MULTIPLE SLUICES WITH SMALL GATES INSTEAD OF SURFACE TYPE
SPILLWAYS CONTROLLED BY ENORMOUS TAINTER TYPE GATES (*)

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1 – INTRODUCTION:

The work presented hereinafter refers to structures for dams reservoir discharge, designed for heavy floods. The improvement consists in adopting multiple sluices structures, controlled by small gates, in lieu of surface type spillways, controlled by large Tainter or segment gates.

2 – ANTECEDENTS:

Several structures, for heavy flood discharge of dams reservoirs, have been provided with very large radial Tainter type gates, “Fig.1” with dimensions reaching 17.00 meters to 20.00 meters width and 20.00 meters to 22.00 meters height. The water that passes under these gates reaches a flow of 3.000 to 4.000 cubic meters per second. Prior to the implementation of a dam, during the rainy season when the flood takes place, the water level raises naturally, spreading towards the river banks, occupying a wider section of the river, absorbing the stream flow. The insertion of a surface type spillway, controlled by very large gates in the river flow, result in directing the large flood to a confined narrow structure, which is the spillway, strangling the stream flow. This is in conflict with the natural flow. The surface type spillway requires thick and heavy reinforced concrete sill and slab foundation, as well as buttresses, walls and still basin. The still basin requires a deep rock excavation, besides a thick reinforced concrete slab, with steel rod anchors on sound rock.

(*) Devesoirs de multiples dechargements de fond composes par multiples petites vannes au lieu de devesoirs de surface avec très grosses vannes Tainter
3 – THE AIM:

Low cost of electric energy is an extremely valuable commodity. The purpose of the innovation is to reduce the costs in the implementation of hydroelectric projects, specifically in the construction of structures required for the discharge of large volumes of rain water floods and reduce, as much as possible, the cost of electric energy production.

4 – THE INNOVATION:

The innovation consists in adopting as main floods discharger “Fig.2” multiple sluices type structure [1] and [2], with small gates, in lieu, or instead of surface type spillways controlled by very large (radial) segment or Tainter type gates, for the discharge of heavy floods. The bottom outlets can also serve as river diversion during construction. This manner, the large volumes of flow water are prorated into multiple smaller channels, along the river width, offering a still and calm horizontal streamflow, instead of the high waves produced by the (radial) Tainter type gates, which require a large and deep still basin structure, downstream of the spillway. When implemented in the river bedrock, the sluice type discharge structure, discard the need for “approach channels”, “still basins” and “restitution channels”, huge excavations mandatory needed for surface type spillways. The water discharge bottom gates can be of the following types: Tainter, (with compressed or tractioned arms), “Fig. 3”, wagon type “Fig. 4”, sector type “Fig. 5”, wheel type and any other feasible type.

5 – CHARACTERISTICS OF THE HYDRAULIC GATES:

5.1 – Tainter or segment type gates

The Tainter type hydraulic gate “Fig.3” is an ingenious extraordinary invention [3]. It allows regulating the water discharge since a minimum flow, when slightly opened, up to a maximum, when entirely opened. The negative points are the reaction forces on the reinforced concrete structures. This applies to both types, either compressed arms, or arms in tension. In the Tainter gate the resulting forces due to the horizontal hydrostatic loads are concentrated in the arms of the gate. The trunion, which receives the loads reaction, is located downstream, in a very high horizontal distance above the still basin concrete slab, thus creating high overturning of the concrete structure and bending moments, resulting horizontal traction forces on the reinforced concrete walls or
pills. These loads cause tension stresses on the concrete. But the concrete is an excellent material to resist compression, not tension. As a result, the Tainter type gate requires very heavy volumes of concrete walls and slabs, to resist against horizontal displacement and overturning of the structure, as well as uplift. Besides this, as more concrete for slabs and walls, more rock excavation is required. Therefore the stability and the cost of the spillway concrete structure are penalized by the Tainter type gates.

5.2 – Wagon gates

The hydrostatic load reaction of a small wagon gate “Fig. 4”, located upstream, at the bottom inlet of the sluice, is against the pillars, in a low position, close to the sill [4]. Therefore, the horizontal load does not penalize the stability of the structure, when compared to the surface type spillways, controlled by the large Tainter type gates. The release of small volumes of incoming flood, thru the wagon gates, is reached when, only one, or a few of the multiple small gates are completely opened.

5.3 – Sector type gates

In the sector type gates “Fig. 5” the reaction due to the hydrostatic forces are transferred directly to the bedrock thru the hinge, fixed in the reinforced concrete slab foundation. The face of the sector gate does not present overturning forces acting against the concrete structure. The pillars or concrete walls in which the upper portion of the structure is supported, are of smaller thickness compared to the pillars or walls in Tainter type gates.

5.4 – Wheel type gates

In the wheel type gates, the load reaction of the hydrostatic forces are similar to the wagon type gates.

5.5 - Remarks

A sluice type structure under a structural steel dam is shown on “Fig. 6”. A sluice type structure at the middle height of a dam, laying on deep bedrock foundation, is shown on “Fig. 7”. A plan and cross section of the sluices channels for Tainter, wagon, and sector gates are shown on “Fig. 8”. A cross section arrangement for sluices for medium height dams, in which the sluices intake are located at the mide height, are shown on “Fig. 9 and 10”. A cross section arrangement for low head dams, with sluices located under a monolytic water intake and powerhouse structure of the hydroelectric project, is shown on “Fig. 11”. A birds view of low level outlets discharging at the THREE GORGES DAM [5], is shown on “Fig. 12”.

The optimization of the hydroelectric plant is probably reached when the arrangement in which the dam, the sluices, the river deviation, the water intake,
and the powerhouse, are combined all in one structure, on the river bed.

6 - LOCALIZATION OF THE SLUICES

The position of the multiple sluices can be as follows:

   a) Preferably at the streamflow, as a dam, with the sill at the river bedrock level; b) At the streamflow occupying, as much as possible, the river width, combined with the low head powerhouse (under the powerhouse); c) At the streamflow, between every other generating units; d) At the stream flow or at riverbanks with the intake at intermediate height between the bottom and the crest of the dam. e) Low level outlets with or without flip still basin; f) Combinations between the above positions; g) Others.

7 - ADVANTAGES

   In the sluices structure with multiple small gates, compression forces are prevailing. In the surface type spillways, controlled by large Tainter gates, traction forces prevail. In the sluices the reinforced concrete is more efficiently and economically used. The length of the dam crest is smaller when the sluices are located under the powerhouse. The volume of reinforced concrete in the sluices is much smaller than in the surface type spillways. The rock excavation for sluices is also much smaller because still basin is not required.

   Besides the primarily use for the discharge of undesirable materials from the dam reservoirs, the sluices operated by multiple small gates can also serve as river deviation during construction phase of the project, as well as, preventive lowering the reservoir, anticipating exceptional floods.

   The savings can reach up to 40% of the civil construction costs.

8 - RECOMMENDATIONS

   It is suggested, for flood discharge from reservoirs on new dams to be built, that the hydroelectric power and dam regulatory authorities request from hydroelectric power concessionaires, from accredited engineering design consultant companies that, in the feasibility studies, in the basic design studies, in the construction detailment and from competent construction contractors, to present alternative design drawings and cost estimates comparison, contemplating the alternative sluice type structure with multiple small gates, preferably located at the natural streamflow.

(*) Deveois de multiples dechargements de fond composes par multiples petites vannes au lieu de deveois de surface avec très grosses vannes Tainter
9 - BENEFITS

The benefits in the sluices type structure with small gates are as follows:

a) The flood discharge is prorated along the river width into a milder flow, meanwhile in the surface type spillway controlled by large Tainter gates, the discharge is strangled in a narrow stream. b) Smaller volumes of earth and rock excavation. c) Less environmental impact. d) Smaller volumes of reinforced concrete. e) It allows to combine, in many cases, all in one structure, at the streamflow, the dam, the sluices, the river divergion, the wather intake and the powerhouse. f) Significant savings in the investiment which can reach up to 40,00% of the total civil construction cost. g) Lower cost of the megawatt-hour produced, which may reach up to 20,00%.

10 - CONCLUSION

In adopting the multiple sluices type structure with small gates, significant savings, up to 40,00% of the civil construction cost of the project, may be reached. This may result up to 20,00% reduction in the cost of the megawatt-hour produced.

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REFERENCES


(*) Devesoirs de multiples dechargements de fond composes par multiples petites vannes au lieu de devesoirs de surface avec très grosses vannes Tainter

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SUMMARY

The present work suggests, for floods discharges from dams reservoirs, that instead of surface type spillways controlled by enormous hydraulic segment or Tainter type gates, rather to adopt multiple sluices with small gates, placed preferably in the stream flow. The goal is to reduce implementation costs of hydroelectric projects and, consequently, the cost of electrical energy produced. The savings are due to significant reduction on earth and rock excavation, required for the approach channel, restitution channel, still basin foundations, as well as, for the reduction on reinforced concrete volumes. It is suggested multiple small wagon, sector or wheel types, and also segment or Tainter type gates, as long as small, with compressed or tractioned arms. The wagon and wheel type gates create compression efforts on the pillars or walls, without penalizing the stability of the structure in relation to safety against overturning. The critical flood discharge is prorated into multiple small discharges when in the stream flow. It is also suggested that for low head dams, the sluice should be placed under a monolithic hydraulic generation circuit (water intake and powerhouse), when the turbines are of horizontal axle, as for example, bulb turbines. Thus, the sluices type spillway becomes the main spillway for the discharge of maximum maximorum floods, without jeopardizing the original function of de sluice, which is siltation control of the reservoir, being also capable to be used for river deviation during construction phase. The layout arrangement of multiple sluices under a monolithic water intake and powerhouse low head structure, working as a dam in the river flow, combined all in one structure, allows a reduction in the civil construction costs, that can reach 40.00%. This reduction in costs reflects on a reduction in the cost generation of the mega-watt/hour. It brings benefits to the whole productive chain that consumes energy. This is what happened in two mega Hydroelectric Developments, Santo Antonio 3.160 MW and Jirau 3.300 MW [6], that went recently auctioned for implementation on the Madeira river, a tributary of the Amazonas river. It is suggested to electric energy regulatory authorities, concessionaires, consulting engineering firms and construction contractors, to perform feasibility studies, basic design and detail engineering comparative alternatives, using multiple sluices with small wagon, or sector, or wheel type gates, including small segment type gates, as long as compressed or tractioned arms, at the riverbed, instead of surface type spillways controlled by enormous segment or Tainter gates. Certainly, this choice will offer considerable savings which will reflect in an important reduction of the mega-watt/hour generated cost, which may reach up to 20.00%.

(*) Devoisir de multiples dechargements de fond composes par multiples petites vannes au lieu de devoisir de surface avec tres grosses vannes Tainter
RÉSUMÉ

Au lieu de déversoirs de surface, controlés par de très grosses vannes hydrauliques du type segment ou Tainter, pour faire l’évacuation de crues, ce travail suggère la construction de multiples déversoirs type de fond, munis de petites vannes, placées de préférence dans la descente du fleuve. Le but est de réduire le coût de l’implantation des entreprises hydroélectriques et, par conséquence, diminuer le coût de la production d’énergie électrique. L’économie est à cause de la réduction considérable des creusements de terre et de rocher, essentiels pour les canaux d’approvisionnement, canaux de restitution, bassin de dissipation, ainsi que pour les fondations des structures en béton armé. On suggère de multiples petites vannes de type chariot, ou secteur, ou tortue, et même des vannes Tainter à la condition que leurs dimensions soient petites, à bras de traction ou à bras de compression. Les vannes chariot et tortue imposent des efforts de compression dans les piliers ou murs du déversoir de fond, sans poser de problèmes à la stabilité de l’structure par rapport à la sécurité de tombage. Le déchargement des crues est dilué en multiples petites décharges situées dans les descentes des fleuves. On suggère, aussi, que pour les barrages de basse chute, avec de grands volumes de crues, les déversoirs de fond soit située sous le circuit hydraulique de génération (prise d’eau et usine) monolitique, quand les turbines ont l’axe horizontal, comme, par exemple, les turbines bulbes. De cette façon, le déversoir de fond deviendra l’évacuateur principal de crues maximum maximorum, sans détérioration de la fonction originale de nettoyage à la anticipation des crues et de l’éjection de détritus et matériaux non désirés, ce qui aussi peut servir à la manipulation et à la déviation du fleuve, pendant la phase de construction de la barrage. La combinaison de déversoirs de fond sous le corps de la prise d’eau et centrale de basse chute, en ayant le rôle de barrage dans la descente du fleuve, permet une réduction de coûts qui peuvent arriver à 40,00% des œuvres civiles de l’entreprise hydroélectrique. Cette réduction du coût de l’implantation de l’entreprise a des réflets aussi dans la diminution considérable du coût dans la génération du megawatt/heure, ce qui bénéficie toute la chaîne productive de consommation d’énergie électrique. Ceci s’est passé dans deux mega-projets récemment vendus dans une vente aux enchères pour l’implantation dans le fleuve Madeira, tributaire du fleuve Amazonas – [6] Centrale SANTO ANTÔNIO 3.160 MW et Centrale JIRAU 3.300 MW. On suggère que les autorités de régulation de l’électricité, les entreprises concessionnaires de génération, les entreprises d’ingénierie ainsi que les constructeurs d’usines hydroélectriques, commencent à étudier et à adopter des projets alternatifs en utilisant des multiples déversoirs de fond dotés de petites vannes de type chariot, ou tortue, ou secteur, ou même Tainter, à la condition qu’il y ait de petites dimensions, à bras comprimée ou de traction, situées de préférence dans la descente des fleuves, au lieu de déversoirs surface munis de grosses vannes type Tainter. Il est sûr que cette option produira une économie importante qui aura des réflets à travers une réduction considérable du coût du megawatt/heure géré, ce qui peut atteindre 20.00%. 

(*) Devesoirs de multiples dechargements de fond composes par multiples petites vannes au lieu de devesoirs de surface avec très grosses vannes Tainter
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(*) Devesoirs de multiples dechargements de fond composés par multiples petites vannes au lieu de devesoirs de surface avec très grosses vannes Tainter
Surface type spillway controlled by Tainter or segment type gates - Cross section
Evacuateur de surface contrôlés par des vannes segments ou de type Tainter – Section transversale

Concrete dam combined with bottom sluices – General Arrangement - Plant
Barrage de béton combine avec des vidange de fond – Arrangement Général - Plan

(*) Devesois de multiples décharges de fond composées par multiples petites vannes au lieu de devesois de surface avec très grosses vannes Tainter
Devesoirs de multiples déchargements de fond composés par multiples petites vannes au lieu
de devesoirs de surface avec très grosses vannes Tainter

Fig. 3
Bottom sluices with Tainter type gates – Typical cross section
Vidange de fond avec des vannes de type Tainter – Section transversale typique

Fig. 4
Bottom sluices with wagon type gates – Typical cross section
Vidange de fond avec des vannes chariot – Section transversale typique

(*) Devesoirs de multiples déchargements de fond composés par multiples petites vannes au lieu
de devesoirs de surface avec très grosses vannes Tainter
Fig. 5
Suices with sector type gates – Typical cross section
Vidange de fond avec des vannes de type secteur – Section transversal typique

(*) Devesois de multiples dechargements de fond composes par multiples petites vannes au lieu de devesois de surface avec très grosses vannes Tainter
Fig. 6
Structural steel dam combined with sluices and wagon gates – Cross section
Barrage d’Acier en combination avec des vidange de fond et des vannes chariot
– Section transversale

(*) Devesois de multiples dechargements de fond composes par multiples petites vannes au lieu de devesois de surface avec très grosses vannes Tainter
Sluices at the intermediate height of a dam, laying on deep bedrock - Typical section

*Vidange de fond en position intermédiaire d’hauteur de barrage à profondeur roche-mère – Section transversale typique*

(*) *Devesoirs de multiples décharsagements de fond composés par multiples petites vannes au lieu de devesoirs de surface avec très grosses vannes Tainter*
(*) Devesoirs de multiples décharges de fond composés par multiples petites vannes au lieu de devesoirs de surface avec très grosses vannes Tainter
Fig. 9
Sluices at intermediate position with flip still basin - Typical cross section
Vidange de fond en position intermédiaire d’hauteur dans barrages de taille moyenne, avec de bassin de dissipation type de saut à ski – Section transversale typique

Fig. 10
Sluices at middle height dams without flip - Typical cross section
Vidange de fond en position intermédiaire d’hauteur dans barrages de taille moyenne, sans saut à ski - Section transversale typique

(*) Devesoirs de multiples déchargements de fond composés par multiples petites vannes au lieu de devesoirs de surface avec très grosses vannes Tainter
Fig. 11
Low head dam with intake, powerhouse and multiple sluices, combined all in one monolithic structure - Typical cross section

Barrages chute avec prise d’eau, centrale et des vidanges de fond combinés dans une seule structure monolitique, au lit du fleuve - Section transversale typique
Fig. 12
Low level outlets discharging at the Three Gorges dam
Deversoirs de multiples déchargements à position intermédiaire à
Three Gorges dam

(*) Deversoirs de multiples déchargements de fond composés par multiples petites vannes au lieu
de deversoirs de surface avec très grosses vannes Tainter