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REGLEMENT D'APPLICATION  
DE LA MARQUE BENOR  
DANS LE SECTEUR DES  
ACIERS DE  
PRECONTRAINTE  
**Modalités de contrôle applicables  
aux Usagers de la Marque**

REVISION 13

BENOR asbl



Approuvé par le Conseil d'Administration le 30/04/2020

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Application Regulation
TRA 282 Revision 13

Application Regulation of the BENOR-mark in the sector of the prestressing steel products - Methods of assessment applicable to the Users of the BENOR-mark

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## 1 Introduction

This Application Regulation (TRA<sup>1</sup>) was prepared by the Technical bureau 2 of OCAB-OCBS, sectoral organization, "Prestressing steels" for the BENOR certification of prestressing steels.

According to the regulation of use and control of the BENOR-mark<sup>2</sup> and its article 9, this Application Regulation of OCAB-OCBS constitutes the reference certification scheme to the BENOR-mark.

## 2 Reference documents and definitions

### 2.1 Reference documents

- Règlement d'usage et de contrôle de la marque BENOR / Algemeen reglement voor het beheer van het Benor-merk<sup>3</sup>.
- Règlement général pour la gestion de la marque BENOR / Algemeen reglement voor het beheer van het Benor-merk<sup>4</sup>.
- Règlement particulier d'usage et de contrôle de la marque BENOR dans le secteur des armatures de précontrainte, BRP 281 / Bijzonder reglement voor gebruik en controle van het Benor-merk in de sector van de voorspanwapeningengewapend betonstaal, BRP 281<sup>5</sup>.

In theory, the last edition of the standards and PTV applies. If necessary, an addendum to the present regulation would be published in the event of incompatibility following the revision of one of the documents quoted hereafter.

- NBN I 10-001, Aciers de précontrainte - Fils, torons et barres - Généralités et prescriptions communes / Voorspanstaal - Draad, strengen en staven - Algemeenheden en gemeenschappelijke voorschriften.
- NBN I 10-002, Aciers de précontrainte - Fils tréfilés / Voorspanstaal - Koudgetrokken draad.
- NBN I 10-003, Aciers de précontrainte – Torons / Voorspanstaal – Strengen.
- NBN I10-201, Armatures de précontrainte - Détermination du caractère d'adhérence au béton des armatures de précontrainte / Voorspanwapeningen - Bepaling van het vermogen tot hechting van de voorspanwapeningen aan het beton.
- NBN EN ISO 15630-3, Aciers pour l'armature et la précontrainte du béton – Méthodes d'essai - Partie 3 : Armatures de précontrainte / Wapeningsstaal en voorspanstaal voor beton - Beproevingmethoden - Deel 3: Voorspanstaal.
- PTV 311, Prescriptions techniques - Aciers de précontrainte – Torons / Technische Voorschriften - Voorspanstaal, Strengen.
- PTV 312, Prescriptions techniques - Aciers de précontrainte - Aciers galvanisés / Technische Voorschriften - Voorspanstaal, Verzinkte voorspanwapeningen.
- PTV 314, Prescriptions techniques - Aciers de précontrainte - Fils tréfilés / Voorspanstaal - Koudgetrokken draden.
- DTD 289, Application de la marque BENOR dans le secteur des aciers de précontrainte, modalités de contrôle applicables aux « usagers de la marque » - Producteurs. Dossier technique / Toepassing van het Benor-merk in de sector van de voorspanstaal, controle modaliteiten van toepassing aan de "gebruikers van het merk" – producenten. Technisch dossier.
- Manuel de qualité de l'OCAB-OCBS / Kwaliteitshandboek van het OCBS<sup>6</sup>.

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<sup>1</sup> **TRA** : Troepassingsreglement – Règlement d'Application

<sup>2</sup> (Reference BENOR<sup>asblvzw</sup> : NBN/RVB.CA/RM2012-10-02 and following editions in force)

<sup>3</sup> (Reference: NBN/RVB.CA/RM2012-10-02 and following editions in force) with Document CM10 1998-12-09 in appendix

<sup>4</sup> (Reference: NBN/RVB.CA/RG2012-10-02 and following editions in force) with Document CM10 1998-12-09 in appendix

<sup>5</sup> According to the last edition in force

<sup>6</sup> According to the last edition in force

## 2.2 Definitions

### 2.2.1 Types of prestressing steels

- **Wire:** the cold drawn wire comes from a wire rod subjected to a heat treatment at the end of the rolling or before wiredrawing and whose mode of cooling is favourable to the further mechanical operations. A distinction is made between smooth wire and indented wire.
- **Strand:** the strand is a set of drawn wires laid out in a helical way. The strand shall consist of 3 or 7 wires of the same nominal diameter spun together in helical form over a theoretical common axis with a lay length of “X”<sup>7</sup> times the nominal strand diameter.
- **Galvanized wires or strands:** by galvanization, it is understood any operation during which the element to be protected (smooth wire or wire constitutive of strand) is covered with zinc or zinc-aluminium by dipping in a zinc bath in fusion, respectively in molten zinc-aluminium alloy bath with 5% aluminium. Only the techniques of “hot” galvanization are allowed.

### 2.2.2 Production unit

The production unit is the coil of wire [or the bundle(s) of cut straight wires from the straightened and cut to length coil] or the reel of strand.

### 2.2.3 Family of products

Products are differentiated by their diameter, their type (wires or strands), the type of wire used (smooth or indented), the tensile characteristic strength and the isothermal relaxation class. Products with a difference for at least one of those characteristics are considered as different.

The products are classified by type (wires or strands) and further subdivided in families. The indication of the family is supplemented for information by the production process used. By family, it is meant the whole set of the reinforcements with the same specified tensile characteristic strength, worked out according to the same process and of the same isothermal relaxation class. Within the same family, the reinforcements are different by their geometrical properties.

Tables I and II below give the composition and the index of the families of reinforcements being the subject of standards NBN I10-002 and 003, PTV 311 and PTV 314.

The smooth and indented products (wires or strands) with the same specified mechanical strength are grouped within a same family.

Considering their relatively limited use, the galvanized reinforcements are grouped in 2 families according to their type (wire or strand). Table III below gives the composition and the index of the families of reinforcements being the subject of the PTV 312.

**Table I – Smooth [Ø] and indented [⊗] wires**

Specified characteristic tensile strength (N/mm <sup>2</sup> )	Nominal diameter (mm)	Family
1.470	Ø 12,2 - 10 ⊗ 12,2 - 10	1
1.570	Ø 12,2 - 10 - 9,4 - 8 - 7 - 5 ⊗ 12,2 - 10 - 9,4 - 8 - 7 - 5	2
1.670	Ø 8 - 7,5 - 7 - 6 - 5 - 4 ⊗ 8 - 7,5 - 7 - 6 - 5 - 4	3
1.770	Ø 7 - 6 - 5 - 4,5 - 4 ⊗ 7 - 6 - 5 - 4,5 - 4	4

<sup>7</sup> With X comprised between 14 to 22 for 3 wires strands and between 12 to 18 for 7 wires strands

1.860	Ø 5 - 4 ⊗ 5 - 4	4bis
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**Table II – 3- and 7-wire strands of smooth [Ø] and indented [⊗] wires**

Specified characteristic tensile strength (N/mm <sup>2</sup> )	Nominal diameter (mm)		Family
	3-wire strands	7-wire strands	
1.670	Ø 9,2	-	5bis
1.770	-	Ø 15,2 - 15,7 - 18,0 ⊗ 15,2 - 15,7 - 18,0	5
1.860	Ø 6,5 - 6,9 - 7,5 - 7,7 - 9,2 ⊗ 6,5 - 6,9 - 7,5	Ø 6,9 - 9,3 - 11,0 - 12,5 - 12,9 - 15,2 - 15,7 ⊗ 9,3 - 11,0 - 12,5 - 12,9 - 15,2 - 15,7	6
1.920	Ø 6,3	-	7
1.960	Ø 4,8 - 5,2 - 5,6 - 6,5 ⊗ 5,2 - 6,5	Ø 9,0 ⊗ 9,0	8
2.060	Ø 5,2 ⊗ 5,2	Ø 6,4 – 6,85 - 7,0 – 8,6 – 11,3 ⊗ 6,4 – 6,85 - 7,0 – 8,6 – 11,3	9
2.160	Ø 5,2	Ø 6,85 ⊗ 6,85	10

**Table III – Galvanized prestressing steels**

Type of steel	Family
Galvanized smooth wire (Z or ZA)	11
Galvanized smooth strand (Z or ZA)	12

#### 2.2.4 Characteristics under reference for BENOR certification

The relevant characteristics or properties are defined hereunder and submitted to acceptance criteria.

##### 2.2.4.1 Characteristics assessed by measurement

The properties being checked by measurements are:

- Tensile yield strength at 0,2% residual elongation ( $F'_{p0,2}$ ),
- Tensile strength ( $F'_m$ ).

##### 2.2.4.2 Characteristics assessed by attributes

The properties being checked by attributes are:

- the cross-section,
- the lay length,
- the depth, the length and the spacing of the indentations for the indented wires or strands,
- the straightness,
- the stress ratio between tensile strength and tensile yield strength ( $F'_m/F'_{p0,2}$ ),



- the elongation at maximum force,
- the reduction of area (for the wires),
- the resistance to reverse bending,
- the time depending properties
  - isothermal relaxation,
  - fatigue behaviour,
  - stress corrosion resistance,
- the deflected tensile test (for 7 wire-strand starting from 12.5 mm),
- and if applicable:
  - the thickness, the continuity and the adherence of the zinc layer.

## **2.2.5 Laboratories**

### **2.2.5.1 Internal laboratory**

It is the own laboratory of the factory (laboratory of the producer). To be recognized as such, this laboratory must fulfil the following requirements:

- The tensile testing machines of this laboratory must be calibrated in accordance with standard NBN EN ISO 15630-3. They must be of class 1 or better; the last calibration carried out by a service independent of the laboratory, cannot go back to more than one year. Moreover, they are equipped with a system of measurement of total elongation under the maximum load.
- All the tensile testing machines used within the framework of certification BENOR must be the subject of paired comparisons with the tensile testing machine of the control laboratory<sup>8</sup> according to the provisions of the preliminary examination.
- During the yearly check by the sectorial organization, the test results of at least one testing machine must be subjected to the ones of a control laboratory. Each tensile testing machine must be subjected to a paired comparison with a control laboratory at least once every three years. If the producer uses other tensile machines in the internal laboratory, those machines are yearly compared with the machine for which the comparison with the control laboratory is carried out. If it is not possible to compare those other tensile machines with this machine (e.g. because of different capacity), a yearly comparison with a control laboratory has to be carried out for each machine concerned.
- All the other measurement and testing devices must be calibrated at least once a year.

### **2.2.5.2 Control laboratory**

Laboratory accredited according to ISO 17025 and quoted by document OCAB-OCBS 503a<sup>9</sup>.

## **3 Preliminary examination prior to the granting of the authorization of use of BENOR-mark**

### **3.1 General information**

#### **3.1.1 Principle**

The conformity of the products to the prescriptions being the subject of standards NBN I10-001 to 003 and technical specifications PTV 311, 312 and 314 is checked by a preliminary examination prior to the granting of the authorization of use of BENOR-mark.

The purpose of this preliminary examination is to make sure that the producer has the capability:

- to manufacture the products for which he asks for the authorization of use of the approval mark;
- to maintain a regularity for the properties of these products in current manufacturing. With this intention, at the time of its request for the granting of the authorization of use of the BENOR-mark, the producer provides a technical file which at least comprises all the elements involved in document OCAB-OCBS 289.

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<sup>8</sup> See definition in 2.2.5.2

<sup>9</sup> Document 503 a, "Lijst – Liste – List, Keuringsinstellingen (OCI), Laboratoria (Labs), Organismes de contrôle (OCI), Laboratoires (Labs), Control Bodies (OCI), Laboratories (Labs) »

As the above-mentioned standards do not fix a criterion in this respect, the property of adherence is not the subject of the BENOR-mark approval.

In the same way, since the aptitude for cold heading (NBN I10-002 - § 5.3) is only being planned for particular supplies, this property is not either the subject of the BENOR-mark approval.

### 3.1.2 Preliminary examination

#### 3.1.2.1 Tests

The preliminary examination is based on the tests of current control carried out by the services of the producing factory and on complementary tests carried out by an external laboratory on request of the sectoral organization or his representative<sup>10</sup>.

#### 3.1.2.2 Examination of the technical file

The preliminary examination is also based on the disposal and the examination by the sectoral organization of the data contained in the technical file, which is delivered at the time of the request for granting of authorization of use of BENOR-mark.

In particular, the producer must mention in his technical file the origin and the identification of the characteristics of his wire rod as well as the controls he carries out on wire rod.

This identification must consist at least of the following information:

- A description of the requested chemical composition involving at least the following elements:
  - Minimum and maximum values, C – Mn – Si;
  - Maximum values, P – S – N – Cr – Cu – Ni – Mo;
  - Necessary information about nitrogen binding elements such as V – Nb – Ti – Al – B.
- Either the test results on the wire rod, carried out and transmitted by the supplier of the wire rod, and from which it can be deduced that the delivered wire rod fulfils the requirements of the producer;
- Or the implementation of an internal procedure of qualification of the wire rod used, from which it can be deduced that the wire rod can be used only after all controls envisaged were carried out, appraised and finally regarded as acceptable.

The qualification of the wire rod by the producer is finalized in a list (see document OCAB-OCBS 289) including, by product, the suppliers and the types of wire rods recognized by the producer. The up to date list at the time of the preliminary examination is submitted to the sectoral organization.

The sectoral organization must be able to examine the aptitude of all the wire rods used and mentioned again in the list. For this purpose, the producer presents, by type, origin and diameter of the wire rod, his file of acceptance including the test results carried out on the prestressing steels manufactured at the beginning of this one (see also document OCAB-OCBS 289), these tests concern:

- mechanical properties (tensile and deflected tensile tests) and special properties depending on time (isothermal relaxation level, fatigue strength and stress corrosion resistance) tested in the internal laboratory or a control laboratory;
- the link between the wire rod of origin and the prestressing steel must be established via labelling: cf. § 3.1.5.1.

#### 3.1.3 Random sampling

The sectoral organization selects, as much as possible randomly, the number of products envisaged for control among the available products. All these available products come from the installations planned for the manufacturing of these products.

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<sup>10</sup> In the following of the text and for simplification reasons, the term "sectoral organization" includes as well his representative as the inspection body and his representative, as it is defined in the quality handbook of OCAB-OCBS.

### 3.1.4 Requirements

It is necessary to check that the specified properties fulfil the criteria defined in the above-mentioned standards and technical specifications.

### 3.1.5 Identification

#### 3.1.5.1 Label

Each production unit carries a label mentioning the enumerated indications to § 9.2 of standard NBN I10-001 as well as the cast number, i.e.:

- identification of the producer;
- number of the production unit;
- cast number;
- weight or length;
- conventional designation of the reinforcement.

The producer informs the sectoral organization of the model of his label. Later on, any modification of the label must be announced beforehand to the sectoral organization.

#### 3.1.5.2 Traceability

The finished products are identified so that the producer can at any time declare which wire rod was used for the products considered (in case of strand, for each of the 3 or 7 wires).

This wire rod must come from a supplier recognized by the producer. The origin of the wire rod must also be able to be found at any time on the list of the suppliers of wire rods recognized by the producer such as initially presented it and held up to date in a permanent way (cf. § 3.1.2).

### 3.1.6 Family of products

This concept is defined in § 2.2.3. The producer, who requests the authorization of use of BENOR-mark for a family of products, is not obliged to engage for all the diameters of this family which are part of its production schedule.

### 3.1.7 Sampling

#### 3.1.7.1 General information

The producer presents the reinforcements in the state where they leave the factory. A preliminary examination is carried out for each product for which the producer requests the authorization of use of BENOR-mark. The batches presented to the preliminary examination are homogeneous batches within the meaning of standards NBN I10-002 and 003 (§ 4.2.2).

Taking into account the constancy of quality of the manufactured products with high added value which are the prestressing reinforcements, the differences between the individual tensile strength values of the specimens can be of the same order of magnitude than the accuracy of measurements. It is admitted, for a given batch, that this situation is met each time the estimate of the standard deviation of the tensile strength is lower than one percent of the characteristic tensile strength.

In this case, and in accordance with § 4.2.4.1 from standards NBN I10-002 and 003, the risk of acceptance remains unchanged during the estimate of the characteristic value of the batch according to § 4.2.3 of the above-mentioned standards in so far as product quality respects a level such that the following condition is satisfied:

$$m - v_{cs} > (k + 0.5) s$$

The presented products are manufactured from a wire rod of a supplier recognized by the producer. The producer gives evidence of that to the sectoral organization by submitting the necessary elements (cf. § 3.1.2 and § 3.1.5.2).

### 3.1.7.2 Sampling of the first family

When the producer requests for the first time the authorization of use of BENOR-mark, he presents, for the first proposed family, the products for which he wishes to obtain the authorization of use of BENOR-mark.

The producer presents at least 120 tons of reinforcements coming from, in equal proportions, at least 2 casts in which the proposed products are present in sufficient quantities for sampling. The producer is entirely responsible for the sampling operation, the handling and the transport of the samples indicated by the sectoral organization to the control laboratory.

#### 3.1.7.2.1 Sampling for the determination of the geometrical and mechanical properties

The sectoral organization chooses 1 product for which 30 reinforcement pieces are sampled. Each sample must present a length sufficient for the achievement of the tests as envisaged in § 3.1.9.1.1 (paired comparison between the tensile testing machine of the internal laboratory and a control laboratory).

If more than one product are presented, additional samples are taken. This sampling is carried out as follows:

- If 2 products are presented, the sectoral organization selects 30 supplementary samples of the other product.
- If 3 products or more are presented, the sectoral organization selects 2 products and takes 30 supplementary samples for each selected product.

If the producer has only 1 tensile testing machine, each supplementary sample must present a length sufficient for the achievement of the tests as envisaged in 3.1.9.1.2.

If the producer uses several tensile testing machines, the sectoral organization designates the products among the additional sampled ones for which a paired comparison shall be performed. Those samples must present a length sufficient for the achievement of the tests as envisaged in 3.1.9.1.1.

The reserve pieces can be employed in the event of problem during the transport or the execution of the tests.

If it is not possible to take the 30 reinforcement pieces from different production units, it is allowed to select a maximum of 2 reinforcement pieces per production unit to obtain those 30 results; the distance between these 2 reinforcement pieces is of at least 20 meters.

In so far as the range of products allows it, the products selected by the sectoral organization include at least 2 products of indented wire or if necessary of strand.

#### 3.1.7.2.2 Sampling intended for the control of time depending properties

The samplings intended for the control of time depending properties are carried out as follows:

- For the first selected product, 4 pieces are sampled in order to carry out 4 isothermal relaxation tests, 4 pieces in order to carry out 4 fatigue tests and a section long enough in order to carry out a stress corrosion test<sup>11</sup>. For each type of test, the samples are taken from different production units. The relaxation tests are not necessarily carried out on the same production units as the fatigue tests and the stress corrosion tests.
- For the second selected product, 4 pieces are sampled in order to carry out 4 isothermal relaxation tests, 4 pieces in order to carry out 4 fatigue tests and a section long enough in order to carry out a stress corrosion test. For each type of test, the samples are taken from different production units. The relaxation tests are not necessarily carried out on the same production units as the fatigue tests and the stress corrosion tests.
- For the third selected product, 4 pieces are sampled in order to carry out 4 isothermal relaxation tests, 4 pieces in order to carry out 4 fatigue tests and a section long enough in order to carry out a stress corrosion test. For each type of test, the samples are taken from different production units. The relaxation tests are not necessarily carried out on the same production units as the fatigue tests and the stress corrosion tests.
- If 4 products or more are presented, among all the products 12 pieces are sampled in order to carry out 12 isothermal relaxation tests, 12 pieces in order to carry out 12 fatigue tests and 3 sections long enough

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<sup>11</sup> According to ISO 15630-3 standard, a stress corrosion test involves at least 6 specimens submitted to the test.

in order to carry out 3 stress corrosion tests. For each type of test, the samples are taken from different production units. The relaxation tests are not necessarily carried out on the same production units as the fatigue tests and the stress corrosion tests.

Each sample must present a length sufficient for the achievement of the tests as envisaged in 3.1.9.2.

In so far as the range of products allows it, the products selected by the sectoral organization include at least 2 products of indented wire or if necessary of strand.

#### **3.1.7.2.3 Sampling for control of the behaviour under multiaxial loads**

For each presented product from family 5, 6 or 12 with a diameter greater than or equal to 12.5 mm, 1 section (10 specimens) is sampled in order to carry out 1 deviated tensile test<sup>12</sup> in the internal laboratory. The length of 5 specimens must make it possible to carry out a deviated tensile test according to the impositions of 3.1.9.3.

#### **3.1.7.3 Sampling for the examination of the other families**

For each product for which the authorization of use of BENOR-mark is requested, the manufacturer presents a batch of at least 50 tons, coming from at least 2 different casts.

##### **3.1.7.3.1 Sampling for the determination of the geometrical and mechanical properties**

For products from family 6, the sampling always takes place as described in 3.1.7.2.1.

For the other families, the sampling depends of the number of already certified products:

- If only 1 product is already certified and only 1 product is presented, 30 pieces of the presented product are sampled.
- If only 1 product is already certified, and several products are presented which belong or not to the same family, then the sectoral organization chooses 1 product per family for which 30 pieces are sampled. At least 2 products shall be sampled, even if the presented products belong to the same family.
- If already 2 or more products are certified, the sectoral organization chooses 1 product per family to sample 30 pieces.

Each sample must present a length sufficient for the achievement of the tests as envisaged in 3.1.9.1.1. or 3.1.9.1.2. The reserve pieces can be employed in the event of problem during the transport or the execution of the tests.

In so far as the range of products allows it, the products selected by the sectoral organization include at least 2 products of indented wire or if necessary of strand.

##### **3.1.7.3.2 Sampling intended for the control of time depending properties**

For products from family 6, the sampling always takes place as described in 3.1.7.2.2.

For the other families, the sampling depends of the number of already certified products:

- If only 1 product is already certified and only 1 product is presented, the sampling is carried out according to 3.1.7.2.2 with the product considered as the second product.
- If only 1 product is certified and 2 products are presented, the sampling is carried out according to 3.1.7.2.2 with the products considered as the second and third products selected.
- If only 1 product is certified and more than 2 products are presented, the sectoral organization selects for each family 4 specimens as described in 3.1.7.2.2 for the isothermal relaxation tests, 4 specimens as described in 3.1.7.2.2 for the fatigue tests, and 1 specimen as described in 3.1.7.2.2 for the stress corrosion test. The samples are chosen randomly distributed over the selected products.
- If only 1 product is certified and all the presented products belong to the same family, the sectoral organization selects 8 specimens as described in 3.1.7.2.2 for the isothermal relaxation tests, 8 specimens

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<sup>12</sup> According to §3.1.9.3, a deviated tensile test involves 5 or 10 specimens submitted to the test.

as described in 3.1.7.2.2 for the fatigue tests, and 2 specimens as described in 3.1.7.2.2 for the stress corrosion test. The samples are chosen randomly distributed over the selected products.

- If 2 or more products are already certified, the sectoral organization selects for each family 4 specimens as described in 3.1.7.2.2 for the isothermal relaxation tests, 4 specimens as described in 3.1.7.2.2 for the fatigue tests, and 1 specimen as described in 3.1.7.2.2 for the stress corrosion test. The samples are chosen randomly distributed over the selected products.

Each sample must present a length sufficient for the achievement in the internal laboratory of the tests as envisaged in 3.1.9.2. For the relaxation tests and the tests of corrosion, each sample is divided into 2 equal pieces, the second one is held in reserve.

In so far as the range of products allows it, the products indicated by the sectoral organization include at least 2 products of indented wire or if necessary of strand.

#### **3.1.7.3.3 Sampling for control of the behaviour under multiaxial loads**

For products from family 6, the sampling takes always place as described in 3.1.7.2.3.

For each selected product from family 5 or 12 with a diameter greater than or equal to 12.5 mm, the sectoral organization selects 1 specimen per family for the execution of the deviated tensile test according to 3.1.9.3.

#### **3.1.8 Calibration of the measurement and testing devices**

The testing machines of the internal laboratory must fulfil the requirements of § 2.2.5.

#### **3.1.9 Tests**

In his laboratories and under the surveillance of the sectoral organization, the producer carries out the tests relating to the geometrical and mechanical properties of the reinforcements, and their behaviour under multiaxial constraints, he carries out the stress corrosion tests and he carries out the start of the relaxation tests. He also carries out the tests concerning the properties taken again for galvanization (see PTV 312).

In addition, the control laboratory carries out the tests relating to the geometrical and mechanical properties of the reinforcements. This laboratory also carries out the tests relating to time depending properties.

##### **3.1.9.1 Tests concerning the geometrical and mechanical characteristics**

###### **3.1.9.1.1 Paired control between the internal laboratory and the control laboratory**

The samples for paired control are divided into 3 equal parts: the first one is intended for control in the internal laboratory, the second one is entrusted to the control laboratory and the third one is held in reserve. Each section must be long enough to be able to carry out the control of all the geometrical and mechanical characteristics of the reinforcement (see PTV 311 or PTV 314) and possibly the characteristics of the zinc layer (see PTV 312).

Except in case of dispute, the control laboratory does not need to carry out the following tests:

- the cross-section,
- the lay length,
- the depth, the length and the spacing of the indentations for the indented wires or strands,
- the straightness,
- the resistance to reverse bending,
- the thickness, the continuity and the adherence of the zinc layer.

###### **3.1.9.1.2 Exclusive control in the internal laboratory**

For the pieces which have not been designated for paired control, all the geometrical and mechanical characteristics of the reinforcement (see PTV 311 or PTV 314) are examined. The characteristics of the zinc layer are examined (see PTV 312 if necessary).



### 3.1.9.2 Tests concerning time depending properties

#### 3.1.9.2.1 Relaxation tests

Each sample is divided into 3 equal pieces: the first one is intended for control in the internal laboratory, the second one is entrusted to the control laboratory and the third one is held in reserve. Each section of a specimen must be long enough to be able to carry out a test according to the prescriptions of standard NBN EN ISO 15630-3. The relaxation tests are carried out during 1000 hours with an initial load at a rate of 70% of the effective tensile load.

The section of reserve can be used in the event of problems during the transport or in the execution of the test.

#### 3.1.9.2.2 Fatigue tests

Each sample is divided into two halves: the first one is intended for the test in the control laboratory and the second one is held in reserve. Each half must be long enough to carry out a fatigue test. The fatigue tests are carried out according to the methods of standard NBN EN ISO 15630-3 up to  $2 \cdot 10^6$  cycles according to the requirements of the product standards.

The reserve can be used in the event of problems during the transport or in the execution of the test.

#### 3.1.9.2.3 Tests of corrosion

Each sample is divided into 3 equal pieces: the first one is intended for control in the internal laboratory, the second one is entrusted to the control laboratory and the third one is held in reserve. Each section must be long enough to carry out a test of corrosion according to the prescriptions of standard NBN EN ISO 15630-3 using the test solution A.

The report specifies the method used: whether anchorings were or not in the solution, whether the ends of the strands were protected or not, etc.

The reserve can be used in the event of problems during the transport or in the execution of the test.

### 3.1.9.3 Tests concerning the behaviour under multiaxial loads

The deviated tensile test is carried out according to the prescriptions of standard NBN EN ISO 15630-3.

In complement to standard NBN EN ISO 15630-3, after obtaining 5 valid test results, the standard deviation of the 5  $D_i$  values is calculated. If the standard deviation does not exceed 15%, the coefficient D is given as in NBN EN ISO 15630-3. If however the standard deviation is higher than 15%, 5 additional specimens are tested. From the series of the 10 individual results, the highest result and the weakest result are omitted. The coefficient D is then given as the average of the 8 remaining  $D_i$  values.

### 3.1.10 Appraisal of the results

Two conditions must be satisfied: on one hand, the results obtained in the internal laboratory and the results of the control laboratory comply with § 3.1.10.1, 3.1.10.2 and 3.1.10.3; in addition, the statistical comparison must comply with 3.1.10.4.

#### 3.1.10.1 Control by measurements

For each property being checked by measurements, i.e.:

- Tensile yield strength at 0,2% residual elongation ( $F'_{p0.2}$ ),
- Tensile strength ( $F'_m$ ),

one calculates per product the average “m”, the estimate of the standard deviation “s” and the estimate of the characteristic value:  $v_c = m - 2.22 s^{13}$ .

One compares the estimates of the characteristic values with the values specified in the standards.

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<sup>13</sup> The coefficient 2,22 corresponds to  $n = 30$  in Table IV of paragraph 4.2.2

### 3.1.10.2 Control by attributes

The properties being checked by attributes are:

- the cross-section,
- the lay length,
- the depth of the indentations for the indented wires or strands,
- the straightness,
- the stress ratio between tensile strength and tensile yield strength ( $F'_m/F'_{p0.2}$ ),
- the elongation at maximum force,
- the reduction of area (for the wires),
- the resistance to reverse bending,
- the time depending properties
  - isothermal relaxation,
  - fatigue behaviour,
  - stress corrosion resistance,
- the deflected tensile test (for 7 wires strands starting from 12.5 mm),
- and if applicable:
  - the thickness, the continuity and the adherence of the zinc layer.

For each property, the number of specimens not fulfilling the criteria of the standard is determined.

### 3.1.10.3 Conditions of acceptance

Each product, selected according to the prescriptions of § 3.1.7, must satisfy all the requirements of the standard, in particular:

- for the characteristics which are controlled by measurement, values  $v_c = m - 2.22 s$  must satisfy the requirements of the standard;
- for the characteristics which are controlled by attribute, no specimen can be defective.

The producer may not attribute non conform results for the fatigue test in particular to surface defects, unless he can prove incontestably that the defects at the surface of the specimens were already present and were caused by thirds and thus apart from its responsibility.

### 3.1.10.4 Corrective actions towards non-conforming tests for time depending properties

Insufficient results for the tests of relaxation, fatigue, stress corrosion, lead automatically to the refusal of the family of products concerned. In such a case, the producer can:

- decide to postpone his request for certification in order to carry out a complementary investigation on the doubtful specimens;
- propose immediately or later to proceed to 2 new series of tests on the same production unit (eventually on the piece held in reserve) and another production unit of the same product or on 2 other production units of the same product and - provided this proposal is approved by the sectoral organization - to submit the results in the necessary form to the sectoral organization. All new sampling must be made under the supervision of the sectoral organization;
- insofar as the results of the 2 new series are positive, the conditions of acceptance are considered as being met;
- insofar as the results of the 2 new series are not entirely positive, the request for certification for the family of products concerned is regarded as null and void;
- The sectoral organization details his observations in his report in order to request the opinion of the technical bureau 2 and of the certification committee.

### 3.1.10.5 Comparison of the results of the tests of the factory with those of the control laboratory

For the tensile yield strength at 0,2% residual elongation ( $F'_{p0.2}$ ) and the tensile strength ( $F'_m$ ), one proceeds with the statistical comparison of the test results of the internal laboratory with those of the control laboratory, by the method of the paired comparisons (see appendix in 7.1).

If the comparison shows that the series of test are non-statistically identical, the producer must search the causes thereof and present his conclusions to the sectoral organization:



- if the causes are inherent to the control by the internal laboratory, the internal laboratory must correct the given lacks immediately and carry out the tests on the products which were held in reserve; the certification is not granted and new samples should be taken and tested to confirm the effectiveness of the corrections.
- if it appears that the causes are inherent to the control laboratory, or if the cause of the differences cannot be discovered, the sectoral organization decides of the actions to be taken.

The flow chart at the end of present chapter 3 summarizes the route to follow.

### **3.1.11 Authorization of use of BENOR-mark**

The success to the preliminary examination leads to the authorization of use of BENOR-mark for the products mentioned in the convention.

### **3.1.12 Extension of authorization of use of BENOR-mark**

#### **3.1.12.1 Extension of an authorization of use of BENOR-mark within a family**

If the present authorization does not yet contain 3 products, the examination of a new product must be performed in accordance with 3.1.7.2. Moreover, for an extension within family 6, the examination must always be performed in accordance with 3.1.7.2 until 3 products within family 6 are certified.

In all other cases, the procedure as described below will be used.

The producer provides the following data per requested product:

- the test results of the geometrical and mechanical characteristics (see PTV 311 and/or PTV 314) and the determination of the possible zinc layer (see PTV 312);
- the result of an isothermal relaxation test which was carried out up to 120 hours (extrapolated up to 1000 hours according to the methods of § 7.1 of standard NBN I10-001) under an initial load of 70% of the effective breaking load, according to the prescriptions of NBN EN ISO 15630-3;
- the results of 3 fatigue tests which were carried out on different units according to the provisions of NBN EN ISO 15630-3 up to  $2 \cdot 10^6$  cycles and according to the suitable requirements from the product standards;
- the result of a stress corrosion test, carried out according to the provisions of NBN EN ISO 15630-3 with solution A.

If within the family 6 at least 3 products are already certified, but not yet the extreme products ( $\emptyset$  6.5 - 6.9 - 15.2 - 15.7), and if the producer requests the authorization of use for 1 extreme product, the procedure below is applied for the provision of the additional data. The technical file of the producer must be adapted as a preliminary.

For the product under examination, the sectoral organization selects 30 reinforcement pieces for the tests relating to the geometrical and mechanical properties. The tests relating to the geometrical and mechanical properties are carried out in the internal laboratory in the presence of a representative of the sectoral organization. If necessary, he also carries out the tests concerning the properties taken again for galvanization.

In the case of an extension to indented wires or strands within a family already recognized in smooth products, at least a batch of 3 fatigue tests on 1 product of indented wire or strand is mandatory. These tests are carried out in accordance with § 3.1.9.2.2.

In the case of an extension comprising products of at least 12.5 mm in families 5, 6 or 12, at least 1 deviated tensile test is carried out on one of these products presented in accordance with 3.1.9.3.

#### **3.1.12.2 Extension of an authorization of use of BENOR-mark to other families**

The producer can request the extension of the authorization of use of BENOR-mark to other families of his production schedule. These families are examined according to the procedure described with § 3.1.7.3.

**3.1.12.3 Case of new production lines**

Whenever a new production line is built or a substantial modification is made to an existing line, the firm must provide a review of the technical file including the results of the ITTs on the different products from these new or modified lines.

Test specimens concerning geometrical and mechanical characteristics and the behaviour under multiaxial loads should be sampled during the next periodic visit from the new or modified lines as part of routine checks. Annual samples concerning time depending properties as part of routine checks must also be made on the new or modified lines for at least one of the products.

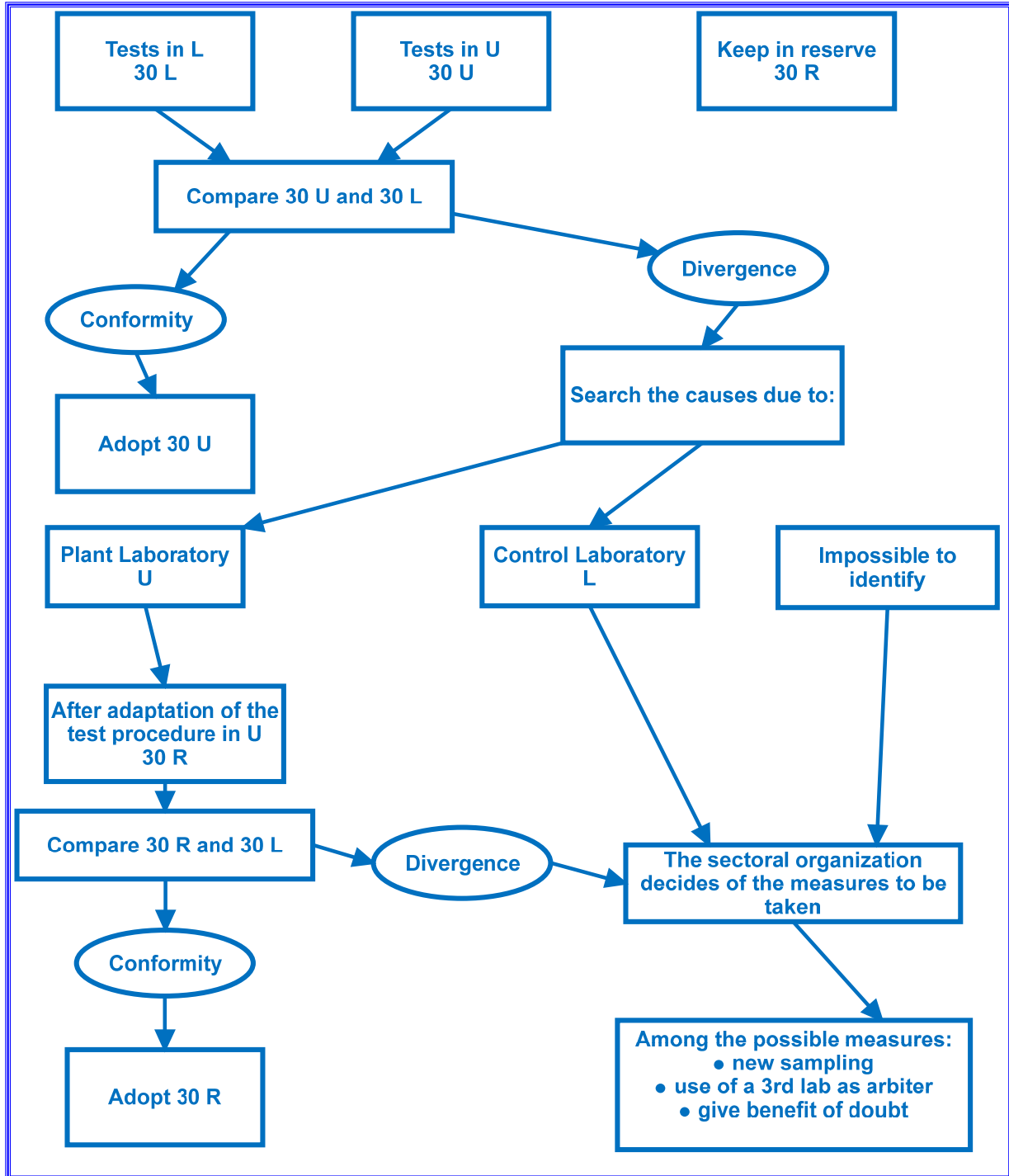
**Flow chart for paired control**

Case of control by measurements according to 3.1.10.4.

L = control laboratory (external)

U = plant laboratory (internal)

R = reserve



## 4 Industrial factory control

### 4.1 General information

#### 4.1.1 Methods of control

##### 4.1.1.1 Material of test and measurement

The producer shall have control methods allowing checking the compliance with the criteria fixed by the standards for the products for which he obtained the authorization of use of BENOR-mark. The testing machines of the internal laboratory must fulfil the requirements of § 2.2.5.1.

However, with regard to the tests of isothermal relaxation, of fatigue and of stress corrosion, the producer can call on an external laboratory beforehand accepted which complies with the requirements of § 2.2.5.

##### 4.1.1.2 Control of the products of origin

The producer must have an internal system which permits to check that any granting of wire rod that will be used for manufacturing of the products fulfils his own specifications.

This system includes recordings to show the application of an internal type-approval procedure based on:

- either results of testing on wire rod realized and communicated by the supplier of the wire rod in accordance with the requirements of the producer of the prestressing steel (methods and frequency);
- or results of testing carried out by the producer of the prestressing steel following an established methodology (methods and frequency).

The records should prove that the wire rod is used only after all controls envisaged were carried out and were considered to be acceptable.

In case of doubt or problems with respect to the quality of the wire rod, the producer of the wire rod must carry out controls on the wire rod.

The evaluation of the quality of the wire rod by the producer is finalized in the development of a list of the suppliers and types and diameters of wire rod approved by the producer (see 3.1.2.2). This list is kept up to date.

#### 4.1.2 Sampling for the control of the geometrical and mechanical properties

##### 4.1.2.1 Wire

For the control of properties 1 to 9 of § 4.1 of standard NBN I10-002, at least 1 sample is taken in a random way by 4 tons of product of the same geometrical configuration, of the same specified characteristic tensile resistance and manufactured according to the same procedure.

This concerns the following properties:

1. geometrical properties (product, cross section and possibly characteristic of the indentations);
2. surface quality and straightness;
3. tensile strength or breaking load (see NBN EN ISO 15630-3);
4. load at the conventional limit of elasticity at 0,2%;
5. the stress ratio between tensile strength and tensile yield strength ( $F'_m/F'_{p0.2}$ );
6. the elongation at maximum force;
7. load-elongation diagram;
8. reduction of area;
9. resistance to reverse bending (see NBN EN ISO 15630-3).

Moreover, one determination of the breaking load is carried out per production unit (per coil of original product) (tensile test without diagram).

The statistical exploitation according to § 4.2 and 4.3 hereafter requires to have at least 10 results per homogeneous production.

However, for the homogeneous productions comprising between 6 and 9 results, one can carry out a statistical evaluation on the basis of NBN I10-002; this interpretation is similar to that of the procedures § 4.2 and 4.3 hereafter, but with the characteristic that a  $\beta$  customer risk of 2,5% is taken in account<sup>14</sup>.

If necessary, the producer will sample 2 specimens per production unit, in order to achieve the minimal number of specimens. These specimens will be sampled with a minimal inter-distance of 20 meters on the production unit.

A production is considered homogeneous if the whole of the tensile test results fulfil the assumption of normality with a degree of confidence with 95%. Normality is checked by the test of SHAPIRO-WILK if the number of results is lower or equal to 50 (appendix I to standard NBN I10-002) and by the test of AGOSTINO for a number higher than 50 (appendix II to standard NBN I10-002). For the productions with weak dispersion of the values of rupture, the considerations in § 3.1.7.1 are applicable.

#### 4.1.2.2 Strands

For the control of properties 1 to 8 of § 4.1 of standard NBN I10-003, at least one sample is sampled per production unit.

This concerns the following properties:

1. geometrical properties (diameter, cross section and possibly characteristic of the indentations);
2. surface quality and straightness;
3. tensile strength or breaking load (see NBN EN ISO 15630-3);
4. load at the conventional limit of elasticity at 0,2%;
5. the stress ratio between tensile strength and tensile yield strength ( $F'_m/F'_{p0.2}$ );
6. the elongation at maximum force;
7. load-elongation diagram;
8. reduction of area.

The statistical exploitation according to § 4.2 and 4.3 hereafter requires to have at least 10 results per homogeneous production.

However, for the homogeneous productions comprising between 6 and 9 results, one can carry out a statistical evaluation on the basis of NBN I10-002; this interpretation is similar to that of the procedures § 4.2 and 4.3 hereafter, but with the characteristic that a  $\beta$  customer risk of 2,5% is taken in account<sup>15</sup>.

If necessary, the producer will sample 2 specimens per production unit, in order to achieve the minimal number of specimens. These specimens will be sampled with a minimal inter-distance of 20 meters on the production unit.

A production is considered homogeneous if the whole of the tensile test results fulfil the assumption of normality with a degree of confidence with 95%. Normality is checked by the test of SHAPIRO-WILK if the number of results is lower or equal to 50 (appendix I to standard NBN I10-002) and by the test of AGOSTINO for a number higher than 50 (appendix II to standard NBN I10-002). For the productions with weak dispersion of the values of rupture, the considerations in § 3.1.7.1 are applicable.

#### 4.1.2.3 Galvanized wire

By 4 tons of galvanized wire, one selects in a random way at least a sample for control of properties 1 to 12 below<sup>16</sup>, namely:

1. geometrical properties (diameter, cross section and possibly characteristic of the indentations);

<sup>14</sup> i. e. for  $n = 6$ ,  $k = 4,39$  ;  $n = 7$ ,  $k = 3,94$  ;  $n = 8$ ,  $k = 3,64$  ;  $n = 9$ ,  $k = 3,42$

<sup>15</sup> i. e. for  $n = 6$ ,  $k = 4,39$  ;  $n = 7$ ,  $k = 3,94$  ;  $n = 8$ ,  $k = 3,64$  ;  $n = 9$ ,  $k = 3,42$

<sup>16</sup> Properties 1 to 9 of § 4.1 from standard NBN I10-002, and 16 to 18 of § 3.1 of the PTV 312

2. surface quality and straightness;
3. tensile strength or breaking load (see NBN EN ISO 15630-3);
4. load at the conventional limit of elasticity at 0,2%;
5. the stress ratio between tensile strength and tensile yield strength ( $F'_m/F'_{p0.2}$ );
6. the elongation at maximum force;
7. load-elongation diagram;
8. reduction of area;
9. resistance to reverse bending (see NBN EN ISO 15630-3);
10. thickness of the zinc layer;
11. continuity of the zinc layer;
12. adherence of the zinc layer.

Moreover, one determination of the breaking load is carried out per production unit (per coil of original product) (tensile test without diagram).

The statistical exploitation according to § 4.2 and 4.3 hereafter requires to have at least 10 results per homogeneous production.

However, for the homogeneous productions comprising between 6 and 9 results, one can carry out a statistical evaluation on the basis of NBN I10-002; this interpretation is similar to that of the procedures § 4.2 and 4.3 hereafter, but with the characteristic that a  $\beta$  customer risk of 2,5% is taken in account<sup>17</sup>.

If necessary, the producer will sample 2 specimens per production unit, in order to achieve the minimal number of specimens. These specimens will be sampled with a minimal inter-distance of 20 meters on the production unit.

A production is considered homogeneous if the whole of the tensile test results fulfil the assumption of normality with a degree of confidence with 95%. Normality is checked by the test of SHAPIRO-WILK if the number of results is lower or equal to 50 (appendix I to standard NBN I10-002) and by the test of AGOSTINO for a number higher than 50 (appendix II to standard NBN I10-002). For the productions with weak dispersion of the values of rupture, the considerations in § 3.1.7.1 are applicable.

#### 4.1.2.4 Galvanized strands

By production unit, one selects in a random way at least a sample for control of properties 1 to 11 below<sup>18</sup>, namely:

1. geometrical properties (product, cross section and possibly characteristic of the indentations);
2. surface quality and straightness;
3. tensile strength or breaking load (see NBN EN ISO 15630-3);
4. load at the conventional limit of elasticity at 0,2%;
5. the stress ratio between tensile strength and tensile yield strength ( $F'_m/F'_{p0.2}$ );
6. the elongation at maximum force;
7. load-elongation diagram;
8. reduction of area;
9. thickness of the zinc layer;
10. continuity of the zinc layer;
11. adherence of the zinc layer.

The statistical exploitation according to § 4.2 and 4.3 hereafter requires to have at least 10 results per homogeneous production.

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<sup>17</sup> i. e. for  $n = 6$ ,  $k = 4,39$  ;  $n = 7$ ,  $k = 3,94$  ;  $n = 8$ ,  $k = 3,64$  ;  $n = 9$ ,  $k = 3,42$

<sup>18</sup> Properties 1 to 8 of § 4.1 of standard NBN I10-003, and properties 15 to 17 of § 4.2 of the PTV 312

However, for the homogeneous productions comprising between 6 and 9 results, one can carry out a statistical evaluation on the basis of NBN I10-002; this interpretation is similar to that of the procedures § 4.2 and 4.3 hereafter, but with the characteristic that a  $\beta$  customer risk of 2,5% is taken in account<sup>19</sup>.

If necessary, the producer will sample 2 specimens per production unit, in order to achieve the minimal number of specimens. These specimens will be sampled with a minimal inter-distance of 20 meters on the production unit.

A production is considered homogeneous if the whole of the tensile test results fulfil the assumption of normality with a degree of confidence with 95%. Normality is checked by the test of SHAPIRO-WILK if the number of results is lower or equal to 50 (appendix I to standard NBN I10-002) and by the test of AGOSTINO for a number higher than 50 (appendix II to standard NBN I10-002). For the productions with weak dispersion of the values of rupture, the considerations in § 3.1.7.1 are applicable.

### **4.1.3 Sampling for the control of time depending properties**

#### **4.1.3.1 Isothermal relaxation**

Once a year and by family being the subject of an authorization of use of BENOR-mark, at least 2 relaxation tests are realized in the internal laboratory of the producer or in the external laboratory accepted by the sectoral organization. These 2 tests are carried out preferably on different products, so that the mostly produced products are examined for each 3-year period. The relaxation test to 70% of the real breaking load of the reinforcement is limited to 120 hours but is extrapolated at 1000 hours according to the methods of § 7.1 of standard NBN I10-001.

#### **4.1.3.2 Fatigue**

Once a year, as well for the whole of the families of the wires as for the whole of the families of the strands, at least a series of 3 fatigue tests are carried out on the same product in the internal laboratory of the producer or in the external laboratory accepted by the sectoral organization; per 3-year period, at least 1 product of each family being the subject of an authorization of use of BENOR-mark must undergo a series of 3 fatigue tests. The tests are distributed as well on the smooth wires and strands as on those with prints. The fatigue test is carried out according to the prescriptions of standard NBN EN ISO 15630-3 and is continued up to  $2 \cdot 10^6$  cycles, as well as following the impositions of the product standards.

#### **4.1.3.3 Stress corrosion**

Once a year and by family being the subject of an authorization of use of BENOR-mark, one carries out at least 1 stress corrosion test in the internal laboratory of the producer or in the external laboratory accepted by the sectoral organization. The test is carried out annually on different products, so that the mostly produced products are examined for each 3-year period. The stress corrosion test is carried out in accordance with the prescriptions of the NBN EN ISO 15630-3, using solution A. The report clarifies the method applied, namely if anchorings are or not plunged in the solution, if the ends of the strands are protected or not.

### **4.1.4 Sampling for the control of the behaviour under multiaxial loads**

By homogeneous production (see § 4.1.2.2 and 4.1.2.4) of strand of a product equal or higher than 12.5 mm of diameter in families 5.6 or 12, one selects in a random way at least a sample for the achievement of the deviated tensile test in the internal laboratory. The deviated tensile test is carried out in accordance with the prescriptions of standard NBN EN ISO 15630-3.

In complement to standard NBN EN ISO 15630-3, after obtaining 5 valid test results, the standard deviation of the 5  $D_i$  values is calculated. If the standard deviation does not exceed 15%, the coefficient D is given as in NBN EN ISO 15630-3. If however the standard deviation is higher than 15%, 5 additional specimens are tested. From the series of the 10 individual results, the highest result and the weakest result are omitted. The coefficient D is then given like the average of the 8 remaining  $D_i$  values.

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<sup>19</sup> i. e. for  $n = 6$ ,  $k = 4,39$  ;  $n = 7$ ,  $k = 3,94$  ;  $n = 8$ ,  $k = 3,64$  ;  $n = 9$ ,  $k = 3,42$



#### **4.1.5 Recording and analysis of the results of the factory control**

All the results of controls are recorded. It is moreover noted which measurement or testing device is used for such control. When a diagram "load-elongation" is drawn, the modulus of elasticity is determined. The modulus of elasticity and the real section are consigned in the register.

The results are preserved during at least 10 years by the producer.

Except for the modulus of elasticity, the results are exploited statistically by the producer while following a calculation programme approved by the sectoral organization and the results of this statistical exploitation are sent quarterly to the sectoral organization: the sectoral organization must be in possession of these results at the latest at the end of the month following the quarter during which the products considered were manufactured. The producer can eliminate from this statistical exploitation the results coming from products withdrawn from the trade-circuit (see 4.5) and if necessary certain too favourable results (see 4.2.2).

All the results of the tests to be carried out by the producer on annual basis must be communicated as soon as possible to the sectoral organization. The sectoral organization must be in possession of the results of the previous year, at the latest end of March. The results transmitted by the supplier of wire rod or the results of internal control of qualification of the quality of the wire rod used are recorded, compared with the quality standards internal and exploited by the producer.

The registers of wire rod and the tests are continuously held at the disposal of the sectoral organization.

## **4.2 Statistical control by measurements**

This control applies to the load at the conventional limit of elasticity at 0,2% and to the tensile strength.

### **4.2.1 Principle**

The interpretation of the results of the tests is done using the statistical methods by adopting a level of quality tolerated (NQT) of 5% associate at the risk of 5%.

### **4.2.2 Statistical interpretation of the results of the tests**

The statistical interpretation of the results of the tests is to be carried out for the products coming from the same homogeneous production. The manufacturer is free to divide his production into several homogeneous batches. However, this division must appear clearly in the documents of statistical interpretation which it submits for control to the sectoral organization (see § 4.1.5).

For each examined property, one determines for "n" available results, the arithmetic mean "m" and the estimate of the standard deviation "s".

The estimate of the characteristic value is calculated ( $m - ks$ ).

Table IV hereafter gives the constant of acceptance "k" according to the number of available results.

If this characteristic value does not satisfy the specified characteristic value, the producer has the ability to withdraw no more than half of the values provided for control considered, but with the condition:

1. to withdraw results in order from high to low values each time starting with the highest value and to take into account ( $m_i - k_i \cdot s_i$ ) applied to the remaining values;
2. that the remaining values satisfy the assumption with normality, with a degree of confidence of 95% (test of SHAPIRO-WILK or AGOSTINO according to the manpower of the results).

If this new value ( $m_i - k_i \cdot s_i$ ) remains lower than the specified value, the whole of the products considered cannot be covered BENOR-mark approval (see § 4.5).



**Table IV**

Number of available results n	Acceptance constant k
10	2,91
11	2,82
12	2,74
13	2,67
14	2,61
15	2,57
16	2,52
17	2,49
18	2,45
19	2,42
20	2,40
22	2,35
24	2,31
26	2,27
28	2,24
30	2,22
35	2,17
40	2,13
45	2,09
50	2,07
60	2,02
70	1,99
80	1,97
90	1,94
100	1,93
150	1,87
200	1,84
250	1,81
300	1,80
400	1,78
500	1,76
1.000	1,73
∞	1,64

### 4.3 Statistical control by attributes

This control applies to the following properties:

1. geometrical properties:
  - diameter, cross section, and possibly characteristic of the indentations in the case of wires;
  - diameter, cross section, lay length and possibly characteristic of the indentations in the case of strands;
2. straightness and surface quality;
3. stress ratio between tensile strength and tensile yield strength ( $F'_m/F'_{p0.2}$ );
4. elongation at maximum force;
5. reduction of area
  - visual examination for the strands,
  - measurements for the wires;
6. resistance to reverse bending (only for the wires);

7. the time depending properties
  - isothermal relaxation,
  - fatigue behaviour,
  - stress corrosion resistance;
8. deflected tensile test;
9. thickness of the zinc layer;
10. continuity of the zinc layer;
11. adherence of the zinc layer.

**4.3.1 Principle**

The interpretation of the results of the tests is done using the statistical methods by adopting a level of quality tolerated (NQT) of 5% associate at the risk of 5%.

**4.3.2 Statistical interpretation of the results of the tests**

The interpretation of the results of the tests applies to the whole of the products coming from the same homogeneous production.

For each examined property, one admits a maximum number of insufficient results according to the number of results necessary to respect the criterion, as indicated in table IV hereafter.

**Table V**

<b>Minimal number of results necessary to respect the criterion</b>	<b>Allowed maximum number of non-satisfactory results</b>
59	0
95	1
126	2
156	3
184	4
211	5

If the number of non-satisfactory results exceeds the allowed maximum number, the whole of the products of the production considered cannot receive the BENOR-mark approval as long as the production units corresponding to the non-satisfactory results were not isolated from the examined population; however, the values of the properties controlled by measurements for the preserved production units must satisfy the assumption with normality on the degree of confidence with 95%.

**4.3.3 Corrective actions towards non-conforming tests for time depending properties**

Insufficient results with the relaxation tests, fatigue, stress corrosion lead automatically to the obligation for the producer of:

- To immediately warn the sectoral organization.
- To proceed immediately to a complete analysis of the causes.
- To withdraw immediately sale for all products concerned not yet delivered.
- To proceed immediately to 2 new series of tests on the reserve piece(s) held eventually in the factory or on a similar product (same diameter, indented or smooth, same wire rod and producer, same processing) and to submit the results in the necessary form to the sectoral organization.
- To immediately warn all his customers touched by the product range concerned in the following cases:
  - Relaxation higher more than 40% (relative) compared to the required maximum,
  - Average behaviour with fatigue lower than 1 200 000 cycles for the series of tests concerned,
  - Corrosion resistance for which 3 individual values out of 6 are lower than the required minimum or the median value is lower than 60% the required minimum.

Insofar as the results of the 2 new series are positive, the conditions of acceptance are considered met for the family of products concerned:

- Certification can be preserved but the producer must take the necessary measures with respect to the batches of products already delivered or concerned by the first defective tests,
- The sectoral organization decides of the actions to be taken regarding the certification.

Insofar as the results of the 2 new series are not entirely positive, certification for the group of products concerned is suspended sine die. The producer must inform the customers with respect to the batches of products already delivered and take the necessary measures (withdrawal of the products or financial repair) and destruction of all the not yet delivered products concerned with the first defective tests.

#### 4.4 Affixing of the BENOR-mark approval

As soon as all the test results relative to a homogeneous production are recorded, exploited and that their interpretation is noted in conformity with the criteria of the product standards, according to § 4.2.2 and 4.3.2, products of the production (including those of the production units corresponding to the results drawn aside according to § 4.2.2) can be provided with a label attesting conformity to the standard.

This label carries, in addition to the indications taken again with § 3.1.5 at least following indications:

- BENOR-logo;
- identification of the reel.

The producer submits the model of the label to the approval of the sectoral organization. Later on, any modification of the label must be authorized beforehand by the sectoral organization.

BENOR labels are used while following the ascending order of the sequence numbers specific to products BENOR.

When it comes a posteriori that a non-conform batch was provided, the producer has the obligation to warn his customer, as well as the sectoral organization.

#### 4.5 Products non-likely to carry BENOR-mark

All precautions must be taken so that the products which do not fulfil the requirements of the standard and which cannot carry BENOR-mark, cannot be confused with those which carry BENOR-mark.

## 5 Checking by the sectoral organization

### 5.1 Products being in the producing factory

#### 5.1.1 General information

The conditions of granting of the authorization of use of BENOR-mark (regularity in the manufacturing of the products and conformity of the products carrying BENOR-mark to the standards) are checked periodically by the sectoral organization.

This checking consists in being ensured:

- that there exists an internal system of qualification of the wire rod;
- that the tensile testing machines are in conformity with the NBN EN ISO 15630- 3, that they are of class 1 or better and that their last calibration does not go back to more than one year;
- that all the other measurement and testing devices are calibrated at least once a year;
- that the industrial factory control was rigorously applied;
- that the results of the industrial factory control are satisfactory. For this purpose the sectoral organization carries out the checking of the statistical exploitation of at least 2 series of results a year;
- that the results obtained and recorded during this industrial factory control are in conformity with reality. This takes place by carrying out additional tests on products manufactured under the name of BENOR-mark and having been subjected to the factory control;
- that all measurements were taken not to introduce scrapped products which cannot be provided with BENOR-mark among the products fulfilling specifications BENOR;
- that when anomalies were noted, corrective actions were applied to cure these.

The producer makes all the provisions to facilitate this checking; in particular, he communicates to the sectoral organization (see OCAB-OCBS document 289):

- the list of the suppliers and qualities and diameters of wire rod which he recognizes;
- the name of the person in charge of the monitoring services of the factory;
- the date of the start-up of a slightly modified production, i.e. products returning within the framework of the contract but comprising certain minor modifications;
- all results of factory control according to § 4.1.2. , 4.1.3. , 4.1. 4 and 4.1.5;
- a list of all the test results of relaxation, fatigue and stress corrosion on prestressing steels which reveals that all the wire rods used are in agreement for the manufacturing of these products.

He also communicates to him, for each quarterly period starting from the date of the issue of a first authorization of use of BENOR-mark, the quantity of products manufactured under the name of BENOR-mark as well as the quantity of scrapped products. These quantities are separately indicated for each factory of the producer and are subdivided by product.

### **5.1.2 Periodicity of the auditing visits**

The checks are carried out by the sectoral organization by means of auditing visits which take place, in theory, 4 times per year.

This periodicity is of a visit every 2 months in the following cases:

- for the 12 first months period which follows the issue of a first authorization of use of BENOR-mark;
- on decision of the sectoral organization, when the results obtained on the samples sampled by the sectoral organization during a routine checking and those obtained by the internal laboratory on the samples coming from the same batches present a statistically significant difference (see § 5.1.5) and that the producer could not justify satisfactorily;
- on decision of the sectoral organization, when other situations make it possible to question the level of product quality or its regularity.

It is not obligatory to check during each visit all the products making the object of the authorization of use of BENOR-mark, the choice is left to the appreciation of the sectoral organization.

### **5.1.3 Sampling**

The sectoral organization indicates products, among those carrying BENOR-mark in the stores of the producing factory, for test sample selection.

#### **5.1.3.1 Sampling for routine checking**

The producer submits to the sectoral organization a quantity of steel already subjected to factory control carrying the BENOR-mark including at least 2 products and corresponding with at least 30 production units.

Moreover, the producer takes care that each family being the subject of an authorization of use of BENOR-mark, can be submitted at least once a year to above mentioned control. In the same way, if necessary, the producer takes care to allow at least once a year the sampling of indented products. The sectoral organization delimits, in this quantity of steel, preferably a batch corresponding to 20 tests of industrial factory control of the same product, or failing this 2 batches corresponding each one to 10 tests of industrial factory control of the same product (this last choice is made exclusively in only one product, in case of insufficient stock). From these batches, the sectoral organization selects 20 samples distributed regularly. The 20 sampled samples have a sufficient length to carry out a tensile test with diagram (wire and strands), a bend test (wire), the measurement of the configuration of surface (wire and strands) and if necessary the measurement of the properties of the zinc layer (galvanized reinforcements). These tests are carried out in the internal laboratory.

In so far as the production comprises strands with diameters equal or greater than 12.5 mm, a deviated tensile test is carried out with each check. Those will be distributed so that at least one test result of deviated tensile can be available per year and per family.

One envisages for this sampling the possible following cases:

- Production of strands with a diameter of at least 12.5 mm in progress at the time of a check: sampling takes place in the presence of the sectoral organization on the work in progress, which is BENOR or of identical quality.
- No production in the course of strands with a diameter of at least 12.5 mm, but there are some on stock carrying BENOR-mark: sampling takes place in the presence of the sectoral organization on one of the production units in stock. The producer will organize himself so that a sampling of 4 single turns (whorls) of a reel, inside of the production unit, can take place easily the day of the periodic visit.

An insufficient production in BENOR-mark cannot cause a reduction of the frequency envisaged of the checks or a reduction of controls to be carried out by the sectoral organization. If necessary, the producer will submit to the sectoral organization a quantity of steel complementary to that manufactured under BENOR-mark, after factory control and having statistically analysed it according to rules BENOR, in order to make possible the achievement of the contractually requested tests.

The samples must be marked immediately in a manner making mistakes impossible.

The samples intended to be controlled elsewhere than in the internal laboratory are the subject of a written form of identification.

If products are frequently absent from stocks, the sectoral organization can impose the conservation of counterparts for the reinforcements concerned.

Nevertheless, it is necessary to realize, at least once a year, control tests on specimens sampled in the presence of the sectoral organization from at least the production of 30 units coming from stocks of the manufacturer.

#### **5.1.3.2 Sampling for annual checking in a control laboratory**

Once a year, at the time of one of its visits, the sectoral organization selects additional samples in order to carry out complementary tests in a control laboratory.

In case of doubt or of abnormal situation, the sectoral organization can renew the operation of sampling and sending of samples at a control laboratory.

##### **5.1.3.2.1 Tensile tests**

For all products which are designated by the sectoral organization for paired control between one tensile testing machine of the internal laboratory and a control laboratory, the taken samples are divided into 3 equal parts: the first one is tested at the internal laboratory, the second one is sent in the control laboratory and the third one is held in reserve.

##### **5.1.3.2.2 Behaviour in time: isothermal relaxation, fatigue and stress corrosion**

The tests are carried out at a rate of a product per type of reinforcement prestressing steels (wire, strands, galvanized reinforcements) for which the producer has the authorization of use of BENOR-mark. If necessary, the sampling is carried out on reinforcements with indentations and this at least once every 3 years. Each family should be tested at least every 3 years. These tests are exclusively carried out in the control laboratory. These tests of behaviour in time are taken into account like tests of industrial factory control.

A relaxation test, 3 fatigue tests and a stress corrosion test are carried out. The relaxation test, the fatigue tests and the stress corrosion test can be carried out on different products. The 3 fatigue tests are carried out on specimens of the same product coming from different production units.

Each sample is divided into 3 equal pieces: the first one is intended for control in a control laboratory, the second one is sent as a reserve to the same control laboratory and the third one is held in reserve in the factory.

The producer is entirely responsible for the sampling, the handling and the transport of the samples to the control laboratory.

#### **5.1.4 Tests**

##### **5.1.4.1 Measurements of configuration of surface and bend tests**

The internal laboratory proceeds, in the presence of the sectoral organization, with the bend tests and measurements of configuration of surface on the 20 specimens in accordance with standard NBN EN ISO 15630-3.

These tests and these measurements are not carried out in the control laboratory.

##### **5.1.4.2 Tensile tests**

The internal laboratory proceeds, in the presence of the sectoral organization, with the tensile tests on the 20 specimens in accordance with the specifications of the standards. These tests are carried out on the same testing machine as that on which the tests of factory control were carried out. Thus the producer records on all the internal reports of tests the identification of the testing devices used. During the annual checking, the control laboratory carries out the tests according to the same procedure.

##### **5.1.4.3 Isothermal relaxation test**

The test is carried out in accordance with the prescriptions of standard NBN EN ISO 15630-3; the duration of test is 1000 hours and the initial load is by preference equal to 70% of the real breaking load.

##### **5.1.4.4 Fatigue tests**

The tests are carried out until  $2 \cdot 10^6$  cycles in accordance with the prescriptions of standard NBN EN ISO 15630-3 supplemented according to the case by the impositions of the product standards.

The producer is entirely responsible for the sampling, the handling and the transport of the samples to the control laboratory.

##### **5.1.4.5 Stress corrosion test**

The test is carried out in accordance with the prescriptions of standard NBN EN ISO 15630-3, in which one uses solution A. the report clarifies the method applied, namely if anchorings are or not plunged in the solution, if the ends of the strands are protected or not...

The producer is entirely responsible for the sampling, the handling and the transport of the samples to the control laboratory.

##### **5.1.4.6 Deviated tensile test**

The internal laboratory proceeds, in the presence of the sectoral organization, with the deviated tensile tests on the sample, in accordance with the prescriptions of standard NBN EN ISO 15630-3.

In complement to standard NBN EN ISO 15630-3, after obtaining 5 valid test results, the standard deviation of the 5  $D_i$  values is calculated. If the standard deviation does not exceed 15%, the coefficient D is given as in NBN EN ISO 15630-3. If however the standard deviation is higher than 15%, 5 additional specimens are tested. From the series of the 10 individual results, the highest result and the weakest result are omitted. The coefficient D is then given as the average of the 8 remaining  $D_i$  values.

##### **5.1.4.7 Determination of the properties of the zinc layer**

The internal laboratory proceeds, in the presence of the sectoral organization, with the determination of the properties of the zinc layer on the 20 samples, in accordance with the prescriptions of the PTV 312. These measurements are not carried out in control laboratory.

## 5.1.5 Interpretation of the results

### 5.1.5.1 Case of routine checking

#### 5.1.5.1.1 *Measurements of configuration of surface, bend tests, deviated tensile test and determination of the properties of the zinc layer*

The results of measurements and the tests carried out in the presence of the sectoral organization must be in conformity with the prescriptions of the standards. The deviated tensile test is evaluated in accordance with § 5.1.4.6. It is not proceeded to a statistical comparison with the results of the factory control.

#### 5.1.5.1.2 *Tensile tests*

The results of measurements and the tests carried out in the presence of the sectoral organization must be in conformity with the prescriptions of the standards. The interpretation of the results of the load in extreme cases conventional of elasticity to 0,2% and of the breaking load consists in checking by the method of comparison of the paired results described with the appendix, that the results obtained on the specimens tested in the presence of the sectoral organization and those obtained by the factory within the framework of the industrial factory control on the batch or the batches from which the specimens result, do not present a statistically significant difference.

For total elongation under maximum loading, the report  $F'_m/F'_{p0.2}$  and the reduction of area (exclusively for the wires), it is not proceeded to a statistical comparison, but the results obtained in the presence of the sectoral organization must fulfil the prescriptions of the standards.

### 5.1.5.2 Case of the annual checks in control laboratory

#### 5.1.5.2.1 *Tensile tests*

The interpretation of the results for the tensile yield strength at 0,2% residual elongation ( $F'_{p0.2}$ ) and the tensile strength ( $F'_m$ ) consists in checking by the method of the paired observations described with the appendix of this document that the results obtained on the specimens tested on the one hand in the presence of the sectoral organization and those tested in control laboratory do not present a statistically significant difference.

For total elongation under maximum loading, the report  $F'_m/F'_{p0.2}$  and the reduction of area (exclusively for the wires), it is not proceeded to a statistical comparison, but the results obtained in control laboratory must fulfil the prescriptions of the standards.

#### 5.1.5.2.2 *Time depending properties*

All the results of these tests must satisfy the prescriptions with the standards.

The producer cannot refer to surface defects as an explanation of possible results not in conformity in particular for the stress corrosion or fatigue tests, except if he can prove in an indubitable way that surface defects are present on the samples and that they were caused by thirds, therefore apart from his responsibility.

Whenever non-conformity occurs when testing the time depending properties, the same tests will be carried out for the same products in the control laboratory during the following year to confirm the effectiveness of the corrective actions.

Insufficient results with the relaxation tests, fatigue, stress corrosion lead automatically to the obligation for the producer:

- To immediately warn the sectoral organization.
- To immediately organize a thorough metallurgical examination on the samples accused in order to be able to determine the cause of it. The complementary examination, whose costs are entirely at the burden of the producer, is carried out in an institute or a laboratory found qualified and proposed by the producer and accepted by the sectoral organization. The content of that metallurgical examination is detailed in chapter 5.1.7.
- To proceed immediately to a complete analysis of the causes.
- To withdraw immediately sale all products concerned not yet delivered.



- To immediately request tests on the reserve pieces (parts 2 and 3):
  - the control laboratory where were sent the samples carries out 1 test on the reserve piece(s) (second part).
  - the producer sends to another control laboratory the reserve piece(s) held in the factory (third part) and this control laboratory carries out 1 test on these samples.
- To immediately warn all its customers touched by the product range concerned in the following cases:
  - Relaxation higher more than 40% (relative) compared to the required maximum,
  - Average behaviour with fatigue lower than 1 200 000 cycles for the series of tests concerned,
  - Corrosion resistance for which 3 individual values out of 6 are lower than the required minimum or the median value is lower than 60% the required minimum.

Insofar as the results of the tests on the reserve pieces are positive and the causes identified, the conditions of acceptance are considered met for the family of products concerned:

- Certification can be preserved but the producer must take the necessary measures with respect to the batches of products already delivered or concerned by the first defective tests,
- The sectoral organization decides of the actions to be taken regarding the certification.

Insofar as the results of the tests on the reserve pieces are not entirely positive, 2 new series of samples are taken in the presence of the sectoral organization out of 2 different casts of the same product for 2 new tests. Each sample is divided into 3 equal pieces: the first one is intended for control in a control laboratory, the second one is sent as a reserve to the same control laboratory and the third one is held in reserve in the factory.

Insofar as the results of one new test are positive and the results of the second new test are not entirely positive, immediately request tests on the reserve pieces (parts 2 and 3) of this second new series:

- the control laboratory where were sent the samples carries out 1 test on the reserve piece(s) (second part).
- the producer sends to another control laboratory the reserve piece(s) held in the factory (third part) and this control laboratory carries out 1 test on these samples.

Insofar as the results of the tests on the all reserve pieces of this second new test are positive, the results of this second sampling and testing are considered positive.

Insofar as the results of this second sampling and testing are considered positive and the causes identified, the conditions of acceptance are considered as being met for the family of products concerned. The file will be closed for the benefit of producer:

- Certification can be preserved but the producer must take the necessary measures with respect to the batches of products already delivered or concerned by the first defective tests,
- The sectoral organization decides of the actions to be taken regarding the certification.

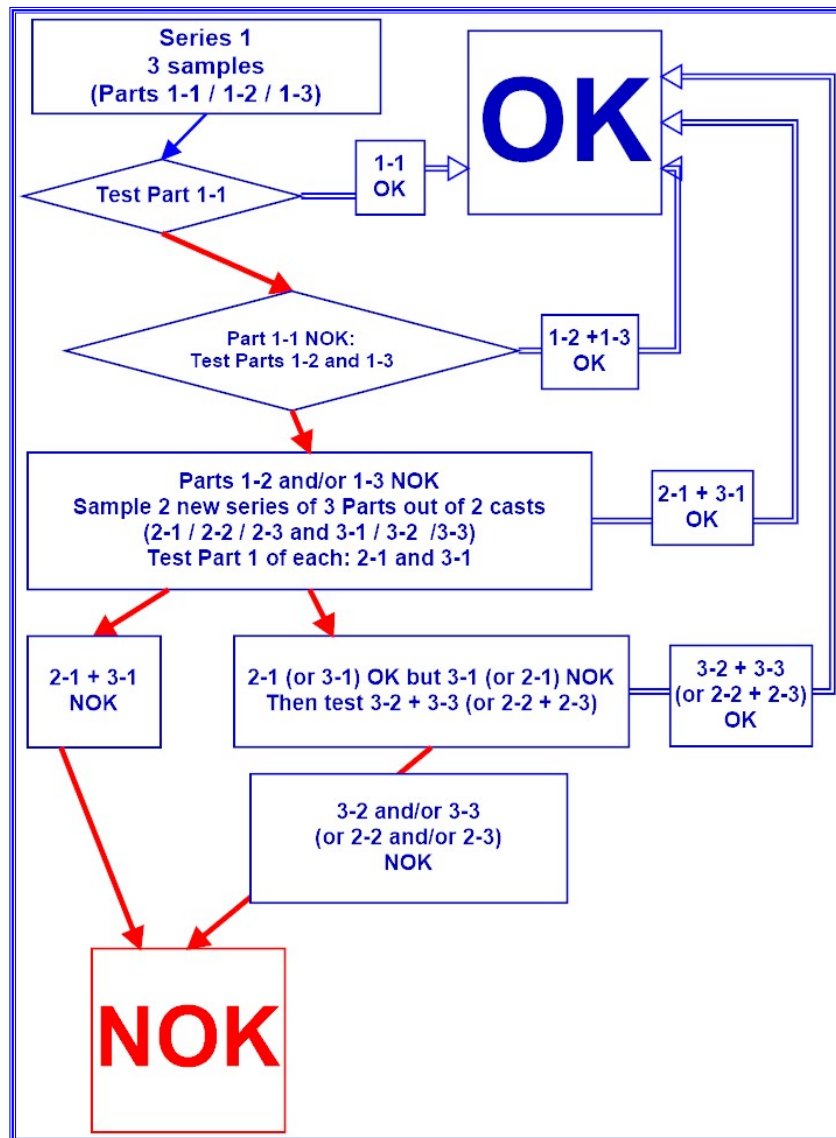
Insofar as the results of the 2 new tests are not entirely positive, the certification for the group of products concerned is suspended sine die until the producer is able to present at the same time 5 satisfactory tests on the type of product concerned and a metallurgical explanation of the encountered problems. The producer must inform the customers with respect to the batches of products already delivered and take the necessary measures (withdrawal of the products or financial repair) and destruction of all the not yet delivered products concerned with the first defective tests.

The sectoral organization makes a decision on the basis of the test results presented and metallurgical explanation brought by the producer.

If the following year, the product does not again fulfil the same test, the BENOR-mark for the family concerned is withdrawn if these same tests do not give satisfaction.

### ***Explanation of this scheme***





### 5.1.6 Official report of monitoring

The results of the monitoring are consigned to each visit in a report drawn up in double specimen.

This report must comprise the following indications:

1. producer and factory;
2. identification of the products;
3. frequency, result and evaluation of control by the services of the factory;
4. data on the test sample selection;
5. results of the tests carried out in the presence of the sectoral organization and corresponding results of the industrial factory control;
6. overall evaluation;
7. place and date;
8. signatures.

The report, if necessary, is supplemented later on by a copy of the official report of the stress corrosion and fatigue, isothermal relaxation, tensile tests of carried out in the control laboratory.

The report must be preserved for one period of at least 10 years in the producer and the sectoral organization.

### 5.1.7 Content of a metallurgical examination

A metallurgical examination comprises a minima the following investigations and tests:

- Full chemical composition of the product including at least: C - Mn - Si - P- S – Al – Nb – V- Ti - B – Cr – Cu – Ni – Mo – N, and all other elements, if significant.
- A non-etched longitudinal cut showing the whole section of the wires of parts of strands and the possible presence of internal or surface defects.
- A non-etched transverse cut showing the whole section of the wires of parts of strands and the possible presence of internal or surface defects.
- An etched macrograph of the longitudinal cross-section.
- An etched macrograph of the transverse cross-section.
- Micrographs showing the microstructure of the metal and the possible presence of martensite
- An evaluation of the maximum percentage of martensitic phases.

## 5.2 Products covered by the BENOR-mark being outside the producing factory

### 5.2.1 Controls carried out on the initiative of the sectoral organization

The sectoral organization can take samples in the manufacturing plants of concrete components or on a building site in order to check that the products there stored and considered to carry BENOR-mark, fulfil indeed the applicable criteria of the Belgian standards.

The sampled specimens are numbered and cut in 3 equal parts. A series of specimens is tested; the 2 others are kept for possible later tests.

They are carried out in a control laboratory or in the internal laboratory in the presence of the sectoral organization. In this case, they are carried out at the time of the following periodic visit.

The results of the tests are communicated to the producer. If anomalies or irregularities are noted, the producer is invited to provide a justification within a given time.

The costs of testing are under the burden of the producer when deficiencies are noted. In the absence of deficiencies, the expenses of tests in the control laboratory are for OCAB-OCBS.

In the event of observation of non-observance of the provisions of the General Regulation or Particular Regulation, the procedure envisaged in article 13 of the Regulation of use and control of BENOR-mark is applied by the sectoral organization to the users of the mark.

In the event of discovery of fraud, the sectoral organization reserves the right to prosecute the person in charge of the fraud.

### 5.2.2 Controls carried out by the sectoral organization in the case of an external claim

In the case of a justified claim of a user, the sampling is carried out contradictorily, on the products being the subject of the litigation, by a delegate of the sectoral organization, the producer or his representative in Belgium having been duly convened.

The taken samples are numbered and cut in 3 equal parts.

The tests are carried out on thirds of samples during the ordinary check in the internal laboratory and on the second thirds in a control laboratory; the third series of specimens is kept for possible later tests.

The results of the tests are communicated to the producer. So anomalies or irregularities are noted, this one is invited to provide a justification within a given time.

The costs of test are at the burden of the producer when deficiencies are noted. In the absence of deficiencies, the costs of tests in the control laboratory are for the user, unless the OCAB-OCBS agrees to cover them.

In the event of observation of non-observance of the provisions of the General Regulation or Particular Regulation, the procedure envisaged in article 13 of the Regulation of use and control of BENOR-mark is applied by the sectoral organization to the users of the mark.

In the event of discovery of fraud, the sectoral organization reserves the right to prosecute the person in charge of the fraud.

**5.2.3 Controls carried out on the initiative of a user**

Whatever the results of the tests, the expenses of those are with exclusive load of the user who took the initiative of it unilaterally.

The users who estimate themselves injured can address their claim, with justification, at the sectoral organization.

As soon as possible, the sectoral organization rules on the admissibility of the claim and possibly decides to carry out controls and tests. The sectoral organization then applies the procedure described to § 5.2.2 if the products being the subject of the litigation are still available or according to the procedure described with § 5.2.1 in the contrary case.

**6 Laboratories and inspection bodies**

The control laboratories and inspection bodies operating on behalf of the OCAB-OCBS within the framework of this document are listed in Document OCAB-OCBS 503a.

**7 Appendix**

**7.1 Method of comparison of the paired observations**

For each examined property, one has N pairs of results (U<sub>i</sub>, L<sub>i</sub>).  
 One calculates:

- the differences d<sub>i</sub> = U<sub>i</sub> - L<sub>i</sub>;
- the average  $\bar{d}$  of these d<sub>i</sub>;
- the ratio  $\bar{d}/S_n$  (S<sub>n</sub> = nominal section);
- the estimate of the standard deviation of the d<sub>i</sub>:

$$s_d = \sqrt{\frac{\sum_{i=1}^n \Sigma (d_i - \bar{d})^2}{n - 1}}$$

- the ratio s<sub>d</sub>/S<sub>n</sub>;
- the value of the coefficient of STUDENT:

$$t = \frac{\bar{d} \sqrt{n}}{s_d}$$

One compares the value found for |t| with the t<sub>0</sub> (ν, 5%) values of reference to the law of STUDENT (A1 table).

One compares the values found for  $\left| \frac{\bar{d}}{S_n} \right|$  and of s<sub>d</sub>/S<sub>n</sub> with the value of 40 N/mm<sup>2</sup> (tests carried out on 2 distinct tensile testing machines); if necessary with the value of 20 N/mm<sup>2</sup> (tests carried out on the same tensile testing machine).

The successive comparison of the experimental values

$$|t|, \left| \frac{\bar{d}}{S_n} \right| \text{ et } s_d / S_n$$

to the comparison values allows classifying the series of results obtained in one or the other type-cases of table A2 which includes also the interpretation to be given to the results.

**Table A1 - Fractiles of the STUDENT's law**

Risk de first species  $\alpha = 0,05$

Level of confidence  $1 - \alpha = 0,95$

Value of  $t_0$

Number of paired results (n)	Bilateral test
10	2,26
11	2,23
12	2,20
13	2,18
14	2,16
15	2,14
16	2,13
17	2,12
18	2,11
19	2,10
20	2,09
21	2,09
22	2,08
23	2,07
24	2,07
25	2,06
26	2,06
27	2,06
28	2,05
29	2,05
30	2,05

**Table A2 - Type-cases and interpretation rules**

$ t  \leq t_0$ non-significant statistical difference	$\left  \frac{\bar{d}}{S_n} \right  \leq 40 \text{ N/mm}^2$	$\frac{S_d}{S_n} \leq 40 \text{ N/mm}^2$	acceptance
		$\frac{S_d}{S_n} > 40 \text{ N/mm}^2$	
	$\left  \frac{\bar{d}}{S_n} \right  > 40 \text{ N/mm}^2$	$\frac{S_d}{S_n} \leq 40 \text{ N/mm}^2$	impossible case
		$\frac{S_d}{S_n} > 40 \text{ N/mm}^2$	refusal
$ t  > t_0$ significant statistical difference	$\left  \frac{\bar{d}}{S_n} \right  \leq 40 \text{ N/mm}^2$	$\frac{S_d}{S_n} \leq 40 \text{ N/mm}^2$	acceptance
		$\frac{S_d}{S_n} > 40 \text{ N/mm}^2$	refusal
	$\left  \frac{\bar{d}}{S_n} \right  > 40 \text{ N/mm}^2$	$\frac{S_d}{S_n} \leq 40 \text{ N/mm}^2$	
		$\frac{S_d}{S_n} > 40 \text{ N/mm}^2$	

## 8 History of revisions

- 8.1 Revisions 0 to 10, creation, adaptations
- 8.2 Revision 11, update of format and rules into English language; among others, previous chapters A, B and C are renumbered 3 - 4 and 5
- 8.3 Revision 12, slight modifications in § 4.1.5 / 5.1.3.1 / 5.1.3.2.2 / 5.1.5.1.2
- 8.4 Revision 13, inclusion of chapter 3.1.12.3 *Case of new production lines*. Modification of chapters 2.2.4.2 and 3.1.9.1.1 for indentation characteristics