Turbomachinery Laboratory

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Overview

In January of 2016, EIC Cryo and the Mechanical Engineering Department at the University of Nevada, Reno partnered together to design and develop hydraulic components for LNG (Liquid Natural Gas) turbomachinery applications. The objective of the project is to expand our understanding of two-phase flow and to improve the overall efficiency of turbines, specifically those utilized in the LNG applications. Two-phase flow is a mix of gas and liquid together, which has completely different attributes than either on its own. Historically, the two-phase condition has been avoided in turbomachines because it can be detrimental to the equipment, if not controlled.

The research in this laboratory will lead to the prediction, experimental verification, and further advancement in the field, to advance the turbine hydraulic technology and to broaden overall education and knowledge in the rotating equipment and turbomachinery fields.

Two-Phase Turbines

The hydraulic components of a turbine are the runner and the nozzle vane, which are the most critical elements in a turbine's operation. In two-phase flow applications, an exducer is added to the runner. The design of these components directly influences efficiency and is also critical to the reliability and dependability of the rotating parts. **Figure-1** displays the 3d model of a two-phase turbine.

Each hydraulic component design receives detailed review in stages, often categorized but not limited to:

1. Theoretical prediction, analysis, and simulation.
2. Experimental verification, validation, and demonstration.

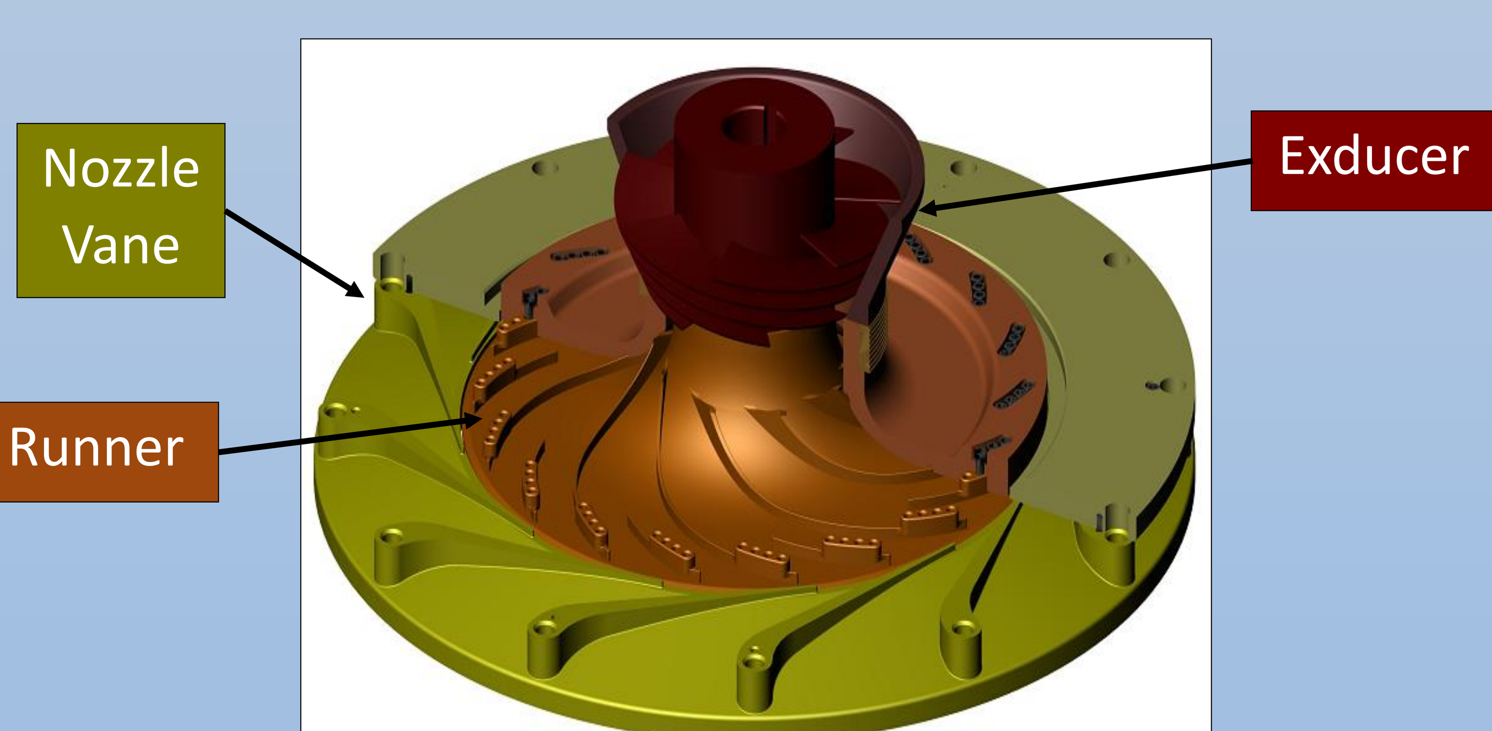

Figure-1 Hydraulic components of a two-phase turbine.

Theoretical Predictions and Simulations

In order to satisfy the first step of the analysis and prediction process, high speed computers are utilized at UNR's Turbomachinery Laboratory to design turbine hydraulic components using Computational Fluid Dynamics (CFD) software specifically written for turbomachinery applications. The hardware and software combination is capable of simulating design cases in excess of speed of sound in two-phase flow conditions. **Figure-2** illustrates the results of some of the simulations performed by the Turbomachinery Lab.

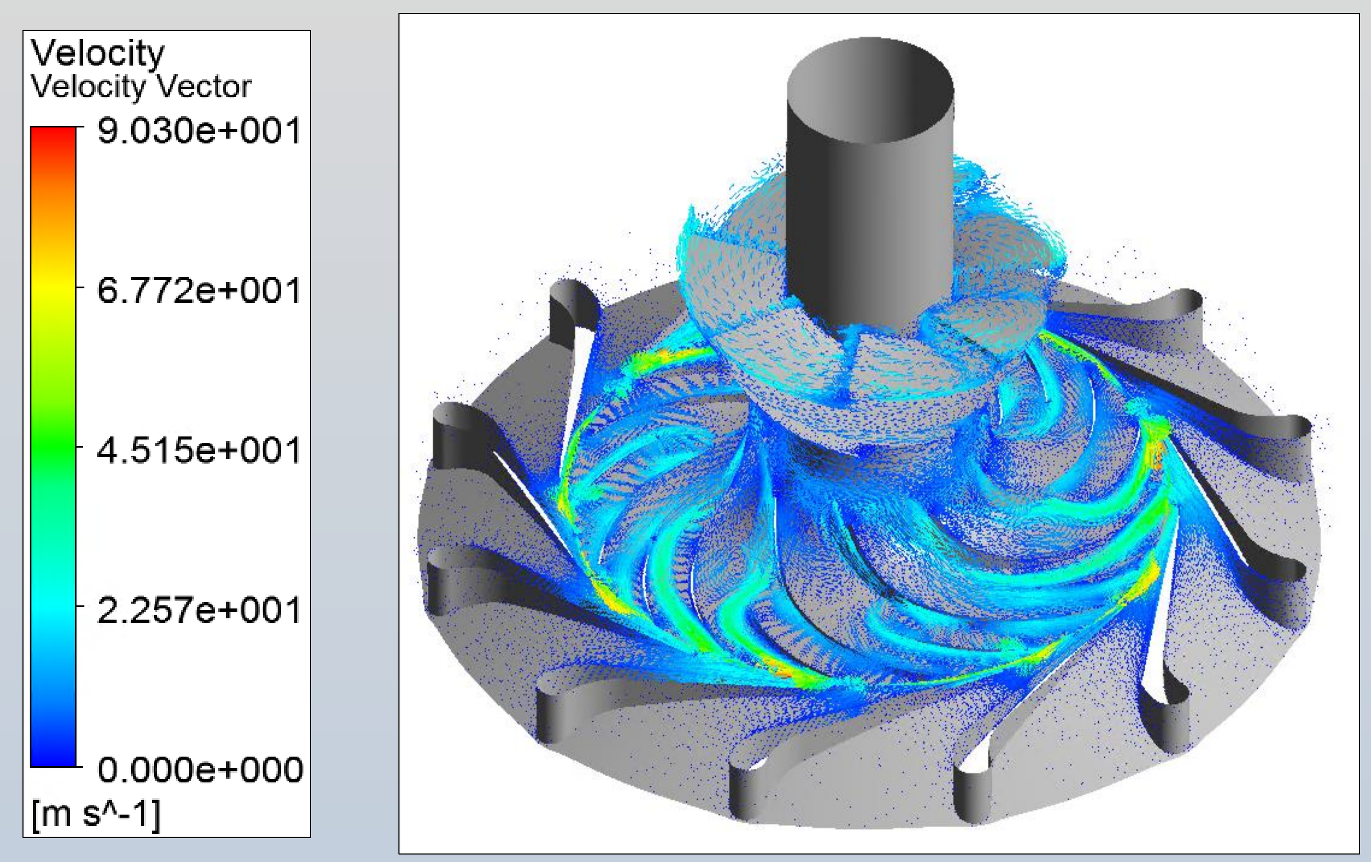

Figure-2: Simulation results, fluid velocity is displayed.

Experimental Setup and Testing

Testing and verification of hydraulic components is extremely costly to perform in a full-scale cryogenic environment. This is primarily due to cryogenic temperatures (LNG at -265 °F) and the hazardous nature of LNG (flammable). Also challenging, the size of a full-scale LNG turbine can be as high as 3 MW in power rating, which makes it impossible to test under limited laboratory conditions. Therefore, the scaled down prototypes of the turbine components are manufactured for laboratory testing. Particle Image Velocimetry (PIV) is used in the laboratory to determine the performance and also to visually observe and understand the flow characteristics of each component. The basics of a PIV system and its operation can be seen in **Figure-3**. "Seeds", typically very small solid particles, are added to the fluid. At each time step, a laser illuminates the seeds for high-speed photography. The PIV software processes and records the seeds' movements, calculating both velocity and its direction. **Figure-4** shows the PIV testing of flow around a 3 blade propeller conducted at Turbomachinery Lab.

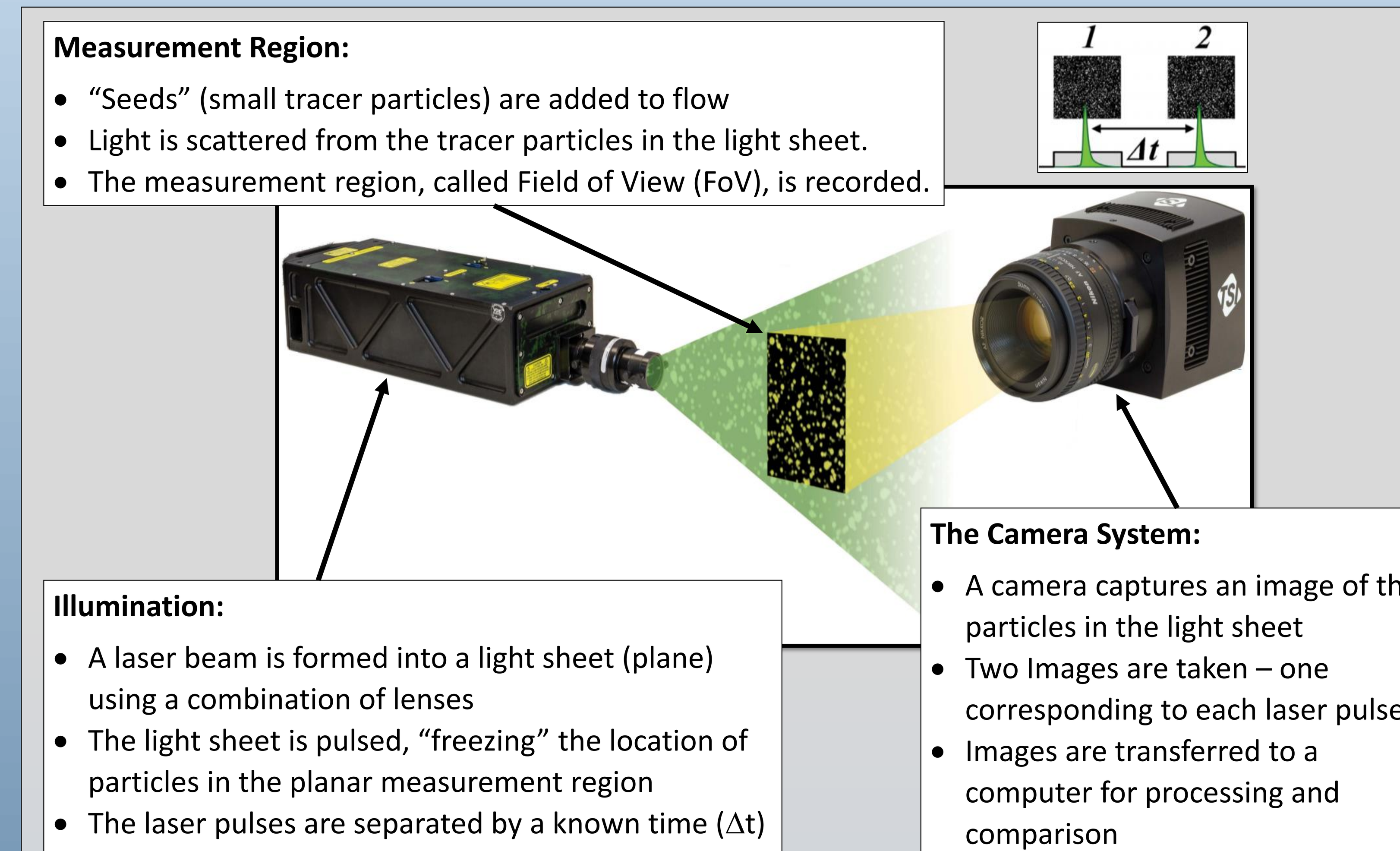

Figure-3: The Basics of the PIV system.

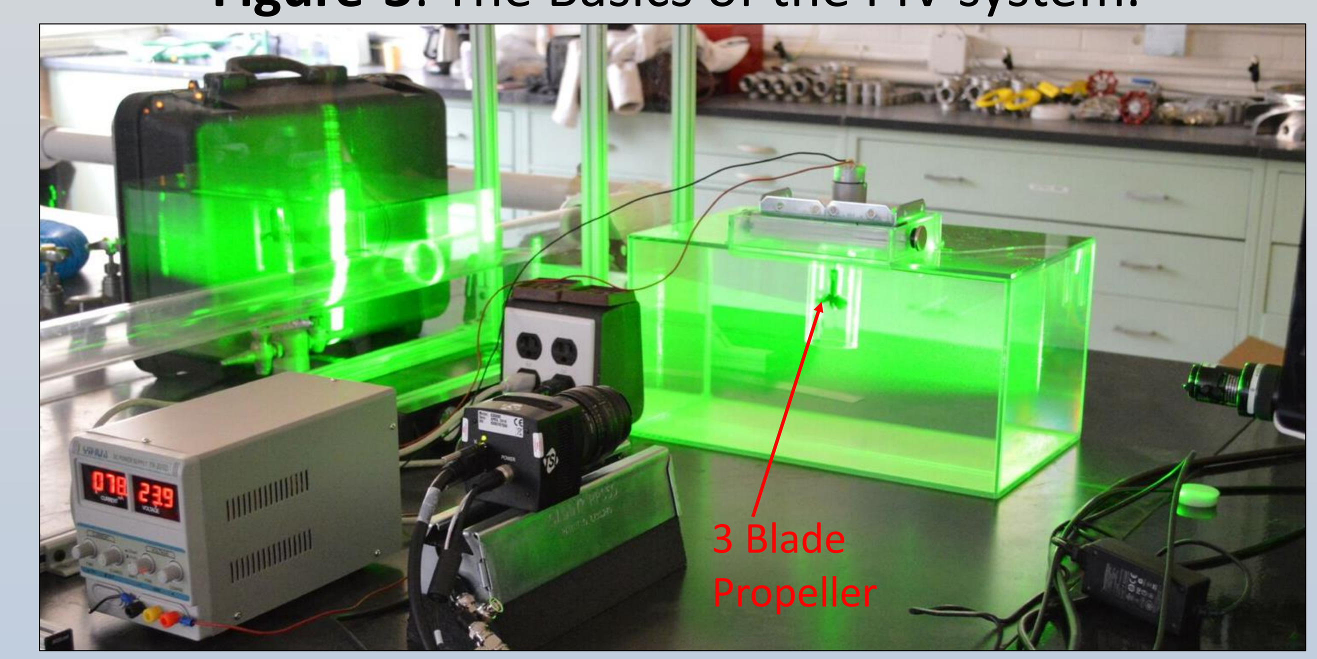

Figure-4 PIV Testing of flow around a 3 blade propeller.

A turbine test setup, displayed in **Figure-5**, is being designed and built to determine the performance of the hydraulic components and flow characteristics. Once the test setup is finalized, two-phase flow hydraulic component, exducer, will be tested to validate the performance enhancement.

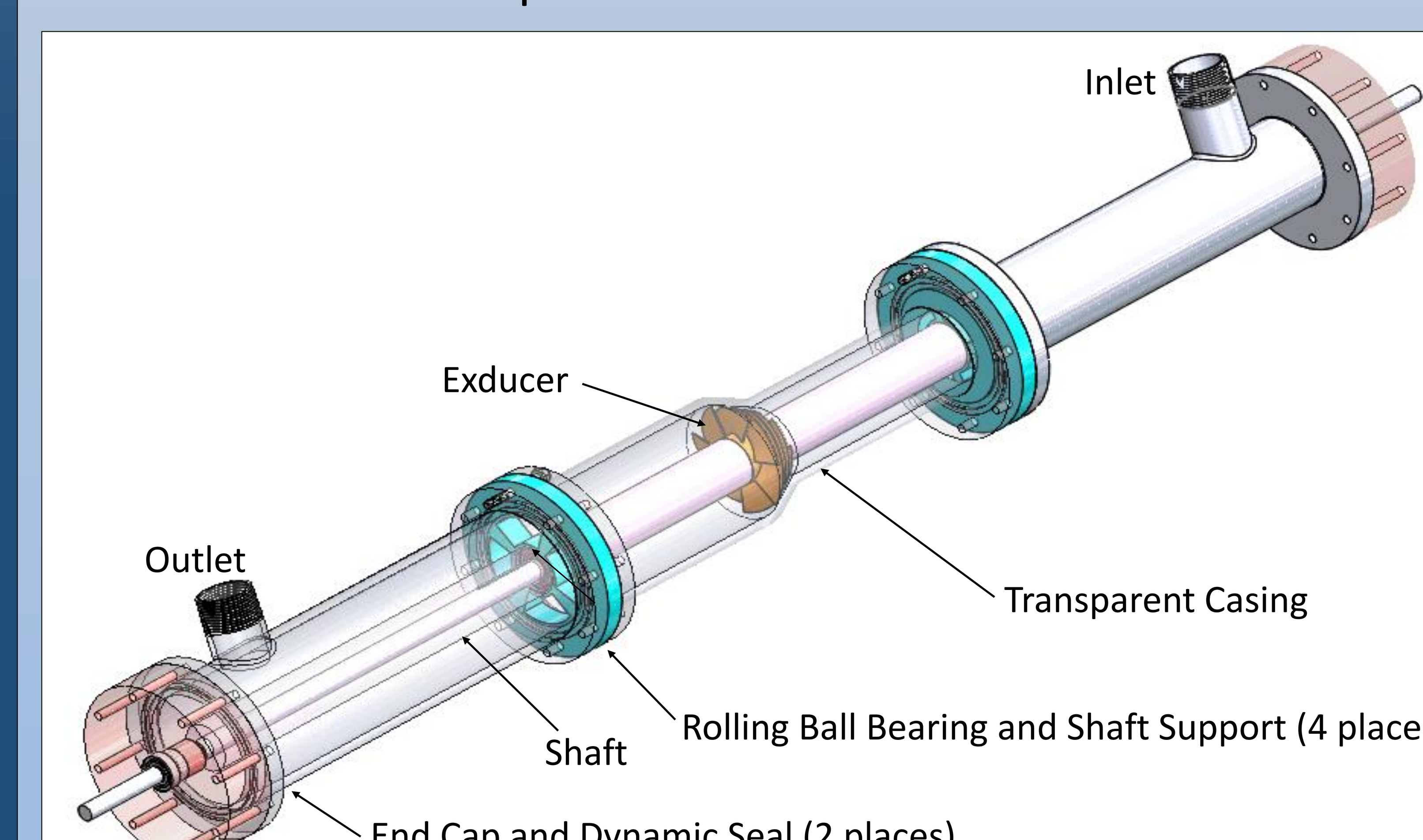

Figure-5 Turbine test setup.