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New Italian norms to regulate the non-destructive inspections in the manufacturing and in the maintenance of parts of hydraulic machinery

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Introduction

This paper presents two proposals of norms (standards) which have been discussed by a Working Group of UNI (Ente Italiano di UNIficazione, Italian expression of ISO) during 1998-2000, and will be soon submitted to examination by the technical verification commission of UNI.

These proposals aim to provide procedures to perform and evaluate inspections on parts of hydraulic machinery (i.e. Francis, Pelton, Kaplan runners, guidevanes, etc.), thus integrating the well-known specifications CCH70-3 and the various applicable European or American norms, normally referred to by the specialists of this sector.

The two proposals emerged from the need, perceived in Italy by the main manufacturers of turbines, and the main energy suppliers, to clarify the field of the non-destructive inspections which has a great importance for hydropower, above all as regards safety in the powerplants.

New technologies have also been developed in recent years (such as, for instance, new methods for the manufacturing of Pelton runners) with a view to increasing safety and taking advantage of the new technological possibilities. These new technologies have been taken into account in these norms, which can be regarded as an updating of existing specifications.

1. What is the reference point today?

At present there is no Italian or European Norm with the specific aim of being a reference point for hydropower. An overview of the standards commonly used for the testing of hydraulic machinery is shown in Figs. 1. and 2.

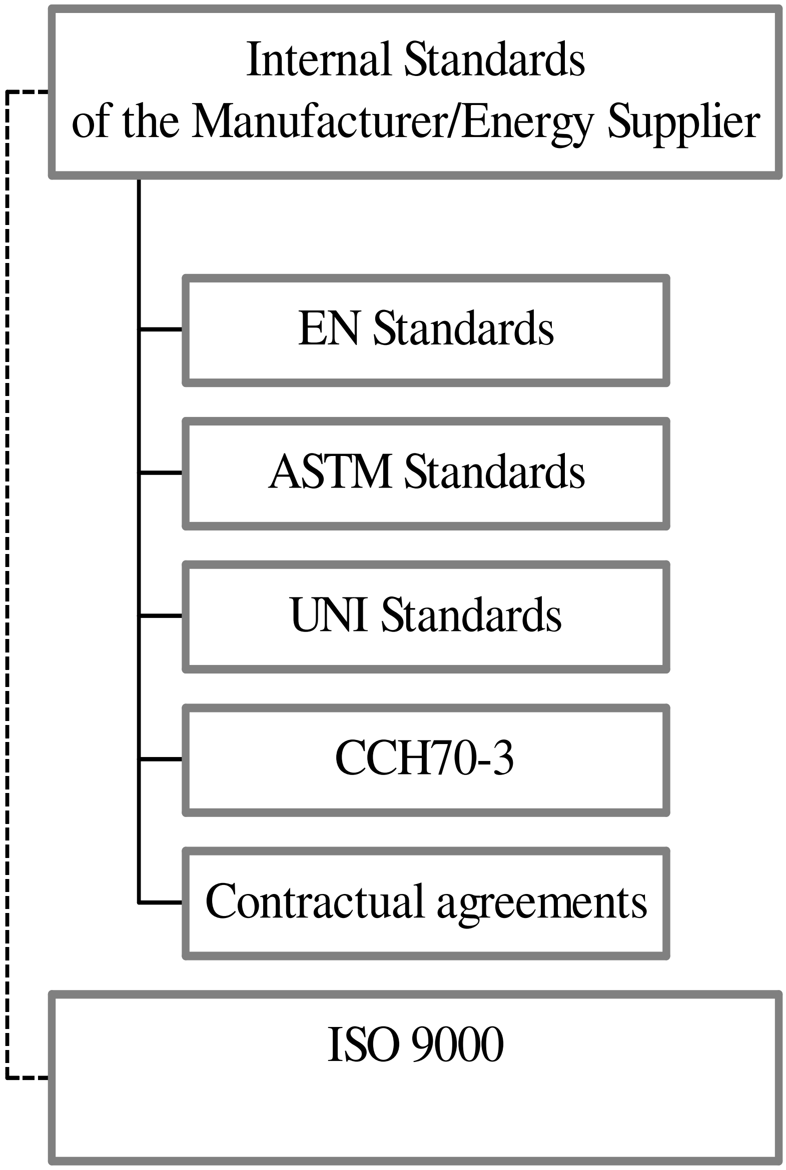


Fig. 1. Standards for destructive-testing in hydropower (overview)

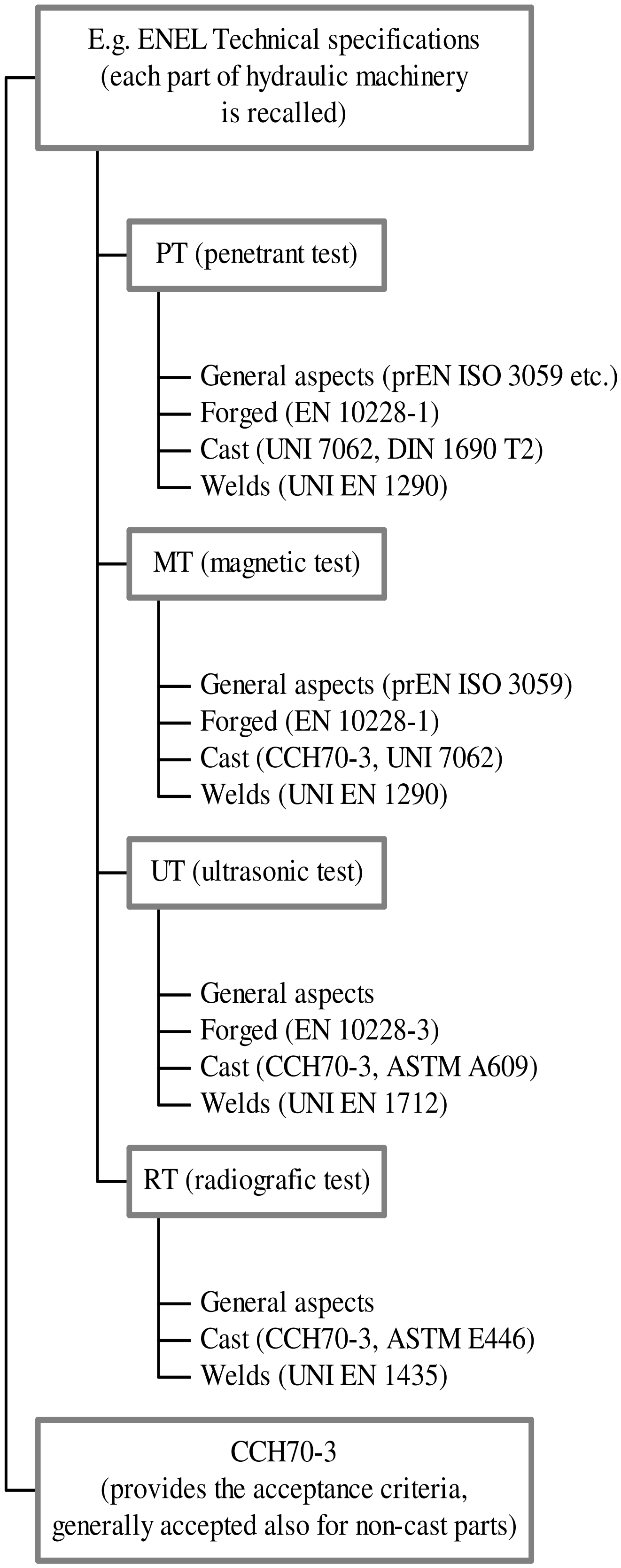

E.g. ENEL Technical specifications
(each part of hydraulic machinery
is recalled)
PT (penetrant test)
General aspects (prEN ISO 3059 etc.)
Forged (EN 10228-1)
Cast (UNI 7062, DIN 1690 T2)
Welds (UNI EN 1290)
MT (magnetic test)
General aspects (prEN ISO 3059)
Forged (EN 10228-1)
Cast (CCH70-3, UNI 7062)
Welds (UNI EN 1290)
UT (ultrasonic test)
General aspects
Forged (EN 10228-3)
Cast (CCH70-3, ASTM A609)
Welds (UNI EN 1712)
RT (radiografic test)
General aspects
Cast (CCH70-3, ASTM E446)
Welds (UNI EN 1435)
CCH70-3
(provides the acceptance criteria,
generally accepted also for non-cast parts)

Fig. 2. Standards for destructive-testing in hydropower (detail)

Turbine manufacturers and energy suppliers have had various experiences since the beginning of 20th Century, but there has not been a single and unique standard. In each European country a few companies gained experience while building the existing powerplants and they made internal standards, which remain a hidden treasure during a long time.

A very important step ahead was taken by the Study Group comprising some European or American Foundries and Turbine Manufacturers. In 1971 they issued the first edition of the famous Cahier des Charges Hydrauliques, CCH70-1. In 1979 the second edition, CCH70-2 followed, and then in 1996 the third edition (CCH70-3).

Today the main turbine manufacturers and energy suppliers mention these papers in the Technical Specifications which govern the contracts, so that de facto they have become the real reference point for all non-destructive tests in hydropower. Also the major Italian Energy Supplier, previously known as ENEL and today split into several smaller companies, has issued Technical Procedures for the maintenance of hydraulic machinery in which the Cahier de Charges Hydrauliques is largely mentioned.

The main limits of the Cahier de Charges Hydrauliques are, in our opinion, as follows:

- they are not official UNI or EN Standards.
- their application (as clearly mentioned in the complete title) is limited to cast materials, so that the most modern technologies which make great use of forged material are not represented
- they do not give indications about the frequency of the tests to be performed

2. New elements of discussion

The newest technological developments have led to the extensive use of forged or welded parts instead of cast ones. This is due to the need for better material quality, and the possibility to perform better non-destructive tests (in particular ultrasonic tests) on forged parts with simple forms and parallel surfaces.

Thanks to the new machining technologies, it is often easier to machine a complex form out of a geometrically simple forged ring or disk, rather than obtaining it directly in the cast version. The former method also assures better material characteristics and less defects.

The idea of producing forged or welded parts instead of cast ones is finding more and more success in many cases: Pelton runners, Francis runners, Kaplan blades and guidevanes, labyrinth rings, and so on.

The new possibilities require norms and specifications which can cover this matter; unfortunately the Cahier de Charges Hydrauliques does not fit these requirements, since it was conceived only for cast pieces. In the authors' opinion, a standard specific to modern requirement is necessary today.

3. Draft Italian standard UNI U45000430: Criteria for the choice of non-destructive testing on hydraulic machinery during production

The scope of this draft Standard is to specify the general principles for the non-destructive inspections associated with the manufacture of new parts.

The criteria can help decide which tests to perform on each type of the hydraulic machinery:

- Pelton
- Francis
- Kaplan
- Pumps

- Other hydraulic machinery (rotary valve, butterfly valve, etc..)

The turbines are divided according to the size, taking into account the output (in MW) and the outer diameter of the runner. In fact, the acceptance criteria are different depending on the importance and the size of the turbines (see Fig. 3.)

Machine		**Reference data**	
Type	*Size*	*Output P (MW)*	*Runner's max diameter D (mm)*
PELTON Turbine	A B C	$P \leq 3$ $3 < P \leq 10$ $P > 10$	$D \leq 1000$ $1000 < D \leq 1500$ $D > 1500$
FRANCIS Turbine	A B C	$P \leq 3$ $3 < P \leq 10$ $P > 10$	$D \leq 1000$ $1000 < D \leq 1500$ $D > 1500$
Turbine-pump Centrifugal pump	A B C	$P \leq 3$ $3 < P \leq 10$ $P > 10$	$D \leq 1000$ $1000 < D \leq 1500$ $D > 1500$
KAPLAN Turbine	A_{TAT} B C	$P \leq 3$ $3 < P \leq 10$ $P > 10$	$D \leq 2000$ $D > 2000$
Both conditions (output/diameter) must be fulfilled for each type			

Fig. 3. Turbine sizes

For each of these main groups, the standard indicates which test should be performed, making reference to:

- Runner
- Guidevanes, as well as nozzle and needles
- Shaft
- Casing, and so on.

4. Draft Italian Standard UNI U45000440: Criteria for the choice of non destructive tests on the hydraulic turbines in service and related intervention programs

The scope of this draft Standard is to specify the general principles for the non-destructive inspections associated with the maintenance of hydraulic turbines.

In Chapter 6 some criteria to determine the frequency of the non-destructive tests are given.

For instance, the following formula (1) is the result of years of experience made by the main manufacturers and energy suppliers and gives a criterion for the test on Pelton runners:

$$T1 = \frac{N}{Z2 \times n \times 60} \qquad (1)$$

($T1$ max = 500 hours)

where:

$T1$= time before a new test (on a new runner or after a complete repair)

N = cycles

$Z2$= no. of jets

n = rpm

Further tests shall be performed after a period $T2 = 4 \times T1$.

In Chapter 7 a table for each type of turbine (Pelton, Francis and Kaplan) helps to decide:

- which test should be performed
- what defects must be sought; and,
- what is the suggested frequency of the test.

In Fig. 4. is shown as instance a table for Pelton turbines. The standard also shows Figures and drawings, to make sure that each part of the turbine is clearly identified (s. Fig. 5 and 6).

These criteria apply to traditionally cast runners; for forged and forged and welded Pelton runners the test frequency should decrease, but not enough data are at disposal to give certain values yet.

Parti da controllare **Figure 1A, 2A, 3A, 4A e 5A** ***(Parts to check s. Fig. 1A, 2S, 3A, 4A and 5A)***	**Tipo di controllo** ***(Test)***	**Tipologia di difetto da ricercare** ***(Defect to seek)***	**Periodicità di controllo** ***(Frequency of test)***
Girante (Runner)			
• Tutte le superfici della girante	VT	Alterazioni dei profili idraulici dovute a: 1) erosione 2) cavitazione	A cadenza annuale
• Pale: 1) Superfici attive 2) Tagliente 3) Tricuspide 4) imbocco 5) Radice del cucchiaio	MT e/o PT	Indicazioni lineari (cricche)	**T1** = $5*10^7/Z_2*n*60$, comunque entro le prime 500 ore di esercizio **T2** = 4*T1 = 2000 ore massimo Δ**T** = intervallo tra T2 e i successivi controlli
• Disco	MT	Indicazioni lineari (cricche)	In occasione dello smontaggio girante, per riparazione e/o rigenerazione.

Albero Turbina (Turbine Shaft)			
• Tutte le superfici dell'albero	VT	Alterazione delle superfici p.es. 1) rigature (colli d'albero) 2) corrosioni (zona calettamento girante)	In occasione della revisione generale turbina
• Flangia e/o spallamento di unione girante-albero • Zona di alloggiamento / calettamento girante	MT	Indicazioni lineari (cricche a fatica) disposte preferenzialmente in senso circonferenziale nella zona di raccordo lato girante	A girante smontata 1) prima di aver totalizzato $1x10^9$ cicli 2) successivamente ogni $5x10^8$ cicli
• Flangia di collegamento albero turbina con albero alternatore	MT	Indicazioni lineari (cricche a fatica)	A girante smontata prima di aver totalizzato $1x10^9$ cicli
• Colli d'albero	PT	Indicazioni lineari (cricche)	In occasione dello smontaggio girante, per riparazione e/o rigenerazione.
• Flangia di unione con girante, zona di raccordo all'albero, lato girante: controllo condotto con sonde OT dal lato opposto alla girante.	UT	Indicazioni lineari (cricche a fatica) disposte preferenzialmente in senso circonferenziale nella zona di raccordo	In sostituzione al controllo MT di questa zona previsto ogni $5x10^8$ cicli
• Volume intero 1) sonde OL da superfici piane di estremità e su superfici cilindriche 2) sonde OT su superfici cilindriche	UT	Indicazioni lineari (cricche)	In occasione della revisione generale turbina
Bulloni e prigionieri (Screws)			
• Testa • Gambo • zona filettata	VT	1) Deformazioni 2) Rotture filetti	In occasione dello smontaggio girante, per sua sostituzione o riparazione.
• Volume intero: sonde OL in direzione assiale	UT	Indicazioni lineari (cricche) 1) sotto testa 2) in corrispondenza dei primi filetti	In occasione della revisione generale turbina
Spine e Bocchelli (Nozzles and Needles) • Superfici accessibili	VT	Alterazioni dei profili dovute a: 1) erosione 2) cavitazione	In occasione del controllo MT della girante
Supporti (Bearings) • Superfici metallo antifrizione	VT	Alterazioni dei profili dovute a: 1) trascinamento particelle solide 2) usura	In occasione della revisione generale della turbina
• Superfici metallo antifrizione • Interfaccia tra metallo antifrizione e supporto	PT	1) Indicazioni lineari (cricche) 2) Indicazioni tondeggianti (porosità)	In occasione della revisione generale della turbina
• Interfaccia metallo antifrizione – Supporto Sonde OL su superficie di lavoro	UT	Mancanza di aderenza tra metallo antifrizione e supporto	In occasione della revisione generale della turbina

Fig. 4. – Tests for Pelton Turbines during maintenance

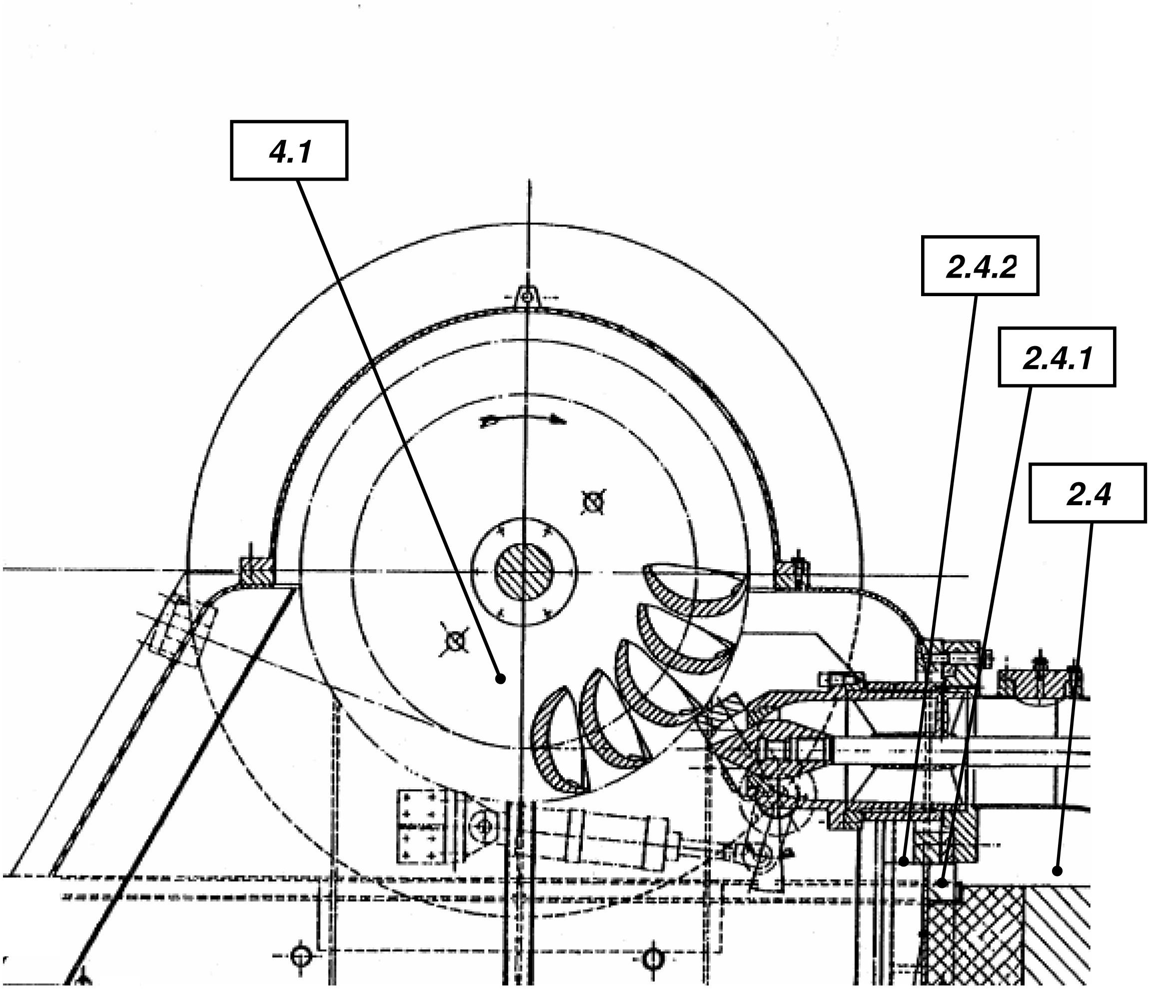


Figura A1 Sezione di una turbina Pelton ad asse orizzontale ad 1 getto

Legenda

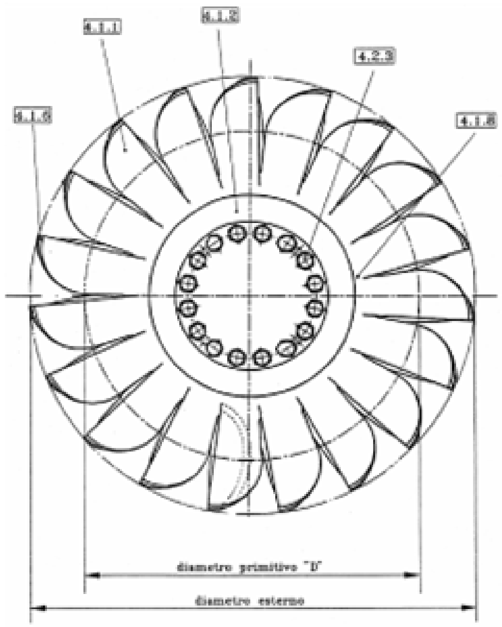
2.4 Iniettore

2.4.1 Spina dell'iniettore

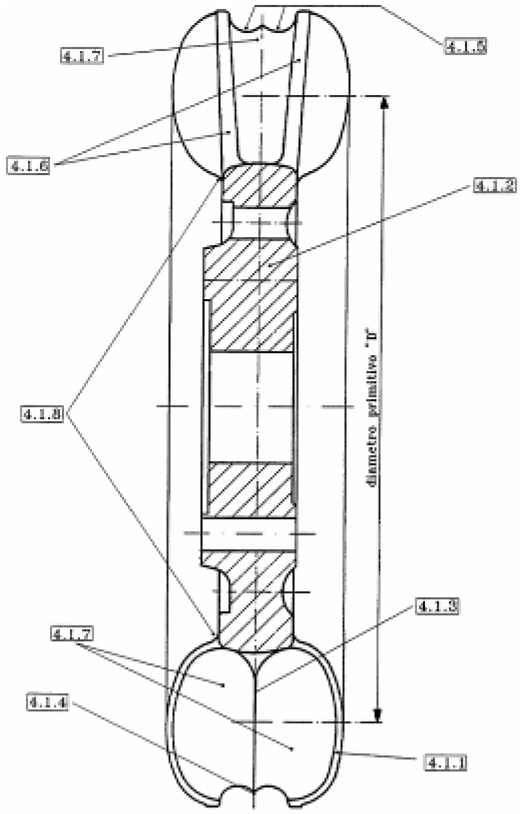
2.4.2 Bocchello dell'iniettore

4.1 Girante Pelton

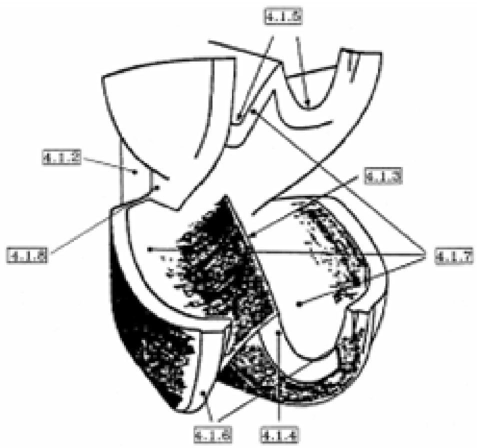
Fig. 5. – This Figure shows the parts of a Pelton turbine and their names, as defined in the standard



(1)



(2)



(3)

Figura A 2 Girante Pelton – (1)Vista frontale, (2) sezione e (3) particolare della pala

Legenda

4.1.1 Pala
4.1.2 Disco
4.1.3 Tagliente
4.1.4 Tricuspide
4.1.5 Imbocco
4.1.6 Nervature
4.1.7 Superfici attive
4.1.8 Radice della pala
4.2.3 Bulloni di accoppiamento della girante all'albero turbina

Fig. 6. – This Figure shows the parts of a Pelton runner and their names, as defined in the standard

5. Conclusions

These two draft standards, soon under examination at UNI, are intended to provide a reference point, while defining the technical aspects for the manufacture of new turbines and their maintenance.

A further aim of the Working Group is to achieve a European Standard eventually, which could be very helpful in increasing safety and quality throughout the European hydroelectric world. This international meeting seems to be a very good place to present these ideas to a wide audience.

The Authors

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Stefano Candaten graduated as a doctor of engineering from the Politecnico di Milano, Italy, in 1995. He worked as material and corrosion engineer in oil and gas gathering and processing plants for three years, and in 1999 joined Savim as maintenance engineer.

Michele Prandi, diplomed as technical engineer, works in the maintenance field since 1988. Since 1998 he is responsible of the mechanical maintenance at Savim.

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