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**Hydraulic machines – Guidelines for dealing with hydro-abrasive erosion
in kaplan, francis, and pelton turbines**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HYDRAULIC MACHINES – GUIDELINES FOR DEALING WITH HYDRO-ABRASIVE EROSION IN KAPLAN, FRANCIS, AND PELTON TURBINES

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This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) the formula for TBO in Pelton reference model has been modified;
- b) the formula for calculating sampling interval has been modified;
- c) the chapter in hydro-abrasive erosion resistant coatings has been substantially modified;
- d) the annex with test data for hydro-abrasive erosion resistant materials has been removed;
- e) a simplified hydro-abrasive erosion evaluation has been added.

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INTRODUCTION

~~Many owners of hydroelectric plants contend with the sometimes very aggressive deterioration of their machines due to particle abrasion. Such owners must find the means to communicate to potential suppliers of machines for their sites, their desire to have the particular attention of the designers at the turbine design phase, directed to the minimization of the severity and effects of particle abrasion.~~

The number of hydro power plants with hydro-abrasive erosion is increasing worldwide.

An overall approach is needed to minimize the impact of this phenomenon. Already at the start of the planning phase an evaluation should be done to quantify the hydro-abrasive erosion and the impact on the operation. For this, the influencing parameters and their impact on the hydro-abrasive erosion have to be known. The necessary information for the evaluation comprises among others the future design, the particle parameters of the water, which will pass the turbine, the reservoir sedimentation and the power plant owner's framework for the future operation like availability or maximum allowable efficiency loss, before an overhaul needs to be done.

Based on this evaluation of the hydro-abrasive erosion, an optimised solution can then be found, by analysing all measures in relation to investments, energy production and maintenance costs as decision parameters. Often a more hydro-abrasive erosion-resistant design, instead of choosing the turbine design with the highest efficiency, will lead to higher revenue. This analysis is best performed by the overall plant designer.

With regards to the machines, owners should find the means to communicate to potential suppliers for their sites, their desire to have the particular attention of the designers at the turbine design phase, directed to the minimization of the severity and effects of hydro-abrasive erosion.

Limited consensus and very little quantitative data exists on the steps which the designer could and should take to extend the useful life before major overhaul of the turbine components when they are operated under severe ~~particle abrasion~~ hydro-abrasive erosion service. This has led some owners to write into their specifications, conditions which cannot be met with known methods and materials.

HYDRAULIC MACHINES – GUIDELINES FOR DEALING WITH HYDRO-ABRASIVE EROSION IN KAPLAN, FRANCIS, AND PELTON TURBINES

1 Scope

This document gives guidelines for:

- a) presenting data on ~~particle abrasion~~ hydro-abrasive erosion rates on several combinations of water quality, operating conditions, component materials, and component properties collected from a variety of hydro sites;
- b) developing guidelines for the methods of minimizing ~~particle abrasion~~ hydro-abrasive erosion by modifications to hydraulic design for clean water. These guidelines do not include details such as hydraulic profile shapes which ~~should be~~ are determined by the hydraulic design experts for a given site;
- c) developing guidelines based on “experience data” concerning the relative resistance of materials faced with ~~particle abrasion~~ hydro-abrasive erosion problems;
- d) developing guidelines concerning the maintainability of ~~abrasion-resistant~~ materials with high resistance to hydro-abrasive erosion and hard ~~facing~~ coatings;
- e) developing guidelines on a recommended approach, which owners could and should take to ensure that specifications communicate the need for particular attention to this aspect of hydraulic design at their sites without establishing criteria which cannot be satisfied because the means are beyond the control of the manufacturers;
- f) developing guidelines concerning operation mode of the hydro turbines in water with particle materials to increase the operation life.

It is assumed in this document that the water is not chemically aggressive. Since chemical aggressiveness is dependent upon so many possible chemical compositions, and the materials of the machine, it is beyond the scope of this document to address these issues.

It is assumed in this document that cavitation is not present in the turbine. Cavitation and ~~abrasion may~~ hydro-abrasive erosion can reinforce each other so that the resulting erosion is larger than the sum of cavitation erosion plus ~~abrasion~~ hydro-abrasive erosion. The quantitative relationship of the resulting ~~abrasion~~ hydro-abrasive erosion is not known and it is beyond the scope of this document to assess it, except to ~~recommend~~ suggest that special efforts be made in the turbine design phase to minimize cavitation.

Large solids (e.g. stones, wood, ice, metal objects, etc.) traveling with the water ~~may~~ can impact turbine components and produce damage. This damage ~~may~~ can in turn increase the flow turbulence thereby accelerating wear by both cavitation and ~~abrasion~~ hydro-abrasive erosion. ~~Abrasion~~ Hydro-abrasive erosion resistant coatings can also be damaged locally by impact of large solids. It is beyond the scope of this document to address these issues.

This document focuses mainly on hydroelectric powerplant equipment. Certain portions ~~may~~ can also be applicable to other hydraulic machines.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Hydraulic machines – Guidelines for dealing with hydro-abrasive erosion
in kaplan, francis, and pelton turbines**

**Machines hydrauliques – Lignes directrices relatives
au traitement de l'érosion hydro-abrasive des turbines kaplan, francis et pelton**

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An overall approach is needed to minimize the impact of this phenomenon. Already at the start of the planning phase an evaluation should be done to quantify the hydro-abrasive erosion and the impact on the operation. For this, the influencing parameters and their impact on the hydro-abrasive erosion have to be known. The necessary information for the evaluation comprises among others the future design, the particle parameters of the water, which will pass the turbine, the reservoir sedimentation and the power plant owner's framework for the future operation like availability or maximum allowable efficiency loss, before an overhaul needs to be done.

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1 Scope

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- b) developing guidelines for the methods of minimizing hydro-abrasive erosion by modifications to hydraulic design for clean water. These guidelines do not include details such as hydraulic profile shapes which are determined by the hydraulic design experts for a given site;
- c) developing guidelines based on “experience data” concerning the relative resistance of materials faced with hydro-abrasive erosion problems;
- d) developing guidelines concerning the maintainability of materials with high resistance to hydro-abrasive erosion and hardcoatings;
- e) developing guidelines on a recommended approach, which owners could and should take to ensure that specifications communicate the need for particular attention to this aspect of hydraulic design at their sites without establishing criteria which cannot be satisfied because the means are beyond the control of the manufacturers;
- f) developing guidelines concerning operation mode of the hydro turbines in water with particle materials to increase the operation life.

It is assumed in this document that the water is not chemically aggressive. Since chemical aggressiveness is dependent upon so many possible chemical compositions, and the materials of the machine, it is beyond the scope of this document to address these issues.

It is assumed in this document that cavitation is not present in the turbine. Cavitation and hydro-abrasive erosion can reinforce each other so that the resulting erosion is larger than the sum of cavitation erosion plus hydro-abrasive erosion. The quantitative relationship of the resulting hydro-abrasive erosion is not known and it is beyond the scope of this document to assess it, except to suggest that special efforts be made in the turbine design phase to minimize cavitation.

Large solids (e.g. stones, wood, ice, metal objects, etc.) traveling with the water can impact turbine components and produce damage. This damage can in turn increase the flow turbulence thereby accelerating wear by both cavitation and hydro-abrasive erosion. Hydro-abrasive erosion resistant coatings can also be damaged locally by impact of large solids. It is beyond the scope of this document to address these issues.

This document focuses mainly on hydroelectric powerplant equipment. Certain portions can also be applicable to other hydraulic machines.

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COMMISSION ELECTROTECHNIQUE INTERNATIONALE

MACHINES HYDRAULIQUES – LIGNES DIRECTRICES RELATIVES AU TRAITEMENT DE L'EROSION HYDRO-ABRASIVE DES TURBINES KAPLAN, FRANCIS ET PELTON

AVANT-PROPOS

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La Norme internationale IEC 62364 a été établie par le comité d'études 4 de l'IEC: Turbines hydrauliques.

Cette deuxième édition annule et remplace la première édition publiée en 2013. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) la formule pour le TBO du modèle de référence des turbines Pelton a été modifiée;
- b) la formule pour le calcul de l'intervalle d'échantillonnage a été modifiée;
- c) le chapitre sur les revêtements résistant à l'érosion hydro-abrasive a été substantiellement modifié;

- d) l'annexe sur les données test pour les matériaux résistant à l'érosion hydro-abrasive a été supprimée;
- e) une évaluation simplifiée de l'érosion hydro-abrasive a été ajoutée.

Le texte de cette Norme Internationale est issu des documents suivants:

FDIS	Rapport de vote
4/351/FDIS	4/366/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

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INTRODUCTION

Le nombre de centrales hydroélectriques concernées par l'érosion hydro-abrasive est en augmentation dans le monde entier.

Une approche globale est nécessaire afin de minimiser l'impact lié à ce phénomène. Dès la phase d'avant-projet, il convient qu'une évaluation soit menée afin de quantifier l'érosion hydro-abrasive et son impact sur l'exploitation de la centrale. Pour ceci, les paramètres influents et leurs impacts sur l'érosion hydro-abrasive doivent être connus. Les informations nécessaires pour l'évaluation comprennent entre autres la conception future, les paramètres liés aux particules présentes dans l'eau et qui passeront dans la turbine, la sédimentation du réservoir et le cadre d'application du propriétaire de la centrale concernant l'exploitation future comme la disponibilité ou la perte de rendement maximale admissible avant la réalisation d'une révision.

Basée sur cette évaluation de l'érosion hydro-abrasive, une solution optimisée peut être trouvée, en considérant toutes les mesures liées à l'investissement, à la production d'énergie et aux coûts de maintenance comme paramètres de décision. Bien souvent, une conception adaptée pour résister à l'érosion hydro-abrasive sera plus rentable qu'une conception visant à atteindre un rendement maximal de la turbine. Cette analyse est plus efficace lorsqu'elle est réalisée par le concepteur de la centrale.

Il revient aux propriétaires de machines de communiquer auprès des fournisseurs potentiels des machines destinées à leurs sites, sur le fait que les concepteurs doivent porter une attention toute particulière, lors de la phase de conception de la turbine, à la minimisation de la gravité et des effets de l'érosion hydro-abrasive.

Les étapes que le concepteur pourrait suivre, et dont il convient qu'il les suive effectivement, de manière à prolonger la durée de vie utile avant toute révision importante des composantes d'une turbine fonctionnant dans des conditions sévères d'érosion hydro-abrasive, font l'objet d'un consensus restreint et très peu de données quantitatives existent. Cette situation a conduit certains propriétaires à intégrer dans leurs spécifications des conditions qui ne peuvent être satisfaites en s'appuyant sur des méthodes et des matériaux connus.

MACHINES HYDRAULIQUES – LIGNES DIRECTRICES RELATIVES AU TRAITEMENT DE L'ÉROSION HYDRO-ABRASIVE DES TURBINES KAPLAN, FRANCIS ET PELTON

1 Domaine d'application

Ce document donne des lignes directrices pour:

- a) présenter les données disponibles concernant les taux d'érosion hydro-abrasive avec diverses combinaisons de qualité de l'eau, conditions d'exploitation, matériaux et propriétés des composants; ces données ayant été obtenues sur différents sites hydroélectriques;
- b) développer des lignes directrices permettant de réduire au minimum l'érosion hydro-abrasive en apportant des modifications à la conception hydraulique normalement utilisée en l'absence de particules. Ces lignes directrices n'abordent pas les détails tels que les profils hydrauliques que les spécialistes en conception hydraulique déterminent pour un site donné;
- c) développer des lignes directrices établies sur le «retour d'expérience» concernant la résistance relative de matériaux confrontés aux problèmes d'érosion hydro-abrasive;
- d) développer des lignes directrices concernant la maintenabilité des matériaux résistants à l'érosion hydro-abrasive et des revêtements de surface durs;
- e) développer des lignes directrices relatives à la recommandation d'une méthode, que les propriétaires pourraient appliquer, et dont il convient qu'ils l'appliquent effectivement, afin de s'assurer que les spécifications montrent la nécessité d'accorder une attention toute particulière à la conception des formes hydrauliques propres à leur site sans imposer des critères qui ne peuvent être satisfaits dans la mesure où les moyens à mettre en œuvre ne sont pas maîtrisables par les constructeurs;
- f) développer des lignes directrices concernant le mode de fonctionnement des turbines hydroélectriques en présence de particules afin d'accroître la durée de vie.

Ce document fait l'hypothèse d'une eau chimiquement non agressive; étant donné que cette agressivité dépend des diverses compositions chimiques possibles, ainsi que des matériaux constitutifs de la machine, le domaine d'application de ce document ne traite pas de cette question.

Ce document fait également l'hypothèse de l'absence de cavitation au niveau de la turbine. En effet la cavitation et l'érosion hydro-abrasive peuvent se renforcer mutuellement de sorte que l'érosion résultante est plus importante que la somme des deux. Comme aucune formulation quantitative de cette érosion résultante n'est connue, ce document n'a pas pour objet de l'évaluer, sauf pour suggérer, lors de la phase de conception de la turbine, des efforts particuliers visant à minimiser la cavitation.

Des objets solides de grandes dimensions (comme des pierres, du bois, de la glace, des objets métalliques, etc.) véhiculés par l'eau peuvent percuter les composants de la turbine et les endommager. Ces dommages peuvent pour leur part accroître la turbulence de l'écoulement et accélérer l'usure par cavitation et par érosion hydro-abrasive. Les revêtements durs résistants à l'érosion hydro-abrasive peuvent également être endommagés localement suite à l'impact de ces particules de grandes dimensions. Ce document ne traite pas de ces questions.

Ce document se concentre principalement sur les équipements des centrales hydroélectriques. Certaines parties de ce document peuvent également s'appliquer à d'autres machines hydrauliques.