LIQUID FUELED HIGH VELOCITY OXY-FUEL THERMAL SPRAYING TECHNIQUE FOR DURABLE COATING

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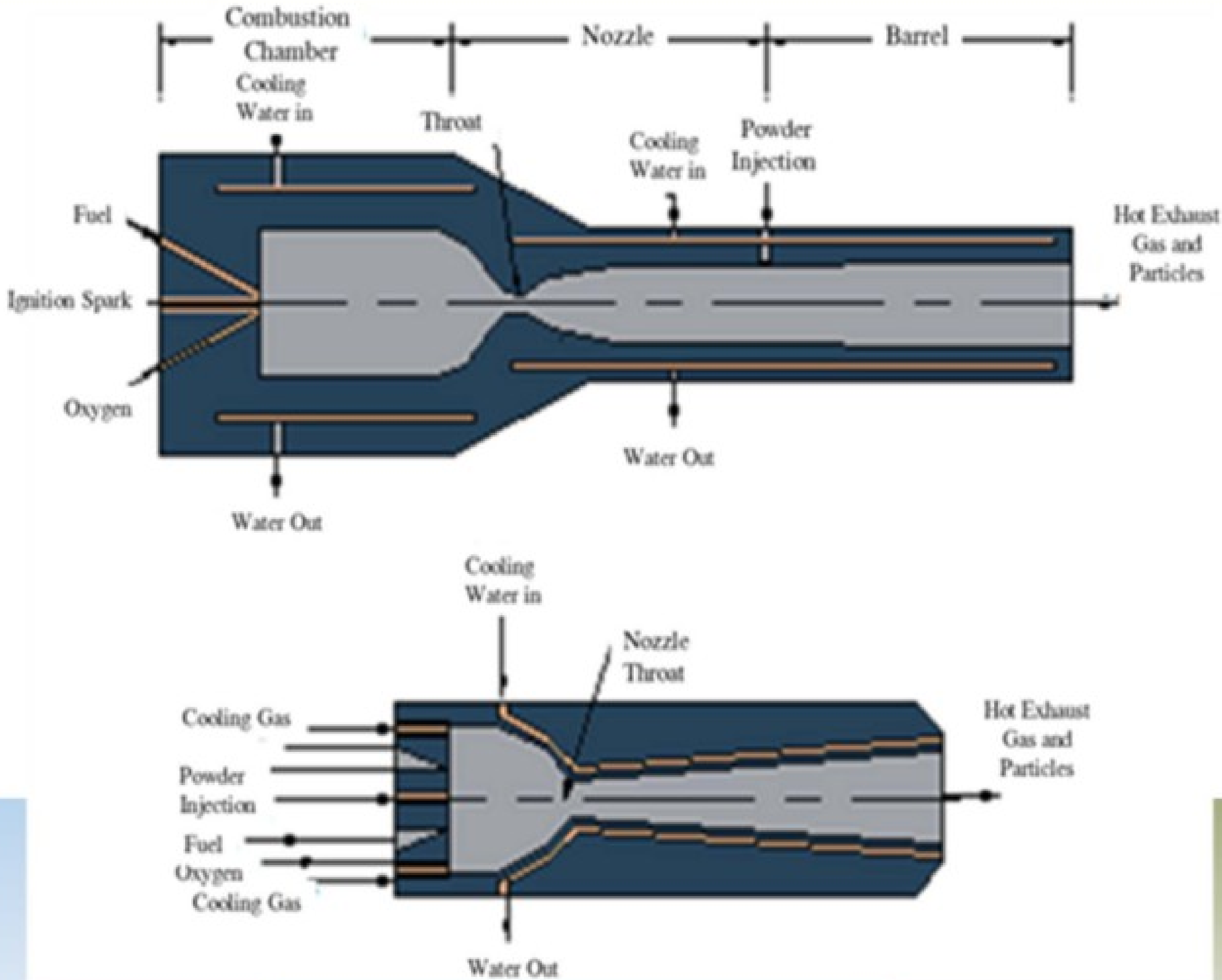

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Introduction

- **Thermal spraying techniques**: are coating processes in which **melted (or heated)** materials are sprayed onto a surface.

- Thermal spraying can provide thick coatings (approx. thickness range is **20 micrometers** to **several mm**, depending on the process and feedstock).

- Coating materials available for thermal spraying include metals, alloys, ceramics, plastics and composites.

- They are fed in powder form, heated to a molten or semi-molten state and accelerated towards substrates in the form of micrometer-size particles.

Introduction

- The flame and powder are accelerated by a **converging / diverging nozzle** to produce **supersonic** gas and particle velocities, which propel the powder particles toward the substrate to be coated.
- The powder particles flatten plastically upon impact with the substrate; cooling and solidifying to form the coating.
- High particle velocities, uniform heating and low dwell time combine to produce coatings that are very dense and tightly bonded to the substrate.

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Background

- The HVOF thermal spraying technique is widely applicable to high-temperature coating materials including iron, nickel, and cobalt-based alloys.

- High Velocity Oxy Fuel (HVOF) thermal spraying system is a highly promising technique for applying durable coatings on structural materials for corrosive/harsh and high temperature environments in advanced ultra-supercritical coal-fired (AUSC) boilers, steam turbines and gas turbines.

Background

- improve efficiency, reduce carbon deposits, and high temperature operations
- most commercially available HVOF thermal spraying systems use gas-fuelled spray guns, there is recent interest/trend in using liquid fuel such as kerosene due to its lower operational cost, superior combustion gas acceleration, and higher tendency to promote momentum output of powder particles compared to gas-fuelled systems.

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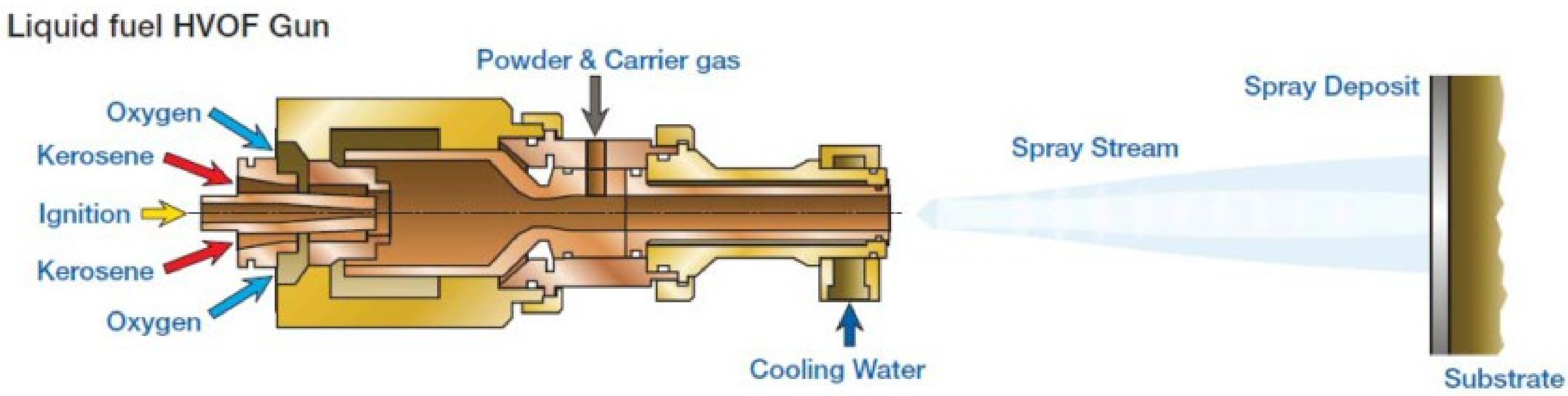

The HVOF (High Velocity Oxy Fuel) Spray process

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Objectives

- The overarching aim of the research team is to develop a comprehensive understanding of the physical and thermo-chemical processes of a LHVOF thermal spraying system and intricate interactions with coating materials.
  - *combustion chamber design,*
  - fuel-oxygen *injector configurations,*
  - *nozzle design,*
  - *oxygen/fuel ratio,*
  - *gas flow rate,*
  - *combustion chamber pressure,*
  - *particle size*, and
  - *position of substrate.*

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Objectives

- Continuous Combustion Mode
- Detonation and Pulsing Mode
- Multi-fuel Fuel Operations

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Objectives

- Inconel 718, Fe-Al, Fe-Ti-Al and Fe-Zr-Al will be systematically studied.
  - Microstructure analysis and Mechanical Characterization
  - Thermo-mechanical and Thermo-chemical
  - A high-pressure combustor rig will be utilized to determine how thermal stress cycling, oxidation degradation (and their complex interactions) can cause coating failures.

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Objectives

Oxidizer	Fuel	Coating Particles
Gaseous Oxygen	Methane/Propene/Hydrogen	Fe-Al
Gaseous Oxygen	Ethanol/Kerosene/Jet-A/	Inconel 718
Liquid Oxygen	Liquid Methane	Fe-Ti-Al
		Fe-Zr-Al

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Project Plan

Year 1 — Design Analysis Hardware Development

Year 2 — Testing and Operational Envelop Determinations

Year 3 — Coatings and Optimizations

Completed — Ongoing — Planned

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- Deep Throttle Capability (4:1)
- Maximum Exit Mach Number: 4
- Exit Temperature: 2000K-3000 K

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- **Five Modular** Sections:
  - **Injection system**
  - **Combustion chamber section**
  - **Converging-Diverging Nozzle**
  - **Barrel section**
  - **Cooling jacket**

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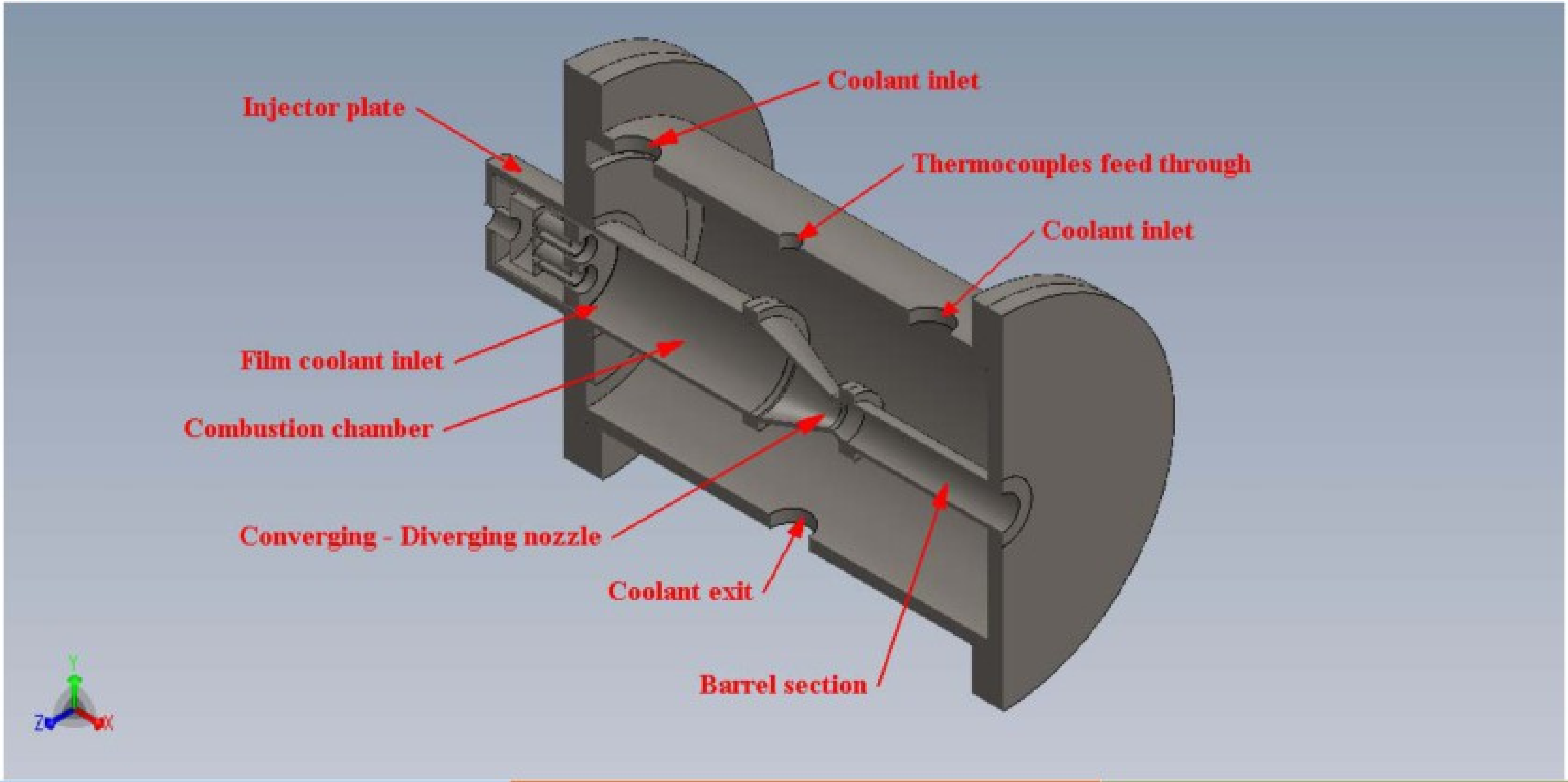
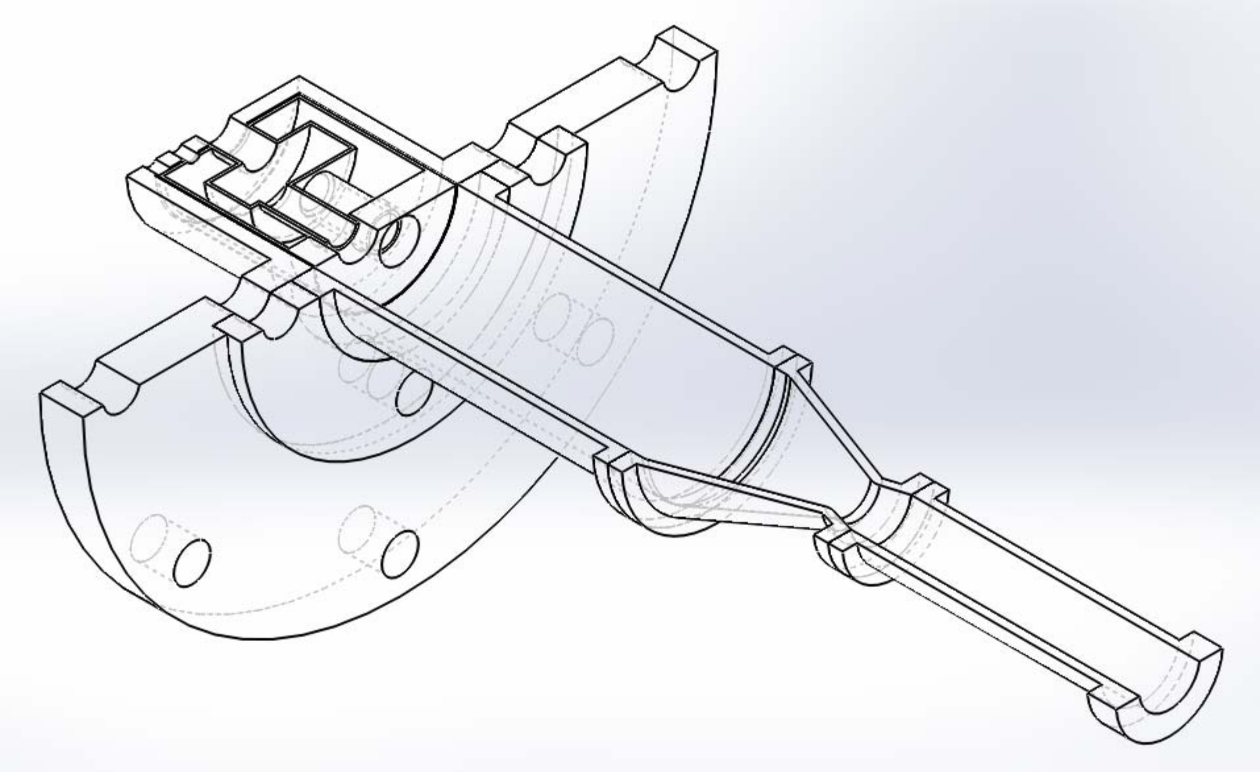
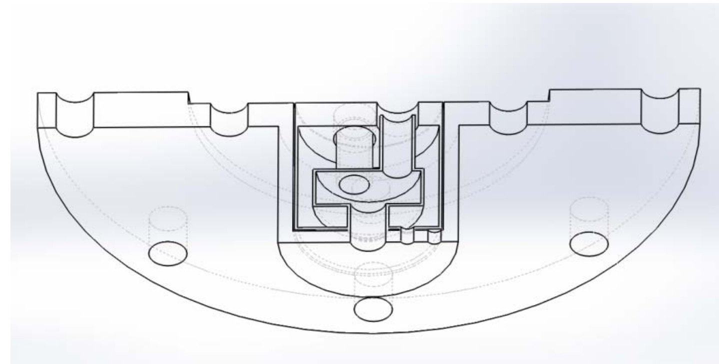
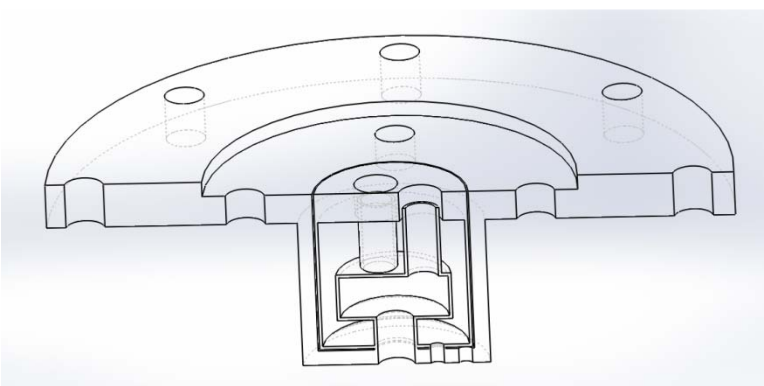
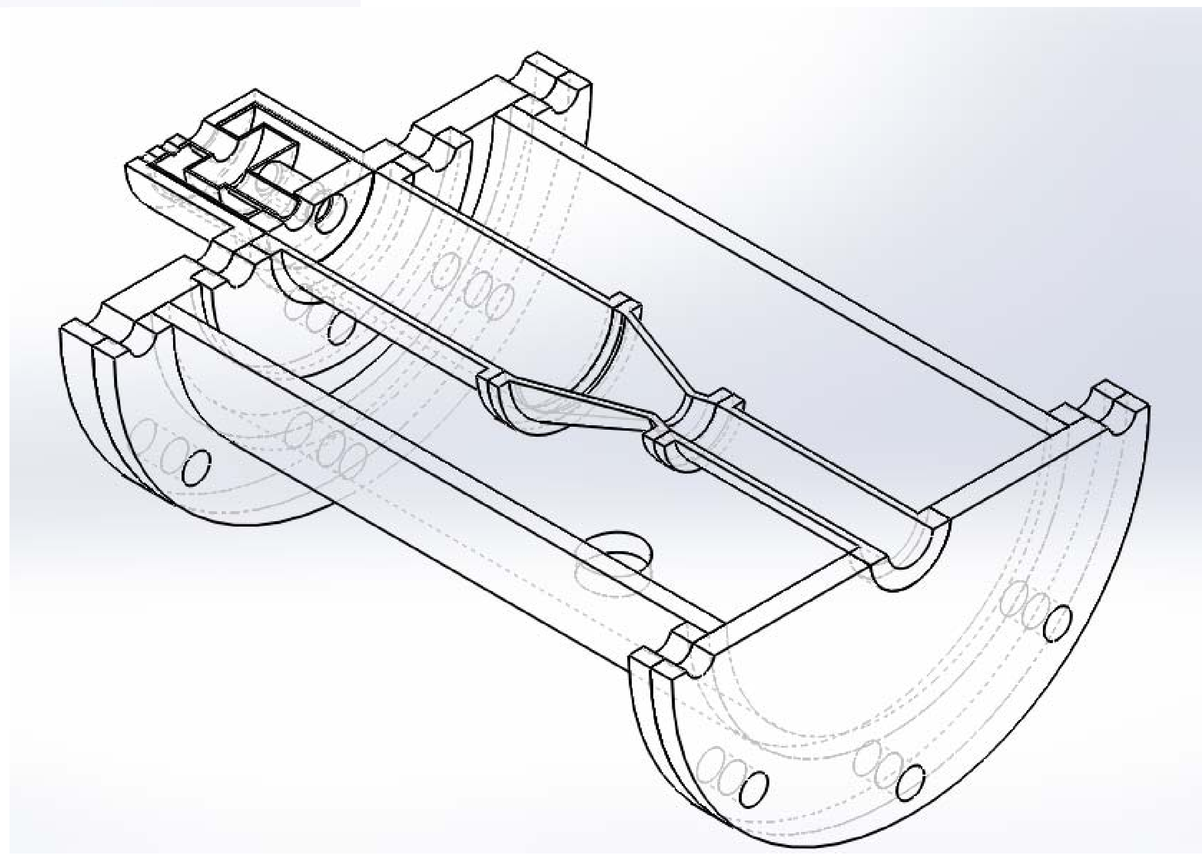
Technical Approach



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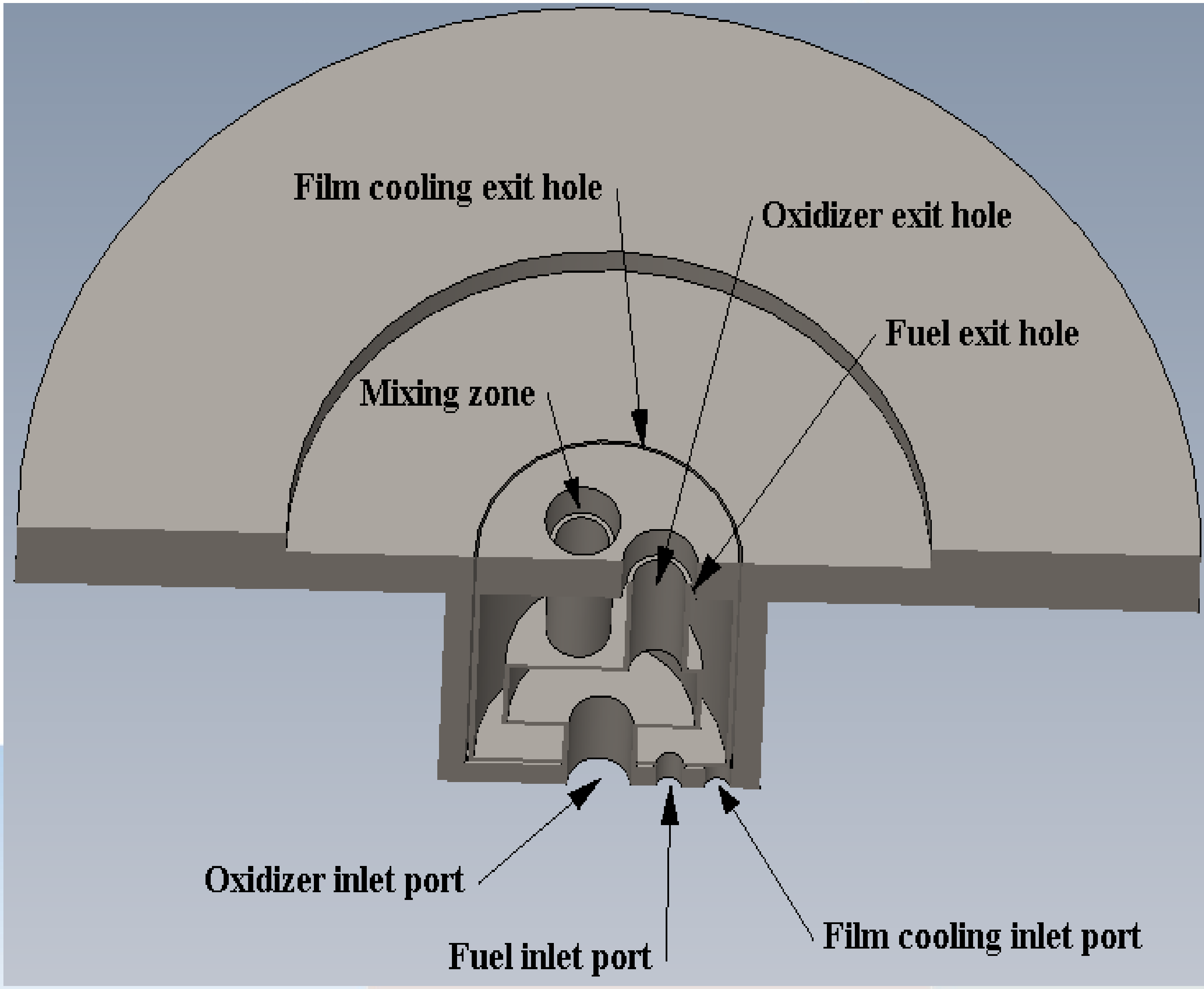

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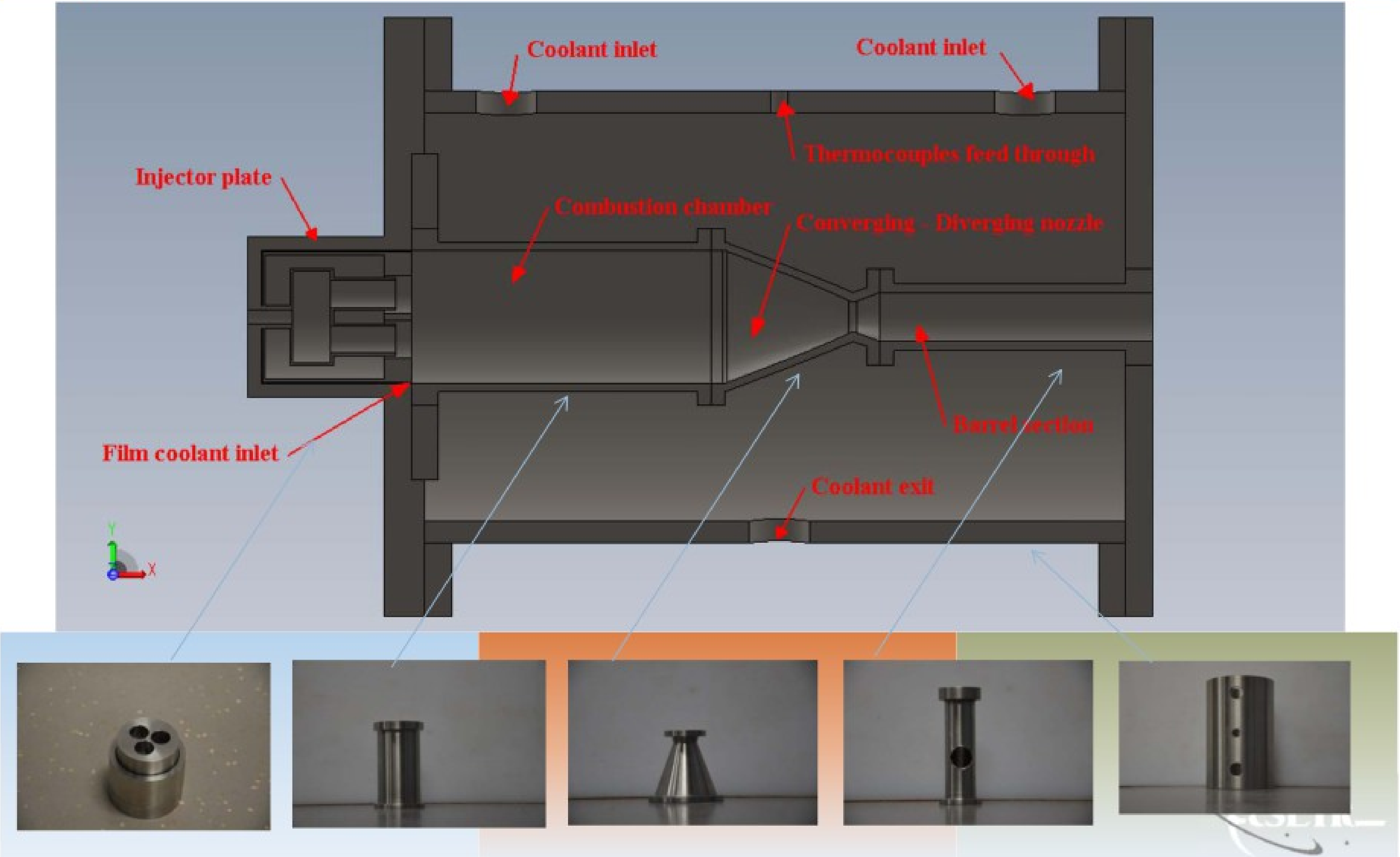

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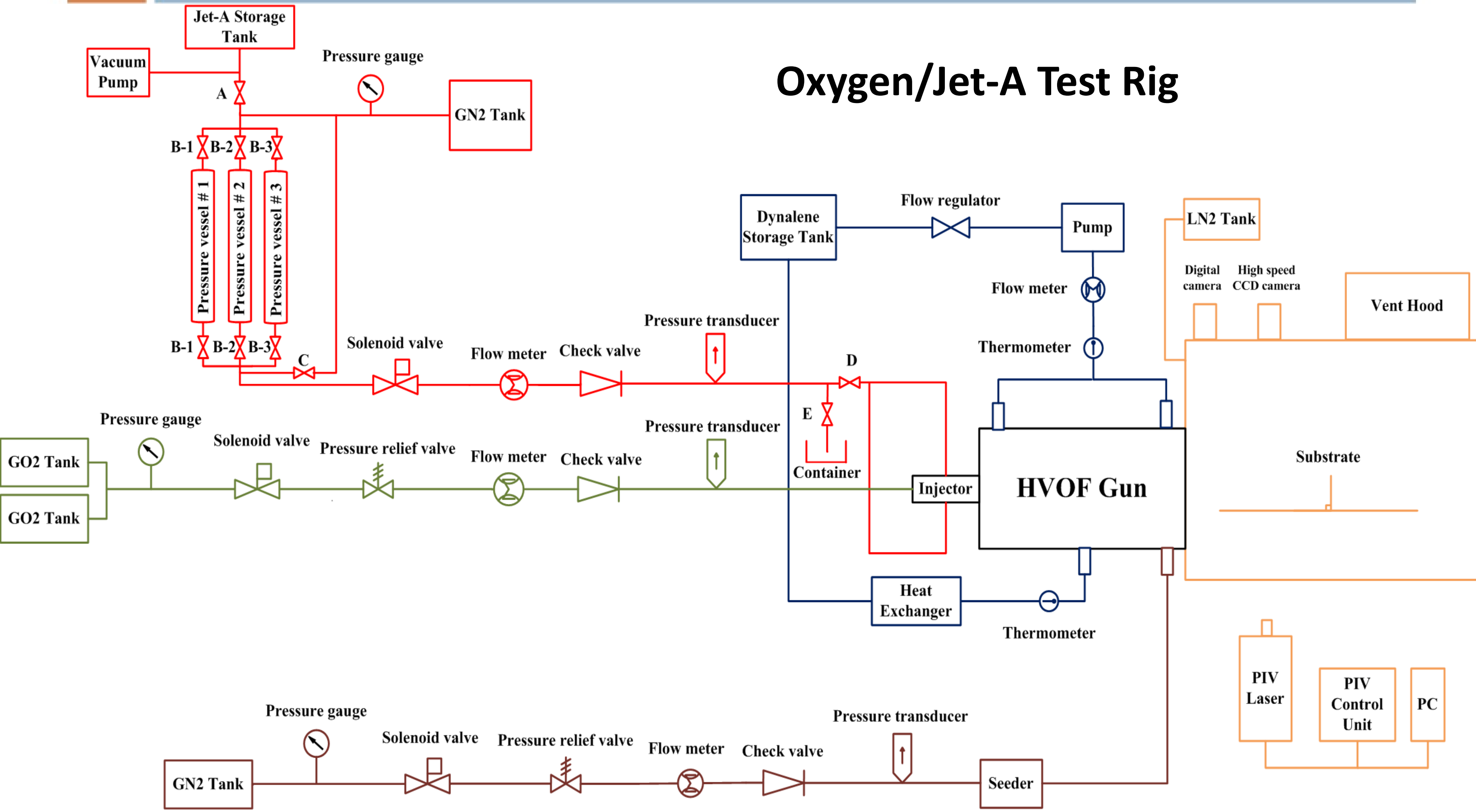
System Layout

Oxygen/Jet-A Test Rig



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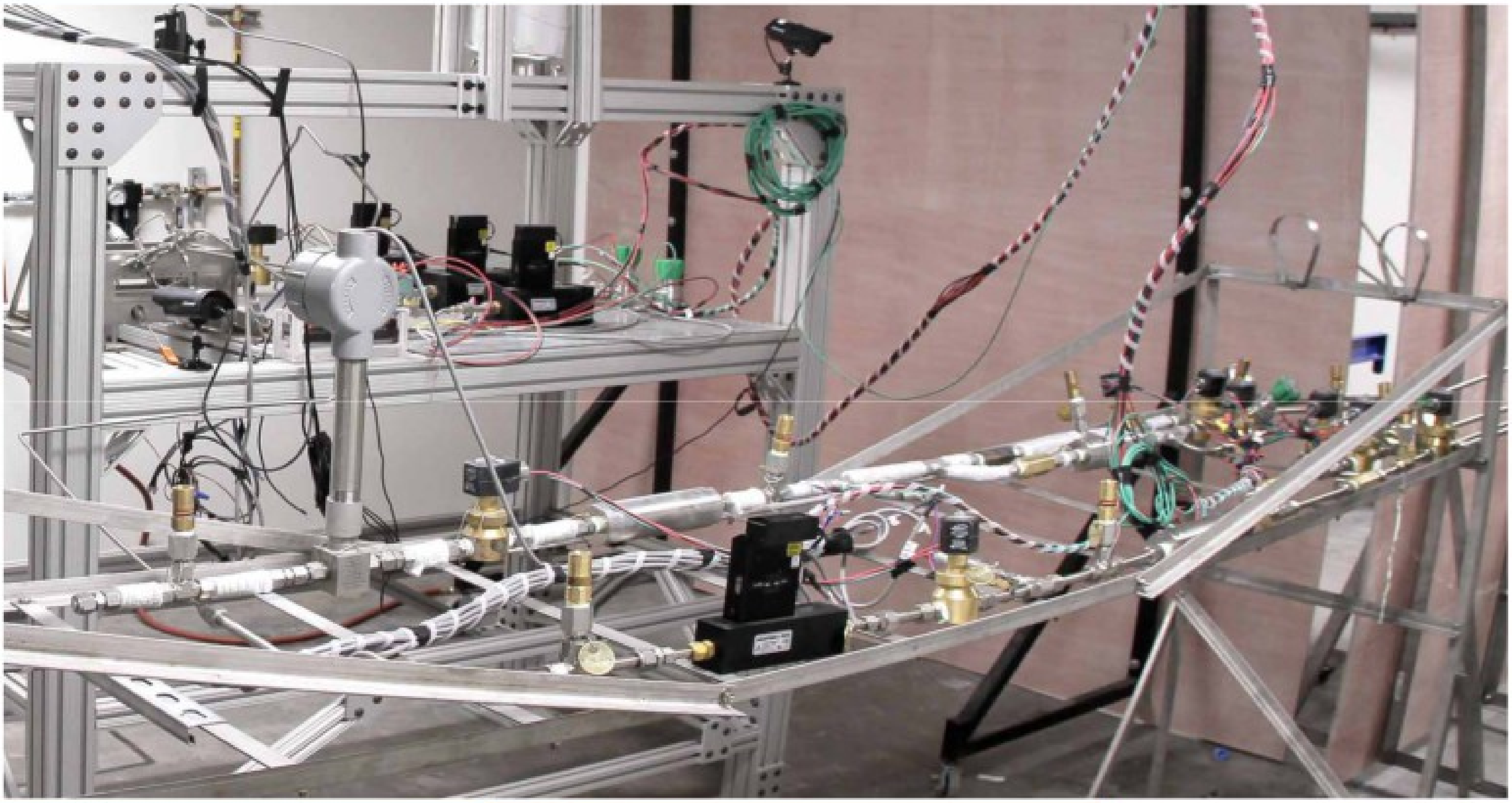

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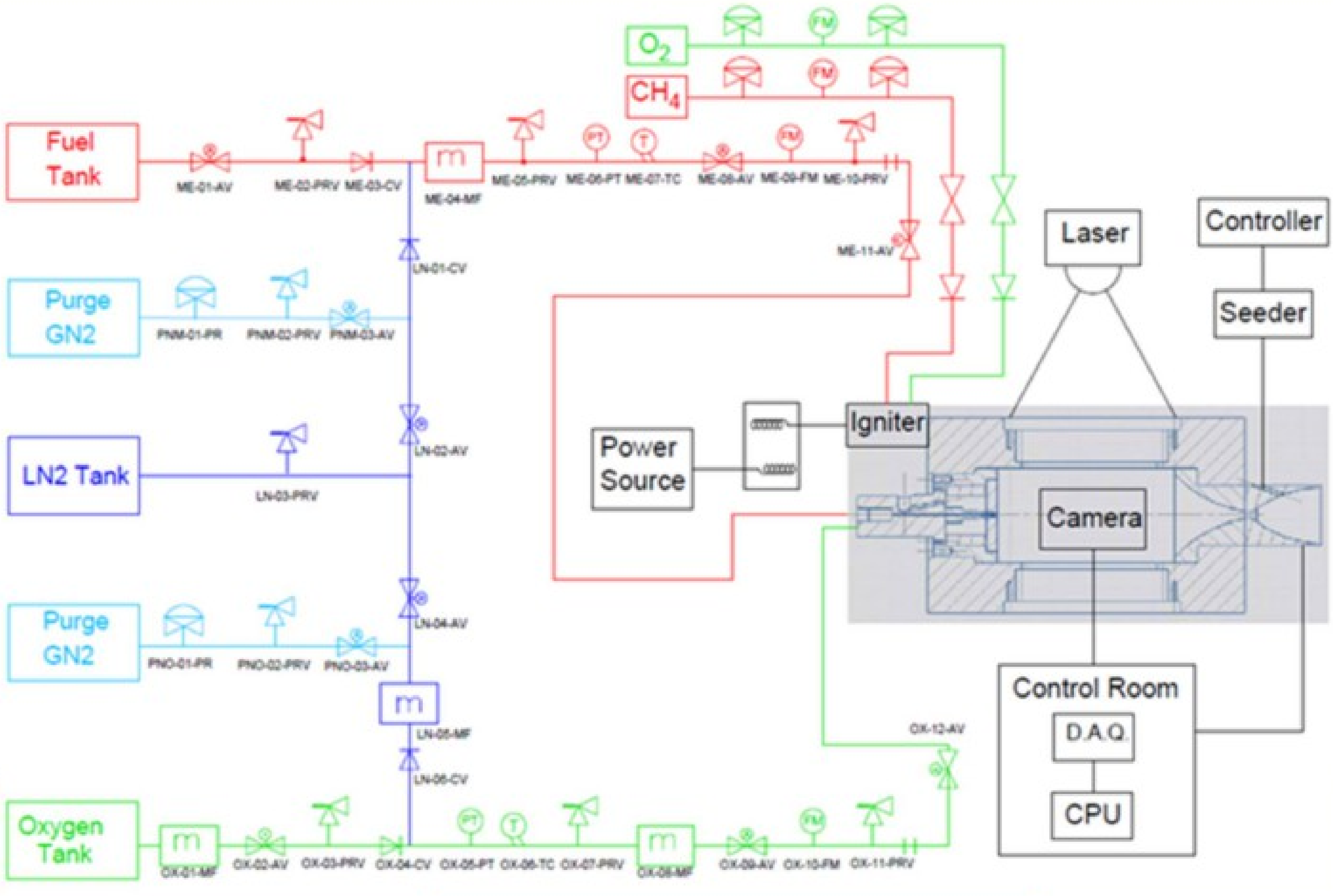

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Methane & Oxygen Test Control Parameter Matrix

Test #	Oxygen to fuel ratio (O/F)	Oxygen mass flow rate (Kg/s)	Methane mass flow rate (Kg/s)
1	3.5	$2.8 * 10^{-4}$	$0.8 * 10^{-4}$
2	3.5	$5.6 * 10^{-4}$	$1.6 * 10^{-4}$
3	3.5	$11.3 * 10^{-4}$	$3.2 * 10^{-4}$

Results

Test #	Exit Mach number	Exit Gas Velocity (m/s)	Exit Temperature (K)
1	0.25	275	3013
2	0.35	386	3008
3	0.50	537	2999

Note: Stoichiometric oxygen to methane ratio is 4.0

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Test 1

Test 2

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Year 3 Plan

- Laser Diagnostics (2D-PIV Study): June 1
- Coatings and Characterization: July 1
- Optimizations: Dec 1

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Hazards overview

HA #	System	Hazard	Severity	Likehood	HA Index	Mitigation
1	HVOF	Fire	3-Significant	2-Infrequent	2	Separation of propellants
2	HVOF	Asphyxiation	3-Significant	2-Infrequent	2	Proper ventilation system
3	HVOF	Over Pressure	2-Moderate	1-Unlikely	1	Installing pressure relief valves
4	HVOF	Kerosene spill	2-Moderate	1-Unlikely	1	Proper ventilation and diking system

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- ## Students
  - Luisa Cabrera (MS Student/ PhD Student)
  - Diaaeldin M (PhD Student)
- ## Publications

- Luisa A. Cabrera, Diaaeldin M, Norman Love and Ahsan Choudhuri, " High Velocity Oxy-Fuel Thermal Spraying Techniques: A review," 3rd Southwest Energy Science and Engineering Symposium, April 27, 2013, El Paso, Texas, USA.

- Diaaeldin M, Luisa A. Cabrera, Norman Love and Ahsan Choudhuri, " High Velocity Oxy-Fuel Thermal Spray Gun Design," AIAA SciTech 2014, Jan 13-17, 2014, Maryland, USA

- Diaaeldin M, Luisa A. Cabrera, Norman Love and Ahsan Choudhuri, " An Experimental Study Using Particle Image Velocimetry to Characterize Flows in High Velocity Oxy-Fuel Thermal Sprays," AIAA Propulsion and Energy Forum 2014, July 28-30, 2014, Cleveland, OH, USA

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Thank you