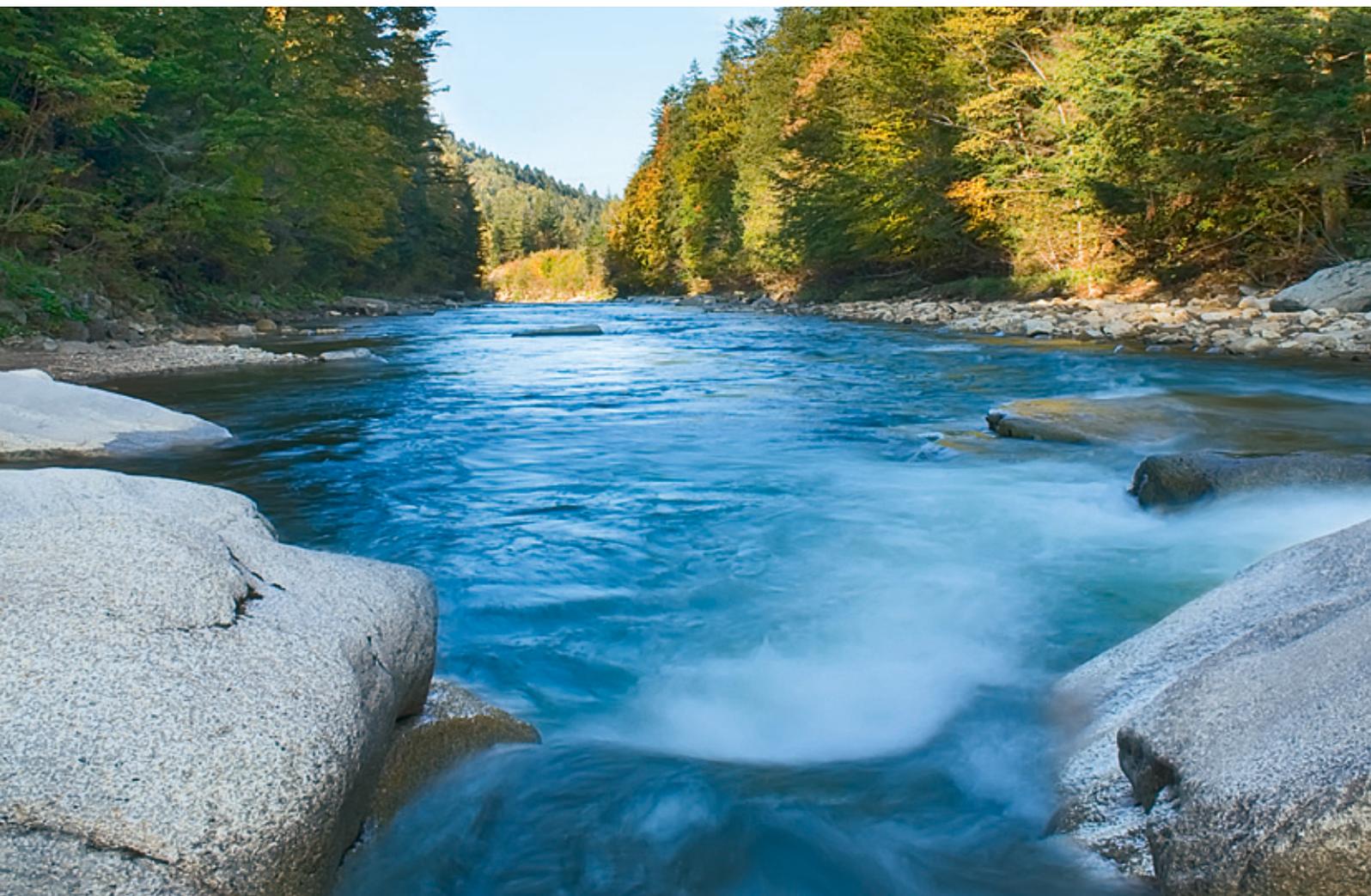


# Environmentally-friendly turbine design





- 1 The Bonneville dam is located 60 km from Portland. Built in 1933-37, the dam now provides fish-friendly technology to the Columbia River.

# Hydropower - The World's Largest Renewable Energy Source

Globally, hydropower is the largest source of renewable energy generation has been in use for over 100 years. Its contribution to a low-emission, reliable and safe energy generation will remain indispensable all around the world.

Hydropower provides clean, safe, reliable, and highly efficient energy in large quantities. In both large and small hydro plants, this proven technology is central to the world's economic and social development.

Global leader in environmentally-friendly turbine design. All forms of energy production require balancing tradeoffs with benefits. Throughout Voith Hydro's unparalleled industrial experience spanning more than 100 years, the organization has been working to minimize the impact of hydropower on the environment. Specifically, ensuring safe fish passage has been one of Voith's industry goals for the last 50 years, leading the company to conduct analytical and physical modeling in its laboratories. Greaseless technologies have been commonly used to maintain water quality for more than twenty years.

Fish migration and survival is paramount issue for hydroelectric facilities across the world. Traditionally, the preferred method for protecting fish involved bypassing them around hydroelectric equipment. Since direct passage through

turbines can subject fish to the increased likelihood of injury and mortality, their populations can be negatively affected.

Developing fish passage technology to allow for direct turbine passage began in earnest in the 1990s and continues to this day. The goal for these efforts is to reach fish passage levels similar to this that existed or to hydropower installation at a given site, while minimizing cost and efficiency loss.

Voith has designed turbines that allow for the successful passage of various fish species in the most critical habitats. In partnership with Alden Research Laboratory and with the support of the Electric Power Research Institute (EPRI) and the Department of Energy, Voith is bringing to market the newest technology in this field.

To address water quality issues, Voith has developed state of the art aerating turbine technologies to improve dissolved oxygen levels with minimal impact on energy generation. Moreover, oil-free turbines now prevent release of pollutants into the water.

- 1 A minimum gap runner – weighing 300 tons and nearly 8 meters in diameter – is lifted into the Wanapum hydroelectric plant on the Columbia River (USA).



# Safe passage for Fish

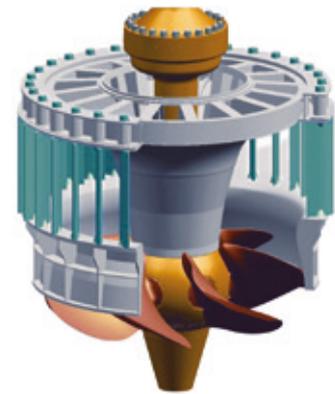
## Minimum Gap Runner

Adjustable blade turbines such as Kaplans or Bulbs feature blades with varying pitch and are characterized by gaps at the inner and outer blade peripheries. These gaps can give rise to leakage flows, resulting in the formation of vortices. These secondary flows cause elevated water velocity, shear and rapid pressure changes and low absolute pressure levels, all of which are potentially harmful to passing fish. Fish can also get trapped or pinched in the gaps themselves.

To minimize the effects of gap flows on fish survival, Voith Hydro developed the Minimum Gap Runner (MGR) technology as part of the Department of Energy's Advanced Hydropower Turbine System (AHTS) program. The MGR blades are contoured to a fully spherical hub and

periphery so that the design gap remains constant across the pitch range. In addition to the stated goal of improving fish survival, the minimal gap also has positive impacts on turbine efficiencies.

Over the past decade, MGR technology has been implemented at several large axial flow units in the field, including Grand County (Washington) Public Utility District's Wanapum Dam, the US Army Corps of Engineers' Bonneville Dam, and American Municipal Power's Ohio River projects. Fish survival rates through MGR units have been documented to be in excess of 95%.



MGR Kaplan Turbine (schematic view)



MGR Turbine: Fully spherical hub minimizes gaps, protects fish, and enhances overall turbines efficiency.



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2 The Alden Turbine is predicted to provide survival rates of 98% to 100%.

# Alden Turbine

One of the newest improvements to fish passage technology comes through development of an innovative runner concept by Alden Research Laboratory. The Alden Turbine features a slower rotational speed and only three blades to reduce fish mortality due to blade strike. Voith Hydro has optimized the final design and tested it at their hydraulic laboratory in York, Pennsylvania (USA).

The blade shapes are specifically designed to improve the fish passage environment through the turbines by minimizing shear, pressure change rates and minimum pressures within the water passage. Depending on the species, fullscale fish survival rates are expected to range from 98% to 100%. Through funding made available by the DOE, EPRI and industry partners, Alden Re-

search Laboratory collaborated with Voith hydro to improve the performance characteristics of the conceptual turbine while maintaining or improving the fish-friendly characteristics. The partnership also focused on ensuring the turbine's cost-effectiveness while maintaining improvements in fish survival rates.

Key benefits include a reduced strike probability by optimizing the numbers of turbine blades, wicket gates and stay vanes as well as improving the hydraulic profile of the turbine components and the rotational speed. The turbine also features optimized water passage geometries to meet specified fish passage criteria.

## At a Glance

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### Alden Turbine

- + Hydraulic contours optimized to meet safe fish passage design criteria
- + Efficiency levels competitive with conventional technology



Alden runner model

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# Improving Water Quality

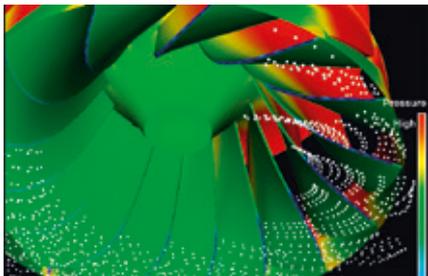
## Aerating Turbine Technology

### At a Glance

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#### Aerating Runner Technology

- + Most efficient aeration solution available today
- + Air naturally drawn through Voith patented aerating hollow runner blades
- + Bubble distribution maximized in draft tube and tailrace
- + Maximum Dissolved Oxygen uptake achievable



Voith aerating runner: blade discharge edge slots allow for maximum bubble distribution

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Over the years, Voith Hydro has become a leader in providing aeration solutions that improve environmental compatibility through the increase of dissolved oxygen uptake downstream of hydropower producers: the advancements address a common issue faced by hydropower producers: the need to improve water quality, specifically dissolved oxygen content, as water is discharged from existing and new hydroelectric equipment. The water in the lower reaches of many reservoirs is oxygen deficient, and passing this low dissolved oxygen water through a hydro site can result in damage to downstream ecosystem.

Often, low pressure regions below the runner can be utilized to draw atmospheric air into the turbine during operation. These machines are referred to as auto-venting turbines (AVT) and are particularly cost-effective for injecting large quantities of air into the discharge.

Auto-venting turbine aeration generally consists of three different aeration options, including distributed, central and peripheral aeration.

The interaction between the incoming bubbles and the surrounding water drives the aeration performance by influencing the pressures at the air injection location, the resulting air flows, the dissolved oxygen uptake efficiency, and the turbine performance.

For each project, individual site characteristics, plant design, and desired operation are incorporated into in-house calculation methodologies which account for the necessary bubble modeling to optimize aeration behavior. Based on the predictions, Voith Hydro selects aeration solutions which provides the best value for the customer by maximizing uptake while minimizing the impact on the turbine performance and aeration costs.



- 1 Conowingo hydroelectric plant is located at the head of the Chesapeake Bay. Voith Hydro has installed four Aerating Francis Turbines to improve water quality.
- 2 Naturally balanced: Voith Hydro Technology is dedicated not only to using, but also to preserving the earth's sustainable resources.

## Oil-Free Hubs

Adjustable blade runner hubs are typically filled with pressurized oil. This oil lubricates runner blade trunnion bearings and sliding parts of the operating mechanism in the hub. However, using hub oil endangers water pollution by oil spill from the hydroelectric facility. In order to eliminate the risk, Voith Hydro has been developing and installing oil-free solutions since 1985.

Pressurized oil has been replaced by selflubricating materials and assures not only the prevention of accidental releases of grease substances into the environment but also allows for easy maintenance, lower friction and good bearing performance with necessity of increasing servo size.

### At a Glance

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#### Oil-free-hub

- + No risk of oil flowing out into the tailrace
- + No need to pressurize the hub or use a balance piston to maintain hub pressure



Advanced technology for Castrelo hydropower plant in Spain: oil-free hub.

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**VOITH**