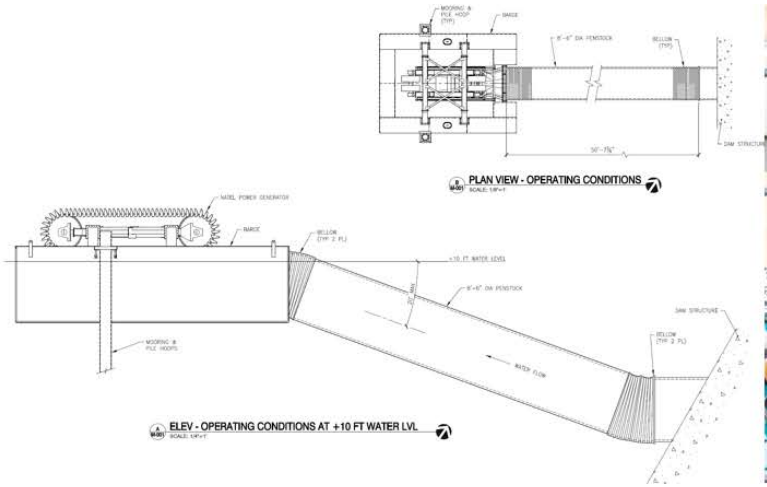


Efficient, Modular Low-head Linear Pelton Turbine with Simple, Low-Cost Civil Works

EE0008011

Hydropower Program

October 09, 2019

Abe Schneider

Natel Energy, Inc.

Project Overview

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Project Summary

- Natel Energy and its team developed a completely new hydraulic turbine, called the Linear Pelton (LP) from conceptual to functional; tested a hydraulic scale model; and designed two alternative civil works implementations (stationary and floating powerhouses). The LP fulfills FOA objectives through the use of an impulse turbine which 1) achieves large specific speed and good efficiency at low head and 2) operates above tailwater, allowing reduction of submerged civil works at non-powered dams.

Project Objective & Impact

- **Objectives**: Develop & demonstrate a Linear Pelton turbine-generator capable of water-to-wire efficiency greater than 80%, scalable to systems accommodating flow from 100 to 1000 cfs per turbine at head less than 50 feet.
- Develop civil works designs accompanying the Linear Pelton turbine enabling reductions in project cost at Non-Powered Dams.
- **Impacts**: Development and demonstration of a totally novel kind of hydraulic turbine which is highly efficient and power dense.
- Inspire & enable improvements in other areas of the hydropower industry that 1) reduce cost and 2) advance fish-friendly designs.

Project Information

Project Principal Investigator(s)

Abe Schneider

WPTO Lead

Erik Mauer
Marisol Bonnet

Project Partners/Subs

Oak Ridge National Laboratory (ORNL), Pacific Northwest Laboratory (PNNL), Small Hydro Consulting, Gracon LLC, Art Anderson Associates, Ballard Marine Construction, Gates Corporation, Rennasonic Inc, MotionPort/Recurdyn, Siemens PLM Software, Highland Composites, Oribi Manufacturing, Eclipse, Janicki, HCSS Software, Western Machine Works, Hester Fabrication

Project Duration

Start: May 01, 2017
Finish: October 31, 2019

Alignment with the Program

Hydropower Program Strategic Priorities

Environmental R&D and Hydrologic Systems Science

Big-Data Access and Analysis

- Technology R&D for Low-Impact Hydropower Growth
- R&D to Support Modernization, Upgrades and Security for Existing Hydropower Fleet
- Understand, Enable, and Improve Hydropower's Contributions to Grid Reliability, Resilience, and Integration

Alignment with the Hydro Program

Technology R&D for Low-Impact Hydropower Growth

- Enable the design and development of new Standard Modular Hydropower (SMH) technologies for both existing water infrastructure and new stream-reach development. This new approach to systems design for hydropower projects incorporates ecological and social objectives for river systems earlier in design processes.
- Leverage new advancements in manufacturing and materials to dramatically lower costs of SMH components and systems designs
- Support development of necessary testing infrastructure for new technologies

- Natel developed a totally new kind of turbine (the Linear Pelton) with potential to significantly reduce civil works cost at Non-Powered Dams by reducing below-tailwater civil works.
- The buckets in the Linear Pelton were optimized using best practices for fish friendliness.
- The turbine relies on advanced materials; carbon fiber is used in multiple places in the powertrain to reduce manufacturing cost while meeting functional requirements.
- The project developed new analytical multibody dynamic models of the entire turbine allowing better design with less time and cost.

Project Budget

Total Project Budget – Award Information		
DOE	Cost-share	Total
$1,725,000.00	$559,517.00	$2,284,517.00

FY17	FY18	FY19 (Q1 & Q2 Only)	Total Actual Costs FY17–FY19 Q1 & Q2 (October 2016 – March 2019)
Costed	Costed	Costed	Total
$280,481.01	$958,643.51	$464,721.98	$1,703,846.50

Lab	FY19 (Q1 & Q2 Only)	Total Project Budget FY17–FY19 Q1 & Q2 (October 2016 – March 2019)	
Lab	Costed	Total Costed	Total Authorized
PNNL	$22K	$22K	$50K
ORNL	$5.87K	$5.87K	$100K
TOTAL	$27.87K	$27.87K	$150K

Variances from planned budget:

Re-scoped BP2 objectives to focus on multi-body dynamic modeling efforts and subsystem testing in place of hydraulically testing a complete 1-MW scale Linear Pelton turbine.

Management and Technical Approach

- **Technical approach:** Despite being a large potential resource, levelized cost of energy (LCOE) for development of hydropower at Non-Powered Dams (NPD) is often not competitive with market rates for new wind and solar power. Natel Energy's team approached the problem of cost reduction of new hydro at NPD's by tackling civil works cost via turbine innovation. By developing a unique large-flow impulse turbine that operates above tailwater, Natel was able to envision novel approaches to civil works that could reduce capital cost relative to baseline cost models at a variety of typical NPD types.
- **Challenges to be overcome:**
  - (1) Fatigue life of powertrain; (2) Head loss in buckets & scale-dependent efficiency losses; (3) Power density; (4) Floating powerhouse limited applicability

Task	Task Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
1	Fluid Design										
Go/No-Go	CFD simulation >88% hydraulic efficiency										
2	Product Family Design										
3	Modular Civil Works Conceptualization										
4	Cost Modeling										
5	Small-Scale Prototype Testing										
Go/No-Go	Demonstrate hydraulic efficiency >80%										
6	Intermediate-scale and Large-scale Design										
7	Civil Works										
8	Intermediate-scale Prototype Test										
9	Cost-Model Integration										
10	Report Writing										

Key Partners & Subcontractors

- Oak Ridge National Laboratory (cost modeling)
- Pacific Northwest Laboratory (sensor fish testing)
- Small Hydro Consulting (civil works design)
- Gracon LLC (civil works cost estimation)
- Art Anderson Associates (floating powerhouse naval architecture)
- Ballard Marine Construction (marine construction methods, feasibility, and cost est's)
- Gates Corporation (carbon fiber reinforced timing belts)
- Rennasonic Inc (hydraulic scale model testing)
- MotionPort/Recurdyn (multibody dynamics modeling and software)
- Siemens PLM Software (multibody dynamics modeling and software)
- Highland Composites (carbon fiber overbraided LP beams)
- Oribi Manufacturing (fiber composite bucket production)
- Eclipse (carbon fiber bucket production)
- Janicki (fiber composite nozzle production)
- HCSS Software (civil works cost modeling)
- Western Machine Works (prototype assembly)
- Hester Fabrication (prototype production)

End-User Engagement and Dissemination Strategy

Who will benefit:

1. **Hydropower project developers** seeking to build profitable projects in an increasingly competitive electricity market.
2. **Equipment manufacturers** (such as Natel, but also including suppliers of all related equipment and components; piping, steel, carbon fiber components, generators, gearboxes, etc), as well as others in the supply chain such as engineering consulting firms.

Advisory groups:

1. **Mechanical and product development** to mitigate technical and business risk
2. **Civil engineering review** group with representation from two leading consulting companies known for providing expertise in the construction of hydropower plants.
3. **Independent engineering firm** to conduct a certification process for the new turbine.

Dissemination strategy:

- By **engaging with advisory groups**, Natel hoped to share the innovative approach and technology with entities capable of serving as informal conduits of information to assist in commercialization and implementation of the product and technology
- Posters, papers at **2018 & 2019 Hydrovision**, **2019 DOE Waterpower Week**
- Participation in industry RFI's, including USBR and ORNL.
- Technical papers (planned) on MBD modeling and turbine performance

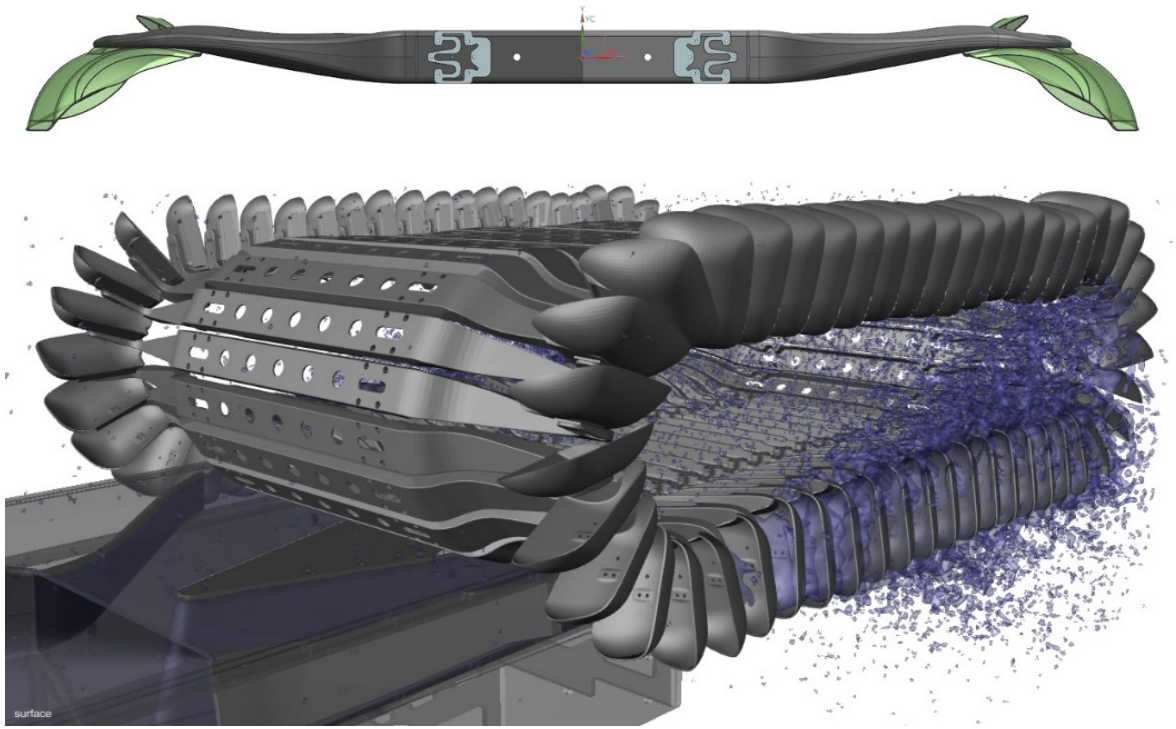
Technical Accomplishments

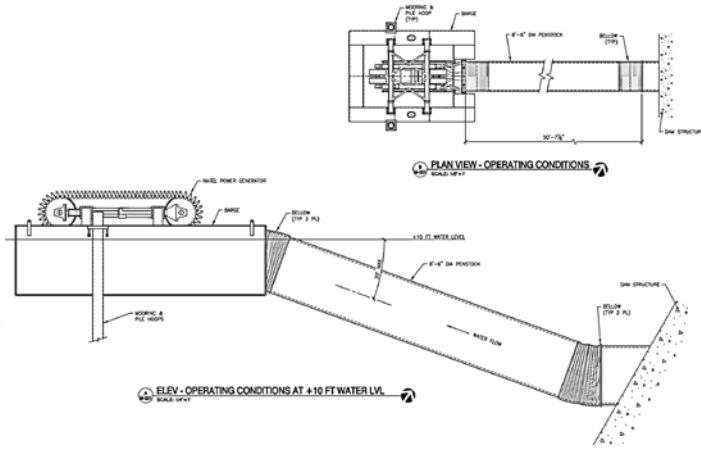
Most significant technical accomplishments:

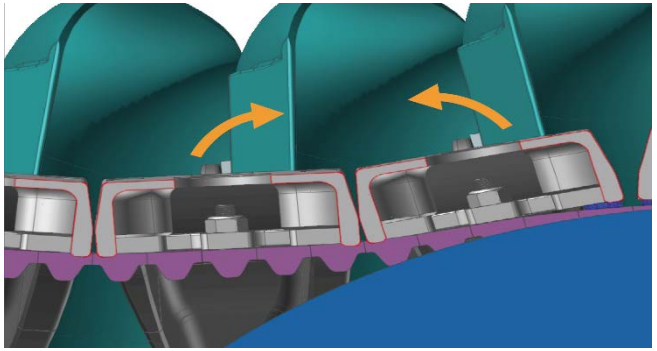
1. Developed and demonstrated **completely new linear hydraulic impulse turbine type**. Scale model performance closely matched 3D multiphase CFD as well as simple mathematical model. This turbine has been patented (US Patent 10,221,830 B2).
2. Developed **high-strength high-fatigue-life belt attachments with no moving parts**.
3. Developed **multibody dynamic model** capable of replicating, and predicting, mechanical system dynamic behavior of linear turbine or similar machinery.
4. Designed, manufactured components of a **1MW scale Linear Pelton turbine, including overbraided carbon beams**. Conducted dynamic tests with full scale LP powertrain.
5. Detailed **civil engineering designs for both stationary and floating LP powerhouses**.

Technical Accomplishments (Cont.)

Natel developed Multibody Dynamic (MBD) models of the entire powertrain, enabling deterministic design for high cycle fatigue, deflection limitation, and other design goals, reducing the number of prototypes needed to result in a reliable product.

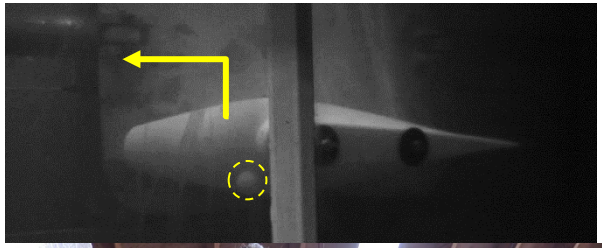


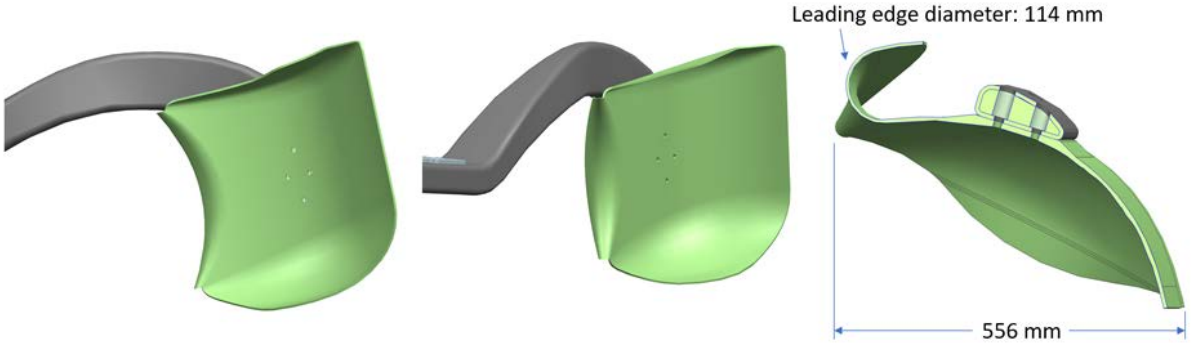


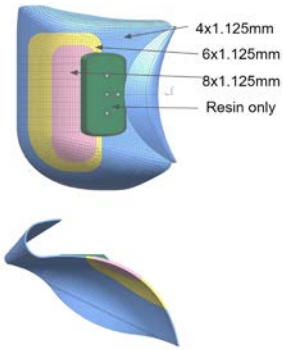


Progress Since Project Summary Submittal

- LP19 (full scale) MBD modeling kick-off
- LP19 bucket manufacturing (see images below)
- ORNL cost modeling
- PNNL sensor fish testing
- Civil work progress







Carbon fiber LP19 buckets

PNNL Sensor Fish strike testing of LP19 blade