

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

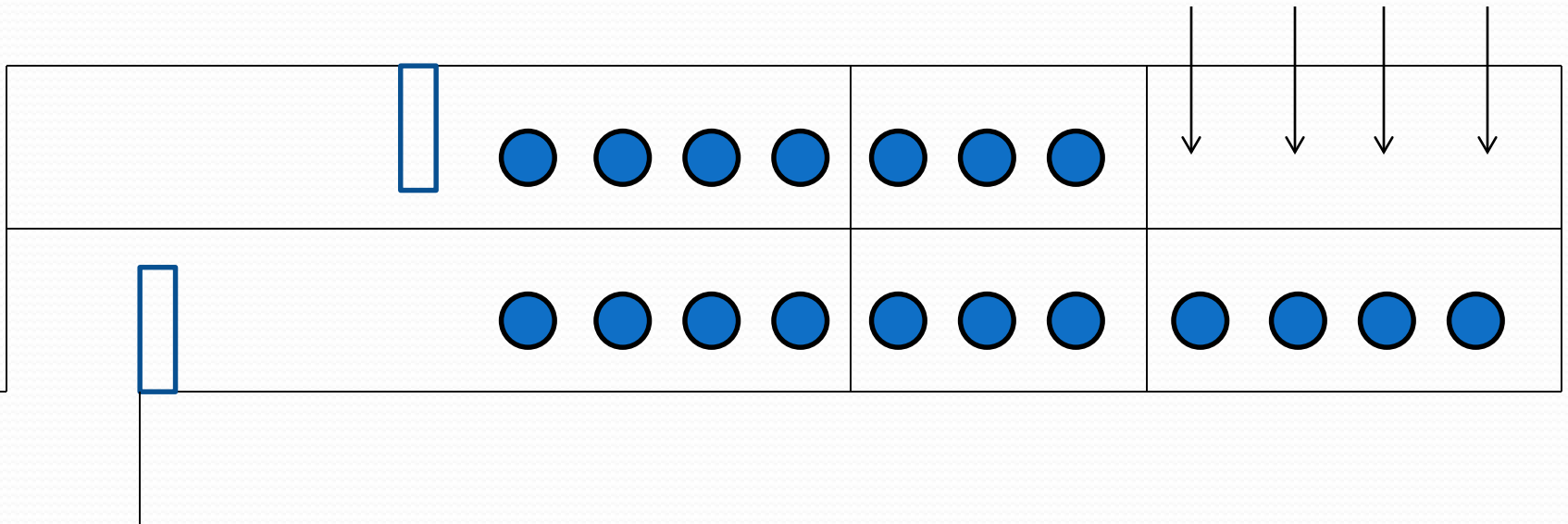
200 TPH

24' UNFIRED

28' PREHEAT

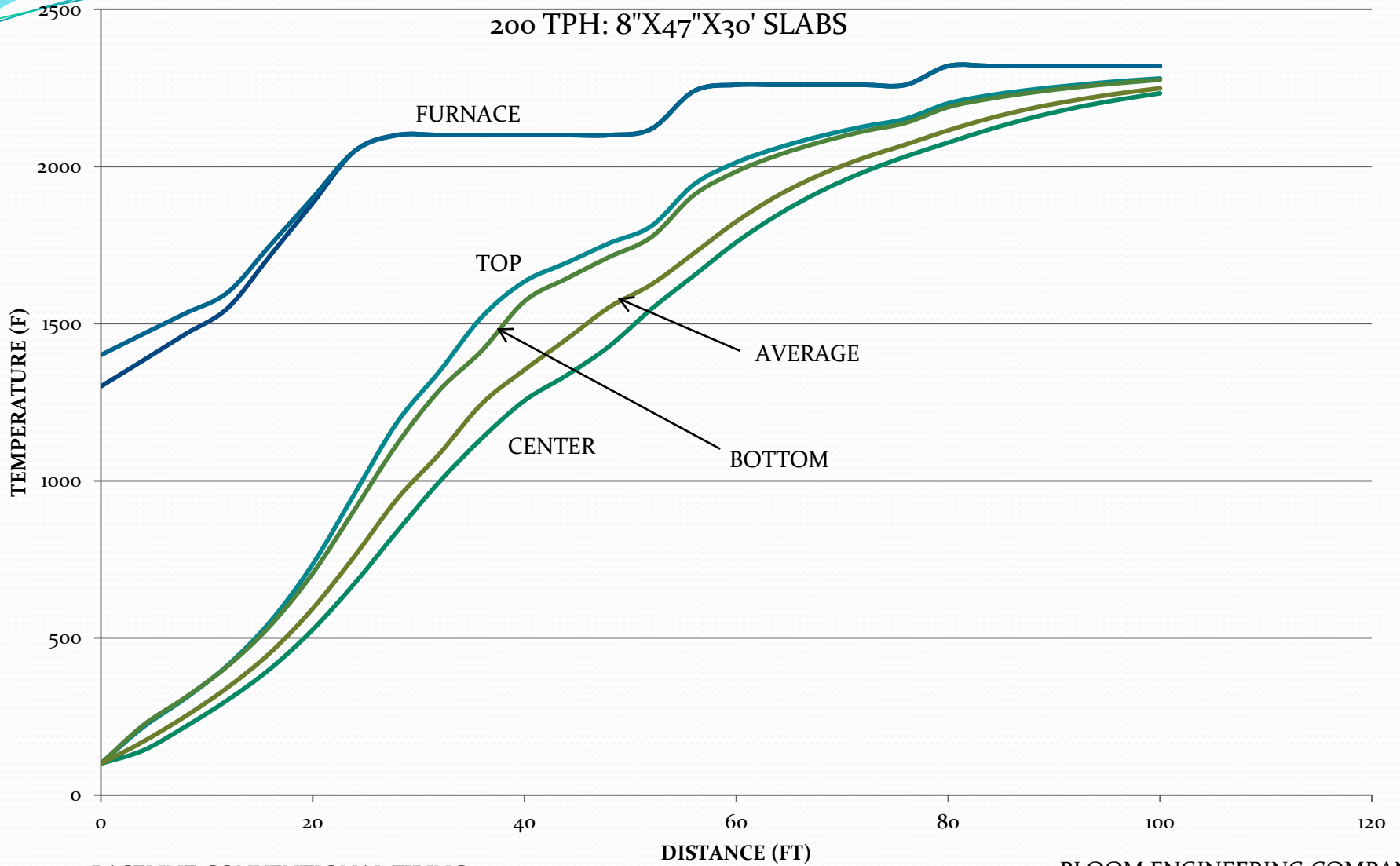
24' HEAT

24' SOAK



HEATING CURVE: WALKING BEAM FURNACE

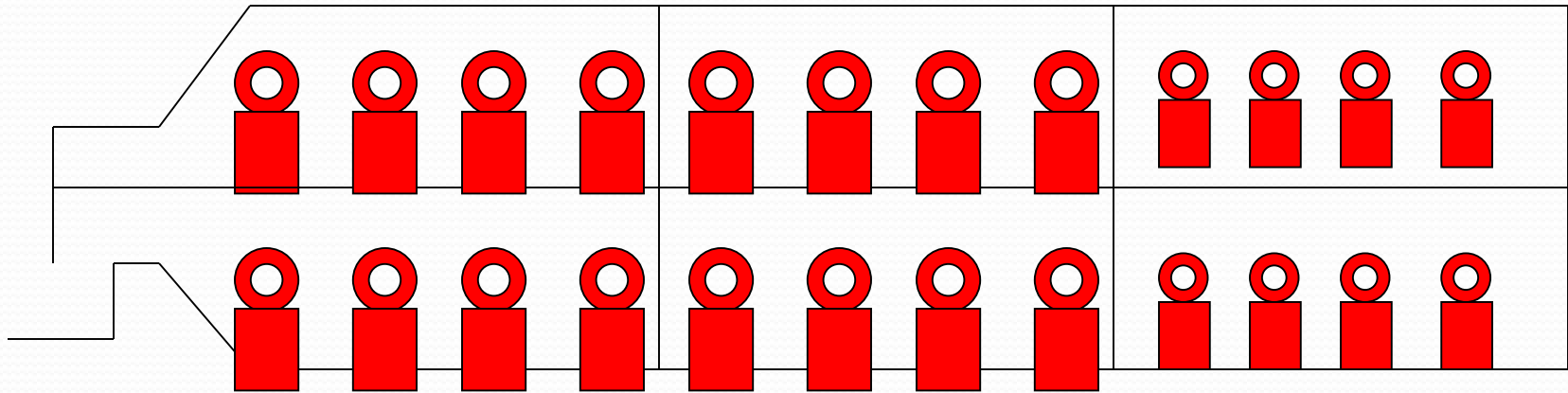
200 TPH: 8"X47"X30' SLABS



BLOOM ENGINEERING COMPAN

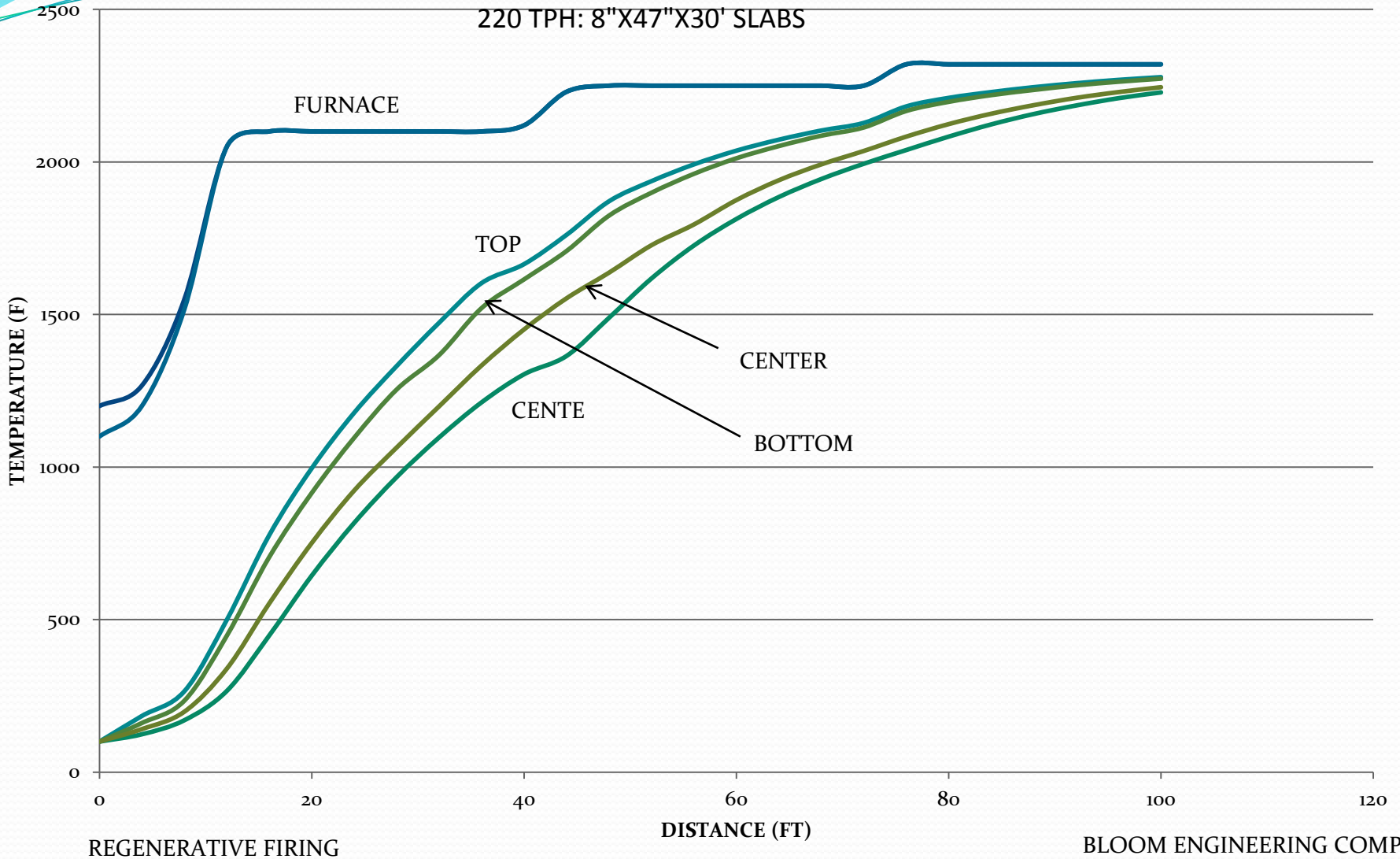
REGENERATIVE FURNACE

220 TPH

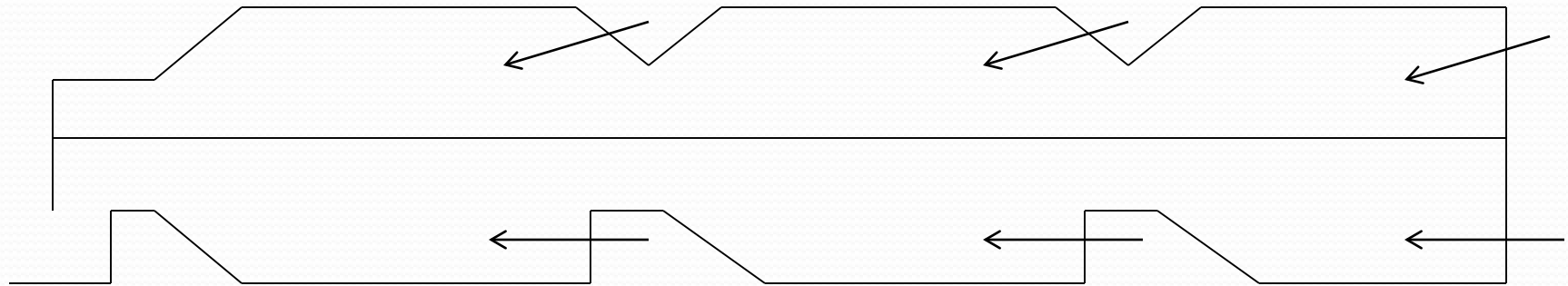


HEATING CURVE: WALKING BEAM FURNACE

220 TPH: 8"X47"X30' SLABS

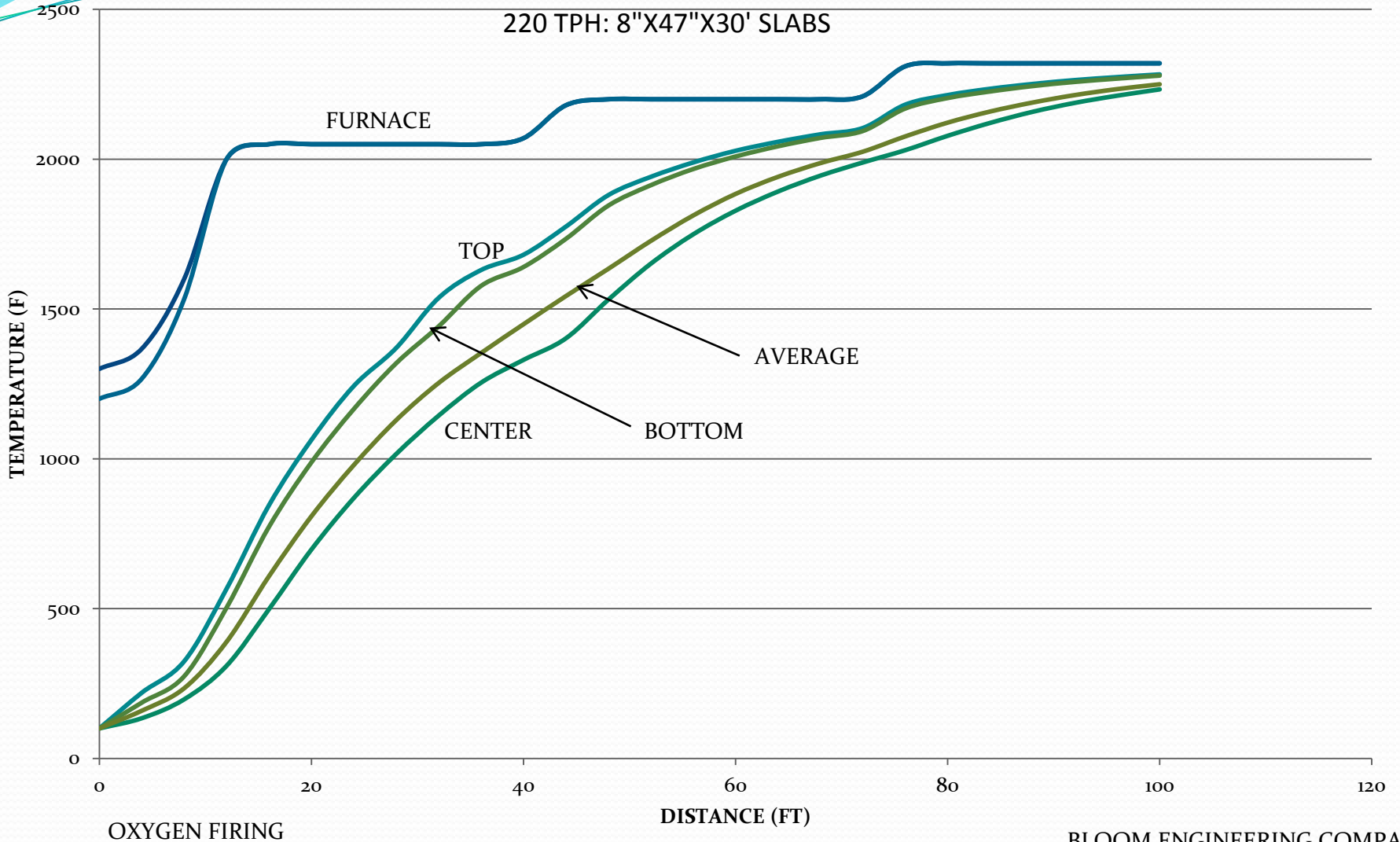


OXY FUEL FURNACE 220 TPH



HEATING CURVE: WALKING BEAM FURNACE

220 TPH: 8"X47"X30' SLABS



BLOOM ENGINEERING COMPAN

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 HORESPOWER FOR REGENERATIVE FANS
- 497640 SCFH 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

- NO_x from FURNACE .08 LB/MMBTU
- NO_x from ELECTRIC POWER GENERATION .002 LB/MBTU
- CO₂ from FURNACE 118 LB/MMBTU
- CO₂ from ELECTRIC POWER GENERATION 5.2 LBS/MMBTU
- **TOTAL NO_x 0.082 LB/MMBTU**
- **TOTAL CO₂ 123.2 LB/MMBTU**

OXY FUEL

- NO_x FROM FURNACE .04 LB/MMBTU
- NO_x 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 NO_x .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

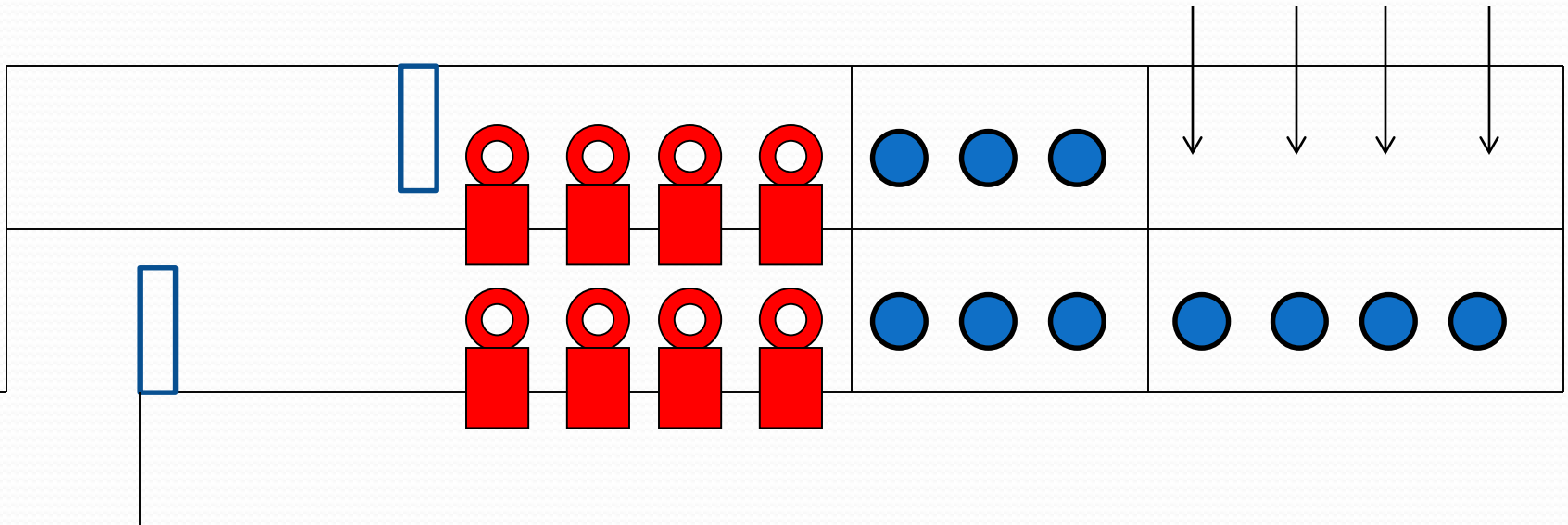
REGENERATIVE HYBRID 200 TPH

24' UNFIRED

28' PREHEAT

24' HEAT

24' SOAK



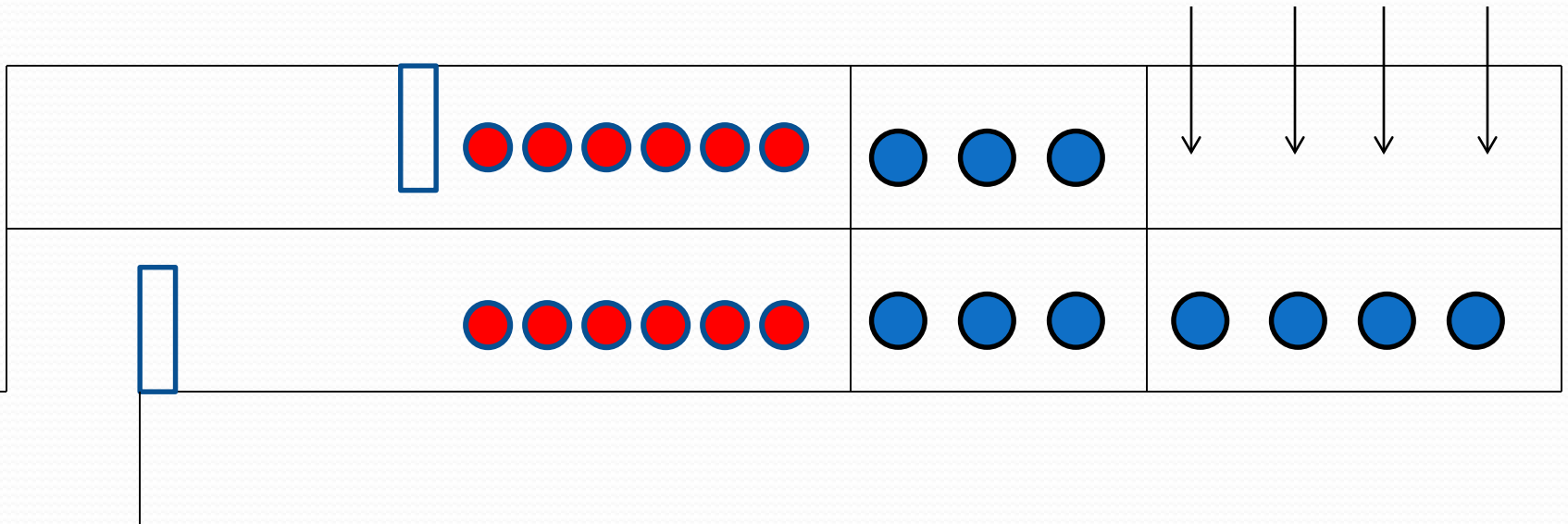
OXYFUEL HYBRID 200 TPH

24' UNFIRED

28' PREHEAT

24' HEAT

24' SOAK



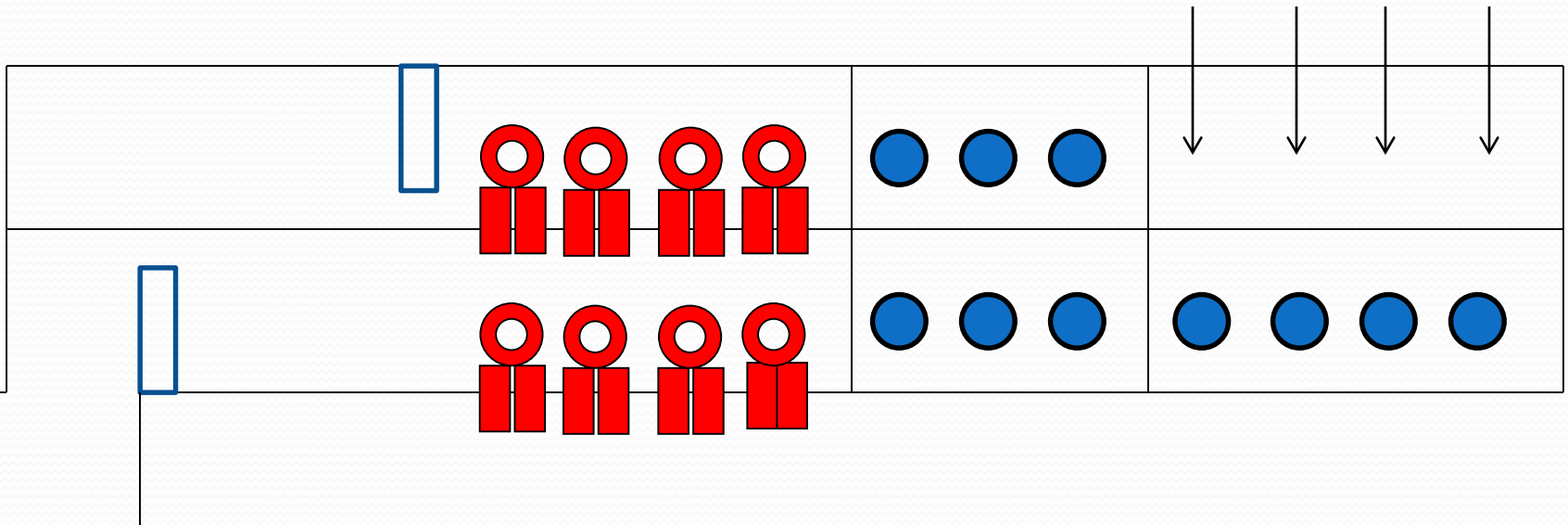
REGENERATIVE HYBRID BLAST FURNACE GAS 200 TPH

24' UNFIRED

28' PREHEAT

24' HEAT

24' SOAK



OXYGEN ENRICHMENT FURNACE

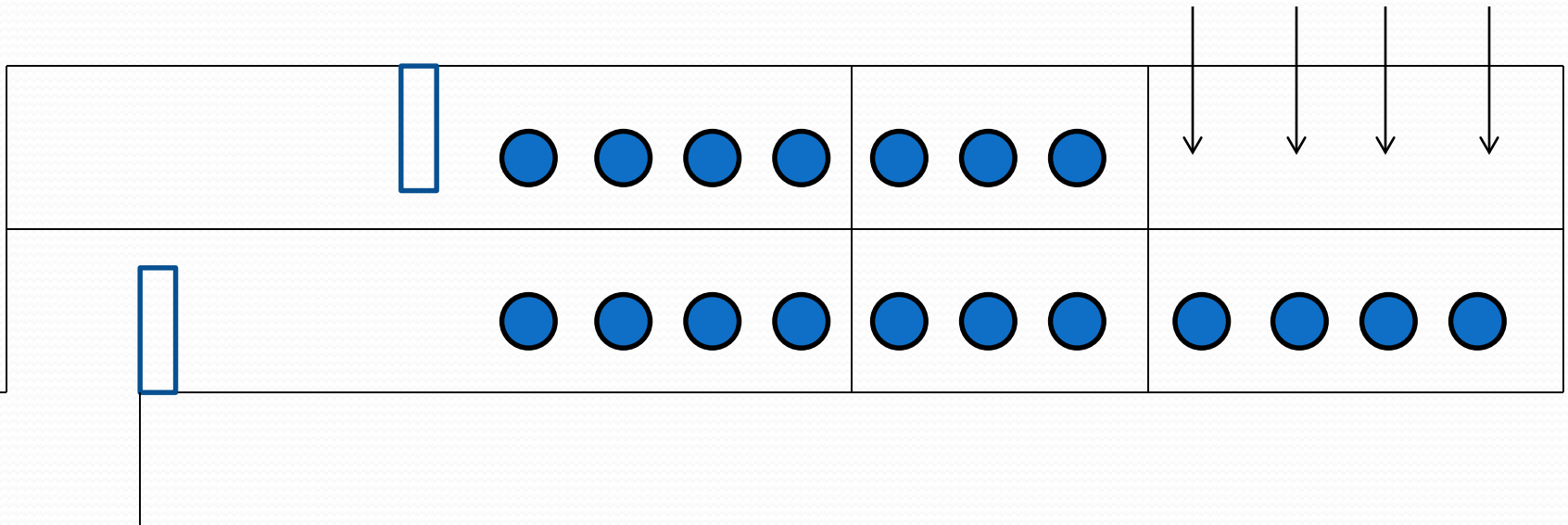
200 TPH

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: .057 LB/MMBTU NO_x; 121.0 LBS/MMBTU CO₂
- REGENERATIVE FURNACE: 0.082 LB/MMBTU NO_x ; 123.2 LB/MMBTU CO₂
- OXY FUEL FURNACE: 0.066 LBS/MMBTU NO_x; 183.3 LBS/MMBTU CO₂
- REGENERATIVE HYBRID: .07 LB/MMBTU NO_x; 122.1 LBS/MMBTU CO₂
- OXY FUEL HYBRID: 0.064 LB/MMBTU NO_x; 147.2 LB/MMBTU CO₂
- BFG HYBRID: 0.068 LB/MMBTU NO_x; 141.7 LB/MMBTU CO₂
- OXYGEN ENRICHMENT: 0.060 LB/MMBTU NO_x; 137.6 LB/MMBTU CO₂

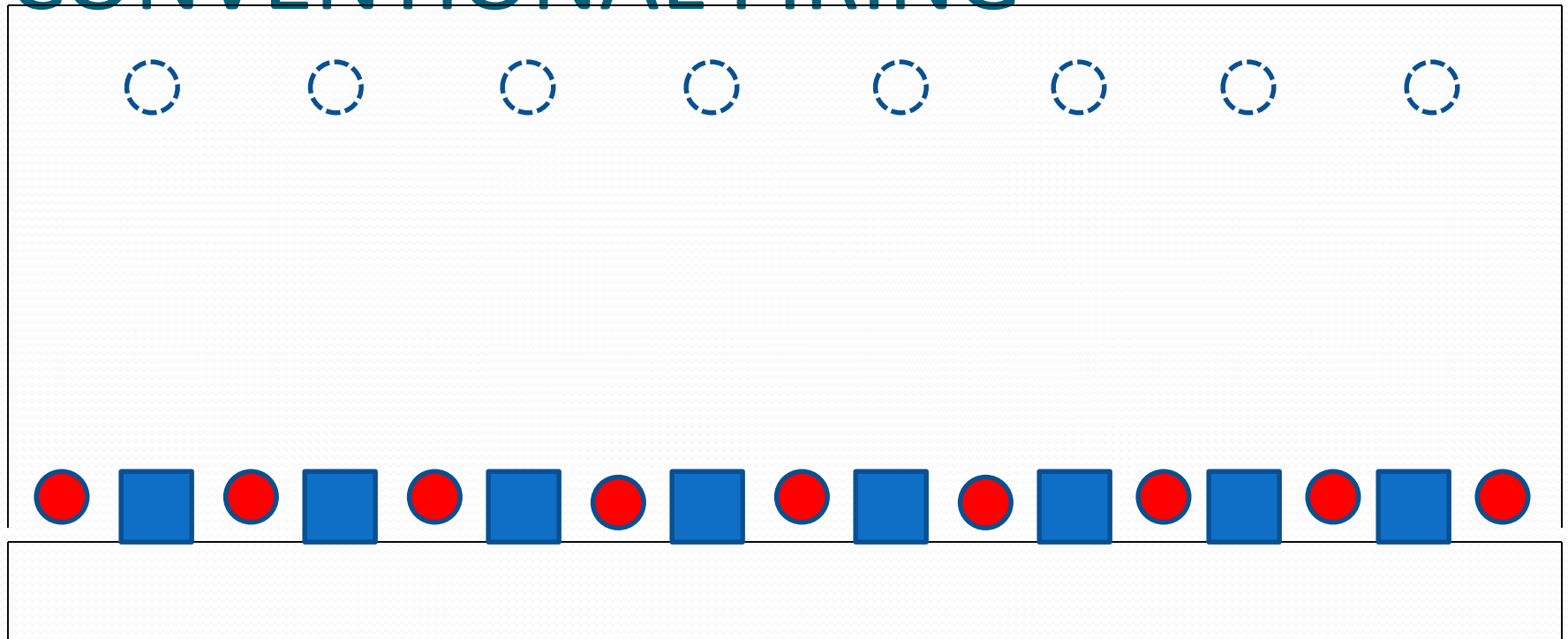
CAPITAL COSTS

- 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

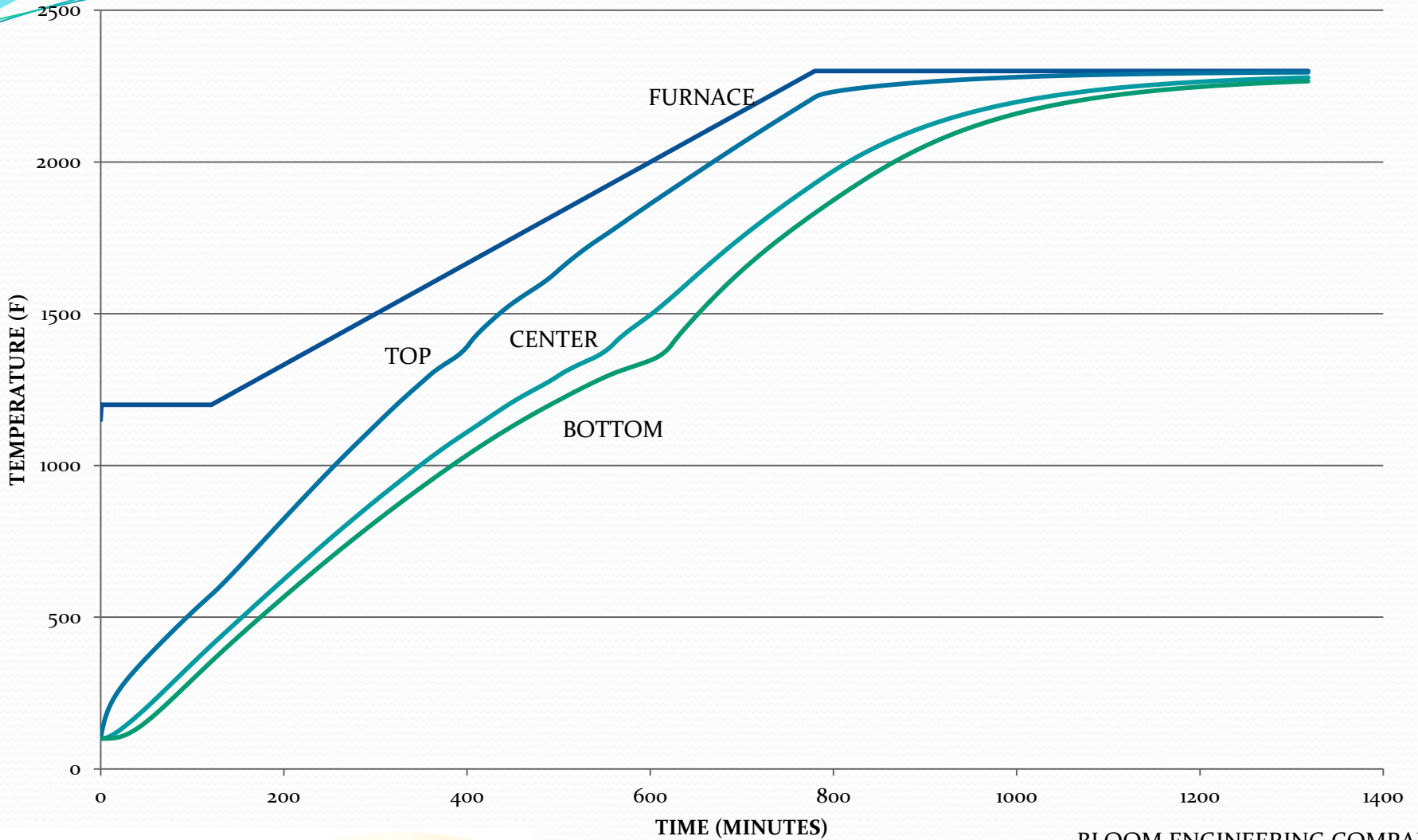
BATCH FURNACE CONVENTIONAL FIRING



DOOR

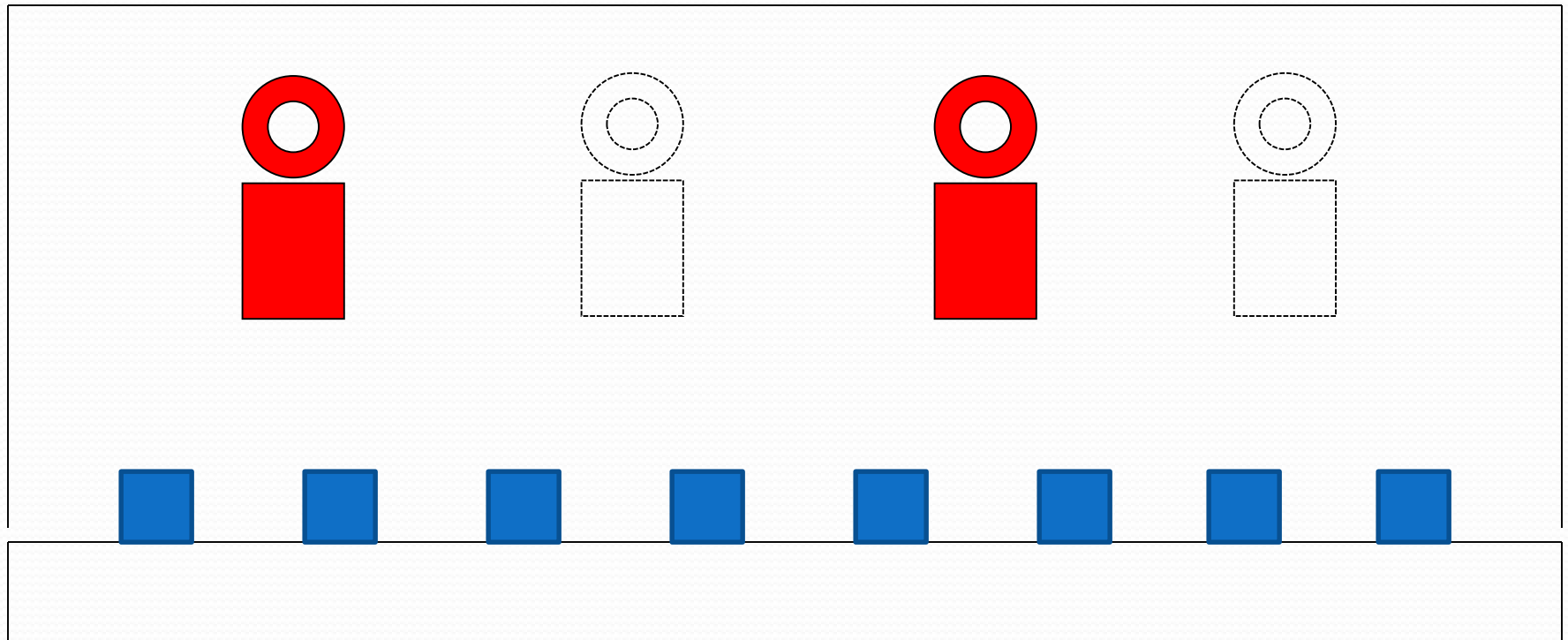
BACK

HEATING CURVE: BATCH FURNACE



BLOOM ENGINEERING COMPAN

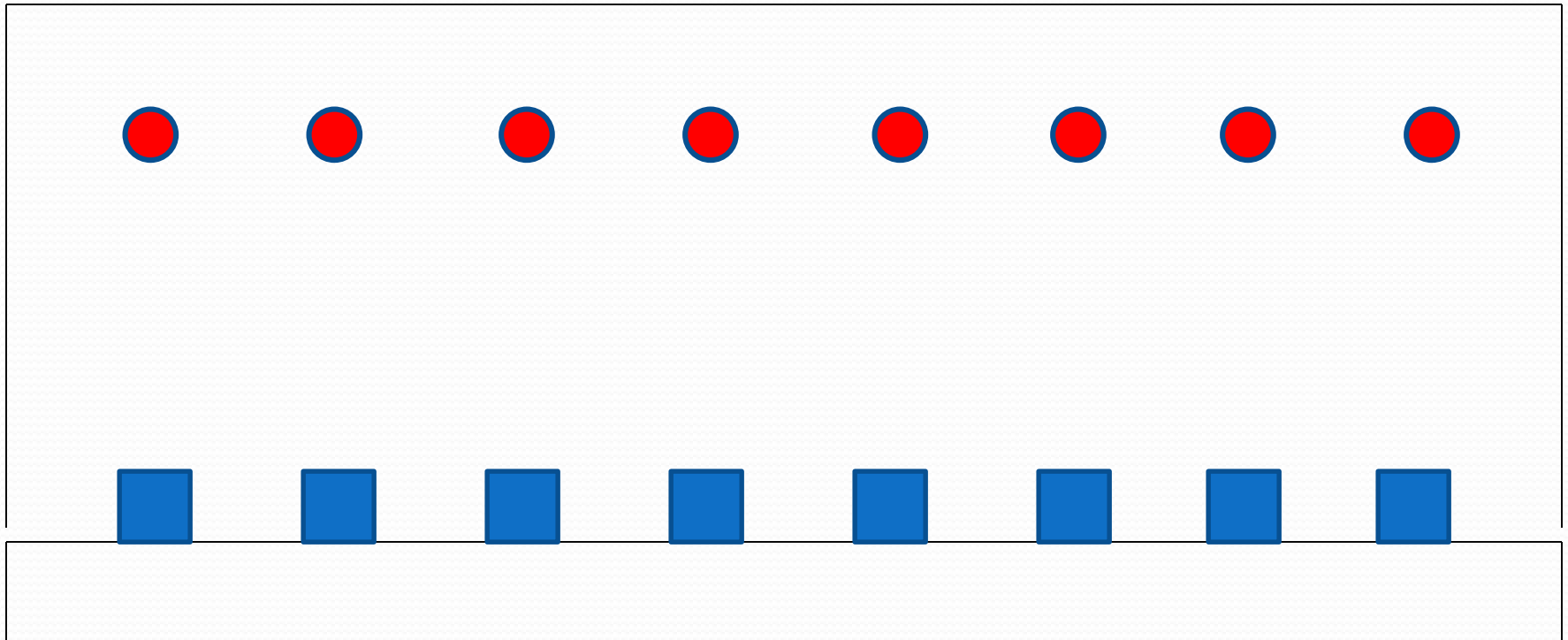
BATCH FURNACE REGENERATIVE FIRING



DOOR

BACK

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

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- NO_x FROM FURNACE .04 LB/MMBTU
- NO_x 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 NO_x .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 NO_x VALUES THAN STATED HERE

THANK YOU

Bloomengineering
GLOBAL ENERGY AND
ENVIRONMENTAL SOLUTIONS