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**APPENDIX**

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# APPENDIX A

## DIAGNOSTIC LEACHING

### A1: DETERMINATION OF SODIUM AND POTASSIUM CHLORIDE

#### Outline and Procedure

Sodium and Potassium chloride are soluble in hot water. The sequence of leaching is to place 10.00 g of the ground dry dust sample in a beaker and add 100 ml of distilled water. Keep at 80-90 °C for 1 hour while stirring. Weigh the filter paper before it was used. Sodium and potassium chloride pass into the filtrate. Allow the residue on the filter paper to dry in the oven at 60 °C for 15 hours. After that weigh the dry residue and filter paper. The weight loss of the residue will give the weight of sodium and potassium chloride. Three control samples were leached under identical conditions.

#### Results

Table A1: Results of Hot Water Leaching.

Run	Weight of EAF Dust (g)		Weight loss of the sample taken (g)	% NaCl+KCl (wt%)
	Before leaching	After leaching		
1	10.00	9.565	0.435	4.35
2	10.00	9.537	0.463	4.63
3	10.00	9.563	0.437	4.37

## Calculation of Percentage of Sodium and Potassium chloride

$$\%NaCl+KCl = w*10$$

where w = weight loss of the sample taken

Mean value of NaCl+KCl percentage equaled to  $(4.35+4.63+4.37)/3 = 4.45\%$

## A2: DETERMINATION OF ZINC OXIDE

### Outline

Zinc oxide is dissolved by dilute sulphuric acid solution. The amount of zinc ferrite and magnetite are then calculated from the remaining zinc and iron values.

### Reagent

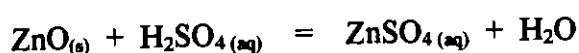
- Sulphuric acid solution containing 2.722 g  $H_2SO_4$  in 100 ml of water

Analytical grade reagent and distilled water were used in all cases.

### Procedure

To 10.00 g of the ground dry dust sample in a beaker add 100 ml of dilute sulphuric acid solution. Keep at 80-90 °C for 1 hour while stirring. Weigh the filter paper before it was used. Zinc sulphate passes into the filtrate. Leave the residue on the filter paper to dry in the oven at 60 °C for 15 hours. After that weigh again. Two control samples were leached under identical conditions.

The reaction involved is :



## Results

**Table A2: Results of Dilute Sulphuric Leaching.**

Run	Weight of EAF Dust (g)		Weight loss of the sample taken (g)	% ZnO (wt%)
	Before leaching	After leaching		
1	10.00	8.564	1.436	7.24
2	10.00	8.344	1.656	8.35

## Calculation of Percentage of Zinc Oxide

$$\% \text{ Zinc Oxide} = [(w * 81.3794) / 161.4436] * 10$$

where w = weight loss of the sample taken

where Molecular weight of ZnO = 81.3794

where Molecular weight of ZnSO<sub>4</sub> = 161.4436

The weight of zinc sulphate was determined from two values. The first value was 1.436 g and the second value was 1.656 g.

$$\begin{aligned} \% \text{ Zinc oxide}_{(1)} &= [(1.436 * 81.3794) / 161.4436] * 10 \\ &= 7.24\% \end{aligned}$$

$$\begin{aligned} \% \text{ Zinc oxide}_{(2)} &= [(1.656 * 81.3794) / 161.4436] * 10 \\ &= 8.35\% \end{aligned}$$

Mean value of zinc oxide percentage equaled to  $(7.24 + 8.35) / 2 = 7.80\%$

## Calculation of Percentage of Zinc Ferrite and Magnetite

In zinc ferrite, one mole of zinc reacts with two moles of iron to form  $ZnO \cdot Fe_2O_3$ .

$$\text{The total zinc in feed dust} = 19.20\%$$

$$\text{The percentage of zinc in zinc oxide} = 7.80\%$$

$$\text{The percentage of zinc in zinc ferrite} = 19.2 - 7.80$$

$$= 11.40\%$$

$$\text{The total percentage of zinc and iron that form zinc ferrite} = 11.40 + 19.48$$

$$= 30.88\%$$

$$\text{The percentage of zinc ferrite} = (30.88 \times 241.10) / 177.07$$

$$= 40.96\%$$

$$[\text{where Molecular weight of zinc ferrite} = 241.10$$

$$\text{and Molecular weight of one mole of zinc plus two moles of iron} = 177.07]$$

$$\text{The total iron in feed dust} = 37.20\%$$

$$\text{The percentage of iron that forms spinel zinc ferrite} = 19.48\%$$

$$\text{The percentage of iron that forms iron oxide} = 37.20 - 19.48$$

$$= 17.72\%$$

$$\text{The percentage of magnetite} = (17.72 \times 231.54) / 167.54$$

$$= 24.49\%$$

$$[\text{where Molecular weight of magnetite} = 231.54$$

$$\text{and Molecular weight of three moles of iron} = 167.54]$$

Hence the concentration of the sodium and potassium chloride, zinc oxide, zinc ferrite and magnetite in the Smorgon Steel works dust are 4.45, 7.80, 40.96 and 24.49 percent by weight respectively.

## APPENDIX B

### IRON ANALYSIS TECHNIQUES

#### B1: WEIGHT DETERMINATION OF METALLIC IRON

##### Outline

The solubility of metallic iron, and insolubility of its oxides in a 2-5% bromine solution in anhydrous ethanol or methanol provides a good procedure for the phase analysis of this metal.

##### Reagents

- Bromine solution
- Methanol

Analytical grade reagents were used in all cases.

##### Procedure

Place 2.0 g of the ground dry dust sample in a beaker and add 50 ml of methanol containing 5% bromine (2.5 ml). Boil for 15 minutes under a covering, cool, filter, and wash thoroughly with methanol. Weigh the filter paper before it was used. Metallic iron passes into the filtrate. Allow the residue on the filter paper to dry in the oven at 60 °C for 15 hours. After that weigh again.



## Calculation of Percent Metallic Iron

$$\% \text{ Metallic Iron} = (w \cdot 100) / 1.98$$

where  $w$  = weight loss of the sample taken

where 1.98 = weight of feed dust that comes from total weight 2.0g. - 1% of bentonite addition ( 2.00-0.02 = 1.98g.)

$$\% \text{ Fractional Reduction} = (\% \text{ Metallic Iron} \cdot 100) / 37.2$$

where 37.2 = percentage of total iron in the feed dust (wt/wt)



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## APPENDIX C

### ZINC ANALYSIS TECHNIQUES

#### C1: WEIGHT DETERMINATION OF VAPORISE ZINC FOR SECOND REDUCTION STAGE IN NITROGEN ATMOSPHERE

##### Outline

The reduction ratio of zinc  $R_{Zn}$  was calculated from the loss of zinc during the experiment. This change in mass was due only to the vaporisation of zinc, and these values could be converted into the percent reduction of zinc oxide.

##### Calculation of Percent Vaporise Zinc

$$\text{Weight of total zinc (z)} = (\text{Before reduction weight} - 1\% \text{ of bentonite addition}) * 19.2/100$$

where 19.2 = percentage of total zinc in the feed dust (wt/wt)

where Before reduction weight = weight of feed dust that comes from total weight minus 1% of bentonite addition

$$\% \text{ Fractional Reduction (\%FR)} = (w * 100) / z$$

where w = weight loss of the sample taken

where z = weight of zinc in that sample

Table C1 shows the sample of the calculation of percent zinc reduction at 900 °C in nitrogen atmosphere.

**Table C1: Sample of the Calculation of Percent Zinc Reduction.**

Conditions:

First stage reduction was at 700 °C,  $p_{CO_2}/p_{CO} = 0.11$ , and reduction time two and a half hours.

Second stage reduction was at 900 °C and varied time for seven hours.

Stage		Sample No			
		F-1 to F-7	F-8 to F-14	Mean	
1 st stage weight(g.)	Before reduction		5.065	5.060	
	After reduction		4.441	4.335	
2 nd stage weight(g.)	0 hr	Sample weight	4.441	4.335	
		w	0	0	
		z	0.963	0.962	
		% FR	0	0	
	1 hr	Sample weight	4.248	4.061	
		w	0.193	0.274	
		z	0.963	0.962	
		% FR	20.04	28.48	
	2 hrs	Sample weight	4.154	3.911	
		w	0.287	0.424	
		z	0.963	0.962	
		% FR	29.8	44.07	
	3 hrs	Sample weight	4.039	3.775	
		w	0.402	0.56	
		z	0.963	0.962	
		% FR	41.74	58.21	
	4 hrs	Sample weight	3.834	3.538	
		w	0.607	0.797	
		z	0.963	0.962	
		% FR	63.03	82.85	
	5 hrs	Sample weight	3.772	3.410	
		w	0.669	0.925	
		z	0.963	0.962	
		% FR	69.47	96.15	
	6 hrs	Sample weight	3.680	3.410	
		w	0.781	0.925	
		z	0.963	0.962	
		% FR	79.02	96.15	
7 hrs	Sample weight	3.680	3.410		
	w	0.781	0.952		
	z	0.963	0.962		
	% FR	79.02	96.15		87.59

Example for calculation at one hour reduction.

$$\begin{aligned}\text{Weight of total zinc (z)} &= (\text{Before reduction weight} - 1\% \text{ of bentonite} \\ &\quad \text{addition}) * 19.2/100 \\ &= (5.065 - 0.01 * 5.065) * 19.2/100 \\ &= 0.963 \text{ g.}\end{aligned}$$

$$\begin{aligned}\% \text{ Fractional Reduction} &= (w * 100) / z \\ &= (0.193 * 100) / 0.963 \\ &= 20.04\%\end{aligned}$$



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## APPENDIX D

### X-RAY DIFFRACTION PATTERNS



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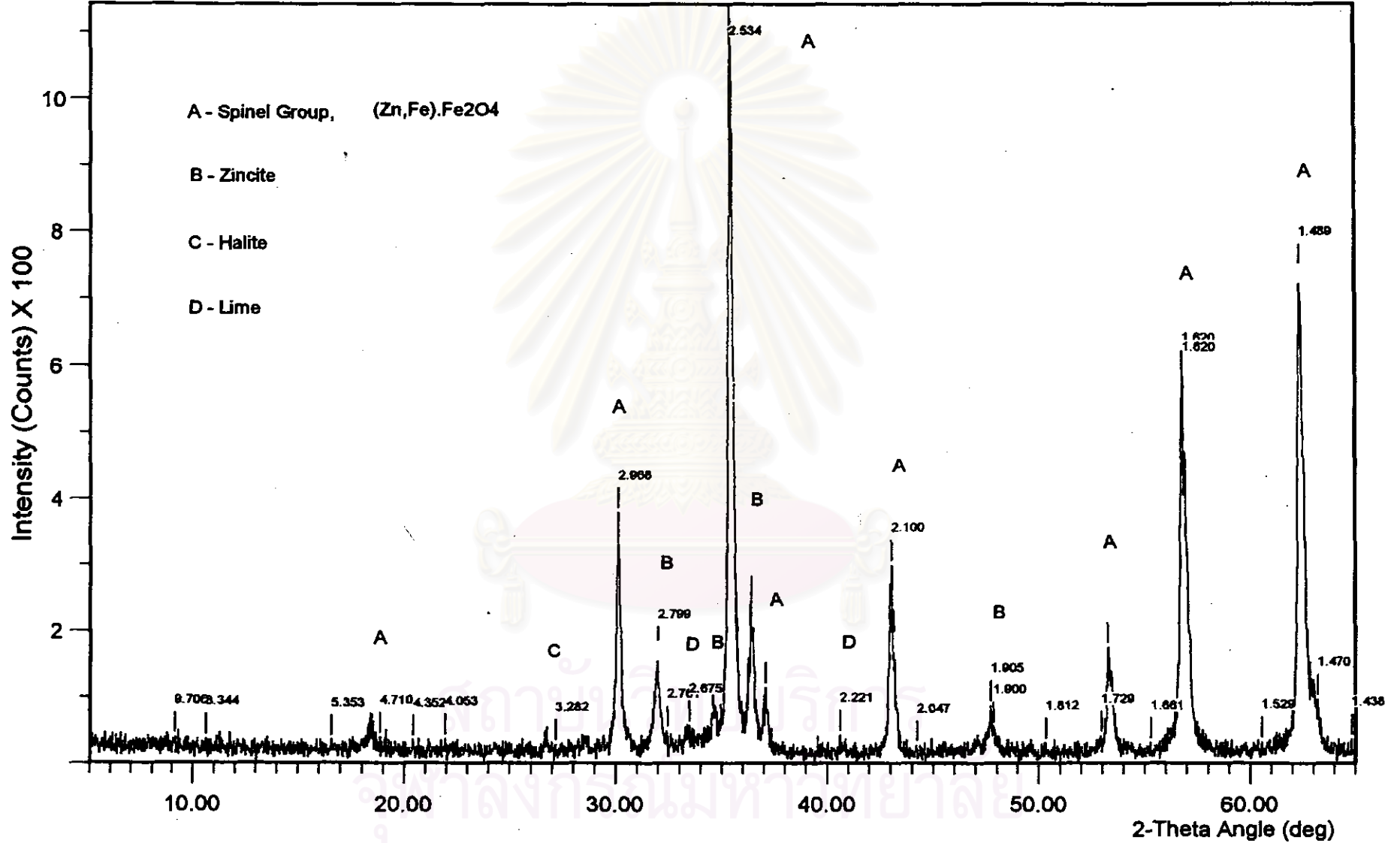


Figure D1: X-ray diffraction patterns of unreacted EAF dust from Smorgon Steel Works.



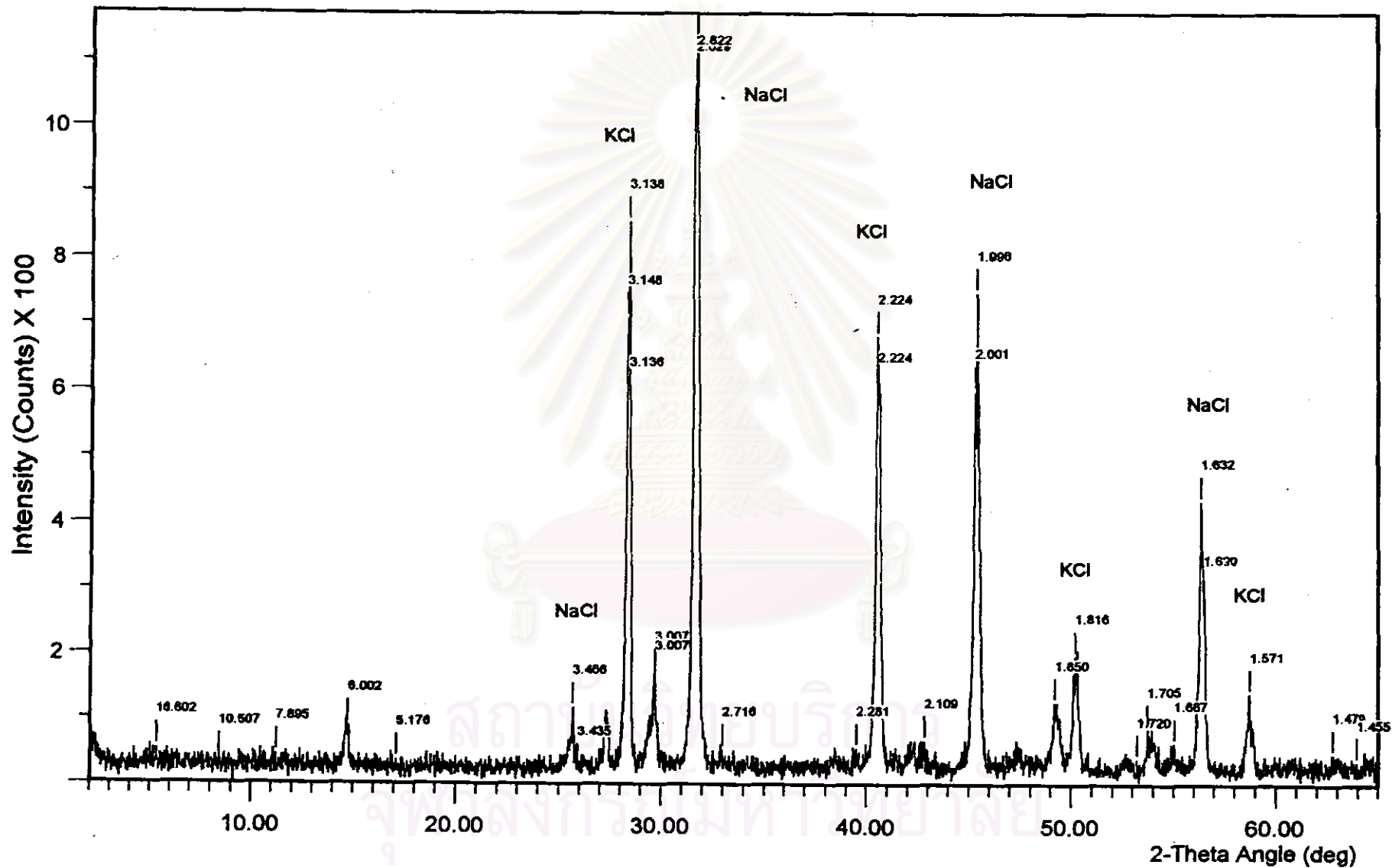


Figure D2: X-ray diffraction patterns of the hot water leached solid residue after evaporation.

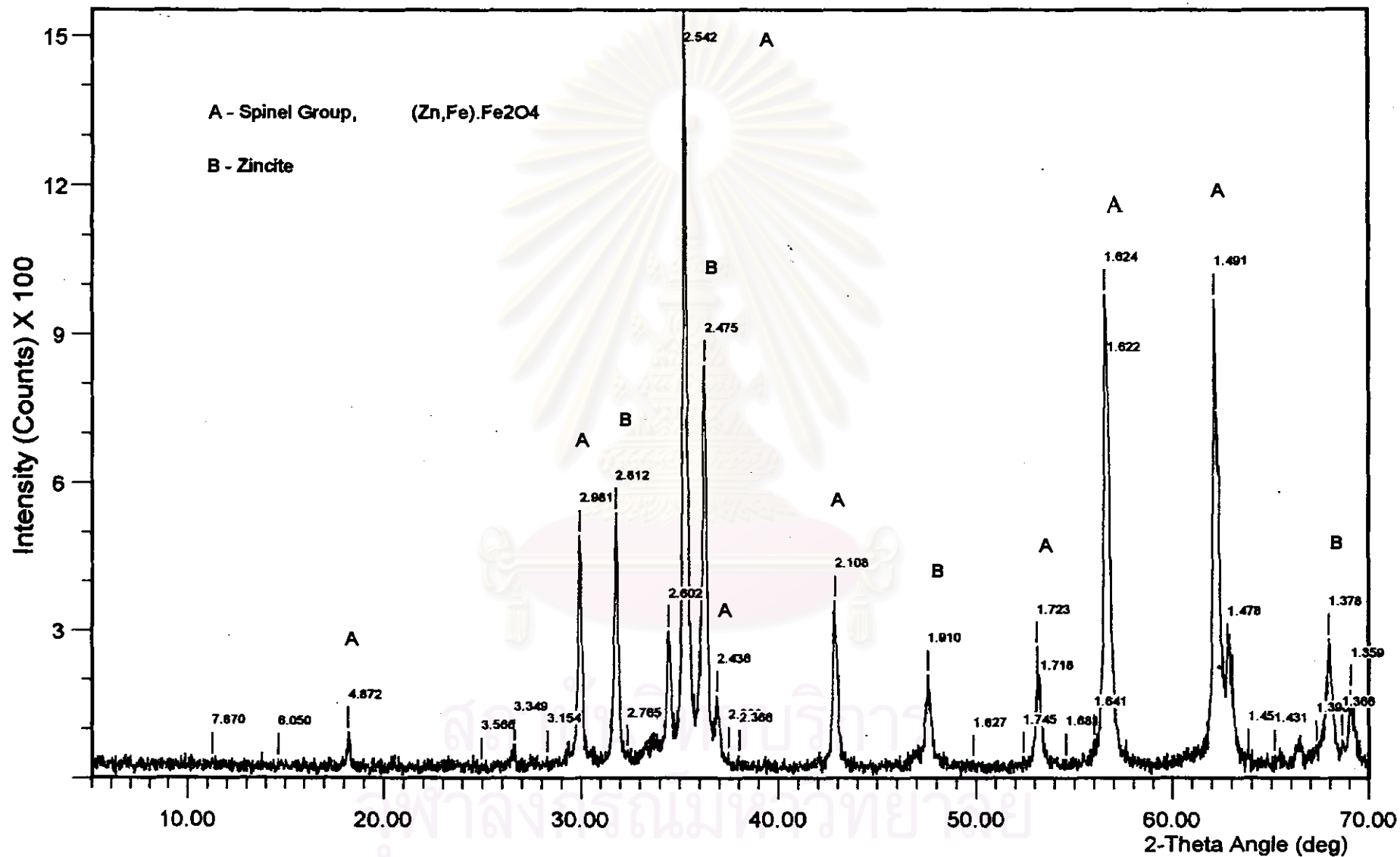


Figure D3: X-ray diffraction patterns of EAF dust after hot water leaching.

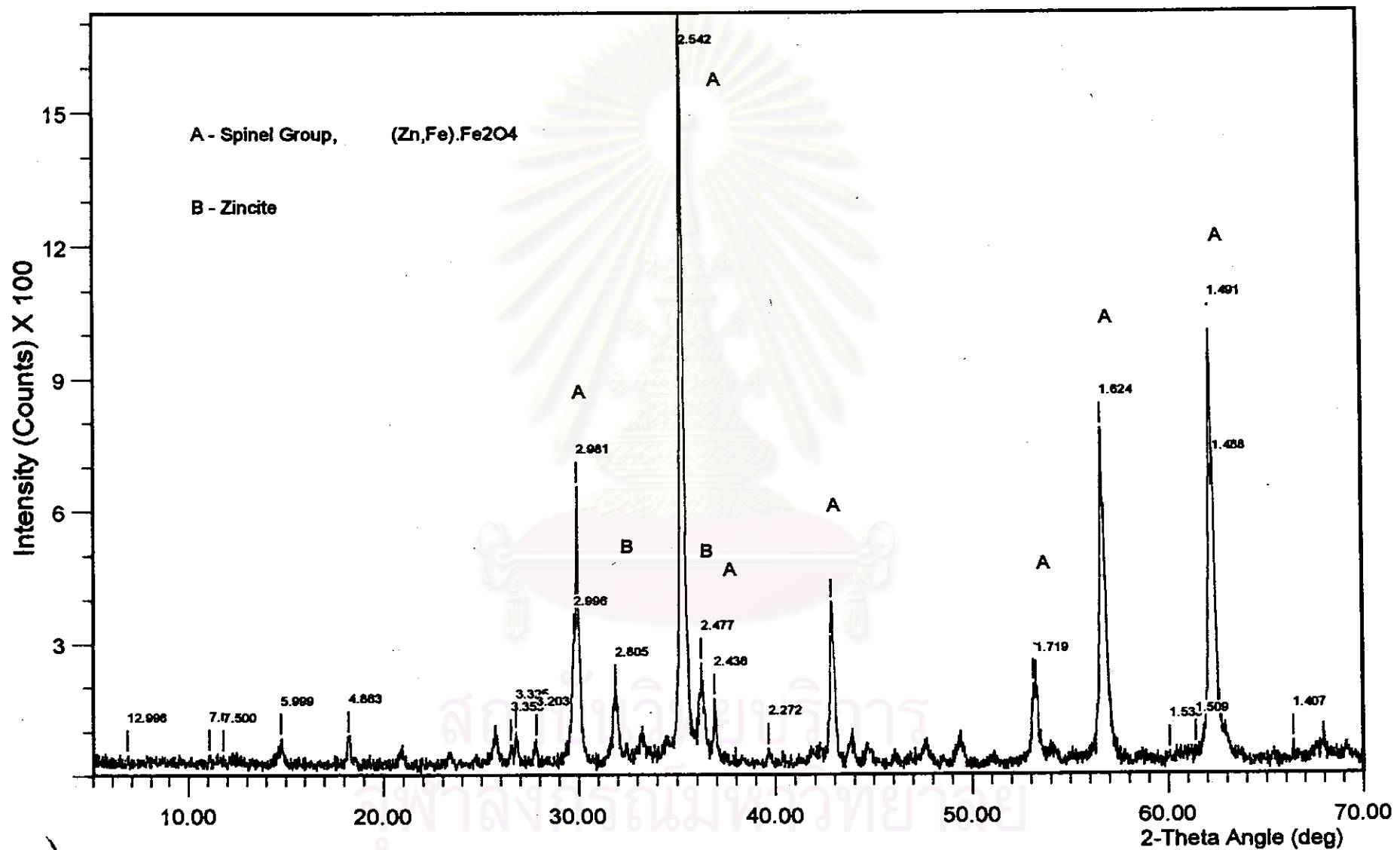


Figure D4: X-ray diffraction patterns of EAF dust after dilute sulphuric acid leaching.

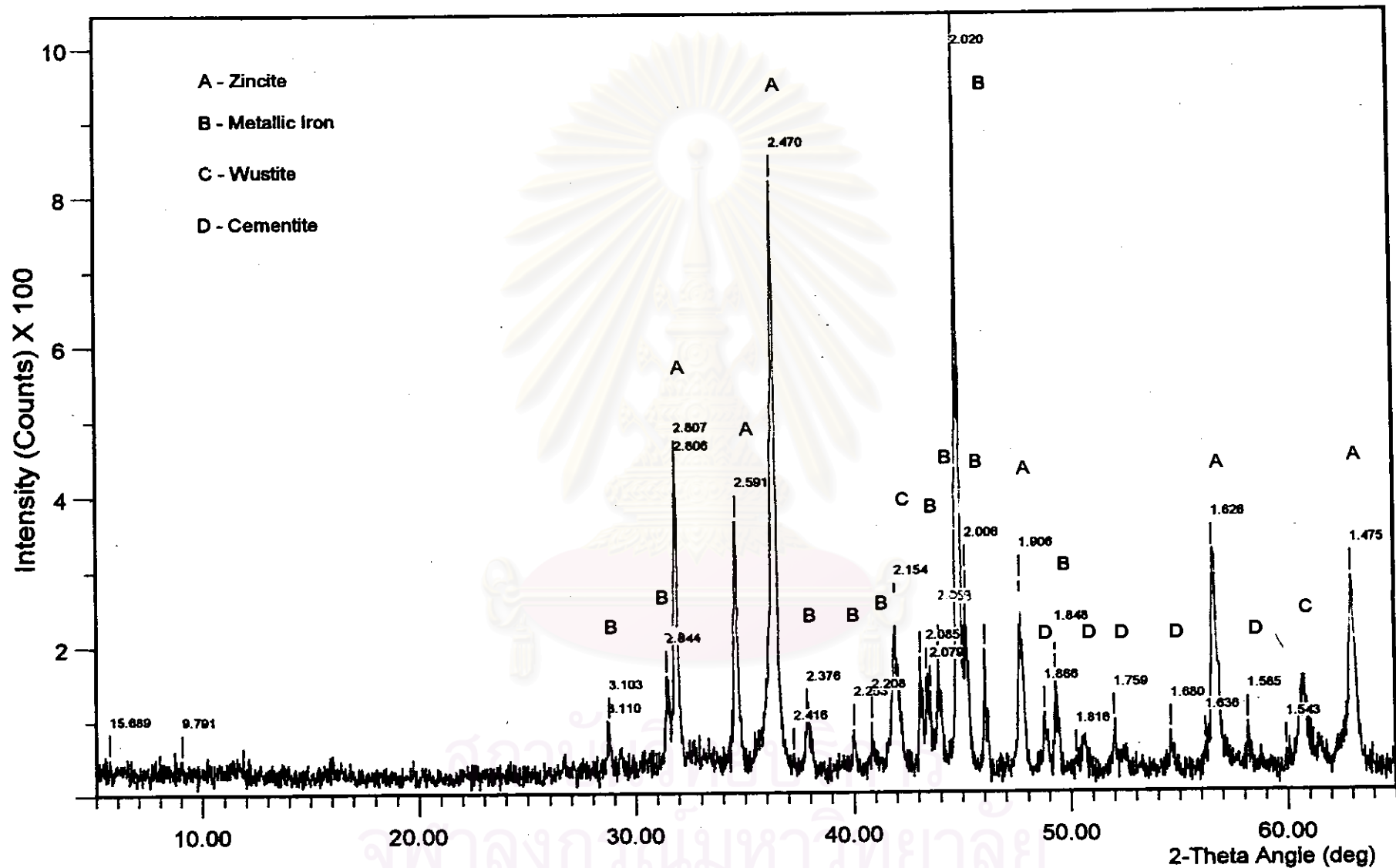


Figure D5: X-ray diffraction patterns of the first reduction stage briquette. The briquette was reduced at 700 °C for two and a half hours and with the CO<sub>2</sub>/CO gas ratio of 0.11 .

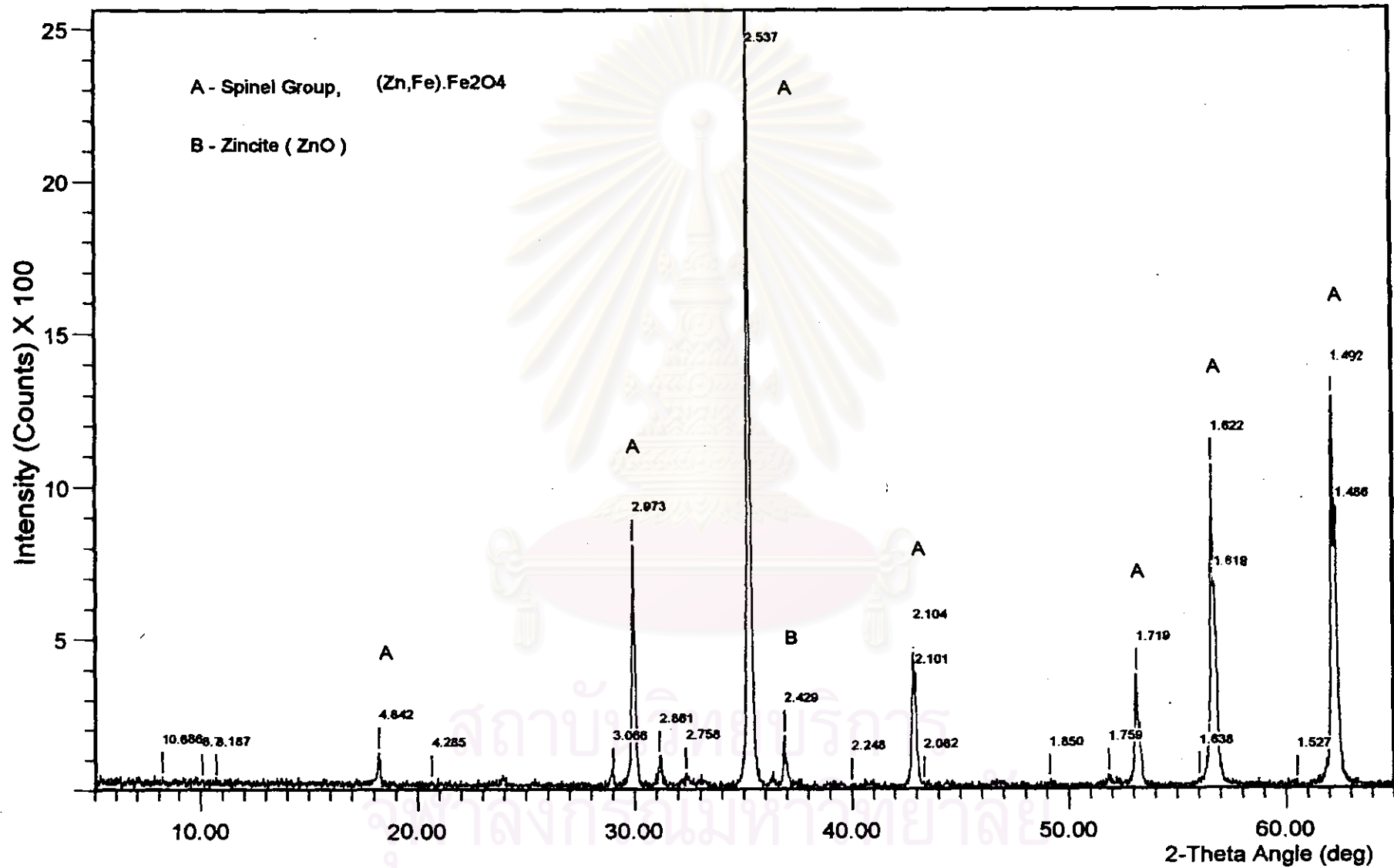


Figure D6: X-ray diffraction patterns of unreacted sintering briquette. The briquette was fired at 1100 °C for 24 hours in muffle furnace.

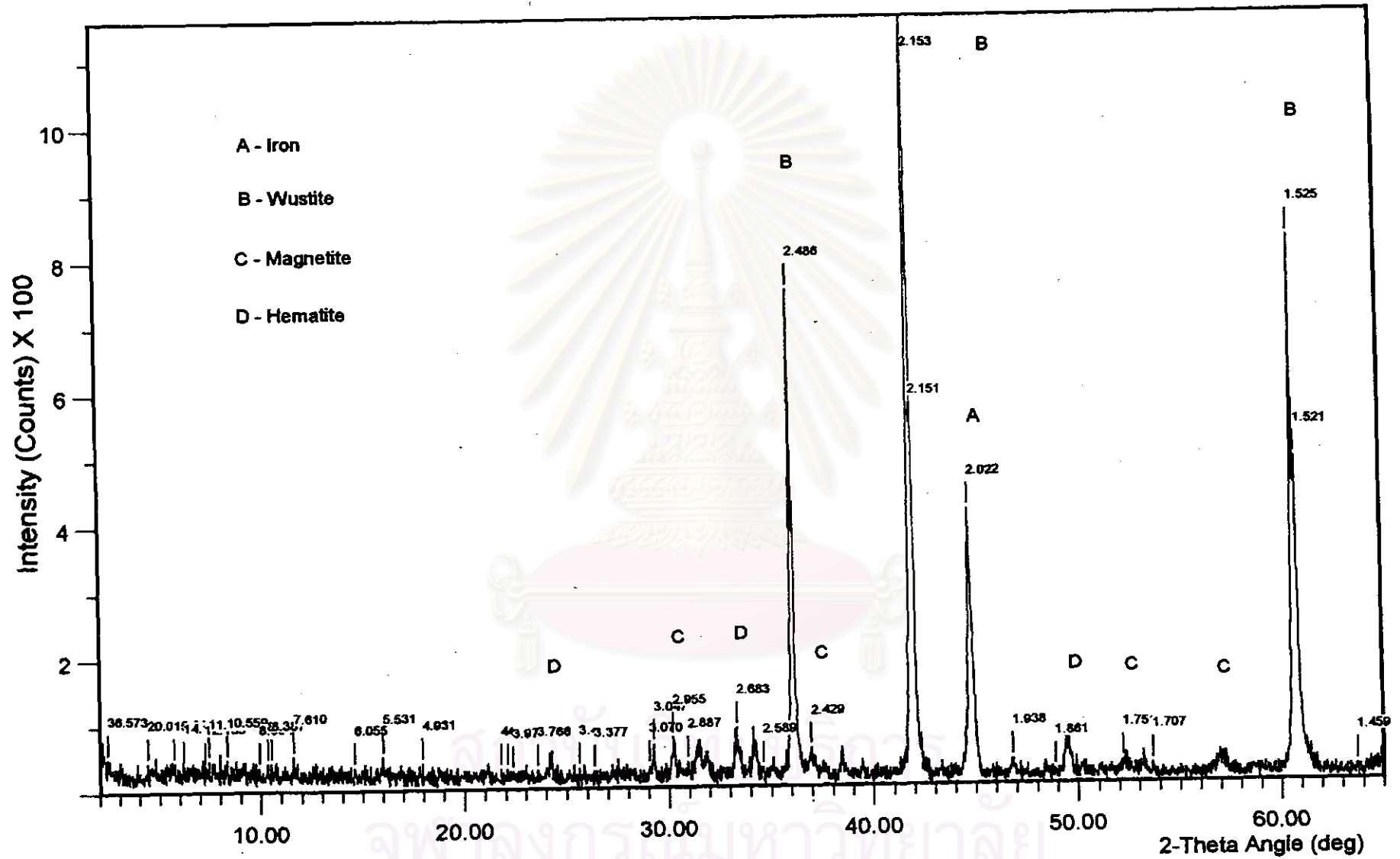


Figure D7: X-ray diffraction patterns of the second reduction stage briquette. The briquette was reduced at 1000 °C for seven hours in a nitrogen atmosphere.



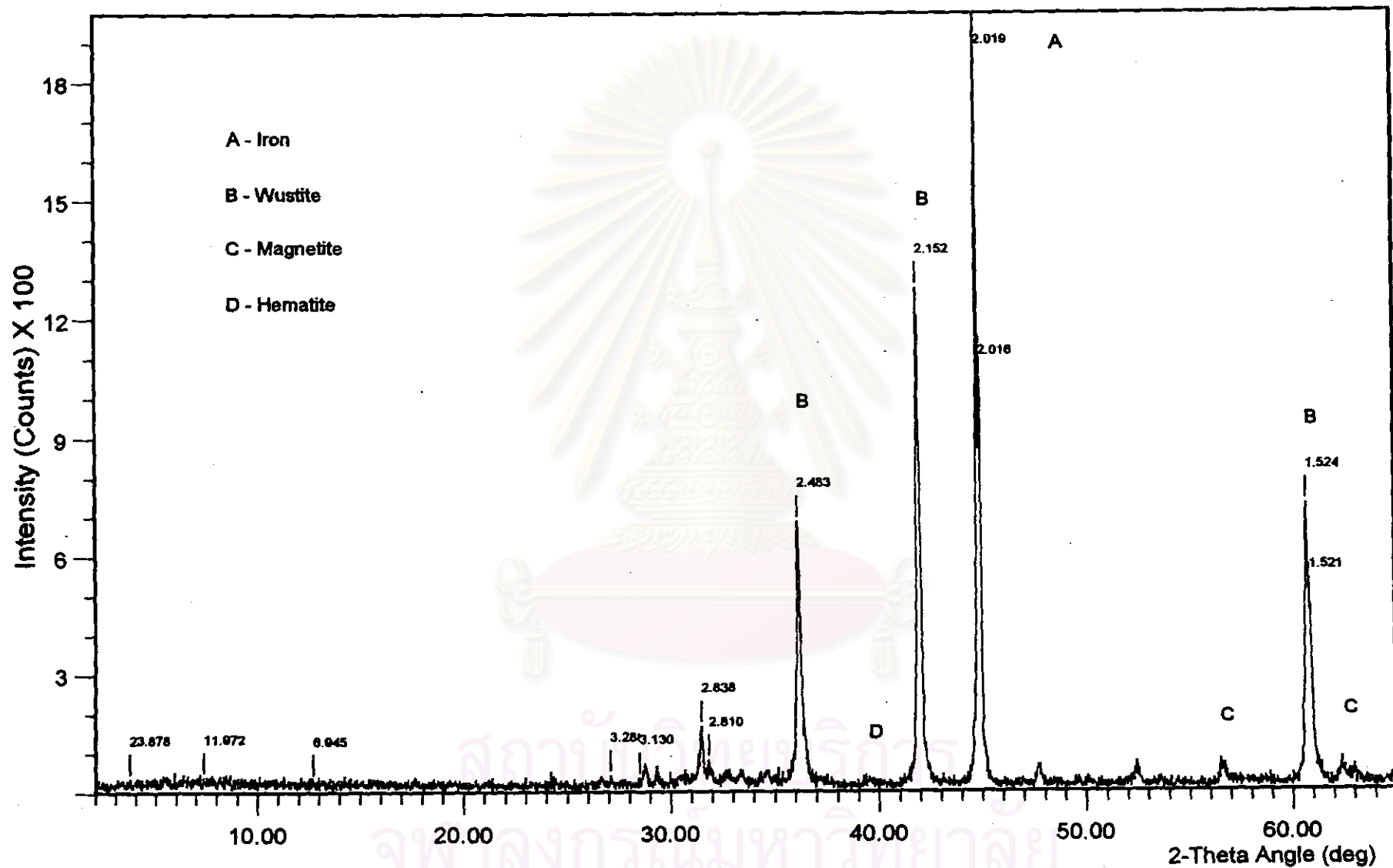


Figure D8: X-ray diffraction patterns of the second reduction stage briquette. The briquette was reduced at 900 °C for eighty minutes under vacuum.

## APPENDIX E

### RESULTS OF THE FIRST REDUCTION STAGE EXPERIMENTS

**Table E1: Results of Experiment A Series.**

Conditions : 600 °C,  $p_{CO}/p_{CO_2} = 9$ , non-sintered briquettes

Runs	Time (hr)	Initial EAF dust mass (g)	After reduction mass (g)	Mass taken for metallic iron analysis (g)	Mass after analysis (g)	Iron fraction reduction (wt%)
A-1	1.5	5.045	4.600	2.000	1.608	53.28
A-2	4.0	5.062	4.594	2.000	1.447	75.00
A-3	6.0	5.057	4.530	2.001	1.353	87.93

**Table E2: Results of Experiment B Series.**

Conditions : 700 °C,  $p_{CO}/p_{CO_2} = 9$ , non-sintered briquettes

Runs	Time (hr)	Initial EAF dust mass (g)	After reduction mass (g)	Mass taken for metallic iron analysis (g)	Mass after analysis (g)	Iron fraction reduction (wt%)
B-1	0.5	5.059	4.523	2.001	1.622	51.43
B-2	1.0	5.041	4.418	2.000	1.480	70.60
B-3	1.5	5.064	4.345	2.001	1.359	87.12
B-4	2.5	5.047	4.282	2.000	1.308	94.00
B-5	4.0	5.043	4.253	2.000	1.307	94.00
B-6	6.0	5.038	4.233	2.000	1.308	94.00

**Table E3: Results of Experiment C Series.**

Conditions : 800 °C,  $p_{CO}/p_{CO_2} = 9$ , non-sintered briquettes

Runs	Time (hr)	Initial EAF dust mass (g)	After reduction mass (g)	Mass taken for metallic iron analysis (g)	Mass after analysis (g)	Iron fraction reduction (wt%)
C-1	0.5	5.034	4.380	2.000	1.657	48.58
C-2	1.0	5.034	4.208	2.000	1.461	73.15
C-3	1.5	5.043	4.018	2.000	1.310	93.77
C-4	2.5	5.040	3.865	2.000	1.298	95.33
C-5	4.0	5.046	3.694	2.000	1.291	96.24
C-6	6.0	5.052	3.603	2.001	1.258	97.00

**Table E4: Results of Experiment D Series.**

Conditions : 700 °C,  $p_{CO}/p_{CO_2} = 3$ , non-sintered briquettes

Runs	Time (hr)	Initial EAF dust mass (g)	After reduction mass (g)	Mass taken for metallic iron analysis (g)	Mass after analysis (g)	Iron fraction reduction (wt%)
D-1	0.5	5.040	4.701	2.001	1.648	47.90
D-2	3.5	5.039	4.600	2.000	1.581	56.89
D-3	5.0	5.065	4.581	2.001	1.495	68.66
D-4	6.0	5.028	4.512	2.000	1.488	69.51

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**Table E5: Results of Experiment E Series.**

Conditions : 700 °C,  $p_{CO}/p_{CO_2} = 9$ , sintered briquettes

Runs	Time (hr)	Initial EAF dust mass (g)	After reduction mass (g)	Mass taken for metallic iron analysis (g)	Mass after analysis (g)	Iron fraction reduction (wt%)
E-1	0.5	4.664	4.429	2.001	1.716	38.67
E-2	1.0	4.688	4.211	2.000	1.449	74.81
E-3	1.5	4.670	4.150	2.001	1.431	77.35
E-4	2.5	4.664	4.110	2.000	1.286	98.94
E-5	4.0	4.660	4.077	2.000	1.298	95.30
E-6	6.0	4.659	4.023	2.000	1.287	98.85



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## APPENDIX F

### RESULTS OF THE SECOND REDUCTION STAGE IN NITROGEN ATMOSPHERE

Initial material obtained from the non-sintering briquettes processed the first reduction stage at 700 °C,  $p_{CO}/p_{CO_2} = 9$  and two and a half hours reduction.

**Table F1: Results of Experiment F Series.**

Operating temperature 900 °C

Runs	First stage		Mass change during second stage (g)							
	Mass before reduction (g)	Mass after reduction (g)	0 hr	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs	7 hrs
F-1 to F-7	5.065	4.441	4.441	4.248	4.154	4.039	3.834	3.772	3.680	3.680
F-8 to F-14	5.080	4.335	4.335	4.061	3.911	3.775	3.538	3.410	3.410	3.410

**Table F2: Results of Experiment G Series.**

Operating temperature 1000 °C

Runs	First stage		Mass change during second stage (g)							
	Mass before reduction (g)	Mass after reduction (g)	0 hr	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	6 hrs	7 hrs
G-1 to G-7	5.046	4.328	4.328	3.653	3.464	3.380	3.369	3.368	3.368	3.368
G-8 to G-14	5.046	4.345	4.345	3.658	3.479	3.397	3.387	3.386	3.386	3.386

**Table F3: Results of Experiment H Series.**

Operating temperature 1100 °C

Runs	First stage		Mass change during second stage (g)					
	Mass before reduction (g)	Mass after reduction (g)	0 hr	30 mins	1 hr	2 hrs	3 hrs	4 hrs
H-1 to H-5	5.049	4.822	4.822	4.122	4.052	3.863	3.862	3.861
H-6 to H-10	5.002	4.384	4.384	3.671	3.585	3.434	3.434	3.433

**Table F4: Results of Experiment I Series.**

Operating temperature 1200 °C

Runs	First stage		Mass change during second stage (g)							
	Mass before reduction (g)	Mass after reduction (g)	0 hr	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	4 hrs
I-1 to I-7	5.037	4.388	4.388	3.683	3.552	3.432	3.431	3.430	3.430	3.430
I-8 to I-14	5.044	4.314	4.314	3.537	3.397	3.356	3.355	3.355	3.354	3.354

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**Table F5: Summary of Results for the Second Reduction Stage in Nitrogen Atmosphere.**

Experimental runs	Zinc fractional reduction (wt%)	Experimental runs	Zinc fractional reduction (wt%)	Zinc fractional reduction (wt%) (mean value)
F-1	20.04	F-8	28.48	24.26
F-2	29.80	F-9	44.07	36.94
F-3	41.74	F-10	58.21	49.98
F-4	63.03	F-11	82.85	72.94
F-5	69.47	F-12	96.15	82.81
F-6	79.02	F-13	96.15	87.59
F-7	79.02	F-14	96.15	87.59
G-1	70.43	G-8	71.63	71.03
G-2	90.09	G-9	90.35	90.22
G-3	98.84	G-10	98.84	98.84
G-4	100.00	G-11	100.00	100.00
G-5	100.00	G-12	100.00	100.00
G-6	100.00	G-13	100.00	100.00
G-7	100.00	G-14	100.00	100.00
H-1	72.88	H-6	74.96	73.92
H-2	80.23	H-7	84.01	82.12
H-3	100.00	H-8	100.00	100.00
H-4	100.00	H-9	100.00	100.00
H-5	100.00	H-10	100.00	100.00
I-1	73.67	I-8	81.02	77.35
I-2	87.36	I-9	95.62	91.49
I-3	100.00	I-10	100.00	100.00
I-4	100.00	I-11	100.00	100.00
I-5	100.00	I-12	100.00	100.00
I-6	100.00	I-13	100.00	100.00
I-7	100.00	I-14	100.00	100.00

The F, G, H and I series were reduced at 900, 1000, 1100 and 1200 °C respectively.

## APPENDIX G

# THE MASS BALANCE CALCULATION FOR ELEMENTAL COMPOSITION OF THE RESIDUES AFTER THE REDUCTION

**Table G1: Elemental Composition (wt%) of the EAF Dust and the Residues after the First and Second Reduction Stage.**

Dust Type	Conditions	Zn	Fe	Cd	Pb	Na	K	Cl	Cr
Feed EAF dust	unreacted	19.20	37.20	0.021	1.52	0.88	0.73	0.93	0.19
1 <sup>st</sup> reduction	CO/CO <sub>2</sub> =9, 700 °C, 2.5 hrs	20.20	40.50	<0.002	1.63	0.93	0.71	1.24	0.21
2 <sup>nd</sup> reduction in N <sub>2</sub> atmosphere	900 °C, 7 hrs	6.66	51.10	<0.002	0.63	N/A	N/A	N/A	N/A
2 <sup>nd</sup> reduction in N <sub>2</sub> atmosphere	1200 °C, 4 hrs	0.63	61.50	<0.002	0.77	0.41	<0.01	<0.01	0.31
2 <sup>nd</sup> reduction in vacuum system	1000 °C, 28 mins	5.56	54.90	<0.002	0.01	0.11	0.02	<0.01	0.28

Table G1 shows the elemental composition (wt%) obtained from the Spectrometer Services PTY.LTD. From this results the calculation of the mass balance is essential for comparing the elemental composition with the feed EAF dust. The calculation was shown as follow :

Feed dust	After first stage (CO/CO <sub>2</sub> =9, 700 °C, 2.5 hrs)	After second stage (N <sub>2</sub> , 1200 °C, 4 hrs)
From 100 g Dust		
Fe    37.20 g	40.50 g	61.50 g
Zn    19.20 g	20.20 g	0.63 g

Assume that have no iron lose during the reduction.

Then calculate the mass balance by based on the feed EAF dust.

Feed dust	After first stage (CO/CO <sub>2</sub> =9, 700 °C, 2.5 hrs)	After second stage (N <sub>2</sub> , 1200 °C, 4 hrs)
100 g →	$(37.20 \cdot 100) / 40.50 = 91.85 \text{ g}$	$(37.20 \cdot 100) / 61.50 = 60.49 \text{ g}$
Fe 37.20 g →	$(40.50 \cdot 91.85) / 100 = 37.20 \text{ g}$	$(60.49 \cdot 61.50) / 100 = 37.20 \text{ g}$
Zn 19.20 g →	$(20.20 \cdot 91.85) / 100 = 18.55 \text{ g}$	$(60.49 \cdot 0.63) / 100 = 0.38 \text{ g}$

For the other elements the same method of the calculation was applied. The results obtained from the mass balance calculation are shown in Table G2.

**Table G2: Elemental Composition (wt%) of the EAF Dust and the Residues after the First and Second Reduction Stage obtained from the Mass Balance Calculation. Basis 100 g feed dust.**

Dust Type	Conditions	Zn	Fe	Cd	Pb	Na	K	Cl	Cr
Feed EAF dust	unreacted	19.20	37.20	0.021	1.52	0.88	0.73	0.93	0.19
1 <sup>st</sup> reduction	CO/CO <sub>2</sub> =9, 700 °C, 2.5 hrs	18.55	37.20	<18 ppm	1.50	0.85	0.85	1.14	0.19
2 <sup>nd</sup> reduction in N <sub>2</sub> atmosphere	900 °C, 7 hrs	4.85	37.20	<18 ppm	0.48	N/A	N/A	N/A	N/A
2 <sup>nd</sup> reduction in N <sub>2</sub> atmosphere	1200 °C, 4 hrs	0.38	37.20	<18 ppm	0.47	0.25	<80 ppm	<80 ppm	0.19
2 <sup>nd</sup> reduction in vacuum system	1000 °C, 28 mins	3.77	37.20	<18 ppm	67 ppm	0.07	0.014	<87 ppm	0.19

From this results found that :

- zinc loss during the first reduction stage was  $19.20 - 18.55 = 0.65$  percent.
- zinc remained in the residue after the second reduction stage in nitrogen was 0.38 percent.
- zinc recovery was  $18.55 - 0.38 = 18.17$  percent.
- percent recovery was  $(18.17 \cdot 100) / 19.20 = 94.64$  percent.
- lead contamination in zinc metal product was varied between 5.5 and 7.6 percent.
- zinc metal purity obtained from the process was 92.3-94.5 percent.

The lead contamination in zinc product can calculate by :

Total zinc and lead product was  $18.17+1.05 = 19.22$  percent( for minimum lead loss).

Therefore 19.22 g of zinc and lead product contained 1.05 g of lead equal to  $(1.05*100)/19.22 = 5.5$  g. and zinc was equal to  $100-5.5 = 94.5$  g.

Total zinc and lead product was  $18.17+1.51 = 19.68$  percent( for maximum lead loss).

Therefore 19.68 g of zinc and lead product contained 1.51 g of lead equal to  $(1.51*100)/19.68 = 7.7$  g. and zinc was equal to  $100-7.7 = 92.3$  g.



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## APPENDIX H

### RESULTS OF THE SECOND REDUCTION STAGE IN VACUUM SYSTEM

During the reduction experiments, the weight loss was determined by the transducer and the data were collected by the LABVIEW software program in computer. The data obtained from the transducer are in the unit of direct current voltage (V DC) which are given in the Table H1, H2 and H3. Table H4 shows the summary results of the second reduction stage under vacuum.



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**Table H1: Results of Experiment J Series.**

Operating temperature 800 °C.

For J1 sample

Mass before reduction in first stage : 5.034 g

Mass after reduction in first stage : 4.301 g

Mass before reduction in second stage : 3.496 g

For J2 sample

Mass before reduction in first stage : 5.037 g

Mass after reduction in first stage : 4.392 g

Mass before reduction in second stage : 3.577 g

Time (min)	Transducer signal recorder data (V DC)	
	J1	J2
0	0.265625	0.253332
8	0.266614	0.254434
16	0.267778	0.255465
24	0.268741	0.256591
32	0.269523	0.257154
40	0.271084	0.258576
48	0.271914	0.259827
56	0.273569	0.261293
64	0.274314	0.261796
72	0.275198	0.263024
80	0.276327	0.264130
88	0.277790	0.265493
96	0.278442	0.266116
104	0.278950	0.267567
112	0.279586	0.267442
120	0.279587	0.267463

**Table H2: Results of Experiment K Series.**

Operating temperature 900 °C.

For K1 sample

Mass before reduction in first stage : 5.043 g

Mass after reduction in first stage : 4.397 g

Mass before reduction in second stage : 3.449 g

For K2 sample

Mass before reduction in first stage : 5.038 g

Mass after reduction in first stage : 4.352 g

Mass before reduction in second stage : 3.403 g

Time (min)	Transducer signal recorder data (V DC)	
	K1	K2
0	0.242735	0.253007
4	0.243507	0.253895
8	0.244395	0.254833
12	0.245594	0.255494
16	0.246333	0.256548
20	0.247110	0.257547
24	0.247759	0.258542
28	0.248697	0.259131
32	0.249882	0.260071
36	0.250656	0.261091
40	0.251443	0.262097
44	0.252510	0.262839
48	0.253398	0.263577
52	0.254519	0.264466
56	0.255165	0.265556
60	0.256025	0.266639
64	0.256976	0.267122
68	0.258029	0.267986
72	0.258741	0.268538
76	0.258787	0.269311
78	0.258935	0.269387
80	0.259148	0.269463
82	0.259148	0.269463



**Table H3: Results of Experiment L Series.**

Operating temperature 1000 °C.

For L1 sample

Mass before reduction in first stage : 5.036 g

Mass after reduction in first stage : 4.300 g

Mass before reduction in second stage : 3.340 g

For L2 sample

Mass before reduction in first stage : 5.039 g

Mass after reduction in first stage : 4.306 g

Mass before reduction in second stage : 3.343 g

Time (min)	Transducer signal recorder data (V DC)	
	L1	L2
0	0.260373	0.252765
2	0.261127	0.253559
4	0.261714	0.254203
6	0.262633	0.254905
8	0.263461	0.256099
10	0.264256	0.256914
12	0.265166	0.257754
14	0.266571	0.258760
16	0.267585	0.259831
18	0.268619	0.261121
20	0.269755	0.261562
22	0.270191	0.262942
24	0.271563	0.263712
26	0.272071	0.264386
28	0.273216	0.265532
30	0.273854	0.266030
32	0.274983	0.267374
34	0.276163	0.268592
36	0.276477	0.268852
38	0.276620	0.269018
40	0.276975	0.269367
42	0.276975	0.269367
44	0.276975	0.269367

**Table H4:** Experimental Results for the Second Reduction Stage under Vacuum.

Time (min)	Zinc fractional reduction (wt%)								
	800 C			900 C			1000 C		
	J1	J2	Mean value for J series	K1	K2	Mean value for K series	L1	L2	Mean value for L series
0	0	0	0	0	0	0	0	0	0
2							4.54	4.78	4.66
4				4.65	5.35	5.00	8.08	8.66	8.37
6							13.61	12.89	13.25
8	5.96	6.64	6.30	10.00	11.00	10.50	16.6	20.08	19.34
10							23.39	24.99	24.19
12				17.22	14.98	16.10	28.87	30.05	29.46
14							37.33	36.11	36.72
16	12.97	12.85	12.91	21.67	21.33	21.50	43.44	42.56	43.00
18							49.67	50.33	50.00
20				26.35	27.65	27.00	56.51	52.99	54.75
22							59.14	61.30	60.22
24	18.77	19.63	19.20	30.26	33.34	31.80	67.40	65.94	66.67
26							70.46	70.00	70.23
28				35.91	36.89	36.40	77.36	76.90	77.13
30							81.2	79.9	80.55
32	23.48	23.02	23.25	43.05	42.55	42.80	88.00	88.00	88.00
34							95.11	95.33	95.22
36				47.71	48.69	48.20	97.00	96.90	96.95
38							97.86	97.90	97.88
40	32.88	31.60	32.24	52.45	54.75	53.60	100	100	100
42							100	100	100
44				58.88	59.22	59.05	100	100	100
48	37.88	39.12	38.50	64.23	63.67	63.95			
52				70.98	69.02	70.00			
56	47.85	47.95	47.90	74.87	75.59	75.23			
60				80.05	82.11	81.08			
64	52.34	50.98	51.66	85.78	85.02	85.40			
68				92.12	90.22	91.17			
72	57.66	58.38	58.02	96.41	93.55	94.98			
76				96.69	98.21	97.45			
78				97.58	98.66	98.12			
80	64.46	65.04	64.75	98.86	99.12	98.99			
82				98.86	99.12	98.99			
88	73.25	73.25	73.25						
96	77.20	77.00	77.10						
104	80.26	85.74	83.00						
112	84.09	84.99	84.54						
120	84.10	85.12	84.62						

# BIOGRAPHY

My name is Miss Sureerat Sukonthanit. I was born on March 22, 1973. I was graduate with a degree of Bachelor of Engineering (Chemical Engineering) from Rangsit University in 1995. After graduation, I worked as a planning engineer for one-year with Zip Metal Works Co., Ltd. whose interests were in electro-plating and finishing business. I have been studying for Master degree at the Faculty of Engineering, Chulalongkorn University in Metallurgical Engineering, since June 1996. In January 1998, I have carried out to work on this thesis as an exchange student at the GK Williams CRC for Extractive Metallurgy, the University of Melbourne, Australia. Nowadays, I serve under the crown as a lecturer at the Department of Materials Engineering, the Faculty of Engineering, Kasetsart University.



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