#### **CONTENTS**

	Page
บทคัดย่อ	(3)
ABSTRACT	(4)
ACKNOWLEDGEMENT	(5)
THE RELEVANCY OF THE RESEARCH WORK TO THAILAND	(6)
CONTENTS	(7)
LIST OF TABLES	(9)
LIST OF FIGURES	(10)
1. INTRODUCTION	1
1.1 Introduction	1
1.2 Review of literature	2
1.3 Objectives	22
2. METHOD OF STUDY	23
2.1 Materials	23
2.2 Equipment	23
2.3 Methods	24
2.3.1 Various methods to upgrade ilmenite ore	24
2.3.2 Measurement of temperature at the soxhlet	32
2.3.3 Determination of acid concentration	35
2.3.4 Qualitative analysis by EDXRF	35
2.3.5 X-ray powder diffraction patterns(XRD)	36
2.3.6 Quantitative analysis by WDXRF	36

# CONTENTS(CONTINUED)

		Page
3	Results	38
	3.1 Leaching methods to upgrade ilmenite ore	38
	3.2 Measurement of temperature at the soxhlet	49
	3.3 Determination of acid concentration	50
	3.4 Qualitative analysis by EDXRF	52
	3.5 X-ray powder diffraction pattern (XRD)	57
	3.6 Quantitative analysis by WDXRF	60
4	Discussion	68
5	Summary	89
Reference		91
Aį	Appendix A	
Appendix B		108
Vitae		111

#### LIST OF TABLES

Cable Cable	
1 Temperature at round bottom flask and outer side of soxhlet.	27
2 The concentration of each element in the standard pellets.	37
3 Residues after leaching by method A by varying temperature at	39
round bottom flask and soxhlet.	
4 Residues after leaching by method A by varying the ratio of ilmenite	40
ore to acid.	
5 Detailed conditions of the leaching to study the effect of NaCl	43
(method B).	
6 Detailed conditions of the leaching to study the effect of H <sub>2</sub> O <sub>2</sub>	44
(method C).	
7 Residues after leaching by methods D1, D2, E, AA, CA, and F.	45
8 Data resulting from effect of leachant temperature.	47
9 Data resulting from effect of the outer side of soxhlet temperature.	47
10 Data resulting from effect of initial ilmenite ore to acid ratio.	48
11 Data resulting from effect of leaching time.	49
12 The temperature measurement in soxhlet in A) no cover on the	49
soxhlet B) cover the soxhlet with beaker.	
13 Acid concentration	52
14 Composition of ilmenite ore and the residues after leaching.	67
15 Composition of ilmenite ore from different locations.	69
16 The initial acid to ilmenite mole ratio.	73
17 Leaching time used in each method at the same ilmenite ore to acid	81
ratio.	

### LIST OF FIGURES

Figure	Page
1 Crystal structure of ilmenite (Bulter, et al.).	4
2 TiO <sub>2</sub> pigment manufactured by the sulfate process (Buchner, et al.,	5
1989: 526).	
3 TiO <sub>2</sub> pigment manufactured by the chloride process (Buchner, et al.,	6
1989: 528).	
4 Sketch of the fluid bed reactor used in the hydrochloric acid leached	16
processes by Lanyon, et al., (1999).	
5 Sketch of set up in the soxhlet section in method A.	25
6 Sketch of the reactor used in method A.	26
7 Sketch of the sintered glass used in method A and method E.	30
8 Sketch of the reactor used in method E.	30
9 Sketch of reactor used in measurement of temperature at the soxhlet	34
experiment.	
10 Residue colors at each level of blackness.	41
11 Titration curve of acid determination in soxhlet on blank	51
experiment in method A after reflux 2 hours.	
12 EDXRF spectrum of an ilmenite ore before leaching.	53
13 EDXRF spectrum of the residue after leaching by method A using	54
ilmenite 15 g with temperature at round bottom flask and soxhlet	
105 and 120°C, respectively.	
14 EDXRF spectrum of the residue after leaching by method B1.	54
15 EDXRF spectrum of the residue afterleaching by method Ci1.	55
16 EDXRF spectrum of the residue after leaching by method D1.	55

### LIST OF FIGURES(CONTINUED)

Figui	igure	
17	EDXRF spectrum of the white precipitate occurred in round bottom	56
	flask after leaching ilmenite ore by method D1	
18	EDXRF spectrum of precipitated obtained by adding 0.1 M. NaOH	56
	to leachant.	
19	XRD spectrum of starting ilmenite ore.	57
20	XRD spectrum of the residue after leaching by method AA.	58
21	XRD spectrum of the residue after leaching by method CA.	58
22	XRD spectrum of the residue after leaching by method B1.	59
23	XRD spectrum of the white precipitate occurred in round bottom	59
	flask after leaching ilmenite ore by method D1.	
24	Calibration graph of Fe.	61
25	Calibration graph of Mn.	61
26	Calibration graph of W.	62
27	Calibration graph of Y.	62
28	Calibration graph of Zr.	63
29	Calibration graph of Nb.	63
30	Data resulting from determination of Fe.	64
31	Data resulting from determination of Mn.	64
32	Data resulting from determination of W.	65
33	Data resulting from determination of Nb.	65
34	Data resulting from determination of Sn.	66
35	Data resulting from determination of Zr.	66
36	Concentrations of Fe remaining in residues from method A and B.	75
	(Data taken from Table 14).	

# LIST OF FIGURES(CONTINUED)

Figure		Page
37	Concentrations of Fe remaining in residues from method A, B, and	76
	C. (Data taken from Table 14).	
38	Concentrations of Fe and Mn in residues from method B, C, and D.	77
	(Data taken from Table 14).	
39	Concentrations of Fe remained in residues in the double leaching	79
	with fresh acid study. (Data taken from Table 14).	
40	Concentration of Fe remained in the residue.(Data taken from Table	80
	14).	
41	The concentration of Fe and Mn remained in residues from method	82
	F in the effect of leachant temperature.	
42	The relation between the amount of Fe and Mn remained in the	83
	residue from method F and outer side of soxhlet temperature.	
43	The relation between the amount of Fe and Mn remained in the	84
	residue from method F and initial ilmenite used.	
44	The relation between the amount of Fe and Mn remained in the	85
	residue from method F and leaching time.	
45	X-ray fluorescence process and energy level diagram (Havrilla,	99
	1997).	
46	Schematic diagrams of wavelength and energy dispersive x-ray	101
	fluorescence instrument(Havrilla, 1997).	
47	Analysis of 316-grade stainless steel(Havrilla, 1997).	104