Marine and Hydrokinetic Technology Readiness Advancement Initiative

Funding Opportunity Announcement Number: DE-FOA-0000293

CFDA Number: 81.087

PROJECT NARRATIVE

Tidewalker Engineering
Trescott, Maine

Title: Optimization of Gorlov Helical Turbine Production

June 2010

Table of Contents:

SUBJECT	PAGE NUMBER
Introduction: Project Narrative	2
Project Objectives	3
Merit Review Criteria Discussion	7
Project Timetable	13
Relevance and Outcomes / Impacts	14
Role of Participants	14
Facilities and Other Resources	15
Equipment	15
Bibliography and References	16
Appendix- A / Letter of Commitment	17
Appendix – B / Velocity Measurements	18
Appendix – C / GHT Applications	19
Appendix – D / Cost Sharing Grant	32

<u>Project Narrative:</u>

Under this proposal Tidewalker Engineering with the assistance of Dr. Alexander Gorlov and other specialists will investigate the feasibility of placing a hydro-kinetic device into a flexible dam system to generate electricity from tidal flows at sites with a substantial tidal range (average value of 18'). The study will also include the design of a turbo-generator unit which optimizes electrical production from this proposed mode of operation. Environmental issues associated with the placement of a flexible dam into a tidal flow will be analyzed in terms of regulatory licensing requirements. The applicability of this proposed mode of operation will be addressed as part of expected project benefits from the development potential of this concept.

The eligibility standard as expressed in published responses within the Federal Connect network for this grant application directly addressed the issue of diversionary structures as excerpted below:

> **DOE will not consider any application under this FOA for the development of a technology that would require blocking or severely altering existing tidal or river flows, as this would be considered a dam or diversionary structure. Technologies designed to be deployed in the flow behind an existing dam or diversionary structure, however, would be eligible. Proposals that include structures to accelerate water flow near or through the turbine may be considered, assuming they meet the above criteria, but any technology's potential environmental impacts will be considered as part of the review process.**

Based on this response, Tidewalker has decided to submit a proposal under the assumption that a flexible / inflatable / collapsible dam <u>will not severely alter existing tidal flow</u>. This statement is based on the fact that the proposed mode of operation will not decrease the volume of tidal flow from a suitable basin during a tidal cycle since it will only shift the curve temporally and slightly modify the shape of the tidal function near the occurrence of high tide and low tide. As explained in the proposal, the installation of sufficient gate capacity to empty / fill the tidal basin combined with a mode of operation based on the maintenance of natural tidal discharge characteristics will not "block" tidal flow and will allow for sufficient mitigative measures to meet environmental standards. The flexible dam is not a typical permanent civil structure since it will be designed to be lowered and raised depending on existing regulatory and stakeholder circumstances.

Guidance provided by DOE within the question / answer feature of FedConnect included the reference below to eligibility requirements:

> **The Energy Independence and Security Act (EISA) of 2007 authorized the U.S. Department of Energy (DOE) to establish a robust program of research, development, demonstration and commercial application activities to expand marine and hydrokinetic renewable energy production. EISA defines "marine and hydrokinetic renewable energy" as electrical energy from—**
>
> **(1) waves, tides, and currents in oceans, estuaries, and tidal areas;**
> **(2) free flowing water in rivers, lakes, and streams;**
> **(3) free flowing water in man-made channels; and,**
> **(4) differentials in ocean temperature (ocean thermal energy conversion),**

From other studies, the placement of hydro-kinetic devices in tidal flows has a theoretical impact on free flowing tidal waters since, by nature, the operation extracts energy from the kinetic energy profile in compliance with conservation of energy principles. The installation of a series of hydro-kinetic devices has a cumulative effect on energy extraction from tidal flows with the potential effect of altering the tidal regime behind the array of current driven units. For our proposal, the total discharge from the tidal system comprised of a flexible dam and efficient hydro-kinetic turbines (GHT) is unaltered for the period from high tide to low tide and from low tide to high tide. The increase of water velocity through the turbine(s) and emptying / filling gate provides the potential energy to counter the energy extracted by the turbine. In summary, the requirement for "free flowing water" under EISA guidelines is met by discharging tidal waters consistent with existing conditions during a normal tide cycle and over the course of time.

In a final response to our queries, the following answer was provided as guidance for project eligibility which, in our opinion, provides justification for this application:

> **DOE will only accept proposals for the development or testing of eligible technologies as described in the FOA. Analyses from related but ineligible fields may be considered as part of an application, but only insofar as it supports the development and/or testing of an eligible technology.**

In this case, the development of a mode of operation which utilizes existing hydro-kinetic devices is consistent with the development objectives of this grant and has positive implications for the use of this approach at other sites including low-impact hydroelectric projects when considered within the matrix of technical, environmental, and economic parameters.

With this as a foreword, the following information is provided in accordance with guidelines for this grant application.

<u>Project Objectives</u>.

The primary objective of this proposal is to develop a concept for improving the efficiency of current driven devices at sites with appropriate tidal flow characteristics. The Gorlov Helical Turbine (GHT), a highly documented and efficient unit, will be used to quantify the benefits associated with enhancing velocity profiles by the installation of a flexible dam and by optimizing the link between turbine specifications and generator design. With this environmentally benign assembly which will not alter the tidal range with the tidal basin, turbine efficiency is expected to approach 70% in contrast to the present efficiency rating of 35% at a traditional hydro-kinetic site.

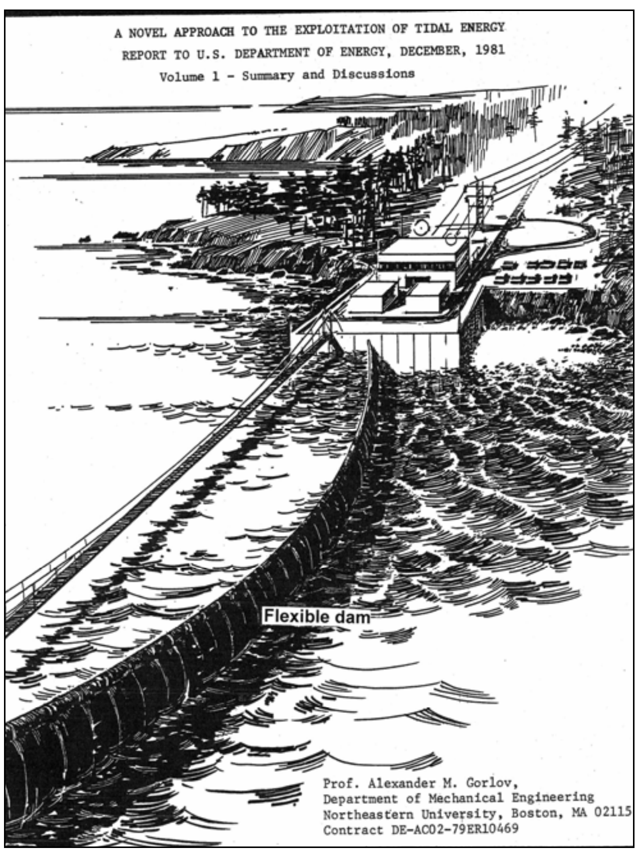
The feasibility of this approach will be investigated at two sites in Cobscook Bay (Maine) presently under consideration for tidal power development by Tidewalker Engineering. The innovative nature of this proposal also refers to the selection of a mode of operation which does not alter the tidal function within the tidal basin and, thereby, reducing environmental concerns below regulatory levels. The two sites in question (Half-Moon Cove and Carryingplace Cove) also have a phase difference of approximately one hour which enables a limited degree of continuous electrical production for regional demands as a linked basin configuration since non-production periods (e.g., at high tide) at one site will be supplemented by production at the other site due to the time delay.

The end product of the investigation will be the preparation of a final report on our findings including a discussion on the applicability of this innovative approach at other suitable sites. The intent is to increase the efficiency of MHK devices from approximately 30% to values approaching 70% by being able to control basin level (i.e., develop hydraulic head) without affecting tidal range within the control area in order to meet eligibility requirements.

In summary, the specific objectives of the proposed study are listed below for an existing technology which is hampered by low turbo-generator efficiencies, uncertainties on environmental impacts, and less than desirable production costs (¢ / kw-hr):

- Outline operational parameters for a tidal power system based on an unaltered tidal regime;
- Calculate energy production for the installation of a GHT(s) at two sites within Cobscook Bay under enhanced conditions;
- Prepare conceptual design for flexible dam with a power house structure at the entrance to a tidal basin as part of an innovative and interactive MHK system;
- Complete turbo-generator design based on a predictable and sustainable production schedule with only minor variations in hydraulic head for a substantial portion of the tidal cycle;
- Perform an environmental assessment and economic analysis based on conceptual design parameters;
- Document project benefits and identify application potential; and,
- Include opportunity for peer review of project documents / conclusions.

A conceptual view of the proposed system appears below from a 1981 DOE study conducted by Dr. Gorlov:



The basic mode of operation for the tidal power facility is summarized below as it appears in a preliminary (successive) permit application filed with the Federal Energy Regulatory Commission in March 2010 and

- A constant head mode of production will be used during both high pool and low pool operation. High pool operation will be initiated approximately one hour after high tide and continue until one hour before low tide. Low pool operation will start 1.25 hour after low tide and continue until 1.25 before high tide. A schematic representation of the mode of operation appears in Figure–01 below. For the proposed Half-Moon Cove barrage, Curve B is the preferred mode of production since it results in less reduction in the natural tidal regime within the impoundment. Curve B is also the representation which most closely resembles the natural tidal function (Curve A) except for the slight shift of approximately one hour on the horizontal scale and the “flattening” of the sinusoidal curve at high tide and low tide. The key element of the process for the “environmental” case refers to the ability to completely empty the tidal basin shortly before or after low tide. Conversely, sufficient gate capacity is needed to completely fill Half-Moon Cove at the cessation of low pool production shortly before the next high tide. Curve D represents the long-time mode of production which would have the most dramatic increase in the level of low tide within the impoundment and which has been the historical mode of operation for tidal dams / barrages.

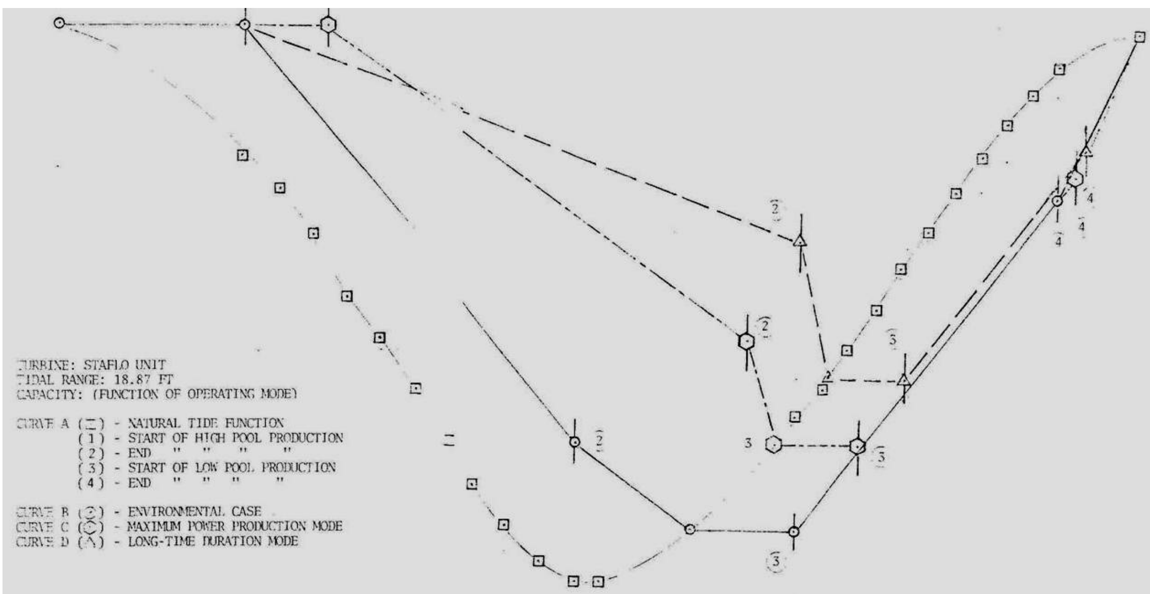


Figure-01 / Tidal Range versus Time for Three Modes of Operation

- Plan for the installation of filling / emptying gates within the causeway north of Carlow Island is a feature of the proposed Half-Moon Cove which will ensure a naturally filling and emptying tidal basin. The gates will allow the flow of tidal waters within the vertical rise of -5’ below mid-tide level to +15 above mid-tide level. The gates will be opened by raising the sealed structures to the appropriate level to allow flow under hydraulic head conditions. Two sites of interest are shown below:

Aerial View of Half-Moon Cove

Entrance to Carryingplace Cove (Trescott)

- Under these specifications, the tidal barrage a Half-Moon Cove will generate approximately forty (40) million kilowatt-hours of predictable, though intermittent, electricity annually. The installation at Carryingplace Cove is expected to have an installaed capacity of approximately one (1) megawatt as compared with ten (10) megawatts at Half-Moon Cove. With the use of emptying / filling gates on the existing causeway and based on some preliminary calculations, an eighteen foot tide will result in less than a six inch increase in the low tide level and a similar decrease in the high tide level. Since neap tide and spring tide conditions represent a difference of approximately seven feet at both ends of the vertical tide spectrum during a periodic lunar cycle, the ecosystem within a tidal basin is forced to adapt to drastic changes in water volume in order to survive. For this proposed mode of operation and based on our assessment, the extremely minor changes to the tidal function fall within the sustainability limits for the environmental parameters for both Half-Moon Cove and Carryingplace Cove.

- Our preferred mode of production for Half-Moon Cove includes provisions to install filling / emptying gates in the causeway between the Passamaquoddy Pleasant Point Reservation and Carlowe Island. The gates will span the water column from mid-tide to highest high tide in order to minimize the amount of dredging required for the project and to reduce permitting / licensing requirements. This arrangement will allow the proposed Half-Moon Cove project to fill starting shortly after mid-tide on the Passamaquoddy Bay side of the structure. Through the installation of filling / emptying gates, Tidewalker will be able to fill Half-Moon Cove to naturally occurring high tide levels and introduce cooler tidal waters during the summer and warmer tidal waters during the winter to counter any changes induced in the water temperature regime of the proposed impoundment.
- In summary, preliminary hydrodynamic calculations have been performed for the preparation of a successive preliminary permit application filed with FERC to document the ability to place a flexible dam at the entrance to Half-Moon Cove in order to control water levels and to generate electricity under nearly constant head conditions which will vary from 4'-6' without altering the tidal range within the basin. Since kinetic energy is proportional to velocity squared, the creation of potential (hydrostatic) energy with the use of a flexible dam will substantially increase energy production under conditions which will also increase the efficiency of the GHT from approximately 35% to nearly 70%. As an example, a five knot current is equivalent to approximately equal to a one foot head and, conversely, a four foot head is equivalent to a ten knot current. Under our proposed mode of operation, a tidal power facility with Gorlov Helical Turbines will also be able to better mitigate differences between neap and spring tide production conditions by being able to control hydraulic head with the use of filling / emptying gates along with the installation of a flexible dam. Since tidal power is prediction and since the flexible dam will allow operation under constant head conditions, the proposed investigation will also include a consideration of generator design to optimize production from the Gorlov Helical Turbine.

The same approach used for Half-Moon Cove will also be applied to Carryingplace Cove. In both cases the average tidal range is approximately 18' and the sites are about thirty miles apart which creates a phase difference of around one hour in the occurrence of high / low tide. This temporal difference will be investigated to determine the benefit of a linked basin configuration of two independently operated facilities to generate continuous power for the region. In terms of an independent, de-centralized system, the establishment of a linked basin system would result in some limited base-load and high predictable capacity for the surrounding region.

<u>Merit Review Criteria Discussion</u>.

The merit review criterion and sub-criterion listed and appearing in the Funding Opportunity Announcement (FOA) are addressed below in accordance with DOE guidance. Specific requirements appear in ***bold italic*** along with Tidewalker comments imbedded in the text.

1. ***Merit Review Criteria***

The following criteria will be used to evaluate Applications within Topic Area 1: <u>MHK Technologies Concept Development (TRLs 1-3)</u>

Criterion 1: Strength of the Scientific / Technical Approach Weight: [40%]

- ***Degree to which application is based on sound principles and defensible assumptions, including how well the application demonstrates a clear understanding of the current state of the science.***

Dr. Gorlov and Dr. Laberge have considerable experience and expertise in tidal power development. Both inidividuals possess PhDs in appropriate fields and are licensed as professional engineers. Dr. Gorlov is the inventor of the Gorlov Helical Turbine and the publisher of numerous articles on tidal power. Dr. Laberge has worked on the development of the Half-Moon Cove tidal power barrage since 2006 while concentrating on regulatory / environmental issues and modifying plans to address institutional limitations.

This combined knowledge in hydro-kinetic technology, engineering, science, and environmental issues has been used to make this innovative proposal which addresses factors which have limited the application of ocean energy devices due to economic, regulatory, and environmental concerns. Dr. Gorlov and Dr. Laberge have a clear understanding of the current state of the science based on their continuing involvement in ocean energy development from the application of sound engineering and scientific principles as outlined in this proposal.

- ***Degree to which proposed plan is clearly stated, organized, achievable and technically feasible, including the adequacy and completeness of proposed tasks and the resources identified to successfully address all elements of the technical plan.***

Dr. Gorlov and Dr. Laberge have considerable experience in research as outlined in the enclosed resumes. This experience includes contacts with support institutions and organizations along with a working knowledge of regulatory standards and the development of concepts. The proposal has been prepared to logically and systematically address technical issues which will incorporate the Gorlov Helical Turbine within a hydro-kinetic systems compatible with environmental standards and with the potential for economic feasibility. As outlined in the project timetable, Dr. Gorlov and Dr. Laberge have devised a plan which meets realistic expectations to refine project specifications. Both individuals are prepared to initiate the effort in October 2010 and have the vision / expertise to determine the feasibility of this innovative approach of combining low-head hydroelectric technology with hydro-kinetic energy initiatives within a framework which does not adversely impact the tidal function.

- ***Viability and completeness of project plan.***

Dr. Gorlov and Dr. Laberge have worked together in preparing this proposal. Based on our experience and expertise, we believe that this innovative concept is viable and has been presented in a comprehensive fashion. The final report will address all critical areas as summarized in this document.

- ***Credibility of approach to predict cost of energy, cost per installed kW, conversion efficiency, annual energy production, and operating and maintenance costs.***

Information derived from the proposed Half-Moon Cove Tidal Power Barrage during the past three years will be used to predict economic variables for this innovative approach. Dr. Gorlov will concentrate on determining the conversion efficiency of the GHT under prescribed operating conditions and will incorporate these factors into the design of civil components. Dr. Laberge will adapt estimates from Half-Moon Cove and other projects to determine capital and O&M costs. Based on the mode of operation described in this proposal, energy calculations will be performed for both sites in order to arrive at a predicted cost of energy. Sensitivity analysis will be used for all calculations. In refining generator specifications and the cost of a flexible dam, Dr. Gorlov and Dr. Laberge will work with vendors and other engineers / scientists active in this area of development as part of the consultation and peer review process. In 2009, the estimated cost of energy from Half-Moon Cove was approximately nine (9) ¢ / kw-hr based on conventional financing. We anticipate that the cost for the innovative GHT / flexible dam design will be considerably less than this estimate.

Criterion 2: Potential Market Impact / Advancement Weight: [20%]

- ***Identification of potential markets and applications for the proposed technology, based on a cogent assessment of the resource potential.***

The use of GHT has a number of possible applications which include other appropriately configured tidal basins and fresh water streams. The proposed mode of operation for the tidal power system expands the number of sites for potential application to areas with tidal ranges less than the Cobscook Bay area since the concept is based on maintaining a constant head and since the system will be designed to operate at neap tide levels of approximately twelve (12) feet. The correlation between generator specifications and GHT production schedule has application potential for other energy systems which include MHK and LIH. Finally, the adaptability of flexible dams has potential applications at other sites with fixed structures (e.g., bridges) and for other objectives (e.g., spill response). In summary, the refinement of project components within an innovative framework increases the application potential for a number of project types served by this type of technology.

- ***Likelihood that proposed technology will result in broadly applicable deployment – application should contain a clear explanation of intended market impact by 2020.***

In theory, construction of the Half-Moon Cove project could be completed by 2013-14 which would mark a significant accomplishment for the development of hydro-kinetic components within an adaptive environment. The linked basin approach also has important implications in being able to generate a limited amount of dependable power as a decentralized source. In this case, three different technologies (GHT under enhanced conditions, flexible dams, and turbo-generator linkage) are being addressed in this proposal under the heading that the work will be performed in an environment without a modification to the tidal range. Though difficult to predict conditions in 2010, we believe that this multi-component approach will eventually result in broad applicability in one or more areas.

- ***Potential to rapidly accelerate MHK technology deployment and achieve competitive cost of electricity (COE).***

Some of the problems experienced by conventional MHK systems at tidal sites have referred to a varying production schedule related to the cyclical dependence on neap and spring tide conditions and a critical relationship to the magnitude of current velocity. Within a discrete tidal function, the availability of a maximum velocity might exist for a relatively short period of time and this behavior complicates the process of finalizing generator specifications in coordination with turbine operation. For a conventional hydro-kinetic system, energy is directly proportional to velocity cubed which emphasizes the importance of site characteristics and which also illustrates the advantages of operating in an area with an extended period of production. The cost of electricity for a fixed site is indirectly proportional to production and is also related to availability over a prolonged period of time. For a “free-flowing” MHK installation, the O&M cost is greater than comparable requirements at the type of facility outlined in this proposal which is factor in determining the cost of electricity. Another factor influencing COE refers to the lifetime of the facility and requirements of interim replacement. For this proposed study, Tidewalker will quantify the cost of a conceptual design while providing an accurate determination of energy production. In comparison, the COE from this proposal should be less than a traditional facility due to: (1) improvements in the quantity and quality of energy production; (2) lower O&M costs; (3) longer lifetime; and, (4) establishment of well-defined environmental parameters. In combination, these factors should accelerate MHK technology by identifying options and by addressing several issues presently limiting MHK expansion.

Criterion 3: Team Member Qualifications / Available Resources Weight: [20%]

- ***Capabilities, experience, qualifications, and credentials of team members, including the applicant’s team experience and record of success in technical innovation and performance.***

Qulifications, experience, and qualifications of Dr. Gorlov and Dr. Laberge appear in a later section along with the resumes of key Tidewalker associates who will work on the project. The selection of a consultant(s) will be based on a review of qualifications and ability to work effectively with the Tidewalker team. Dr. Gorlov is the inventor of GHT which has been used and tested at numerous sites and Dr. Gorlov will be performing the work to adapt the unit into this innovative application. Dr. Laberge is familiar with site conditions and tidal power technology to assist in the evaluation and assessment of this innovative concept.

- ***Availability of required equipment, laboratory and demonstration facilities, analytic support, and other necessary resources for performing the proposed project.***

Specialized equipment will not be needed other than the requests appearing in the budget proposal. Dr. Gorlov maintains an office at Northeastern University and Tidewalker Engineering’s headquarters are within twenty-five (25) miles of the two tidal power sites of interest. Any special capability requirements for consultant(s) will be considered during the selection process.

- ***Demonstrated support of each team member's participation.***

Tidewalker Enginering and Dr. Gorlov are committed for providing the expertise and time to complete the work as outlined in this proposal.

Criterion 4: Innovation Weight: [20%]

- ***Degree to which application presents a novel approach or novel technological solution to enhance and/or advance MHK technologies and/or the deployment of MHK systems.***

Based on our collective experience and expertise, this proposal represents a novel approach since it utilizes existing components (GHT / flexible dams) within an innovative mode of operation (tidal barrage with affecting tidal volume exchange). Eligibility requirements have been addressed in this proposal with the assistance of clarifications from DOE on program interpretation. The proposal addresses all the factors involved in developing a viable MHK system.

- ***Degree to which the proposed innovation could improve upon the current state of the art, including but not limited to increased efficiency, improved reliability, or lower costs.***

In terms of applying known / refined technology, Tidewalker proposes to incorporate innovative applications at two sites with well defined production potential. The state of art as applied to MHK technology will be advanced by adding flexible dams to the mix, considering linked basin configurations, and turbo-generator optimization as part of a program to increase efficiency, to improve product quality, and to lower costs.

- ***Likelihood that the critical enabling technologies needed to achieve success can be developed.***

The expertise and availability exists to absorb these features within a tidal power system which is fully compatible with the natural environment. The Gorlov Helical Turbine has been tested under a number of conditions and technology exists for the use of flexible dams and generator interface capabilities to develop this innovative concept. Innovative concepts presented in this proposal are all based on know engineering and scientific principles. The final report will document the results of this investigation and outline any limitiations or additional research needed to achieve national policy objectives.

2. Other Selection Factors

The selection official may consider the following program policy factors in the selection process:

1. ***Technological diversity of projects (includes TRL level, resource, component vs systems, etc.)***

The proposal is directed at developing components for eventual utilization within a functioning system. The TRL level is appropriate based on our interpretation of DOE guidelines. This project might be unique in terms of the personnel, site availability, and mix of concepts.

2. Cost share offered above the minimum amount required

Tidewalker is offering 25% cost sharing above the minimum level of 20%. Tidewalker considers the 20% indirect rate as being highly competive along with the potential for providing a higher level of cost sharing. A reference to the cost-sharing, non-federal grant appears in Appendix D.

3. Significance of environmental considerations

During 2008 and 2009, Tidewalker concentrated on characterizing Half-Moon Cove under FERC requirements for project licensing. This process led to the adoption of a mode of operation which does not result in a change to the tidal range within the basin. This mode of operation has been incorporated into this proposal as a way to ensure environmental acceptance on a regulatory and stakeholder level. Comments from regulatory agencies during the FERC process has provided the characterizations needed to comprehensively address environmental concerns. The use of flexible dams successively addressing de-commissioning requirements and adds options responding to specific environmental concerns.

4. Alignment with the mission and goals of the Wind and Hydropower Technologies Program

Based on a review of DOE policies, Tidewalker thinks that this proposal is in alighnment with the mission and goals of DOE’s Wind and Hydropower Technologies Program. As previously mentioned, the results of this investigation will have value for other related programs with energy and national policy objectives.

<u>Project Timetable:</u>

The proposed schedule for completing the investigation is outlined below in terms of five (5) major tasks which will be taken over a twelve (12) month period. After the completion of the investigation, Tidewalker and Associates plan to incorporate these innovative features into on-going development efforts at Half-Moon Cove and Carryinbplace Cove. Progress reports will be filed quarterly and a final report will document the results of the proposed investigation.

Project Timetable													
Optimization of Gorlov Helical Turbine Production													
Tidewalker Engineering / Trescott, Maine													
Assumption: Start-up Date of 01.October.2010													
Major Tasks	**Sub-Tasks**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Mode of Operation	Quantify Tidal Flow	■	■										
	Establish Production Parameters		■	■									
	Model Operational Mechanism			■	■								
	Simulate Annual Schedule			■	■								
	Calculate Energy Output					■	■	■					
GHT Parameters	Review Existing Data	■	■										
	Determine Performance Profile	■	■										
	Model Operational Mechanism			■	■	■	■						
	Compare with Conventional MHK							■	■				
Turbo-Generator Specifications	Quantify Production Schedule				■	■							
	Research Technology					■							
	Commission Consultants						■						
	Coordinate Design Elements							■	■				
	Finalize Energy Calculations									■	■		
Flexible Dam	Research Literature			■	■								
	Visit Installations				■	■							
	Determine Site Conditions					■	■						
	Complete Conceptual design							■	■	■			
Administrative	Progress Reports			■			■			■			
	Prepare Draft Report									■	■		
	Peer Review										■	■	
	Prepare Final Report											■	■

Relevance and Outcomes/Impacts:

Tidewalker has reviewed the program announcement to assess the relevance of this proposal under guidance for Technology Relevance Levels. We have prepared this proposal with these goals as guidance for an innovative concept development project which will: (1) improve the efficiency of operation for a turbo-generator unit for off-the-shelf technology (e.g., GHT); (2) develop a mode of operation in compliance with environmental sustainability guidelines; and, (3) quantify cost effectiveness for a mode of operation which enhances site conditions without severely impacting natural conditions and without severely altering the natural tide cycle.

Specifically, the proposal is directed at two sites in Cobscook Bay (Maine) which experience significant tidal ranges. The immediate beneficiaries is the scientific and engineering community with the opportunity to apply this innovative concept. Peer review and dissemination of information is an important part of the proposal for applications at other sites either as a system or component approach. In the long-term, the isolated communities along Cobscook Bay will share in the benefits of a tidal project(s) from an independent source of electricity with the potential for indirect benefits (e.g., tourism) from local consumption of Half-Moon Cove / Carryingplace Cove energy.

Quoting directly from the FOA, Tidewalker's proposal is consistent with the objective as related to innovative concept development:

> ***"… to advance the technical and operational readiness of marine and hydrokinetic systems and components across a range of TRLs, with the unified goal of accelerating the development and deployment of these technologies to provide a domestic source of clean, affordable energy that is both economical and ecologically responsible."***

The linked basin concept of multiple pools is especially relevant to the objective of providing baseload (continuous / dependable) energy to a specific area without dependence on grid capability.

Roles of Participants:

Dr. Laberge will serve as principal investigator to ensure completion of all tasks as outlined in this proposal. His familiarity with the site and assessment of environmental, engineering, and economic factors will be used throughout the process in the determining project compatability. Dr. Laberge will work with Dr. Gorlov in a professional arrangement to complete tasks as outlined in the timetable. Dr. Laberge will oversee the finalization of parameters for the desired mode of operation, work with Dr. Gorlov on refining GHT variables, coordinate with consultants on finalizing turbo-generator specifications and flexible dam / barrage parameters, and assist with administrative tasks. Dr. Laberge also serves as principal investigator for the feasibility study grant awarded by Washington County (Maine) Commissioners to investigate tidal power feasibility in

Carryingplace Cove.

Dr. Gorlov will supervise selection of principal parameters of the GHT, including description of its history and present status in the world. Dr. Gorlov I will also recommend turbine size and its overall configuration (blades, shaft, hubs, bearings, etc.) for the Half Moon Cove project based on hydraulic tidal data. He will also be involved into selection of flexible barrage along with a review of hydrological data for the calculation of energy production. Dr. Gorlov's experience in the construction of dam and coordination with consultants and vendors will provide invaluable experience. Experiments used by Dr. Gorlov to test and document GHT will serve as the basis for estimating efficiency, component costs, and construction parameters.

Ms.Leslie Bowman will operate as primary project coordinator with responsibilities for community interaction and the completion of administrative tasks; e.g., report preparation. Ms. Bowman's experience in communications and program management in addition with her familiarity with the Half-Moon Cove project will assist in the completion of proposal goals.

Mr. Ernst Hunter serves as legal counsel for Tidewalker and will assist in the assessment of economic analyses and the completion of administrative tasks.

Ms. Zel Bowman-Laberge, a fifth year student of architecture at Rhode Island School of Design, will assist in the preparation of project drawings and in the collection of field data to characterize site features.

Facilities and Other Resources:

Dr. Gorlov will work in his office in Boston and in Falmouth, Massachusetts and take periodic trips to the Cobscook Bay area. Dr. Gorlov will use his own equipment and support material.

Tidewalker has offices in Trescott and Eastport (Maine) and will also use available equipment / information to perform technical studies and assessment. Tidewalker has the computer capability and access to communication systems to complete the tasks as outlined in this proposal.

Equipment:

The grant includes the purchase of a small boat / motor, GPS, and a current meter to supplement existing data. Tidewalker does not have comparable equipment to assist in the performance of proposal tasks.

Bibliography and References, if applicable:

n/a

Appendix A
Letter of Commitment

Letter of Commitment:

From: Tidewalker Engineering / Associates
Trescott, Maine 04652

46 Place Cove Rd
Trescott, ME 04652

June 06, 2010

U.S. Department of Energy
Marine & Hydro-kinetic Technology Readiness Advancement Initiative

This letter represents a commitment by Tidewalker Engineering to provide a minimum of $30,000 in matching support for the project entitled, "Optimization of Gorlov Helical Turbine for Production."

The cost-sharing which amounts to 25% of the project will be comprised of the following components:

- $18,000 of indirect funds which represents 20% of the total project cost excluding an amount budgeted for consultants
- $2,000 for domestic travel which will be absorbed by Tidewalker Engineering
- $10,000 from a grant awarded by Washington County Commissioners to Tidewalker Engineering on 03.June.2010 to study the feasibility of tidal power development in Trescott, an Unorganized Territory, at the entrance to Carryingplace Cove. This source of funding is non-federal and is derived from a Tax Initiative Financing for a project in Washington County.

Sincerely yours,

Dr Normand Laberge
President / Owner, Tidewalker Engineering

Appendix B:
Previous Performance Data

Appendix C:

HELICAL TURBINE FOR HYDROPOWER

A. M. Gorlov (Vienna, 2004)

Abstract: The objective of this paper is to introduce an environmentally friendly Helical Turbine that can extract power from free or ultra low-head water currents without dams. The turbine is a cross flow unidirectional rotation machine that makes it particularly valuable for its application in reversible tidal and other open ocean streams. It can also be used for hydropower in rivers without dams, in tail downstream from dams, for cooling water flows of other conventional plants, hydraulic canals, and tunnels. The turbine needs no deep water for its horizontal configuration and can work in shallow sites.

1 Introduction

The helical turbine, shown in Figure 1, is a reaction cross flow machine designed for extracting power from unconstrained water currents. It was developed in 1993-1995 at Northeastern University in Boston, Massachusetts under R&D contracts from the US Department of Energy and the National Science Foundation. The turbine has been tested both in laboratories at Northeastern and Michigan Universities and in the tidal currents of the Cape Cod Canal (Massachusetts), Vinalhaven Island (Maine), Uldolmok Strait (South Korea). During these and other recent field tests the triple-helix turbine demonstrated its reliability and up to 35% efficiency in the free streams, which makes it one of the best hydraulic machines for such applications.

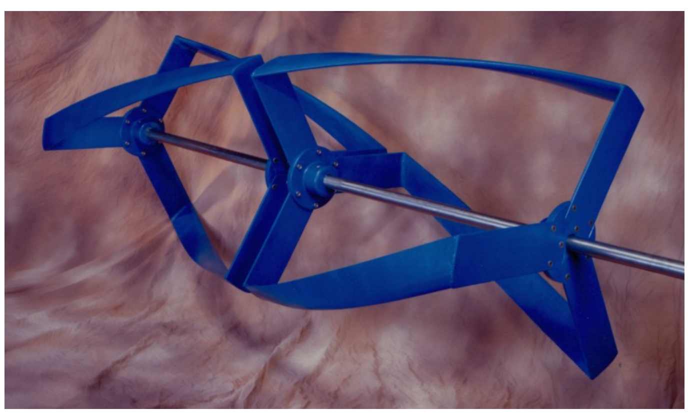


Fig. 1 Triple-helix twin turbine.
Diameter 1m, Length (Height) 2.5m. Total weight including steel shaft is about 90 kg.
Material: aluminum with plastic antifouling coating. Plastic rotors are also available.

The turbine is practically "immune" to the direction of the water flow and its axis can be set up vertically, horizontally or with any inclination in the vertical plane depending on water depth and characteristics of the specific project. This turbine is similar by its orientation to the well-known Darrieus wind turbine, patented in 20th of the last century, which has straight or curved-in plane airfoil blades. However, the Darrieus turbine has not received wide practical applications mostly because of pulsation in rotation when straight blades change angles of attack traveling along the circular path. It is also not self-starting in the flow. In contrast, the helical arrangement of blades provides self-starting and uniform rotation for our turbine that is the principal advantage of this machine compared with Darrieus type turbines.

2 Content

2.1 Turbine performance

Turbine blades have hydrofoil profiles that provide reliable torque to the rotor in the flow perpendicular to the axis of rotation (turbine shaft). The foil NACA-0020 is used for design of the turbine shown in Figure 1. Various configurations of the turbine models have been extensively tested in laboratory and field experiments starting from 1994. The following charts show well-documented test results conducted in the Hydrodynamic Laboratory of the University of Michigan in 1998.

The diameter of the unit tested is 1.0m and its length – 0.85m. Three hydrofoil blades have the same cross-section chord of 0.15m and NACA-0020 profile. Diagrams of Figure 2 demonstrate major results of the measurements.

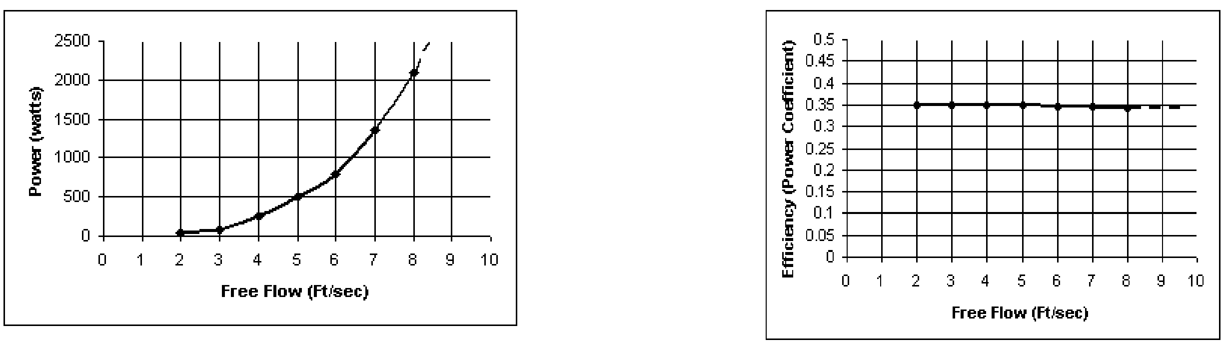


Fig. 2 Power and Turbine Efficiency versus Water Velocity

The data shown in these charts are calculated for maximum turbine power for different water velocities. As one can see, the turbine develops a stable efficiency around 35% at all water velocities tested. Starting with a firm rotation at water flow of about one knot, the turbine increases its power in proportion to the water velocity cubed.

We obtained similar characteristics in field experiments for fully immersed helical turbines in later tests. Power characteristics remain the same for both vertical and horizontal turbines.

2.2 3D Helical Turbine versus 2D Propeller in the water

Various research laboratories and institutions work on projects that use wind-type horizontal axis propellers for harnessing power from open ocean and tidal streams. It would be interesting in this context to compare the helical and propeller turbines for free flow applications. Leaving aside efficiencies of turbines, which are comparable, we point out the following engineering advantages of the helical turbine:

Unidirectional rotation. The helical turbine is the unidirectional rotation machine that provides important benefits over propeller turbines for use in reversible streams, such as tidal currents. In contrast, the propeller must operate in reversible flow either with a yaw drive mechanism or with adjustable blades, which complicates the entire system and increases its cost.

Application in shallow water. Helical turbines, in their horizontal configuration can work in very shallow water such as at sea shoals or near shore tidal sites. Indeed, the horizontal helical turbine needs water depth of only a little more than its diameter to be fully submerged. For example, the turbine of one meter in diameter, shown in Fig. 1, needs about 1.2 meter of water depth for its horizontal underwater installation. Moreover, a number of such turbines can be mounted on the same shaft across the shallow stream, using a single generator. Big propellers cannot be used in shallow waters.

Out of water generator installation (See Fig. 5 below). Indeed, the generator as well as the gearbox and electrical system associated with it can sit above the water for the vertical turbine shaft assembly. This simplifies design and maintenance of the power system. In contrast, the generator for the propeller must always be inside a sealed underwater chamber.

Better use of the sweeping area. The helical turbine extracts kinetic energy from the flow uniformly across its entire rectangular frontal area. In contrast, the circular propellers harness most of the energy by very ends of their blades, while the remaining part of blade works mostly as a supporting structure that does not generate sizable power.

Cavitations. Wind propellers become economical for using big rotors, some times up to 100 meters or more in diameter. However, what is possible for wind is not always practical for water. As the result of the high speed of the propeller ends, the structural integrity of the hydraulic rotor creates a problem associated with possibility of **cavitations** whereby instantaneous water vapor can cause blade vibration and fatigue failure. The helical turbine has no such problem since its entire helixes are at the periphery of a much smaller diameter avoiding development too high linear (tangential) speed.

Modular assembly (Fig. 5). Multiple helical turbines can be assembled in vertical or horizontal modular systems with common shaft and single generator. Addition of new turbines on the shaft increases the power of the system without the need for fundamental redesign. The propeller tower, in contrast, is usually designed as an independent power system on the sea floor with individual propellers and a complicated underwater generator. There is no practical way to combine a series of propellers in a single mechanical system with common shaft.

Additional power from spokes. The standard helical turbine (Fig. 1) has a system of spokes to joint blades with the shaft. These spokes have the same hydrofoil shape as the blades, so the turbine can extract power from both horizontal flow (by blades) and vertical flow (by spokes). Thus, the spokes work as a kind of horizontal propeller in upward streams. Note that any water barrier, including turbines, always deflects some of the stream, creating vertical flows with power that can also be captured.

Rectangular projection (Fig. 5). The important engineering advantage of the helical turbine is its rectangular frontal projection. This makes it possible to combine a number of side-by-side turbines in the single power array, reflecting a sort of “transparent” water dam. Such a “dam” will develop a hydraulic head that, in its turn, adds a bit of potential energy to kinetic energy of the free flow. This should increase the total power of the system.

2.3 Field tests and demonstration projects

Testing Helical Turbines in Tidal Currents of the Cape Cod Canal

The first field tests of plastic triple-helix turbines of about 0.6 meter in diameter were performed in the Cape Cod Canal near Boston, Massachusetts from June to August of 1996 (Fig. 3). The tidal current in the Canal changes direction four times a day reaching 2.2 m/s.

The four turbines tested had different design of blades, including their hydrofoils, angles of twist and inclination with respect to the axis of rotation. The turbines were mounted vertically under the raft. The three months testing of the turbines demonstrated good performance with up to 35% efficiency measured in about 1.7 m/s tidal current. Description of these tests and data collected can be found in the technical report "Testing of Helical Turbines in the Cape Cod Canal (MA)," report to the US DOE, Northeastern University, Boston, MA, 1996.

Fig. 3 Installation of Triple-Helix Turbine in the Cape Cod Canal

The testing continued in 1998 and 1999 with some changes in the turbine geometry. The measured characteristics include mechanical torque, turbines angular velocity, and water current. No electric generators have been used for this testing.

Helical Turbines in Uldolmok Strait (Korean Peninsula)

The Korean peninsula has a number of ocean sites where tides develop strong ocean currents. The kinetic energy of these currents can be efficiently exploited by using helical turbines. A general description of this concept, as well as various possible applications of helical turbines, has been demonstrated in the exposition ENEXPO'99 (Seoul, Korea, 1999).

The Twin Triple-helix Turbine, similar to that of Fig. 1 was installed in the Uldolmok Strait at the south end of the Korean Peninsula in 2002. This is a unique tidal site, where the reversible tidal current develops up to 12 knots (about 6 m/s) water velocity. Figure 4 shows the vertical installation of the turbine in the Strait where monitoring of the turbine performance is presently under way. The Korean Ocean Research and Development Institute (KORDI) have conducted turbine installation and all tests.

Fig. 4 Twin Triple-helix Turbine in the Uldolmok Strait (Courtesy of the KORDI Institute)

In 2004 KORDI installed the new larger steel triple-helix turbine of 2.2 meter in diameter next to the existing turbine shown in Figure 4. Testing of this turbine is presently in progress.

Figure 5 shows the artist rendition of a full-scale floating tidal power plant with vertical triple-helix turbines proposed for use in currents similar to the Uldolmok Strait. There are two options for the design of the supporting structure of the tidal power plant, namely, a floatation system or a stationary frame system. The first one, shown in Fig. 5, represents an expended system of trusses and frames containing helical turbines attached to the interconnected pontoons. The entire floating structure is moored to the ocean floor.

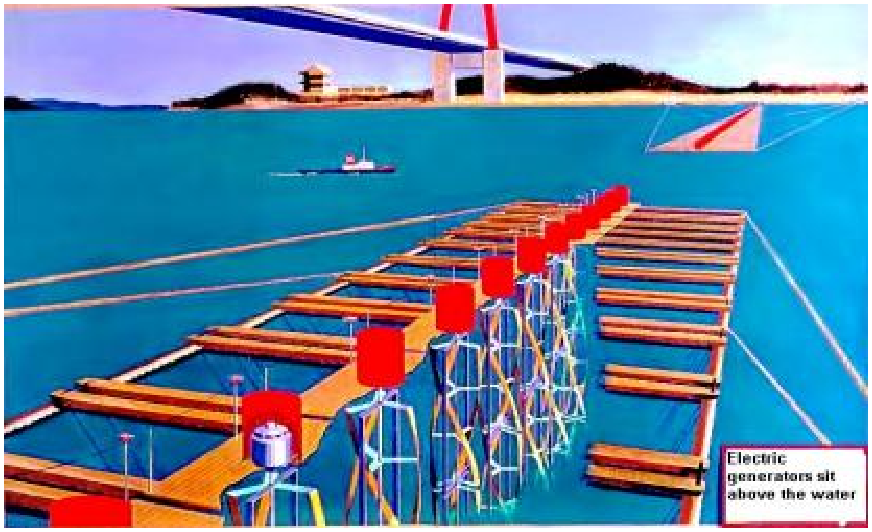


Fig. 5 Artist rendition of the floating power plant with helical turbines

Option two, which is not considered in this text, consists of a system of rigid vertical frames (cages) that sit on foundations on the ocean floor. A detailed technical and economic analysis of both options will answer the question of which approach is better for the project.

2004 Mobile power station at Long Island, NY

A strong tidal current of up to 5 knots characterizes the aquatic region at Plum Gut Sound near Long Island, New York. The New York State Energy Research And Development Authority (NYSERDA), in cooperation with the Long Island Power Authority, are sponsoring first phase of demonstration tidal power project using helical turbines in this water region.

The power system consists of two helical turbines similar to the shown in Figure 1. Turbines assembled horizontally side-by-side inside the movable frame on the barge. The frame can move on rails along the barge and tilt at a 90° over its stern, submerging turbines into the water in vertical position. The power station can sale in different points of the tidal current to conduct measurements. Figure 6 shows the platform cruising in the Long Island region and installation of the turbines into the water.

Fig. 6 Mobile power station with two twin triple-helix turbines near Long Island

Turbines use two independent generator systems. The belt transmission conveys torque from each turbine to its electric generator. The transmission consists of the pulley mounted on the turbine shaft and a small sprocket on the electric generator shaft (not seen in Fig.6). The pulley/sprocket ratio is 10/1. The flat face of the turbine aluminum pulley is covered with traction tape used to prevent slippage of the belt.

Turbines start rotating and developing power in current of about two knots (about 1.0m/s). In the 2 m/s water velocity each turbine develops rotation speed of about 95 RPM generating 3.5 – 3.7 kilowatts.

Amesbury tidal power project in Massachusetts

The following is a brief description of another new power project that uses helical turbines to harness tidal power. This project is presently under construction and scheduled to demonstrate power production by the end of 2004. The site of the installation is in the estuary of the Merrimack River near the town of Amesbury, Massachusetts, about 60 miles north of Boston. Tidal current at the site can reach velocity up to 6 knots. The water flow reverses four times a day corresponding to tidal fluctuations at the Atlantic shoreline.

Fig. 7 Amesbury project. Measurements of turbine and water flow characteristics. The 2.5m height vertical helical turbine sits about 0.5m below the water surface

The Massachusetts Technology Collaborative (MTC) sponsors this project in amount of $500,000. Two companies, Verdant Power of Virginia and GCK Technology of Texas, perform design, construction and conducting all tests and demonstration.

The power system will consist of six vertical helical turbines of the same size and configuration shown in Figure 1. Turbines attached to the flotation support (a barge) and positioned side-by-side across the river flow. Each helical turbine has its own individual generator that sits above the water. Initial measurement of the turbine performance is shown in Figure 7.

Tidal power system on Vinalhaven Island in Maine

This is the first tidal power project with three helical turbines combined in one system (Figure 8).

Tidal power system with three GHTs under motel, Maine, 5/03

Fig. 8 Helical turbines in the channel under Tidewater Motel, Maine.

The channel connects the Atlantic Ocean with the Island's inner bay.
The belt transmission synchronizes rotation of three vertical helical turbines, assembling them into the tidal energy system to provide electric power for the motel. The tidal water flow in the channel reaches velocity up to 3m/s reversing its direction four times a day. Turbines size is 0.85m (diameter) by 0.9m (height). Unfortunately the turbines are not fully submerged during the ebb cycles as is shown at the top of Figure 8. This substantially reduces their power at that cycle.

3 Conclusion

Electrification of all aspects of modern civilization has led to the development of various converters for transforming energy from natural power sources into electricity. However the power plants that use fossil and nuclear fuels create huge new environmental pollution problems along with the fact that these resources are quickly becoming depleted. Thus clean renewable energy sources for generating electric power are attracting much attention around the world. Energy from ocean and tidal currents is one of the best available renewable energy sources. In contrast to other clean sources, such as wind, solar, geothermal etc., kinetic ocean energy can be predicted for centuries ahead. However, this energy, like wind and solar, is distributed over large areas that presents difficult problems for collecting it. The helical turbine described above is an efficient, low cost and environmentally friendly apparatus for extracting power from free flowing water. This is novel technology. Laboratory and field studies of the turbine and its further optimization should be continued, focusing on better materials and systems with power transmission and generators. Nevertheless, the turbine as already developed is ready for manufacturing and practical deployment.

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Dr. A. M. Gorlov
Professor Emeritus and Director Hydro-Pneumatic Power Laboratory at Northeastern University, Boston, MA 02115

<u>Appendix D</u>
Cost Sharing Reference to Washington County Grant

Washington County approves first TIF projects

6/4/10
By Sharon Kiley Mack
BDN Staff
MACHIAS, Maine — The first three projects resulting from a landmark tax increment financing district were approved Thursday by the Washington County commissioners.

The UPC Wind Power Project on Stetson Mountain in northern Washington County became the first TIF project in Maine's Unorganized Territory last year, and income to the county from the TIF — expected at more than $450,000 annually — was funneled into a special grant fund.

• $10,000 to Dr. Normand Laberge of Tidewalker Engineering of Trescott for a feasibility study and regulatory analysis for tidal power development in Carryingplace Cove. Two jobs should be retained, and the entire project has a $45,000 budget.