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The Knowledge Stream
Research Update

# Detecting Cavitation to Protect and Maintain Hydraulic Turbines

*Detecting, monitoring, and preventing cavitation damage at Reclamation's powerplants*

## Bottom Line

**This research develops effective cavitation detection and monitor techniques to accurately predict erosive cavitation and thus substantially reduce hydro turbine maintenance costs.**

## Better, Faster, Cheaper

**Turbine cavitation damage is usually the most costly maintenance item on a hydroelectric turbine, and there is no effective method to detect ongoing erosive cavitation on an operating turbine. This research provides a better understanding of cavitation to identify ranges where damaging cavitation occurs so that the turbine can be operated to avoid those ranges.**

## Principal Investigator

**John Germann**
**Mechanical Engineer**
**Mechanical Equipment Group**
**Technical Service Center**
**303-445-2295**
**jgermann@usbr.gov**

## Research Office Contact

**Erin Foraker**
**Renewable Energy**
**Research Coordinator**
**303-445-3635**
**eforaker@usbr.gov**

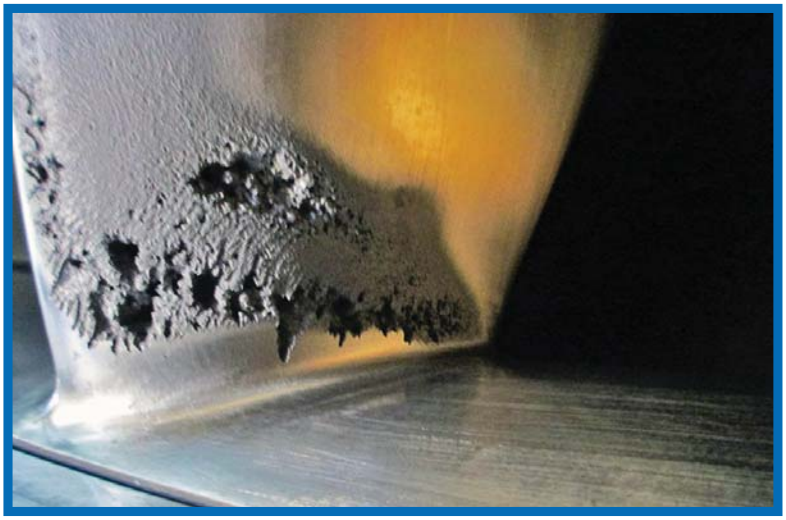
## Collaborators

**Reclamation's Northern California Area Office**

## Problem

It is crucial to our Nation's power system that Reclamation's powerplants keep running. Moreover, changing reservoir levels due to droughts or floods can require powerplants to operate at water conditions that they were not designed for, which can cause damage.

Vapor bubbles form when exposed to an area of subatmospheric conditions. When these tiny bubbles of vapor are subjected to pressure in a liquid, they can implode onto a surface (such as a turbine runner blade) causing damage called "cavitation." Cavitation commonly occurs in a wide variety of equipment (e.g., marine propellers, hydrofoils, nozzles, and injectors). When damaging cavitation occurs in the turbine, unexpected shutdowns and unplanned maintenance is required for repairs. The Judge Francis Carr Powerplant (J.F. Carr) in California has two units, both with recent cavitation issues that have cost an estimated $5 million in lost generation and repairs, not including long-term costs related to lost operational ranges, future repairs, and future lost generation. This unexpected repair work should be minimized to maximize hydroelectric production. Although hundreds of papers have been written on the subject, minimal research has focused on preventing cavitation damage occurring within an actual operating hydropower turbine.



*Cavitation damage to a turbine runner blade of J.F. Carr Unit 2 in February 2013. Photograph courtesy of John Germann.*

Various types of cavitation can occur, which require different detection, prevention, and mitigation measures. Cavitation commonly occurs in hydroelectric turbines around guide vanes, wicket gates, the turbine runner, and in the draft tube. Cavitation damages to the machinery components are compounded with other associated problems, including losses of efficiency and output, lengthy repair outages, and severe vibrations.

Cavitation in hydraulic turbines is primarily influenced by hydraulic design and operating conditions. Detecting cavitation in an operating hydroelectric turbine is difficult, as this is a complex phenomenon that is difficult to assess. Direct access to

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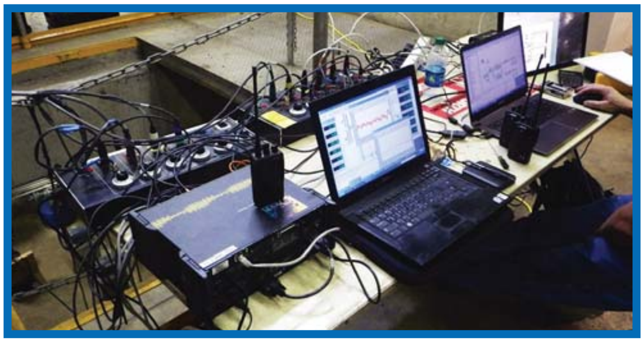
assess cavitation occurring within the water passage of the turbine when the unit is running is impossible, and thus it is hard to determine if the cavitation is damaging the unit—until it is too late. Reclamation initially began researching cavitation detection in hydro turbines in 2004, purchasing and testing several commercially available cavitation monitors. These monitors used a very simplistic approach and did not perform well, as they could not distinguish damaging (erosive) cavitation from non-erosive cavitation within the fluid stream. Thus, Reclamation and the hydropower industry need a machine condition monitoring tool to detect cavitation problems while the turbine is operating.

## Solution and Application

This Reclamation Science and Technology Program research project is developing better techniques and instrumentation that will be used as a machine condition monitoring tool. One goal is to build an online cavitation monitor to identify, alarm, and record cavitation activity over long-term operations. This allows better prediction of cavitation behavior over varying unit operations and reservoir elevation. A prototype system was tested in 2011 at the Fremont Canyon Powerplant in Wyoming.

A shaft mounted cavitation detector was developed to better detect damaging cavitation. This new package uses a shaft-mounted accelerometer and acoustic emission sensor, and then a wireless transmitter to send high frequency signals from the turbine shaft. Online tests showed this wireless system operation to be reliable. As well as accelerometers, acoustic emission sensors are used to assess cavitation impact signals and track cavitation activity, as very high frequency noises unique to cavitation can often be identified.

*Jim DeHaan of Reclamation's TSC installing a cavitation monitor at the J.F. Carr Powerplant.*



*Monitoring for cavitation.*

Current cavitation research is focused on the existing runners at the J.F. Carr Powerplant in northern California. These units are an excellent research platform for these studies because they exhibit severe erosive cavitation. This powerplant has two hydro turbines with new turbine runners that are exhibiting extremely aggressive cavitation. In 2013, Reclamation's Technical Service Center (TSC) and Northern California Area Office (NCAO) partnered to conduct machine condition monitoring and cavitation detection research at J.F. Carr Powerplant. These tests were to determine if it is possible to detect and measure cavitation-induced vibration and acoustic signals created by cavitation that is causing severe erosion on the leading edges of the turbine blades.

The tests identified the operating ranges where peak cavitation is occurring on the turbine runners. Online cavitation monitors are being developed that will monitor and map conditions over long-term operations. Current cavitation damage is being repaired and the new monitors are being installed.

***"Besides predicting and reducing the damaging effects of cavitation, this research could reduce the hazards employees are exposed to during cavitation repairs. Cavitation is very damaging and requires extensive corrective maintenance to repair. Any steps that can be taken to reduce cavitation would be beneficial."***

**Russell Anderson**
**Reliability Program Analyst, Reclamation's Power Resources Office**

## Future Plans

**Reclamation's TSC and NCAO will work together over the long term to determine cavitation trends and further identify operational ranges to avoid cavitation, and hopes to continue to improve on cavitation detection and analysis and to refine past techniques. These new monitors could potentially be adapted to monitor and avoid cavitation in a wide variety of cavitation-prone hydro turbines. Findings will be shared through technical papers with Reclamation and the hydropower community.**

## More information

**www.usbr.gov/research/projects/detail.cfm?id=2386**

**www.usbr.gov/research/projects/detail.cfm?id=9933**

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