Technology Demonstration of a High Pressure Swirl Oxy-Coal Combustor

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KEY TECHNOLOGICAL CHALLENGES

- Oxy-combustion produces higher flame temperatures compared to air-combustion
- High pressure and relatively low temperature environments may result in a negative pressure dependence of the mass burning rate
- Current studies limited to atmospheric conditions

PROJECT OBJECTIVES

Objective 1: Systems Configuration Analysis of a 1 MW_{th} Pressurized Oxy-Coal Swirl Combustor [Project Year:1]

- Task 1.1: Systems analysis
- Task 1.2. Systems engineering design and evaluations
- Task 1.3: TRL and technology gap analysis

Objective 2: Design Analysis and Modeling of the Proposed Pressurized Oxy-Fuel Combustor [Project Years:1-2]

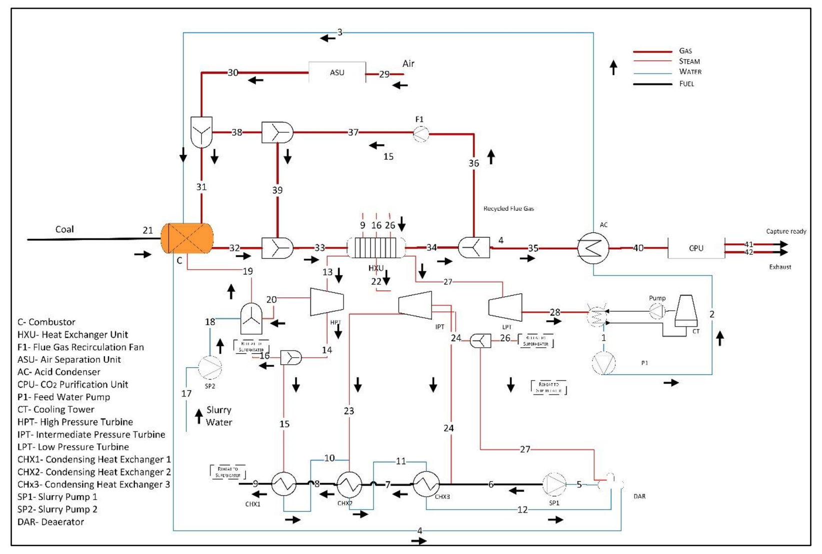
- Task 2.1: Definition of system level technical specifications and operating conditions
- Task 2.2: Preliminary configurational design and feasibility analysis
- Task 2.3: Detailed component development and design analysis
- Task 2.4: Preliminary component procurement plan and design documentation
- Task 2.5: Fabrications of combustor components, testing and assembly and integrations of subsystems

Objective 3: Test of the Combustor Performance and Operability [Project Years:2-3]

- Task 3.1: Combustor shake-down experimentations
- Task 3.2: Systematically characterize flame stability and pollutant emission characteristics
- Task 3.3: System analysis with realistic combustor output conditions incorporating experimentally determined combustor characteristics

OBJECTIVE 1: SYSTEMS CONFIGURATION ANALYSIS OF A 1 MW_{TH} PRESSURIZED OXY-COAL SWIRL COMBUSTOR

ENEL



TIPS

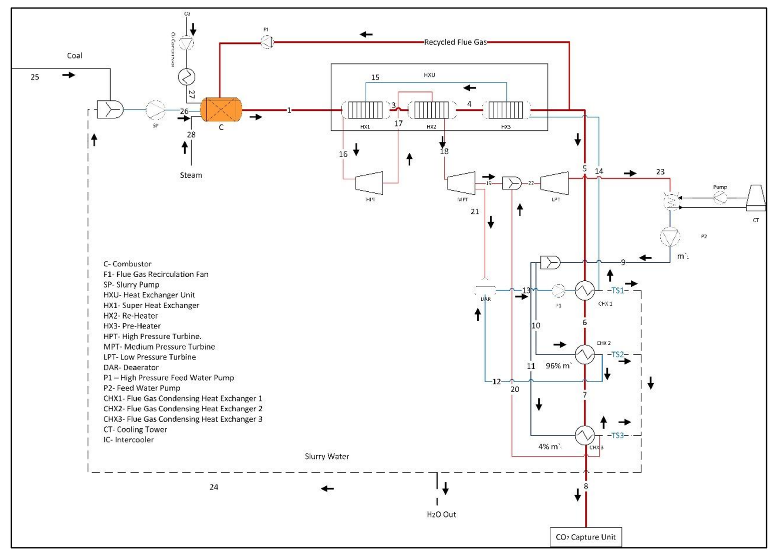


Table 1: Cycle analysis parameters [3-4]

	O_2 (vol %)	CO_2 (vol %)	CO_2 Flowrate (kg/s)	Flame Temperature (°C)
Case 1	28%	72%	169	1400
Case 2	35%	65%	123	1495
Case 3	42%	58%	91	1650

Table 2: Coal Composition [3-4]

Moisture (wt%)(dry)	1.08	*Ultimate (wt%)(dry)*	
Proximate (wt%)(dry)		Carbon	77.81
Ash	8.86	Hydrogen	5.05
Volatile matter	35.78	Nitrogen	1.49
Fixed Carbon	55.56	Sulfur	0.95
		Ash	8.86
Heating Value (MJ/kg)	32.51	Oxygen	6.04

RESULTS AND DISCUSSION

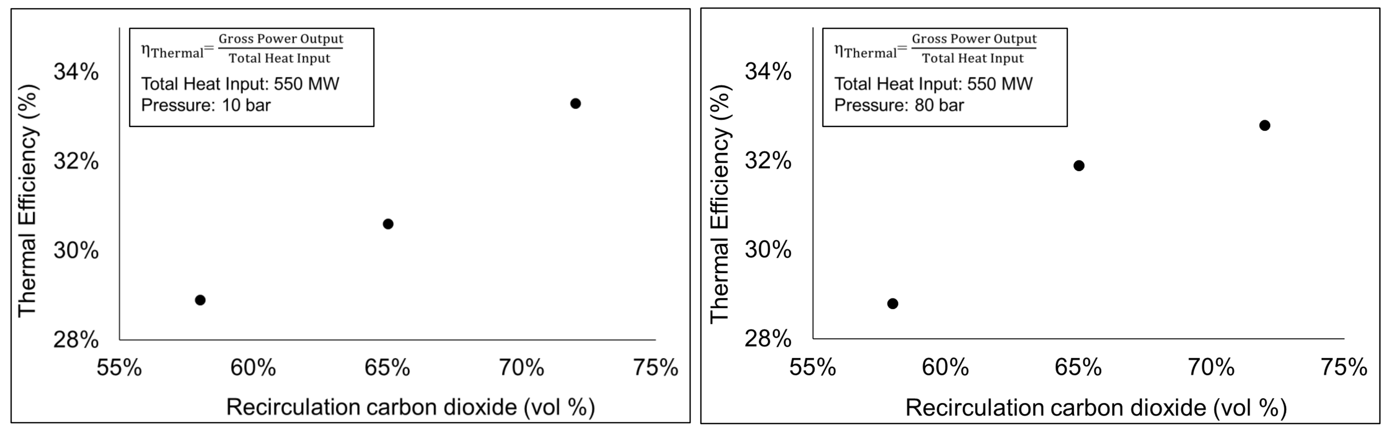


Figure 1: Thermal efficiency analysis (a) ENEL, (b) TIPS

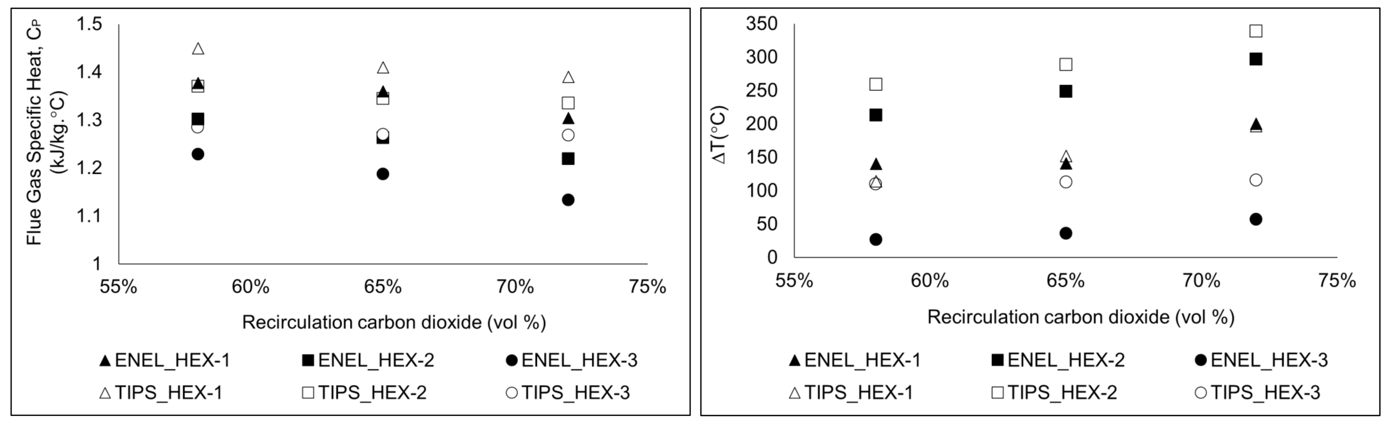


Figure 2: (a) Flue gas specific heat across the heat exchanges for different case studies, (b) Temperature gradient across the heat exchanges for different case studies

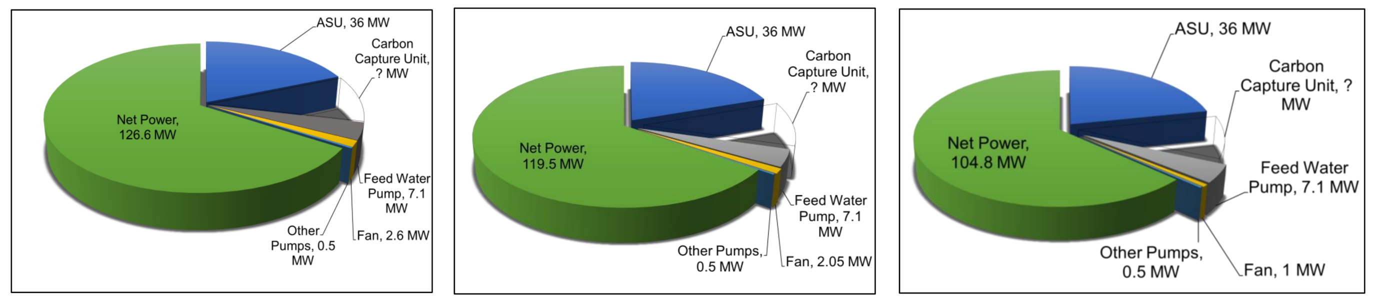


Figure 3: Power distribution of ENEL cycle (a) Case 1, (b) Case 2, (c) Case 3

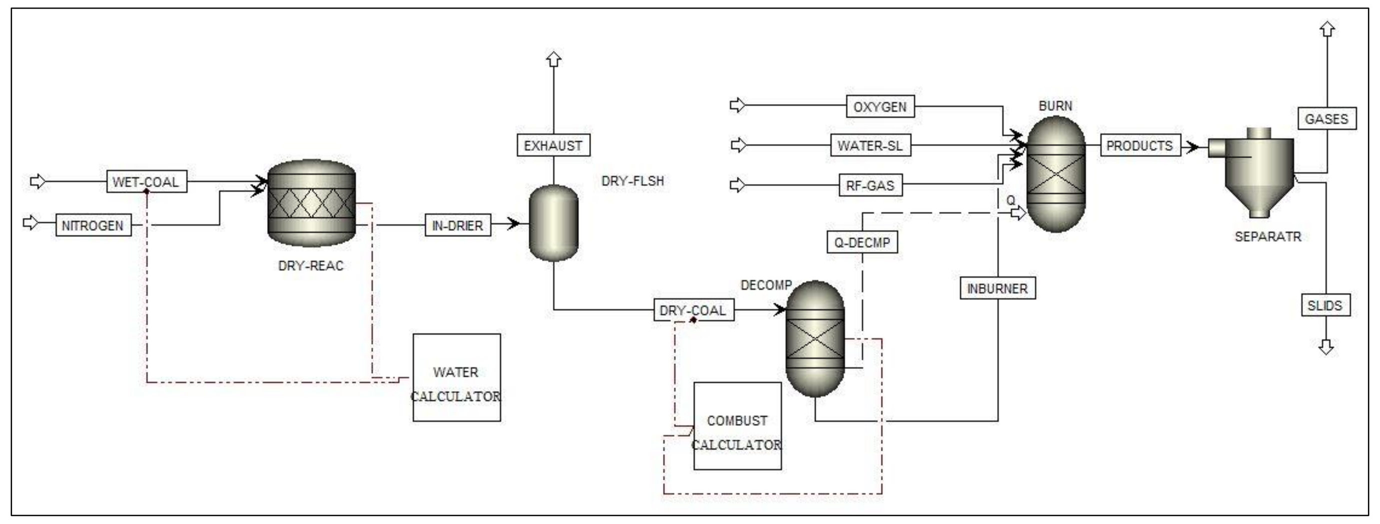


Figure 4: Oxy-coal combustor design in ASPEN Plus®

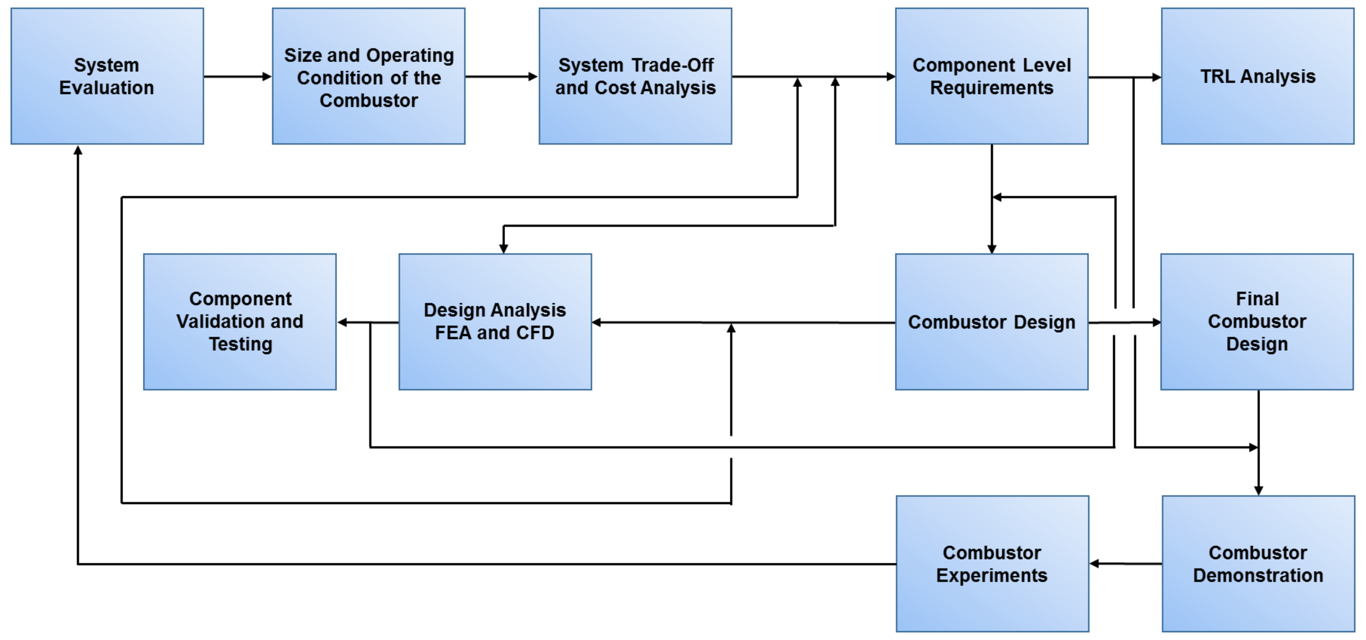


Figure 5: Technical approach

OBJECTIVE 2: DESIGN ANALYSIS AND MODELING OF THE PROPOSED PRESSURIZED OXY-FUEL COMBUSTOR

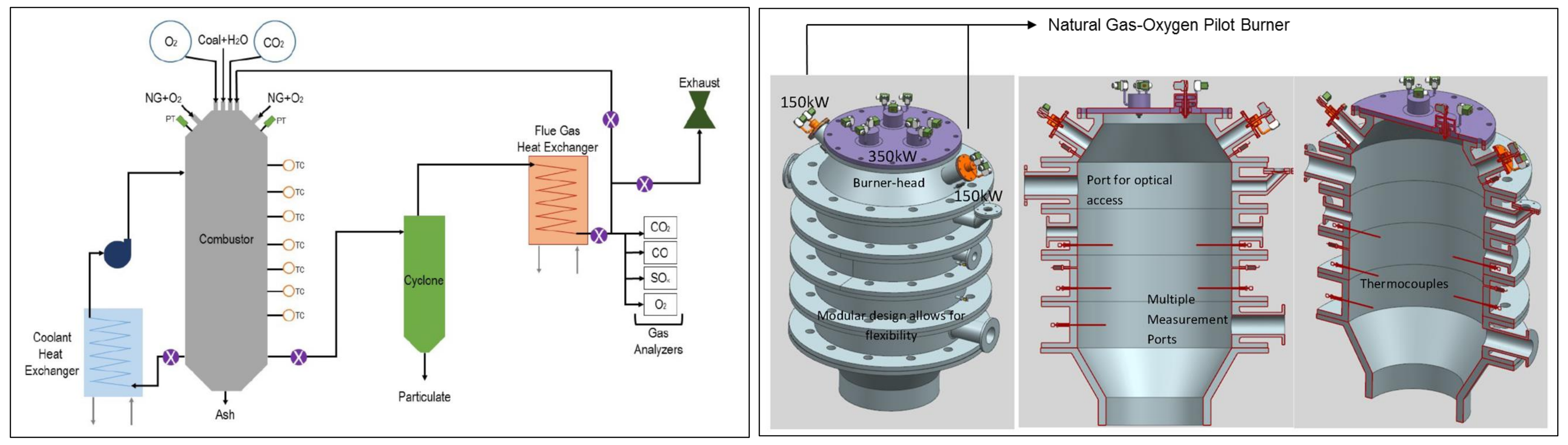


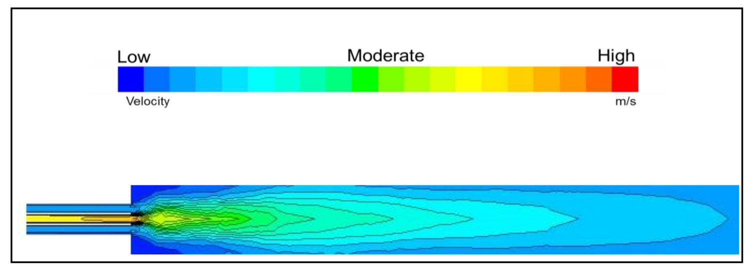
Figure 6: (a) Simplified layout of the combustor system, (b) Proposed 1 MW_{th} High Pressure Oxy-Coal combustor concept design

Pilot Burner Parameters

- Shear co-axial injection
- Oxy-methane combustion
- Operational range of firing input

Fabrication Method

- Additive Manufacturing (EBM)



Shear mixing due to momentum exchange

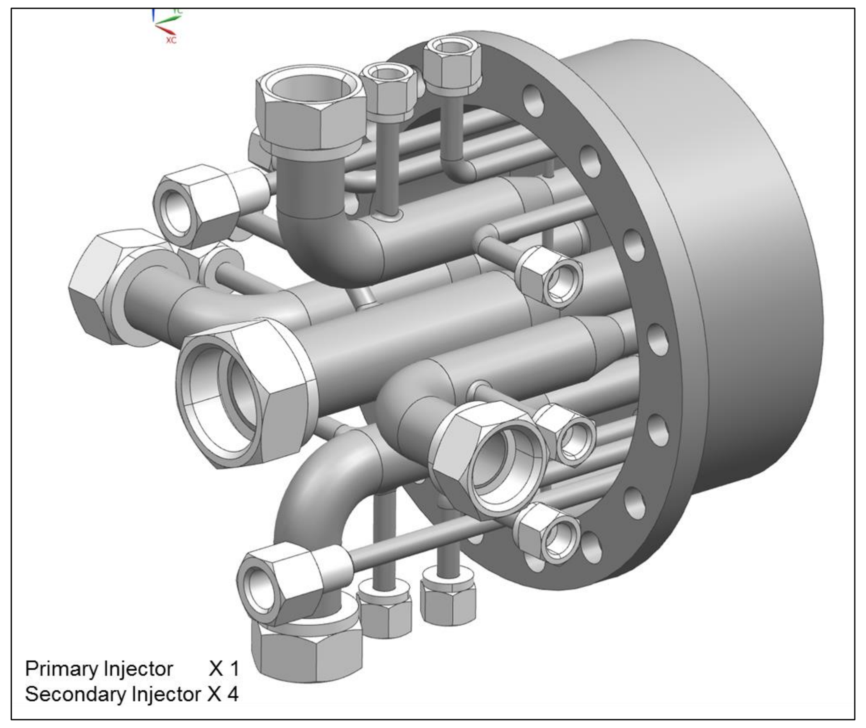


Figure 7: Pilot burner (Isometric view)

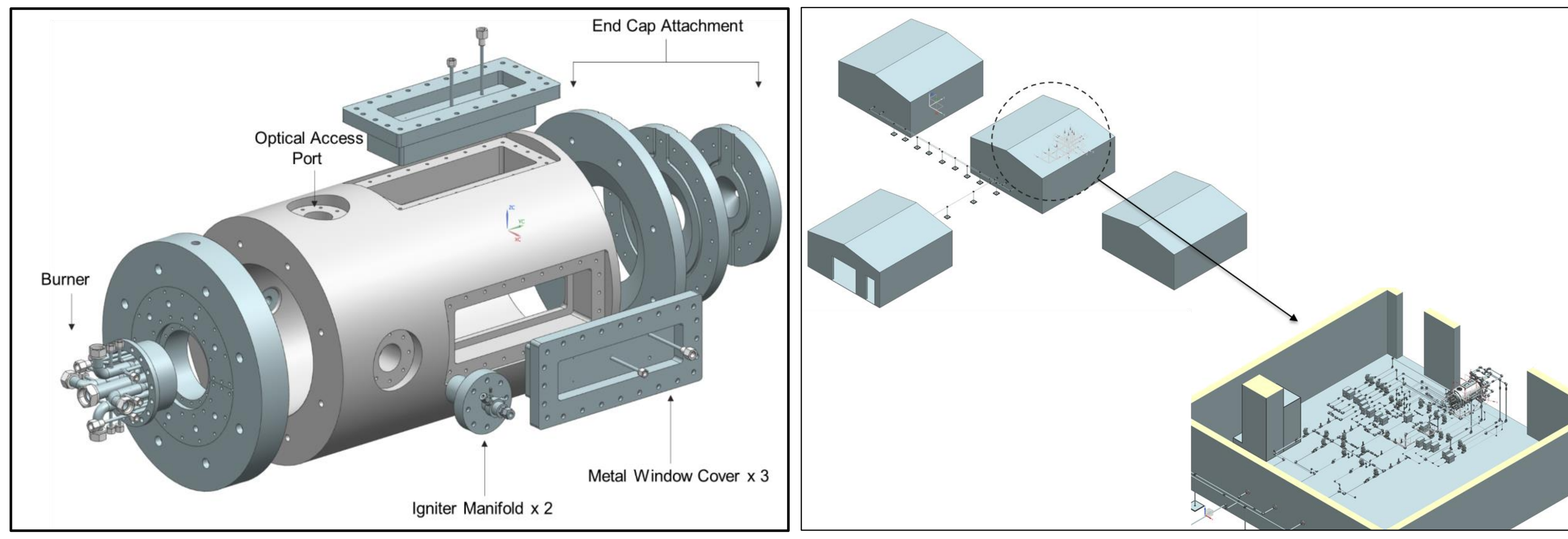


Figure 8: (a) Pilot burner test apparatus (b) Off-campus test facility at Fabens, Texas

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REFERENCES: [1] Chen, Lei, Sze Zheng Yong, and Ahmed F. Ghoniem. "Oxy-fuel combustion of pulverized coal: characterization, fundamentals, stabilization and CFD modeling." *Progress in Energy and Combustion Science* 38, no. [2] (2012): 156-214. 2U.Renz. *Investigation of a High Pressure Oxy-Coal Process.* The 7th International Symposium on Coal Combustion (ISCC), 3. Hu, Y., & Yan, J. (2012). [3] Characterization of flue gas in oxy-coal combustion processes for CO 2 capture. *Applied Energy*, *90*(1), 113-121. [4] Ghosal, S., & Self, S. A. (1995). Particle size-density relation and cenosphere content of coal fly ash. *Fuel*, *74*(4), 522-529. [5] Croiset, E., Thambimuthu, K., & Palmer, A. (2000). Coal combustion in O2/CO2 mixtures compared with air. *The Canadian Journal of Chemical Engineering*, *78*(2), 402-407. [6] Lux, J., & Haidn, O. (2009). Effect of recess in high-pressure liquid oxygen/methane coaxial injection and combustion. *Journal of Propulsion and Power*, *25*(1), 24.