Performance Testing of a Moving-Bed Gasifier Using Coal, Biomass, and Waste Plastic Blends to Generate White Hydrogen

FY23 FECM Spring R&D Project Review Mtg

Award Number: DE-FE0032044

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Project Objectives

- Qualify coal, biomass, and plastic waste blends based on performance testing of selected pellet recipes in a laboratory-scale updraft moving-bed gasifier
- Testing will provide relevant data to advance the commercial-scale design of the moving-bed gasifier to use these feedstocks to produce hydrogen
- Effects of the waste plastics on feedstock preparation (i.e., blending and pelletizing) and the resulting products (i.e., syngas compositions, organic condensate production, and ash characteristics) will be a focus

Funding: $625k ($500k gov't, $125k cost share)

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Project Team Organizations

EPRI	• Prime, lead organization, overall project management, and administration (Task 1) • Leading Test Plan Development (Task 3) • Key personnel – George Booras and Horst Hack
Hamilton Maurer International, Inc. (HMI)	• Gasification technology developer (sub-recipient) • Leading Feedstock Procurement and Preparation (Task 2) and Data Analysis and Reporting (Task 5) • Key personnel – Rolf Mauer and David Thimsen
Sotacarbo S.p.A	• R&D organization in Carbonia, Italy (sub-recipient) • Leading Gasifier Testing (Task 4) • Key personnel – Dr. Alberto Pettinau and Simone Meloni

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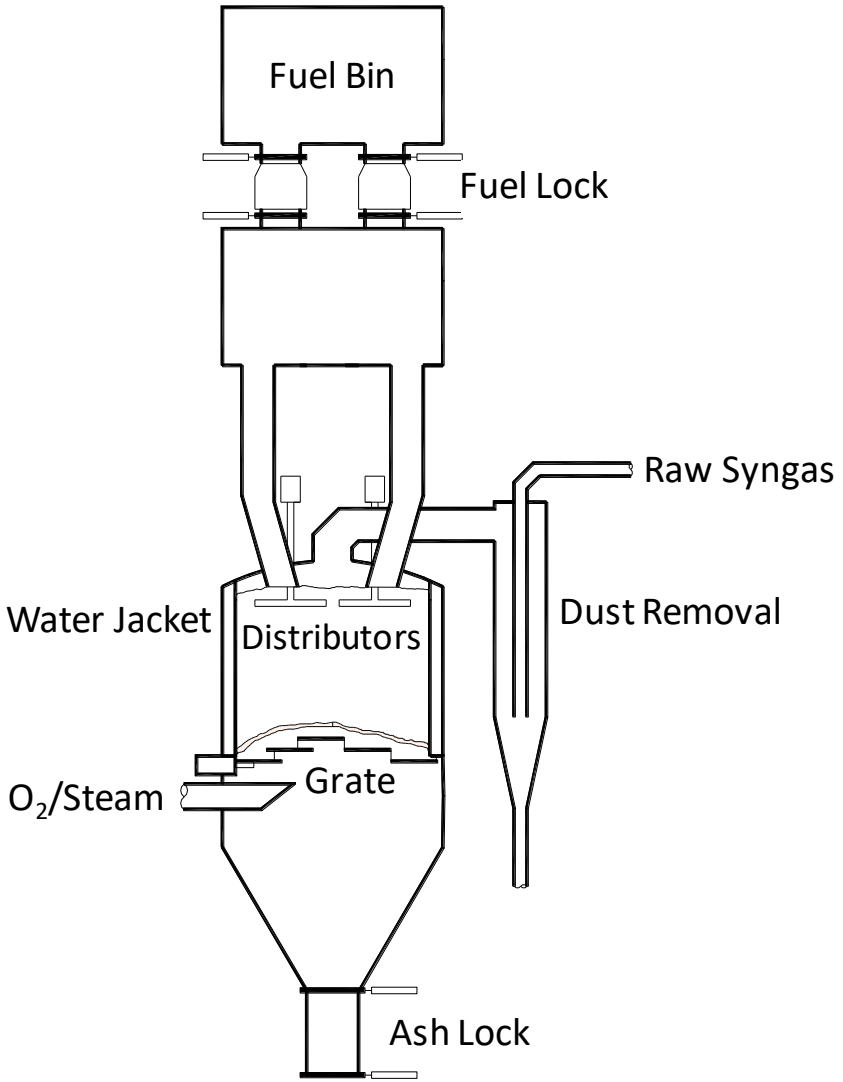
HMI Moving Bed Gasifier

- Moving-bed gasification has demonstrated gasifying many coal ranks as well as biomass. Testing suggests that it should be well suited for blends of coal, biomass, and plastic waste.
- As the fuel descends, it is dried, devolatilized, and the resulting char is gasified. Ash is removed through a grate and collected in a lock hopper.
- CO_2 produced by combustion and the steam from the blast react with the char in the gasification zone to produce CO and H_2
- Streams leaving are ash out the bottom and dry gas/tar/water vapor/dust out the top



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Major Project Tasks

- **Task 2 – Feedstock Procurement and Preparation:** Finalize feedstock selection and pellet formulations. Prepare and ship pellets.
- **Task 3 – Test Plan Development:** Specify test data to be reported, review facility instrumentation, and specify sampling procedures
- **Task 4 – Gasifier Testing:** Perform baseline coal gasification test, and tests for 9 different pellet formulations
- **Task 5 – Data Analysis and Reporting:** Correlate gasifier performance with pellet composition, assess overall prospects for gasification of mixed blends, and prepare the final report

Overall project schedule is two years (7/1/21 to 6/30/23)

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Task 2 – Feedstock Procurement and Preparation

- Biomass is corn stover
- Coal is Powder River Basin (PRB) subbituminous
- Plastic waste is auto-shredder residue (ASR), a.k.a. “Car Fluff” provided by OmniSource
- Pellets were produced by CPM at their test facility in Waterloo, IA

Feed % Based on Heat Input

No.	Biomass	Coal	Plastic
1	0	100	0
2	25	75	0
3	25	56	19
4	25	38	38
5	40	60	0
6	40	45	15
7	40	30	30
8	60	40	0
9	60	30	10
10	60	20	20

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Feedstock Supply

- Corn stover supplier was identified in NE
  - Stover was chopped to minus 1” (2.5 cm) before delivery to CPM
- Peabody provided PRB coal from their North Antelope Rochelle mine near Gillette, WY
  - Three supersacks of PRB coal were delivered to CPM
- OmniSource provided 2 tons of ASR from Indianapolis and 2 tons from Toledo
  - As-received ASR had much larger pieces than anticipated, and was shredded to -1/2” (1.3 cm) before delivery to CPM
  - After shredding, ASR still contained small fragments of metals and wire
  - Additional pre-treatment of the ASR was required

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Additional Pre-Treatment of the ASR

- Ball milling of ASR at a facility in RI was used to reduce size of the ASR and metal particles to prevent damage to CPM's pelletizing die
  - Ball mill had 40-gauge mesh screens (0.015" [0.4 mm] opening)
- Ball milling of ASR was required to produce ¼ inch pellets for lab scale gasifier operation. Ball milling would not be required to densify the three fuel components for a pilot or commercial scale gasifier

Ball-milled ASR -40 mesh (left), +40 mesh (right)

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Tri-Fuel Pelletizing Tests Were Successful

- Pelletizing tests at CPM were conducted from July 18–25, 2022
- Pelletizing 100% PRB was not successful (will use lump coal for baseline)

Recipe 3 (left) and Recipe 7 (right)

Close-up of pellets

Pelletizing head open. See the pencils sticking out of the die.

Weighing pellet sample for Pellet Durability Index test

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Pelletizing Report: Final Tri-Fuel Pellet Formulations Produced

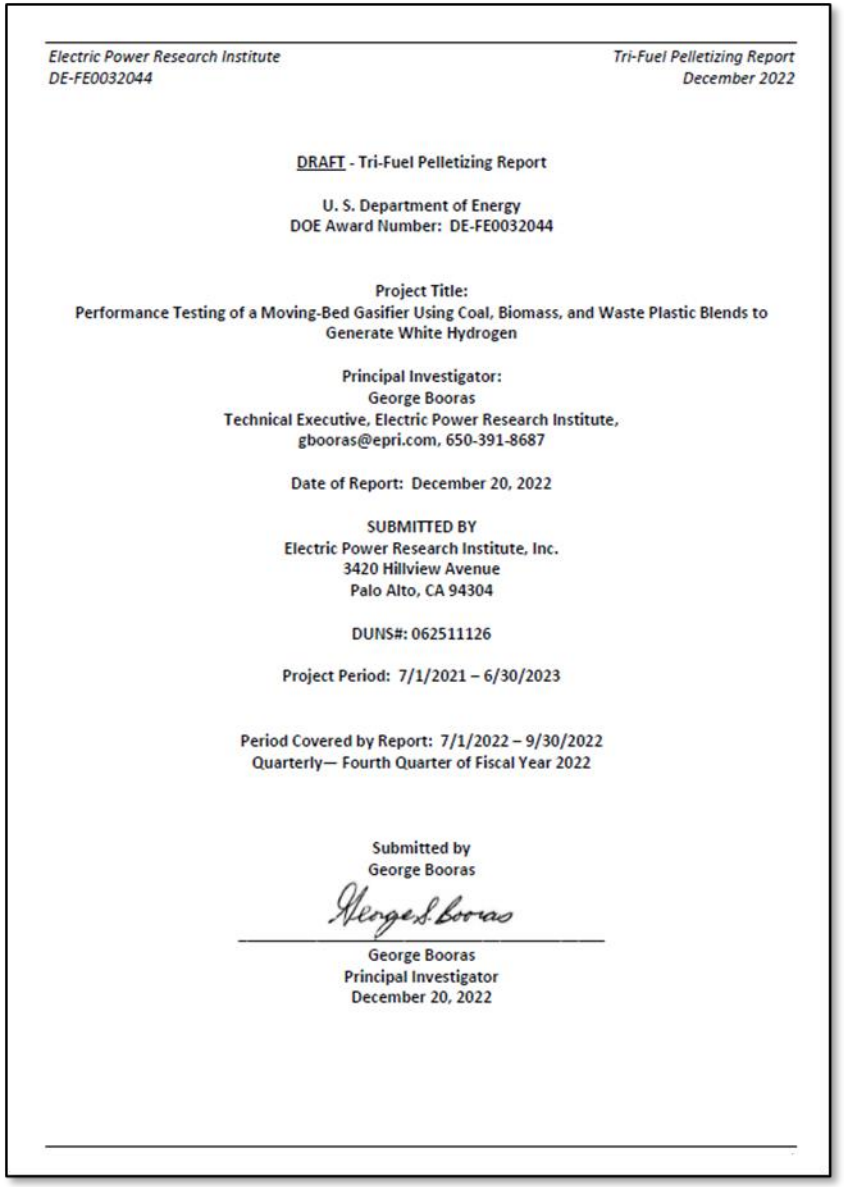
weight %, as-received

Formulation	Corn Stover	Coal	ASR (*)
1		100%	
2		69%	31% (**)
3	31%	53%	15%
4	32%	36%	32%
5	47%		53%
6	48%	40%	12%
7	49%	27%	24%
8		50%	50% (***)
9	67%	25%	7%
10	68%	17%	15%

(*) -40 mesh unless otherwise indicated

(**) ASR component was 28% + 40 mesh, 72% -40 mesh

(***) ASR Component 100% +40 mesh



Electric Power Research Institute *Tri-Fuel Pelletizing Report*
DE-FE0032044 *December 2022*

DRAFT - Tri-Fuel Pelletizing Report

U. S. Department of Energy
DOE Award Number: DE-FE0032044

Project Title:
Performance Testing of a Moving-Bed Gasifier Using Coal, Biomass, and Waste Plastic Blends to Generate White Hydrogen

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Date of Report: December 20, 2022

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Project Period: 7/1/2021 – 6/30/2023

Period Covered by Report: 7/1/2022 – 9/30/2022
Quarterly— Fourth Quarter of Fiscal Year 2022

Submitted by
George Booras

George Booras
Principal Investigator
December 20, 2022

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Pelletizing Report: Pellet Fuel Analysis

Formula		2	3	4	5	6	7	8	9	10
Moisture	% AR	12.4%	8.6%	9.5%	9.7%	6.9%	8.2%	15.5%	7.1%	9.2%
Ash	% AR	15.0%	14.8%	21.8%	30.5%	14.6%	16.5%	28.1%	14.3%	15.8%
VM	% AR	44.1%	50.5%	46.5%	49.2%	53.6%	51.5%	36.8%	57.1%	55.4%
FC	% AR	28.6%	26.2%	22.2%	10.6%	24.9%	23.9%	19.7%	21.5%	19.6%
Calorific Value	Btu/lb HHV	9,253	8,234	7,166	5,278	7,936	7,740	6,363	7,526	6,951
Moisture	% AR	12.40%	8.57%	9.52%	9.65%	6.90%	8.15%	15.50%	7.14%	9.21%
Ash	% AR	15.00%	14.80%	21.80%	30.50%	14.60%	16.50%	28.10%	14.30%	15.80%
S	% AR	0.23%	0.16%	0.20%	0.16%	0.19%	0.21%	0.14%	0.14%	0.13%
C	% AR	53.80%	48.60%	40.90%	30.40%	44.20%	37.50%	37.40%	43.80%	42.20%
H	% AR	4.20%	4.20%	3.76%	3.16%	4.36%	3.97%	3.14%	4.57%	4.37%
N	% AR	0.81%	0.81%	0.79%	0.67%	0.76%	1.18%	0.66%	0.80%	0.87%
O	% AR	13.30%	22.80%	22.80%	25.30%	28.90%	32.30%	14.90%	29.10%	27.30%
Cl	ppmw	3,320	1,300	1,620	1,960	1,460	1,660	1,850	1,480	1,130

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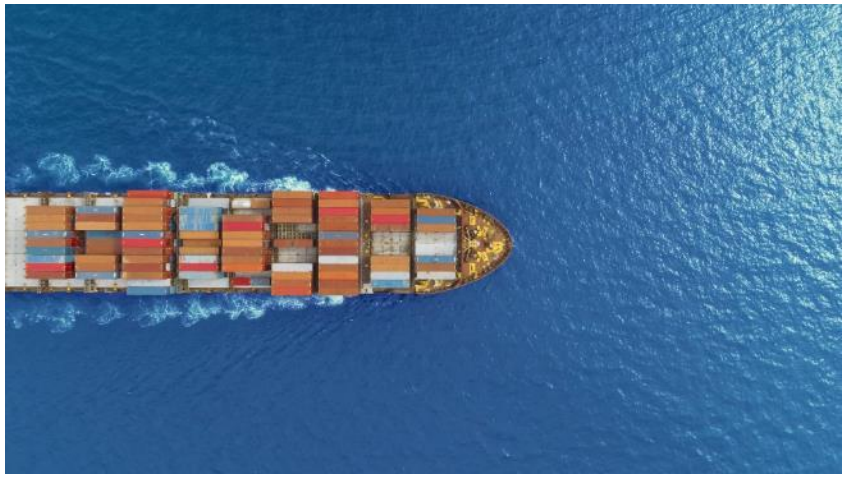
Shipping of Tri-Fuel Pellets and PRB to Sotacarbo

- Containers with 9 barrels of tri-fuel pellets were ocean shipped to Sotacarbo by CH Robinson along with 1 barrel of fresh PRB coal
- Ocean transport Norfolk, VA (10/29/22) to Genova, Italy (11/27/22)
- Italian Customs (November 30 to January 9)
- Final delivery to Sotacarbo was January 12, 2023



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Task 3 – Test Plan Development

- Sotacarbo's lab-scale gasifier process flow diagram (PFDs) and piping and instrumentation diagrams have been reviewed
- Sampling and testing procedures have been finalized
- Gasifier startup procedure has been reviewed
- Each gasification test run will last one day
  - Requires up to 12 hours from startup to cool down
  - Anticipate 4 to 5 hours of steady state operation
- The gasifier and other equipment will be cleaned up between runs

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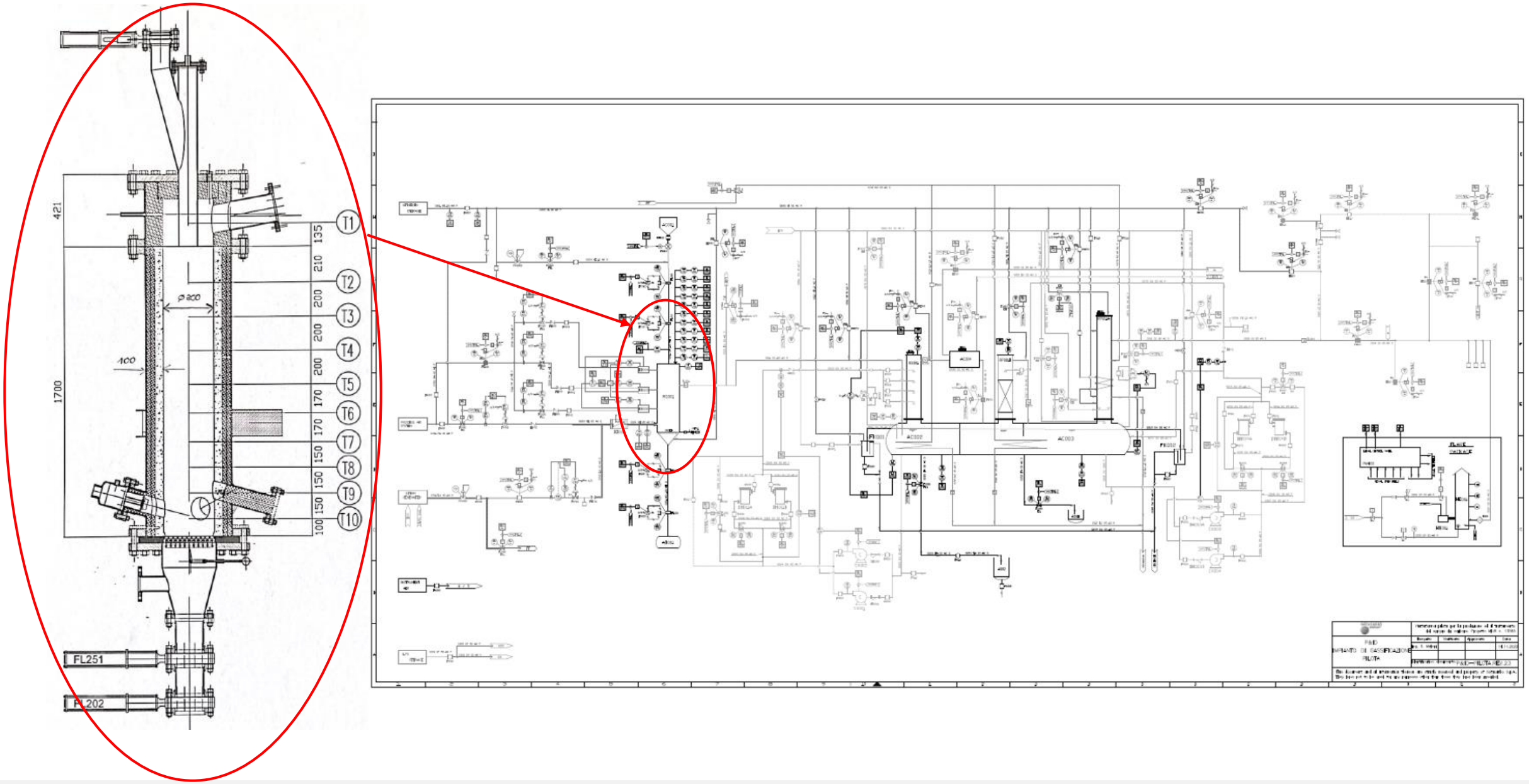
PFD for Sotacarbo 12” Inner Diameter (ID) Gasifier



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Feeding Hopper and Ceramic IR-radiators of the ignition system

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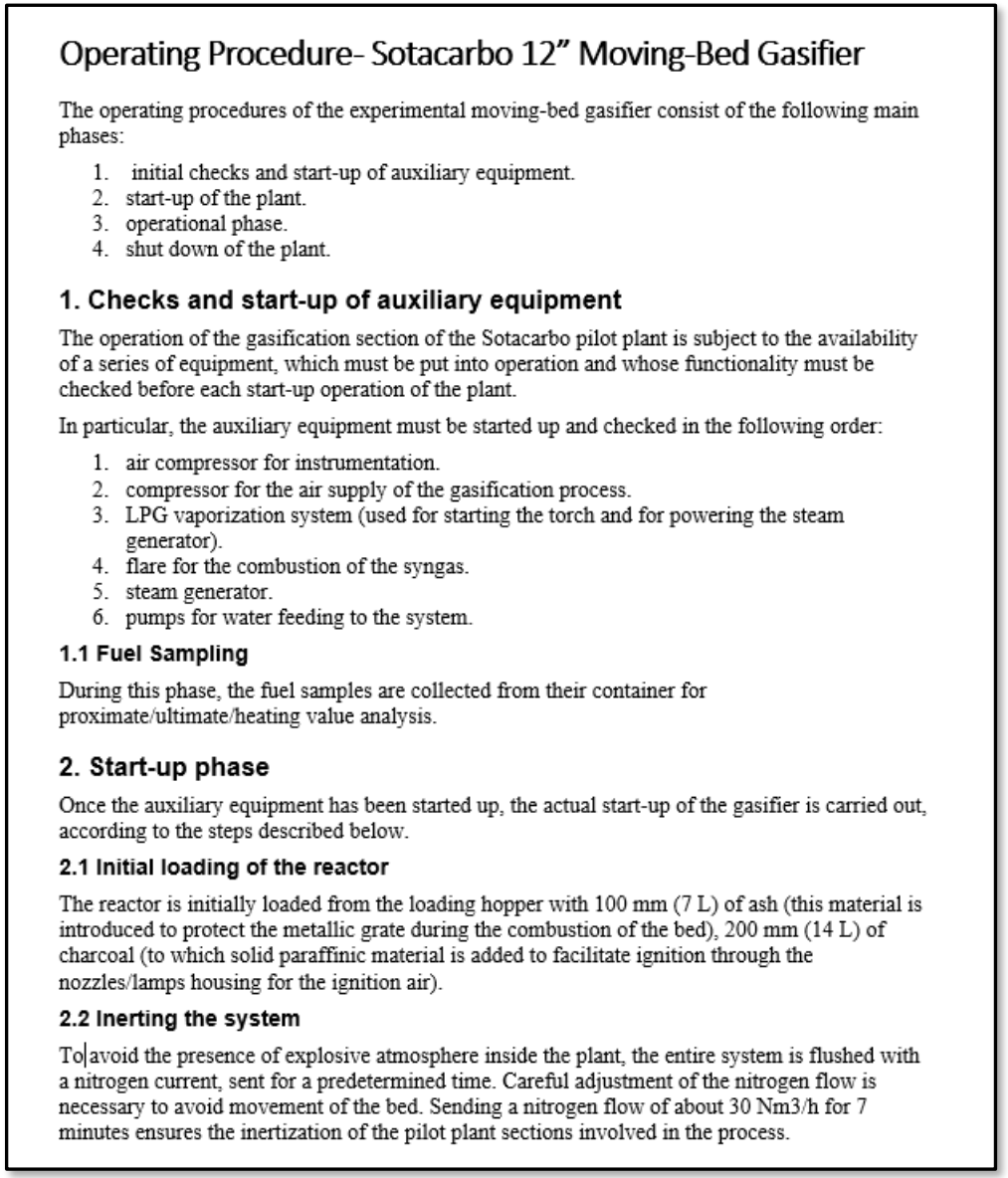
Gasifier Operating Procedure Is Being Fine Tuned

- The operating procedure for the Sotacarbo pilot scale moving bed gasifier has been reviewed
- Comments from HMI were addressed by Sotacarbo
- A visual timeline was prepared that shows all of the start-up, operational, and shut-down procedures.
- Test plan is being fine tuned after shake down testing has been completed



Operating Procedure- Sotacarbo 12" Moving-Bed Gasifier

The operating procedures of the experimental moving-bed gasifier consist of the following main phases:

1. initial checks and start-up of auxiliary equipment.
2. start-up of the plant.
3. operational phase.
4. shut down of the plant.

1. Checks and start-up of auxiliary equipment

The operation of the gasification section of the Sotacarbo pilot plant is subject to the availability of a series of equipment, which must be put into operation and whose functionality must be checked before each start-up operation of the plant.

In particular, the auxiliary equipment must be started up and checked in the following order:

1. air compressor for instrumentation.
2. compressor for the air supply of the gasification process.
3. LPG vaporization system (used for starting the torch and for powering the steam generator).
4. flare for the combustion of the syngas.
5. steam generator.
6. pumps for water feeding to the system.

1.1 Fuel Sampling

During this phase, the fuel samples are collected from their container for proximate/ultimate/heating value analysis.

2. Start-up phase

Once the auxiliary equipment has been started up, the actual start-up of the gasifier is carried out, according to the steps described below.

2.1 Initial loading of the reactor

The reactor is initially loaded from the loading hopper with 100 mm (7 L) of ash (this material is introduced to protect the metallic grate during the combustion of the bed), 200 mm (14 L) of charcoal (to which solid paraffinic material is added to facilitate ignition through the nozzles/lamps housing for the ignition air).

2.2 Inerting the system

To avoid the presence of explosive atmosphere inside the plant, the entire system is flushed with a nitrogen current, sent for a predetermined time. Careful adjustment of the nitrogen flow is necessary to avoid movement of the bed. Sending a nitrogen flow of about 30 Nm3/h for 7 minutes ensures the inertization of the pilot plant sections involved in the process.

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Task 4 – Gasifier Testing

- Sotacarbo has completed modifications to their 12” ID lab-scale moving bed gasifier
  - The gasifier was refurbished, including new refractory wall
  - Piping was reinstalled after the refractory is replaced
  - Other maintenance activities were performed
- The gasification system began shake-down testing in the first quarter of 2023
  - Initial run with coke for simplicity and minimal tar production
  - Subsequent run with PRB coal (~1 inch) for comparison to data from MIFGA’s 2-meter ID commercial scale gasifier

Upper Part of Gasification Reactor

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Lessons Learned from Shake Down Testing

- Nitrogen inerting during pre-startup no longer required
- Pre-heating system (~3 hours) while gasifying charcoal minimizes tar/dust deposition throughout operation
- Frequency of lock-hopper fuel feeding being studied to optimize steady state operation
- Optimizing air/steam flow to maximize steady state operation for up to 5 hours

White Smoke From Vent Confirmed Ignition of the Gasifier

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Next Steps

- Finalize the gasification test plan and reporting format
  - Test plan will be fine tuned after shake down tests are completed
  - Will include an outline of the individual gasification test reports
- Complete test runs for all 9 tri-fuel pellet formulations
- Assemble and analyze all gasification data sets
- Assess overall prospects for gasification of mixed blends, and prepare the final report

Gasification test runs scheduled for first half of 2023

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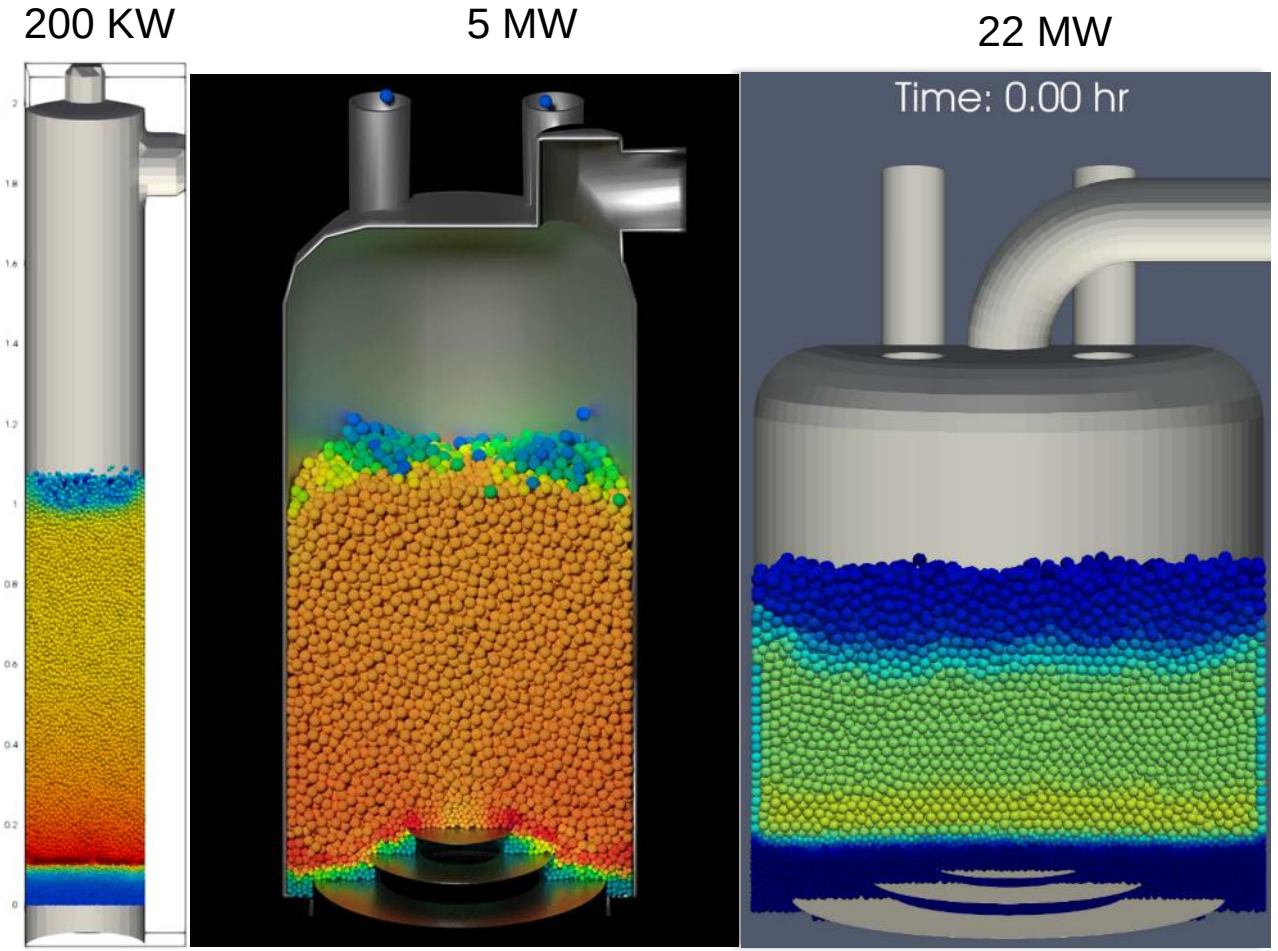
Application of NETL Simulation-based Engineering Tools to Design and Operation of the Moving Bed Gasifier

- NETL MFiX model has been validated in previous campaigns for design and optimization of the 200kw, 5MW and 22 MW modular moving bed gasifiers in collaboration with HMI, University of Alaska Fairbanks, and Sotacarbo research center.
- MFiX model will be applied to operating conditions of interest to help guide design and operations
- Transient response of gasifier to load variations, ramp-rate and turndown can be simulated



Lab-scale test results to be shared with NETL gasification modeling group

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Acknowledgment and Disclaimer

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