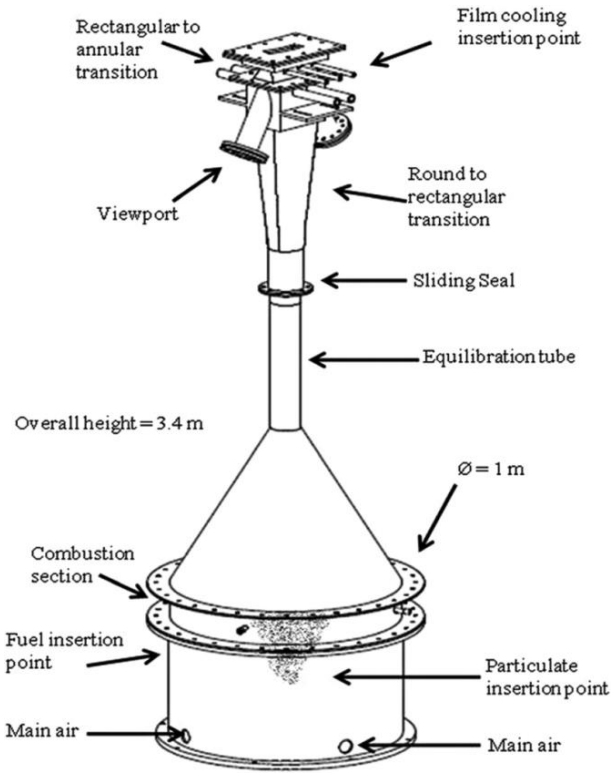
Turbine Accelerated Deposition Research at ARC

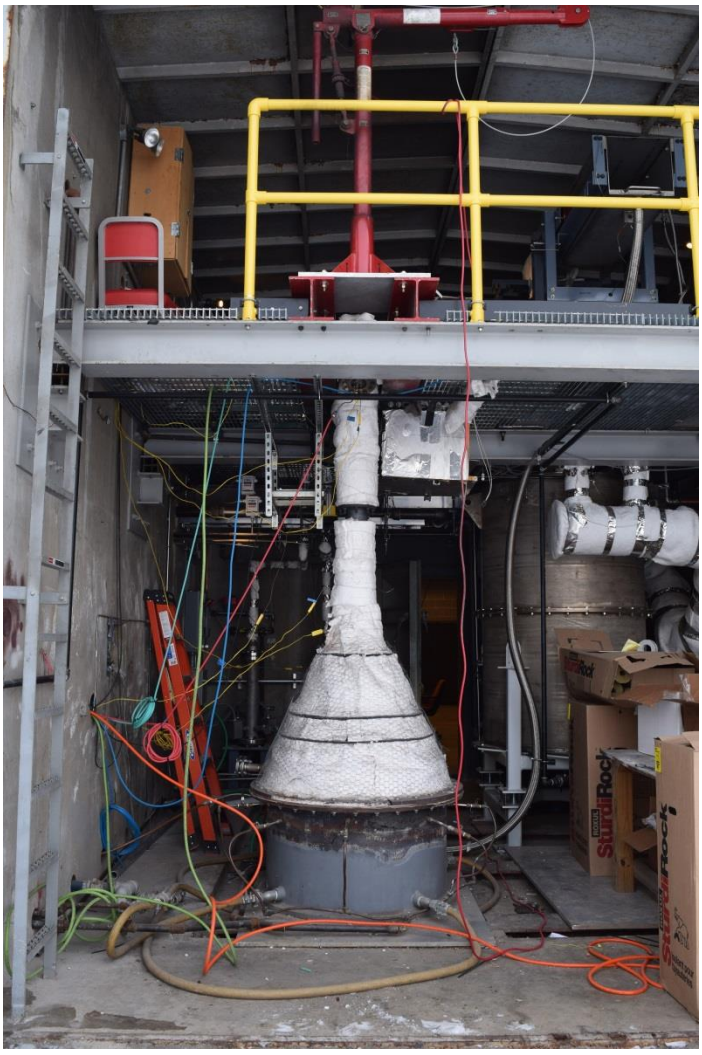
Turbine Reacting Flow Rig (TuRFR) Facilities

The demand for higher fuel efficiency and reduced noise continues to push the trend of increasingly larger bypass ratio turbofan engines with increasingly higher turbine inlet temperature. These trends in aircraft propulsion have levied increasing demands on the turbine (hot) section of modern turbofan engines and on the low-pressure turbine efficiency and work output. Additionally, growth markets for turbofan engines have moved from North America and Europe to the Middle and Far East. Air quality concerns in these new markets are presenting increasing hardship for turbines as airborne deposits collect in cooling passages in the gas turbine and reduce performance. A turbine accelerated deposition facility was commissioned to address the issue of harsh operating environments and high temperature.

A unique Turbine Reacting Flow Rig (TuRFR) was constructed for the Turbine Aerothermal Laboratory (TAL) at the ARC in 2008 that simulates the flow exiting a gas turbine combustor as it impacts the first stage turbine nozzle guide vanes (NGVs). This early facility is capable of providing main gas path flow temperatures up to 2,100° F with an inlet Mach number of 0.1 and coolant temperatures up to 1,000° F. Airborne particulate can be added to the main gas path and/or the coolant flow to simulate in an experimental environment the deposition build-up observed on NGVs in the field. The spatial temperature distribution in the inlet plane can be modified to simulate various pattern factors typical of modern engines. Optical access allows for video footage of deposition growth as well as surface temperature measurement with infrared imaging. Temperature, velocity, and pressure probes can be traversed across both the inlet and exit planes.

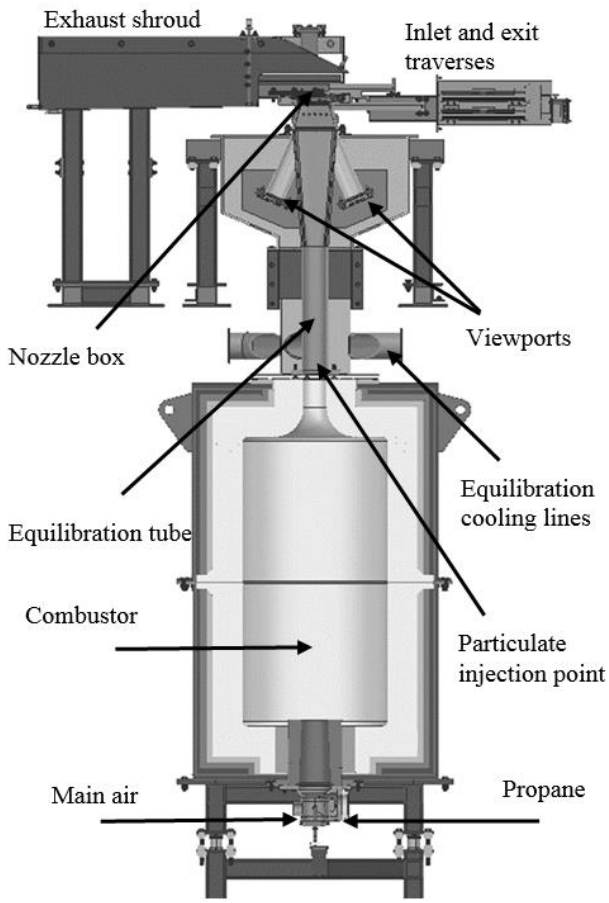


Schematic of the Turbine Reacting Flow Rig (TuRFR I) at the ARC

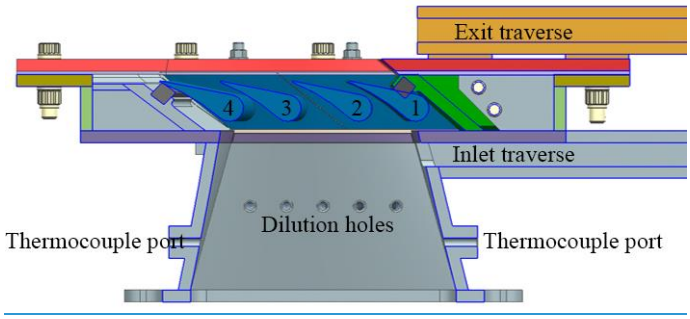


Photograph of TuRFR I

Design and construction of an upgraded and world class “TuRFR II” facility was completed in the summer of 2015 representing a $2M infrastructure investment at the ARC. This impressive facility simulates a more modern engine environment, capable of operating at significantly higher temperatures and mass flow rates. An industrial burner, capable of temperatures up to 3,000° F, provides heated airflow to the NGVs downstream. A double walled construction with liner cooling permits the test section to operate in excess of 2,600° F while internal cooling airflow to the engine parts is provided at up to 1,200° F. TuRFR II shares the testing capabilities of its predecessor, including: particulate injection options, inlet flow pattern factor variations, optical access for infrared thermography, and inlet and exit plane instrumented traverse access. The modular nozzle box test section allows for experiments to be designed for a



large array of current engine nozzle guide vane hardware. The TuRFR II facility is employed in exciting research sponsored by various industry leaders.



Schematic of the TuRFR II facility and nozzle box test section