IMPLEMENTATION RULES	TRA	282
	VERSION 16	2024/4

IMPLEMENTATION RULES OF THE BENOR-MARK IN THE SECTOR OF PRESTRESSING STEEL PRODUCTS –

METHODS OF ASSESSMENT APPLICABLE TO THE USERS OF THE BENOR-MARK

The valid version is available on the PROCERTUS website.

Use the QR code below:

FOREWORD

On 01.04.2024, the npo's PROBETON, BE-CERT, OCAB-OCBS and PROCERTUS merged in accordance with article 13 of the Code of Companies and Associations. On that date, PROBETON, BE-CERT and OCAB-OCBS were automatically dissolved, and all their rights and obligations were transferred to PROCERTUS, which alone continues their activities.

CONTENT

1 INTRODUCTION

These Implementation Rules (TRA[1]) of PROCERTUS, sectoral organisation, were initially established by the Technical bureau 2 "Prestressing steels" of OCAB-OCBS, and are managed by PROCERTUS for the BENOR certification of prestressing steels.

According to the Rules for the use and control of the BENOR-mark[2] and its article 9, these Implementation Rules constitute the reference certification scheme to the BENOR-mark.

2 REFERENCE DOCUMENTS AND DEFINITIONS

2.1 Reference documents

The following certification rules apply:

- Règlement d'usage et de contrôle de la marque BENOR / Algemeen reglement voor het beheer van het BENOR-merk[3].
- Règlement général pour la gestion de la marque BENOR / Algemeen reglement voor het beheer van het BENOR-merk[4].
- 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[5].

The last edition of the standards and PTV applies. In the event of an incompatibility following the revision of one of the documents quoted hereafter, an addendum to the present Implementation Rules will be published if necessary.

- 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 I 10-008, Armatures de précontrainte - Torons protégés gainés / Voorspanwapeningen – Beschermde omhulde strengen.
- 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 - Beproevingsmethoden - 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.

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[1] **TRA**: **T**oepassings**r**eglement – **R**èglement d'**A**pplication

[2] Reference asbl BENOR vzw : NBN/RVB.CA/RM2012-10-02 and following editions in force

[3] Reference: NBN/RVB.CA/RM2012-10-02 and following editions in force

[4] Reference: NBN/RVB.CA/RG2012-10-02 and following editions in force

[5] According to the last edition in force

- PTV 314, Prescriptions techniques - Aciers de précontrainte - Fils tréfilés / Technische voorschriften - Voorspanstaal - Koudgetrokken draden.
- PTV 315, Prescriptions techniques - Aciers de précontrainte - Torons protégés gainés / Technische voorschriften – Voorspanstaal – Beschermde omhulde strengen.
- 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.

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[7]" times the nominal strand diameter.
- **Galvanised 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" galvanisation are allowed.
- **Protected and sheathed strands type SC/P**: coated with a protective product and wrapped by a not adhere (type P) or adhere (type SC) sheath to the strand.

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 type of sheath used (none, not adhere or adhere), 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.

[7] With X comprised between 14 to 22 for 3 wires strands and between 12 to 18 for 7 wires strands

The protected and sheathed strands are grouped in 2 families according to their type (P or SC). Table IV below gives the composition and the index of the families of reinforcements being the subject of the PTV 315.

Table I – Smooth [∅] and indented [⊗] wires

Specified characteristic tensile strength (N/mm²)	Nominal diameter (mm)	Family
1.470	∅ 12,2 - 10 ⊗ 12,2 - 10	1
1.570	∅ 12,2 - 10 - 9,4 - 8 – 7 - 5 ⊗ 12,2 - 10 - 9,4 - 8 – 7 - 5	2
1.670	∅ 8 - 7,5 - 7 - 6 - 5 - 4 ⊗ 8 - 7,5 - 7 - 6 - 5 - 4	3
1.770	∅ 7 - 6 - 5 – 4,5 - 4 ⊗ 7 - 6 - 5 – 4,5 - 4	4
1.860	∅ 5 - 4 ⊗ 5 - 4	4bis

Table II – 3- and 7-wire strands of smooth [∅] and indented [⊗] wires

Specified characteristic tensile strength (N/mm²)	Nominal diameter (mm)		Family
	3-wire strands	7-wire strands	
1.670	∅ 9,2	-	5bis
1.770	-	∅ 15,2 - 15,7 - 18,0 ⊗ 15,2 - 15,7 - 18,0	5
1.860	∅ 6,5 - 6,9 - 7,5 - 7,7 - 9,2 ⊗ 6,5 - 6,9 - 7,5	∅ 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	∅ 6,3	-	7
1.960	∅ 4,8 - 5,2 - 5,6 - 6,5 ⊗ 5,2 - 6,5	∅ 9,0 ⊗ 9,0	8
2.060	∅ 5,2 ⊗ 5,2	∅ 6,4 – 6,85 - 7,0 – 8,6 – 11,3 ⊗ 6,4 – 6,85 - 7,0 – 8,6 – 11,3	9
2.160	∅ 5,2	∅ 6,85 ⊗ 6,85	10

Table III – Galvanised prestressing steels

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

Table IV – Protected and sheathed strands

Specified characteristic tensile strength (N/mm²)	Nominal diameter (mm)	Family
1.770	∅ 15,2 - 15,7	P
1.860	∅ 12,5 - 12,9 - 15,2 - 15,7	
1.770	∅ 15,2 - 15,7	SC
1.860	∅ 12,5 - 12,9 - 15,2 - 15,7	

2.2.4 Laboratories

2.2.4.1 Internal laboratory

It is the own laboratory of the factory (laboratory of the producer). To be recognised 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 be older 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 BENOR certification must be the subject to paired comparisons with the tensile testing machine of the control laboratory[8] according to the provisions of the preliminary examination.
- During the annual controls by the certification body, the test results of at least one testing machine must be compared to the ones of a control laboratory. Each tensile testing machine must be subject 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 annually 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), an annual 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.

Furthermore, the internal laboratory must comply to the requirements from ECU 625.

2.2.4.2 Control laboratory

Laboratory accredited according to ISO/IEC 17025 and listed in document 503a[9].

3 PRELIMINARY EXAMINATION PRIOR TO THE GRANTING OF THE AUTHORISATION OF USE OF BENOR-MARK

3.1 Principle

The conformity of the products to the requirements of standards NBN I10-001 to 003 and technical specifications PTV 311, 312, 314 and 315 is checked by a preliminary examination prior to the granting of the authorisation 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 authorisation of use of the BENOR-mark;
- to maintain a regularity for the properties of these products in current manufacturing. Hereto, at the time of his application for the granting of the authorisation of use of the BENOR-mark, the producer provides a technical file which comprises at least all elements given in document DTD 289.

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.

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.

[8] See definition in 2.2.4.2

[9] Document 503 a, "Lijst – Liste – List, Keuringsinstellingen, Laboratoria, Organismes d'inspection, Laboratoires, Inspection Bodies, Laboratories »

3.2 Preliminary examination

3.2.1 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 certification body or its representative[10].

3.2.2 Examination of the technical file

The preliminary examination is also based on the providing to and the examination by the certification body of the data contained in the technical file, which is delivered at the time of the application for granting authorisation 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 shown that the wire rod can be used only after all foreseen controls were carried out, evaluated and finally regarded as acceptable.

The qualification of the wire rod by the producer is finalised in a list (see document 289) including, for each product, the suppliers and the types of wire rods recognised by the producer. At the time of the preliminary examination, the up-to-date list is submitted to the certification body.

The certification body must be able to examine the suitability of all the wire rods used and mentioned in the list. Hereto, the producer presents, by type, origin and diameter of wire rod, his file of acceptance including the test results carried out on the prestressing steels manufactured at the beginning of this (see also document 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.

For the protected and sheathed strands, the internal control plan including the entry control, the controls during production and the controls on the finished product will be described. The test frequencies, recording method and acceptance criteria shall be indicated.

[10] In the following of the text and for simplification reasons, the term "certification body" includes as well its representative as the inspection body and its representative.

3.3 Identification

3.3.1 Label

Each production unit carries a label mentioning the indications listed in § 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 (according to PTV 311, 312, 314, 315)

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

3.3.2 Traceability

The finished products are identified in such way that the producer can declare at any time 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 recognised 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 recognised by the producer such as initially presented and kept up to date in a permanent way.

3.4 Family of products

This concept is defined in § 2.2.3. The producer, who applies for the authorisation of use of BENOR-mark for a family of products, is not obliged to apply for all the diameters of this family which are part of his production programme.

3.5 Sampling

3.5.1 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 applies for the authorisation of use of BENOR-mark. The batches presented to the preliminary examination are homogeneous batches according to the meaning of standards NBN I10-002 and 003 (§ 4.2.2).

The certification body selects, as much as possible randomly, the number of products foreseen for control among the available products. All these available products come from the installations planned for the manufacturing of these products.

Taking into account the constancy of quality of manufactured products with high added value such as prestressing reinforcements, the differences between the individual tensile strength values of the specimens can be of the same order of magnitude as the measurement accuracy. 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 recognised by the producer. The producer gives evidence of that to the certification body by submitting the necessary elements.

The number of test samples for each characteristic are presented in **Table V** below.

Table V – Test frequencies preliminary examination

Characteristics	Number of samples	Control
Tensile mechanical characteristics		
Tensile yield strength at 0,2% residual elongation ($F'_{p\,0.2}$) Tensile strength (f'_m)	30	S
Stress ratio between tensile strength tensile yield strength ($f'_m/F'_{p\,0.2}$) Elongation at maximum force	30	A
Reduction of area (for the wires)	30	A
Resistance to reverse bending (for the wires)	30	A
Geometrical characteristics		
Cross-section, Lay length, Depth, length and spacing of the indentations for the indented wires or strands, Straightness	30	A
Specific properties		
Isothermal relaxation	4	A
Fatigue behaviour	4	A
Stress corrosion resistance	1	A
Deflected tensile test (for 7 wire-strand starting from 12.5 mm)	5 (10)	A
If applicable:		
Thickness, continuity and adherence of the zinc layer	30	A
Mass of the sheath and protection products (grease, wax), Thickness of the sheath, Initial resistance to friction of the sheath	3	A
Mechanical properties of the sheath, Sheath stress cracking resistance, Water tightness, Impact resistance of the sheath, Bond conservation under thermal variations (only for type sc)	1	A

A, S: control by attribute, statistical control by measurements

3.5.2 Sampling of the first family

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

The producer presents at least 120 tons of reinforcements coming, in equal proportions, from 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 to the control laboratory of the samples indicated by the certification body.

If among the proposed families there are sheathed protected strands, the first family chosen will preferably be one of those comprising sheathed protected strands in order to determine if the authorisation of use of the BENOR-mark can be granted for those products.

The certification body samples all presented products in the family with a maximum of 3 to carry out the tests following **Table V**.

If it is not possible to sample the reinforcement pieces form different production units, it is allowed to select a maximum of 2 reinforcement pieces per production unit if the distance between these 2 reinforcement pieces is of at least 20 meters.

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

When relevant, the products selected by the certification body include at least 1 product with protected and sheathed strands.

3.5.3 Sampling for the examination of the other families

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

For products from family 6, the sampling always takes place as for the first family.

The certification body samples 1 product for each other family to carry out the tests following **Table V**.

Unless the requested authorisation concerns only one product, at least 2 products shall be sampled, even if the presented products belong to the same family.

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

When relevant, the products selected by the certification body include at least 1 product with protected and sheathed strands.

3.6 Tests

The tests are carried out in the internal laboratory of the producer under the surveillance of the certification body or in the control laboratory in accordance with the following provisions.

3.6.1 Tests concerning the geometrical and mechanical characteristics

3.6.1.1 Paired control between the internal laboratory and the control laboratory

One product for each tensile testing machine is selected for 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 mechanical characteristics of the reinforcement (see PTV 311 or PTV 314).

3.6.1.2 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).

3.6.2 Tests concerning time depending properties

3.6.2.1 Relaxation

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.

3.6.2.2 Fatigue

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 2.10^6 cycles according to the requirements of the product standards.

3.6.2.3 Stress 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.

3.6.3 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% of the average value, the coefficient D is given as in NBN EN ISO 15630-3. However, if the standard deviation is higher than 15% of the average value, 5 additional specimens are tested. From the series of the 10 individual results, the highest result and the weakest result are excluded. The coefficient D is then given as the average of the 8 remaining D_i values.

3.6.4 Tests concerning the protection material and the sheath

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 be able to carry out all the tests of the protection material and the sheath (see PTV 315).

3.7 Evaluation of the results

3.7.1 Control by measurements

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

- tensile yield strength at 0,2% residual elongation ($F'_{p\,0.2}$),
- 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: $v_c = m - 2.22\ s$[11].

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

[11] The coefficient 2,22 corresponds to n = 30 in Table IV of paragraph 4.2.2

3.7.2 Control by attributes

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

3.7.3 Conditions of acceptance

Each product 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.

3.7.4 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 application 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 certification body - to submit the results in the necessary form to the certification body. All new sampling must be made under the supervision of the certification body;
- 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 application for certification for the family of products concerned is regarded as null and void;

The certification body details its observations in his report in order to request the opinion of the technical advice bureau 2 and of the certification committee.

3.7.5 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 ($F'_{p\ 0.2}$) 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 statistically non-identical, the producer must search the causes thereof and present his conclusions to the certification body:

- If the causes are due 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 due to the control laboratory, or if the cause of the differences cannot be discovered, the certification body decides on the actions to be taken.

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

3.8 Authorisation of use of the BENOR-mark

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

3.9 Extension of authorisation of use of BENOR-mark

3.9.1 Extension of an authorisation of use of BENOR-mark within a family

If the present authorisation does not yet contain 3 products or concerns family 6, the examination must always be performed by testing of the products in accordance with the above, until 3 products of this family are certified.

If within the family 6 at least 3 products are already certified, but not yet the extreme products (Ø 6.5 - 6.9 - 15.2 - 15.7), and if the producer applies for the authorisation of use for 1 extreme product, the examination must always be performed by testing those products in accordance with the above. The technical file of the producer must be adapted as a preliminary.

In the case of an extension to indented wires or strands within a family already recognised in smooth products, at least a batch of 3 fatigue tests on 1 product of indented wire or strand is mandatory.

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

The producer provides the following data per product applied for:

- 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 2.10^6 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.

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 case of an extension in a family already certified with protected and sheathed strands, the tests on the protection material and the sheath are carried out for one product in the internal laboratory in the presence of a representative of the certification body.

3.9.2 Extension of an authorisation of use of BENOR-mark to other families

The producer can request the extension of the authorisation of use of BENOR-mark to other families of his production programme. These families are sampled and examined according to the procedure described above for the sampling of other families.

3.9.3 Case of new production lines

The firm must provide a revision of the technical file including the results of the ITTs on the different products from these new lines.

Test specimens should be sampled, during the next periodic visit, from the new line as part of routine controls. Annual samples must also be taken on the new line for at least one of the products.

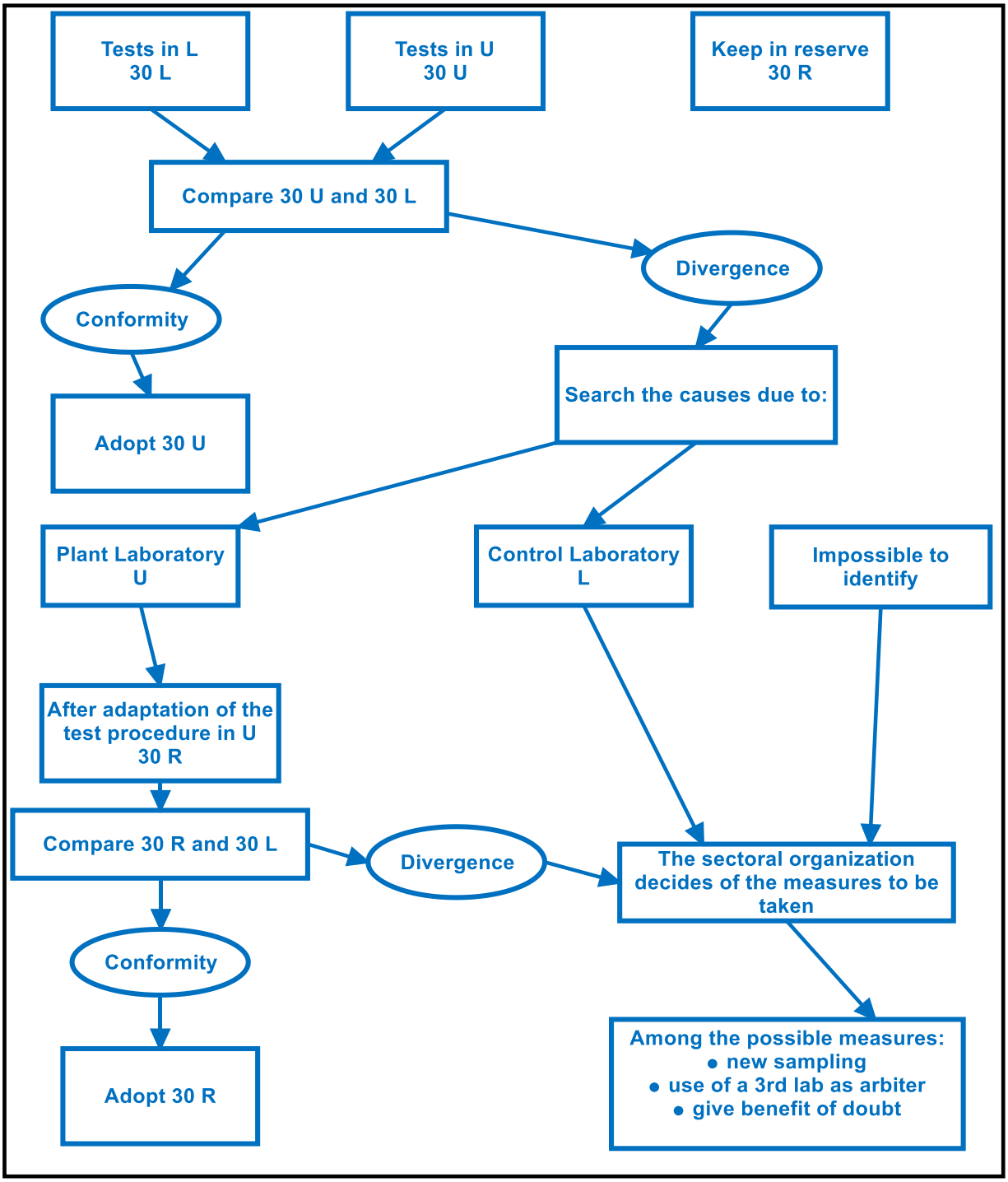
Flow chart for paired control

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 Methods of control

4.1.1 Equipment for testing and measuring

The producer shall have control methods allowing for checking the compliance with the criteria fixed by the standards for the products for which he obtained the authorisation of use of BENOR-mark. The testing machines of the internal laboratory must fulfil the requirements of §2.2.4.1.

However, with regard to the tests of isothermal relaxation, of fatigue and of stress corrosion, the producer can call upon a priorly accepted external laboratory that complies with the requirements of §2.2.4.

4.1.2 Control of the origin of products

The producer must have an internal system which permits to check that every incoming product (e.g. wire rod or sheathing material) that will be used for manufacturing of the products fulfils its own specifications.

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

- either result of tests realised and provided by the supplier of the incoming product in accordance with the requirements of the producer of the prestressing steel (methods and frequency);
- or results of tests carried out by the producer of the prestressing steel following an established methodology (methods and frequency).

The records should prove that the incoming product is used only after all planned controls were carried out and were found to be acceptable.

In case of doubt or problems with respect to the quality of the incoming product, the supplier must carry out additional controls.

The evaluation of the quality of the wire rod by the producer leads to establishing a list of suppliers and types and diameters of wire rod approved by the producer (see 3.2.2). This list is kept up to date. The same applies to the sheathing and protection material.

4.2 Sampling

Samples are taken in a random way and tested for the control of the characteristics according to the frequencies in the **Table VI** hereafter.

Table VI – Test frequencies industrial factory control

<table>
<tr><th>Characteristics[12]</th><th>Wires, galvanised wires</th><th>Strands, galvanised strands</th><th>Control</th></tr>
<tr><td>1. Geometrical properties (product, cross-section and possibly characteristics of the indentations)</td><td rowspan="2">1 sample by 4 tons of product of the same geometrical configuration, of the same specified characteristic tensile resistance and manufactured according to the same procedure</td><td rowspan="2">1 sample per production unit</td><td>A</td></tr>
<tr><td>2. Surface quality and straightness</td><td>A</td></tr>
<tr><td>3. Tensile strength or breaking load (see NBN EN ISO 15630-3)</td><td colspan="2">1 sample per production unit</td><td>S</td></tr>
<tr><td>4. Load at the conventional limit of elasticity at 0,2%</td><td rowspan="5">1 sample by 4 tons of product of the same geometrical configuration, of the same specified characteristic tensile resistance and manufactured according to the same procedure</td><td rowspan="5">1 sample per production unit</td><td>S</td></tr>
<tr><td>5. Stress ratio between tensile strength and tensile yield strength ($f'_m/F'_{p\,0.2}$)</td><td>A</td></tr>
<tr><td>6. Elongation at maximum force</td><td>A</td></tr>
<tr><td>7. Load-elongation diagram</td><td>A</td></tr>
<tr><td>8. Reduction of area</td><td>A</td></tr>
<tr><td>9. Resistance to reverse bending (see NBN EN ISO 15630-3)</td><td></td><td>A</td></tr>
<tr><td>10. Thickness of the zinc layer</td><td rowspan="3">1 sample by 4 tons of product of the same geometrical configuration, of the same specified characteristic tensile resistance and manufactured according to the same procedure</td><td rowspan="3">1 sample per production unit</td><td>A</td></tr>
<tr><td>11. Continuity of the zinc layer</td><td>A</td></tr>
<tr><td>12. Adherence of the zinc layer</td><td>A</td></tr>
<tr><td>13. Behaviour under multiaxial loads</td><td></td><td>5 (10) samples per homogeneous production of 7 wire-strand starting from 12.5 mm</td><td>A</td></tr>
<tr><td rowspan="2">14. Isothermal relaxation*</td><td colspan="2">2 samples (different products) per family per year</td><td rowspan="2">A</td></tr>
<tr><td colspan="2">1 sample every 3 years on protected sheathed strands</td></tr>
<tr><td rowspan="3">15. Fatigue*</td><td>3 samples (same product) per year</td><td>3 samples (same product) per year</td><td rowspan="3">A</td></tr>
<tr><td colspan="2">3 samples (same product) per family every 3 years</td></tr>
<tr><td colspan="2">3 samples (same product) every 3 years on protected sheathed strands</td></tr>
<tr><td>16. Stress corrosion*</td><td colspan="2">1 sample per family per year</td><td>A</td></tr>
<tr><td>17. Protection material and the sheath:
• Mass of the sheath and protection products (grease, wax)
• Thickness of the sheath
• Initial resistance to friction of the sheath
• Water tightness
• Impact resistance of the sheath</td><td colspan="2">1 sample per homogeneous production</td><td>A</td></tr>
</table>

A, S: control by attribute, statistical control by measurements

* The tests are distributed as well on the smooth wires and strands as on those with prints.

[12] Properties 1 to 8 of § 4.1 of standards NBN I10-002 (wire), NBN I10-003 (strands), property 9 of standard NBN I10-002 (wire) and properties 10 to 11 of § 4.2 of the PTV 312.

The statistical analysis according to §4.5 and 4.6 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 §4.5 and 4.6 hereafter, but with the characteristic that a β customer risk of 2,5% is taken in account[13].

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 interdistance of 20 meters on the production unit.

A production is considered homogeneous if the whole of the tensile test results fulfils the assumption of normality with a degree of confidence of 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 §3.5.1 are applicable.

4.3 Tests

The tests are carried out in the internal laboratory of the producer or in the external laboratory accepted by the certification body.

4.3.1 Tests concerning time depending properties

4.3.1.1 Relaxation

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.

4.3.1.2 Fatigue

The fatigue test is carried out according to the prescriptions of standard NBN EN ISO 15630-3 and is continued up to 2.10^6 cycles, as well as following the requirements of the product standards.

4.3.1.3 Stress corrosion

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.

4.3.2 Behaviour under multiaxial loads

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% of the average value, the coefficient D is given as in NBN EN ISO 15630-3. However, if the standard deviation is higher than 15% of the average value, 5 additional specimens are tested. From the series of the 10 individual results, the highest result and the weakest result are excluded. The coefficient D is then given like the average of the 8 remaining D_i values.

[13] i. e. for n = 6, k = 4,39 ; n = 7, k = 3,94 ; n = 8, k = 3,64 ; n = 9, k = 3,42

4.3.3 Tests concerning the protection material and the sheath

In the event of a change in the materials or installations used to manufacture the protected strands, the producer must immediately inform the certification body and provide proof that the characteristics of the product have not been modified by presenting test results concerning:

1. the mechanical properties of the sheath,
2. the sheath stress cracking resistance,
3. the bond conservation under thermal variations (only for type SC),

In addition, in the case of a modification of the production facilities, it must be demonstrated that the mechanical characteristics (relaxation, fatigue, etc.) of the products are not affected.

The measurement of these properties is carried out in accordance with the relevant provisions of PTV 315.

4.4 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 recorded in the register.

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

Except for the modulus of elasticity, the results are analysed statistically by the producer while following a calculation programme approved by the certification body, and the results of this statistical analysis are sent quarterly to the certification body: the certification body 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 analysis 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 sent to the certification body as soon as possible. The certification body 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 internal quality standards and analysis by the producer.

The registers of wire rod and the tests are continuously held at the disposal of the certification body.

4.5 Statistical control by measurements

4.5.1 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%.

4.5.2 Statistical interpretation of the results of the tests

The statistical interpretation of the test results 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 he submits for control to the certification body.

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 VII 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 possibility 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 . 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 . s_i) remains lower than the specified value, the whole of the products considered cannot be covered by the BENOR-mark (see §4.8).

Table VII

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

4.6 Statistical control by attributes

4.6.1 Principle

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

4.6.2 Statistical interpretation of the results of the tests

The interpretation of the test results applies to the whole of 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 VIII** hereafter.

Table VIII

Minimal number of results necessary to respect the criterion	Allowed maximum number of non-satisfactory results
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 products of the considered production cannot bear the BENOR-mark 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%.

4.6.3 Corrective actions for non-conforming tests for time-depending properties

Non-conforming results for the relaxation, fatigue, stress corrosion tests, lead automatically to the obligations for the producer:

- to immediately warn the certification body;
- to immediately proceed with a complete root causes analysis ;
- to immediately withdraw the sale for all products concerned not yet delivered;
- to immediately proceed 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 certification body;
- 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.

If the results of the 2 new series are satisfactory, 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 certification body decides on the actions to be taken regarding the certification.

If the results of the 2 new series are not satisfactory, 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.

4.7 Affixing of the BENOR-mark

As soon as all test results relative to a homogeneous production are recorded, analysed and that their interpretation is noted as being conform to the criteria, the production can be marked with a label attesting conformity to the standard.

This label carries at least following indications:

- BENOR-logo;
- identification of the reel.

The producer submits the model of the label to the approval of the certification body. Later on, any modification of the label must be authorised in beforehand by the certification body.

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

When it is found a posteriori that a non-conform batch has been delivered, the producer has the obligation to warn his customer, as well as the certification body.

4.8 Products not to bear the BENOR-mark

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

5 CONTROLS BY THE CERTIFICATION BODY

5.1 Products being in the producing factory

5.1.1 General information

The requirements on which the authorisation of use of the BENOR-mark is based on (regularity in the manufacturing of the products and conformity to the standards of the products carrying BENOR-mark), are controlled periodically by the certification body.

This controls consist in making sure:

- that there exists an internal system of qualification of the wire rod;
- that the tensile testing machines are in conformity with NBN EN ISO 15630- 3, that they are of class 1 or better and that their last calibration is not older than one year;
- that all the other measurement and testing devices are calibrated at least once a year;
- that the industrial factory control is rigorously applied;
- that the results of the industrial factory control are satisfactory. For this purpose, the certification body carries out the checking of the statistical analysis of at least 2 series of results a year;
- that the results obtained and recorded during this industrial factory control are in line with reality. This is done by

carrying out verification tests on products manufactured under the BENOR-mark and subjected to the factory control;

- that all measures were taken to not introduce scrapped products which cannot bear the BENOR-mark among the products fulfilling BENOR specifications;
- that when anomalies were noted, corrective actions were taken to cure them;
- whether the protection and sheathing material and the extrusion equipment have been modified.

The producer takes all measures to facilitate these controls; in particular, he transmits to the certification body (see document 289):

- the list of suppliers and qualities and diameters of wire rod which he accepts;
- the list of protection products and polyethylene used and of extrusion equipment used;
- the name of the person in charge of the monitoring services of the factory;
- the date of starting-any slightly modified production, i.e. products lying within the scope of the agreement but comprising certain minor modifications;
- all results of factory control;
- a list of all test results of relaxation, fatigue and stress corrosion on prestressing steels that shows that all wire rods used are satisfactory for the manufacturing of these products.

He also informs the certification body, for each quarterly period starting from the date of the issue of a first authorisation of use of BENOR-mark, about the quantity of products manufactured under the 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 inspection visits

The controls are carried out by the certification body by means of inspection visits which take place, in theory, 4 times per year.

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

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

It is not mandatory to control during each visit all products comprised in the scope of the authorisation of use of the BENOR-mark, the choice is left to the appreciation of the certification body.

5.1.3 Sampling

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

5.1.3.1 Sampling for routine control

The producer submits to the certification body a quantity of steel already subject to factory control carrying the BENOR-mark, including at least 2 products and corresponding with at least 30 production units, for the execution of the tests following the table below.

Table IX – Frequencies of tests in the internal laboratory under supervision of the certification body

Characteristics	Wires	Strands
• Geometrical properties: • Cross-section, • Lay length, • Depth, the length and the spacing of the indentations for the indented wires or strands • Straightness	20 samples per audit	
• Resistance to reverse bending • Reduction of area	20 samples per audit	
• Mechanical properties: • Tensile strength or breaking load • Load at the conventional limit of elasticity at 0,2% • Stress ratio between tensile strength and tensile yield strength ($f'_m/F'_{p\,0.2}$) • Elongation at maximum force • Load-elongation diagram	20 samples per audit	
• Thickness of the zinc layer • Continuity of the zinc layer • Adherence of the zinc layer	20 samples per audit	
• Behaviour under multiaxial loads (for 7 wire-strand starting from 12.5 mm)		5 (10) samples per audit when strands $\Phi \geq 12.5$ mm are certified 1 control per family per year
• Mass of the sheath and protection products (grease, wax), • Thickness of the sheath, • Initial resistance to friction of the sheath • Impact resistance of the sheath	3 samples per audit	
• Water tightness, • Bond conservation under thermal variations (only for type SC)	1 sample per audit	

Moreover, the producer ensures that each family being the subject of an authorisation of use of the BENOR-mark, can be submitted at least once a year to above mentioned control. In the same way, if necessary, the producer ensures to allow at least once a year the sampling of indented products and protected sheathed products. The certification body 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 for only one product, in case of insufficient stock).

Provided that the protection and sheathing operations do not affect all other characteristics, those may be checked on the unsheathed strand without protection of sheathing. Otherwise, the tests are carried out on the sheathed protected strand, previously stripped of its sheath and its protective product in order to be able to carry out the necessary measurements.

In so far as the production comprises strands with diameters equal or greater than 12.5 mm or protected sheathed strands, one foresees the possible following cases:

- Production of these products at the time of a control visit: sampling takes place in the presence of the certification body on the work in progress, which is BENOR or of identical quality.
- No production in course, but there are some on stock carrying BENOR-mark: sampling takes place in the presence of the certification body 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 foreseen frequency of controls or a reduction of controls to be carried out by the certification body. If necessary, the producer will submit to the certification body a quantity of steel complementary to that manufactured under BENOR-mark, after factory control, and after having statistically analysed it according to BENOR rules, in order to allow for the executing the contractually requested tests.

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

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

If products are frequently absent from stocks, the certification body 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 certification body from at least the production of 30 units coming from stocks of the manufacturer.

5.1.3.2 Sampling for annual control in a control laboratory

Once a year, at the time of one of its visits, the certification body selects additional samples in order to carry out additional tests in a control laboratory following the table below.

Table X – Frequencies of tests in the control laboratory

<table>
<tr><th>Characteristics</th><th>Wires</th><th>Strands</th><th>Galvanised</th></tr>
<tr><td>Mechanical properties:
• Tensile strength or breaking load
• Load at the conventional limit of elasticity at 0,2%
• Stress ratio between tensile strength and tensile yield strength ($f'_m/F'_{p\,0.2}$)
• Elongation at maximum force
• Load-elongation diagram</td><td colspan="3">20 samples per year for paired control</td></tr>
<tr><td rowspan="2">• Isothermal relaxation
• Stress corrosion</td><td>1 sample per year</td><td>1 sample per year</td><td>1 sample per year</td></tr>
<tr><td colspan="3">1 sample for each family every 3 years</td></tr>
<tr><td rowspan="2">• Fatigue</td><td>3 samples per year</td><td>3 samples per year</td><td>3 samples per year</td></tr>
<tr><td colspan="3">3 samples for each family every 3 years</td></tr>
<tr><td>• Mass of the sheath and protection products (grease, wax),
• Thickness of the sheath,
• Initial resistance to friction of the sheath
• Impact resistance of the sheath</td><td colspan="3">3 samples for each family (P or SC) every 3 years</td></tr>
<tr><td>• Mechanical properties of the sheath,
• Sheath stress cracking resistance,
• Water tightness,
• Bond conservation under thermal variations (only for type SC)</td><td colspan="3">1 sample for each family (P or SC) every 3 years</td></tr>
</table>

In case of doubt or of abnormal situation, the certification body can renew the operation of sampling and sending of samples to a control laboratory. The producer is entirely responsible for the sampling, the handling and the transport of the samples to the control laboratory.

Tensile tests

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

Behaviour in time: isothermal relaxation, fatigue and stress corrosion

These tests are taken into account as tests of industrial factory control.

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 and the third ones are held in reserve in the factory.

Sampling of protected and sheathed strands

These tests are taken into account as tests of industrial factory control.

5.1.4 Tests

5.1.4.1 Measurements of configuration of surface and bend tests

These tests are in accordance with standard NBN EN ISO 15630-3.

5.1.4.2 Tensile tests

This test is in accordance with standard NBN EN ISO 15630-3. 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 test reports the identification of the testing devices used. During the annual control, 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 2.10^6 cycles in accordance with the prescriptions of standard NBN EN ISO 15630-3 completed by the requirements of the relevant product standards.

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 shows the method applied, namely if anchorings are plunged in the solution or not, if the ends of the strands are protected or not, …

5.1.4.6 Deviated tensile test

The internal laboratory proceeds, in the presence of the certification body, 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 Di values is calculated. If the standard deviation does not exceed 15% of the average value, the coefficient D is given as in NBN EN ISO 15630-3. However, if the standard deviation is higher than 15% of the average value, 5 additional specimens are tested. From the series of the 10 individual results, the highest result and the weakest result are excluded. The coefficient D is then given as the average of the 8 remaining D_i values.

5.1.4.7 Properties of the zinc layer

The internal laboratory proceeds, in the presence of the certification body, with the determination of the properties of the zinc layer in accordance with the prescriptions of PTV 312.

5.1.4.8 Testing of protected and sheathed strands

These tests are carried out in accordance with the prescriptions of PTV 315.

5.1.5 Interpretation of results

5.1.5.1 Case of routine control

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

The results of measurements and tests carried out in the presence of the certification body must be in conformity with the requirements of the standards. The deviated tensile test is evaluated in accordance with §5.1.4.6.

Tensile tests

The results of measurements and tests carried out in the presence of the certification body must be in conformity with the requirements 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 paired results described in the annex of document NRN 418, that the results obtained on the specimens tested in the presence of the certification body and those obtained by the factory within the framework of the industrial factory control on the batch or the batches from which the specimens come, do not present a statistically significant difference.

For total elongation under maximum loading, the ratio $F'_m/F'_{p0.2}$ and the area reduction (exclusively for wires), a statistical comparison is not carried out, but the results obtained in the presence of the certification body must fulfil the requirements of the standards.

5.1.5.2 Case of the annual control in control laboratory

Tensile tests

The interpretation of the results for the tensile yield strength at 0,2% residual elongation ($F'_{p\,0.2}$) and the tensile strength (F'_m) consists in checking, by the method of paired observations described in the appendix of this document, that the results obtained on the specimens tested in the presence of the certification body and those tested in a control laboratory, do not present a statistically significant difference.

For total elongation under maximum loading, the ratio $F'_m/F'_{p\ 0.2}$ and the area reduction (exclusively for wires), a statistical comparison is not carried out, but the results obtained in a control laboratory must fulfil the requirements of the standards.

Time-depending properties

All results of these tests must satisfy the requirements of the standards.

The producer cannot refer to surface defects as an explanation of possible nonconforming results, 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 others, therefore not under 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[14] automatically lead to the obligation for the producer:

- to immediately warn the certification body;
- to immediately proceed with a complete root cause analysis. This root cause analysis can include a metallurgical examination on the samples. When a metallurgical examination is performed, it contains at least all elements listed in § 5.1.7. The additional examination, whose costs are entirely at the burden of the producer, is carried out in a qualified institute or laboratory proposed by the producer and accepted by the certification body;
- to immediately withdraw from sale all concerned products not yet delivered;
- to immediately request tests on the reserve pieces (parts 2 and 3) in two control laboratories chosen by the certification body;
- to immediately warn all customers touched by the product range concerned, in the following cases:
  - relaxation more than 40% (relative) compared to the required maximum,
  - average behaviour with fatigue lower than 1 200 000 cycles for the concerned test series ,
  - corrosion resistance for which 3 individual values out of 6 are lower than the required minimum, or the median value is lower than 50% of the required minimum.

When the test results 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 certification body decides of the actions to be taken regarding the certification.

When the test results on the reserve pieces are not entirely positive, 2 new series of samples are taken in the presence of the certification body 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 and the third ones are held in reserve in the factory.

When the results of one new test are positive and the results of the second new test are not entirely positive, immediately tests are requested on the reserve pieces (parts 2 and 3) of this second new series in two control laboratories chosen by the certification body.

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

When 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 case will be closed in favour of the producer.

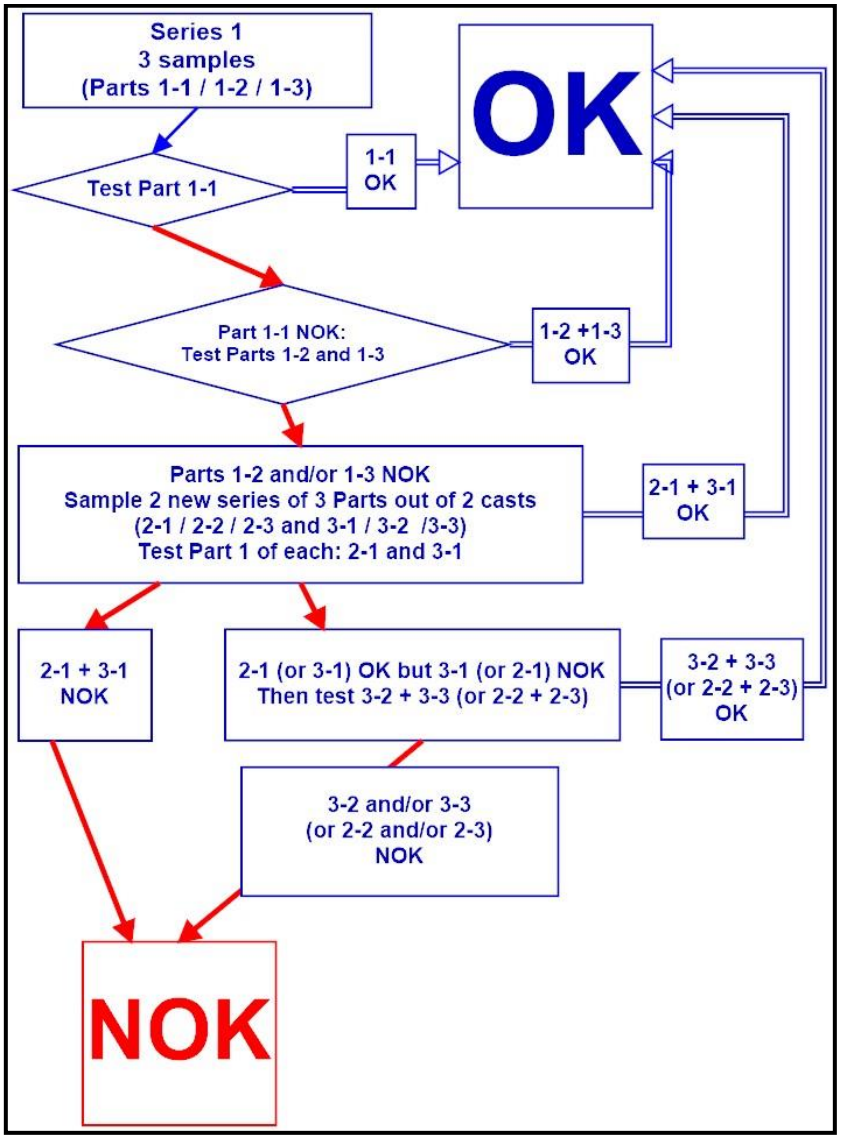
When the results of the 2 new tests are not entirely positive, the certification for the product concerned is suspended sine die until the producer is able to present at the same time 5 satisfactory tests on the type of product concerned and a metallurgical explanation of the encountered problems. The 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.

[14] Remark regarding stress corrosion tests: the criteria regarding stress corrosion tests apply to both the minimum duration for each of 6 tests in a series and the median value of those 6 tests. Considering the significant measurement uncertainty inherent in this test method, the appraisal of conformity of the median is performed according to the requirements of ISO 17025:2017 §7.8.6.1 stating that the statement of conformity must account for the level of risk (such as false accept and false reject and statistical assumptions) associated with the decision rule employed. Consequently, the measurement uncertainty of the median value, which can be estimated, should be taken into account for the conformity appraisal. The uncertainty of the median value is considered at the same level as the uncertainty of the mean value, thus accounting for 2 times the standard deviation of the duration of the six individual tests divided by the square root of 6.

The certification body takes a decision on the basis of the test results presented and metallurgical explanation brought by the producer.

If the following year, the product again does not 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



Protected and sheathed strands

All results of these measurements must comply with the requirements of PTV 315.

5.1.6 Official report of controls

The results of the controls are recorded every visit in a report drawn up in twofold.

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 certification body and corresponding results of the industrial factory control;
6. overall evaluation;
7. place and date;
8. signatures.

If necessary, the report is completed later on with a copy of the official report of the stress corrosion and fatigue, isothermal relaxation, tensile tests carried out in the control laboratory.

The report must be preserved for a period of at least 10 years by the producer and by the certification body.

5.1.7 Content of a metallurgical examination

A metallurgical examination comprises at least 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 certification body

The certification body can take samples in the manufacturing plants of concrete elements or on a building site in order to check that the products stored and there considered to carry BENOR-mark, meet the applicable requirements 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.

The tests are carried out in a control laboratory or in the internal laboratory in the presence of the certification body. In the latter case, they are carried out at the time of the next periodic visit.

The test results are provided to the producer. If anomalies or irregularities are found, 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 found. In the absence of deficiencies, the expenses of tests in the control laboratory are for PROCERTUS.

In the event of observing of disrespect of the provisions of the General Rules or Particular Rules, the procedure foreseen in article 13 of the Rules for the use and control of BENOR-mark is applied by the certification body.

In the event of discovery of fraud, the certification body reserves itself the right to prosecute the party responsible for the fraud.

5.2.2 Controls carried out by the certification body in the case of an external complaint

In the case of a justified complaint of a user, a delegate of the certification body carries out a contradictory sampling on the products being the subject of the litigation, the producer or his representative in Belgium having been duly convened to assist.

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

The tests are carried out on thirds of samples during the ordinary control 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 test results are provided to the producer. If anomalies or irregularities are found, the producer is invited to provide a justification within a given time.

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

In the event of observation of disrespect of the provisions of the General Rules or Particular Rules, the procedure foreseen in article 13 of the Rules for the of use and control of BENOR-mark is applied by the certification body.

In the event of discovery of fraud, the certification body reserves itself the right to prosecute the party responsible of fraud.

5.2.3 Controls carried out on the initiative of a user

Whatever the results of the tests, the expenses of those are at the exclusive charge of the user who took the initiative thereto in an unilateral way.

Users who consider themselves disadvantaged can address their substantiated complaint to the certification body.

As soon as possible, the certification body decides on the admissibility of the complaint and, if necessary, decides to carry out controls and tests. The certification body then applies the procedure described in §5.2.2 if the products being the subject of the litigation are still available or according to the procedure described in §5.2.1 in the contrary case.

6 LABORATORIES AND INSPECTION BODIES

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

7 APPENDIX

7.1 Method of comparison of paired observations

For each examined property, one has N pairs of results (U_i, L_i).

One calculates:

- the differences $d_i = U_i - L_i$;
- the average $\bar{d}$ of these di;
- the ratio $\bar{d}$ /Sn (Sn = nominal section);
- the estimate of the standard deviation of the di:

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

- the ratio sd/Sn;
- the value of the STUDENT coefficient:

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

One compares the value found for |t| with the t_o (υ, 5%) values of reference to the law of STUDENT (table A1).

One compares the values found for $\left|\bar{d} / S_n\right|$ and of s_d/Sn with the value of 40 N/mm² (tests carried out on 2 distinct tensile testing machines); if necessary with the value of 20 N/mm² (tests carried out on the same tensile testing machine).

The successive comparison of the experimental values

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

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

Table A1 - Fractiles of the STUDENT's law

Risk of first order α **= 0,05**

Level of confidence **1 - α = 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

$\lvert t \rvert \leq t_0$ non-significant statistical difference	$\left\lvert \frac{\overline{d}}{S_n} \right\rvert \leq$ 40 N/mm²	$\frac{s_d}{S_n} \leq$ 40 N/mm²	acceptance
		$\frac{s_d}{S_n} >$ 40 N/mm²	
	$\left\lvert \frac{\overline{d}}{S_n} \right\rvert >$ 40 N/mm²	$\frac{s_d}{S_n} \leq$ 40 N/mm²	impossible case
		$\frac{s_d}{S_n} >$ 40 N/mm²	refusal
$\lvert t \rvert > t_0$ significant statistical difference	$\left\lvert \frac{\overline{d}}{S_n} \right\rvert \leq$ 40 N/mm²	$\frac{s_d}{S_n} \leq$ 40 N/mm²	acceptance
		$\frac{s_d}{S_n} >$ 40 N/mm²	refusal
	$\left\lvert \frac{\overline{d}}{S_n} \right\rvert >$ 40 N/mm²	$\frac{s_d}{S_n} \leq$ 40 N/mm²	
		$\frac{s_d}{S_n} >$ 40 N/mm²	

8 HISTORY OF REVISIONS

Revisions 0 to 10

- Creation, adaptations.

Revision 11

- Update of format and rules into English language; among others, previous chapters A, B and C are renumbered 3 - 4 and 5.

Revision 12

- Slight modifications in § 4.1.5 / 5.1.3.1 / 5.1.3.2.2 / 5.1.5.1.2.

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.

Revision 14

- Inclusion of prescriptions regarding the protected and sheathed strands, transfer information from text to tables with test frequencies.

Revision 15

- §2.2.4.1: reference to ECU 625, table IX: testing frequency for the deflected tensile testing + sheath stress cracking resistance only external, §5.1.5.2.2: actions in case of non-conformity for the long-term properties

Revision 16

- Transfer from OCAB-OCBS to PROCERTUS
- Change of vocabulary, where relevant, from sectoral organisation to certification body
- Editorial and linguistical corrections