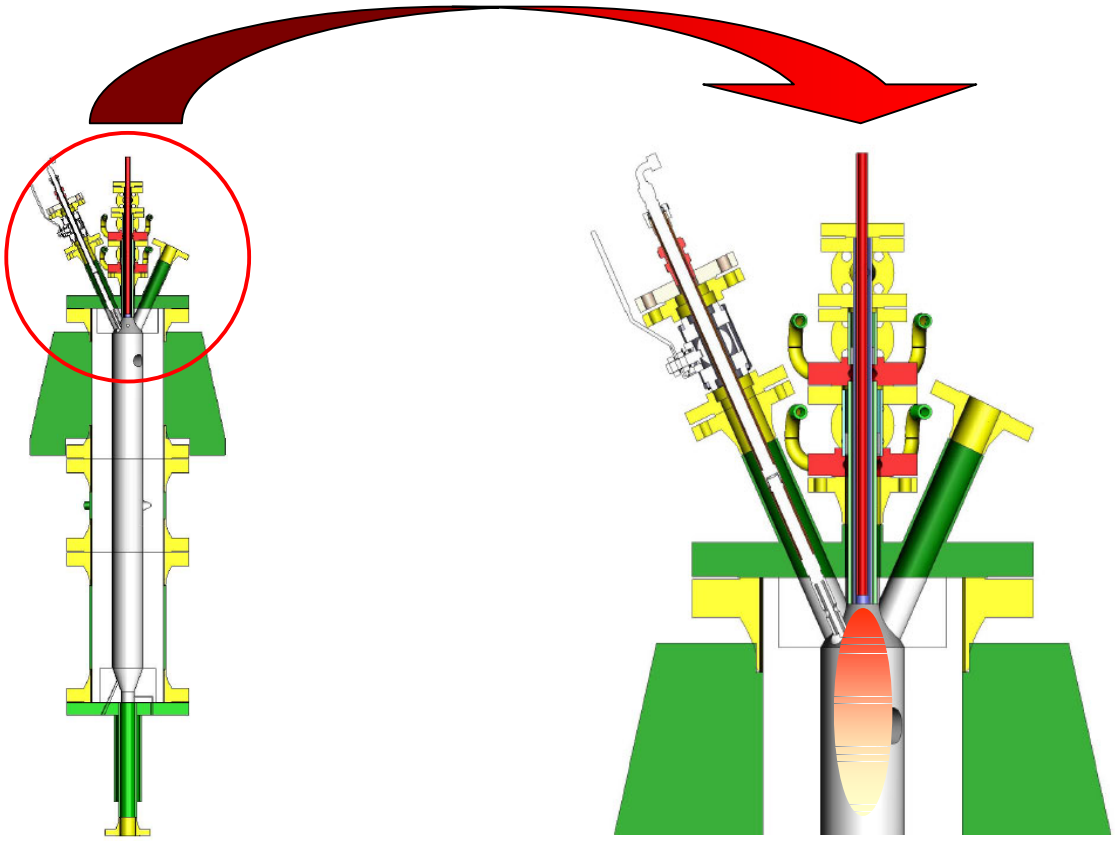
CETC-Ottawa 0.3 MWt Pressurized Slagging Entrained Flow Gasifier

Process Description



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PROCESS OVERVIEW

The entrained flow gasifier at CETC-O is capable of running dry feed or with a slurry feed. The gasifier reactor is sectional in design allowing the addition or removal of sections to investigate alternate gasifier geometries.

FEED OPTIONS

Slurry Feed

The slurry feed module is capable of delivering 40 kg/h of slurry at a solids content of up to 65%. The feed is pumped to the gasifier feed nozzle using two progressing cavity pumps. The maximum normal run time is 8 h; however, slurry can be mixed on the fly to increase run times.

Dry feed

The dry feed module is capable of delivering 3 to 20 kg/h of dry feed. The feed is conveyed to the gasifier feed nozzle pneumatically using inert gas. The maximum normal run time for dry feed at this time is 8 h.

OXYGEN SUPPLY

Oxygen is supplied by pressurized gas cylinders and is let down to 1800 kPa where it is heated by electric heaters to 150ºC or 500ºC. The oxygen is used for oxidation in the entrained flow gasifier reactor.

STEAM SUPPLY

Steam is generated at 237ºC in an electric boiler at 3000 kPa. It is then heated to 500ºC in an electric superheater. Steam is supplied to the entrained flow gasifier reactor for the gasification reaction and slurry atomization.

REACTION

The reactor operates at 1500 kPa and 1400ºC normally.

QUENCH

The entrained flow gasifier reactor effluent is cooled with quench water to 150ºC, solidifying slag, which is separated from the gas stream in the quench vessel.

GAS SCRUBBING

The syngas leaving the quench vessel is scrubbed and filtered removing any fine particles (> 3 µm) that are not separated in the quench vessel. The high-pressure syngas is let-down to atmospheric pressure after filtration.

PROCESS CONDENSATE PURIFICATION

Process water leaving the quench vessel and cyclone demister passes through bag filters to remove particulates before pressure let-down. All water is directed to a central blow-down tank (V-93). The water leaving the blow-down tank passes through activated carbon filters before being sent to the drain.

Table 1: CETC-Ottawa Entrained Flow Gasifier Reactant Specifications

Reactant	Max. Design Flow	Pressure	Temperature
Steam	60 kg/hr	Max 3000 kPa	Max: 500ºC
Oxygen	40 kg/hr	1500 kPa	Max 500ºC
Fuel			
Dry coal	20 kg/hr	1500 kPa	Ambient
Slurry	40 kg/hr	1500 kPa	Ambient
Syngas	2-2.5 kmol/hr CO + H_2 + CO_2 where CO_2 < 25 mol%[†]	1500 kPa	Max 500ºC at quench vessel inlet Max 230ºC at quench vessel outlet

[†]Syngas flow rate and composition are strongly dependent on gasifier operating conditions; syngas flow rate and CO_2 mol% are given on a dry syngas basis

Table 2: Expected Syngas Composition with Gasifier Reactor at 1400ºC; 1500 kPa w/ generic coke – dry basis as determined by CETC-Ottawa Entrained Flow Gasifier ASPEN Plus simulation

	50:50 Slurry Feed (mol%)	Entrained Feed (mol%)
CO	44%	43%
H_2	26%	19%
CO_2	22%	10%
N_2 [‡]	5%	25%
H_2S, trace, etc…	Balance	Balance

[‡] N_2 is used for sight glass purging and solids entrainment, if lower N_2 concentrations are required, N_2 can be substituted by an alternate gas.

Table 3: CETC-Ottawa Entrained Flow Gasifier Equipment Specifications

			Design		Normal Operating	
			MAWP*	Design Temperature	Pressure	Temperature
Device	Tag**	Manufacturer	kPag	ºC	kPag	ºC
Filters, Hoppers, Reactors, Tanks, and Vessels	F-81	TM Industrial	1816.4	65.6	1500	25
	F-92	Rosedale Filters	2068	148	1500	145
	F-93	Rosedale Filters	2068	148	1500	25
	R-401	Patterson Industries	1823	1800	1500	1400
	T-510	George A. Wright	101	Not specified	101	Not specified
	V-52	Crane	6700	65.6	1500	20
	V-91	All-Weld Co.	1928	237	1500	145
	V-92	All-Weld Co.	2170	232	1500	30
	V-100	George A. Wright	200	150	110	25
	V-93	Caloritech	2170	204	120	50
Heat Exchangers, Heaters	HE-94	Howard Marten Co Ltd	6893	454	6893	25
	H-300	Caloritech	3447	243	3000	237
	H-308	Caloritech	3585	621	3000	500
	H-21A1	Gaumer Process Heaters	2200	551.6	1500	300
	H-21A2	Gaumer Process Heaters	2200	551.6	1500	500
	H-21B	Gaumer Process Heaters	4466	167	1500	150
Pumps, compressors	P-152	Grundfos	3447	40	3000	20
	P-510	Moyno	1792	160	1000	20
	P-520	Viscotec	2619	200	2000	20

MAWP - Maximum Allowable Working Pressure

** See Figure 2 for tag designations.

Figure 1: CETC-Ottawa Entrained Flow Gasifier Process Flow Diagram

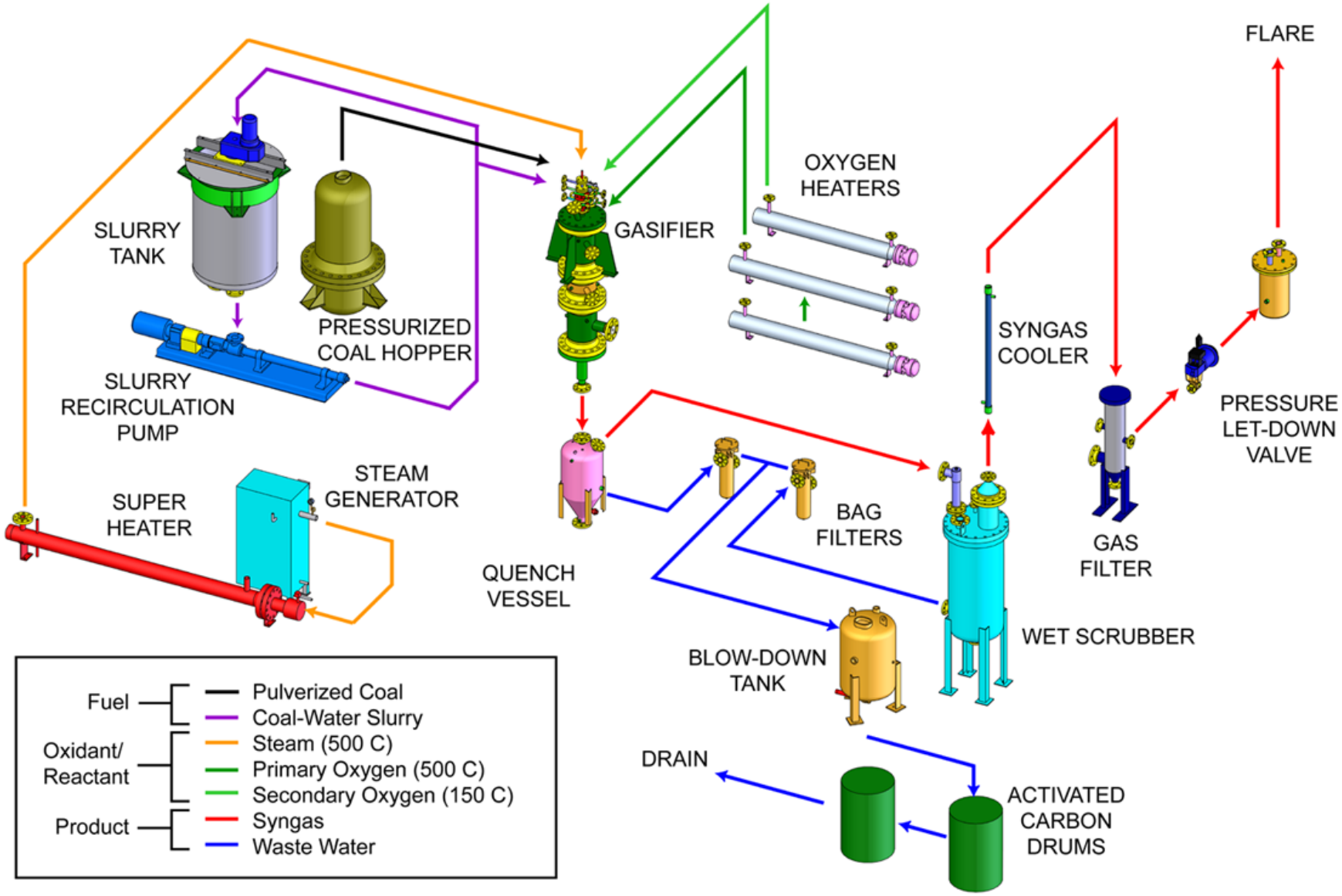
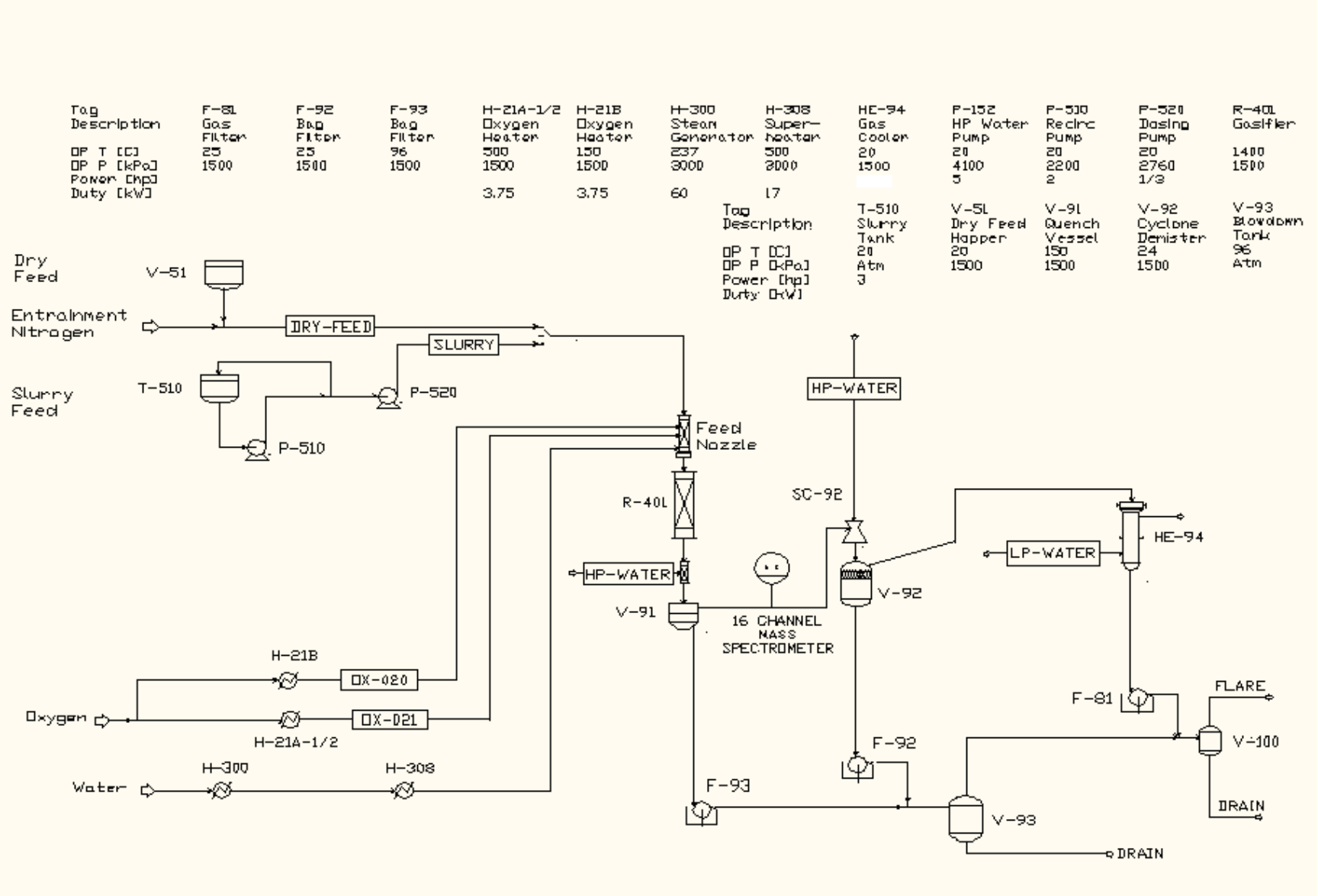


Figure 2: CETC-Ottawa Entrained Flow Gasifier Process Flow Diagram Based on ASPEN PLUS Simulation



PROCESS DESCRIPTION SIMPLIFIED

Please see Figure 1 for the gasifier process flow diagram.

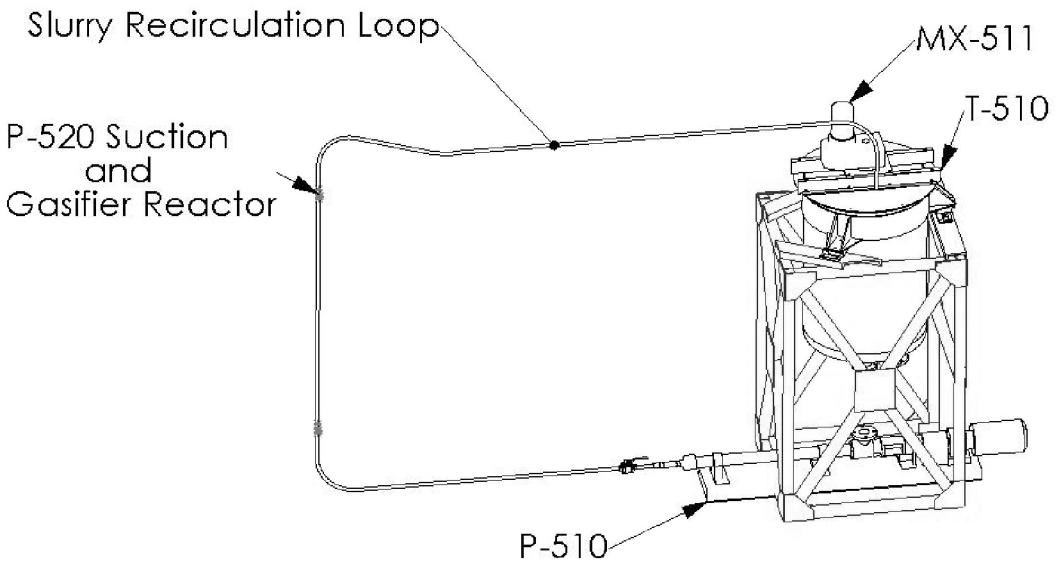
SLURRY SYSTEM

The purpose of the slurry system is to prepare and deliver a solid-liquid slurry to the gasifier burner at a pressure of 1500 kPa. The slurry will typically consist of a coal-water or petroleum coke-water mixture.

The slurry system consists of a slurry tank (T-510) with a mixer (MX-510), slurry recirculating pump (P-510) and a slurry dosing pump (P-520). Burner supply pressure is primarily controlled by the pumping rate of P-510 and P-520 and the position of PV-530 (Fetterolf valve).

The slurry tank is a SS 316 vertical vessel with a conical bottom operating at atmospheric pressure. The mixer operates at low RPM with a helical type impeller to minimize shear leading to particle size reduction and to minimize power requirements for mixing the slurry. The slurry pumps are both of the progressive cavity type. PV-530 is a Fetterolf valve with 2 manually operated rams that can independently adjust the pressure drop across the valve. PV-530 adjusts the pressure supplied to P-520 suction.

Figure 3: CETC-Ottawa Slurry Feed System

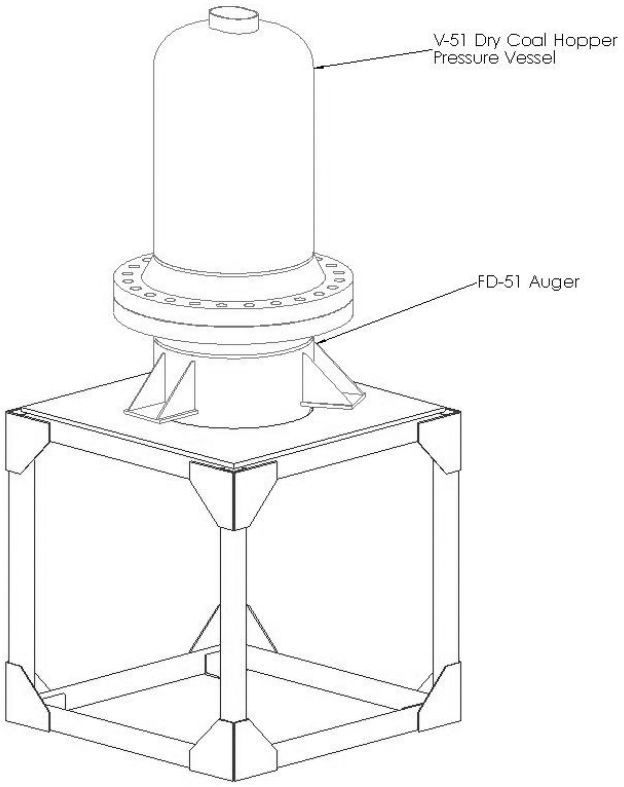


ENTRAINED COAL

The purpose of the coal entrainment system is to pneumatically convey coal from the dry feed hopper to the gasifier burner at elevated pressure.

Coal or petroleum coke is loaded into V-51A, a conical stainless steel hopper prior to gasifier start-up. V-51A is contained within the V-51 pressure vessel.

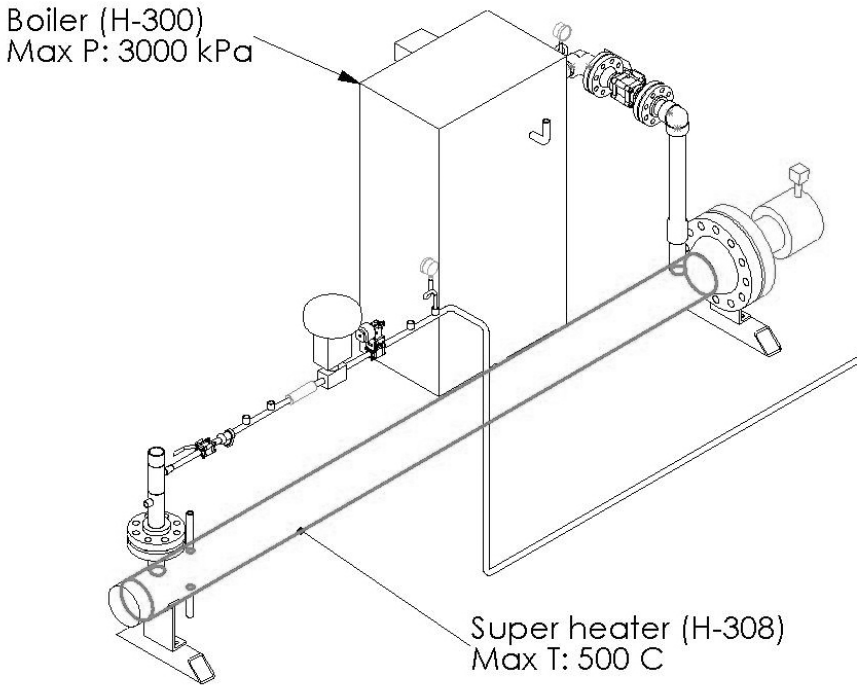
Figure 4: CETC-Ottawa Entrained Flow Gasifier Feed System



STEAM SUPPLY

Steam is generated at 237ºC in an electric boiler at 3000 kPa. It is then heated to 500ºC in an electric superheater. Steam is supplied to the entrained flow gasifier reactor for the gasification reaction and slurry atomization. Burner swirl can be modified by adjusting the ratio of tangential:axial steam supplied.

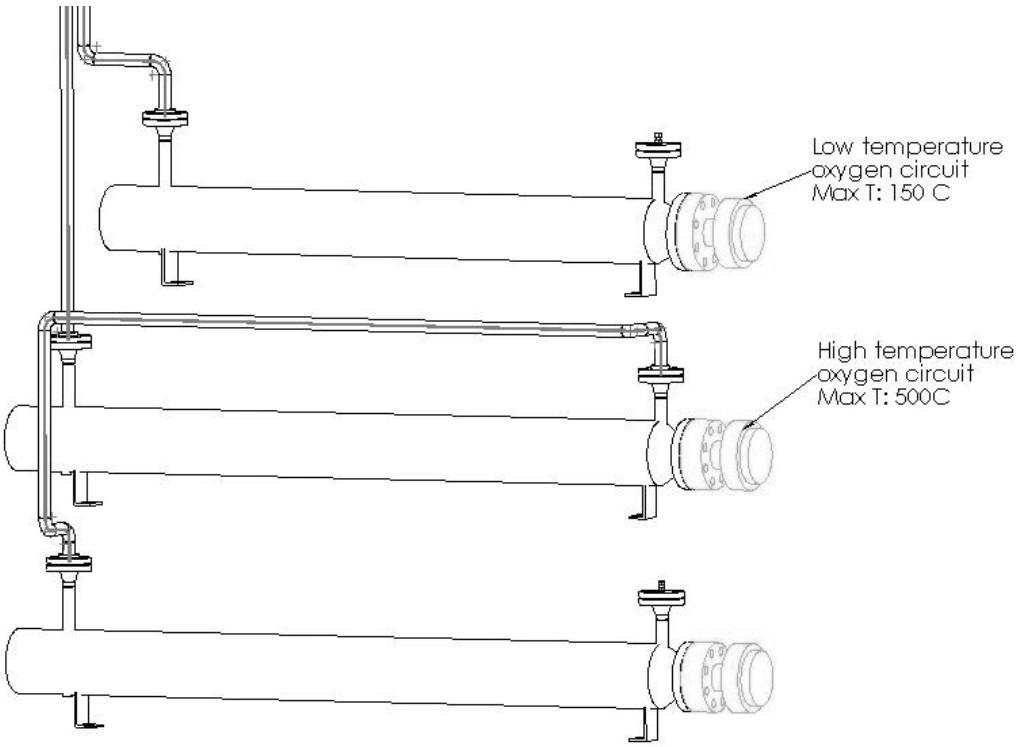
Figure 5: CETC-Ottawa Entrained Flow Gasifier Boiler (H-300) & Superheater (H-308)



OXYGEN SUPPLY

Oxygen is supplied by pressurized gas cylinders and is let down to 1800 kPa where it is heated by electric heaters to 150 ºC or 500 ºC. Oxygen is heated in the pilot plant to maximize the extent of gasification of the supplied fuel. Burner swirl can be modified by adjusting the ratio of tangential:axial oxygen supplied.

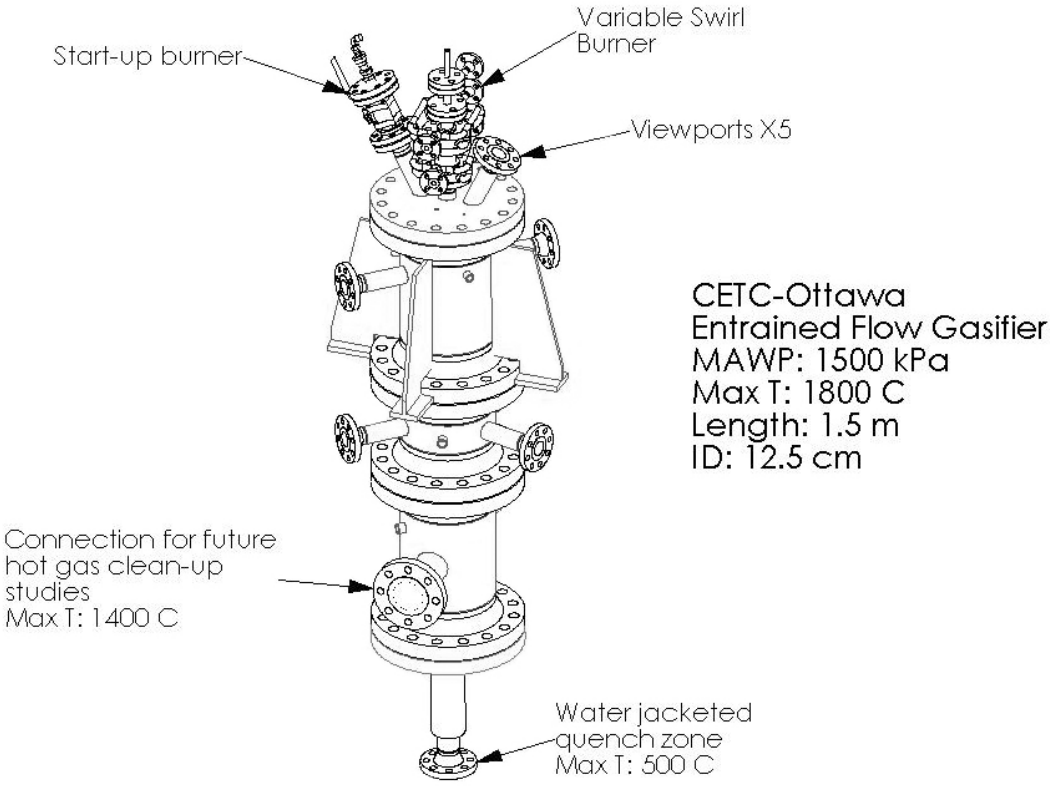
Figure 6: CETC-Ottawa Entrained Flow Gasifier Oxygen Heaters



GASIFIER REACTOR

The reactor (R-401) consists of a refractory-lined, reaction chamber (height 1.5 m, ID 12.5 cm). Oxygen and slurry feeds or oxygen, steam and dry entrained feeds are charged through the variable swirl burner into the reaction chamber where they react under highly reducing conditions to produce raw syngas and molten slag. The gasifier temperature is measured and controlled to maintain an operating temperature sufficient to convert the ash into molten slag by adjusting the oxygen-to-feed rate ratio.

Figure 7: CETC-Ottawa Entrained Flow Gasifier Reactor



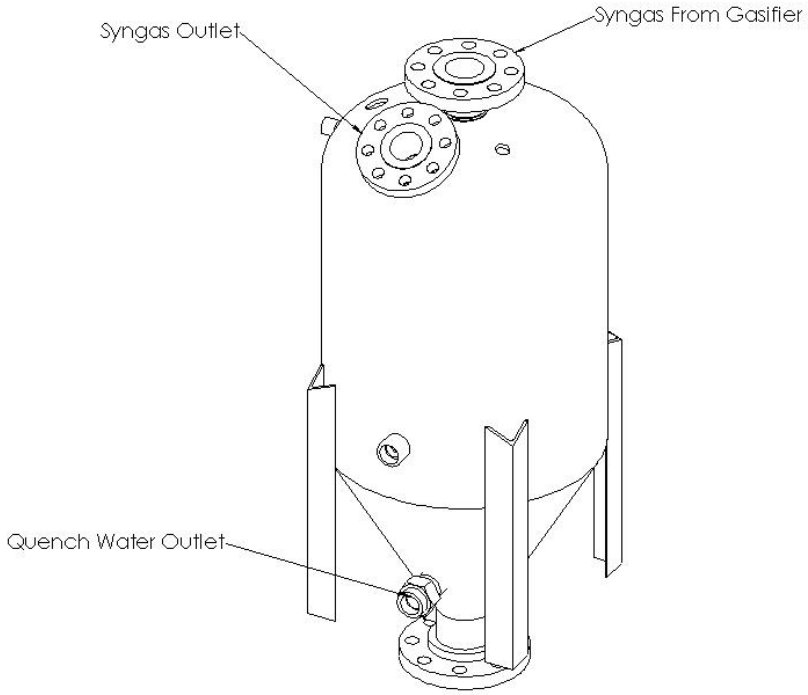
QUENCH

The purpose of the quench vessel (V-91) is to rapidly reduce the temperature of the gas and slag exiting the bottom of the reactor. In the space of a few feet, the temperature is reduced from 1400ºC to 150ºC (typically). This cooling is completed by spraying water into the gas stream between the reactor and the quench vessel. The inlet nozzle of the quench vessel extends into the vessel to force the gases to bubble through the water that is contained in the bottom of the vessel.

Gases pass out through the top of V-91 to be cleaned in the gas scrubbing section.

Water and solids leave V-91 near the bottom of the vessel. The solids are separated from the process condensate in the bag filters. Level is controlled by LV-91.

Figure 8: CETC-Ottawa Entrained Flow Gasifier Quench Vessel (V-91)

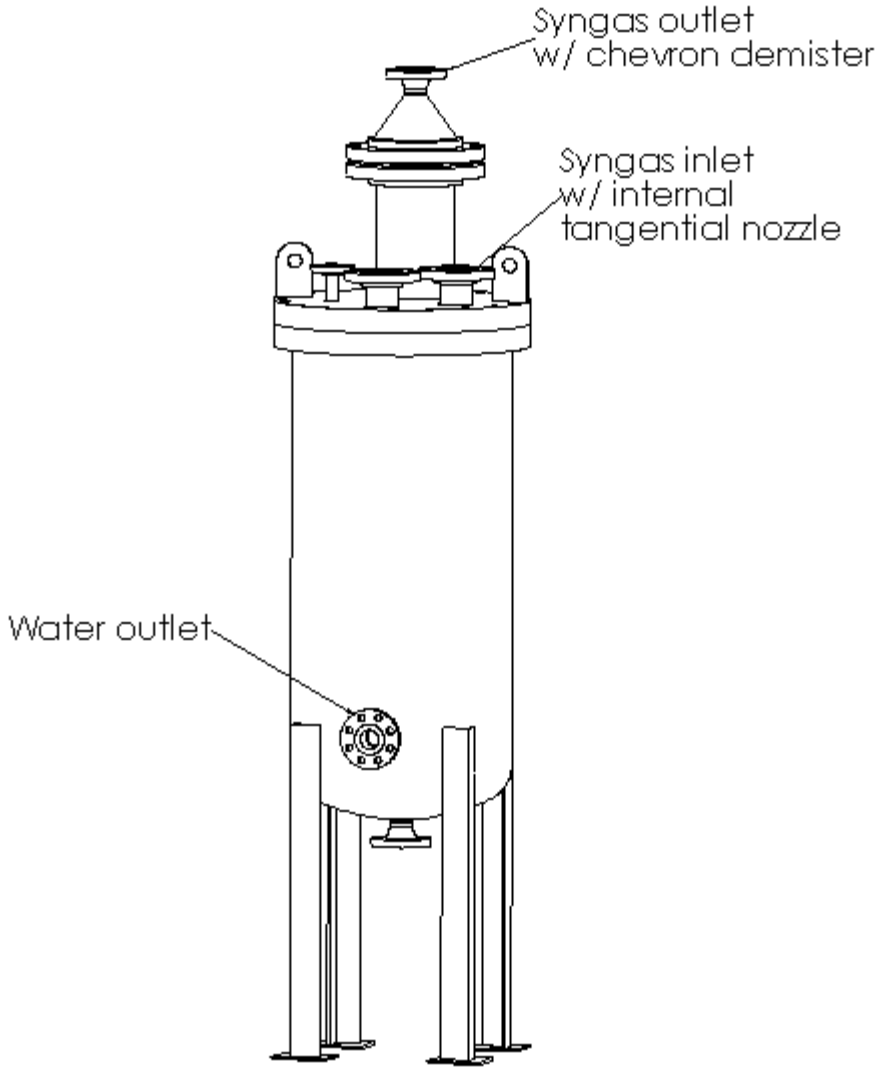


GAS SCRUBBING

The purpose of the gas scrubbing section is to remove ash entrained in the gas leaving the quench vessel and to reduce gas temperature to 25ºC.

The gas scrubbing section consists of a venturi scrubber (SC-92) and a cyclone demister (V-92). The venturi scrubber atomizes 15 L/min of water to capture particles in the gas stream. The water introduced in the scrubber is removed in the cyclone demister. The demister is a SS 316 vertical cylindrical vessel with the tangential inlet nozzle oriented to create a cyclonic effect inside the vessel improving gas/liquid separation. The outlet nozzle of the cyclone demister contains an Otto-Koch demister pad and a Flexichevron vane demister to minimize liquid entrainment in the gas stream. Liquid level is controlled by LV-92.

Figure 9: CETC-Ottawa Entrained Flow Gasifier Cyclone Demister (V-92)



HIGH PRESSURE WATER SUPPLY

High-pressure water is supplied to the quench assembly, venturi scrubber (SC-92), and (V-52) by a multi-stage centrifugal pump (P-152). A pressure regulator (PRV-152) controls the pump discharge pressure.

GAS COOLER

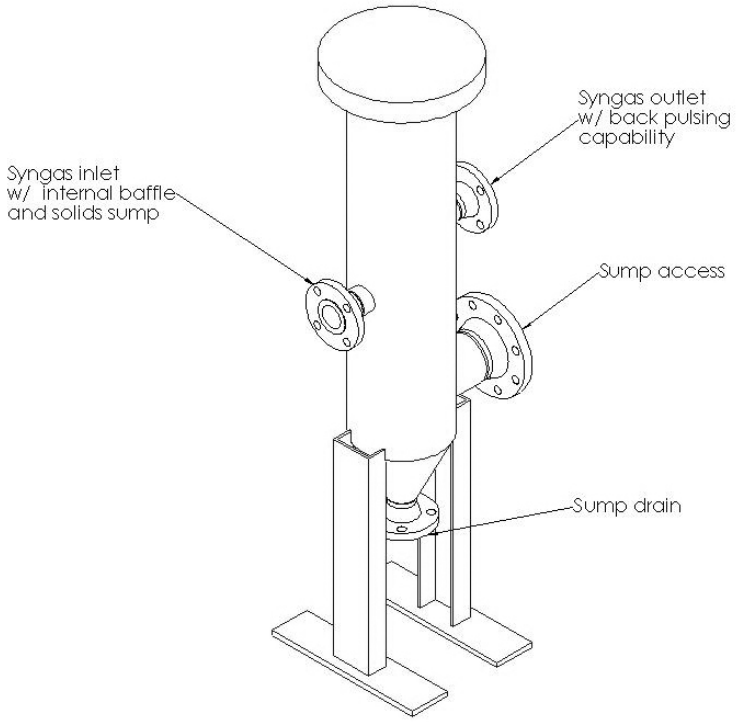
The purpose of the gas cooler (HE-94) is to cool reactor effluent in the event of a loss of the high-pressure water that is supplied to the quench assembly and venturi scrubber.

The gas cooler is a SS 316 2" tube in shell heat exchanger operated with city water supplied at low pressure.

GAS FILTER

The cool syngas passes through a 3 µm filter (F-81) to remove fine particles before pressure let-down, gas analysis, and combustion in the flare. Gas flows out, then through a polypropylene filter element. A baffle at the inlet nozzle to the filter improves gas/solids separation by preventing short-circuiting to the filter element. The gas filter can be back-pulsed to remove solids build-up on the filter. Back-pulsed solids drop to the bottom of the filter housing.

Figure 10: CETC-Ottawa Entrained Flow Gasifier Gas Filter (F-81)

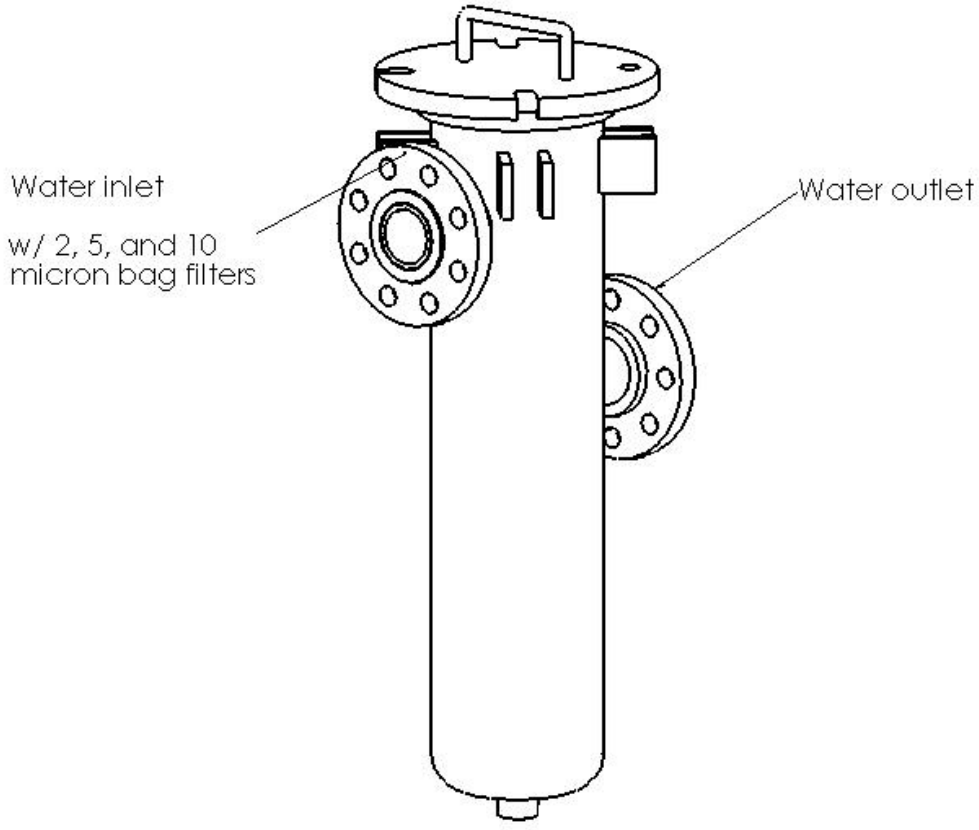


BAG FILTERS

Water phase particulates are removed in the bag filters F-92 and F-93. The particulates will be composed of both slag and char. The materials will be collected for leaching studies and closure of mass balance calculations. Unfiltered liquid enters the filter housing above the filter bag and passes downward through the filter. Solids are contained inside the bag where they are easily removed when the unit is serviced.

Fluid bypass around the basket is prevented because the outside diameter of the bag filter seals against the housing inside diameter. Generally, the bags will use one of 3 filters – they are rated at 2, 5, and 10 µm. Larger filter ratings are available if needed. The filters are Rosedale filter #6-18-2F3-300-S316-0.

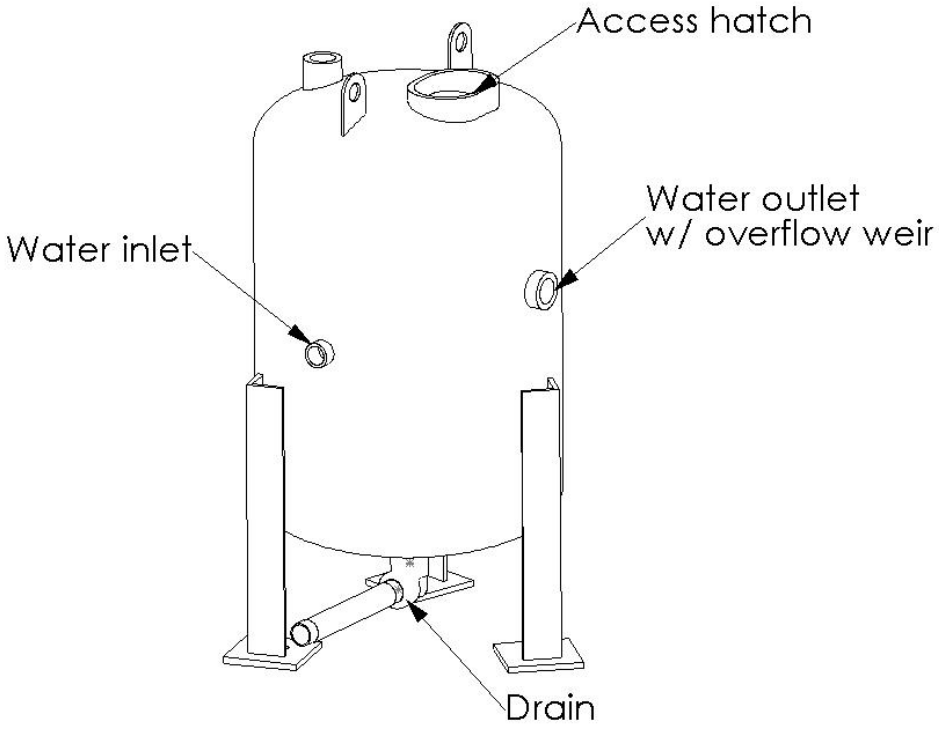
Figure 11: CETC-Ottawa Entrained Flow Gasifier Bag Filters (F-92 & F-93)



BLOW-DOWN TANK

All water in the system is directed to the blow-down tank (V-93) for surge control prior to disposal. The blow-down tank is a carbon steel, vertical, cylindrical vessel. An overflow weir maintains liquid level in the blow-down tank.

Figure 12: CETC-Ottawa Entrained Flow Gasifier Blow-down Tank



FLARE

Syngas is combusted by the flare for safe disposal.

PROCESS CONTROL & GAS ANALYSIS

Gasifier control and data acquisition are performed using Freelance 2000 software from ABB. The system is a fully functional and expandable 3rd generation distributed control system used widely in industry. All major systems are automatically controlled.

Advanced process control schemes can be tested and verified using 3rd party software integrated with the gasifier control system using the DDE (dynamic data exchange) protocol or OPC - an industrial process control protocol based on Windows object linking & embedding.

Flow rates of O_2, H_2O, and N_2 entering the reactor are monitored using mass flow meters. Flow of slurry and dry coal are monitored through loss-in-weight scales.

Product gas analyses are performed using a Hamilton & Sundstrand mass spectrometer (MGA 1600ES) capable of measuring concentrations of up to 16 chemical species at a sampling interval of 20 seconds.

ELECTRICAL

Electrical hook-up is available at 600 V, 208 V, and 110 V.

COMPRESSED AIR & INSTRUMENT AIR

Compressed air is shared among three separate pilot-plant facilities. Air is available at 30 scfm @ 100 psi. Available flow may be reduced if other users are utilizing the air system.