Oxy-Fuel sCO2 Cycle Injector Design & LH_2 Facility Design

UTSR 2017 Gas Turbine Industrial Fellowship Program

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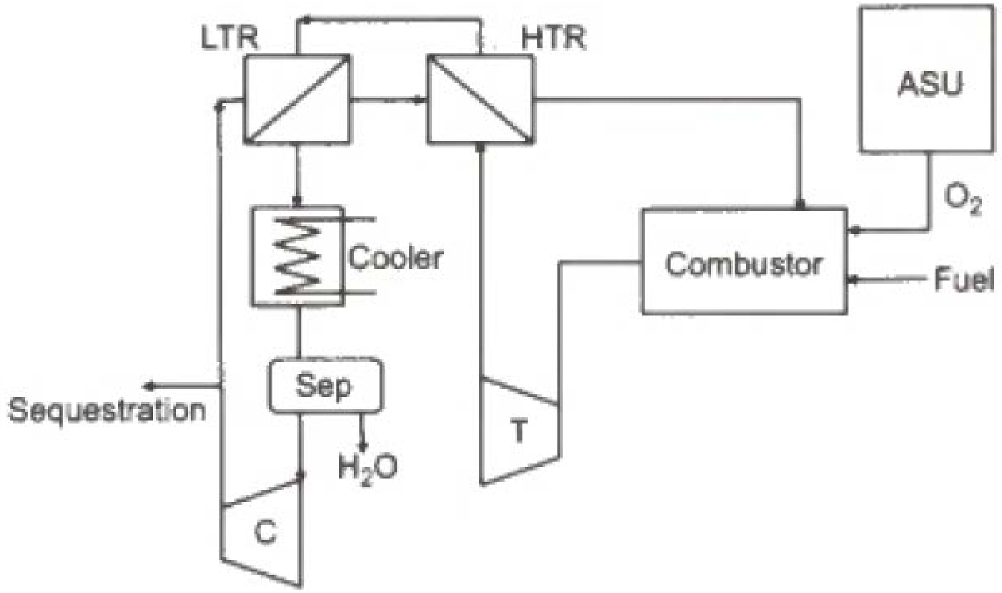
Introduction

- Southwest Research Institute is an independent, non-profit research company whose expertise spans a wide range of technologies.
- Div. 18 Mechanical Engineering
  - Fluid & Rotating Machinery
    - Performs combustion, flow and rotary testing.
    - Owns and operates a 10MW scale sCO_2 demonstration loop

Supercritical CO_2 Brayton Cycle

- Similar to Brayton (Gas Turbine) and Rankine (Steam Turbine) power cycles commonly employed for power generation
- Supercritical CO_2 as a working fluid provides a number of advantages
  - Theoretical efficiencies much greater than traditional Rankine cycle
  - Flow components approx. ten times smaller



- Direct-Fire (combustion within the working fluid, as in a gas turbine) possible, allowing greater efficiency, and direct carbon sequestration
- See cycle process diagram, left

Objective

- Injector Design for Direct-fire sCO2 Combustor
  - One of the main goals of the fellowship was to design an injector for the inlet of oxygen, methane and carbon dioxide to combustor.
  - Main purpose of the design was for numerical flow simulation to assist in combustor development.
- Combustor window design
  - An objective of the proposed combustor was to provide optical access to the flame for analysis. Required access fom 3 sides.
  - 3-walled combustor (consisting of 2 inner liners and a pressure container) required 3 window designs.
- LH_2 Facility Component Specification
  - Planning of facility to test components of a liquid hydrogen transfer system

Injector Design

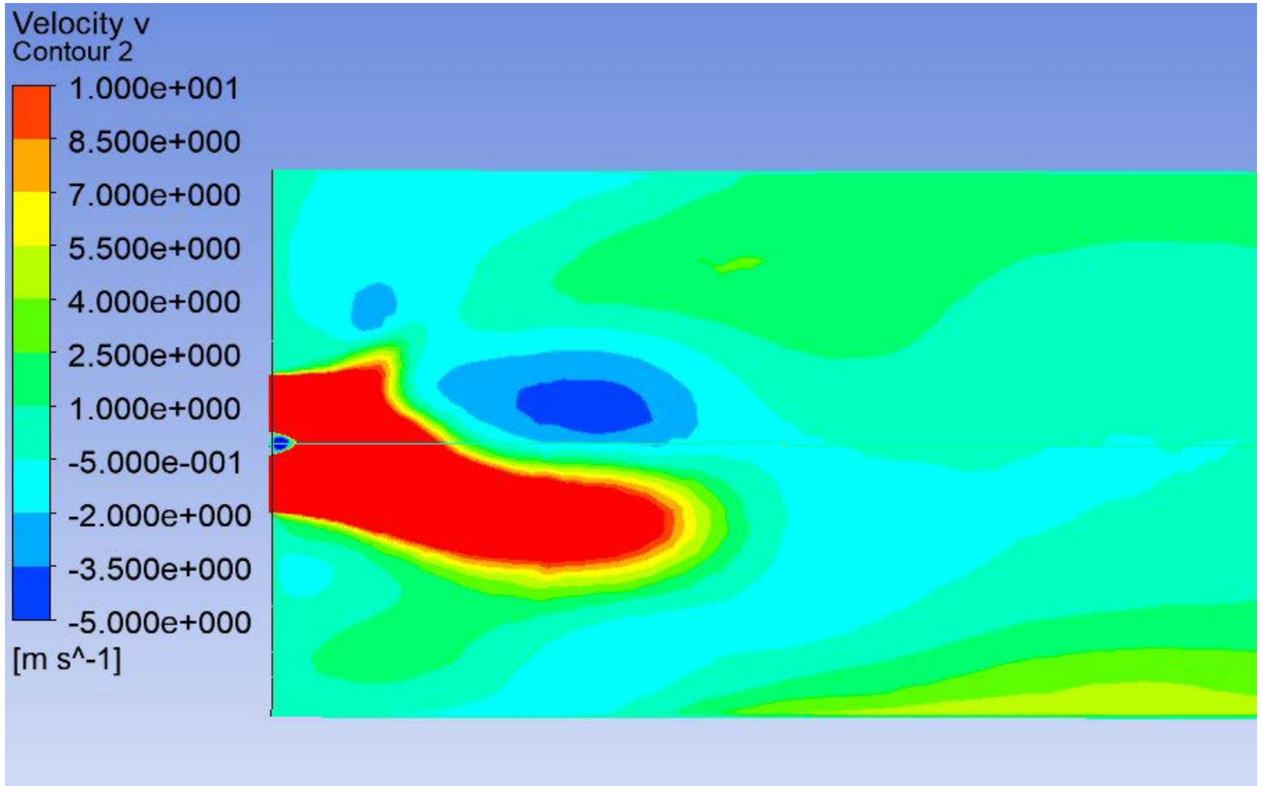
- Injection of dilute Oxygen in sCO_2 and methane into combustor
- Swirl Stabilized Combustor
    - Central recirculation zone anchors flame in the combustor
    - Swirl Number (S) is a measurement of the swirl intensity
        - Ratio of tangent to axial momentum flux
        - Most practical combustors S = 0.6 - 1.5
        - S approx. for straight-vane swirler:

$$S = \frac{2}{3}\frac{[1-(d_h/d)^3]}{[1-(d_h/d)^2]}tan\phi$$

    - Multiple injector geometries produced
    - Final Specifications: 25m/s injection velocity, S=1

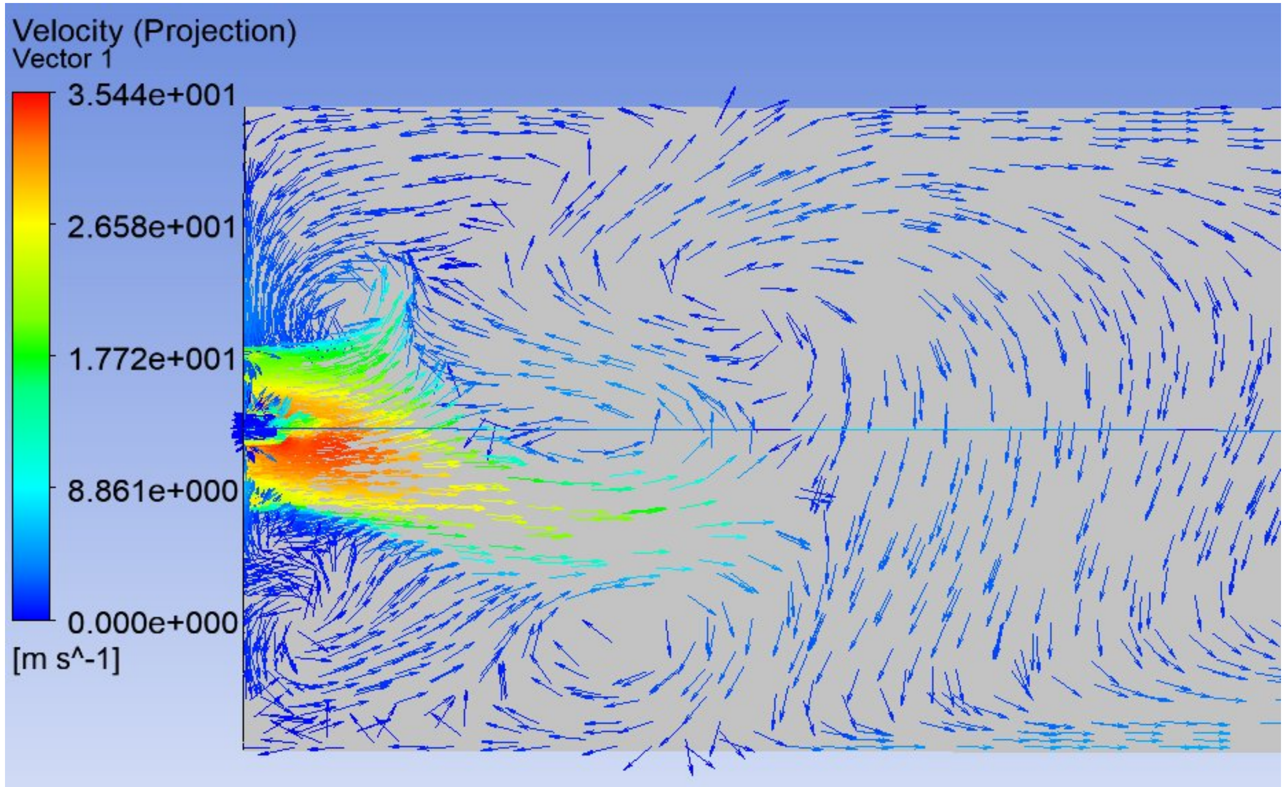
Flow Simulation

- FLUENT simulation
  - Transient solution required for convergence
  - Strong recirculation zone between two jet diameters downstream



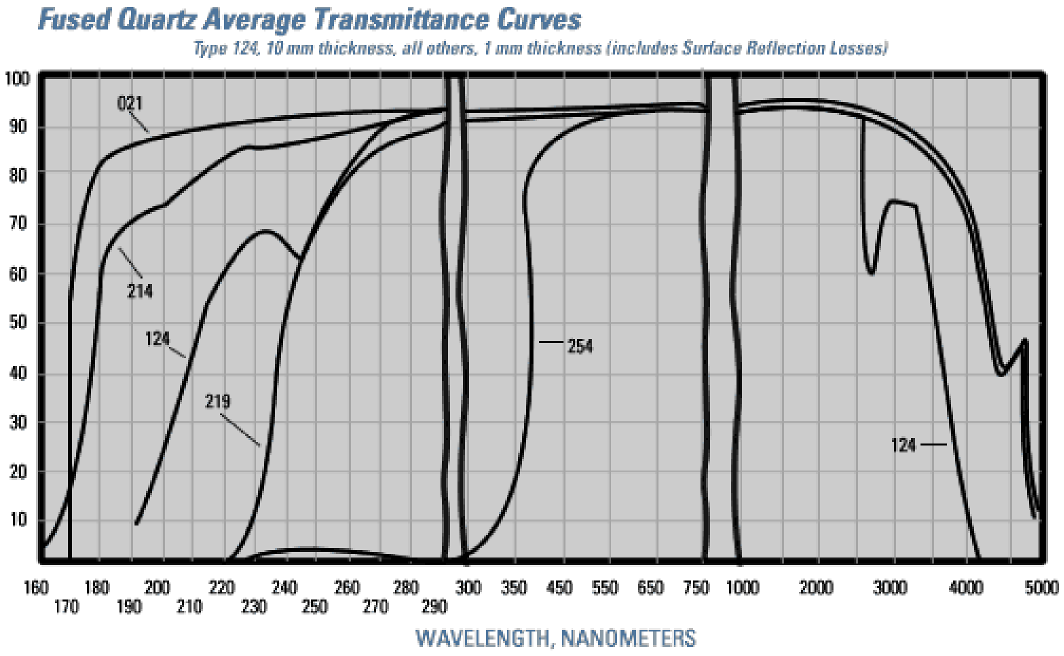
Flow Simulation

- Precessing Toroidal Recirculation Zone
  - Recirculation biased to one side of combustor, but rotates about central axis in time.



Combustor Windows

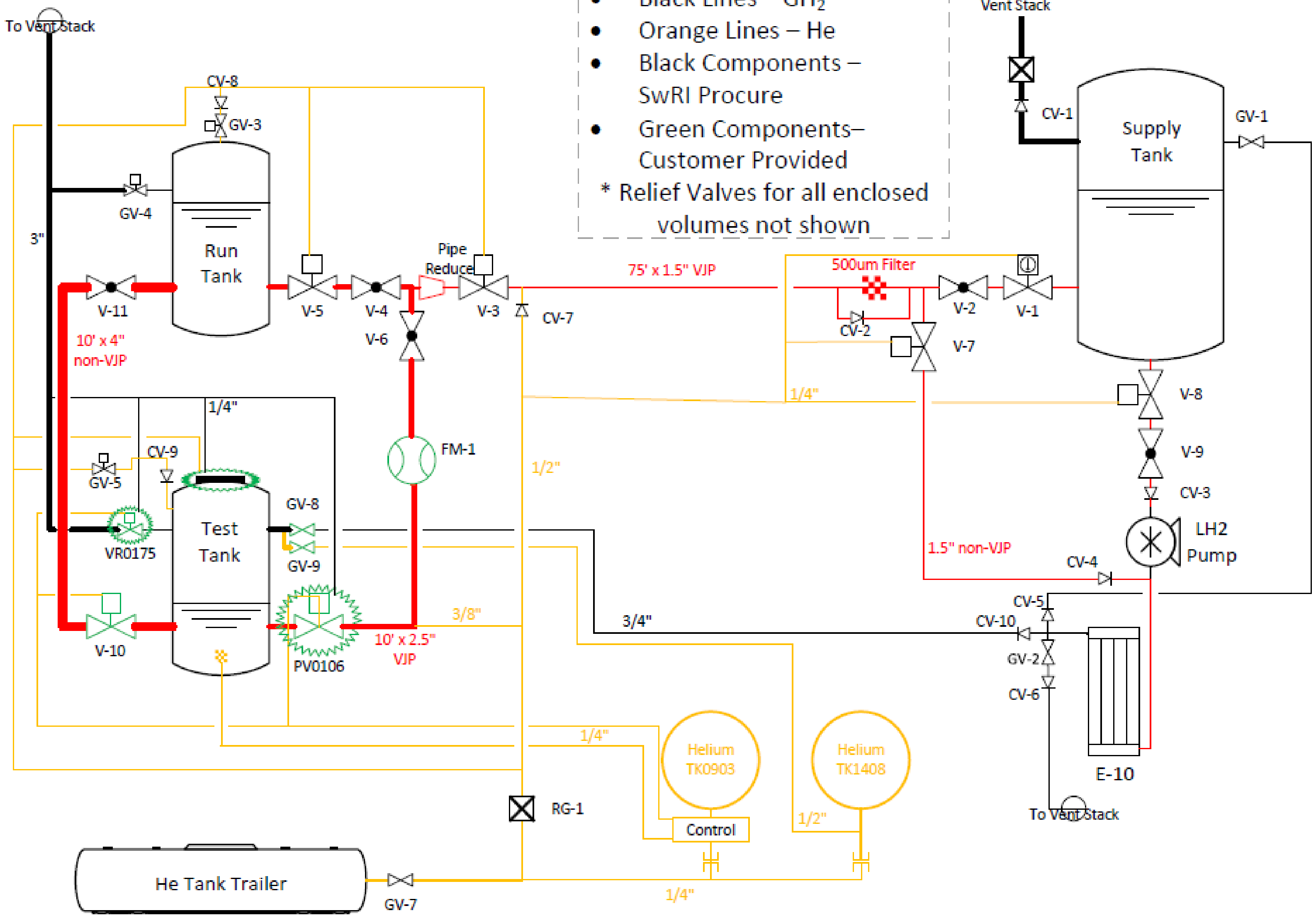
- The cylindrical combustor contsists of three layers, which all must be transparent to obtain optical access
  - Full cylindrical transparent section for innermost liner, flat windows for outer
  - Pressure rated site glass for outermost pressure container.
- Window material selection to obtain transparency up to 4000nm (mid-IR)



Liquid Hydrogen Test Facility

- Planning for new LH_2 Facility included:
  - Specification of system components for LH_2, gaseous H_2, and He.
    - Line sizing for flowrates, tank sizing, insulation
  - Data acquisition
  - Power requirements for backup systems
  - Fire and safety code compliance, siting restrictions.

Facility P&ID



Color Code:
- Red Lines – LH_2
- Black Lines – GH_2
- Orange Lines – He
- Black Components – SwRI Procure
- Green Components– Customer Provided

* Relief Valves for all enclosed volumes not shown

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