APPENDIX A

Conversion factor

Given	Result wanted: As received basis	Air dried basis	Dry basis	Dry ash free basis	Dry mineral matter free basis
As received basis	-	$\frac{100-M_{ad}}{100-M_{ar}}$	$\frac{100}{100-M_{ar}}$	$\frac{100}{100-(M_{ad}+A_{ar})}$	$\frac{100}{100-(M_{ar}+MM_{ar})}$
Air dried basis	$\frac{100-M_{ar}}{100-M_{ad}}$	-	$\frac{100}{100-M_{ad}}$	$\frac{100}{100-(M_{ad}+A_{ad})}$	$\frac{100}{100-(M_{ad}+MM_{ad})}$
Dry basis	$\frac{100-M_{ar}}{100}$	$\frac{100-M_{ad}}{100}$	-	$\frac{100}{100-A_d}$	$\frac{100}{100-MM_d}$
Dry ash free basis	$\frac{100-(M_{ar}+A_{ar})}{100}$	$\frac{100-(M_{ad}+A_{ad})}{100}$	$\frac{100-A_d}{100}$	-	$\frac{100-A_d}{100-MM_d}$
Dry mineral matter free basis	$\frac{100-(M_{ar}+MM_{ar})}{100}$	$\frac{100-(M_{ad}+MM_{ad})}{100}$	$\frac{100-MM_d}{100}$	$\frac{100-MM_d}{100-A_d}$	-

M = moisture (%)
A = ash (%)
MM = mineral matter (%)
ad = air dried basis
ar = as received basis
d = dry basis

Figure A.1 Conversion formula for calculation of different bases results (Thomas, 1992; ASTM D3180-07)

Appendix B

SEM, EDS, XRD results

B.1 The results of raw coals

B.1.1 Surface morphology from SEM

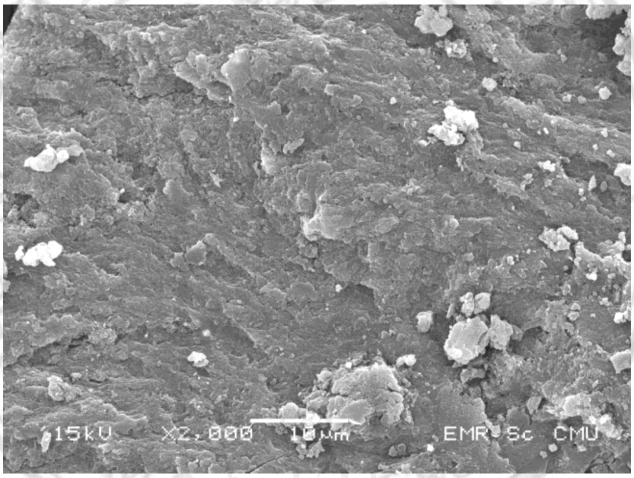

Figure B.1 Surface morphology of C1 lignite

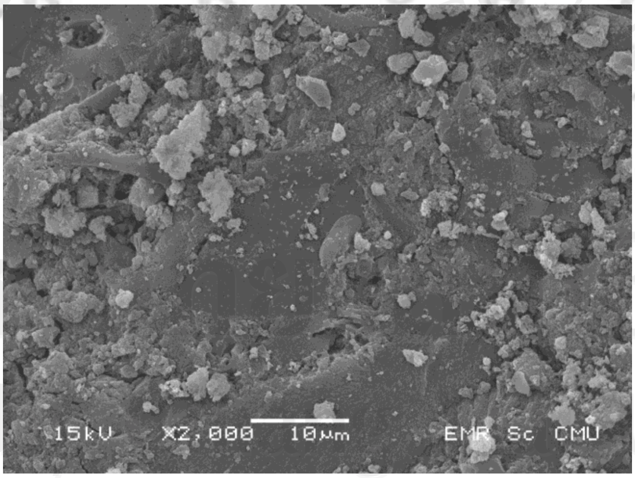

Figure B.2 Surface morphology of SE lignite

B.1.2 Element compositions from EDS

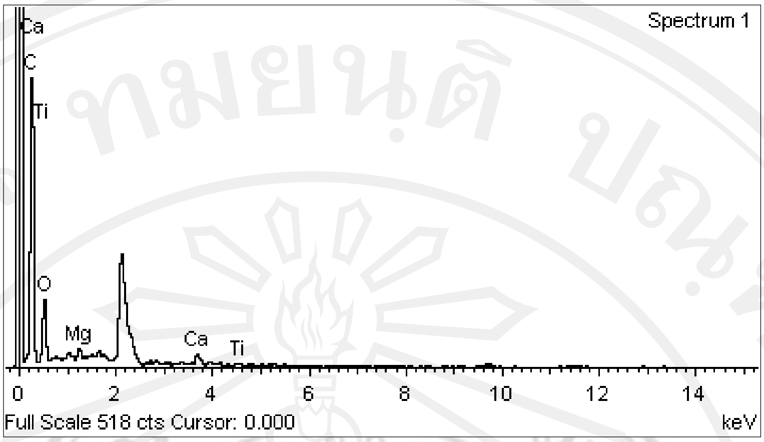

Figure B.3 Graph pattern of C1 lignite

Table B.1 Element compositions of the C1 lignite

Element	C	O	Mg	Ca	Ti
weight	60.72	34.52	1.29	2.48	0.99

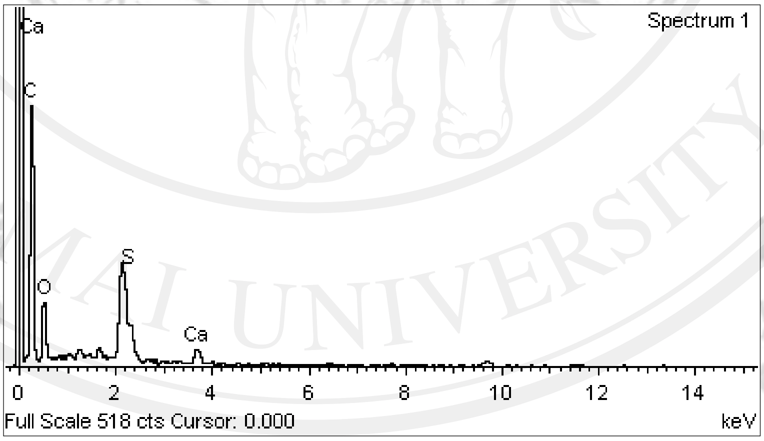

Figure B.4 Graph pattern of SE lignite

Table B.2 Element compositions of the SE lignite

Element	C	O	Mg	Ca
weight	60.97	33.11	1.50	4.42

B.1.3 Mineral compositions from XRD

1) Lignite C1

Match! Phase Analysis Report

Sample: Powder

Sample Data

Filename	q4c1.raw
File path	d:\phd-phrae [pc]\ผลวิเคราะห์ xrd\lignite&standard ash 29-08-12\
Data collected	29/8/2012 15:57:48
Data range	9.990ฐ to 79.995ฐ
Number of points	4668
Step size	0.015
Alpha2 subtracted	No
Background subtr.	No
Data smoothed	Yes
2theta correction	-0.01°
Radiation	Cu-Ka1
Wavelength	1.540562 Å

Candidates

Name	*Formula*	*Entry No.*	*FoM*
Cs6[(UO2)(MoO4)4])	Cs6 Mo4 O18 U	96-900-4674	0.939241
Chabourneite)	As19 Pb4 S68 Sb21 Tl8	96-901-1430	0.938386
Anorthite)	Al2 Ca O8 Si2	96-900-0362	0.936723
Dadsonite)	Cl Pb21.994 S60 Sb26.006	96-901-0613	0.936423
(NH4)2[(UO2)6(MoO4)7(H2O)2])	H4 Mo7 N3 O42 U6	96-900-4625	0.936067
Vandendriesscheite)	H33 O48 Pb2 U10	96-900-1892	0.935067
Anorthite)	Al2 Ca O8 Si2	96-900-1259	0.935008
Anorthite)	Al2 Ca O8 Si2	96-900-1260	0.934933
Paderaite)	Ag0.2 Bi11.34 Cu7.09 Pb1.37 S22	96-900-4985	0.934483
Eclarite)	Bi11.4 Cu0.6 Fe0.4 Pb9 S28 Sb0.6	96-901-1961	0.933018
Andorite VI)	Ag Pb S6 Sb3	96-900-8386	0.932640
Tl2[(UO2)2O(MoO5)])	Mo2 O20 Tl4 U4	96-900-4797	0.932590
Rebulite)	As8.55 S22 Sb4.45 Tl5	96-900-8304	0.932587
K5[(UO2)10O8(OH)9](H2O))	H11 K5 O38 U10	96-900-4552	0.932527
Anorthite)	Al2 Ca O8 Si2	96-900-0363	0.932512
Bergenite)	Ba3.694 Ca2.306 H32 O64 P6 U9	96-900-4736	0.932312
C12H28N(RuCl4(C7H5N)2))	C64 Cl4 N6 Ru	96-900-7866	0.931899
Vonbezingite)	Ca6 Cu3 O26 S3	96-900-1506	0.931127
Dadsonite)	Cl0.5 Pb10.57 S30 Sb13.43	96-901-0614	0.930941
Kobellite)	Bi7.89 Cu0.888 Fe1.112 Pb12 S35 Sb6.11	96-901-1584	0.930702
Metaschoepite)	H34 Na0.48 O37.91 U8	96-901-0195	0.930533
Metaschoepite)	H34 Na0.47 O37.082 U8	96-901-0199	0.930414
Paderaite)	Ag Bi12 Cu5.9 Pb S22	96-900-4187	0.930302
Kornelite)	Fe2 H15.34 O19.25 S3	96-900-0314	0.929566
Bytownite)	Al7.76 Ca3.44 Na0.56 O32 Si8.24	96-901-1202	0.929401
Metaschoepite)	H32 Na1.09 O38.328 U8	96-901-0196	0.929188
Antigorite)	H62 Mg48 O147 Si34	96-900-4515	0.929059
Analcime)	Al1.806 H4 Na1.71 O14 Si4.194	96-900-4015	0.928912
Pierrotite)	As2 S8 Sb3 Tl	96-901-1448	0.928624
Ramdohrite)	Ag1.5 Pb3 S12 Sb5.5	96-901-1731	0.928299
Bementite)	Mn6.683 O23 Si6	96-900-1585	0.928279
Pellouxite)	Ag0.26 Cl0.5 Cu0.68 O0.5 Pb10.44 S27.5 Sb11.56	96-900-5692	0.928106
Steropesite)	Bi Br0.558 Cl5.322 Tl3	96-901-3383	0.927990
Schoepite)	H18 O21 U4	96-900-4445	0.927943
Metaschoepite)	H34 O40 U8	96-901-1299	0.927917
Cs2Cr3O10)	Cr3 Cs2 O10	96-900-7958	0.927672
Paderaite)	Bi11.34 Cu7.32 Pb1.34 S22	96-900-4986	0.927643
Liveingite)	As13 Pb9 S28	96-901-1048	0.927589
Metaschoepite)	H34 Na1.16 O37.9 U8	96-901-0198	0.927525
Tinaksite)	Ca2 H K2 Na O20 Si7 Ti	96-900-7637	0.927473
Cs2[(UO2)(MoO4)2](H2O))	Cs2 H2 Mo2 O11 U	96-900-4910	0.927400
Na2[(UO2)(MoO4)2](H2O)4)	H6 Mo2 Na2 O14 U	96-900-4766	0.927391
Cs2[(UO2)(PO4)]2(H2O)5)	Cs2 H10 O17 P2 U2	96-900-4861	0.927317
Selenium)	Se	96-901-2105	0.927273
Cs2[(UO2)6(MoO4)7(H2O)2])	Cs3 H4 Mo7 O42 U6	96-900-4624	0.927103
Analcime)	Al1.806 H4 Na1.71 O14 Si4.194	96-900-4014	0.927094
Devilline)	Ca Cu4 H12 O17 S2	96-900-7551	0.926952
Sulfur)	S	96-901-2334	0.926919

(Jordanite)	As6 Pb13.88 S23	96-900-8239	0.926387
(Richetite)	Fe0.47 H24 Mg0.83 O173 Pb8.74 U36	96-900-4468	0.926266
(Wyartite)	C H15 Ca O19 U3	96-900-2233	0.926184

and 150 others...

Search-Match

Settings

Profile data used	No
Automatic zeropoint adaptation	Yes
Minimum figure-of-merit (FoM)	0.60
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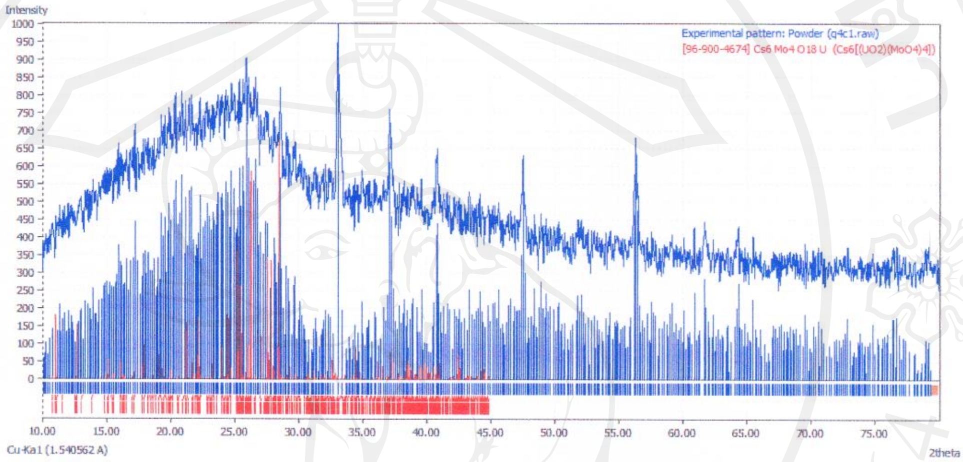
Parameter/influence intensities	0.50
Parameter multiple/single phase(s)	0.50

Diffraction Pattern Graphics



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2) Lignite SE

Match! Phase Analysis Report

Sample: Powder

Sample Data

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Data range	9.930ฐ to 79.935ฐ
Number of points	4668
Step size	0.015
Alpha2 subtracted	No
Background subtr.	No
Data smoothed	Yes
2theta correction	-0.07°
Radiation	Cu-Ka1
Wavelength	1.540562 Å

Candidates

Name	*Formula*	*Entry No.*	*FoM*
(Cs2ThSi6O15)	Cs2 O15 Si6 Th	96-900-7985	0.933658
(Fluorthalenite-(Y))	F O10 Si3 Y3	96-901-2350	0.932986
(Roubaultite)	C2 H10 Cu2 O20 U3	96-901-1355	0.931853
(Marthozite)	Cu H16 O22 Se2 U3	96-900-4630	0.931635
(K2C6H11O9P(H2O)5)	C6 H10 K2 O14 P	96-900-7857	0.930234
(Minasragrite)	H10 O10 S V	96-901-1210	0.929649
(RbMn6(As2O7)2(As3O10))	As7 Mn6 O24 Rb	96-900-7970	0.929099
(Melanterite)	Fe H14 O11 S	96-900-7896	0.928508
(Li3B7O12)	B7 Li3 O12	96-900-7832	0.928132
(Eakerite)	Al2 Ca2 H6 O22 Si6 Sn	96-900-0519	0.927951
(Penobsquisite)	B9 Ca2 Cl Fe H15 O23	96-900-4427	0.927792
(Fluckite)	As2 Ca H6 Mn O10	96-900-9708	0.927442
(Melanterite)	D13.16 Fe H0.84 O11 S	96-901-0625	0.927285
(Thalenite-(Y))	Al0.15 Fe0.15 H O11 Si2.85 Y2.85	96-901-1893	0.927262
(Brewsterite-Ba)	Al2.1 Ba0.9 H9.3 K0.02 Mg0.04 Na0.035 O20.88 Si5.9	96-900-5136	0.927118
(Kernite)	B4 Na2 O11	96-900-0291	0.927004
(Fe7(AsO4)6)	As6 Fe7 O24	96-900-7983	0.926868
(Brewsterite-Sr)	Al2 Ba0.24 H10 K0.01 O21 Si6 Sr0.71	96-900-7623	0.926789
(Brewsterite-Sr)	Al2 Ba0.24 H9.667 K0.01 O21 Si6 Sr0.71	96-901-1177	0.926789
(Ca4(PO4)2O)	Ca4 O9 P2	96-901-1145	0.926728
(Palygorskite)	Al Mg O10.4 Si4	96-901-0434	0.926723
(Sulfur)	S	96-901-2783	0.926687
(Rosickyite)	S	96-901-2782	0.926687
(Krautite)	As H2 Mn O5	96-900-0741	0.926526
(Na3AsO3S.12H2O)	As Na3 O15 S	96-900-7766	0.926497
(Vajdakite)	As H3 Mo O6	96-900-2782	0.926381
(Kernite)	B4 H8 Na2 O11	96-900-0292	0.926358
(Pb4O(VO4)2)	O9 Pb4 V2	96-900-4785	0.926048
(Brewsterite-Sr)	Al1.98 Ba0.3 Ca0.14 H8 O20.9 Si6.02 Sr0.58	96-900-7480	0.925991
(Tuzlaite)	B5 Ca H8 Na O13	96-900-1611	0.925787
(Na6[(UO2)2O(MoO4)4])	Mo4 Na6 O21 U2	96-900-4621	0.925731
(Na3Tl5[(UO2)(MoO4)2]2(H2O)3)	H4 Mo3 Na1.5 O15.5 Tl2.5 U	96-900-4765	0.925202
(Melanterite)	Fe H14 O11 S	96-900-7483	0.924937
(Ankinovichite)	Al4 H16 Ni0.72 O20 V1.88 Zn0.28	96-901-2778	0.924918
(Wyartite)	C H15 Ca O19 U3	96-900-2233	0.924797
(Metaschoepite)	H34 O40 U8	96-901-1299	0.924535
(Preisingerite)	As2 Bi3 O10	96-900-0855	0.924443
(Chalconatronite)	C2 H2 Cu Na2 O9	96-900-8273	0.923966
(Rossite)	Ca O10 V2	96-900-4063	0.923261
(Ferrowyllieite)	Al1.5 Ca0.5 Fe4 Mg0.5 Mn0.5 Na2.31 O24 P6	96-900-0389	0.923089
(Khademite)	Al F H10 O9 S	96-900-9710	0.922816
(Bultfonteinite)	Ca2 F H3 O5 Si	96-900-7475	0.922747
(Inyoite)	B3 Ca H13 O12	96-900-7448	0.922551
(Inyoite)	B3 Ca H13 O12	96-901-1033	0.922551
(As2(SO4)3)	As2 O12 S3	96-901-1231	0.922538
(Wicksite)	Al0.18 Ca2 Fe4.24 H4 Mg0.96 Mn0.6 Na O26 P6	96-900-4456	0.922501
(2(H3AsO4).H2O)	As2 H8 O9	96-900-7505	0.922183
(Na2Si2O5)	Na2 O5 Si2	96-900-7073	0.922146

(NaFe2(PO4)2(OH)*2H2O)	Fe2 H5 Na O11 P2	96-900-8006	0.922102
(Cr(HP2O7)(NH3)3(H2O).2H2O)	Cr H18 N3 O9 P2	96-900-7775	0.921967
(Goosecreekite)	Al2 Ca H5 O16 Si6	96-900-1041	0.921851

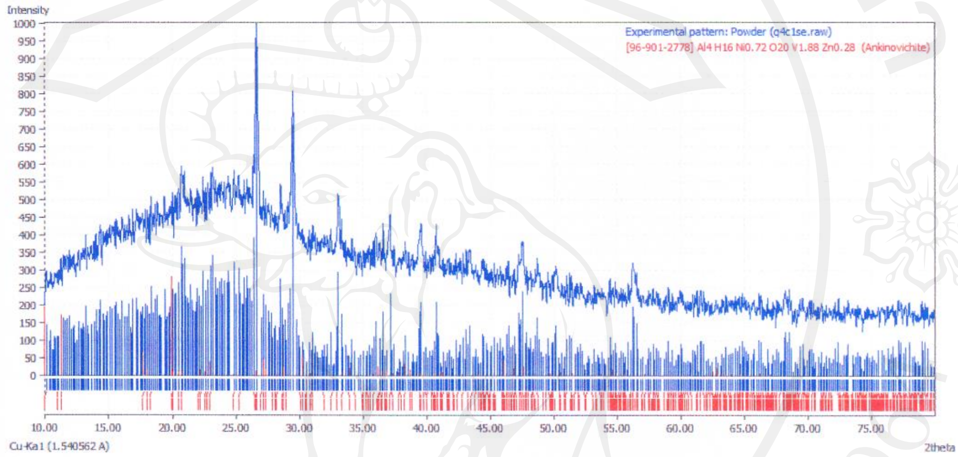
and 150 others...

Search-Match

Settings

Profile data used	Yes
Automatic zeropoint adaptation	Yes
Minimum figure-of-merit (FoM)	0.60
Parameter/influence 2theta	0.50
Parameter/influence intensities	0.50
Parameter multiple/single phase(s)	0.50

Diffraction Pattern Graphics



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B.2 The results of real slags

B.2.1 Element compositions from EDS

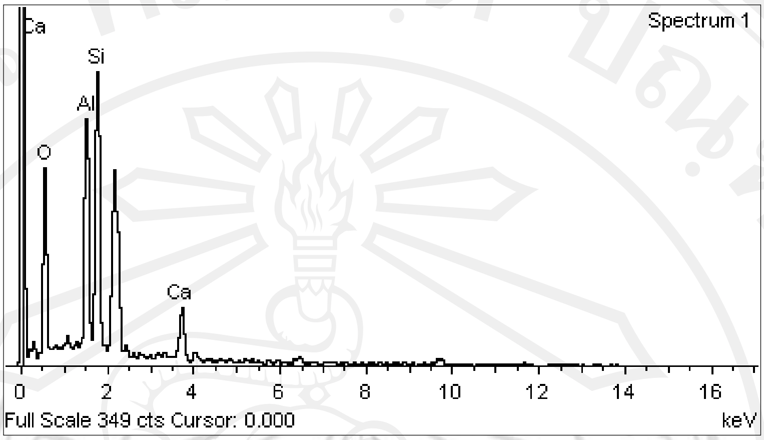


Figure B.5 Graph pattern of slag a

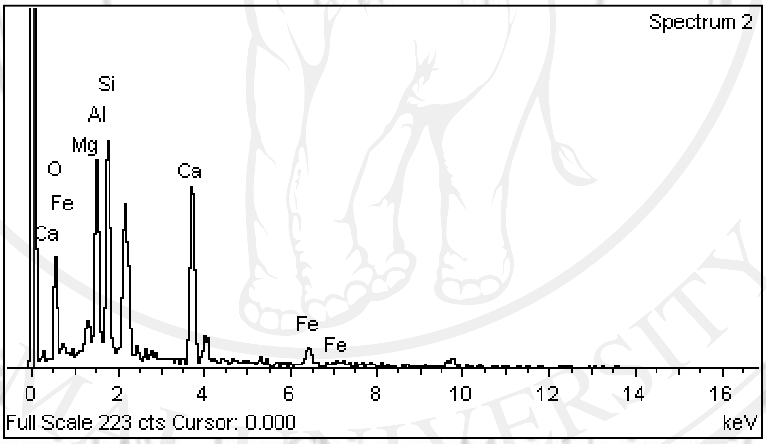


Figure B.6 Graph pattern of slag b

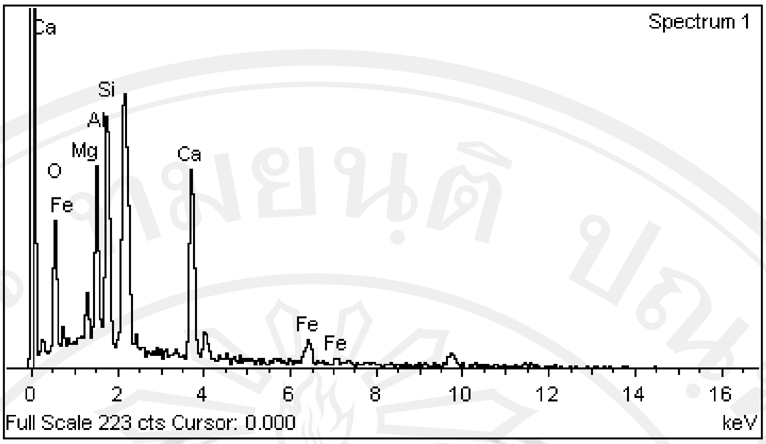


Figure B.7 Graph pattern of slag c

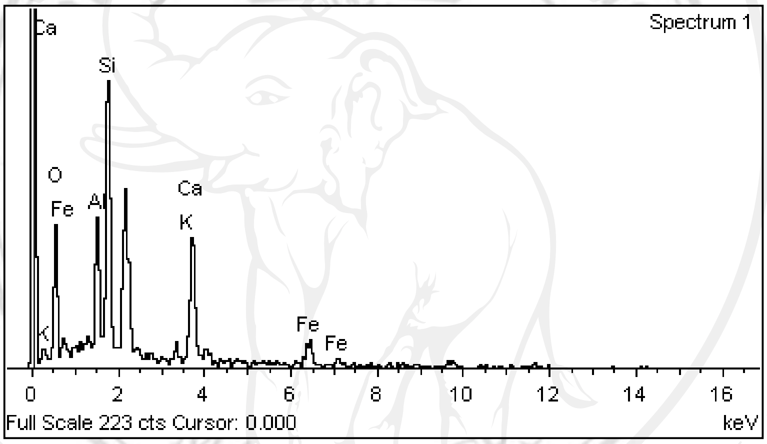


Figure B.8 Graph pattern of slag d

B.2.2 Mineral compositions from XRD

1) Slag a

Match! Phase Analysis Report

Sample: no-1

Sample Data

Filename	no-1.uxd
File path	d:\pakamon\phd-phrae\ผลวิเคราะห์ xrd\
Data collected	
Data range	2.160ǥ to 80.160ǥ
Number of points	1950
Step size	0.040
Alpha2 subtracted	Yes
Background subtr.	No
Data smoothed	Yes
2theta correction	0.16°
Radiation	Cu-Ka
Wavelength	1.541874 Å

Matched Phases

A: (Anorthite)

Formula	Al2 Ca O8 Si2
Entry number	96-900-1259
Figure-of-Merit (FoM)	0.854150
Total number of peaks	500
Peaks in range	500
Peaks matched	409
Intensity scale factor	0.51
Quant. (weight %)	100.00

Candidates

Name	*Formula*	*Entry No.*	*FoM*
(Becquerelite)	Ca H22 O30 U6	96-900-2701	0.880553
(Pb4O(VO4)2)	O9 Pb4 V2	96-900-4785	0.879225
(Metaschoepite)	H32 Na1.09 O38.328 U8	96-901-0196	0.879057
(Metaschoepite)	H34 Na0.48 O37.91 U8	96-901-0195	0.878489
(Metaschoepite)	H34 Na1.16 O37.9 U8	96-901-0198	0.876709
(Metaschoepite)	H34 Na0.47 O37.082 U8	96-901-0199	0.875673
(Metaschoepite)	H34 O40 U8	96-901-1299	0.875216
(Albite)	Al Na O8 Si3	96-900-0703	0.874987
(Albite)	Al Na O8 Si3	96-900-0526	0.874780
(Becquerelite)	Ca H22 O30 U6	96-901-2088	0.874639
(KAlGeO4)	Al Ge K O4	96-901-1775	0.873954
(Metaschoepite)	H32 Na1.22 O39.09 U8	96-901-0197	0.873722
(Oligoclase)	Al1.277 Ca0.277 Na0.723 O8 Si2.723	96-901-1424	0.872932
(Albite)	Al Na O8 Si3	96-900-0529	0.872443
(Marthozite)	Cu H16 O22 Se2 U3	96-900-4630	0.871235
(Labradorite)	Al0.824 Ca0.325 Na0.175 O4 Si1.174	96-900-0748	0.871206
(Billietite)	Ba H6 O30 U6	96-901-0600	0.871019
(Labradorite)	Al0.83 Ca0.34 Na0.15 O4 Si1.17	96-900-0750	0.870906
(Labradorite)	Al0.81 Ca0.325 Na0.16 O4 Si1.19	96-900-0745	0.870666
(Labradorite)	Al0.81 Ca0.325 Na0.16 O4 Si1.19	96-900-0746	0.870408
(Labradorite)	Al0.824 Ca0.317 Na0.183 O4 Si1.174	96-900-0747	0.870023
(Anorthite)	Al2 Ca O8 Si2	96-900-1174	0.869685
(RbMn6(As2O7)2(As3O10))	As7 Mn6 O24 Rb	96-900-7970	0.869369
(Fourmarierite)	H10 O19 Pb U4	96-900-4592	0.867979
(Anorthite)	Al2 Ca O8 Si2	96-900-1260	0.867871
(Bytownite)	Al7.76 Ca3.44 Na0.56 O32 Si8.24	96-901-1202	0.867199
(Compreignacite)	H12.62 K2.04 O28.84 U6	96-900-4487	0.866767
(K4(CrO4)(NO3)2)	Cr K4 N2 O10	96-900-7929	0.866004
(Ca.2Sr.8Al2Si2O8)	Al2 Ca0.2 O8 Si2 Sr0.8	96-901-0291	0.866003
(Farneseite)	Al21 Ca4.26 Cl0.24 F0.078 H10 K4.59 Na17.826 O111.512 S5.366 Si21	96-901-0734	0.865474
(Albite)	Ga1.001 Na O8 Si2.999	96-900-1314	0.864852
(Billietite)	Ba O23 U6	96-900-1112	0.864704
(Wyartite)	C H15 Ca O19 U3	96-900-2233	0.864630
(Hodrushite)	Bi5.875 Cu4.25 S11	96-900-4833	0.864506

(Andesine)	Al0.735 Ca0.24 Na0.26 O4 Si1.265	96-900-1032	0.864424
(Albite)	Al K0.2 Na0.8 O8 Si3	96-900-0682	0.864328
(Boggildite)	Al2 F9 Na2 O4 P Sr2	96-900-4165	0.864236
(Albite)	Al Na O8 Si3	96-900-0705	0.863889
(Andesine)	Al0.735 Ca0.24 Na0.26 O4 Si1.265	96-900-1031	0.863727
(Anorthite)	Al2 Ca O8 Si2	96-900-0362	0.863438
(Albite)	Al Na O8 Si3	96-900-1258	0.863336
(Jamesonite)	Fe Pb4 S14 Sb6	96-901-2801	0.863326
(Becquerelite)	Ca O30 U6	96-900-1111	0.863291
(Albite)	Al Na O8 Si3	96-900-0528	0.863215
(Sarkinite)	As H Mn2 O5	96-900-9578	0.863204
(Cs2ThSi6O15)	Cs2 O15 Si6 Th	96-900-7985	0.862780
(Jensenite)	Cu3 H4 O8 Te	96-900-4404	0.862647
(Cu1.6Pb1.6Bi6.4S12)	Bi13 Cu2.87 Pb3 S24	96-900-4555	0.862057
(Howardevansite)	Cu2 Fe4 Na2 O24 V6	96-900-1117	0.862052
(Epididymite)	Be H Na O8 Si3	96-901-0483	0.862046
(Albite)	Al Na O8 Si3	96-900-2197	0.861787

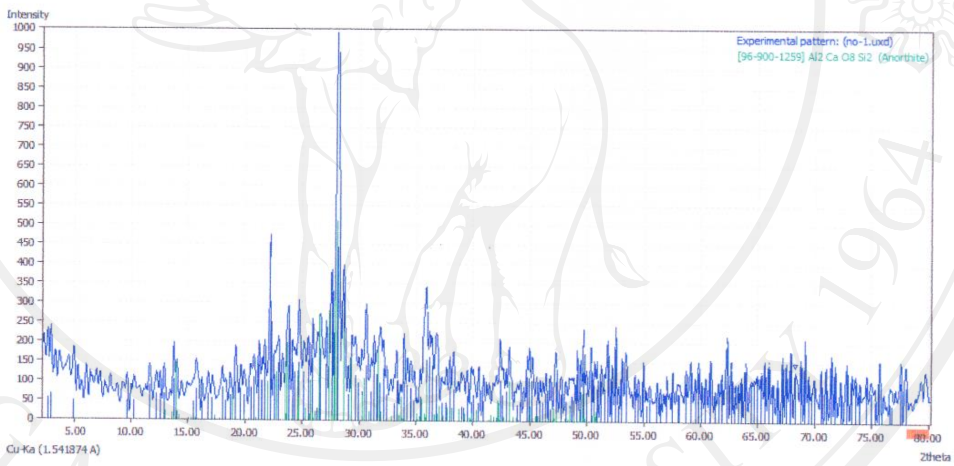
and 148 others...

Search-Match

Settings

Profile data used	No
Automatic zeropoint adaptation	Yes
Minimum figure-of-merit (FoM)	0.60
Parameter/influence 2theta	0.50
Parameter/influence intensities	0.50
Parameter multiple/single phase(s)	0.50

Diffraction Pattern Graphics



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1) Slag b

Match! Phase Analysis Report

Sample: no-2

Sample Data

Filename	no-2.uxd
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Data range	1.970ฐ to 79.970ฐ
Number of points	1950
Step size	0.040
Alpha2 subtracted	Yes
Background subtr.	No
Data smoothed	Yes
2theta correction	-0.03°
Radiation	Cu-Ka
Wavelength	1.541874 Å

Matched Phases

A: (Akermanite)

Formula	Al0.99 Ca2 Mg0.46 O7 Si1.52
Entry number	96-900-6115
Figure-of-Merit (FoM)	0.847957
Total number of peaks	109
Peaks in range	70
Peaks matched	68
Intensity scale factor	0.60
Quant. (weight %)	40.08

B: (Gehlenite)

Formula	Al0.729 Ca0.968 O5.265 Si0.488
Entry number	96-900-4072
Figure-of-Merit (FoM)	0.781969
Total number of peaks	110
Peaks in range	70
Peaks matched	62
Intensity scale factor	0.42
Quant. (weight %)	59.92

Candidates

Name	***Formula***	***Entry No.***	***FoM***
(Xanthiosite)	As2 Ni3 O8	96-900-7685	0.794348
(Cr(HP2O7)(NH3)3(H2O).2H2O)	Cr H18 N3 O9 P2	96-900-7775	0.763552
(Laihunite)	Fe4.74 O12 Si3	96-900-1036	0.749636
(Carmichaelite)	Al0.36 Cr2.09 Fe0.96 Mg0.6 Nb0.05 O22 Ti6.83 V0.12	96-900-2375	0.742500
(Melilite)	Al0.09 Ca1.87 K0.02 Mg0.96 Na0.1 O7 Si1.98 Sr0.02	96-900-7370	0.729445
(Simonite)	As3 Hg S6 Tl	96-900-8306	0.728632
(Ca2Co.9Zn.1Si2O7)	Ca2 Co0.9 O7 Si2 Zn0.1	96-901-1316	0.727601
(Ca2Co.9Zn.1Si2O7)	Ca2 Co0.9 O7 Si2 Zn0.1	96-901-1317	0.725676
(Calzirtite)	Ca Fe0.1 Nb0.15 O8 Ti0.75 Zr2.5	96-900-1013	0.725347
(Hagendorfite)	Ca0.17 Fe2 Mn Na1.83 O12 P3	96-900-5745	0.721901
(Cuspidine)	Ca2 F2 Lu Na O7 Si2	96-900-4387	0.721704
(Ronneburgite)	K2 Mn O12 V4	96-900-2584	0.719704
(Tassieite)	Ca2 Fe3.254 H4 Mg2.746 Na0.478 O26 P6	96-901-0618	0.718111
(Hydrohalite)	Cl H4 Na O2	96-901-1149	0.717651
(Tassieite)	Ca2 Fe3.314 H4 Mg2.686 Na0.463 O26 P6	96-901-0617	0.717392
(Enstatite)	Ca0.15 Mg1.85 O6 Si2	96-900-5542	0.714318
(Zoisite)	Al3 Ca0.96 H O13 Si3 Sr1.04	96-901-0271	0.714008
(Clinoenstatite)	Ca0.15 Mg1.85 O6 Si2	96-900-2713	0.713200
(Ca2(Mg.55Fe.45)Si2O7)	Ca2 Fe0.45 Mg0.55 O7 Si2	96-900-6950	0.713175
(Ca4(PO4)2O)	Ca4 O9 P2	96-901-1145	0.712877
(Ca2(Mg.55Fe.45)Si2O7)	Ca2 Fe0.45 Mg0.55 O7 Si2	96-900-6951	0.712405
(Magnussonite)	As4 Cl0.534 Cu0.34 H0.134 Mg0.37 Mn5.922 O12.134	96-900-0701	0.711828
(Piemontite)	Al1.75 Ca1.48 Ce0.04 Fe0.39 H La0.16 Mg0.08 Mn0.98 Nd0.06 O13 Pr0.02 Si3 Sm0.003 Sr0.03 Th0.004	96-900-5090	0.710933
(Clinozoisite)	Al3 Ca1.504 H O13 Si3 Sr0.496	96-901-0282	0.710163

'Piemontite)	Al1.75 Ca1.48 Ce0.04 Fe0.39 H La0.16 Mg0.08 Mn0.98 Nd0.06 O13 Pr0.02 Si3 Sm0.003 Sr0.03 Th0.004	96-900-5091	0.710075
'Ca2(Mg.55Fe.45)Si2O7)	Ca2 Fe0.45 Mg0.55 O7 Si2	96-900-6949	0.708916
'Sursassite)	Al2.83 H3 Mn2.17 O14 Si3	96-900-5775	0.708729
'Piemontite)	Al1.96 Ca2 H Mn1.04 O13 Si3	96-900-3502	0.708386
'Zoisite)	Al3 Ca0.73 H O13 Si3 Sr1.27	96-901-0272	0.708325
'Piemontite)	Al2 Ca2 H Mn O13 Si3	96-900-3500	0.708314
'Melilite)	Al0.09 Ca1.87 K0.02 Mg0.96 Na0.1 O7 Si1.98 Sr0.02	96-900-7369	0.708081
'Zoisite)	Al3 Ca0.67 H O13 Si3 Sr1.33	96-901-0273	0.707843
'Beta-As4S4)	As S	96-900-4631	0.707267
'Piemontite)	Al1.97 Ca2 H Mn1.03 O13 Si3	96-900-3503	0.706413
'Clinozoisite)	Al3 Ca1.416 H O13 Si3 Sr0.584	96-901-0283	0.706191
'Clinozoisite)	Al3 Ca2 H O13 Si3	96-900-0181	0.706112
'Piemontite)	Al1.88 Ca1.73 Ce0.02 Fe0.51 H La0.02 Mg0.01 Mn0.81 Nd0.01 O13 Pr0.002 Si2.97 Sr0.04	96-900-5092	0.706019
'Normandite)	Ca0.936 F Mn0.784 Na1.28 Nb0.124 O8 Si2 Ti0.876	96-900-4559	0.705731
'Pigeonite)	Ca0.15 Mg1.85 O6 Si2	96-900-3109	0.705523
'Clinozoisite)	Al2.79 Ca2 Fe0.21 H O13 Si3	96-900-1800	0.705519
'Ca2(Mg.55Fe.45)Si2O7)	Ca2 Fe0.45 Mg0.55 O7 Si2	96-900-6948	0.705379
'Normandite)	Ca0.83 F Mn Na1.17 O8 Si2 Ti0.612 Zr0.388	96-900-4558	0.705229
'Zoisite)	Al3 Ca1.74 H O13 Si3 Sr0.26	96-901-0263	0.705056
'Clinozoisite)	Al3 Ca1.518 H O13 Si3 Sr0.482	96-901-0280	0.704916
'Enstatite)	Ca0.2 Mg1.8 O6 Si2	96-900-4958	0.704729
'Piemontite)	Al1.88 Ca1.73 Ce0.02 Fe0.51 H La0.02 Mg0.01 Mn0.81 Nd0.01 O13 Pr0.002 Si2.97 Sr0.04	96-900-5093	0.704662
'Ca2(Mg.55Fe.45)Si2O7)	Ca2 Fe0.45 Mg0.55 O7 Si2	96-900-6946	0.704508
'Clinozoisite)	Al3 Ca1.085 H O13 Si3 Sr0.915	96-901-0285	0.704480
'Pumpellyite-(Mg))	Al2.71 Ca1.9 Fe0.15 H3 Mg0.45 O14 Si2.79	96-900-7510	0.704412
'Ca2(Mg.55Fe.45)Si2O7)	Ca2 Fe0.45 Mg0.55 O7 Si2	96-900-6947	0.704078
'Pyroxene-ideal)	Mg O3 Si	96-900-3431	0.704037

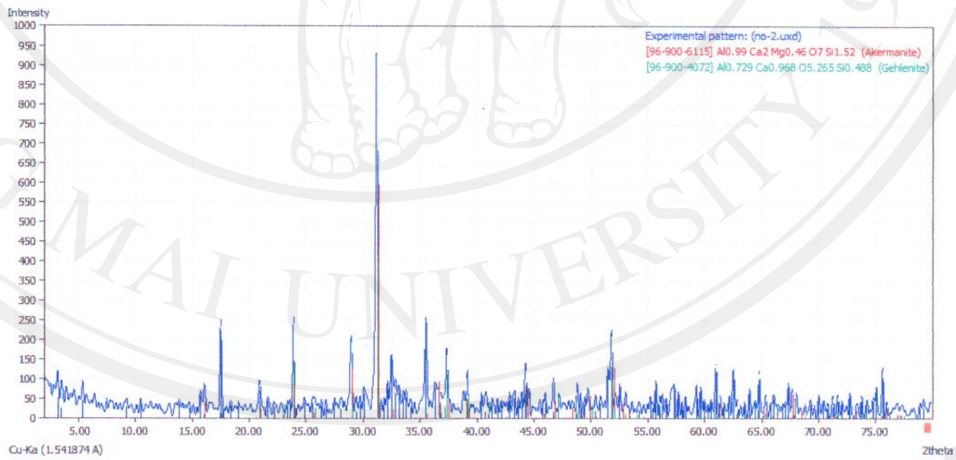
and 144 others...

Search-Match

Settings

Profile data used	No
Automatic zeropoint adaptation	Yes
Minimum figure-of-merit (FoM)	0.60
Parameter/influence 2theta	0.50
Parameter/influence intensities	0.50
Parameter multiple/single phase(s)	0.50

Diffraction Pattern Graphics



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1) Slag c

Match! Phase Analysis Report

Sample: No-3

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Data range	2.020ฐ to 80.020ฐ
Number of points	1951
Step size	0.040
Alpha2 subtracted	Yes
Background subtr.	No
Data smoothed	Yes
2theta correction	0.02°
Radiation	Cu-Ka
Wavelength	1.541874 Å

Matched Phases

A: (Akermanite)	
Formula	Al0.51 Ca2 Mg0.71 O7 Si1.74
Entry number	96-900-6116
Figure-of-Merit (FoM)	0.829170
Total number of peaks	109
Peaks in range	69
Peaks matched	66
Intensity scale factor	0.66
Quant. (weight %)	45.93

B: (Diopside)	
Formula	Ca Mg O6 Si2
Entry number	96-900-0333
Figure-of-Merit (FoM)	0.783210
Total number of peaks	234
Peaks in range	129
Peaks matched	105
Intensity scale factor	0.19
Quant. (weight %)	28.45

C: (Gehlenite)	
Formula	Al1.91 Ca2 Fe0.02 Mg0.05 O7 Si1.02
Entry number	96-901-0521
Figure-of-Merit (FoM)	0.755943
Total number of peaks	110
Peaks in range	68
Peaks matched	65
Intensity scale factor	0.35
Quant. (weight %)	25.62

Candidates

Name	*Formula*	*Entry No.*	*FoM*
(Xanthiosite)	As2 Ni3 O8	96-900-7685	0.776467
(Olympite)	Li Na5 O8 P2	96-901-2623	0.775851
(Takeuchiite)	B12 Mg20.58 Mn15.42 O60	96-900-8387	0.774461
(Langbanite)	Mn13 O24 Sb Si2	96-900-1364	0.772175
(Suanite)	B2 Mg2 O5	96-901-1383	0.770448
(Orthopinakiolite)	B8 Fe1.76 Mg11.384 Mn10.446 O40	96-900-4135	0.766002
(Clinokurchatovite)	B2 Ca Mg O5	96-901-0723	0.763401
(Clinokurchatovite)	B2 Ca Mg O5	96-901-1895	0.754900
(Chestermanite)	Al0.66 B4 Fe1.475 Mg9.314 O20 Sb0.482 Ti0.069	96-901-2587	0.752839
(Korshunovskite)	Cl H11 Mg2 O7	96-901-0976	0.745531
(Seidozerite)	Ca1.28 F2 Fe0.42 Mn0.56 Na3.56 O16 Si4 Ti0.78 Zr1.4	96-901-1850	0.738610
(Seidozerite)	Al0.1 Ca0.4 F2 Fe0.19 Mg0.34 Mn0.46 Na3.6 Nb0.04 O16 Si4 Ti1.26 Zr1.44	96-901-1836	0.738590
(Haycockite)	Cu4 Fe5 S8	96-901-1157	0.738167
(Melanterite)	Cu0.48 Fe1.52 H28 O22 S2	96-900-4777	0.737578

Friedelite)	Cl H9 Mn8 O24 Si6	96-901-2818	0.732731
Fluorthalenite-(Y))	F O10 Si3 Y3	96-901-2350	0.732474
Omphacite)	Al0.51 Ca0.5 Fe0.06 Mg0.46 Na0.5 O6 Si1.97	96-901-1810	0.729886
Thalenite-(Y))	Al0.15 Fe0.15 H O11 Si2.85 Y2.85	96-901-1893	0.725564
Omphacite)	Al0.885 Ca1.165 Fe0.31 Mg0.805 Na0.835 O12 Si4	96-900-0171	0.724960
Glaukosphaerite)	C H2 Cu1.5 Ni0.5 O5	96-901-0771	0.724475
Omphacite)	Al0.905 Ca0.952 Fe0.159 Mg0.936 Na1.048 O12 Si4	96-900-9603	0.722395
Wollastonite-2M)	Ca O3 Si	96-901-1914	0.722031
Omphacite)	Al0.525 Ca0.492 Fe0.475 Na0.508 O6 Si2	96-900-4085	0.721124
Ca2SiO3OHOH)	Ca2 O5 Si	96-901-1377	0.720633
Omphacite)	Al0.868 Ca1.03 Fe0.317 Mg0.815 Na0.97 O12 Si4	96-900-0456	0.720201
Poldervaartite)	Ca2 H2 O5 Si	96-901-1379	0.717508
Marinellite)	Al18 Ca2.91 Cl0.99 H14 K5.37 Na15.5 O90.98 S4 Si18	96-900-5632	0.717049
Omphacite)	Al0.51 Ca0.5 Fe0.06 Mg0.46 Na0.5 O6 Si1.97	96-901-1811	0.717019
Omphacite)	Al0.51 Ca0.5 Fe0.06 Mg0.46 Na0.5 O6 Si1.97	96-901-1809	0.716226
Pigeonite)	Ca0.15 Mg1.85 O6 Si2	96-900-3109	0.715039
Clinoenstatite)	Mg O3 Si	96-900-8078	0.713944
Tinzenite)	Al1.88 B Ca1.42 Fe0.21 H Mg0.03 Mn1.46 O16 Si4	96-901-2643	0.713074
Tinzenite)	Al1.88 B Ca1.42 Fe0.21 H0.5 Mg0.03 Mn1.46 O16 Si4	96-900-9954	0.713074
Clinoenstatite)	Ca0.15 Mg1.85 O6 Si2	96-900-2712	0.711783
Vihorlatite)	Bi21.68 S1.7 Se15.3 Te6.32	96-901-0805	0.710513
Calzirtite)	Ca Fe0.1 Nb0.15 O8 Ti0.75 Zr2.5	96-900-1013	0.709456
Hydrohalite)	Cl H4 Na O2	96-901-1149	0.707072
Ferroaxinite)	Al1.893 B Ca2 Fe0.657 H K0.022 Mg0.185 Mn0.13 Na0.065 O16 Si4 Ti0.005	96-900-0816	0.707059
Zoisite)	Al3 Ca0.46 H O13 Si3 Sr1.54	96-901-0274	0.706826
Zoisite)	Al3 Ca1.74 H O13 Si3 Sr0.26	96-901-0263	0.703574
Zoisite)	Al3 Ca1.68 H O13 Si3 Sr0.32	96-901-0264	0.702635
Ca2Co.9Zn.1Si2O7)	Ca2 Co0.9 O7 Si2 Zn0.1	96-901-1316	0.702522
Gehlenite)	Al0.729 Ca0.968 O5.265 Si0.488	96-900-4072	0.701706
Diopside)	Al Ca Mg0.5 O6 Si1.5	96-900-5281	0.701523
Ca2Co.9Zn.1Si2O7)	Ca2 Co0.9 O7 Si2 Zn0.1	96-901-1317	0.700761
Tassieite)	Ca2 Fe3.314 H4 Mg2.686 Na0.463 O26 P6	96-901-0617	0.699195
Clinozoisite)	Al3 Ca1.843 H O13 Si3 Sr0.157	96-901-0278	0.699073
Tassieite)	Ca2 Fe3.254 H4 Mg2.746 Na0.478 O26 P6	96-901-0618	0.699024
Yeatmanite)	Fe0.2 Mn9 O28 Sb2 Si3.8 Zn6	96-900-9727	0.698838
Zoisite)	Al3 Ca1.5 H O13 Si3 Sr0.5	96-901-0267	0.698633
Zoisite)	Al3 Ca0.67 H O13 Si3 Sr1.33	96-901-0273	0.697633

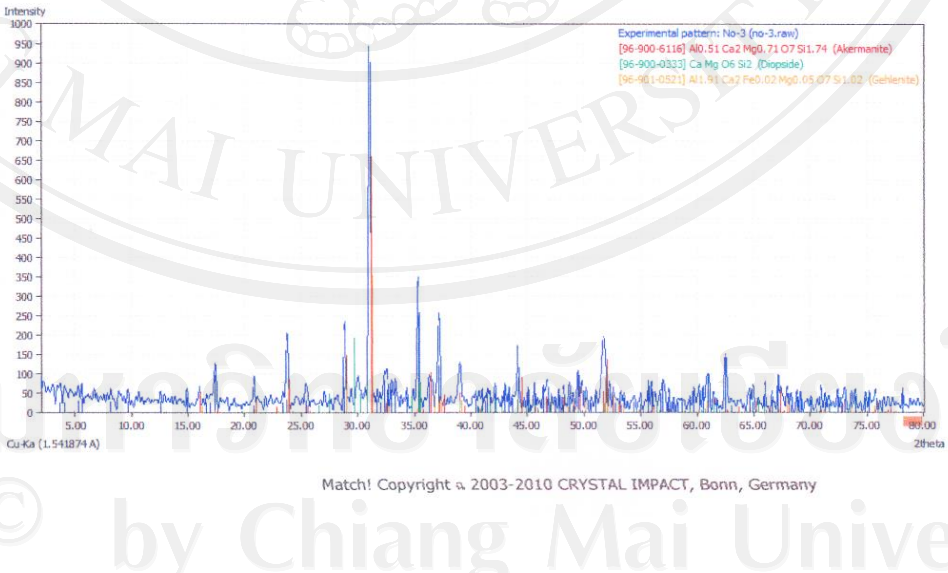
and 143 others...

Search-Match

Settings

Profile data used	No
Automatic zeropoint adaptation	Yes
Minimum figure-of-merit (FoM)	0.60
Parameter/influence 2theta	0.50
Parameter/influence intensities	0.50
Parameter multiple/single phase(s)	0.50

Diffraction Pattern Graphics



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1) Slag d

Match! Phase Analysis Report

Sample: no-5

Sample Data

Filename	no-5.uxd
File path	d:\pakamon\phd-phrae\ผลวิเคราะห์ xrd\
Data collected	
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Number of points	1950
Step size	0.040
Alpha2 subtracted	Yes
Background subtr.	No
Data smoothed	Yes
2theta correction	0.01°
Radiation	Cu-Ka
Wavelength	1.541874 Å

Matched Phases

A: (Esseneite)

Formula	Al1.34 Ca0.97 Fe0.61 O6 Si1.08
Entry number	96-900-1042
Figure-of-Merit (FoM)	0.861139
Total number of peaks	234
Peaks in range	128
Peaks matched	122
Intensity scale factor	0.69
Quant. (weight %)	100.00

Candidates

Name	*Formula*	*Entry No.*	*FoM*
(Derbylite)	Fe4 H O14 Sb Ti3	96-900-9249	0.873776
(Seidozerite)	Al0.1 Ca0.4 F2 Fe0.19 Mg0.34 Mn0.46 Na3.6 Nb0.04 O16 Si4 Ti1.26 Zr1.44	96-901-1836	0.871263
(Antimonpearceite)	Ag14.691 Cu1.309 S8.37 Sb2 Se2.63	96-901-1319	0.869624
(Ca2Co.9Zn.1Si2O7)	Ca2 Co0.9 O7 Si2 Zn0.1	96-901-1316	0.869441
(Normandite)	Ca0.936 F Mn0.784 Na1.28 Nb0.124 O8 Si2 Ti0.876	96-900-4559	0.869013
(Zoisite)	Al3 Ca1.5 H O13 Si3 Sr0.5	96-901-0267	0.868234
(Caryinite)	As2.892 Ca1.91 Mg0.56 Mn1.77 Na1.376 O12 P0.09 Pb0.384 V0.018	96-900-9486	0.868154
(Ca2Co.9Zn.1Si2O7)	Ca2 Co0.9 O7 Si2 Zn0.1	96-901-1317	0.868102
(Zoisite)	Al3 Ca1.37 H O13 Si3 Sr0.63	96-901-0268	0.868010
(Ho2Ba2Cu1.1Pt0.9O8)	Ba2 Cu1.1 Ho2 O8 Pt0.9	96-900-7781	0.867687
(Zoisite)	Al3 Ca1.68 H O13 Si3 Sr0.32	96-901-0264	0.867227
(Zoisite)	Al3 Ca1.74 H O13 Si3 Sr0.26	96-901-0263	0.866956
(Zoisite)	Al3 Ca1.5 H O13 Si3 Sr0.5	96-901-0266	0.866900
(Seidozerite)	Ca1.28 F2 Fe0.42 Mn0.56 Na3.56 O16 Si4 Ti0.78 Zr1.4	96-901-1850	0.866479
(Zoisite)	Al3 Ca1.57 H O13 Si3 Sr0.43	96-901-0265	0.866071
(Kilchoanite)	Ca2.33 Mn0.67 O7 Si2	96-900-9476	0.865082
(Seidozerite)	Ca0.26 F3 Fe0.32 Mg0.305 Mn0.425 Na3.91 Nb0.04 O15 Si4 Ti1.36 Zr1.38	96-900-4796	0.864632
(Zoisite)	Al3 Ca1.89 H O13 Si3 Sr0.11	96-901-0262	0.864630
(Stokesite)	Ca H4 O11 Si3 Sn	96-900-9434	0.863199
(Magniotriplite)	F0.68 Fe0.88 H2 Mg0.89 Mn0.23 O4.32 P	96-900-9713	0.862918
(IMA2004-009)	H Mg2 O5 P	96-901-1483	0.862402
(Mg2PO4OH)	H Mg2 O5 P	96-901-1482	0.862402
(Hilgardite-3A)	B5 Ca2 Cl H2 O10	96-900-0883	0.861827
(Wagnerite)	F Mg2 O4 P	96-901-2767	0.861458
(Wagnerite)	F Mg2 O4 P	96-901-2717	0.861458
(Normandite)	Ca0.83 F Mn Na1.17 O8 Si2 Ti0.612 Zr0.388	96-900-4558	0.861111
(Ternesite)	Ca5 O12 S Si2	96-900-9847	0.859647
(Wagnerite)	F Mg2 O4 P	96-901-2770	0.859639
(Whitlockite)	Ca9.5 Mg O28 P7	96-901-2138	0.858969
(Wittichenite)	Bi Cu3 S3	96-900-7579	0.858215
(Zoisite)	Al3 Ca2 H O13 Si3	96-900-2767	0.857732
(Samfowlerite)	Be7.24 Ca14 H6 Mn3 O58 Si14 Zn2.76	96-900-4289	0.857724

(Zoisite)	Al2.88 Ca2 Fe0.12 H O13 Si3	96-900-1804	0.857438
(Pigeonite)	Ca0.15 Mg1.85 O6 Si2	96-900-3110	0.857422
(Bustamite)	Ca0.36 Mn0.64 O3 Si	96-900-0607	0.857395
(Zoisite)	Al2.938 Ca2 Fe0.062 H O13 Si3	96-900-2769	0.857095
(Carmichaelite)	Al0.36 Cr2.09 Fe0.96 Mg0.6 Nb0.05 O22 Ti6.83 V0.12	96-900-2375	0.857057
(Hammarite)	Bi4 Cu2 Pb2 S9	96-900-4109	0.856967
(Cuspidine)	Ca2.01 F2 Na1.99 O7 P2	96-900-2505	0.856315
(Zoisite)	Al3 Ca2 H O13 Si3	96-900-0180	0.855348
(Zoisite)	Al2.904 Ca2 Fe0.096 H O13 Si3	96-900-2770	0.854437
(Enstatite)	Al0.23 Mg0.874 O3 Si0.875	96-901-0242	0.853744
(Zoisite)	Al2.965 Ca2 Fe0.035 H O13 Si3	96-900-2768	0.853401
(Benjaminite)	Ag2.3 Bi6.7 Cu0.5 Pb0.4 S12	96-900-4148	0.853378
(Cuspidine)	Ca1.005 F Na0.995 O3.5 P	96-900-2506	0.852485
(Zoisite)	Al2.884 Ca2 Fe0.116 H O13 Si3	96-900-2771	0.851775
(Enstatite)	Fe0.41 Mg0.59 O3 Si	96-900-6430	0.851772
(Triplite)	Ca0.1 F Fe0.25 Mg0.7 Mn0.95 O4 P	96-900-8179	0.851622
(Emilite)	Bi11 Cu5.99 Pb5 S24	96-900-4677	0.851400
(Pectolite)	Ca1.23 Mn0.77 Na O9 Si3	96-900-0613	0.849039
(Na2Se*9H2O)	H18 Na2 O9 Se	96-900-8102	0.848876

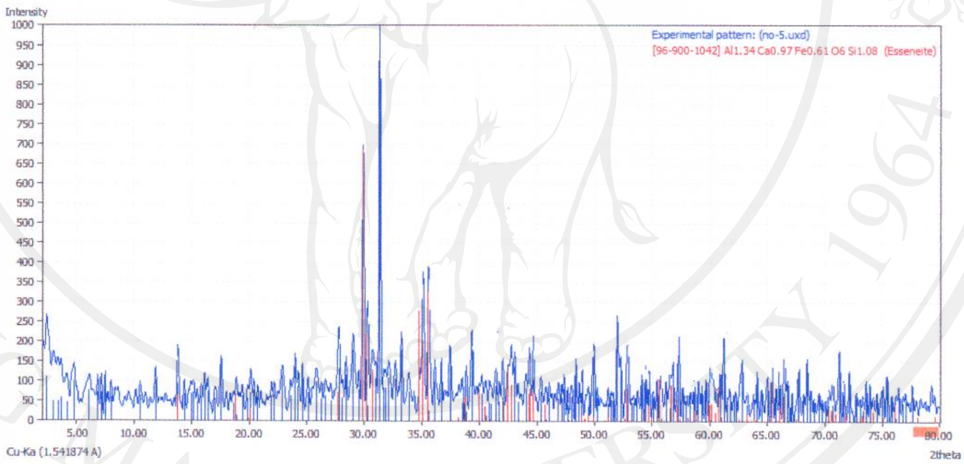
and 142 others...

Search-Match

Settings

Profile data used	No
Automatic zeropoint adaptation	Yes
Minimum figure-of-merit (FoM)	0.60
Parameter/influence 2theta	0.50
Parameter/influence intensities	0.50
Parameter multiple/single phase(s)	0.50

Diffraction Pattern Graphics



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B.3 The results of blended coals

B.3.1 Element compositions from EDS

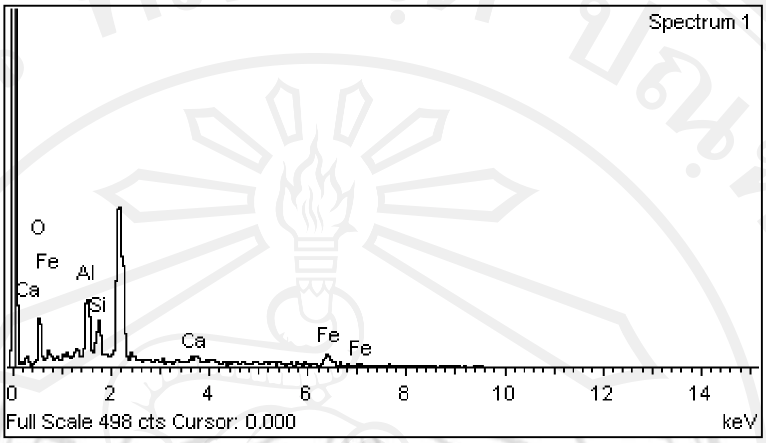

Figure B.9 Graph pattern of fused ash from lignite A from EDS

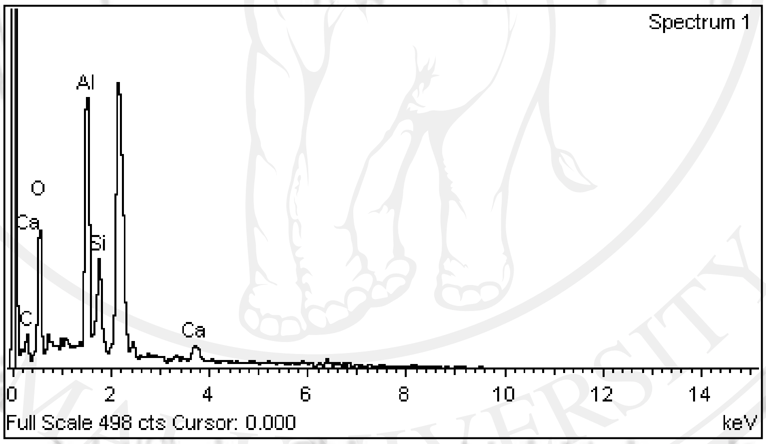

Figure B.10 Graph pattern of fused ash from lignite B from EDS

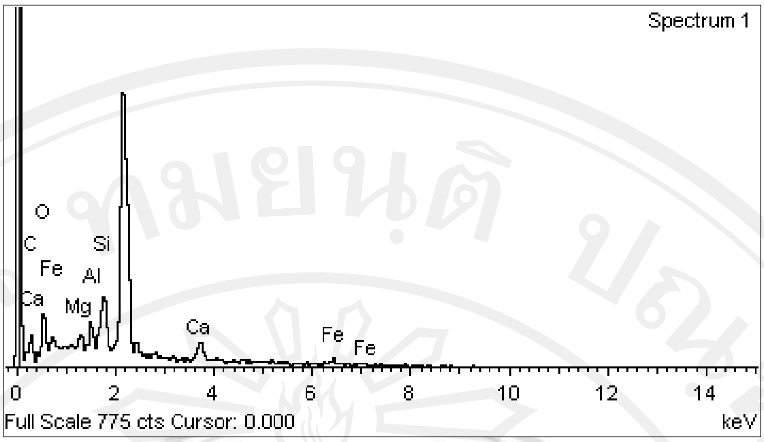

Figure B.11 Graph pattern of fused ash from lignite C from EDS

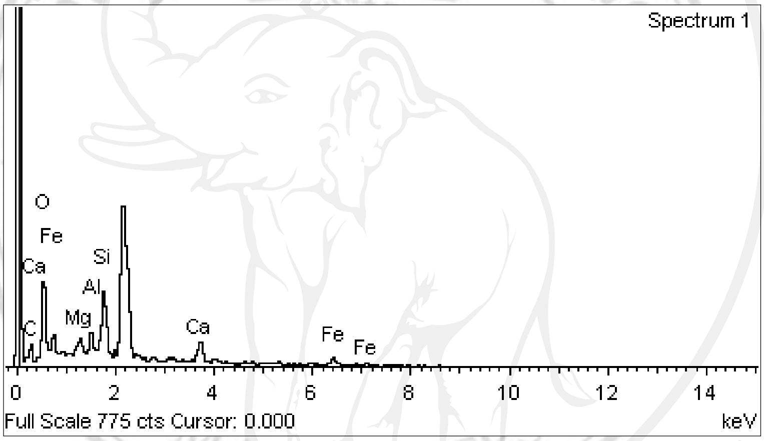

Figure B.12 Graph pattern of fused ash from lignite D from EDS

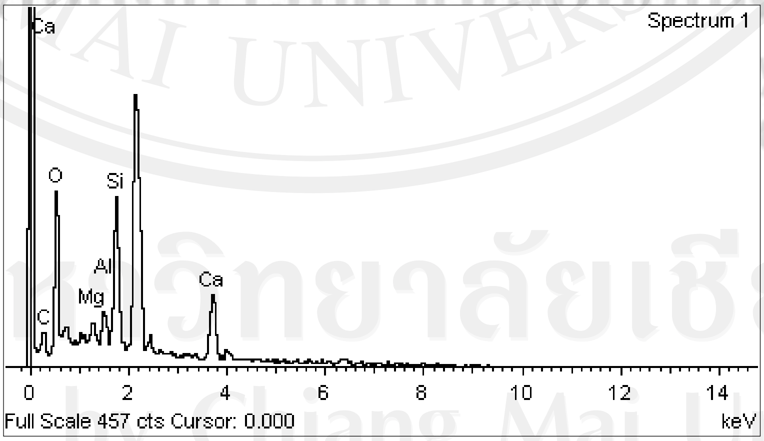

Figure B.13 Graph pattern of fused ash from lignite E from EDS

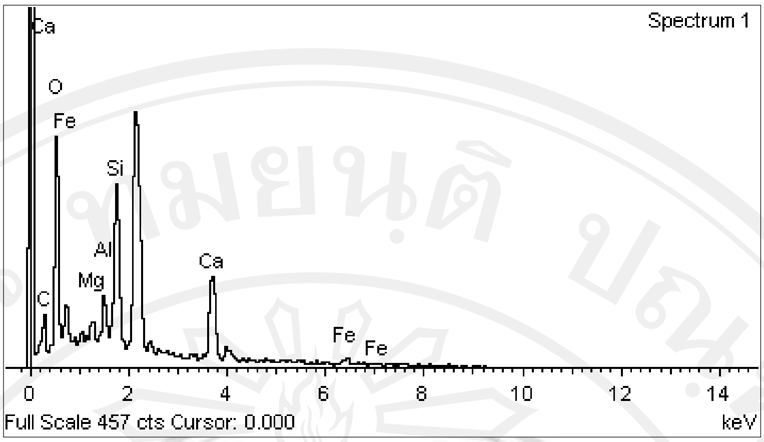

Figure B.14 Graph pattern of fused ash from lignite F from EDS

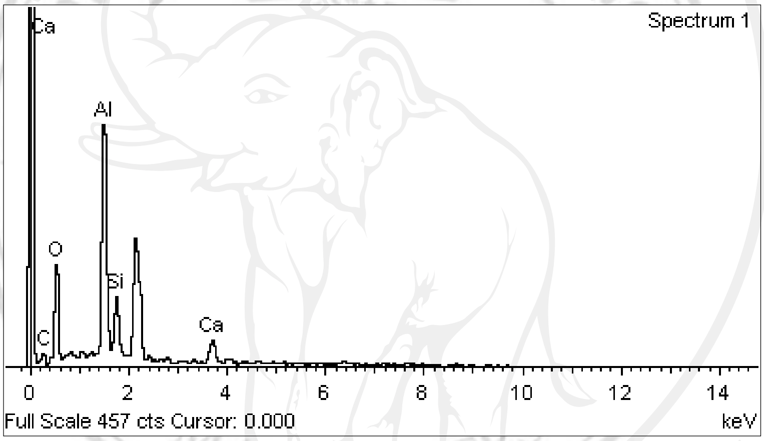

Figure B.15 Graph pattern of fused ash from lignite G from EDS

Appendix C

FACTSAGE results

C.1 The results from Equilib model

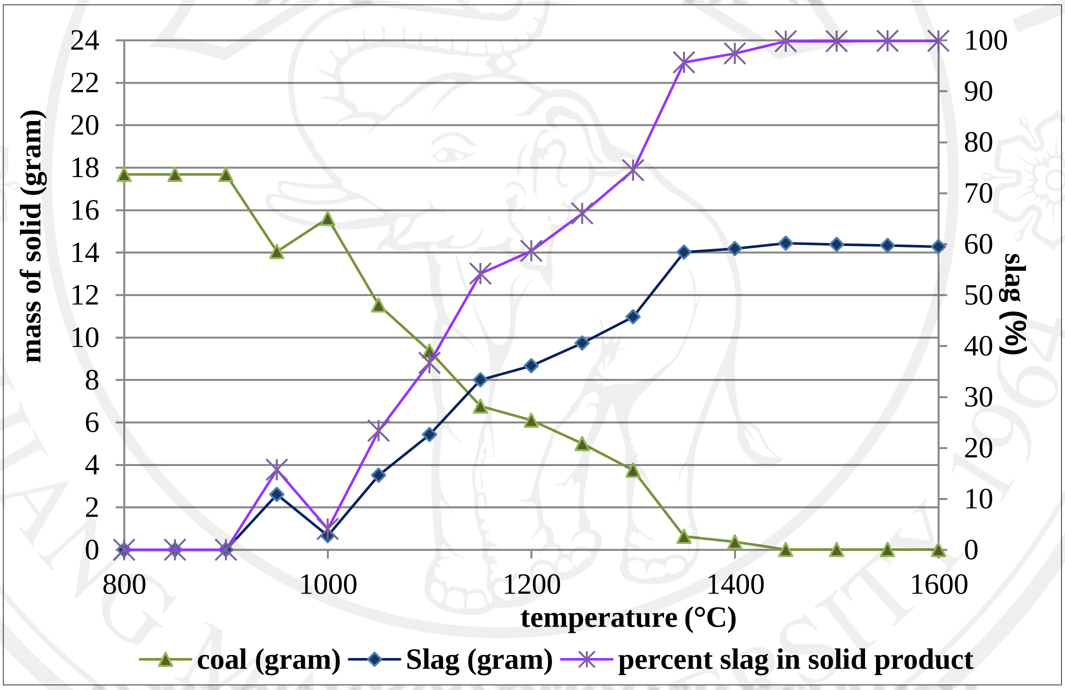

Figure C.1 Trend of mass loss and slag formation from lignite A

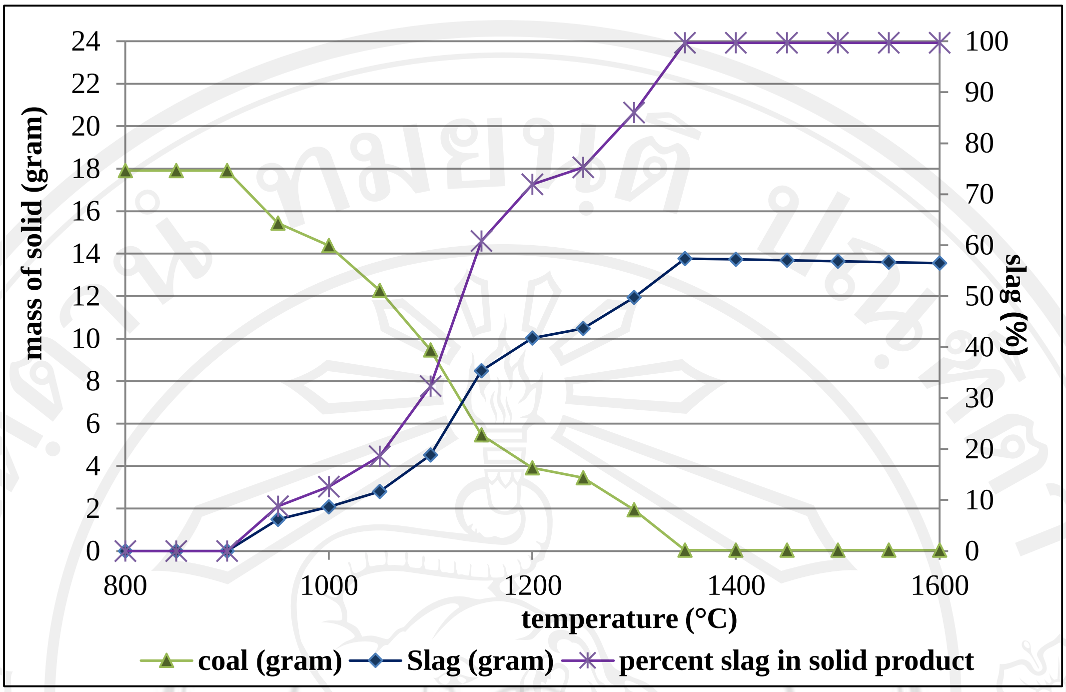

Figure C.2 Trend of mass loss and slag formation from lignite B

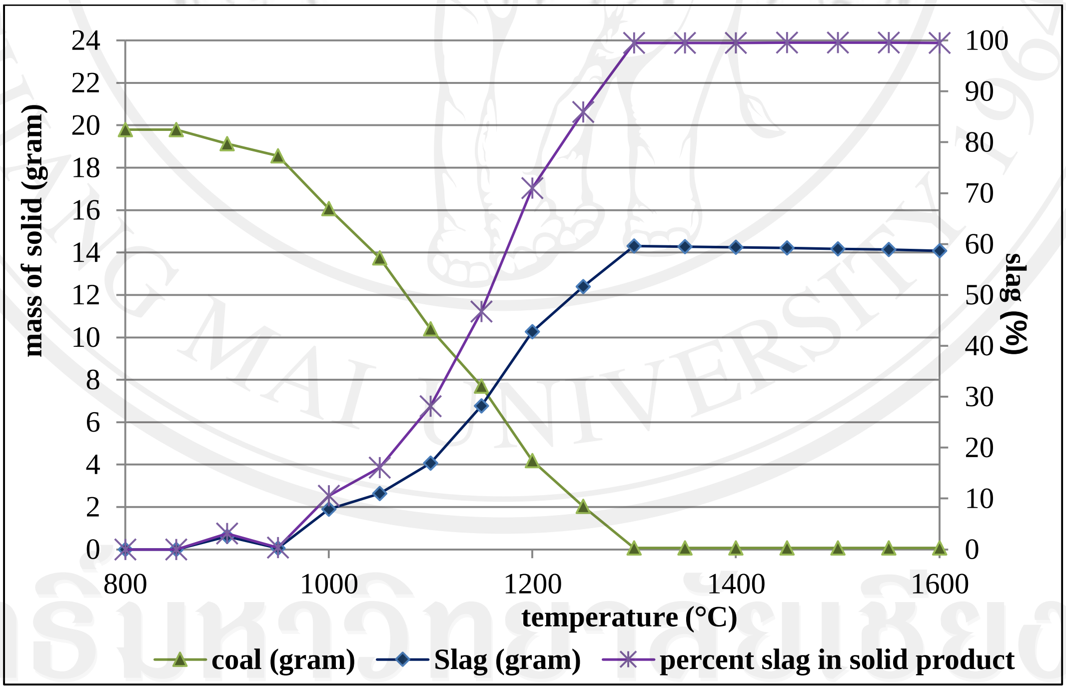

Figure C.3 Trend of mass loss and slag formation from lignite C

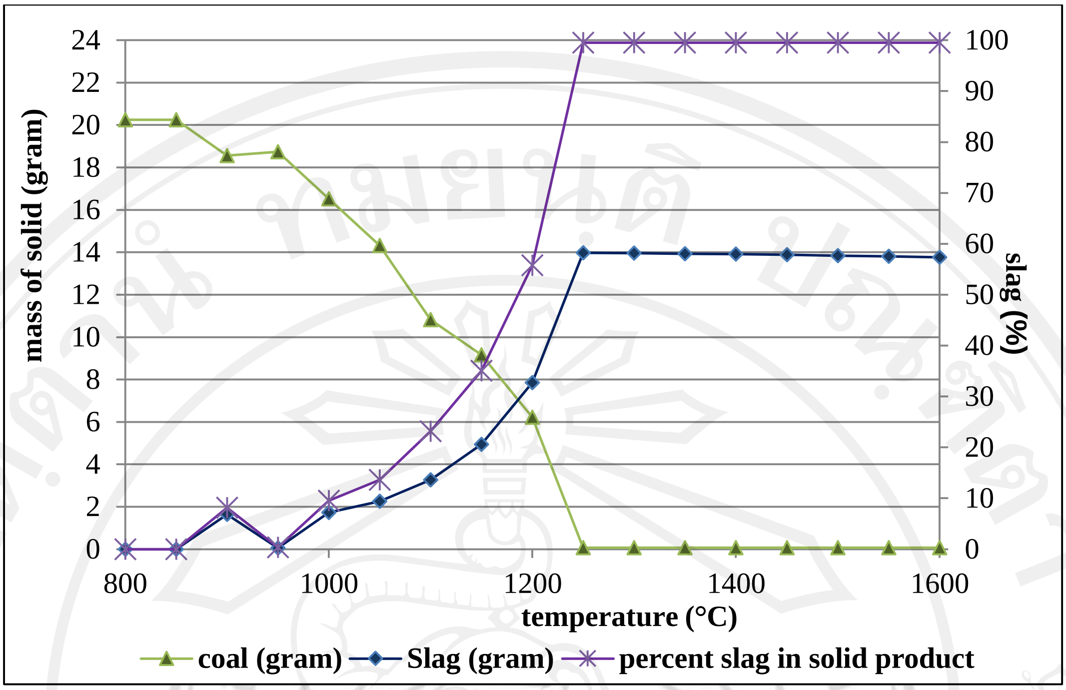

Figure C.4 Trend of mass loss and slag formation from lignite D

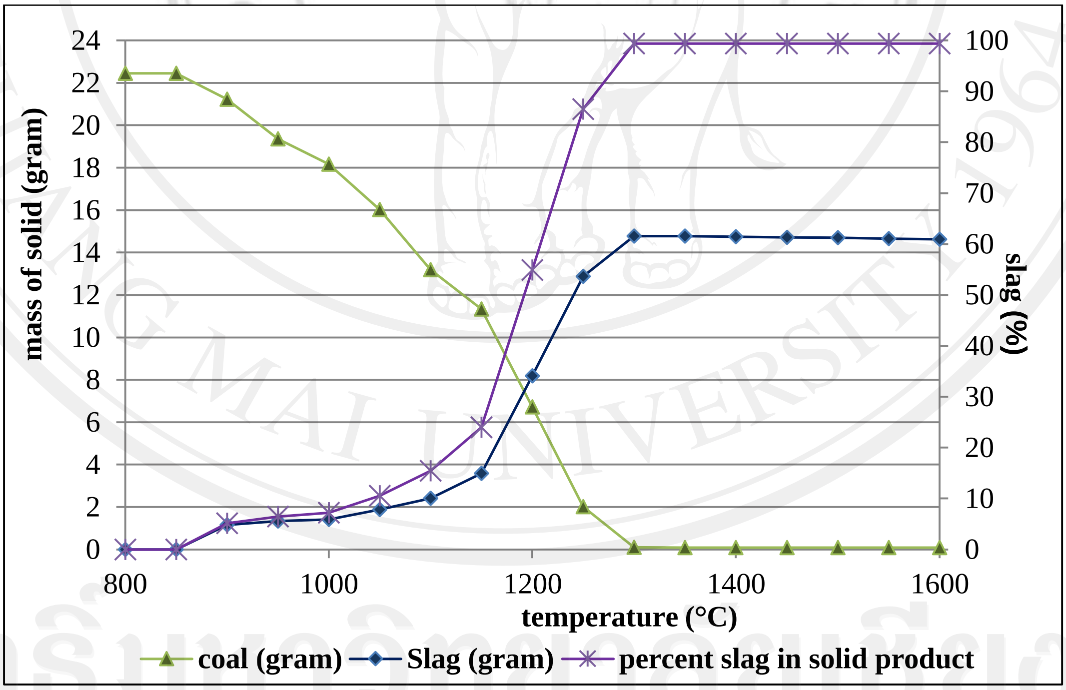

Figure C.5 Trend of mass loss and slag formation from lignite E

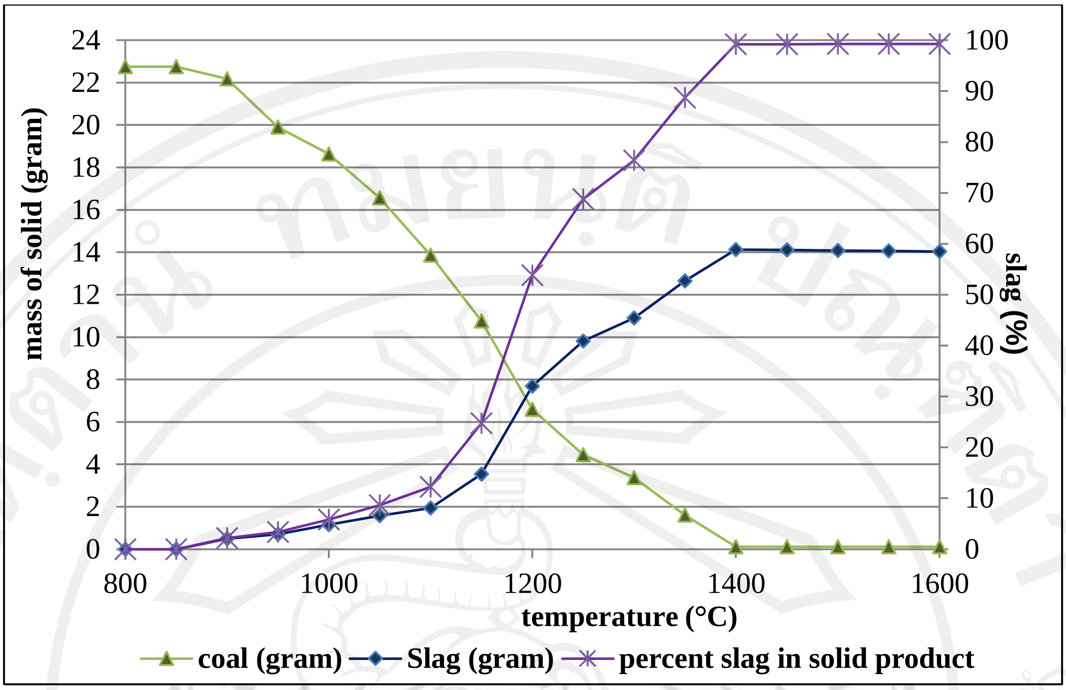

Figure C.6 Trend of mass loss and slag formation from lignite F

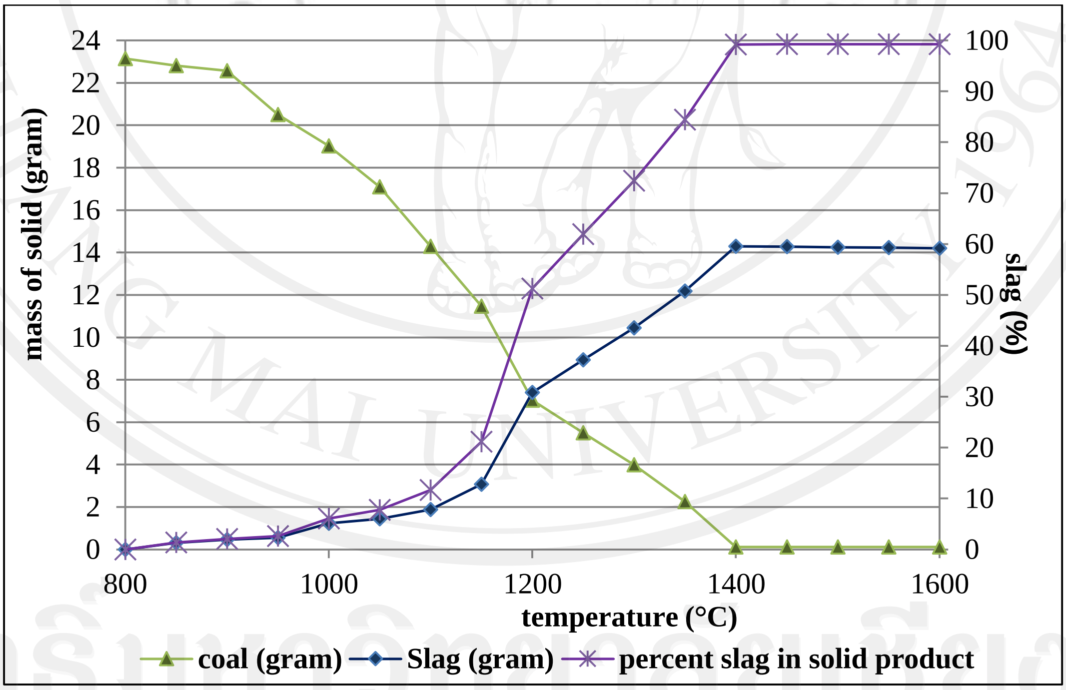

Figure C.7 Trend of mass loss and slag formation from lignite G

Table C.1 Mineral of solid from lignite sample A

Solid \Temperature(°C)	800	900	1000	1100	1200	1300	1400	1500	1600
Fe_2O_3 hematite	5.100	5.100	5.098	4.993	4.530	3.107	-	-	-
$CaSO_4$ Anhydrite	4.904	4.904	2.546	-	-	-	-	-	-
$NaAlSi_3O_8$ High-Albite	2.877	2.877	-	-	-	-	-	-	-
$Mg_2Al_4Si_5O_{18}$ Cordierite	1.807	1.807	-	-	-	-	-	-	-
$Mg_4Al_{10}Si_2O_{23}$ Sapphirine	1.538	1.538	-	1.436	0.798	-	-	-	-
$KAlSi_2O_6$ Leucite(RHF)-B	1.112	1.112	1.109	0.846	0.754	0.620	0.350	-	-
Mg_2SiO_4 forsterite	0.278	0.278	1.214	-	-	-	-	-	-
TiO_2 Rutile	0.040	0.031	-	-	-	-	-	-	-
$Mg_3P_2O_8$	0.019	0.019	-	-	-	-	-	-	-
Mn_2O_3 Bixbyite-HT(cubic)	0.009	-	-	-	-	-	-	-	-
$MnTiO_3$ Pyrophanite	-	0.017	-	-	-	-	-	-	-
$CaAl_2Si_2O_8$ Anorthite	-	-	4.419	0.780	-	-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-	-	0.024	0.024	0.024	-	-	-	-
$NaAlSiO_4$ Nepheline	-	-	1.153	-	-	-	-	-	-
$CaTiO_3$ Perovskite-A	-	-	0.064	-	-	-	-	-	-
$Ca_2MgSi_2O_7$ Akermanite (melilite)	-	-	-	1.283	-	-	-	-	-
$Ca_3(PO_4)_2$	-	-	-	-	-	0.022	0.022	0.021	0.016
Total (g)	17.683	17.682	15.626	9.361	6.104	3.749	0.372	0.021	0.016

Table C.2 Mineral of solid from lignite sample B

Solid \Temperature(°C)	800	900	1000	1100	1200	1300	1400	1500	1600
Fe_2O_3 hematite	4.620	4.620	4.617	4.534	3.871	1.900	-	-	-
$CaSO_4$ Anhydrite	6.652	6.652	4.177	-	-	-	-	-	-
$NaAlSi_3O_8$ High-Albite	2.285	2.285	-	-	-	-	-	-	-
$Mg_2Al_4Si_5O_{18}$ Cordierite	2.728	2.729	-	-	-	-	-	-	-
$Mg_4Al_{10}Si_2O_{23}$ Sapphirine	0.388	0.388	-	0.561	-	-	-	-	-
$KAlSi_2O_6$ Leucite(RHF)-B	0.834	0.834	0.784	0.531	-	-	-	-	-
Mg_2SiO_4 forsterite	0.328	0.328	0.878	-	-	-	-	-	-
TiO_2 Rutile	0.030	0.021	-	-	-	-	-	-	-
$Mg_3P_2O_8$	0.037	0.037	-	-	-	-	-	-	-
Mn_2O_3 Bixbyite-HT(cubic)	0.009	-	-	-	-	-	-	-	-
$MnTiO_3$ Pyrophanite	-	0.017	-	-	-	-	-	-	-
$CaAl_2Si_2O_8$ Anorthite	-	-	3.186	-	-	-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-	-	0.047	0.047	0.047	-	-	-	-
$CaTiO_3$ Perovskite-A	-	-	0.040	-	-	-	-	-	-
$Ca_2MgSi_2O_7$ Akermanite (melilite)	-	-	-	2.476	-	-	-	-	-
$Ca_3(PO_4)_2$	-	-	-	-	-	0.044	0.044	0.044	0.042
$CaMgSi_2O_6$ diopside(cl-pyroxene)	-	-	0.650	-	-	-	-	-	-
$Ca_2Al_2SiO_7$ Gehlenite	-	-	-	1.314	-	-	-	-	-
Total (g)	17.911	17.910	14.379	9.463	3.918	1.944	0.044	0.044	0.042

Table C.3 Mineral of solid from lignite sample C

Solid \Temperature(°C)	800	900	1000	1100	1200	1300	1400	1500	1600
Fe_2O_3 hematite	4.45	4.45	4.449	4.406	3.358	-	-	-	-
$CaSO_4$ Anhydrite	8.983	8.896	5.864	-	-	-	-	-	-
$NaAlSi_3O_8$ High-Albite	2.115	1.871	-	-	-	-	-	-	-
$Mg_2Al_4Si_5O_{18}$ Cordierite	2.488	2.523	-	-	-	-	-	-	-
$KAlSi_2O_6$ Leucite(RHF)-B	2.488	0.475	0.319	-	-	-	-	-	-
Mg_2SiO_4 forsterite	-	-	0.293	-	-	-	-	-	-
TiO_2 Rutile	2.488	0.028	-	-	-	-	-	-	-
$Mg_3P_2O_8$	0.056	-	-	-	-	-	-	-	-
Mn_2O_3 Bixbyite-HT(cubic)	0.009	-	-	-	-	-	-	-	-
$CaAl_2Si_2O_8$ Anorthite	-	-	2.410			-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-	-	0.071	0.071	0.071	-	-	-	-
$CaTiO_3$ Perovskite-A	-	-	0.044	0.002	-	-	-	-	-
$Ca_2MgSi_2O_7$ Akermanite (melilite)	-	-	-	3.083	-	-	-	-	-
$Ca_3(PO_4)_2$	-	-	-	-	-	0.066	0.066	0.065	0.065
$MgSiO_3$ ortho-enstatite	0.751	0.803	-	-	-	-	-	-	-
SiO_2 Quartz	0.261	-	-	-	-	-	-	-	-
$Ca_3(PO_4)_2$ Whitlockite	-	0.066	-	-	-	-	-	-	-
$Mn_3Al_2Si_3O_{12}$ Mn-Pyrope	-	0.019	-	-	-	-	-	-	-
$CaMgSi_2O_6$ diopside	-	-	2.620	-	-	-	-	-	-
$Ca_2Al_2SiO_7$ Gehlenite	-	-	-	1.877	-	-	-	-	-
$Ca_3MgSi_2O_8$ Merwinite	-	-	-	0.954	0.764	-	-	-	-
Total (g)	22.249	19.130	16.071	10.395	4.193	0.066	0.066	0.065	0.065

Table C.4 Mineral of solid from lignite sample D

Solid \Temperature(°C)	800	900	1000	1100	1200	1300	1400	1500	1600
Fe_2O_3 hematite	4.090	4.090	4.089	3.785	3.000		-	-	-
$CaSO_4$ Anhydrite	10.415	10.328	7.013	-	-	-	-	-	-
$NaAlSi_3O_8$ High-Albite	1.777	1.118	-	-	-	-	-	-	-
$Mg_2Al_4Si_5O_{18}$ Cordierite	1.624	1.737	-	-	-	-	-	-	-
$KAlSi_2O_6$ Leucite(RHF)-B	0.463	-	0.395	-	-	-	-	-	-
TiO_2 Rutile	0.020	0.016	-	-	-	-	-	-	-
$Mg_3P_2O_8$	0.056		-	-	-	-	-	-	-
Mn_2O_3 Bixbyite-HT(cubic)	0.009	-	-	-	-	-	-	-	-
$CaAl_2Si_2O_8$ Anorthite	-	-	1.453	0.071		-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-	-	0.072		0.071	0.071	-	-	-
$CaTiO_3$ Perovskite-A	-	-	0.024	-	-	-	-	-	-
$Ca_2MgSi_2O_7$ Akermanite (melilite)	-	-	-	-	-	-	-	-	-
$Ca_3(PO_4)_2$	-	-	-	-	-		0.066	0.066	0.066
SiO_3 ortho-enstatite	1.023	1.048	-	-	-	-	-	-	-
SiO_2 Quartz	0.777	-	-	-	-	-	-	-	-
$Ca_3(PO_4)_2$ Whitlockite	-	0.066	-	-	-	-	-	-	-
$Mn_3Al_2Si_3O_{12}$ Mn-Pyrope	-	0.018	-	-	-	-	-	-	-
SiO2 Tridymite	-	0.138	-	-	-	-	-	-	-
$CaMgSi_2O_6$ diopside	-	-	3.474	-	-	-	-	-	-
$Ca_2Al_2SiO_7$ Gehlenite	-	-	1.204	-	-	-	-	-	-
$Ca_3MgSi_2O_8$ Merwinite	-	-	-	-	3.154	-	-	-	-
Total (g)	20.254	18.558	10.824	10.824	6.224	0.071	0.066	0.066	0.066

Table C.5 Mineral of solid from lignite sample E

Solid \Temperature(°C)	800	900	1000	1100	1200	1300	1400	1500	1600
Fe_2O_3 hematite	3.990	3.990	3.319	3.130	2.348		-	-	-
$CaSO_4$ Anhydrite	12.746	12.63	7.847	1.000	-	-	-	-	-
$NaAlSi_3O_8$ High-Albite	1.439	0.977	-	-	-	-	-	-	-
$Mg_2Al_4Si_5O_{18}$ Cordierite	1.0171	1.0927	-	-	-	-	-	-	-
$KAlSi_2O_6$ Leucite(RHF)-B	0.324	-	0.273	-	-	-	-	-	-
TiO_2 Rutile	0.020	0.017	-	-	-	-	-	-	-
$Mg_3P_2O_8$	0.074	-	-	0.131	-	-	-	-	-
Mn_2O_3 Bixbyite-HT(cubic)	0.009	-	-	-	-	-	-	-	-
$CaAl_2Si_2O_8$ Anorthite	-	-	0.900	-	-	-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-		0.094	0.094	0.094	0.094	-	-	-
$NaAlSiO_4$ Nepheline	-	-	-	-	-	-	-	-	-
$CaTiO_3$ Perovskite-A	-	-	0.027	0.007	-	-	-	-	-
$Ca_3(PO_4)_2$	-	-	-	-	-	-	0.087	0.087	0.087
$MgSiO_3$ ortho-enstatite	1.260	1.319	-	-	-	-	-	-	-
SiO_2 Quartz	1.576	-	-	-	-	-	-	-	-
$Mn_3Al_2Si_3O_{12}$ Mn-Pyrope	-	0.018	-	-	-	-	-	-	-
$Ca_3(PO_4)_2$ Whitlockite	-	0.087	-	-	-	-	-	-	-
SiO_2 Tridymite	-	1.104	-	-	-	-	-	-	-
$CaMgSi_2O_6$ diopside	-		3.587	-	-	-	-	-	-
$Ca_3Fe_2Si_3O_{12}$ Andradite	-	-	2.132	-	-	-	-	-	-
$Ca_2Al_2SiO_7$ Gehlenite	-	-	-	0.878	-	-	-	-	-
$Ca_3MgSi_2O_8$ Merwinite	-	-	-	5.330	4.282	-	-	-	-
$Ca_3Fe_2Si_3O_{12}$ Andradite	-	-	-	2.617	-	-	-	-	-
Total (g)	22.455	21.235	18.169	13.186	6.724	0.094	0.087	0.087	0.087

Table C.6 Mineral of solid from lignite sample F

Solid \Temperature(°C)	800	900	1000	1100	1200	1300	1400	1500	1600
Fe_2O_3 hematite	3.45	3.45	2.573	3.420	0.228	-	-	-	-
$CaSO_4$ Anhydrite	14.324	14.180	9.276	2.538	-	-	-	-	-
$NaAlSi_3O_8$ High-Albite	1.185	0.986	-	-	-	-	-	-	-
$Mg_2Al_4Si_5O_{18}$ Cordierite	0.193	0.219	-	-	-	-	-	-	-
$KAlSi_2O_6$ Leucite(RHF)-B	0.139	-	0.098	-	-	-	-	-	-
TiO_2 Rutile	0.010	0.009	-	-	-	-	-	-	-
$Mg_3P_2O_8$	0.092	-	-	-	-	-	-	-	-
Mn_2O_3 Bixbyite-HT(cubic)	0.009	-	-	-	-	-	-	-	-
$CaAl_2Si_2O_8$ Anorthite	-	-	0.118	-	-	-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-	-	0.118	0.118	0.118	0.118	0.118	-	-
$CaTiO_3$ Perovskite-A	-	-	0.012	-	-	-	-	-	-
$Ca_2MgSi_2O_7$ Akermanite (melilite)	-	-	-	-	-	-	-	-	-
$Ca_3(PO_4)_2$	-	-	-	-	-	-	-	0.109	0.109
$MgSiO_3$ ortho-enstatite	1.546	1.643	-	-	-	-	-	-	-
SiO_2 Quartz	1.805	-	-	-	-	-	-	-	-
$Ca_3(PO_4)_2$ Whitlockite	-	0.109	-	-	-	-	-	-	-
$Mn_3Al_2Si_3O_{12}$ Mn-Pyrope	-	0.019	-	-	-	-	-	-	-
SiO_2 Tridymite	-	1.558	-	-	-	-	-	-	-
$CaMgSi_2O_6$ diopside	-	-	3.648	-	-	-	-	-	-
$Ca_3Fe_2Si_3O_{12}$ Andradite	-	-	2.787	-	-	-	-	-	-
$Ca_2Al_2SiO_7$ Gehlenite	-	-	-	0.059	-	-	-	-	-
$Ca_3MgSi_2O_8$ Merwinite	-	-	-	5.457	5.028	3.252	-	-	-
$Ca_3Si_2O_7$ Rankinite	-	-	-	2.279	-	-	-	-	-
Ca_2SiO_4 Alpha-prime	-	-	-	-	1.219	-	-	-	-
Total (g)	22.753	22.174	18.630	13.870	6.593	3.370	0.118	0.109	0.109

Table C.7 Mineral of solid from lignite sample G

Solid \Temperature(°C)	800	900	1000	1100	1200	1300	1400	1500	1600
Fe_2O_3 hematite	3.450	3.450	2.653	3.425	-	-	-	-	-
$CaSO_4$ Anhydrite	14.663	14.504	9.780	2.875	-	-	-	-	-
$NaAlSi_3O_8$ High-Albite	1.334	1.170	-	-	-	-	-	-	-
$KAlSi_2O_6$ Leucite(RHF)-B	0.089	-	-	-	-	-	-	-	-
TiO_2 Rutile	0.010	-	-	-	-	-	-	-	-
$Mg_3P_2O_8$	0.092	-	-	-	-	-	-	-	-
Mn_2O_3 Bixbyite-HT(cubic)	0.018	-	-	-	-	-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-	-	-	0.118	-	-	-	-	-
$CaTiO_3$ Perovskite-A	-	-	0.012	--	-	-	-	-	-
$Ca_3(PO_4)_2$	-	-		-	-	-	-	0.109	0.109
$MgSiO_3$ ortho-enstatite	1.762	1.868	-	-	-	-	-	-	-
SiO_2 Quartz	1.70	-	-	-	-	-	-	-	-
SiO_2 Tridymite	-	1.430	-	-	-	-	-	-	-
$CaMgSi_2O_6$ diopside	-	-	3.936	-	-	-	-	-	-
$Ca_3Fe_2Si_3O_{12}$ Andradite	-	-	2.533	-	-	-	-	-	-
$Ca_3MgSi_2O_8$ Merwinite	-	-	-	5.953	5.553	3.866	-	-	-
$Ca_3Si_2O_7$ Rankinite	-	-	-	1.920	-	-	-	-	-
Ca_2SiO_4 Alpha-prime	-	-	-	-	1.370	-	-	-	-
$K_3Na(SO_4)_2$	0.025	-	-	-	-	-	-	-	-
$MnTiO_3$ Pyrophanite	-	0.017	-	-	-	-	-	-	-
$Ca_5HO_{13}P_3$ Hydroxyapatite	-	0.118	0.118	-	0.118	0.118	0.118	-	-
MnSiO Rhodonite	-	0.015	-	-	-	-	-	-	-
Total (g)	23.143	22.572	19.030	14.291	7.040	3.984	0.118	0.109	0.109

C.2 The results from Phase Diagram model

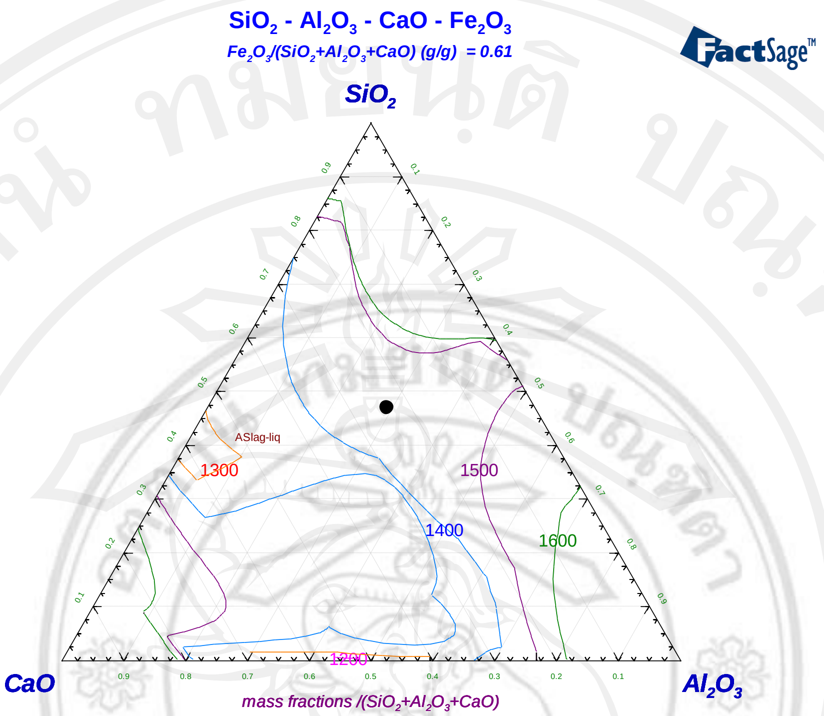

Figure C.8 Quaternary diagram of SiO_2-Al_2O_3-CaO-Fe_2O_3 system of Lignite A

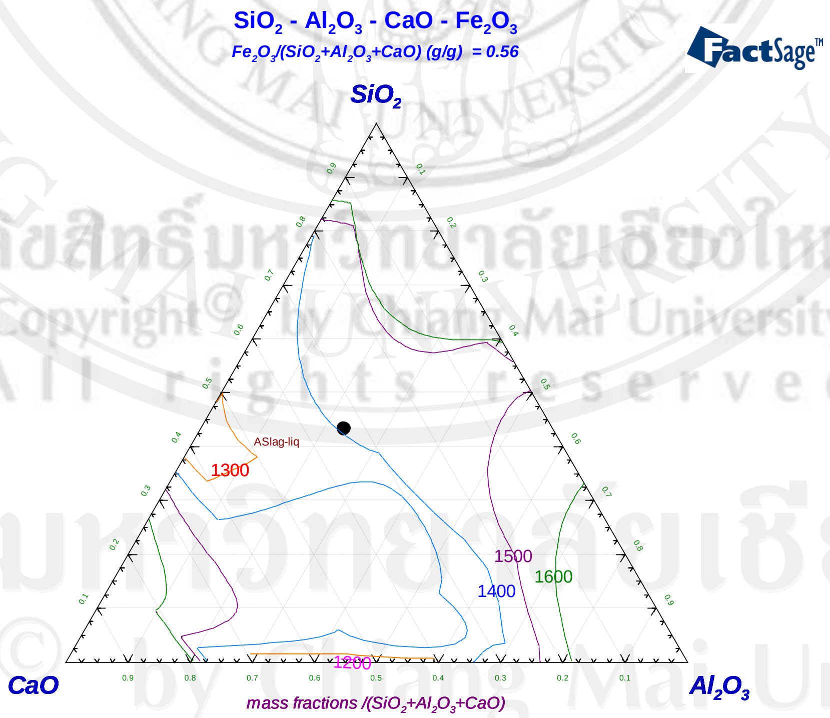

Figure C.9 Quaternary diagram of SiO_2-Al_2O_3-CaO-Fe_2O_3 system of Lignite B

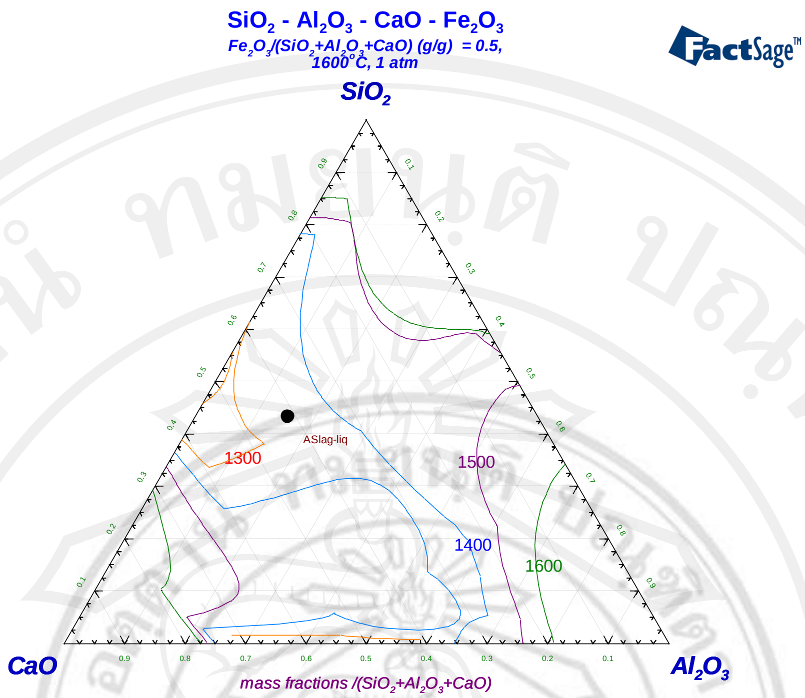

Figure C.10 Quaternary diagram of SiO_2-Al_2O_3-CaO-Fe_2O_3 system of Lignite C

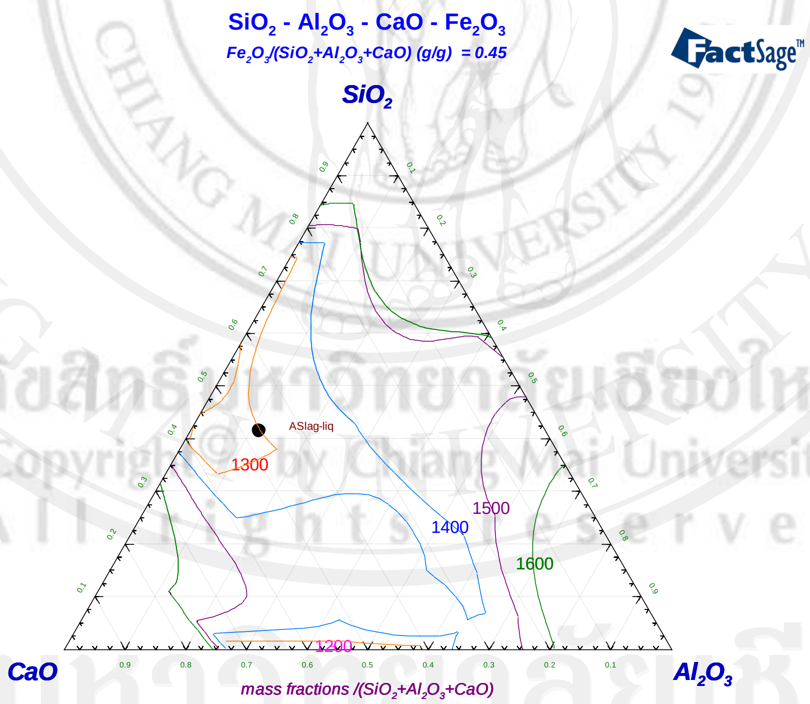

Figure C.11 Quaternary diagram of SiO_2-Al_2O_3-CaO-Fe_2O_3 system of Lignite D

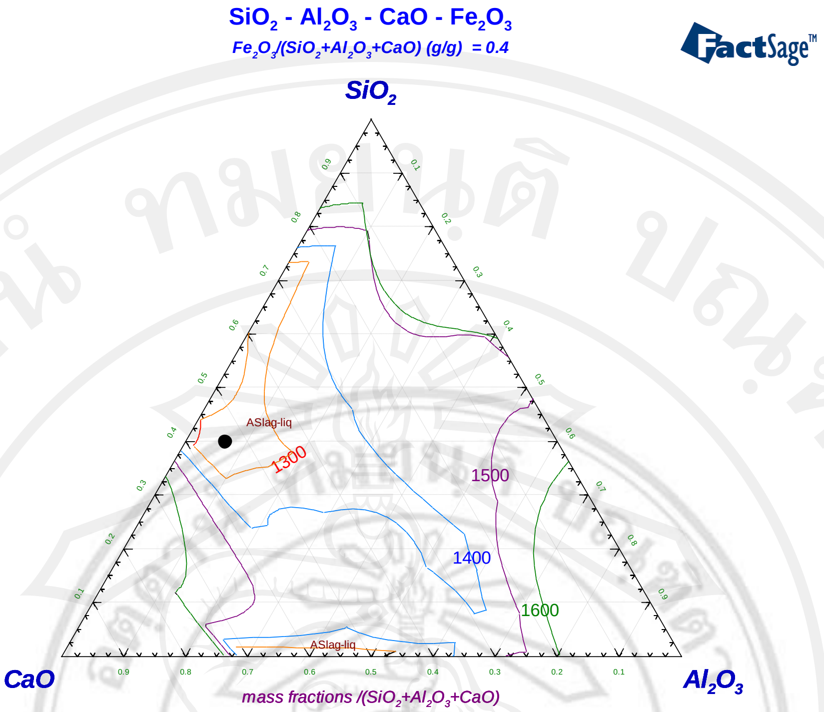

Figure C.12 Quaternary diagram of SiO_2-Al_2O_3-CaO-Fe_2O_3 system of Lignite E

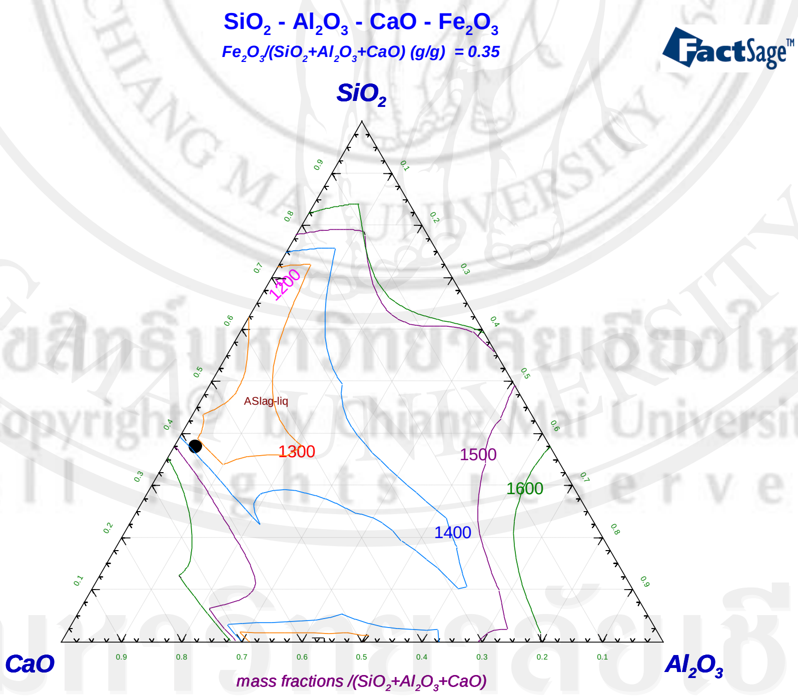

Figure C.13 Quaternary diagram of SiO_2-Al_2O_3-CaO-Fe_2O_3 system of Lignite F

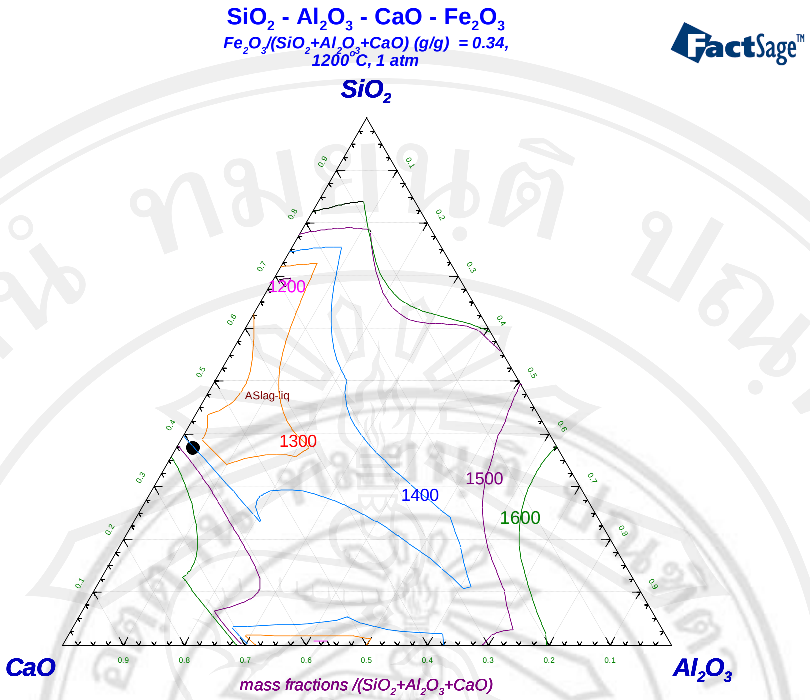

Figure C.14 Quaternary diagram of SiO_2-Al_2O_3-CaO-Fe_2O_3 system of Lignite G

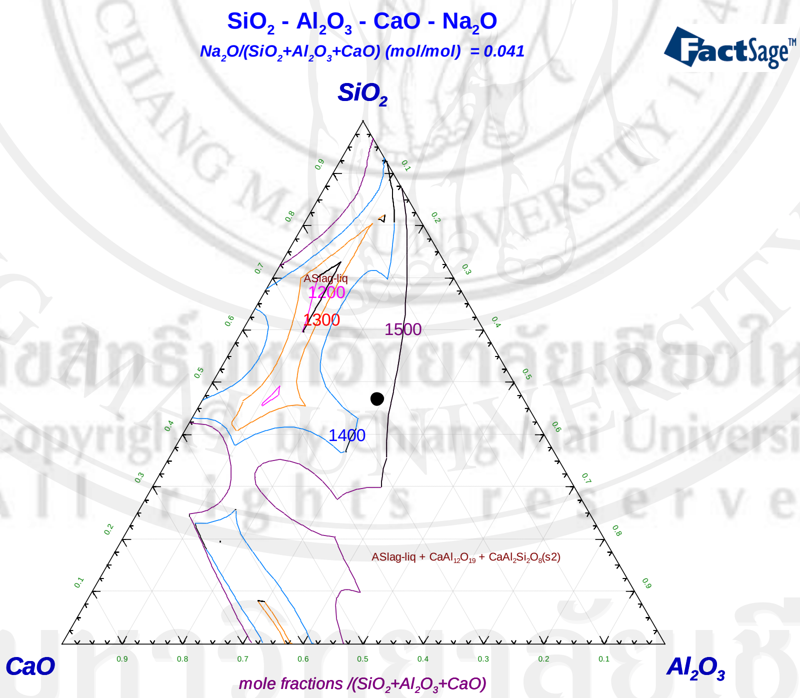

Figure C.15 Quaternary diagram of SiO_2-Al_2O_3-CaO-Na_2O system of Lignite A

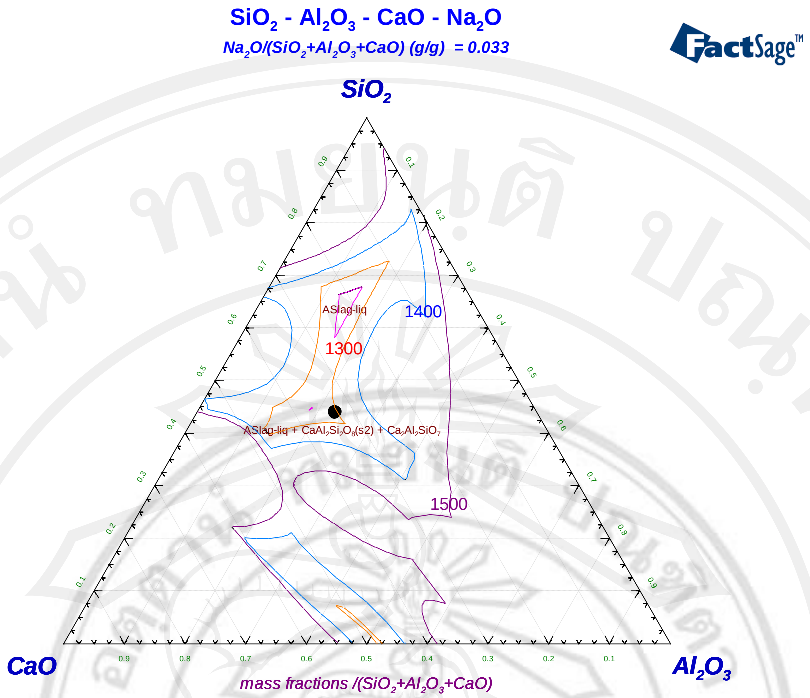

Figure C.16 Quaternary diagram of SiO_2-Al_2O_3-CaO-Na_2O system of Lignite B

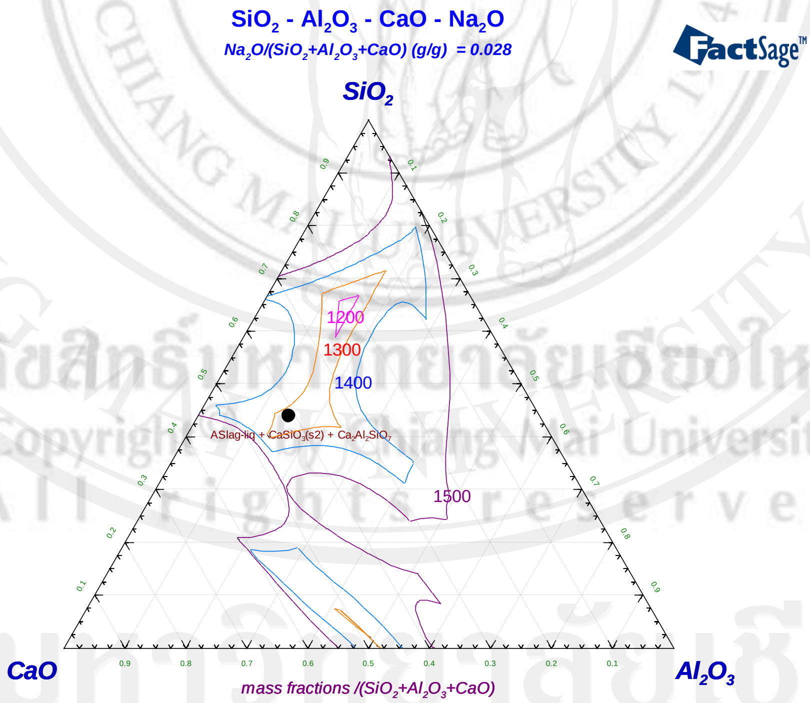

Figure C.17 Quaternary diagram of SiO_2-Al_2O_3-CaO-Na_2O system of Lignite C

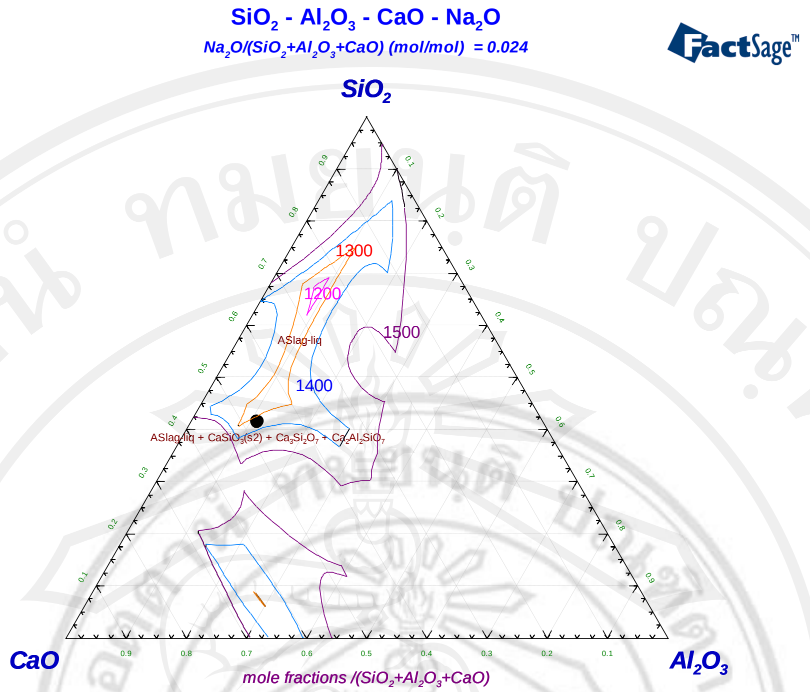

Figure C.18 Quaternary diagram of SiO_2-Al_2O_3-CaO-Na_2O system of Lignite D

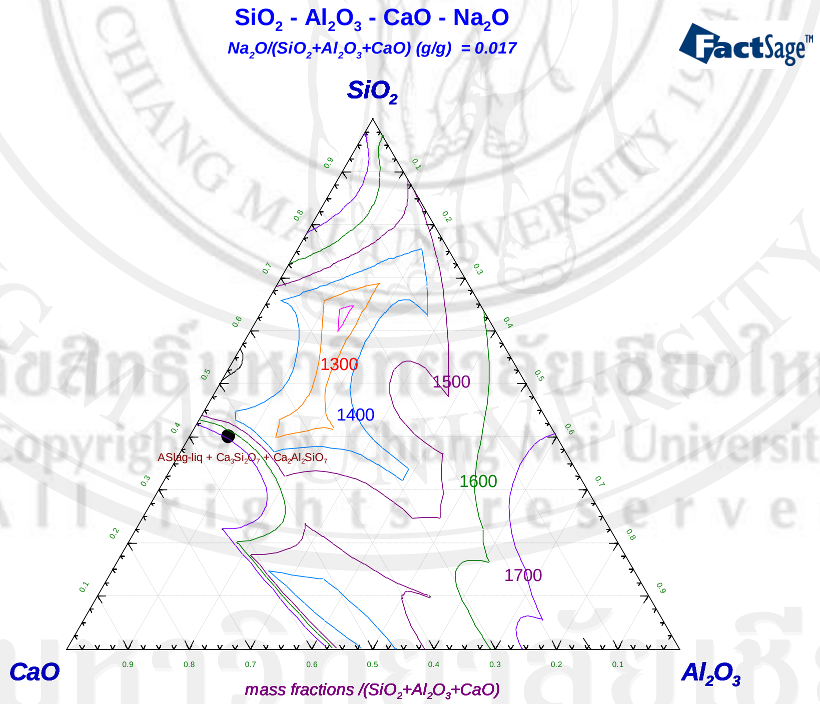

Figure C.19 Quaternary diagram of SiO_2-Al_2O_3-CaO-Na_2O system of Lignite E

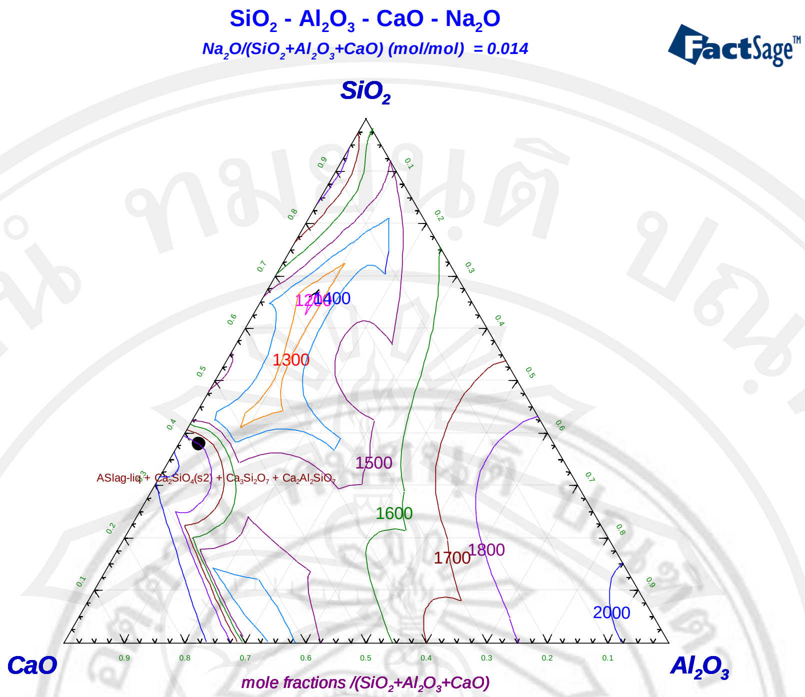

Figure C.20 Quaternary diagram of SiO_2-Al_2O_3-CaO-Na_2O system of Lignite F

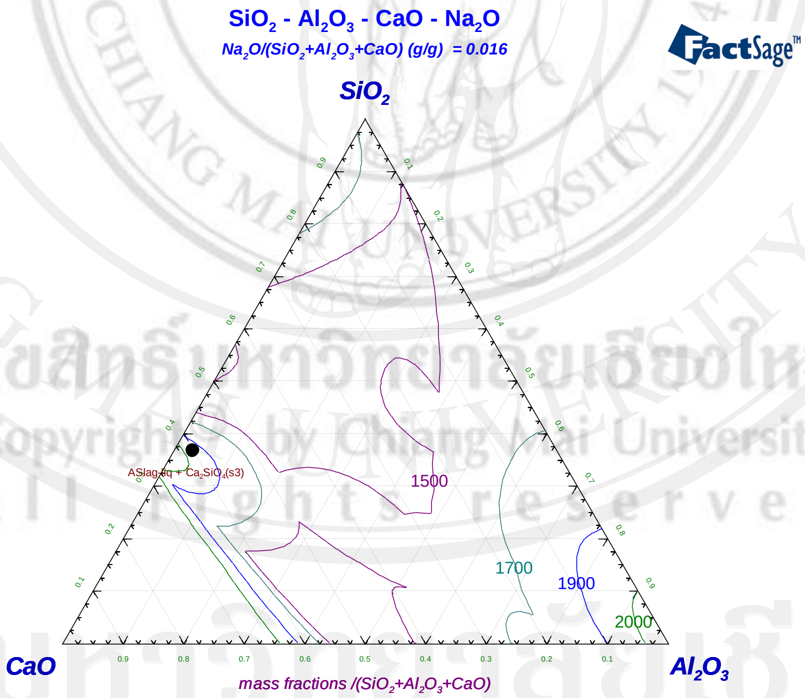

Figure C.21 Quaternary diagram of SiO_2-Al_2O_3-CaO-Na_2O system of Lignite G

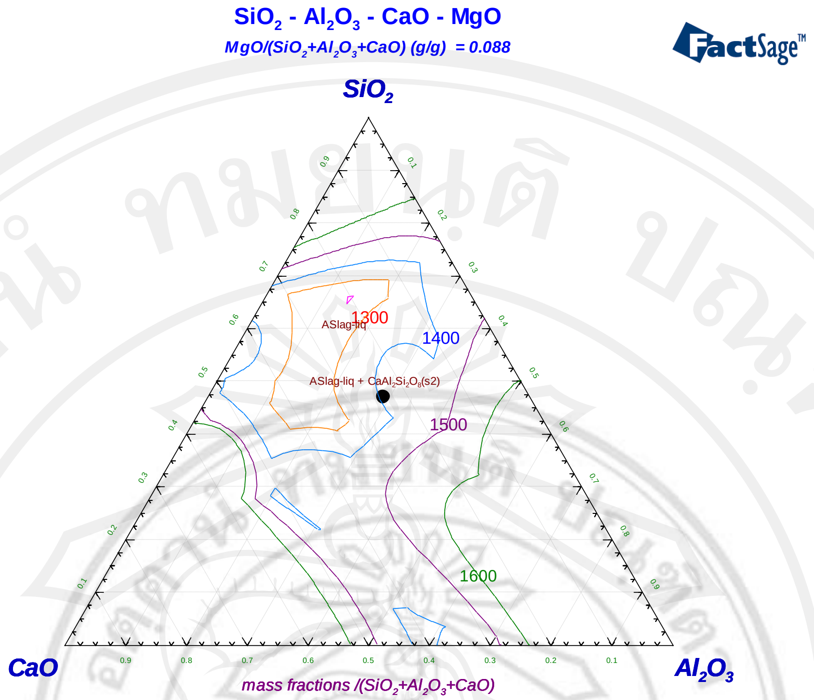

Figure C.22 Quaternary diagram of SiO_2-Al_2O_3-CaO-MgO system of Lignite A

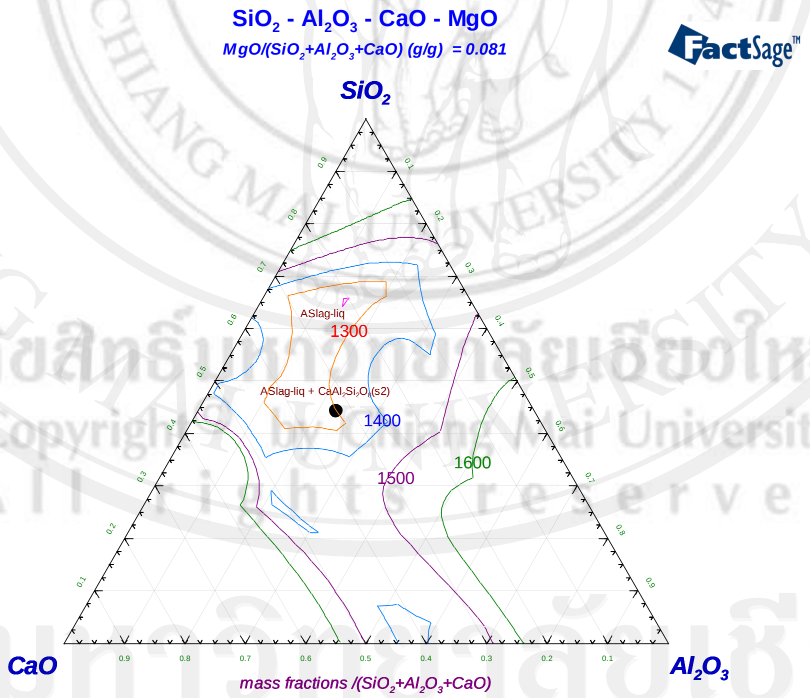

Figure C.23 Quaternary diagram of SiO_2-Al_2O_3-CaO-MgO system of Lignite B

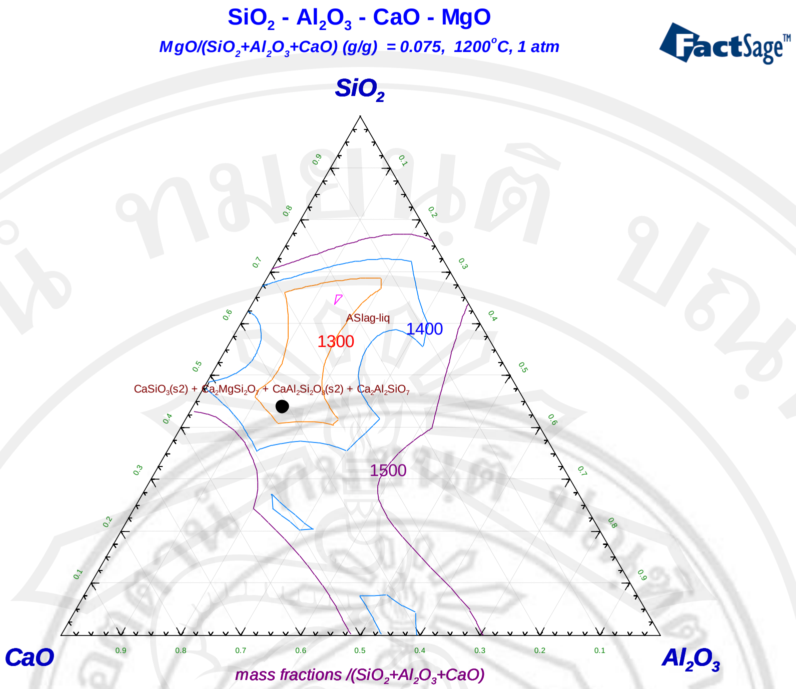

Figure C.24 Quaternary diagram of SiO_2-Al_2O_3-CaO-MgO system of Lignite C

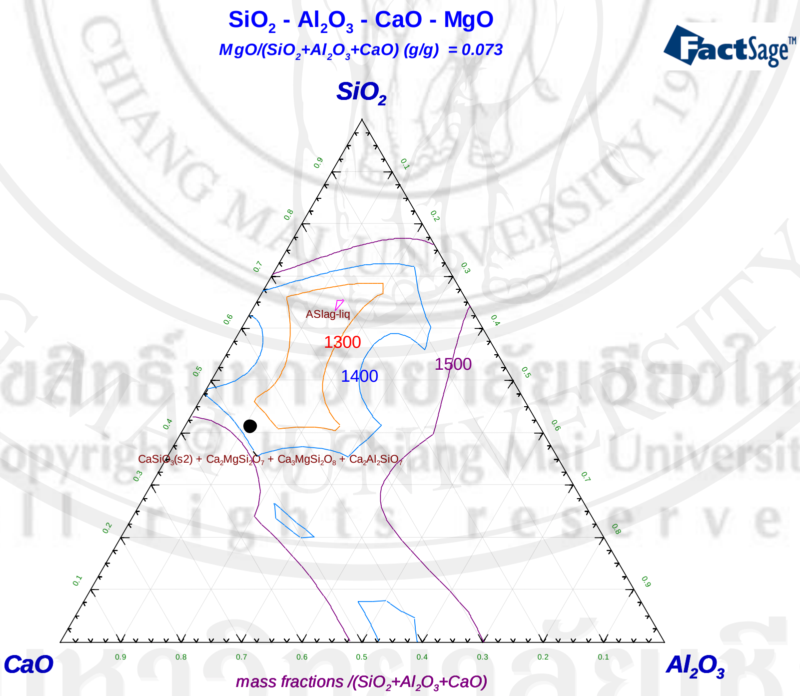

Figure C.25 Quaternary diagram of SiO_2-Al_2O_3-CaO-MgO system of Lignite D

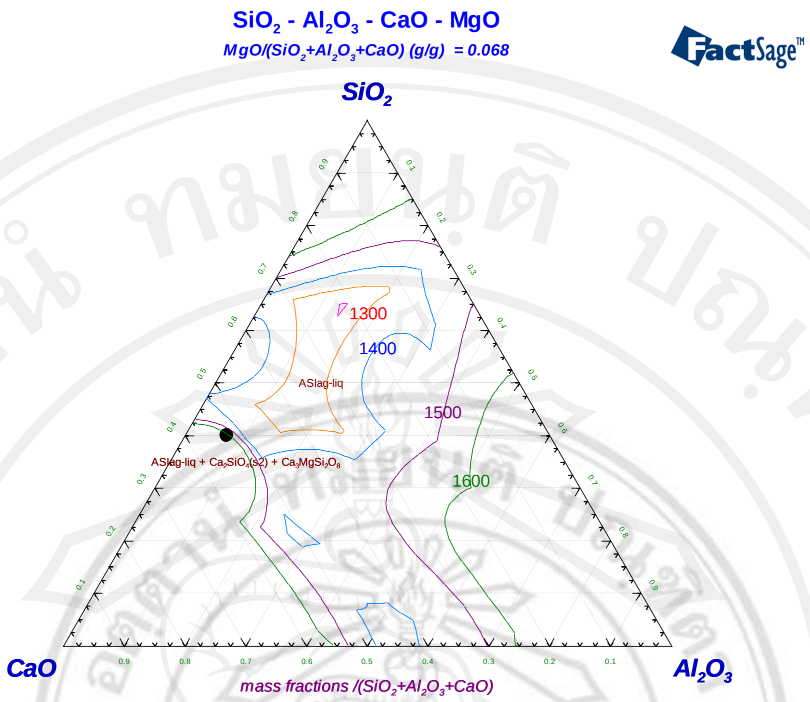

Figure C.26 Quaternary diagram of SiO_2-Al_2O_3-CaO-MgO system of Lignite E

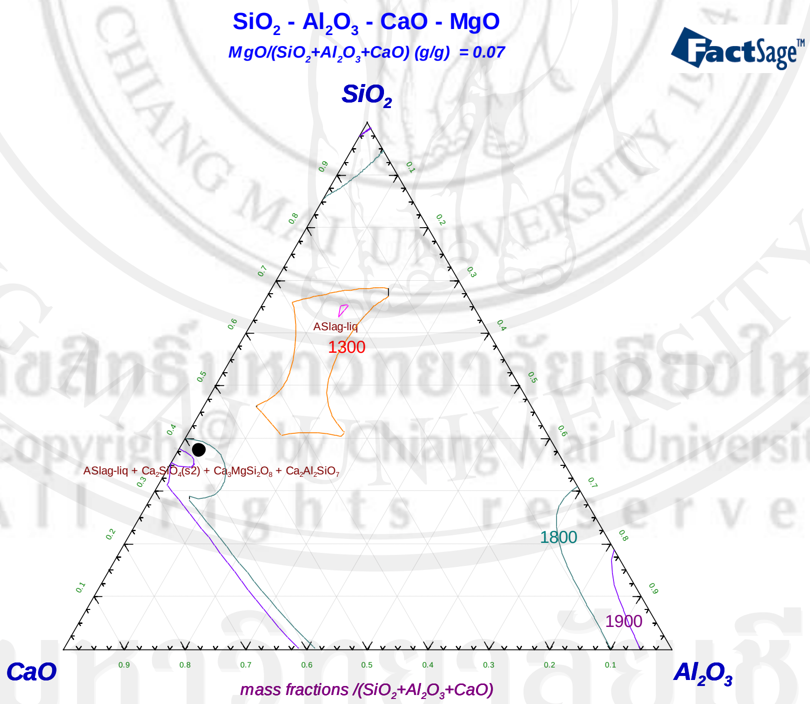

Figure C.27 Quaternary diagram of SiO_2-Al_2O_3-CaO-MgO system of Lignite F

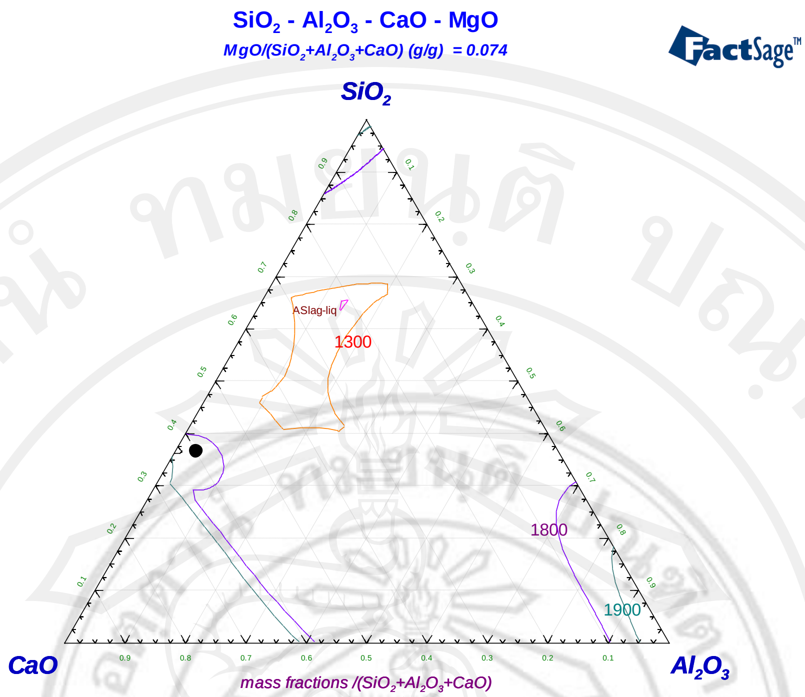

Figure C.28 Quaternary diagram of SiO_2-Al_2O_3-CaO-MgO system of Lignite G

Appendix D

Case study in CFD simulation

D.1 Parameter usage in CFD program

Table D.1 The data of Mae Moh operation case study

Operation Date	16 January 2006
Generator Active Power (kW)	300,217
Total Coal Flow (kg/s)	75
Total Air Flow (kg/s)	338
Air/Fuel Ratio	4.53
Primary Air Flow (kg/s)	159
Secondary Air Flow (kg/s)	178
O_2 (%)	3
Pulverizer#1 Outlet Temperature (°C)	56.19
Pulverizer#2 Outlet Temperature (°C)	54.00
Pulverizer#3 Outlet Temperature (°C)	58.79
Pulverizer#4 Outlet Temperature (°C)	53.29
Pulverizer#5 Outlet Temperature (°C)	60.13
Auxiliary Air Temperature (°C)	268.63
Winbox/Furnace Different Pressure (Pa)	1,590.08
Boiler Efficiency (%)	87.32
Coal (kg)	6,554,000
HHV Coal (MJ/kg)	11.438

Proximate analysis	
Moisture (%)	30.48
Ash (%)	27.56
Volatile (%)	25.00
Fixed Carbon (%)	16.96
Sulfur (%)	2.68
Ultimate analysis	
C (%)	28.84
H (%)	5.34
N (%)	1.06
O (%)	34.16
S (%)	2.70
Ash Composition	
Na_2O (%)	0.79
MgO (%)	2.09
Al_2O_3 (%)	19.39
SiO_2 (%)	35.16
P_2O_5 (%)	0.16
SO_3 (%)	12.97
K_2O (%)	2.47
CaO (%)	14.60
TiO_2 (%)	0.38
MnO_2 (%)	0.12
Fe_2O_3 (%)	11.86
CaO (freeSO_3) (%)	16.78

Ash Fusibility Temperature	
IT (°C)	1,299
ST (°C)	1,312
HT (°C)	1,328
FT (°C)	1,433
Heat Flux (kW/m^2) @ Boiler Level	
15 m.	102
20 m.	94
23 m.	51
27 m.	55
30 m.	84
34 m.	120
38 m.	104
Furnace Gas Exit Temperature (°C)	1,089
Outlet Flue Gas Temperature (°C)	469
Boiler Exit Temperature (°C)	165
Above Burner 54 (°C)	1,037

D.2 Setup and Solution

Step 1: Grid

1.1 Read the mesh file from ICEM

1.2 Check the grid.

1.3 Display the grid.

1.3.1 Select all the surfaces from the Surfaces selection list.

1.3.2 Click Display and close the Grid Display panel.

Step 2: Models

2.1 Select the standard k-ε turbulence model.

2.2 Enable the Energy Equation.

2.3 Select the Species Transport model.

2.3.1 Select Species Transport from the Model list.

2.3.2 Enable Volumetric from the Reactions list.

2.3.3 Select coal-hv-volatiles-air from the Mixture Material drop-down list.

2.3.4 Select Eddy Dissipation from the Turbulence-Chemistry Interaction list.

2.3.5 Click OK to close the Species Model panel.

2.4 Select the DO radiation model.

2.5 Enable the Discrete Phase model.

2.5.1 Enter 40000 for Max. Number of Steps.

2.5.2 Enable Specify Length Scale and enter 0.0025 m for Length Scale.

2.5.3 Click OK to close the Discrete Phase Model panel.

Step 3: Injections

3.1 Define 4 injections from surface of coal panels.

3.1.1 Click the Create button to open the Set Injection Properties panel.

3.1.2 The common properties for 4 injections are shown in below:

1) Particle Type: Combusting
2) Material: coal-hv
3) Devolatilizing Species: hv_vol
4) Product Species: co
5) Oxidizing Species: o2
6) Point Properties: Temperature= 333 (K) , Z and X direction of velocity (m/s), Diameter $7.4e^{-5}$ (m), and Total Flow Rate 18.25 (kg/s)
7) Turbulent Dispersion: Stochastic Model with values for Number of Tries and Time Scale Constant as 10 and 0.15 respectively.

3.2 Retain the default values for the other parameters.

3.3 Close the Injections panel.

Step 4: Materials

4.1 Modify the properties for the coal-hv-volatiles-air mixture.

4.1.1 Add carbon-monoxide (co) from the FLUENT materials database.

1) Click the Fluent Database…button to open the Fluent Database Materials panel.

2) Select fluid from the Material Type drop-down list.

3) Select carbon-monoxide (co) from Fluent Fluid Materials panel.

4) Click Copy and close the Fluent Database Materials panel.

4.2 Click the Edit…button to the right of the Mixture Species drop-down list to open the Species panel.

1) Add carbon-monoxide (co) to the list of Mixture Species.
Note: Make sure nitrogen is the last species in the list. If not, remove nitrogen and add it again.

2) Click OK to close the Species panel.

4.3 Click the Edit…button to the right of the Reaction drop-down list to open the Reactions panel.

1) Edit the Eddy-Dissipation reaction model as follows:

a. Click 2-step reaction

b. Include so2 in the combustion

c. Input the parameter from Proximate analysis (as-received)

d. Input the parameter form Ulimate analysis (ash dry free)

e. Click wet combustion

2) Set the properties for the coal

a. Coal As-Received HCV = 800 (j/kg)

b. Volatile Molecular weight = 30 (kg/kgmole)

c. CO/CO2 Split in Reaction 1 Products = 1

d. High Temperature Volatile Yield =1.5

e. Fraction of N in Char (DAF) = 0.7

3) Retain the default values for the other parameters.

4) Click OK to close the Reactions panel.

4.4 Set the properties for the combusting particle coal-hv.

4.4.1 Density = 800 (kg/m3)

4.4.2 Cp (Secific Heat) = 1100 (J/kg-K)

4.4.3 Thermal Conductivity = 0 (w/m-K)

4.4.4 Latent Heat = 0 (J/kg)

4.4.5 Vaporization Temperature = 700 (K)

4.4.6 Volatile Component Fraction = 55 (%)

4.4.7 Binary Diffusivity = 3e-05 (m2/s)

4.4.8 Selling Coefficient = 2

4.4.9 Burnout Stoichiometric Ratio = 1.33

4.4.10 Combustible Fraction = 36.7 (%)

4.4.11 Heat of Reaction for Burnout = 9.210416e6 (j/kg)

4.4.12 React. Heat Fraction Absorbed by solid = 100 (%)

4.4.13 Devolatilization Model = Single rate; Pre-Exponential Factor, Activation Energy (J/kgmol)

4.4.14 Combustion Model = Intrinsic Model

4.5 Set properties for o2, co2, h2o, co, and n2. Select piecewise-polynomial from the Cp drop-down list for o2, co2, h2o, co, and n2 species and accept the default values.

4.6 Set properties for coal volatiles coal_hv_volatiles. Enter 50 for Molecule Weight and -1.8474e7 for Standard State Enthalpy.

4.7 Click Chang/Create and close the Materials panel.

Step 5: Cell Zone Conditions

Set all zone for fluid type.

Step 6: Boundary Conditions

6.1 Set the boundary condition for inlet of coal and air as specified in follows:

6.1.1 Velocity Specification method = Components (m/s)

6.1.2 Coordinate System = Cartesian (x, y, z)

6.1.3 Temperature (K)

6.1.4 Turbulence Intensity (%)

6.1.5 Hydraulic Diameter (m)

6.1.6 Species Mass Fraction of o2 = 0.2315

6.2 Set the boundary condition for outlet as outflow. The bottom outlet was set as an escape wall

6.3 Set the boundary condition for the wall zones. The all of the wall surfaces were set as the no-slip condition.

6.3.1 Thickness = 0.004572 (m)

6.3.2 Temperature = 673 (K)

6.3.3 Internal Emissivity = 0.8

6.3.4 Thermal Conductivity of material = 1.5 W/m-K

6.4 Close the Boundary Condition panel.

Step 7: Initiate Reacting Flow Solution

7.1 Patch high temperature and product species mass fractions in reaction zone.

7.1.1 Select Inside in the Options list and Hex in the Shapes list.

7.1.2 Enter the Input Coordinates

1) X-Axis; Min = 1 (m), Max = 14 (m)

2) Y-Axis; Min = 10 (m), Max = 25 (m)

3) Z-Axis; Min = -6 (m), Max = 6 (m)

7.1.3 Click Mark and close the Region Adaption panel.

7.2 Patch the following values in the reaction zone.

7.2.1 Select Hex-01 from the Registers to Patch selection list and patch the following values:

1) Temperature = 2000 (K)

2) h2o mass fraction = 0.01

3) co2 mass fraction = 0.01

7.3 Close the Patch panel.

7.4 Set the Under-Relaxation Factors as follows:

7.4.1 Energy = 0.95

7.4.2 Species = 0.95

7.4.3 Discrete Phase Sources = 1

Step 8: Obtain Converged Solution

8.1 Set the Residual Monitors as follows:

8.1.1 Click on for Print to console

8.1.2 Click on Plot; Window = 1, Iterations to Plot = 1000, Iterations to start = 1000

8.1.3 Convergence Criterion = absolute

8.1.4 Equation = 0.001, Energy = 1e-06

8.1.5 Create the Surface Monitors:

1) Area-weighted Average of Temperature for outflow

2) Area-weighted Average of Velocity of outflow

8.2 Run calculation; 10000 Number of iterations.

Step 9: Post-processing

9.1 Check the mass balance for convergence.

9.1.1 Select Mass Flow Rate from the Options list.

9.1.2 Select all the zones from the Boundaries selection list and click Compute (this is net gas phase mass flux, the negative number indicates net gas mass leaving the domain).

9.1.3 Close the Flux Reports panel.

9.1.4 Select Sum from the Report Type list.

9.1.5 Select Discrete Phase Model… and DPM Mass Source from the Field Variable drop-down lists.

9.1.6 Select fluid from the Cell Zones selection list and click Compute (this is net mass transfer from the discrete phase coal particles to the gas phase).

9.1.7 Close the Volume Integrals panel.

9.2 Check the net heat transfer.

9.2.1 Select Total Heat Transfer Rate from the Options list.

9.2.2 Select all the zones from the Boundaries selection list and click Compute (this is net gas phase heat transfer).

9.2.3 Close the Flux Reports panel.

9.2.4 Select Sum from the Report Type list.

9.2.5 Select Discrete Phase Model… and DPM Enthalpy Source from the Field Variable drop-down lists.

9.2.6 Select fluid from the Cell Zones selection list and Compute (this is net discrete phase heat transfer).

9.2.7 Close the Volume Integrals panel.

9.3 Display filled contours of velocity magnitude.

9.4 Display filled contours of static temperature.

9.5 Display filled contours of wall heat flux.

9.6 Display particle tracks for 4 injections.

D.3 Results of raw coals

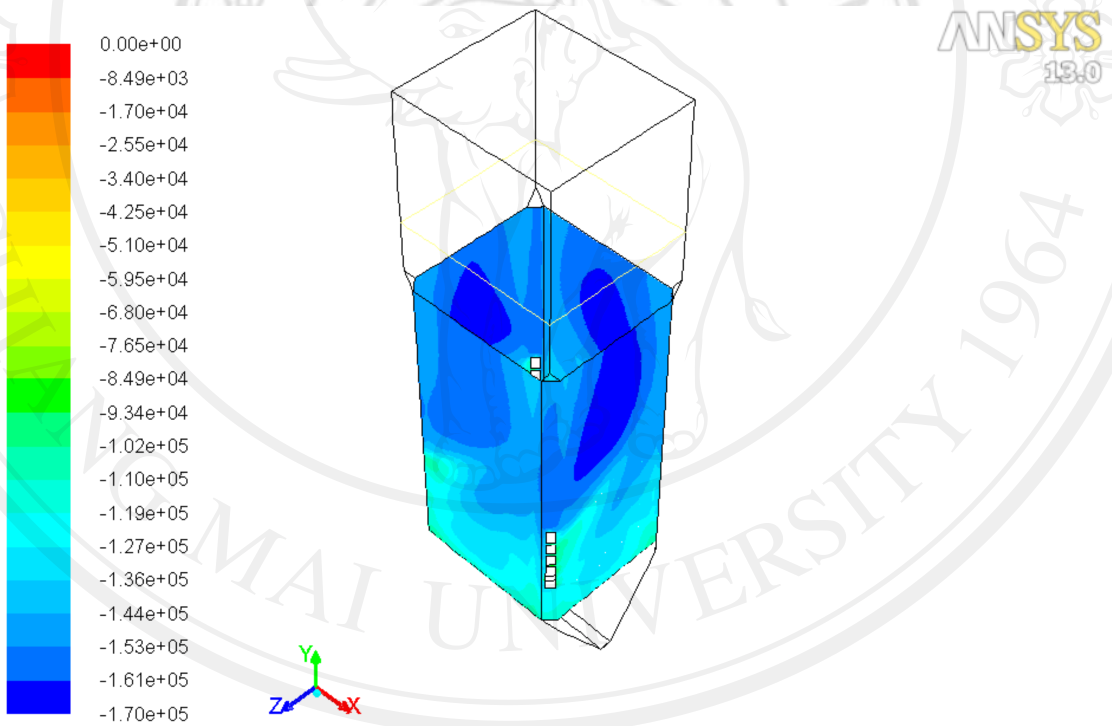

Figure D.1 Predicted surface heat flux of lignite C1

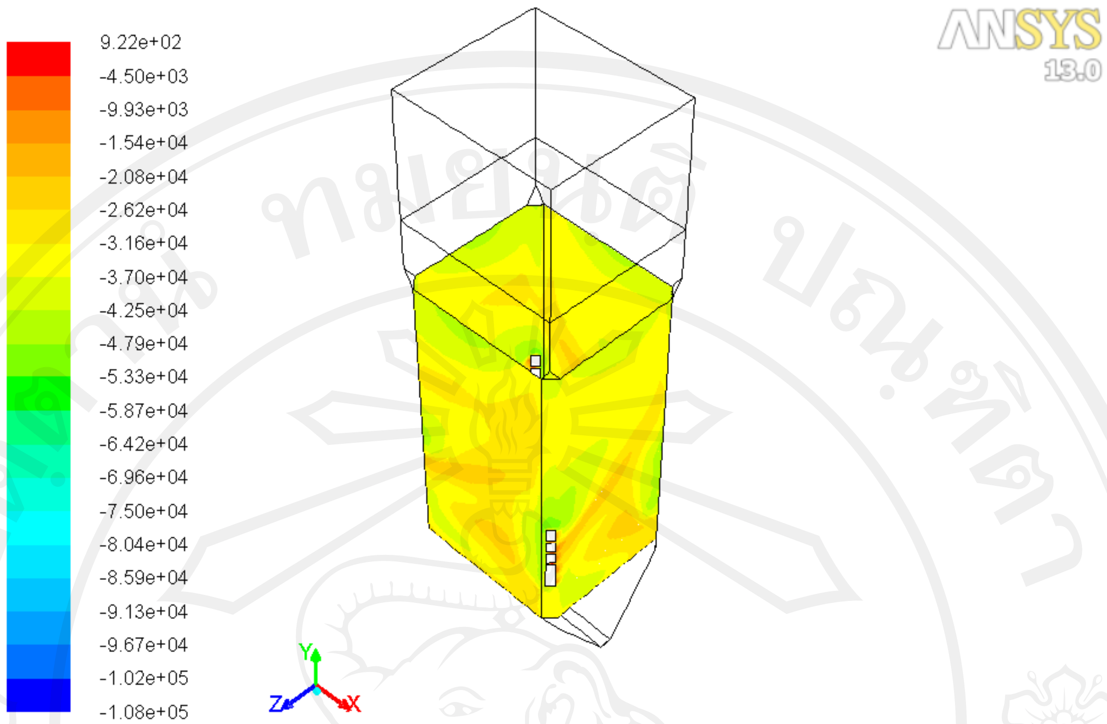

Figure D.2 Predicted surface heat flux of lignite SE

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Publications

Pintana, P., Tippayawong, N., "Pridiction of Slag Occurrence in a Lignite-Fired Utility Boiler," WSEAS Transactions on Environment and Development, Vol. 10, 2014, 202-210.

Pintana, P., Tippayawong, N., Nuntaphun, A., Thongchiew, P., "Characterization of slag from combustion of pulverized lignite with high calcium content in utility boiler," Energy Exploration & Exploitation, Vol. 32, No. 3, 2014, 471-482.

Pintana, P., Tippayawong, N., Ingham, D.B., Pourkashanian, M., Ma, L., Jones, J., Williams, A., "Assessing Potential Occurrence of Slag in Combustion of Thai Coal by Evaluation of The Ash Melting Temperature," 13th International Conference on Clean Energy (ICCE-2014), Istanbul, Turkey, 8-12 June 2014, 117-123.

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Pintana, P., Tippayawong, N., Nuntaphun, A., Thongchiew, P., “Physical Characterization of Slag from Combustion of Lignite with High Ca Content,” International Conference on Green and Sustainable Innovation 2012 (ICGSI 2012), Chiang Mai, Thailand, 2012, 194-201.

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