinery fulfilled all the relevant provisions of this directive and where appropriate a similar sentence declaring the conformity with other directives and/or relevant provisions with which the machinery complies. These references must be those of the text published in the official journal of the European Union;
- 5) where appropriate, the name, address and identification number of the notified body which carried out the EC type-examination referred to in Annexe IX and the number of the EC type-examination certificate;
- 6) where appropriate, the name, address and identification number of the notified body which approved the full quality assurance system referred to in Annexe X;
- 7) where appropriate, a reference to the harmonised standard used as referred to in Article 7, Paragraph 2;
- 8) where appropriate, the reference to other technical standards and specifications used;
- 9) the place and date of the declaration;
- 10) identification and signature of the person empowered to draw up the declaration on behalf of the manufacturer or his authorised representative."

➤ An instruction manual

5/ Marking on the equipment (2006/42 – 1.7.3)

"I. – Each machinery must be marked visibly, legibly and indelibly with the following minimum particulars:

- a) The business and full address of the manufacturer;

- b) Designation of the machinery;
 - c) The CE marking;
 - d) The designation of series or type;
 - e) The serial number if any;
 - f) The year of construction, that is, the year in which the manufacturing process is completed. It is prohibited to predate or postdate the machinery when affixing the CE marking.
- Furthermore, machinery designed and constructed for use in a potentially explosive atmosphere must be marked accordingly.

II. – Machinery must bear full information relevant to its type and essential for safe use.

III. – Where a machine part must be handled during use with lifting equipment, it must be indicated legibly, indelibly and unambiguously.”