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Utilization of Lightweight Materials Made from Coal Gasification Slags

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PB.19 Utilization of Lightweight Materials Made from Coal Gasification Slags

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Abstract

The integrated gasification combined-cycle (IGCC) coal conversion process has been demonstrated to be a clean, efficient, and environmentally acceptable method of generating power; however, it generates solid waste materials in relatively large quantities. For example, a 400-MW power plant using 4000 tons of 10% ash coal per day may generate over 440 tons/day of solid waste or slag, consisting of vitrified mineral matter and unburned carbon. The disposal of these wastes represents significant costs, Regulatory trends with respect to solid waste disposal, landfill development costs, and public concern make utilization of solid wastes a high-priority issue. As coal gasification technologies find increasing commercial applications for power generation or production of chemical feed stocks, it becomes imperative that slag utilization methods be developed, tested, and commercialized in order to offset disposal costs.

Praxis is working on a DOE/METC funded project to demonstrate the technical and economic feasibility of making lightweight and ultra-lightweight aggregates from slags left as solid by-products from the coal gasification process. These aggregates are produced by controlled heating of the slags to temperatures ranging between 1600 and 1900°F. Over 10 tons of expanded slag lightweight aggregates (SLA) were produced using a direct-fired rotary kiln and a fluidized bed calciner with unit weights varying between 20 and 50 lb/ft^3. The slag-based aggregates are being evaluated at the laboratory scale as substitutes for conventional lightweight aggregates in making lightweight structural concrete, roof tiles, blocks, insulating concrete, and a number of other applications. Based on the laboratory data, large-scale testing will be performed and the durability of the finished products evaluated. Conventional lightweight aggregates are made from pyroprocessing of expansible shale or clay and sell at $30-40/ton. The net production costs of SLA are in the range of $22 to $24/ton. Thus, the technology provides a good opportunity for economic use of gasification slags.

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Utilization of Lightweight Materials Made from Coal Gasification Slags

Praxis Engineers, Inc.
Milpitas, California 95035

Funding Sources: METC, EPRI, and ICCI

Project Objectives

- Develop and demonstrate the technology for producing slag-based lightweight aggregates (SLA)

- Produce 10 tons of SLA Products with different unit weights from two slags

- Collect operational and emissions data from pilot-scale operations

- Laboratory- and commercial-scale evaluation of SLA with conventional lightweight and ultra-lightweight aggregates (LWA and ULWA)

Project Objectives (contd)

Characterize SLA products for leachability and conduct applications testing

Evaluate recovered char for recycle to the gasifier, and for use as a fuel during slag expansion or in the boiler

Conduct preliminary economics of SLA production

Slag, LWA, ULWA, & SLA: Definitions

- Slag is a solid residue by-product of coal gasification combined-cycle process

- Gasification slag is vitrified ash containing some unconverted carbon

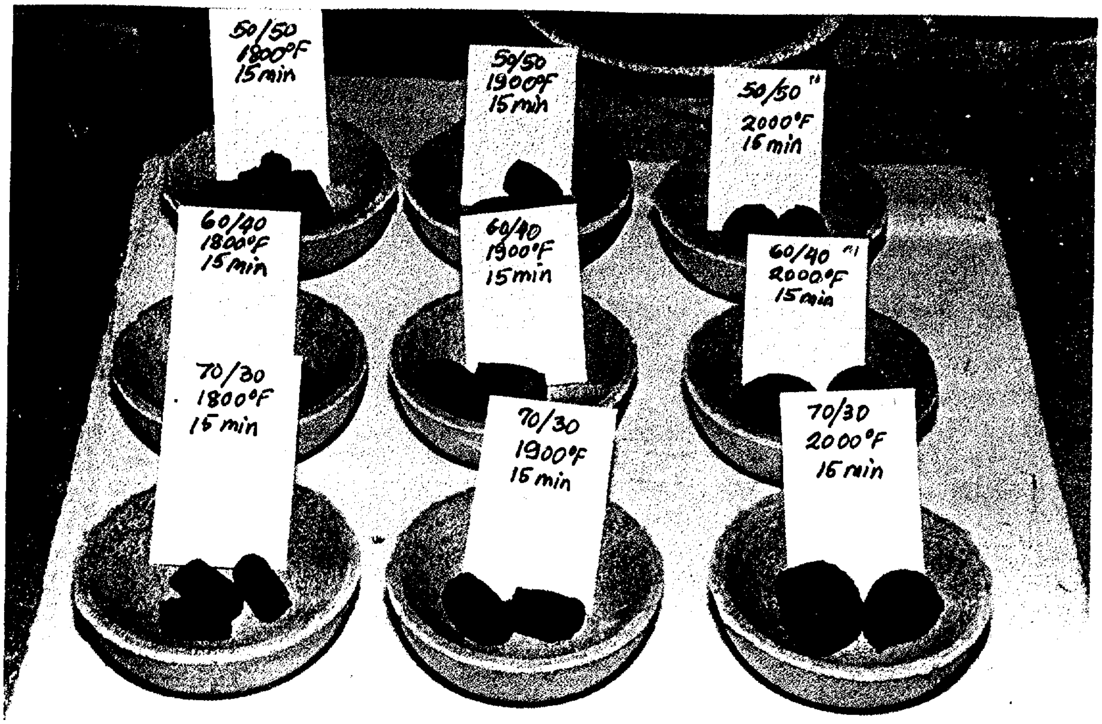
- Conventional LWA:
  - Produced by pyroprocessing clays and shales at 2 100”F
  - Unit weight is 50 lb/ft^3
  - Used to make lightweight structural concrete, blocks, and roof tiles
  Market price is $20-30 / ton

Definitions (contd)

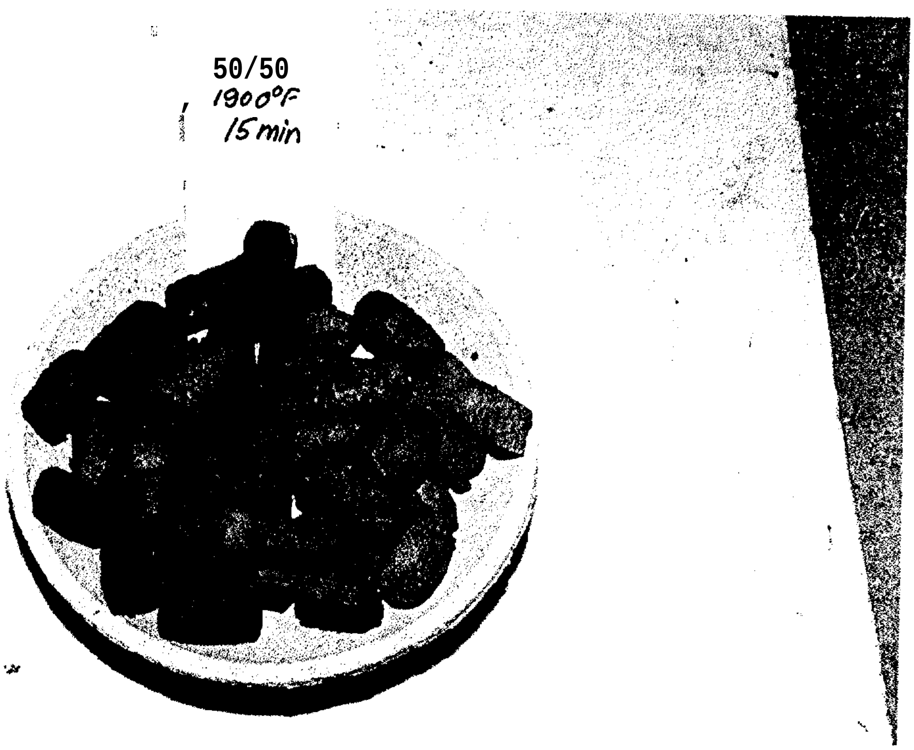
- Conventional ULWA:
  - Produced by pyroprocessing perlite ores at 2000ºF
  - Unit weight is 4-12 lb/ft^3
  - Used for horticultural and insulation applications
  - Market price is over $200/ton

- Slag can be expanded under controlled conditions to produce lightweight materials, termed slag-based LWA or SLA:
  - Produced by pyroprocessing at 1600-1800”F
  - Unit weight is 12-50 lb/ft3
  - Blendable with existing raw materials
  - Can be substituted for all or part of the ingredients of some LWA and ULWA applications

MUFFLE BURN TESTS - EXTRUDED MIXTURES



BURN TESTS ALL THREE BLENDS

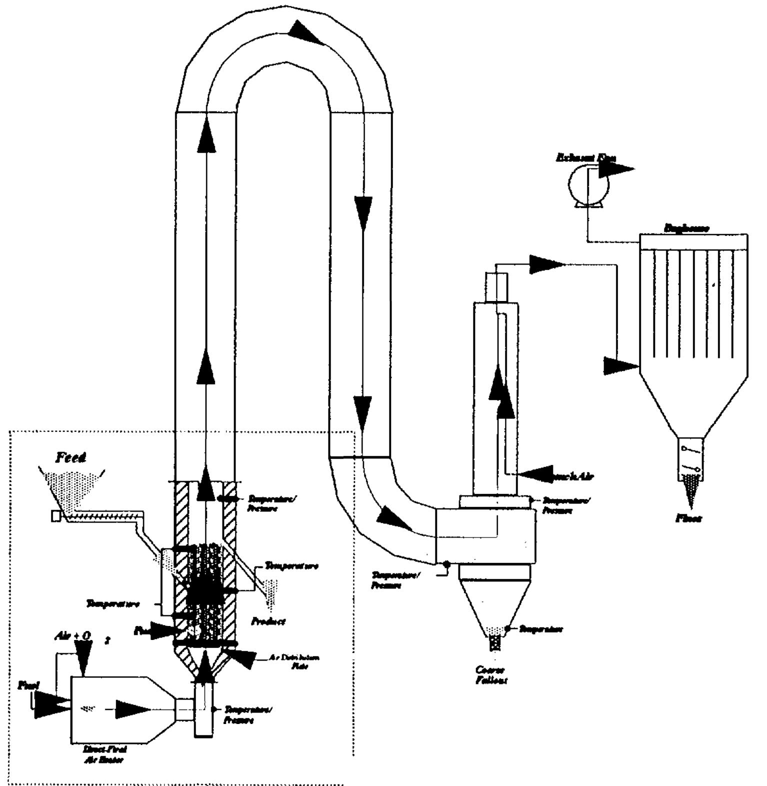


50/50 MIX-COMPLETE CUP BURN - 1900°F

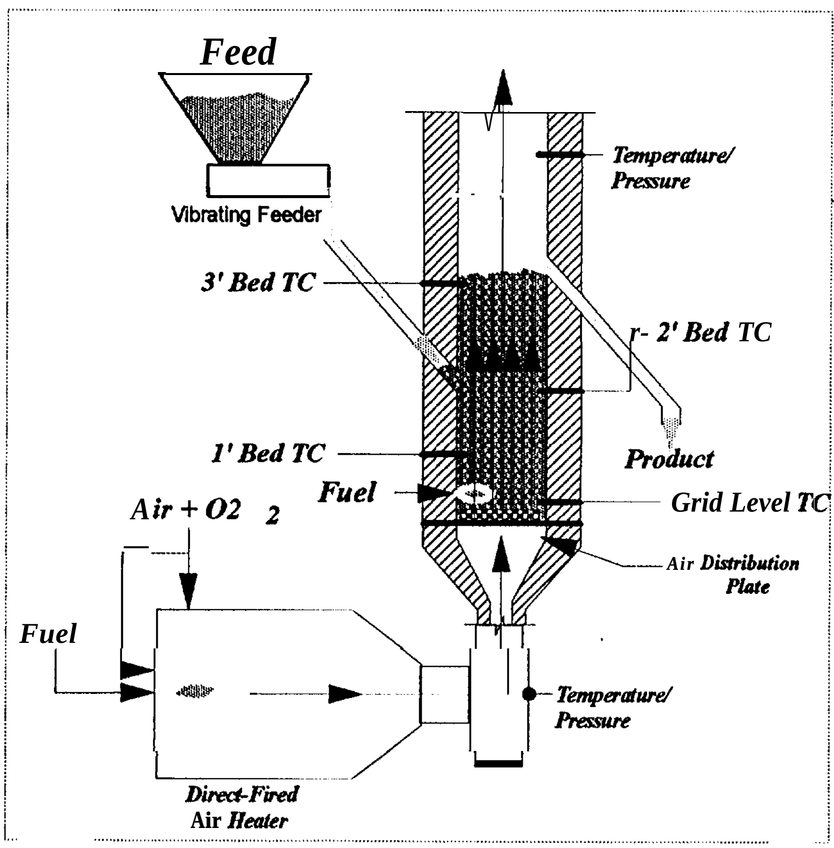
6" Diameter Bench-Scale Fluid Bed Reactor

Specifications

Bed Height:	*3 ft*
Feed Height (Above Grid):	*2 ft*
Inside Diameter:	*0.5 ft*
Temperature:	*+1420°C*
Fuel:	*Gas/Oil*



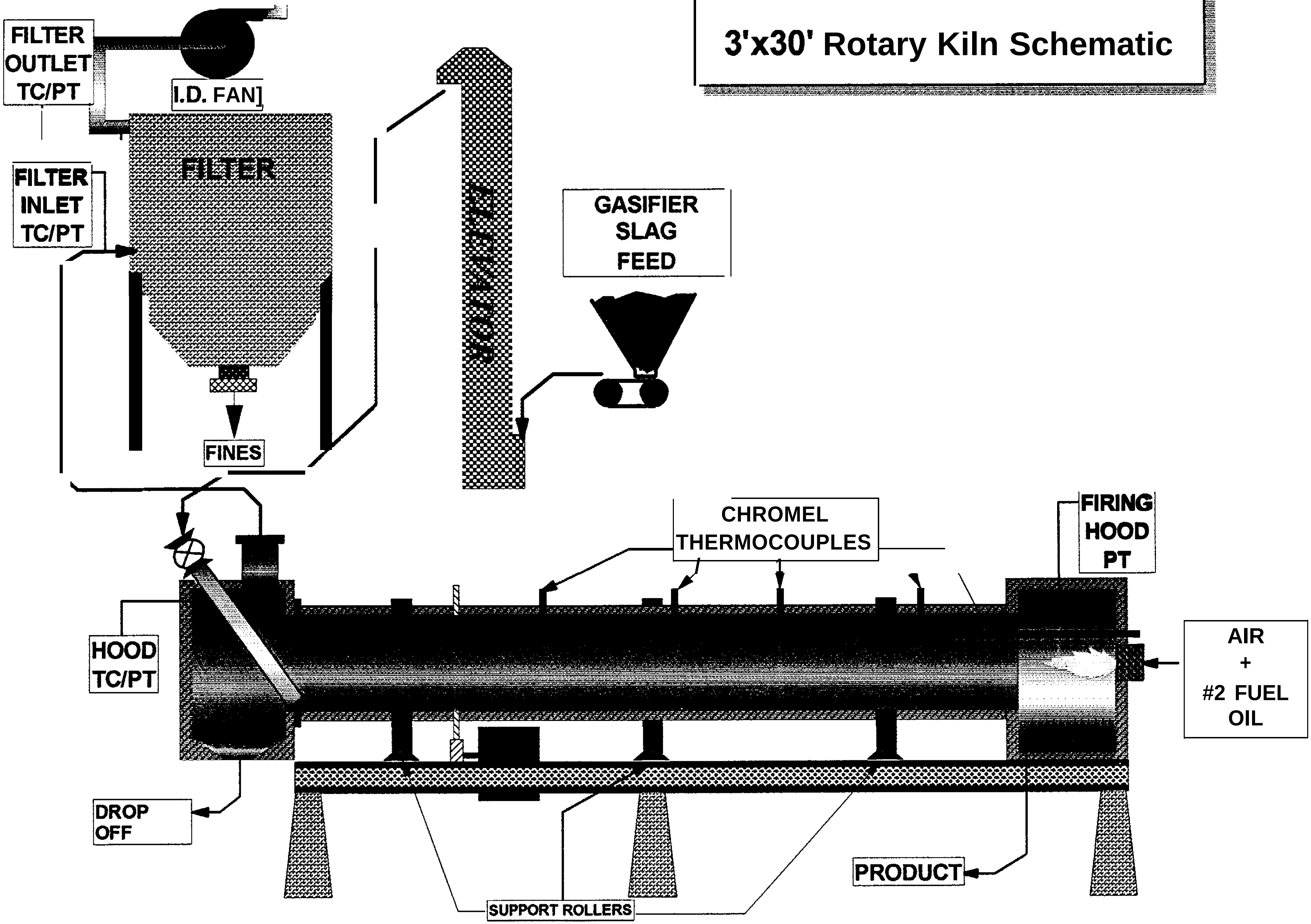
Reactor Section Detail

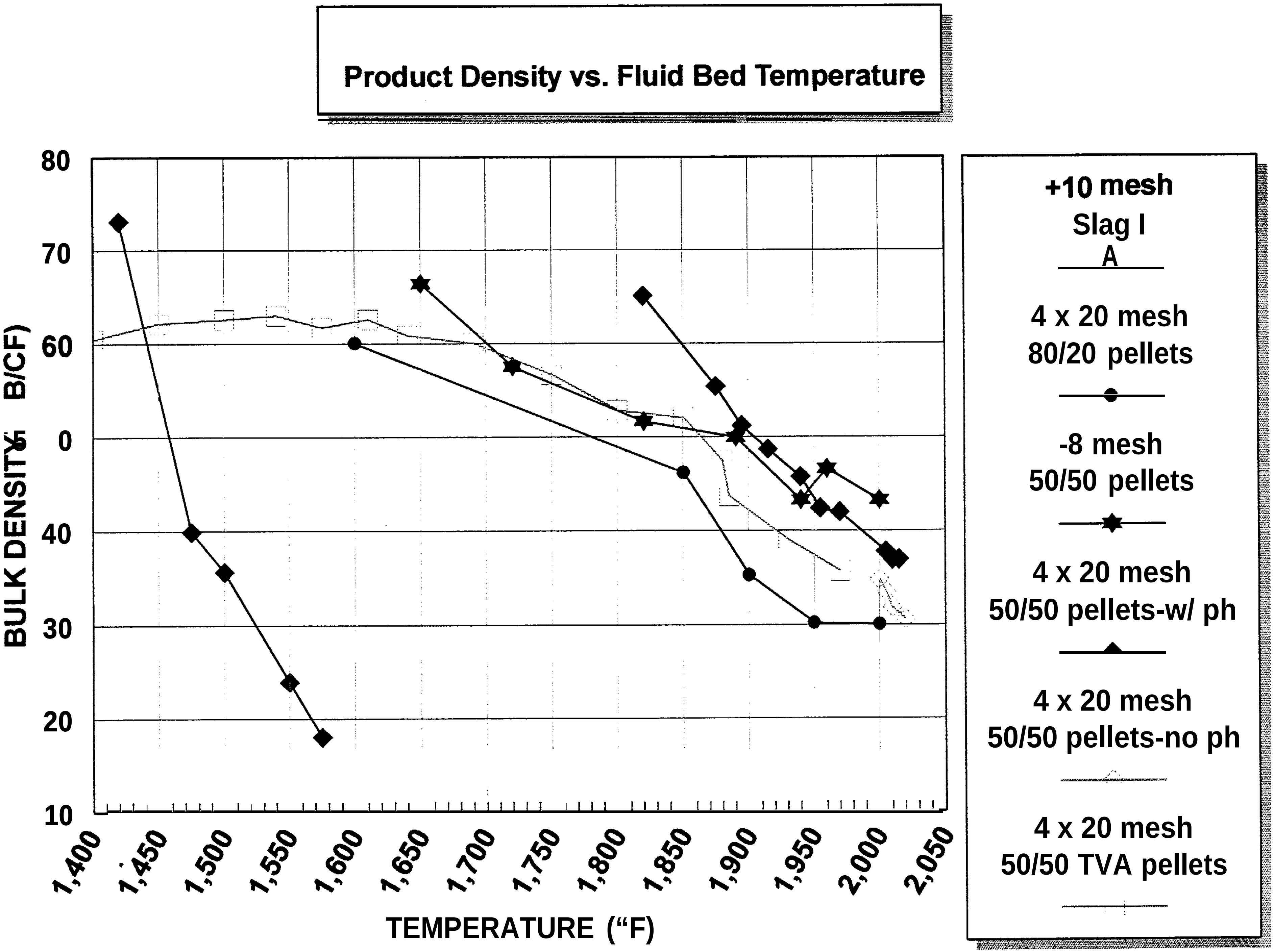


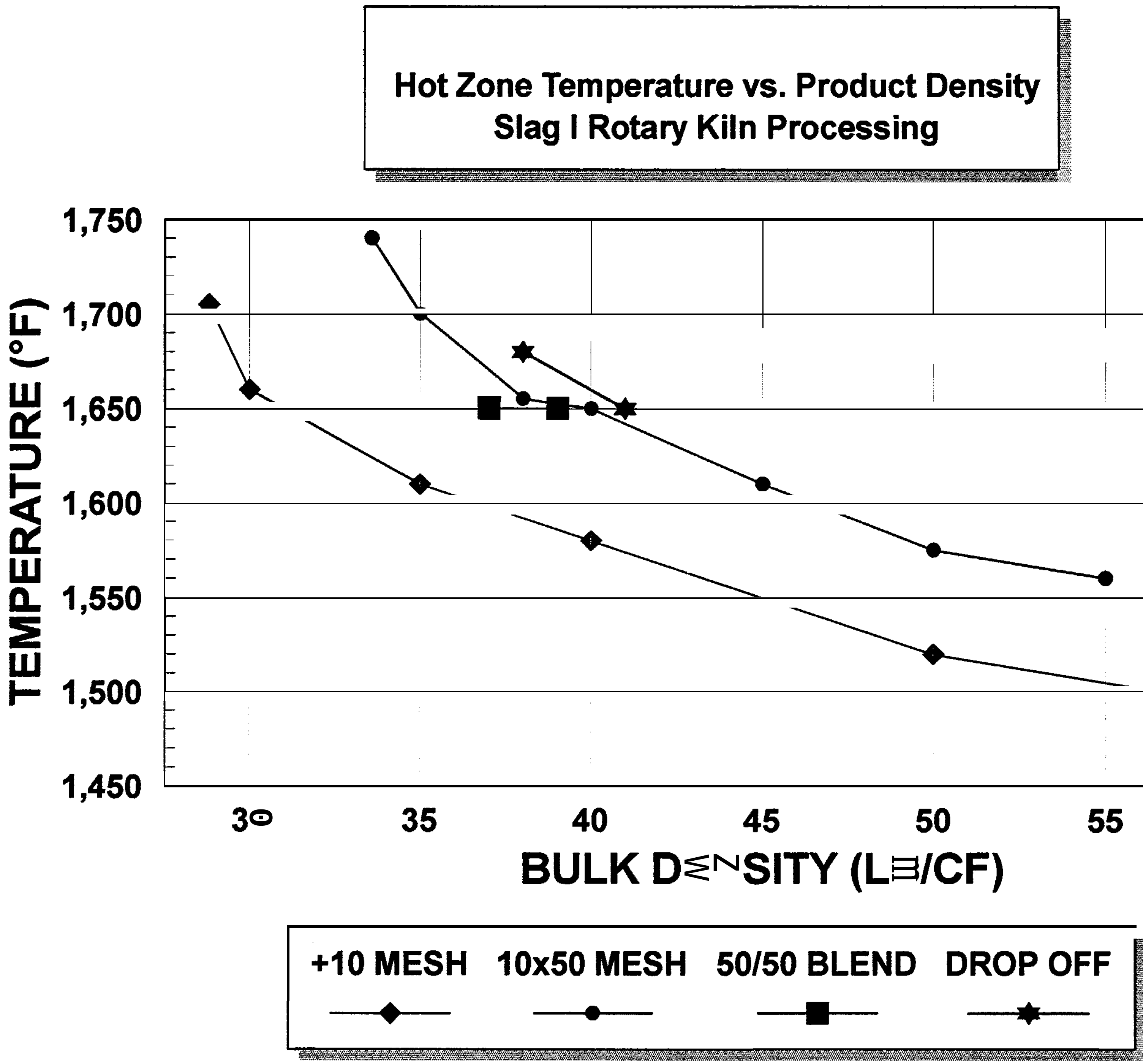
Material Flow

Gas Flow

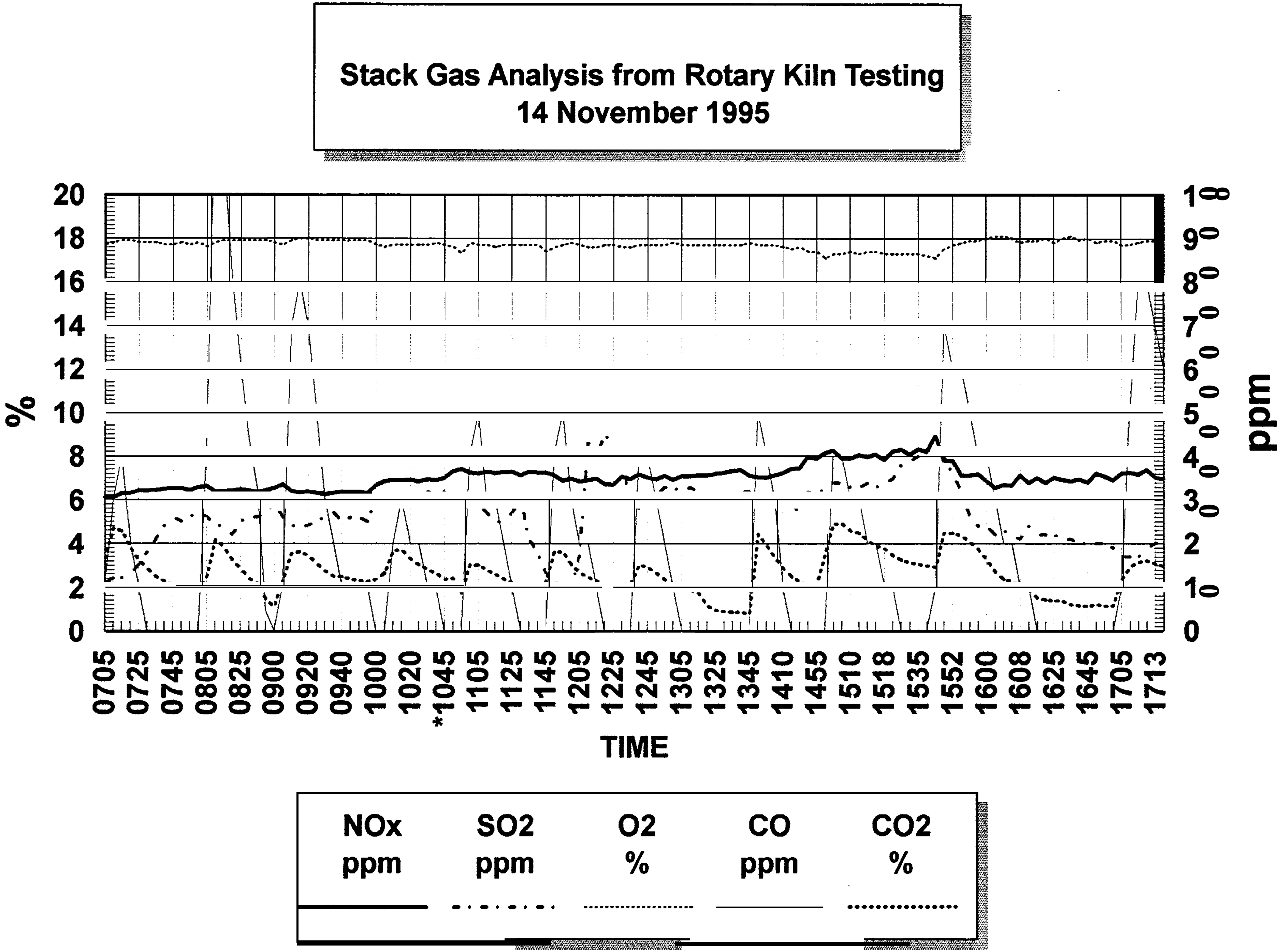
3'x30' Rotary Kiln Schematic



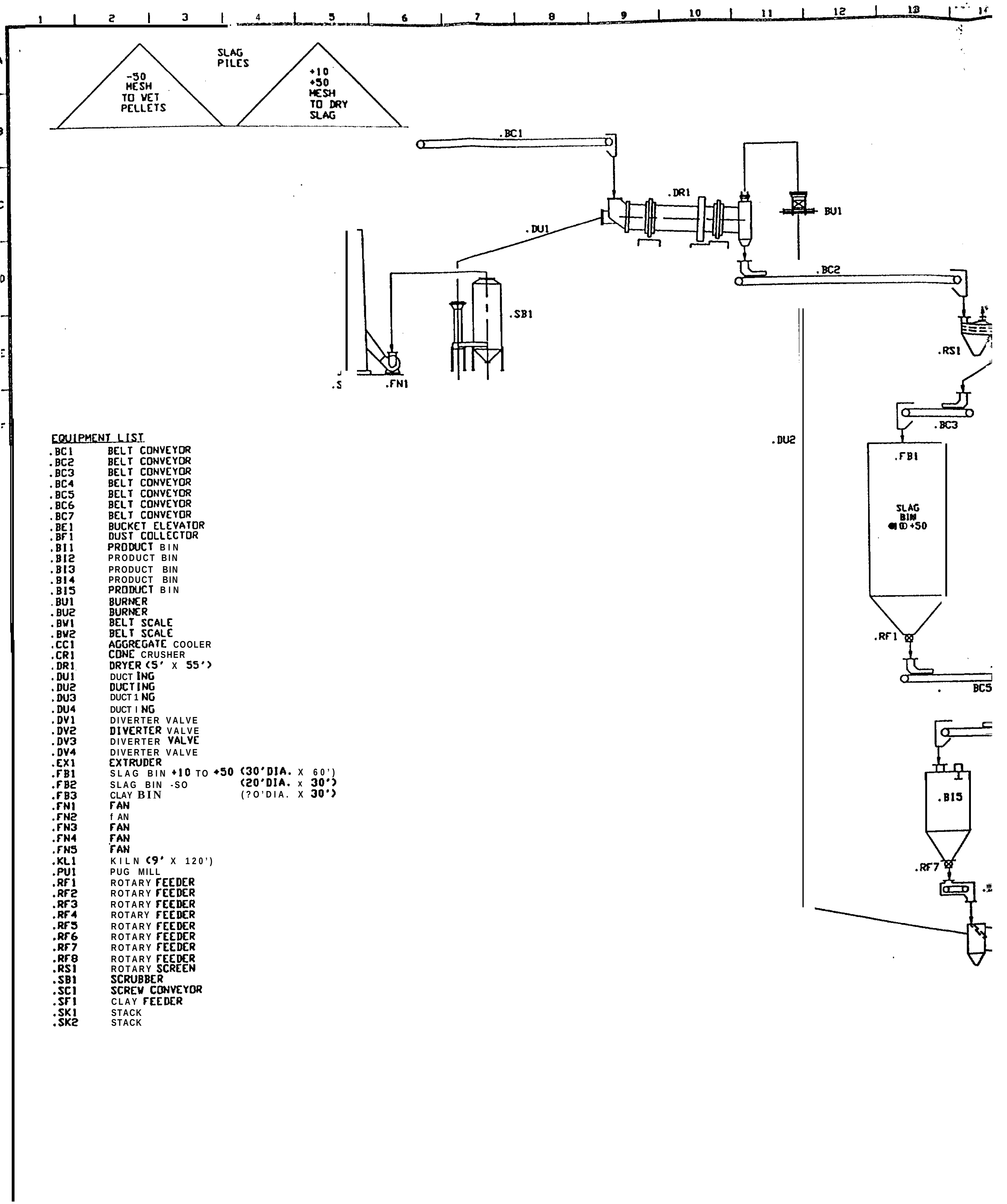

Product Density vs. Fluid Bed Temperature
BULK DENSITY (LB/CF)
80
70
60
50
40
30
20
10
1,400
1,450
1,500
1,550
1,600
1,650
1,700
1,750
1,800
1,850
1,900
1,950
2,000
2,050
TEMPERATURE (°F)
+10 mesh
Slag I
A
4 x 20 mesh
80/20 pellets
-8 mesh
50/50 pellets
4 x 20 mesh
50/50 pellets-w/ ph
4 x 20 mesh
50/50 pellets-no ph
4 x 20 mesh
50/50 TVA pellets



Hot Zone Temperature vs. Product Density
Slag I Rotary Kiln Processing
TEMPERATURE (°F)
1,750
1,700
1,650
1,600
1,550
1,500
1,450
30
35
40
45
50
55
60
BULK DENSITY (LB/CF)
+10 MESH
10x50 MESH
50/50 BLEND
DROP OFF

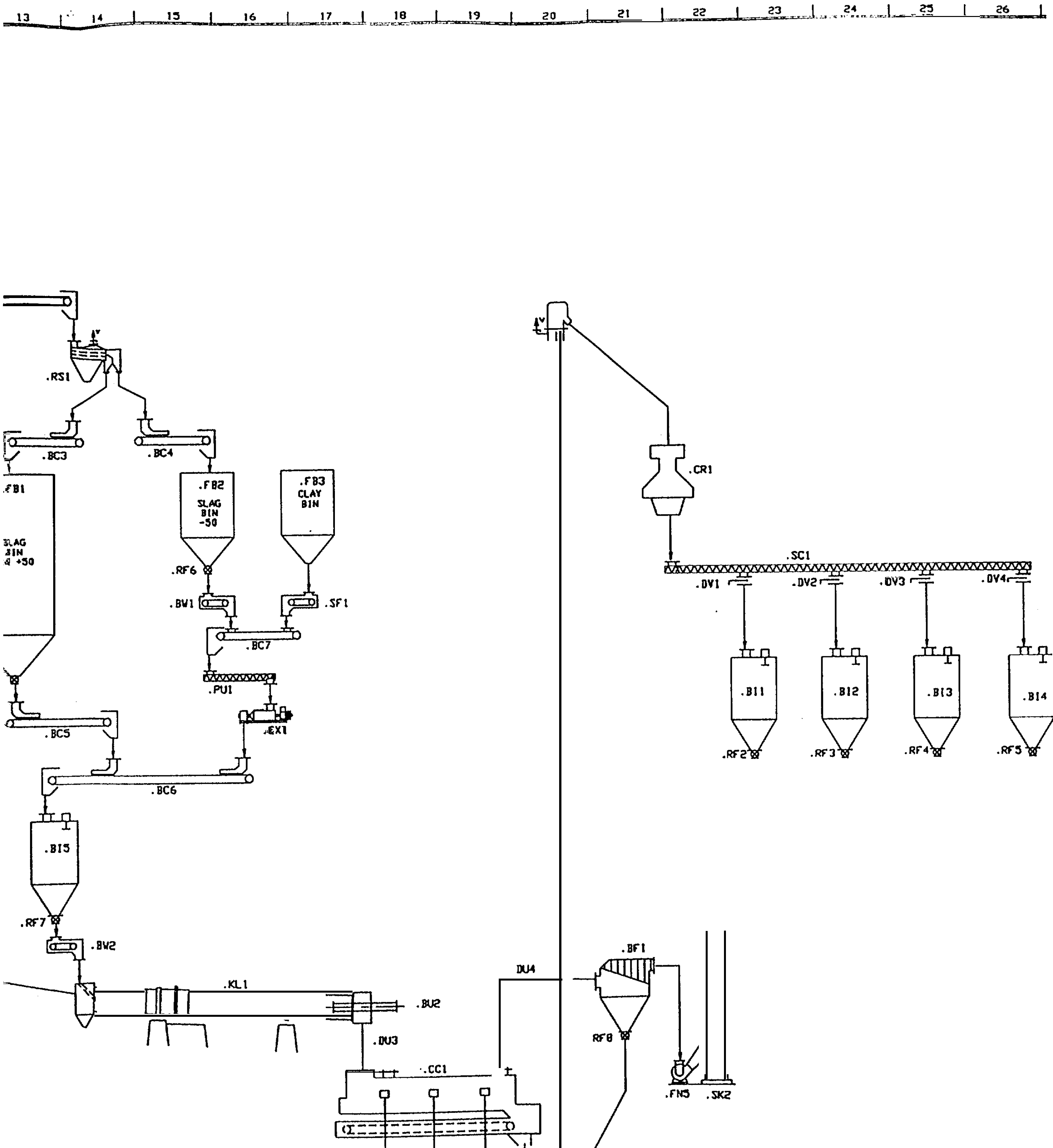


Stack Gas Analysis from Rotary Kiln Testing
14 November 1995
%
ppm
20
18
16
14
12
10
8
6
4
2
0
100
90
80
70
60
50
40
30
20
10
0
0705 0725 0745 0805 0825 0900 0920 0940 1000 1020 *1045 1105 1125 1145 1205 1225 1245 1305 1325 1345 1410 1455 1510 1518 1535 1552 1600 1608 1625 1645 1705 1713
TIME
NOx ppm
SO2 ppm
O2 %
CO ppm
CO2 %



EQUIPMENT LIST

.BC1	BELT CONVEYOR
.BC2	BELT CONVEYOR
.BC3	BELT CONVEYOR
.BC4	BELT CONVEYOR
.BC5	BELT CONVEYOR
.BC6	BELT CONVEYOR
.BC7	BELT CONVEYOR
.BE1	BUCKET ELEVATOR
.BF1	DUST COLLECTOR
.BI1	PRODUCT BIN
.BI2	PRODUCT BIN
.BI3	PRODUCT BIN
.BI4	PRODUCT BIN
.BI5	PRODUCT BIN
.BU1	BURNER
.BU2	BURNER
.BW1	BELT SCALE
.BW2	BELT SCALE
.CC1	AGGREGATE COOLER
.CR1	CONE CRUSHER
.DR1	DRYER (5' X 55')
.DU1	DUCTING
.DU2	DUCTING
.DU3	DUCTING
.DU4	DUCTING
.DV1	DIVERTER VALVE
.DV2	DIVERTER VALVE
.DV3	DIVERTER VALVE
.DV4	DIVERTER VALVE
.EX1	EXTRUDER
.FB1	SLAG BIN +10 TO +50 (30'DIA. X 60')
.FB2	SLAG BIN -SO (20'DIA. x 30')
.FB3	CLAY BIN (?O'DIA. X 30')
.FN1	FAN
.FN2	FAN
.FN3	FAN
.FN4	FAN
.FN5	FAN
.KL1	KILN (9' X 120')
.PU1	PUG MILL
.RF1	ROTARY FEEDER
.RF2	ROTARY FEEDER
.RF3	ROTARY FEEDER
.RF4	ROTARY FEEDER
.RF5	ROTARY FEEDER
.RF6	ROTARY FEEDER
.RF7	ROTARY FEEDER
.RF8	ROTARY FEEDER
.RS1	ROTARY SCREEN
.SB1	SCRUBBER
.SC1	SCREW CONVEYOR
.SF1	CLAY FEEDER
.SK1	STACK
.SK2	STACK



Original	20MAY96	DJW	HRM	HRM	Revision in zone / Description
Scale:	Date	Sign.	Sign.	Sign.	Mat.:
NONE	Drawn		Chkd	Appr	Welds: ⊗

PROPOSED EQUIPMENT FLOW SHEET
LIGHT WEIGHT AGGREGATE PLANT
235 TPD WET PELETS
200 TPD DRY SLAG

⊗ Pattern number, embossed/counter...
Where nothing else is stated, adhere to general instructions No. 52053...

PC: 143

FULLER.
PROPOSAL

Drawing Number
1.725762

SLA Products Made at Pilot Scale

Slag/Size/ Mix Type	Direct-Fired Kiln lb/ft^3	Fluidized Bed Expander lb/ft^3
Slag I: +1OM	28-67	24-73
Char injection	--	16-26
Slag I: 10x 50M	34-58	--
Slag I: +50M	38	16-58
Extruded Slag I/Clay		
80/20	27-62	--
50/50	21-42	--
0/100	18-41	--
Slag I/Clay Granules		
80/20 4 x 20M	.-	30-60
80/20 4 x 30M	--	37-42
50/50 4 x 20M	--	31-65
50/50 -8M	--	43-66
Slag II: +1OM	**22-82**	--
Slag 11/Clay Granules		
50/50 4 x 20M	--	33-63

Production Costs of SLA vs. LWA and ULWA ($/Ton)

Cost Item	Shale/Clay LWA[1]	Perlite ULWA[2]	SLA[3]
System	Rotary Kiln	Vert.Shaft Furnace	Rotary Kiln
Fuel	011	Natl gas	Coal/char
Mining/prep	6.00	40.00	-
Transport	0.50	40.00	
Clay binder			1.45
Labor	6.23	12.00	6.25
Fuel	5.09	8.00	1.64
Power	1.37	4.50	1.35
M&S	1.85	3.00	1.48
Other	1.11	2.00	1.10
Overhead	2.24	10.00	-
Depreciate	5.71	4.75	4.28
Interest	excluded	excluded	6.85
Total	30.10	124.25	24.40

Estimated by(1) Fuller Co., (2) Silbrico, (3) Praxis/Fuller

Conclusions: Slag Processing

- Slag I was expanded to unit weights of 30-50 lb/ft^3 and Slag II to 20-50 lb/ft^3 by means of temperature control. Attempts to lower these further resulted in fusion which is a function of slag chemistry.

- The entire 1/4" x 50M fraction can be processed in the kiln as a single feed.

- Minus 50M fines must be extruded prior to kiln processing. Extruded pellets using 20-50% expansive clay binder yielded product unit weights of 27-33 lb/ft^3 at 1800 -1900°F.

Conclusions: Char Utilization

- Char can be recovered from slag easily and used as a fuel

- A char product containing 45-54% ash was upgraded successfully to 70!% carbon

- Char can be utilized as a substitute for 50% of the fuel in a rotary kiln and 80°/0 of the fuel in a fluidized bed system

Conclusions: SLA Economics

- Expansion temperature for slag is 300-400 “F lower than that typically required for expansible clays and shales and represents significant energy savings

- SLA production costs from a large (440 t/d) facility were estimated at $24.40/ton using rotary kiln and $21.87/ton using fluidized bed vs. $30. 10/ton for conventional LWA plant

- Preliminary analyses also indicate that small SLA plants can be economically attractive if the avoided costs of slag disposal ($10-$20/ton) are factored in.

Planned Product Evaluation (Phase II)

Commercial-scale testing of SLA as a substitute for LWA and ULWA in the following applications:

- Structural concrete using 3/4” coarse and 3/8” LWA
- Lightweight blocks (2-3 blends)
- Insulating concrete (ASTM C 332 Group II concrete, 45-90 lb/ft^3)
- Lightweight roof tile aggregate
- Loose fill insulation (ASTM C 549)
- Horticultural applications