Leveraging Connected Digital and Analytical Tools to Address Furnace-Specific Combustion Inefficiencies at GC Olefin Plant

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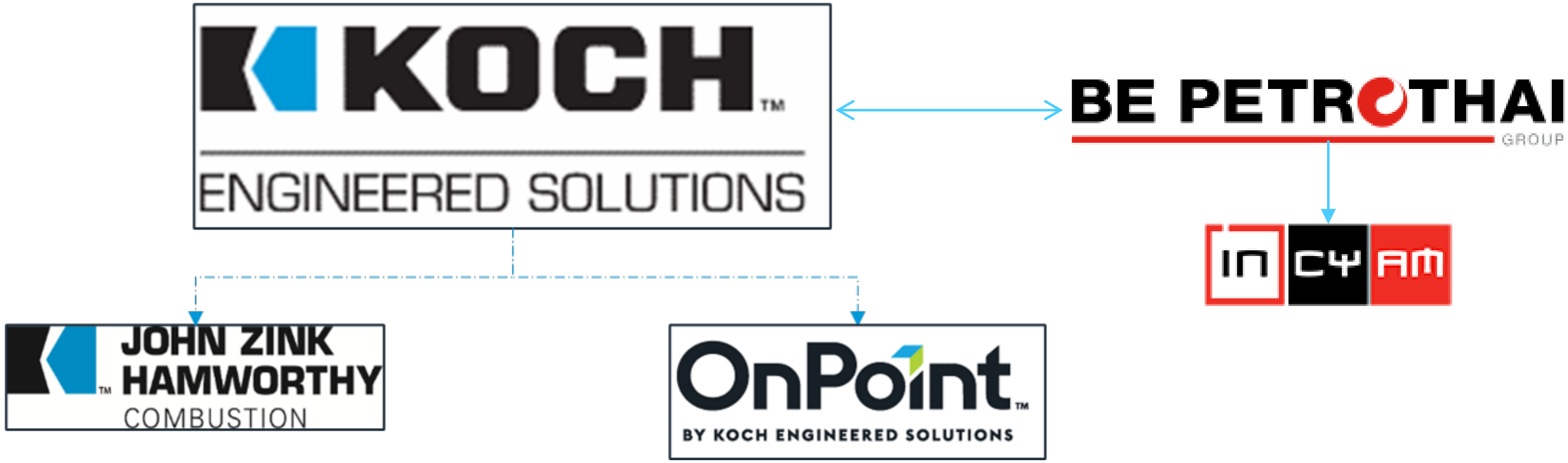
Company Overview

OnPoint Digital Solutions, LLC (a Koch Engineered Solutions company)

- Digital Solutions provider for large range of industries
- Refining, Petrochemical, Steel, Power Generation, Glass, Paper, etc.
- Based in Wichita, Kansas USA

EMBER™ (an OnPoint Digital Solutions service)

- Developed in collaboration with John Zink
- Over 35 active subscriptions around the world. Over $10MM expected benefit.



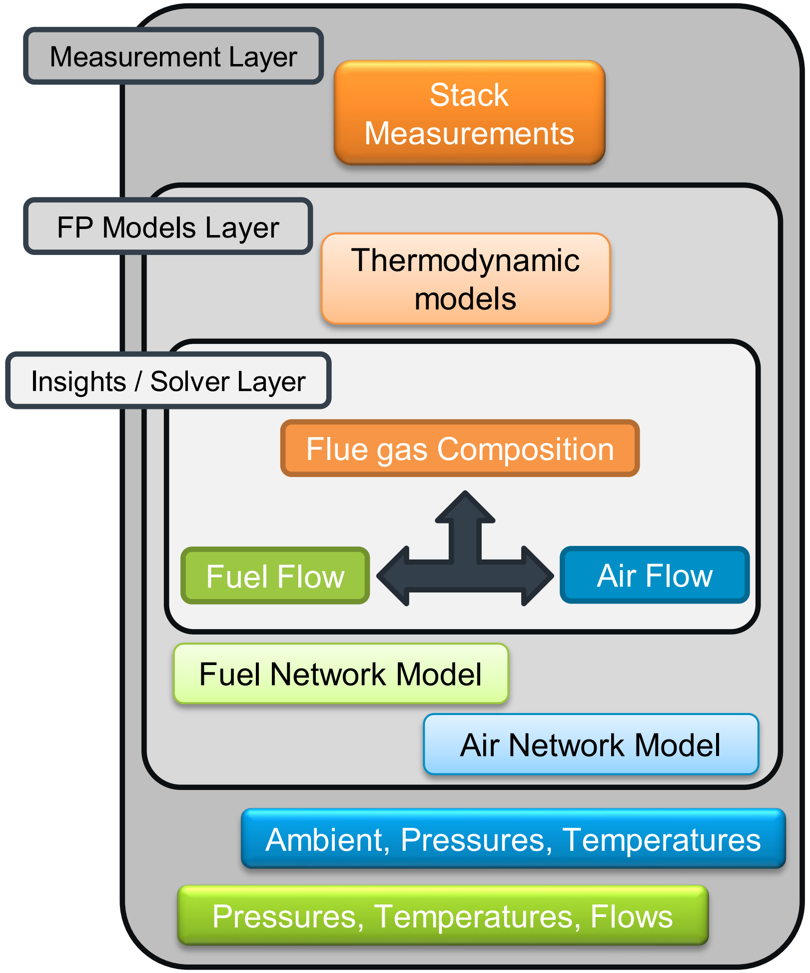
GC OLE 2/1 Olefins Plant

- 11x furnaces
- 3x different furnace designs
- EMBER deployed on all furnaces in December 2022 after successful trial on single furnace.

EMBER

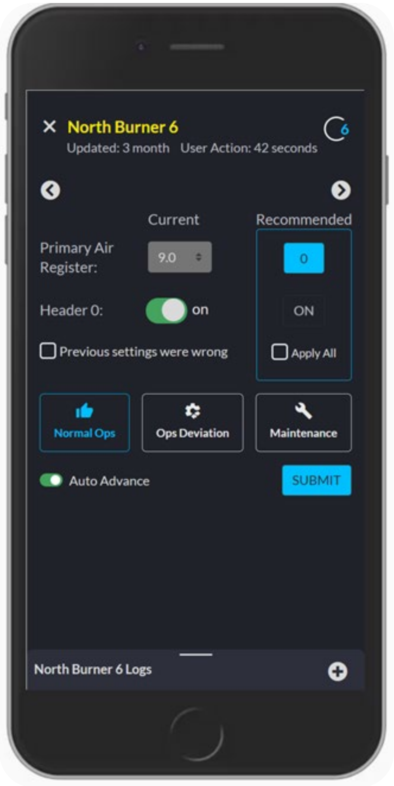
Algorithms & analytics developed by industry leading combustion experts at John Zink

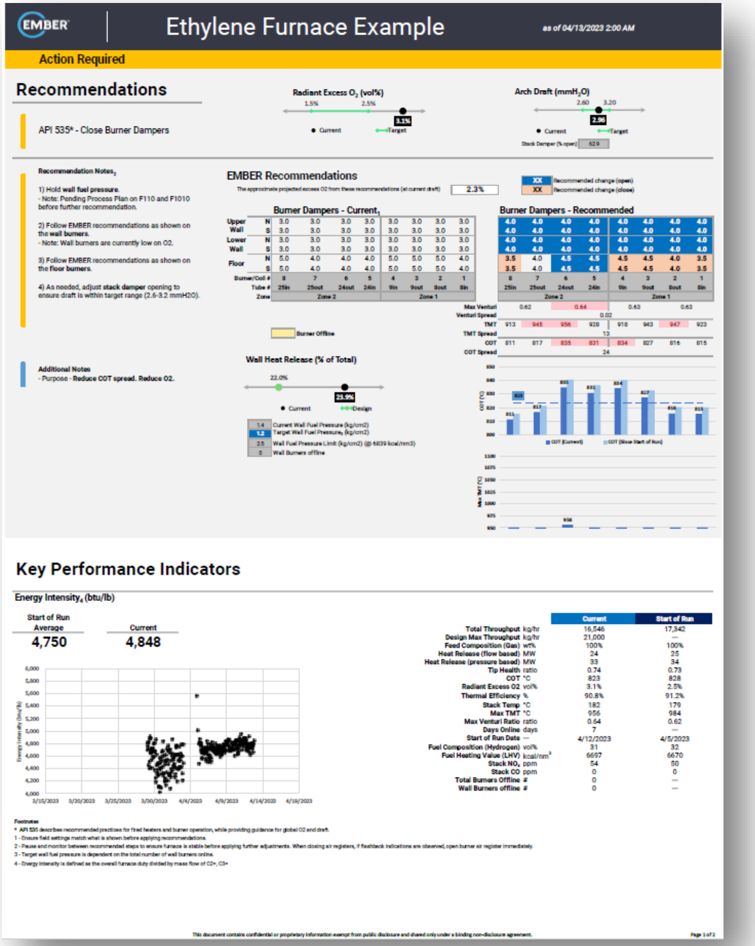
- A digital solution that leverages existing furnace instrumentation and combustion ‘digital twin’ to provide proprietary process burner combustion optimization and monitoring insights.
- EMBER leverages proprietary First Principle (FP) thermodynamic models and computational fluid dynamics (CFD) from John Zink Hamworthy Combustion.
- Data connection is established with site historian to gather model inputs from existing instrumentation on a scheduled basis.
- EMBER solves for the appropriate air register setting for each burner based on the desired, or required, stoichiometry (local and global) to reach furnace performance goals.



EMBER Services Approach

- Model outputs can be accessed at anytime directly by site personnel through EMBER web portal.
- Routine asset specific tuning reports, created by EMBER engineers, provide furnace operational insights and recommendations
  - Collaboration to overcome asset specific pain points through combustion tuning
  - Furnace KPI tracking including value realized from combustion tuning
  - Guided prioritization of work based on value
- Direct collaboration and support from EMBER and John Zink engineers on a weekly basis
  - Reduce tuning time and institutionalize combustion knowledge
  - Value realization reporting





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Fleet Wide Monitoring

EMBER | Multi-Asset Prioritization Report

Report data as of 6/2/2022

Summary Scores

Max scores	
Value	250
Ease of Tuning	100
Process Uniformity	75
Safety and Env.	75
Est. Shut Down	75

Furnaces	A	B	C	G	H	I	J	D (Offline)	E (Offline)	F (Offline)
Rank	3	1	2	4	7	6	5	9	8	10
Prioritization Scores	#	#	#	#	#	#	#	0	0	0
Value	84	250	179	35	10	20	30	0	0	0
Ease of Tuning	100	67	54	55	40	45	50	73	57	90
Process Uniformity	61	51	75	50	35	40	45	15	15	15
Safety/Environmental*	0	39	31	44	20	35	40	12	15	-1
Estimated Shut Down	50	62	60	82	10	40	80	34	100	2

Key Performance Indicators

Category		KPI	Unit	A	B	C	G	H	I	J	D	E	F
Value	"Driving KPI's" "Weight Per Category"	Excess O2**	vol%	2.6	7.0	3.6	2.5	2.5	2.5	2.5	2.3	2.3	2.3
		Total Feed	mlb/hr	53	29	45	49	49	49	49	0	0	8
		Heat Release (flow based)	mmbtu/hr	226	134	191	231	231	231	231	47	57	2
		Energy Intensity***	mbtu/lb	2.91	4.08	3.50	3.77	3.77	3.77	3.77	0.00	0.00	0.00
		COT	F	1589	1576	1587	1591	1591	1591	1591	1528	1527	1524
		Arch Temp	F	2165	1836	2008	2150	2150	2150	2150	1459	1515	2497
		Stack Temp	F	646	520	515	577	577	577	577	425	420	208
		Venturi Pressure STDEV	psig	1.94	0.49	4.72	0.84	0.10	0.10	0.10	0.00	0.00	0.00
		FG Reduction (opportunity cost)	$/yr	$58,603	$519,437	$169,896	$34,019	$30,000	$20,000	$10,000	$0	$0	$0
		Run Length Extension (opportunity cost)	$/yr	$121,337	$16,273	$213,846	$40,436	$15,000	$10,000	$9,000	$0	$0	$0
Ease of Tuning		Total dampers that need changes	#	86	144	168	168	50	20	20	120	168	104
		Draft	inH2O	0.58	0.61	0.45	0.49	0.70	0.60	0.68	0.50	0.53	0.72
Process Uniformity		COT STDEV	F	22	22	15	13	36	3	39	0	0	0
		XOT STDEV	F	15	23	5	575	18	66	14	0	0	0
		Venturi Pressure STDEV	psig	1.94	0.49	4.72	0.84	4.6	1.4	6.2	0	0	0
		Overall Burner Tip Health	ratio	0.89	0.78	0.83	0.86	5.8	3.5	2.2	100	100	100
Safety and Environmental		Stack CO	ppm	-	67	63	79	0	0	0	332	332	171
		Stack Nox	ppm	82	57	37	63	41	49	-5	37	37	60
Estimated Shut Down		Max Venturi RO	ratio	0.57	0.52	0.54	0.49	0.63	0.77	0.68	0.66	0.50	0.79
		Days Online	days	25	0	2	3	34	34	22	0	0	0
		Est. Days Remaining****	days	25	31	30	41	7	15	22	17	50	1

Site Summary

	mlb/hr
Total Feed	183
Monthly plan	300

7 of 10 furnaces currently online

Footnotes

*Escalated if greater than permit limit

**Target Excess O2 is 2.25%

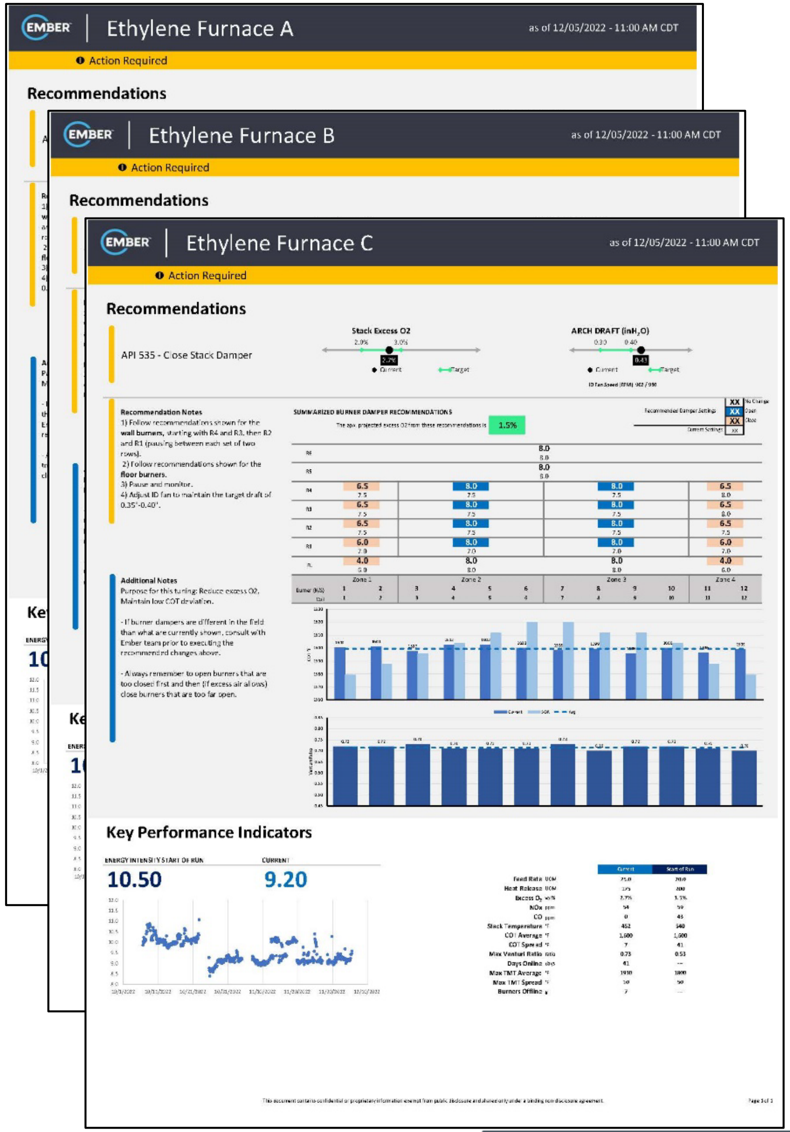
***Radiant absorbed duty / desired product throughput

****Assumes historic creep rate from current max RO and buffer remaining until 0.80 EOR conditions

Note about ease of tuning number

Legend

If using different colors throughout the KPI table and summary scores it might be good to have a legend here (red, green, grey, etc.)



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Dynamic Optimization

Drive burner/furnace operation closer to the "As Design" state

- Maintain balanced air flow through direct burner-by-burner recommendations with proven ability to reduce hotspots
- Achieve optimized heat and oxygen uniformity for reduced TMT and COT deviation leading to:
  - Increased yields
  - Improved furnace thermal efficiency and reduced fuel consumption
  - Increased run lengths by over 30%
  - Reduce carbon impact of fired heaters
- Active monitoring of fireside stoichiometric conditions with timely qualitative feedback on needed burner air adjustments
  - Fuel composition changes (high H_2 firing)
  - Optimize fuel usage and emissions
  - Reduce tuning time

Results

Operational Data

COT Average (°C)

Furnace	Baseline	EMBER	Delta
A	835	834	-1
B	835	836	1
C	832	828	-4
D	830	828	-1
E	834	832	-2
F	834	834	0
G	834	826	-8
H	833	825	-8
I	828	831	4
J	835	830	-5
K	832	828	-4
Fleet Average	833	830	**-3**
			-0.3%

Total Feed (kg/hr)

Furnace	Baseline	EMBER	Delta
A	16,866	16,353	-512
B	17,101	16,409	-692
C	16,987	16,578	-409
D	19,108	18,896	-213
E	18,598	18,579	-20
F	18,303	17,121	-1182
G	17,189	16,680	-509
H	16,752	17,063	311
I	16,670	16,954	284
J	16,349	16,900	551
K	17,435	16,667	-768
Fleet Average	17,396	17,109	**-287**
			-1.7%

Gas Feed (% of total Feed)

Furnace	Baseline	EMBER	Delta
A	0%	0%	0%
B	0%	0%	0%
C	90%	41%	-49%
D	92%	96%	4%
E	64%	93%	29%
F	58%	95%	38%
G	98%	16%	-82%
H	2%	41%	39%
I	42%	74%	32%
J	52%	41%	-11%
K	0%	0%	0%
Fleet Average	45%	45%	**0%**

Steam Flow (kg/hr)

Furnace	Baseline	EMBER	Delta
A	7,839	7,530	-310
B	7,937	8,166	229
C	6,288	6,646	358
D	6,002	6,038	36
E	7,511	6,424	-1087
F	6,886	6,869	-17
G	6,069	5,933	-136
H	6,183	5,968	-215
I	6,736	6,850	114
J	5,856	5,861	4
K	6,461	6,185	-275
Fleet Average	6,706	6,588	**-118**
			-1.8%

- All subsequent aggregated results shown are estimates and will have the following criteria applied:
- Baseline period:
  - 10/11/22 - 1/19/23
  - 100 days
- EMBER period:
  - 1/19/23 - 5/27/23
  - 128 days
- COT, total feed, steam flow and feed composition are all expected to impact the degree of firing required.
- Lower COT, total feed and steam flow will require less fired duty.
- Feed type also determines fired duty required (i.e., harder to crack ethane than propane).
- Steam/feed ratio ranged between 36%-43% across both periods.

Coil Outlet Temperature (COT) Optimization

Furnace	Baseline (all)	EMBER (all)	EMBER (post tuning)	Delta (all)	Delta (post tuning)
	COT Spread (°C)				
A	19	20	11	1	-8
B	27	15	7	-12	-20
C	23	28	20	5	-3
D	6	10	4	4	-2
E	25	17	7	-8	-18
F	12	7	4	-5	-8
G	10	13	8	2	-2
H	14	7	4	-7	-10
I	19	16	9	-3	-10
J	16	11	6	-5	-10
K	19	15	7	-4	-12
Fleet Average	17	14	8	**-2.9**	**-9.3**
				-17%	**-54%**

- COT spread was a primary objective for these tunings as it is an indicator for heat uniformity in the firebox.
- COT is an indication of reaction severity. A higher than setpoint COT results in over-cracking (production of undesirable species like acetylene) and lower than setpoint COT results in under-cracking (unconverted ethane being recycled).
- Post tuning includes a smaller sample size looking at the data directly following an EMBER tuning. Because:
  - Furnaces come back online after decoke, unoptimized for a time.
  - Changing operational conditions.

Excess O_2 Optimization

Furnace	Baseline (all)	EMBER (all)	EMBER (post tuning)	Delta (all)	Delta (post tuning)
	Excess O2 (vol% wet)				
A	3.1	2.8	1.8	-0.3	-1.3
B	3.2	2.6	1.5	-0.6	-1.7
C	3.4	3.1	1.9	-0.3	-1.5
D	3.2	3.1	2.0	-0.1	-1.2
E	2.9	3.1	2.4	0.2	-0.5
F	2.6	2.4	2.0	-0.2	-0.6
G	2.9	3.1	2.1	0.2	-0.8
H	3.3	2.9	1.9	-0.4	-1.4
I	3.3	2.8	2.1	-0.5	-1.2
J	3.0	2.6	2.0	-0.4	-1.0
K	3.0	2.7	1.9	-0.3	-1.1
Fleet Average	3.1	2.8	2.0	**-0.3**	**-1.1**

Furnace	Baseline (all)	EMBER (all)	EMBER (post tuning)	Delta (all)	Delta (post tuning)
	Stack Temp (°C)				
A	120	121	114	1	-6
B	131	127	119	-5	-12
C	154	146	142	-8	-12
D	151	144	138	-7	-13
E	177	164	135	-12	-42
F	166	177	166	11	0
G	175	146	138	-29	-37
H	151	155	140	4	-11
I	178	186	178	8	0
J	160	155	140	-5	-20
K	151	145	138	-6	-13
Fleet Average	156	151	141	**-4**	**-15**

- Target operational range for excess O_2 was 1.5-2.5%.
- Note: excess O_2 was not the sole emphasis for these tunings (also considered COT/TMT/venturi spread, among others).
- Typically, O_2 will decrease as furnace firing increases (at fixed burner damper settings). However, firing during the EMBER use period, was lower than the baseline period. In other words, with EMBER, O_2 can be safely controlled to a lower excess O_2, even with a lower degree of firing.

Total Fired Duty Optimization

	Heat Release (mmbtu/hr)		
Furnace	Baseline (all)	EMBER (all)	Delta (all)
A	146	141	-5
B	143	133	-11
C	88	81	-7
D	88	82	-6
E	91	82	-8
F	93	86	-6
G	85	79	-5
H	86	82	-4
I	85	85	0
J	82	82	0
K	88	82	-6
Fleet Average	98	92	**-5.3**

-5.3	Actual Reduction in Firing (mmbtu/hr) (per furnace)
-3.0	Expected Reduction in Firing (mmbtu/hr) (per furnace)
-2.3	Adjusted Reduction in Firing (mmbtu/hr) (per furnace)
10	Furnaces online
-23.0	Adjusted Reduction in Firing (mmbtu/hr) (per fleet)
8.0	Fuel Cost ($/mmbtu)
95%	Asset Availability
$ 1,531,231	**Annualized fuel savings ($/yr)**

- Expected reduction in firing is derived from an empirical model (0.81 RSQ) that predicts firing as a function of COT, total feed, steam flow and feed gas composition.
- It was expected that, to a degree, firing would be less from reduced operational setpoints.
- Adjusted reduction in firing is a result of the improved thermal efficiency (indicated by excess O2) and heater uniformity (indicated by COT spread) that was present during the EMBER use period.

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Furnace Run Length Optimization

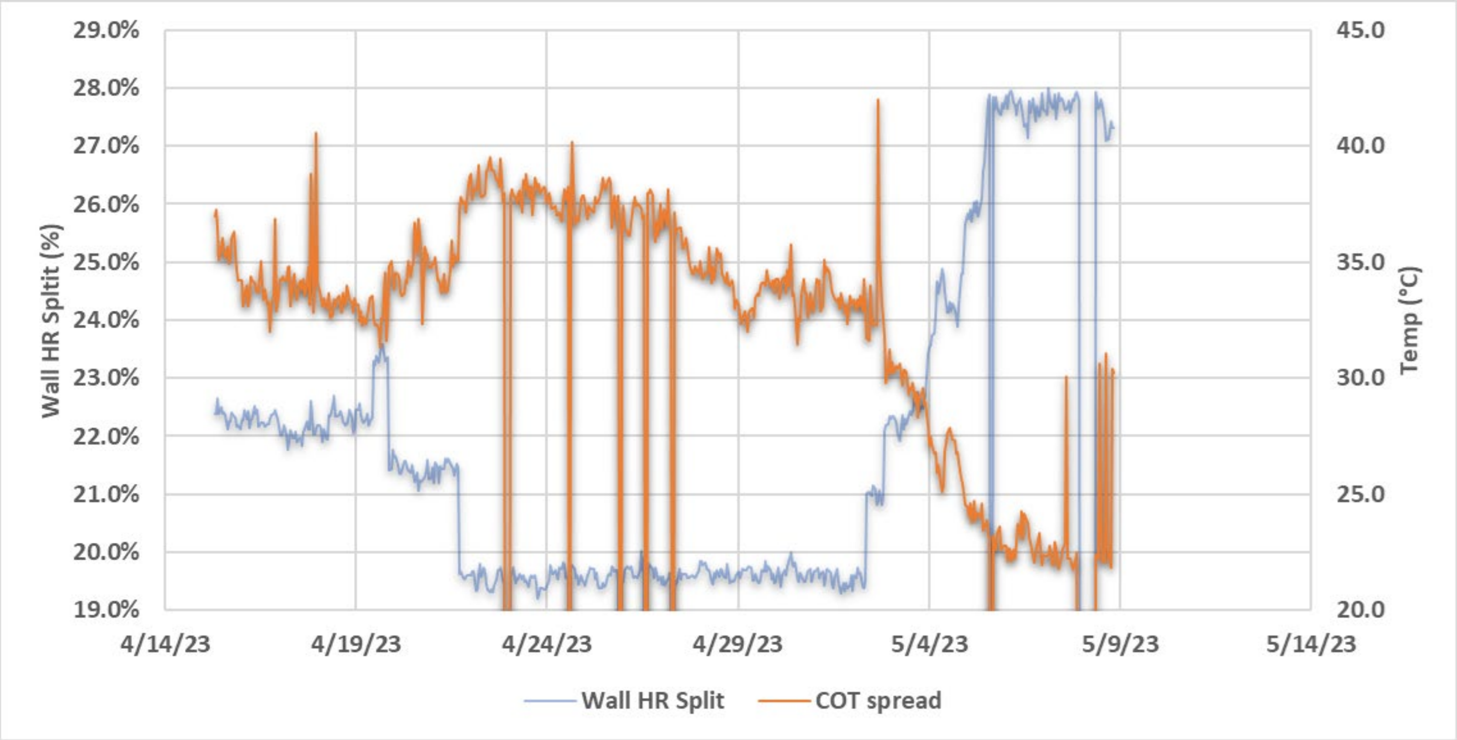
Days online (days)

	Run Count	A	B	C	D	E	F	G	H	I	J	K		
	1	68	65	59	71	71	58	72	32	39	64	58		
BASELINE	2	41	43	48	25		52		55	34	36	22		
	3	35					39							
	Avg	48	54	54	48	71	50	72	44	37	50	40	51	Fleet Average
	1	72	79	77	74	75	100	55	81	32	81	81		
EMBER	2		70	100	100	92		100	100	30	100	41		
	3									100				
	Avg (w/ Projections)	72	75	89	87	84	100	78	91	54	91	61	80	Fleet Average (w/ Projections)
	Avg (w/o Projections)	72	79	77	74	75	100	55	81	31	81	81	73	Fleet Average (w/o Projections)

28	Run Length Extension (w/ Projections) (days)
55%	Run Length Extension (w/ Projections) (%)
6.8	Average SD/yr per furnace (baseline)
4.5	Average SD/yr per furnace (EMBER)
2.4	Reduction in SD/yr per furnace (EMBER)
10	Furnaces online
23.7	Annualized SD/yr reduction (EMBER) (Fleet)
$ 25,000	Utility Cost per SD (USD/SD)
$ 592,534	**Annualized value from increased run length ($/yr)**

- Excludes runs that are <20 days.
- Projections (orange highlight) utilize linear extrapolation of furnace coke growth rates from current until EOR reliability thresholds.
- Projections were conservatively limited to 100 days.
- Projections assume SOR TMT and EOR TMT were 1000°C and 1100°C, respectively (historical expectation).

Floor-to-Wall HR Split (Process Plan)



- In May 2023, the EMBER team designed and coordinated a process plan to prove the relationship (empirical observation) between floor-to-wall heat release split and COT spread.
- This plan was performed on three furnaces, each with a different design.
- To ensure safe burner operation, wall fuel pressure was increased while using EMBER to monitor excess air ratios.
- Post Process Plan evaluation indicated a 44% reduction in COT spread, from 39->22 °C (F110).
- Reduced COT spread has resulted in improved energy intensity (EI).

Summary of Results

- $1.53MM annual fuel savings from O_2 reduction.
- 9,223 MTPY CO_2 reduction (~2% reduction)
- $592K per year utility savings from increasing furnace run length between decoke.
- Increased visibility into combustion performance.
- Regular collaboration with EMBER team on furnace operation and troubleshooting.

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THANK YOU

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