REGENERATIVE vs. OXY FUEL: AN APPLICATIONS APPROACH

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Burners Evaluated

- Regenerative Burners
  - Very efficient with high air preheat entering the burner head
  - 80% of the waste gases leave the regenerator at a low temperature
- Oxy fuel burners
  - High flame temperature
  - Elimination of Nitrogen from the combustion process reduces waste gas volume approximately 75%
Furnaces Evaluated

- 200-220TPH Walking Beam Furnace
- 44 Ton Batch Furnace
CONTINUOUS FURNACE PARAMETERS

- 200 TPH
- 100’ EFFECTIVE LENGTH
- SIX ZONES (3 TOP 3 BOTTOM)
- 8”X47”X30’ SLABS
- 850 F AIR PREHEAT
- 2250 F AVERAGE DISCHARGE TEMPERATURE
- PLAIN CARBON STEEL
- NATURAL GAS FIRED (1000 BTU/SCF HHV)
## CONTINUOUS FURNACE
### 200 TPH

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<th>24’ UNFIRED</th>
<th>28’ PREHEAT</th>
<th>24’ HEAT</th>
<th>24’ SOAK</th>
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*Figure showing the layout of the continuous furnace with lengths in feet.*
HEATING CURVE: WALKING BEAM FURNACE

200 TPH: 8"X47"X30' SLABS

FURNACE

TOP

CENTER

BOTTOM

AVERAGE

BASELINE CONVENTIONAL FIRING
REGENERATIVE FURNACE
220 TPH
HEATING CURVE: WALKING BEAM FURNACE

220 TPH: 8"X47"X30' SLABS

FURNACE

TOP

CENTER

CENTE

BOTTOM

REGENERATIVE FIRING

DISTANCE (FT)

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OXY FUEL FURNACE
220 TPH
HEATING CURVE: WALKING BEAM FURNACE

220 TPH: 8"X47"X30' SLABS

- Furnace
- Top
- Center
- Bottom
- Average

TEMPERATURE (F) vs DISTANCE (FT)

OXYGEN FIRING

BLOOM ENGINEERING COMPANY

GLOBAL ENERGY AND ENVIRONMENTAL SOLUTIONS
FUEL SUMMARY

- FUEL RATE CONVENTIONAL: 1.245 MMBTU/TON
- FUEL RATE REGENERATIVE: 1.049 MMBTU/TON
- FUEL RATE OXY FUEL 1.054 MMBTU/TON
OPERATING COST BASIS
CONTINUOUS FURNACE

- FUEL $3.37/1000SCF
- ELECTRICITY $0.075/KWH
- OXYGEN $0.20/ 100 CUBIC FEET
- TOTAL FUEL 232 MMBTU/Hr BOTH CASES
- 561 OPERATING HORSEPOWER FOR REGENERATIVE FANS
- 497640 SCF/H OXYGEN
OPERATING COSTS

REGENERATIVE

- FUEL $781.84/HOUR
- ELECTRICITY $31.39/HOUR
- MEDIA REPLACEMENT $0.89/HOUR
- TOTAL $814.12/HOUR

OXY FUEL

- FUEL $781.84/HOUR
- OXYGEN $995.28/HOUR
- TOTAL $1777.12/HOUR
ENVIRONMENTAL CONSIDERATIONS

REGENERATIVE
- NOx from FURNACE .08 LB/MMBTU
- NOx from ELECTRIC POWER GENERATION .002 LB/MMBTU
- CO2 from FURNACE 118 LB/MMBTU
- CO2 from ELECTRIC POWER GENERATION 5.2 LBS/MMBTU
- TOTAL NOx 0.082 LB/MMBTU
- TOTAL CO2 123.2 LB/MMBTU

OXY FUEL
- NOx FROM FURNACE .04 LB/MMBTU
- NOx from MANUFACTURE of OXYGEN .026 LB/MMBTU (SEPARATION ONLY)
- CO2 from FURNACE 118 LB/MMBTU
- CO2 from MANUFACTURE of OXYGEN 65.03 LB/MMBTU (SEPARATION ONLY)
- TOTAL NOx .066 LB/MMBTU
- TOTAL CO2 183.03 LB/MMBTU
CAPITAL COSTS

- REGENERATIVE BURNERS $3,000,000
- OXY FUEL BURNERS $480,000
- CONVENTIONAL BURNERS $1,200,000
- PRICING DOES NOT INCLUDE PIPING, RECUPERATORS OR INSTALLATION
HYBRID FURNACES

- INVESTMENT AND OPERATING COSTS BECOME MORE REASONABLE
- EASIER TO MODIFY AN EXISTING FURNACE WITHOUT INCORPORATING ANY SPECIAL DESIGN
HYBRIDS CONSIDERED

- REGENERATIVE PREHEAT ZONES
- OXY FUEL PREHEAT ZONES
- BLAST FURNACE GAS REGENERATIVE
- OXYGEN ENRICHMENT TO 27% OXYGEN
REGENERATIVE HYBRID 200 TPH

24’ UNFIRED  | 28’ PREHEAT  | 24’ HEAT  | 24’ SOAK

[Bloomengineering logo]
GLOBAL ENERGY AND ENVIRONMENTAL SOLUTIONS
OXYFUEL HYBRID 200 TPH

24’ UNFIRED

28’ PREHEAT

24’ HEAT

24’ SOAK
REGENERATIVE HYBRID BLAST FURNACE GAS 200 TPH

24’ UNFIRED  28’ PREHEAT  24’ HEAT  24’ SOAK
OXYGEN ENRICHMENT FURNACE
200 TPH

24’ UNFIRED  28’ PREHEAT  24’ HEAT  24’ SOAK
FUEL SUMMARY

- FUEL RATE CONVENTIONAL: 1.245 MMBTU/TON
- FUEL RATE REGENERATIVE: 1.049 MMBTU/TON
- FUEL RATE OXY FUEL: 1.054 MMBTU/TON
- FUEL RATE HYBRID REGENERATIVE: 1.112 MMBTU/TON
- FUEL RATE HYBRID OXY FUEL: 1.108 MMBTU/TON
- FUEL RATE BFG HYBRID: 1.275 MMBTU/TON; 48% NATURAL GAS REDUCTION
- FUEL RATE OXYGEN ENRICHMENT: 1.115 MMBTU/TON
OPERATING COSTS PER TON

- BASE CASE: $4.13/TON
- REGENERATIVE FURNACE: $3.70/TON
- OXY FUEL FURNACE: $8.08/TON
- REGENERATIVE HYBRID: $3.82/TON
- OXY FUEL HYBRID: $5.48/TON
- BLAST FURNACE GAS HYBRID: $2.38/TON
- OXYGEN ENRICHMENT: $5.09/TON
ENVIRONMENTAL CONSIDERATIONS

- **BASE CASE**: 0.057 LB/MMBTU NOx; 121.0 LBS/MMBTU CO2
- **REGENERATIVE FURNACE**: 0.082 LB/MMBTU NOx; 123.2 LB/MMBTU CO2
- **OXY FUEL FURNACE**: 0.066 LBS/MMBTU NOx; 183.3 LBS/MMBTU CO2
- **REGENERATIVE HYBRID**: 0.07 LB/MMBTU NOx; 122.1 LBS/MMBTU CO2
- **OXY FUEL HYBRID**: 0.064 LB/MMBTU NOx; 147.2 LB/MMBTU CO2
- **BFG HYBRID**: 0.068 LB/MMBTU NOx; 141.7 LB/MMBTU CO2
- **OXYGEN ENRICHMENT**: 0.060 LB/MMBTU NOx; 137.6 LB/MMBTU CO2
CAPITAL COSTS

- BASE CASE: $1,200,000
- REGENERATIVE BURNERS $3,000,000
- OXY FUEL BURNERS $480,000
- REGENERATIVE HYBRID: $2,200,000
- OXY FUEL HYBRID: $1,150,000
- BFG HYBRID: $2,800,000
- OXYGEN ENRICHMENT: CASE DEPENDENT
BATCH FURNACE

- 44 TON LOAD
- 8-20”X20”X194” PIECES
- COLD AIR FIRING
- NATURAL GAS (1000 BTU/SCF)
- 2250 F AVERAGE DISCHARGE TEMPERATURE
BATCH FURNACE
CONVENTIONAL FIRING

DOOR       BACK
HEATING CURVE: BATCH FURNACE

- **FURNACE**
- **TOP**
- **CENTER**
- **BOTTOM**

**TEMPERATURE (F)**

**TIME (MINUTES)**
BATCH FURNACE
REGENERATIVE FIRING
BATCH FURNACE
OXY FUEL FIRING

DOOR

BACK
FUEL SUMMARY

- COLD AIR FIRING: 158.73 MMBTU = 3.607 MMBTU/TON
- REGENERATIVE FIRING: 102.95 MMBTU = 2.340 MMBTU/TON
- OXY FUEL FIRING: 103.96 MMBTU = 2.363 MMBTU/TON
OPERATING COSTS

REGENERATIVE
- FUEL $15.94/HOUR
- ELECTRICITY $1.68/HOUR
- MEDIA REPLACEMENT $0.03/HOUR
- TOTAL $17.65/HOUR

OXY FUEL
- FUEL $15.94/HOUR
- OXYGEN $20.34/HOUR
- TOTAL $36.28/HOUR
ENVIRONMENTAL CONSIDERATIONS

REGENERATIVE

- NOx from FURNACE .08 LB/MMBTU
- NOx from ELECTRIC POWER GENERATION .002 LB/MMBTU
- CO2 from FURNACE 118 LB/MMBTU
- CO2 from ELECTRIC POWER GENERATION 5.2 LBS/MMBTU
- TOTAL NOx 0.082 LB/MMBTU
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OXY FUEL

- NOx FROM FURNACE .04 LB/MMBTU
- NOx from MANUFACTURE of OXYGEN .026 LB/MMBTU (SEPARATION ONLY)
- CO2 from FURNACE 118 LB/MMBTU
- CO2 from MANUFACTURE of OXYGEN 65.03 LB/MMBTU (SEPARATION ONLY)
- TOTAL NOx .066 LB/MMBTU
- TOTAL CO2 183.03 LB/MMBTU
CAPITAL COSTS

- REGENERATIVE BURNERS $375,000
- OXY FUEL BURNERS $50,000
- CONVENTIONAL BURNERS $100,000
- PRICING DOES NOT INCLUDE PIPING, RECUPERATORS OR INSTALLATION
CONCLUDING REMARKS

Regenerative Burners

- HIGH CAPITAL COST
- ACCEPTABLE OPERATING COST
- ACCEPTABLE ENVIRONMENTAL ISSUES
- INTANGIBLES ARE MAINTENANCE AND THE AMOUNT OF SPACE THAT THEY TAKE UP

Oxy Fuel Burners

- LOW CAPITAL COST
- HIGH OPERATING COST
- ACCEPTABLE ENVIRONMENTAL ISSUES
- INTANGIBLES ARE POTENTIAL SAFETY ISSUES AND MORE EXPENSIVE COMPONENTS AND REFRACTORIES
CONCLUDING REMARKS

- HYBRID FURNACES MAY BE MORE COST EFFECTIVE
- A NEW GENERATION REGENERATIVE BURNER WILL BE RELEASED IN LATE 2013 WITH LOWER NOₓ VALUES THAN STATED HERE
THANK YOU