

# APPENDIX E

## METSIM® IRONMAKING PROCESS SIMULATIONS

- E-1: BASE CASE MIDREX SHAFT FURNACE
- E-2: HYLSA IVM (REFORMERLESS WITH HOT DRI CHARGE TO EAF)
- E-3: TECNORED SHAFT MELTER
- E-4: HISMELT OXYGEN REACTOR
- E-5: REDSMELT ROTARY HEARTH FURNACE
- E-6: CIRCORED FLUID-BED REDUCTION PROCESS (NATURAL GAS REDUCTANT)
- E-7: CIRCOFER FLUID-BED REDUCTION PROCESS (COAL REDUCTANT)
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**APPENDIX E-1:**  
**BASE CASE MIDREX SHAFT FURNACE**

# IRONMAKING PROCESS DESCRIPTION

## MIDREX® SHAFT FURNACE

### PROCESS BACKGROUND:

The Midrex™ Direct Reduction process is based upon a low pressure, moving bed shaft furnace where the reducing gas moves counter-current to the lump iron oxide ore or iron oxide pellet solids in the bed. The reducing gas (from 10-20% CO and 80-90% H<sub>2</sub>) is produced from natural gas using Midrex's CO<sub>2</sub> reforming process and their proprietary catalyst (instead of steam reforming).

A single reformer is utilized instead of a reformer/heater combination. The reformed gas does not need to be cooled before introduction to the process. There is also no need for a separate CO<sub>2</sub> removal system.

The process can produce cold or hot DRI as well as HBI for subsequent use as a scrap substitute feed to a steelmaking melting furnace (SAF, EAF or oxygen steelmaking process).

Over 50 Midrex™ Modules have been built worldwide since 1969. They have supplied over 60% of the worlds DRI since 1989.

### Standard sizes:

|                           |                       |
|---------------------------|-----------------------|
| MIDREX™ MINIMOD Plant     | (0.25-0.5 MM mt/year) |
| MIDREX™ Series 500 Module | (0.5-0.8 MM mt/year)  |
| MIDREX™ Series 750 Module | (0.8-1.0 MM mt/year)  |
| MIDREX MEGAMOD™           | (1.0-1.6 MM mt/year)  |
| MIDREX SUPER MEGAMOD™     | (1.6-2.7 MM mt/year)  |

### PROCESS DESCRIPTION:

The iron oxide feed to a Midrex® shaft furnace can be in the form of pellets, lump ore or a mixture of the two (in 0 to 100% proportions). The solid feed is discharged into a feed hopper on top of a proportioning hopper that evenly distributes the solids into the shaft furnace.

A dynamic seal leg keeps the reducing gas inside the furnace. The shaft furnace operates at low pressure, under 1 bar gauge, which allows dynamic seals to be used on the furnace inlet and discharge. The iron ore burden in the shaft furnace is first heated, then reduced by the upward flowing, counter-current reducing gas that is injected through tuyeres located in a bustle distributor at the bottom

of the cylindrical section of the shaft. The ore is reduced to a metallization typically in the range of 93% to 94% by the time it reaches the bustle area.

Below the bustle area, it goes through a transition zone (with design to reduce agglomeration or lumping) and then reaches the lower conical section of the furnace. Lower carbon reduced iron (<1.5% C) is cooled using a circulating stream of cooled exhaust gas that is introduced in the conical section for cold DRI discharge. Higher carbon DRI (up to 4.0% C) can be produced by introduction of natural gas into this cooling gas. It readily reacts (and cracks) with the highly reactive metallic DRI.

For hot discharge of DRI to be used for hot charging of EAF's (i.e. Midrex's Hotlink™ Process) or for feed to hot briquetting presses (to produce HBI), the lower part of the furnace is modified to allow handling of hot burden.

The Midrex gas generation system consists of a CO<sub>2</sub> reformer using their own catalyst. The feed to the reformer is a mixture of process gas recycled from the furnace and makeup natural gas. The top gas leaving the shaft furnace at a temperature of 400 to 450C is cooled and dust is removed in a top gas scrubber. About two-thirds of the gas is recycled back to the process (process gas) and the rest is used as a fuel. The process gas is compressed, mixed with natural gas and is preheated in the reformer recuperator before entering the tubes of the reformer.

The reformed gas comprising of mostly CO and H<sub>2</sub> exits the reformer at about 850 °C and passes through collection headers to the reformed gas line. The ratio of H<sub>2</sub> to CO is controlled at about 1.5 to 1.8, and reducing quality at 11 to 12 for best operation.

#### PROCESS ADVANTAGES:

World-wide commercial use

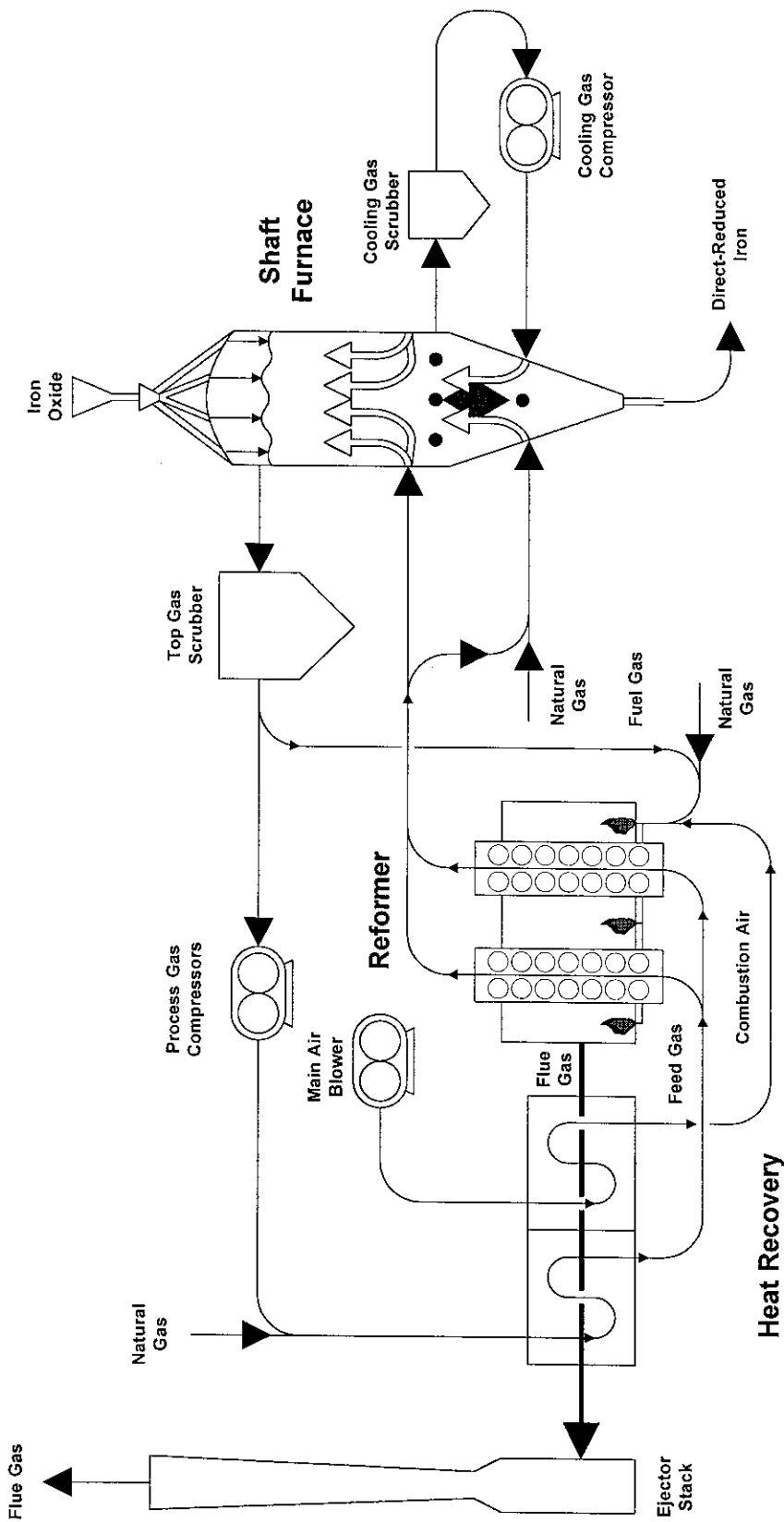
Proven performance

"Relatively-forgiving" operation

Raw material flexibility

CO<sub>2</sub> reformer eliminates need for steam system, reformed gas quench, reducing gas heating and CO<sub>2</sub> removal system.

# MIDREX PROCESS FLOWSHEET





## Midrex Process — MetSim Model — Description

The MetSim model for this process is largely based upon a basic flowsheet for a Midrex Megamod reactor for Tondu Corporation by Midrex Direct Reduction Corporation, Charlotte, USA.

### Flowsheet Description

Stream 101 representing the lump ore feed consists of 82% Fe<sub>2</sub>O<sub>3</sub>, 12% Fe<sub>3</sub>O<sub>4</sub> and 6% SiO<sub>2</sub>. In the Reduction furnace, this feed is heated and reduced by the upcoming reducing gases or Bustle gas (Stream 12) into DRI (Stream 105). Stream 1 representing the Top gas is passed through a Gas Scrubber and a stream splitter to divide the Top gas into Process gas and Fuel gas. The Process gas is mixed with some natural gas and passed through a Mist Eliminator (Both unit operations performed by one MetSim unit operation called Reformed feed gas mixer). Stream 7 representing the process gas to reformer undergoes reforming reactions in the Reformer. Fuel gas (Stream 19) is mixed with some natural gas (Stream 25) and burned in the main Burner. Also additional natural gas (Stream 26) is burned with air (Stream 30) in the auxiliary Burner. This leads to hot flue gases (Stream 65). This stream is used to keep the reformer hot. The hot reformed gases (Stream 8) are again mixed with some natural gas (Stream 27) to yield the Bustle gas (Stream 12).

### Model Assumptions:

Reduction Furnace: The temperature of hot bustle gas is 840C. The top gas comes out at 402C. Complete reduction of iron ore takes place along with some reaction between metallic Fe and natural gas to give Fe<sub>3</sub>C. No carry-over of solid particles in the Top gas is assumed.

Top Gas Scrubber: The hot Top gases are mixed with some recycle stream and divided into two parts: Process gas and Fuel gas.

Stream Splitter: Only a MetSim unit operation; does not exist in reality. Process gas is divided into the portion required to carry out complete reduction. Rest goes back as recycle stream.

Reformed Feed Gas Mixer: All liquid water is separated.

Reformer: The reactions reach equilibrium.

Reformer H/E: The temperature of hot reformed gases is 940C.



## **Results**

It was decided to achieve same operating conditions as were outlined in the Tondu proposal by Midrex. In the absence of information on gas compositions and amounts for certain feed streams, a few assumptions were made. These led to some differences between the MetSim Model results and the data by Midrex.

It was observed that although complete metallization took place in the furnace, the amount of gases flowing in and around the reduction furnace were higher than those outlined in the proposal by Midrex. This is partly due to the unknowns about the bustle gas composition.





### MIDREX PROCESS --- STREAM SUMMARY

| Stream Number             | 30        | 65         | 66         | 100    | 101      | 105          |
|---------------------------|-----------|------------|------------|--------|----------|--------------|
| Stream Names              | AIR       | HOT FLUE G | COOLED FL  | MIST   | IRON ORE | REDUCED IRON |
| MT/HR SOLIDS              | 0         | 0          | 0          | 0      | 215      | 155.9        |
| MT/HR AQUEOUS             | 0         | 0          | 0          | 16.869 | 0        | 0            |
| MT/HR GASEOUS             | 7.0785    | 340.28     | 340.28     | 0      | 0        | 0            |
| MT/HR TOTAL               | 7.0785    | 340.28     | 340.28     | 16.869 | 215      | 155.9        |
| Percent Solids            | 0         | 0          | 0          | 0      | 100      | 100          |
| Sp.Gr.SOLIDS              | 0         | 0          | 0          | 0      | 4.9432   | 4.2899       |
| Sp.Gr.AQUEOUS             | 0         | 0          | 0          | 0.9581 | 0        | 0            |
| Sp.Gr.GASEOUS             | 0.0011408 | 0.00013292 | 0.00020363 | 0      | 0        | 0            |
| Sp.Gr.TOTAL               | 0.0011408 | 0.00013292 | 0.00020363 | 0.9581 | 4.9432   | 4.2899       |
| Temperature C             | 35        | 2316.2     | 1417       | 100    | 35       | 300          |
| Pressure kPa              | 101.33    | 101.33     | 101.33     | 101.33 | 101.33   | 101.33       |
| Gas nm3/hr                | 5500      | 2.70E+05   | 2.70E+05   | 0      | 0        | 0            |
| Component Mass Flow Rates |           |            |            |        |          |              |
| 1 Fe2O3 MT/HR             | 0         | 0          | 0          | 0      | 176.3    | 0            |
| 2 Fe3O4 MT/HR             | 0         | 0          | 0          | 0      | 25.8     | 0            |
| 4 Fe1 MT/HR               | 0         | 0          | 0          | 0      | 0        | 127.78       |
| 5 H2O MT/HR               | 0         | 0          | 0          | 16.869 | 0        | 0            |
| 6 H2O MT/HR               | 0         | 50.535     | 50.535     | 0      | 0        | 0            |
| 7 C1H4 MT/HR              | 0         | 0          | 0          | 0      | 0        | 0            |
| 8 C2H6 MT/HR              | 0         | 0.00043492 | 0.00043492 | 0      | 0        | 0            |
| 10 C1O1 MT/HR             | 0         | 0          | 0          | 0      | 0        | 0            |
| 11 C1O2 MT/HR             | 0         | 84.402     | 84.402     | 0      | 0        | 0            |
| 12 H2 MT/HR               | 0         | 0          | 0          | 0      | 0        | 0            |
| 13 N2 MT/HR               | 5.4363    | 204.39     | 204.39     | 0      | 0        | 0            |
| 14 O2 MT/HR               | 1.6422    | 0.95997    | 0.95997    | 0      | 0        | 0            |
| 17 SiO2 MT/HR             | 0         | 0          | 0          | 0      | 12.9     | 12.9         |
| 18 Fe3C MT/HR             | 0         | 0          | 0          | 0      | 0        | 15.216       |
| Element Mass Flow Rates   |           |            |            |        |          |              |
| 1 H 1                     | 0         | 5.655      | 5.655      | 1.8877 | 0        | 0            |
| 2 C 6                     | 0         | 23.035     | 23.035     | 0      | 0        | 1.0179       |
| 3 N 7                     | 5.4363    | 204.39     | 204.39     | 0      | 0        | 0            |
| 4 O 8                     | 1.6422    | 107.21     | 107.21     | 14.982 | 66.991   | 6.87         |
| 5 Si 14                   | 0         | 0          | 0          | 0      | 6.03     | 6.03         |
| 7 Fe 26                   | 0         | 0          | 0          | 0      | 141.98   | 141.98       |

## MIDREX PROCESS

## INPUT DATA

TITLE : MIDREX PROCESS

CASE :

DATA STORAGE FILE NAME : midrex6.sfw

HEAT BALANCE OPTION : ON

UNITS OF MASS/TIME : MT/HR

| ROW | CNM   | CHF      | PHC      | CMW    | SGF    |
|-----|-------|----------|----------|--------|--------|
| 1   | Fe2O3 | Fe2O3SI1 | 159.6922 | 5.2400 | 0.0000 |
| 2   | Fe3O4 | Fe3O4SI1 | 231.5386 | 5.1800 | 0.0000 |
| 3   | Fe1O1 | Fe1O1SI1 | 71.8464  | 5.7000 | 0.0000 |
| 4   | Fe1   | Fe1 SI1  | 55.8470  | 7.8600 | 0.0000 |
| 5   | H2O   | H2O LI3  | 18.0153  | 1.0000 | 0.0000 |
| 6   | H2O   | H2O GC8  | 18.0153  | 0.0008 | 0.0000 |
| 7   | C1H4  | C1H4 GC8 | 16.0430  | 0.0007 | 0.0000 |
| 8   | C2H6  | C2H6 GC8 | 30.0701  | 0.0013 | 0.0000 |
| 9   | C4H10 | C4H10GC8 | 58.1243  | 0.0026 | 0.0000 |
| 10  | C1O1  | C1O1 GC8 | 28.0106  | 0.0012 | 0.0000 |
| 11  | C1O2  | C1O2 GC8 | 44.0100  | 0.0020 | 0.0000 |
| 12  | H2    | H2 GC8   | 2.0159   | 0.0001 | 0.0000 |
| 13  | N2    | N2 GC8   | 28.0134  | 0.0012 | 0.0000 |
| 14  | O2    | O2 GC8   | 31.9988  | 0.0014 | 0.0000 |
| 15  | H2S1  | H2S1 GC8 | 34.0799  | 0.0015 | 0.0000 |
| 16  | S1O2  | S1O2 GC8 | 64.0628  | 0.0029 | 0.0000 |
| 17  | SiO2  | SiO2 SI1 | 60.0848  | 2.6500 | 0.0000 |
| 18  | Fe3C  | Fe3C SI1 | 179.5521 | 1.0000 | 0.0000 |

| ROW | CNM   | REFERENCE | H25     | HTE-A  | HTE-B   | HTE-C   | HTE-D   |
|-----|-------|-----------|---------|--------|---------|---------|---------|
| 1   | Fe2O3 | B672158   | -197000 | -20749 | 46.1517 | -3.8751 | 21.9462 |
| 2   | Fe3O4 | B672160   | -267300 | -31312 | 71.0525 | -7.8736 | 32.0732 |
| 3   | Fe1O1 | B672157   | -65000  | -3998  | 12.1207 | 1.0479  | 0.8685  |
| 4   | Fe1   | B672151   | 0       | -7903  | 14.0914 | -1.3293 | 11.6233 |
| 5   | H2O   | B672180   | -68315  | -5071  | 16.1848 | 2.7637  | 0.0000  |
| 6   | H2O   | B672182   | -57795  | -2403  | 7.2906  | 1.3003  | 0.3596  |
| 7   | C1H4  | B6772217  | -17880  | -6424  | 11.8424 | 2.9907  | 8.0422  |
| 8   | C2H6  | B6772223  | -20240  | -5819  | 11.3274 | 9.4527  | 4.7951  |
| 9   | C4H10 | BAK1126   | -29800  | -17099 | 32.8367 | 11.3643 | 18.9320 |
| 10  | C1O1  | B672093   | -26417  | -2962  | 7.7460  | 0.2285  | 1.9749  |
| 11  | C1O2  | B672094   | -94051  | -5911  | 12.9357 | 0.3891  | 6.1869  |
| 12  | H2    | B672174   | 0       | -1837  | 6.3659  | 0.4428  | -0.2847 |
| 13  | N2    | B672244   | 0       | -2846  | 7.5728  | 0.2525  | 1.7794  |
| 14  | O2    | B672277   | 0       | -2979  | 7.9696  | 0.2720  | 1.7697  |
| 15  | H2S1  | B689140   | -4930   | -3383  | 8.6760  | 1.2152  | 2.1081  |
| 16  | S1O2  | B672348   | -70940  | -5603  | 13.1364 | 0.2172  | 5.0762  |
| 17  | SiO2  | B672387   | -217720 | -8654  | 19.1651 | -0.5456 | 8.8977  |
| 18  | Fe3C  | B6771332  | 5985    | -5013  | 21.1456 | 4.1225  | -5.0322 |

| ROW | CNM   | TEMP  | RANGE  | OK | HTG-A   | HTG-B    | HTG-C    | HTG-D    |
|-----|-------|-------|--------|----|---------|----------|----------|----------|
| 1   | Fe2O3 | 298.2 | 1800.0 |    | -182323 | -34.6418 | -13.7715 | -28.2755 |
| 2   | Fe3O4 | 298.2 | 1800.0 |    | -243067 | -58.6967 | -18.9430 | -46.8195 |
| 3   | Fe1O1 | 298.2 | 1600.0 |    | -60048  | -19.0598 | -5.9536  | -9.2221  |
| 4   | Fe1   | 298.2 | 1811.0 |    | 2679    | -8.2139  | -4.0925  | -5.4957  |
| 5   | H2O   | 298.2 | 373.2  |    | -70630  | -1.0739  | -26.4253 | 0.0000   |
| 6   | H2O   | 298.2 | 2000.0 |    | -54212  | -48.4557 | -3.8711  | -6.7579  |
| 7   | C1H4  | 298.2 | 2000.0 |    | -14673  | -45.4106 | -7.1789  | -6.9854  |
| 8   | C2H6  | 298.2 | 1000.0 |    | -19821  | -48.2326 | -15.8609 | -2.9266  |
| 9   | C4H10 | 298.2 | 1500.0 |    | -24334  | -69.8380 | -25.6515 | -13.3922 |
| 10  | C1O1  | 298.2 | 3000.0 |    | -21272  | -52.8075 | -2.2569  | -10.0674 |
| 11  | C1O2  | 298.2 | 3000.0 |    | -86430  | -58.7976 | -3.7771  | -15.3476 |
| 12  | H2    | 298.2 | 3000.0 |    | 4863    | -36.6465 | -2.1036  | -9.3536  |
| 13  | N2    | 298.2 | 3000.0 |    | 5078    | -51.3044 | -2.2358  | -9.9139  |
| 14  | O2    | 298.2 | 3000.0 |    | 5395    | -54.8302 | -2.3535  | -10.5960 |
| 15  | H2S1  | 298.2 | 2000.0 |    | -1229   | -52.4032 | -4.2869  | -7.0969  |
| 16  | S1O2  | 298.2 | 3000.0 |    | -62759  | -67.8617 | -3.6510  | -16.3249 |
| 17  | SiO2  | 298.2 | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464 |
| 18  | Fe3C  | 298.2 | 1400.0 |    | 15085   | -32.7885 | -13.6625 | -16.6593 |

MIDREX PROCESS

INPUT DATA

| FLOL      |                             | FLO |     |     |     |     |     |     |     |     |     |     |     |     |   |   |
|-----------|-----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|---|
| TYP LABEL |                             | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  |   |   |
| NO        | OPR UNIT PROCESS            | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |   |   |
| 1         | SEC MIDREX PROCESS          | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0 | 0 |
| 2         | MIX FUEL GAS MIXER          | 25  | 19  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 21  | 0   | 0   | 0   | 0 | 0 |
| 3         | SPP REFORMER FEED GAS MIXER | 5   | 23  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 7   | 100 | 0   | 0   | 0 | 0 |
| 4         | MIX BURNERS                 | 26  | 30  | 21  | 29  | 0   | 0   | 0   | 0   | 65  | 0   | 0   | 0   | 0   | 0 | 0 |
| 5         | HTX REFORMER H/E            | 65  | 0   | 0   | 6   | 0   | 0   | 0   | 0   | 66  | 8   | 0   | 0   | 0   | 0 | 0 |
| 6         | MIX REFORMED GAS MIXER      | 8   | 27  | 0   | 0   | 0   | 0   | 0   | 0   | 12  | 0   | 0   | 0   | 0   | 0 | 0 |
| 7         | SPP FURNACE                 | 101 | 12  | 0   | 0   | 0   | 0   | 0   | 0   | 105 | 1   | 0   | 0   | 0   | 0 | 0 |
| 8         | SPS TOP GAS SCRUBBER        | 1   | 14  | 0   | 0   | 0   | 0   | 0   | 0   | 2   | 19  | 0   | 0   | 0   | 0 | 0 |
| 9         | SUB STREAM SPLITTER         | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 4   | 5   | 0   | 0   | 0   | 0 | 0 |
| 10        | FEM REFORMER                | 7   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 6   | 0   | 0   | 0   | 0   | 0 | 0 |

## MIDREX PROCESS

| HEAT BALANCE SUMMARY - 1000 KCAL/HOUR |                 |               |               |                 |              |               |                  |       |
|---------------------------------------|-----------------|---------------|---------------|-----------------|--------------|---------------|------------------|-------|
| OP PROCESS STEP                       | INPUT<br>STREAM | HEAT<br>REACT | HEAT<br>SOLUT | ENERGY<br>INPUT | HEAT<br>LOSS | HEAT<br>REQRD | OUTPUT<br>STREAM | TOTAL |
| 1 MIDREX PROCESS                      | 0               | 0             | 0             | 0               | 0            | 0             | 0                | 0     |
| 2 FUEL GAS MIXER                      | 10582           | 0             | 0             | 0               | 0            | -2120         | -8462            | 0     |
| 3 REFORMER FEED GA                    | 27571           | 9851          | 0             | 0               | 0            | 12844         | -50265           | 0     |
| 4 BURNERS                             | 51534           | 213270        | 0             | 0               | 0            | 0             | -264803          | 0     |
| 5 REFORMER H/E                        | 265120          | 0             | 0             | 0               | -26512       | 0             | -238608          | 0     |
| 6 REFORMED GAS MIX                    | 87919           | -63320        | 0             | 0               | 0            | 58595         | -83194           | 0     |
| 7 FURNACE                             | 83490           | -34940        | 0             | 0               | 0            | -1473         | -47077           | 0     |
| 8 TOP GAS SCRUBBER                    | 42237           | 0             | 0             | 0               | 0            | 0             | -42237           | 0     |
| 9 STREAM SPLITTER                     | 31678           | 0             | 0             | 0               | 0            | 0             | -31678           | 0     |
| 10 REFORMER                           | 48999           | 2805          | 0             | 0               | 0            | -51489        | -315             | 0     |

## MIDREX PROCESS

| NO. STREAM             | STREAM TEMPERATURES AND ENTHALPIES |         |              |              |              |
|------------------------|------------------------------------|---------|--------------|--------------|--------------|
|                        | TEMP-C                             | TEMP-F  | KCAL/HR      | BTU/HR       | KJ/HR        |
| 1 TOP GAS              | 402.00                             | 755.60  | 41601545.00  | 165088272.0  | 174060864.0  |
| 2 PROCESS GAS          | 369.31                             | 696.77  | 31677782.00  | 125707600.0  | 132539842.0  |
| 3                      | 0.00                               | 32.00   | 29628815.00  | 117576638.0  | 123966960.0  |
| 4 TO COOLING GAS CYCLE | 369.31                             | 696.77  | 4204697.00   | 16685584.0   | 17592450.0   |
| 5 TOP GAS FOR REFORMER | 369.31                             | 696.77  | 27473086.00  | 109022015.0  | 114947391.0  |
| 6 GAS FROM REFORMER    | 25.00                              | 77.00   | 315131.00    | 1250540.0    | 1318507.0    |
| 7 GAS TO REFORMER      | 560.00                             | 1040.00 | 48999147.00  | 194444329.0  | 205012431.0  |
| 8 REFORMED GAS         | 940.00                             | 1724.00 | 87887098.00  | 348764190.0  | 367719617.0  |
| 12 GAS FOR REDUCTION   | 840.00                             | 1544.00 | 83193513.00  | 330138541.0  | 348081659.0  |
| 14 RECYCLE PROCESS GAS | 77.00                              | 170.60  | 635498.00    | 2521861.0    | 2658925.0    |
| 19 FUEL GAS            | 369.31                             | 696.77  | 10559261.00  | 41902533.0   | 44179947.0   |
| 21 FUEL TO MAIN BURNER | 290.00                             | 554.00  | 8461842.00   | 33579305.0   | 35404349.0   |
| 23 NATURAL GAS         | 25.00                              | 77.00   | 97442.00     | 386682.0     | 407698.0     |
| 25 NATURAL GAS         | 35.00                              | 95.00   | 22921.00     | 90957.0      | 95901.0      |
| 26 N.G. TO AUX. BURNER | 35.00                              | 95.00   | 2665.00      | 10576.0      | 11151.0      |
| 27 NATURAL GAS         | 35.00                              | 95.00   | 31450.00     | 124802.0     | 131585.0     |
| 29 HOT AIR             | 675.00                             | 1247.00 | 43047939.00  | 170828027.0  | 180112576.0  |
| 30 AIR                 | 35.00                              | 95.00   | 21127.00     | 83837.0      | 88394.0      |
| 35                     | 814.36                             | 1497.85 | 3712815.00   | 14733641.0   | 15534418.0   |
| 65 HOT FLUE GAS        | 2316.15                            | 4201.08 | 264803304.00 | 1050824432.0 | 1107937023.0 |
| 66 COOLED FLUE GAS     | 1417.02                            | 2582.63 | 150720507.00 | 598107307.0  | 630614600.0  |
| 67                     | 814.36                             | 1497.85 | 70543487.00  | 279939179.0  | 295153949.0  |
| 100 MIST               | 100.00                             | 212.00  | 1266320.00   | 5025165.0    | 5298284.0    |
| 101 IRON ORE           | 35.00                              | 95.00   | 296156.00    | 1175244.0    | 1239118.0    |
| 105 REDUCED IRON       | 300.00                             | 572.00  | 5475021.00   | 21726638.0   | 22907487.0   |



## MIDREX PROCESS

## VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM             | TIME     | ACFM    | SCFM     | M3/HR   | NM3/HR   |
|------------------------|----------|---------|----------|---------|----------|
| 1 TOP GAS              | 100.0000 | 447971  | 181238.7 | 761108  | 307926.6 |
| 2 PROCESS GAS          | 100.0000 | 359167  | 152703.5 | 610229  | 259444.9 |
| 3                      | 100.0000 | 142550  | 142549.7 | 242193  | 242193.5 |
| 4 TO COOLING GAS CYCLE | 100.0000 | 47673   | 20268.8  | 80998   | 34437.0  |
| 5 TOP GAS FOR REFORMER | 100.0000 | 311494  | 132434.7 | 529232  | 225007.9 |
| 6 GAS FROM REFORMER    | 100.0000 | 145954  | 133716.1 | 247978  | 227185.1 |
| 7 GAS TO REFORMER      | 100.0000 | 421920  | 138327.5 | 716847  | 235019.9 |
| 8 REFORMED GAS         | 100.0000 | 593013  | 133521.3 | 1007535 | 226854.1 |
| 12 GAS FOR REDUCTION   | 100.0000 | 673489  | 165263.9 | 1144265 | 280785.2 |
| 14 RECYCLE PROCESS GAS | 100.0000 | 28671   | 22366.0  | 48712   | 38000.0  |
| 19 FUEL GAS            | 100.0000 | 119722  | 50901.2  | 203410  | 86481.6  |
| 21 FUEL TO MAIN BURNER | 100.0000 | 110160  | 53432.1  | 187163  | 90781.6  |
| 23 NATURAL GAS         | 100.0000 | 19916   | 18245.9  | 33837   | 31000.0  |
| 25 NATURAL GAS         | 100.0000 | 2855    | 2530.9   | 4851    | 4300.0   |
| 26 N.G. TO AUX. BURNER | 100.0000 | 332     | 294.3    | 564     | 500.0    |
| 27 NATURAL GAS         | 100.0000 | 3918    | 3472.6   | 6656    | 5900.0   |
| 29 HOT AIR             | 100.0000 | 410449  | 118245.3 | 697358  | 200900.0 |
| 30 AIR                 | 100.0000 | 3652    | 3237.2   | 6205    | 5500.0   |
| 35                     | 100.0000 | 32736   | 8222.4   | 55620   | 13970.0  |
| 65 HOT FLUE GAS        | 100.0000 | 1506796 | 158954.5 | 2560063 | 270065.4 |
| 66 COOLED FLUE GAS     | 100.0000 | 983560  | 158954.5 | 1671080 | 270065.4 |
| 67                     | 100.0000 | 621993  | 156226.2 | 1056773 | 265430.0 |

## VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM       | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|------------------|----------|----------|----------|----------|----------|
| 100 MIST         | 100.0000 | 77.5206  | 4.89082  | 17.60695 | 422.567  |
| 101 IRON ORE     | 100.0000 | 191.4957 | 12.08157 | 43.49366 | 1043.848 |
| 105 REDUCED IRON | 100.0000 | 160.0028 | 10.09467 | 36.34080 | 872.179  |

## MASS FLOW RATES - MT/HR

| NO. STREAM             | MT/HR-SI | MT/HR-LI | MT/HR-GC | MT/HR-TC |
|------------------------|----------|----------|----------|----------|
| 1 TOP GAS              | 0.0000   | 0.00000  | 254.1434 | 254.1434 |
| 2 PROCESS GAS          | 0.0000   | 0.00000  | 213.6325 | 213.6325 |
| 3                      | 0.0000   | 0.00000  | 204.7725 | 204.7725 |
| 4 TO COOLING GAS CYCLE | 0.0000   | 0.00000  | 28.3562  | 28.3562  |
| 5 TOP GAS FOR REFORMER | 0.0000   | 0.00000  | 185.2764 | 185.2764 |
| 6 GAS FROM REFORMER    | 0.0000   | 0.00000  | 190.5957 | 190.5957 |
| 7 GAS TO REFORMER      | 0.0000   | 0.00000  | 190.5957 | 190.5957 |
| 8 REFORMED GAS         | 0.0000   | 0.00000  | 190.8172 | 190.8172 |
| 12 GAS FOR REDUCTION   | 0.0000   | 0.00000  | 195.0402 | 195.0402 |
| 14 RECYCLE PROCESS GAS | 0.0000   | 0.00000  | 30.7000  | 30.7000  |
| 19 FUEL GAS            | 0.0000   | 0.00000  | 71.2108  | 71.2108  |
| 21 FUEL TO MAIN BURNER | 0.0000   | 0.00000  | 74.2886  | 74.2886  |
| 23 NATURAL GAS         | 0.0000   | 0.00000  | 22.1885  | 22.1885  |
| 25 NATURAL GAS         | 0.0000   | 0.00000  | 3.0778   | 3.0778   |
| 26 N.G. TO AUX. BURNER | 0.0000   | 0.00000  | 0.3579   | 0.3579   |
| 27 NATURAL GAS         | 0.0000   | 0.00000  | 4.2230   | 4.2230   |
| 29 HOT AIR             | 0.0000   | 0.00000  | 258.5594 | 258.5594 |
| 30 AIR                 | 0.0000   | 0.00000  | 7.0785   | 7.0785   |
| 35                     | 0.0000   | 0.00000  | 14.0495  | 14.0495  |
| 65 HOT FLUE GAS        | 0.0000   | 0.00000  | 340.2844 | 340.2844 |
| 66 COOLED FLUE GAS     | 0.0000   | 0.00000  | 340.2844 | 340.2844 |
| 67                     | 0.0000   | 0.00000  | 266.9407 | 266.9407 |
| 100 MIST               | 0.0000   | 16.86920 | 0.0000   | 16.8692  |
| 101 IRON ORE           | 215.0000 | 0.00000  | 0.0000   | 215.0000 |
| 105 REDUCED IRON       | 155.8967 | 0.00000  | 0.0000   | 155.8967 |

## MIDREX PROCESS

## SPECIFIC GRAVITIES

| NO. STREAM             | PCS      | SG-SI  | SG-LI  | SG-GC  | SG-TC  |
|------------------------|----------|--------|--------|--------|--------|
| 1 TOP GAS              | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 2 PROCESS GAS          | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 3                      | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 4 TO COOLING GAS CYCLE | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 5 TOP GAS FOR REFORMER | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 6 GAS FROM REFORMER    | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 7 GAS TO REFORMER      | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 8 REFORMED GAS         | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 12 GAS FOR REDUCTION   | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 14 RECYCLE PROCESS GAS | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 19 FUEL GAS            | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 21 FUEL TO MAIN BURNER | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 23 NATURAL GAS         | 0.0000   | 0.0000 | 0.0000 | 0.0007 | 0.0007 |
| 25 NATURAL GAS         | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 26 N.G. TO AUX. BURNER | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 27 NATURAL GAS         | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 29 HOT AIR             | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 30 AIR                 | 0.0000   | 0.0000 | 0.0000 | 0.0011 | 0.0011 |
| 35                     | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 65 HOT FLUE GAS        | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 66 COOLED FLUE GAS     | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 67                     | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 100 MIST               | 0.0000   | 0.0000 | 0.9581 | 0.0000 | 0.9581 |
| 101 IRON ORE           | 100.0000 | 4.9432 | 0.0000 | 0.0000 | 4.9432 |
| 105 REDUCED IRON       | 100.0000 | 4.2899 | 0.0000 | 0.0000 | 4.2899 |

## MIDREX PROCESS

## STREAM DATA

## SOLIDS - MT/HR

| NO. STREAM       | Fe2O3   | Fe3O4   | Fe1O1   | Fe1     | SiO2    | Fe3C    |
|------------------|---------|---------|---------|---------|---------|---------|
| 101 IRON ORE     | 176.300 | 25.8000 | 0.00000 | 0.000   | 12.9000 | 0.0000  |
| 105 REDUCED IRON | 0.000   | 0.0000  | 0.00000 | 127.781 | 12.9000 | 15.2157 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM       | Fe2O3   | Fe3O4   | Fe1O1   | Fe1     | SiO2    | Fe3C    |
|------------------|---------|---------|---------|---------|---------|---------|
| 101 IRON ORE     | 82.0000 | 12.0000 | 0.00000 | 0.0000  | 6.00000 | 0.00000 |
| 105 REDUCED IRON | 0.0000  | 0.0000  | 0.00000 | 81.9651 | 8.27471 | 9.76014 |

## AQUEOUS - MT/HR

| NO. STREAM | H2O     |
|------------|---------|
| 100 MIST   | 16.8692 |

## AQUEOUS - WEIGHT PERCENT

| NO. STREAM | H2O     |
|------------|---------|
| 100 MIST   | 100.000 |

## AQUEOUS - GRAMS PER LITER

| NO. STREAM | H2O     |
|------------|---------|
| 100 MIST   | 958.099 |

## GASEOUS - MT/HR

| NO. STREAM             | H2O     | ClH4    | C2H6    | C4H10   | ClO1    | ClO2    | H2      |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 TOP GAS              | 27.8524 | 6.7962  | 0.00174 | 0.00000 | 69.897  | 136.224 | 12.3828 |
| 2 PROCESS GAS          | 22.1034 | 5.6683  | 0.00130 | 0.00000 | 61.505  | 112.745 | 10.4764 |
| 3                      | 28.5421 | 0.9039  | 0.00000 | 0.00000 | 51.458  | 113.366 | 9.5077  |
| 4 TO COOLING GAS CYCLE | 2.9339  | 0.7524  | 0.00017 | 0.00000 | 8.164   | 14.965  | 1.3906  |
| 5 TOP GAS FOR REFORMER | 19.1695 | 4.9160  | 0.00113 | 0.00000 | 53.341  | 97.780  | 9.0859  |
| 6 GAS FROM REFORMER    | 16.0763 | 29.9078 | 0.00171 | 0.00000 | 64.969  | 71.818  | 6.8397  |
| 7 GAS TO REFORMER      | 2.3003  | 27.1045 | 0.00113 | 0.00000 | 53.341  | 97.780  | 9.0859  |
| 8 REFORMED GAS         | 15.9191 | 30.1557 | 0.00174 | 0.00000 | 65.030  | 71.936  | 6.7862  |
| 12 GAS FOR REDUCTION   | 15.9191 | 17.1893 | 0.00174 | 0.00000 | 125.054 | 24.781  | 11.1062 |
| 14 RECYCLE PROCESS GAS | 1.6188  | 0.7616  | 0.00000 | 0.00000 | 12.109  | 14.102  | 1.5858  |
| 19 FUEL GAS            | 7.3678  | 1.8894  | 0.00043 | 0.00000 | 20.502  | 37.582  | 3.4921  |
| 21 FUEL TO MAIN BURNER | 7.3678  | 4.9672  | 0.00043 | 0.00000 | 20.502  | 37.582  | 3.4921  |
| 23 NATURAL GAS         | 0.0000  | 22.1885 | 0.00000 | 0.00000 | 0.000   | 0.000   | 0.0000  |
| 25 NATURAL GAS         | 0.0000  | 3.0778  | 0.00000 | 0.00000 | 0.000   | 0.000   | 0.0000  |
| 26 N.G. TO AUX. BURNER | 0.0000  | 0.3579  | 0.00000 | 0.00000 | 0.000   | 0.000   | 0.0000  |
| 27 NATURAL GAS         | 0.0000  | 4.2230  | 0.00000 | 0.00000 | 0.000   | 0.000   | 0.0000  |
| 35                     | 0.4453  | 0.0000  | 0.00000 | 0.00000 | 0.161   | 0.656   | 0.2860  |
| 65 HOT FLUE GAS        | 50.5347 | 0.0000  | 0.00043 | 0.00000 | 0.000   | 84.402  | 0.0000  |
| 66 COOLED FLUE GAS     | 50.5347 | 0.0000  | 0.00043 | 0.00000 | 0.000   | 84.402  | 0.0000  |
| 67                     | 8.4605  | 0.0000  | 0.00000 | 0.00000 | 3.057   | 12.460  | 5.4340  |

## MIDREX PROCESS

## STREAM DATA

## GASEOUS - MT/HR

| NO. STREAM             | N2      | O2      | H2S1    | S1O2    |
|------------------------|---------|---------|---------|---------|
| 1 TOP GAS              | 0.989   | 0.0000  | 0.00000 | 0.00000 |
| 2 PROCESS GAS          | 1.134   | 0.0000  | 0.00000 | 0.00000 |
| 3                      | 0.994   | 0.0000  | 0.00000 | 0.00000 |
| 4 TO COOLING GAS CYCLE | 0.150   | 0.0000  | 0.00000 | 0.00000 |
| 5 TOP GAS FOR REFORMER | 0.983   | 0.0000  | 0.00000 | 0.00000 |
| 6 GAS FROM REFORMER    | 0.983   | 0.0000  | 0.00000 | 0.00000 |
| 7 GAS TO REFORMER      | 0.983   | 0.0000  | 0.00000 | 0.00000 |
| 8 REFORMED GAS         | 0.989   | 0.0000  | 0.00000 | 0.00000 |
| 12 GAS FOR REDUCTION   | 0.989   | 0.0000  | 0.00000 | 0.00000 |
| 14 RECYCLE PROCESS GAS | 0.522   | 0.0000  | 0.00000 | 0.00000 |
| 19 FUEL GAS            | 0.378   | 0.0000  | 0.00000 | 0.00000 |
| 21 FUEL TO MAIN BURNER | 0.378   | 0.0000  | 0.00000 | 0.00000 |
| 29 HOT AIR             | 198.574 | 59.9858 | 0.00000 | 0.00000 |
| 30 AIR                 | 5.436   | 1.6422  | 0.00000 | 0.00000 |
| 35                     | 10.200  | 2.3011  | 0.00000 | 0.00000 |
| 65 HOT FLUE GAS        | 204.388 | 0.9600  | 0.00000 | 0.00000 |
| 66 COOLED FLUE GAS     | 204.388 | 0.9600  | 0.00000 | 0.00000 |
| 67                     | 193.809 | 43.7202 | 0.00000 | 0.00000 |

## GASEOUS - WEIGHT PERCENT

| NO. STREAM             | H2O     | C1H4    | C2H6    | C4H10   | C1O1    | C1O2    | H2      |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 TOP GAS              | 10.9593 | 2.674   | 0.00068 | 0.00000 | 27.5029 | 53.6014 | 4.87235 |
| 2 PROCESS GAS          | 10.3465 | 2.653   | 0.00061 | 0.00000 | 28.7899 | 52.7751 | 4.90396 |
| 3                      | 13.9384 | 0.441   | 0.00000 | 0.00000 | 25.1295 | 55.3620 | 4.64307 |
| 4 TO COOLING GAS CYCLE | 10.3465 | 2.653   | 0.00061 | 0.00000 | 28.7899 | 52.7751 | 4.90396 |
| 5 TOP GAS FOR REFORMER | 10.3465 | 2.653   | 0.00061 | 0.00000 | 28.7899 | 52.7751 | 4.90396 |
| 6 GAS FROM REFORMER    | 8.4348  | 15.692  | 0.00090 | 0.00000 | 34.0873 | 37.6809 | 3.58859 |
| 7 GAS TO REFORMER      | 1.2069  | 14.221  | 0.00059 | 0.00000 | 27.9864 | 51.3022 | 4.76709 |
| 8 REFORMED GAS         | 8.3426  | 15.803  | 0.00091 | 0.00000 | 34.0795 | 37.6988 | 3.55638 |
| 12 GAS FOR REDUCTION   | 8.1620  | 8.813   | 0.00089 | 0.00000 | 64.1168 | 12.7057 | 5.69429 |
| 14 RECYCLE PROCESS GAS | 5.2728  | 2.481   | 0.00000 | 0.00000 | 39.4447 | 45.9345 | 5.16561 |
| 19 FUEL GAS            | 10.3465 | 2.653   | 0.00061 | 0.00000 | 28.7899 | 52.7751 | 4.90396 |
| 21 FUEL TO MAIN BURNER | 9.9178  | 6.686   | 0.00059 | 0.00000 | 27.5972 | 50.5886 | 4.70079 |
| 23 NATURAL GAS         | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.00000 |
| 25 NATURAL GAS         | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.00000 |
| 26 N.G. TO AUX. BURNER | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.00000 |
| 27 NATURAL GAS         | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.00000 |
| 35                     | 3.1694  | 0.000   | 0.00000 | 0.00000 | 1.1451  | 4.6677  | 2.03566 |
| 65 HOT FLUE GAS        | 14.8507 | 0.000   | 0.00013 | 0.00000 | 0.0000  | 24.8032 | 0.00000 |
| 66 COOLED FLUE GAS     | 14.8507 | 0.000   | 0.00013 | 0.00000 | 0.0000  | 24.8032 | 0.00000 |
| 67                     | 3.1694  | 0.000   | 0.00000 | 0.00000 | 1.1451  | 4.6677  | 2.03566 |

## MIDREX PROCESS

## STREAM DATA

## GASEOUS - WEIGHT PERCENT

| NO. STREAM             | N2      | O2      | H2S1    | S1O2    |
|------------------------|---------|---------|---------|---------|
| 1 TOP GAS              | 0.3892  | 0.0000  | 0.00000 | 0.00000 |
| 2 PROCESS GAS          | 0.5306  | 0.0000  | 0.00000 | 0.00000 |
| 3                      | 0.4856  | 0.0000  | 0.00000 | 0.00000 |
| 4 TO COOLING GAS CYCLE | 0.5306  | 0.0000  | 0.00000 | 0.00000 |
| 5 TOP GAS FOR REFORMER | 0.5306  | 0.0000  | 0.00000 | 0.00000 |
| 6 GAS FROM REFORMER    | 0.5158  | 0.0000  | 0.00000 | 0.00000 |
| 7 GAS TO REFORMER      | 0.5158  | 0.0000  | 0.00000 | 0.00000 |
| 8 REFORMED GAS         | 0.5183  | 0.0000  | 0.00000 | 0.00000 |
| 12 GAS FOR REDUCTION   | 0.5071  | 0.0000  | 0.00000 | 0.00000 |
| 14 RECYCLE PROCESS GAS | 1.7017  | 0.0000  | 0.00000 | 0.00000 |
| 19 FUEL GAS            | 0.5306  | 0.0000  | 0.00000 | 0.00000 |
| 21 FUEL TO MAIN BURNER | 0.5086  | 0.0000  | 0.00000 | 0.00000 |
| 29 HOT AIR             | 76.8000 | 23.2000 | 0.00000 | 0.00000 |
| 30 AIR                 | 76.8000 | 23.2000 | 0.00000 | 0.00000 |
| 35                     | 72.6039 | 16.3783 | 0.00000 | 0.00000 |
| 65 HOT FLUE GAS        | 60.0638 | 0.2821  | 0.00000 | 0.00000 |
| 66 COOLED FLUE GAS     | 60.0638 | 0.2821  | 0.00000 | 0.00000 |
| 67                     | 72.6039 | 16.3783 | 0.00000 | 0.00000 |

## GASEOUS - VOLUME PERCENT

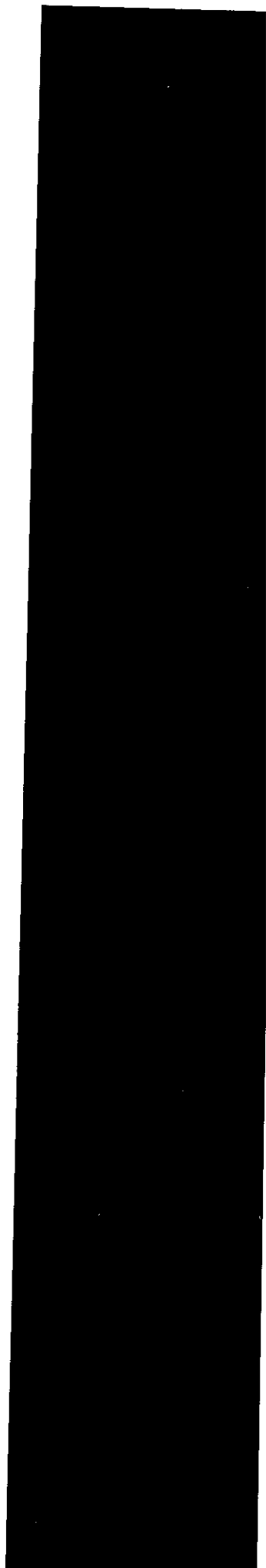
| NO. STREAM             | H2O     | C1H4    | C2H6    | C4H10   | C1O1    | C1O2    | H2      |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 TOP GAS              | 11.2536 | 3.084   | 0.00042 | 0.00000 | 18.1638 | 22.5308 | 44.7107 |
| 2 PROCESS GAS          | 10.5996 | 3.052   | 0.00037 | 0.00000 | 18.9697 | 22.1320 | 44.8963 |
| 3                      | 14.6622 | 0.521   | 0.00000 | 0.00000 | 17.0016 | 23.8391 | 43.6471 |
| 4 TO COOLING GAS CYCLE | 10.5996 | 3.052   | 0.00037 | 0.00000 | 18.9697 | 22.1320 | 44.8963 |
| 5 TOP GAS FOR REFORMER | 10.5996 | 3.052   | 0.00037 | 0.00000 | 18.9697 | 22.1320 | 44.8963 |
| 6 GAS FROM REFORMER    | 8.8041  | 18.392  | 0.00056 | 0.00000 | 22.8836 | 16.0999 | 33.4733 |
| 7 GAS TO REFORMER      | 1.2178  | 16.113  | 0.00036 | 0.00000 | 18.1616 | 21.1891 | 42.9837 |
| 8 REFORMED GAS         | 8.7307  | 18.572  | 0.00057 | 0.00000 | 22.9384 | 16.1498 | 33.2599 |
| 12 GAS FOR REDUCTION   | 7.0538  | 8.553   | 0.00046 | 0.00000 | 35.6385 | 4.4949  | 43.9776 |
| 14 RECYCLE PROCESS GAS | 5.3000  | 2.800   | 0.00000 | 0.00000 | 25.5000 | 18.9000 | 46.4000 |
| 19 FUEL GAS            | 10.5996 | 3.052   | 0.00037 | 0.00000 | 18.9697 | 22.1320 | 44.8963 |
| 21 FUEL TO MAIN BURNER | 10.0976 | 7.644   | 0.00036 | 0.00000 | 18.0712 | 21.0836 | 42.7697 |
| 23 NATURAL GAS         | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.0000  |
| 25 NATURAL GAS         | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.0000  |
| 26 N.G. TO AUX. BURNER | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.0000  |
| 27 NATURAL GAS         | 0.0000  | 100.000 | 0.00000 | 0.00000 | 0.0000  | 0.0000  | 0.0000  |
| 35                     | 3.9657  | 0.000   | 0.00000 | 0.00000 | 0.9215  | 2.3908  | 22.7621 |
| 65 HOT FLUE GAS        | 23.2808 | 0.000   | 0.00012 | 0.00000 | 0.0000  | 15.9166 | 0.0000  |
| 66 COOLED FLUE GAS     | 23.2808 | 0.000   | 0.00012 | 0.00000 | 0.0000  | 15.9166 | 0.0000  |
| 67                     | 3.9657  | 0.000   | 0.00000 | 0.00000 | 0.9215  | 2.3908  | 22.7621 |

## MIDREX PROCESS

## STREAM DATA

## GASEOUS - VOLUME PERCENT

| NO. STREAM             | N2      | O2      | H2S1    | S1O2    |
|------------------------|---------|---------|---------|---------|
| 1 TOP GAS              | 0.2570  | 0.0000  | 0.00000 | 0.00000 |
| 2 PROCESS GAS          | 0.3496  | 0.0000  | 0.00000 | 0.00000 |
| 3                      | 0.3285  | 0.0000  | 0.00000 | 0.00000 |
| 4 TO COOLING GAS CYCLE | 0.3496  | 0.0000  | 0.00000 | 0.00000 |
| 5 TOP GAS FOR REFORMER | 0.3496  | 0.0000  | 0.00000 | 0.00000 |
| 6 GAS FROM REFORMER    | 0.3462  | 0.0000  | 0.00000 | 0.00000 |
| 7 GAS TO REFORMER      | 0.3347  | 0.0000  | 0.00000 | 0.00000 |
| 8 REFORMED GAS         | 0.3488  | 0.0000  | 0.00000 | 0.00000 |
| 12 GAS FOR REDUCTION   | 0.2818  | 0.0000  | 0.00000 | 0.00000 |
| 14 RECYCLE PROCESS GAS | 1.1000  | 0.0000  | 0.00000 | 0.00000 |
| 19 FUEL GAS            | 0.3496  | 0.0000  | 0.00000 | 0.00000 |
| 21 FUEL TO MAIN BURNER | 0.3330  | 0.0000  | 0.00000 | 0.00000 |
| 29 HOT AIR             | 79.0852 | 20.9148 | 0.00000 | 0.00000 |
| 30 AIR                 | 79.0852 | 20.9148 | 0.00000 | 0.00000 |
| 35                     | 58.4223 | 11.5377 | 0.00000 | 0.00000 |
| 65 HOT FLUE GAS        | 60.5535 | 0.2490  | 0.00000 | 0.00000 |
| 66 COOLED FLUE GAS     | 60.5535 | 0.2490  | 0.00000 | 0.00000 |
| 67                     | 58.4223 | 11.5377 | 0.00000 | 0.00000 |



## **APPENDIX E-2:**

**HYLSA IVM (REFORMERLESS WITH HOT DRI  
CHARGE TO EAF)**



## **HYLSA PROCESS (HYL III)**

### **PROCESS BACKGROUND:**

The HYL process uses reducing gases within a moving bed shaft furnace reactor to remove the oxygen from iron ore pellets and lump ore. In comparison to other similar technologies, it operates at slightly higher reduction temperatures (about 50 °C higher) and intermediate reduction pressures (up to 6 bars). The process can produce cold/hot DRI as well as HBI.

The HYL process can utilize higher-sulfur ore and gas feeds since it is equipped with a sulfur removal step (prior to the conventional steam reformer). A more-positive control is obtained for the reducing gas (CO to H<sub>2</sub> ratio) is obtained by utilizing a selective CO<sub>2</sub> removal circuit (typically PSA) in the circulating gas systems. This allows a wide range of CO to H<sub>2</sub> ratios (from 0.1 to 0.3) to be utilized depending on the required degree of metallization and/or carbon content of the final product.

### **PROCESS DESCRIPTION:**

The iron oxide feed to a HYL shaft furnace can be pellets, lump, or a mixture of the two. The solids are fed to the top of the shaft furnace by conveyor. An automatic system of bins and pressure locks receives the ore at atmospheric pressure in an open bin, pressurizes in intermediate bins and charges it continuously to the reactor.

Hylsa divides the process into two independent sections: reducing gas generation and iron ore reduction. The natural gas (makeup to the reducing gas stream) is mixed with reducing gases recycled from the CO<sub>2</sub> removal system. The pressurized reducing gas is passed through a gas heater (where it is heated up to 930 °C) and is introduced to the reactor at up to 6 bar gauge. The higher gas pressure system reduces the tendency for bed fluidization, permits higher capacity from a given-diameter shaft furnace and reduces the effective volumetric flow rates or circulating gases. Higher mole ratios of reducing gas to iron oxide solids can be obtained (as compared to other shaft furnace processes).

The exhaust reducing gas from the reactor (at about 400 °C) is cooled in a quenching/scrubbing system that removes most of the water produced during the reduction process from the gas stream. Also most of the dust in the exhaust gas is also removed. The scrubbed gas is compressed, fed to the CO<sub>2</sub> removal system (and optionally to a SO<sub>2</sub> removal system) before being fed back to the lower part of the shaft furnace.

In the reducing gas generation system, natural gas is passed through a section of the reformer recuperator to preheat it, and is then desulfurized to reduce the sulfur content to less than 1 ppm. This is to prevent poisoning of the reformer catalyst with sulfur compounds. The natural gas is mixed with superheated steam from the reformer steam circuit in a steam to carbon ratio of around 2.4 to 1 by volume, and the mixture is further superheated to 620C in the reformer recuperator.

The gas mixture is heated in the tubes by gas-fired burners to a temperature of about 830 °C where the reforming reactions take place. The reformed gas passes through a waste heat boiler and through a boiler feed water preheater to recover heat. It is then quenched to remove water remaining in the gas. The product gas contains around 72% H<sub>2</sub> and 16% H<sub>2</sub>. The reactor has a cylindrical upper section with reducing gas inlets and outlets for top gas and cooling gas. The lower part is conical and has inlets for the cooling gas when cold DRI is produced.

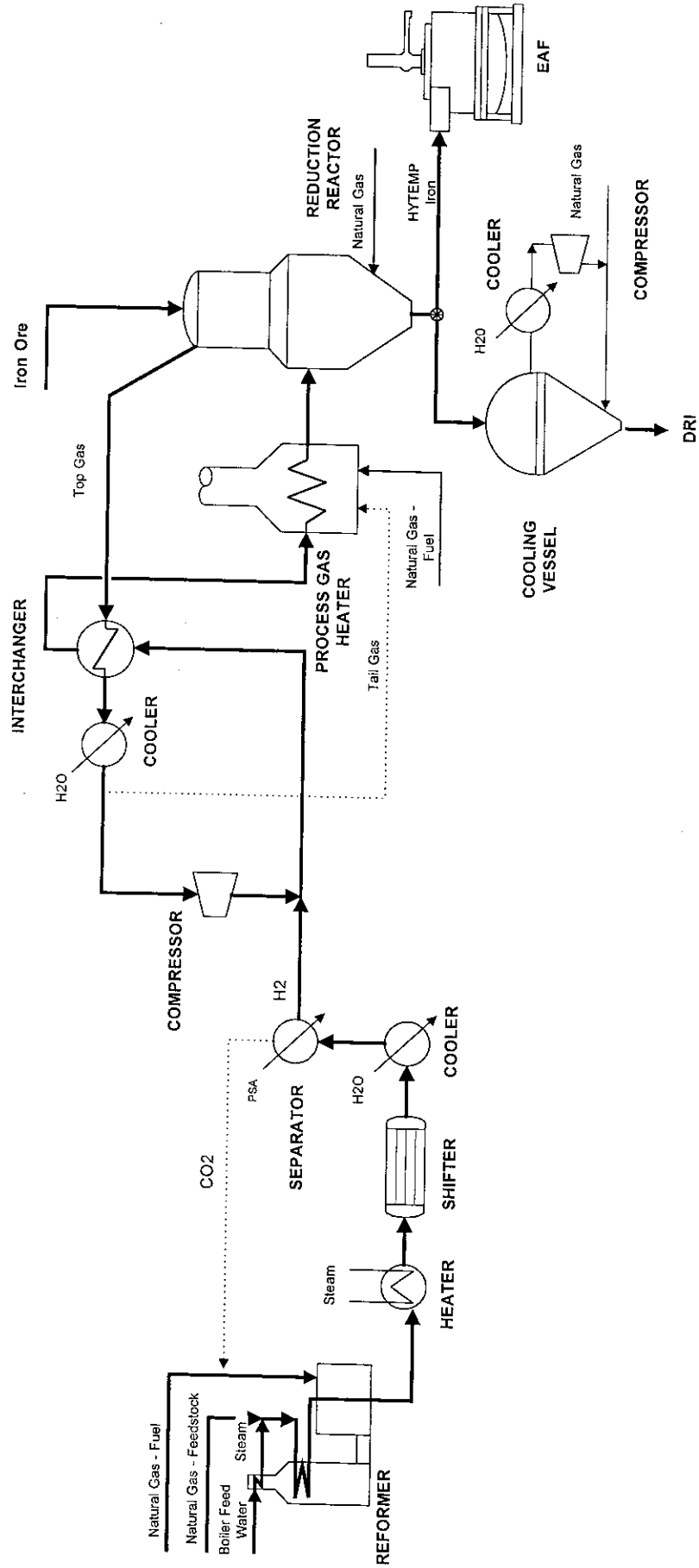
The use of a reformer that does not process gas from the reduction section isolates it from any gas-side changes which might occur in the reactor.

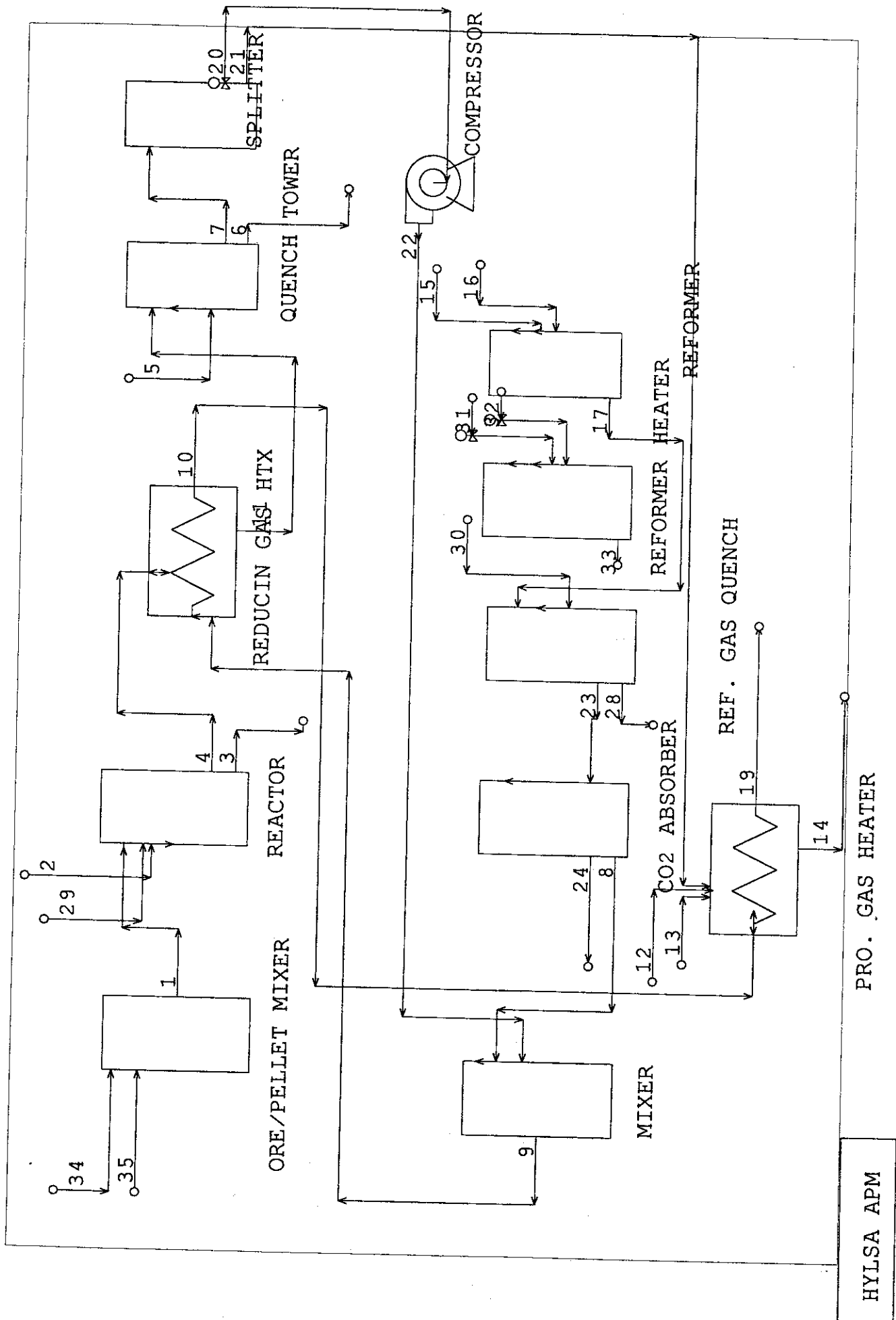
As the solid feed moves down the reactor by gravity flow, it is heated and reduced by reducing gas flowing upwards. The major reductant is H<sub>2</sub> due to its higher concentration in the reducing gas. In the conical lower part of the reactor, the burden is cooled and carburized by a circulating cooling gas that is enriched with natural gas. The product is reduced to a metallization up to 95% and carbon can be controlled in a range of 1.5% to 4.5%. For hot discharge of DRI, Hylsa's HYTEMP™ system is used which links the reactor discharge to the melt shop by way of a pneumatic conveying system.

## PROCESS ADVANTAGES

- Proven performance
- Raw material flexibility (high S ore and natural gas)
- Conventional Steam reforming
- Selective elimination of H<sub>2</sub>O and CO<sub>2</sub> from the reducing gas circuit allows maximum recycle of reducing gases to the reduction reactor.
- Higher pressure operation reducing circulating gas volumetric flow at high molar
- Flexibility to generate electric power by high pressure steam produced in the reformer.

# HYLSA PROCESS FLOWSHEET





HYLSA APM

## **Hylsa Process — MetSim Model — Description**

The MetSim model for this process is largely based upon a basic flowsheet for a Hylsa reactor from HYL, Mexico.

### **Flowsheet Description**

In this case, the ore (Stream 34) is mixed with pellets (Stream 35) to form the iron feed (Stream 1) for the Reduction reactor. The combined stream consists of approx. 96% Fe<sub>2</sub>O<sub>3</sub> and rest other oxides. In the Reduction furnace, this feed is heated and reduced by the upcoming reducing gases (Stream 2) into DRI (Stream 3). Stream 4 representing the Top gas is passed through a Reducing gas Heat Exchanger to recover some heat and a Quench Tower to get rid of excess moisture. Then stream 7, the remaining top gas is split into two parts viz, process gas (Stream 20) and tail gas (Stream 21). The process gas is mixed with Reformed gas (Stream 8) to form Stream 9. This stream is preheated with the help of hot Top gases first and then heated further in the Process Gas Heater where heat is provided by burning tail gas and some natural gas (Stream 12).

Hylsa's reforming system is independent of its reduction system. Steam reforming of natural gas (Stream 15) occurs in the Reformer to give Reformed gas (mostly H<sub>2</sub>). The Reformer Heater supplies the energy for reforming reactions by burning natural gas (Stream 31) with air (Stream 32). The Reformer and the Reformer Heater are coupled in the model such that heat required by the Reformer is equal to the heat loss of the Reformer Heater. The hot reformed gas is cooled down and its carbon-di-oxide/ carbon-mono oxide/ water content reduced so it is almost totally H<sub>2</sub> (Stream 8). This is then mixed with the process gas to generate the Reducing gas.

### **Model Assumptions:**

**Reduction Reactor:** The temperature of hot reducing gases is 930C. The top gas comes out at 730C. Complete reduction of iron ore takes place along with some reaction between metallic Fe and natural gas to give Fe<sub>3</sub>C. No carry-over of solid particles in the Top gas is assumed.

**Reducing Gas Heat Exchanger:** The hot top gases are used to preheat cold incoming reducing gases. 100% efficiency is assumed.

**Quench Tower:** Thermal equilibrium is assumed.

**Stream Splitter:** CO<sub>2</sub> content of the Reducing gas is controlled by adjusting the amount of tail gas.

Compressor: No increase in temperature on compression.

Reformer: The reactions reach equilibrium.

Reformer Heater: The heat required by the Reformer is equal to the heat lost by the Reformer Heater.

Reformed Gas Quench: All water is condensed and removed.

CO<sub>2</sub> Absorber: CO, CO<sub>2</sub>, etc. are absorbed so that remaining gas contains only hydrogen.

Process Gas Heater: The exhaust stream is at 138C. Stream 19 is equivalent to stream 2 (the reducing gases entering the Reduction Reactor).

### **Results**

It was decided to achieve same operating conditions as were outlined in the APM proposal by HYL. In the absence of information on gas compositions and amounts for certain feed streams, a few assumptions were made. These led to some differences between the MetSim Model results and the data by HYL.

It was observed that although complete metallization took place in the furnace, the amount of natural gas required, the amount of gases flowing in and around the reduction reactor were higher than those outlined in the proposal by HYL. This is partly due to the unknowns about the various gas composition.







**HYLSA PROCESS -- STREAM SUMMARY**

| Stream Number                    | 29         | 30       | 31         | 32        | 33         | 34       | 35       |
|----------------------------------|------------|----------|------------|-----------|------------|----------|----------|
| Stream Names                     | NATURAL G  | QUENCH W | NATURAL G  | COMBUSTI  | EXHAUST    | ORE      | PELLET   |
| KG/HR SOLIDS                     | 0          | 0        | 0          | 0         | 0          | 207.2    | 1161.1   |
| KG/HR AQUEOUS                    | 0          | 800      | 0          | 0         | 0          | 0        | 0        |
| KG/HR GASEOUS                    | 23.2       | 0        | 47.913     | 804.31    | 852.22     | 0        | 0        |
| KG/HR TOTAL                      | 23.2       | 800      | 47.913     | 804.31    | 852.22     | 207.2    | 1161.1   |
| Percent Solids                   | 0          | 0        | 0          | 0         | 0          | 100      | 100      |
| Sp.Gr.SOLIDS                     | 0          | 0        | 0          | 0         | 0          | 4.9507   | 5.127    |
| Sp.Gr.AQUEOUS                    | 0          | 0.99985  | 0          | 0         | 0          | 0        | 0        |
| Sp.Gr.GASEOUS                    | 0.00081212 | 0        | 0.00091251 | 0.0011598 | 0.00084924 | 0        | 0        |
| Sp.Gr.TOTAL                      | 0.00081212 | 0.99985  | 0.00091251 | 0.0011598 | 0.00084924 | 4.9507   | 5.127    |
| Temperature C                    | 30         | 1        | 30         | 30        | 130        | 30       | 30       |
| Pressure kPa                     | 101.33     | 101.33   | 101.33     | 101.33    | 101.33     | 101.33   | 101.33   |
| Gas nm3/hr                       | 25.74      | 0        | 47.311     | 624.87    | 679.92     | 0        | 0        |
| Sol/Liq m3/hr                    | 0          | 0.80012  | 0          | 0         | 0          | 0.041853 | 0.22646  |
| Sol/Liq gpm                      | 0          | 3.5228   | 0          | 0         | 0          | 0.18427  | 0.99708  |
| <b>Component Mass Flow Rates</b> |            |          |            |           |            |          |          |
| 1 Fe2O3 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 190.96   | 1123.1   |
| 2 Fe1O1 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 2.2378   | 3.0188   |
| 3 Fe1 KG/HR                      | 0          | 0        | 0          | 0         | 0          | 0        | 0        |
| 4 Ca1O1 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 0.06216  | 6.6182   |
| 5 Mg1O1 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 0.04144  | 0.46443  |
| 6 Al2O3 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 1.8648   | 8.3598   |
| 7 Si1O2 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 11.52    | 18.113   |
| 8 Mn1O1 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 0.16576  | 0.58054  |
| 10 Ti1O2 KG/HR                   | 0          | 0        | 0          | 0         | 0          | 0.16576  | 0        |
| 11 S1 KG/HR                      | 0          | 0        | 0          | 0         | 0          | 0.033152 | 0.023222 |
| 12 P1 KG/HR                      | 0          | 0        | 0          | 0         | 0          | 0.15333  | 0.55732  |
| 13 Na2O1 KG/HR                   | 0          | 0        | 0          | 0         | 0          | 0        | 0.11611  |
| 14 K2O1 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 0        | 0.11611  |
| 16 H2O KG/HR                     | 0          | 800      | 0          | 0         | 0          | 0        | 0        |
| 17 C1H4 KG/HR                    | 14.942     | 0        | 25.736     | 0         | 0          | 0        | 0        |
| 18 N2 KG/HR                      | 0          | 0        | 0          | 616.97    | 616.97     | 0        | 0        |
| 19 O2 KG/HR                      | 0          | 0        | 0          | 187.34    | 29.12      | 0        | 0        |
| 20 C1O1 KG/HR                    | 0          | 0        | 0          | 0         | 0          | 0        | 0        |
| 21 C1O2 KG/HR                    | 4.0432     | 0        | 6.8742     | 0         | 123.27     | 0        | 0        |
| 22 H2O KG/HR                     | 0          | 0        | 0          | 0         | 82.859     | 0        | 0        |
| 23 H2 KG/HR                      | 0          | 0        | 0          | 0         | 0          | 0        | 0        |
| 24 C2H6 KG/HR                    | 3.1079     | 0        | 6.0932     | 0         | 0          | 0        | 0        |
| 25 C3H8 KG/HR                    | 0.50641    | 0        | 1.7685     | 0         | 0          | 0        | 0        |
| 26 C4H10 KG/HR                   | 0.60074    | 0        | 1.3496     | 0         | 0          | 0        | 0        |
| 27 C5H12 KG/HR                   | 0          | 0        | 6.0918     | 0         | 0          | 0        | 0        |
| 28 Fe3C1 KG/HR                   | 0          | 0        | 0          | 0         | 0          | 0        | 0        |
| <b>Element Mass Flow Rates</b>   |            |          |            |           |            |          |          |
| 1 H 1                            | 4.5769     | 89.521   | 9.272      | 0         | 9.272      | 0        | 0        |
| 2 C 6                            | 15.683     | 0        | 33.643     | 0         | 33.643     | 0        | 0        |
| 3 N 7                            | 0          | 0        | 0          | 616.97    | 616.97     | 0        | 0        |
| 4 O 8                            | 2.9398     | 710.48   | 4.9981     | 187.34    | 192.34     | 65.044   | 354.08   |
| 5 Na 11                          | 0          | 0        | 0          | 0         | 0          | 0        | 0.086136 |
| 6 Mg 12                          | 0          | 0        | 0          | 0         | 0          | 0.024993 | 0.2801   |
| 7 Al 13                          | 0          | 0        | 0          | 0         | 0          | 0.98695  | 4.4244   |
| 8 Si 14                          | 0          | 0        | 0          | 0         | 0          | 5.3851   | 8.4667   |
| 9 P 15                           | 0          | 0        | 0          | 0         | 0          | 0.15333  | 0.55732  |
| 10 S 16                          | 0          | 0        | 0          | 0         | 0          | 0.033152 | 0.023222 |
| 11 K 19                          | 0          | 0        | 0          | 0         | 0          | 0        | 0.096387 |
| 12 Ca 20                         | 0          | 0        | 0          | 0         | 0          | 0.044426 | 4.73     |
| 13 Ti 22                         | 0          | 0        | 0          | 0         | 0          | 0.099375 | 0        |
| 15 Mn 25                         | 0          | 0        | 0          | 0         | 0          | 0.12837  | 0.4496   |
| 16 Fe 26                         | 0          | 0        | 0          | 0         | 0          | 135.3    | 787.89   |

## HYLSA PROJECT

## INPUT DATA

TITLE : HYLSA PROJECT  
CASE :  
DATA STORAGE FILE NAME : hylsapm8V.sfw  
HEAT BALANCE OPTION : ON  
UNITS OF MASS/TIME : KG/HR

| ROW | CNM   | CHF      |          | PHC    | CMW    | SGF    |
|-----|-------|----------|----------|--------|--------|--------|
| 1   | Fe2O3 | Fe2O3SI1 | 159.6922 | 5.2400 | 0.0000 | 0.0000 |
| 2   | Fe1O1 | Fe1O1SI1 | 71.8464  | 5.7000 | 0.0000 | 0.0000 |
| 3   | Fe1   | Fe1 SI1  | 55.8470  | 7.8600 | 0.0000 | 0.0000 |
| 4   | Ca1O1 | Ca1O1SI1 | 56.0794  | 3.3100 | 0.0000 | 0.0000 |
| 5   | Mg1O1 | Mg1O1SI1 | 40.3114  | 3.5800 | 0.0000 | 0.0000 |
| 6   | Al2O3 | Al2O3SI1 | 101.9612 | 3.9650 | 0.0000 | 0.0000 |
| 7   | Si1O2 | Si1O2SI1 | 60.0848  | 2.6500 | 0.0000 | 0.0000 |
| 8   | Mn1O1 | Mn1O1SI1 | 70.9374  | 5.4500 | 0.0000 | 0.0000 |
| 9   | V2O5  | V2O5 SI1 | 181.8810 | 3.3570 | 0.0000 | 0.0000 |
| 10  | Ti1O2 | Ti1O2SI1 | 79.8988  | 4.2600 | 0.0000 | 0.0000 |
| 11  | S1    | S1 SI1   | 32.0640  | 2.0000 | 0.0000 | 0.0000 |
| 12  | P1    | P1 SI1   | 30.9738  | 1.8200 | 0.0000 | 0.0000 |
| 13  | Na2O1 | Na2O1SI1 | 61.9790  | 2.2700 | 0.0000 | 0.0000 |
| 14  | K2O1  | K2O1 SI1 | 94.1954  | 2.3200 | 0.0000 | 0.0000 |
| 15  | C1    | C1 SI1   | 12.0112  | 2.2500 | 0.0000 | 0.0000 |
| 16  | H2O   | H2O LI3  | 18.0153  | 1.0000 | 0.0000 | 0.0000 |
| 17  | C1H4  | C1H4 GC8 | 16.0430  | 0.0007 | 0.0000 | 0.0000 |
| 18  | N2    | N2 GC8   | 28.0134  | 0.0012 | 0.0000 | 0.0000 |
| 19  | O2    | O2 GC8   | 31.9988  | 0.0014 | 0.0000 | 0.0000 |
| 20  | C1O1  | C1O1 GC8 | 28.0106  | 0.0012 | 0.0000 | 0.0000 |
| 21  | C1O2  | C1O2 GC8 | 44.0100  | 0.0020 | 0.0000 | 0.0000 |
| 22  | H2O   | H2O GC8  | 18.0153  | 0.0008 | 0.0000 | 0.0000 |
| 23  | H2    | H2 GC8   | 2.0159   | 0.0001 | 0.0000 | 0.0000 |
| 24  | C2H6  | C2H6 GC8 | 30.0701  | 0.0013 | 0.0000 | 0.0000 |
| 25  | C3H8  | C3H8 GC8 | 44.0972  | 0.0020 | 0.0000 | 0.0000 |
| 26  | C4H10 | C4H10GC8 | 58.1243  | 0.0026 | 0.0000 | 0.0000 |
| 27  | C5H12 | C5H12GC8 | 72.1514  | 0.0032 | 0.0000 | 0.0000 |
| 28  | Fe3C1 | Fe3C1SI1 | 179.5521 | 1.0000 | 0.0000 | 0.0000 |

| ROW | CNM   | REFERENCE | H25     | HTE-A  | HTE-B    | HTE-C    | HTE-D    |
|-----|-------|-----------|---------|--------|----------|----------|----------|
| 1   | Fe2O3 | B672158   | -197000 | -20749 | 46.1517  | -3.8751  | 21.9462  |
| 2   | Fe1O1 | BAK2248   | -62382  | 8754   | -8.5950  | 9.1416   | -21.4692 |
| 3   | Fe1   | B672151   | 0       | -7903  | 14.0914  | -1.3293  | 11.6233  |
| 4   | Ca1O1 | B672098   | -151790 | -4315  | 12.0730  | 0.4606   | 2.0088   |
| 5   | Mg1O1 | B672227   | -143760 | -4612  | 11.8081  | 0.3610   | 3.1765   |
| 6   | Al2O3 | B672042   | -400500 | -12425 | 28.9653  | 1.0071   | 11.1085  |
| 7   | Si1O2 | B672387   | -217720 | -8654  | 19.1651  | -0.5456  | 8.8977   |
| 8   | Mn1O1 | B672232   | -92070  | -3551  | 10.8451  | 1.0861   | 0.6565   |
| 9   | V2O5  | B672460   | -370600 | -11011 | 31.3186  | 6.3456   | 3.2973   |
| 10  | Ti1O2 | B672431   | -225670 | -6260  | 16.8540  | 0.6334   | 3.4762   |
| 11  | S1    | B672335   | 0       | 13015  | -44.4133 | 56.5440  | -14.3084 |
| 12  | P1    | B672282   | 0       | -2816  | 12.9239  | -11.6659 | 0.0000   |
| 13  | Na2O1 | B672257   | -99700  | 1345   | 3.7517   | 9.6170   | -10.1495 |
| 14  | K2O1  | B672209   | -81260  | -6064  | 18.1536  | 2.0456   | 1.3980   |
| 15  | C1    | B672086   | 0       | -2999  | 5.1802   | 0.2246   | 4.3597   |
| 16  | H2O   | B672180   | -68315  | -5071  | 16.1848  | 2.7637   | 0.0000   |
| 17  | C1H4  | B672217   | -17880  | -6424  | 11.8424  | 2.9907   | 8.0422   |
| 18  | N2    | B672244   | 0       | -2846  | 7.5728   | 0.2525   | 1.7794   |
| 19  | O2    | B672277   | 0       | -2979  | 7.9696   | 0.2720   | 1.7697   |
| 20  | C1O1  | B672093   | -26417  | -2962  | 7.7460   | 0.2285   | 1.9749   |
| 21  | C1O2  | B672094   | -94051  | -5911  | 12.9357  | 0.3891   | 6.1869   |
| 22  | H2O   | B672182   | -57795  | -2403  | 7.2906   | 1.3003   | 0.3596   |
| 23  | H2    | B672174   | 0       | -1837  | 6.3659   | 0.4428   | -0.2847  |
| 24  | C2H6  | B6722223  | -20240  | -5819  | 11.3274  | 9.4527   | 4.7951   |
| 25  | C3H8  | BAK1139A  | 12720   | 3185   | -13.5908 | 43.9657  | -9.0826  |
| 26  | C4H10 | BAK1126   | -29800  | -17099 | 32.8367  | 11.3643  | 18.9320  |
| 27  | C5H12 | BAK1132B  | -34800  | -17182 | 34.9823  | 9.5671   | 17.7272  |
| 28  | Fe3C1 | B6771332  | 5985    | -5013  | 21.1456  | 4.1225   | -5.0322  |

HYLSA PROJECT

INPUT DATA

| ROW | CNM   | TEMP  | RANGE  | OK | HTG-A   | HTG-B    | HTG-C    | HTG-D    |
|-----|-------|-------|--------|----|---------|----------|----------|----------|
| 1   | Fe2O3 | 298.2 | 1800.0 |    | -182323 | -34.6418 | -13.7715 | -28.2755 |
| 2   | Fe1O1 | 298.2 | 1650.0 |    | -58450  | -19.5576 | -4.9564  | -7.3814  |
| 3   | Fe1   | 298.2 | 1811.0 |    | 2679    | -8.2139  | -4.0925  | -5.4957  |
| 4   | Ca1O1 | 298.2 | 2000.0 |    | -146099 | -14.8629 | -4.7096  | -10.7418 |
| 5   | Mg1O1 | 298.2 | 2000.0 |    | -138544 | -11.5487 | -4.4916  | -9.9661  |
| 6   | Al2O3 | 298.2 | 2327.0 |    | -386441 | -25.8901 | -10.0349 | -27.6544 |
| 7   | Si1O2 | 298.2 | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464 |
| 8   | Mn1O1 | 298.2 | 1500.0 |    | -88030  | -17.6692 | -5.7458  | -7.5421  |
| 9   | V2O5  | 298.2 | 950.0  |    | -364423 | -29.8510 | -24.3174 | -13.1309 |
| 10  | Ti1O2 | 298.2 | 2000.0 |    | -217923 | -19.7530 | -6.5095  | -14.7172 |
| 11  | S1    | 298.2 | 388.4  |    | -5700   | 12.4302  | -23.6630 | 5.4073   |
| 12  | P1    | 298.2 | 317.3  |    | -2534   | 6.8556   | -27.4268 | 0.0000   |
| 13  | Na2O1 | 298.2 | 1300.0 |    | -95586  | -19.3198 | -11.2023 | -8.1549  |
| 14  | K2O1  | 298.2 | 1100.0 |    | -76733  | -26.1416 | -11.7119 | -8.8698  |
| 15  | C1    | 298.2 | 3000.0 |    | 2405    | -3.3866  | -1.5836  | -5.1587  |
| 16  | H2O   | 298.2 | 373.2  |    | -70630  | -1.0739  | -26.4253 | 0.0000   |
| 17  | C1H4  | 298.2 | 2000.0 |    | -14673  | -45.4106 | -7.1789  | -6.9854  |
| 18  | N2    | 298.2 | 3000.0 |    | 5078    | -51.3044 | -2.2358  | -9.9139  |
| 19  | O2    | 298.2 | 3000.0 |    | 5395    | -54.8302 | -2.3535  | -10.5960 |
| 20  | C1O1  | 298.2 | 3000.0 |    | -21272  | -52.8075 | -2.2569  | -10.0674 |
| 21  | C1O2  | 298.2 | 3000.0 |    | -86430  | -58.7976 | -3.7771  | -15.3476 |
| 22  | H2O   | 298.2 | 2000.0 |    | -54212  | -48.4557 | -3.8711  | -6.7579  |
| 23  | H2    | 298.2 | 3000.0 |    | 4863    | -36.6465 | -2.1036  | -9.3536  |
| 24  | C2H6  | 298.2 | 1000.0 |    | -19821  | -48.2326 | -15.8609 | -2.9266  |
| 25  | C3H8  | 298.2 | 1000.0 |    | 8420    | -33.7154 | -36.2585 | 1.8620   |
| 26  | C4H10 | 298.2 | 1500.0 |    | -24334  | -69.8380 | -25.6515 | -13.3922 |
| 27  | C5H12 | 298.2 | 1500.0 |    | -27854  | -78.1190 | -24.7443 | -15.6889 |
| 28  | Fe3C1 | 298.2 | 1400.0 |    | 15085   | -32.7885 | -13.6625 | -16.6593 |

| FLOL      |                      | FLO |     |     |     |     |     |     |     |     |     |     |     |     |
|-----------|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| TYP LABEL |                      | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  |
| NO        | OPR UNIT PROCESS     | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |
| 1         | SEC HYLSA APM        | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 2         | MIX ORE/PELLET MIXER | 34  | 35  | 0   | 0   | 0   | 0   | 0   | 1   | 0   | 0   | 0   | 0   | 0   |
| 3         | SPP REACTOR          | 1   | 2   | 29  | 0   | 0   | 0   | 0   | 3   | 4   | 0   | 0   | 0   | 0   |
| 4         | HTX REDUCIN GAS HTX  | 9   | 0   | 0   | 4   | 0   | 0   | 0   | 10  | 11  | 0   | 0   | 0   | 0   |
| 5         | SPP QUENCH TOWER     | 11  | 5   | 0   | 0   | 0   | 0   | 0   | 6   | 7   | 0   | 0   | 0   | 0   |
| 6         | SUB SPLITTER         | 7   | 0   | 0   | 0   | 0   | 0   | 0   | 21  | 20  | 0   | 0   | 0   | 0   |
| 7         | PMC COMPRESSOR       | 20  | 0   | 0   | 0   | 0   | 0   | 0   | 22  | 0   | 0   | 0   | 0   | 0   |
| 8         | SPP REFORMER         | 15  | 16  | 0   | 0   | 0   | 0   | 0   | 17  | 0   | 0   | 0   | 0   | 0   |
| 9         | SPP REFORMER HEATER  | 31  | 32  | 0   | 0   | 0   | 0   | 0   | 33  | 0   | 0   | 0   | 0   | 0   |
| 10        | SPP REF. GAS QUENCH  | 17  | 30  | 0   | 0   | 0   | 0   | 0   | 28  | 23  | 0   | 0   | 0   | 0   |
| 11        | SPC CO2 ABSORBER     | 23  | 0   | 0   | 0   | 0   | 0   | 0   | 8   | 24  | 0   | 0   | 0   | 0   |
| 12        | MIX MIXER            | 22  | 8   | 0   | 0   | 0   | 0   | 0   | 9   | 0   | 0   | 0   | 0   | 0   |
| 13        | HTX PRO. GAS HEATER  | 10  | 0   | 0   | 12  | 13  | 21  | 0   | 19  | 14  | 0   | 0   | 0   | 0   |



HYLSA PROJECT

| NO. STREAM                  | STREAM TEMPERATURES AND ENTHALPIES |         |            |           |           |
|-----------------------------|------------------------------------|---------|------------|-----------|-----------|
|                             | TEMP-C                             | TEMP-F  | KCAL/HR    | BTU/HR    | KJ/HR     |
| 1 SIZED ORE/PELLET          | 30.000                             | 86.00   | 1064.00    | 4221.0    | 4450.0    |
| 2 REDUCING GAS              | 930.000                            | 1706.00 | 616934.00  | 2448194.0 | 2581254.0 |
| 3 DRI PRODUCT               | 730.000                            | 1346.00 | 111496.00  | 442451.0  | 466498.0  |
| 4 REACTOR EXHAUST           | 397.256                            | 747.06  | 260302.00  | 1032963.0 | 1089105.0 |
| 5 QUENCH WATER              | 1.000                              | 33.80   | -108121.00 | -429058.0 | -452378.0 |
| 6 WARM WATER                | 82.447                             | 180.41  | 282524.00  | 1121147.0 | 1182082.0 |
| 7 COOLED REDUCING GAS       | 82.447                             | 180.41  | 27616.00   | 109589.0  | 115545.0  |
| 8 FRESH REFORMED GAS        | 307.641                            | 585.75  | 48246.00   | 191456.0  | 201861.0  |
| 9 COMB. REDUCING GAS        | 142.685                            | 288.83  | 74890.00   | 297188.0  | 313341.0  |
| 10 PREHEATED REDUCING GAS   | 277.965                            | 532.34  | 163837.00  | 650158.0  | 685494.0  |
| 11 RECYCLE REDUCING GAS     | 277.965                            | 532.34  | 173383.00  | 688041.0  | 725437.0  |
| 12 FUEL                     | 30.000                             | 86.00   | 160.00     | 634.0     | 669.0     |
| 13 AIR                      | 30.000                             | 86.00   | 1339.00    | 5312.0    | 5601.0    |
| 14 EXHAUST                  | 138.000                            | 280.40  | 21455.00   | 85140.0   | 89768.0   |
| 15 DESULFURIZED NATURAL GAS | 30.000                             | 86.00   | 735.00     | 2918.0    | 3076.0    |
| 16 WATER                    | 120.000                            | 248.00  | 14491.00   | 57503.0   | 60629.0   |
| 17 REFORMED GAS             | 900.000                            | 1652.00 | 301153.00  | 1195070.0 | 1260022.0 |
| 18                          | 0.000                              | 32.00   | 27783.00   | 110251.0  | 116243.0  |
| 19 REDUCING GAS EQ 2        | 939.771                            | 1723.59 | 633288.00  | 2513088.0 | 2649675.0 |
| 20 GAS TO COMPRESSOR        | 82.447                             | 180.41  | 26644.00   | 105733.0  | 111479.0  |
| 21 TAIL GAS                 | 82.447                             | 180.41  | 972.00     | 3856.0    | 4066.0    |
| 22 COMPRESSED GAS           | 82.447                             | 180.41  | 26644.00   | 105733.0  | 111479.0  |
| 23 QUENCHED REFORMED GAS    | 307.641                            | 585.75  | 72416.00   | 287371.0  | 302990.0  |
| 24 CO2                      | 307.641                            | 585.75  | 24170.00   | 95916.0   | 101129.0  |
| 26                          | 78.882                             | 173.99  | 21253.00   | 84337.0   | 88921.0   |
| 27                          | 78.882                             | 173.99  | 0.00       | 0.0       | 0.0       |
| 28 WARM WATER               | 307.641                            | 585.75  | 284921.00  | 1130657.0 | 1192108.0 |
| 29 NATURAL GAS              | 30.000                             | 86.00   | 105.00     | 417.0     | 440.0     |
| 30 QUENCH WATER             | 1.000                              | 33.80   | -19221.00  | -76277.0  | -80423.0  |
| 31 NATURAL GAS              | 30.000                             | 86.00   | 198.00     | 787.0     | 829.0     |
| 32 COMBUSTION AIR PREHEAT   | 30.000                             | 86.00   | 1576.00    | 6255.0    | 6595.0    |
| 33 EXHAUST                  | 130.000                            | 266.00  | 22200.00   | 88097.0   | 92885.0   |
| 34 ORE                      | 30.000                             | 86.00   | 157.00     | 624.0     | 658.0     |
| 35 PELLET                   | 30.000                             | 86.00   | 906.00     | 3596.0    | 3792.0    |

HYLSA PROJECT

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM                  | TIME     | ACFM     | SCFM     | M3/HR    | NM3/HR   |
|-----------------------------|----------|----------|----------|----------|----------|
| 2 REDUCING GAS              | 100.0000 | 1107.441 | 1168.168 | 1881.554 | 1984.730 |
| 4 REACTOR EXHAUST           | 100.0000 | 663.011  | 1201.397 | 1126.462 | 2041.186 |
| 7 COOLED REDUCING GAS       | 100.0000 | 310.442  | 894.313  | 527.444  | 1519.448 |
| 8 FRESH REFORMED GAS        | 100.0000 | 690.379  | 324.690  | 1172.962 | 551.652  |
| 9 COMB. REDUCING GAS        | 100.0000 | 1807.866 | 1187.534 | 3071.584 | 2017.633 |
| 10 PREHEATED REDUCING GAS   | 100.0000 | 2396.002 | 1187.534 | 4070.833 | 2017.633 |
| 11 RECYCLE REDUCING GAS     | 100.0000 | 584.783  | 1201.397 | 993.553  | 2041.186 |
| 12 FUEL                     | 100.0000 | 25.541   | 23.013   | 43.394   | 39.100   |
| 13 AIR                      | 100.0000 | 346.664  | 312.358  | 588.987  | 530.700  |
| 14 EXHAUST                  | 100.0000 | 534.163  | 354.875  | 907.549  | 602.936  |
| 15 DESULFURIZED NATURAL GAS | 100.0000 | 117.514  | 105.885  | 199.658  | 179.900  |
| 16 WATER                    | 100.0000 | 363.936  | 252.853  | 618.331  | 429.600  |
| 17 REFORMED GAS             | 100.0000 | 2317.709 | 539.643  | 3937.812 | 916.859  |
| 18                          | 100.0000 | 894.313  | 894.313  | 1519.448 | 1519.448 |
| 19 REDUCING GAS EQ 2        | 100.0000 | 5273.236 | 1187.534 | 8959.286 | 2017.633 |
| 20 GAS TO COMPRESSOR        | 100.0000 | 1123.284 | 862.844  | 1908.472 | 1465.981 |
| 21 TAIL GAS                 | 100.0000 | 40.968   | 31.469   | 69.605   | 53.467   |
| 22 COMPRESSED GAS           | 100.0000 | 241.761  | 862.844  | 410.755  | 1465.981 |
| 23 QUENCHED REFORMED GAS    | 100.0000 | 946.364  | 445.082  | 1607.883 | 756.198  |
| 24 CO2                      | 100.0000 | 255.985  | 120.391  | 434.921  | 204.546  |
| 26                          | 100.0000 | 958.117  | 743.427  | 1627.851 | 1263.090 |
| 29 NATURAL GAS              | 100.0000 | 16.814   | 15.150   | 28.567   | 25.740   |
| 31 NATURAL GAS              | 100.0000 | 30.904   | 27.846   | 52.507   | 47.311   |
| 32 COMBUSTION AIR PREHEAT   | 100.0000 | 408.179  | 367.785  | 693.501  | 624.872  |
| 33 EXHAUST                  | 100.0000 | 590.644  | 400.184  | 1003.510 | 679.918  |

VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM         | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|--------------------|----------|----------|----------|----------|----------|
| 1 SIZED ORE/PELLET | 100.0000 | 1.18135  | 0.074532 | 0.268315 | 6.4396   |
| 3 DRI PRODUCT      | 100.0000 | 1.26888  | 0.080054 | 0.288196 | 6.9167   |
| 5 QUENCH WATER     | 100.0000 | 19.81568 | 1.250183 | 4.500658 | 108.0158 |
| 6 WARM WATER       | 100.0000 | 22.32712 | 1.408631 | 5.071071 | 121.7057 |
| 28 WARM WATER      | 100.0000 | 5.88098  | 0.371034 | 1.335724 | 32.0574  |
| 30 QUENCH WATER    | 100.0000 | 3.52279  | 0.222255 | 0.800117 | 19.2028  |
| 34 ORE             | 100.0000 | 0.18427  | 0.011626 | 0.041853 | 1.0045   |
| 35 PELLET          | 100.0000 | 0.99708  | 0.062906 | 0.226462 | 5.4351   |

HYLSA PROJECT

MASS FLOW RATES - KG/HR

| NO. STREAM                  | KG/HR-SI | KG/HR-LI | KG/HR-GC | KG/HR-TC |
|-----------------------------|----------|----------|----------|----------|
| 1 SIZED ORE/PELLET          | 1368.280 | 0.000    | 0.000    | 1368.280 |
| 2 REDUCING GAS              | 0.000    | 0.000    | 614.814  | 614.814  |
| 3 DRI PRODUCT               | 1001.977 | 0.000    | 0.000    | 1001.977 |
| 4 REACTOR EXHAUST           | 0.000    | 0.000    | 1004.317 | 1004.317 |
| 5 QUENCH WATER              | 0.000    | 4500.000 | 0.000    | 4500.000 |
| 6 WARM WATER                | 0.000    | 4919.349 | 0.000    | 4919.349 |
| 7 COOLED REDUCING GAS       | 0.000    | 0.000    | 584.968  | 584.968  |
| 8 FRESH REFORMED GAS        | 0.000    | 0.000    | 49.616   | 49.616   |
| 9 COMB. REDUCING GAS        | 0.000    | 0.000    | 614.000  | 614.000  |
| 10 PREHEATED REDUCING GAS   | 0.000    | 0.000    | 614.000  | 614.000  |
| 11 RECYCLE REDUCING GAS     | 0.000    | 0.000    | 1004.317 | 1004.317 |
| 12 FUEL                     | 0.000    | 0.000    | 35.241   | 35.241   |
| 13 AIR                      | 0.000    | 0.000    | 683.094  | 683.094  |
| 14 EXHAUST                  | 0.000    | 0.000    | 738.920  | 738.920  |
| 15 DESULFURIZED NATURAL GAS | 0.000    | 0.000    | 162.147  | 162.147  |
| 16 WATER                    | 0.000    | 0.000    | 345.293  | 345.293  |
| 17 REFORMED GAS             | 0.000    | 0.000    | 507.439  | 507.439  |
| 18                          | 0.000    | 0.000    | 584.968  | 584.968  |
| 19 REDUCING GAS EQ 2        | 0.000    | 0.000    | 614.000  | 614.000  |
| 20 GAS TO COMPRESSOR        | 0.000    | 0.000    | 564.384  | 564.384  |
| 21 TAIL GAS                 | 0.000    | 0.000    | 20.584   | 20.584   |
| 22 COMPRESSED GAS           | 0.000    | 0.000    | 564.384  | 564.384  |
| 23 QUENCHED REFORMED GAS    | 0.000    | 0.000    | 378.308  | 378.308  |
| 24 CO2                      | 0.000    | 0.000    | 328.692  | 328.692  |
| 26                          | 0.000    | 0.000    | 327.736  | 327.736  |
| 28 WARM WATER               | 0.000    | 929.132  | 0.000    | 929.132  |
| 29 NATURAL GAS              | 0.000    | 0.000    | 23.200   | 23.200   |
| 30 QUENCH WATER             | 0.000    | 800.000  | 0.000    | 800.000  |
| 31 NATURAL GAS              | 0.000    | 0.000    | 47.913   | 47.913   |
| 32 COMBUSTION AIR PREHEAT   | 0.000    | 0.000    | 804.308  | 804.308  |
| 33 EXHAUST                  | 0.000    | 0.000    | 852.221  | 852.221  |
| 34 ORE                      | 207.200  | 0.000    | 0.000    | 207.200  |
| 35 PELLET                   | 1161.080 | 0.000    | 0.000    | 1161.080 |

HYLSA PROJECT

SPECIFIC GRAVITIES

| NO. STREAM                  | PCS      | SG-SI  | SG-LI  | SG-GC  | SG-TC  |
|-----------------------------|----------|--------|--------|--------|--------|
| 1 SIZED ORE/PELLET          | 100.0000 | 5.0995 | 0.0000 | 0.0000 | 5.0995 |
| 2 REDUCING GAS              | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 3 DRI PRODUCT               | 100.0000 | 3.4767 | 0.0000 | 0.0000 | 3.4767 |
| 4 REACTOR EXHAUST           | 0.0000   | 0.0000 | 0.0000 | 0.0009 | 0.0009 |
| 5 QUENCH WATER              | 0.0000   | 0.0000 | 0.9999 | 0.0000 | 0.9999 |
| 6 WARM WATER                | 0.0000   | 0.0000 | 0.9701 | 0.0000 | 0.9701 |
| 7 COOLED REDUCING GAS       | 0.0000   | 0.0000 | 0.0000 | 0.0011 | 0.0011 |
| 8 FRESH REFORMED GAS        | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 9 COMB. REDUCING GAS        | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 10 PREHEATED REDUCING GAS   | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 11 RECYCLE REDUCING GAS     | 0.0000   | 0.0000 | 0.0000 | 0.0010 | 0.0010 |
| 12 FUEL                     | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 13 AIR                      | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 14 EXHAUST                  | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 15 DESULFURIZED NATURAL GAS | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 16 WATER                    | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 17 REFORMED GAS             | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 18                          | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 19 REDUCING GAS EQ 2        | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 20 GAS TO COMPRESSOR        | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 21 TAIL GAS                 | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 22 COMPRESSED GAS           | 0.0000   | 0.0000 | 0.0000 | 0.0014 | 0.0014 |
| 23 QUENCHED REFORMED GAS    | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 24 CO2                      | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 26                          | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 28 WARM WATER               | 0.0000   | 0.0000 | 0.6956 | 0.0000 | 0.6956 |
| 29 NATURAL GAS              | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 30 QUENCH WATER             | 0.0000   | 0.0000 | 0.9999 | 0.0000 | 0.9999 |
| 31 NATURAL GAS              | 0.0000   | 0.0000 | 0.0000 | 0.0009 | 0.0009 |
| 32 COMBUSTION AIR PREHEAT   | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 33 EXHAUST                  | 0.0000   | 0.0000 | 0.0000 | 0.0008 | 0.0008 |
| 34 ORE                      | 100.0000 | 4.9507 | 0.0000 | 0.0000 | 4.9507 |
| 35 PELLET                   | 100.0000 | 5.1270 | 0.0000 | 0.0000 | 5.1270 |



## HYLSA PROJECT

## STREAM DATA

## SOLIDS - KG/HR

| NO. STREAM         | Fe2O3   | Fe1O1   | Fe1     | Ca1O1   | Mg1O1   | Al2O3   | Si1O2   |
|--------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 SIZED ORE/PELLET | 1314.07 | 5.2566  | 0.000   | 6.68032 | 0.50587 | 10.2246 | 29.6332 |
| 3 DRI PRODUCT      | 0.00    | 83.6119 | 701.784 | 6.68032 | 0.50587 | 10.2246 | 29.6332 |
| 34 ORE             | 190.96  | 2.2378  | 0.000   | 0.06216 | 0.04144 | 1.8648  | 11.5203 |
| 35 PELLET          | 1123.11 | 3.0188  | 0.000   | 6.61816 | 0.46443 | 8.3598  | 18.1128 |

## SOLIDS - KG/HR

| NO. STREAM         | Mn1O1   | V2O5    | Ti1O2   | S1      | P1      | Na2O1   | K2O1    |
|--------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 SIZED ORE/PELLET | 0.74630 | 0.00000 | 0.16576 | 0.05637 | 0.71065 | 0.11611 | 0.11611 |
| 3 DRI PRODUCT      | 0.74630 | 0.00000 | 0.16576 | 0.05637 | 0.71065 | 0.11611 | 0.11611 |
| 34 ORE             | 0.16576 | 0.00000 | 0.16576 | 0.03315 | 0.15333 | 0.00000 | 0.00000 |
| 35 PELLET          | 0.58054 | 0.00000 | 0.00000 | 0.02322 | 0.55732 | 0.11611 | 0.11611 |

## SOLIDS - KG/HR

| NO. STREAM    | C1      | Fe3C1   |
|---------------|---------|---------|
| 3 DRI PRODUCT | 0.00000 | 167.625 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM         | Fe2O3   | Fe1O1   | Fe1     | Ca1O1   | Mg1O1   | Al2O3   | Si1O2   |
|--------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 SIZED ORE/PELLET | 96.0380 | 0.38417 | 0.0000  | 0.48823 | 0.03697 | 0.74726 | 2.16572 |
| 3 DRI PRODUCT      | 0.0000  | 8.34470 | 70.0400 | 0.66671 | 0.05049 | 1.02044 | 2.95747 |
| 34 ORE             | 92.1600 | 1.08000 | 0.0000  | 0.03000 | 0.02000 | 0.90000 | 5.56000 |
| 35 PELLET          | 96.7300 | 0.26000 | 0.0000  | 0.57000 | 0.04000 | 0.72000 | 1.56000 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM         | Mn1O1   | V2O5    | Ti1O2   | S1      | P1      | Na2O1   | K2O1    |
|--------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 SIZED ORE/PELLET | 0.05454 | 0.00000 | 0.01211 | 0.00412 | 0.05194 | 0.00849 | 0.00849 |
| 3 DRI PRODUCT      | 0.07448 | 0.00000 | 0.01654 | 0.00563 | 0.07092 | 0.01159 | 0.01159 |
| 34 ORE             | 0.08000 | 0.00000 | 0.08000 | 0.01600 | 0.07400 | 0.00000 | 0.00000 |
| 35 PELLET          | 0.05000 | 0.00000 | 0.00000 | 0.00200 | 0.04800 | 0.01000 | 0.01000 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM    | C1      | Fe3C1   |
|---------------|---------|---------|
| 3 DRI PRODUCT | 0.00000 | 16.7295 |

## AQUEOUS - KG/HR

| NO. STREAM      | H2O     |
|-----------------|---------|
| 5 QUENCH WATER  | 4500.00 |
| 6 WARM WATER    | 4919.35 |
| 28 WARM WATER   | 929.13  |
| 30 QUENCH WATER | 800.00  |

## AQUEOUS - WEIGHT PERCENT

| NO. STREAM      | H2O     |
|-----------------|---------|
| 5 QUENCH WATER  | 100.000 |
| 6 WARM WATER    | 100.000 |
| 28 WARM WATER   | 100.000 |
| 30 QUENCH WATER | 100.000 |

## AQUEOUS - GRAMS PER LITER

| NO. STREAM      | H2O    |
|-----------------|--------|
| 5 QUENCH WATER  | 999.85 |
| 6 WARM WATER    | 970.08 |
| 28 WARM WATER   | 695.60 |
| 30 QUENCH WATER | 999.85 |

HYLSA PROJECT

STREAM DATA

GASEOUS - KG/HR

| NO. STREAM                  | C1H4    | N2      | O2      | C1O1    | C1O2    | H2O     | H2      |
|-----------------------------|---------|---------|---------|---------|---------|---------|---------|
| 2 REDUCING GAS              | 54.693  | 0.000   | 0.000   | 186.320 | 208.374 | 18.856  | 146.572 |
| 4 REACTOR EXHAUST           | 55.685  | 0.000   | 0.000   | 188.907 | 217.965 | 437.734 | 104.026 |
| 7 COOLED REDUCING GAS       | 55.685  | 0.000   | 0.000   | 188.907 | 217.965 | 18.385  | 104.026 |
| 8 FRESH REFORMED GAS        | 0.000   | 0.000   | 0.000   | 0.000   | 0.000   | 0.000   | 49.616  |
| 9 COMB. REDUCING GAS        | 53.726  | 0.000   | 0.000   | 182.260 | 210.295 | 17.738  | 149.982 |
| 10 PREHEATED REDUCING GAS   | 53.726  | 0.000   | 0.000   | 182.260 | 210.295 | 17.738  | 149.982 |
| 11 RECYCLE REDUCING GAS     | 55.685  | 0.000   | 0.000   | 188.907 | 217.965 | 437.734 | 104.026 |
| 12 FUEL                     | 22.697  | 0.000   | 0.000   | 0.000   | 6.142   | 0.000   | 0.000   |
| 13 AIR                      | 0.000   | 523.990 | 159.105 | 0.000   | 0.000   | 0.000   | 0.000   |
| 14 EXHAUST                  | 0.000   | 523.990 | 4.260   | 0.000   | 110.780 | 99.890  | 0.000   |
| 15 DESULFURIZED NATURAL GAS | 104.429 | 0.000   | 0.000   | 0.000   | 28.259  | 0.000   | 0.000   |
| 16 WATER                    | 0.000   | 0.000   | 0.000   | 0.000   | 0.000   | 345.293 | 0.000   |
| 17 REFORMED GAS             | 26.107  | 0.000   | 0.000   | 48.013  | 254.571 | 129.132 | 49.616  |
| 18                          | 55.685  | 0.000   | 0.000   | 188.907 | 217.965 | 18.385  | 104.026 |
| 19 REDUCING GAS EQ 2        | 53.726  | 0.000   | 0.000   | 182.260 | 210.295 | 17.738  | 149.982 |
| 20 GAS TO COMPRESSOR        | 53.726  | 0.000   | 0.000   | 182.260 | 210.295 | 17.738  | 100.366 |
| 21 TAIL GAS                 | 1.959   | 0.000   | 0.000   | 6.647   | 7.670   | 0.647   | 3.660   |
| 22 COMPRESSED GAS           | 53.726  | 0.000   | 0.000   | 182.260 | 210.295 | 17.738  | 100.366 |
| 23 QUENCHED REFORMED GAS    | 26.107  | 0.000   | 0.000   | 48.013  | 254.571 | 0.000   | 49.616  |
| 24 CO2                      | 26.107  | 0.000   | 0.000   | 48.013  | 254.571 | 0.000   | 0.000   |
| 26                          | 36.895  | 25.356  | 0.000   | 145.169 | 11.510  | 14.230  | 94.575  |
| 29 NATURAL GAS              | 14.942  | 0.000   | 0.000   | 0.000   | 4.043   | 0.000   | 0.000   |
| 31 NATURAL GAS              | 25.736  | 0.000   | 0.000   | 0.000   | 6.874   | 0.000   | 0.000   |
| 32 COMBUSTION AIR PREHEAT   | 0.000   | 616.970 | 187.337 | 0.000   | 0.000   | 0.000   | 0.000   |
| 33 EXHAUST                  | 0.000   | 616.970 | 29.120  | 0.000   | 123.271 | 82.859  | 0.000   |

GASEOUS - KG/HR

| NO. STREAM                  | C2H6    | C3H8    | C4H10   | C5H12   |
|-----------------------------|---------|---------|---------|---------|
| 12 FUEL                     | 4.7210  | 0.76925 | 0.91255 | 0.00000 |
| 15 DESULFURIZED NATURAL GAS | 21.7215 | 3.53935 | 4.19867 | 0.00000 |
| 29 NATURAL GAS              | 3.1079  | 0.50641 | 0.60074 | 0.00000 |
| 31 NATURAL GAS              | 6.0932  | 1.76850 | 1.34956 | 6.09180 |

GASEOUS - WEIGHT PERCENT

| NO. STREAM                  | C1H4    | N2      | O2      | C1O1    | C1O2    | H2O     | H2      |
|-----------------------------|---------|---------|---------|---------|---------|---------|---------|
| 2 REDUCING GAS              | 8.8958  | 0.0000  | 0.0000  | 30.3051 | 33.8922 | 3.067   | 23.840  |
| 4 REACTOR EXHAUST           | 5.5446  | 0.0000  | 0.0000  | 18.8095 | 21.7028 | 43.585  | 10.358  |
| 7 COOLED REDUCING GAS       | 9.5193  | 0.0000  | 0.0000  | 32.2936 | 37.2609 | 3.143   | 17.783  |
| 8 FRESH REFORMED GAS        | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.000   | 100.000 |
| 9 COMB. REDUCING GAS        | 8.7501  | 0.0000  | 0.0000  | 29.6840 | 34.2500 | 2.889   | 24.427  |
| 10 PREHEATED REDUCING GAS   | 8.7501  | 0.0000  | 0.0000  | 29.6840 | 34.2500 | 2.889   | 24.427  |
| 11 RECYCLE REDUCING GAS     | 5.5446  | 0.0000  | 0.0000  | 18.8095 | 21.7028 | 43.585  | 10.358  |
| 12 FUEL                     | 64.4037 | 0.0000  | 0.0000  | 0.0000  | 17.4279 | 0.000   | 0.000   |
| 13 AIR                      | 0.0000  | 76.7082 | 23.2918 | 0.0000  | 0.0000  | 0.000   | 0.000   |
| 14 EXHAUST                  | 0.0000  | 70.9129 | 0.5765  | 0.0000  | 14.9922 | 13.518  | 0.000   |
| 15 DESULFURIZED NATURAL GAS | 64.4037 | 0.0000  | 0.0000  | 0.0000  | 17.4279 | 0.000   | 0.000   |
| 16 WATER                    | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.000   |
| 17 REFORMED GAS             | 5.1449  | 0.0000  | 0.0000  | 9.4618  | 50.1678 | 25.448  | 9.778   |
| 18                          | 9.5193  | 0.0000  | 0.0000  | 32.2936 | 37.2609 | 3.143   | 17.783  |
| 19 REDUCING GAS EQ 2        | 8.7501  | 0.0000  | 0.0000  | 29.6840 | 34.2500 | 2.889   | 24.427  |
| 20 GAS TO COMPRESSOR        | 9.5193  | 0.0000  | 0.0000  | 32.2936 | 37.2609 | 3.143   | 17.783  |
| 21 TAIL GAS                 | 9.5193  | 0.0000  | 0.0000  | 32.2936 | 37.2609 | 3.143   | 17.783  |
| 22 COMPRESSED GAS           | 9.5193  | 0.0000  | 0.0000  | 32.2936 | 37.2609 | 3.143   | 17.783  |
| 23 QUENCHED REFORMED GAS    | 6.9010  | 0.0000  | 0.0000  | 12.6915 | 67.2922 | 0.000   | 13.115  |
| 24 CO2                      | 7.9427  | 0.0000  | 0.0000  | 14.6073 | 77.4500 | 0.000   | 0.000   |
| 26                          | 11.2575 | 7.7368  | 0.0000  | 44.2944 | 3.5121  | 4.342   | 28.857  |
| 29 NATURAL GAS              | 64.4037 | 0.0000  | 0.0000  | 0.0000  | 17.4279 | 0.000   | 0.000   |
| 31 NATURAL GAS              | 53.7137 | 0.0000  | 0.0000  | 0.0000  | 14.3472 | 0.000   | 0.000   |
| 32 COMBUSTION AIR PREHEAT   | 0.0000  | 76.7082 | 23.2918 | 0.0000  | 0.0000  | 0.000   | 0.000   |
| 33 EXHAUST                  | 0.0000  | 72.3956 | 3.4170  | 0.0000  | 14.4647 | 9.723   | 0.000   |

HYLSA PROJECT

STREAM DATA

GASEOUS - WEIGHT PERCENT

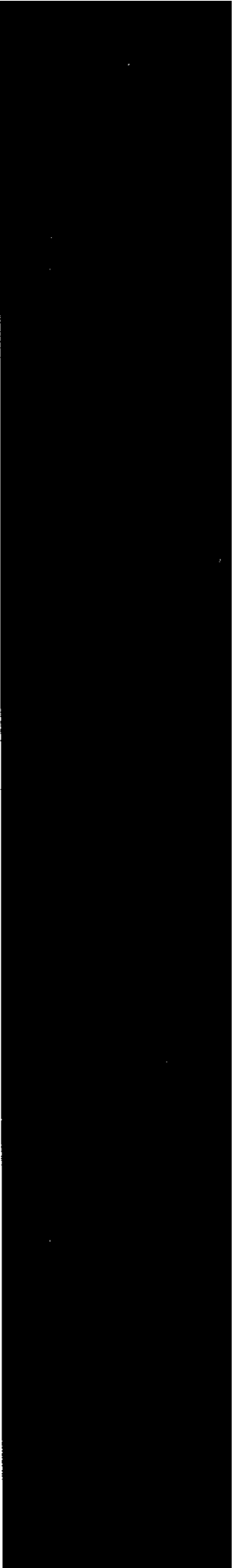
| NO. STREAM                  | C2H6    | C3H8    | C4H10   | C5H12   |
|-----------------------------|---------|---------|---------|---------|
| 12 FUEL                     | 13.3962 | 2.18280 | 2.58943 | 0.0000  |
| 15 DESULFURIZED NATURAL GAS | 13.3962 | 2.18280 | 2.58943 | 0.0000  |
| 29 NATURAL GAS              | 13.3962 | 2.18280 | 2.58943 | 0.0000  |
| 31 NATURAL GAS              | 12.7172 | 3.69105 | 2.81667 | 12.7142 |

GASEOUS - VOLUME PERCENT

| NO. STREAM                  | ClH4    | N2      | O2      | C1O1    | C1O2    | H2O     | H2      |
|-----------------------------|---------|---------|---------|---------|---------|---------|---------|
| 2 REDUCING GAS              | 3.8500  | 0.0000  | 0.0000  | 7.5120  | 5.3470  | 1.182   | 82.109  |
| 4 REACTOR EXHAUST           | 3.8114  | 0.0000  | 0.0000  | 7.4057  | 5.4384  | 26.681  | 56.663  |
| 7 COOLED REDUCING GAS       | 5.1202  | 0.0000  | 0.0000  | 9.9486  | 7.3058  | 1.505   | 76.120  |
| 8 FRESH REFORMED GAS        | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.000   | 100.000 |
| 9 COMB. REDUCING GAS        | 3.7203  | 0.0000  | 0.0000  | 7.2285  | 5.3083  | 1.094   | 82.649  |
| 10 PREHEATED REDUCING GAS   | 3.7203  | 0.0000  | 0.0000  | 7.2285  | 5.3083  | 1.094   | 82.649  |
| 11 RECYCLE REDUCING GAS     | 3.8114  | 0.0000  | 0.0000  | 7.4057  | 5.4384  | 26.681  | 56.663  |
| 12 FUEL                     | 81.1000 | 0.0000  | 0.0000  | 0.0000  | 8.0000  | 0.000   | 0.000   |
| 13 AIR                      | 0.0000  | 79.0000 | 21.0000 | 0.0000  | 0.0000  | 0.000   | 0.000   |
| 14 EXHAUST                  | 0.0000  | 69.5352 | 0.4949  | 0.0000  | 9.3575  | 20.612  | 0.000   |
| 15 DESULFURIZED NATURAL GAS | 81.1000 | 0.0000  | 0.0000  | 0.0000  | 8.0000  | 0.000   | 0.000   |
| 16 WATER                    | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.000   |
| 17 REFORMED GAS             | 3.9782  | 0.0000  | 0.0000  | 4.1904  | 14.1409 | 17.523  | 60.168  |
| 18                          | 5.1202  | 0.0000  | 0.0000  | 9.9486  | 7.3058  | 1.505   | 76.120  |
| 19 REDUCING GAS EQ 2        | 3.7203  | 0.0000  | 0.0000  | 7.2285  | 5.3083  | 1.094   | 82.649  |
| 20 GAS TO COMPRESSOR        | 5.1202  | 0.0000  | 0.0000  | 9.9486  | 7.3058  | 1.505   | 76.120  |
| 21 TAIL GAS                 | 5.1202  | 0.0000  | 0.0000  | 9.9486  | 7.3058  | 1.505   | 76.120  |
| 22 COMPRESSED GAS           | 5.1202  | 0.0000  | 0.0000  | 9.9486  | 7.3058  | 1.505   | 76.120  |
| 23 QUENCHED REFORMED GAS    | 4.8234  | 0.0000  | 0.0000  | 5.0807  | 17.1452 | 0.000   | 72.951  |
| 24 CO2                      | 17.8320 | 0.0000  | 0.0000  | 18.7830 | 63.3850 | 0.000   | 0.000   |
| 26                          | 4.0810  | 1.6062  | 0.0000  | 9.1968  | 0.4641  | 1.402   | 83.250  |
| 29 NATURAL GAS              | 81.1000 | 0.0000  | 0.0000  | 0.0000  | 8.0000  | 0.000   | 0.000   |
| 31 NATURAL GAS              | 76.0000 | 0.0000  | 0.0000  | 0.0000  | 7.4000  | 0.000   | 0.000   |
| 32 COMBUSTION AIR PREHEAT   | 0.0000  | 79.0000 | 21.0000 | 0.0000  | 0.0000  | 0.000   | 0.000   |
| 33 EXHAUST                  | 0.0000  | 72.6042 | 3.0000  | 0.0000  | 9.2337  | 15.162  | 0.000   |

GASEOUS - VOLUME PERCENT

| NO. STREAM                  | C2H6    | C3H8    | C4H10   | C5H12   |
|-----------------------------|---------|---------|---------|---------|
| 12 FUEL                     | 9.00000 | 1.00000 | 0.90000 | 0.00000 |
| 15 DESULFURIZED NATURAL GAS | 9.00000 | 1.00000 | 0.90000 | 0.00000 |
| 29 NATURAL GAS              | 9.00000 | 1.00000 | 0.90000 | 0.00000 |
| 31 NATURAL GAS              | 9.60000 | 1.90000 | 1.10000 | 4.00000 |



# **APPENDIX E-3**

## **TECNORED SHAFT MELTER**

## TECNORED PROCESS

### PROCESS BACKGROUND:

The Tecnored process is based upon a low pressure moving bed reduction furnace which reduces pellets made out of iron ore fines with cement and coke fines. Reduction is carried out at typical reduction temperatures. The process produces liquid pig iron.

### PROCESS DESCRIPTION:

The Tecnored process consists of pelletizing of the iron ore fines with cement and coke fines. The pellet size is controlled for the optimum reaction in the reduction furnace. The pellets are cured and dried at 200C and fed to the top of the furnace. The furnace internal pressure is about 3.5 to 5.2 psig. The total furnace residence time is 30 to 40 minutes against 6 to 8 hours in blast furnace.

Lump coke is fed into side feeders in the furnace below the hot pellet area. Hot blast air at about 1550C is blown in through tuyeres located in the side of the furnace to provide combustion air for the coke. A small amount of furnace gas is allowed to flow through the side feeders to use for pet coke drying and preheating. Cold blast air is blown in at a higher point to promote post combustion of CO in the upper shaft. The use of coke with sulfur (pet coke) necessitates an elaborate furnace clean-up system in order to meet environmental regulations.

The pig iron produced is tapped into a ladle on a ladle car, which can tilt the ladle for deslagging. The liquid iron is desulfurized in the ladle, and slag raked into a slag pot.

### PROCESS ADVANTAGES

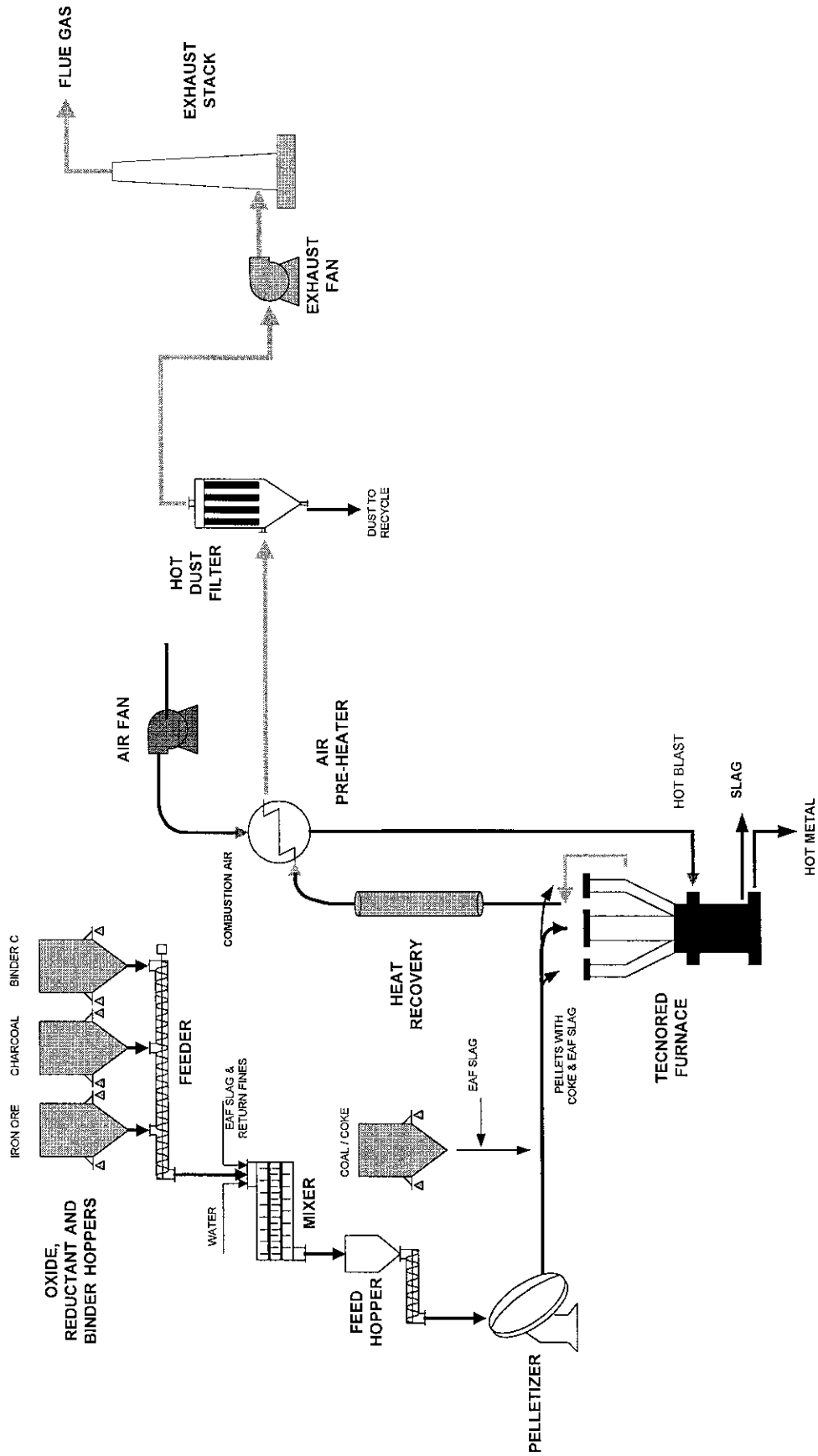
Low cost raw materials

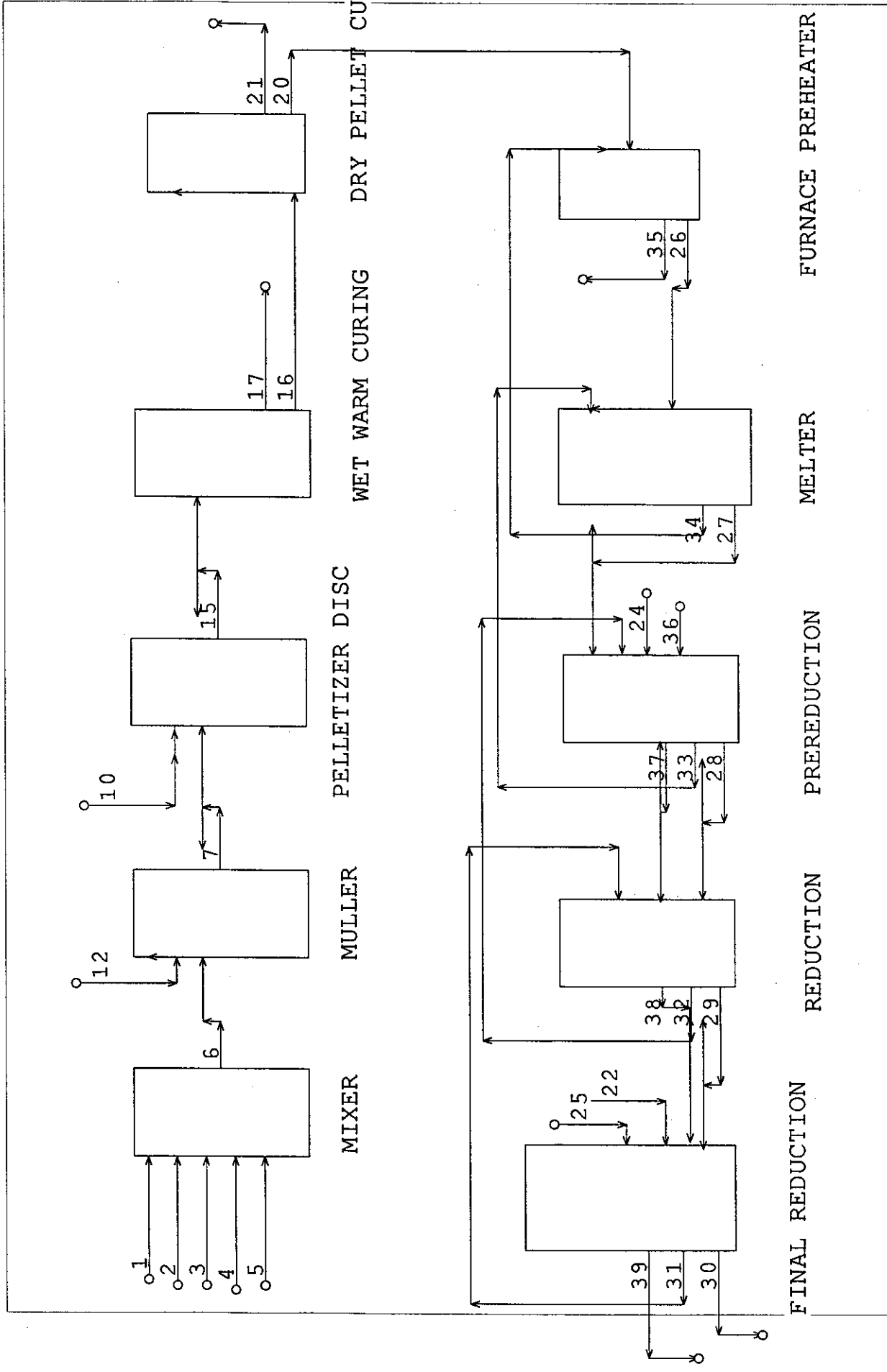
Low melting costs using low cost fuels to reduce electric power and electrode cost.

High productivity and energy efficiency in the furnace

Full metallization (upto 99%)

# TECNORED PROCESS FLOWSHEET





TECNORED PROCESS



## **Tecnored Process --- MetSim Model --- Description**

The MetSim model for this process is largely based upon a production flowsheet for North Star BHP by Tecnored - Tecnologia de Auto-Reducao Ltd., Brazil.

### **Flowsheet Description**

In this case, the Iron Ore Fines (Stream 1) is first mixed with Pet-Coke (Stream 2), Sand (Stream 3), Cement (Stream 4) and water (Stream 5) to form disc feed (Stream 6). This feed passes through a Muller where Return Fines (Stream 12) are added and then through Pelletizing discs to form Green Pellets (Stream 15). These pellets then undergo two curing operations: Wet warm Curing and Dry Pellet Curing. These operations make the pellets (Stream 20) ready to be charged in the Furnace.

For this model, the Tecnored furnace has been divided into five unit operation steps: Preheater, Melter, Prereduction, Reduction and Final Reduction. The Furnace preheater represents the topmost part of the Tecnored furnace where the pellets are preheated and Top gases leave the Furnace at almost equilibrium conditions. In the Melter, the preheated pellets undergo further heating. The reducing gases (Stream 33) carry the thermal energy needed for this step. In the prereductor,  $\text{Fe}_2\text{O}_3$  converts to  $\text{Fe}_3\text{O}_4$  with the help of upcoming reducing gases (Stream 32). Also, Petroleum Coke (Stream 36) is added along with Cold Blast of Air (Stream 24) to help in reduction. The Coke reacts with Air to form CO and  $\text{H}_2$ , main reductants. Next, in the Reductor, the pellets undergo further reduction from  $\text{Fe}_3\text{O}_4$  to FeO with the help of upcoming reducing gases (Stream 31). The Pet-Coke moving downwards reacts with  $\text{CO}_2$  and  $\text{H}_2\text{O}$  from reducing gases to form CO and  $\text{H}_2$ . In the Final Reductor, the metallization takes place and FeO is converted into metallic Fe. The metallic iron and Slag (Stream 30) are withdrawn from the Furnace. Stream 39, the solid organic part, when combined with Stream 21, Fume losses is quantitatively similar to the Return Fines (Stream 12).

### **Model Assumptions:**

Wet Warm Curing: 6616 kg/h of water comes out as Stream 17 as per NorthStar BHP flowsheet.

Dry Pellet Cure: 710 kg/h of solids loss is assumed.

Furnace Preheater: No carry-over of solid particles in the Top gas is assumed.

Prereduction: Complete reduction of  $\text{Fe}_2\text{O}_3$  to  $\text{Fe}_3\text{O}_4$  takes place in this unit operation.

Reduction: Again complete reduction of  $\text{Fe}_3\text{O}_4$  to  $\text{FeO}$  takes place here.

Final Reduction: About 99.9% reduction of  $\text{FeO}$  to  $\text{Fe}$  takes place. 4 - 4.5% C shows up in the pig iron. Pig iron and Slag together form Stream 30. Stream 39 represents extra organic solids. This along with fume losses account for the Return Fines.

### **Results**

It was decided to achieve same operating conditions as were outlined in the North Star BHP proposal by Tecnoled. In the absence of information on coal/coke accurate compositions, a few assumptions were made. The model results are very close to the numbers provided by Tecnoled.

TECNORED PROCESS --- STREAM SUMMARY

| Stream Number             | 1             | 2            | 3       | 4       | 5       | 6         | 7            | 10            | 12           | 15             | 16          |
|---------------------------|---------------|--------------|---------|---------|---------|-----------|--------------|---------------|--------------|----------------|-------------|
| Stream Names              | Iron Ore Fine | Pet Coke Fin | Sand    | Cement  | Water   | Disc Feed | Muller Disch | Water to Pell | Return Fines | Pelletizer Dis | Wet Cured P |
| KG/HR SOLIDS              | 51273         | 575          | 1747.5  | 3930.2  | 0       | 57526     | 58957        | 0             | 1431.7       | 58957          | 58957       |
| KG/HR SLD-ORG             | 0             | 8925         | 0       | 0       | 0       | 8925      | 10242        | 0             | 1317         | 10242          | 10242       |
| KG/HR AQUEOUS             | 0             | 0            | 0       | 982.5   | 6102.8  | 7085.3    | 7085.3       | 1556.8        | 0            | 8642.1         | 2025.6      |
| KG/HR MOLTEN1             | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| KG/HR MOLTEN3             | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| KG/HR GASEOUS             | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| KG/HR TOTAL               | 51273         | 9500         | 1747.5  | 4912.7  | 6102.8  | 73536     | 76285        | 1556.8        | 2748.7       | 77841          | 71225       |
| Percent Solids            | 100           | 100          | 100     | 80.001  | 0       | 90.365    | 90.712       | 0             | 100          | 88.898         | 97.156      |
| Sp.Gr.SOLIDS              | 5.1929        | 2.1267       | 2.6622  | 3.2642  | 0       | 4.792     | 4.7176       | 0             | 2.9057       | 4.7176         | 4.7176      |
| Sp.Gr.SLD-ORG             | 0             | 2.25         | 0       | 0       | 0       | 2.25      | 2.25         | 0             | 2.25         | 2.25           | 2.25        |
| Sp.Gr.AQUEOUS             | 0             | 0            | 0       | 0.99826 | 0.99826 | 0.99826   | 0.99801      | 0.99826       | 0            | 0.99803        | 0.97766     |
| Sp.Gr.MOLTEN1             | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| Sp.Gr.MOLTEN3             | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| Sp.Gr.GASEOUS             | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| Sp.Gr.TOTAL               | 5.1929        | 2.2421       | 2.6622  | 2.2451  | 0.99826 | 3.1877    | 3.159        | 0.99826       | 2.5497       | 3.0279         | 3.7249      |
| Temperature C             | 20            | 20           | 20      | 20      | 20      | 20        | 21.233       | 20            | 80           | 21.115         | 70          |
| Pressure kPa              | 101.33        | 101.33       | 101.33  | 101.33  | 101.33  | 101.33    | 101.33       | 101.33        | 101.33       | 101.33         | 101.33      |
| Gas nm3/hr                | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| Sol/Liq m3/hr             | 9.8737        | 4.237        | 0.65641 | 2.1882  | 6.1134  | 23.069    | 24.149       | 1.5595        | 1.0781       | 25.708         | 19.121      |
| Sol/Liq gpm               | 43.472        | 18.655       | 2.8901  | 9.6344  | 26.917  | 101.57    | 106.32       | 6.8663        | 4.7465       | 113.19         | 84.187      |
| Component Mass Flow Rates |               |              |         |         |         |           |              |               |              |                |             |
| 1 Fe2O3 KG/HR             | 50365         | 0            | 0       | 0       | 0       | 50365     | 50938        | 0             | 572.82       | 50938          | 50938       |
| 2 Fe3O4 KG/HR             | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 4 Si1O2 KG/HR             | 427.89        | 0            | 1712.6  | 652.41  | 0       | 2792.9    | 2835.8       | 0             | 42.951       | 2835.8         | 2835.8      |
| 5 Al2O3 KG/HR             | 182.64        | 6.0375       | 0       | 193.37  | 0       | 382.04    | 389.63       | 0             | 7.588        | 389.63         | 389.63      |
| 6 Ca1O1 KG/HR             | 0             | 0            | 17.475  | 2582.1  | 0       | 2599.6    | 2699.8       | 0             | 100.22       | 2699.8         | 2699.8      |
| 7 Mg1O1 KG/HR             | 0             | 0            | 17.475  | 393.02  | 0       | 410.5     | 410.5        | 0             | 0            | 410.5          | 410.5       |
| 9 Fe1O1 KG/HR             | 0             | 0            | 0       | 109.26  | 0       | 109.26    | 109.26       | 0             | 0            | 109.26         | 109.26      |
| 10 Mn1O1 KG/HR            | 297.44        | 0            | 0       | 0       | 0       | 297.44    | 297.44       | 0             | 0            | 297.44         | 297.44      |
| 13 S1 KG/HR               | 0             | 28.75        | 0       | 0       | 0       | 28.75     | 65.258       | 0             | 36.508       | 65.258         | 65.258      |
| 14 C1 KG/HR               | 0             | 540.21       | 0       | 0       | 0       | 540.21    | 1211.8       | 0             | 671.61       | 1211.8         | 1211.8      |
| 15 C1 KG/HR               | 0             | 8925         | 0       | 0       | 0       | 8925      | 10242        | 0             | 1317         | 10242          | 10242       |
| 16 H2O KG/HR              | 0             | 0            | 0       | 982.5   | 6102.8  | 7085.3    | 7085.3       | 1556.8        | 0            | 8642.1         | 2025.6      |
| 17 Fe1 KG/HR              | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 19 C1 KG/HR               | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 22 C6H14 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 23 C7H16 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 24 Ca1O1 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 26 Si1O2 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 28 Al2O3 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 30 Mn1O1 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 31 Fe1O1 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 32 Mg1O1 KG/HR            | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 33 N2 KG/HR               | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 34 O2 KG/HR               | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 35 H2 KG/HR               | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 36 CO KG/HR               | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 37 CO2 KG/HR              | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| Element Mass Flow Rates   |               |              |         |         |         |           |              |               |              |                |             |
| 1 H 1                     | 0             | 0            | 0       | 109.94  | 682.91  | 792.85    | 792.85       | 174.21        | 0            | 967.06         | 226.67      |
| 2 C 6                     | 0             | 9465.2       | 0       | 0       | 0       | 9465.2    | 11454        | 0             | 1988.6       | 11454          | 11454       |
| 3 N 7                     | 0             | 0            | 0       | 0       | 0       | 0         | 0            | 0             | 0            | 0              | 0           |
| 4 O 8                     | 15519         | 2.8422       | 923.96  | 2228    | 5419.9  | 24094     | 24321        | 1382.6        | 227.21       | 25704          | 19827       |
| 6 Mg 12                   | 0             | 0            | 10.539  | 237.03  | 0       | 247.57    | 247.57       | 0             | 0            | 247.57         | 247.57      |
| 7 Al 13                   | 96.661        | 3.1953       | 0       | 102.34  | 0       | 202.2     | 206.21       | 0             | 4.016        | 206.21         | 206.21      |
| 8 Si 14                   | 200.01        | 0            | 800.51  | 304.96  | 0       | 1305.5    | 1325.6       | 0             | 20.077       | 1325.6         | 1325.6      |
| 9 S 16                    | 0             | 28.75        | 0       | 0       | 0       | 28.75     | 65.258       | 0             | 36.508       | 65.258         | 65.258      |
| 10 Ca 20                  | 0             | 0            | 12.489  | 1845.5  | 0       | 1857.9    | 1929.6       | 0             | 71.627       | 1929.6         | 1929.6      |
| 11 Mn 25                  | 230.35        | 0            | 0       | 0       | 0       | 230.35    | 230.35       | 0             | 0            | 230.35         | 230.35      |
| 12 Fe 26                  | 35227         | 0            | 0       | 84.929  | 0       | 35312     | 35712        | 0             | 400.65       | 35712          | 35712       |

TECNORED PROCESS --- STREAM SUMMARY

| Stream Number             | 17          | 20          | 21         | 22        | 24         | 25        | 26           | 27          | 28         | 29          | 30           |
|---------------------------|-------------|-------------|------------|-----------|------------|-----------|--------------|-------------|------------|-------------|--------------|
| Stream Names              | Water Vapor | Dry Cured P | Fume Losse | Oxygen    | Cold Blast | Hot Blast | Preheat prod | Post combus | Prereduced | Reduced ore | Metal & Slag |
| KG/HR SOLIDS              | 0           | 58247       | 710        | 0         | 0          | 0         | 57050        | 57050       | 55532      | 6887.8      | 161.73       |
| KG/HR SLD-ORG             | 0           | 10242       | 0          | 0         | 0          | 0         | 11439        | 10089       | 0          | 0           | 0            |
| KG/HR AQUEOUS             | 6616.5      | 2025.6      | 0          | 0         | 0          | 0         | 2025.6       | 0           | 0          | 0           | 0            |
| KG/HR MOLTEN1             | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 36857        |
| KG/HR MOLTEN3             | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 45282       | 6663.6       |
| KG/HR GASEOUS             | 0           | 0           | 0          | 526.79    | 20184      | 72025     | 0            | 0           | 0          | 0           | 0            |
| KG/HR TOTAL               | 6616.5      | 70515       | 710        | 526.79    | 20184      | 72025     | 70515        | 67139       | 55532      | 52170       | 43683        |
| Percent Solids            | 0           | 97.127      | 100        | 0         | 0          | 0         | 97.127       | 100         | 100        | 13.203      | 0.37024      |
| Sp.Gr.SOLIDS              | 0           | 4.7176      | 4.7176     | 0         | 0          | 0         | 4.8288       | 4.8288      | 4.7369     | 2.953       | 1            |
| Sp.Gr.SLD-ORG             | 0           | 2.25        | 0          | 0         | 0          | 0         | 2.25         | 2.25        | 0          | 0           | 0            |
| Sp.Gr.AQUEOUS             | 0.97766     | 0.9726      | 0          | 0         | 0          | 0         | 0.57358      | 0           | 0          | 0           | 0            |
| Sp.Gr.MOLTEN1             | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 7.0879       |
| Sp.Gr.MOLTEN3             | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 1           | 3.0327       |
| Sp.Gr.GASEOUS             | 0           | 0           | 0          | 0.0013302 | 0.0011992  | 0.000313  | 0            | 0           | 0          | 0           | 0            |
| Sp.Gr.TOTAL               | 0.97766     | 3.7149      | 4.7176     | 0.0013302 | 0.0011992  | 0.000313  | 3.4515       | 4.1193      | 4.7369     | 1.0957      | 5.7789       |
| Temperature C             | 70          | 78.44       | 70         | 20        | 20         | 850       | 350          | 530.78      | 728.62     | 1012.1      | 1447.1       |
| Pressure kPa              | 101.33      | 101.33      | 101.33     | 101.33    | 101.33     | 101.33    | 101.33       | 101.33      | 101.33     | 101.33      | 108.2        |
| Gas nm3/hr                | 0           | 0           | 0          | 369       | 15683      | 55963     | 0            | 0           | 0          | 0           | 0            |
| Sol/Liq m3/hr             | 6.7677      | 18.991      | 0.1505     | 0         | 0          | 0         | 20.43        | 16.299      | 11.723     | 47.615      | 50.393       |
| Sol/Liq gpm               | 29.797      | 83.572      | 0.66263    | 0         | 0          | 0         | 89.951       | 71.76       | 51.615     | 209.64      | 221.87       |
| Component Mass Flow Rates |             |             |            |           |            |           |              |             |            |             |              |
| 1 Fe2O3 KG/HR             | 0           | 50324       | 613.42     | 0         | 0          | 0         | 50324        | 50324       | 0          | 0           | 0            |
| 2 Fe3O4 KG/HR             | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 48644      | 0           | 0            |
| 4 Si1O2 KG/HR             | 0           | 2801.7      | 34.151     | 0         | 0          | 0         | 2801.7       | 2801.7      | 2866.5     | 2866.5      | 0            |
| 5 Al2O3 KG/HR             | 0           | 384.94      | 4.6921     | 0         | 0          | 0         | 384.94       | 384.94      | 384.94     | 384.94      | 0            |
| 6 Ca1O1 KG/HR             | 0           | 2667.3      | 32.513     | 0         | 0          | 0         | 2667.3       | 2667.3      | 2667.3     | 2667.3      | 0            |
| 7 Mg1O1 KG/HR             | 0           | 405.55      | 4.9434     | 0         | 0          | 0         | 405.55       | 405.55      | 405.55     | 405.55      | 0            |
| 9 Fe1O1 KG/HR             | 0           | 107.94      | 1.3158     | 0         | 0          | 0         | 107.94       | 107.94      | 107.94     | 107.94      | 0            |
| 10 Mn1O1 KG/HR            | 0           | 293.86      | 3.5819     | 0         | 0          | 0         | 293.86       | 293.86      | 293.86     | 293.86      | 0            |
| 13 S1 KG/HR               | 0           | 64.472      | 0.78588    | 0         | 0          | 0         | 64.472       | 64.472      | 161.73     | 161.73      | 161.73       |
| 14 C1 KG/HR               | 0           | 1197.2      | 14.594     | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 0            |
| 15 C1 KG/HR               | 0           | 10242       | 0          | 0         | 0          | 0         | 11439        | 10089       | 0          | 0           | 0            |
| 16 H2O KG/HR              | 6616.5      | 2025.6      | 0          | 0         | 0          | 0         | 2025.6       | 0           | 0          | 0           | 0            |
| 17 Fe1 KG/HR              | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 0            |
| 19 C1 KG/HR               | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 35247        |
| 22 C6H14 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 1610.3       |
| 23 C7H16 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 0            |
| 24 Ca1O1 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 2667.3       |
| 26 Si1O2 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 2866.5       |
| 28 Al2O3 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 384.94       |
| 30 Mn1O1 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 293.86       |
| 31 Fe1O1 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 45282       | 45.39        |
| 32 Mg1O1 KG/HR            | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 405.55       |
| 33 N2 KG/HR               | 0           | 0           | 0          | 0         | 15501      | 55315     | 0            | 0           | 0          | 0           | 0            |
| 34 O2 KG/HR               | 0           | 0           | 0          | 526.79    | 4682.7     | 16710     | 0            | 0           | 0          | 0           | 0            |
| 35 H2 KG/HR               | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 0            |
| 36 CO KG/HR               | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 0            |
| 37 CO2 KG/HR              | 0           | 0           | 0          | 0         | 0          | 0         | 0            | 0           | 0          | 0           | 0            |
| Element Mass Flow Rates   |             |             |            |           |            |           |              |             |            |             |              |
| 1 H 1                     | 740.39      | 226.67      | 0          | 0         | 0          | 0         | 226.67       | 0           | 0          | 0           | 0            |
| 2 C 6                     | 0           | 11439       | 14.594     | 0         | 0          | 0         | 11439        | 10089       | 0          | 0           | 1610.3       |
| 3 N 7                     | 0           | 0           | 0          | 0         | 15501      | 55315     | 0            | 0           | 0          | 0           | 0            |
| 4 O 8                     | 5876.1      | 19610       | 217.11     | 526.79    | 4682.7     | 16710     | 19610        | 17811       | 16165      | 12804       | 2706.1       |
| 6 Mg 12                   | 0           | 244.59      | 2.9814     | 0         | 0          | 0         | 244.59       | 244.59      | 244.59     | 244.59      | 244.59       |
| 7 Al 13                   | 0           | 203.73      | 2.4833     | 0         | 0          | 0         | 203.73       | 203.73      | 203.73     | 203.73      | 203.73       |
| 8 Si 14                   | 0           | 1309.6      | 15.963     | 0         | 0          | 0         | 1309.6       | 1309.6      | 1339.9     | 1339.9      | 1339.9       |
| 9 S 16                    | 0           | 64.472      | 0.78588    | 0         | 0          | 0         | 64.472       | 64.472      | 161.73     | 161.73      | 161.73       |
| 10 Ca 20                  | 0           | 1906.3      | 23.237     | 0         | 0          | 0         | 1906.3       | 1906.3      | 1906.3     | 1906.3      | 1906.3       |
| 11 Mn 25                  | 0           | 227.58      | 2.7741     | 0         | 0          | 0         | 227.58       | 227.58      | 227.58     | 227.58      | 227.58       |
| 12 Fe 26                  | 0           | 35282       | 430.07     | 0         | 0          | 0         | 35282        | 35282       | 35282      | 35282       | 35282        |



Tecnored Pig Iron Process  
Mass and Energy Balance

INPUT DATA

TITLE : Tecnored Pig Iron Process  
CASE : Mass and Energy Balance  
DATA STORAGE FILE NAME : tecnored3.sfw  
HEAT BALANCE OPTION : ON  
UNITS OF MASS/TIME : KG/HR

| ROW | CNM   | CHF      |          | PHC    | CMW    | SGF    |
|-----|-------|----------|----------|--------|--------|--------|
| 1   | Fe2O3 | Fe2O3SI1 | 159.6922 | 5.2400 | 0.0000 | 0.0000 |
| 2   | Fe3O4 | Fe3O4SI1 | 231.5386 | 5.1800 | 0.0000 | 0.0000 |
| 3   | Fe1   | Fe1 SI1  | 55.8470  | 7.8600 | 0.0000 | 0.0000 |
| 4   | Si1O2 | Si1O2SI1 | 60.0848  | 2.6500 | 0.0000 | 0.0000 |
| 5   | Al2O3 | Al2O3SI1 | 101.9612 | 3.9650 | 0.0000 | 0.0000 |
| 6   | Ca1O1 | Ca1O1SI1 | 56.0794  | 3.3100 | 0.0000 | 0.0000 |
| 7   | Mg1O1 | Mg1O1SI1 | 40.3114  | 3.5800 | 0.0000 | 0.0000 |
| 8   | Si1   | Si1 SI1  | 28.0860  | 2.3300 | 0.0000 | 0.0000 |
| 9   | Fe1O1 | Fe1O1SI1 | 71.8464  | 5.7000 | 0.0000 | 0.0000 |
| 10  | Mn1O1 | Mn1O1SI1 | 70.9374  | 5.4500 | 0.0000 | 0.0000 |
| 11  | Mn1   | Mn1 SI1  | 54.9380  | 7.2000 | 0.0000 | 0.0000 |
| 12  | Ca1   | Ca1 SI1  | 40.0800  | 1.5400 | 0.0000 | 0.0000 |
| 13  | S1    | S1 SI1   | 32.0640  | 1.0000 | 0.0000 | 0.0000 |
| 14  | C1    | C1 SI1   | 12.0112  | 2.2500 | 0.0000 | 0.0000 |
| 15  | C1    | C1 SO2   | 12.0112  | 2.2500 | 0.0000 | 0.0000 |
| 16  | H2O   | H2O LI3  | 18.0153  | 1.0000 | 0.0000 | 0.0000 |
| 17  | Fe1   | Fe1 M15  | 55.8470  | 7.8600 | 0.0000 | 0.0000 |
| 18  | Mn1   | Mn1 M15  | 54.9380  | 7.2000 | 0.0000 | 0.0000 |
| 19  | C1    | C1 M15   | 12.0112  | 2.2500 | 0.0000 | 0.0000 |
| 20  | Si1   | Si1 M15  | 28.0860  | 1.0000 | 0.0000 | 0.0000 |
| 21  | S1    | S1 M15   | 32.0640  | 2.0000 | 0.0000 | 0.0000 |
| 22  | C6H14 | C6H14SO2 | 86.1785  | 1.0000 | 0.0000 | 0.0000 |
| 23  | C7H16 | C7H16SO2 | 100.2056 | 1.0000 | 0.0000 | 0.0000 |
| 24  | Ca1O1 | Ca1O1M37 | 56.0794  | 3.3100 | 0.0000 | 0.0000 |
| 25  | Ca1F2 | Ca1F2M37 | 78.0768  | 1.0000 | 0.0000 | 0.0000 |
| 26  | Si1O2 | Si1O2M37 | 60.0848  | 2.6500 | 0.0000 | 0.0000 |
| 27  | S1    | S1 M37   | 32.0640  | 1.0000 | 0.0000 | 0.0000 |
| 28  | Al2O3 | Al2O3M37 | 101.9612 | 3.9650 | 0.0000 | 0.0000 |
| 29  | Ca1S1 | Ca1S1M37 | 72.1440  | 2.5000 | 0.0000 | 0.0000 |
| 30  | Mn1O1 | Mn1O1M37 | 70.9374  | 5.4500 | 0.0000 | 0.0000 |
| 31  | Fe1O1 | Fe1O1M37 | 71.8464  | 1.0000 | 0.0000 | 0.0000 |
| 32  | Mg1O1 | Mg1O1M37 | 40.3114  | 3.5800 | 0.0000 | 0.0000 |
| 33  | N2    | N2 GC8   | 28.0134  | 0.0012 | 0.0000 | 0.0000 |
| 34  | O2    | O2 GC8   | 31.9988  | 0.0014 | 0.0000 | 0.0000 |
| 35  | H2    | H2 GC8   | 2.0159   | 0.0001 | 0.0000 | 0.0000 |
| 36  | CO    | CO GC8   | 28.0106  | 0.0012 | 0.0000 | 0.0000 |
| 37  | CO2   | CO2 GC8  | 44.0100  | 0.0020 | 0.0000 | 0.0000 |
| 38  | H2O   | H2O GC8  | 18.0153  | 0.0008 | 0.0000 | 0.0000 |
| 39  | COS   | COS GC8  | 60.0746  | 0.0027 | 0.0000 | 0.0000 |
| 40  | H2S1  | H2S1 GC8 | 34.0799  | 0.0015 | 0.0000 | 0.0000 |
| 41  | CH4   | CH4 GC8  | 16.0430  | 0.0007 | 0.0000 | 0.0000 |
| 42  | C2H6  | C2H6 GC8 | 30.0701  | 0.0013 | 0.0000 | 0.0000 |
| 43  | S1O2  | S1O2 GC8 | 64.0628  | 0.0029 | 0.0000 | 0.0000 |
| 44  | F1    | F1 GC8   | 18.9984  | 0.0008 | 0.0000 | 0.0000 |
| 45  | S1    | S1 GC8   | 32.0640  | 0.0014 | 0.0000 | 0.0000 |



Tecnored Pig Iron Process  
Mass and Energy Balance

INPUT DATA

| ROW | CNM   | CRIT    | T       | CRIT    | P       | CRIT    | V       | ANTOINE | VAPOR | PRES | A     | B   | C | HENRY |
|-----|-------|---------|---------|---------|---------|---------|---------|---------|-------|------|-------|-----|---|-------|
| 1   | Fe2O3 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 2   | Fe3O4 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 3   | Fe1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 4   | Si1O2 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 5   | Al2O3 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 6   | Ca1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 7   | Mg1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 8   | Si1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 9   | Fe1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 10  | Mn1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 11  | Mn1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 12  | Ca1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 13  | S1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 14  | C1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 15  | C1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 16  | H2O   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 17  | Fe1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 18  | Mn1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 19  | C1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 20  | Si1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 21  | S1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 22  | C6H14 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 23  | C7H16 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 24  | Ca1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 25  | Ca1F2 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 26  | Si1O2 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 27  | S1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 28  | Al2O3 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 29  | Ca1S1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 30  | Mn1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 31  | Fe1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 32  | Mg1O1 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 33  | N2    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 34  | O2    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 35  | H2    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.00    | 0.000 | 0.00 | 0.000 | 0.0 |   |       |
| 36  | CO    | 133.400 | 35.4638 | 93.100  | 6.24020 | 230.27  | 260.010 | 63426.0 |       |      |       |     |   |       |
| 37  | CO2   | 304.200 | 74.8792 | 94.800  | 9.81060 | 1347.79 | 273.000 | 1215.7  |       |      |       |     |   |       |
| 38  | H2O   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |       |      |       |     |   |       |
| 39  | COS   | 378.000 | 62.6189 | 141.700 | 6.90723 | 804.48  | 250.000 | 2812.5  |       |      |       |     |   |       |
| 40  | H2S1  | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |       |      |       |     |   |       |
| 41  | CH4   | 190.700 | 46.9135 | 98.900  | 6.69561 | 405.42  | 267.777 | 35389.5 |       |      |       |     |   |       |
| 42  | C2H6  | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |       |      |       |     |   |       |
| 43  | S1O2  | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |       |      |       |     |   |       |
| 44  | F1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |       |      |       |     |   |       |
| 45  | S1    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |       |      |       |     |   |       |



Tecnoered Pig Iron Process  
Mass and Energy Balance

INPUT DATA

| ROW | CNM   | REFERENCE | H25     | HTE-A  | HTE-B    | HTE-C    | HTE-D    |
|-----|-------|-----------|---------|--------|----------|----------|----------|
| 1   | Fe2O3 | 1452165   | -197094 | -19152 | 43.5138  | -2.6706  | 19.1514  |
| 2   | Fe3O4 | B672160   | -267300 | -31312 | 71.0525  | -7.8736  | 32.0732  |
| 3   | Fe1   | B672151   | 0       | -7903  | 14.0914  | -1.3293  | 11.6233  |
| 4   | Si1O2 | B672387   | -217720 | -8654  | 19.1651  | -0.5456  | 8.8977   |
| 5   | Al2O3 | B672042   | -400500 | -12425 | 28.9653  | 1.0071   | 11.1085  |
| 6   | Ca1O1 | B672098   | -151790 | -4315  | 12.0730  | 0.4606   | 2.0088   |
| 7   | Mg1O1 | B672227   | -143760 | -4612  | 11.8081  | 0.3610   | 3.1765   |
| 8   | Si1   | B672382   | 0       | -2201  | 5.8656   | 0.2868   | 1.2792   |
| 9   | Fe1O1 | B672157   | -65000  | -3998  | 12.1207  | 1.0479   | 0.8685   |
| 10  | Mn1O1 | B672232   | -92070  | -3551  | 10.8451  | 1.0861   | 0.6565   |
| 11  | Mn1   | B672229   | 0       | -578   | 2.8728   | 3.5454   | -1.8081  |
| 12  | Ca1   | B672095   | 0       | -1526  | 4.1007   | 2.8398   | 0.1633   |
| 13  | S1    | B672335   | 0       | -9791  | 24.2677  | -10.4646 | 11.4735  |
| 14  | C1    | B672086   | 0       | -2999  | 5.1802   | 0.2246   | 4.3597   |
| 15  | C1    | B672086   | 0       | -2999  | 5.1802   | 0.2246   | 4.3597   |
| 16  | H2O   | B672180   | -68315  | -5071  | 16.1848  | 2.7637   | 0.0000   |
| 17  | Fe1   | B672151   | 0       | -2609  | 11.0000  | 0.0000   | 0.0000   |
| 18  | Mn1   | B672229   | 0       | -1889  | 11.0000  | 0.0000   | -0.0001  |
| 19  | C1    | B672086   | 0       | -2999  | 5.1802   | 0.2246   | 4.3597   |
| 20  | Si1   | B672382   | 0       | 9241   | 6.7069   | -0.1082  | 7.0337   |
| 21  | S1    | B672335   | 0       | 13015  | -44.4133 | 56.5440  | -14.3084 |
| 22  | C6H14 | BAK1127   | -47510  | -14269 | 49.2252  | -4.5786  | 0.0000   |
| 23  | C7H16 | BAK1128   | -53630  | -15340 | 49.4035  | 6.8713   | 0.0000   |
| 24  | Ca1O1 | B672098   | -151790 | -4315  | 12.0730  | 0.4606   | 2.0088   |
| 25  | Ca1F2 | B674125   | -293800 | -10219 | 29.2494  | -1.0693  | 55.2944  |
| 26  | Si1O2 | B672387   | -217720 | -8654  | 19.1651  | -0.5456  | 8.8977   |
| 27  | S1    | B672335   | 0       | -9791  | 24.2677  | -10.4646 | 11.4735  |
| 28  | Al2O3 | B672042   | -400500 | -19492 | 46.0000  | 0.0000   | 0.0000   |
| 29  | Ca1S1 | B689066   | -113100 | -4092  | 12.2005  | 0.4197   | 1.2535   |
| 30  | Mn1O1 | 1452186   | -92070  | -4090  | 11.6219  | 0.7611   | 1.6782   |
| 31  | Fe1O1 | BAK2248   | -62382  | -3623  | 16.3000  | 0.0000   | 0.0000   |
| 32  | Mg1O1 | B672227   | -143760 | -4612  | 11.8081  | 0.3610   | 3.1765   |
| 33  | N2    | B672244   | 0       | -2846  | 7.5728   | 0.2525   | 1.7794   |
| 34  | O2    | B672277   | 0       | -2979  | 7.9696   | 0.2720   | 1.7697   |
| 35  | H2    | B672174   | 0       | -1837  | 6.3659   | 0.4428   | -0.2847  |
| 36  | CO    | YAWS      | -26420  | -1787  | 6.0661   | 0.9368   | -0.3112  |
| 37  | CO2   | YAWS      | -94050  | -3105  | 8.4720   | 2.5871   | 1.0415   |
| 38  | H2O   | B672182   | -57795  | -2403  | 7.2906   | 1.3003   | 0.3596   |
| 39  | COS   | YAWS      | -33080  | -3637  | 10.1215  | 2.0671   | 1.2989   |
| 40  | H2S1  | B689140   | -4930   | -3383  | 8.6760   | 1.2152   | 2.1081   |
| 41  | CH4   | YAWS      | -17890  | -1649  | 3.8363   | 7.1302   | -0.3830  |
| 42  | C2H6  | B6772223  | -20240  | -5819  | 11.3274  | 9.4527   | 4.7951   |
| 43  | SiO2  | B672348   | -70940  | -5603  | 13.1364  | 0.2172   | 5.0762   |
| 44  | F1    | B672147   | 18860   | -1326  | 5.0561   | -0.0161  | -0.5489  |
| 45  | S1    | B672336   | 66200   | -1100  | 4.9085   | 0.0430   | -1.1282  |

Tecnoled Pig Iron Process  
Mass and Energy Balance

INPUT DATA

| ROW | CNM   | TEMP   | RANGE  | oK | HTG-A   | HTG-B    | HTG-C    | HTG-D     |
|-----|-------|--------|--------|----|---------|----------|----------|-----------|
| 1   | Fe2O3 | 298.2  | 1800.0 |    | -182416 | -34.5250 | -13.8053 | -28.6100  |
| 2   | Fe3O4 | 298.2  | 1800.0 |    | -243067 | -58.6967 | -18.9430 | -46.8195  |
| 3   | Fe1   | 298.2  | 1811.0 |    | 2679    | -8.2139  | -4.0925  | -5.4957   |
| 4   | Si1O2 | 298.2  | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464  |
| 5   | Al2O3 | 298.2  | 2327.0 |    | -386441 | -25.8901 | -10.0349 | -27.6544  |
| 6   | Ca1O1 | 298.2  | 2000.0 |    | -146099 | -14.8629 | -4.7096  | -10.7418  |
| 7   | Mg1O1 | 298.2  | 2000.0 |    | -138544 | -11.5487 | -4.4916  | -9.9661   |
| 8   | Si1   | 298.2  | 1687.0 |    | 2177    | -6.4390  | -2.6130  | -4.1096   |
| 9   | Fe1O1 | 298.2  | 1600.0 |    | -60048  | -19.0598 | -5.9536  | -9.2221   |
| 10  | Mn1O1 | 298.2  | 1500.0 |    | -88030  | -17.6692 | -5.7458  | -7.5421   |
| 11  | Mn1   | 298.2  | 1517.0 |    | 1277    | -7.4008  | -4.8754  | -2.7466   |
| 12  | Ca1   | 298.2  | 1112.0 |    | 950     | -9.1634  | -4.9597  | -2.2181   |
| 13  | S1    | 388.4  | 717.8  |    | 3293    | -10.8450 | -4.2603  | -5.7915   |
| 14  | C1    | 298.2  | 3000.0 |    | 2405    | -3.3866  | -1.5836  | -5.1587   |
| 15  | C1    | 298.2  | 3000.0 |    | 2405    | -3.3866  | -1.5836  | -5.1587   |
| 16  | H2O   | 298.2  | 373.2  |    | -70630  | -1.0739  | -26.4253 | 0.0000    |
| 17  | Fe1   | 1811.0 | 3000.0 |    | 23276   | -21.2611 | -1.5440  | -100.5828 |
| 18  | Mn1   | 1517.0 | 2000.0 |    | 3724    | -12.2196 | -3.5366  | 24.2905   |
| 19  | C1    | 298.2  | 3000.0 |    | 2405    | -3.3866  | -1.5836  | -5.1587   |
| 20  | Si1   | 1687.0 | 2000.0 |    | 14952   | -16.3206 | -1.5743  | 12.0020   |
| 21  | S1    | 298.2  | 388.4  |    | -5700   | 12.4302  | -23.6630 | 5.4073    |
| 22  | C6H14 | 298.2  | 342.0  |    | -53950  | -27.4686 | -72.7203 | 0.0000    |
| 23  | C7H16 | 298.2  | 371.0  |    | -60793  | -30.1668 | -81.1627 | 0.0000    |
| 24  | Ca1O1 | 298.2  | 2000.0 |    | -146099 | -14.8629 | -4.7096  | -10.7418  |
| 25  | Ca1F2 | 1690.0 | 1800.0 |    | -281936 | -29.9150 | -7.6022  | 49.9481   |
| 26  | Si1O2 | 298.2  | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464  |
| 27  | S1    | 388.4  | 717.8  |    | 3293    | -10.8450 | -4.2603  | -5.7915   |
| 28  | Al2O3 | 2327.0 | 2500.0 |    | -364648 | -36.7635 | -9.5560  | 0.0000    |
| 29  | Ca1S1 | 298.2  | 2000.0 |    | -107098 | -19.8175 | -4.7200  | -11.1981  |
| 30  | Mn1O1 | 298.2  | 1800.0 |    | -87077  | -19.0502 | -5.1431  | -9.4245   |
| 31  | Fe1O1 | 1700.0 | 3000.0 |    | -28942  | -36.8962 | -2.3586  | -138.6148 |
| 32  | Mg1O1 | 298.2  | 2000.0 |    | -138544 | -11.5487 | -4.4916  | -9.9661   |
| 33  | N2    | 298.2  | 3000.0 |    | 5078    | -51.3044 | -2.2358  | -9.9139   |
| 34  | O2    | 298.2  | 3000.0 |    | 5395    | -54.8302 | -2.3535  | -10.5960  |
| 35  | H2    | 298.2  | 3000.0 |    | 4863    | -36.6465 | -2.1036  | -9.3536   |
| 36  | CO    | 298.0  | 700.0  |    | -25393  | -46.6664 | -5.1645  | -2.2650   |
| 37  | CO2   | 298.0  | 700.0  |    | -93224  | -48.5944 | -8.4916  | -2.4252   |
| 38  | H2O   | 298.2  | 2000.0 |    | -54212  | -48.4557 | -3.8711  | -6.7579   |
| 39  | COS   | 298.0  | 700.0  |    | -32021  | -52.9787 | -9.1212  | -2.8701   |
| 40  | H2S1  | 298.2  | 2000.0 |    | -1229   | -52.4032 | -4.2869  | -7.0969   |
| 41  | CH4   | 298.0  | 700.0  |    | -17759  | -40.3353 | -9.8039  | -1.5255   |
| 42  | C2H6  | 298.2  | 1000.0 |    | -19821  | -48.2326 | -15.8609 | -2.9266   |
| 43  | SiO2  | 298.2  | 3000.0 |    | -62759  | -67.8617 | -3.6510  | -16.3249  |
| 44  | F1    | 298.2  | 3000.0 |    | 22872   | -42.6161 | -1.3003  | -7.6415   |
| 45  | S1    | 298.2  | 3000.0 |    | 70298   | -44.9239 | -1.3180  | -7.7688   |

| FLOL      |                       | FLO |     |     |     |     |     |     |     |     |     |     |     |     |
|-----------|-----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| TYP LABEL |                       | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  |
| NO        | OPR UNIT PROCESS      | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |
| 1         | SEC TECNOLED PROCESS  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 2         | MIX MIXER             | 1   | 2   | 3   | 4   | 5   | 0   | 0   | 6   | 0   | 0   | 0   | 0   | 0   |
| 3         | MIX MULLER            | 6   | 12  | 0   | 0   | 0   | 0   | 0   | 7   | 0   | 0   | 0   | 0   | 0   |
| 4         | MIX PELLETIZER DISC   | 7   | 10  | 0   | 0   | 0   | 0   | 0   | 15  | 0   | 0   | 0   | 0   | 0   |
| 5         | SPP WET WARM CURING   | 15  | 0   | 0   | 0   | 0   | 0   | 0   | 16  | 17  | 0   | 0   | 0   | 0   |
| 6         | SPP DRY PELLET CURE   | 16  | 0   | 0   | 0   | 0   | 0   | 0   | 20  | 21  | 0   | 0   | 0   | 0   |
| 7         | SPP FURNACE PREHEATER | 0   | 34  | 20  | 0   | 0   | 0   | 0   | 26  | 35  | 0   | 0   | 0   | 0   |
| 8         | SPP MELTER            | 26  | 33  | 0   | 0   | 0   | 0   | 0   | 27  | 34  | 0   | 0   | 0   | 0   |
| 9         | SPP PREREDUCTION      | 27  | 32  | 24  | 36  | 0   | 0   | 0   | 28  | 33  | 37  | 0   | 0   | 0   |
| 10        | SPP REDUCTION         | 28  | 31  | 37  | 0   | 0   | 0   | 0   | 29  | 32  | 38  | 0   | 0   | 0   |
| 11        | SPP FINAL REDUCTION   | 29  | 0   | 25  | 22  | 38  | 0   | 0   | 30  | 31  | 39  | 0   | 0   | 0   |

Tecnored Pig Iron Process  
Mass and Energy Balance

| HEAT BALANCE SUMMARY - 1000 KCAL/HOUR |                 |               |               |                 |              |               |                  |       |
|---------------------------------------|-----------------|---------------|---------------|-----------------|--------------|---------------|------------------|-------|
| OP PROCESS STEP                       | INPUT<br>STREAM | HEAT<br>REACT | HEAT<br>SOLUT | ENERGY<br>INPUT | HEAT<br>LOSS | HEAT<br>REQRD | OUTPUT<br>STREAM | TOTAL |
| 1 TECNORED PROCESS                    | 0               | 0             | 0             | 0               | 0            | 0             | 0                | 0     |
| 2 MIXER                               | -49             | 0             | 0             | 0               | 0            | 0             | 49               | 0     |
| 3 MULLER                              | -27             | 0             | 0             | 0               | 0            | 0             | 27               | 0     |
| 4 PELLETIZER DISC                     | -34             | 0             | 0             | 0               | 0            | 0             | 34               | 0     |
| 5 WET WARM CURING                     | -34             | 0             | 0             | 0               | 0            | 884           | -850             | 0     |
| 6 DRY PELLET CURE                     | 552             | 0             | 0             | 110             | 0            | 0             | -663             | 0     |
| 7 FURNACE PREHEATE                    | 19356           | 0             | 0             | 0               | 0            | -4227         | -15130           | 0     |
| 8 MELTER                              | 30942           | -4711         | 0             | 0               | 0            | 0             | -26231           | 0     |
| 9 PREREDUCTION                        | 35391           | 3539          | 0             | 0               | 0            | 0             | -38930           | 0     |
| 10 REDUCTION                          | 50809           | -5787         | 0             | 0               | 0            | 0             | -45022           | 0     |
| 11 FINAL REDUCTION                    | 32707           | 19040         | 0             | 0               | 0            | 0             | -51747           | 0     |

Tecnored Pig Iron Process  
Mass and Energy Balance

| NO. | STREAM                 | STREAM TEMPERATURES AND ENTHALPIES |         |             |             |             |
|-----|------------------------|------------------------------------|---------|-------------|-------------|-------------|
|     |                        | TEMP-C                             | TEMP-F  | KCAL/HR     | BTU/HR      | KJ/HR       |
| 1   | Iron Ore Fines         | 20.00                              | 68.00   | -29710.00   | -117900.0   | -124308.0   |
| 2   | Pet Coke Fines         | 20.00                              | 68.00   | 20811.00    | 82583.0     | 87072.0     |
| 3   | Sand                   | 20.00                              | 68.00   | -1387.00    | -5506.0     | -5805.0     |
| 4   | Cement                 | 20.00                              | 68.00   | -8304.00    | -32953.0    | -34744.0    |
| 5   | Water                  | 20.00                              | 68.00   | -30469.00   | -120910.0   | -127482.0   |
| 6   | Disc Feed              | 20.00                              | 68.00   | -49060.00   | -194685.0   | -205266.0   |
| 7   | Muller Discharge       | 21.23                              | 70.22   | -26666.00   | -105819.0   | -111571.0   |
| 10  | Water to Pelletizer    | 20.00                              | 68.00   | -7772.00    | -30844.0    | -32520.0    |
| 12  | Return Fines           | 80.00                              | 176.00  | 22394.00    | 88866.0     | 93696.0     |
| 15  | Pelletizer Discharge   | 21.12                              | 70.01   | -34439.00   | -136663.0   | -144091.0   |
| 16  | Wet Cured Pellets      | 70.00                              | 158.00  | 552393.00   | 2192074.0   | 2311213.0   |
| 17  | Water Vapor            | 70.00                              | 158.00  | 297405.00   | 1180200.0   | 1244344.0   |
| 18  | not used               | 70.00                              | 158.00  | 17671.00    | 70126.0     | 73937.0     |
| 19  | not used               | 70.00                              | 158.00  | 100135.00   | 397369.0    | 418966.0    |
| 20  | Dry Cured Pellets      | 78.44                              | 173.19  | 658091.00   | 2611517.0   | 2753454.0   |
| 21  | *Fume Losses           | 70.00                              | 158.00  | 4781.00     | 18971.0     | 20002.0     |
| 22  | Oxygen                 | 20.00                              | 68.00   | -255.00     | -1011.0     | -1066.0     |
| 23  | not used               | 20.00                              | 68.00   | 21143.00    | 83901.0     | 88462.0     |
| 24  | Cold Blast             | 20.00                              | 68.00   | -1078.00    | -4279.0     | -4512.0     |
| 25  | Hot Blast              | 850.00                             | 1562.00 | 15495890.00 | 61492662.0  | 64834804.0  |
| 26  | Preheat product        | 350.00                             | 662.00  | 5355193.00  | 21251122.0  | 22406127.0  |
| 27  | Post combust product   | 530.78                             | 987.40  | 7531664.00  | 29888057.0  | 31512481.0  |
| 28  | Prereduced ore         | 728.62                             | 1343.52 | 8534090.00  | 33866006.0  | 35706632.0  |
| 29  | Reduced ore            | 1012.07                            | 1853.73 | 12562707.00 | 49852850.0  | 52562366.0  |
| 30  | Metal & Slag           | 1447.11                            | 2636.80 | 13667709.00 | 54237851.0  | 57185693.0  |
| 31  | Gas off Final Reductor | 1447.11                            | 2636.80 | 37468541.00 | 148687188.0 | 156768377.0 |
| 32  | Gas off Reductor       | 1012.07                            | 1853.73 | 27811237.00 | 110363908.0 | 116362217.0 |
| 33  | Gas off Prereductor    | 728.62                             | 1343.52 | 25588620.00 | 101543851.0 | 107062787.0 |
| 34  | Gas off Postcombustor  | 530.78                             | 987.40  | 18699551.00 | 74205816.0  | 78238922.0  |
| 35  | Furnace gas            | 300.00                             | 572.00  | 9774409.00  | 38787988.0  | 40896126.0  |
| 36  | Solid fuel Carbon      | 32.00                              | 89.60   | 50183.00    | 199143.0    | 209966.0    |
| 37  |                        | 728.62                             | 1343.52 | 4807373.00  | 19077197.0  | 20114048.0  |
| 38  |                        | 1012.07                            | 1853.73 | 4648464.00  | 18446595.0  | 19449172.0  |
| 39  | Eq to Return Fines     | 1447.11                            | 2636.80 | 610464.00   | 2422519.0   | 2554183.0   |

Tecnoored Pig Iron Process  
Mass and Energy Balance

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM                | TIME     | ACFM     | SCFM     | M3/HR    | NM3/HR   |
|---------------------------|----------|----------|----------|----------|----------|
| 18 not used               | 15.0000  | 5685.5   | 4833.37  | 9659.7   | 8211.9   |
| 19 not used               | 85.0000  | 5685.3   | 4833.20  | 9659.4   | 8211.7   |
| 22 Oxygen                 | 100.0000 | 233.1    | 217.19   | 396.0    | 369.0    |
| 24 Cold Blast             | 100.0000 | 9906.5   | 9230.67  | 16831.3  | 15683.0  |
| 25 Hot Blast              | 100.0000 | 135438.3 | 32938.58 | 230111.1 | 55963.0  |
| 31 Gas off Final Reductor | 85.0000  | 272915.4 | 46272.97 | 463686.2 | 78618.3  |
| 32 Gas off Reductor       | 100.0000 | 213386.6 | 45347.86 | 362546.2 | 77046.5  |
| 33 Gas off Prereductor    | 100.0000 | 225607.1 | 61511.30 | 383308.8 | 104508.4 |
| 34 Gas off Postcombustor  | 100.0000 | 189779.9 | 64477.94 | 322438.0 | 109548.7 |
| 35 Furnace gas            | 100.0000 | 135290.6 | 64477.94 | 229860.2 | 109548.7 |

VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM              | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|-------------------------|----------|----------|----------|----------|----------|
| 1 Iron Ore Fines        | 100.0000 | 43.4725  | 2.74270  | 9.87374  | 236.970  |
| 2 Pet Coke Fines        | 100.0000 | 18.6550  | 1.17695  | 4.23703  | 101.689  |
| 3 Sand                  | 100.0000 | 2.8901   | 0.18234  | 0.65641  | 15.754   |
| 4 Cement                | 100.0000 | 9.6344   | 0.60784  | 2.18823  | 52.517   |
| 5 Water                 | 100.0000 | 26.9165  | 1.69818  | 6.11344  | 146.723  |
| 6 Disc Feed             | 100.0000 | 101.5685 | 6.40801  | 23.06885 | 553.652  |
| 7 Muller Discharge      | 100.0000 | 106.3228 | 6.70797  | 24.14869 | 579.568  |
| 10 Water to Pelletizer  | 100.0000 | 6.8663   | 0.43320  | 1.55951  | 37.428   |
| 12 Return Fines         | 100.0000 | 4.7465   | 0.29946  | 1.07805  | 25.873   |
| 15 Pelletizer Discharge | 100.0000 | 113.1899 | 7.14121  | 25.70837 | 617.001  |
| 16 Wet Cured Pellets    | 100.0000 | 84.1873  | 5.31143  | 19.12114 | 458.907  |
| 17 Water Vapor          | 100.0000 | 29.7972  | 1.87992  | 6.76772  | 162.425  |
| 20 Dry Cured Pellets    | 100.0000 | 83.5722  | 5.27262  | 18.98141 | 455.554  |
| 21 *Fume Losses         | 100.0000 | 0.6626   | 0.04181  | 0.15050  | 3.612    |
| 26 Preheat product      | 100.0000 | 89.9513  | 5.67508  | 20.43027 | 490.327  |
| 27 Post combust product | 100.0000 | 71.7598  | 4.52737  | 16.29852 | 391.164  |
| 28 Prereduced ore       | 100.0000 | 51.6152  | 3.25643  | 11.72316 | 281.356  |
| 29 Reduced ore          | 100.0000 | 209.6408 | 13.22635 | 47.61488 | 1142.757 |
| 30 Metal & Slag         | 15.0000  | 221.8737 | 13.99814 | 50.39329 | 1209.439 |
| 36 Solid fuel Carbon    | 100.0000 | 41.4010  | 2.61201  | 9.40324  | 225.678  |
| 37                      | 100.0000 | 39.6338  | 2.50052  | 9.00186  | 216.045  |
| 38                      | 100.0000 | 25.0083  | 1.57779  | 5.68004  | 136.321  |
| 39 Eq to Return Fines   | 100.0000 | 2.1007   | 0.13253  | 0.47712  | 11.451   |

Tecnored Pig Iron Process  
Mass and Energy Balance

MASS FLOW RATES - KG/HR

| NO. STREAM                | KG/HR-SI | KG/HR-SO | KG/HR-LI | KG/HR-M1 | KG/HR-M3 | KG/HR-GC | KG/HR-TC |
|---------------------------|----------|----------|----------|----------|----------|----------|----------|
| 1 Iron Ore Fines          | 51272.90 | 0.00     | 0.000    | 0.0      | 0.00     | 0.0      | 51272.9  |
| 2 Pet Coke Fines          | 575.00   | 8925.00  | 0.000    | 0.0      | 0.00     | 0.0      | 9500.0   |
| 3 Sand                    | 1747.50  | 0.00     | 0.000    | 0.0      | 0.00     | 0.0      | 1747.5   |
| 4 Cement                  | 3930.20  | 0.00     | 982.500  | 0.0      | 0.00     | 0.0      | 4912.7   |
| 5 Water                   | 0.00     | 0.00     | 6102.800 | 0.0      | 0.00     | 0.0      | 6102.8   |
| 6 Disc Feed               | 57525.60 | 8925.00  | 7085.300 | 0.0      | 0.00     | 0.0      | 73535.9  |
| 7 Muller Discharge        | 58957.30 | 10242.00 | 7085.300 | 0.0      | 0.00     | 0.0      | 76284.6  |
| 10 Water to Pelletizer    | 0.00     | 0.00     | 1556.800 | 0.0      | 0.00     | 0.0      | 1556.8   |
| 12 Return Fines           | 1431.70  | 1317.00  | 0.000    | 0.0      | 0.00     | 0.0      | 2748.7   |
| 15 Pelletizer Discharge   | 58957.30 | 10242.00 | 8642.100 | 0.0      | 0.00     | 0.0      | 77841.4  |
| 16 Wet Cured Pellets      | 58957.30 | 10242.00 | 2025.600 | 0.0      | 0.00     | 0.0      | 71224.9  |
| 17 Water Vapor            | 0.00     | 0.00     | 6616.500 | 0.0      | 0.00     | 0.0      | 6616.5   |
| 18 not used               | 0.00     | 0.00     | 39.722   | 0.0      | 0.00     | 3298.3   | 3338.0   |
| 19 not used               | 0.00     | 0.00     | 39.728   | 0.0      | 0.00     | 3298.7   | 3338.5   |
| 20 Dry Cured Pellets      | 58247.30 | 10242.00 | 2025.600 | 0.0      | 0.00     | 0.0      | 70514.9  |
| 21 *Fume Losses           | 710.00   | 0.00     | 0.000    | 0.0      | 0.00     | 0.0      | 710.0    |
| 22 Oxygen                 | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 526.8    | 526.8    |
| 24 Cold Blast             | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 20184.1  | 20184.1  |
| 25 Hot Blast              | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 72024.7  | 72024.7  |
| 26 Preheat product        | 57050.07 | 11439.23 | 2025.600 | 0.0      | 0.00     | 0.0      | 70514.9  |
| 27 Post combust product   | 57050.07 | 10088.73 | 0.000    | 0.0      | 0.00     | 0.0      | 67138.8  |
| 28 Prereduced ore         | 55531.52 | 0.00     | 0.000    | 0.0      | 0.00     | 0.0      | 55531.5  |
| 29 Reduced ore            | 6887.84  | 0.00     | 0.000    | 0.0      | 45282.39 | 0.0      | 52170.2  |
| 30 Metal & Slag           | 1078.22  | 0.00     | 0.000    | 245716.1 | 44423.69 | 0.0      | 291218.0 |
| 31 Gas off Final Reductor | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 109112.4 | 109112.4 |
| 32 Gas off Reductor       | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 103581.0 | 103581.0 |
| 33 Gas off Prereductor    | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 131331.7 | 131331.7 |
| 34 Gas off Postcombustor  | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 134707.9 | 134707.9 |
| 35 Furnace gas            | 0.00     | 0.00     | 0.000    | 0.0      | 0.00     | 134707.9 | 134707.9 |
| 36 Solid fuel Carbon      | 162.10   | 15241.50 | 810.000  | 0.0      | 0.00     | 0.0      | 16213.6  |
| 37                        | 0.00     | 20254.19 | 0.000    | 0.0      | 0.00     | 0.0      | 20254.2  |
| 38                        | 0.00     | 12780.10 | 0.000    | 0.0      | 0.00     | 0.0      | 12780.1  |
| 39 Eq to Return Fines     | 0.00     | 1073.53  | 0.000    | 0.0      | 0.00     | 0.0      | 1073.5   |

Tecnoled Pig Iron Process  
Mass and Energy Balance

SPECIFIC GRAVITIES

| NO. STREAM                | PCS      | SG-SI  | SG-SO  | SG-LI  | SG-M1  | SG-M3  | SG-GC  | SG-TC  |
|---------------------------|----------|--------|--------|--------|--------|--------|--------|--------|
| 1 Iron Ore Fines          | 100.0000 | 5.1929 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 5.1929 |
| 2 Pet Coke Fines          | 100.0000 | 2.1267 | 2.2500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2.2421 |
| 3 Sand                    | 100.0000 | 2.6622 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2.6622 |
| 4 Cement                  | 80.0008  | 3.2642 | 0.0000 | 0.9983 | 0.0000 | 0.0000 | 0.0000 | 2.2451 |
| 5 Water                   | 0.0000   | 0.0000 | 0.0000 | 0.9983 | 0.0000 | 0.0000 | 0.0000 | 0.9983 |
| 6 Disc Feed               | 90.3648  | 4.7920 | 2.2500 | 0.9983 | 0.0000 | 0.0000 | 0.0000 | 3.1877 |
| 7 Muller Discharge        | 90.7120  | 4.7176 | 2.2500 | 0.9980 | 0.0000 | 0.0000 | 0.0000 | 3.1590 |
| 10 Water to Pelletizer    | 0.0000   | 0.0000 | 0.0000 | 0.9983 | 0.0000 | 0.0000 | 0.0000 | 0.9983 |
| 12 Return Fines           | 100.0000 | 2.9057 | 2.2500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2.5497 |
| 15 Pelletizer Discharge   | 88.8978  | 4.7176 | 2.2500 | 0.9980 | 0.0000 | 0.0000 | 0.0000 | 3.0279 |
| 16 Wet Cured Pellets      | 97.1561  | 4.7176 | 2.2500 | 0.9777 | 0.0000 | 0.0000 | 0.0000 | 3.7249 |
| 17 Water Vapor            | 0.0000   | 0.0000 | 0.0000 | 0.9777 | 0.0000 | 0.0000 | 0.0000 | 0.9777 |
| 18 not used               | 0.0000   | 0.0000 | 0.0000 | 0.9777 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 19 not used               | 0.0000   | 0.0000 | 0.0000 | 0.9777 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 20 Dry Cured Pellets      | 97.1274  | 4.7176 | 2.2500 | 0.9726 | 0.0000 | 0.0000 | 0.0000 | 3.7149 |
| 21 *Fume Losses           | 100.0000 | 4.7176 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 4.7176 |
| 22 Oxygen                 | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0013 | 0.0013 |
| 24 Cold Blast             | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 25 Hot Blast              | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 26 Preheat product        | 97.1274  | 4.8288 | 2.2500 | 0.5736 | 0.0000 | 0.0000 | 0.0000 | 3.4515 |
| 27 Post combust product   | 100.0000 | 4.8288 | 2.2500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 4.1193 |
| 28 Prereduced ore         | 100.0000 | 4.7369 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 4.7369 |
| 29 Reduced ore            | 13.2026  | 2.9530 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 1.0957 |
| 30 Metal & Slag           | 0.3702   | 1.0000 | 0.0000 | 0.0000 | 7.0879 | 3.0327 | 0.0000 | 5.7789 |
| 31 Gas off Final Reductor | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 32 Gas off Reductor       | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 33 Gas off Prereductor    | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 34 Gas off Postcombustor  | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 35 Furnace gas            | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 36 Solid fuel Carbon      | 95.0042  | 1.3317 | 1.8000 | 0.9951 | 0.0000 | 0.0000 | 0.0000 | 1.7243 |
| 37                        | 100.0000 | 0.0000 | 2.2500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2.2500 |
| 38                        | 100.0000 | 0.0000 | 2.2500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2.2500 |
| 39 Eq to Return Fines     | 100.0000 | 0.0000 | 2.2500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2.2500 |

Tecnored Pig Iron Process  
Mass and Energy Balance

STREAM DATA

SOLIDS - KG/HR

| NO. STREAM              | Fe2O3   | Fe3O4   | Fe1     | Si1O2   | Al2O3   | Ca1O1   | Mg1O1   |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore Fines        | 50364.9 | 0.0     | 0.00000 | 427.89  | 182.637 | 0.00    | 0.000   |
| 2 Pet Coke Fines        | 0.0     | 0.0     | 0.00000 | 0.00    | 6.038   | 0.00    | 0.000   |
| 3 Sand                  | 0.0     | 0.0     | 0.00000 | 1712.55 | 0.000   | 17.48   | 17.475  |
| 4 Cement                | 0.0     | 0.0     | 0.00000 | 652.41  | 193.366 | 2582.14 | 393.020 |
| 6 Disc Feed             | 50364.9 | 0.0     | 0.00000 | 2792.86 | 382.041 | 2599.62 | 410.495 |
| 7 Muller Discharge      | 50937.8 | 0.0     | 0.00000 | 2835.81 | 389.629 | 2699.84 | 410.495 |
| 12 Return Fines         | 572.8   | 0.0     | 0.00000 | 42.95   | 7.588   | 100.22  | 0.000   |
| 15 Pelletizer Discharge | 50937.8 | 0.0     | 0.00000 | 2835.81 | 389.629 | 2699.84 | 410.495 |
| 16 Wet Cured Pellets    | 50937.8 | 0.0     | 0.00000 | 2835.81 | 389.629 | 2699.84 | 410.495 |
| 20 Dry Cured Pellets    | 50324.3 | 0.0     | 0.00000 | 2801.66 | 384.937 | 2667.32 | 405.552 |
| 21 *Fume Losses         | 613.4   | 0.0     | 0.00000 | 34.15   | 4.692   | 32.51   | 4.943   |
| 23 not used             | 0.0     | 0.0     | 0.00000 | 769.46  | 0.000   | 204.54  | 0.000   |
| 26 Preheat product      | 50324.3 | 0.0     | 0.00000 | 2801.66 | 384.937 | 2667.32 | 405.552 |
| 27 Post combust product | 50324.3 | 0.0     | 0.00000 | 2801.66 | 384.937 | 2667.32 | 405.552 |
| 28 Prereduced ore       | 0.0     | 48643.7 | 0.00000 | 2866.50 | 384.937 | 2667.32 | 405.552 |
| 29 Reduced ore          | 0.0     | 0.0     | 0.00000 | 2866.50 | 384.937 | 2667.32 | 405.552 |
| 36 Solid fuel Carbon    | 0.0     | 0.0     | 0.00000 | 64.84   | 0.000   | 0.00    | 0.000   |

SOLIDS - KG/HR

| NO. STREAM              | Si1     | Fe1O1   | Mn1O1   | Mn1     | Ca1     | S1      | C1      |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore Fines        | 0.00000 | 0.000   | 297.438 | 0.00000 | 0.00000 | 0.000   | 0.00    |
| 2 Pet Coke Fines        | 0.00000 | 0.000   | 0.000   | 0.00000 | 0.00000 | 28.750  | 540.21  |
| 4 Cement                | 0.00000 | 109.260 | 0.000   | 0.00000 | 0.00000 | 0.000   | 0.00    |
| 6 Disc Feed             | 0.00000 | 109.260 | 297.438 | 0.00000 | 0.00000 | 28.750  | 540.21  |
| 7 Muller Discharge      | 0.00000 | 109.260 | 297.438 | 0.00000 | 0.00000 | 65.258  | 1211.82 |
| 12 Return Fines         | 0.00000 | 0.000   | 0.000   | 0.00000 | 0.00000 | 36.508  | 671.61  |
| 15 Pelletizer Discharge | 0.00000 | 109.260 | 297.438 | 0.00000 | 0.00000 | 65.258  | 1211.82 |
| 16 Wet Cured Pellets    | 0.00000 | 109.260 | 297.438 | 0.00000 | 0.00000 | 65.258  | 1211.82 |
| 20 Dry Cured Pellets    | 0.00000 | 107.944 | 293.856 | 0.00000 | 0.00000 | 64.472  | 1197.23 |
| 21 *Fume Losses         | 0.00000 | 1.316   | 3.582   | 0.00000 | 0.00000 | 0.786   | 14.59   |
| 26 Preheat product      | 0.00000 | 107.944 | 293.856 | 0.00000 | 0.00000 | 64.472  | 0.00    |
| 27 Post combust product | 0.00000 | 107.944 | 293.856 | 0.00000 | 0.00000 | 64.472  | 0.00    |
| 28 Prereduced ore       | 0.00000 | 107.944 | 293.856 | 0.00000 | 0.00000 | 161.732 | 0.00    |
| 29 Reduced ore          | 0.00000 | 107.944 | 293.856 | 0.00000 | 0.00000 | 161.732 | 0.00    |
| 30 Metal & Slag         | 0.00000 | 0.000   | 0.000   | 0.00000 | 0.00000 | 161.732 | 0.00    |
| 36 Solid fuel Carbon    | 0.00000 | 0.000   | 0.000   | 0.00000 | 0.00000 | 97.260  | 0.00    |

SOLIDS - WEIGHT PERCENT

| NO. STREAM              | Fe2O3   | Fe3O4   | Fe1     | Si1O2   | Al2O3   | Ca1O1   | Mg1O1   |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore Fines        | 98.2291 | 0.0000  | 0.00000 | 0.8345  | 0.35621 | 0.0000  | 0.0000  |
| 2 Pet Coke Fines        | 0.0000  | 0.0000  | 0.00000 | 0.0000  | 1.05000 | 0.0000  | 0.0000  |
| 3 Sand                  | 0.0000  | 0.0000  | 0.00000 | 98.0000 | 0.00000 | 1.0000  | 1.0000  |
| 4 Cement                | 0.0000  | 0.0000  | 0.00000 | 16.6000 | 4.92000 | 65.7000 | 10.0000 |
| 6 Disc Feed             | 87.5522 | 0.0000  | 0.00000 | 4.8550  | 0.66412 | 4.5191  | 0.7136  |
| 7 Muller Discharge      | 86.3977 | 0.0000  | 0.00000 | 4.8099  | 0.66087 | 4.5793  | 0.6963  |
| 12 Return Fines         | 40.0100 | 0.0000  | 0.00000 | 3.0000  | 0.53000 | 7.0000  | 0.0000  |
| 15 Pelletizer Discharge | 86.3977 | 0.0000  | 0.00000 | 4.8099  | 0.66087 | 4.5793  | 0.6963  |
| 16 Wet Cured Pellets    | 86.3977 | 0.0000  | 0.00000 | 4.8099  | 0.66087 | 4.5793  | 0.6963  |
| 20 Dry Cured Pellets    | 86.3977 | 0.0000  | 0.00000 | 4.8099  | 0.66087 | 4.5793  | 0.6963  |
| 21 *Fume Losses         | 86.3977 | 0.0000  | 0.00000 | 4.8099  | 0.66087 | 4.5793  | 0.6963  |
| 23 not used             | 0.0000  | 0.0000  | 0.00000 | 79.0000 | 0.00000 | 21.0000 | 0.0000  |
| 26 Preheat product      | 88.2108 | 0.0000  | 0.00000 | 4.9109  | 0.67473 | 4.6754  | 0.7109  |
| 27 Post combust product | 88.2108 | 0.0000  | 0.00000 | 4.9109  | 0.67473 | 4.6754  | 0.7109  |
| 28 Prereduced ore       | 0.0000  | 87.5965 | 0.00000 | 5.1619  | 0.69319 | 4.8033  | 0.7303  |
| 29 Reduced ore          | 0.0000  | 0.0000  | 0.00000 | 41.6168 | 5.58864 | 38.7251 | 5.8879  |
| 36 Solid fuel Carbon    | 0.0000  | 0.0000  | 0.00000 | 40.0000 | 0.00000 | 0.0000  | 0.0000  |



Tecored Pig Iron Process  
Mass and Energy Balance

STREAM DATA

SOLIDS - WEIGHT PERCENT

| NO. STREAM              | Si1     | Fe1O1   | Mn1O1   | Mn1     | Ca1     | S1      | C1      |
|-------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore Fines        | 0.00000 | 0.00000 | 0.58011 | 0.00000 | 0.00000 | 0.000   | 0.0000  |
| 2 Pet Coke Fines        | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.000   | 93.9500 |
| 4 Cement                | 0.00000 | 2.78000 | 0.00000 | 0.00000 | 0.00000 | 0.000   | 0.0000  |
| 6 Disc Feed             | 0.00000 | 0.18993 | 0.51705 | 0.00000 | 0.00000 | 0.050   | 0.9391  |
| 7 Muller Discharge      | 0.00000 | 0.18532 | 0.50450 | 0.00000 | 0.00000 | 0.111   | 2.0554  |
| 12 Return Fines         | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 2.550   | 46.9100 |
| 15 Pelletizer Discharge | 0.00000 | 0.18532 | 0.50450 | 0.00000 | 0.00000 | 0.111   | 2.0554  |
| 16 Wet Cured Pellets    | 0.00000 | 0.18532 | 0.50450 | 0.00000 | 0.00000 | 0.111   | 2.0554  |
| 20 Dry Cured Pellets    | 0.00000 | 0.18532 | 0.50450 | 0.00000 | 0.00000 | 0.111   | 2.0554  |
| 21 *Fume Losses         | 0.00000 | 0.18532 | 0.50450 | 0.00000 | 0.00000 | 0.111   | 2.0554  |
| 26 Preheat product      | 0.00000 | 0.18921 | 0.51508 | 0.00000 | 0.00000 | 0.113   | 0.0000  |
| 27 Post combust product | 0.00000 | 0.18921 | 0.51508 | 0.00000 | 0.00000 | 0.113   | 0.0000  |
| 28 Prereduced ore       | 0.00000 | 0.19438 | 0.52917 | 0.00000 | 0.00000 | 0.291   | 0.0000  |
| 29 Reduced ore          | 0.00000 | 1.56716 | 4.26630 | 0.00000 | 0.00000 | 2.348   | 0.0000  |
| 30 Metal & Slag         | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 100.000 | 0.0000  |
| 36 Solid fuel Carbon    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 60.000  | 0.0000  |

SLD-ORG - KG/HR

| NO. STREAM              | C1      | C6H14   | C7H16   |
|-------------------------|---------|---------|---------|
| 2 Pet Coke Fines        | 8925.0  | 0.00    | 0.00    |
| 6 Disc Feed             | 8925.0  | 0.00    | 0.00    |
| 7 Muller Discharge      | 10242.0 | 0.00    | 0.00    |
| 12 Return Fines         | 1317.0  | 0.00    | 0.00    |
| 15 Pelletizer Discharge | 10242.0 | 0.00    | 0.00    |
| 16 Wet Cured Pellets    | 10242.0 | 0.00    | 0.00    |
| 20 Dry Cured Pellets    | 10242.0 | 0.00    | 0.00    |
| 23 not used             | 12954.0 | 1143.00 | 1143.00 |
| 26 Preheat product      | 11439.2 | 0.00    | 0.00    |
| 27 Post combust product | 10088.7 | 0.00    | 0.00    |
| 36 Solid fuel Carbon    | 12193.2 | 1524.15 | 1524.15 |
| 37                      | 20254.2 | 0.00    | 0.00    |
| 38                      | 12780.1 | 0.00    | 0.00    |
| 39 Eq to Return Fines   | 1073.5  | 0.00    | 0.00    |

SLD-ORG - WEIGHT PERCENT

| NO. STREAM              | C1      | C6H14   | C7H16   |
|-------------------------|---------|---------|---------|
| 2 Pet Coke Fines        | 100.000 | 0.0000  | 0.0000  |
| 6 Disc Feed             | 100.000 | 0.0000  | 0.0000  |
| 7 Muller Discharge      | 100.000 | 0.0000  | 0.0000  |
| 12 Return Fines         | 100.000 | 0.0000  | 0.0000  |
| 15 Pelletizer Discharge | 100.000 | 0.0000  | 0.0000  |
| 16 Wet Cured Pellets    | 100.000 | 0.0000  | 0.0000  |
| 20 Dry Cured Pellets    | 100.000 | 0.0000  | 0.0000  |
| 23 not used             | 85.000  | 7.5000  | 7.5000  |
| 26 Preheat product      | 100.000 | 0.0000  | 0.0000  |
| 27 Post combust product | 100.000 | 0.0000  | 0.0000  |
| 36 Solid fuel Carbon    | 80.000  | 10.0000 | 10.0000 |
| 37                      | 100.000 | 0.0000  | 0.0000  |
| 38                      | 100.000 | 0.0000  | 0.0000  |
| 39 Eq to Return Fines   | 100.000 | 0.0000  | 0.0000  |

Tecnored Pig Iron Process  
Mass and Energy Balance

STREAM DATA

AQUEOUS - KG/HR

| NO. STREAM              | H2O     |
|-------------------------|---------|
| 4 Cement                | 982.50  |
| 5 Water                 | 6102.80 |
| 6 Disc Feed             | 7085.30 |
| 7 Muller Discharge      | 7085.30 |
| 10 Water to Pelletizer  | 1556.80 |
| 15 Pelletizer Discharge | 8642.10 |
| 16 Wet Cured Pellets    | 2025.60 |
| 17 Water Vapor          | 6616.50 |
| 18 not used             | 5.96    |
| 19 not used             | 33.77   |
| 20 Dry Cured Pellets    | 2025.60 |
| 26 Preheat product      | 2025.60 |
| 36 Solid fuel Carbon    | 810.00  |

AQUEOUS - WEIGHT PERCENT

| NO. STREAM              | H2O     |
|-------------------------|---------|
| 4 Cement                | 100.000 |
| 5 Water                 | 100.000 |
| 6 Disc Feed             | 100.000 |
| 7 Muller Discharge      | 100.000 |
| 10 Water to Pelletizer  | 100.000 |
| 15 Pelletizer Discharge | 100.000 |
| 16 Wet Cured Pellets    | 100.000 |
| 17 Water Vapor          | 100.000 |
| 18 not used             | 100.000 |
| 19 not used             | 100.000 |
| 20 Dry Cured Pellets    | 100.000 |
| 26 Preheat product      | 100.000 |
| 36 Solid fuel Carbon    | 100.000 |

AQUEOUS - GRAMS PER LITER

| NO. STREAM              | H2O     |
|-------------------------|---------|
| 4 Cement                | 998.259 |
| 5 Water                 | 998.259 |
| 6 Disc Feed             | 998.259 |
| 7 Muller Discharge      | 998.008 |
| 10 Water to Pelletizer  | 998.259 |
| 15 Pelletizer Discharge | 998.034 |
| 16 Wet Cured Pellets    | 977.655 |
| 17 Water Vapor          | 977.655 |
| 18 not used             | 977.655 |
| 19 not used             | 977.655 |
| 20 Dry Cured Pellets    | 972.597 |
| 26 Preheat product      | 573.576 |
| 36 Solid fuel Carbon    | 995.067 |

MOLTEN1 - KG/HR

| NO. STREAM      | Fe1     | Mn1     | Cl      | Si1     | S1      |
|-----------------|---------|---------|---------|---------|---------|
| 30 Metal & Slag | 35247.1 | 0.00000 | 1610.29 | 0.00000 | 0.00000 |

MOLTEN1 - WEIGHT PERCENT

| NO. STREAM      | Fe1     | Mn1     | Cl      | Si1     | S1      |
|-----------------|---------|---------|---------|---------|---------|
| 30 Metal & Slag | 95.6310 | 0.00000 | 4.36898 | 0.00000 | 0.00000 |

MOLTEN3 - KG/HR

| NO. STREAM      | Ca1O1   | Ca1F2   | Si1O2   | S1      | Al2O3   | Ca1S1   | Mn1O1   |
|-----------------|---------|---------|---------|---------|---------|---------|---------|
| 30 Metal & Slag | 2667.32 | 0.00000 | 2866.50 | 0.00000 | 384.937 | 0.00000 | 293.856 |

Tecnored Pig Iron Process  
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STREAM DATA

MOLTEN3 - KG/HR

| NO. STREAM      | Fe101   | Mg101   |
|-----------------|---------|---------|
| 29 Reduced ore  | 45282.4 | 0.000   |
| 30 Metal & Slag | 45.4    | 405.552 |

MOLTEN3 - WEIGHT PERCENT

| NO. STREAM      | Ca101   | Ca1F2   | Si102   | S1      | Al2O3   | Ca1S1   | Mn101   |
|-----------------|---------|---------|---------|---------|---------|---------|---------|
| 30 Metal & Slag | 40.0285 | 0.00000 | 43.0175 | 0.00000 | 5.77675 | 0.00000 | 4.40990 |

MOLTEN3 - WEIGHT PERCENT

| NO. STREAM      | Fe101   | Mg101   |
|-----------------|---------|---------|
| 29 Reduced ore  | 100.000 | 0.00000 |
| 30 Metal & Slag | 0.681   | 6.08612 |

GASEOUS - KG/HR

| NO. STREAM                | N2      | O2      | H2      | CO      | CO2     | H2O     | COS     |
|---------------------------|---------|---------|---------|---------|---------|---------|---------|
| 18 not used               | 240.9   | 0.0     | 82.480  | 100.3   | 63.4    | 0.00000 | 0.15021 |
| 19 not used               | 1365.2  | 0.0     | 467.341 | 568.7   | 359.3   | 0.00000 | 0.96482 |
| 22 Oxygen                 | 0.0     | 526.8   | 0.000   | 0.0     | 0.0     | 0.00000 | 0.00000 |
| 24 Cold Blast             | 15501.4 | 4682.7  | 0.000   | 0.0     | 0.0     | 0.00000 | 0.00000 |
| 25 Hot Blast              | 55315.0 | 16709.7 | 0.000   | 0.0     | 0.0     | 0.00000 | 0.00000 |
| 31 Gas off Final Reductor | 55315.0 | 5320.0  | 0.000   | 8548.8  | 23561.9 | 0.00000 | 0.00000 |
| 32 Gas off Reductor       | 55315.0 | 0.0     | 0.000   | 28210.2 | 20055.8 | 0.00000 | 0.00000 |
| 33 Gas off Prereductor    | 70816.3 | 0.0     | 585.520 | 37177.2 | 22752.7 | 0.00000 | 0.00000 |
| 34 Gas off Postcombustor  | 70816.3 | 0.0     | 812.188 | 40326.7 | 22752.7 | 0.00000 | 0.00000 |
| 35 Furnace gas            | 70816.3 | 0.0     | 812.188 | 40326.7 | 22752.7 | 0.00000 | 0.00000 |

GASEOUS - KG/HR

| NO. STREAM  | H2S1    | CH4     | C2H6    | S1O2    | F1      | S1      |
|-------------|---------|---------|---------|---------|---------|---------|
| 18 not used | 0.45063 | 6.3088  | 0.00000 | 0.73603 | 0.00000 | 0.00000 |
| 19 not used | 2.55393 | 35.7550 | 0.00000 | 4.17142 | 0.00000 | 0.00000 |

GASEOUS - WEIGHT PERCENT

| NO. STREAM                | N2      | O2      | H2      | CO      | CO2     | H2O     | COS     |
|---------------------------|---------|---------|---------|---------|---------|---------|---------|
| 18 not used               | 48.6894 | 0.000   | 16.6714 | 20.2813 | 12.8125 | 0.00000 | 0.03036 |
| 19 not used               | 48.6894 | 0.000   | 16.6673 | 20.2813 | 12.8125 | 0.00000 | 0.03441 |
| 22 Oxygen                 | 0.0000  | 100.000 | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 |
| 24 Cold Blast             | 76.8000 | 23.200  | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 |
| 25 Hot Blast              | 76.8000 | 23.200  | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 |
| 31 Gas off Final Reductor | 59.6416 | 5.736   | 0.0000  | 9.2175  | 25.4048 | 0.00000 | 0.00000 |
| 32 Gas off Reductor       | 53.4026 | 0.000   | 0.0000  | 27.2349 | 19.3624 | 0.00000 | 0.00000 |
| 33 Gas off Prereductor    | 53.9217 | 0.000   | 0.4458  | 28.3079 | 17.3246 | 0.00000 | 0.00000 |
| 34 Gas off Postcombustor  | 52.5703 | 0.000   | 0.6029  | 29.9364 | 16.8904 | 0.00000 | 0.00000 |
| 35 Furnace gas            | 52.5703 | 0.000   | 0.6029  | 29.9364 | 16.8904 | 0.00000 | 0.00000 |

GASEOUS - WEIGHT PERCENT

| NO. STREAM  | H2S1    | CH4     | C2H6    | S1O2    | F1      | S1      |
|-------------|---------|---------|---------|---------|---------|---------|
| 18 not used | 0.09108 | 1.27517 | 0.00000 | 0.14877 | 0.00000 | 0.00000 |
| 19 not used | 0.09108 | 1.27517 | 0.00000 | 0.14877 | 0.00000 | 0.00000 |

Tecnored Pig Iron Process  
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STREAM DATA

GASEOUS - VOLUME PERCENT

| NO. STREAM                | N2      | O2      | H2      | CO      | CO2     | H2O     | COS     |
|---------------------------|---------|---------|---------|---------|---------|---------|---------|
| 18 not used               | 15.6470 | 0.000   | 74.4487 | 6.5184  | 2.6209  | 0.00000 | 0.00455 |
| 19 not used               | 15.6497 | 0.000   | 74.4436 | 6.5195  | 2.6213  | 0.00000 | 0.00516 |
| 22 Oxygen                 | 0.0000  | 100.000 | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 |
| 24 Cold Blast             | 79.0852 | 20.915  | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 |
| 25 Hot Blast              | 79.0852 | 20.915  | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 |
| 31 Gas off Final Reductor | 66.2298 | 5.576   | 0.0000  | 10.2367 | 17.9571 | 0.00000 | 0.00000 |
| 32 Gas off Reductor       | 57.4438 | 0.000   | 0.0000  | 29.2989 | 13.2573 | 0.00000 | 0.00000 |
| 33 Gas off Prereductor    | 54.2171 | 0.000   | 6.2292  | 28.4658 | 11.0879 | 0.00000 | 0.00000 |
| 34 Gas off Postcombustor  | 51.7225 | 0.000   | 8.2431  | 29.4566 | 10.5777 | 0.00000 | 0.00000 |
| 35 Furnace gas            | 51.7225 | 0.000   | 8.2431  | 29.4566 | 10.5777 | 0.00000 | 0.00000 |

GASEOUS - VOLUME PERCENT

| NO. STREAM  | H2S1    | CH4     | C2H6    | SiO2    | F1      | S1      |
|-------------|---------|---------|---------|---------|---------|---------|
| 18 not used | 0.02406 | 0.71556 | 0.00000 | 0.02091 | 0.00000 | 0.00000 |
| 19 not used | 0.02406 | 0.71569 | 0.00000 | 0.02091 | 0.00000 | 0.00000 |

# **APPENDIX E-4:**

## **HISMELT OXYGEN REACTOR**

## HISMELT PROCESS

### PROCESS BACKGROUND:

The HIs melt process was initially developed as an air-blown, bottom-injected, refractory-lined process. But due to excessive refractory wear, the initial horizontal design was abandoned and a new Vertical smelt reduction vessel (SRV) was proposed.

### PROCESS DESCRIPTION:

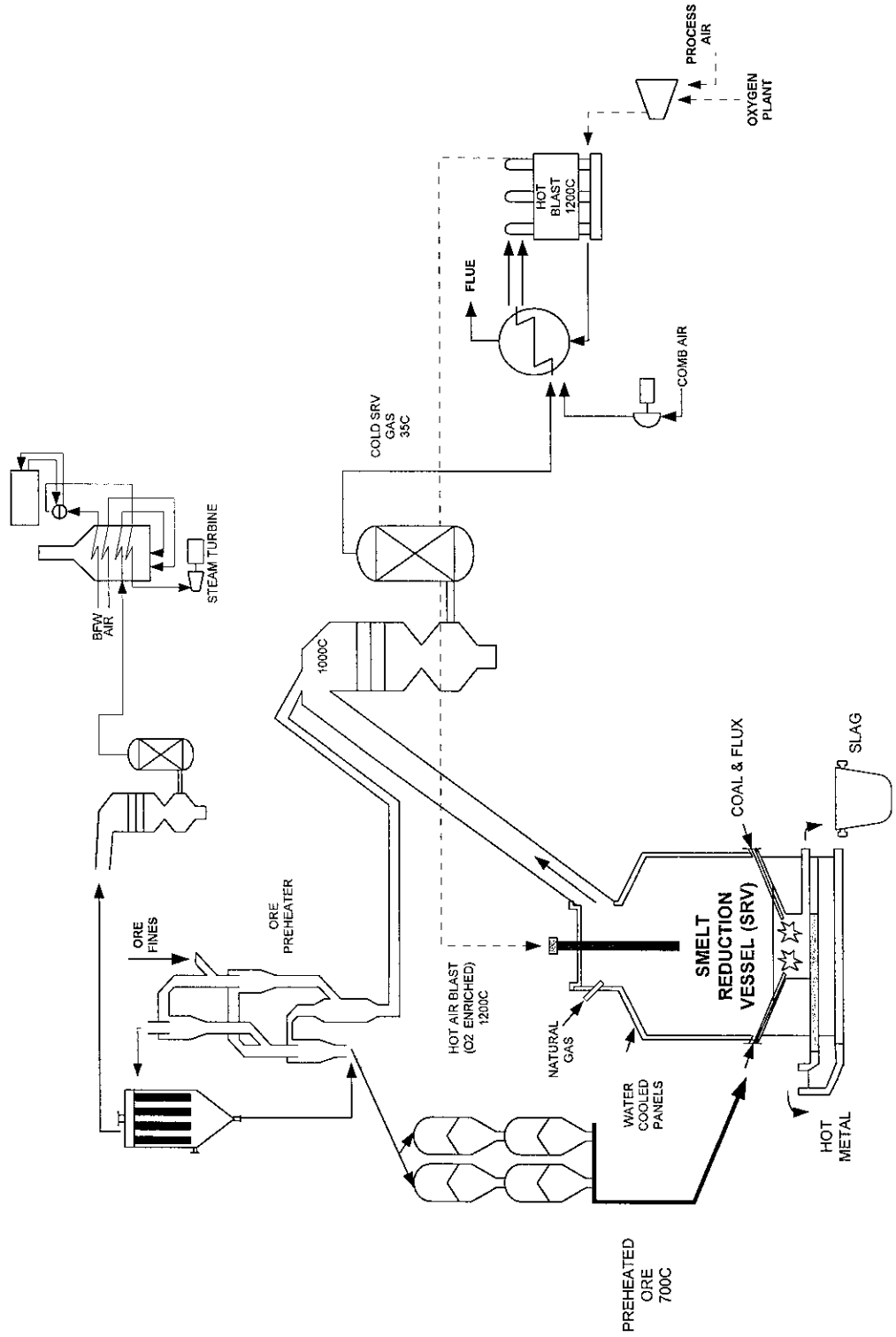
In this process, the iron ore is preheated (and optionally prereduced as far as magnetite) in a lean-phase cyclone preheat system similar to that on many cement kilns. It is then injected into the SRV, along with coal and flux materials through two water-cooled solids injection lances such that the mixture is carried predominantly into the metal phase. Rapid dissolution and smelting occur in the metal and the resulting product gases (mainly hydrogen and carbon monoxide) rise under buoyancy to generate the large liquid fountain, a characteristic of HIs melt. The result is strong mixing within the metal and slag phases with effective elimination of any significant thermal gradients.

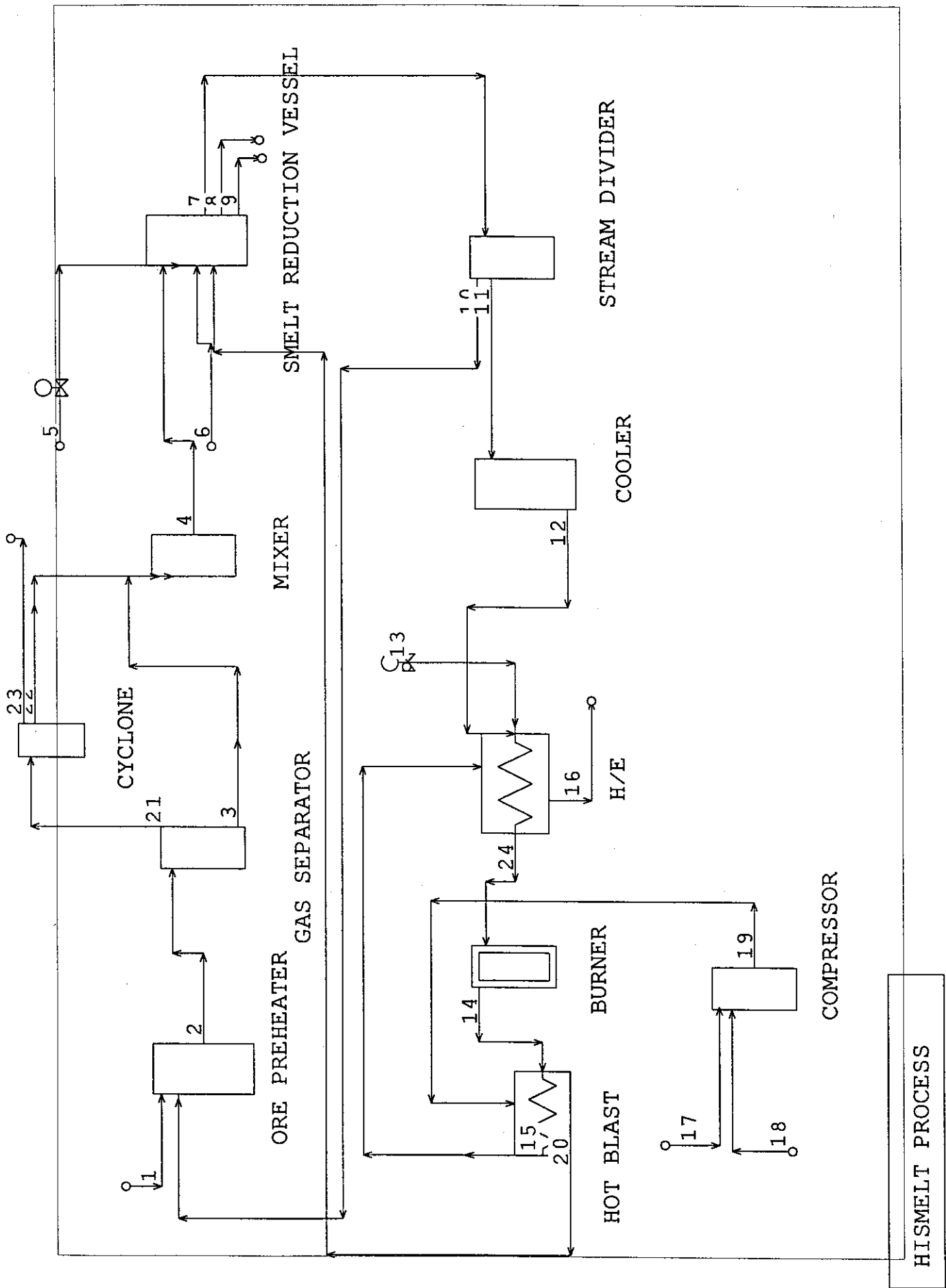
Hot offgas from the SRV is enriched with a small quantity of natural gas, the resulting mixture being roughly equivalent to blast furnace gas. This gas is cooled to around 1000C and split into roughly equal proportions. One portion is used (hot) in the preheater, whilst the other is scrubbed and subsequently burned as fuel in the hot blast stoves.

### PROCESS ADVANTAGES

Direct smelting

# HISMELT PROCESS FLOWSHEET





HISMELT PROCESS



## **HIsmelt Process --- MetSim Model --- Description**

The MetSim model for this process is largely based upon a typical commercial flowsheet published in a technical article, "HIsmelt - The Future in Direct Ironmaking" by HIsmelt Corporation, Kwinana, Australia.

### **Flowsheet Description**

Stream 1 representing the ore fines feed consists of 82% Fe<sub>2</sub>O<sub>3</sub>, 12% Fe<sub>3</sub>O<sub>4</sub> and 6% SiO<sub>2</sub>. In the Ore Preheater, this feed is heated upto 700C and also partially prereduced (~11% prereduction) by the stream 10 representing a portion of hot gases generated from the Smelt Reduction Vessel. The preheated ore (Stream 2) is passed through a Gas Separator (MetSim unit op) and a Cyclone to capture lost particles (stream 22) . The combined prereduced ore (stream 4) is introduced in the Smelt Reduction Vessel along with coal and flux (stream 6).

The oxygen enriched air (30% O<sub>2</sub>) at 1200C comes into the Reduction vessel as stream 20. Process Air (Stream 17) and Oxygen (Stream 18) are combined and compressed (Stream 19) and then heated to generate stream 20 by using hot gases (stream 14) from the Burner.

Hot gases (Stream 7), Slag (Stream 8) and Hot Metal (Stream 9) are the outgoing streams from the Smelt Reduction Vessel at about 1500C. Hot gases are enriched with Natural Gas (Stream 5) and divided in two parts: one for use in the Ore Preheater, the other for burning as fuel in Burner (hot blast stoves). The latter (stream 11) is first cooled to 35C (stream 12), mixed with combustion air (stream 13) and then preheated by flue gases (Stream 15) before burning. The gases (stream 24) when burned produce sufficient heat to increase the temperature of cold oxygen enriched air (Stream 19) to about 1200C.

### **Model Assumptions:**

Ore Preheater: The temperature of preheated ore fines is 700C. The model requires some external heating.

Gas Separator: 5% solids enter the Cyclone along with hot gases.

Cyclone: 100% efficient, all solid particles are separated from gases and mixed with preheated ore.

Smelt Reduction Vessel: All oxides are grouped together as slag. Hot Metal contains about 5% Carbon. No reaction occurs between Natural gas and hot SRV gases. 10% heat loss.

Stream Divider: 70% of hot SRV gases are burned to heat oxygen enriched air. Rest is used for preheating fine ore.

Cooler: Cold SRV gas temperature is 35C.

H/E: Air is mixed to burn cold SRV gas and preheated by flue gases.

Burner: The reactions reach equilibrium.

Hot Blast: 100% Efficient.

Compressor: No increase in temperature.

### **Results**

It was decided to achieve same operating conditions as were outlined in the article by Hismelt Corporation. In the absence of information on gas compositions and amounts for certain feed streams, a few assumptions were made. These led to some differences between the MetSim Model results and the Commercial flowsheet data by Hismelt Corp. It was observed that Natural gas added to the SRV gas was not sufficient to increase the temperature of oxygen enriched air to 1200C. Hence, instead of 9000Nm<sup>3</sup>/hr of natural gas, 15000 Nm<sup>3</sup>/hr of natural gas was needed. Also 70% of the SRV was routed for burners and 30% for preheating instead of equal portions as shown in the Commercial flowsheet. The Ore preheater also required external heating. The natural gas in the SRV gases routed to the Ore Preheater went waste in the absence of any air. More natural gas meant more combustion air to burn than that outlined in the commercial flowsheet.

### HISMELT PROCESS --- STREAM SUMMARY

| Stream Number             | 1         | 2          | 3        | 4        | 5          | 6         | 7          | 8      |
|---------------------------|-----------|------------|----------|----------|------------|-----------|------------|--------|
| Stream Names              | ORE FINES | HOT ORE FI | PREHEATE | PREHEATE | NATURAL G  | COAL FLUX | HOT SRV G  | SLAG   |
| KG/HR SOLIDS              | 2.87E+05  | 2.78E+05   | 2.64E+05 | 2.78E+05 | 0          | 1.42E+05  | 0          | 0      |
| KG/HR AQUEOUS             | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 0      |
| KG/HR MOLTEN3             | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 67737  |
| KG/HR GASEOUS             | 0         | 1.67E+05   | 0        | 0        | 10736      | 0         | 5.26E+05   | 0      |
| KG/HR TOTAL               | 2.87E+05  | 4.45E+05   | 2.64E+05 | 2.78E+05 | 10736      | 1.42E+05  | 5.26E+05   | 67737  |
| Percent Solids            | 100       | 62.471     | 100      | 100      | 0          | 100       | 0          | 0      |
| Sp.Gr.SOLIDS              | 4.9432    | 4.9167     | 4.9167   | 4.9167   | 0          | 2.4691    | 0          | 0      |
| Sp.Gr.AQUEOUS             | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 0      |
| Sp.Gr.MOLTEN3             | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 3.0287 |
| Sp.Gr.GASEOUS             | 0         | 0.00038945 | 0        | 0        | 0.00063446 | 0         | 0.00021782 | 0      |
| Sp.Gr.TOTAL               | 4.9432    | 0.0010376  | 4.9167   | 4.9167   | 0.00063446 | 2.4691    | 0.00021782 | 3.0287 |
| Temperature C             | 35        | 700        | 700      | 700      | 35         | 35        | 1504.7     | 1504.7 |
| Pressure kPa              | 101.33    | 101.33     | 101.33   | 101.33   | 101.33     | 101.33    | 101.33     | 101.33 |
| Gas nm3/hr                | 0         | 1.20E+05   | 0        | 0        | 14999      | 0         | 3.71E+05   | 0      |
| Sol/Liq m3/hr             | 58.059    | 56.517     | 53.691   | 56.517   | 0          | 57.51     | 0          | 22.365 |
| Sol/Liq gpm               | 255.62    | 248.83     | 236.39   | 248.83   | 0          | 253.21    | 0          | 98.471 |
| Component Mass Flow rates |           |            |          |          |            |           |            |        |
| 1 C KG/HR                 | 0         | 0          | 0        | 0        | 0          | 95140     | 0          | 0      |
| 2 CO KG/HR                | 0         | 28719      | 0        | 0        | 0          | 0         | 74010      | 0      |
| 3 CO2 KG/HR               | 0         | 56622      | 0        | 0        | 0          | 0         | 1.93E+05   | 0      |
| 4 Fe KG/HR                | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 0      |
| 5 FeO KG/HR               | 0         | 17068      | 16214    | 17068    | 0          | 0         | 0          | 0      |
| 6 Fe2O3 KG/HR             | 2.35E+05  | 0          | 0        | 0        | 0          | 0         | 0          | 0      |
| 7 Fe3O4 KG/HR             | 34440     | 2.44E+05   | 2.31E+05 | 2.44E+05 | 0          | 0         | 0          | 0      |
| 9 H2O KG/HR               | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 0      |
| 10 H2O KG/HR              | 0         | 7233.5     | 0        | 0        | 0          | 0         | 0          | 0      |
| 11 N2 KG/HR               | 0         | 74357      | 0        | 0        | 0          | 0         | 2.48E+05   | 0      |
| 12 O2 KG/HR               | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 0      |
| 15 CaO KG/HR              | 0         | 0          | 0        | 0        | 0          | 32660     | 0          | 0      |
| 17 SiO2 KG/HR             | 17220     | 17220      | 16359    | 17220    | 0          | 14200     | 0          | 0      |
| 18 CH4 KG/HR              | 0         | 0          | 0        | 0        | 10736      | 0         | 10736      | 0      |
| 20 CaO KG/HR              | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 32660  |
| 22 SiO2 KG/HR             | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 31420  |
| 23 FeO KG/HR              | 0         | 0          | 0        | 0        | 0          | 0         | 0          | 3657.3 |
| Element Mass Flow Rates   |           |            |          |          |            |           |            |        |
| 1 H 1                     | 0         | 809.44     | 0        | 0        | 2698.1     | 0         | 2698.1     | 0      |
| 2 C 6                     | 0         | 27768      | 0        | 0        | 8037.9     | 95140     | 92560      | 0      |
| 3 N 7                     | 0         | 74357      | 0        | 0        | 0          | 0         | 2.48E+05   | 0      |
| 4 O 8                     | 89425     | 1.44E+05   | 76284    | 80299    | 0          | 16880     | 1.83E+05   | 26865  |
| 7 Si 14                   | 8049.3    | 8049.3     | 7646.8   | 8049.3   | 0          | 6637.6    | 0          | 14687  |
| 8 Ca 20                   | 0         | 0          | 0        | 0        | 0          | 23342     | 0          | 23342  |
| 9 Fe 26                   | 1.90E+05  | 1.90E+05   | 1.80E+05 | 1.90E+05 | 0          | 0         | 0          | 2842.9 |

HISMELT PROCESS --- STREAM SUMMARY

| Stream Number             | 9         | 10         | 11         | 12        | 13        | 14         | 15         | 16         |
|---------------------------|-----------|------------|------------|-----------|-----------|------------|------------|------------|
| Stream Names              | HOT METAL | HOT GASES  | HOT GASES  | COLD SRV  | COMBUSTI  |            | BURNT SRV  | FLUE       |
| KG/HR SOLIDS              | 1.97E+05  | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| KG/HR AQUEOUS             | 0         | 0          | 0          | 0         | 0         | 14325      | 14325      | 14325      |
| KG/HR MOLTEN3             | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| KG/HR GASEOUS             | 0         | 1.58E+05   | 3.68E+05   | 3.68E+05  | 2.90E+05  | 6.44E+05   | 6.44E+05   | 6.44E+05   |
| KG/HR TOTAL               | 1.97E+05  | 1.58E+05   | 3.68E+05   | 3.68E+05  | 2.90E+05  | 6.58E+05   | 6.58E+05   | 6.58E+05   |
| Percent Solids            | 100       | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| Sp.Gr.SOLIDS              | 6.9301    | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| Sp.Gr.AQUEOUS             | 0         | 0          | 0          | 0         | 0         | 0.31545    | 0.31545    | 0.31545    |
| Sp.Gr.MOLTEN3             | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| Sp.Gr.GASEOUS             | 0         | 0.00030416 | 0.00030416 | 0.0013853 | 0.0011376 | 0.00019093 | 0.00026396 | 0.00042448 |
| Sp.Gr.TOTAL               | 6.9301    | 0.00030416 | 0.00030416 | 0.0013853 | 0.0011376 | 0.00019518 | 0.00026983 | 0.00043391 |
| Temperature C             | 1504.7    | 1000       | 1000       | 35        | 35        | 1786.9     | 1217       | 653.48     |
| Pressure kPa              | 101.33    | 101.33     | 101.33     | 111.69    | 101.33    | 101.33     | 101.33     | 101.33     |
| Gas nm3/hr                | 0         | 1.11E+05   | 2.60E+05   | 2.60E+05  | 2.26E+05  | 4.47E+05   | 4.47E+05   | 4.47E+05   |
| Sol/Liq m3/hr             | 28.47     | 0          | 0          | 0         | 0         | 45.412     | 45.412     | 45.412     |
| Sol/Liq gpm               | 125.35    | 0          | 0          | 0         | 0         | 199.94     | 199.94     | 199.94     |
| Component Mass Flow rates |           |            |            |           |           |            |            |            |
| 1 C KG/HR                 | 10618     | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 2 CO KG/HR                | 0         | 22203      | 51807      | 51807     | 0         | 0          | 0          | 0          |
| 3 CO2 KG/HR               | 0         | 58024      | 1.35E+05   | 1.35E+05  | 0         | 2.37E+05   | 2.37E+05   | 2.37E+05   |
| 4 Fe KG/HR                | 1.87E+05  | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 5 FeO KG/HR               | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 6 Fe2O3 KG/HR             | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 7 Fe3O4 KG/HR             | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 9 H2O KG/HR               | 0         | 0          | 0          | 0         | 0         | 14325      | 14325      | 14325      |
| 10 H2O KG/HR              | 0         | 0          | 0          | 0         | 0         | 2553.2     | 2553.2     | 2553.2     |
| 11 N2 KG/HR               | 0         | 74357      | 1.74E+05   | 1.74E+05  | 2.29E+05  | 4.03E+05   | 4.03E+05   | 4.03E+05   |
| 12 O2 KG/HR               | 0         | 0          | 0          | 0         | 60900     | 1329.3     | 1329.3     | 1329.3     |
| 15 CaO KG/HR              | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 17 SiO2 KG/HR             | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 18 CH4 KG/HR              | 0         | 3220.8     | 7515.2     | 7515.2    | 0         | 0          | 0          | 0          |
| 20 CaO KG/HR              | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 22 SiO2 KG/HR             | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 23 FeO KG/HR              | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| Element Mass Flow Rates   |           |            |            |           |           |            |            |            |
| 1 H 1                     | 0         | 809.44     | 1888.7     | 1888.7    | 0         | 1888.7     | 1888.7     | 1888.7     |
| 2 C 6                     | 10618     | 27768      | 64792      | 64792     | 0         | 64792      | 64792      | 64792      |
| 3 N 7                     | 0         | 74357      | 1.74E+05   | 1.74E+05  | 2.29E+05  | 4.03E+05   | 4.03E+05   | 4.03E+05   |
| 4 O 8                     | 0         | 54870      | 1.28E+05   | 1.28E+05  | 60900     | 1.89E+05   | 1.89E+05   | 1.89E+05   |
| 7 Si 14                   | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 8 Ca 20                   | 0         | 0          | 0          | 0         | 0         | 0          | 0          | 0          |
| 9 Fe 26                   | 1.87E+05  | 0          | 0          | 0         | 0         | 0          | 0          | 0          |

### HISMELT PROCESS --- STREAM SUMMARY

| Stream Number             | 17        | 18        | 19        | 20         | 21         | 22       | 23         | 24         |
|---------------------------|-----------|-----------|-----------|------------|------------|----------|------------|------------|
| Stream Names              | PROCESS A | OXYGEN    | O2 ENRICH | HOT AIR BL | FINES+GAS  | PREHEATE | GASES      |            |
| KG/HR SOLIDS              | 0         | 0         | 0         | 0          | 13894      | 13894    | 0          | 0          |
| KG/HR AQUEOUS             | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| KG/HR MOLTEN3             | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| KG/HR GASEOUS             | 3.13E+05  | 47300     | 3.60E+05  | 3.60E+05   | 1.67E+05   | 0        | 1.67E+05   | 6.58E+05   |
| KG/HR TOTAL               | 3.13E+05  | 47300     | 3.60E+05  | 3.60E+05   | 1.81E+05   | 13894    | 1.67E+05   | 6.58E+05   |
| Percent Solids            | 0         | 0         | 0         | 0          | 7.6835     | 100      | 0          | 0          |
| Sp.Gr.SOLIDS              | 0         | 0         | 0         | 0          | 4.9167     | 4.9167   | 0          | 0          |
| Sp.Gr.AQUEOUS             | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| Sp.Gr.MOLTEN3             | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| Sp.Gr.GASEOUS             | 0.0011376 | 0.0012637 | 0.0011527 | 0.00023838 | 0.00038945 | 0        | 0.00038945 | 0.00039948 |
| Sp.Gr.TOTAL               | 0.0011376 | 0.0012637 | 0.0011527 | 0.00023838 | 0.00042186 | 4.9167   | 0.00038945 | 0.00039948 |
| Temperature C             | 35        | 35        | 35        | 1217       | 700        | 700      | 700        | 653.48     |
| Pressure kPa              | 101.33    | 101.33    | 101.33    | 101.33     | 101.33     | 101.33   | 101.33     | 101.33     |
| Gas nm3/hr                | 2.44E+05  | 33179     | 2.77E+05  | 2.77E+05   | 1.20E+05   | 0        | 1.20E+05   | 4.86E+05   |
| Sol/Liq m3/hr             | 0         | 0         | 0         | 0          | 2.8258     | 2.8258   | 0          | 0          |
| Sol/Liq gpm               | 0         | 0         | 0         | 0          | 12.442     | 12.442   | 0          | 0          |
| Component Mass Flow rates |           |           |           |            |            |          |            |            |
| 1 C KG/HR                 | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 2 CO KG/HR                | 0         | 0         | 0         | 0          | 28719      | 0        | 28719      | 51807      |
| 3 CO2 KG/HR               | 0         | 0         | 0         | 0          | 56622      | 0        | 56622      | 1.35E+05   |
| 4 Fe KG/HR                | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 5 FeO KG/HR               | 0         | 0         | 0         | 0          | 853.38     | 853.38   | 0          | 0          |
| 6 Fe2O3 KG/HR             | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 7 Fe3O4 KG/HR             | 0         | 0         | 0         | 0          | 12179      | 12179    | 0          | 0          |
| 9 H2O KG/HR               | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 10 H2O KG/HR              | 0         | 0         | 0         | 0          | 7233.5     | 0        | 7233.5     | 0          |
| 11 N2 KG/HR               | 2.47E+05  | 473       | 2.48E+05  | 2.48E+05   | 74357      | 0        | 74357      | 4.03E+05   |
| 12 O2 KG/HR               | 65761     | 46827     | 1.13E+05  | 1.13E+05   | 0          | 0        | 0          | 60900      |
| 15 CaO KG/HR              | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 17 SiO2 KG/HR             | 0         | 0         | 0         | 0          | 861        | 861      | 0          | 0          |
| 18 CH4 KG/HR              | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 7515.2     |
| 20 CaO KG/HR              | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 22 SiO2 KG/HR             | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 23 FeO KG/HR              | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| Element Mass Flow Rates   |           |           |           |            |            |          |            |            |
| 1 H 1                     | 0         | 0         | 0         | 0          | 809.44     | 0        | 809.44     | 1888.7     |
| 2 C 6                     | 0         | 0         | 0         | 0          | 27768      | 0        | 27768      | 64792      |
| 3 N 7                     | 2.47E+05  | 473       | 2.48E+05  | 2.48E+05   | 74357      | 0        | 74357      | 4.03E+05   |
| 4 O 8                     | 65761     | 46827     | 1.13E+05  | 1.13E+05   | 68012      | 4014.9   | 63997      | 1.89E+05   |
| 7 Si 14                   | 0         | 0         | 0         | 0          | 402.47     | 402.47   | 0          | 0          |
| 8 Ca 20                   | 0         | 0         | 0         | 0          | 0          | 0        | 0          | 0          |
| 9 Fe 26                   | 0         | 0         | 0         | 0          | 9476.3     | 9476.3   | 0          | 0          |

## HISMELT PROCESS

## INPUT DATA

TITLE : HISMELT PROCESS  
CASE :  
DATA STORAGE FILE NAME : Hismelt4.sfw  
HEAT BALANCE OPTION : ON  
UNITS OF MASS/TIME : KG/HR

| ROW | CNM   | CHF   |     | PHC      | CMW    | SGF    |
|-----|-------|-------|-----|----------|--------|--------|
| 1   | C     | C     | SI1 | 12.0112  | 2.2500 | 0.0000 |
| 2   | CO    | CO    | GC8 | 28.0106  | 0.0012 | 0.0000 |
| 3   | CO2   | CO2   | GC8 | 44.0100  | 0.0020 | 0.0000 |
| 4   | Fe    | Fe    | SI1 | 55.8470  | 7.8600 | 0.0000 |
| 5   | FeO   | FeO   | SI1 | 71.8464  | 5.7000 | 0.0000 |
| 6   | Fe2O3 | Fe2O3 | SI1 | 159.6922 | 5.2400 | 0.0000 |
| 7   | Fe3O4 | Fe3O4 | SI1 | 231.5386 | 5.1800 | 0.0000 |
| 8   | H2    | H2    | GC8 | 2.0159   | 0.0001 | 0.0000 |
| 9   | H2O   | H2O   | LI3 | 18.0153  | 1.0000 | 0.0000 |
| 10  | H2O   | H2O   | GC8 | 18.0153  | 0.0008 | 0.0000 |
| 11  | N2    | N2    | GC8 | 28.0134  | 0.0012 | 0.0000 |
| 12  | O2    | O2    | GC8 | 31.9988  | 0.0014 | 0.0000 |
| 13  | C5H8  | C5H8  | GC8 | 68.1195  | 0.0030 | 0.0000 |
| 14  | Al2O3 | Al2O3 | SI1 | 101.9612 | 3.9650 | 0.0000 |
| 15  | CaO   | CaO   | SI1 | 56.0794  | 3.3100 | 0.0000 |
| 16  | MgO   | MgO   | SI1 | 40.3114  | 3.5800 | 0.0000 |
| 17  | SiO2  | SiO2  | SI1 | 60.0848  | 2.6500 | 0.0000 |
| 18  | CH4   | CH4   | GC8 | 16.0430  | 0.0007 | 0.0000 |
| 19  | Al2O3 | Al2O3 | M37 | 101.9612 | 1.0000 | 0.0000 |
| 20  | CaO   | CaO   | M37 | 56.0794  | 3.3100 | 0.0000 |
| 21  | MgO   | MgO   | M37 | 40.3114  | 3.5800 | 0.0000 |
| 22  | SiO2  | SiO2  | M37 | 60.0848  | 2.6500 | 0.0000 |
| 23  | FeO   | FeO   | M37 | 71.8464  | 5.7000 | 0.0000 |

| ROW | CNM   | REFERENCE | H25     | HTE-A  | HTE-B   | HTE-C   | HTE-D   |
|-----|-------|-----------|---------|--------|---------|---------|---------|
| 1   | C     | B672086   | 0       | -2999  | 5.1802  | 0.2246  | 4.3597  |
| 2   | CO    | B672093   | -26417  | -2962  | 7.7460  | 0.2285  | 1.9749  |
| 3   | CO2   | B672094   | -94051  | -5911  | 12.9357 | 0.3891  | 6.1869  |
| 4   | Fe    | B672151   | 0       | -7903  | 14.0914 | -1.3293 | 11.6233 |
| 5   | FeO   | B672157   | -65000  | -3998  | 12.1207 | 1.0479  | 0.8685  |
| 6   | Fe2O3 | B672158   | -197000 | -20749 | 46.1517 | -3.8751 | 21.9462 |
| 7   | Fe3O4 | B672160   | -267300 | -31312 | 71.0525 | -7.8736 | 32.0732 |
| 8   | H2    | B672174   | 0       | -1837  | 6.3659  | 0.4428  | -0.2847 |
| 9   | H2O   | B672180   | -68315  | -5071  | 16.1848 | 2.7637  | 0.0000  |
| 10  | H2O   | B672182   | -57795  | -2403  | 7.2906  | 1.3003  | 0.3596  |
| 11  | N2    | B672244   | 0       | -2846  | 7.5728  | 0.2525  | 1.7794  |
| 12  | O2    | B672277   | 0       | -2979  | 7.9696  | 0.2720  | 1.7697  |
| 13  | C5H8  | BAK1132B  | -34800  | -17182 | 34.9823 | 9.5671  | 17.7272 |
| 14  | Al2O3 | B672042   | -400500 | -12425 | 28.9653 | 1.0071  | 11.1085 |
| 15  | CaO   | B672098   | -151790 | -4315  | 12.0730 | 0.4606  | 2.0088  |
| 16  | MgO   | B672227   | -143760 | -4612  | 11.8081 | 0.3610  | 3.1765  |
| 17  | SiO2  | B672387   | -217720 | -8654  | 19.1651 | -0.5456 | 8.8977  |
| 18  | CH4   | B6772217  | -17880  | -6424  | 11.8424 | 2.9907  | 8.0422  |
| 19  | Al2O3 | B672042   | -400500 | -19492 | 46.0000 | 0.0000  | 0.0000  |
| 20  | CaO   | B672098   | -151790 | -4315  | 12.0730 | 0.4606  | 2.0088  |
| 21  | MgO   | B672227   | -143760 | -4612  | 11.8081 | 0.3610  | 3.1765  |
| 22  | SiO2  | BAR1359   | -217700 | -6112  | 20.5000 | 0.0000  | 0.0000  |
| 23  | FeO   | B672157   | -65000  | -3998  | 12.1207 | 1.0479  | 0.8685  |

HISMELT PROCESS

INPUT DATA

| ROW | CNM   | TEMP   | RANGE  | oK | HTG-A   | HTG-B    | HTG-C    | HTG-D     |
|-----|-------|--------|--------|----|---------|----------|----------|-----------|
| 1   | C     | 298.2  | 3000.0 |    | 2405    | -3.3866  | -1.5836  | -5.1587   |
| 2   | CO    | 298.2  | 3000.0 |    | -21272  | -52.8075 | -2.2569  | -10.0674  |
| 3   | CO2   | 298.2  | 3000.0 |    | -86430  | -58.7976 | -3.7771  | -15.3476  |
| 4   | Fe    | 298.2  | 1811.0 |    | 2679    | -8.2139  | -4.0925  | -5.4957   |
| 5   | FeO   | 298.2  | 1600.0 |    | -60048  | -19.0598 | -5.9536  | -9.2221   |
| 6   | Fe2O3 | 298.2  | 1800.0 |    | -182323 | -34.6418 | -13.7715 | -28.2755  |
| 7   | Fe3O4 | 298.2  | 1800.0 |    | -243067 | -58.6967 | -18.9430 | -46.8195  |
| 8   | H2    | 298.2  | 3000.0 |    | 4863    | -36.6465 | -2.1036  | -9.3536   |
| 9   | H2O   | 298.2  | 373.2  |    | -70630  | -1.0739  | -26.4253 | 0.0000    |
| 10  | H2O   | 298.2  | 2000.0 |    | -54212  | -48.4557 | -3.8711  | -6.7579   |
| 11  | N2    | 298.2  | 3000.0 |    | 5078    | -51.3044 | -2.2358  | -9.9139   |
| 12  | O2    | 298.2  | 3000.0 |    | 5395    | -54.8302 | -2.3535  | -10.5960  |
| 13  | C5H8  | 298.2  | 1500.0 |    | -27854  | -78.1190 | -24.7443 | -15.6889  |
| 14  | Al2O3 | 298.2  | 2327.0 |    | -386441 | -25.8901 | -10.0349 | -27.6544  |
| 15  | CaO   | 298.2  | 2000.0 |    | -146099 | -14.8629 | -4.7096  | -10.7418  |
| 16  | MgO   | 298.2  | 2000.0 |    | -138544 | -11.5487 | -4.4916  | -9.9661   |
| 17  | SiO2  | 298.2  | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464  |
| 18  | CH4   | 298.2  | 2000.0 |    | -14673  | -45.4106 | -7.1789  | -6.9854   |
| 19  | Al2O3 | 2327.0 | 2500.0 |    | -364648 | -36.7635 | -9.5560  | 0.0000    |
| 20  | CaO   | 298.2  | 2000.0 |    | -146099 | -14.8629 | -4.7096  | -10.7418  |
| 21  | MgO   | 298.2  | 2000.0 |    | -138544 | -11.5487 | -4.4916  | -9.9661   |
| 22  | SiO2  | 1996.0 | 3000.0 |    | -177514 | -35.2811 | -2.7700  | -203.7107 |
| 23  | FeO   | 298.2  | 1600.0 |    | -60048  | -19.0598 | -5.9536  | -9.2221   |

| ROW | CNM   | PRES | RANGE | kPa |
|-----|-------|------|-------|-----|
| 1   | C     | 0.0  | 0.0   |     |
| 2   | CO    | 0.0  | 0.0   |     |
| 3   | CO2   | 0.0  | 0.0   |     |
| 4   | Fe    | 0.0  | 0.0   |     |
| 5   | FeO   | 0.0  | 0.0   |     |
| 6   | Fe2O3 | 0.0  | 0.0   |     |
| 7   | Fe3O4 | 0.0  | 0.0   |     |
| 8   | H2    | 0.0  | 0.0   |     |
| 9   | H2O   | 0.0  | 0.0   |     |
| 10  | H2O   | 50.0 | 120.0 |     |
| 11  | N2    | 0.0  | 0.0   |     |
| 12  | O2    | 0.0  | 0.0   |     |
| 13  | C5H8  | 0.0  | 0.0   |     |
| 14  | Al2O3 | 0.0  | 0.0   |     |
| 15  | CaO   | 0.0  | 0.0   |     |
| 16  | MgO   | 0.0  | 0.0   |     |
| 17  | SiO2  | 0.0  | 0.0   |     |
| 18  | CH4   | 0.0  | 0.0   |     |
| 19  | Al2O3 | 0.0  | 0.0   |     |
| 20  | CaO   | 0.0  | 0.0   |     |
| 21  | MgO   | 0.0  | 0.0   |     |
| 22  | SiO2  | 0.0  | 0.0   |     |
| 23  | FeO   | 0.0  | 0.0   |     |

| FLOL      |                            | FLO |     |     |     |     |     |     |     |     |     |     |     |     |   |
|-----------|----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---|
| TYP LABEL |                            | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  |   |
| NO        | OPR UNIT PROCESS           | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |   |
| 1         | SEC HISMELT PROCESS        |     |     | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0 |
| 2         | MIX ORE PREHEATER          |     |     | 1   | 10  | 0   | 0   | 0   | 0   | 0   | 2   | 0   | 0   | 0   | 0 |
| 3         | SPP GAS SEPARATOR          |     |     | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 3   | 21  | 0   | 0   | 0 |
| 4         | SPP CYCLONE                |     |     | 21  | 0   | 0   | 0   | 0   | 0   | 0   | 22  | 23  | 0   | 0   | 0 |
| 5         | MIX MIXER                  |     |     | 3   | 22  | 0   | 0   | 0   | 0   | 0   | 4   | 0   | 0   | 0   | 0 |
| 6         | SPP SMELT REDUCTION VESSEL |     |     | 4   | 5   | 6   | 20  | 0   | 0   | 0   | 9   | 8   | 7   | 0   | 0 |
| 7         | SPS STREAM DIVIDER         |     |     | 7   | 0   | 0   | 0   | 0   | 0   | 0   | 10  | 11  | 0   | 0   | 0 |
| 8         | SPS COOLER                 |     |     | 11  | 0   | 0   | 0   | 0   | 0   | 0   | 12  | 0   | 0   | 0   | 0 |
| 9         | HTX H/E                    |     |     | 12  | 13  | 0   | 15  | 0   | 0   | 0   | 24  | 16  | 0   | 0   | 0 |
| 10        | FEM BURNER                 |     |     | 24  | 0   | 0   | 0   | 0   | 0   | 0   | 14  | 0   | 0   | 0   | 0 |
| 11        | HTX HOT BLAST              |     |     | 19  | 0   | 0   | 14  | 0   | 0   | 0   | 20  | 15  | 0   | 0   | 0 |
| 12        | MIX COMPRESSOR             |     |     | 17  | 18  | 0   | 0   | 0   | 0   | 0   | 19  | 0   | 0   | 0   | 0 |

## HISMELT PROCESS

| HEAT BALANCE SUMMARY - 1000 KCAL/HOUR |                 |               |               |                 |              |               |                  |       |
|---------------------------------------|-----------------|---------------|---------------|-----------------|--------------|---------------|------------------|-------|
| OP PROCESS STEP                       | INPUT<br>STREAM | HEAT<br>REACT | HEAT<br>SOLUT | ENERGY<br>INPUT | HEAT<br>LOSS | HEAT<br>REQRD | OUTPUT<br>STREAM | TOTAL |
| 1 HISMELT PROCESS                     | 0               | 0             | 0             | 0               | 0            | 0             | 0                | 0     |
| 2 ORE PREHEATER                       | 44004           | -10666        | 0             | 0               | 0            | 37698         | -71036           | 0     |
| 3 GAS SEPARATOR                       | 71036           | 0             | 0             | 0               | 0            | 0             | -71036           | 0     |
| 4 CYCLONE                             | 32549           | 0             | 0             | 0               | 0            | 0             | -32549           | 0     |
| 5 MIXER                               | 40512           | 0             | 0             | 0               | 0            | 0             | -40512           | 0     |
| 6 SMELT REDUCTION                     | 155456          | 189782        | 0             | 0               | -34524       | 0             | -310714          | 0     |
| 7 STREAM DIVIDER                      | 231087          | 0             | 0             | 0               | 0            | -85725        | -145362          | 0     |
| 8 COOLER                              | 101753          | 0             | 0             | 0               | 0            | -100619       | -1134            | 0     |
| 9 H/E                                 | 220900          | 0             | 0             | 0               | 0            | 0             | -220900          | 0     |
| 10 BURNER                             | 109076          | 223286        | 0             | 0               | 0            | 0             | -332362          | 0     |
| 11 HOT BLAST                          | 333416          | 0             | 0             | 0               | 0            | 0             | -333416          | 0     |
| 12 COMPRESSOR                         | 1054            | 0             | 0             | 0               | 0            | 0             | -1054            | 0     |



HISMELT PROCESS

| NO. STREAM                 | STREAM TEMPERATURES AND ENTHALPIES |         |              |              |              |
|----------------------------|------------------------------------|---------|--------------|--------------|--------------|
|                            | TEMP-C                             | TEMP-F  | KCAL/HR      | BTU/HR       | KJ/HR        |
| 1 ORE FINES                | 35.00                              | 95.00   | 395334.00    | 1568813.0    | 1654079.0    |
| 2 HOT ORE FINES+GASES      | 700.00                             | 1292.00 | 71035713.00  | 281892490.0  | 297213423.0  |
| 3 PREHEATED COARSE ORE     | 700.00                             | 1292.00 | 38486540.00  | 152726934.0  | 161027684.0  |
| 4 PREHEATED ORE            | 700.00                             | 1292.00 | 40512147.00  | 160765193.0  | 169502825.0  |
| 5 NATURAL GAS              | 35.00                              | 95.00   | 79954.00     | 317282.0     | 334526.0     |
| 6 COAL FLUX                | 35.00                              | 95.00   | 343801.00    | 1364311.0    | 1438461.0    |
| 7 HOT SRV GAS              | 1504.68                            | 2740.42 | 231087283.00 | 917028450.0  | 966869193.0  |
| 8 SLAG                     | 1504.68                            | 2740.42 | 27827718.00  | 110429308.0  | 116431171.0  |
| 9 HOT METAL                | 1504.68                            | 2740.42 | 51798975.00  | 205554945.0  | 216726912.0  |
| 10 HOT GASES FOR PREHEATER | 1000.00                            | 1832.00 | 43608595.00  | 173052891.0  | 182458362.0  |
| 11 HOT GASES TO COOLER     | 1000.00                            | 1832.00 | 101753389.00 | 403790078.0  | 425736178.0  |
| 12 COLD SRV GAS            | 35.00                              | 95.00   | 1134438.00   | 4501815.0    | 4746489.0    |
| 13 COMBUSTION AIR          | 35.00                              | 95.00   | 870306.00    | 3453654.0    | 3641361.0    |
| 14                         | 1786.91                            | 3248.44 | 332361759.00 | 1318918047.0 | 1390601598.0 |
| 15 BURNT SRV GAS           | 1216.97                            | 2222.54 | 218895751.00 | 868648541.0  | 915859824.0  |
| 16 FLUE                    | 653.48                             | 1208.26 | 111824590.00 | 443755837.0  | 467874086.0  |
| 17 PROCESS AIR             | 35.00                              | 95.00   | 939768.00    | 3729300.0    | 3931989.0    |
| 18 OXYGEN                  | 35.00                              | 95.00   | 114372.00    | 453864.0     | 478531.0     |
| 19 O2 ENRICHED PROCESS AIR | 35.00                              | 95.00   | 1054140.00   | 4183164.0    | 4410520.0    |
| 20 HOT AIR BLAST           | 1216.97                            | 2222.54 | 114520147.00 | 454452670.0  | 479152295.0  |
| 21 FINES+GAS               | 700.00                             | 1292.00 | 32549173.00  | 129165557.0  | 136185739.0  |
| 22 PREHEATED FINES         | 700.00                             | 1292.00 | 2025607.00   | 8038260.0    | 8475141.0    |
| 23 GASES                   | 700.00                             | 1292.00 | 30523566.00  | 121127297.0  | 127710598.0  |
| 24                         | 653.48                             | 1208.26 | 109075905.00 | 432848171.0  | 456373586.0  |

HISMELT PROCESS

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM                 | TIME     | ACFM    | SCFM     | M3/HR   | NM3/HR   |
|----------------------------|----------|---------|----------|---------|----------|
| 2 HOT ORE FINES+GASES      | 100.0000 | 252319  | 70846.4  | 428692  | 120368.8 |
| 5 NATURAL GAS              | 100.0000 | 9960    | 8828.3   | 16921   | 14999.5  |
| 7 HOT SRV GAS              | 100.0000 | 1421399 | 218387.1 | 2414973 | 371042.1 |
| 10 HOT GASES FOR PREHEATER | 100.0000 | 305370  | 65516.1  | 518827  | 111312.6 |
| 11 HOT GASES TO COOLER     | 100.0000 | 712530  | 152871.0 | 1210597 | 259729.4 |
| 12 COLD SRV GAS            | 100.0000 | 156448  | 152871.0 | 265806  | 259729.4 |
| 13 COMBUSTION AIR          | 100.0000 | 150040  | 132998.0 | 254919  | 225965.1 |
| 14                         | 100.0000 | 1984885 | 263187.4 | 3372342 | 447158.3 |
| 15 BURNT SRV GAS           | 100.0000 | 1435747 | 263187.4 | 2439350 | 447158.3 |
| 16 FLUE                    | 100.0000 | 892829  | 263187.4 | 1516926 | 447158.3 |
| 17 PROCESS AIR             | 100.0000 | 162015  | 143613.0 | 275265  | 244000.0 |
| 18 OXYGEN                  | 100.0000 | 22031   | 19528.5  | 37430   | 33179.1  |
| 19 O2 ENRICHED PROCESS AIR | 100.0000 | 184046  | 163141.4 | 312695  | 277179.1 |
| 20 HOT AIR BLAST           | 100.0000 | 889985  | 163141.4 | 1512095 | 277179.1 |
| 21 FINES+GAS               | 100.0000 | 252287  | 70814.8  | 428639  | 120315.1 |
| 23 GASES                   | 100.0000 | 252286  | 70813.1  | 428636  | 120312.3 |
| 24                         | 100.0000 | 969775  | 285869.0 | 1647658 | 485694.5 |

VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM             | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|------------------------|----------|----------|----------|----------|----------|
| 1 ORE FINES            | 100.0000 | 255.6245 | 16.12749 | 58.05898 | 1393.415 |
| 3 PREHEATED COARSE ORE | 100.0000 | 236.3926 | 14.91414 | 53.69092 | 1288.582 |
| 4 PREHEATED ORE        | 100.0000 | 248.8343 | 15.69910 | 56.51675 | 1356.402 |
| 6 COAL FLUX            | 100.0000 | 253.2074 | 15.97500 | 57.51000 | 1380.240 |
| 8 SLAG                 | 100.0000 | 98.4709  | 6.21259  | 22.36531 | 536.767  |
| 9 HOT METAL            | 100.0000 | 125.3485 | 7.90831  | 28.46991 | 683.278  |
| 22 PREHEATED FINES     | 100.0000 | 12.4417  | 0.78495  | 2.82584  | 67.820   |

MASS FLOW RATES - KG/HR

| NO. STREAM                 | KG/HR-SI | KG/HR-LI | KG/HR-M3 | KG/HR-GC | KG/HR-TC |
|----------------------------|----------|----------|----------|----------|----------|
| 1 ORE FINES                | 287000.0 | 0.00     | 0.00     | 0.0      | 287000.0 |
| 2 HOT ORE FINES+GASES      | 277873.6 | 0.00     | 0.00     | 166931.8 | 444805.4 |
| 3 PREHEATED COARSE ORE     | 263979.9 | 0.00     | 0.00     | 0.0      | 263979.9 |
| 4 PREHEATED ORE            | 277873.6 | 0.00     | 0.00     | 0.0      | 277873.6 |
| 5 NATURAL GAS              | 0.0      | 0.00     | 0.00     | 10736.0  | 10736.0  |
| 6 COAL FLUX                | 142000.0 | 0.00     | 0.00     | 0.0      | 142000.0 |
| 7 HOT SRV GAS              | 0.0      | 0.00     | 0.00     | 526017.9 | 526017.9 |
| 8 SLAG                     | 0.0      | 0.00     | 67737.33 | 0.0      | 67737.3  |
| 9 HOT METAL                | 197300.1 | 0.00     | 0.00     | 0.0      | 197300.1 |
| 10 HOT GASES FOR PREHEATER | 0.0      | 0.00     | 0.00     | 157805.4 | 157805.4 |
| 11 HOT GASES TO COOLER     | 0.0      | 0.00     | 0.00     | 368212.5 | 368212.5 |
| 12 COLD SRV GAS            | 0.0      | 0.00     | 0.00     | 368212.5 | 368212.5 |
| 13 COMBUSTION AIR          | 0.0      | 0.00     | 0.00     | 290000.0 | 290000.0 |
| 14                         | 0.0      | 14325.03 | 0.00     | 643887.5 | 658212.5 |
| 15 BURNT SRV GAS           | 0.0      | 14325.03 | 0.00     | 643887.5 | 658212.5 |
| 16 FLUE                    | 0.0      | 14325.03 | 0.00     | 643887.5 | 658212.5 |
| 17 PROCESS AIR             | 0.0      | 0.00     | 0.00     | 313145.7 | 313145.7 |
| 18 OXYGEN                  | 0.0      | 0.00     | 0.00     | 47300.0  | 47300.0  |
| 19 O2 ENRICHED PROCESS AIR | 0.0      | 0.00     | 0.00     | 360445.7 | 360445.7 |
| 20 HOT AIR BLAST           | 0.0      | 0.00     | 0.00     | 360445.7 | 360445.7 |
| 21 FINES+GAS               | 13893.7  | 0.00     | 0.00     | 166931.8 | 180825.5 |
| 22 PREHEATED FINES         | 13893.7  | 0.00     | 0.00     | 0.0      | 13893.7  |
| 23 GASES                   | 0.0      | 0.00     | 0.00     | 166931.8 | 166931.8 |
| 24                         | 0.0      | 0.00     | 0.00     | 658212.5 | 658212.5 |

## HISMELT PROCESS

## SPECIFIC GRAVITIES

| NO. STREAM                 | PCS      | SG-SI  | SG-LI  | SG-M3  | SG-GC  | SG-TC  |
|----------------------------|----------|--------|--------|--------|--------|--------|
| 1 ORE FINES                | 100.0000 | 4.9432 | 0.0000 | 0.0000 | 0.0000 | 4.9432 |
| 2 HOT ORE FINES+GASES      | 62.4708  | 4.9167 | 0.0000 | 0.0000 | 0.0004 | 0.0010 |
| 3 PREHEATED COARSE ORE     | 100.0000 | 4.9167 | 0.0000 | 0.0000 | 0.0000 | 4.9167 |
| 4 PREHEATED ORE            | 100.0000 | 4.9167 | 0.0000 | 0.0000 | 0.0000 | 4.9167 |
| 5 NATURAL GAS              | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 6 COAL FLUX                | 100.0000 | 2.4691 | 0.0000 | 0.0000 | 0.0000 | 2.4691 |
| 7 HOT SRV GAS              | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 8 SLAG                     | 0.0000   | 0.0000 | 0.0000 | 3.0287 | 0.0000 | 3.0287 |
| 9 HOT METAL                | 100.0000 | 6.9301 | 0.0000 | 0.0000 | 0.0000 | 6.9301 |
| 10 HOT GASES FOR PREHEATER | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 11 HOT GASES TO COOLER     | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 12 COLD SRV GAS            | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0014 | 0.0014 |
| 13 COMBUSTION AIR          | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0011 | 0.0011 |
| 14                         | 0.0000   | 0.0000 | 0.3154 | 0.0000 | 0.0002 | 0.0002 |
| 15 BURNT SRV GAS           | 0.0000   | 0.0000 | 0.3154 | 0.0000 | 0.0003 | 0.0003 |
| 16 FLUE                    | 0.0000   | 0.0000 | 0.3154 | 0.0000 | 0.0004 | 0.0004 |
| 17 PROCESS AIR             | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0011 | 0.0011 |
| 18 OXYGEN                  | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0013 | 0.0013 |
| 19 O2 ENRICHED PROCESS AIR | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 20 HOT AIR BLAST           | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 21 FINES+GAS               | 7.6835   | 4.9167 | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 22 PREHEATED FINES         | 100.0000 | 4.9167 | 0.0000 | 0.0000 | 0.0000 | 4.9167 |
| 23 GASES                   | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 24                         | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0004 |

## HISMELT PROCESS

## STREAM DATA

## SOLIDS - KG/HR

| NO. STREAM             | C       | Fe     | FeO     | Fe2O3  | Fe3O4  | Al2O3   | CaO     |
|------------------------|---------|--------|---------|--------|--------|---------|---------|
| 1 ORE FINES            | 0.0     | 0      | 0.0     | 235340 | 34440  | 0.00000 | 0.0     |
| 2 HOT ORE FINES+GASES  | 0.0     | 0      | 17067.5 | 0      | 243586 | 0.00000 | 0.0     |
| 3 PREHEATED COARSE ORE | 0.0     | 0      | 16214.1 | 0      | 231407 | 0.00000 | 0.0     |
| 4 PREHEATED ORE        | 0.0     | 0      | 17067.5 | 0      | 243586 | 0.00000 | 0.0     |
| 6 COAL FLUX            | 95140.0 | 0      | 0.0     | 0      | 0      | 0.00000 | 32660.0 |
| 9 HOT METAL            | 10617.7 | 186682 | 0.0     | 0      | 0      | 0.00000 | 0.0     |
| 21 FINES+GAS           | 0.0     | 0      | 853.4   | 0      | 12179  | 0.00000 | 0.0     |
| 22 PREHEATED FINES     | 0.0     | 0      | 853.4   | 0      | 12179  | 0.00000 | 0.0     |

## SOLIDS - KG/HR

| NO. STREAM             | MgO     | SiO2    |
|------------------------|---------|---------|
| 1 ORE FINES            | 0.00000 | 17220.0 |
| 2 HOT ORE FINES+GASES  | 0.00000 | 17220.0 |
| 3 PREHEATED COARSE ORE | 0.00000 | 16359.0 |
| 4 PREHEATED ORE        | 0.00000 | 17220.0 |
| 6 COAL FLUX            | 0.00000 | 14200.0 |
| 21 FINES+GAS           | 0.00000 | 861.0   |
| 22 PREHEATED FINES     | 0.00000 | 861.0   |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM             | C       | Fe      | FeO     | Fe2O3   | Fe3O4   | Al2O3   | CaO     |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 ORE FINES            | 0.0000  | 0.0000  | 0.00000 | 82.0000 | 12.0000 | 0.00000 | 0.0000  |
| 2 HOT ORE FINES+GASES  | 0.0000  | 0.0000  | 6.14219 | 0.0000  | 87.6607 | 0.00000 | 0.0000  |
| 3 PREHEATED COARSE ORE | 0.0000  | 0.0000  | 6.14219 | 0.0000  | 87.6607 | 0.00000 | 0.0000  |
| 4 PREHEATED ORE        | 0.0000  | 0.0000  | 6.14219 | 0.0000  | 87.6607 | 0.00000 | 0.0000  |
| 6 COAL FLUX            | 67.0000 | 0.0000  | 0.00000 | 0.0000  | 0.0000  | 0.00000 | 23.0000 |
| 9 HOT METAL            | 5.3815  | 94.6185 | 0.00000 | 0.0000  | 0.0000  | 0.00000 | 0.0000  |
| 21 FINES+GAS           | 0.0000  | 0.0000  | 6.14219 | 0.0000  | 87.6607 | 0.00000 | 0.0000  |
| 22 PREHEATED FINES     | 0.0000  | 0.0000  | 6.14219 | 0.0000  | 87.6607 | 0.00000 | 0.0000  |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM             | MgO     | SiO2    |
|------------------------|---------|---------|
| 1 ORE FINES            | 0.00000 | 6.0000  |
| 2 HOT ORE FINES+GASES  | 0.00000 | 6.1971  |
| 3 PREHEATED COARSE ORE | 0.00000 | 6.1971  |
| 4 PREHEATED ORE        | 0.00000 | 6.1971  |
| 6 COAL FLUX            | 0.00000 | 10.0000 |
| 21 FINES+GAS           | 0.00000 | 6.1971  |
| 22 PREHEATED FINES     | 0.00000 | 6.1971  |

## AQUEOUS - KG/HR

| NO. STREAM       | H2O     |
|------------------|---------|
| 14               | 14325.0 |
| 15 BURNT SRV GAS | 14325.0 |
| 16 FLUE          | 14325.0 |

## AQUEOUS - WEIGHT PERCENT

| NO. STREAM       | H2O     |
|------------------|---------|
| 14               | 100.000 |
| 15 BURNT SRV GAS | 100.000 |
| 16 FLUE          | 100.000 |

## AQUEOUS - GRAMS PER LITER

| NO. STREAM       | H2O     |
|------------------|---------|
| 14               | 315.448 |
| 15 BURNT SRV GAS | 315.448 |
| 16 FLUE          | 315.448 |

## HISMELT PROCESS

## STREAM DATA

## MOLTEN3 - KG/HR

| NO. STREAM | Al2O3   | CaO     | MgO     | SiO2    | FeO     |
|------------|---------|---------|---------|---------|---------|
| 8 SLAG     | 0.00000 | 32660.0 | 0.00000 | 31420.0 | 3657.33 |

## MOLTEN3 - WEIGHT PERCENT

| NO. STREAM | Al2O3   | CaO     | MgO     | SiO2    | FeO     |
|------------|---------|---------|---------|---------|---------|
| 8 SLAG     | 0.00000 | 48.2157 | 0.00000 | 46.3851 | 5.39928 |

## GASEOUS - KG/HR

| NO. STREAM                 | CO      | CO2    | H2      | H2O     | N2     | O2     | C5H8    |
|----------------------------|---------|--------|---------|---------|--------|--------|---------|
| 2 HOT ORE FINES+GASES      | 28718.7 | 56622  | 0.00000 | 7233.52 | 74357  | 0      | 0.00000 |
| 7 HOT SRV GAS              | 74009.7 | 193414 | 0.00000 | 0.00    | 247858 | 0      | 0.00000 |
| 10 HOT GASES FOR PREHEATER | 22202.9 | 58024  | 0.00000 | 0.00    | 74357  | 0      | 0.00000 |
| 11 HOT GASES TO COOLER     | 51806.8 | 135390 | 0.00000 | 0.00    | 173501 | 0      | 0.00000 |
| 12 COLD SRV GAS            | 51806.8 | 135390 | 0.00000 | 0.00    | 173501 | 0      | 0.00000 |
| 13 COMBUSTION AIR          | 0.0     | 0      | 0.00000 | 0.00    | 229100 | 60900  | 0.00000 |
| 14                         | 0.0     | 237404 | 0.00000 | 2553.18 | 402601 | 1329   | 0.00000 |
| 15 BURNT SRV GAS           | 0.0     | 237404 | 0.00000 | 2553.18 | 402601 | 1329   | 0.00000 |
| 16 FLUE                    | 0.0     | 237404 | 0.00000 | 2553.18 | 402601 | 1329   | 0.00000 |
| 17 PROCESS AIR             | 0.0     | 0      | 0.00000 | 0.00    | 247385 | 65761  | 0.00000 |
| 18 OXYGEN                  | 0.0     | 0      | 0.00000 | 0.00    | 473    | 46827  | 0.00000 |
| 19 O2 ENRICHED PROCESS AIR | 0.0     | 0      | 0.00000 | 0.00    | 247858 | 112588 | 0.00000 |
| 20 HOT AIR BLAST           | 0.0     | 0      | 0.00000 | 0.00    | 247858 | 112588 | 0.00000 |
| 21 FINES+GAS               | 28718.7 | 56622  | 0.00000 | 7233.52 | 74357  | 0      | 0.00000 |
| 23 GASES                   | 28718.7 | 56622  | 0.00000 | 7233.52 | 74357  | 0      | 0.00000 |
| 24                         | 51806.8 | 135390 | 0.00000 | 0.00    | 402601 | 60900  | 0.00000 |

## GASEOUS - KG/HR

| NO. STREAM                 | CH4     |
|----------------------------|---------|
| 5 NATURAL GAS              | 10736.0 |
| 7 HOT SRV GAS              | 10736.0 |
| 10 HOT GASES FOR PREHEATER | 3220.8  |
| 11 HOT GASES TO COOLER     | 7515.2  |
| 12 COLD SRV GAS            | 7515.2  |
| 24                         | 7515.2  |

## GASEOUS - WEIGHT PERCENT

| NO. STREAM                 | CO      | CO2     | H2      | H2O     | N2      | O2      | C5H8    |
|----------------------------|---------|---------|---------|---------|---------|---------|---------|
| 2 HOT ORE FINES+GASES      | 17.2038 | 33.9193 | 0.00000 | 4.33322 | 44.5436 | 0.0000  | 0.00000 |
| 7 HOT SRV GAS              | 14.0698 | 36.7695 | 0.00000 | 0.00000 | 47.1197 | 0.0000  | 0.00000 |
| 10 HOT GASES FOR PREHEATER | 14.0698 | 36.7695 | 0.00000 | 0.00000 | 47.1197 | 0.0000  | 0.00000 |
| 11 HOT GASES TO COOLER     | 14.0698 | 36.7695 | 0.00000 | 0.00000 | 47.1197 | 0.0000  | 0.00000 |
| 12 COLD SRV GAS            | 14.0698 | 36.7695 | 0.00000 | 0.00000 | 47.1197 | 0.0000  | 0.00000 |
| 13 COMBUSTION AIR          | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 79.0000 | 21.0000 | 0.00000 |
| 14                         | 0.0000  | 36.8705 | 0.00000 | 0.39653 | 62.5266 | 0.2065  | 0.00000 |
| 15 BURNT SRV GAS           | 0.0000  | 36.8705 | 0.00000 | 0.39653 | 62.5266 | 0.2065  | 0.00000 |
| 16 FLUE                    | 0.0000  | 36.8705 | 0.00000 | 0.39653 | 62.5266 | 0.2065  | 0.00000 |
| 17 PROCESS AIR             | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 79.0000 | 21.0000 | 0.00000 |
| 18 OXYGEN                  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 1.0000  | 99.0000 | 0.00000 |
| 19 O2 ENRICHED PROCESS AIR | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 68.7643 | 31.2357 | 0.00000 |
| 20 HOT AIR BLAST           | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 68.7643 | 31.2357 | 0.00000 |
| 21 FINES+GAS               | 17.2038 | 33.9193 | 0.00000 | 4.33322 | 44.5436 | 0.0000  | 0.00000 |
| 23 GASES                   | 17.2038 | 33.9193 | 0.00000 | 4.33322 | 44.5436 | 0.0000  | 0.00000 |
| 24                         | 7.8708  | 20.5693 | 0.00000 | 0.00000 | 61.1658 | 9.2523  | 0.00000 |

HISMELT PROCESS

STREAM DATA

GASEOUS - WEIGHT PERCENT

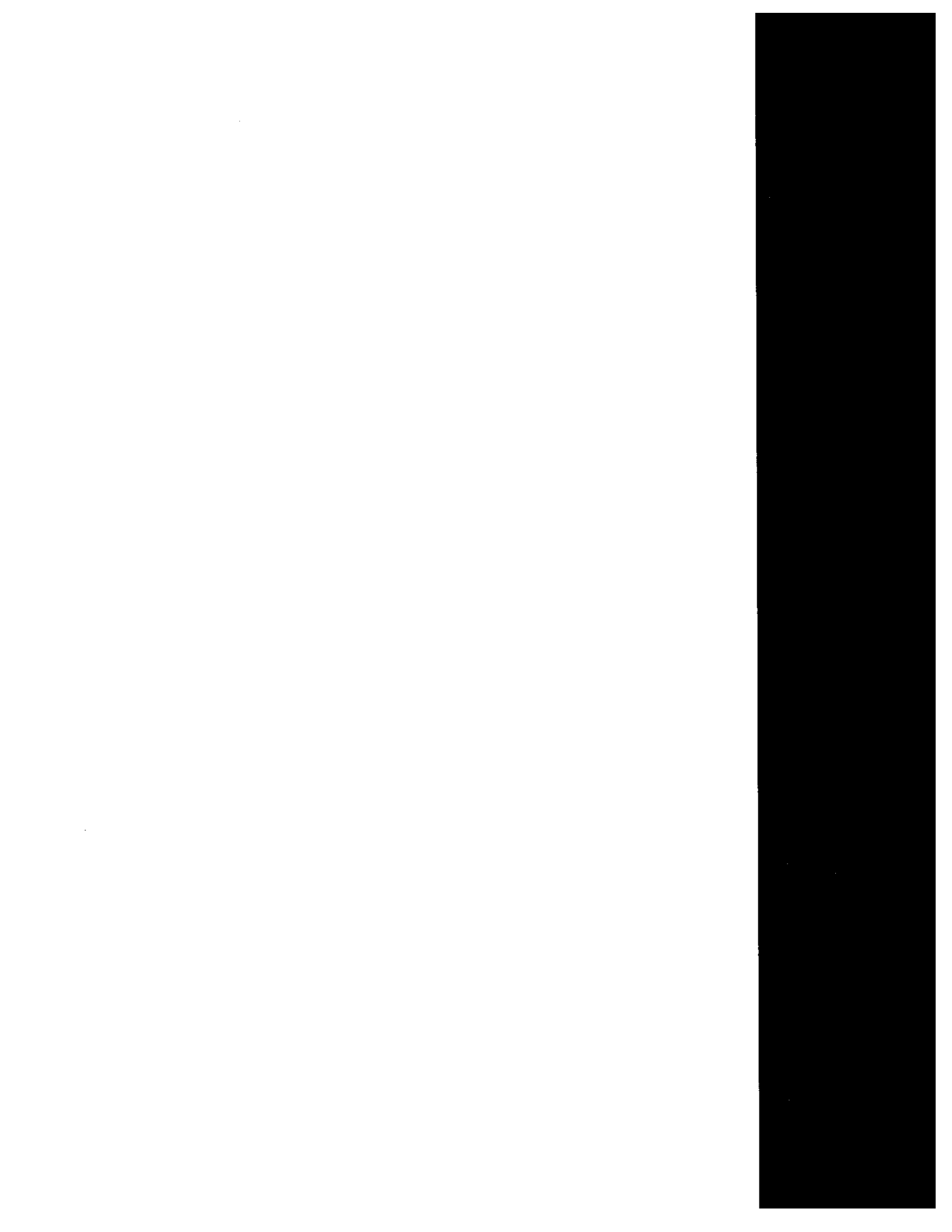
| NO. STREAM                 | CH4     |
|----------------------------|---------|
| 5 NATURAL GAS              | 100.000 |
| 7 HOT SRV GAS              | 2.041   |
| 10 HOT GASES FOR PREHEATER | 2.041   |
| 11 HOT GASES TO COOLER     | 2.041   |
| 12 COLD SRV GAS            | 2.041   |
| 24                         | 1.142   |

GASEOUS - VOLUME PERCENT

| NO. STREAM                 | CO      | CO2     | H2      | H2O     | N2      | O2      | C5H8    |
|----------------------------|---------|---------|---------|---------|---------|---------|---------|
| 2 HOT ORE FINES+GASES      | 19.1008 | 23.9687 | 0.00000 | 7.48026 | 49.4502 | 0.0000  | 0.00000 |
| 7 HOT SRV GAS              | 15.9611 | 26.5481 | 0.00000 | 0.00000 | 53.4483 | 0.0000  | 0.00000 |
| 10 HOT GASES FOR PREHEATER | 15.9611 | 26.5481 | 0.00000 | 0.00000 | 53.4483 | 0.0000  | 0.00000 |
| 11 HOT GASES TO COOLER     | 15.9611 | 26.5481 | 0.00000 | 0.00000 | 53.4483 | 0.0000  | 0.00000 |
| 12 COLD SRV GAS            | 15.9611 | 26.5481 | 0.00000 | 0.00000 | 53.4483 | 0.0000  | 0.00000 |
| 13 COMBUSTION AIR          | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 81.1218 | 18.8782 | 0.00000 |
| 14                         | 0.0000  | 27.0402 | 0.00000 | 0.71041 | 72.0412 | 0.2082  | 0.00000 |
| 15 BURNT SRV GAS           | 0.0000  | 27.0402 | 0.00000 | 0.71041 | 72.0412 | 0.2082  | 0.00000 |
| 16 FLUE                    | 0.0000  | 27.0402 | 0.00000 | 0.71041 | 72.0412 | 0.2082  | 0.00000 |
| 17 PROCESS AIR             | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 81.1218 | 18.8782 | 0.00000 |
| 18 OXYGEN                  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 1.1406  | 98.8594 | 0.00000 |
| 19 O2 ENRICHED PROCESS AIR | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 71.5478 | 28.4522 | 0.00000 |
| 20 HOT AIR BLAST           | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 71.5478 | 28.4522 | 0.00000 |
| 21 FINES+GAS               | 19.1008 | 23.9687 | 0.00000 | 7.48026 | 49.4502 | 0.0000  | 0.00000 |
| 23 GASES                   | 19.1008 | 23.9687 | 0.00000 | 7.48026 | 49.4502 | 0.0000  | 0.00000 |
| 24                         | 8.5354  | 14.1968 | 0.00000 | 0.00000 | 66.3231 | 8.7829  | 0.00000 |

GASEOUS - VOLUME PERCENT

| NO. STREAM                 | CH4     |
|----------------------------|---------|
| 5 NATURAL GAS              | 100.000 |
| 7 HOT SRV GAS              | 4.043   |
| 10 HOT GASES FOR PREHEATER | 4.043   |
| 11 HOT GASES TO COOLER     | 4.043   |
| 12 COLD SRV GAS            | 4.043   |
| 24                         | 2.162   |



**APPENDIX E-5:**  
**REDSMELT ROTARY HEARTH FURNACE**



## REDSMELT PROCESS

### PROCESS BACKGROUND:

The Redsmelt process is based upon a rotary hearth furnace which reduces green pellets made out of iron ore, reductant fines and binders to produce hot, metallized DRI that is charged to a Submerged Arc Furnace. The process operates at high temperature and atmospheric pressure.

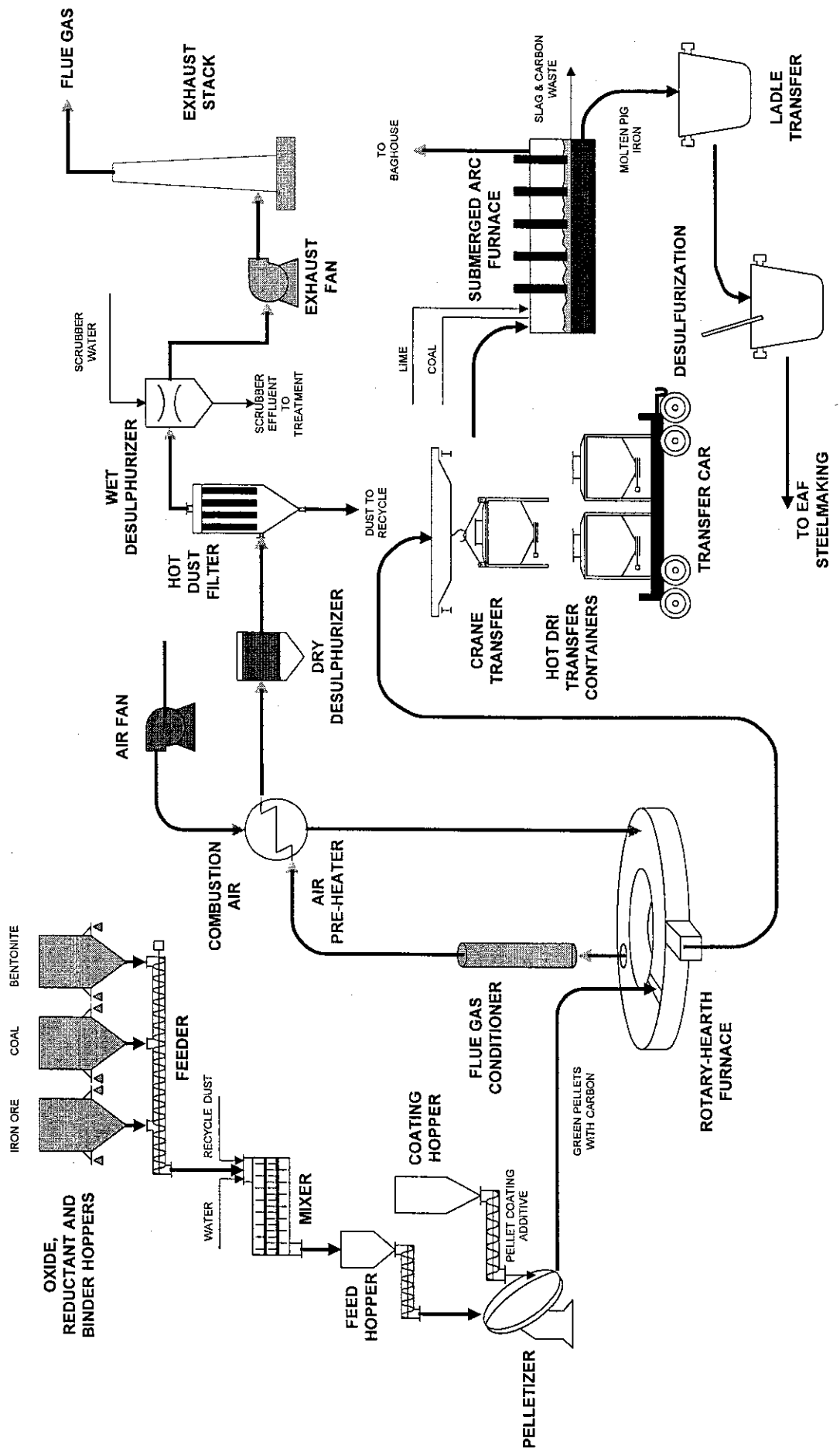
### PROCESS DESCRIPTION:

The iron oxide feed to a Redsmelt furnace is in the form of green pellets made of fine iron ore, reductant and binders. Binders are to give to the green pellets sufficient mechanical strength to support the handling shocks downstream. Pellets are screened on a roller-type screen to a size between 8 to 16 mm. Under and oversize materials are recirculated to feed the pelletizing disks. Pellets are then distributed onto the RHF in a layer up to 30 kg/m<sup>2</sup>. While travelling throughout the furnace in 12 to 18 minutes, pellets are heated up to 1370C. Drying of the pellets, coal devolatilization and iron oxide reduction takes place during the heating process. The intimate contact between iron oxide and carbon at a very high temperature results in a very fast reaction rate. To prevent reoxidation of metallized iron the final zones of the furnace are operated in sub-stoichiometric atmosphere. The hot DRI product is then fed to the submerged arc furnace (SAF) for smelting into Hot metal and slag.

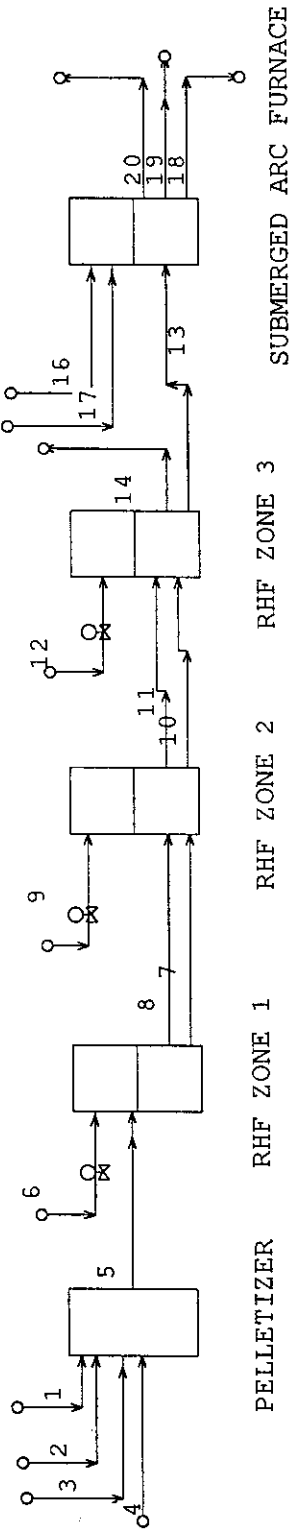
### PROCESS ADVANTAGES

- Iron ore fines as raw material
- Wide variety of solid reductants
- Less reduction time (12 to 18 minutes)
- Proven equipment usage

# MANNESMANN DEMAG REDSMELT PROCESS FLOWSHEET



REDSMELT PROCESS -



REDSMELT PROCESS

## **Redsmelt Process --- MetSim Model --- Description**

The MetSim model for this process is largely based upon a basic flowsheet developed by Mannesmann Demag.

### **Flowsheet Description**

Iron ore fines (Stream 1), coal (Stream 2) and an organic or inorganic binder (Stream 3) are mixed with water and pelletized on a disc to green pellets. Then the pellets pass through three furnace zones: Heating (RHF Zone 1), Main Reduction (RHF Zone 2) and Final Reduction (RHF Zone 3). The temperature in the three zones is adjusted with the burners and the air to match the process requirement. In Zone 1, the pellets are heated so that all moisture is released, the coal is volatilized and some reduction takes place. This generates streams 7 (solids) and 8 (gases). In Zone 2, main reduction takes place. Then the solids (stream 10) and gases (Stream 11) enter in third zone where final reduction takes place. This leads to the formation of DRI (Stream 13) and the gases (Stream 14) go to the exhaust after some treatment to control hazardous emissions. DRI is then conveyed to a Submerged Arc Furnace where some coal (Stream 16) and lime (stream 17) are added. This leads to separation of slag (Stream 19) from hot metal (Stream 18). Gases from the SAF (Stream 20) have lots of calorific value and can be used elsewhere.

### **Model Assumptions:**

RHF Zone 1: Partial reduction of iron ore to  $\text{Fe}_3\text{O}_4$  takes place in this zone.

RHF Zone 2: Reduction of  $\text{Fe}_3\text{O}_4$  to  $\text{FeO}$  takes place in this zone.

RHF Zone 3: Reduction of  $\text{FeO}$  to  $\text{Fe}$  takes place in this zone.

Submerged Arc Furnace: Separation of Slag from Hot metal occurs here.

### **Results**

With the information available about the rotary hearth furnace, several estimates have been made in the model. A more complete analysis can be carried out on receiving more information about the process flows and conditions.

**REDSMELT PROCESS --- STREAM SUMMARY**

| Stream Number                    | 1        | 2       | 3         | 4       | 5            | 6          | 7            | 8            |
|----------------------------------|----------|---------|-----------|---------|--------------|------------|--------------|--------------|
| Description                      | Iron Ore | Coal    | Binder    | Water   | Green Pellet | Combustion | Pellets from | Gases from Z |
| KG/HR SOLIDS                     | 1446     | 490.2   | 16        | 0       | 1952.2       | 0          | 1739.3       | 0            |
| KG/HR AQUEOUS                    | 0        | 25.8    | 0         | 100     | 125.8        | 0          | 0            | 0            |
| KG/HR MOLTEN3                    | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 0            |
| KG/HR GASEOUS                    | 0        | 0       | 0         | 0       | 0            | 1261.5     | 0            | 1600.1       |
| KG/HR TOTAL                      | 1446     | 516     | 16        | 100     | 2078         | 1261.5     | 1739.3       | 1600.1       |
| Percent Solids                   | 100      | 95      | 100       | 0       | 93.946       | 0          | 100          | 0            |
| Sp.Gr.SOLIDS                     | 5.1103   | 1.6075  | 3.31      | 0       | 3.2935       | 0          | 4.1027       | 0            |
| Sp.Gr.AQUEOUS                    | 0        | 0.99712 | 0         | 0.99712 | 0.99712      | 0          | 0            | 0            |
| Sp.Gr.MOLTEN3                    | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 0            |
| Sp.Gr.GASEOUS                    | 0        | 0       | 0         | 0       | 0            | 0.0006132  | 0            | 0.00019492   |
| Sp.Gr.TOTAL                      | 5.1103   | 1.5598  | 3.31      | 0.99712 | 2.8905       | 0.0006132  | 4.1027       | 0.00019492   |
| Temperature C                    | 25       | 25      | 25        | 25      | 25           | 300        | 1400         | 1400         |
| Pressure kPa                     | 101.33   | 101.33  | 101.33    | 101.33  | 101.33       | 101.33     | 101.33       | 101.33       |
| Gas nm3/hr                       | 0        | 0       | 0         | 0       | 0            | 980.41     | 0            | 1340.2       |
| Sol/Liq m3/hr                    | 0.28296  | 0.33082 | 0.0048338 | 0.10029 | 0.7189       | 0          | 0.42395      | 0            |
| <b>Component Mass Flow Rates</b> |          |         |           |         |              |            |              |              |
| 1 CaO KG/HR                      | 14.46    | 0       | 16        | 0       | 30.46        | 0          | 30.46        | 0            |
| 2 CaO KG/HR                      | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 0            |
| 3 CO KG/HR                       | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 280.82       |
| 4 CO2 KG/HR                      | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 128.85       |
| 5 C KG/HR                        | 0        | 372.55  | 0         | 0       | 372.55       | 0          | 294.76       | 0            |
| 6 Fe KG/HR                       | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 0            |
| 7 FeO KG/HR                      | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 0            |
| 8 Fe2O3 KG/HR                    | 1402.6   | 0       | 0         | 0       | 1402.6       | 0          | 0            | 0            |
| 9 Fe3O4 KG/HR                    | 0        | 0       | 0         | 0       | 0            | 0          | 1355.8       | 0            |
| 10 H2O KG/HR                     | 0        | 25.8    | 0         | 100     | 125.8        | 0          | 0            | 0            |
| 11 H2O KG/HR                     | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 219.14       |
| 12 N2 KG/HR                      | 0        | 0       | 0         | 0       | 0            | 971.33     | 0            | 971.33       |
| 13 O2 KG/HR                      | 0        | 0       | 0         | 0       | 0            | 290.14     | 0            | 0            |
| 14 SiO2 KG/HR                    | 28.92    | 29.412  | 0         | 0       | 58.332       | 0          | 58.332       | 0            |
| 15 SiO2 KG/HR                    | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 0            |
| 16 C5H8 KG/HR                    | 0        | 88.236  | 0         | 0       | 88.236       | 0          | 0            | 0            |
| 17 C5H8 KG/HR                    | 0        | 0       | 0         | 0       | 0            | 0          | 0            | 0            |
| <b>Element Mass Flow Rates</b>   |          |         |           |         |              |            |              |              |
| 1 H 1                            | 0        | 13.332  | 0         | 11.19   | 24.522       | 0          | 0            | 24.522       |
| 2 C 6                            | 0        | 450.34  | 0         | 0       | 450.34       | 0          | 294.76       | 155.58       |
| 3 N 7                            | 0        | 0       | 0         | 0       | 0            | 971.33     | 0            | 971.33       |
| 4 O 8                            | 441.11   | 38.577  | 4.5648    | 88.81   | 573.06       | 290.14     | 414.49       | 448.7        |
| 5 Si 14                          | 13.518   | 13.748  | 0         | 0       | 27.267       | 0          | 27.267       | 0            |
| 6 Ca 20                          | 10.335   | 0       | 11.435    | 0       | 21.77        | 0          | 21.77        | 0            |
| 7 Fe 26                          | 981.04   | 0       | 0         | 0       | 981.04       | 0          | 981.04       | 0            |

**REDSMELT PROCESS --- STREAM SUMMARY**

| Stream Number                    | 9          | 10           | 11         | 12         | 13      | 14         | 16       | 17       |
|----------------------------------|------------|--------------|------------|------------|---------|------------|----------|----------|
| Description                      | Combustion | Pellets from | Gases from | Combustion | DRI     | Gases from | Coal     | Lime     |
| KG/HR SOLIDS                     | 0          | 1610.5       | 0          | 0          | 1153.6  | 0          | 40       | 60       |
| KG/HR AQUEOUS                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| KG/HR MOLTEN3                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| KG/HR GASEOUS                    | 0.001      | 0            | 1729       | 0.86988    | 0       | 2186.7     | 0        | 0        |
| KG/HR TOTAL                      | 0.001      | 1610.5       | 1729       | 0.86988    | 1153.6  | 2186.7     | 40       | 60       |
| Percent Solids                   | 0          | 100          | 0          | 0          | 100     | 0          | 100      | 100      |
| Sp.Gr.SOLIDS                     | 0          | 4.3762       | 0          | 0          | 6.103   | 0          | 1.6075   | 3.31     |
| Sp.Gr.AQUEOUS                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| Sp.Gr.MOLTEN3                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| Sp.Gr.GASEOUS                    | 0.0006132  | 0            | 0.00020078 | 0.0006132  | 0       | 0.00019687 | 0        | 0        |
| Sp.Gr.TOTAL                      | 0.0006132  | 4.3762       | 0.00020078 | 0.0006132  | 6.103   | 0.00019687 | 1.6075   | 3.31     |
| Temperature C                    | 300        | 1400         | 1400       | 300        | 1100    | 1400       | 25       | 25       |
| Pressure kPa                     | 101.33     | 101.33       | 101.33     | 101.33     | 101.33  | 101.33     | 101.33   | 101.33   |
| Gas nm3/hr                       | 0.0007772  | 0            | 1405.8     | 0.67607    | 0       | 1813.2     | 0        | 0        |
| Sol/Liq m3/hr                    | 0          | 0.36801      | 0          | 0          | 0.18903 | 0          | 0.024883 | 0.018127 |
| <b>Component Mass Flow Rates</b> |            |              |            |            |         |            |          |          |
| 1 CaO KG/HR                      | 0          | 30.46        | 0          | 0          | 30.46   | 0          | 0        | 60       |
| 2 CaO KG/HR                      | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| 3 CO KG/HR                       | 0          | 0            | 280.82     | 0          | 0       | 879.15     | 0        | 0        |
| 4 CO2 KG/HR                      | 0          | 0            | 257.7      | 0          | 0       | 116.22     | 0        | 0        |
| 5 C KG/HR                        | 0          | 259.6        | 0          | 0          | 41.638  | 0          | 30.4     | 0        |
| 6 Fe KG/HR                       | 0          | 0            | 0          | 0          | 833.88  | 0          | 0        | 0        |
| 7 FeO KG/HR                      | 0          | 1262.1       | 0          | 0          | 189.31  | 0          | 0        | 0        |
| 8 Fe2O3 KG/HR                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| 9 Fe3O4 KG/HR                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| 10 H2O KG/HR                     | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| 11 H2O KG/HR                     | 0          | 0            | 219.14     | 0          | 0       | 219.14     | 0        | 0        |
| 12 N2 KG/HR                      | 0.00077    | 0            | 971.34     | 0.66981    | 0       | 972.01     | 0        | 0        |
| 13 O2 KG/HR                      | 0.00023    | 0            | 0.00023    | 0.20007    | 0       | 0.2003     | 0        | 0        |
| 14 SiO2 KG/HR                    | 0          | 58.332       | 0          | 0          | 58.332  | 0          | 2.4      | 0        |
| 15 SiO2 KG/HR                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| 16 C5H8 KG/HR                    | 0          | 0            | 0          | 0          | 0       | 0          | 7.2      | 0        |
| 17 C5H8 KG/HR                    | 0          | 0            | 0          | 0          | 0       | 0          | 0        | 0        |
| <b>Element Mass Flow Rates</b>   |            |              |            |            |         |            |          |          |
| 1 H 1                            | 0          | 0            | 24.522     | 0          | 0       | 24.522     | 0.85231  | 0        |
| 2 C 6                            | 0          | 259.6        | 190.75     | 0          | 41.638  | 408.7      | 36.748   | 0        |
| 3 N 7                            | 0.00077    | 0            | 971.34     | 0.66981    | 0       | 972.01     | 0        | 0        |
| 4 O 8                            | 0.00023    | 320.81       | 542.39     | 0.20007    | 81.914  | 781.49     | 1.2781   | 17.118   |
| 5 Si 14                          | 0          | 27.267       | 0          | 0          | 27.267  | 0          | 1.1219   | 0        |
| 6 Ca 20                          | 0          | 21.77        | 0          | 0          | 21.77   | 0          | 0        | 42.882   |
| 7 Fe 26                          | 0          | 981.04       | 0          | 0          | 981.04  | 0          | 0        | 0        |

**REDSMELT PROCESS --- STREAM SUMMARY**

| Stream Number                    | 18        | 19       | 20             |
|----------------------------------|-----------|----------|----------------|
| Description                      | Hot Metal | Slag     | Gases from SAF |
| KG/HR SOLIDS                     | 1021.8    | 0        | 0              |
| KG/HR AQUEOUS                    | 0         | 0        | 0              |
| KG/HR MOLTEN3                    | 0         | 151.19   | 0              |
| KG/HR GASEOUS                    | 0         | 0        | 80.638         |
| KG/HR TOTAL                      | 1021.8    | 151.19   | 80.638         |
| Percent Solids                   | 100       | 0        | 0              |
| Sp.Gr.SOLIDS                     | 7.1501    | 0        | 0              |
| Sp.Gr.AQUEOUS                    | 0         | 0        | 0              |
| Sp.Gr.MOLTEN3                    | 0         | 3.009    | 0              |
| Sp.Gr.GASEOUS                    | 0         | 0        | 0.00042395     |
| Sp.Gr.TOTAL                      | 7.1501    | 3.009    | 0.00042395     |
| Temperature C                    | 576.54    | 576.54   | 576.54         |
| Pressure kPa                     | 101.33    | 101.33   | 101.33         |
| Gas nm3/hr                       | 0         | 0        | 61.134         |
| Sol/Liq m3/hr                    | 0.14291   | 0.050247 | 0              |
| <b>Component Mass Flow Rates</b> |           |          |                |
| 1 CaO KG/HR                      | 0         | 0        | 0              |
| 2 CaO KG/HR                      | 0         | 90.46    | 0              |
| 3 CO KG/HR                       | 0         | 0        | 73.438         |
| 4 CO2 KG/HR                      | 0         | 0        | 0              |
| 5 C KG/HR                        | 40.547    | 0        | 0              |
| 6 Fe KG/HR                       | 980.3     | 0        | 0              |
| 7 FeO KG/HR                      | 0.94657   | 0        | 0              |
| 8 Fe2O3 KG/HR                    | 0         | 0        | 0              |
| 9 Fe3O4 KG/HR                    | 0         | 0        | 0              |
| 10 H2O KG/HR                     | 0         | 0        | 0              |
| 11 H2O KG/HR                     | 0         | 0        | 0              |
| 12 N2 KG/HR                      | 0         | 0        | 0              |
| 13 O2 KG/HR                      | 0         | 0        | 0              |
| 14 SiO2 KG/HR                    | 0         | 0        | 0              |
| 15 SiO2 KG/HR                    | 0         | 60.732   | 0              |
| 16 C5H8 KG/HR                    | 0         | 0        | 0              |
| 17 C5H8 KG/HR                    | 0         | 0        | 7.2            |
| <b>Element Mass Flow Rates</b>   |           |          |                |
| 1 H 1                            | 0         | 0        | 0.85231        |
| 2 C 6                            | 40.547    | 0        | 37.839         |
| 3 N 7                            | 0         | 0        | 0              |
| 4 O 8                            | 0.21079   | 58.152   | 41.947         |
| 5 Si 14                          | 0         | 28.389   | 0              |
| 6 Ca 20                          | 0         | 64.652   | 0              |
| 7 Fe 26                          | 981.04    | 0        | 0              |

REDSMELT PROCESS

CASE DEFINITION

Title : REDSMELT PROCESS  
Case :

Data Storage File Name : Redsmelt2.sfw  
Mass Balance Option : ON  
Heat Balance Option : ON  
Units of Mass : kilogram  
Units of Time : hour  
Ambient Air Pressure : 101.325 kPa  
Standard Pressure : 101.325 kPa  
Ambient Air Temperature : 20.00 C  
Standard Temperature : 0.00 C  
Plant Site Latitude : 0.00 Degrees  
Plant Site Elevation : 0.00 Meters



REDSMELT PROCESS

COMPONENT DATA

| ROW | CNM   | CHF   |     | PHC      | CMW    | SGF    |
|-----|-------|-------|-----|----------|--------|--------|
| 1   | CaO   | CaO   | SI1 | 56.0794  | 3.3100 | 0.0000 |
| 2   | CaO   | CaO   | M37 | 56.0794  | 3.3100 | 0.0000 |
| 3   | CO    | CO    | GC8 | 28.0106  | 0.0012 | 0.0000 |
| 4   | CO2   | CO2   | GC8 | 44.0100  | 0.0020 | 0.0000 |
| 5   | C     | C     | SI1 | 12.0112  | 2.2500 | 0.0000 |
| 6   | Fe    | Fe    | SI1 | 55.8470  | 7.8600 | 0.0000 |
| 7   | FeO   | FeO   | SI1 | 71.8464  | 5.7000 | 0.0000 |
| 8   | Fe2O3 | Fe2O3 | SI1 | 159.6922 | 5.2400 | 0.0000 |
| 9   | Fe3O4 | Fe3O4 | SI1 | 231.5386 | 5.1800 | 0.0000 |
| 10  | H2O   | H2O   | LI3 | 18.0153  | 1.0000 | 0.0000 |
| 11  | H2O   | H2O   | GC8 | 18.0153  | 0.0008 | 0.0000 |
| 12  | N2    | N2    | GC8 | 28.0134  | 0.0012 | 0.0000 |
| 13  | O2    | O2    | GC8 | 31.9988  | 0.0014 | 0.0000 |
| 14  | SiO2  | SiO2  | SI1 | 60.0848  | 2.6500 | 0.0000 |
| 15  | SiO2  | SiO2  | M37 | 60.0848  | 2.6500 | 0.0000 |
| 16  | C5H8  | C5H8  | SI1 | 68.1195  | 0.6879 | 0.2491 |
| 17  | C5H8  | C5H8  | GC8 | 68.1195  | 0.0030 | 0.2491 |

| ROW | CNM   | SOL     | A       | B       | C       | pH      | Wl      | COV     | A       | B       | C       |
|-----|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1   | CaO   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2   | CaO   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 3   | CO    | 23.77   | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 4   | CO2   | 1950.00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 5   | C     | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 6   | Fe    | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 7   | FeO   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 8   | Fe2O3 | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 9   | Fe3O4 | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 10  | H2O   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 11  | H2O   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 12  | N2    | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 13  | O2    | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 14  | SiO2  | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 15  | SiO2  | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 16  | C5H8  | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 17  | C5H8  | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |

| ROW | CNM   | CRIT T  | CRIT P  | CRIT V  | ANTOINE | VAPOR PRES | A       | B       | C | HENRY |
|-----|-------|---------|---------|---------|---------|------------|---------|---------|---|-------|
| 1   | CaO   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 2   | CaO   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 3   | CO    | 133.400 | 35.4638 | 93.100  | 6.24020 | 230.27     | 260.010 | 63426.0 |   |       |
| 4   | CO2   | 304.200 | 74.8792 | 94.800  | 9.81060 | 1347.79    | 273.000 | 1215.7  |   |       |
| 5   | C     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 6   | Fe    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 7   | FeO   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 8   | Fe2O3 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 9   | Fe3O4 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 10  | H2O   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 11  | H2O   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 12  | N2    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 13  | O2    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 14  | SiO2  | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 15  | SiO2  | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00       | 0.000   |         |   | 0.0   |
| 16  | C5H8  | 503.000 | 41.2393 | 276.000 | 6.91820 | 1104.99    | 228.851 |         |   | 0.0   |
| 17  | C5H8  | 503.000 | 41.2393 | 276.000 | 6.91820 | 1104.99    | 228.851 |         |   | 0.0   |

REDSMELT PROCESS

COMPONENT DATA

| ROW | CNM   | REFERENCE | H25     | HTE-A  | HTE-B   | HTE-C   | HTE-D   |
|-----|-------|-----------|---------|--------|---------|---------|---------|
| 1   | CaO   | B672098   | -151790 | -4315  | 12.0730 | 0.4606  | 2.0088  |
| 2   | CaO   | B672098   | -151790 | -4315  | 12.0730 | 0.4606  | 2.0088  |
| 3   | CO    | YAWS      | -26420  | -1787  | 6.0661  | 0.9368  | -0.3112 |
| 4   | CO2   | YAWS      | -94050  | -3105  | 8.4720  | 2.5871  | 1.0415  |
| 5   | C     | B672086   | 0       | -2999  | 5.1802  | 0.2246  | 4.3597  |
| 6   | Fe    | B672151   | 0       | -7903  | 14.0914 | -1.3293 | 11.6233 |
| 7   | FeO   | B672157   | -65000  | -3998  | 12.1207 | 1.0479  | 0.8685  |
| 8   | Fe2O3 | B672158   | -197000 | -20749 | 46.1517 | -3.8751 | 21.9462 |
| 9   | Fe3O4 | B672160   | -267300 | -31312 | 71.0525 | -7.8736 | 32.0732 |
| 10  | H2O   | B672180   | -68315  | -5071  | 16.1848 | 2.7637  | 0.0000  |
| 11  | H2O   | B672182   | -57795  | -2403  | 7.2906  | 1.3003  | 0.3596  |
| 12  | N2    | B672244   | 0       | -2846  | 7.5728  | 0.2525  | 1.7794  |
| 13  | O2    | B672277   | 0       | -2979  | 7.9696  | 0.2720  | 1.7697  |
| 14  | SiO2  | B672387   | -217720 | -8654  | 19.1651 | -0.5456 | 8.8977  |
| 15  | SiO2  | B672387   | -217720 | -8654  | 19.1651 | -0.5456 | 8.8977  |
| 16  | C5H8  | YAWS      | 27950   | -8316  | 19.7382 | 30.7726 | -0.9067 |
| 17  | C5H8  | YAWS      | 27950   | -8316  | 19.7382 | 30.7726 | -0.9067 |

| ROW | CNM   | TEMP RANGE | oK     | HTG-A   | HTG-B    | HTG-C    | HTG-D    |
|-----|-------|------------|--------|---------|----------|----------|----------|
| 1   | CaO   | 298.2      | 2000.0 | -146099 | -14.8629 | -4.7096  | -10.7418 |
| 2   | CaO   | 298.2      | 2000.0 | -146099 | -14.8629 | -4.7096  | -10.7418 |
| 3   | CO    | 298.0      | 700.0  | -25393  | -46.6664 | -5.1645  | -2.2650  |
| 4   | CO2   | 298.0      | 700.0  | -93224  | -48.5944 | -8.4916  | -2.4252  |
| 5   | C     | 298.2      | 3000.0 | 2405    | -3.3866  | -1.5836  | -5.1587  |
| 6   | Fe    | 298.2      | 1811.0 | 2679    | -8.2139  | -4.0925  | -5.4957  |
| 7   | FeO   | 298.2      | 1600.0 | -60048  | -19.0598 | -5.9536  | -9.2221  |
| 8   | Fe2O3 | 298.2      | 1800.0 | -182323 | -34.6418 | -13.7715 | -28.2755 |
| 9   | Fe3O4 | 298.2      | 1800.0 | -243067 | -58.6967 | -18.9430 | -46.8195 |
| 10  | H2O   | 298.2      | 373.2  | -70630  | -1.0739  | -26.4253 | 0.0000   |
| 11  | H2O   | 298.2      | 2000.0 | -54212  | -48.4557 | -3.8711  | -6.7579  |
| 12  | N2    | 298.2      | 3000.0 | 5078    | -51.3044 | -2.2358  | -9.9139  |
| 13  | O2    | 298.2      | 3000.0 | 5395    | -54.8302 | -2.3535  | -10.5960 |
| 14  | SiO2  | 298.2      | 2000.0 | -210342 | -16.8483 | -6.1496  | -14.5464 |
| 15  | SiO2  | 298.2      | 2000.0 | -210342 | -16.8483 | -6.1496  | -14.5464 |
| 16  | C5H8  | 135.9      | 318.0  | 23803   | -68.4779 | -61.0649 | -1.8797  |
| 17  | C5H8  | 135.9      | 318.0  | 23803   | -68.4779 | -61.0649 | -1.8797  |

| ROW | CNM   | PRES RANGE | kPa   |
|-----|-------|------------|-------|
| 1   | CaO   | 0.0        | 0.0   |
| 2   | CaO   | 0.0        | 0.0   |
| 3   | CO    | 0.0        | 0.0   |
| 4   | CO2   | 0.0        | 0.0   |
| 5   | C     | 0.0        | 0.0   |
| 6   | Fe    | 0.0        | 0.0   |
| 7   | FeO   | 0.0        | 0.0   |
| 8   | Fe2O3 | 0.0        | 0.0   |
| 9   | Fe3O4 | 0.0        | 0.0   |
| 10  | H2O   | 0.0        | 0.0   |
| 11  | H2O   | 50.0       | 120.0 |
| 12  | N2    | 0.0        | 0.0   |
| 13  | O2    | 0.0        | 0.0   |
| 14  | SiO2  | 0.0        | 0.0   |
| 15  | SiO2  | 0.0        | 0.0   |
| 16  | C5H8  | 0.0        | 0.0   |
| 17  | C5H8  | 0.0        | 0.0   |

REDSMELT PROCESS

FLWSHEET DATA

| NO | OPR | UNIT       | PROCESS     | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |
|----|-----|------------|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | SEC | REDSMELT   | PROCESS     | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 2  | MIX | PELLETIZER |             | 1   | 2   | 3   | 4   | 0   | 0   | 0   | 5   | 0   | 0   | 0   | 0   | 0   |
| 3  | SPP | RHF        | ZONE 1      | 6   | 5   | 0   | 0   | 0   | 0   | 0   | 7   | 8   | 0   | 0   | 0   | 0   |
| 4  | SPP | RHF        | ZONE 2      | 9   | 0   | 0   | 8   | 7   | 0   | 0   | 10  | 11  | 0   | 0   | 0   | 0   |
| 5  | SPP | RHF        | ZONE 3      | 12  | 0   | 0   | 11  | 10  | 0   | 0   | 13  | 14  | 0   | 0   | 0   | 0   |
| 6  | SPP | SUBMERGED  | ARC FURNACE | 16  | 17  | 0   | 13  | 0   | 0   | 0   | 18  | 19  | 20  | 0   | 0   | 0   |

REDSMELT PROCESS

| HEAT BALANCE SUMMARY - 1000 KCAL/HOUR |                 |               |               |                 |              |               |                          |       |
|---------------------------------------|-----------------|---------------|---------------|-----------------|--------------|---------------|--------------------------|-------|
| OP PROCESS STEP                       | INPUT<br>STREAM | HEAT<br>REACT | HEAT<br>SOLUT | ENERGY<br>INPUT | HEAT<br>LOSS | HEAT<br>REQRD | HEAT<br>OUTPUT<br>STREAM | TOTAL |
| 1 REDSMELT PROCESS                    | 0               | 0             | 0             | 0               | 0            | 0             | 0                        | 0     |
| 2 PELLETIZER                          | 1               | 0             | 0             | 0               | 0            | 0             | -1                       | 0     |
| 3 RHF ZONE 1                          | 85              | 637           | 0             | 0               | 0            | 561           | -1283                    | 0     |
| 4 RHF ZONE 2                          | 1283            | -148          | 0             | 0               | 0            | 126           | -1261                    | 0     |
| 5 RHF ZONE 3                          | 1261            | -709          | 0             | 0               | 0            | 598           | -1151                    | 0     |
| 6 SUBMERGED ARC FU                    | 226             | -101          | 0             | 0               | -6           | 0             | -118                     | 0     |

REDSMELT PROCESS

| NO. STREAM             | STREAM TEMPERATURES AND ENTHALPIES |         |           |           |           |
|------------------------|------------------------------------|---------|-----------|-----------|-----------|
|                        | TEMP-C                             | TEMP-F  | KCAL/HR   | BTU/HR    | KJ/HR     |
| 1 Iron Ore             | 25.00                              | 77.00   | 240.00    | 953.0     | 1004.0    |
| 2 Coal                 | 25.00                              | 77.00   | 856.00    | 3395.0    | 3580.0    |
| 3 Binder               | 25.00                              | 77.00   | 0.00      | -1.0      | -1.0      |
| 4 Water                | 25.00                              | 77.00   | 0.00      | 0.0       | 0.0       |
| 5 Green Pellets        | 25.00                              | 77.00   | 1096.00   | 4347.0    | 4584.0    |
| 6 Combustion Air       | 300.00                             | 572.00  | 83455.00  | 331177.0  | 349177.0  |
| 7 Pellets from Zone 1  | 1400.00                            | 2552.00 | 587002.00 | 2329413.0 | 2456017.0 |
| 8 Gases from Zone 1    | 1400.00                            | 2552.00 | 696261.00 | 2762986.0 | 2913155.0 |
| 9 Combustion Air       | 300.00                             | 572.00  | 0.00      | 0.0       | 0.0       |
| 10 Pellets from Zone 2 | 1400.00                            | 2552.00 | 511340.00 | 2029162.0 | 2139448.0 |
| 11 Gases from Zone 2   | 1400.00                            | 2552.00 | 750057.00 | 2976465.0 | 3138237.0 |
| 12 Combustion Air      | 300.00                             | 572.00  | 58.00     | 228.0     | 241.0     |
| 13 DRI                 | 1100.00                            | 2012.00 | 225639.00 | 895408.0  | 944074.0  |
| 14 Gases from RHF      | 1400.00                            | 2552.00 | 925556.00 | 3672902.0 | 3872525.0 |
| 15 Air                 | 25.00                              | 77.00   | 418.00    | 1658.0    | 1748.0    |
| 16 Coal                | 25.00                              | 77.00   | 70.00     | 277.0     | 292.0     |
| 17 Lime                | 25.00                              | 77.00   | -1.00     | -2.0      | -2.0      |
| 18 Hot Metal           | 576.54                             | 1069.78 | 85718.00  | 340156.0  | 358644.0  |
| 19 Slag                | 576.54                             | 1069.78 | 18878.00  | 74914.0   | 78986.0   |
| 20 Gases from SAF      | 576.54                             | 1069.78 | 13735.00  | 54505.0   | 57468.0   |

REDSMELT PROCESS

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM           | TIME     | ACFM     | SCFM     | M3/HR    | NM3/HR   |
|----------------------|----------|----------|----------|----------|----------|
| 6 Combustion Air     | 100.0000 | 1210.822 | 577.050  | 2057.20  | 980.413  |
| 8 Gases from Zone 1  | 100.0000 | 4831.826 | 788.789  | 8209.33  | 1340.161 |
| 9 Combustion Air     | 100.0000 | 0.001    | 0.000    | 0.00     | 0.001    |
| 11 Gases from Zone 2 | 100.0000 | 5068.443 | 827.413  | 8611.34  | 1405.784 |
| 12 Combustion Air    | 100.0000 | 0.835    | 0.398    | 1.42     | 0.676    |
| 14 Gases from RHF    | 100.0000 | 6537.567 | 1067.204 | 11107.40 | 1813.190 |
| 15 Air               | 100.0000 | 219.851  | 201.416  | 373.53   | 342.209  |
| 20 Gases from SAF    | 100.0000 | 111.951  | 35.982   | 190.21   | 61.134   |

VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM             | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|------------------------|----------|----------|----------|----------|----------|
| 1 Iron Ore             | 100.0000 | 1.245816 | 0.078599 | 0.282957 | 6.79098  |
| 2 Coal                 | 100.0000 | 1.456539 | 0.091894 | 0.330818 | 7.93963  |
| 3 Binder               | 100.0000 | 0.021283 | 0.001343 | 0.004834 | 0.11601  |
| 4 Water                | 100.0000 | 0.441558 | 0.027858 | 0.100289 | 2.40694  |
| 5 Green Pellets        | 100.0000 | 3.165196 | 0.199694 | 0.718898 | 17.25356 |
| 7 Pellets from Zone 1  | 100.0000 | 1.866596 | 0.117765 | 0.423953 | 10.17486 |
| 10 Pellets from Zone 2 | 100.0000 | 1.620290 | 0.102225 | 0.368010 | 8.83224  |
| 13 DRI                 | 100.0000 | 0.832248 | 0.052507 | 0.189025 | 4.53661  |
| 16 Coal                | 100.0000 | 0.109557 | 0.006912 | 0.024883 | 0.59720  |
| 17 Lime                | 100.0000 | 0.079810 | 0.005035 | 0.018127 | 0.43505  |
| 18 Hot Metal           | 100.0000 | 0.629199 | 0.039697 | 0.142907 | 3.42978  |
| 19 Slag                | 100.0000 | 0.221230 | 0.013958 | 0.050247 | 1.20593  |

MASS FLOW RATES - KG/HR

| NO. STREAM             | KG/HR-SI | KG/HR-LI | KG/HR-M3 | KG/HR-GC | KG/HR-TC |
|------------------------|----------|----------|----------|----------|----------|
| 1 Iron Ore             | 1446.000 | 0.0000   | 0.0000   | 0.000    | 1446.000 |
| 2 Coal                 | 490.200  | 25.8000  | 0.0000   | 0.000    | 516.000  |
| 3 Binder               | 16.000   | 0.0000   | 0.0000   | 0.000    | 16.000   |
| 4 Water                | 0.000    | 100.0000 | 0.0000   | 0.000    | 100.000  |
| 5 Green Pellets        | 1952.200 | 125.8000 | 0.0000   | 0.000    | 2078.000 |
| 6 Combustion Air       | 0.000    | 0.0000   | 0.0000   | 1261.474 | 1261.474 |
| 7 Pellets from Zone 1  | 1739.331 | 0.0000   | 0.0000   | 0.000    | 1739.331 |
| 8 Gases from Zone 1    | 0.000    | 0.0000   | 0.0000   | 1600.143 | 1600.143 |
| 9 Combustion Air       | 0.000    | 0.0000   | 0.0000   | 0.001    | 0.001    |
| 10 Pellets from Zone 2 | 1610.480 | 0.0000   | 0.0000   | 0.000    | 1610.480 |
| 11 Gases from Zone 2   | 0.000    | 0.0000   | 0.0000   | 1728.994 | 1728.994 |
| 12 Combustion Air      | 0.000    | 0.0000   | 0.0000   | 0.870    | 0.870    |
| 13 DRI                 | 1153.627 | 0.0000   | 0.0000   | 0.000    | 1153.627 |
| 14 Gases from RHF      | 0.000    | 0.0000   | 0.0000   | 2186.718 | 2186.718 |
| 15 Air                 | 0.000    | 0.0000   | 0.0000   | 440.311  | 440.311  |
| 16 Coal                | 40.000   | 0.0000   | 0.0000   | 0.000    | 40.000   |
| 17 Lime                | 60.000   | 0.0000   | 0.0000   | 0.000    | 60.000   |
| 18 Hot Metal           | 1021.797 | 0.0000   | 0.0000   | 0.000    | 1021.797 |
| 19 Slag                | 0.000    | 0.0000   | 151.1920 | 0.000    | 151.192  |
| 20 Gases from SAF      | 0.000    | 0.0000   | 0.0000   | 80.638   | 80.638   |

REDSMELT PROCESS

SPECIFIC GRAVITIES

| NO. STREAM             | PCS      | SG-SI  | SG-LI  | SG-M3  | SG-GC  | SG-TC  |
|------------------------|----------|--------|--------|--------|--------|--------|
| 1 Iron Ore             | 100.0000 | 5.1103 | 0.0000 | 0.0000 | 0.0000 | 5.1103 |
| 2 Coal                 | 95.0000  | 1.6075 | 0.9971 | 0.0000 | 0.0000 | 1.5598 |
| 3 Binder               | 100.0000 | 3.3100 | 0.0000 | 0.0000 | 0.0000 | 3.3100 |
| 4 Water                | 0.0000   | 0.0000 | 0.9971 | 0.0000 | 0.0000 | 0.9971 |
| 5 Green Pellets        | 93.9461  | 3.2935 | 0.9971 | 0.0000 | 0.0000 | 2.8905 |
| 6 Combustion Air       | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 7 Pellets from Zone 1  | 100.0000 | 4.1027 | 0.0000 | 0.0000 | 0.0000 | 4.1027 |
| 8 Gases from Zone 1    | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 9 Combustion Air       | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 10 Pellets from Zone 2 | 100.0000 | 4.3762 | 0.0000 | 0.0000 | 0.0000 | 4.3762 |
| 11 Gases from Zone 2   | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 12 Combustion Air      | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 13 DRI                 | 100.0000 | 6.1030 | 0.0000 | 0.0000 | 0.0000 | 6.1030 |
| 14 Gases from RHF      | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 15 Air                 | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 16 Coal                | 100.0000 | 1.6075 | 0.0000 | 0.0000 | 0.0000 | 1.6075 |
| 17 Lime                | 100.0000 | 3.3100 | 0.0000 | 0.0000 | 0.0000 | 3.3100 |
| 18 Hot Metal           | 100.0000 | 7.1501 | 0.0000 | 0.0000 | 0.0000 | 7.1501 |
| 19 Slag                | 0.0000   | 0.0000 | 0.0000 | 3.0090 | 0.0000 | 3.0090 |
| 20 Gases from SAF      | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0004 |

REDSMELT PROCESS

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. | STREAM            | TIME     | ACFM     | SCFM     | M3/HR    | NM3/HR   |
|-----|-------------------|----------|----------|----------|----------|----------|
| 6   | Combustion Air    | 100.0000 | 1210.822 | 577.050  | 2057.20  | 980.413  |
| 8   | Gases from Zone 1 | 100.0000 | 4831.826 | 788.789  | 8209.33  | 1340.161 |
| 9   | Combustion Air    | 100.0000 | 0.001    | 0.000    | 0.00     | 0.001    |
| 11  | Gases from Zone 2 | 100.0000 | 5068.443 | 827.413  | 8611.34  | 1405.784 |
| 12  | Combustion Air    | 100.0000 | 0.835    | 0.398    | 1.42     | 0.676    |
| 14  | Gases from RHF    | 100.0000 | 6537.567 | 1067.204 | 11107.40 | 1813.190 |
| 15  | Air               | 100.0000 | 219.851  | 201.416  | 373.53   | 342.209  |
| 20  | Gases from SAF    | 100.0000 | 111.951  | 35.982   | 190.21   | 61.134   |

VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. | STREAM              | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|-----|---------------------|----------|----------|----------|----------|----------|
| 1   | Iron Ore            | 100.0000 | 1.245816 | 0.078599 | 0.282957 | 6.79098  |
| 2   | Coal                | 100.0000 | 1.456539 | 0.091894 | 0.330818 | 7.93963  |
| 3   | Binder              | 100.0000 | 0.021283 | 0.001343 | 0.004834 | 0.11601  |
| 4   | Water               | 100.0000 | 0.441558 | 0.027858 | 0.100289 | 2.40694  |
| 5   | Green Pellets       | 100.0000 | 3.165196 | 0.199694 | 0.718898 | 17.25356 |
| 7   | Pellets from Zone 1 | 100.0000 | 1.866596 | 0.117765 | 0.423953 | 10.17486 |
| 10  | Pellets from Zone 2 | 100.0000 | 1.620290 | 0.102225 | 0.368010 | 8.83224  |
| 13  | DRI                 | 100.0000 | 0.832248 | 0.052507 | 0.189025 | 4.53661  |
| 16  | Coal                | 100.0000 | 0.109557 | 0.006912 | 0.024883 | 0.59720  |
| 17  | Lime                | 100.0000 | 0.079810 | 0.005035 | 0.018127 | 0.43505  |
| 18  | Hot Metal           | 100.0000 | 0.629199 | 0.039697 | 0.142907 | 3.42978  |
| 19  | Slag                | 100.0000 | 0.221230 | 0.013958 | 0.050247 | 1.20593  |

MASS FLOW RATES - KG/HR

| NO. | STREAM              | KG/HR-SI | KG/HR-LI | KG/HR-M3 | KG/HR-GC | KG/HR-TC |
|-----|---------------------|----------|----------|----------|----------|----------|
| 1   | Iron Ore            | 1446.000 | 0.0000   | 0.0000   | 0.000    | 1446.000 |
| 2   | Coal                | 490.200  | 25.8000  | 0.0000   | 0.000    | 516.000  |
| 3   | Binder              | 16.000   | 0.0000   | 0.0000   | 0.000    | 16.000   |
| 4   | Water               | 0.000    | 100.0000 | 0.0000   | 0.000    | 100.000  |
| 5   | Green Pellets       | 1952.200 | 125.8000 | 0.0000   | 0.000    | 2078.000 |
| 6   | Combustion Air      | 0.000    | 0.0000   | 0.0000   | 1261.474 | 1261.474 |
| 7   | Pellets from Zone 1 | 1739.331 | 0.0000   | 0.0000   | 0.000    | 1739.331 |
| 8   | Gases from Zone 1   | 0.000    | 0.0000   | 0.0000   | 1600.143 | 1600.143 |
| 9   | Combustion Air      | 0.000    | 0.0000   | 0.0000   | 0.001    | 0.001    |
| 10  | Pellets from Zone 2 | 1610.480 | 0.0000   | 0.0000   | 0.000    | 1610.480 |
| 11  | Gases from Zone 2   | 0.000    | 0.0000   | 0.0000   | 1728.994 | 1728.994 |
| 12  | Combustion Air      | 0.000    | 0.0000   | 0.0000   | 0.870    | 0.870    |
| 13  | DRI                 | 1153.627 | 0.0000   | 0.0000   | 0.000    | 1153.627 |
| 14  | Gases from RHF      | 0.000    | 0.0000   | 0.0000   | 2186.718 | 2186.718 |
| 15  | Air                 | 0.000    | 0.0000   | 0.0000   | 440.311  | 440.311  |
| 16  | Coal                | 40.000   | 0.0000   | 0.0000   | 0.000    | 40.000   |
| 17  | Lime                | 60.000   | 0.0000   | 0.0000   | 0.000    | 60.000   |
| 18  | Hot Metal           | 1021.797 | 0.0000   | 0.0000   | 0.000    | 1021.797 |
| 19  | Slag                | 0.000    | 0.0000   | 151.1920 | 0.000    | 151.192  |
| 20  | Gases from SAF      | 0.000    | 0.0000   | 0.0000   | 80.638   | 80.638   |



REDSMELT PROCESS

SPECIFIC GRAVITIES

| NO. STREAM             | PCS      | SG-SI  | SG-LI  | SG-M3  | SG-GC  | SG-TC  |
|------------------------|----------|--------|--------|--------|--------|--------|
| 1 Iron Ore             | 100.0000 | 5.1103 | 0.0000 | 0.0000 | 0.0000 | 5.1103 |
| 2 Coal                 | 95.0000  | 1.6075 | 0.9971 | 0.0000 | 0.0000 | 1.5598 |
| 3 Binder               | 100.0000 | 3.3100 | 0.0000 | 0.0000 | 0.0000 | 3.3100 |
| 4 Water                | 0.0000   | 0.0000 | 0.9971 | 0.0000 | 0.0000 | 0.9971 |
| 5 Green Pellets        | 93.9461  | 3.2935 | 0.9971 | 0.0000 | 0.0000 | 2.8905 |
| 6 Combustion Air       | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 7 Pellets from Zone 1  | 100.0000 | 4.1027 | 0.0000 | 0.0000 | 0.0000 | 4.1027 |
| 8 Gases from Zone 1    | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 9 Combustion Air       | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 10 Pellets from Zone 2 | 100.0000 | 4.3762 | 0.0000 | 0.0000 | 0.0000 | 4.3762 |
| 11 Gases from Zone 2   | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 12 Combustion Air      | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 13 DRI                 | 100.0000 | 6.1030 | 0.0000 | 0.0000 | 0.0000 | 6.1030 |
| 14 Gases from RHF      | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 15 Air                 | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 16 Coal                | 100.0000 | 1.6075 | 0.0000 | 0.0000 | 0.0000 | 1.6075 |
| 17 Lime                | 100.0000 | 3.3100 | 0.0000 | 0.0000 | 0.0000 | 3.3100 |
| 18 Hot Metal           | 100.0000 | 7.1501 | 0.0000 | 0.0000 | 0.0000 | 7.1501 |
| 19 Slag                | 0.0000   | 0.0000 | 0.0000 | 3.0090 | 0.0000 | 3.0090 |
| 20 Gases from SAF      | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0004 | 0.0004 |

REDSMELT PROCESS

STREAM DATA

SOLIDS - KG/HR

| NO. STREAM             | CaO     | C       | Fe      | FeO     | Fe2O3   | Fe3O4   | SiO2    |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore             | 14.4600 | 0.000   | 0.000   | 0.00    | 1402.62 | 0.00    | 28.9200 |
| 2 Coal                 | 0.0000  | 372.552 | 0.000   | 0.00    | 0.00    | 0.00    | 29.4120 |
| 3 Binder               | 16.0000 | 0.000   | 0.000   | 0.00    | 0.00    | 0.00    | 0.0000  |
| 5 Green Pellets        | 30.4600 | 372.552 | 0.000   | 0.00    | 1402.62 | 0.00    | 58.3320 |
| 7 Pellets from Zone 1  | 30.4600 | 294.761 | 0.000   | 0.00    | 0.00    | 1355.78 | 58.3320 |
| 10 Pellets from Zone 2 | 30.4600 | 259.595 | 0.000   | 1262.09 | 0.00    | 0.00    | 58.3320 |
| 13 DRI                 | 30.4600 | 41.638  | 833.883 | 189.31  | 0.00    | 0.00    | 58.3320 |
| 16 Coal                | 0.0000  | 30.400  | 0.000   | 0.00    | 0.00    | 0.00    | 2.4000  |
| 17 Lime                | 60.0000 | 0.000   | 0.000   | 0.00    | 0.00    | 0.00    | 0.0000  |
| 18 Hot Metal           | 0.0000  | 40.547  | 980.303 | 0.95    | 0.00    | 0.00    | 0.0000  |

SOLIDS - KG/HR

| NO. STREAM      | C5H8    |
|-----------------|---------|
| 2 Coal          | 88.2360 |
| 5 Green Pellets | 88.2360 |
| 16 Coal         | 7.2000  |

SOLIDS - WEIGHT PERCENT

| NO. STREAM             | CaO     | C       | Fe      | FeO     | Fe2O3   | Fe3O4   | SiO2    |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore             | 1.000   | 0.0000  | 0.0000  | 0.0000  | 97.0000 | 0.0000  | 2.00000 |
| 2 Coal                 | 0.000   | 76.0000 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 6.00000 |
| 3 Binder               | 100.000 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.00000 |
| 5 Green Pellets        | 1.560   | 19.0837 | 0.0000  | 0.0000  | 71.8482 | 0.0000  | 2.98801 |
| 7 Pellets from Zone 1  | 1.751   | 16.9468 | 0.0000  | 0.0000  | 0.0000  | 77.9482 | 3.35370 |
| 10 Pellets from Zone 2 | 1.891   | 16.1191 | 0.0000  | 78.3675 | 0.0000  | 0.0000  | 3.62203 |
| 13 DRI                 | 2.640   | 3.6093  | 72.2836 | 16.4103 | 0.0000  | 0.0000  | 5.05640 |
| 16 Coal                | 0.000   | 76.0000 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 6.00000 |
| 17 Lime                | 100.000 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.00000 |
| 18 Hot Metal           | 0.000   | 3.9682  | 95.9391 | 0.0926  | 0.0000  | 0.0000  | 0.00000 |

SOLIDS - WEIGHT PERCENT

| NO. STREAM      | C5H8    |
|-----------------|---------|
| 2 Coal          | 18.0000 |
| 5 Green Pellets | 4.5198  |
| 16 Coal         | 18.0000 |

AQUEOUS - KG/HR

| NO. STREAM      | H2O     |
|-----------------|---------|
| 2 Coal          | 25.800  |
| 4 Water         | 100.000 |
| 5 Green Pellets | 125.800 |

AQUEOUS - WEIGHT PERCENT

| NO. STREAM      | H2O     |
|-----------------|---------|
| 2 Coal          | 100.000 |
| 4 Water         | 100.000 |
| 5 Green Pellets | 100.000 |

AQUEOUS - GRAMS PER LITER

| NO. STREAM      | H2O     |
|-----------------|---------|
| 2 Coal          | 997.116 |
| 4 Water         | 997.116 |
| 5 Green Pellets | 997.116 |

REDSMELT PROCESS

STREAM DATA

MOLTEN3 - KG/HR

| NO. STREAM | CaO     | SiO2    |
|------------|---------|---------|
| 19 Slag    | 90.4600 | 60.7320 |

MOLTEN3 - WEIGHT PERCENT

| NO. STREAM | CaO     | SiO2    |
|------------|---------|---------|
| 19 Slag    | 59.8312 | 40.1688 |

GASEOUS - KG/HR

| NO. STREAM           | CO      | CO2     | H2O     | N2      | O2      | C5H8    |
|----------------------|---------|---------|---------|---------|---------|---------|
| 6 Combustion Air     | 0.000   | 0.000   | 0.000   | 971.335 | 290.139 | 0.00000 |
| 8 Gases from Zone 1  | 280.816 | 128.850 | 219.142 | 971.335 | 0.000   | 0.00000 |
| 9 Combustion Air     | 0.000   | 0.000   | 0.000   | 0.001   | 0.000   | 0.00000 |
| 11 Gases from Zone 2 | 280.816 | 257.701 | 219.142 | 971.336 | 0.000   | 0.00000 |
| 12 Combustion Air    | 0.000   | 0.000   | 0.000   | 0.670   | 0.200   | 0.00000 |
| 14 Gases from RHF    | 879.147 | 116.223 | 219.142 | 972.005 | 0.200   | 0.00000 |
| 15 Air               | 0.000   | 0.000   | 0.000   | 339.040 | 101.272 | 0.00000 |
| 20 Gases from SAF    | 73.438  | 0.000   | 0.000   | 0.000   | 0.000   | 7.20000 |

GASEOUS - WEIGHT PERCENT

| NO. STREAM           | CO      | CO2     | H2O     | N2      | O2      | C5H8    |
|----------------------|---------|---------|---------|---------|---------|---------|
| 6 Combustion Air     | 0.0000  | 0.0000  | 0.0000  | 77.0000 | 23.0000 | 0.00000 |
| 8 Gases from Zone 1  | 17.5494 | 8.0524  | 13.6951 | 60.7030 | 0.0000  | 0.00000 |
| 9 Combustion Air     | 0.0000  | 0.0000  | 0.0000  | 77.0000 | 23.0000 | 0.00000 |
| 11 Gases from Zone 2 | 16.2416 | 14.9047 | 12.6745 | 56.1792 | 0.0000  | 0.00000 |
| 12 Combustion Air    | 0.0000  | 0.0000  | 0.0000  | 77.0000 | 23.0000 | 0.00000 |
| 14 Gases from RHF    | 40.2040 | 5.3149  | 10.0215 | 44.4504 | 0.0092  | 0.00000 |
| 15 Air               | 0.0000  | 0.0000  | 0.0000  | 77.0000 | 23.0000 | 0.00000 |
| 20 Gases from SAF    | 91.0712 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 8.92877 |

GASEOUS - VOLUME PERCENT

| NO. STREAM           | CO      | CO2     | H2O     | N2      | O2      | C5H8    |
|----------------------|---------|---------|---------|---------|---------|---------|
| 6 Combustion Air     | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 8 Gases from Zone 1  | 16.7673 | 4.89663 | 20.3444 | 57.9917 | 0.0000  | 0.00000 |
| 9 Combustion Air     | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 11 Gases from Zone 2 | 15.9846 | 9.33611 | 19.3947 | 55.2846 | 0.0000  | 0.00000 |
| 12 Combustion Air    | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 14 Gases from RHF    | 38.7986 | 3.26450 | 15.0369 | 42.8922 | 0.0077  | 0.00000 |
| 15 Air               | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 20 Gases from SAF    | 96.1248 | 0.00000 | 0.0000  | 0.0000  | 0.0000  | 3.87521 |

REDSMELT PROCESS

STREAM DATA IN MOLES

SOLIDS - KG MOLES/HR

| NO. STREAM             | CaO     | C       | Fe      | FeO     | Fe2O3   | Fe3O4   | SiO2    |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore             | 0.25785 | 0.0000  | 0.0000  | 0.0000  | 8.78327 | 0.00000 | 0.48132 |
| 2 Coal                 | 0.00000 | 31.0172 | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.48951 |
| 3 Binder               | 0.28531 | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00000 |
| 5 Green Pellets        | 0.54316 | 31.0172 | 0.0000  | 0.0000  | 8.78327 | 0.00000 | 0.97083 |
| 7 Pellets from Zone 1  | 0.54316 | 24.5406 | 0.0000  | 0.0000  | 0.00000 | 5.85551 | 0.97083 |
| 10 Pellets from Zone 2 | 0.54316 | 21.6129 | 0.0000  | 17.5665 | 0.00000 | 0.00000 | 0.97083 |
| 13 DRI                 | 0.54316 | 3.4666  | 14.9316 | 2.6350  | 0.00000 | 0.00000 | 0.97083 |
| 16 Coal                | 0.00000 | 2.5310  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.03994 |
| 17 Lime                | 1.06991 | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00000 |
| 18 Hot Metal           | 0.00000 | 3.3758  | 17.5534 | 0.0132  | 0.00000 | 0.00000 | 0.00000 |

SOLIDS - KG MOLES/HR

| NO. STREAM      | C5H8    |
|-----------------|---------|
| 2 Coal          | 1.29531 |
| 5 Green Pellets | 1.29531 |
| 16 Coal         | 0.10570 |

SOLIDS - MOLE PERCENT

| NO. STREAM             | CaO     | C       | Fe      | FeO     | Fe2O3   | Fe3O4   | SiO2    |
|------------------------|---------|---------|---------|---------|---------|---------|---------|
| 1 Iron Ore             | 2.708   | 0.0000  | 0.0000  | 0.0000  | 92.2376 | 0.0000  | 5.05458 |
| 2 Coal                 | 0.000   | 94.5588 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 1.49231 |
| 3 Binder               | 100.000 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.00000 |
| 5 Green Pellets        | 1.275   | 72.7936 | 0.0000  | 0.0000  | 20.6133 | 0.0000  | 2.27842 |
| 7 Pellets from Zone 1  | 1.702   | 76.9054 | 0.0000  | 0.0000  | 0.0000  | 18.3500 | 3.04238 |
| 10 Pellets from Zone 2 | 1.335   | 53.1115 | 0.0000  | 43.1680 | 0.0000  | 0.0000  | 2.38571 |
| 13 DRI                 | 2.409   | 15.3750 | 66.2237 | 11.6865 | 0.0000  | 0.0000  | 4.30577 |
| 16 Coal                | 0.000   | 94.5588 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 1.49231 |
| 17 Lime                | 100.000 | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.00000 |
| 18 Hot Metal           | 0.000   | 16.1195 | 83.8176 | 0.0629  | 0.0000  | 0.0000  | 0.00000 |

SOLIDS - MOLE PERCENT

| NO. STREAM      | C5H8    |
|-----------------|---------|
| 2 Coal          | 3.94888 |
| 5 Green Pellets | 3.03994 |
| 16 Coal         | 3.94888 |

MOLTEN3 - KG MOLES/HR

| NO. STREAM | CaO     | SiO2    |
|------------|---------|---------|
| 19 Slag    | 1.61307 | 1.01077 |

MOLTEN3 - MOLE PERCENT

| NO. STREAM | CaO     | SiO2    |
|------------|---------|---------|
| 19 Slag    | 61.4774 | 38.5226 |

GASEOUS - KG MOLES/HR

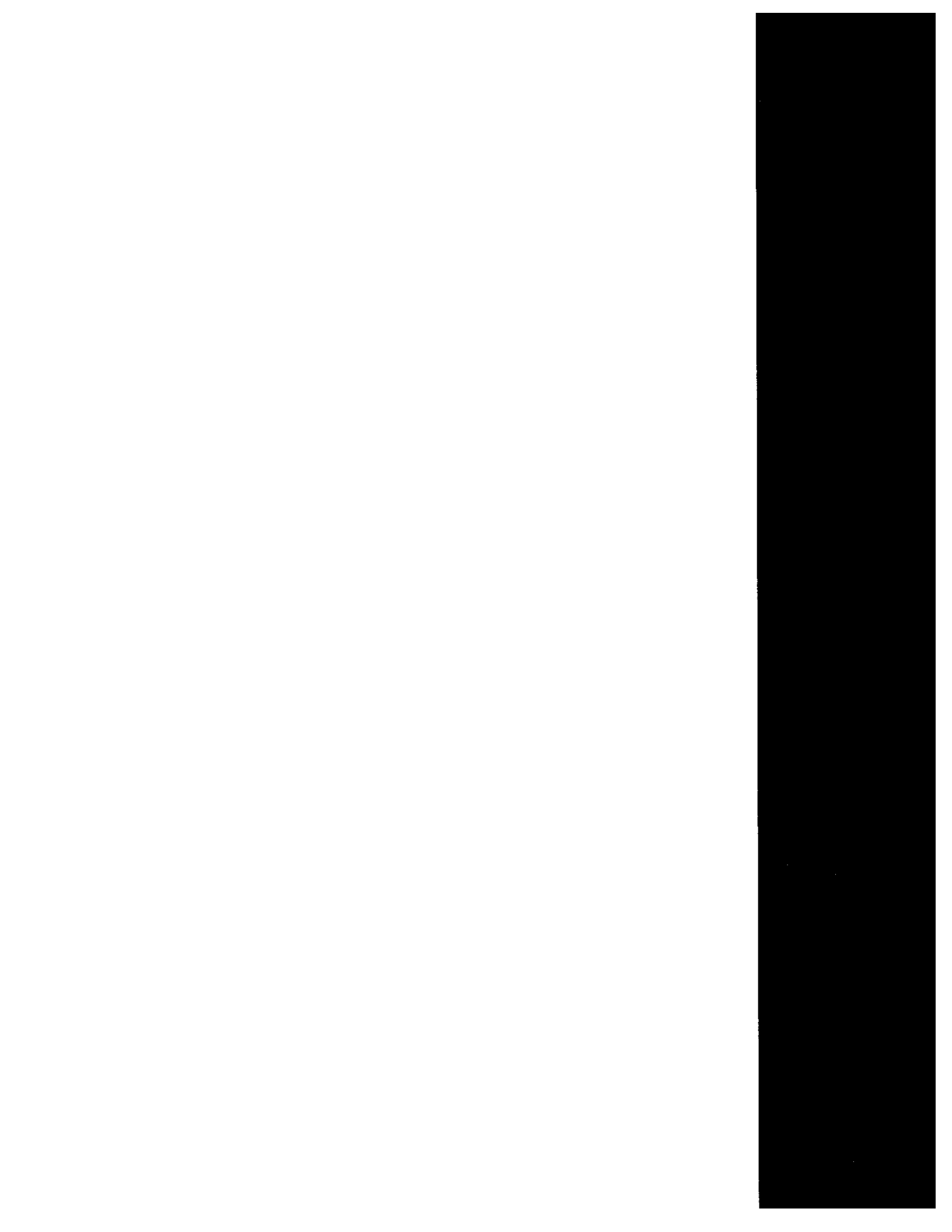
| NO. STREAM           | CO      | CO2     | H2O     | N2      | O2      | C5H8    |
|----------------------|---------|---------|---------|---------|---------|---------|
| 6 Combustion Air     | 0.0000  | 0.00000 | 0.0000  | 34.6739 | 9.06718 | 0.00000 |
| 8 Gases from Zone 1  | 10.0254 | 2.92776 | 12.1642 | 34.6739 | 0.00000 | 0.00000 |
| 9 Combustion Air     | 0.0000  | 0.00000 | 0.0000  | 0.0000  | 0.00001 | 0.00000 |
| 11 Gases from Zone 2 | 10.0254 | 5.85551 | 12.1642 | 34.6740 | 0.00001 | 0.00000 |
| 12 Combustion Air    | 0.0000  | 0.00000 | 0.0000  | 0.0239  | 0.00625 | 0.00000 |
| 14 Gases from RHF    | 31.3863 | 2.64083 | 12.1642 | 34.6979 | 0.00626 | 0.00000 |
| 15 Air               | 0.0000  | 0.00000 | 0.0000  | 12.1028 | 3.16486 | 0.00000 |
| 20 Gases from SAF    | 2.6218  | 0.00000 | 0.0000  | 0.0000  | 0.00000 | 0.10570 |

REDSMELT PROCESS

STREAM DATA IN MOLES

GASEOUS - MOLE PERCENT

| NO. STREAM           | CO      | CO2     | H2O     | N2      | O2      | C5H8    |
|----------------------|---------|---------|---------|---------|---------|---------|
| 6 Combustion Air     | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 8 Gases from Zone 1  | 16.7673 | 4.89663 | 20.3444 | 57.9917 | 0.0000  | 0.00000 |
| 9 Combustion Air     | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 11 Gases from Zone 2 | 15.9846 | 9.33611 | 19.3947 | 55.2846 | 0.0000  | 0.00000 |
| 12 Combustion Air    | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 14 Gases from RHF    | 38.7986 | 3.26450 | 15.0369 | 42.8922 | 0.0077  | 0.00000 |
| 15 Air               | 0.0000  | 0.00000 | 0.0000  | 79.2708 | 20.7292 | 0.00000 |
| 20 Gases from SAF    | 96.1248 | 0.00000 | 0.0000  | 0.0000  | 0.0000  | 3.87521 |



**APPENDIX E-6:**  
**CIRCORED FLUID-BED REDUCTION PROCESS**  
**(NATURAL GAS REDUCTANT)**

## CIRCORED PROCESS

### PROCESS BACKGROUND:

The Circored process is a two stage fluidized bed process that operates at low reducing temperatures and uses natural gas to produce reducing gas by means of reforming. The process uses ore fines that have a particle size between 1mm and 0.03mm and produces HBI.

### PROCESS DESCRIPTION:

The iron ore fines are first dried and heated to about 800C in a fluid bed preheater system. The dried fines are then charged to a circulating fluidized bed (CFB). The heat required is generated by the combustion of natural gas and air that is introduced into the CFB. The fines are reduced to about 70% metallization in CFB. The process reactions are endothermic and the required energy is introduced in the form of preheated iron ore fines and process gases. The pressure in the CFB is about 4 bars and the reaction temperature is about 630C. This temperature is lower than that used for other reduction processes, and hence avoids the sticking problems that occur with high temperature fines-based processes. The fluidizing gas in the CFB is a mixture of heated process gas which enters the lower part of the CFB, and the off-gas from the second stage conventional fluidized bed reactor, Stage II Reactor, FB. The retention time in the CFB is relatively short, of the order of 15 to 20 minutes.

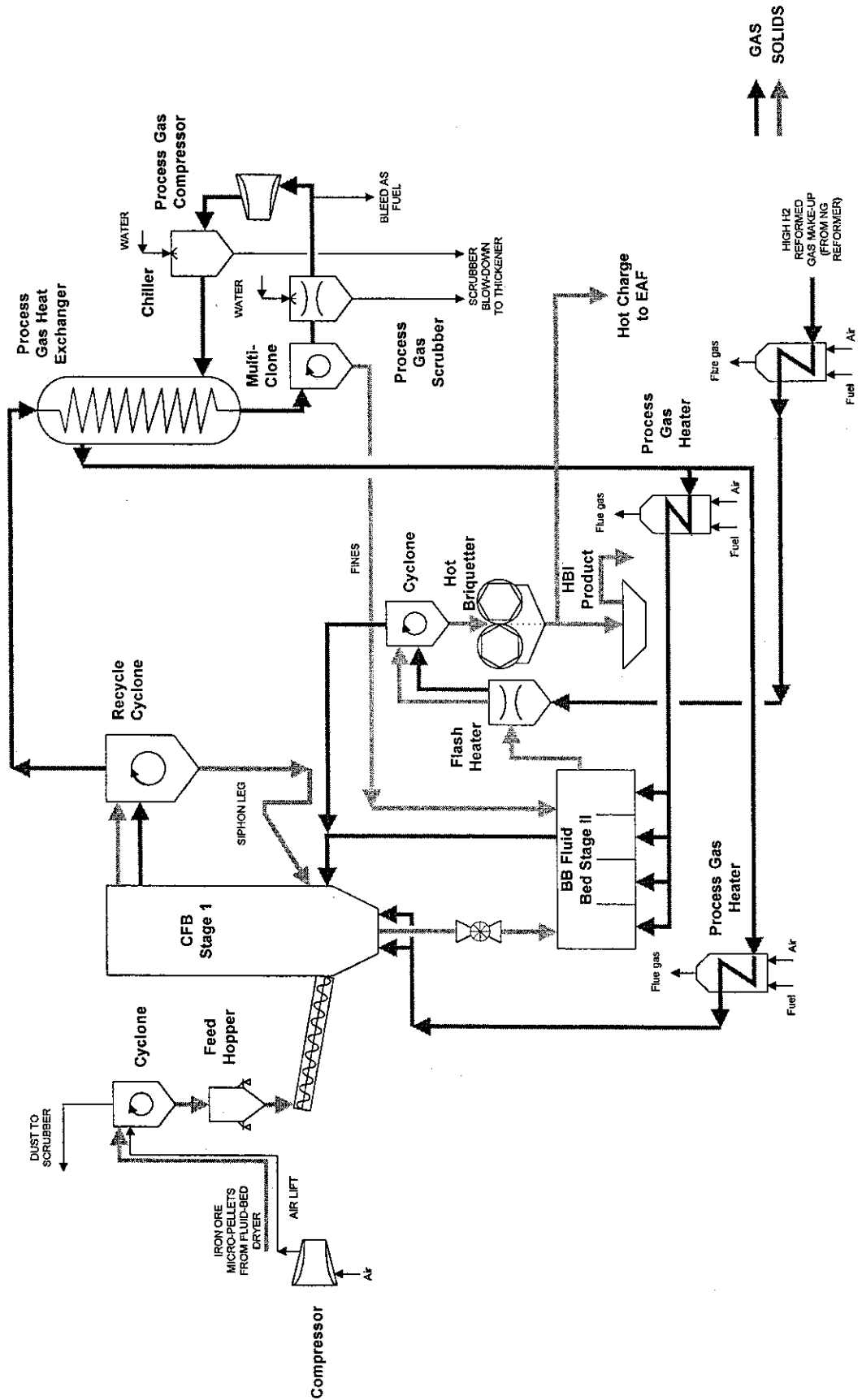
A portion of the partially metallized fines are withdrawn from CFB and enter the FB reactor. The FB reactor is compartmentalized into several sections, and has gas velocities in the range of 0.5 to 0.6 m/s. The fines reach a final metallization of 92 to 93% in the FB reactor. The off-gas leaving the top of the FB passes on to the CFB. The product leaves the FB reactor at about 630C, is then heated to about 680C, and briquetted.

### PROCESS ADVANTAGES

- Ability to process directly low cost fine ore
- Excellent heat and mass transfer conditions in CFB
- Low investment costs
- Low operating cost



# LURGI CIRCORED PROCESS FLOWSHEET





## **Circored Process --- MetSim Model --- Description**

The MetSim model for this process is largely based upon a production flowsheet for SAIDR, Maputo by Lurgi.

### **Flowsheet Description**

For this case, in the MetSim model several unit operations (from Lock hopper through Cyclone 2) are shown. These are based on a flowsheet developed by Lurgi on the micro-pelletization of iron ore fines. Some of these unit operations are not included in the process flowsheet as the main stress is on the conversion of iron ore to DRI. In this early portion of the process, the Iron Ore Fines (Stream 1) enter into the Lockhopper along with some air (Stream 2) and then moves towards Venturi 1 along with a recycle stream where moisture from the ore fines is absorbed by air as Stream 6. Stream 5, containing dried iron ore fines is separated as Stream 7 in Cyclone 1 from Stream 8. The stream 7 passes through an Air Classifier where under-sized particles are removed from ore fines and micropelletized and sent back to the Lockhopper. With the help of compressed air (Stream 14) Fuel is burnt (not shown) to heat the ore fines to about 870C. Again very fine iron ore is separated in Cyclone 2 and remaining ore at 750C (Stream 15) now enters the CFB Stage 1 Reactor.

In the Circulating Fluidized Bed, iron ore is partially reduced with the help of one-third of fresh reformed gas (Stream 25) and the upcoming gases (Stream 37) from the Stage 2 reactor called Bubbling Bed reactor. The partially reduced ore (Stream 29) is sent to BB Stage 2 reactor. Very fine iron ore (Stream 38) gets entrapped in the outgoing top gas (Stream 39). The Recycle Cyclone separates solid particles from the gas and recycles them back to CFB reactor as Stream 30. Stream 31, Top gas is used to preheat incoming reformed gas (Stream 33). The cooled top gas (Stream 32) can either be used for reforming reactions or any other purpose as the stream has high calorific value. The preheated reforming gas stream (90% H<sub>2</sub> and 10% CO) is split in two parts: Stream 24 (one-third portion) for CFB and Stream 35 (two-thirds portion) for BB. Both these are further heated to 675C in two Process Gas Heaters by burning Natural gas and Air. These hot streams then enter the reactors and perform reduction of iron ore fines. Stream 50 is the final reduced iron or called Direct Reduced Iron containing almost no carbon but almost all slag.

### **Model Assumptions:**

Cyclone 1: 100% efficiency is assumed.

Air Classifier: 15% very fine particles are assumed.

Compressor: No temperature increase during compression.

Calciner: The output temperature is 870C.

Cyclone 2: 100% efficiency is assumed. The output temperature is 750C.

CFB Stage 1: Partial reduction takes place in this reactor. Out of that only 1% reduction takes place with CO. Rest takes place with H<sub>2</sub>.

Recycle Cyclone: 100% efficiency is assumed.

Process Gas Heat Exchanger: 100% efficient; No heat losses are assumed. Both outlet temperatures are same.

BB Stage 2: 97% reduction of FeO to Fe takes place. No carry over of particles in top gas is assumed.

### **Results**

It was decided to achieve same operating conditions as were outlined in the SAIDR proposal by Lurgi. Assumptions were made about the composition of the ore fines. The model results are very close to the numbers provided by Lurgi.

**CIRCORED PROCESS -- STREAM SUMMARY**

| Stream Number                    | 1             | 2            | 3             | 4             | 5             | 6          | 7           | 8          | 10              | 11         |
|----------------------------------|---------------|--------------|---------------|---------------|---------------|------------|-------------|------------|-----------------|------------|
| Description                      | Iron Ore to L | Conveyor Air | Iron Ore from | Fine Iron Ore | Dried Iron Or | Moist Air  | Coarse Iron | Moist Air  | Air for Classif | Fines      |
| MT/HR SOLIDS                     | 1095.6        | 0            | 1323.1        | 193.34        | 1516.4        | 0          | 1516.4      | 0          | 0               | 227.46     |
| MT/HR AQUEOUS                    | 95.3          | 0            | 95.3          | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| MT/HR GASEOUS                    | 0             | 1            | 1.15          | 2.85          | 0             | 99.3       | 0           | 99.3       | 1               | 0.15       |
| MT/HR TOTAL                      | 1190.9        | 1            | 1419.5        | 196.19        | 1516.4        | 99.3       | 1516.4      | 99.3       | 1               | 227.61     |
| Percent Solids                   | 91.998        | 0            | 93.205        | 98.547        | 100           | 0          | 100         | 0          | 0               | 99.934     |
| Sp.Gr.SOLIDS                     | 5.0205        | 0            | 5.0205        | 5.0205        | 5.0205        | 0          | 5.0205      | 0          | 0               | 5.0205     |
| Sp.Gr.AQUEOUS                    | 0.99507       | 0            | 0.97631       | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| Sp.Gr.GASEOUS                    | 0             | 0.001152     | 0.0010176     | 0.0014224     | 0             | 0.00038893 | 0           | 0.00038893 | 0.001152        | 0.00061356 |
| Sp.Gr.TOTAL                      | 3.7927        | 0.001152     | 0.9519        | 0.09607       | 5.0205        | 0.00038893 | 5.0205      | 0.00038893 | 0.001152        | 0.78545    |
| Temperature C                    | 32            | 32           | 72.313        | -26           | 300           | 300        | 300         | 300        | 32              | 299.81     |
| Pressure kPa                     | 101.33        | 101.33       | 101.33        | 101.33        | 101.33        | 1.01E+02   | 101.33      | 1.01E+02   | 101.33          | 101.33     |
| Gas nm3/hr                       | 0             | 777          | 893.55        | 2214.4        | 0             | 1.22E+05   | 0           | 1.22E+05   | 777             | 116.55     |
| Sol/Liq lps                      | 8.72E+01      | 0            | 1.00E+02      | 10.697        | 8.39E+01      | 0          | 8.39E+01    | 0          | 0               | 12.585     |
| Sol/Liq lph                      | 3.14E+05      | 0            | 3.61E+05      | 38510         | 3.02E+05      | 0          | 3.02E+05    | 0          | 0               | 45306      |
| <b>Component Mass Flow Rates</b> |               |              |               |               |               |            |             |            |                 |            |
| 1 Fe2O3 MT/HR                    | 101.12        | 0            | 122.12        | 17.845        | 139.96        | 0          | 139.96      | 0          | 0               | 20.995     |
| 2 Fe3O4 MT/HR                    | 918.22        | 0            | 1108.9        | 162.04        | 1270.9        | 0          | 1270.9      | 0          | 0               | 190.64     |
| 3 FeO MT/HR                      | 0             | 0            | 0             | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| 4 Fe1 MT/HR                      | 0             | 0            | 0             | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| 5 SiO2 MT/HR                     | 11.723        | 0            | 14.157        | 2.0688        | 16.226        | 0          | 16.226      | 0          | 0               | 2.4338     |
| 6 Al2O3 MT/HR                    | 8.8744        | 0            | 10.717        | 1.5661        | 12.283        | 0          | 12.283      | 0          | 0               | 1.8424     |
| 7 P1 MT/HR                       | 0.66832       | 0            | 0.80707       | 0.11794       | 0.92501       | 0          | 0.92501     | 0          | 0               | 0.13875    |
| 8 Cu1 MT/HR                      | 0.39442       | 0            | 0.4763        | 0.069603      | 0.54591       | 0          | 0.54591     | 0          | 0               | 0.081886   |
| 9 Ca1O1 MT/HR                    | 7.7788        | 0            | 9.3938        | 1.3727        | 10.767        | 0          | 10.767      | 0          | 0               | 1.615      |
| 10 Mg1O1 MT/HR                   | 31.992        | 0            | 38.634        | 5.6456        | 44.279        | 0          | 44.279      | 0          | 0               | 6.6419     |
| 11 Ti1O2 MT/HR                   | 12.052        | 0            | 14.554        | 2.1268        | 16.681        | 0          | 16.681      | 0          | 0               | 2.5021     |
| 12 S1 MT/HR                      | 0.32868       | 0            | 0.39692       | 0.058003      | 0.45492       | 0          | 0.45492     | 0          | 0               | 0.068238   |
| 13 V1 MT/HR                      | 0.71214       | 0            | 0.85999       | 0.12567       | 0.98567       | 0          | 0.98567     | 0          | 0               | 0.14785    |
| 14 Co1 MT/HR                     | 0.28486       | 0            | 0.344         | 0.050269      | 0.39427       | 0          | 0.39427     | 0          | 0               | 0.05914    |
| 15 Ni1 MT/HR                     | 0.32868       | 0            | 0.39692       | 0.058003      | 0.45492       | 0          | 0.45492     | 0          | 0               | 0.068238   |
| 16 Zn1 MT/HR                     | 0.4492        | 0            | 0.54246       | 0.07927       | 0.62173       | 0          | 0.62173     | 0          | 0               | 0.093259   |
| 17 Pb1 MT/HR                     | 0.66832       | 0            | 0.80707       | 0.11794       | 0.92501       | 0          | 0.92501     | 0          | 0               | 0.13875    |
| 19 H2O MT/HR                     | 95.3          | 0            | 95.3          | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| 20 H2O MT/HR                     | 0             | 0            | 0             | 0             | 0             | 95.3       | 0           | 95.3       | 0               | 0          |
| 21 N2 MT/HR                      | 0             | 0.768        | 0.8832        | 2.1888        | 0             | 3.072      | 0           | 3.072      | 0.768           | 0.1152     |
| 22 O2 MT/HR                      | 0             | 0.232        | 0.2668        | 0.6612        | 0             | 0.928      | 0           | 0.928      | 0.232           | 0.0348     |
| 23 C1H4 MT/HR                    | 0             | 0            | 0             | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| 24 C1O2 MT/HR                    | 0             | 0            | 0             | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| 25 H2 MT/HR                      | 0             | 0            | 0             | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| 26 CO MT/HR                      | 0             | 0            | 0             | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| <b>Element Mass flow Rates</b>   |               |              |               |               |               |            |             |            |                 |            |
| 1 H 1                            | 10.664        | 0            | 10.664        | 0             | 0             | 10.664     | 0           | 10.664     | 0               | 0          |
| 2 C 6                            | 0             | 0            | 0             | 0             | 0             | 0          | 0           | 0          | 0               | 0          |
| 3 N 7                            | 0             | 0.768        | 0.8832        | 2.1888        | 0             | 3.072      | 0           | 3.072      | 0.768           | 0.1152     |
| 4 O 8                            | 398.99        | 0.232        | 464.53        | 56.136        | 435.1         | 85.564     | 435.1       | 85.564     | 0.232           | 65.299     |
| 5 Mg 12                          | 19.294        | 0            | 23.3          | 3.4049        | 26.705        | 0          | 26.705      | 0          | 0               | 4.0057     |
| 6 Al 13                          | 4.6968        | 0            | 5.6719        | 0.82884       | 6.5007        | 0          | 6.5007      | 0          | 0               | 0.97511    |
| 7 Si 14                          | 5.4798        | 0            | 6.6175        | 0.96702       | 7.5845        | 0          | 7.5845      | 0          | 0               | 1.1377     |
| 8 P 15                           | 0.66832       | 0            | 0.80707       | 0.11794       | 0.92501       | 0          | 0.92501     | 0          | 0               | 0.13875    |
| 9 S 16                           | 0.32868       | 0            | 0.39692       | 0.058003      | 0.45492       | 0          | 0.45492     | 0          | 0               | 0.068238   |
| 10 Ca 20                         | 5.5595        | 0            | 6.7137        | 0.98109       | 7.6948        | 0          | 7.6948      | 0          | 0               | 1.1542     |
| 11 Ti 22                         | 7.225         | 0            | 8.7251        | 1.275         | 10            | 0          | 10          | 0          | 0               | 1.5        |
| 12 V 23                          | 0.71214       | 0            | 0.85999       | 0.12567       | 0.98567       | 0          | 0.98567     | 0          | 0               | 0.14785    |
| 13 Fe 26                         | 735.15        | 0            | 887.79        | 129.73        | 1017.5        | 0          | 1017.5      | 0          | 0               | 152.63     |
| 14 Co 27                         | 0.28486       | 0            | 0.344         | 0.050269      | 0.39427       | 0          | 0.39427     | 0          | 0               | 0.05914    |
| 15 Ni 28                         | 0.32868       | 0            | 0.39692       | 0.058003      | 0.45492       | 0          | 0.45492     | 0          | 0               | 0.068238   |
| 16 Cu 29                         | 0.39442       | 0            | 0.4763        | 0.069603      | 0.54591       | 0          | 0.54591     | 0          | 0               | 0.081886   |
| 17 Zn 30                         | 0.4492        | 0            | 0.54246       | 0.07927       | 0.62173       | 0          | 0.62173     | 0          | 0               | 0.093259   |
| 18 Pb 82                         | 0.66832       | 0            | 0.80707       | 0.11794       | 0.92501       | 0          | 0.92501     | 0          | 0               | 0.13875    |

CIRCORED PROCESS -- STREAM SUMMARY

| Stream Number             | 12          | 13           | 14         | 15            | 18            | 19            | 20             | 21         | 22            | 23           | 24          |
|---------------------------|-------------|--------------|------------|---------------|---------------|---------------|----------------|------------|---------------|--------------|-------------|
| Description               | Coarse Iron | Air to Compr | Compressed | Iron Ore from | Iron Ore to C | Air to Cyclon | Air to Calcine | Combustion | Natural gas t | Exhaust from | Preheated R |
| MT/HR SOLIDS              | 1288.9      | 0            | 0          | 1095.6        | 1288.9        | 0             | 0              | 0          | 0             | 0            | 0           |
| MT/HR AQUEOUS             | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 0            | 0           |
| MT/HR GASEOUS             | 0.85        | 1            | 1          | 0             | 0             | 2.85          | 1              | 4187.3     | 205.47        | 4392.7       | 772.2       |
| MT/HR TOTAL               | 1289.8      | 1            | 1          | 1095.6        | 1288.9        | 2.85          | 1              | 4187.3     | 205.47        | 4392.7       | 772.2       |
| Percent Solids            | 99.934      | 0            | 0          | 100           | 100           | 0             | 0              | 0          | 0             | 0            | 0           |
| Sp.Gr.SOLIDS              | 5.0205      | 0            | 0          | 5.0205        | 5.0205        | 0             | 0              | 0          | 0             | 0            | 0           |
| Sp.Gr.AQUEOUS             | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 0            | 0           |
| Sp.Gr.GASEOUS             | 0.00061356  | 0.001152     | 0.001152   | 0             | 0             | 0.00030752    | 0.001152       | 0.001152   | 0.0006407     | 0.00035743   | 4.3836E-05  |
| Sp.Gr.TOTAL               | 0.78545     | 0.001152     | 0.001152   | 5.0205        | 5.0205        | 0.00030752    | 0.001152       | 0.001152   | 0.0006407     | 0.00035743   | 4.3836E-05  |
| Temperature C             | 299.81      | 32           | 32         | 750           | 870           | 870           | 32             | 32         | 32            | 675          | 344.62      |
| Pressure kPa              | 101.33      | 101.33       | 101.33     | 101.33        | 101.33        | 101.33        | 101.33         | 101.33     | 101.33        | 1.01E+02     | 1.01E+02    |
| Gas nm3/hr                | 660.45      | 777          | 777        | 0             | 0             | 2214.4        | 777            | 3.25E+06   | 2.87E+05      | 3.54E+06     | 7.79E+06    |
| Sol/Liq ips               | 71.316      | 0            | 0          | 6.06E+01      | 7.13E+01      | 0             | 0.00E+00       | 0          | 0             | 0            | 0           |
| Sol/Liq iph               | 2.57E+05    | 0            | 0          | 2.18E+05      | 2.57E+05      | 0             | 0              | 0          | 0             | 0            | 0           |
| Component Mass Flow Rates |             |              |            |               |               |               |                |            |               |              |             |
| 1 Fe2O3 MT/HR             | 118.97      | 0            | 0          | 101.12        | 118.97        | 0             | 0              | 0          | 0             | 0            | 0           |
| 2 Fe3O4 MT/HR             | 1080.3      | 0            | 0          | 918.23        | 1080.3        | 0             | 0              | 0          | 0             | 0            | 0           |
| 3 FeO MT/HR               | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 0            | 0           |
| 4 Fe1 MT/HR               | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 0            | 0           |
| 5 Si1O2 MT/HR             | 13.792      | 0            | 0          | 11.723        | 13.792        | 0             | 0              | 0          | 0             | 0            | 0           |
| 6 Al2O3 MT/HR             | 10.44       | 0            | 0          | 8.8744        | 10.44         | 0             | 0              | 0          | 0             | 0            | 0           |
| 7 P1 MT/HR                | 0.78626     | 0            | 0          | 0.66832       | 0.78626       | 0             | 0              | 0          | 0             | 0            | 0           |
| 8 Cu1 MT/HR               | 0.46402     | 0            | 0          | 0.39442       | 0.46402       | 0             | 0              | 0          | 0             | 0            | 0           |
| 9 Ca1O1 MT/HR             | 9.1515      | 0            | 0          | 7.7788        | 9.1515        | 0             | 0              | 0          | 0             | 0            | 0           |
| 10 Mg1O1 MT/HR            | 37.637      | 0            | 0          | 31.992        | 37.637        | 0             | 0              | 0          | 0             | 0            | 0           |
| 11 Ti1O2 MT/HR            | 14.178      | 0            | 0          | 12.052        | 14.178        | 0             | 0              | 0          | 0             | 0            | 0           |
| 12 S1 MT/HR               | 0.38668     | 0            | 0          | 0.32868       | 0.38668       | 0             | 0              | 0          | 0             | 0            | 0           |
| 13 V1 MT/HR               | 0.83782     | 0            | 0          | 0.71214       | 0.83782       | 0             | 0              | 0          | 0             | 0            | 0           |
| 14 Co1 MT/HR              | 0.33513     | 0            | 0          | 0.28486       | 0.33513       | 0             | 0              | 0          | 0             | 0            | 0           |
| 15 Ni1 MT/HR              | 0.38668     | 0            | 0          | 0.32868       | 0.38668       | 0             | 0              | 0          | 0             | 0            | 0           |
| 16 Zn1 MT/HR              | 0.52847     | 0            | 0          | 0.4492        | 0.52847       | 0             | 0              | 0          | 0             | 0            | 0           |
| 17 Pb1 MT/HR              | 0.78626     | 0            | 0          | 0.66832       | 0.78626       | 0             | 0              | 0          | 0             | 0            | 0           |
| 19 H2O MT/HR              | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 0            | 0           |
| 20 H2O MT/HR              | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 461.45       | 0           |
| 21 N2 MT/HR               | 0.6528      | 0.768        | 0.768      | 0             | 0             | 2.1888        | 0.768          | 3215.8     | 0             | 3215.8       | 0           |
| 22 O2 MT/HR               | 0.1972      | 0.232        | 0.232      | 0             | 0             | 0.6612        | 0.232          | 971.45     | 0             | 151.81       | 0           |
| 23 C1H4 MT/HR             | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 205.47        | 0            | 0           |
| 24 C1O2 MT/HR             | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 563.65       | 0           |
| 25 H2 MT/HR               | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 0            | 694.98      |
| 26 CO MT/HR               | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 0             | 0            | 77.22       |
| Element Mass flow Rates   |             |              |            |               |               |               |                |            |               |              |             |
| 1 H 1                     | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 51.637        | 51.637       | 694.98      |
| 2 C 6                     | 0           | 0            | 0          | 0             | 0             | 0             | 0              | 0          | 153.83        | 153.83       | 33.113      |
| 3 N 7                     | 0.6528      | 0.768        | 0.768      | 0             | 0             | 2.1888        | 0.768          | 3215.8     | 0             | 3215.8       | 0           |
| 4 O 8                     | 370.03      | 0.232        | 0.232      | 314.36        | 369.83        | 0.6612        | 0.232          | 971.45     | 0             | 971.45       | 44.107      |
| 5 Mg 12                   | 22.699      | 0            | 0          | 19.294        | 22.699        | 0             | 0              | 0          | 0             | 0            | 0           |
| 6 Al 13                   | 5.5256      | 0            | 0          | 4.6968        | 5.5256        | 0             | 0              | 0          | 0             | 0            | 0           |
| 7 Si 14                   | 6.4468      | 0            | 0          | 5.4798        | 6.4468        | 0             | 0              | 0          | 0             | 0            | 0           |
| 8 P 15                    | 0.78626     | 0            | 0          | 0.66832       | 0.78626       | 0             | 0              | 0          | 0             | 0            | 0           |
| 9 S 16                    | 0.38668     | 0            | 0          | 0.32868       | 0.38668       | 0             | 0              | 0          | 0             | 0            | 0           |
| 10 Ca 20                  | 6.5406      | 0            | 0          | 5.5595        | 6.5406        | 0             | 0              | 0          | 0             | 0            | 0           |
| 11 Ti 22                  | 8.5001      | 0            | 0          | 7.2251        | 8.5001        | 0             | 0              | 0          | 0             | 0            | 0           |
| 12 V 23                   | 0.83782     | 0            | 0          | 0.71214       | 0.83782       | 0             | 0              | 0          | 0             | 0            | 0           |
| 13 Fe 26                  | 864.89      | 0            | 0          | 735.16        | 864.89        | 0             | 0              | 0          | 0             | 0            | 0           |
| 14 Co 27                  | 0.33513     | 0            | 0          | 0.28486       | 0.33513       | 0             | 0              | 0          | 0             | 0            | 0           |
| 15 Ni 28                  | 0.38668     | 0            | 0          | 0.32868       | 0.38668       | 0             | 0              | 0          | 0             | 0            | 0           |
| 16 Cu 29                  | 0.46402     | 0            | 0          | 0.39442       | 0.46402       | 0             | 0              | 0          | 0             | 0            | 0           |
| 17 Zn 30                  | 0.52847     | 0            | 0          | 0.4492        | 0.52847       | 0             | 0              | 0          | 0             | 0            | 0           |
| 18 Pb 82                  | 0.78626     | 0            | 0          | 0.66832       | 0.78626       | 0             | 0              | 0          | 0             | 0            | 0           |

**CIRCORED PROCESS --- STREAM SUMMARY**

| Stream Number             | 25          | 26            | 27         | 28          | 29            | 30           | 31         | 32         | 33           | 34          | 35          |
|---------------------------|-------------|---------------|------------|-------------|---------------|--------------|------------|------------|--------------|-------------|-------------|
| Description               | Reducing ga | Natural gas f | Combustion | Exhaust for | Partially Red | Fines to CFB | Top Gas    | Cooled Top | High H2 Refo | Preheated R | Preheated R |
| MT/HR SOLIDS              | 0           | 0             | 0          | 0           | 1063.6        | 10.743       | 0          | 0          | 0            | 0           | 0           |
| MT/HR AQUEOUS             | 0           | 0             | 0          | 0           | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| MT/HR GASEOUS             | 772.2       | 101.19        | 2061.8     | 2163        | 0             | 0            | 2613.7     | 2613.7     | 2340         | 2340        | 1567.8      |
| MT/HR TOTAL               | 772.2       | 101.19        | 2061.8     | 2163        | 1063.6        | 10.743       | 2613.7     | 2613.7     | 2340         | 2340        | 1567.8      |
| Percent Solids            | 0           | 0             | 0          | 0           | 100           | 100          | 0          | 0          | 0            | 0           | 0           |
| Sp.Gr.SOLIDS              | 0           | 0             | 0          | 0           | 5.1765        | 5.1765       | 0          | 0          | 0            | 0           | 0           |
| Sp.Gr.AQUEOUS             | 0           | 0             | 0          | 0           | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| Sp.Gr.GASEOUS             | 2.8561E-05  | 0.0006407     | 0.001152   | 0.00035742  | 0             | 0            | 3.2766E-05 | 4.8963E-05 | 8.9331E-05   | 4.3836E-05  | 4.3836E-05  |
| Sp.Gr.TOTAL               | 2.8561E-05  | 0.0006407     | 0.001152   | 0.00035742  | 5.1765        | 5.1765       | 3.2766E-05 | 4.8963E-05 | 8.9331E-05   | 4.3836E-05  | 4.3836E-05  |
| Temperature C             | 675         | 32            | 32         | 675         | 650           | 650          | 650        | 344.62     | 30           | 344.62      | 344.62      |
| Pressure kPa              | 101.33      | 1.01E+02      | 1.01E+02   | 1.01E+02    | 1.01E+02      | 1.01E+02     | 1.01E+02   | 101.33     | 101.33       | 1.01E+02    | 1.01E+02    |
| Gas nm3/hr                | 7.79E+06    | 1.41E+05      | 1.60E+06   | 1.74E+06    | 0             | 0            | 2.36E+07   | 2.36E+07   | 2.36E+07     | 2.36E+07    | 1.58E+07    |
| Sol/Liq lps               | 0           | 0             | 0          | 0           | 57.072        | 0.57648      | 0          | 0.00E+00   | 0            | 0           | 0           |
| Sol/Liq lph               | 0           | 0             | 0          | 0           | 2.05E+05      | 2075.3       | 0          | 0          | 0            | 0           | 0           |
| Component Mass Flow Rates |             |               |            |             |               |              |            |            |              |             |             |
| 1 Fe2O3 MT/HR             | 0           | 0             | 0          | 0           | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| 2 Fe3O4 MT/HR             | 0           | 0             | 0          | 0           | 601.02        | 6.0709       | 0          | 0          | 0            | 0           | 0           |
| 3 FeO MT/HR               | 0           | 0             | 0          | 0           | 386.28        | 3.9018       | 0          | 0          | 0            | 0           | 0           |
| 4 Fe1 MT/HR               | 0           | 0             | 0          | 0           | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| 5 Si1O2 MT/HR             | 0           | 0             | 0          | 0           | 11.723        | 0.11841      | 0          | 0          | 0            | 0           | 0           |
| 6 Al2O3 MT/HR             | 0           | 0             | 0          | 0           | 8.8744        | 0.08964      | 0          | 0          | 0            | 0           | 0           |
| 7 P1 MT/HR                | 0           | 0             | 0          | 0           | 0.66832       | 0.0067507    | 0          | 0          | 0            | 0           | 0           |
| 8 Cu1 MT/HR               | 0           | 0             | 0          | 0           | 0.39442       | 0.003984     | 0          | 0          | 0            | 0           | 0           |
| 9 Ca1O1 MT/HR             | 0           | 0             | 0          | 0           | 7.7788        | 0.078574     | 0          | 0          | 0            | 0           | 0           |
| 10 Mg1O1 MT/HR            | 0           | 0             | 0          | 0           | 31.992        | 0.32315      | 0          | 0          | 0            | 0           | 0           |
| 11 Ti1O2 MT/HR            | 0           | 0             | 0          | 0           | 12.062        | 0.12173      | 0          | 0          | 0            | 0           | 0           |
| 12 S1 MT/HR               | 0           | 0             | 0          | 0           | 0.32868       | 0.00332      | 0          | 0          | 0            | 0           | 0           |
| 13 V1 MT/HR               | 0           | 0             | 0          | 0           | 0.71214       | 0.0071934    | 0          | 0          | 0            | 0           | 0           |
| 14 Co1 MT/HR              | 0           | 0             | 0          | 0           | 0.28486       | 0.0028773    | 0          | 0          | 0            | 0           | 0           |
| 15 Ni1 MT/HR              | 0           | 0             | 0          | 0           | 0.32868       | 0.00332      | 0          | 0          | 0            | 0           | 0           |
| 16 Zn1 MT/HR              | 0           | 0             | 0          | 0           | 0.4492        | 0.0045374    | 0          | 0          | 0            | 0           | 0           |
| 17 Pb1 MT/HR              | 0           | 0             | 0          | 0           | 0.66832       | 0.0067507    | 0          | 0          | 0            | 0           | 0           |
| 19 H2O MT/HR              | 0           | 0             | 0          | 0           | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| 20 H2O MT/HR              | 0           | 0             | 0          | 227.26      | 0             | 0            | 307.31     | 307.31     | 0            | 0           | 0           |
| 21 N2 MT/HR               | 0           | 0             | 1583.4     | 1583.4      | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| 22 O2 MT/HR               | 0           | 0             | 478.33     | 74.666      | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| 23 C1H4 MT/HR             | 0           | 101.19        | 0          | 0           | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| 24 C1O2 MT/HR             | 0           | 0             | 0          | 277.59      | 0             | 0            | 2.0356     | 2.0356     | 0            | 0           | 0           |
| 25 H2 MT/HR               | 694.98      | 0             | 0          | 0           | 0             | 0            | 2071.6     | 2071.6     | 2106         | 2106        | 1411        |
| 26 CO MT/HR               | 77.22       | 0             | 0          | 0           | 0             | 0            | 232.7      | 232.7      | 234          | 234         | 156.78      |
| Element Mass flow Rates   |             |               |            |             |               |              |            |            |              |             |             |
| 1 H 1                     | 694.98      | 25.431        | 0          | 25.431      | 0             | 0            | 2106       | 2106       | 2106         | 2106        | 1411        |
| 2 C 6                     | 33.113      | 75.76         | 0          | 75.76       | 0             | 0            | 100.34     | 100.34     | 100.34       | 100.34      | 67.229      |
| 3 N 7                     | 0           | 0             | 1583.4     | 1583.4      | 0             | 0            | 0          | 0          | 0            | 0           | 0           |
| 4 O 8                     | 44.107      | 0             | 478.33     | 478.33      | 282.31        | 2.8516       | 407.32     | 407.32     | 133.66       | 133.66      | 89.551      |
| 5 Mg 12                   | 0           | 0             | 0          | 0           | 19.294        | 0.19489      | 0          | 0          | 0            | 0           | 0           |
| 6 Al 13                   | 0           | 0             | 0          | 0           | 4.6968        | 0.047442     | 0          | 0          | 0            | 0           | 0           |
| 7 Si 14                   | 0           | 0             | 0          | 0           | 5.4798        | 0.055351     | 0          | 0          | 0            | 0           | 0           |
| 8 P 15                    | 0           | 0             | 0          | 0           | 0.66832       | 0.0067507    | 0          | 0          | 0            | 0           | 0           |
| 9 S 16                    | 0           | 0             | 0          | 0           | 0.32868       | 0.00332      | 0          | 0          | 0            | 0           | 0           |
| 10 Ca 20                  | 0           | 0             | 0          | 0           | 5.5595        | 0.056157     | 0          | 0          | 0            | 0           | 0           |
| 11 Ti 22                  | 0           | 0             | 0          | 0           | 7.2251        | 0.072981     | 0          | 0          | 0            | 0           | 0           |
| 12 V 23                   | 0           | 0             | 0          | 0           | 0.71214       | 0.0071934    | 0          | 0          | 0            | 0           | 0           |
| 13 Fe 26                  | 0           | 0             | 0          | 0           | 735.16        | 7.4258       | 0          | 0          | 0            | 0           | 0           |
| 14 Co 27                  | 0           | 0             | 0          | 0           | 0.28486       | 0.0028773    | 0          | 0          | 0            | 0           | 0           |
| 15 Ni 28                  | 0           | 0             | 0          | 0           | 0.32868       | 0.00332      | 0          | 0          | 0            | 0           | 0           |
| 16 Cu 29                  | 0           | 0             | 0          | 0           | 0.39442       | 0.003984     | 0          | 0          | 0            | 0           | 0           |
| 17 Zn 30                  | 0           | 0             | 0          | 0           | 0.4492        | 0.0045374    | 0          | 0          | 0            | 0           | 0           |
| 18 Pb 82                  | 0           | 0             | 0          | 0           | 0.66832       | 0.006751     | 0          | 0          | 0            | 0           | 0           |

CIRCORED PROCESS --- STREAM SUMMARY

| Stream Number             | 36          | 37          | 38            | 39           | 50       |
|---------------------------|-------------|-------------|---------------|--------------|----------|
| Description               | Hot Reducin | Reducing ga | Partially Red | Top Gas with | DRI      |
| MT/HR SOLIDS              | 0           | 0           | 10.743        | 0            | 821.94   |
| MT/HR AQUEOUS             | 0           | 0           | 0             | 0            | 0        |
| MT/HR GASEOUS             | 1567.8      | 1809.4      | 0             | 2613.7       | 0        |
| MT/HR TOTAL               | 1567.8      | 1809.4      | 10.743        | 2613.7       | 821.94   |
| Percent Solids            | 0           | 0           | 100           | 0            | 100      |
| Sp.Gr.SOLIDS              | 0           | 0           | 5.1765        | 0            | 6.9179   |
| Sp.Gr.AQUEOUS             | 0           | 0           | 0             | 0            | 0        |
| Sp.Gr.GASEOUS             | 2.8561E-05  | 0.00003358  | 0             | 3.2766E-05   | 0        |
| Sp.Gr.TOTAL               | 2.8561E-05  | 0.00003358  | 5.1765        | 3.2766E-05   | 6.9179   |
| Temperature C             | 675         | 657.59      | 650           | 650          | 660      |
| Pressure kPa              | 101.33      | 1.01E+02    | 1.01E+02      | 1.01E+02     | 1.01E+02 |
| Gas nm3/hr                | 1.58E+07    | 1.58E+07    | 0             | 2.36E+07     | 0        |
| Sol/Liq lps               | 0           | 0           | 0.57648       | 0            | 33.004   |
| Sol/Liq lph               | 0           | 0           | 2075.3        | 0            | 1.19E+05 |
| Component Mass Flow Rates |             |             |               |              |          |
| 1 Fe2O3 MT/HR             | 0           | 0           | 0             | 0            | 0        |
| 2 Fe3O4 MT/HR             | 0           | 0           | 6.0709        | 0            | 0        |
| 3 FeO MT/HR               | 0           | 0           | 3.9018        | 0            | 47.289   |
| 4 Fe1 MT/HR               | 0           | 0           | 0             | 0            | 698.4    |
| 5 Si1O2 MT/HR             | 0           | 0           | 0.11841       | 0            | 11.723   |
| 6 Al2O3 MT/HR             | 0           | 0           | 0.08964       | 0            | 8.8744   |
| 7 P1 MT/HR                | 0           | 0           | 0.0067507     | 0            | 0.66832  |
| 8 Cu1 MT/HR               | 0           | 0           | 0.003984      | 0            | 0.39442  |
| 9 Ca1O1 MT/HR             | 0           | 0           | 0.078574      | 0            | 7.7788   |
| 10 Mg1O1 MT/HR            | 0           | 0           | 0.32315       | 0            | 31.992   |
| 11 Ti1O2 MT/HR            | 0           | 0           | 0.12173       | 0            | 12.052   |
| 12 S1 MT/HR               | 0           | 0           | 0.00332       | 0            | 0.32868  |
| 13 V1 MT/HR               | 0           | 0           | 0.0071934     | 0            | 0.71214  |
| 14 Co1 MT/HR              | 0           | 0           | 0.0028773     | 0            | 0.28486  |
| 15 Ni1 MT/HR              | 0           | 0           | 0.00332       | 0            | 0.32868  |
| 16 Zn1 MT/HR              | 0           | 0           | 0.0045374     | 0            | 0.4492   |
| 17 Pb1 MT/HR              | 0           | 0           | 0.0067507     | 0            | 0.66832  |
| 19 H2O MT/HR              | 0           | 0           | 0             | 0            | 0        |
| 20 H2O MT/HR              | 0           | 272.06      | 0             | 307.31       | 0        |
| 21 N2 MT/HR               | 0           | 0           | 0             | 0            | 0        |
| 22 O2 MT/HR               | 0           | 0           | 0             | 0            | 0        |
| 23 C1H4 MT/HR             | 0           | 0           | 0             | 0            | 0        |
| 24 C1O2 MT/HR             | 0           | 0           | 0             | 2.0356       | 0        |
| 25 H2 MT/HR               | 1411        | 1380.6      | 0             | 2071.6       | 0        |
| 26 CO MT/HR               | 156.78      | 156.78      | 0             | 232.7        | 0        |
| Element Mass flow Rates   |             |             |               |              |          |
| 1 H 1                     | 1411        | 1411        | 0             | 2106         | 0        |
| 2 C 6                     | 67.229      | 67.229      | 0             | 100.34       | 0        |
| 3 N 7                     | 0           | 0           | 0             | 0            | 0        |
| 4 O 8                     | 89.551      | 331.16      | 2.8516        | 407.32       | 40.695   |
| 5 Mg 12                   | 0           | 0           | 0.19489       | 0            | 19.294   |
| 6 Al 13                   | 0           | 0           | 0.047442      | 0            | 4.6968   |
| 7 Si 14                   | 0           | 0           | 0.055351      | 0            | 5.4798   |
| 8 P 15                    | 0           | 0           | 0.0067507     | 0            | 0.66832  |
| 9 S 16                    | 0           | 0           | 0.00332       | 0            | 0.32868  |
| 10 Ca 20                  | 0           | 0           | 0.056157      | 0            | 5.5595   |
| 11 Ti 22                  | 0           | 0           | 0.072981      | 0            | 7.2251   |
| 12 V 23                   | 0           | 0           | 0.0071934     | 0            | 0.71214  |
| 13 Fe 26                  | 0           | 0           | 7.4258        | 0            | 735.16   |
| 14 Co 27                  | 0           | 0           | 0.0028773     | 0            | 0.28486  |
| 15 Ni 28                  | 0           | 0           | 0.00332       | 0            | 0.32868  |
| 16 Cu 29                  | 0           | 0           | 0.003984      | 0            | 0.39442  |
| 17 Zn 30                  | 0           | 0           | 0.0045374     | 0            | 0.4492   |
| 18 Pb 82                  | 0           | 0           | 0.006751      | 0            | 0.66832  |



CIRCORED MODEL

CASE DEFINITION

Title : CIRCORED MODEL  
Case :

Data Storage File Name : CIRCORED4.sfw  
Mass Balance Option : ON  
Heat Balance Option : ON  
Size Analysis Option : ON  
Units of Mass : metric tonne  
Units of Time : hour  
Ambient Air Pressure : 101.325 kPa  
Standard Pressure : 101.325 kPa  
Ambient Air Temperature : 20.00 C  
Standard Temperature : 0.00 C  
Plant Site Latitude : 0.00 Degrees  
Plant Site Elevation : 0.00 Meters



## CIRCORED MODEL

## COMPONENT DATA

| ROW | CNM     | CRIT T  | CRIT P  | CRIT V  | ANTOINE | VAPOR   | PRES A  | B | C | HENRY   |
|-----|---------|---------|---------|---------|---------|---------|---------|---|---|---------|
| 1   | Fe2O3   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 2   | Fe3O4   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 3   | FeO     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 4   | Fe1     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 5   | Si1O2   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 6   | Al2O3   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 7   | P1      | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 8   | Cu1     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 9   | Ca1O1   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 10  | Mg1O1   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 11  | Ti1O2   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 12  | S1      | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 13  | V1      | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 14  | Co1     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 15  | Ni1     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 16  | Zn1     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 17  | Pb1     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 18  | Ca1C1O3 | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 19  | H2O     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 20  | H2O     | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 21  | N2      | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 22  | O2      | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 23  | C1H4    | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 24  | C1O2    | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 25  | H2      | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.000   | 0.000   |   |   | 0.0     |
| 26  | CO      | 133.400 | 35.4638 | 93.1000 | 6.24020 | 230.270 | 260.010 |   |   | 63426.0 |

| ROW | CNM     | REFERENCE | H25     | HTE-A  | HTE-B    | HTE-C    | HTE-D    |
|-----|---------|-----------|---------|--------|----------|----------|----------|
| 1   | Fe2O3   | B672158   | -197000 | -20749 | 46.1517  | -3.8751  | 21.9462  |
| 2   | Fe3O4   | B672160   | -267300 | -31312 | 71.0525  | -7.8736  | 32.0732  |
| 3   | FeO     | BAK2248   | -62382  | 8754   | -8.5950  | 9.1416   | -21.4692 |
| 4   | Fe1     | B672151   | 0       | -7903  | 14.0914  | -1.3293  | 11.6233  |
| 5   | Si1O2   | B672387   | -217720 | -8654  | 19.1651  | -0.5456  | 8.8977   |
| 6   | Al2O3   | B672042   | -400500 | -12425 | 28.9653  | 1.0071   | 11.1085  |
| 7   | P1      | B672282   | 0       | -2816  | 12.9239  | -11.6659 | 0.0000   |
| 8   | Cu1     | B672129   | 0       | -1423  | 5.0156   | 0.9276   | -0.4694  |
| 9   | Ca1O1   | B672098   | -151790 | -4315  | 12.0730  | 0.4606   | 2.0088   |
| 10  | Mg1O1   | B672227   | -143760 | -4612  | 11.8081  | 0.3610   | 3.1765   |
| 11  | Ti1O2   | B672431   | -225670 | -6260  | 16.8540  | 0.6334   | 3.4762   |
| 12  | S1      | B672335   | 0       | 13015  | -44.4133 | 56.5440  | -14.3084 |
| 13  | V1      | B672454   | 0       | -999   | 4.4929   | 1.2791   | -1.3985  |
| 14  | Co1     | B672113   | 0       | -3885  | 7.9629   | 0.8444   | 4.4112   |
| 15  | Ni1     | B672270   | 0       | -1763  | 6.2394   | 0.7740   | -0.5571  |
| 16  | Zn1     | B672480   | 0       | -1445  | 4.7430   | 1.6445   | -0.3435  |
| 17  | Pb1     | B672294   | 0       | -1512  | 4.9651   | 1.6774   | -0.3504  |
| 18  | Ca1C1O3 | B6771413  | -288610 | -9122  | 23.8351  | 3.2146   | 5.1569   |
| 19  | H2O     | B672180   | -68315  | -5071  | 16.1848  | 2.7637   | 0.0000   |
| 20  | H2O     | B672182   | -57795  | -2403  | 7.2906   | 1.3003   | 0.3596   |
| 21  | N2      | B672244   | 0       | -2846  | 7.5728   | 0.2525   | 1.7794   |
| 22  | O2      | B672277   | 0       | -2979  | 7.9696   | 0.2720   | 1.7697   |
| 23  | C1H4    | B6772217  | -17880  | -6424  | 11.8424  | 2.9907   | 8.0422   |
| 24  | C1O2    | B672094   | -94051  | -5911  | 12.9357  | 0.3891   | 6.1869   |
| 25  | H2      | B672174   | 0       | -1837  | 6.3659   | 0.4428   | -0.2847  |
| 26  | CO      | YAWS      | -26420  | -1787  | 6.0661   | 0.9368   | -0.3112  |

## CIRCORED MODEL

## COMPONENT DATA

| ROW | CNM     | TEMP  | RANGE  | oK | HTG-A   | HTG-B    | HTG-C    | HTG-D    |
|-----|---------|-------|--------|----|---------|----------|----------|----------|
| 1   | Fe2O3   | 298.2 | 1800.0 |    | -182323 | -34.6418 | -13.7715 | -28.2755 |
| 2   | Fe3O4   | 298.2 | 1800.0 |    | -243067 | -58.6967 | -18.9430 | -46.8195 |
| 3   | FeO     | 298.2 | 1650.0 |    | -58450  | -19.5576 | -4.9564  | -7.3814  |
| 4   | Fe1     | 298.2 | 1811.0 |    | 2679    | -8.2139  | -4.0925  | -5.4957  |
| 5   | Si1O2   | 298.2 | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464 |
| 6   | Al2O3   | 298.2 | 2327.0 |    | -386441 | -25.8901 | -10.0349 | -27.6544 |
| 7   | P1      | 298.2 | 317.3  |    | -2534   | 6.8556   | -27.4268 | 0.0000   |
| 8   | Cu1     | 298.2 | 1357.6 |    | 1948    | -9.4355  | -3.1931  | -3.6331  |
| 9   | Ca1O1   | 298.2 | 2000.0 |    | -146099 | -14.8629 | -4.7096  | -10.7418 |
| 10  | Mg1O1   | 298.2 | 2000.0 |    | -138544 | -11.5487 | -4.4916  | -9.9661  |
| 11  | Ti1O2   | 298.2 | 2000.0 |    | -217923 | -19.7530 | -6.5095  | -14.7172 |
| 12  | S1      | 298.2 | 388.4  |    | -5700   | 12.4302  | -23.6630 | 5.4073   |
| 13  | V1      | 298.2 | 2190.0 |    | 2969    | -9.8550  | -2.7412  | -5.5855  |
| 14  | Co1     | 298.2 | 1768.0 |    | 2071    | -8.3546  | -3.9177  | -4.1323  |
| 15  | Ni1     | 298.2 | 1728.0 |    | 3122    | -10.1656 | -3.1379  | -5.8385  |
| 16  | Zn1     | 298.2 | 692.7  |    | 834     | -9.1557  | -4.7988  | -1.9233  |
| 17  | Pb1     | 298.2 | 600.7  |    | 544     | -13.9080 | -5.5553  | -1.5560  |
| 18  | Ca1ClO3 | 298.2 | 1200.0 |    | -283124 | -23.3813 | -15.1456 | -11.0884 |
| 19  | H2O     | 298.2 | 373.2  |    | -70630  | -1.0739  | -26.4253 | 0.0000   |
| 20  | H2O     | 298.2 | 2000.0 |    | -54212  | -48.4557 | -3.8711  | -6.7579  |
| 21  | N2      | 298.2 | 3000.0 |    | 5078    | -51.3044 | -2.2358  | -9.9139  |
| 22  | O2      | 298.2 | 3000.0 |    | 5395    | -54.8302 | -2.3535  | -10.5960 |
| 23  | C1H4    | 298.2 | 2000.0 |    | -14673  | -45.4106 | -7.1789  | -6.9854  |
| 24  | C1O2    | 298.2 | 3000.0 |    | -86430  | -58.7976 | -3.7771  | -15.3476 |
| 25  | H2      | 298.2 | 3000.0 |    | 4863    | -36.6465 | -2.1036  | -9.3536  |
| 26  | CO      | 298.0 | 700.0  |    | -25393  | -46.6664 | -5.1645  | -2.2650  |

## CIRCORED MODEL

## FLOWSHEET DATA

| NO | OPR | UNIT       | PROCESS    | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |
|----|-----|------------|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | SEC | CIRCORED   | PROCESS    | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 2  | HPR | LOCK       | HOPPER     | 1   | 2   | 11  | 0   | 0   | 0   | 0   | 3   | 0   | 0   | 0   | 0   | 0   |
| 3  | SPP | VENTURI    | 1          | 3   | 4   | 0   | 0   | 0   | 0   | 0   | 5   | 6   | 0   | 0   | 0   | 0   |
| 4  | SPP | CYCLONE1   |            | 6   | 5   | 0   | 0   | 0   | 0   | 0   | 7   | 8   | 0   | 0   | 0   | 0   |
| 5  | SPS | AIR        | CLASSIFIER | 10  | 7   | 0   | 0   | 0   | 0   | 0   | 12  | 11  | 0   | 0   | 0   | 0   |
| 6  | MIX | COMPRESSOR |            | 13  | 0   | 0   | 0   | 0   | 0   | 0   | 14  | 0   | 0   | 0   | 0   | 0   |
| 7  | SPP | CALCINER   |            | 12  | 14  | 0   | 20  | 0   | 0   | 0   | 18  | 19  | 0   | 0   | 0   | 0   |
| 8  | SPP | CYCLONE    | 2          | 18  | 19  | 0   | 0   | 0   | 0   | 0   | 15  | 4   | 0   | 0   | 0   | 0   |
| 9  | SPP | CFB        | STAGE 1    | 15  | 25  | 37  | 30  | 0   | 0   | 0   | 29  | 38  | 39  | 0   | 0   | 0   |
| 10 | SPP | RECYCLE    | CYCLONE    | 39  | 38  | 0   | 0   | 0   | 0   | 0   | 30  | 31  | 0   | 0   | 0   | 0   |
| 11 | HTX | PROCESS    | GAS H/E    | 31  | 0   | 0   | 33  | 0   | 0   | 0   | 32  | 34  | 0   | 0   | 0   | 0   |
| 12 | SPS | STREAM     | SPLITTER   | 34  | 0   | 0   | 0   | 0   | 0   | 0   | 35  | 24  | 0   | 0   | 0   | 0   |
| 13 | HTX | PROGAS     | HEATER 2   | 35  | 0   | 0   | 21  | 22  | 0   | 0   | 36  | 23  | 0   | 0   | 0   | 0   |
| 14 | HTX | PROGAS     | HEATER 1   | 24  | 0   | 0   | 26  | 27  | 0   | 0   | 25  | 28  | 0   | 0   | 0   | 0   |
| 15 | SPP | BB         | STAGE 2    | 29  | 36  | 0   | 0   | 0   | 0   | 0   | 50  | 37  | 0   | 0   | 0   | 0   |

## CIRCORED MODEL

| HEAT BALANCE SUMMARY - 1000000 KCAL/HOUR |                 |               |               |                 |              |               |                          |       |
|--|-----------------|---------------|---------------|-----------------|--------------|---------------|--------------------------|-------|
| OP PROCESS STEP                          | INPUT<br>STREAM | HEAT<br>REACT | HEAT<br>SOLUT | ENERGY<br>INPUT | HEAT<br>LOSS | HEAT<br>REQRD | HEAT<br>OUTPUT<br>STREAM | TOTAL |
| 1 CIRCORED PROCESS                       | 0               | 0             | 0             | 0               | 0            | 0             | 0                        | 0     |
| 2 LOCK HOPPER                            | 14              | 0             | 0             | 0               | 0            | 0             | -14                      | 0     |
| 3 VENTURI 1                              | -40             | -56           | 0             | 0               | 0            | 190           | -94                      | 0     |
| 4 CYCLONE1                               | 94              | 0             | 0             | 0               | 0            | 0             | -94                      | 0     |
| 5 AIR CLASSIFIER                         | 82              | 0             | 0             | 0               | 0            | 0             | -82                      | 0     |
| 6 COMPRESSOR                             | 0               | 0             | 0             | 0               | 0            | 0             | 0                        | 0     |
| 7 CALCINER                               | 70              | 0             | 0             | 0               | 0            | 170           | -239                     | 0     |
| 8 CYCLONE 2                              | 239             | 0             | 0             | 0               | -120         | 0             | -120                     | 0     |
| 9 CFB STAGE 1                            | 4913            | -39           | 0             | 0               | 0            | -107          | -4766                    | 0     |
| 10 RECYCLE CYCLONE                       | 4640            | 0             | 0             | 0               | 0            | 0             | -4640                    | 0     |
| 11 PROCESS GAS H/E                       | 4680            | 0             | 0             | 0               | 0            | 0             | -4680                    | 0     |
| 12 STREAM SPLITTER                       | 2336            | 0             | 0             | 0               | 0            | 0             | -2336                    | 0     |
| 13 PROGAS HEATER 2                       | 1577            | 2458          | 0             | 0               | 0            | 0             | -4032                    | 2     |
| 14 PROGAS HEATER 1                       | 777             | 1211          | 0             | 0               | 0            | 0             | -1986                    | 1     |
| 15 BB STAGE 2                            | 3349            | -115          | 0             | 0               | 0            | 0             | -3234                    | 0     |

## CIRCORED MODEL

| NO. | STREAM                         | STREAM TEMPERATURES AND ENTHALPIES |         |              |             |            |
|-----|--------------------------------|------------------------------------|---------|--------------|-------------|------------|
|     |                                | TEMP-C                             | TEMP-F  | KCAL/HR      | BTU/HR      | KJ/H       |
| 1   | Iron Ore to Lockhopper         | 32.000                             | 89.60   | 1455227.0    | 5774809     | 608867     |
| 2   | Conveyor Air                   | 32.000                             | 89.60   | 2369.0       | 9400        | 991        |
| 3   | Iron Ore from Lockhopper       | 72.313                             | 162.16  | 13750979.0   | 54568295    | 5753409    |
| 4   | Fine Iron Ore from Cyclone 2   | -26.000                            | -14.80  | -53567526.0  | -212573124  | -22412653  |
| 5   | Dried Iron Ore                 | 300.000                            | 572.00  | 81951615.0   | 325210290   | 34288555   |
| 6   | Moist Air                      | 300.000                            | 572.00  | 12250507.0   | 48613940    | 5125612    |
| 7   | Coarse Iron Ore                | 300.000                            | 572.00  | 81951615.0   | 325210290   | 34288555   |
| 8   | Moist Air                      | 300.000                            | 572.00  | 12250507.0   | 48613940    | 5125612    |
| 9   |                                | 0.000                              | 32.00   | 27223107.0   | 108030018   | 11390147   |
| 10  | Air for Classifier             | 32.000                             | 89.60   | 2369.0       | 9400        | 991        |
| 11  | Fines                          | 299.815                            | 571.67  | 12293098.0   | 48782953    | 5143432    |
| 12  | Coarse Iron Ore Feed           | 299.815                            | 571.67  | 69660886.0   | 276436736   | 29146114   |
| 13  | Air to Compressor              | 32.000                             | 89.60   | 2369.0       | 9400        | 991        |
| 14  | Compressed Air                 | 32.000                             | 89.60   | 2369.0       | 9400        | 991        |
| 15  | Iron Ore from Cyclone 2        | 750.000                            | 1382.00 | 173218033.0  | 687384708   | 72474425   |
| 16  | Feed to CFB                    | 750.000                            | 1382.00 | 142215195.0  | 564355503   | 59502837   |
| 17  | Iron Ore Recycle               | 750.000                            | 1382.00 | 47405065.0   | 188118501   | 19834279   |
| 18  | Iron Ore to Cyclone 2          | 870.000                            | 1598.00 | 238671842.0  | 947126412   | 99860298   |
| 19  | Air to Cyclone 2               | 870.000                            | 1598.00 | 629172.0     | 2496755     | 263245     |
| 20  | Air to Calciner                | 32.000                             | 89.60   | 2369.0       | 9400        | 991        |
| 21  | Combustion Air to Heater 2     | 32.000                             | 89.60   | 9918111.0    | 39358247    | 4149737    |
| 22  | Natural gas to Heater 2        | 32.000                             | 89.60   | 1333293.0    | 5290933     | 557849     |
| 23  | Exhaust from Heater 2          | 675.000                            | 1247.00 | 809492155.0  | 3212324474  | 338691517  |
| 24  | Preheated Reformed gas for CFB | 344.620                            | 652.32  | 770969189.0  | 3059452993  | 322573508  |
| 25  | Reducing gas for CFB           | 675.000                            | 1247.00 | 1587444530.0 | 6299488990  | 664186791  |
| 26  | Natural gas for Heater 1       | 32.000                             | 89.60   | 656639.0     | 2605756     | 274737     |
| 27  | Combustion Air for Heater 1    | 32.000                             | 89.60   | 4883594.0    | 19379667    | 2043295    |
| 28  | Exhaust for Heater 1           | 675.000                            | 1247.00 | 398598647.0  | 1581767262  | 166773674  |
| 29  | Partially Reduced Ore          | 650.000                            | 1202.00 | 126085243.0  | 500346678   | 52754065   |
| 30  | Fines to CFB                   | 650.000                            | 1202.00 | 1273588.0    | 5054007     | 532869     |
| 31  | Top Gas                        | 650.000                            | 1202.00 | 4638735895.0 | 18407991673 | 1940847098 |
| 32  | Cooled Top Gas                 | 344.620                            | 652.32  | 2343776800.0 | 9300857992  | 980636213  |
| 33  | High H2 Reformed gas makeup    | 30.000                             | 86.00   | 41311176.0   | 163935994   | 17284596   |
| 34  | Preheated Reformed Gas         | 344.620                            | 652.32  | 2336270270.0 | 9271069675  | 977495481  |
| 35  | Preheated Reformed Gas for BB  | 344.620                            | 652.32  | 1565301081.0 | 6211616682  | 654921972  |
| 36  | Hot Reducing gas for BB        | 675.000                            | 1247.00 | 3222993441.0 | 12789871586 | 1348500455 |
| 37  | Reducing gas from BB           | 657.589                            | 1215.66 | 3150840386.0 | 12503545126 | 1318311617 |
| 38  | Partially Reduced Fines        | 650.000                            | 1202.00 | 1273588.0    | 5054007     | 532869     |
| 39  | Top Gas with Fines             | 650.000                            | 1202.00 | 4638735895.0 | 18407991673 | 1940847098 |
| 40  | Natural gas for Reformer       | 32.000                             | 89.60   | 1622269.0    | 6437683     | 678757     |
| 41  | Reformed Gas                   | 600.000                            | 1112.00 | 4332245513.0 | 17191739546 | 1812611522 |
| 42  | Cold water for Chiller         | 32.000                             | 89.60   | 209587.0     | 831707      | 87691      |
| 43  | Waste Water from Chiller       | 238.769                            | 461.78  | 14967617.0   | 59396305    | 6262451    |
| 44  | Calcium Oxide                  | 32.000                             | 89.60   | 377168.0     | 1496725     | 157807     |
| 45  | Calcium Carbonate              | 550.000                            | 1022.00 | 33056359.0   | 131178235   | 13830780   |
| 46  | Reformed Gas w/o CO2           | 600.000                            | 1112.00 | 29725648.0   | 117960903   | 12437210   |
| 47  | Excess Reformed Gas            | 600.000                            | 1112.00 | 0.0          | 0           | 0          |
| 50  | DRI                            | 660.000                            | 1220.00 | 82836032.0   | 328719939   | 34658595   |

## CIRCORED MODEL

## VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM                        | TIME     | ACFM     | SCFM     | M3/HR    | NM3/HR   |
|-----------------------------------|----------|----------|----------|----------|----------|
| 2 Conveyor Air                    | 100.0000 | 511      | 457      | 868      | 777      |
| 3 Iron Ore from Lockhopper        | 100.0000 | 878      | 737      | 1491     | 1252     |
| 4 Fine Iron Ore from Cyclone 2    | 100.0000 | 1202     | 1326     | 2042     | 2253     |
| 6 Moist Air                       | 100.0000 | 150272   | 71616    | 255314   | 121677   |
| 8 Moist Air                       | 100.0000 | 150272   | 71616    | 255314   | 121677   |
| 9                                 | 100.0000 | 449493   | 449493   | 763694   | 763694   |
| 10 Air for Classifier             | 100.0000 | 511      | 457      | 868      | 777      |
| 11 Fines                          | 100.0000 | 171      | 95       | 290      | 162      |
| 12 Coarse Iron Ore Feed           | 100.0000 | 967      | 540      | 1642     | 917      |
| 13 Air to Compressor              | 100.0000 | 511      | 457      | 868      | 777      |
| 14 Compressed Air                 | 100.0000 | 511      | 457      | 868      | 777      |
| 19 Air to Cyclone 2               | 100.0000 | 5455     | 1303     | 9268     | 2214     |
| 20 Air to Calciner                | 100.0000 | 511      | 457      | 868      | 777      |
| 21 Combustion Air to Heater 2     | 100.0000 | 2139273  | 1914935  | 3634648  | 3253496  |
| 22 Natural gas to Heater 2        | 100.0000 | 188752   | 168958   | 320692   | 287062   |
| 23 Exhaust from Heater 2          | 100.0000 | 7233548  | 2083894  | 12289876 | 3540558  |
| 24 Preheated Reformed gas for CFB | 100.0000 | 10368202 | 4584343  | 17615688 | 7788848  |
| 25 Reducing gas for CFB           | 100.0000 | 15913063 | 4584343  | 27036466 | 7788848  |
| 26 Natural gas for Heater 1       | 100.0000 | 92959    | 83211    | 157939   | 141376   |
| 27 Combustion Air for Heater 1    | 100.0000 | 1053360  | 942898   | 1789670  | 1601994  |
| 28 Exhaust for Heater 1           | 100.0000 | 3561798  | 1026109  | 6051533  | 1743370  |
| 31 Top Gas                        | 100.0000 | 46949943 | 13891947 | 79768460 | 23602568 |
| 32 Cooled Top Gas                 | 100.0000 | 31418795 | 13891947 | 53380871 | 23602568 |
| 33 High H2 Reformed gas makeup    | 100.0000 | 15417604 | 13891947 | 26194676 | 23602568 |
| 34 Preheated Reformed Gas         | 100.0000 | 31418795 | 13891947 | 53380872 | 23602568 |
| 35 Preheated Reformed Gas for BB  | 100.0000 | 21050593 | 9307605  | 35765184 | 15813721 |
| 36 Hot Reducing gas for BB        | 100.0000 | 32308341 | 9307605  | 54892219 | 15813721 |
| 37 Reducing gas from BB           | 100.0000 | 31715067 | 9307605  | 53884241 | 15813721 |
| 39 Top Gas with Fines             | 100.0000 | 46949943 | 13891947 | 79768460 | 23602568 |
| 40 Natural gas for Reformer       | 100.0000 | 229662   | 205578   | 390198   | 349279   |
| 41 Reformed Gas                   | 100.0000 | 44386805 | 13885650 | 75413661 | 23591869 |
| 43 Waste Water from Chiller       | 100.0000 | 103277   | 55113    | 175469   | 93637    |
| 46 Reformed Gas w/o CO2           | 100.0000 | 176116   | 55095    | 299223   | 93607    |

## VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM                 | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|----------------------------|----------|----------|----------|----------|----------|
| 1 Iron Ore to Lockhopper   | 100.0000 | 1382.480 | 87.22143 | 313.9972 | 7535.932 |
| 5 Dried Iron Ore           | 100.0000 | 1329.846 | 83.90074 | 302.0427 | 7249.024 |
| 7 Coarse Iron Ore          | 100.0000 | 1329.846 | 83.90074 | 302.0427 | 7249.024 |
| 15 Iron Ore from Cyclone 2 | 100.0000 | 960.814  | 60.61829 | 218.2258 | 5237.420 |
| 18 Iron Ore to Cyclone 2   | 100.0000 | 1130.369 | 71.31563 | 256.7363 | 6161.671 |
| 29 Partially Reduced Ore   | 100.0000 | 904.604  | 57.07196 | 205.4591 | 4931.018 |
| 30 Fines to CFB            | 100.0000 | 9.137    | 0.57648  | 2.0753   | 49.808   |
| 38 Partially Reduced Fines | 100.0000 | 9.137    | 0.57648  | 2.0753   | 49.808   |
| 50 DRI                     | 100.0000 | 523.121  | 33.00403 | 118.8145 | 2851.548 |



## CIRCORED MODEL

## MASS FLOW RATES - MT/HR

| NO. STREAM                        | MT/HR-SI | MT/HR-LI | MT/HR-GC | MT/HR-TC |
|-----------------------------------|----------|----------|----------|----------|
| 1 Iron Ore to Lockhopper          | 1095.600 | 95.30000 | 0.000    | 1190.900 |
| 2 Conveyor Air                    | 0.000    | 0.00000  | 1.000    | 1.000    |
| 3 Iron Ore from Lockhopper        | 1323.067 | 95.30000 | 1.150    | 1419.517 |
| 4 Fine Iron Ore from Cyclone 2    | 193.342  | 0.00000  | 2.850    | 196.192  |
| 5 Dried Iron Ore                  | 1516.409 | 0.00000  | 0.000    | 1516.409 |
| 6 Moist Air                       | 0.000    | 0.00000  | 99.300   | 99.300   |
| 7 Coarse Iron Ore                 | 1516.409 | 0.00000  | 0.000    | 1516.409 |
| 8 Moist Air                       | 0.000    | 0.00000  | 99.300   | 99.300   |
| 9                                 | 0.000    | 0.00000  | 364.892  | 364.892  |
| 10 Air for Classifier             | 0.000    | 0.00000  | 1.000    | 1.000    |
| 11 Fines                          | 227.461  | 0.00000  | 0.150    | 227.611  |
| 12 Coarse Iron Ore Feed           | 1288.948 | 0.00000  | 0.850    | 1289.798 |
| 13 Air to Compressor              | 0.000    | 0.00000  | 1.000    | 1.000    |
| 14 Compressed Air                 | 0.000    | 0.00000  | 1.000    | 1.000    |
| 15 Iron Ore from Cyclone 2        | 1095.606 | 0.00000  | 0.000    | 1095.606 |
| 18 Iron Ore to Cyclone 2          | 1288.948 | 0.00000  | 0.000    | 1288.948 |
| 19 Air to Cyclone 2               | 0.000    | 0.00000  | 2.850    | 2.850    |
| 20 Air to Calciner                | 0.000    | 0.00000  | 1.000    | 1.000    |
| 21 Combustion Air to Heater 2     | 0.000    | 0.00000  | 4187.266 | 4187.266 |
| 22 Natural gas to Heater 2        | 0.000    | 0.00000  | 205.467  | 205.467  |
| 23 Exhaust from Heater 2          | 0.000    | 0.00000  | 4392.734 | 4392.734 |
| 24 Preheated Reformed gas for CFB | 0.000    | 0.00000  | 772.200  | 772.200  |
| 25 Reducing gas for CFB           | 0.000    | 0.00000  | 772.200  | 772.200  |
| 26 Natural gas for Heater 1       | 0.000    | 0.00000  | 101.192  | 101.192  |
| 27 Combustion Air for Heater 1    | 0.000    | 0.00000  | 2061.774 | 2061.774 |
| 28 Exhaust for Heater 1           | 0.000    | 0.00000  | 2162.966 | 2162.966 |
| 29 Partially Reduced Ore          | 1063.555 | 0.00000  | 0.000    | 1063.555 |
| 30 Fines to CFB                   | 10.743   | 0.00000  | 0.000    | 10.743   |
| 31 Top Gas                        | 0.000    | 0.00000  | 2613.663 | 2613.663 |
| 32 Cooled Top Gas                 | 0.000    | 0.00000  | 2613.663 | 2613.663 |
| 33 High H2 Reformed gas makeup    | 0.000    | 0.00000  | 2340.000 | 2340.000 |
| 34 Preheated Reformed Gas         | 0.000    | 0.00000  | 2340.000 | 2340.000 |
| 35 Preheated Reformed Gas for BB  | 0.000    | 0.00000  | 1567.800 | 1567.800 |
| 36 Hot Reducing gas for BB        | 0.000    | 0.00000  | 1567.800 | 1567.800 |
| 37 Reducing gas from BB           | 0.000    | 0.00000  | 1809.413 | 1809.413 |
| 38 Partially Reduced Fines        | 10.743   | 0.00000  | 0.000    | 10.743   |
| 39 Top Gas with Fines             | 0.000    | 0.00000  | 2613.663 | 2613.663 |
| 40 Natural gas for Reformer       | 0.000    | 0.00000  | 250.000  | 250.000  |
| 41 Reformed Gas                   | 0.000    | 0.00000  | 2817.159 | 2817.159 |
| 43 Waste Water from Chiller       | 0.000    | 30.00000 | 67.000   | 97.000   |
| 46 Reformed Gas w/o CO2           | 0.000    | 0.00000  | 67.000   | 67.000   |
| 50 DRI                            | 821.942  | 0.00000  | 0.000    | 821.942  |

## CIRCORED MODEL

## SPECIFIC GRAVITIES

| NO. STREAM                        | PCS      | SG-SI  | SG-LI  | SG-GC  | SG-TC  |
|-----------------------------------|----------|--------|--------|--------|--------|
| 1 Iron Ore to Lockhopper          | 91.9976  | 5.0205 | 0.9951 | 0.0000 | 3.7927 |
| 2 Conveyor Air                    | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 3 Iron Ore from Lockhopper        | 93.2054  | 5.0205 | 0.9763 | 0.0010 | 0.9519 |
| 4 Fine Iron Ore from Cyclone 2    | 98.5473  | 5.0205 | 0.0000 | 0.0014 | 0.0961 |
| 5 Dried Iron Ore                  | 100.0000 | 5.0205 | 0.0000 | 0.0000 | 5.0205 |
| 6 Moist Air                       | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 7 Coarse Iron Ore                 | 100.0000 | 5.0205 | 0.0000 | 0.0000 | 5.0205 |
| 8 Moist Air                       | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 9                                 | 0.0000   | 0.0000 | 0.0000 | 0.0005 | 0.0005 |
| 10 Air for Classifier             | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 11 Fines                          | 99.9341  | 5.0205 | 0.0000 | 0.0006 | 0.7855 |
| 12 Coarse Iron Ore Feed           | 99.9341  | 5.0205 | 0.0000 | 0.0006 | 0.7855 |
| 13 Air to Compressor              | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 14 Compressed Air                 | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 15 Iron Ore from Cyclone 2        | 100.0000 | 5.0205 | 0.0000 | 0.0000 | 5.0205 |
| 18 Iron Ore to Cyclone 2          | 100.0000 | 5.0205 | 0.0000 | 0.0000 | 5.0205 |
| 19 Air to Cyclone 2               | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 20 Air to Calciner                | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 21 Combustion Air to Heater 2     | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 22 Natural gas to Heater 2        | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 23 Exhaust from Heater 2          | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 24 Preheated Reformed gas for CFB | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 25 Reducing gas for CFB           | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 26 Natural gas for Heater 1       | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 27 Combustion Air for Heater 1    | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 28 Exhaust for Heater 1           | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 29 Partially Reduced Ore          | 100.0000 | 5.1765 | 0.0000 | 0.0000 | 5.1765 |
| 30 Fines to CFB                   | 100.0000 | 5.1765 | 0.0000 | 0.0000 | 5.1765 |
| 31 Top Gas                        | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 32 Cooled Top Gas                 | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 33 High H2 Reformed gas makeup    | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 34 Preheated Reformed Gas         | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 35 Preheated Reformed Gas for BB  | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 36 Hot Reducing gas for BB        | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 37 Reducing gas from BB           | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 38 Partially Reduced Fines        | 100.0000 | 5.1765 | 0.0000 | 0.0000 | 5.1765 |
| 39 Top Gas with Fines             | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 40 Natural gas for Reformer       | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 41 Reformed Gas                   | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 43 Waste Water from Chiller       | 0.0000   | 0.0000 | 0.8154 | 0.0004 | 0.0006 |
| 46 Reformed Gas w/o CO2           | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 50 DRI                            | 100.0000 | 6.9179 | 0.0000 | 0.0000 | 6.9179 |

## CIRCORED MODEL

## STREAM DATA

## SOLIDS - MT/HR

| NO. STREAM                     | Fe2O3   | Fe3O4   | FeO     | Fe1     | Si1O2   |
|--------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 101.124 | 918.22  | 0.000   | 0.000   | 11.7229 |
| 3 Iron Ore from Lockhopper     | 122.119 | 1108.86 | 0.000   | 0.000   | 14.1568 |
| 4 Fine Iron Ore from Cyclone 2 | 17.845  | 162.04  | 0.000   | 0.000   | 2.0688  |
| 5 Dried Iron Ore               | 139.965 | 1270.90 | 0.000   | 0.000   | 16.2256 |
| 7 Coarse Iron Ore              | 139.965 | 1270.90 | 0.000   | 0.000   | 16.2256 |
| 11 Fines                       | 20.995  | 190.64  | 0.000   | 0.000   | 2.4338  |
| 12 Coarse Iron Ore Feed        | 118.970 | 1080.27 | 0.000   | 0.000   | 13.7917 |
| 15 Iron Ore from Cyclone 2     | 101.124 | 918.23  | 0.000   | 0.000   | 11.7230 |
| 16 Feed to CFB                 | 83.025  | 753.88  | 0.000   | 0.000   | 9.6248  |
| 17 Iron Ore Recycle            | 27.675  | 251.29  | 0.000   | 0.000   | 3.2083  |
| 18 Iron Ore to Cyclone 2       | 118.970 | 1080.27 | 0.000   | 0.000   | 13.7917 |
| 29 Partially Reduced Ore       | 0.000   | 601.02  | 386.277 | 0.000   | 11.7230 |
| 30 Fines to CFB                | 0.000   | 6.07    | 3.902   | 0.000   | 0.1184  |
| 38 Partially Reduced Fines     | 0.000   | 6.07    | 3.902   | 0.000   | 0.1184  |
| 50 DRI                         | 0.000   | 0.00    | 47.289  | 698.400 | 11.7230 |

## SOLIDS - MT/HR

| NO. STREAM                     | Al2O3   | P1      | Cu1     | Ca1O1   | Mg1O1   |
|--------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 8.8744  | 0.66832 | 0.39442 | 7.779   | 31.9915 |
| 3 Iron Ore from Lockhopper     | 10.7168 | 0.80707 | 0.47630 | 9.394   | 38.6335 |
| 4 Fine Iron Ore from Cyclone 2 | 1.5661  | 0.11794 | 0.06960 | 1.373   | 5.6456  |
| 5 Dried Iron Ore               | 12.2829 | 0.92501 | 0.54591 | 10.767  | 44.2792 |
| 7 Coarse Iron Ore              | 12.2829 | 0.92501 | 0.54591 | 10.767  | 44.2792 |
| 11 Fines                       | 1.8424  | 0.13875 | 0.08189 | 1.615   | 6.6419  |
| 12 Coarse Iron Ore Feed        | 10.4405 | 0.78626 | 0.46402 | 9.152   | 37.6373 |
| 15 Iron Ore from Cyclone 2     | 8.8744  | 0.66832 | 0.39442 | 7.779   | 31.9917 |
| 16 Feed to CFB                 | 7.2861  | 0.54870 | 0.32382 | 6.387   | 26.2658 |
| 17 Iron Ore Recycle            | 2.4287  | 0.18290 | 0.10794 | 2.129   | 8.7553  |
| 18 Iron Ore to Cyclone 2       | 10.4405 | 0.78626 | 0.46402 | 9.152   | 37.6373 |
| 29 Partially Reduced Ore       | 8.8744  | 0.66832 | 0.39442 | 7.779   | 31.9917 |
| 30 Fines to CFB                | 0.0896  | 0.00675 | 0.00398 | 0.079   | 0.3231  |
| 38 Partially Reduced Fines     | 0.0896  | 0.00675 | 0.00398 | 0.079   | 0.3231  |
| 44 Calcium Oxide               | 0.0000  | 0.00000 | 0.00000 | 300.000 | 0.0000  |
| 45 Calcium Carbonate           | 0.0000  | 0.00000 | 0.00000 | 300.000 | 0.0000  |
| 50 DRI                         | 8.8744  | 0.66832 | 0.39442 | 7.779   | 31.9917 |

## SOLIDS - MT/HR

| NO. STREAM                     | Ti1O2   | S1      | V1      | Co1     | Ni1     |
|--------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 3 Iron Ore from Lockhopper     | 14.5537 | 0.39692 | 0.85999 | 0.34400 | 0.39692 |
| 4 Fine Iron Ore from Cyclone 2 | 2.1268  | 0.05800 | 0.12567 | 0.05027 | 0.05800 |
| 5 Dried Iron Ore               | 16.6805 | 0.45492 | 0.98567 | 0.39427 | 0.45492 |
| 7 Coarse Iron Ore              | 16.6805 | 0.45492 | 0.98567 | 0.39427 | 0.45492 |
| 11 Fines                       | 2.5021  | 0.06824 | 0.14785 | 0.05914 | 0.06824 |
| 12 Coarse Iron Ore Feed        | 14.1784 | 0.38668 | 0.83782 | 0.33513 | 0.38668 |
| 15 Iron Ore from Cyclone 2     | 12.0517 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 16 Feed to CFB                 | 9.8946  | 0.26985 | 0.58468 | 0.23387 | 0.26985 |
| 17 Iron Ore Recycle            | 3.2982  | 0.08995 | 0.19489 | 0.07796 | 0.08995 |
| 18 Iron Ore to Cyclone 2       | 14.1784 | 0.38668 | 0.83782 | 0.33513 | 0.38668 |
| 29 Partially Reduced Ore       | 12.0517 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 30 Fines to CFB                | 0.1217  | 0.00332 | 0.00719 | 0.00288 | 0.00332 |
| 38 Partially Reduced Fines     | 0.1217  | 0.00332 | 0.00719 | 0.00288 | 0.00332 |
| 50 DRI                         | 12.0517 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |

## CIRCORED MODEL

## STREAM DATA

## SOLIDS - MT/HR

| NO. STREAM                     | Zn1     | Pb1     | Ca1C1O3 |
|--------------------------------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 0.44920 | 0.66832 | 0.00000 |
| 3 Iron Ore from Lockhopper     | 0.54246 | 0.80707 | 0.00000 |
| 4 Fine Iron Ore from Cyclone 2 | 0.07927 | 0.11794 | 0.00000 |
| 5 Dried Iron Ore               | 0.62173 | 0.92501 | 0.00000 |
| 7 Coarse Iron Ore              | 0.62173 | 0.92501 | 0.00000 |
| 11 Fines                       | 0.09326 | 0.13875 | 0.00000 |
| 12 Coarse Iron Ore Feed        | 0.52847 | 0.78626 | 0.00000 |
| 15 Iron Ore from Cyclone 2     | 0.44920 | 0.66832 | 0.00000 |
| 16 Feed to CFB                 | 0.36880 | 0.54870 | 0.00000 |
| 17 Iron Ore Recycle            | 0.12293 | 0.18290 | 0.00000 |
| 18 Iron Ore to Cyclone 2       | 0.52847 | 0.78626 | 0.00000 |
| 29 Partially Reduced Ore       | 0.44920 | 0.66832 | 0.00000 |
| 30 Fines to CFB                | 0.00454 | 0.00675 | 0.00000 |
| 38 Partially Reduced Fines     | 0.00454 | 0.00675 | 0.00000 |
| 50 DRI                         | 0.44920 | 0.66832 | 0.00000 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                     | Fe2O3   | Fe3O4   | FeO     | Fe1     | Si1O2   |
|--------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 3 Iron Ore from Lockhopper     | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 4 Fine Iron Ore from Cyclone 2 | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 5 Dried Iron Ore               | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 7 Coarse Iron Ore              | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 11 Fines                       | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 12 Coarse Iron Ore Feed        | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 15 Iron Ore from Cyclone 2     | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 16 Feed to CFB                 | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 17 Iron Ore Recycle            | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 18 Iron Ore to Cyclone 2       | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.07000 |
| 29 Partially Reduced Ore       | 0.00000 | 56.5108 | 36.3194 | 0.0000  | 1.10224 |
| 30 Fines to CFB                | 0.00000 | 56.5108 | 36.3194 | 0.0000  | 1.10224 |
| 38 Partially Reduced Fines     | 0.00000 | 56.5108 | 36.3194 | 0.0000  | 1.10224 |
| 50 DRI                         | 0.00000 | 0.0000  | 5.7533  | 84.9694 | 1.42625 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                     | Al2O3   | P1      | Cu1     | Ca1O1   | Mg1O1   |
|--------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 3 Iron Ore from Lockhopper     | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 4 Fine Iron Ore from Cyclone 2 | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 5 Dried Iron Ore               | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 7 Coarse Iron Ore              | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 11 Fines                       | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 12 Coarse Iron Ore Feed        | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 15 Iron Ore from Cyclone 2     | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 16 Feed to CFB                 | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 17 Iron Ore Recycle            | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 18 Iron Ore to Cyclone 2       | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 29 Partially Reduced Ore       | 0.83441 | 0.06284 | 0.03708 | 0.731   | 3.00799 |
| 30 Fines to CFB                | 0.83441 | 0.06284 | 0.03708 | 0.731   | 3.00799 |
| 38 Partially Reduced Fines     | 0.83441 | 0.06284 | 0.03708 | 0.731   | 3.00799 |
| 44 Calcium Oxide               | 0.00000 | 0.00000 | 0.00000 | 100.000 | 0.00000 |
| 45 Calcium Carbonate           | 0.00000 | 0.00000 | 0.00000 | 100.000 | 0.00000 |
| 50 DRI                         | 1.07969 | 0.08131 | 0.04799 | 0.946   | 3.89221 |

## CIRCORED MODEL

## STREAM DATA

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                     | Ti1O2   | S1      | V1      | Co1     | Ni1     |
|--------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 3 Iron Ore from Lockhopper     | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 4 Fine Iron Ore from Cyclone 2 | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 5 Dried Iron Ore               | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 7 Coarse Iron Ore              | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 11 Fines                       | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 12 Coarse Iron Ore Feed        | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 15 Iron Ore from Cyclone 2     | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 16 Feed to CFB                 | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 17 Iron Ore Recycle            | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 18 Iron Ore to Cyclone 2       | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 29 Partially Reduced Ore       | 1.13315 | 0.03090 | 0.06696 | 0.02678 | 0.03090 |
| 30 Fines to CFB                | 1.13315 | 0.03090 | 0.06696 | 0.02678 | 0.03090 |
| 38 Partially Reduced Fines     | 1.13315 | 0.03090 | 0.06696 | 0.02678 | 0.03090 |
| 50 DRI                         | 1.46624 | 0.03999 | 0.08664 | 0.03466 | 0.03999 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                     | Zn1     | Pb1     | Ca1ClO3 |
|--------------------------------|---------|---------|---------|
| 1 Iron Ore to Lockhopper       | 0.04100 | 0.06100 | 0.00000 |
| 3 Iron Ore from Lockhopper     | 0.04100 | 0.06100 | 0.00000 |
| 4 Fine Iron Ore from Cyclone 2 | 0.04100 | 0.06100 | 0.00000 |
| 5 Dried Iron Ore               | 0.04100 | 0.06100 | 0.00000 |
| 7 Coarse Iron Ore              | 0.04100 | 0.06100 | 0.00000 |
| 11 Fines                       | 0.04100 | 0.06100 | 0.00000 |
| 12 Coarse Iron Ore Feed        | 0.04100 | 0.06100 | 0.00000 |
| 15 Iron Ore from Cyclone 2     | 0.04100 | 0.06100 | 0.00000 |
| 16 Feed to CFB                 | 0.04100 | 0.06100 | 0.00000 |
| 17 Iron Ore Recycle            | 0.04100 | 0.06100 | 0.00000 |
| 18 Iron Ore to Cyclone 2       | 0.04100 | 0.06100 | 0.00000 |
| 29 Partially Reduced Ore       | 0.04224 | 0.06284 | 0.00000 |
| 30 Fines to CFB                | 0.04224 | 0.06284 | 0.00000 |
| 38 Partially Reduced Fines     | 0.04224 | 0.06284 | 0.00000 |
| 50 DRI                         | 0.05465 | 0.08131 | 0.00000 |

## AQUEOUS - MT/HR

| NO. STREAM                  | H2O     |
|-----------------------------|---------|
| 1 Iron Ore to Lockhopper    | 95.3000 |
| 3 Iron Ore from Lockhopper  | 95.3000 |
| 42 Cold water for Chiller   | 30.0000 |
| 43 Waste Water from Chiller | 30.0000 |

## AQUEOUS - WEIGHT PERCENT

| NO. STREAM                  | H2O     |
|-----------------------------|---------|
| 1 Iron Ore to Lockhopper    | 100.000 |
| 3 Iron Ore from Lockhopper  | 100.000 |
| 42 Cold water for Chiller   | 100.000 |
| 43 Waste Water from Chiller | 100.000 |

## AQUEOUS - GRAMS PER LITER

| NO. STREAM                  | H2O     |
|-----------------------------|---------|
| 1 Iron Ore to Lockhopper    | 995.067 |
| 3 Iron Ore from Lockhopper  | 976.314 |
| 42 Cold water for Chiller   | 995.067 |
| 43 Waste Water from Chiller | 815.430 |

## CIRCORED MODEL

## STREAM DATA

GASEOUS - MT/HR

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 2 Conveyor Air                 | 0.000   | 0.77    | 0.232   | 0.000   | 0.000   |
| 3 Iron Ore from Lockhopper     | 0.000   | 0.88    | 0.267   | 0.000   | 0.000   |
| 4 Fine Iron Ore from Cyclone 2 | 0.000   | 2.19    | 0.661   | 0.000   | 0.000   |
| 6 Moist Air                    | 95.300  | 3.07    | 0.928   | 0.000   | 0.000   |
| 8 Moist Air                    | 95.300  | 3.07    | 0.928   | 0.000   | 0.000   |
| 9                              | 38.786  | 0.00    | 0.000   | 0.000   | 274.324 |
| 10 Air for Classifier          | 0.000   | 0.77    | 0.232   | 0.000   | 0.000   |
| 11 Fines                       | 0.000   | 0.12    | 0.035   | 0.000   | 0.000   |
| 12 Coarse Iron Ore Feed        | 0.000   | 0.65    | 0.197   | 0.000   | 0.000   |
| 13 Air to Compressor           | 0.000   | 0.77    | 0.232   | 0.000   | 0.000   |
| 14 Compressed Air              | 0.000   | 0.77    | 0.232   | 0.000   | 0.000   |
| 19 Air to Cyclone 2            | 0.000   | 2.19    | 0.661   | 0.000   | 0.000   |
| 20 Air to Calciner             | 0.000   | 0.77    | 0.232   | 0.000   | 0.000   |
| 21 Combustion Air to Heater 2  | 0.000   | 3215.82 | 971.446 | 0.000   | 0.000   |
| 22 Natural gas to Heater 2     | 0.000   | 0.00    | 0.000   | 205.467 | 0.000   |
| 23 Exhaust from Heater 2       | 461.454 | 3215.82 | 151.812 | 0.000   | 563.647 |
| 26 Natural gas for Heater 1    | 0.000   | 0.00    | 0.000   | 101.192 | 0.000   |
| 27 Combustion Air for Heater 1 | 0.000   | 1583.44 | 478.332 | 0.000   | 0.000   |
| 28 Exhaust for Heater 1        | 227.264 | 1583.44 | 74.666  | 0.000   | 277.593 |
| 31 Top Gas                     | 307.312 | 0.00    | 0.000   | 0.000   | 2.036   |
| 32 Cooled Top Gas              | 307.312 | 0.00    | 0.000   | 0.000   | 2.036   |
| 37 Reducing gas from BB        | 272.056 | 0.00    | 0.000   | 0.000   | 0.000   |
| 39 Top Gas with Fines          | 307.312 | 0.00    | 0.000   | 0.000   | 2.036   |
| 40 Natural gas for Reformer    | 0.000   | 0.00    | 0.000   | 250.000 | 0.000   |
| 41 Reformed Gas                | 400.136 | 0.00    | 0.000   | 378.829 | 0.763   |
| 43 Waste Water from Chiller    | 0.000   | 0.00    | 0.000   | 67.000  | 0.000   |
| 46 Reformed Gas w/o CO2        | 0.000   | 0.00    | 0.000   | 67.000  | 0.000   |

GASEOUS - MT/HR

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 9                                 | 51.78   | 0.000   |
| 24 Preheated Reformed gas for CFB | 694.98  | 77.220  |
| 25 Reducing gas for CFB           | 694.98  | 77.220  |
| 31 Top Gas                        | 2071.61 | 232.704 |
| 32 Cooled Top Gas                 | 2071.61 | 232.704 |
| 33 High H2 Reformed gas makeup    | 2106.00 | 234.000 |
| 34 Preheated Reformed Gas         | 2106.00 | 234.000 |
| 35 Preheated Reformed Gas for BB  | 1411.02 | 156.780 |
| 36 Hot Reducing gas for BB        | 1411.02 | 156.780 |
| 37 Reducing gas from BB           | 1380.58 | 156.780 |
| 39 Top Gas with Fines             | 2071.61 | 232.704 |
| 41 Reformed Gas                   | 2028.85 | 8.583   |

## CIRCORED MODEL

## STREAM DATA

## GASEOUS - WEIGHT PERCENT

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 2 Conveyor Air                 | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 3 Iron Ore from Lockhopper     | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 4 Fine Iron Ore from Cyclone 2 | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 6 Moist Air                    | 95.9718 | 3.0937  | 0.9345  | 0.000   | 0.0000  |
| 8 Moist Air                    | 95.9718 | 3.0937  | 0.9345  | 0.000   | 0.0000  |
| 9                              | 10.6295 | 0.0000  | 0.0000  | 0.000   | 75.1796 |
| 10 Air for Classifier          | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 11 Fines                       | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 12 Coarse Iron Ore Feed        | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 13 Air to Compressor           | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 14 Compressed Air              | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 19 Air to Cyclone 2            | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 20 Air to Calciner             | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 21 Combustion Air to Heater 2  | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 22 Natural gas to Heater 2     | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 23 Exhaust from Heater 2       | 10.5049 | 73.2077 | 3.4560  | 0.000   | 12.8313 |
| 26 Natural gas for Heater 1    | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 27 Combustion Air for Heater 1 | 0.0000  | 76.8000 | 23.2000 | 0.000   | 0.0000  |
| 28 Exhaust for Heater 1        | 10.5070 | 73.2070 | 3.4520  | 0.000   | 12.8339 |
| 31 Top Gas                     | 11.7579 | 0.0000  | 0.0000  | 0.000   | 0.0779  |
| 32 Cooled Top Gas              | 11.7579 | 0.0000  | 0.0000  | 0.000   | 0.0779  |
| 37 Reducing gas from BB        | 15.0356 | 0.0000  | 0.0000  | 0.000   | 0.0000  |
| 39 Top Gas with Fines          | 11.7579 | 0.0000  | 0.0000  | 0.000   | 0.0779  |
| 40 Natural gas for Reformer    | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 41 Reformed Gas                | 14.2035 | 0.0000  | 0.0000  | 13.447  | 0.0271  |
| 43 Waste Water from Chiller    | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 46 Reformed Gas w/o CO2        | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |

## GASEOUS - WEIGHT PERCENT

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 9                                 | 14.1909 | 0.0000  |
| 24 Preheated Reformed gas for CFB | 90.0000 | 10.0000 |
| 25 Reducing gas for CFB           | 90.0000 | 10.0000 |
| 31 Top Gas                        | 79.2608 | 8.9034  |
| 32 Cooled Top Gas                 | 79.2608 | 8.9034  |
| 33 High H2 Reformed gas makeup    | 90.0000 | 10.0000 |
| 34 Preheated Reformed Gas         | 90.0000 | 10.0000 |
| 35 Preheated Reformed Gas for BB  | 90.0000 | 10.0000 |
| 36 Hot Reducing gas for BB        | 90.0000 | 10.0000 |
| 37 Reducing gas from BB           | 76.2997 | 8.6647  |
| 39 Top Gas with Fines             | 79.2608 | 8.9034  |
| 41 Reformed Gas                   | 72.0175 | 0.3047  |

## CIRCORED MODEL

## STREAM DATA

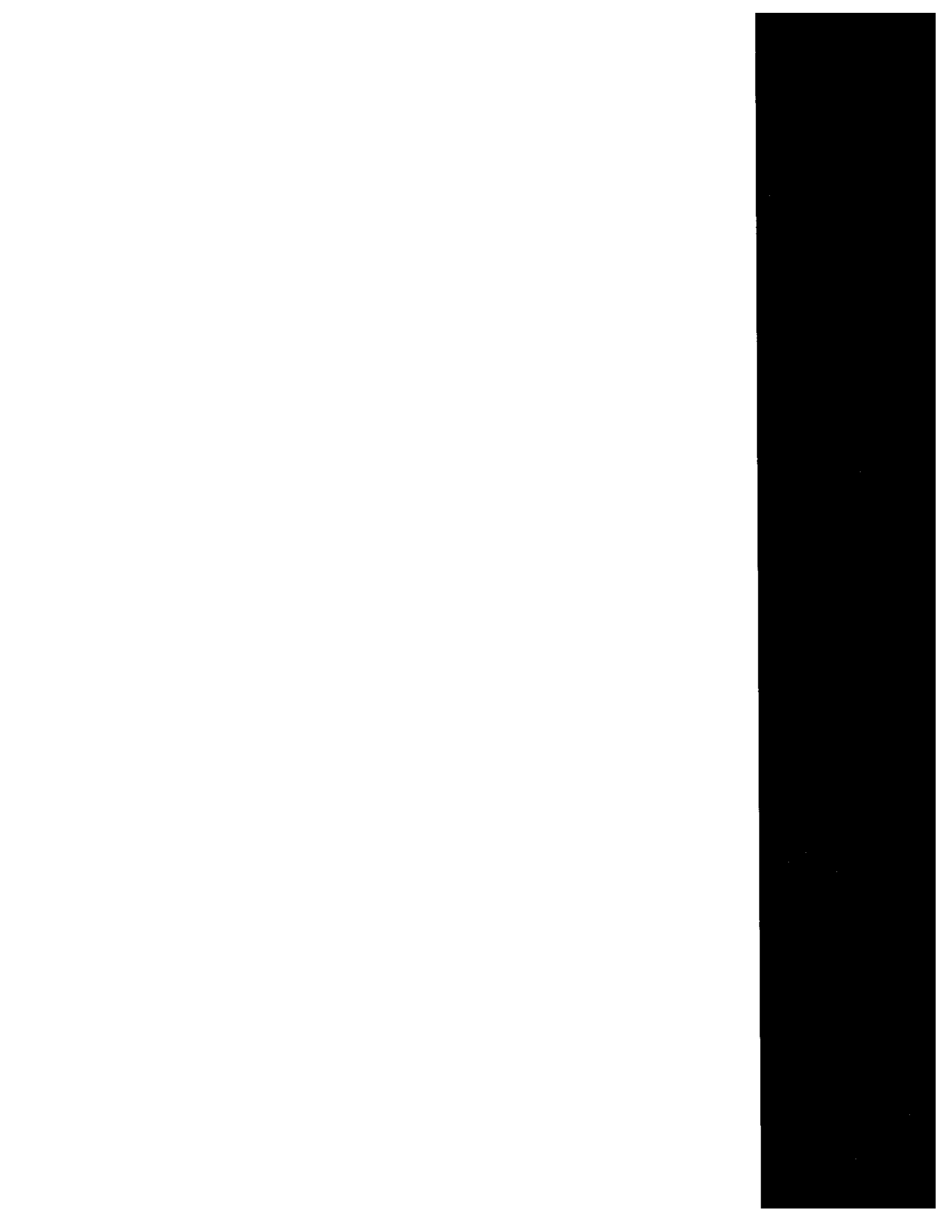
## GASEOUS - VOLUME PERCENT

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 2 Conveyor Air                 | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 3 Iron Ore from Lockhopper     | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 4 Fine Iron Ore from Cyclone 2 | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 6 Moist Air                    | 97.4457 | 2.0201  | 0.5342  | 0.000   | 0.0000  |
| 8 Moist Air                    | 97.4457 | 2.0201  | 0.5342  | 0.000   | 0.0000  |
| 9                              | 6.3188  | 0.0000  | 0.0000  | 0.000   | 18.2942 |
| 10 Air for Classifier          | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 11 Fines                       | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 12 Coarse Iron Ore Feed        | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 13 Air to Compressor           | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 14 Compressed Air              | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 19 Air to Cyclone 2            | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 20 Air to Calciner             | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 21 Combustion Air to Heater 2  | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 22 Natural gas to Heater 2     | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 23 Exhaust from Heater 2       | 16.2156 | 72.6731 | 3.0034  | 0.000   | 8.1078  |
| 26 Natural gas for Heater 1    | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 27 Combustion Air for Heater 1 | 0.0000  | 79.0852 | 20.9148 | 0.000   | 0.0000  |
| 28 Exhaust for Heater 1        | 16.2188 | 72.6719 | 3.0000  | 0.000   | 8.1094  |
| 31 Top Gas                     | 1.6199  | 0.0000  | 0.0000  | 0.000   | 0.0044  |
| 32 Cooled Top Gas              | 1.6199  | 0.0000  | 0.0000  | 0.000   | 0.0044  |
| 37 Reducing gas from BB        | 2.1404  | 0.0000  | 0.0000  | 0.000   | 0.0000  |
| 39 Top Gas with Fines          | 1.6199  | 0.0000  | 0.0000  | 0.000   | 0.0044  |
| 40 Natural gas for Reformer    | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 41 Reformed Gas                | 2.1102  | 0.0000  | 0.0000  | 2.243   | 0.0016  |
| 43 Waste Water from Chiller    | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |
| 46 Reformed Gas w/o CO2        | 0.0000  | 0.0000  | 0.0000  | 100.000 | 0.0000  |

## GASEOUS - VOLUME PERCENT

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 9                                 | 75.3870 | 0.00000 |
| 24 Preheated Reformed gas for CFB | 99.2067 | 0.79333 |
| 25 Reducing gas for CFB           | 99.2067 | 0.79333 |
| 31 Top Gas                        | 97.5867 | 0.78894 |
| 32 Cooled Top Gas                 | 97.5867 | 0.78894 |
| 33 High H2 Reformed gas makeup    | 99.2067 | 0.79333 |
| 34 Preheated Reformed Gas         | 99.2067 | 0.79333 |
| 35 Preheated Reformed Gas for BB  | 99.2067 | 0.79333 |
| 36 Hot Reducing gas for BB        | 99.2067 | 0.79333 |
| 37 Reducing gas from BB           | 97.0662 | 0.79333 |
| 39 Top Gas with Fines             | 97.5867 | 0.78894 |
| 41 Reformed Gas                   | 95.6156 | 0.02911 |





**APPENDIX E-7:**  
**CIRCOFER FLUID-BED REDUCTION PROCESS**  
**(COAL REDUCTANT)**

## CIRCOFER PROCESS

### PROCESS BACKGROUND:

The Circofer process is a two stage fluidized bed process that uses iron ore fines and a solid carbon source such as coal to produce reducing gas. Reduction is carried out at high reduction temperatures. The process produces hot briquetted iron, HBI.

### PROCESS DESCRIPTION:

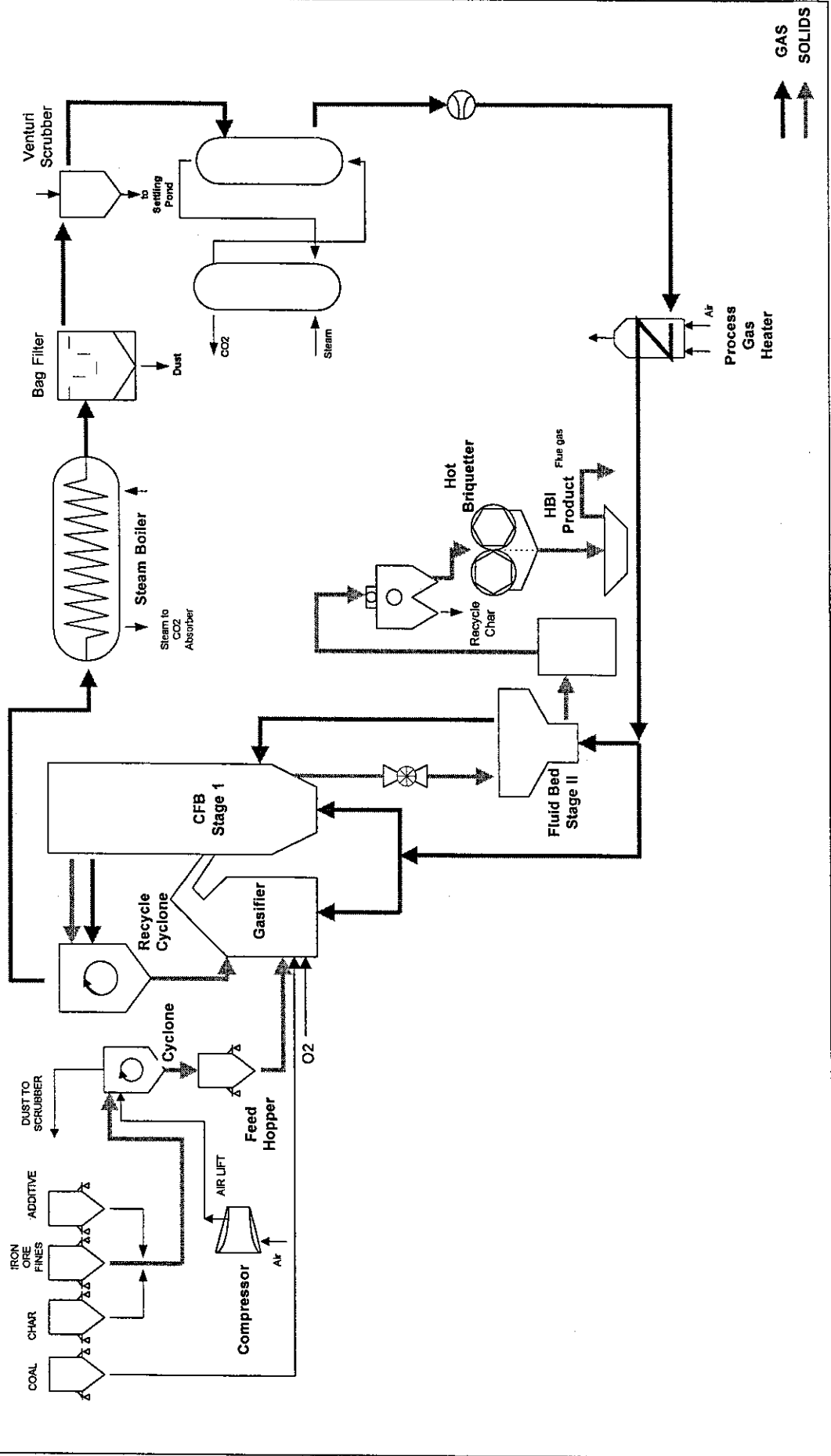
The iron oxide feed to the Circofer process is in the form of iron fines between 1mm and 0.03mm in size. The coal to be used as the energy source and reductant must have an ash softening temperature above 1500C due to operating temperature of the gasifying process. The fines, lime and char are first preheated by the hot exhaust gases. These then enter the gasifier, where O<sub>2</sub> is injected and coal is fed in from the charge hopper. The gasifier operates at about 1000C and at these conditions, the O<sub>2</sub> partially combusts the carbon contained in the coal, producing heat and a CO/CO<sub>2</sub> gas mixture. The heat produced in the gasifier heats the ore and char to process temperatures. In the CFB, the ore fines are reduced to about 70% metallization. The fluidizing gas in the CFB is a mixture of heated recycle gas which enters the lower part of the CFB, and the offgas from the second reducer (FB) which enters further up in the CFB. The fines and char are carried out of the CFB due to the high gas velocity in the reactor, are captured by the cyclone, and returned to the CFB via the gasifier. Thus a circulation pattern is set up which allows the heat to be transferred to the CFB reactor.

Reduced solids from the CFB enter the FB reactor, which is a conventional bubbling bed. In this second reduction stage, the fines reach a final metallization of 92 to 93%. The gas leaving the top of the FB passes on to the CFB. The product from the second reducer is partially cooled, the char and ash are removed by magnetic separation, and the product is briquetted and cooled.

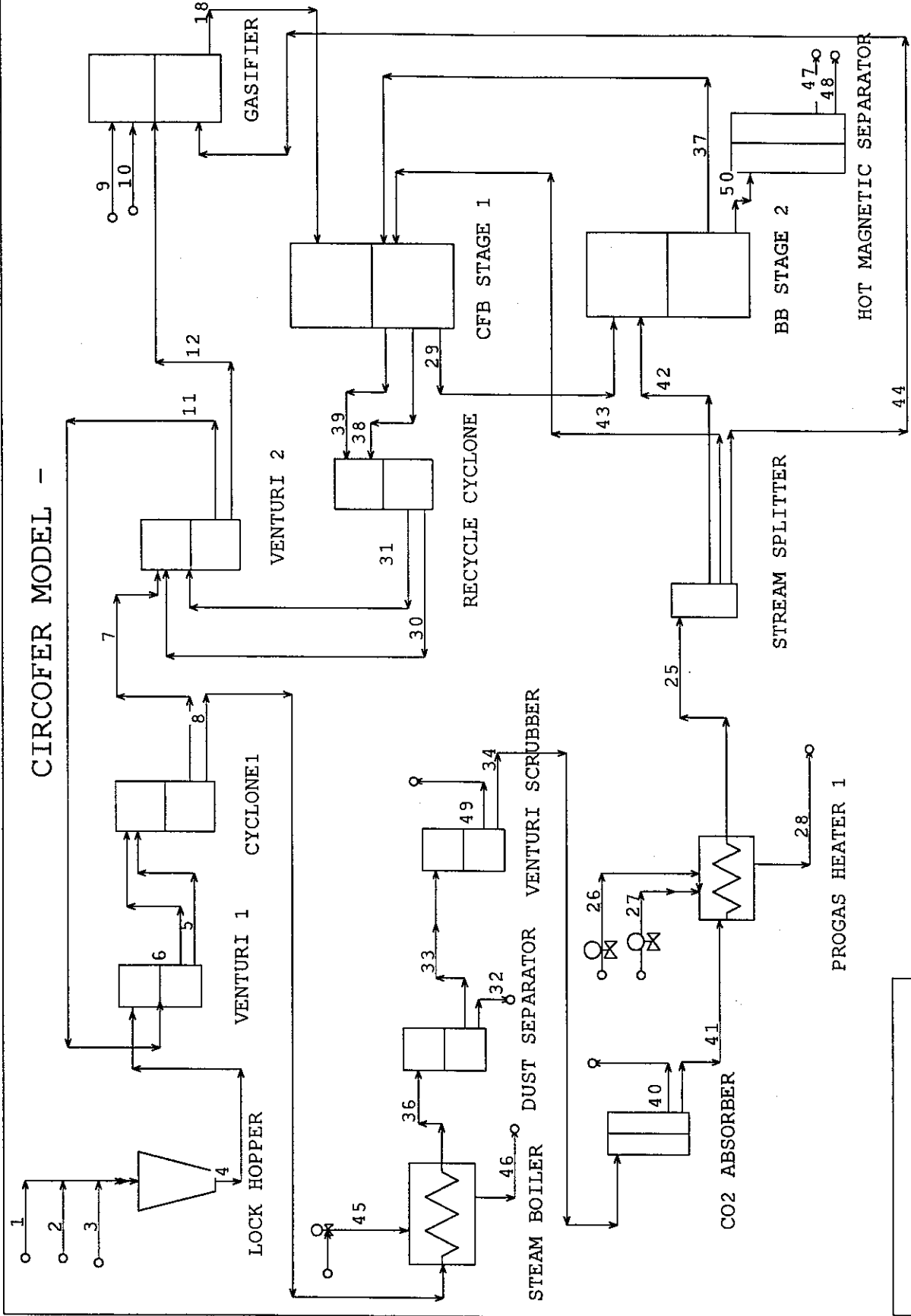
### PROCESS ADVANTAGES

- Direct use of low cost iron ore fines
- Proven fluid bed technology
- High quality product

# LURGI CIRCOFER PROCESS FLOWSHEET



# CIRCOFER MODEL -



CIRCOFER PROCESS

## **Circofer Process --- MetSim Model --- Description**

The MetSim model for this process is largely based upon information from Lurgi. This process is at the pilot-plant development stage. Hence, only conceptual information is available.

### **Flowsheet Description**

In this process, the Iron Ore Fines (Stream 1) along with Char (Stream 2) and Additive (Stream 3) enter into the Lockhopper and move towards Venturi 1 along with a recycle stream (Stream 11) where moisture from the ore fines is absorbed by the recycle gases as Stream 6. Stream 5, containing dried iron ore fines is separated as Stream 7 in Cyclone 1 from gases, Stream 8. The stream 7 along with top gas (Stream 30) and reduced solid particles (Stream 31) from CFB passes through Venturi 2 where solids are separated from gases and sent forward to the Gasifier. In the Gasifier, Coal (Stream 9) and Oxygen (Stream 10) are injected. The heat produced in the Gasifier by the reaction between Coal and Oxygen heats the ore and char to 1000C. The combined ore and gases (Stream 18) enters into the CFB Stage 1 where hot gases from BB Stage 2 (Stream 37) and fresh reducing gases from Process Gas Heater (Stream 43) are also injected. Here, partial reduction of iron ore takes place and the partially reduced ore (Stream 29) is sent to the Bubbling Bed Stage 2 reactor. Very fine iron ore (Stream 38) gets entrapped in the outgoing top gas (Stream 39). The Recycle Cyclone separates solid particles from the gas and recycles them back to Venturi 2 as Stream 30. Stream 31, Top gas is also sent to the Venturi 2, Venturi 1 and then finally it comes out as Stream 8 from the Cyclone 1. It is then cooled by using a steam boiler to about 220C. The cooled gas (Stream 36) is then passed through a Dust Separator to remove dust if any. Then it is stripped of water and CO<sub>2</sub> and preheated. The preheating is done in a Process Gas Heater by burning natural gas with air. Then this hot stream at 750C is divided into three parts to be used in two reducing reactors (Streams 42 and 43) and the gasifier (Stream 44). Final reduction takes place in the BB Stage 2 reactor. Stream 50 is the final reduced iron or called Direct Reduced Iron containing char and all slag. It is passed through a Hot Magnetic Separator for separation of DRI (Stream 47) from char and slag (Stream 48).

### **Model Assumptions:**

Cyclone 1: 100% efficiency is assumed.

Gasifier: No reduction of ore in the gasifier is assumed. The output temperature is 1000C.

CFB Stage 1: Partial reduction takes place in this reactor.

Recycle Cyclone: 100% efficiency is assumed.

Process Gas Heat Exchanger: 100% efficient; No heat losses are assumed. Both outlet temperatures are same.

BB Stage 2: 95% reduction of FeO to Fe takes place. No carry over of particles in top gas is assumed.

### **Results**

Since not much information is available in terms of operation data, it was decided to achieve same operating conditions as were outlined by Lurgi in their articles. Assumptions were made about the composition of the ore fines, reduced ore, ash coal and char, etc. The model results are qualitatively close to the those provided by Lurgi.

CIRCOFER PROCESS -- STREAM SUMMARY

| Stream Number             | 1             | 2         | 3        | 4             | 5             | 6            | 7        | 8            | 9        | 10        | 11           |
|---------------------------|---------------|-----------|----------|---------------|---------------|--------------|----------|--------------|----------|-----------|--------------|
| Description               | Iron Ore to L | Char      | Additive | Iron Ore from | Dried Iron Or | top gas from | Iron Ore | Top Gas to S | Coat     | Oxygen    | Top gas recy |
| MT/HR SOLIDS              | 1095.6        | 200       | 50       | 1345.6        | 1345.6        | 0            | 1345.6   | 0            | 200      | 0         | 0            |
| MT/HR AQUEOUS             | 95.3          | 0         | 0        | 95.3          | 0             | 0            | 0        | 0            | 0        | 0         | 0            |
| MT/HR GASEOUS             | 0             | 0         | 0        | 0             | 0             | 13204        | 0        | 13204        | 0        | 190       | 13109        |
| MT/HR TOTAL               | 1190.9        | 200       | 50       | 1440.9        | 1345.6        | 13204        | 1345.6   | 13204        | 200      | 190       | 13109        |
| Percent Solids            | 91.998        | 100       | 100      | 93.366        | 100           | 0            | 100      | 0            | 100      | 0         | 0            |
| Sp.Gr.SOLIDS              | 5.0205        | 2.1034    | 3.31     | 4.0973        | 4.0973        | 0            | 4.0973   | 0            | 1.232    | 0         | 0            |
| Sp.Gr.AQUEOUS             | 0.99507       | 0         | 0        | 0.99514       | 0             | 0            | 0        | 0            | 0        | 0         | 0            |
| Sp.Gr.GASEOUS             | 0             | 0         | 0        | 0             | 0             | 0.00060097   | 0        | 0.00060097   | 0        | 0.0012779 | 0.00032591   |
| Sp.Gr.TOTAL               | 3.7927        | 2.1034    | 3.31     | 3.3969        | 4.0973        | 0.00060097   | 4.0973   | 0.00060097   | 1.232    | 0.0012779 | 0.00032591   |
| Temperature C             | 32            | 32        | 25       | 31.768        | 300           | 300          | 300      | 300          | 25       | 32        | 786.05       |
| Pressure kPa              | 101.33        | 101.33    | 101.33   | 101.33        | 101.33        | 101.33       | 101.33   | 101.33       | 101.33   | 101.33    | 101.33       |
| Gas nm3/hr                | 0             | 0         | 0        | 0             | 0             | 1.05E+07     | 0        | 1.05E+07     | 0        | 1.33E+05  | 1.04E+07     |
| Sol/Liq lps               | 87.221        | 26.412    | 4.196    | 117.83        | 91.226        | 0            | 91.226   | 0            | 45.093   | 0         | 0            |
| Sol/Liq lph               | 3.14E+05      | 95083     | 15106    | 4.24E+05      | 3.28E+05      | 0            | 3.28E+05 | 0            | 1.62E+05 | 0         | 0            |
| Sol/Liq m3/hr             | 314           | 95.083    | 15.106   | 424.18        | 328.41        | 0            | 328.41   | 0            | 162.34   | 0         | 0            |
| Component Mass Flow Rates |               |           |          |               |               |              |          |              |          |           |              |
| 1 Fe2O3 MT/HR             | 101.12        | -4.44E-14 | 2.78E-14 | 101.12        | 101.12        | 0            | 101.12   | 0            | 0        | 0         | 0            |
| 2 Fe3O4 MT/HR             | 918.22        | 0         | 0        | 918.22        | 918.22        | 0            | 918.22   | 0            | 0        | 0         | 0            |
| 3 FeO MT/HR               | 0             | 0         | 0        | 0             | 0             | 0            | 0        | 0            | 0        | 0         | 0            |
| 4 Fe1 MT/HR               | 0             | 0         | 0        | 0             | 0             | 0            | 0        | 0            | 0        | 0         | 0            |
| 5 SiO2 MT/HR              | 11.723        | 19        | 0        | 30.723        | 30.723        | 0            | 30.723   | 0            | 12.4     | 0         | 0            |
| 6 Al2O3 MT/HR             | 8.8744        | 0         | 0        | 8.8744        | 8.8744        | 0            | 8.8744   | 0            | 0        | 0         | 0            |
| 7 P1 MT/HR                | 0.66832       | 0         | 0        | 0.66832       | 0.66832       | 0            | 0.66832  | 0            | 0        | 0         | 0            |
| 8 Cu1 MT/HR               | 0.39442       | 0         | 0        | 0.39442       | 0.39442       | 0            | 0.39442  | 0            | 0        | 0         | 0            |
| 9 Ca1O1 MT/HR             | 7.7788        | 0         | 50       | 57.779        | 57.779        | 0            | 57.779   | 0            | 0        | 0         | 0            |
| 10 Mg1O1 MT/HR            | 31.992        | 0         | 0        | 31.992        | 31.992        | 0            | 31.992   | 0            | 0        | 0         | 0            |
| 11 TiO2 MT/HR             | 12.052        | 0         | 0        | 12.052        | 12.052        | 0            | 12.052   | 0            | 0        | 0         | 0            |
| 12 S1 MT/HR               | 0.32868       | 0         | 0        | 0.32868       | 0.32868       | 0            | 0.32868  | 0            | 0        | 0         | 0            |
| 13 V1 MT/HR               | 0.71214       | 0         | 0        | 0.71214       | 0.71214       | 0            | 0.71214  | 0            | 0        | 0         | 0            |
| 14 Co1 MT/HR              | 0.28486       | 0         | 0        | 0.28486       | 0.28486       | 0            | 0.28486  | 0            | 0        | 0         | 0            |
| 15 Ni1 MT/HR              | 0.32868       | 0         | 0        | 0.32868       | 0.32868       | 0            | 0.32868  | 0            | 0        | 0         | 0            |
| 16 Zn1 MT/HR              | 0.4492        | 0         | 0        | 0.4492        | 0.4492        | 0            | 0.4492   | 0            | 0        | 0         | 0            |
| 17 Pb1 MT/HR              | 0.66832       | 0         | 0        | 0.66832       | 0.66832       | 0            | 0.66832  | 0            | 0        | 0         | 0            |
| 19 H2O MT/HR              | 95.3          | 0         | 0        | 95.3          | 0             | 0            | 0        | 0            | 0        | 0         | 0            |
| 20 H2O MT/HR              | 0             | 0         | 0        | 0             | 0             | 190.6        | 0        | 190.6        | 0        | 2.11E-14  | 95.3         |
| 21 N2 MT/HR               | 0             | 0         | 0        | 0             | 0             | 0            | 0        | 0            | 0        | 0         | 0            |
| 22 O2 MT/HR               | 0             | 0         | 0        | 0             | 0             | 0            | 0        | 0            | 0        | 190       | 0            |
| 23 C1H4 MT/HR             | 0             | 0         | 0        | 0             | 0             | 67           | 0        | 67           | 0        | 0         | 67           |
| 24 C1O2 MT/HR             | 0             | 0         | 0        | 0             | 0             | 760.37       | 0        | 760.37       | 0        | 0         | 760.37       |
| 26 CO MT/HR               | 0             | 0         | 0        | 0             | 0             | 12186        | 0        | 12186        | 0        | 0         | 12186        |
| 27 C MT/HR                | 0             | 173.6     | 0        | 173.6         | 173.6         | 0            | 173.6    | 0            | 114      | 0         | 0            |
| 28 C5H8 MT/HR             | 0             | 7.4       | 0        | 7.4           | 7.4           | 0            | 7.4      | 0            | 73.6     | 0         | 0            |
| Element Mass Flow Rates   |               |           |          |               |               |              |          |              |          |           |              |
| 1 H 1                     | 10.664        | 0.87599   | 0        | 11.54         | 0.87599       | 38.167       | 0.87599  | 38.167       | 6.7125   | 2.36E-15  | 27.502       |
| 2 C 6                     | 0             | 180.12    | 0        | 180.12        | 180.12        | 5483.1       | 180.12   | 5483.1       | 178.89   | 0         | 5483.1       |
| 3 N 7                     | 0             | 0         | 0        | 0             | 0             | 0            | 0        | 0            | 0        | 0         | 0            |
| 4 O 8                     | 398.99        | 10.119    | 14.265   | 423.38        | 338.74        | 7682.6       | 338.74   | 7682.6       | 6.6038   | 190       | 7598         |
| 5 Mg 12                   | 19.294        | 0         | 0        | 19.294        | 19.294        | 0            | 19.294   | 0            | 0        | 0         | 0            |
| 6 Al 13                   | 4.6968        | 0         | 0        | 4.6968        | 4.6968        | 0            | 4.6968   | 0            | 0        | 0         | 0            |
| 7 Si 14                   | 5.4798        | 8.8813    | 0        | 14.361        | 14.361        | 0            | 14.361   | 0            | 5.7962   | 0         | 0            |
| 8 P 15                    | 0.66832       | 0         | 0        | 0.66832       | 0.66832       | 0            | 0.66832  | 0            | 0        | 0         | 0            |
| 9 S 16                    | 0.32868       | 0         | 0        | 0.32868       | 0.32868       | 0            | 0.32868  | 0            | 0        | 0         | 0            |
| 10 Ca 20                  | 5.5595        | 0         | 35.735   | 41.295        | 41.295        | 0            | 41.295   | 0            | 0        | 0         | 0            |
| 11 Ti 22                  | 7.225         | 0         | 0        | 7.225         | 7.225         | 0            | 7.225    | 0            | 0        | 0         | 0            |
| 12 V 23                   | 0.71214       | 0         | 0        | 0.71214       | 0.71214       | 0            | 0.71214  | 0            | 0        | 0         | 0            |
| 13 Fe 26                  | 735.15        | -3.11E-14 | 1.94E-14 | 735.15        | 735.15        | 0            | 735.15   | 0            | 0        | 0         | 0            |
| 14 Co 27                  | 0.28486       | 0         | 0        | 0.28486       | 0.28486       | 0            | 0.28486  | 0            | 0        | 0         | 0            |
| 15 Ni 28                  | 0.32868       | 0         | 0        | 0.32868       | 0.32868       | 0            | 0.32868  | 0            | 0        | 0         | 0            |
| 16 Cu 29                  | 0.39442       | 0         | 0        | 0.39442       | 0.39442       | 0            | 0.39442  | 0            | 0        | 0         | 0            |
| 17 Zn 30                  | 0.4492        | 0         | 0        | 0.4492        | 0.4492        | 0            | 0.4492   | 0            | 0        | 0         | 0            |
| 18 Pb 82                  | 0.66832       | 0         | 0        | 0.66832       | 0.66832       | 0            | 0.66832  | 0            | 0        | 0         | 0            |



**CIRCOFER PROCESS --- STREAM SUMMARY**

| Stream Number                    | 12           | 18            | 25          | 26            | 27         | 28          | 29            | 30         | 31            | 32     | 33            |
|----------------------------------|--------------|---------------|-------------|---------------|------------|-------------|---------------|------------|---------------|--------|---------------|
| Description                      | Iron Ore Fee | Iron Ore to C | Reducing ga | Natural gas f | Combustion | Exhaust for | Partially Red | Top gas    | Recycle solid | Dust   | Clean cool to |
| MT/HR SOLIDS                     | 1359.5       | 1416.8        | 0           | 0             | 0          | 0           | 1371.3        | 0          | 13.852        | 0      | 0             |
| MT/HR AQUEOUS                    | 0            | 0             | 0           | 0             | 0          | 0           | 0             | 0          | 0             | 0      | 0             |
| MT/HR GASEOUS                    | 0            | 4533.6        | 12356       | 232.32        | 4733.5     | 4965.9      | 0             | 12962      | 0             | 0      | 13204         |
| MT/HR TOTAL                      | 1359.5       | 5950.4        | 12356       | 232.32        | 4733.5     | 4965.9      | 1371.3        | 12962      | 13.852        | 0      | 13204         |
| Percent Solids                   | 100          | 23.81         | 0           | 0             | 0          | 0           | 100           | 0          | 100           | 0      | 0             |
| Sp.Gr.SOLIDS                     | 4.0873       | 3.2831        | 0           | 0             | 0          | 0           | 3.3063        | 0          | 3.3063        | 0      | 0             |
| Sp.Gr.AQUEOUS                    | 0            | 0             | 0           | 0             | 0          | 0           | 0             | 0          | 0             | 0      | 0             |
| Sp.Gr.GASEOUS                    | 0            | 0.00026606    | 0.00033087  | 0.0006407     | 0.001152   | 0.00033122  | 0             | 0.00031304 | 0             | 0      | 0.00069852    |
| Sp.Gr.TOTAL                      | 4.0873       | 0.0003492     | 0.00033087  | 0.0006407     | 0.001152   | 0.00033122  | 3.3063        | 0.00031304 | 3.3063        | 0      | 0.00069852    |
| Temperature C                    | 788.05       | 1000          | 750         | 32            | 32         | 750         | 950           | 831.83     | 831.83        | 220    | 220           |
| Pressure kPa                     | 101.33       | 101.33        | 101.33      | 101.33        | 101.33     | 101.33      | 101.33        | 101.33     | 101.33        | 101.33 | 101.33        |
| Gas nm3/hr                       | 0            | 3.66E+06      | 9.97E+06    | 3.25E+05      | 3.68E+06   | 4.00E+06    | 0             | 1.02E+07   | 0             | 0      | 1.05E+07      |
| Sol/Liq lps                      | 92.39        | 119.87        | 0           | 0             | 0          | 0           | 115.21        | 0          | 1.1638        | 0      | 0             |
| Sol/Liq lph                      | 3.33E+05     | 4.32E+05      | 0           | 0             | 0          | 0           | 4.15E+05      | 0          | 4189.6        | 0      | 0             |
| Sol/Liq m3/hr                    | 332.6        | 431.54        | 0           | 0             | 0          | 0           | 414.77        | 0          | 4.1896        | 0      | 0             |
| <b>Component Mass Flow Rates</b> |              |               |             |               |            |             |               |            |               |        |               |
| 1 Fe2O3 MT/HR                    | 101.12       | 101.12        | 0           | 0             | 0          | 0           | 0             | 0          | 0             | 0      | 0             |
| 2 Fe3O4 MT/HR                    | 924.35       | 924.35        | 0           | 0             | 0          | 0           | 607.13        | 0          | 6.1326        | 0      | 0             |
| 3 FeO MT/HR                      | 3.8443       | 3.8443        | 0           | 0             | 0          | 0           | 380.59        | 0          | 3.8443        | 0      | 0             |
| 4 Fe1 MT/HR                      | 0            | 0             | 0           | 0             | 0          | 0           | 0             | 0          | 0             | 0      | 0             |
| 5 SiO2 MT/HR                     | 31.159       | 43.559        | 0           | 0             | 0          | 0           | 43.123        | 0          | 0.43559       | 0      | 0             |
| 6 Al2O3 MT/HR                    | 8.964        | 8.964         | 0           | 0             | 0          | 0           | 8.8744        | 0          | 0.08964       | 0      | 0             |
| 7 P1 MT/HR                       | 0.67507      | 0.67507       | 0           | 0             | 0          | 0           | 0.66832       | 0          | 0.0067507     | 0      | 0             |
| 8 Cu1 MT/HR                      | 0.3984       | 0.3984        | 0           | 0             | 0          | 0           | 0.39442       | 0          | 0.003984      | 0      | 0             |
| 9 CaO1 MT/HR                     | 58.362       | 58.362        | 0           | 0             | 0          | 0           | 57.779        | 0          | 0.58362       | 0      | 0             |
| 10 Mg1O1 MT/HR                   | 32.315       | 32.315        | 0           | 0             | 0          | 0           | 31.992        | 0          | 0.32315       | 0      | 0             |
| 11 TiO2 MT/HR                    | 12.173       | 12.173        | 0           | 0             | 0          | 0           | 12.052        | 0          | 0.12173       | 0      | 0             |
| 12 S1 MT/HR                      | 0.332        | 0.332         | 0           | 0             | 0          | 0           | 0.32868       | 0          | 0.00332       | 0      | 0             |
| 13 V1 MT/HR                      | 0.71933      | 0.71933       | 0           | 0             | 0          | 0           | 0.71214       | 0          | 0.0071933     | 0      | 0             |
| 14 Co1 MT/HR                     | 0.28773      | 0.28773       | 0           | 0             | 0          | 0           | 0.28486       | 0          | 0.0028773     | 0      | 0             |
| 15 Ni1 MT/HR                     | 0.332        | 0.332         | 0           | 0             | 0          | 0           | 0.32868       | 0          | 0.00332       | 0      | 0             |
| 16 Zn1 MT/HR                     | 0.45373      | 0.45373       | 0           | 0             | 0          | 0           | 0.4492        | 0          | 0.0045373     | 0      | 0             |
| 17 Pb1 MT/HR                     | 0.67507      | 0.67507       | 0           | 0             | 0          | 0           | 0.66832       | 0          | 0.0067507     | 0      | 0             |
| 19 H2O MT/HR                     | 0            | 0             | 0           | 0             | 0          | 0           | 0             | 0          | 0             | 0      | 0             |
| 20 H2O MT/HR                     | 0            | 32.402        | 95.3        | 0             | 0          | 521.76      | 0             | 95.3       | 0             | 0      | 190.6         |
| 21 N2 MT/HR                      | 0            | 0             | 0           | 0             | 3635.4     | 3635.4      | 0             | 0          | 0             | 0      | 0             |
| 22 O2 MT/HR                      | 0            | 0             | 0           | 0             | 1098.2     | 171.42      | 0             | 0          | 0             | 0      | 0             |
| 23 C1H4 MT/HR                    | 0            | 22.78         | 67          | 232.32        | 0          | 0           | 0             | 67         | 0             | 0      | 67            |
| 24 C1O2 MT/HR                    | 0            | 2.5853        | 7.6037      | 0             | 0          | 637.31      | 0             | 760.37     | 0             | 0      | 760.37        |
| 26 CO MT/HR                      | 0            | 4475.8        | 12186       | 0             | 0          | 0           | 0             | 12039      | 0             | 0      | 12186         |
| 27 C MT/HR                       | 175.06       | 146.43        | 0           | 0             | 0          | 0           | 144.96        | 0          | 1.4643        | 0      | 0             |
| 28 C5H8 MT/HR                    | 8.2182       | 81.818        | 0           | 0             | 0          | 0           | 81            | 0          | 0.81818       | 0      | 0             |
| <b>Element Mass Flow Rates</b>   |              |               |             |               |            |             |               |            |               |        |               |
| 1 H 1                            | 0.97284      | 19.036        | 27.502      | 58.386        | 0          | 58.386      | 9.5885        | 27.502     | 0.096854      | 0      | 38.167        |
| 2 C 6                            | 182.31       | 2155.6        | 5277.6      | 173.93        | 0          | 173.93      | 216.37        | 5420.3     | 2.1856        | 0      | 5483.1        |
| 3 N 7                            | 0            | 0             | 0           | 0             | 3635.4     | 3635.4      | 0             | 0          | 0             | 0      | 0             |
| 4 O 8                            | 341.91       | 2935.7        | 7050.6      | 0             | 1098.2     | 1098.2      | 313.72        | 7514.3     | 3.1688        | 0      | 7682.6        |
| 5 Mg 12                          | 19.489       | 19.489        | 0           | 0             | 0          | 0           | 19.294        | 0          | 0.19489       | 0      | 0             |
| 6 Al 13                          | 4.7442       | 4.7442        | 0           | 0             | 0          | 0           | 4.6968        | 0          | 0.047442      | 0      | 0             |
| 7 Si 14                          | 14.565       | 20.361        | 0           | 0             | 0          | 0           | 20.157        | 0          | 0.20361       | 0      | 0             |
| 8 P 15                           | 0.67507      | 0.67507       | 0           | 0             | 0          | 0           | 0.66832       | 0          | 0.0067507     | 0      | 0             |
| 9 S 16                           | 0.332        | 0.332         | 0           | 0             | 0          | 0           | 0.32868       | 0          | 0.00332       | 0      | 0             |
| 10 Ca 20                         | 41.712       | 41.712        | 0           | 0             | 0          | 0           | 41.295        | 0          | 0.41712       | 0      | 0             |
| 11 Ti 22                         | 7.298        | 7.298         | 0           | 0             | 0          | 0           | 7.225         | 0          | 0.07298       | 0      | 0             |
| 12 V 23                          | 0.71933      | 0.71933       | 0           | 0             | 0          | 0           | 0.71214       | 0          | 0.0071933     | 0      | 0             |
| 13 Fe 26                         | 742.58       | 742.58        | 0           | 0             | 0          | 0           | 735.15        | 0          | 7.4258        | 0      | 0             |
| 14 Co 27                         | 0.28773      | 0.28773       | 0           | 0             | 0          | 0           | 0.28486       | 0          | 0.0028773     | 0      | 0             |
| 15 Ni 28                         | 0.332        | 0.332         | 0           | 0             | 0          | 0           | 0.32868       | 0          | 0.00332       | 0      | 0             |
| 16 Cu 29                         | 0.3984       | 0.3984        | 0           | 0             | 0          | 0           | 0.39442       | 0          | 0.003984      | 0      | 0             |
| 17 Zn 30                         | 0.45373      | 0.45373       | 0           | 0             | 0          | 0           | 0.4492        | 0          | 0.0045373     | 0      | 0             |
| 18 Pb 82                         | 0.67507      | 0.67507       | 0           | 0             | 0          | 0           | 0.66832       | 0          | 0.0067507     | 0      | 0             |

**CIRCOFER PROCESS -- STREAM SUMMARY**

| Stream Number                    | 34          | 36           | 37          | 38            | 39               | 40        | 41           | 42            | 43            | 44            | 45       |
|----------------------------------|-------------|--------------|-------------|---------------|------------------|-----------|--------------|---------------|---------------|---------------|----------|
| Description                      | Dry top gas | Cold top gas | Reducing ga | Partially Red | Top Gas with CO2 | CO2       | Cold Recycle | Recycle gas f | Recycle gas f | Recycle gas f | Water    |
| MT/HR SOLIDS                     | 0           | 0            | 0           | 13.852        | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| MT/HR AQUEOUS                    | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 1379.8   |
| MT/HR GASEOUS                    | 13109       | 13204        | 4319.4      | 0             | 12962            | 752.77    | 12356        | 4077.4        | 4077.4        | 4201          | 0        |
| MT/HR TOTAL                      | 13109       | 13204        | 4319.4      | 13.852        | 12962            | 752.77    | 12356        | 4077.4        | 4077.4        | 4201          | 1379.8   |
| Percent Solids                   | 0           | 0            | 0           | 100           | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| Sp.Gr.SOLIDS                     | 0           | 0            | 0           | 3.3063        | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| Sp.Gr.AQUEOUS                    | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 0.99712  |
| Sp.Gr.GASEOUS                    | 0.00068356  | 0.00069852   | 0.00032639  | 0             | 0.0003025        | 0.0010599 | 0.00066908   | 0.00033087    | 0.00033087    | 0.00033087    | 0        |
| Sp.Gr.TOTAL                      | 0.00068356  | 0.00069852   | 0.00032639  | 3.3063        | 0.0003025        | 0.0010599 | 0.00066908   | 0.00033087    | 0.00033087    | 0.00033087    | 0.99712  |
| Temperature C                    | 232.88      | 220          | 825.64      | 870.33        | 870.33           | 232.88    | 232.88       | 750           | 750           | 750           | 25       |
| Pressure kPa                     | 101.33      | 101.33       | 101.33      | 101.33        | 101.33           | 101.33    | 101.33       | 101.33        | 101.33        | 101.33        | 101.33   |
| Gas nm3/hr                       | 1.04E+07    | 1.05E+07     | 3.29E+06    | 0             | 1.02E+07         | 3.83E+05  | 9.97E+06     | 3.29E+06      | 3.29E+06      | 3.39E+06      | 0        |
| Sol/Liq lps                      | 0           | 0            | 0           | 1.1638        | 0                | 0         | 0            | 0             | 0             | 0             | 384.37   |
| Sol/Liq lph                      | 0           | 0            | 0           | 4189.6        | 0                | 0         | 0            | 0             | 0             | 0             | 1.38E+06 |
| Sol/Liq m3/hr                    | 0           | 0            | 0           | 4.1896        | 0                | 0         | 0            | 0             | 0             | 0             | 1383.7   |
| <b>Component Mass Flow Rates</b> |             |              |             |               |                  |           |              |               |               |               |          |
| 1 Fe2O3 MT/HR                    | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 2 Fe3O4 MT/HR                    | 0           | 0            | 0           | 6.1326        | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 3 FeO MT/HR                      | 0           | 0            | 0           | 3.8443        | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 4 Fe1 MT/HR                      | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 5 Si1O2 MT/HR                    | 0           | 0            | 0           | 0.43559       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 6 Al2O3 MT/HR                    | 0           | 0            | 0           | 0.08964       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 7 P1 MT/HR                       | 0           | 0            | 0           | 0.0067507     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 8 Cu1 MT/HR                      | 0           | 0            | 0           | 0.003984      | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 9 Ca1O1 MT/HR                    | 0           | 0            | 0           | 0.58362       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 10 Mg1O1 MT/HR                   | 0           | 0            | 0           | 0.32315       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 11 Ti1O2 MT/HR                   | 0           | 0            | 0           | 0.12173       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 12 S1 MT/HR                      | 0           | 0            | 0           | 0.00332       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 13 V1 MT/HR                      | 0           | 0            | 0           | 0.0071933     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 14 Co1 MT/HR                     | 0           | 0            | 0           | 0.0028773     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 15 Ni1 MT/HR                     | 0           | 0            | 0           | 0.00332       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 16 Zn1 MT/HR                     | 0           | 0            | 0           | 0.0045373     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 17 Pb1 MT/HR                     | 0           | 0            | 0           | 0.0067507     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 19 H2O MT/HR                     | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 1379.8   |
| 20 H2O MT/HR                     | 95.3        | 190.6        | 31.449      | 0             | 95.3             | 0         | 95.3         | 31.449        | 31.449        | 32.402        | 0        |
| 21 N2 MT/HR                      | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 22 O2 MT/HR                      | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 23 C1H4 MT/HR                    | 67          | 67           | 22.11       | 0             | 67               | 0         | 67           | 22.11         | 22.11         | 22.78         | 0        |
| 24 C1O2 MT/HR                    | 760.37      | 760.37       | 668.28      | 0             | 760.37           | 752.77    | 7.6037       | 2.5092        | 2.5092        | 2.5853        | 0        |
| 26 CO MT/HR                      | 12186       | 12186        | 3597.6      | 0             | 12039            | 0         | 12186        | 4021.3        | 4021.3        | 4143.2        | 0        |
| 27 C MT/HR                       | 0           | 0            | 0           | 1.4643        | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 28 C5H8 MT/HR                    | 0           | 0            | 0           | 0.81818       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| <b>Element Mass Flow Rates</b>   |             |              |             |               |                  |           |              |               |               |               |          |
| 1 H 1                            | 27.502      | 38.167       | 9.0758      | 0.096854      | 27.502           | 0         | 27.502       | 9.0758        | 9.0758        | 9.3508        | 154.4    |
| 2 C 6                            | 5483.1      | 5483.1       | 1741.6      | 2.1856        | 5420.3           | 205.44    | 5277.6       | 1741.6        | 1741.6        | 1794.4        | 0        |
| 3 N 7                            | 0           | 0            | 0           | 0             | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 4 O 8                            | 7598        | 7682.6       | 2568.7      | 3.1688        | 7514.3           | 547.32    | 7050.6       | 2326.7        | 2326.7        | 2397.2        | 1225.4   |
| 5 Mg 12                          | 0           | 0            | 0           | 0.19489       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 6 Al 13                          | 0           | 0            | 0           | 0.047442      | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 7 Si 14                          | 0           | 0            | 0           | 0.20361       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 8 P 15                           | 0           | 0            | 0           | 0.0067507     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 9 S 16                           | 0           | 0            | 0           | 0.00332       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 10 Ca 20                         | 0           | 0            | 0           | 0.41712       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 11 Ti 22                         | 0           | 0            | 0           | 0.07298       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 12 V 23                          | 0           | 0            | 0           | 0.0071933     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 13 Fe 26                         | 0           | 0            | 0           | 7.4258        | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 14 Co 27                         | 0           | 0            | 0           | 0.0028773     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 15 Ni 28                         | 0           | 0            | 0           | 0.00332       | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 16 Cu 29                         | 0           | 0            | 0           | 0.003984      | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 17 Zn 30                         | 0           | 0            | 0           | 0.0045373     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |
| 18 Pb 82                         | 0           | 0            | 0           | 0.0067507     | 0                | 0         | 0            | 0             | 0             | 0             | 0        |

**CIRCOFER PROCESS --- STREAM SUMMARY**

| Stream Number                    | 46       | 47     | 48          | 49       | 50           |
|----------------------------------|----------|--------|-------------|----------|--------------|
| Description                      | Steam    | DRI    | Char and As | Water    | Reduced Iron |
| MT/HR SOLIDS                     | 0        | 738.23 | 391.07      | 0        | 1129.3       |
| MT/HR AQUEOUS                    | 1379.8   | 0      | 0           | 95.3     | 0            |
| MT/HR GASEOUS                    | 0        | 0      | 0           | 0        | 0            |
| MT/HR TOTAL                      | 1379.8   | 738.23 | 391.07      | 95.3     | 1129.3       |
| Percent Solids                   | 0        | 100    | 100         | 0        | 100          |
| Sp.Gr.SOLIDS                     | 0        | 7.6755 | 1.6874      | 0        | 3.4436       |
| Sp.Gr.AQUEOUS                    | 0.84013  | 0      | 0           | 0.82339  | 0            |
| Sp.Gr.GASEOUS                    | 0        | 0      | 0           | 0        | 0            |
| Sp.Gr.TOTAL                      | 0.84013  | 7.6755 | 1.6874      | 0.82339  | 3.4436       |
| Temperature C                    | 220      | 484.03 | 484.03      | 232.88   | 825.64       |
| Pressure kPa                     | 101.33   | 101.33 | 101.33      | 101.33   | 101.33       |
| Gas nm3/hr                       | 0        | 0      | 0           | 0        | 0            |
| Sol/Liq lps                      | 456.2    | 26.716 | 64.379      | 32.15    | 91.095       |
| Sol/Liq lph                      | 1.64E+06 | 96.179 | 2.32E+05    | 1.16E+05 | 3.28E+05     |
| Sol/Liq m3/hr                    | 1642.3   | 96.179 | 231.76      | 115.74   | 327.94       |
| <b>Component Mass Flow Rates</b> |          |        |             |          |              |
| 1 Fe2O3 MT/HR                    | 0        | 0      | 0           | 0        | 0            |
| 2 Fe3O4 MT/HR                    | 0        | 0      | 0           | 0        | 0            |
| 3 FeO MT/HR                      | 0        | 46.815 | 0.47288     | 0        | 47.288       |
| 4 Fe1 MT/HR                      | 0        | 691.41 | 6.984       | 0        | 698.4        |
| 5 SiO2 MT/HR                     | 0        | 0      | 43.123      | 0        | 43.123       |
| 6 Al2O3 MT/HR                    | 0        | 0      | 8.8744      | 0        | 8.8744       |
| 7 P1 MT/HR                       | 0        | 0      | 0.66832     | 0        | 0.66832      |
| 8 Cu1 MT/HR                      | 0        | 0      | 0.39442     | 0        | 0.39442      |
| 9 CaO1 MT/HR                     | 0        | 0      | 57.779      | 0        | 57.779       |
| 10 Mg1O1 MT/HR                   | 0        | 0      | 31.992      | 0        | 31.992       |
| 11 TiO2 MT/HR                    | 0        | 0      | 12.052      | 0        | 12.052       |
| 12 S1 MT/HR                      | 0        | 0      | 0.32868     | 0        | 0.32868      |
| 13 V1 MT/HR                      | 0        | 0      | 0.71214     | 0        | 0.71214      |
| 14 Co1 MT/HR                     | 0        | 0      | 0.28486     | 0        | 0.28486      |
| 15 Ni1 MT/HR                     | 0        | 0      | 0.32868     | 0        | 0.32868      |
| 16 Zn1 MT/HR                     | 0        | 0      | 0.4492      | 0        | 0.4492       |
| 17 Pb1 MT/HR                     | 0        | 0      | 0.66832     | 0        | 0.66832      |
| 19 H2O MT/HR                     | 1379.8   | 0      | 0           | 95.3     | 0            |
| 20 H2O MT/HR                     | 0        | 0      | 0           | 0        | 0            |
| 21 N2 MT/HR                      | 0        | 0      | 0           | 0        | 0            |
| 22 O2 MT/HR                      | 0        | 0      | 0           | 0        | 0            |
| 23 C1H4 MT/HR                    | 0        | 0      | 0           | 0        | 0            |
| 24 C1O2 MT/HR                    | 0        | 0      | 0           | 0        | 0            |
| 26 CO MT/HR                      | 0        | 0      | 0           | 0        | 0            |
| 27 C MT/HR                       | 0        | 0      | 144.96      | 0        | 144.96       |
| 28 C5H8 MT/HR                    | 0        | 0      | 81          | 0        | 81           |
| <b>Element Mass Flow Rates</b>   |          |        |             |          |              |
| 1 H 1                            | 154.4    | 0      | 9.5885      | 10.664   | 9.5885       |
| 2 C 6                            | 0        | 0      | 216.37      | 0        | 216.37       |
| 3 N 7                            | 0        | 0      | 0           | 0        | 0            |
| 4 O 8                            | 1225.4   | 10.425 | 61.257      | 84.636   | 71.682       |
| 5 Mg 12                          | 0        | 0      | 19.294      | 0        | 19.294       |
| 6 Al 13                          | 0        | 0      | 4.6968      | 0        | 4.6968       |
| 7 Si 14                          | 0        | 0      | 20.157      | 0        | 20.157       |
| 8 P 15                           | 0        | 0      | 0.66832     | 0        | 0.66832      |
| 9 S 16                           | 0        | 0      | 0.32868     | 0        | 0.32868      |
| 10 Ca 20                         | 0        | 0      | 41.295      | 0        | 41.295       |
| 11 Ti 22                         | 0        | 0      | 7.225       | 0        | 7.225        |
| 12 V 23                          | 0        | 0      | 0.71214     | 0        | 0.71214      |
| 13 Fe 26                         | 0        | 727.8  | 7.3515      | 0        | 735.15       |
| 14 Co 27                         | 0        | 0      | 0.28486     | 0        | 0.28486      |
| 15 Ni 28                         | 0        | 0      | 0.32868     | 0        | 0.32868      |
| 16 Cu 29                         | 0        | 0      | 0.39442     | 0        | 0.39442      |
| 17 Zn 30                         | 0        | 0      | 0.4492      | 0        | 0.4492       |
| 18 Pb 82                         | 0        | 0      | 0.66832     | 0        | 0.66832      |

CIRCOFER MODEL

CASE DEFINITION

Title : CIRCOFER MODEL  
Case :

Data Storage File Name : Circofer.sfw  
Mass Balance Option : ON  
Heat Balance Option : ON  
Units of Mass : metric tonne  
Units of Time : hour  
Ambient Air Pressure : 101.325 kPa  
Standard Pressure : 101.325 kPa  
Ambient Air Temperature : 20.00 C  
Standard Temperature : 0.00 C  
Plant Site Latitude : 0.00 Degrees  
Plant Site Elevation : 0.00 Meters



## CIRCOFER MODEL

## COMPONENT DATA

| ROW | CNM     | CRIT T  | CRIT P  | CRIT V  | ANTOINE | VAPOR   | PRES    | A       | B | C | HENRY |
|-----|---------|---------|---------|---------|---------|---------|---------|---------|---|---|-------|
| 1   | Fe2O3   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 2   | Fe3O4   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 3   | FeO     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 4   | Fe1     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 5   | Si1O2   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 6   | Al2O3   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 7   | P1      | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 8   | Cu1     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 9   | Ca1O1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 10  | Mg1O1   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 11  | Ti1O2   | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 12  | S1      | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 13  | V1      | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 14  | Co1     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 15  | Ni1     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 16  | Zn1     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 17  | Pb1     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 18  | Ca1C1O3 | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 19  | H2O     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 20  | H2O     | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 21  | N2      | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 22  | O2      | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 23  | C1H4    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 24  | C1O2    | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 25  | H2      | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 26  | CO      | 133.400 | 35.4638 | 93.100  | 6.24020 | 230.27  | 260.010 | 63426.0 |   |   |       |
| 27  | C       | 0.000   | 0.0000  | 0.000   | 0.00000 | 0.00    | 0.000   | 0.0     |   |   |       |
| 28  | C5H8    | 503.000 | 41.2393 | 276.000 | 6.91820 | 1104.99 | 228.851 | 0.0     |   |   |       |

| ROW | CNM     | REFERENCE | H25     | HTE-A  | HTE-B    | HTE-C    | HTE-D    |
|-----|---------|-----------|---------|--------|----------|----------|----------|
| 1   | Fe2O3   | B672158   | -197000 | -20749 | 46.1517  | -3.8751  | 21.9462  |
| 2   | Fe3O4   | B672160   | -267300 | -31312 | 71.0525  | -7.8736  | 32.0732  |
| 3   | FeO     | BAK2248   | -62382  | 8754   | -8.5950  | 9.1416   | -21.4692 |
| 4   | Fe1     | B672151   | 0       | -7903  | 14.0914  | -1.3293  | 11.6233  |
| 5   | Si1O2   | B672387   | -217720 | -8654  | 19.1651  | -0.5456  | 8.8977   |
| 6   | Al2O3   | B672042   | -400500 | -12425 | 28.9653  | 1.0071   | 11.1085  |
| 7   | P1      | B672282   | 0       | -2816  | 12.9239  | -11.6659 | 0.0000   |
| 8   | Cu1     | B672129   | 0       | -1423  | 5.0156   | 0.9276   | -0.4694  |
| 9   | Ca1O1   | B672098   | -151790 | -4315  | 12.0730  | 0.4606   | 2.0088   |
| 10  | Mg1O1   | B672227   | -143760 | -4612  | 11.8081  | 0.3610   | 3.1765   |
| 11  | Ti1O2   | B672431   | -225670 | -6260  | 16.8540  | 0.6334   | 3.4762   |
| 12  | S1      | B672335   | 0       | 13015  | -44.4133 | 56.5440  | -14.3084 |
| 13  | V1      | B672454   | 0       | -999   | 4.4929   | 1.2791   | -1.3985  |
| 14  | Co1     | B672113   | 0       | -3885  | 7.9629   | 0.8444   | 4.4112   |
| 15  | Ni1     | B672270   | 0       | -1763  | 6.2394   | 0.7740   | -0.5571  |
| 16  | Zn1     | B672480   | 0       | -1445  | 4.7430   | 1.6445   | -0.3435  |
| 17  | Pb1     | B672294   | 0       | -1512  | 4.9651   | 1.6774   | -0.3504  |
| 18  | Ca1C1O3 | B6771413  | -288610 | -9122  | 23.8351  | 3.2146   | 5.1569   |
| 19  | H2O     | B672180   | -68315  | -5071  | 16.1848  | 2.7637   | 0.0000   |
| 20  | H2O     | B672182   | -57795  | -2403  | 7.2906   | 1.3003   | 0.3596   |
| 21  | N2      | B672244   | 0       | -2846  | 7.5728   | 0.2525   | 1.7794   |
| 22  | O2      | B672277   | 0       | -2979  | 7.9696   | 0.2720   | 1.7697   |
| 23  | C1H4    | B6772217  | -17880  | -6424  | 11.8424  | 2.9907   | 8.0422   |
| 24  | C1O2    | B672094   | -94051  | -5911  | 12.9357  | 0.3891   | 6.1869   |
| 25  | H2      | B672174   | 0       | -1837  | 6.3659   | 0.4428   | -0.2847  |
| 26  | CO      | YAWS      | -26420  | -1787  | 6.0661   | 0.9368   | -0.3112  |
| 27  | C       | B672086   | 0       | -2999  | 5.1802   | 0.2246   | 4.3597   |
| 28  | C5H8    | YAWS      | 27950   | -8316  | 19.7382  | 30.7726  | -0.9067  |

## CIRCOFER MODEL

## COMPONENT DATA

| ROW | CNM     | TEMP  | RANGE  | oK | HTG-A   | HTG-B    | HTG-C    | HTG-D    |
|-----|---------|-------|--------|----|---------|----------|----------|----------|
| 1   | Fe2O3   | 298.2 | 1800.0 |    | -182323 | -34.6418 | -13.7715 | -28.2755 |
| 2   | Fe3O4   | 298.2 | 1800.0 |    | -243067 | -58.6967 | -18.9430 | -46.8195 |
| 3   | FeO     | 298.2 | 1650.0 |    | -58450  | -19.5576 | -4.9564  | -7.3814  |
| 4   | Fe1     | 298.2 | 1811.0 |    | 2679    | -8.2139  | -4.0925  | -5.4957  |
| 5   | Si1O2   | 298.2 | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464 |
| 6   | Al2O3   | 298.2 | 2327.0 |    | -386441 | -25.8901 | -10.0349 | -27.6544 |
| 7   | P1      | 298.2 | 317.3  |    | -2534   | 6.8556   | -27.4268 | 0.0000   |
| 8   | Cu1     | 298.2 | 1357.6 |    | 1948    | -9.4355  | -3.1931  | -3.6331  |
| 9   | Ca1O1   | 298.2 | 2000.0 |    | -146099 | -14.8629 | -4.7096  | -10.7418 |
| 10  | Mg1O1   | 298.2 | 2000.0 |    | -138544 | -11.5487 | -4.4916  | -9.9661  |
| 11  | Ti1O2   | 298.2 | 2000.0 |    | -217923 | -19.7530 | -6.5095  | -14.7172 |
| 12  | S1      | 298.2 | 388.4  |    | -5700   | 12.4302  | -23.6630 | 5.4073   |
| 13  | V1      | 298.2 | 2190.0 |    | 2969    | -9.8550  | -2.7412  | -5.5855  |
| 14  | Co1     | 298.2 | 1768.0 |    | 2071    | -8.3546  | -3.9177  | -4.1323  |
| 15  | Ni1     | 298.2 | 1728.0 |    | 3122    | -10.1656 | -3.1379  | -5.8385  |
| 16  | Zn1     | 298.2 | 692.7  |    | 834     | -9.1557  | -4.7988  | -1.9233  |
| 17  | Pb1     | 298.2 | 600.7  |    | 544     | -13.9080 | -5.5553  | -1.5560  |
| 18  | Ca1C1O3 | 298.2 | 1200.0 |    | -283124 | -23.3813 | -15.1456 | -11.0884 |
| 19  | H2O     | 298.2 | 373.2  |    | -70630  | -1.0739  | -26.4253 | 0.0000   |
| 20  | H2O     | 298.2 | 2000.0 |    | -54212  | -48.4557 | -3.8711  | -6.7579  |
| 21  | N2      | 298.2 | 3000.0 |    | 5078    | -51.3044 | -2.2358  | -9.9139  |
| 22  | O2      | 298.2 | 3000.0 |    | 5395    | -54.8302 | -2.3535  | -10.5960 |
| 23  | C1H4    | 298.2 | 2000.0 |    | -14673  | -45.4106 | -7.1789  | -6.9854  |
| 24  | C1O2    | 298.2 | 3000.0 |    | -86430  | -58.7976 | -3.7771  | -15.3476 |
| 25  | H2      | 298.2 | 3000.0 |    | 4863    | -36.6465 | -2.1036  | -9.3536  |
| 26  | CO      | 298.0 | 700.0  |    | -25393  | -46.6664 | -5.1645  | -2.2650  |
| 27  | C       | 298.2 | 3000.0 |    | 2405    | -3.3866  | -1.5836  | -5.1587  |
| 28  | C5H8    | 135.9 | 318.0  |    | 23803   | -68.4779 | -61.0649 | -1.8797  |

## CIRCOFER MODEL

## FLOWSHEET DATA

| NO | OPR | UNIT     | PROCESS            | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |
|----|-----|----------|--------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | SEC | CIRCOFER | PROCESS            | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 2  | HPR | LOCK     | HOPPER             | 1   | 2   | 3   | 0   | 0   | 0   | 0   | 4   | 0   | 0   | 0   | 0   | 0   |
| 3  | SPP | VENTURI  | 1                  | 4   | 0   | 11  | 0   | 0   | 0   | 0   | 5   | 6   | 0   | 0   | 0   | 0   |
| 4  | SPP | CYCLONE1 |                    | 6   | 5   | 0   | 0   | 0   | 0   | 0   | 8   | 7   | 0   | 0   | 0   | 0   |
| 5  | SPP | VENTURI  | 2                  | 7   | 30  | 31  | 0   | 0   | 0   | 0   | 12  | 11  | 0   | 0   | 0   | 0   |
| 6  | SPP | GASIFIER |                    | 9   | 10  | 12  | 0   | 44  | 0   | 0   | 18  | 0   | 0   | 0   | 0   | 0   |
| 7  | SPP | CFB      | STAGE 1            | 18  | 0   | 37  | 43  | 0   | 0   | 0   | 29  | 38  | 39  | 0   | 0   | 0   |
| 8  | SPP | RECYCLE  | CYCLONE            | 39  | 38  | 0   | 0   | 0   | 0   | 0   | 30  | 31  | 0   | 0   | 0   | 0   |
| 9  | HTX | STEAM    | BOILER             | 8   | 0   | 0   | 45  | 0   | 0   | 0   | 36  | 46  | 0   | 0   | 0   | 0   |
| 10 | HTX | PROGAS   | HEATER 1           | 41  | 0   | 0   | 26  | 27  | 0   | 0   | 25  | 28  | 0   | 0   | 0   | 0   |
| 11 | SPP | BB       | STAGE 2            | 29  | 42  | 0   | 0   | 0   | 0   | 0   | 50  | 37  | 0   | 0   | 0   | 0   |
| 12 | SPP | DUST     | SEPARATOR          | 36  | 0   | 0   | 0   | 0   | 0   | 0   | 32  | 33  | 0   | 0   | 0   | 0   |
| 13 | SPP | VENTURI  | SCRUBBER           | 33  | 0   | 0   | 0   | 0   | 0   | 0   | 34  | 49  | 0   | 0   | 0   | 0   |
| 14 | SPS | STREAM   | SPLITTER           | 25  | 0   | 0   | 0   | 0   | 0   | 0   | 44  | 43  | 42  | 0   | 0   | 0   |
| 15 | SPC | CO2      | ABSORBER           | 34  | 0   | 0   | 0   | 0   | 0   | 0   | 41  | 40  | 0   | 0   | 0   | 0   |
| 16 | SPC | HOT      | MAGNETIC SEPARATOR | 50  | 0   | 0   | 0   | 0   | 0   | 0   | 48  | 47  | 0   | 0   | 0   | 0   |



## CIRCOFER MODEL

| OP PROCESS STEP     | HEAT BALANCE SUMMARY - 1000000 KCAL/HOUR |               |               |                 |              |               |                  |       |
|---------------------|--|---------------|---------------|-----------------|--------------|---------------|------------------|-------|
|                     | INPUT<br>STREAM                          | HEAT<br>REACT | HEAT<br>SOLUT | ENERGY<br>INPUT | HEAT<br>LOSS | HEAT<br>REQRD | OUTPUT<br>STREAM | TOTAL |
| 1 CIRCOFER PROCESS  | 0  | 0             | 0             | 0               | 0            | 0             | 0                | 0     |
| 2 LOCK HOPPER       | 2  | 0             | 0             | 0               | 0            | 0             | -2               | 0     |
| 3 VENTURI 1         | 2703                                     | -56           | 0             | 0               | 0            | -1643         | -1004            | 0     |
| 4 CYCLONE1          | 1004                                     | 0             | 0             | 0               | 0            | 0             | -1004            | 0     |
| 5 VENTURI 2         | 2949                                     | 0             | 0             | 0               | 0            | 0             | -2949            | 0     |
| 6 GASIFIER          | 1069                                     | 314           | 0             | 0               | 0            | 229           | -1612            | 0     |
| 7 CFB STAGE 1       | 3345                                     | -20           | 0             | 0               | 0            | 0             | -3326            | 0     |
| 8 RECYCLE CYCLONE   | 2992                                     | 0             | 0             | 0               | -150         | 0             | -2842            | 0     |
| 9 STEAM BOILER      | 927                                      | 0             | 0             | 0               | 0            | 0             | -927             | 0     |
| 10 PROGAS HEATER 1  | 665                                      | 2777          | 0             | 0               | 0            | 0             | -3442            | 0     |
| 11 BB STAGE 2       | 1129                                     | 33            | 0             | 0               | 0            | 0             | -1162            | 0     |
| 12 DUST SEPARATOR   | 651                                      | 0             | 0             | 0               | 0            | 0             | -651             | 0     |
| 13 VENTURI SCRUBBER | 651                                      | 56            | 0             | 0               | 0            | 0             | -707             | 0     |
| 14 STREAM SPLITTER  | 2412                                     | 0             | 0             | 0               | 0            | 0             | -2412            | 0     |
| 15 CO2 ABSORBER     | 686                                      | 0             | 0             | 0               | 0            | 0             | -686             | 0     |
| 16 HOT MAGNETIC SEP | 225                                      | 0             | 0             | 0               | -112         | 0             | -112             | 0     |

## CIRCOFER MODEL

| NO. STREAM                        | STREAM TEMPERATURES AND ENTHALPIES |         |              |             |            |
|-----------------------------------|------------------------------------|---------|--------------|-------------|------------|
|                                   | TEMP-C                             | TEMP-F  | KCAL/HR      | BTU/HR      | KJ/H       |
| 1 Iron Ore to Lockhopper          | 32.00                              | 89.60   | 1455227.0    | 5774809     | 608867     |
| 2 Char                            | 32.00                              | 89.60   | 501240.0     | 1989080     | 209718     |
| 3 Additive                        | 25.00                              | 77.00   | -443.0       | -1756       | -185       |
| 4 Iron Ore from Lockhopper        | 31.77                              | 89.18   | 1956024.0    | 7762132     | 818400     |
| 5 Dried Iron Ore                  | 300.00                             | 572.00  | 76183568.0   | 302320830   | 31875204   |
| 6 top gas from Venturi 1          | 300.00                             | 572.00  | 927454477.0  | 3680436798  | 388046953  |
| 7 Iron Ore                        | 300.00                             | 572.00  | 76183568.0   | 302320830   | 31875204   |
| 8 Top Gas to Steam boiler         | 300.00                             | 572.00  | 927454477.0  | 3680436798  | 388046953  |
| 9 Coal                            | 25.00                              | 77.00   | 261576.0     | 1038016     | 109443     |
| 10 Oxygen                         | 32.00                              | 89.60   | 346590.0     | 1375380     | 145013     |
| 11 Top gas recycled               | 788.05                             | 1450.49 | 2700813369.0 | 10717693601 | 1130020313 |
| 12 Iron Ore Feed to Gasifier      | 788.05                             | 1450.49 | 248165743.0  | 984801255   | 103832546  |
| 13 Air for Classifier             | 32.00                              | 89.60   | 2369.0       | 9400        | 991        |
| 14 Compressed Air                 | 32.00                              | 89.60   | 2369.0       | 9400        | 991        |
| 15 Iron Ore from Cyclone 2        | 750.00                             | 1382.00 | 173218033.0  | 687384708   | 72474425   |
| 16 Feed to CFB                    | 750.00                             | 1382.00 | 142215195.0  | 564355503   | 59502837   |
| 17 Iron Ore Recycle               | 750.00                             | 1382.00 | 47405065.0   | 188118501   | 19834279   |
| 18 Iron Ore to Cyclone 2          | 1000.00                            | 1832.00 | 1611926247.0 | 6396640294  | 674429941  |
| 19 Air to Cyclone 2               | 870.00                             | 1598.00 | 629172.0     | 2496755     | 263245     |
| 20 Air to Calciner                | 32.00                              | 89.60   | 2369.0       | 9400        | 991        |
| 21 Combustion Air to Heater 2     | 32.00                              | 89.60   | 9918111.0    | 39358247    | 4149737    |
| 22 Natural gas to Heater 2        | 32.00                              | 89.60   | 1333293.0    | 5290933     | 557849     |
| 23 Exhaust from Heater 2          | 675.00                             | 1247.00 | 809492155.0  | 3212324474  | 338691517  |
| 24 Preheated Reformed gas for CFB | 344.62                             | 652.32  | 770969189.0  | 3059452993  | 322573508  |
| 25 Reducing gas for CFB           | 750.00                             | 1382.00 | 2411598512.0 | 9569996297  | 1009012817 |
| 26 Natural gas for Heater 1       | 32.00                              | 89.60   | 1507548.0    | 5982433     | 630758     |
| 27 Combustion Air for Heater 1    | 32.00                              | 89.60   | 11212015.0   | 44492873    | 4691107    |
| 28 Exhaust for Heater 1           | 750.00                             | 1382.00 | 1030746480.0 | 4090332592  | 431264327  |
| 29 Partially Reduced Ore          | 950.00                             | 1742.00 | 333510716.0  | 1323477477  | 139540883  |
| 30 Top gas                        | 831.83                             | 1529.30 | 2839569431.0 | 11268322150 | 1188075849 |
| 31 Recycle solids                 | 831.83                             | 1529.30 | 2863614.0    | 11363740    | 1198136    |
| 32 Dust                           | 220.00                             | 428.00  | 0.0          | 0           | 0          |
| 33 Clean cool top gas             | 220.00                             | 428.00  | 651000067.0  | 2583377042  | 272378428  |
| 34 Dry top gas                    | 232.88                             | 451.19  | 686185734.0  | 2723005054  | 287100111  |
| 35 35                             | 344.62                             | 652.32  | 1565301081.0 | 6211616682  | 654921972  |
| 36 Cold top gas                   | 220.00                             | 428.00  | 651000067.0  | 2583377042  | 272378428  |
| 37 Reducing gas from BB           | 825.64                             | 1518.15 | 937533667.0  | 3720434258  | 392264086  |
| 38 Partially Reduced Fines        | 870.33                             | 1598.59 | 3026007.0    | 12008166    | 1266081    |
| 39 Top Gas with Fines             | 870.33                             | 1598.59 | 2989008777.0 | 11861345403 | 1250601272 |
| 40 CO2                            | 232.88                             | 451.19  | 33472450.0   | 132829416   | 14004873   |
| 41 Cold Recycle gas               | 232.88                             | 451.19  | 652713285.0  | 2590175638  | 273095238  |
| 42 Recycle gas for BB             | 750.00                             | 1382.00 | 795827509.0  | 3158098778  | 332974229  |
| 43 Recycle gas for CFB            | 750.00                             | 1382.00 | 795827509.0  | 3158098778  | 332974229  |
| 44 Recycle gas for Gasifier       | 750.00                             | 1382.00 | 819943494.0  | 3253798741  | 343064358  |
| 45 Water                          | 25.00                              | 77.00   | -220.0       | -874        | -92        |
| 46 Steam                          | 220.00                             | 428.00  | 276454189.0  | 1097058882  | 115668432  |
| 47 DRI                            | 484.03                             | 903.26  | 46850596.0   | 185918192   | 19602289   |
| 48 Char and Ash                   | 484.03                             | 903.26  | 65453819.0   | 259741743   | 27385877   |
| 49 Water                          | 232.88                             | 451.19  | 20464462.0   | 81209548    | 8562330    |
| 50 Reduced Iron                   | 825.64                             | 1518.15 | 224608830.0  | 891319870   | 93976334   |

## CIRCOFER MODEL

## VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM                        | TIME     | ACFM     | SCFM    | M3/HR    | NM3/HR   |
|-----------------------------------|----------|----------|---------|----------|----------|
| 6 top gas from Venturi 1          | 100.0000 | 12931532 | 6161888 | 21970812 | 10469114 |
| 8 Top Gas to Steam boiler         | 100.0000 | 12931532 | 6161888 | 21970812 | 10469114 |
| 10 Oxygen                         | 100.0000 | 87510    | 78333   | 148680   | 133088   |
| 11 Top gas recycled               | 100.0000 | 23673628 | 6092101 | 40221749 | 10350546 |
| 13 Air for Classifier             | 100.0000 | 511      | 457     | 868      | 777      |
| 14 Compressed Air                 | 100.0000 | 511      | 457     | 868      | 777      |
| 18 Iron Ore to Cyclone 2          | 100.0000 | 10029545 | 2151513 | 17040305 | 3655444  |
| 19 Air to Cyclone 2               | 100.0000 | 5455     | 1303    | 9268     | 2214     |
| 20 Air to Calciner                | 100.0000 | 511      | 457     | 868      | 777      |
| 21 Combustion Air to Heater 2     | 100.0000 | 2139273  | 1914935 | 3634648  | 3253496  |
| 22 Natural gas to Heater 2        | 100.0000 | 188752   | 168958  | 320692   | 287062   |
| 23 Exhaust from Heater 2          | 100.0000 | 7233548  | 2083894 | 12289876 | 3540558  |
| 24 Preheated Reformed gas for CFB | 100.0000 | 10368202 | 4584343 | 17615688 | 7788848  |
| 25 Reducing gas for CFB           | 100.0000 | 21979638 | 5866452 | 37343642 | 9967165  |
| 26 Natural gas for Heater 1       | 100.0000 | 213421   | 191040  | 362605   | 324580   |
| 27 Combustion Air for Heater 1    | 100.0000 | 2418360  | 2164755 | 4108820  | 3677942  |
| 28 Exhaust for Heater 1           | 100.0000 | 8824207  | 2355796 | 14992423 | 4002522  |
| 30 Top gas                        | 100.0000 | 24371199 | 6023117 | 41406930 | 10233342 |
| 33 Clean cool top gas             | 100.0000 | 11125605 | 6161888 | 18902524 | 10469114 |
| 34 Dry top gas                    | 100.0000 | 11287139 | 6092101 | 19176972 | 10350546 |
| 35 35                             | 100.0000 | 21050593 | 9307605 | 35765184 | 15813721 |
| 36 Coldtop gas                    | 100.0000 | 11125605 | 6161888 | 18902524 | 10469114 |
| 37 Reducing gas from BB           | 100.0000 | 7789251  | 1935929 | 13234022 | 3289165  |
| 39 Top Gas with Fines             | 100.0000 | 25220140 | 6023117 | 42849290 | 10233342 |
| 40 CO2                            | 100.0000 | 418033   | 225649  | 710243   | 383380   |
| 41 Cold Recycle gas               | 100.0000 | 10869106 | 5866452 | 18466729 | 9967165  |
| 42 Recycle gas for BB             | 100.0000 | 7253281  | 1935929 | 12323402 | 3289165  |
| 43 Recycle gas for CFB            | 100.0000 | 7253281  | 1935929 | 12323402 | 3289165  |
| 44 Recycle gas for Gasifier       | 100.0000 | 7473077  | 1994594 | 12696838 | 3388836  |

## VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM                   | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|------------------------------|----------|----------|----------|----------|----------|
| 1 Iron Ore to Lockhopper     | 100.0000 | 1382.480 | 87.2214  | 313.997  | 7535.93  |
| 2 Char                       | 100.0000 | 418.633  | 26.4118  | 95.083   | 2281.98  |
| 3 Additive                   | 100.0000 | 66.508   | 4.1960   | 15.106   | 362.54   |
| 4 Iron Ore from Lockhopper   | 100.0000 | 1867.591 | 117.8273 | 424.178  | 10180.28 |
| 5 Dried Iron Ore             | 100.0000 | 1445.950 | 91.2258  | 328.413  | 7881.91  |
| 7 Iron Ore                   | 100.0000 | 1445.950 | 91.2258  | 328.413  | 7881.91  |
| 9 Coal                       | 100.0000 | 714.739  | 45.0933  | 162.336  | 3896.06  |
| 12 Iron Ore Feed to Gasifier | 100.0000 | 1464.396 | 92.3896  | 332.603  | 7982.46  |
| 29 Partially Reduced Ore     | 100.0000 | 1826.163 | 115.2136 | 414.769  | 9954.46  |
| 31 Recycle solids            | 100.0000 | 18.446   | 1.1638   | 4.190    | 100.55   |
| 38 Partially Reduced Fines   | 100.0000 | 18.446   | 1.1638   | 4.190    | 100.55   |
| 45 Water                     | 100.0000 | 6092.407 | 384.3734 | 1383.744 | 33209.86 |
| 46 Steam                     | 100.0000 | 7230.858 | 456.1989 | 1642.316 | 39415.59 |
| 47 DRI                       | 100.0000 | 423.462  | 26.7164  | 96.179   | 2308.30  |
| 48 Char and Ash              | 100.0000 | 1020.421 | 64.3790  | 231.764  | 5562.34  |
| 49 Water                     | 100.0000 | 509.588  | 32.1502  | 115.741  | 2777.78  |
| 50 Reduced Iron              | 100.0000 | 1443.883 | 91.0954  | 327.943  | 7870.64  |

## CIRCOFER MODEL

## MASS FLOW RATES - MT/HR

| NO. STREAM                        | MT/HR-SI | MT/HR-LI | MT/HR-GC | MT/HR-TC |
|-----------------------------------|----------|----------|----------|----------|
| 1 Iron Ore to Lockhopper          | 1095.600 | 95.300   | 0.00     | 1190.90  |
| 2 Char                            | 200.000  | 0.000    | 0.00     | 200.00   |
| 3 Additive                        | 50.000   | 0.000    | 0.00     | 50.00    |
| 4 Iron Ore from Lockhopper        | 1345.600 | 95.300   | 0.00     | 1440.90  |
| 5 Dried Iron Ore                  | 1345.600 | 0.000    | 0.00     | 1345.60  |
| 6 top gas from Venturi 1          | 0.000    | 0.000    | 13203.85 | 13203.85 |
| 7 Iron Ore                        | 1345.600 | 0.000    | 0.00     | 1345.60  |
| 8 Top Gas to Steam boiler         | 0.000    | 0.000    | 13203.85 | 13203.85 |
| 9 Coal                            | 200.000  | 0.000    | 0.00     | 200.00   |
| 10 Oxygen                         | 0.000    | 0.000    | 190.00   | 190.00   |
| 11 Top gas recycled               | 0.000    | 0.000    | 13108.55 | 13108.55 |
| 12 Iron Ore Feed to Gasifier      | 1359.452 | 0.000    | 0.00     | 1359.45  |
| 13 Air for Classifier             | 0.000    | 0.000    | 1.00     | 1.00     |
| 14 Compressed Air                 | 0.000    | 0.000    | 1.00     | 1.00     |
| 18 Iron Ore to Cyclone 2          | 1416.814 | 0.000    | 4533.60  | 5950.42  |
| 19 Air to Cyclone 2               | 0.000    | 0.000    | 2.85     | 2.85     |
| 20 Air to Calciner                | 0.000    | 0.000    | 1.00     | 1.00     |
| 21 Combustion Air to Heater 2     | 0.000    | 0.000    | 4187.27  | 4187.27  |
| 22 Natural gas to Heater 2        | 0.000    | 0.000    | 205.47   | 205.47   |
| 23 Exhaust from Heater 2          | 0.000    | 0.000    | 4392.73  | 4392.73  |
| 24 Preheated Reformed gas for CFB | 0.000    | 0.000    | 772.20   | 772.20   |
| 25 Reducing gas for CFB           | 0.000    | 0.000    | 12355.78 | 12355.78 |
| 26 Natural gas for Heater 1       | 0.000    | 0.000    | 232.32   | 232.32   |
| 27 Combustion Air for Heater 1    | 0.000    | 0.000    | 4733.53  | 4733.53  |
| 28 Exhaust for Heater 1           | 0.000    | 0.000    | 4965.85  | 4965.85  |
| 29 Partially Reduced Ore          | 1371.334 | 0.000    | 0.00     | 1371.33  |
| 30 Top gas                        | 0.000    | 0.000    | 12962.08 | 12962.08 |
| 31 Recycle solids                 | 13.852   | 0.000    | 0.00     | 13.85    |
| 33 Clean cool top gas             | 0.000    | 0.000    | 13203.85 | 13203.85 |
| 34 Dry top gas                    | 0.000    | 0.000    | 13108.55 | 13108.55 |
| 35 35                             | 0.000    | 0.000    | 1567.80  | 1567.80  |
| 36 Cold top gas                   | 0.000    | 0.000    | 13203.85 | 13203.85 |
| 37 Reducing gas from BB           | 0.000    | 0.000    | 4319.44  | 4319.44  |
| 38 Partially Reduced Fines        | 13.852   | 0.000    | 0.00     | 13.85    |
| 39 Top Gas with Fines             | 0.000    | 0.000    | 12962.08 | 12962.08 |
| 40 CO2                            | 0.000    | 0.000    | 752.77   | 752.77   |
| 41 Cold Recycle gas               | 0.000    | 0.000    | 12355.78 | 12355.78 |
| 42 Recycle gas for BB             | 0.000    | 0.000    | 4077.41  | 4077.41  |
| 43 Recycle gas for CFB            | 0.000    | 0.000    | 4077.41  | 4077.41  |
| 44 Recycle gas for Gasifier       | 0.000    | 0.000    | 4200.96  | 4200.96  |
| 45 Water                          | 0.000    | 1379.753 | 0.00     | 1379.75  |
| 46 Steam                          | 0.000    | 1379.753 | 0.00     | 1379.75  |
| 47 DRI                            | 738.227  | 0.000    | 0.00     | 738.23   |
| 48 Char and Ash                   | 391.073  | 0.000    | 0.00     | 391.07   |
| 49 Water                          | 0.000    | 95.300   | 0.00     | 95.30    |
| 50 Reduced Iron                   | 1129.300 | 0.000    | 0.00     | 1129.30  |

## CIRCOFER MODEL

## SPECIFIC GRAVITIES

| NO. STREAM                        | PCS      | SG-SI  | SG-LI  | SG-GC  | SG-TC  |
|-----------------------------------|----------|--------|--------|--------|--------|
| 1 Iron Ore to Lockhopper          | 91.9976  | 5.0205 | 0.9951 | 0.0000 | 3.7927 |
| 2 Char                            | 100.0000 | 2.1034 | 0.0000 | 0.0000 | 2.1034 |
| 3 Additive                        | 100.0000 | 3.3100 | 0.0000 | 0.0000 | 3.3100 |
| 4 Iron Ore from Lockhopper        | 93.3861  | 4.0973 | 0.9951 | 0.0000 | 3.3969 |
| 5 Dried Iron Ore                  | 100.0000 | 4.0973 | 0.0000 | 0.0000 | 4.0973 |
| 6 top gas from Venturi 1          | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 7 Iron Ore                        | 100.0000 | 4.0973 | 0.0000 | 0.0000 | 4.0973 |
| 8 Top Gas to Steam boiler         | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 9 Coal                            | 100.0000 | 1.2320 | 0.0000 | 0.0000 | 1.2320 |
| 10 Oxygen                         | 0.0000   | 0.0000 | 0.0000 | 0.0013 | 0.0013 |
| 11 Top gas recycled               | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 12 Iron Ore Feed to Gasifier      | 100.0000 | 4.0873 | 0.0000 | 0.0000 | 4.0873 |
| 13 Air for Classifier             | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 14 Compressed Air                 | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 18 Iron Ore to Cyclone 2          | 23.8103  | 3.2831 | 0.0000 | 0.0003 | 0.0003 |
| 19 Air to Cyclone 2               | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 20 Air to Calciner                | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 21 Combustion Air to Heater 2     | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 22 Natural gas to Heater 2        | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 23 Exhaust from Heater 2          | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 24 Preheated Reformed gas for CFB | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 25 Reducing gas for CFB           | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 26 Natural gas for Heater 1       | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 27 Combustion Air for Heater 1    | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 28 Exhaust for Heater 1           | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 29 Partially Reduced Ore          | 100.0000 | 3.3063 | 0.0000 | 0.0000 | 3.3063 |
| 30 Top gas                        | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 31 Recycle solids                 | 100.0000 | 3.3063 | 0.0000 | 0.0000 | 3.3063 |
| 33 Clean cool top gas             | 0.0000   | 0.0000 | 0.0000 | 0.0007 | 0.0007 |
| 34 Dry top gas                    | 0.0000   | 0.0000 | 0.0000 | 0.0007 | 0.0007 |
| 35 35                             | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 36 Cold top gas                   | 0.0000   | 0.0000 | 0.0000 | 0.0007 | 0.0007 |
| 37 Reducing gas from BB           | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 38 Partially Reduced Fines        | 100.0000 | 3.3063 | 0.0000 | 0.0000 | 3.3063 |
| 39 Top Gas with Fines             | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 40 CO2                            | 0.0000   | 0.0000 | 0.0000 | 0.0011 | 0.0011 |
| 41 Cold Recycle gas               | 0.0000   | 0.0000 | 0.0000 | 0.0007 | 0.0007 |
| 42 Recycle gas for BB             | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 43 Recycle gas for CFB            | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 44 Recycle gas for Gasifier       | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 45 Water                          | 0.0000   | 0.0000 | 0.9971 | 0.0000 | 0.9971 |
| 46 Steam                          | 0.0000   | 0.0000 | 0.8401 | 0.0000 | 0.8401 |
| 47 DRI                            | 100.0000 | 7.6755 | 0.0000 | 0.0000 | 7.6755 |
| 48 Char and Ash                   | 100.0000 | 1.6874 | 0.0000 | 0.0000 | 1.6874 |
| 49 Water                          | 0.0000   | 0.0000 | 0.8234 | 0.0000 | 0.8234 |
| 50 Reduced Iron                   | 100.0000 | 3.4436 | 0.0000 | 0.0000 | 3.4436 |

## CIRCOFER MODEL

## STREAM DATA

SOLIDS - MT/HR

| NO. STREAM                   | Fe2O3   | Fe3O4   | FeO     | Fe1     | Si1O2   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 101.124 | 918.222 | 0.000   | 0.000   | 11.7229 |
| 2 Char                       | 0.000   | 0.000   | 0.000   | 0.000   | 19.0000 |
| 3 Additive                   | 0.000   | 0.000   | 0.000   | 0.000   | 0.0000  |
| 4 Iron Ore from Lockhopper   | 101.124 | 918.222 | 0.000   | 0.000   | 30.7229 |
| 5 Dried Iron Ore             | 101.124 | 918.222 | 0.000   | 0.000   | 30.7229 |
| 7 Iron Ore                   | 101.124 | 918.222 | 0.000   | 0.000   | 30.7229 |
| 9 Coal                       | 0.000   | 0.000   | 0.000   | 0.000   | 12.4000 |
| 12 Iron Ore Feed to Gasifier | 101.124 | 924.355 | 3.844   | 0.000   | 31.1585 |
| 15 Iron Ore from Cyclone 2   | 101.124 | 918.227 | 0.000   | 0.000   | 11.7230 |
| 16 Feed to CFB               | 83.025  | 753.881 | 0.000   | 0.000   | 9.6248  |
| 17 Iron Ore Recycle          | 27.675  | 251.294 | 0.000   | 0.000   | 3.2083  |
| 18 Iron Ore to Cyclone 2     | 101.124 | 924.355 | 3.844   | 0.000   | 43.5585 |
| 29 Partially Reduced Ore     | 0.000   | 607.128 | 380.590 | 0.000   | 43.1229 |
| 31 Recycle solids            | 0.000   | 6.133   | 3.844   | 0.000   | 0.4356  |
| 38 Partially Reduced Fines   | 0.000   | 6.133   | 3.844   | 0.000   | 0.4356  |
| 47 DRI                       | 0.000   | 0.000   | 46.815  | 691.412 | 0.0000  |
| 48 Char and Ash              | 0.000   | 0.000   | 0.473   | 6.984   | 43.1229 |
| 50 Reduced Iron              | 0.000   | 0.000   | 47.288  | 698.396 | 43.1229 |

SOLIDS - MT/HR

| NO. STREAM                   | Al2O3   | P1      | Cu1     | Ca1O1   | Mg1O1   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 8.87436 | 0.66832 | 0.39442 | 7.7788  | 31.9915 |
| 3 Additive                   | 0.00000 | 0.00000 | 0.00000 | 50.0000 | 0.0000  |
| 4 Iron Ore from Lockhopper   | 8.87436 | 0.66832 | 0.39442 | 57.7788 | 31.9915 |
| 5 Dried Iron Ore             | 8.87436 | 0.66832 | 0.39442 | 57.7788 | 31.9915 |
| 7 Iron Ore                   | 8.87436 | 0.66832 | 0.39442 | 57.7788 | 31.9915 |
| 12 Iron Ore Feed to Gasifier | 8.96400 | 0.67507 | 0.39840 | 58.3624 | 32.3147 |
| 15 Iron Ore from Cyclone 2   | 8.87441 | 0.66832 | 0.39442 | 7.7788  | 31.9917 |
| 16 Feed to CFB               | 7.28605 | 0.54870 | 0.32382 | 6.3865  | 26.2658 |
| 17 Iron Ore Recycle          | 2.42868 | 0.18290 | 0.10794 | 2.1288  | 8.7553  |
| 18 Iron Ore to Cyclone 2     | 8.96400 | 0.67507 | 0.39840 | 58.3624 | 32.3147 |
| 29 Partially Reduced Ore     | 8.87436 | 0.66832 | 0.39442 | 57.7788 | 31.9915 |
| 31 Recycle solids            | 0.08964 | 0.00675 | 0.00398 | 0.5836  | 0.3231  |
| 38 Partially Reduced Fines   | 0.08964 | 0.00675 | 0.00398 | 0.5836  | 0.3231  |
| 48 Char and Ash              | 8.87436 | 0.66832 | 0.39442 | 57.7788 | 31.9915 |
| 50 Reduced Iron              | 8.87436 | 0.66832 | 0.39442 | 57.7788 | 31.9915 |

SOLIDS - MT/HR

| NO. STREAM                   | Ti1O2   | S1      | V1      | Co1     | Ni1     |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 4 Iron Ore from Lockhopper   | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 5 Dried Iron Ore             | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 7 Iron Ore                   | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 12 Iron Ore Feed to Gasifier | 12.1733 | 0.33200 | 0.71933 | 0.28773 | 0.33200 |
| 15 Iron Ore from Cyclone 2   | 12.0517 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 16 Feed to CFB               | 9.8946  | 0.26985 | 0.58468 | 0.23387 | 0.26985 |
| 17 Iron Ore Recycle          | 3.2982  | 0.08995 | 0.19489 | 0.07796 | 0.08995 |
| 18 Iron Ore to Cyclone 2     | 12.1733 | 0.33200 | 0.71933 | 0.28773 | 0.33200 |
| 29 Partially Reduced Ore     | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 31 Recycle solids            | 0.1217  | 0.00332 | 0.00719 | 0.00288 | 0.00332 |
| 38 Partially Reduced Fines   | 0.1217  | 0.00332 | 0.00719 | 0.00288 | 0.00332 |
| 48 Char and Ash              | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |
| 50 Reduced Iron              | 12.0516 | 0.32868 | 0.71214 | 0.28486 | 0.32868 |

## CIRCOFER MODEL

## STREAM DATA

## SOLIDS - MT/HR

| NO. STREAM                   | Zn1     | Pb1     | Ca1ClO3 | C       | C5H8    |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.44920 | 0.66832 | 0.00000 | 0.000   | 0.0000  |
| 2 Char                       | 0.00000 | 0.00000 | 0.00000 | 173.600 | 7.4000  |
| 4 Iron Ore from Lockhopper   | 0.44920 | 0.66832 | 0.00000 | 173.600 | 7.4000  |
| 5 Dried Iron Ore             | 0.44920 | 0.66832 | 0.00000 | 173.600 | 7.4000  |
| 7 Iron Ore                   | 0.44920 | 0.66832 | 0.00000 | 173.600 | 7.4000  |
| 9 Coal                       | 0.00000 | 0.00000 | 0.00000 | 114.000 | 73.6000 |
| 12 Iron Ore Feed to Gasifier | 0.45373 | 0.67507 | 0.00000 | 175.064 | 8.2182  |
| 15 Iron Ore from Cyclone 2   | 0.44920 | 0.66832 | 0.00000 | 0.000   | 0.0000  |
| 16 Feed to CFB               | 0.36880 | 0.54870 | 0.00000 | 0.000   | 0.0000  |
| 17 Iron Ore Recycle          | 0.12293 | 0.18290 | 0.00000 | 0.000   | 0.0000  |
| 18 Iron Ore to Cyclone 2     | 0.45373 | 0.67507 | 0.00000 | 146.427 | 81.8182 |
| 29 Partially Reduced Ore     | 0.44920 | 0.66832 | 0.00000 | 144.962 | 81.0000 |
| 31 Recycle solids            | 0.00454 | 0.00675 | 0.00000 | 1.464   | 0.8182  |
| 38 Partially Reduced Fines   | 0.00454 | 0.00675 | 0.00000 | 1.464   | 0.8182  |
| 48 Char and Ash              | 0.44920 | 0.66832 | 0.00000 | 144.962 | 81.0000 |
| 50 Reduced Iron              | 0.44920 | 0.66832 | 0.00000 | 144.962 | 81.0000 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                   | Fe2O3   | Fe3O4   | FeO     | Fe1     | Si1O2   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.0700  |
| 2 Char                       | 0.00000 | 0.0000  | 0.0000  | 0.0000  | 9.5000  |
| 3 Additive                   | 0.00000 | 0.0000  | 0.0000  | 0.0000  | 0.0000  |
| 4 Iron Ore from Lockhopper   | 7.51515 | 68.2389 | 0.0000  | 0.0000  | 2.2832  |
| 5 Dried Iron Ore             | 7.51515 | 68.2389 | 0.0000  | 0.0000  | 2.2832  |
| 7 Iron Ore                   | 7.51515 | 68.2389 | 0.0000  | 0.0000  | 2.2832  |
| 9 Coal                       | 0.00000 | 0.0000  | 0.0000  | 0.0000  | 6.2000  |
| 12 Iron Ore Feed to Gasifier | 7.43858 | 67.9947 | 0.2828  | 0.0000  | 2.2920  |
| 15 Iron Ore from Cyclone 2   | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.0700  |
| 16 Feed to CFB               | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.0700  |
| 17 Iron Ore Recycle          | 9.23000 | 83.8100 | 0.0000  | 0.0000  | 1.0700  |
| 18 Iron Ore to Cyclone 2     | 7.13741 | 65.2418 | 0.2713  | 0.0000  | 3.0744  |
| 29 Partially Reduced Ore     | 0.00000 | 44.2728 | 27.7532 | 0.0000  | 3.1446  |
| 31 Recycle solids            | 0.00000 | 44.2728 | 27.7532 | 0.0000  | 3.1446  |
| 38 Partially Reduced Fines   | 0.00000 | 44.2728 | 27.7532 | 0.0000  | 3.1446  |
| 47 DRI                       | 0.00000 | 0.0000  | 6.3416  | 93.6584 | 0.0000  |
| 48 Char and Ash              | 0.00000 | 0.0000  | 0.1209  | 1.7858  | 11.0268 |
| 50 Reduced Iron              | 0.00000 | 0.0000  | 4.1874  | 61.8433 | 3.8186  |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                   | Al2O3   | P1      | Cu1     | Ca1O1   | Mg1O1   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 3 Additive                   | 0.00000 | 0.00000 | 0.00000 | 100.000 | 0.00000 |
| 4 Iron Ore from Lockhopper   | 0.65951 | 0.04967 | 0.02931 | 4.294   | 2.37749 |
| 5 Dried Iron Ore             | 0.65951 | 0.04967 | 0.02931 | 4.294   | 2.37749 |
| 7 Iron Ore                   | 0.65951 | 0.04967 | 0.02931 | 4.294   | 2.37749 |
| 12 Iron Ore Feed to Gasifier | 0.65938 | 0.04966 | 0.02931 | 4.293   | 2.37704 |
| 15 Iron Ore from Cyclone 2   | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 16 Feed to CFB               | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 17 Iron Ore Recycle          | 0.81000 | 0.06100 | 0.03600 | 0.710   | 2.92000 |
| 18 Iron Ore to Cyclone 2     | 0.63269 | 0.04765 | 0.02812 | 4.119   | 2.28080 |
| 29 Partially Reduced Ore     | 0.64713 | 0.04873 | 0.02876 | 4.213   | 2.33288 |
| 31 Recycle solids            | 0.64713 | 0.04873 | 0.02876 | 4.213   | 2.33288 |
| 38 Partially Reduced Fines   | 0.64713 | 0.04873 | 0.02876 | 4.213   | 2.33288 |
| 48 Char and Ash              | 2.26923 | 0.17089 | 0.10085 | 14.774  | 8.18045 |
| 50 Reduced Iron              | 0.78583 | 0.05918 | 0.03493 | 5.116   | 2.83286 |

## CIRCOFER MODEL

## STREAM DATA

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                   | Ti102   | Si      | V1      | Co1     | Ni1     |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 4 Iron Ore from Lockhopper   | 0.89563 | 0.02443 | 0.05292 | 0.02117 | 0.02443 |
| 5 Dried Iron Ore             | 0.89563 | 0.02443 | 0.05292 | 0.02117 | 0.02443 |
| 7 Iron Ore                   | 0.89563 | 0.02443 | 0.05292 | 0.02117 | 0.02443 |
| 12 Iron Ore Feed to Gasifier | 0.89546 | 0.02442 | 0.05291 | 0.02117 | 0.02442 |
| 15 Iron Ore from Cyclone 2   | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 16 Feed to CFB               | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 17 Iron Ore Recycle          | 1.10000 | 0.03000 | 0.06500 | 0.02600 | 0.03000 |
| 18 Iron Ore to Cyclone 2     | 0.85920 | 0.02343 | 0.05077 | 0.02031 | 0.02343 |
| 29 Partially Reduced Ore     | 0.87882 | 0.02397 | 0.05193 | 0.02077 | 0.02397 |
| 31 Recycle solids            | 0.87882 | 0.02397 | 0.05193 | 0.02077 | 0.02397 |
| 38 Partially Reduced Fines   | 0.87882 | 0.02397 | 0.05193 | 0.02077 | 0.02397 |
| 48 Char and Ash              | 3.08168 | 0.08405 | 0.18210 | 0.07284 | 0.08405 |
| 50 Reduced Iron              | 1.06717 | 0.02910 | 0.06306 | 0.02522 | 0.02910 |

## SOLIDS - WEIGHT PERCENT

| NO. STREAM                   | Zn1     | Pb1     | Ca1ClO3 | C       | C5H8    |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.04100 | 0.06100 | 0.00000 | 0.0000  | 0.0000  |
| 2 Char                       | 0.00000 | 0.00000 | 0.00000 | 86.8000 | 3.7000  |
| 4 Iron Ore from Lockhopper   | 0.03338 | 0.04967 | 0.00000 | 12.9013 | 0.5499  |
| 5 Dried Iron Ore             | 0.03338 | 0.04967 | 0.00000 | 12.9013 | 0.5499  |
| 7 Iron Ore                   | 0.03338 | 0.04967 | 0.00000 | 12.9013 | 0.5499  |
| 9 Coal                       | 0.00000 | 0.00000 | 0.00000 | 57.0000 | 36.8000 |
| 12 Iron Ore Feed to Gasifier | 0.03338 | 0.04966 | 0.00000 | 12.8776 | 0.6045  |
| 15 Iron Ore from Cyclone 2   | 0.04100 | 0.06100 | 0.00000 | 0.0000  | 0.0000  |
| 16 Feed to CFB               | 0.04100 | 0.06100 | 0.00000 | 0.0000  | 0.0000  |
| 17 Iron Ore Recycle          | 0.04100 | 0.06100 | 0.00000 | 0.0000  | 0.0000  |
| 18 Iron Ore to Cyclone 2     | 0.03202 | 0.04765 | 0.00000 | 10.3349 | 5.7748  |
| 29 Partially Reduced Ore     | 0.03276 | 0.04873 | 0.00000 | 10.5709 | 5.9067  |
| 31 Recycle solids            | 0.03276 | 0.04873 | 0.00000 | 10.5709 | 5.9067  |
| 38 Partially Reduced Fines   | 0.03276 | 0.04873 | 0.00000 | 10.5709 | 5.9067  |
| 48 Char and Ash              | 0.11486 | 0.17089 | 0.00000 | 37.0678 | 20.7123 |
| 50 Reduced Iron              | 0.03978 | 0.05918 | 0.00000 | 12.8365 | 7.1726  |

## AQUEOUS - MT/HR

| NO. STREAM                 | H2O     |
|----------------------------|---------|
| 1 Iron Ore to Lockhopper   | 95.30   |
| 4 Iron Ore from Lockhopper | 95.30   |
| 45 Water                   | 1379.75 |
| 46 Steam                   | 1379.75 |
| 49 Water                   | 95.30   |

## AQUEOUS - WEIGHT PERCENT

| NO. STREAM                 | H2O     |
|----------------------------|---------|
| 1 Iron Ore to Lockhopper   | 100.000 |
| 4 Iron Ore from Lockhopper | 100.000 |
| 45 Water                   | 100.000 |
| 46 Steam                   | 100.000 |
| 49 Water                   | 100.000 |

## AQUEOUS - GRAMS PER LITER

| NO. STREAM                 | H2O     |
|----------------------------|---------|
| 1 Iron Ore to Lockhopper   | 995.067 |
| 4 Iron Ore from Lockhopper | 995.139 |
| 45 Water                   | 997.116 |
| 46 Steam                   | 840.126 |
| 49 Water                   | 823.392 |



## CIRCOFER MODEL

## STREAM DATA

GASEOUS - MT/HR

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 6 top gas from Venturi 1       | 190.600 | 0.00    | 0.00    | 67.000  | 760.372 |
| 8 Top Gas to Steam boiler      | 190.600 | 0.00    | 0.00    | 67.000  | 760.372 |
| 10 Oxygen                      | 0.000   | 0.00    | 190.00  | 0.000   | 0.000   |
| 11 Top gas recycled            | 95.300  | 0.00    | 0.00    | 67.000  | 760.372 |
| 13 Air for Classifier          | 0.000   | 0.77    | 0.23    | 0.000   | 0.000   |
| 14 Compressed Air              | 0.000   | 0.77    | 0.23    | 0.000   | 0.000   |
| 18 Iron Ore to Cyclone 2       | 32.402  | 0.00    | 0.00    | 22.780  | 2.585   |
| 19 Air to Cyclone 2            | 0.000   | 2.19    | 0.66    | 0.000   | 0.000   |
| 20 Air to Calciner             | 0.000   | 0.77    | 0.23    | 0.000   | 0.000   |
| 21 Combustion Air to Heater 2  | 0.000   | 3215.82 | 971.45  | 0.000   | 0.000   |
| 22 Natural gas to Heater 2     | 0.000   | 0.00    | 0.00    | 205.467 | 0.000   |
| 23 Exhaust from Heater 2       | 461.454 | 3215.82 | 151.81  | 0.000   | 563.647 |
| 25 Reducing gas for CFB        | 95.300  | 0.00    | 0.00    | 67.000  | 7.604   |
| 26 Natural gas for Heater 1    | 0.000   | 0.00    | 0.00    | 232.321 | 0.000   |
| 27 Combustion Air for Heater 1 | 0.000   | 3635.35 | 1098.18 | 0.000   | 0.000   |
| 28 Exhaust for Heater 1        | 521.764 | 3635.35 | 171.42  | 0.000   | 637.313 |
| 30 Top gas                     | 95.300  | 0.00    | 0.00    | 67.000  | 760.372 |
| 33 Clean cool top gas          | 190.600 | 0.00    | 0.00    | 67.000  | 760.372 |
| 34 Dry top gas                 | 95.300  | 0.00    | 0.00    | 67.000  | 760.372 |
| 36 Cold top gas                | 190.600 | 0.00    | 0.00    | 67.000  | 760.372 |
| 37 Reducing gas from BB        | 31.449  | 0.00    | 0.00    | 22.110  | 668.277 |
| 39 Top Gas with Fines          | 95.300  | 0.00    | 0.00    | 67.000  | 760.372 |
| 40 CO2                         | 0.000   | 0.00    | 0.00    | 0.000   | 752.769 |
| 41 Cold Recycle gas            | 95.300  | 0.00    | 0.00    | 67.000  | 7.604   |
| 42 Recycle gas for BB          | 31.449  | 0.00    | 0.00    | 22.110  | 2.509   |
| 43 Recycle gas for CFB         | 31.449  | 0.00    | 0.00    | 22.110  | 2.509   |
| 44 Recycle gas for Gasifier    | 32.402  | 0.00    | 0.00    | 22.780  | 2.585   |

GASEOUS - MT/HR

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 6 top gas from Venturi 1          | 0.00    | 12185.9 |
| 8 Top Gas to Steam boiler         | 0.00    | 12185.9 |
| 11 Top gas recycled               | 0.00    | 12185.9 |
| 18 Iron Ore to Cyclone 2          | 0.00    | 4475.8  |
| 24 Preheated Reformed gas for CFB | 694.98  | 77.2    |
| 25 Reducing gas for CFB           | 0.00    | 12185.9 |
| 30 Top gas                        | 0.00    | 12039.4 |
| 33 Clean cool top gas             | 0.00    | 12185.9 |
| 34 Dry top gas                    | 0.00    | 12185.9 |
| 35 35                             | 1411.02 | 156.8   |
| 36 Cold top gas                   | 0.00    | 12185.9 |
| 37 Reducing gas from BB           | 0.00    | 3597.6  |
| 39 Top Gas with Fines             | 0.00    | 12039.4 |
| 41 Cold Recycle gas               | 0.00    | 12185.9 |
| 42 Recycle gas for BB             | 0.00    | 4021.3  |
| 43 Recycle gas for CFB            | 0.00    | 4021.3  |
| 44 Recycle gas for Gasifier       | 0.00    | 4143.2  |

## CIRCOFER MODEL

## STREAM DATA

## GASEOUS - WEIGHT PERCENT

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 6 top gas from Venturi 1       | 1.4435  | 0.0000  | 0.000   | 0.507   | 5.759   |
| 8 Top Gas to Steam boiler      | 1.4435  | 0.0000  | 0.000   | 0.507   | 5.759   |
| 10 Oxygen                      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.000   |
| 11 Top gas recycled            | 0.7270  | 0.0000  | 0.000   | 0.511   | 5.801   |
| 13 Air for Classifier          | 0.0000  | 76.8000 | 23.200  | 0.000   | 0.000   |
| 14 Compressed Air              | 0.0000  | 76.8000 | 23.200  | 0.000   | 0.000   |
| 18 Iron Ore to Cyclone 2       | 0.7147  | 0.0000  | 0.000   | 0.502   | 0.057   |
| 19 Air to Cyclone 2            | 0.0000  | 76.8000 | 23.200  | 0.000   | 0.000   |
| 20 Air to Calciner             | 0.0000  | 76.8000 | 23.200  | 0.000   | 0.000   |
| 21 Combustion Air to Heater 2  | 0.0000  | 76.8000 | 23.200  | 0.000   | 0.000   |
| 22 Natural gas to Heater 2     | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.000   |
| 23 Exhaust from Heater 2       | 10.5049 | 73.2077 | 3.456   | 0.000   | 12.831  |
| 25 Reducing gas for CFB        | 0.7713  | 0.0000  | 0.000   | 0.542   | 0.062   |
| 26 Natural gas for Heater 1    | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.000   |
| 27 Combustion Air for Heater 1 | 0.0000  | 76.8000 | 23.200  | 0.000   | 0.000   |
| 28 Exhaust for Heater 1        | 10.5070 | 73.2070 | 3.452   | 0.000   | 12.834  |
| 30 Top gas                     | 0.7352  | 0.0000  | 0.000   | 0.517   | 5.866   |
| 33 Clean cool top gas          | 1.4435  | 0.0000  | 0.000   | 0.507   | 5.759   |
| 34 Dry top gas                 | 0.7270  | 0.0000  | 0.000   | 0.511   | 5.801   |
| 36 Cold top gas                | 1.4435  | 0.0000  | 0.000   | 0.507   | 5.759   |
| 37 Reducing gas from BB        | 0.7281  | 0.0000  | 0.000   | 0.512   | 15.471  |
| 39 Top Gas with Fines          | 0.7352  | 0.0000  | 0.000   | 0.517   | 5.866   |
| 40 CO2                         | 0.0000  | 0.0000  | 0.000   | 0.000   | 100.000 |
| 41 Cold Recycle gas            | 0.7713  | 0.0000  | 0.000   | 0.542   | 0.062   |
| 42 Recycle gas for BB          | 0.7713  | 0.0000  | 0.000   | 0.542   | 0.062   |
| 43 Recycle gas for CFB         | 0.7713  | 0.0000  | 0.000   | 0.542   | 0.062   |
| 44 Recycle gas for Gasifier    | 0.7713  | 0.0000  | 0.000   | 0.542   | 0.062   |

## GASEOUS - WEIGHT PERCENT

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 6 top gas from Venturi 1          | 0.0000  | 92.2903 |
| 8 Top Gas to Steam boiler         | 0.0000  | 92.2903 |
| 11 Top gas recycled               | 0.0000  | 92.9613 |
| 18 Iron Ore to Cyclone 2          | 0.0000  | 98.7258 |
| 24 Preheated Reformed gas for CFB | 90.0000 | 10.0000 |
| 25 Reducing gas for CFB           | 0.0000  | 98.6249 |
| 30 Top gas                        | 0.0000  | 92.8818 |
| 33 Clean cool top gas             | 0.0000  | 92.2903 |
| 34 Dry top gas                    | 0.0000  | 92.9613 |
| 35 35                             | 90.0000 | 10.0000 |
| 36 Cold top gas                   | 0.0000  | 92.2903 |
| 37 Reducing gas from BB           | 0.0000  | 83.2887 |
| 39 Top Gas with Fines             | 0.0000  | 92.8818 |
| 41 Cold Recycle gas               | 0.0000  | 98.6249 |
| 42 Recycle gas for BB             | 0.0000  | 98.6249 |
| 43 Recycle gas for CFB            | 0.0000  | 98.6249 |
| 44 Recycle gas for Gasifier       | 0.0000  | 98.6249 |

## CIRCOFER MODEL

## STREAM DATA

## GASEOUS - VOLUME PERCENT

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 6 top gas from Venturi 1       | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 8 Top Gas to Steam boiler      | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 10 Oxygen                      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.000   |
| 11 Top gas recycled            | 1.1455  | 0.0000  | 0.000   | 0.904   | 3.741   |
| 13 Air for Classifier          | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 14 Compressed Air              | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 18 Iron Ore to Cyclone 2       | 1.1030  | 0.0000  | 0.000   | 0.871   | 0.036   |
| 19 Air to Cyclone 2            | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 20 Air to Calciner             | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 21 Combustion Air to Heater 2  | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 22 Natural gas to Heater 2     | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.000   |
| 23 Exhaust from Heater 2       | 16.2156 | 72.6731 | 3.003   | 0.000   | 8.108   |
| 25 Reducing gas for CFB        | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 26 Natural gas for Heater 1    | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.000   |
| 27 Combustion Air for Heater 1 | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 28 Exhaust for Heater 1        | 16.2188 | 72.6719 | 3.000   | 0.000   | 8.109   |
| 30 Top gas                     | 1.1587  | 0.0000  | 0.000   | 0.915   | 3.784   |
| 33 Clean cool top gas          | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 34 Dry top gas                 | 1.1455  | 0.0000  | 0.000   | 0.904   | 3.741   |
| 36 Cold top gas                | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 37 Reducing gas from BB        | 1.1896  | 0.0000  | 0.000   | 0.939   | 10.348  |
| 39 Top Gas with Fines          | 1.1587  | 0.0000  | 0.000   | 0.915   | 3.784   |
| 40 CO2                         | 0.0000  | 0.0000  | 0.000   | 0.000   | 100.000 |
| 41 Cold Recycle gas            | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 42 Recycle gas for BB          | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 43 Recycle gas for CFB         | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 44 Recycle gas for Gasifier    | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |

## GASEOUS - VOLUME PERCENT

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 6 top gas from Venturi 1          | 0.0000  | 93.1418 |
| 8 Top Gas to Steam boiler         | 0.0000  | 93.1418 |
| 11 Top gas recycled               | 0.0000  | 94.2087 |
| 18 Iron Ore to Cyclone 2          | 0.0000  | 97.9903 |
| 24 Preheated Reformed gas for CFB | 99.2067 | 0.7933  |
| 25 Reducing gas for CFB           | 0.0000  | 97.8324 |
| 30 Top gas                        | 0.0000  | 94.1424 |
| 33 Clean cool top gas             | 0.0000  | 93.1418 |
| 34 Dry top gas                    | 0.0000  | 94.2087 |
| 35 35                             | 99.2067 | 0.7933  |
| 36 Cold top gas                   | 0.0000  | 93.1418 |
| 37 Reducing gas from BB           | 0.0000  | 87.5237 |
| 39 Top Gas with Fines             | 0.0000  | 94.1424 |
| 41 Cold Recycle gas               | 0.0000  | 97.8324 |
| 42 Recycle gas for BB             | 0.0000  | 97.8324 |
| 43 Recycle gas for CFB            | 0.0000  | 97.8324 |
| 44 Recycle gas for Gasifier       | 0.0000  | 97.8324 |

## CIRCOFER MODEL

## STREAM DATA IN MOLES

## SOLIDS - MT MOLES/HR

| NO. STREAM                   | Fe2O3   | Fe3O4   | FeO     | Fe1     | Si1O2   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.63324 | 3.96574 | 0.00000 | 0.0000  | 0.19511 |
| 2 Char                       | 0.00000 | 0.00000 | 0.00000 | 0.0000  | 0.31622 |
| 3 Additive                   | 0.00000 | 0.00000 | 0.00000 | 0.0000  | 0.00000 |
| 4 Iron Ore from Lockhopper   | 0.63324 | 3.96574 | 0.00000 | 0.0000  | 0.51133 |
| 5 Dried Iron Ore             | 0.63324 | 3.96574 | 0.00000 | 0.0000  | 0.51133 |
| 7 Iron Ore                   | 0.63324 | 3.96574 | 0.00000 | 0.0000  | 0.51133 |
| 9 Coal                       | 0.00000 | 0.00000 | 0.00000 | 0.0000  | 0.20637 |
| 12 Iron Ore Feed to Gasifier | 0.63324 | 3.99223 | 0.05351 | 0.0000  | 0.51858 |
| 15 Iron Ore from Cyclone 2   | 0.63325 | 3.96576 | 0.00000 | 0.0000  | 0.19511 |
| 16 Feed to CFB               | 0.51991 | 3.25596 | 0.00000 | 0.0000  | 0.16019 |
| 17 Iron Ore Recycle          | 0.17330 | 1.08532 | 0.00000 | 0.0000  | 0.05340 |
| 18 Iron Ore to Cyclone 2     | 0.63324 | 3.99223 | 0.05351 | 0.0000  | 0.72495 |
| 29 Partially Reduced Ore     | 0.00000 | 2.62215 | 5.29727 | 0.0000  | 0.71770 |
| 31 Recycle solids            | 0.00000 | 0.02649 | 0.05351 | 0.0000  | 0.00725 |
| 38 Partially Reduced Fines   | 0.00000 | 0.02649 | 0.05351 | 0.0000  | 0.00725 |
| 47 DRI                       | 0.00000 | 0.00000 | 0.65160 | 12.3805 | 0.00000 |
| 48 Char and Ash              | 0.00000 | 0.00000 | 0.00658 | 0.1251  | 0.71770 |
| 50 Reduced Iron              | 0.00000 | 0.00000 | 0.65819 | 12.5055 | 0.71770 |

## SOLIDS - MT MOLES/HR

| NO. STREAM                   | Al2O3   | P1      | Cu1     | Ca1O1   | Mg1O1   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.08704 | 0.02158 | 0.00621 | 0.13871 | 0.79361 |
| 3 Additive                   | 0.00000 | 0.00000 | 0.00000 | 0.89159 | 0.00000 |
| 4 Iron Ore from Lockhopper   | 0.08704 | 0.02158 | 0.00621 | 1.03030 | 0.79361 |
| 5 Dried Iron Ore             | 0.08704 | 0.02158 | 0.00621 | 1.03030 | 0.79361 |
| 7 Iron Ore                   | 0.08704 | 0.02158 | 0.00621 | 1.03030 | 0.79361 |
| 12 Iron Ore Feed to Gasifier | 0.08792 | 0.02179 | 0.00627 | 1.04071 | 0.80163 |
| 15 Iron Ore from Cyclone 2   | 0.08704 | 0.02158 | 0.00621 | 0.13871 | 0.79361 |
| 16 Feed to CFB               | 0.07146 | 0.01772 | 0.00510 | 0.11388 | 0.65157 |
| 17 Iron Ore Recycle          | 0.02382 | 0.00591 | 0.00170 | 0.03796 | 0.21719 |
| 18 Iron Ore to Cyclone 2     | 0.08792 | 0.02179 | 0.00627 | 1.04071 | 0.80163 |
| 29 Partially Reduced Ore     | 0.08704 | 0.02158 | 0.00621 | 1.03030 | 0.79361 |
| 31 Recycle solids            | 0.00088 | 0.00022 | 0.00006 | 0.01041 | 0.00802 |
| 38 Partially Reduced Fines   | 0.00088 | 0.00022 | 0.00006 | 0.01041 | 0.00802 |
| 48 Char and Ash              | 0.08704 | 0.02158 | 0.00621 | 1.03030 | 0.79361 |
| 50 Reduced Iron              | 0.08704 | 0.02158 | 0.00621 | 1.03030 | 0.79361 |

## SOLIDS - MT MOLES/HR

| NO. STREAM                   | Ti1O2   | S1      | V1      | Co1     | Ni1     |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |
| 4 Iron Ore from Lockhopper   | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |
| 5 Dried Iron Ore             | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |
| 7 Iron Ore                   | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |
| 12 Iron Ore Feed to Gasifier | 0.15236 | 0.01035 | 0.01412 | 0.00488 | 0.00565 |
| 15 Iron Ore from Cyclone 2   | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |
| 16 Feed to CFB               | 0.12384 | 0.00842 | 0.01148 | 0.00397 | 0.00460 |
| 17 Iron Ore Recycle          | 0.04128 | 0.00281 | 0.00383 | 0.00132 | 0.00153 |
| 18 Iron Ore to Cyclone 2     | 0.15236 | 0.01035 | 0.01412 | 0.00488 | 0.00565 |
| 29 Partially Reduced Ore     | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |
| 31 Recycle solids            | 0.00152 | 0.00010 | 0.00014 | 0.00005 | 0.00006 |
| 38 Partially Reduced Fines   | 0.00152 | 0.00010 | 0.00014 | 0.00005 | 0.00006 |
| 48 Char and Ash              | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |
| 50 Reduced Iron              | 0.15084 | 0.01025 | 0.01398 | 0.00483 | 0.00560 |

## CIRCOFER MODEL

## STREAM DATA IN MOLES

## SOLIDS - MT MOLES/HR

| NO. STREAM                   | Zn1     | Pb1     | Ca1ClO3 | C       | C5H8    |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.00687 | 0.00323 | 0.00000 | 0.0000  | 0.00000 |
| 2 Char                       | 0.00000 | 0.00000 | 0.00000 | 14.4532 | 0.10863 |
| 4 Iron Ore from Lockhopper   | 0.00687 | 0.00323 | 0.00000 | 14.4532 | 0.10863 |
| 5 Dried Iron Ore             | 0.00687 | 0.00323 | 0.00000 | 14.4532 | 0.10863 |
| 7 Iron Ore                   | 0.00687 | 0.00323 | 0.00000 | 14.4532 | 0.10863 |
| 9 Coal                       | 0.00000 | 0.00000 | 0.00000 | 9.4912  | 1.08045 |
| 12 Iron Ore Feed to Gasifier | 0.00694 | 0.00326 | 0.00000 | 14.5751 | 0.12064 |
| 15 Iron Ore from Cyclone 2   | 0.00687 | 0.00323 | 0.00000 | 0.0000  | 0.00000 |
| 16 Feed to CFB               | 0.00564 | 0.00265 | 0.00000 | 0.0000  | 0.00000 |
| 17 Iron Ore Recycle          | 0.00188 | 0.00088 | 0.00000 | 0.0000  | 0.00000 |
| 18 Iron Ore to Cyclone 2     | 0.00694 | 0.00326 | 0.00000 | 12.1909 | 1.20110 |
| 29 Partially Reduced Ore     | 0.00687 | 0.00323 | 0.00000 | 12.0690 | 1.18909 |
| 31 Recycle solids            | 0.00007 | 0.00003 | 0.00000 | 0.1219  | 0.01201 |
| 38 Partially Reduced Fines   | 0.00007 | 0.00003 | 0.00000 | 0.1219  | 0.01201 |
| 48 Char and Ash              | 0.00687 | 0.00323 | 0.00000 | 12.0690 | 1.18909 |
| 50 Reduced Iron              | 0.00687 | 0.00323 | 0.00000 | 12.0690 | 1.18909 |

## SOLIDS - MOLE PERCENT

| NO. STREAM                   | Fe2O3   | Fe3O4   | FeO     | Fe1     | Si1O2   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 10.4897 | 65.6925 | 0.0000  | 0.0000  | 3.23193 |
| 2 Char                       | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 2.12541 |
| 3 Additive                   | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 0.00000 |
| 4 Iron Ore from Lockhopper   | 2.9039  | 18.1860 | 0.0000  | 0.0000  | 2.34483 |
| 5 Dried Iron Ore             | 2.9039  | 18.1860 | 0.0000  | 0.0000  | 2.34483 |
| 7 Iron Ore                   | 2.9039  | 18.1860 | 0.0000  | 0.0000  | 2.34483 |
| 9 Coal                       | 0.0000  | 0.0000  | 0.0000  | 0.0000  | 1.91478 |
| 12 Iron Ore Feed to Gasifier | 2.8719  | 18.1060 | 0.2427  | 0.0000  | 2.35190 |
| 15 Iron Ore from Cyclone 2   | 10.4897 | 65.6925 | 0.0000  | 0.0000  | 3.23193 |
| 16 Feed to CFB               | 10.4897 | 65.6925 | 0.0000  | 0.0000  | 3.23193 |
| 17 Iron Ore Recycle          | 10.4897 | 65.6925 | 0.0000  | 0.0000  | 3.23193 |
| 18 Iron Ore to Cyclone 2     | 3.0224  | 19.0544 | 0.2554  | 0.0000  | 3.46009 |
| 29 Partially Reduced Ore     | 0.0000  | 10.9122 | 22.0448 | 0.0000  | 2.98675 |
| 31 Recycle solids            | 0.0000  | 10.9122 | 22.0448 | 0.0000  | 2.98675 |
| 38 Partially Reduced Fines   | 0.0000  | 10.9122 | 22.0448 | 0.0000  | 2.98675 |
| 47 DRI                       | 0.0000  | 0.0000  | 5.0000  | 95.0000 | 0.00000 |
| 48 Char and Ash              | 0.0000  | 0.0000  | 0.0405  | 0.7700  | 4.41887 |
| 50 Reduced Iron              | 0.0000  | 0.0000  | 2.2484  | 42.7192 | 2.45168 |

## SOLIDS - MOLE PERCENT

| NO. STREAM                   | Al2O3   | P1      | Cu1     | Ca1O1   | Mg1O1   |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 1.44176 | 0.35742 | 0.10282 | 2.298   | 13.1461 |
| 3 Additive                   | 0.00000 | 0.00000 | 0.00000 | 100.000 | 0.0000  |
| 4 Iron Ore from Lockhopper   | 0.39913 | 0.09895 | 0.02847 | 4.725   | 3.6393  |
| 5 Dried Iron Ore             | 0.39913 | 0.09895 | 0.02847 | 4.725   | 3.6393  |
| 7 Iron Ore                   | 0.39913 | 0.09895 | 0.02847 | 4.725   | 3.6393  |
| 12 Iron Ore Feed to Gasifier | 0.39873 | 0.09885 | 0.02844 | 4.720   | 3.6356  |
| 15 Iron Ore from Cyclone 2   | 1.44176 | 0.35742 | 0.10282 | 2.298   | 13.1461 |
| 16 Feed to CFB               | 1.44176 | 0.35742 | 0.10282 | 2.298   | 13.1461 |
| 17 Iron Ore Recycle          | 1.44176 | 0.35742 | 0.10282 | 2.298   | 13.1461 |
| 18 Iron Ore to Cyclone 2     | 0.41961 | 0.10402 | 0.02993 | 4.967   | 3.8260  |
| 29 Partially Reduced Ore     | 0.36221 | 0.08979 | 0.02583 | 4.288   | 3.3026  |
| 31 Recycle solids            | 0.36221 | 0.08979 | 0.02583 | 4.288   | 3.3026  |
| 38 Partially Reduced Fines   | 0.36221 | 0.08979 | 0.02583 | 4.288   | 3.3026  |
| 48 Char and Ash              | 0.53588 | 0.13285 | 0.03822 | 6.344   | 4.8862  |
| 50 Reduced Iron              | 0.29732 | 0.07371 | 0.02120 | 3.520   | 2.7110  |

## CIRCOFER MODEL

## STREAM DATA IN MOLES

## SOLIDS - MOLE PERCENT

| NO. STREAM                   | Ti102   | S1      | V1      | Co1     | Ni1     |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 2.49859 | 0.16980 | 0.23157 | 0.08007 | 0.09274 |
| 4 Iron Ore from Lockhopper   | 0.69170 | 0.04701 | 0.06411 | 0.02217 | 0.02567 |
| 5 Dried Iron Ore             | 0.69170 | 0.04701 | 0.06411 | 0.02217 | 0.02567 |
| 7 Iron Ore                   | 0.69170 | 0.04701 | 0.06411 | 0.02217 | 0.02567 |
| 12 Iron Ore Feed to Gasifier | 0.69100 | 0.04696 | 0.06404 | 0.02214 | 0.02565 |
| 15 Iron Ore from Cyclone 2   | 2.49859 | 0.16980 | 0.23157 | 0.08007 | 0.09274 |
| 16 Feed to CFB               | 2.49859 | 0.16980 | 0.23157 | 0.08007 | 0.09274 |
| 17 Iron Ore Recycle          | 2.49859 | 0.16980 | 0.23157 | 0.08007 | 0.09274 |
| 18 Iron Ore to Cyclone 2     | 0.72719 | 0.04942 | 0.06740 | 0.02330 | 0.02699 |
| 29 Partially Reduced Ore     | 0.62771 | 0.04266 | 0.05818 | 0.02012 | 0.02330 |
| 31 Recycle solids            | 0.62771 | 0.04266 | 0.05818 | 0.02012 | 0.02330 |
| 38 Partially Reduced Fines   | 0.62771 | 0.04266 | 0.05818 | 0.02012 | 0.02330 |
| 48 Char and Ash              | 0.92869 | 0.06311 | 0.08607 | 0.02976 | 0.03447 |
| 50 Reduced Iron              | 0.51526 | 0.03502 | 0.04775 | 0.01651 | 0.01912 |

## SOLIDS - MOLE PERCENT

| NO. STREAM                   | Zn1     | Pb1     | Ca1C1O3 | C       | C5H8    |
|------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore to Lockhopper     | 0.11381 | 0.05343 | 0.00000 | 0.0000  | 0.0000  |
| 2 Char                       | 0.00000 | 0.00000 | 0.00000 | 97.1444 | 0.7302  |
| 4 Iron Ore from Lockhopper   | 0.03151 | 0.01479 | 0.00000 | 66.2795 | 0.4982  |
| 5 Dried Iron Ore             | 0.03151 | 0.01479 | 0.00000 | 66.2795 | 0.4982  |
| 7 Iron Ore                   | 0.03151 | 0.01479 | 0.00000 | 66.2795 | 0.4982  |
| 9 Coal                       | 0.00000 | 0.00000 | 0.00000 | 88.0606 | 10.0246 |
| 12 Iron Ore Feed to Gasifier | 0.03147 | 0.01478 | 0.00000 | 66.1027 | 0.5472  |
| 15 Iron Ore from Cyclone 2   | 0.11381 | 0.05343 | 0.00000 | 0.0000  | 0.0000  |
| 16 Feed to CFB               | 0.11381 | 0.05343 | 0.00000 | 0.0000  | 0.0000  |
| 17 Iron Ore Recycle          | 0.11381 | 0.05343 | 0.00000 | 0.0000  | 0.0000  |
| 18 Iron Ore to Cyclone 2     | 0.03312 | 0.01555 | 0.00000 | 58.1854 | 5.7327  |
| 29 Partially Reduced Ore     | 0.02859 | 0.01342 | 0.00000 | 50.2256 | 4.9484  |
| 31 Recycle solids            | 0.02859 | 0.01342 | 0.00000 | 50.2256 | 4.9484  |
| 38 Partially Reduced Fines   | 0.02859 | 0.01342 | 0.00000 | 50.2256 | 4.9484  |
| 48 Char and Ash              | 0.04230 | 0.01986 | 0.00000 | 74.3084 | 7.3212  |
| 50 Reduced Iron              | 0.02347 | 0.01102 | 0.00000 | 41.2279 | 4.0619  |

## CIRCOFER MODEL

## STREAM DATA IN MOLES

GASEOUS - MT MOLES/HR

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 6 top gas from Venturi 1       | 10.5799 | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 8 Top Gas to Steam boiler      | 10.5799 | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 10 Oxygen                      | 0.0000  | 0.000   | 5.9377  | 0.0000  | 0.0000  |
| 11 Top gas recycled            | 5.2899  | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 13 Air for Classifier          | 0.0000  | 0.027   | 0.0073  | 0.0000  | 0.0000  |
| 14 Compressed Air              | 0.0000  | 0.027   | 0.0073  | 0.0000  | 0.0000  |
| 18 Iron Ore to Cyclone 2       | 1.7986  | 0.000   | 0.0000  | 1.4199  | 0.0587  |
| 19 Air to Cyclone 2            | 0.0000  | 0.078   | 0.0207  | 0.0000  | 0.0000  |
| 20 Air to Calciner             | 0.0000  | 0.027   | 0.0073  | 0.0000  | 0.0000  |
| 21 Combustion Air to Heater 2  | 0.0000  | 114.796 | 30.3588 | 0.0000  | 0.0000  |
| 22 Natural gas to Heater 2     | 0.0000  | 0.000   | 0.0000  | 12.8073 | 0.0000  |
| 23 Exhaust from Heater 2       | 25.6145 | 114.796 | 4.7443  | 0.0000  | 12.8073 |
| 25 Reducing gas for CFB        | 5.2899  | 0.000   | 0.0000  | 4.1763  | 0.1728  |
| 26 Natural gas for Heater 1    | 0.0000  | 0.000   | 0.0000  | 14.4811 | 0.0000  |
| 27 Combustion Air for Heater 1 | 0.0000  | 129.772 | 34.3194 | 0.0000  | 0.0000  |
| 28 Exhaust for Heater 1        | 28.9622 | 129.772 | 5.3572  | 0.0000  | 14.4811 |
| 30 Top gas                     | 5.2899  | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 33 Clean cool top gas          | 10.5799 | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 34 Dry top gas                 | 5.2899  | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 36 Cold top gas                | 10.5799 | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 37 Reducing gas from BB        | 1.7457  | 0.000   | 0.0000  | 1.3782  | 15.1847 |
| 39 Top Gas with Fines          | 5.2899  | 0.000   | 0.0000  | 4.1763  | 17.2773 |
| 40 CO2                         | 0.0000  | 0.000   | 0.0000  | 0.0000  | 17.1045 |
| 41 Cold Recycle gas            | 5.2899  | 0.000   | 0.0000  | 4.1763  | 0.1728  |
| 42 Recycle gas for BB          | 1.7457  | 0.000   | 0.0000  | 1.3782  | 0.0570  |
| 43 Recycle gas for CFB         | 1.7457  | 0.000   | 0.0000  | 1.3782  | 0.0570  |
| 44 Recycle gas for Gasifier    | 1.7986  | 0.000   | 0.0000  | 1.4199  | 0.0587  |

GASEOUS - MT MOLES/HR

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 6 top gas from Venturi 1          | 0.000   | 435.046 |
| 8 Top Gas to Steam boiler         | 0.000   | 435.046 |
| 11 Top gas recycled               | 0.000   | 435.046 |
| 18 Iron Ore to Cyclone 2          | 0.000   | 159.791 |
| 24 Preheated Reformed gas for CFB | 344.742 | 2.757   |
| 25 Reducing gas for CFB           | 0.000   | 435.046 |
| 30 Top gas                        | 0.000   | 429.817 |
| 33 Clean cool top gas             | 0.000   | 435.046 |
| 34 Dry top gas                    | 0.000   | 435.046 |
| 35 35                             | 699.932 | 5.597   |
| 36 Cold top gas                   | 0.000   | 435.046 |
| 37 Reducing gas from BB           | 0.000   | 128.437 |
| 39 Top Gas with Fines             | 0.000   | 429.817 |
| 41 Cold Recycle gas               | 0.000   | 435.046 |
| 42 Recycle gas for BB             | 0.000   | 143.565 |
| 43 Recycle gas for CFB            | 0.000   | 143.565 |
| 44 Recycle gas for Gasifier       | 0.000   | 147.916 |

## CIRCOFER MODEL

## STREAM DATA IN MOLES

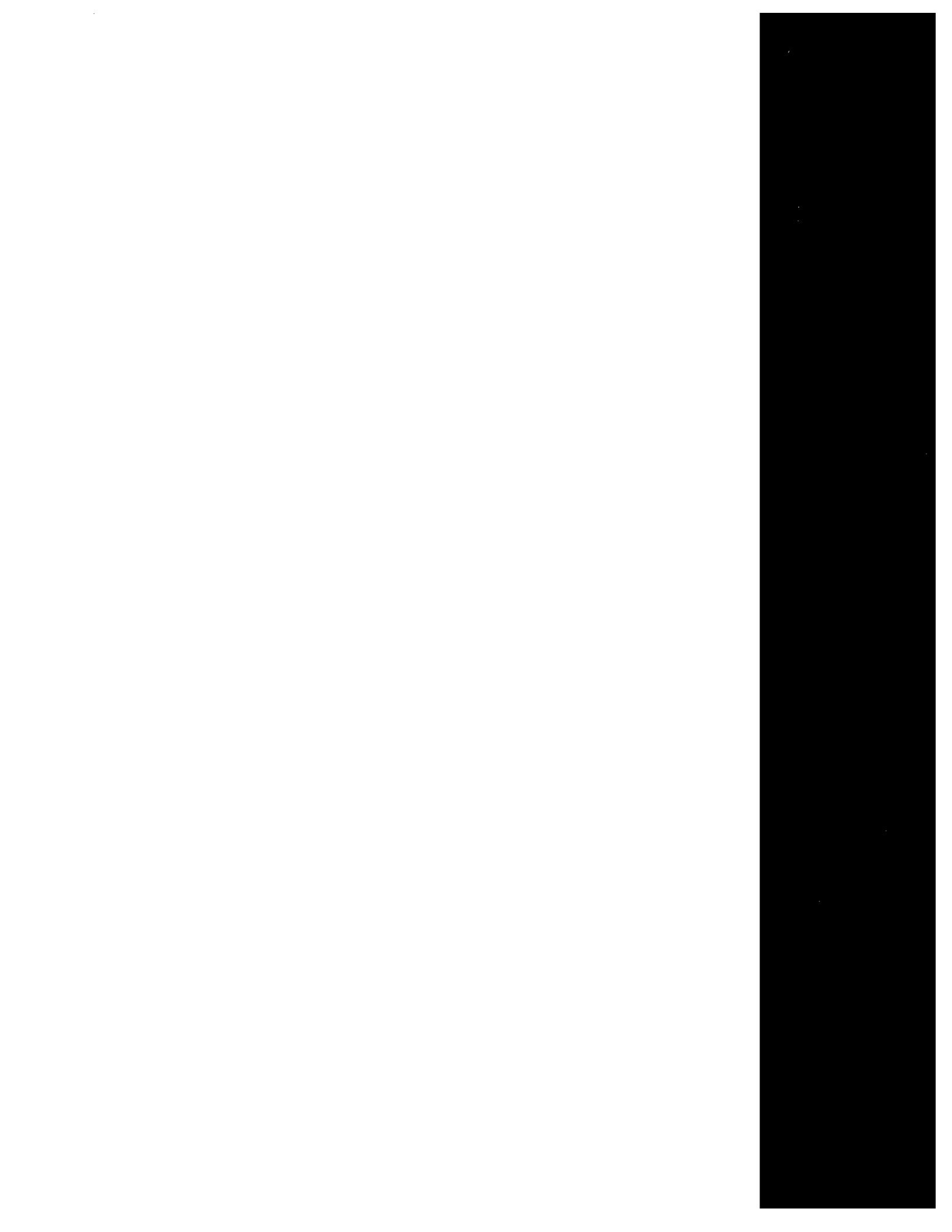
## GASEOUS - MOLE PERCENT

| NO. STREAM                     | H2O     | N2      | O2      | C1H4    | C1O2    |
|--------------------------------|---------|---------|---------|---------|---------|
| 6 top gas from Venturi 1       | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 8 Top Gas to Steam boiler      | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 10 Oxygen                      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.000   |
| 11 Top gas recycled            | 1.1455  | 0.0000  | 0.000   | 0.904   | 3.741   |
| 13 Air for Classifier          | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 14 Compressed Air              | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 18 Iron Ore to Cyclone 2       | 1.1030  | 0.0000  | 0.000   | 0.871   | 0.036   |
| 19 Air to Cyclone 2            | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 20 Air to Calciner             | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 21 Combustion Air to Heater 2  | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 22 Natural gas to Heater 2     | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.000   |
| 23 Exhaust from Heater 2       | 16.2156 | 72.6731 | 3.003   | 0.000   | 8.108   |
| 25 Reducing gas for CFB        | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 26 Natural gas for Heater 1    | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.000   |
| 27 Combustion Air for Heater 1 | 0.0000  | 79.0852 | 20.915  | 0.000   | 0.000   |
| 28 Exhaust for Heater 1        | 16.2188 | 72.6719 | 3.000   | 0.000   | 8.109   |
| 30 Top gas                     | 1.1587  | 0.0000  | 0.000   | 0.915   | 3.784   |
| 33 Clean cool top gas          | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 34 Dry top gas                 | 1.1455  | 0.0000  | 0.000   | 0.904   | 3.741   |
| 36 Cold top gas                | 2.2651  | 0.0000  | 0.000   | 0.894   | 3.699   |
| 37 Reducing gas from BB        | 1.1896  | 0.0000  | 0.000   | 0.939   | 10.348  |
| 39 Top Gas with Fines          | 1.1587  | 0.0000  | 0.000   | 0.915   | 3.784   |
| 40 CO2                         | 0.0000  | 0.0000  | 0.000   | 0.000   | 100.000 |
| 41 Cold Recycle gas            | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 42 Recycle gas for BB          | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 43 Recycle gas for CFB         | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |
| 44 Recycle gas for Gasifier    | 1.1896  | 0.0000  | 0.000   | 0.939   | 0.039   |

## GASEOUS - MOLE PERCENT

| NO. STREAM                        | H2      | CO      |
|-----------------------------------|---------|---------|
| 6 top gas from Venturi 1          | 0.0000  | 93.1418 |
| 8 Top Gas to Steam boiler         | 0.0000  | 93.1418 |
| 11 Top gas recycled               | 0.0000  | 94.2087 |
| 18 Iron Ore to Cyclone 2          | 0.0000  | 97.9903 |
| 24 Preheated Reformed gas for CFB | 99.2067 | 0.7933  |
| 25 Reducing gas for CFB           | 0.0000  | 97.8324 |
| 30 Top gas                        | 0.0000  | 94.1424 |
| 33 Clean cool top gas             | 0.0000  | 93.1418 |
| 34 Dry top gas                    | 0.0000  | 94.2087 |
| 35 35                             | 99.2067 | 0.7933  |
| 36 Cold top gas                   | 0.0000  | 93.1418 |
| 37 Reducing gas from BB           | 0.0000  | 87.5237 |
| 39 Top Gas with Fines             | 0.0000  | 94.1424 |
| 41 Cold Recycle gas               | 0.0000  | 97.8324 |
| 42 Recycle gas for BB             | 0.0000  | 97.8324 |
| 43 Recycle gas for CFB            | 0.0000  | 97.8324 |
| 44 Recycle gas for Gasifier       | 0.0000  | 97.8324 |





**APPENDIX E-8:**  
**GENERIC IRON CARBIDE PROCESS**

## IRON CARBIDE PROCESS

### PROCESS BACKGROUND:

Iron carbide ( $\text{Fe}_3\text{C}$ ) is a chemical compound of 94% iron and 6% carbon in pure form. It can be used as the only feed for BOFs and EAFs. In that role it eliminates the need for coke ovens and the blast furnace, and all the ancillary equipment for coal and lime. The Iron Carbide process is a two stage fluidized bed process that operates at a lower temperature than other DR processes. It operates at low pressures and uses steam reforming to produce the  $\text{H}_2$  which is mixed with  $\text{CH}_4$  to make the carburizing gas. It produces  $\text{Fe}_3\text{C}$  powder which contains about 6% carbon.

### PROCESS DESCRIPTION:

The iron oxide feed to the iron carbide process is in the form of iron ore fines in the range of 1mm to 0.1 mm. Iron ore fines are preheated in a series of cyclones and then pressurized to reactor pressure in lockhoppers, and fed to the reactor by a screw feeder.

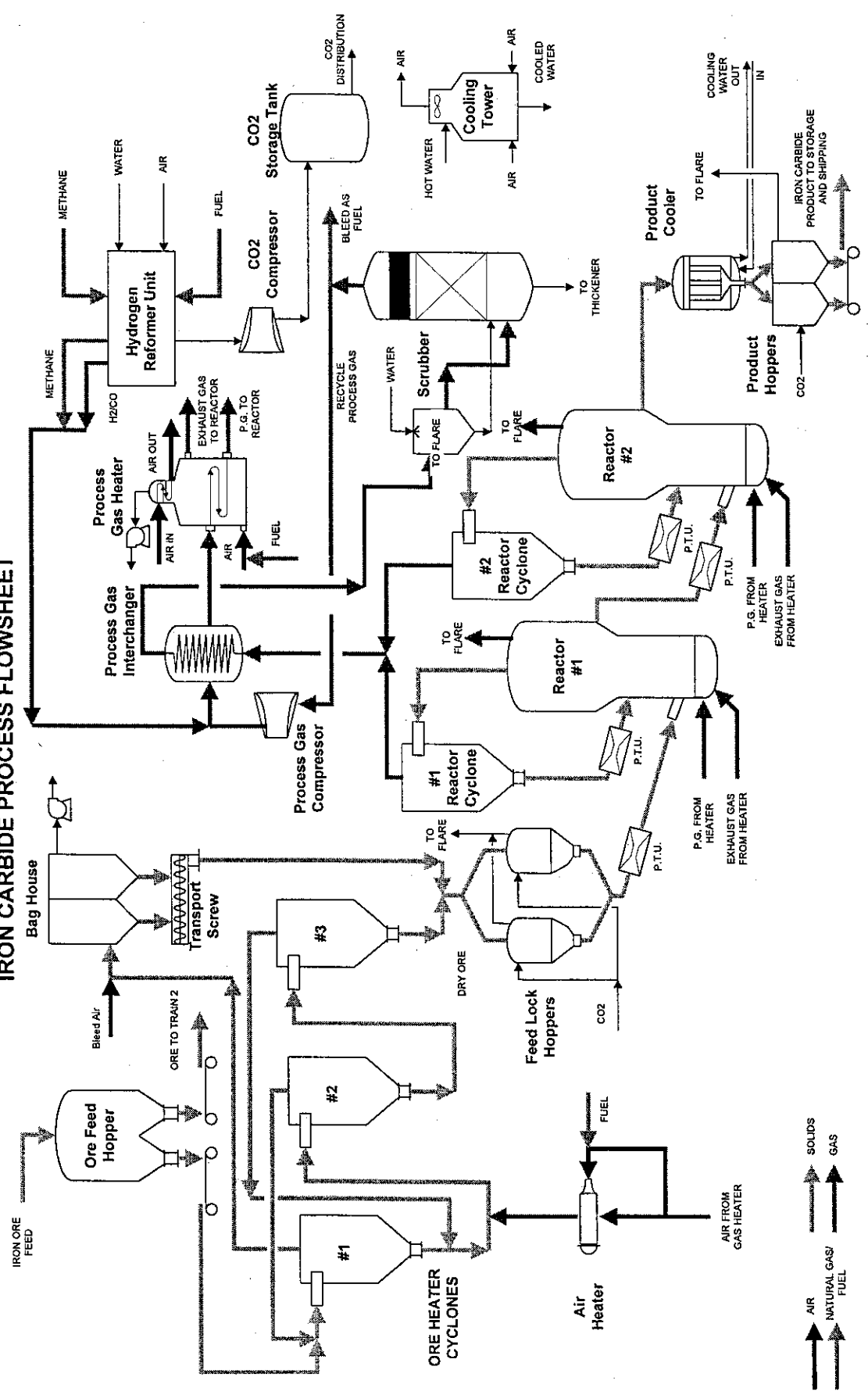
The fluidized bed reactors have the upward moving stream of 730C gas composed of  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{H}_2$ ,  $\text{CH}_4$  and  $\text{H}_2\text{O}$ . The hydrogen reacts with the iron ore, combining with its oxygen to form water (the only process by-product). Carbon from the carbonaceous gases combines with the elemental iron to form iron carbide. The methane provides the gas system equilibrium. After the reactions in the fluid bed reactors, the off gases are condensed to get rid of water vapor, reconstituted with  $\text{H}_2$  and carbonaceous gases, raised to reactor working pressure to 1.8 atm, heated to 730C, and reintroduced in the windbox of the reactor.

An indication of the inherent thermal efficiency of the process is gained from the fact that the temperature of formation of iron carbide in the fluid bed reactor is only 730C as against around 1000C for reduction of iron in DRI processes and 1500C to produce hot metal in the blast furnace.

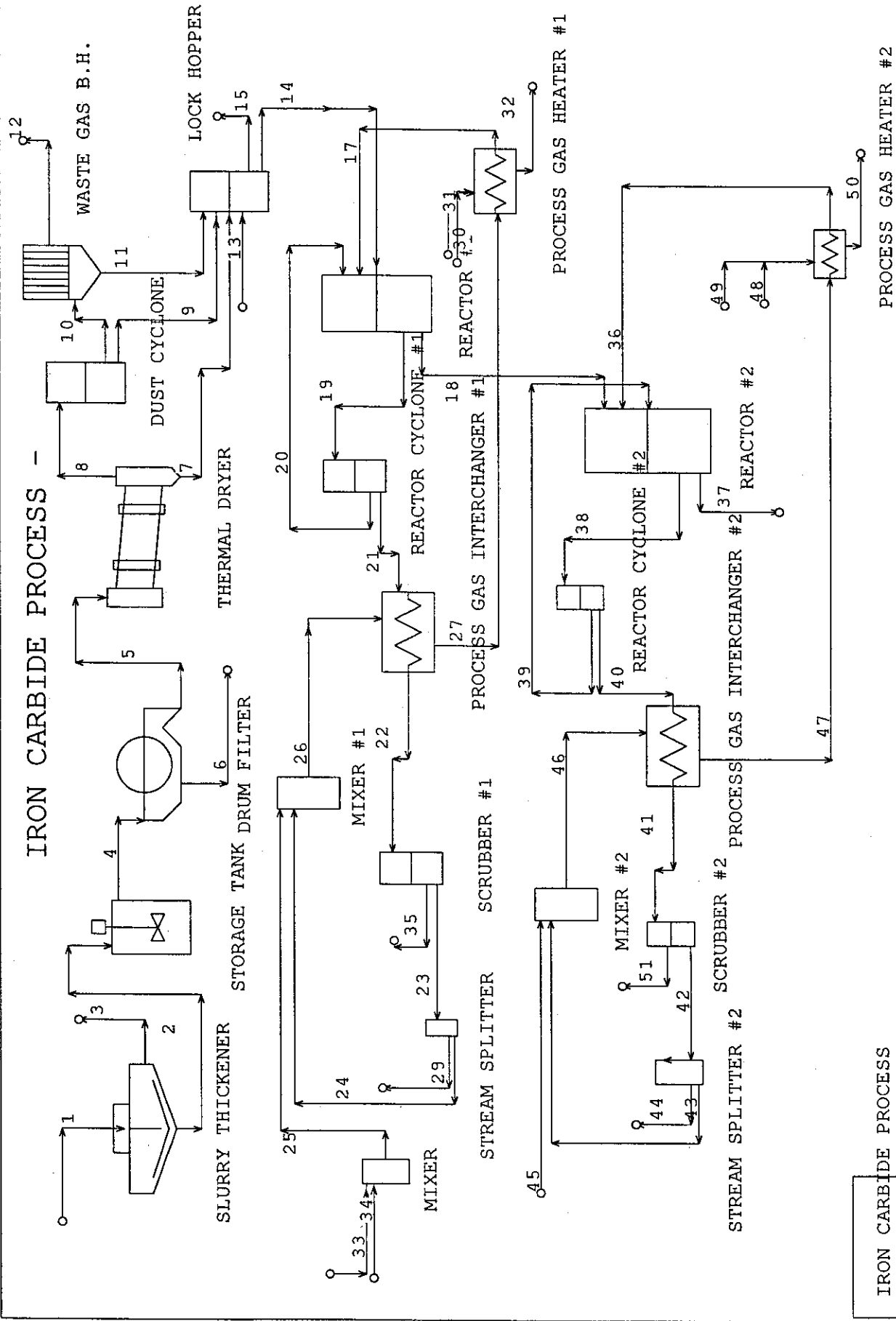
### PROCESS ADVANTAGES

- Lower operating temperature
- Lower production costs
- No storage costs as the product does not oxidize
- Steelmaking cheaper with  $\text{Fe}_3\text{C}$

# IRON CARBIDE PROCESS FLOWSHEET



# IRON CARBIDE PROCESS -



## Iron Carbide Process --- MetSim Model --- Description

The MetSim model for this process is largely based upon a basic flowsheet developed for Qualitech Steel Corporation by Iron Carbide Holdings Ltd, USA.

### Flowsheet Description

Stream 1 representing the fine ore slurry is first thickened, filtered, dried to get rid of excess water, heated and pressurized. Unit operations starting from Slurry Thickener to Lock Hopper are used to carry out these functions. Then in the Reactor #1, the ore feed (Stream 14) is further heated and partially reduced to FeO by the reducing gases (Stream 17) consisting mainly Hydrogen. The gases from the Reactor #1 are then cleaned off the dust (Recycled back to the Reactor #1 as Stream 20) in a Reactor Cyclone #1. The cleaned reduced gases are used for preheating incoming reducing gases (Stream 26) in a Process Gas Interchanger #1. The water from these gases is scrubbed off in a scrubber and part of these gases are bled off to maintain N<sub>2</sub> content of the reducing gases and are used as fuel elsewhere. Then the gases (Stream 24) are mixed with fresh Reformed gas (Stream 33) and Natural gas (Stream 34). This mixed gas (Stream 26) is preheated and then further heated to 730C in a Process Gas Heater #1 and injected in Reactor #1 as Stream 17.

The partially reduced ore (Stream 18) is carburized as Fe<sub>3</sub>C in the Reactor #2 by the help of CH<sub>4</sub> - rich reducing gas (Stream 36). Again as for the Reactor # 1, the top gases are passed through a Reactor Cyclone #2, then used for preheating incoming reducing gases in Process Gas Interchanger #2, scrubbed off excess water, mixed with make-up CH<sub>4</sub> and heated further in Process Gas Heater #2 to get ready for carburization in the Reactor #2.

### Model Assumptions:

Reactor #1: Partial reduction of iron ore to FeO takes place in this reactor. 5% carry-over of solid particles in the Top gas is assumed.

Reactor #2: Carburization of FeO to Fe<sub>3</sub>C takes place in this reactor. 5% carry-over of solid particles in the Top gas is assumed.

Reactor Cyclones: 100% Efficiency.

Process Gas Interchangers: 100% Efficiency.

Stream Splitter: 5% gases are bled off.

Process Gas Heaters: 100% Efficiency.

**Results**

With the limited information available about the two-reactor system, several estimates have been made in the model. A more complete analysis can be carried out on receiving more information about the process flows and conditions.

**IRON CARBIDE PROCESS --- STREAM SUMMARY**

| Stream Number                    | 1             | 2            | 3            | 4               | 5              | 6         | 7            | 8             | 9            |
|----------------------------------|---------------|--------------|--------------|-----------------|----------------|-----------|--------------|---------------|--------------|
| Description                      | Iron Ore Stur | Thickener Un | Thickener Ov | Slurry to Filte | Filtered Solid | Filterate | Dried Solids | Fines to Cycl | Dust Cyclone |
| MT/HR SOLIDS                     | 1000          | 999.9        | 0.10004      | 999.9           | 997.9          | 1.9998    | 979.63       | 18.27         | 17.357       |
| MT/HR AQUEOUS                    | 1500          | 999.9        | 500.1        | 999.9           | 136.08         | 863.82    | 19.371       | 0.9943        | 0.9943       |
| MT/HR GASEOUS                    | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 115.71        | 0            |
| MT/HR TOTAL                      | 2500          | 1999.8       | 500.2        | 1999.8          | 1134           | 865.82    | 999          | 134.98        | 18.351       |
| Percent Solids                   | 40            | 50           | 0.02         | 50              | 88             | 0.23097   | 98.061       | 13.536        | 94.582       |
| Sp.Gr.SOLIDS                     | 4.9467        | 4.9467       | 4.9467       | 4.9467          | 4.9467         | 4.9467    | 4.9704       | 3.9409        | 3.9409       |
| Sp.Gr.AQUEOUS                    | 0.99826       | 0.99826      | 0.99826      | 0.99826         | 0.99826        | 0.99826   | 0.31545      | 0.31545       | 0.31545      |
| Sp.Gr.GASEOUS                    | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0.00025289    | 0            |
| Sp.Gr.TOTAL                      | 1.4665        | 1.6613       | 0.99842      | 1.6613          | 3.3545         | 1.0001    | 3.8646       | 0.00029499    | 2.4286       |
| Temperature C                    | 20            | 20           | 20           | 20              | 20             | 20        | 595          | 595           | 595          |
| Gas nm3/hr                       | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 1.44E+05      | 0            |
| Sol/Liq m3/hr                    | 1704.8        | 1203.8       | 500.99       | 1203.8          | 338.05         | 865.73    | 258.5        | 7.7881        | 7.5563       |
| <b>Component Mass Flow Rates</b> |               |              |              |                 |                |           |              |               |              |
| 1 Fe3O4 MT/HR                    | 900           | 899.91       | 0.090036     | 899.91          | 898.11         | 1.7998    | 892.02       | 6.0901        | 5.7856       |
| 2 Fe2O3 MT/HR                    | 50            | 49.995       | 0.005002     | 49.995          | 49.895         | 0.09999   | 43.805       | 6.0901        | 5.7856       |
| 3 Fe3C1 MT/HR                    | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 7 Si1O2 MT/HR                    | 50            | 49.995       | 0.005002     | 49.995          | 49.895         | 0.09999   | 43.805       | 6.0901        | 5.7856       |
| 8 H2O MT/HR                      | 1500          | 999.9        | 500.1        | 999.9           | 136.08         | 863.82    | 19.371       | 0.9943        | 0.9943       |
| 9 N2 MT/HR                       | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 10 O2 MT/HR                      | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 11 H2O MT/HR                     | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 115.71        | 0            |
| 12 CH4 MT/HR                     | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 14 H2 MT/HR                      | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 15 CO2 MT/HR                     | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 16 CO MT/HR                      | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 17 FeO MT/HR                     | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| <b>Element Mass Flow Rates</b>   |               |              |              |                 |                |           |              |               |              |
| 1 H 1                            | 167.85        | 111.89       | 55.962       | 111.89          | 15.227         | 96.663    | 2.1676       | 13.06         | 0.11126      |
| 2 C 6                            | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 3 N 7                            | 0             | 0            | 0            | 0               | 0              | 0         | 0            | 0             | 0            |
| 4 O 8                            | 1622.6        | 1178.4       | 444.17       | 1178.4          | 410.66         | 767.74    | 300.25       | 110.4         | 7.3023       |
| 5 Si 14                          | 23.372        | 23.37        | 0.0023381    | 23.37           | 23.323         | 0.046739  | 20.476       | 2.8468        | 2.7044       |
| 6 Fe 26                          | 686.21        | 686.14       | 0.068648     | 686.14          | 684.77         | 1.3723    | 676.1        | 8.6664        | 8.2331       |



**IRON CARBIDE PROCESS --- STREAM SUMMARY**

| Stream Number             | 10           | 11          | 12            | 13        | 14          | 15          | 17           | 18            | 19           |
|---------------------------|--------------|-------------|---------------|-----------|-------------|-------------|--------------|---------------|--------------|
| Description               | Dust Cyclone | Baghouse Di | Bag Filter Ex | CO2       | Lock Hopper | Lock Hopper | H2-rich Redu | Partially Red | Top gas with |
| MT/HR SOLIDS              | 0.91352      | 0.8788      | 0.034717      | 0         | 997.87      | 0           | 0            | 930.81        | 48.99        |
| MT/HR AQUEOUS             | 0            | 0           | 0             | 0         | 20.365      | 0           | 0            | 0             | 0            |
| MT/HR GASEOUS             | 115.71       | 0           | 115.71        | 10        | 0           | 10          | 898.29       | 0             | 985.69       |
| MT/HR TOTAL               | 116.63       | 0.8788      | 115.75        | 10        | 1018.2      | 10          | 898.29       | 930.81        | 1034.7       |
| Percent Solids            | 0.78329      | 100         | 0.029994      | 0         | 98          | 0           | 0            | 100           | 4.7348       |
| Sp.Gr.SOLIDS              | 3.9409       | 3.9409      | 3.9409        | 0         | 4.9467      | 0           | 0            | 5.3688        | 5.3688       |
| Sp.Gr.AQUEOUS             | 0            | 0           | 0             | 0         | 0.31545     | 0           | 0            | 0             | 0            |
| Sp.Gr.GASEOUS             | 0.00025289   | 0           | 0.00025289    | 0.0018064 | 0           | 0.00062225  | 2.9184E-05   | 0             | 3.2846E-05   |
| Sp.Gr.TOTAL               | 0.00025489   | 3.9409      | 0.00025296    | 0.0018064 | 3.8239      | 0.00062225  | 2.9184E-05   | 5.3688        | 3.4478E-05   |
| Temperature C             | 595          | 595         | 595           | 25        | 588.88      | 588.88      | 730          | 701.98        | 701.98       |
| Gas nm3/hr                | 1.44E+05     | 0           | 1.44E+05      | 5092.9    | 0           | 5092.9      | 8.38E+06     | 0             | 8.41E+06     |
| Sol/Liq m3/hr             | 0.2318       | 0.22299     | 0.0088094     | 0         | 266.28      | 0           | 0            | 173.37        | 9.1249       |
| Component Mass Flow Rates |              |             |               |           |             |             |              |               |              |
| 1 Fe3O4 MT/HR             | 0.30451      | 0.29293     | 0.011572      | 0         | 898.1       | 0           | 0            | 0             | 0            |
| 2 Fe2O3 MT/HR             | 0.30451      | 0.29293     | 0.011572      | 0         | 49.883      | 0           | 0            | 0             | 0            |
| 3 Fe3C1 MT/HR             | 0            | 0           | 0             | 0         | 0           | 0           | 0            | 0             | 0            |
| 7 Si1O2 MT/HR             | 0.30451      | 0.29293     | 0.011572      | 0         | 49.883      | 0           | 0            | 49.883        | 2.6254       |
| 8 H2O MT/HR               | 0            | 0           | 0             | 0         | 20.365      | 0           | 0            | 0             | 0            |
| 9 N2 MT/HR                | 0            | 0           | 0             | 0         | 0           | 0           | 0            | 0             | 0            |
| 10 O2 MT/HR               | 0            | 0           | 0             | 0         | 0           | 0           | 0            | 0             | 0            |
| 11 H2O MT/HR              | 115.71       | 0           | 115.71        | 0         | 0           | 0           | 1.8568       | 0             | 97.728       |
| 12 CH4 MT/HR              | 0            | 0           | 0             | 0         | 0           | 0           | 57.261       | 0             | 57.261       |
| 14 H2 MT/HR               | 0            | 0           | 0             | 0         | 0           | 0           | 739.2        | 0             | 730.74       |
| 15 CO2 MT/HR              | 0            | 0           | 0             | 10        | 0           | 10          | 0            | 0             | 0            |
| 16 CO MT/HR               | 0            | 0           | 0             | 0         | 0           | 0           | 99.968       | 0             | 99.966       |
| 17 FeO MT/HR              | 0            | 0           | 0             | 0         | 0           | 0           | 0            | 880.93        | 46.364       |
| Element Mass Flow Rates   |              |             |               |           |             |             |              |               |              |
| 1 H 1                     | 12.948       | 0           | 12.948        | 0         | 2.2789      | 0           | 753.8        | 0             | 756.07       |
| 2 C 6                     | 0            | 0           | 0             | 2.7292    | 0           | 2.7292      | 85.737       | 0             | 85.736       |
| 3 N 7                     | 0            | 0           | 0             | 0         | 0           | 0           | 0            | 0             | 0            |
| 4 O 8                     | 103.1        | 0.32502     | 102.78        | 7.2708    | 307.88      | 7.2708      | 58.75        | 222.74        | 155.61       |
| 5 Si 14                   | 0.14234      | 0.13693     | 0.0054094     | 0         | 23.317      | 0           | 0            | 23.317        | 1.2272       |
| 6 Fe 26                   | 0.43332      | 0.41685     | 0.016468      | 0         | 684.75      | 0           | 0            | 684.75        | 36.04        |



**IRON CARBIDE PROCESS --- STREAM SUMMARY**

| Stream Number                    | 33         | 34         | 35           | 36           | 37            | 38           | 39            | 40           | 41           |
|----------------------------------|------------|------------|--------------|--------------|---------------|--------------|---------------|--------------|--------------|
| Description                      | SYN GAS    | METHANE    | Excess Water | Hot Reducing | Final Product | Top gas with | Recycle Solid | Top gas from | Cooled Top g |
| MT/HR SOLIDS                     | 0          | 0          | 0            | 0            | 787.93        | 41.47        | 41.47         | 0            | 0            |
| MT/HR AQUEOUS                    | 0          | 0          | 95.773       | 0            | 0             | 0            | 0             | 0            | 0            |
| MT/HR GASEOUS                    | 50         | 2.863      | 0            | 1663.8       | 0             | 1806.9       | 0             | 1806.9       | 1806.9       |
| MT/HR TOTAL                      | 50         | 2.863      | 95.773       | 1663.8       | 787.93        | 1848.4       | 41.47         | 1806.9       | 1806.9       |
| Percent Solids                   | 0          | 0          | 0            | 0            | 100           | 2.2436       | 100           | 0            | 0            |
| Sp.Gr.SOLIDS                     | 0          | 0          | 0            | 0            | 6.7988        | 6.7988       | 6.7988        | 0            | 0            |
| Sp.Gr.AQUEOUS                    | 0          | 0          | 0.9581       | 0            | 0             | 0            | 0             | 0            | 0            |
| Sp.Gr.GASEOUS                    | 9.0829E-05 | 0.00071758 | 0            | 0.00012038   | 0             | 0.00013731   | 0             | 0.00013731   | 0.0001882    |
| Sp.Gr.TOTAL                      | 9.0829E-05 | 0.00071758 | 0.9581       | 0.00012038   | 6.7988        | 0.00014047   | 6.7988        | 0.00013731   | 0.0001882    |
| Temperature C                    | 25         | 0          | 100          | 730          | 659.76        | 659.76       | 659.76        | 659.76       | 407.56       |
| Gas nm3/hr                       | 5.04E+05   | 4000       | 0            | 3.76E+06     | 0             | 3.85E+06     | 0             | 3.85E+06     | 3.85E+06     |
| Sol/Liq m3/hr                    | 0          | 0          | 99.962       | 0            | 115.89        | 6.0996       | 6.0996        | 0            | 0            |
| <b>Component Mass Flow Rates</b> |            |            |              |              |               |              |               |              |              |
| 1 Fe3O4 MT/HR                    | 0          | 0          | 0            | 0            | 0             | 0            | 0             | 0            | 0            |
| 2 Fe2O3 MT/HR                    | 0          | 0          | 0            | 0            | 0             | 0            | 0             | 0            | 0            |
| 3 Fe3C1 MT/HR                    | 0          | 0          | 0            | 0            | 712.9         | 37.521       | 37.521        | 0            | 0            |
| 7 SiO2 MT/HR                     | 0          | 0          | 0            | 0            | 49.883        | 2.6254       | 2.6254        | 0            | 0            |
| 8 H2O MT/HR                      | 0          | 0          | 95.773       | 0            | 0             | 0            | 0             | 0            | 0            |
| 9 N2 MT/HR                       | 0          | 0          | 0            | 0            | 0             | 0            | 0             | 0            | 0            |
| 10 O2 MT/HR                      | 0          | 0          | 0            | 0            | 0             | 0            | 0             | 0            | 0            |
| 11 H2O MT/HR                     | 0          | 0          | 0            | 22.526       | 0             | 237.11       | 0             | 237.11       | 237.11       |
| 12 CH4 MT/HR                     | 0          | 2.863      | 0            | 1493         | 0             | 1429.4       | 0             | 1429.4       | 1429.4       |
| 14 H2 MT/HR                      | 45         | 0          | 0            | 148.33       | 0             | 140.34       | 0             | 140.34       | 140.34       |
| 15 CO2 MT/HR                     | 0          | 0          | 0            | 0            | 0             | 0            | 0             | 0            | 0            |
| 16 CO MT/HR                      | 5          | 0          | 0            | 0            | 0             | 0            | 0             | 0            | 0            |
| 17 FeO MT/HR                     | 0          | 0          | 0            | 0            | 25.144        | 1.3234       | 1.3234        | 0            | 0            |
| <b>Element Mass Flow Rates</b>   |            |            |              |              |               |              |               |              |              |
| 1 H 1                            | 45         | 0.71953    | 10.717       | 526.06       | 0             | 526.12       | 0             | 526.12       | 526.12       |
| 2 C 6                            | 2.144      | 2.1435     | 0            | 1117.8       | 47.689        | 1072.7       | 2.51          | 1070.2       | 1070.2       |
| 3 N 7                            | 0          | 0          | 0            | 0            | 0             | 0            | 0             | 0            | 0            |
| 4 O 8                            | 2.856      | 0          | 85.056       | 20.005       | 32.165        | 212.27       | 1.6929        | 210.58       | 210.58       |
| 5 Si 14                          | 0          | 0          | 0            | 0            | 23.317        | 1.2272       | 1.2272        | 0            | 0            |
| 6 Fe 26                          | 0          | 0          | 0            | 0            | 684.75        | 36.04        | 36.04         | 0            | 0            |

**IRON CARBIDE PROCESS --- STREAM SUMMARY**

| Stream Number                    | 42          | 43          | 44         | 45         | 46           | 47          | 51           |
|----------------------------------|-------------|-------------|------------|------------|--------------|-------------|--------------|
| Description                      | Dry Top Gas | Recycle gas | Bleed      | Methane    | Cold Reducin | Preheated R | Excess Water |
| MT/HR SOLIDS                     | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| MT/HR AQUEOUS                    | 0           | 0           | 0          | 0          | 0            | 0           | 213.4        |
| MT/HR GASEOUS                    | 1593.5      | 1513.8      | 79.675     | 150        | 1663.8       | 1663.8      | 0            |
| MT/HR TOTAL                      | 1593.5      | 1513.8      | 79.675     | 150        | 1663.8       | 1663.8      | 213.4        |
| Percent Solids                   | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| Sp.Gr.SOLIDS                     | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| Sp.Gr.AQUEOUS                    | 0           | 0           | 0          | 0          | 0            | 0           | 0.9581       |
| Sp.Gr.GASEOUS                    | 0.00032537  | 0.00032537  | 0.00032537 | 0.00042264 | 0.0003319    | 0.00017742  | 0            |
| Sp.Gr.TOTAL                      | 0.00032537  | 0.00032537  | 0.00032537 | 0.00042264 | 0.0003319    | 0.00017742  | 0.9581       |
| Temperature C                    | 100         | 100         | 100        | 0          | 90.952       | 407.56      | 100          |
| Gas nm3/hr                       | 3.59E+06    | 3.41E+06    | 1.79E+05   | 3.55E+05   | 3.76E+06     | 3.76E+06    | 0            |
| Sol/Liq m3/hr                    | 0           | 0           | 0          | 0          | 0            | 0           | 222.73       |
| <b>Component Mass Flow Rates</b> |             |             |            |            |              |             |              |
| 1 Fe3O4 MT/HR                    | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 2 Fe2O3 MT/HR                    | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 3 Fe3C1 MT/HR                    | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 7 Si1O2 MT/HR                    | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 8 H2O MT/HR                      | 0           | 0           | 0          | 0          | 0            | 0           | 213.4        |
| 9 N2 MT/HR                       | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 10 O2 MT/HR                      | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 11 H2O MT/HR                     | 23.711      | 22.526      | 1.1856     | 0          | 22.526       | 22.526      | 0            |
| 12 CH4 MT/HR                     | 1429.4      | 1358        | 71.472     | 135        | 1493         | 1493        | 0            |
| 14 H2 MT/HR                      | 140.34      | 133.33      | 7.0172     | 15         | 148.33       | 148.33      | 0            |
| 15 CO2 MT/HR                     | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 16 CO MT/HR                      | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 17 FeO MT/HR                     | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| <b>Element Mass Flow Rates</b>   |             |             |            |            |              |             |              |
| 1 H 1                            | 502.24      | 477.13      | 25.112     | 48.928     | 526.06       | 526.06      | 23.88        |
| 2 C 6                            | 1070.2      | 1016.7      | 53.51      | 101.07     | 1117.8       | 1117.8      | 0            |
| 3 N 7                            | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 4 O 8                            | 21.058      | 20.005      | 1.0529     | 0          | 20.005       | 20.005      | 189.52       |
| 5 Si 14                          | 0           | 0           | 0          | 0          | 0            | 0           | 0            |
| 6 Fe 26                          | 0           | 0           | 0          | 0          | 0            | 0           | 0            |

IRON CARBIDE PROCESS

CASE DEFINITION

Title : IRON CARBIDE PROCESS  
Case :

Data Storage File Name : ironcarb3.sfw  
Mass Balance Option : ON  
Heat Balance Option : ON  
Units of Mass : metric tonne  
Units of Time : hour  
Ambient Air Pressure : 101.325 kPa  
Standard Pressure : 101.325 kPa  
Ambient Air Temperature : 20.00 C  
Standard Temperature : 0.00 C  
Plant Site Latitude : 0.00 Degrees  
Plant Site Elevation : 0.00 Meters

IRON CARBIDE PROCESS

COMPONENT DATA

| ROW | CNM   | CHF   |     | PHC      | CMW    | SGF    |
|-----|-------|-------|-----|----------|--------|--------|
| 1   | Fe3O4 | Fe3O4 | SI1 | 231.5386 | 5.1800 | 0.0000 |
| 2   | Fe2O3 | Fe2O3 | SI1 | 159.6922 | 5.2400 | 0.0000 |
| 3   | Fe3C1 | Fe3C1 | SI1 | 179.5521 | 7.6940 | 0.0000 |
| 4   | C1    | C1    | SI1 | 12.0112  | 2.2500 | 0.0000 |
| 5   | Fe1   | Fe1   | SI1 | 55.8470  | 7.8600 | 0.0000 |
| 6   | Si1   | Si1   | SI1 | 28.0860  | 2.3300 | 0.0000 |
| 7   | Si1O2 | Si1O2 | SI1 | 60.0848  | 2.6500 | 0.0000 |
| 8   | H2O   | H2O   | LI3 | 18.0153  | 1.0000 | 0.0000 |
| 9   | N2    | N2    | GC8 | 28.0134  | 0.0012 | 0.0000 |
| 10  | O2    | O2    | GC8 | 31.9988  | 0.0014 | 0.0000 |
| 11  | H2O   | H2O   | GC8 | 18.0153  | 0.0008 | 0.0000 |
| 12  | CH4   | CH4   | GC8 | 16.0430  | 0.0007 | 0.0000 |
| 13  | C2H6  | C2H6  | GC8 | 30.0701  | 0.0013 | 0.0000 |
| 14  | H2    | H2    | GC8 | 2.0159   | 0.0001 | 0.0000 |
| 15  | CO2   | CO2   | GC8 | 44.0100  | 0.0020 | 0.0000 |
| 16  | CO    | CO    | GC8 | 28.0106  | 0.0012 | 0.0000 |
| 17  | FeO   | FeO   | SI1 | 71.8464  | 5.7000 | 0.0000 |

| ROW | CNM   | SOL     | A       | B       | C       | pH      | Wi      | COV     | A       | B       | C       |
|-----|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 1   | Fe3O4 | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2   | Fe2O3 | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 3   | Fe3C1 | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 4   | C1    | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 5   | Fe1   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 6   | Si1   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 7   | Si1O2 | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 8   | H2O   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 9   | N2    | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 10  | O2    | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 11  | H2O   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 12  | CH4   | 24.40   | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 13  | C2H6  | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 14  | H2    | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 15  | CO2   | 1950.00 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 16  | CO    | 23.77   | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 17  | FeO   | 0.00    | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |

| ROW | CNM   | CRIT    | T       | CRIT    | P       | CRIT    | V       | ANTOINE | VAPOR | PRES  | A   | B | C | HENRY |
|-----|-------|---------|---------|---------|---------|---------|---------|---------|-------|-------|-----|---|---|-------|
| 1   | Fe3O4 | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 2   | Fe2O3 | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 3   | Fe3C1 | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 4   | C1    | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 5   | Fe1   | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 6   | Si1   | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 7   | Si1O2 | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 8   | H2O   | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 9   | N2    | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 10  | O2    | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 11  | H2O   | 0.000   | 0.0000  | 0.0000  | 0.0000  | 0.00000 | 0.00000 | 0.00    | 0.000 | 0.000 | 0.0 |   |   | 0.0   |
| 12  | CH4   | 190.700 | 46.9135 | 98.9000 | 6.69561 | 405.42  | 267.777 | 35389.5 |       |       |     |   |   |       |
| 13  | C2H6  | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.00    | 0.000   | 0.0     |       |       |     |   |   |       |
| 14  | H2    | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.00    | 0.000   | 0.0     |       |       |     |   |   |       |
| 15  | CO2   | 304.200 | 74.8792 | 94.8000 | 9.81060 | 1347.79 | 273.000 | 1215.7  |       |       |     |   |   |       |
| 16  | CO    | 133.400 | 35.4638 | 93.1000 | 6.24020 | 230.27  | 260.010 | 63426.0 |       |       |     |   |   |       |
| 17  | FeO   | 0.000   | 0.0000  | 0.0000  | 0.00000 | 0.00    | 0.000   | 0.0     |       |       |     |   |   |       |

IRON CARBIDE PROCESS

COMPONENT DATA

| ROW | CNM   | REFERENCE | H25     | HTE-A  | HTE-B   | HTE-C   | HTE-D    |
|-----|-------|-----------|---------|--------|---------|---------|----------|
| 1   | Fe3O4 | B672160   | -267300 | -31312 | 71.0525 | -7.8736 | 32.0732  |
| 2   | Fe2O3 | B672158   | -197000 | -20749 | 46.1517 | -3.8751 | 21.9462  |
| 3   | Fe3C1 | B6771332  | 5985    | -5013  | 21.1456 | 4.1225  | -5.0322  |
| 4   | C1    | B672086   | 0       | -2999  | 5.1802  | 0.2246  | 4.3597   |
| 5   | Fe1   | B672151   | 0       | -7903  | 14.0914 | -1.3293 | 11.6233  |
| 6   | Si1   | B672382   | 0       | -2201  | 5.8656  | 0.2868  | 1.2792   |
| 7   | Si1O2 | B672387   | -217720 | -8654  | 19.1651 | -0.5456 | 8.8977   |
| 8   | H2O   | B672180   | -68315  | -5071  | 16.1848 | 2.7637  | 0.0000   |
| 9   | N2    | B672244   | 0       | -2846  | 7.5728  | 0.2525  | 1.7794   |
| 10  | O2    | B672277   | 0       | -2979  | 7.9696  | 0.2720  | 1.7697   |
| 11  | H2O   | B672182   | -57795  | -2403  | 7.2906  | 1.3003  | 0.3596   |
| 12  | CH4   | YAWS      | -17890  | -1649  | 3.8363  | 7.1302  | -0.3830  |
| 13  | C2H6  | B6772223  | -20240  | -5819  | 11.3274 | 9.4527  | 4.7951   |
| 14  | H2    | B672174   | 0       | -1837  | 6.3659  | 0.4428  | -0.2847  |
| 15  | CO2   | YAWS      | -94050  | -3105  | 8.4720  | 2.5871  | 1.0415   |
| 16  | CO    | YAWS      | -26420  | -1787  | 6.0661  | 0.9368  | -0.3112  |
| 17  | FeO   | BAK2248   | -62382  | 8754   | -8.5950 | 9.1416  | -21.4692 |

| ROW | CNM   | TEMP  | RANGE  | oK | HTG-A   | HTG-B    | HTG-C    | HTG-D    |
|-----|-------|-------|--------|----|---------|----------|----------|----------|
| 1   | Fe3O4 | 298.2 | 1800.0 |    | -243067 | -58.6967 | -18.9430 | -46.8195 |
| 2   | Fe2O3 | 298.2 | 1800.0 |    | -182323 | -34.6418 | -13.7715 | -28.2755 |
| 3   | Fe3C1 | 298.2 | 1400.0 |    | 15085   | -32.7885 | -13.6625 | -16.6593 |
| 4   | C1    | 298.2 | 3000.0 |    | 2405    | -3.3866  | -1.5836  | -5.1587  |
| 5   | Fe1   | 298.2 | 1811.0 |    | 2679    | -8.2139  | -4.0925  | -5.4957  |
| 6   | Si1   | 298.2 | 1687.0 |    | 2177    | -6.4390  | -2.6130  | -4.1096  |
| 7   | Si1O2 | 298.2 | 2000.0 |    | -210342 | -16.8483 | -6.1496  | -14.5464 |
| 8   | H2O   | 298.2 | 373.2  |    | -70630  | -1.0739  | -26.4253 | 0.0000   |
| 9   | N2    | 298.2 | 3000.0 |    | 5078    | -51.3044 | -2.2358  | -9.9139  |
| 10  | O2    | 298.2 | 3000.0 |    | 5395    | -54.8302 | -2.3535  | -10.5960 |
| 11  | H2O   | 298.2 | 2000.0 |    | -54212  | -48.4557 | -3.8711  | -6.7579  |
| 12  | CH4   | 298.0 | 700.0  |    | -17759  | -40.3353 | -9.8039  | -1.5255  |
| 13  | C2H6  | 298.2 | 1000.0 |    | -19821  | -48.2326 | -15.8609 | -2.9266  |
| 14  | H2    | 298.2 | 3000.0 |    | 4863    | -36.6465 | -2.1036  | -9.3536  |
| 15  | CO2   | 298.0 | 700.0  |    | -93224  | -48.5944 | -8.4916  | -2.4252  |
| 16  | CO    | 298.0 | 700.0  |    | -25393  | -46.6664 | -5.1645  | -2.2650  |
| 17  | FeO   | 298.2 | 1650.0 |    | -58450  | -19.5576 | -4.9564  | -7.3814  |

IRON CARBIDE PROCESS

FLWSHEET DATA

| NO | OPR | UNIT                        | PROCESS | IS1 | IS2 | IS3 | IS4 | IS5 | IS6 | INV | OS1 | OS2 | OS3 | OS4 | OS5 | OS6 |
|----|-----|-----------------------------|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1  | SEC | IRON CARBIDE PROCESS        |         | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   |
| 2  | THK | SLURRY THICKENER            |         | 1   | 0   | 0   | 0   | 0   | 0   | 0   | 3   | 2   | 0   | 0   | 0   | 0   |
| 3  | TAK | STORAGE TANK                |         | 2   | 0   | 0   | 0   | 0   | 0   | 0   | 4   | 0   | 0   | 0   | 0   | 0   |
| 4  | FIL | DRUM FILTER                 |         | 4   | 0   | 0   | 0   | 0   | 0   | 0   | 5   | 6   | 0   | 0   | 0   | 0   |
| 5  | DRY | THERMAL DRYER               |         | 5   | 0   | 0   | 0   | 0   | 0   | 0   | 7   | 8   | 0   | 0   | 0   | 0   |
| 6  | SPP | DUST CYCLONE                |         | 8   | 0   | 0   | 0   | 0   | 0   | 0   | 9   | 10  | 0   | 0   | 0   | 0   |
| 7  | DCB | WASTE GAS B.H.              |         | 10  | 0   | 0   | 0   | 0   | 0   | 0   | 11  | 12  | 0   | 0   | 0   | 0   |
| 8  | SPP | LOCK HOPPER                 |         | 11  | 9   | 7   | 13  | 0   | 0   | 0   | 14  | 15  | 0   | 0   | 0   | 0   |
| 9  | SPP | REACTOR #1                  |         | 20  | 17  | 14  | 0   | 0   | 0   | 0   | 18  | 19  | 0   | 0   | 0   | 0   |
| 10 | SPP | REACTOR CYCLONE #1          |         | 19  | 0   | 0   | 0   | 0   | 0   | 0   | 21  | 20  | 0   | 0   | 0   | 0   |
| 11 | HTX | PROCESS GAS INTERCHANGER #1 |         | 21  | 0   | 0   | 26  | 0   | 0   | 0   | 22  | 27  | 0   | 0   | 0   | 0   |
| 12 | SPP | SCRUBBER #1                 |         | 22  | 0   | 0   | 0   | 0   | 0   | 0   | 23  | 35  | 0   | 0   | 0   | 0   |
| 13 | SPS | STREAM SPLITTER             |         | 23  | 0   | 0   | 0   | 0   | 0   | 0   | 24  | 29  | 0   | 0   | 0   | 0   |
| 14 | MIX | MIXER #1                    |         | 25  | 24  | 0   | 0   | 0   | 0   | 0   | 26  | 0   | 0   | 0   | 0   | 0   |
| 15 | HTX | PROCESS GAS HEATER #1       |         | 27  | 0   | 0   | 30  | 31  | 0   | 0   | 17  | 32  | 0   | 0   | 0   | 0   |
| 16 | MIX | MIXER                       |         | 33  | 34  | 0   | 0   | 0   | 0   | 0   | 25  | 0   | 0   | 0   | 0   | 0   |
| 17 | SPP | REACTOR #2                  |         | 18  | 36  | 39  | 0   | 0   | 0   | 0   | 37  | 38  | 0   | 0   | 0   | 0   |
| 18 | SPP | REACTOR CYCLONE #2          |         | 38  | 0   | 0   | 0   | 0   | 0   | 0   | 40  | 39  | 0   | 0   | 0   | 0   |
| 19 | HTX | PROCESS GAS INTERCHANGER #2 |         | 40  | 0   | 0   | 46  | 0   | 0   | 0   | 41  | 47  | 0   | 0   | 0   | 0   |
| 20 | SPP | SCRUBBER #2                 |         | 41  | 0   | 0   | 0   | 0   | 0   | 0   | 42  | 0   | 0   | 51  | 0   | 0   |
| 21 | SPS | STREAM SPLITTER #2          |         | 42  | 0   | 0   | 0   | 0   | 0   | 0   | 43  | 44  | 0   | 0   | 0   | 0   |
| 22 | MIX | MIXER #2                    |         | 45  | 43  | 0   | 0   | 0   | 0   | 0   | 46  | 0   | 0   | 0   | 0   | 0   |
| 23 | HTX | PROCESS GAS HEATER #2       |         | 47  | 0   | 0   | 48  | 49  | 0   | 0   | 36  | 50  | 0   | 0   | 0   | 0   |



IRON CARBIDE PROCESS

| HEAT BALANCE SUMMARY - 1000000 KCAL/HOUR |                  |                 |               |               |                 |              |               |                  |       |
|--|------------------|-----------------|---------------|---------------|-----------------|--------------|---------------|------------------|-------|
| OP                                       | PROCESS STEP     | INPUT<br>STREAM | HEAT<br>REACT | HEAT<br>SOLUT | ENERGY<br>INPUT | HEAT<br>LOSS | HEAT<br>REQRD | OUTPUT<br>STREAM | TOTAL |
| 1  | IRON CARBIDE PRO | 0               | 0             | 0             | 0               | 0            | 0             | 0                | 0     |
| 2  | SLURRY THICKENER | -8              | 0             | 0             | 0               | 0            | 0             | 8                | 0     |
| 3  | STORAGE TANK     | -6              | 0             | 0             | 0               | 0            | 0             | 6                | 0     |
| 4  | DRUM FILTER      | -6              | 0             | 0             | 0               | 0            | 0             | 6                | 0     |
| 5  | THERMAL DRYER    | -2              | -68           | 0             | 0               | 0            | 233           | -164             | 0     |
| 6  | DUST CYCLONE     | 35              | 0             | 0             | 0               | 0            | 0             | -35              | 0     |
| 7  | WASTE GAS B.H.   | 32              | 0             | 0             | 0               | 0            | 0             | -32              | 0     |
| 8  | LOCK HOPPER      | 132             | 0             | 0             | 0               | 0            | 0             | -132             | 0     |
| 9  | REACTOR #1       | 2009            | -103          | 0             | 0               | 0            | 0             | -1906            | 0     |
| 10                                       | REACTOR CYCLONE  | 1813            | 0             | 0             | 0               | 0            | 0             | -1813            | 0     |
| 11                                       | PROCESS GAS INTE | 1992            | 0             | 0             | 0               | 0            | 0             | -1992            | 0     |
| 12                                       | SCRUBBER #1      | 999             | 56            | 0             | 0               | 0            | -854          | -201             | 0     |
| 13                                       | STREAM SPLITTER  | 194             | 0             | 0             | 0               | 0            | 0             | -194             | 0     |
| 14                                       | MIXER #1         | 184             | 0             | 0             | 0               | 0            | 0             | -184             | 0     |
| 15                                       | PROCESS GAS HEAT | 993             | 12            | 0             | 0               | 0            | 873           | -1878            | 0     |
| 16                                       | MIXER            | 0               | 0             | 0             | 0               | 0            | 0             | 0                | 0     |
| 17                                       | REACTOR #2       | 1339            | -149          | 0             | 0               | 0            | 0             | -1190            | 0     |
| 18                                       | REACTOR CYCLONE  | 1109            | 0             | 0             | 0               | 0            | 0             | -1109            | 0     |
| 19                                       | PROCESS GAS INTE | 1194            | 0             | 0             | 0               | 0            | 0             | -1194            | 0     |
| 20                                       | SCRUBBER #2      | 603             | 125           | 0             | 0               | 0            | -614          | -113             | 0     |
| 21                                       | STREAM SPLITTER  | 97              | 0             | 0             | 0               | 0            | 0             | -97              | 0     |
| 22                                       | MIXER #2         | 89              | 0             | 0             | 0               | 0            | 0             | -89              | 0     |
| 23                                       | PROCESS GAS HEAT | 591             | 0             | 0             | 0               | 0            | 0             | -591             | 0     |

IRON CARBIDE PROCESS

| NO. STREAM                         | STREAM TEMPERATURES AND ENTHALPIES |         |              |               |              |
|------------------------------------|------------------------------------|---------|--------------|---------------|--------------|
|                                    | TEMP-C                             | TEMP-F  | KCAL/HR      | BTU/HR        | KJ/H         |
| 1 Iron Ore Slurry                  | 20.000                             | 68.00   | -8399856.0   | -33333324.0   | -35145000.   |
| 2 Thickener Underflow              | 20.000                             | 68.00   | -5902967.0   | -23424865.0   | -24698013.   |
| 3 Thickener Overflow               | 20.000                             | 68.00   | -2496890.0   | -9908459.0    | -10446986.   |
| 4 Slurry to Filter                 | 20.000                             | 68.00   | -5902967.0   | -23424865.0   | -24698013.   |
| 5 Filtered Solids                  | 20.000                             | 68.00   | -1588426.0   | -6303382.0    | -6645973.    |
| 6 Filterate                        | 20.000                             | 68.00   | -4314541.0   | -17121483.0   | -18052040.   |
| 7 Dried Solids                     | 595.000                            | 1103.00 | 129106767.0  | 512337056.0   | 540182714.   |
| 8 Fines to Cyclone                 | 595.000                            | 1103.00 | 34590193.0   | 137264979.0   | 144725368.   |
| 9 Dust Cyclone Unders              | 595.000                            | 1103.00 | 2692071.0    | 10683002.0    | 11263626.    |
| 10 Dust Cyclone Overs              | 595.000                            | 1103.00 | 31898122.0   | 126581977.0   | 133461742.   |
| 11 Baghouse Discharge              | 595.000                            | 1103.00 | 112224.0     | 445340.0      | 469544.      |
| 12 Bag Filter Exhaust              | 595.000                            | 1103.00 | 31785898.0   | 126136637.0   | 132992197.   |
| 13 CO2                             | 25.000                             | 77.00   | 0.0          | 0.0           | 0.           |
| 14 Lock Hopper Discharge           | 588.879                            | 1091.98 | 130492942.0  | 517837843.0   | 545982469.   |
| 15 Lock Hopper Flare               | 588.879                            | 1091.98 | 1418120.0    | 5627556.0     | 5933415.     |
| 16 CAKE TO DRYER                   | 20.000                             | 68.00   | -1588426.0   | -6303382.0    | -6645973.    |
| 17 H2-rich Reducing gas            | 730.000                            | 1346.00 | 1873432343.0 | 7434380347.0  | 7838440924.  |
| 18 Partially Reduced Ore           | 701.984                            | 1295.57 | 92812189.0   | 368308532.0   | 388326200.   |
| 19 Top gas with Fines              | 701.984                            | 1295.57 | 1812833656.0 | 7193905321.0  | 7584896015.  |
| 20 Recycled Solids from Reactor #1 | 701.984                            | 1295.57 | 4884852.0    | 19384660.0    | 20438221.    |
| 21 Top gas from Reactor #1         | 701.984                            | 1295.57 | 1807948803.0 | 7174520661.0  | 7564457794.  |
| 22 Cooled Top gas                  | 404.927                            | 760.87  | 999141467.0  | 3964913767.0  | 4180407899.  |
| 23 Dry Top gas                     | 100.000                            | 212.00  | 194075162.0  | 770152484.0   | 812010479.   |
| 24 Recycle gases                   | 100.000                            | 212.00  | 184371404.0  | 731644860.0   | 771409955.   |
| 25 Make-up gases                   | 24.763                             | 76.57   | 63735.0      | 252921.0      | 266667.      |
| 26 Cold Reducing gas               | 95.431                             | 203.78  | 184435139.0  | 731897781.0   | 771676622.   |
| 27 Preheated Reducing gas          | 404.927                            | 760.87  | 993242475.0  | 3941504675.0  | 4155726517.  |
| 28 28                              | 730.000                            | 1346.00 | 712672346.0  | 2828112422.0  | 2981821095.  |
| 29 Bleed                           | 100.000                            | 212.00  | 9703758.0    | 38507624.0    | 40600524.    |
| 30 Natural Gas                     | 25.000                             | 77.00   | 0.0          | 0.0           | 0.           |
| 31 Air                             | 25.000                             | 77.00   | 19525.0      | 77483.0       | 81694.       |
| 32 32                              | 730.000                            | 1346.00 | 4343561.0    | 17236642.0    | 18173458.    |
| 33 SYN GAS                         | 25.000                             | 77.00   | 101123.0     | 401288.0      | 423098.      |
| 34 METHANE                         | 0.000                              | 32.00   | -37388.0     | -148368.0     | -156431.     |
| 35 Excess Water                    | 100.000                            | 212.00  | 7189427.0    | 28529954.0    | 30080565.    |
| 36 Hot Reducing gas                | 730.000                            | 1346.00 | 1242031439.0 | 4928779071.0  | 5196659542.  |
| 37 Final Product                   | 659.762                            | 1219.57 | 80817228.0   | 320708678.0   | 338139281.   |
| 38 Top gas with Fines              | 659.762                            | 1219.57 | 1109000676.0 | 4400870338.0  | 4640058827.  |
| 39 Recycle Solids from Reactor #2  | 659.762                            | 1219.57 | 4253538.0    | 16879404.0    | 17796804.    |
| 40 Top gas from Reactor #2         | 659.762                            | 1219.57 | 1104747137.0 | 4383990934.0  | 4622262023.  |
| 41 Cooled Top gas                  | 407.557                            | 765.60  | 602555707.0  | 2391134285.0  | 2521093078.  |
| 42 Dry Top Gas                     | 100.000                            | 212.00  | 97148416.0   | 385516070.0   | 406468972.   |
| 43 Recycle gas                     | 100.000                            | 212.00  | 92290995.0   | 366240267.0   | 386145524.   |
| 44 Bleed                           | 100.000                            | 212.00  | 4857421.0    | 19275804.0    | 20323449.    |
| 45 Methane                         | 0.000                              | 32.00   | -3025486.0   | -12006098.0   | -12658632.   |
| 46 Cold Reducing Gas               | 90.952                             | 195.71  | 89265509.0   | 354234169.0   | 373486891.   |
| 47 Preheated Reducing Gas          | 407.557                            | 765.60  | 591456940.0  | 2347090817.0  | 2474655836.  |
| 50 50                              | 0.000                              | 32.00   | -650574500.0 | -2581688253.0 | -2722003706. |
| 51 Excess Water                    | 100.000                            | 212.00  | 16019284.0   | 63569657.0    | 67024685.    |

IRON CARBIDE PROCESS

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

| NO. STREAM                 | TIME     | ACFM     | SCFM    | M3/HR    | NM3/HR  |
|----------------------------|----------|----------|---------|----------|---------|
| 8 Fines to Cyclone         | 100.0000 | 269315   | 84738   | 457569   | 143970  |
| 10 Dust Cyclone Overs      | 100.0000 | 269310   | 84734   | 457561   | 143965  |
| 12 Bag Filter Exhaust      | 100.0000 | 269310   | 84734   | 457561   | 143964  |
| 13 CO2                     | 100.0000 | 3258     | 2998    | 5536     | 5093    |
| 15 Lock Hopper Flare       | 100.0000 | 9459     | 2998    | 16071    | 5093    |
| 17 H2-rich Reducing gas    | 100.0000 | 18116257 | 4932897 | 30779716 | 8381045 |
| 19 Top gas with Fines      | 100.0000 | 17663233 | 4947724 | 30010023 | 8406237 |
| 21 Top gas from Reactor #1 | 100.0000 | 17663228 | 4947719 | 30010014 | 8406227 |
| 22 Cooled Top gas          | 100.0000 | 12282411 | 4947719 | 20867949 | 8406227 |
| 23 Dry Top gas             | 100.0000 | 6663184  | 4877585 | 11320822 | 8287070 |
| 24 Recycle gases           | 100.0000 | 6330025  | 4633706 | 10754781 | 7872716 |
| 25 Make-up gases           | 100.0000 | 326308   | 299191  | 554400   | 508328  |
| 26 Cold Reducing gas       | 100.0000 | 6656222  | 4932897 | 11308993 | 8381045 |
| 27 Preheated Reducing gas  | 100.0000 | 12245617 | 4932897 | 20805435 | 8381045 |
| 28 28                      | 100.0000 | 6055222  | 1648741 | 10287888 | 2801228 |
| 29 Bleed                   | 100.0000 | 333159   | 243879  | 566041   | 414353  |
| 30 Natural Gas             | 100.0000 | 896      | 822     | 1522     | 1397    |
| 31 Air                     | 100.0000 | 10277    | 9416    | 17461    | 15997   |
| 32 32                      | 100.0000 | 37599    | 10238   | 63880    | 17394   |
| 33 SYN GAS                 | 100.0000 | 324002   | 296836  | 550483   | 504328  |
| 34 METHANE                 | 100.0000 | 2348     | 2354    | 3990     | 4000    |
| 36 Hot Reducing gas        | 100.0000 | 8134866  | 2214845 | 13821225 | 3763046 |
| 38 Top gas with Fines      | 100.0000 | 7745051  | 2267508 | 13158925 | 3852520 |
| 40 Top gas from Reactor #2 | 100.0000 | 7745047  | 2267504 | 13158919 | 3852514 |
| 41 Cooled Top gas          | 100.0000 | 5650864  | 2267504 | 9600878  | 3852514 |
| 42 Dry Top Gas             | 100.0000 | 2882563  | 2111234 | 4897505  | 3587010 |
| 43 Recycle gas             | 100.0000 | 2738435  | 2005673 | 4652630  | 3407659 |
| 44 Bleed                   | 100.0000 | 144128   | 105562  | 244875   | 179350  |
| 45 Methane                 | 100.0000 | 208892   | 209173  | 354909   | 355387  |
| 46 Cold Reducing Gas       | 100.0000 | 2950567  | 2214845 | 5013045  | 3763046 |
| 47 Preheated Reducing Gas  | 100.0000 | 5519639  | 2214845 | 9377927  | 3763046 |

VOLUMETRIC FLOW RATE OF STREAMS WITH LIQUIDS AND SOLIDS ONLY

| NO. STREAM                         | TIME     | USGPM    | LPS      | M3/HR    | M3/DY    |
|------------------------------------|----------|----------|----------|----------|----------|
| 1 Iron Ore Slurry                  | 100.0000 | 7505.837 | 473.5475 | 1704.771 | 40914.50 |
| 2 Thickener Underflow              | 100.0000 | 5300.047 | 334.3829 | 1203.779 | 28890.69 |
| 3 Thickener Overflow               | 100.0000 | 2205.790 | 139.1646 | 500.992  | 12023.82 |
| 4 Slurry to Filter                 | 100.0000 | 5300.047 | 334.3829 | 1203.779 | 28890.69 |
| 5 Filtered Solids                  | 100.0000 | 1488.359 | 93.9014  | 338.045  | 8113.08  |
| 6 Filterate                        | 100.0000 | 3811.687 | 240.4815 | 865.733  | 20777.60 |
| 7 Dried Solids                     | 100.0000 | 1138.145 | 71.8062  | 258.502  | 6204.06  |
| 9 Dust Cyclone Unders              | 100.0000 | 33.269   | 2.0990   | 7.556    | 181.35   |
| 11 Baghouse Discharge              | 100.0000 | 0.982    | 0.0619   | 0.223    | 5.35     |
| 14 Lock Hopper Discharge           | 100.0000 | 1172.396 | 73.9671  | 266.282  | 6390.76  |
| 18 Partially Reduced Ore           | 100.0000 | 763.331  | 48.1590  | 173.372  | 4160.93  |
| 20 Recycled Solids from Reactor #1 | 100.0000 | 40.175   | 2.5347   | 9.125    | 219.00   |
| 35 Excess Water                    | 100.0000 | 440.117  | 27.7672  | 99.962   | 2399.09  |
| 37 Final Product                   | 100.0000 | 510.252  | 32.1921  | 115.891  | 2781.40  |
| 39 Recycle Solids from Reactor #2  | 100.0000 | 26.855   | 1.6943   | 6.100    | 146.39   |
| 51 Excess Water                    | 100.0000 | 980.656  | 61.8701  | 222.732  | 5345.58  |

IRON CARBIDE PROCESS

MASS FLOW RATES - MT/HR

| NO. STREAM                         | MT/HR-SI | MT/HR-LI | MT/HR-GC | MT/HR-TC |
|------------------------------------|----------|----------|----------|----------|
| 1 Iron Ore Slurry                  | 1000.000 | 1500.000 | 0.000    | 2500.000 |
| 2 Thickener Underflow              | 999.900  | 999.900  | 0.000    | 1999.800 |
| 3 Thickener Overflow               | 0.100    | 500.100  | 0.000    | 500.200  |
| 4 Slurry to Filter                 | 999.900  | 999.900  | 0.000    | 1999.800 |
| 5 Filtered Solids                  | 997.900  | 136.077  | 0.000    | 1133.977 |
| 6 Filtrate                         | 2.000    | 863.823  | 0.000    | 865.822  |
| 7 Dried Solids                     | 979.630  | 19.371   | 0.000    | 999.001  |
| 8 Fines to Cyclone                 | 18.270   | 0.994    | 115.712  | 134.977  |
| 9 Dust Cyclone Unders              | 17.357   | 0.994    | 0.000    | 18.351   |
| 10 Dust Cyclone Overs              | 0.914    | 0.000    | 115.712  | 116.626  |
| 11 Baghouse Discharge              | 0.879    | 0.000    | 0.000    | 0.879    |
| 12 Bag Filter Exhaust              | 0.035    | 0.000    | 115.712  | 115.747  |
| 13 CO2                             | 0.000    | 0.000    | 10.000   | 10.000   |
| 14 Lock Hopper Discharge           | 997.865  | 20.365   | 0.000    | 1018.231 |
| 15 Lock Hopper Flare               | 0.000    | 0.000    | 10.000   | 10.000   |
| 17 H2-rich Reducing gas            | 0.000    | 0.000    | 898.288  | 898.288  |
| 18 Partially Reduced Ore           | 930.809  | 0.000    | 0.000    | 930.809  |
| 19 Top gas with Fines              | 48.990   | 0.000    | 985.694  | 1034.684 |
| 20 Recycled Solids from Reactor #1 | 48.990   | 0.000    | 0.000    | 48.990   |
| 21 Top gas from Reactor #1         | 0.000    | 0.000    | 985.694  | 985.694  |
| 22 Cooled Top gas                  | 0.000    | 0.000    | 985.694  | 985.694  |
| 23 Dry Top gas                     | 0.000    | 0.000    | 889.921  | 889.921  |
| 24 Recycle gases                   | 0.000    | 0.000    | 845.425  | 845.425  |
| 25 Make-up gases                   | 0.000    | 0.000    | 52.863   | 52.863   |
| 26 Cold Reducing gas               | 0.000    | 0.000    | 898.288  | 898.288  |
| 27 Preheated Reducing gas          | 0.000    | 0.000    | 898.288  | 898.288  |
| 28 28                              | 0.000    | 0.000    | 578.467  | 578.467  |
| 29 Bleed                           | 0.000    | 0.000    | 44.496   | 44.496   |
| 30 Natural Gas                     | 0.000    | 0.000    | 1.000    | 1.000    |
| 31 Air                             | 0.000    | 0.000    | 20.583   | 20.583   |
| 32 32                              | 0.000    | 0.000    | 21.583   | 21.583   |
| 33 SYN GAS                         | 0.000    | 0.000    | 50.000   | 50.000   |
| 34 METHANE                         | 0.000    | 0.000    | 2.863    | 2.863    |
| 35 Excess Water                    | 0.000    | 95.773   | 0.000    | 95.773   |
| 36 Hot Reducing gas                | 0.000    | 0.000    | 1663.827 | 1663.827 |
| 37 Final Product                   | 787.925  | 0.000    | 0.000    | 787.925  |
| 38 Top gas with Fines              | 41.470   | 0.000    | 1806.902 | 1848.372 |
| 39 Recycle Solids from Reactor #2  | 41.470   | 0.000    | 0.000    | 41.470   |
| 40 Top gas from Reactor #2         | 0.000    | 0.000    | 1806.902 | 1806.902 |
| 41 Cooled Top gas                  | 0.000    | 0.000    | 1806.902 | 1806.902 |
| 42 Dry Top Gas                     | 0.000    | 0.000    | 1593.502 | 1593.502 |
| 43 Recycle gas                     | 0.000    | 0.000    | 1513.827 | 1513.827 |
| 44 Bleed                           | 0.000    | 0.000    | 79.675   | 79.675   |
| 45 Methane                         | 0.000    | 0.000    | 150.000  | 150.000  |
| 46 Cold Reducing Gas               | 0.000    | 0.000    | 1663.827 | 1663.827 |
| 47 Preheated Reducing Gas          | 0.000    | 0.000    | 1663.827 | 1663.827 |
| 51 Excess Water                    | 0.000    | 213.400  | 0.000    | 213.400  |

IRON CARBIDE PROCESS

SPECIFIC GRAVITIES

| NO. | STREAM                          | PCS      | SG-SI  | SG-LI  | SG-GC  | SG-TC  |
|-----|---------------------------------|----------|--------|--------|--------|--------|
| 1   | Iron Ore Slurry                 | 40.0000  | 4.9467 | 0.9983 | 0.0000 | 1.4665 |
| 2   | Thickener Underflow             | 50.0000  | 4.9467 | 0.9983 | 0.0000 | 1.6613 |
| 3   | Thickener Overflow              | 0.0200   | 4.9467 | 0.9983 | 0.0000 | 0.9984 |
| 4   | Slurry to Filter                | 50.0000  | 4.9467 | 0.9983 | 0.0000 | 1.6613 |
| 5   | Filtered Solids                 | 88.0000  | 4.9467 | 0.9983 | 0.0000 | 3.3545 |
| 6   | Filterate                       | 0.2310   | 4.9467 | 0.9983 | 0.0000 | 1.0001 |
| 7   | Dried Solids                    | 98.0610  | 4.9704 | 0.3154 | 0.0000 | 3.8646 |
| 8   | Fines to Cyclone                | 13.5359  | 3.9409 | 0.3154 | 0.0003 | 0.0003 |
| 9   | Dust Cyclone Unders             | 94.5818  | 3.9409 | 0.3154 | 0.0000 | 2.4286 |
| 10  | Dust Cyclone Overs              | 0.7833   | 3.9409 | 0.0000 | 0.0003 | 0.0003 |
| 11  | Baghouse Discharge              | 100.0000 | 3.9409 | 0.0000 | 0.0000 | 3.9409 |
| 12  | Bag Filter Exhaust              | 0.0300   | 3.9409 | 0.0000 | 0.0003 | 0.0003 |
| 13  | CO2                             | 0.0000   | 0.0000 | 0.0000 | 0.0018 | 0.0018 |
| 14  | Lock Hopper Discharge           | 97.9999  | 4.9467 | 0.3154 | 0.0000 | 3.8239 |
| 15  | Lock Hopper Flare               | 0.0000   | 0.0000 | 0.0000 | 0.0006 | 0.0006 |
| 17  | H2-rich Reducing gas            | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 18  | Partially Reduced Ore           | 100.0000 | 5.3688 | 0.0000 | 0.0000 | 5.3688 |
| 19  | Top gas with Fines              | 4.7348   | 5.3688 | 0.0000 | 0.0000 | 0.0000 |
| 20  | Recycled Solids from Reactor #1 | 100.0000 | 5.3688 | 0.0000 | 0.0000 | 5.3688 |
| 21  | Top gas from Reactor #1         | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 22  | Cooled Top gas                  | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 23  | Dry Top gas                     | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 24  | Recycle gases                   | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 25  | Make-up gases                   | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 26  | Cold Reducing gas               | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 27  | Preheated Reducing gas          | 0.0000   | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 28  | 28                              | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 29  | Bleed                           | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 30  | Natural Gas                     | 0.0000   | 0.0000 | 0.0000 | 0.0007 | 0.0007 |
| 31  | Air                             | 0.0000   | 0.0000 | 0.0000 | 0.0012 | 0.0012 |
| 32  | 32                              | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 33  | SYN GAS                         | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 34  | METHANE                         | 0.0000   | 0.0000 | 0.0000 | 0.0007 | 0.0007 |
| 35  | Excess Water                    | 0.0000   | 0.0000 | 0.9581 | 0.0000 | 0.9581 |
| 36  | Hot Reducing gas                | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 37  | Final Product                   | 100.0000 | 6.7988 | 0.0000 | 0.0000 | 6.7988 |
| 38  | Top gas with Fines              | 2.2436   | 6.7988 | 0.0000 | 0.0001 | 0.0001 |
| 39  | Recycle Solids from Reactor #2  | 100.0000 | 6.7988 | 0.0000 | 0.0000 | 6.7988 |
| 40  | Top gas from Reactor #2         | 0.0000   | 0.0000 | 0.0000 | 0.0001 | 0.0001 |
| 41  | Cooled Top gas                  | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 42  | Dry Top Gas                     | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 43  | Recycle gas                     | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 44  | Bleed                           | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 45  | Methane                         | 0.0000   | 0.0000 | 0.0000 | 0.0004 | 0.0004 |
| 46  | Cold Reducing Gas               | 0.0000   | 0.0000 | 0.0000 | 0.0003 | 0.0003 |
| 47  | Preheated Reducing Gas          | 0.0000   | 0.0000 | 0.0000 | 0.0002 | 0.0002 |
| 51  | Excess Water                    | 0.0000   | 0.0000 | 0.9581 | 0.0000 | 0.9581 |

IRON CARBIDE PROCESS

STREAM DATA

SOLIDS - MT/HR

| NO. STREAM                        | Fe3O4   | Fe2O3   | Fe3C1   | C1      | Fe1     |
|-----------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore Slurry                 | 900.000 | 50.0000 | 0.000   | 0.00000 | 0.00000 |
| 2 Thickener Underflow             | 899.910 | 49.9950 | 0.000   | 0.00000 | 0.00000 |
| 3 Thickener Overflow              | 0.090   | 0.0050  | 0.000   | 0.00000 | 0.00000 |
| 4 Slurry to Filter                | 899.910 | 49.9950 | 0.000   | 0.00000 | 0.00000 |
| 5 Filtered Solids                 | 898.110 | 49.8950 | 0.000   | 0.00000 | 0.00000 |
| 6 Filterate                       | 1.800   | 0.1000  | 0.000   | 0.00000 | 0.00000 |
| 7 Dried Solids                    | 892.020 | 43.8049 | 0.000   | 0.00000 | 0.00000 |
| 8 Fines to Cyclone                | 6.090   | 6.0901  | 0.000   | 0.00000 | 0.00000 |
| 9 Dust Cyclone Unders             | 5.786   | 5.7856  | 0.000   | 0.00000 | 0.00000 |
| 10 Dust Cyclone Overs             | 0.305   | 0.3045  | 0.000   | 0.00000 | 0.00000 |
| 11 Baghouse Discharge             | 0.293   | 0.2929  | 0.000   | 0.00000 | 0.00000 |
| 12 Bag Filter Exhaust             | 0.012   | 0.0116  | 0.000   | 0.00000 | 0.00000 |
| 14 Lock Hopper Discharge          | 898.099 | 49.8834 | 0.000   | 0.00000 | 0.00000 |
| 16 CAKE TO DRYER                  | 898.110 | 49.8950 | 0.000   | 0.00000 | 0.00000 |
| 37 Final Product                  | 0.000   | 0.0000  | 712.898 | 0.00000 | 0.00000 |
| 38 Top gas with Fines             | 0.000   | 0.0000  | 37.521  | 0.00000 | 0.00000 |
| 39 Recycle Solids from Reactor #2 | 0.000   | 0.0000  | 37.521  | 0.00000 | 0.00000 |

SOLIDS - MT/HR

| NO. STREAM                         | Si1     | Si1O2   | FeO     |
|------------------------------------|---------|---------|---------|
| 1 Iron Ore Slurry                  | 0.00000 | 50.0000 | 0.000   |
| 2 Thickener Underflow              | 0.00000 | 49.9950 | 0.000   |
| 3 Thickener Overflow               | 0.00000 | 0.0050  | 0.000   |
| 4 Slurry to Filter                 | 0.00000 | 49.9950 | 0.000   |
| 5 Filtered Solids                  | 0.00000 | 49.8950 | 0.000   |
| 6 Filterate                        | 0.00000 | 0.1000  | 0.000   |
| 7 Dried Solids                     | 0.00000 | 43.8049 | 0.000   |
| 8 Fines to Cyclone                 | 0.00000 | 6.0901  | 0.000   |
| 9 Dust Cyclone Unders              | 0.00000 | 5.7856  | 0.000   |
| 10 Dust Cyclone Overs              | 0.00000 | 0.3045  | 0.000   |
| 11 Baghouse Discharge              | 0.00000 | 0.2929  | 0.000   |
| 12 Bag Filter Exhaust              | 0.00000 | 0.0116  | 0.000   |
| 14 Lock Hopper Discharge           | 0.00000 | 49.8834 | 0.000   |
| 16 CAKE TO DRYER                   | 0.00000 | 49.8950 | 0.000   |
| 18 Partially Reduced Ore           | 0.00000 | 49.8834 | 880.925 |
| 19 Top gas with Fines              | 0.00000 | 2.6254  | 46.364  |
| 20 Recycled Solids from Reactor #1 | 0.00000 | 2.6254  | 46.364  |
| 37 Final Product                   | 0.00000 | 49.8834 | 25.144  |
| 38 Top gas with Fines              | 0.00000 | 2.6254  | 1.323   |
| 39 Recycle Solids from Reactor #2  | 0.00000 | 2.6254  | 1.323   |

SOLIDS - WEIGHT PERCENT

| NO. STREAM                        | Fe3O4   | Fe2O3   | Fe3C1   | C1      | Fe1     |
|-----------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore Slurry                 | 90.0000 | 5.0000  | 0.0000  | 0.00000 | 0.00000 |
| 2 Thickener Underflow             | 90.0000 | 5.0000  | 0.0000  | 0.00000 | 0.00000 |
| 3 Thickener Overflow              | 90.0000 | 5.0000  | 0.0000  | 0.00000 | 0.00000 |
| 4 Slurry to Filter                | 90.0000 | 5.0000  | 0.0000  | 0.00000 | 0.00000 |
| 5 Filtered Solids                 | 90.0000 | 5.0000  | 0.0000  | 0.00000 | 0.00000 |
| 6 Filterate                       | 90.0000 | 5.0000  | 0.0000  | 0.00000 | 0.00000 |
| 7 Dried Solids                    | 91.0568 | 4.4716  | 0.0000  | 0.00000 | 0.00000 |
| 8 Fines to Cyclone                | 33.3333 | 33.3333 | 0.0000  | 0.00000 | 0.00000 |
| 9 Dust Cyclone Unders             | 33.3333 | 33.3333 | 0.0000  | 0.00000 | 0.00000 |
| 10 Dust Cyclone Overs             | 33.3333 | 33.3333 | 0.0000  | 0.00000 | 0.00000 |
| 11 Baghouse Discharge             | 33.3333 | 33.3333 | 0.0000  | 0.00000 | 0.00000 |
| 12 Bag Filter Exhaust             | 33.3333 | 33.3333 | 0.0000  | 0.00000 | 0.00000 |
| 14 Lock Hopper Discharge          | 90.0020 | 4.9990  | 0.0000  | 0.00000 | 0.00000 |
| 16 CAKE TO DRYER                  | 90.0000 | 5.0000  | 0.0000  | 0.00000 | 0.00000 |
| 37 Final Product                  | 0.0000  | 0.0000  | 90.4778 | 0.00000 | 0.00000 |
| 38 Top gas with Fines             | 0.0000  | 0.0000  | 90.4778 | 0.00000 | 0.00000 |
| 39 Recycle Solids from Reactor #2 | 0.0000  | 0.0000  | 90.4778 | 0.00000 | 0.00000 |

IRON CARBIDE PROCESS

STREAM DATA

SOLIDS - WEIGHT PERCENT

| NO. STREAM                         | Si1     | Si1O2   | FeO     |
|------------------------------------|---------|---------|---------|
| 1 Iron Ore Slurry                  | 0.00000 | 5.0000  | 0.0000  |
| 2 Thickener Underflow              | 0.00000 | 5.0000  | 0.0000  |
| 3 Thickener Overflow               | 0.00000 | 5.0000  | 0.0000  |
| 4 Slurry to Filter                 | 0.00000 | 5.0000  | 0.0000  |
| 5 Filtered Solids                  | 0.00000 | 5.0000  | 0.0000  |
| 6 Filterate                        | 0.00000 | 5.0000  | 0.0000  |
| 7 Dried Solids                     | 0.00000 | 4.4716  | 0.0000  |
| 8 Fines to Cyclone                 | 0.00000 | 33.3333 | 0.0000  |
| 9 Dust Cyclone Unders              | 0.00000 | 33.3333 | 0.0000  |
| 10 Dust Cyclone Overs              | 0.00000 | 33.3333 | 0.0000  |
| 11 Baghouse Discharge              | 0.00000 | 33.3333 | 0.0000  |
| 12 Bag Filter Exhaust              | 0.00000 | 33.3333 | 0.0000  |
| 14 Lock Hopper Discharge           | 0.00000 | 4.9990  | 0.0000  |
| 16 CAKE TO DRYER                   | 0.00000 | 5.0000  | 0.0000  |
| 18 Partially Reduced Ore           | 0.00000 | 5.3591  | 94.6409 |
| 19 Top gas with Fines              | 0.00000 | 5.3591  | 94.6409 |
| 20 Recycled Solids from Reactor #1 | 0.00000 | 5.3591  | 94.6409 |
| 37 Final Product                   | 0.00000 | 6.3310  | 3.1912  |
| 38 Top gas with Fines              | 0.00000 | 6.3310  | 3.1912  |
| 39 Recycle Solids from Reactor #2  | 0.00000 | 6.3310  | 3.1912  |

AQUEOUS - MT/HR

| NO. STREAM               | H2O     |
|--------------------------|---------|
| 1 Iron Ore Slurry        | 1500.00 |
| 2 Thickener Underflow    | 999.90  |
| 3 Thickener Overflow     | 500.10  |
| 4 Slurry to Filter       | 999.90  |
| 5 Filtered Solids        | 136.08  |
| 6 Filterate              | 863.82  |
| 7 Dried Solids           | 19.37   |
| 8 Fines to Cyclone       | 0.99    |
| 9 Dust Cyclone Unders    | 0.99    |
| 14 Lock Hopper Discharge | 20.37   |
| 16 CAKE TO DRYER         | 136.08  |
| 35 Excess Water          | 95.77   |
| 51 Excess Water          | 213.40  |

AQUEOUS - WEIGHT PERCENT

| NO. STREAM               | H2O     |
|--------------------------|---------|
| 1 Iron Ore Slurry        | 100.000 |
| 2 Thickener Underflow    | 100.000 |
| 3 Thickener Overflow     | 100.000 |
| 4 Slurry to Filter       | 100.000 |
| 5 Filtered Solids        | 100.000 |
| 6 Filterate              | 100.000 |
| 7 Dried Solids           | 100.000 |
| 8 Fines to Cyclone       | 100.000 |
| 9 Dust Cyclone Unders    | 100.000 |
| 14 Lock Hopper Discharge | 100.000 |
| 16 CAKE TO DRYER         | 100.000 |
| 35 Excess Water          | 100.000 |
| 51 Excess Water          | 100.000 |

IRON CARBIDE PROCESS

STREAM DATA

AQUEOUS - GRAMS PER LITER

| NO. STREAM               | H2O     |
|--------------------------|---------|
| 1 Iron Ore Slurry        | 998.259 |
| 2 Thickener Underflow    | 998.259 |
| 3 Thickener Overflow     | 998.259 |
| 4 Slurry to Filter       | 998.259 |
| 5 Filtered Solids        | 998.259 |
| 6 Filterate              | 998.259 |
| 7 Dried Solids           | 315.448 |
| 8 Fines to Cyclone       | 315.448 |
| 9 Dust Cyclone Unders    | 315.448 |
| 14 Lock Hopper Discharge | 315.448 |
| 16 CAKE TO DRYER         | 998.259 |
| 35 Excess Water          | 958.099 |
| 51 Excess Water          | 958.099 |

GASEOUS - MT/HR

| NO. STREAM                 | N2      | O2      | H2O     | CH4     | C2H6    |
|----------------------------|---------|---------|---------|---------|---------|
| 8 Fines to Cyclone         | 0.0000  | 0.00000 | 115.712 | 0.00    | 0.00000 |
| 10 Dust Cyclone Overs      | 0.0000  | 0.00000 | 115.712 | 0.00    | 0.00000 |
| 12 Bag Filter Exhaust      | 0.0000  | 0.00000 | 115.712 | 0.00    | 0.00000 |
| 17 H2-rich Reducing gas    | 0.0000  | 0.00000 | 1.857   | 57.26   | 0.00000 |
| 19 Top gas with Fines      | 0.0000  | 0.00000 | 97.728  | 57.26   | 0.00000 |
| 21 Top gas from Reactor #1 | 0.0000  | 0.00000 | 97.728  | 57.26   | 0.00000 |
| 22 Cooled Top gas          | 0.0000  | 0.00000 | 97.728  | 57.26   | 0.00000 |
| 23 Dry Top gas             | 0.0000  | 0.00000 | 1.955   | 57.26   | 0.00000 |
| 24 Recycle gases           | 0.0000  | 0.00000 | 1.857   | 54.40   | 0.00000 |
| 25 Make-up gases           | 0.0000  | 0.00000 | 0.000   | 2.86    | 0.00000 |
| 26 Cold Reducing gas       | 0.0000  | 0.00000 | 1.857   | 57.26   | 0.00000 |
| 27 Preheated Reducing gas  | 0.0000  | 0.00000 | 1.857   | 57.26   | 0.00000 |
| 28 28                      | 6.5303  | 0.00000 | 5.762   | 332.39  | 0.00000 |
| 29 Bleed                   | 0.0000  | 0.00000 | 0.098   | 2.86    | 0.00000 |
| 30 Natural Gas             | 0.0000  | 0.00000 | 0.000   | 1.00    | 0.00000 |
| 31 Air                     | 15.8489 | 4.73409 | 0.000   | 0.00    | 0.00000 |
| 32 32                      | 15.8489 | 0.74497 | 2.246   | 0.00    | 0.00000 |
| 34 METHANE                 | 0.0000  | 0.00000 | 0.000   | 2.86    | 0.00000 |
| 36 Hot Reducing gas        | 0.0000  | 0.00000 | 22.526  | 1492.97 | 0.00000 |
| 38 Top gas with Fines      | 0.0000  | 0.00000 | 237.111 | 1429.45 | 0.00000 |
| 40 Top gas from Reactor #2 | 0.0000  | 0.00000 | 237.111 | 1429.45 | 0.00000 |
| 41 Cooled Top gas          | 0.0000  | 0.00000 | 237.111 | 1429.45 | 0.00000 |
| 42 Dry Top Gas             | 0.0000  | 0.00000 | 23.711  | 1429.45 | 0.00000 |
| 43 Recycle gas             | 0.0000  | 0.00000 | 22.526  | 1357.97 | 0.00000 |
| 44 Bleed                   | 0.0000  | 0.00000 | 1.186   | 71.47   | 0.00000 |
| 45 Methane                 | 0.0000  | 0.00000 | 0.000   | 135.00  | 0.00000 |
| 46 Cold Reducing Gas       | 0.0000  | 0.00000 | 22.526  | 1492.97 | 0.00000 |
| 47 Preheated Reducing Gas  | 0.0000  | 0.00000 | 22.526  | 1492.97 | 0.00000 |



IRON CARBIDE PROCESS

STREAM DATA

GASEOUS - MT/HR

| NO. STREAM                 | H2      | CO2     | CO      |
|----------------------------|---------|---------|---------|
| 13 CO2                     | 0.000   | 10.0000 | 0.0000  |
| 15 Lock Hopper Flare       | 0.000   | 10.0000 | 0.0000  |
| 17 H2-rich Reducing gas    | 739.203 | 0.0000  | 99.9677 |
| 19 Top gas with Fines      | 730.740 | 0.0000  | 99.9660 |
| 21 Top gas from Reactor #1 | 730.740 | 0.0000  | 99.9660 |
| 22 Cooled Top gas          | 730.740 | 0.0000  | 99.9660 |
| 23 Dry Top gas             | 730.740 | 0.0000  | 99.9660 |
| 24 Recycle gases           | 694.203 | 0.0000  | 94.9677 |
| 25 Make-up gases           | 45.000  | 0.0000  | 5.0000  |
| 26 Cold Reducing gas       | 739.203 | 0.0000  | 99.9677 |
| 27 Preheated Reducing gas  | 739.203 | 0.0000  | 99.9677 |
| 28 28                      | 207.514 | 13.0606 | 13.2093 |
| 29 Bleed                   | 36.537  | 0.0000  | 4.9983  |
| 32 32                      | 0.000   | 2.7432  | 0.0000  |
| 33 SYN GAS                 | 45.000  | 0.0000  | 5.0000  |
| 36 Hot Reducing gas        | 148.327 | 0.0000  | 0.0000  |
| 38 Top gas with Fines      | 140.344 | 0.0000  | 0.0000  |
| 40 Top gas from Reactor #2 | 140.344 | 0.0000  | 0.0000  |
| 41 Cooled Top gas          | 140.344 | 0.0000  | 0.0000  |
| 42 Dry Top Gas             | 140.344 | 0.0000  | 0.0000  |
| 43 Recycle gas             | 133.327 | 0.0000  | 0.0000  |
| 44 Bleed                   | 7.017   | 0.0000  | 0.0000  |
| 45 Methane                 | 15.000  | 0.0000  | 0.0000  |
| 46 Cold Reducing Gas       | 148.327 | 0.0000  | 0.0000  |
| 47 Preheated Reducing Gas  | 148.327 | 0.0000  | 0.0000  |

GASEOUS - WEIGHT PERCENT

| NO. STREAM                 | N2      | O2      | H2O     | CH4     | C2H6    |
|----------------------------|---------|---------|---------|---------|---------|
| 8 Fines to Cyclone         | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 10 Dust Cyclone Overs      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 12 Bag Filter Exhaust      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 17 H2-rich Reducing gas    | 0.0000  | 0.0000  | 0.207   | 6.374   | 0.00000 |
| 19 Top gas with Fines      | 0.0000  | 0.0000  | 9.915   | 5.809   | 0.00000 |
| 21 Top gas from Reactor #1 | 0.0000  | 0.0000  | 9.915   | 5.809   | 0.00000 |
| 22 Cooled Top gas          | 0.0000  | 0.0000  | 9.915   | 5.809   | 0.00000 |
| 23 Dry Top gas             | 0.0000  | 0.0000  | 0.220   | 6.434   | 0.00000 |
| 24 Recycle gases           | 0.0000  | 0.0000  | 0.220   | 6.434   | 0.00000 |
| 25 Make-up gases           | 0.0000  | 0.0000  | 0.000   | 5.416   | 0.00000 |
| 26 Cold Reducing gas       | 0.0000  | 0.0000  | 0.207   | 6.374   | 0.00000 |
| 27 Preheated Reducing gas  | 0.0000  | 0.0000  | 0.207   | 6.374   | 0.00000 |
| 28 28                      | 1.1289  | 0.0000  | 0.996   | 57.461  | 0.00000 |
| 29 Bleed                   | 0.0000  | 0.0000  | 0.220   | 6.434   | 0.00000 |
| 30 Natural Gas             | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.00000 |
| 31 Air                     | 77.0000 | 23.0000 | 0.000   | 0.000   | 0.00000 |
| 32 32                      | 73.4324 | 3.4517  | 10.406  | 0.000   | 0.00000 |
| 34 METHANE                 | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.00000 |
| 36 Hot Reducing gas        | 0.0000  | 0.0000  | 1.354   | 89.731  | 0.00000 |
| 38 Top gas with Fines      | 0.0000  | 0.0000  | 13.123  | 79.110  | 0.00000 |
| 40 Top gas from Reactor #2 | 0.0000  | 0.0000  | 13.123  | 79.110  | 0.00000 |
| 41 Cooled Top gas          | 0.0000  | 0.0000  | 13.123  | 79.110  | 0.00000 |
| 42 Dry Top Gas             | 0.0000  | 0.0000  | 1.488   | 89.705  | 0.00000 |
| 43 Recycle gas             | 0.0000  | 0.0000  | 1.488   | 89.705  | 0.00000 |
| 44 Bleed                   | 0.0000  | 0.0000  | 1.488   | 89.705  | 0.00000 |
| 45 Methane                 | 0.0000  | 0.0000  | 0.000   | 90.000  | 0.00000 |
| 46 Cold Reducing Gas       | 0.0000  | 0.0000  | 1.354   | 89.731  | 0.00000 |
| 47 Preheated Reducing Gas  | 0.0000  | 0.0000  | 1.354   | 89.731  | 0.00000 |

IRON CARBIDE PROCESS

STREAM DATA

GASEOUS - WEIGHT PERCENT

| NO. STREAM                 | H2      | CO2     | CO      |
|----------------------------|---------|---------|---------|
| 13 CO2                     | 0.0000  | 100.000 | 0.0000  |
| 15 Lock Hopper Flare       | 0.0000  | 100.000 | 0.0000  |
| 17 H2-rich Reducing gas    | 82.2902 | 0.000   | 11.1287 |
| 19 Top gas with Fines      | 74.1345 | 0.000   | 10.1417 |
| 21 Top gas from Reactor #1 | 74.1345 | 0.000   | 10.1417 |
| 22 Cooled Top gas          | 74.1345 | 0.000   | 10.1417 |
| 23 Dry Top gas             | 82.1129 | 0.000   | 11.2331 |
| 24 Recycle gases           | 82.1129 | 0.000   | 11.2331 |
| 25 Make-up gases           | 85.1256 | 0.000   | 9.4584  |
| 26 Cold Reducing gas       | 82.2902 | 0.000   | 11.1287 |
| 27 Preheated Reducing gas  | 82.2902 | 0.000   | 11.1287 |
| 28 28                      | 35.8732 | 2.258   | 2.2835  |
| 29 Bleed                   | 82.1129 | 0.000   | 11.2331 |
| 32 32                      | 0.0000  | 12.710  | 0.0000  |
| 33 SYN GAS                 | 90.0000 | 0.000   | 10.0000 |
| 36 Hot Reducing gas        | 8.9148  | 0.000   | 0.0000  |
| 38 Top gas with Fines      | 7.7671  | 0.000   | 0.0000  |
| 40 Top gas from Reactor #2 | 7.7671  | 0.000   | 0.0000  |
| 41 Cooled Top gas          | 7.7671  | 0.000   | 0.0000  |
| 42 Dry Top Gas             | 8.8073  | 0.000   | 0.0000  |
| 43 Recycle gas             | 8.8073  | 0.000   | 0.0000  |
| 44 Bleed                   | 8.8073  | 0.000   | 0.0000  |
| 45 Methane                 | 10.0000 | 0.000   | 0.0000  |
| 46 Cold Reducing Gas       | 8.9148  | 0.000   | 0.0000  |
| 47 Preheated Reducing Gas  | 8.9148  | 0.000   | 0.0000  |

GASEOUS - VOLUME PERCENT

| NO. STREAM                 | N2      | O2      | H2O     | CH4     | C2H6    |
|----------------------------|---------|---------|---------|---------|---------|
| 8 Fines to Cyclone         | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 10 Dust Cyclone Overs      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 12 Bag Filter Exhaust      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 17 H2-rich Reducing gas    | 0.0000  | 0.0000  | 0.028   | 0.955   | 0.00000 |
| 19 Top gas with Fines      | 0.0000  | 0.0000  | 1.446   | 0.952   | 0.00000 |
| 21 Top gas from Reactor #1 | 0.0000  | 0.0000  | 1.446   | 0.952   | 0.00000 |
| 22 Cooled Top gas          | 0.0000  | 0.0000  | 1.446   | 0.952   | 0.00000 |
| 23 Dry Top gas             | 0.0000  | 0.0000  | 0.029   | 0.965   | 0.00000 |
| 24 Recycle gases           | 0.0000  | 0.0000  | 0.029   | 0.965   | 0.00000 |
| 25 Make-up gases           | 0.0000  | 0.0000  | 0.000   | 0.787   | 0.00000 |
| 26 Cold Reducing gas       | 0.0000  | 0.0000  | 0.028   | 0.955   | 0.00000 |
| 27 Preheated Reducing gas  | 0.0000  | 0.0000  | 0.028   | 0.955   | 0.00000 |
| 28 28                      | 0.1865  | 0.0000  | 0.256   | 16.578  | 0.00000 |
| 29 Bleed                   | 0.0000  | 0.0000  | 0.029   | 0.965   | 0.00000 |
| 30 Natural Gas             | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.00000 |
| 31 Air                     | 79.2708 | 20.7292 | 0.000   | 0.000   | 0.00000 |
| 32 32                      | 72.9037 | 3.0000  | 16.064  | 0.000   | 0.00000 |
| 34 METHANE                 | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.00000 |
| 36 Hot Reducing gas        | 0.0000  | 0.0000  | 0.745   | 55.430  | 0.00000 |
| 38 Top gas with Fines      | 0.0000  | 0.0000  | 7.657   | 51.839  | 0.00000 |
| 40 Top gas from Reactor #2 | 0.0000  | 0.0000  | 7.657   | 51.839  | 0.00000 |
| 41 Cooled Top gas          | 0.0000  | 0.0000  | 7.657   | 51.839  | 0.00000 |
| 42 Dry Top Gas             | 0.0000  | 0.0000  | 0.822   | 55.676  | 0.00000 |
| 43 Recycle gas             | 0.0000  | 0.0000  | 0.822   | 55.676  | 0.00000 |
| 44 Bleed                   | 0.0000  | 0.0000  | 0.822   | 55.676  | 0.00000 |
| 45 Methane                 | 0.0000  | 0.0000  | 0.000   | 53.072  | 0.00000 |
| 46 Cold Reducing Gas       | 0.0000  | 0.0000  | 0.745   | 55.430  | 0.00000 |
| 47 Preheated Reducing Gas  | 0.0000  | 0.0000  | 0.745   | 55.430  | 0.00000 |

IRON CARBIDE PROCESS

STREAM DATA

GASEOUS - VOLUME PERCENT

| NO. STREAM                 | H2      | CO2     | CO      |
|----------------------------|---------|---------|---------|
| 13 CO2                     | 0.0000  | 100.000 | 0.00000 |
| 15 Lock Hopper Flare       | 0.0000  | 100.000 | 0.00000 |
| 17 H2-rich Reducing gas    | 98.0634 | 0.000   | 0.95446 |
| 19 Top gas with Fines      | 96.6503 | 0.000   | 0.95159 |
| 21 Top gas from Reactor #1 | 96.6503 | 0.000   | 0.95159 |
| 22 Cooled Top gas          | 96.6503 | 0.000   | 0.95159 |
| 23 Dry Top gas             | 98.0400 | 0.000   | 0.96527 |
| 24 Recycle gases           | 98.0400 | 0.000   | 0.96527 |
| 25 Make-up gases           | 98.4260 | 0.000   | 0.78709 |
| 26 Cold Reducing gas       | 98.0634 | 0.000   | 0.95446 |
| 27 Preheated Reducing gas  | 98.0634 | 0.000   | 0.95446 |
| 28 28                      | 82.3647 | 0.237   | 0.37734 |
| 29 Bleed                   | 98.0400 | 0.000   | 0.96527 |
| 32 32                      | 0.0000  | 8.032   | 0.00000 |
| 33 SYN GAS                 | 99.2067 | 0.000   | 0.79333 |
| 36 Hot Reducing gas        | 43.8251 | 0.000   | 0.00000 |
| 38 Top gas with Fines      | 40.5035 | 0.000   | 0.00000 |
| 40 Top gas from Reactor #2 | 40.5035 | 0.000   | 0.00000 |
| 41 Cooled Top gas          | 40.5035 | 0.000   | 0.00000 |
| 42 Dry Top Gas             | 43.5015 | 0.000   | 0.00000 |
| 43 Recycle gas             | 43.5015 | 0.000   | 0.00000 |
| 44 Bleed                   | 43.5015 | 0.000   | 0.00000 |
| 45 Methane                 | 46.9280 | 0.000   | 0.00000 |
| 46 Cold Reducing Gas       | 43.8251 | 0.000   | 0.00000 |
| 47 Preheated Reducing Gas  | 43.8251 | 0.000   | 0.00000 |

IRON CARBIDE PROCESS

STREAM DATA IN MOLES

SOLIDS - MT MOLES/HR

| NO. STREAM                        | Fe3O4   | Fe2O3   | Fe3C1   | C1      | Fe1     |
|-----------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore Slurry                 | 3.88704 | 0.31310 | 0.00000 | 0.00000 | 0.00000 |
| 2 Thickener Underflow             | 3.88665 | 0.31307 | 0.00000 | 0.00000 | 0.00000 |
| 3 Thickener Overflow              | 0.00039 | 0.00003 | 0.00000 | 0.00000 | 0.00000 |
| 4 Slurry to Filter                | 3.88665 | 0.31307 | 0.00000 | 0.00000 | 0.00000 |
| 5 Filtered Solids                 | 3.87888 | 0.31244 | 0.00000 | 0.00000 | 0.00000 |
| 6 Filterate                       | 0.00777 | 0.00063 | 0.00000 | 0.00000 | 0.00000 |
| 7 Dried Solids                    | 3.85258 | 0.27431 | 0.00000 | 0.00000 | 0.00000 |
| 8 Fines to Cyclone                | 0.02630 | 0.03814 | 0.00000 | 0.00000 | 0.00000 |
| 9 Dust Cyclone Unders             | 0.02499 | 0.03623 | 0.00000 | 0.00000 | 0.00000 |
| 10 Dust Cyclone Overs             | 0.00132 | 0.00191 | 0.00000 | 0.00000 | 0.00000 |
| 11 Baghouse Discharge             | 0.00127 | 0.00183 | 0.00000 | 0.00000 | 0.00000 |
| 12 Bag Filter Exhaust             | 0.00005 | 0.00007 | 0.00000 | 0.00000 | 0.00000 |
| 14 Lock Hopper Discharge          | 3.87883 | 0.31237 | 0.00000 | 0.00000 | 0.00000 |
| 16 CAKE TO DRYER                  | 3.87888 | 0.31244 | 0.00000 | 0.00000 | 0.00000 |
| 37 Final Product                  | 0.00000 | 0.00000 | 3.97042 | 0.00000 | 0.00000 |
| 38 Top gas with Fines             | 0.00000 | 0.00000 | 0.20897 | 0.00000 | 0.00000 |
| 39 Recycle Solids from Reactor #2 | 0.00000 | 0.00000 | 0.20897 | 0.00000 | 0.00000 |

SOLIDS - MT MOLES/HR

| NO. STREAM                         | Si1     | SiO2    | FeO     |
|------------------------------------|---------|---------|---------|
| 1 Iron Ore Slurry                  | 0.00000 | 0.83216 | 0.0000  |
| 2 Thickener Underflow              | 0.00000 | 0.83207 | 0.0000  |
| 3 Thickener Overflow               | 0.00000 | 0.00008 | 0.0000  |
| 4 Slurry to Filter                 | 0.00000 | 0.83207 | 0.0000  |
| 5 Filtered Solids                  | 0.00000 | 0.83041 | 0.0000  |
| 6 Filterate                        | 0.00000 | 0.00166 | 0.0000  |
| 7 Dried Solids                     | 0.00000 | 0.72905 | 0.0000  |
| 8 Fines to Cyclone                 | 0.00000 | 0.10136 | 0.0000  |
| 9 Dust Cyclone Unders              | 0.00000 | 0.09629 | 0.0000  |
| 10 Dust Cyclone Overs              | 0.00000 | 0.00507 | 0.0000  |
| 11 Baghouse Discharge              | 0.00000 | 0.00488 | 0.0000  |
| 12 Bag Filter Exhaust              | 0.00000 | 0.00019 | 0.0000  |
| 14 Lock Hopper Discharge           | 0.00000 | 0.83022 | 0.0000  |
| 16 CAKE TO DRYER                   | 0.00000 | 0.83041 | 0.0000  |
| 18 Partially Reduced Ore           | 0.00000 | 0.83022 | 12.2612 |
| 19 Top gas with Fines              | 0.00000 | 0.04370 | 0.6453  |
| 20 Recycled Solids from Reactor #1 | 0.00000 | 0.04370 | 0.6453  |
| 37 Final Product                   | 0.00000 | 0.83022 | 0.3500  |
| 38 Top gas with Fines              | 0.00000 | 0.04370 | 0.0184  |
| 39 Recycle Solids from Reactor #2  | 0.00000 | 0.04370 | 0.0184  |

SOLIDS - MOLE PERCENT

| NO. STREAM                        | Fe3O4   | Fe2O3   | Fe3C1   | C1      | Fe1     |
|-----------------------------------|---------|---------|---------|---------|---------|
| 1 Iron Ore Slurry                 | 77.2418 | 6.2219  | 0.0000  | 0.00000 | 0.00000 |
| 2 Thickener Underflow             | 77.2418 | 6.2219  | 0.0000  | 0.00000 | 0.00000 |
| 3 Thickener Overflow              | 77.2418 | 6.2219  | 0.0000  | 0.00000 | 0.00000 |
| 4 Slurry to Filter                | 77.2418 | 6.2219  | 0.0000  | 0.00000 | 0.00000 |
| 5 Filtered Solids                 | 77.2418 | 6.2219  | 0.0000  | 0.00000 | 0.00000 |
| 6 Filterate                       | 77.2418 | 6.2219  | 0.0000  | 0.00000 | 0.00000 |
| 7 Dried Solids                    | 79.3375 | 5.6489  | 0.0000  | 0.00000 | 0.00000 |
| 8 Fines to Cyclone                | 15.8644 | 23.0018 | 0.0000  | 0.00000 | 0.00000 |
| 9 Dust Cyclone Unders             | 15.8644 | 23.0018 | 0.0000  | 0.00000 | 0.00000 |
| 10 Dust Cyclone Overs             | 15.8644 | 23.0018 | 0.0000  | 0.00000 | 0.00000 |
| 11 Baghouse Discharge             | 15.8644 | 23.0018 | 0.0000  | 0.00000 | 0.00000 |
| 12 Bag Filter Exhaust             | 15.8644 | 23.0018 | 0.0000  | 0.00000 | 0.00000 |
| 14 Lock Hopper Discharge          | 77.2457 | 6.2208  | 0.0000  | 0.00000 | 0.00000 |
| 16 CAKE TO DRYER                  | 77.2418 | 6.2219  | 0.0000  | 0.00000 | 0.00000 |
| 37 Final Product                  | 0.0000  | 0.0000  | 77.0864 | 0.00000 | 0.00000 |
| 38 Top gas with Fines             | 0.0000  | 0.0000  | 77.0864 | 0.00000 | 0.00000 |
| 39 Recycle Solids from Reactor #2 | 0.0000  | 0.0000  | 77.0864 | 0.00000 | 0.00000 |

IRON CARBIDE PROCESS

STREAM DATA IN MOLES

SOLIDS - MOLE PERCENT

| NO. STREAM                         | Si1     | Si1O2   | FeO     |
|------------------------------------|---------|---------|---------|
| 1 Iron Ore Slurry                  | 0.00000 | 16.5363 | 0.0000  |
| 2 Thickener Underflow              | 0.00000 | 16.5363 | 0.0000  |
| 3 Thickener Overflow               | 0.00000 | 16.5363 | 0.0000  |
| 4 Slurry to Filter                 | 0.00000 | 16.5363 | 0.0000  |
| 5 Filtered Solids                  | 0.00000 | 16.5363 | 0.0000  |
| 6 Filterate                        | 0.00000 | 16.5363 | 0.0000  |
| 7 Dried Solids                     | 0.00000 | 15.0136 | 0.0000  |
| 8 Fines to Cyclone                 | 0.00000 | 61.1338 | 0.0000  |
| 9 Dust Cyclone Unders              | 0.00000 | 61.1338 | 0.0000  |
| 10 Dust Cyclone Overs              | 0.00000 | 61.1338 | 0.0000  |
| 11 Baghouse Discharge              | 0.00000 | 61.1338 | 0.0000  |
| 12 Bag Filter Exhaust              | 0.00000 | 61.1338 | 0.0000  |
| 14 Lock Hopper Discharge           | 0.00000 | 16.5335 | 0.0000  |
| 16 CAKE TO DRYER                   | 0.00000 | 16.5363 | 0.0000  |
| 18 Partially Reduced Ore           | 0.00000 | 6.3417  | 93.6583 |
| 19 Top gas with Fines              | 0.00000 | 6.3417  | 93.6583 |
| 20 Recycled Solids from Reactor #1 | 0.00000 | 6.3417  | 93.6583 |
| 37 Final Product                   | 0.00000 | 16.1188 | 6.7947  |
| 38 Top gas with Fines              | 0.00000 | 16.1188 | 6.7947  |
| 39 Recycle Solids from Reactor #2  | 0.00000 | 16.1188 | 6.7947  |

GASEOUS - MT MOLES/HR

| NO. STREAM                 | N2      | O2      | H2O     | CH4     | C2H6    |
|----------------------------|---------|---------|---------|---------|---------|
| 8 Fines to Cyclone         | 0.00000 | 0.00000 | 6.4230  | 0.0000  | 0.00000 |
| 10 Dust Cyclone Overs      | 0.00000 | 0.00000 | 6.4230  | 0.0000  | 0.00000 |
| 12 Bag Filter Exhaust      | 0.00000 | 0.00000 | 6.4230  | 0.0000  | 0.00000 |
| 17 H2-rich Reducing gas    | 0.00000 | 0.00000 | 0.1031  | 3.5692  | 0.00000 |
| 19 Top gas with Fines      | 0.00000 | 0.00000 | 5.4247  | 3.5692  | 0.00000 |
| 21 Top gas from Reactor #1 | 0.00000 | 0.00000 | 5.4247  | 3.5692  | 0.00000 |
| 22 Cooled Top gas          | 0.00000 | 0.00000 | 5.4247  | 3.5692  | 0.00000 |
| 23 Dry Top gas             | 0.00000 | 0.00000 | 0.1085  | 3.5692  | 0.00000 |
| 24 Recycle gases           | 0.00000 | 0.00000 | 0.1031  | 3.3907  | 0.00000 |
| 25 Make-up gases           | 0.00000 | 0.00000 | 0.0000  | 0.1785  | 0.00000 |
| 26 Cold Reducing gas       | 0.00000 | 0.00000 | 0.1031  | 3.5692  | 0.00000 |
| 27 Preheated Reducing gas  | 0.00000 | 0.00000 | 0.1031  | 3.5692  | 0.00000 |
| 28 28                      | 0.23311 | 0.00000 | 0.3198  | 20.7187 | 0.00000 |
| 29 Bleed                   | 0.00000 | 0.00000 | 0.0054  | 0.1785  | 0.00000 |
| 30 Natural Gas             | 0.00000 | 0.00000 | 0.0000  | 0.0623  | 0.00000 |
| 31 Air                     | 0.56576 | 0.14795 | 0.0000  | 0.0000  | 0.00000 |
| 32 32                      | 0.56576 | 0.02328 | 0.1247  | 0.0000  | 0.00000 |
| 34 METHANE                 | 0.00000 | 0.00000 | 0.0000  | 0.1785  | 0.00000 |
| 36 Hot Reducing gas        | 0.00000 | 0.00000 | 1.2504  | 93.0606 | 0.00000 |
| 38 Top gas with Fines      | 0.00000 | 0.00000 | 13.1616 | 89.1008 | 0.00000 |
| 40 Top gas from Reactor #2 | 0.00000 | 0.00000 | 13.1616 | 89.1008 | 0.00000 |
| 41 Cooled Top gas          | 0.00000 | 0.00000 | 13.1616 | 89.1008 | 0.00000 |
| 42 Dry Top Gas             | 0.00000 | 0.00000 | 1.3162  | 89.1008 | 0.00000 |
| 43 Recycle gas             | 0.00000 | 0.00000 | 1.2504  | 84.6457 | 0.00000 |
| 44 Bleed                   | 0.00000 | 0.00000 | 0.0658  | 4.4550  | 0.00000 |
| 45 Methane                 | 0.00000 | 0.00000 | 0.0000  | 8.4149  | 0.00000 |
| 46 Cold Reducing Gas       | 0.00000 | 0.00000 | 1.2504  | 93.0606 | 0.00000 |
| 47 Preheated Reducing Gas  | 0.00000 | 0.00000 | 1.2504  | 93.0606 | 0.00000 |

IRON CARBIDE PROCESS

STREAM DATA IN MOLES

GASEOUS - MT MOLES/HR

| NO. STREAM                 | H2      | CO2     | CO      |
|----------------------------|---------|---------|---------|
| 13 CO2                     | 0.000   | 0.22722 | 0.00000 |
| 15 Lock Hopper Flare       | 0.000   | 0.22722 | 0.00000 |
| 17 H2-rich Reducing gas    | 366.679 | 0.00000 | 3.56893 |
| 19 Top gas with Fines      | 362.481 | 0.00000 | 3.56887 |
| 21 Top gas from Reactor #1 | 362.481 | 0.00000 | 3.56887 |
| 22 Cooled Top gas          | 362.481 | 0.00000 | 3.56887 |
| 23 Dry Top gas             | 362.481 | 0.00000 | 3.56887 |
| 24 Recycle gases           | 344.357 | 0.00000 | 3.39042 |
| 25 Make-up gases           | 22.322  | 0.00000 | 0.17850 |
| 26 Cold Reducing gas       | 366.679 | 0.00000 | 3.56893 |
| 27 Preheated Reducing gas  | 366.679 | 0.00000 | 3.56893 |
| 28 28                      | 102.937 | 0.29676 | 0.47158 |
| 29 Bleed                   | 18.124  | 0.00000 | 0.17844 |
| 32 32                      | 0.000   | 0.06233 | 0.00000 |
| 33 SYN GAS                 | 22.322  | 0.00000 | 0.17850 |
| 36 Hot Reducing gas        | 73.577  | 0.00000 | 0.00000 |
| 38 Top gas with Fines      | 69.617  | 0.00000 | 0.00000 |
| 40 Top gas from Reactor #2 | 69.617  | 0.00000 | 0.00000 |
| 41 Cooled Top gas          | 69.617  | 0.00000 | 0.00000 |
| 42 Dry Top Gas             | 69.617  | 0.00000 | 0.00000 |
| 43 Recycle gas             | 66.137  | 0.00000 | 0.00000 |
| 44 Bleed                   | 3.481   | 0.00000 | 0.00000 |
| 45 Methane                 | 7.441   | 0.00000 | 0.00000 |
| 46 Cold Reducing Gas       | 73.577  | 0.00000 | 0.00000 |
| 47 Preheated Reducing Gas  | 73.577  | 0.00000 | 0.00000 |

GASEOUS - MOLE PERCENT

| NO. STREAM                 | N2      | O2      | H2O     | CH4     | C2H6    |
|----------------------------|---------|---------|---------|---------|---------|
| 8 Fines to Cyclone         | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 10 Dust Cyclone Overs      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 12 Bag Filter Exhaust      | 0.0000  | 0.0000  | 100.000 | 0.000   | 0.00000 |
| 17 H2-rich Reducing gas    | 0.0000  | 0.0000  | 0.028   | 0.955   | 0.00000 |
| 19 Top gas with Fines      | 0.0000  | 0.0000  | 1.446   | 0.952   | 0.00000 |
| 21 Top gas from Reactor #1 | 0.0000  | 0.0000  | 1.446   | 0.952   | 0.00000 |
| 22 Cooled Top gas          | 0.0000  | 0.0000  | 1.446   | 0.952   | 0.00000 |
| 23 Dry Top gas             | 0.0000  | 0.0000  | 0.029   | 0.965   | 0.00000 |
| 24 Recycle gases           | 0.0000  | 0.0000  | 0.029   | 0.965   | 0.00000 |
| 25 Make-up gases           | 0.0000  | 0.0000  | 0.000   | 0.787   | 0.00000 |
| 26 Cold Reducing gas       | 0.0000  | 0.0000  | 0.028   | 0.955   | 0.00000 |
| 27 Preheated Reducing gas  | 0.0000  | 0.0000  | 0.028   | 0.955   | 0.00000 |
| 28 28                      | 0.1865  | 0.0000  | 0.256   | 16.578  | 0.00000 |
| 29 Bleed                   | 0.0000  | 0.0000  | 0.029   | 0.965   | 0.00000 |
| 30 Natural Gas             | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.00000 |
| 31 Air                     | 79.2708 | 20.7292 | 0.000   | 0.000   | 0.00000 |
| 32 32                      | 72.9037 | 3.0000  | 16.064  | 0.000   | 0.00000 |
| 34 METHANE                 | 0.0000  | 0.0000  | 0.000   | 100.000 | 0.00000 |
| 36 Hot Reducing gas        | 0.0000  | 0.0000  | 0.745   | 55.430  | 0.00000 |
| 38 Top gas with Fines      | 0.0000  | 0.0000  | 7.657   | 51.839  | 0.00000 |
| 40 Top gas from Reactor #2 | 0.0000  | 0.0000  | 7.657   | 51.839  | 0.00000 |
| 41 Cooled Top gas          | 0.0000  | 0.0000  | 7.657   | 51.839  | 0.00000 |
| 42 Dry Top Gas             | 0.0000  | 0.0000  | 0.822   | 55.676  | 0.00000 |
| 43 Recycle gas             | 0.0000  | 0.0000  | 0.822   | 55.676  | 0.00000 |
| 44 Bleed                   | 0.0000  | 0.0000  | 0.822   | 55.676  | 0.00000 |
| 45 Methane                 | 0.0000  | 0.0000  | 0.000   | 53.072  | 0.00000 |
| 46 Cold Reducing Gas       | 0.0000  | 0.0000  | 0.745   | 55.430  | 0.00000 |
| 47 Preheated Reducing Gas  | 0.0000  | 0.0000  | 0.745   | 55.430  | 0.00000 |

IRON CARBIDE PROCESS

STREAM DATA IN MOLES

GASEOUS - MOLE PERCENT

| NO. STREAM                 | H2      | CO2     | CO      |
|----------------------------|---------|---------|---------|
| 13 CO2                     | 0.0000  | 100.000 | 0.00000 |
| 15 Lock Hopper Flare       | 0.0000  | 100.000 | 0.00000 |
| 17 H2-rich Reducing gas    | 98.0634 | 0.000   | 0.95446 |
| 19 Top gas with Fines      | 96.6503 | 0.000   | 0.95159 |
| 21 Top gas from Reactor #1 | 96.6503 | 0.000   | 0.95159 |
| 22 Cooled Top gas          | 96.6503 | 0.000   | 0.95159 |
| 23 Dry Top gas             | 98.0400 | 0.000   | 0.96527 |
| 24 Recycle gases           | 98.0400 | 0.000   | 0.96527 |
| 25 Make-up gases           | 98.4260 | 0.000   | 0.78709 |
| 26 Cold Reducing gas       | 98.0634 | 0.000   | 0.95446 |
| 27 Preheated Reducing gas  | 98.0634 | 0.000   | 0.95446 |
| 28 28                      | 82.3647 | 0.237   | 0.37734 |
| 29 Bleed                   | 98.0400 | 0.000   | 0.96527 |
| 32 32                      | 0.0000  | 8.032   | 0.00000 |
| 33 SYN GAS                 | 99.2067 | 0.000   | 0.79333 |
| 36 Hot Reducing gas        | 43.8251 | 0.000   | 0.00000 |
| 38 Top gas with Fines      | 40.5035 | 0.000   | 0.00000 |
| 40 Top gas from Reactor #2 | 40.5035 | 0.000   | 0.00000 |
| 41 Cooled Top gas          | 40.5035 | 0.000   | 0.00000 |
| 42 Dry Top Gas             | 43.5015 | 0.000   | 0.00000 |
| 43 Recycle gas             | 43.5015 | 0.000   | 0.00000 |
| 44 Bleed                   | 43.5015 | 0.000   | 0.00000 |
| 45 Methane                 | 46.9280 | 0.000   | 0.00000 |
| 46 Cold Reducing Gas       | 43.8251 | 0.000   | 0.00000 |
| 47 Preheated Reducing Gas  | 43.8251 | 0.000   | 0.00000 |