

CONTENTS – VOLUME 2

Preface	vii
---------------	-----

CHAPTER 1

DEVELOPMENT OF THE SOLVENT EXTRACTION PROCESS..... 1

1.1 INTRODUCTION	2
1.2 SOLVENT CONDITIONING	5
1.3 SOLVENT PRE-TREATMENT	6
1.4 INITIAL STUDIES	8
1.4.1 Extractant Screening	8
1.5 DISTRIBUTION DATA	10
1.5.1 Extraction	10
1.5.2 Stripping	16
1.5.3 Kinetics of Extraction and Stripping	17
1.6 EXTRACTANT CONCENTRATION	18
1.7 TEMPERATURE EFFECTS	20
1.8 METALS SEPARATIONS IN A STAGEWISE PROCESS.....	21
1.9 SCRUBBING	23
1.10 DILUENT AND MODIFIER REQUIREMENTS.....	25
1.10.1 Shake-Out Tests	25
1.10.2 Phase Continuity Tests	26
1.10.3 Third Phase Formation	26
1.10.4 Modifier Tests	26
1.11 CONCENTRATION OF SOLVENT CONSTITUENTS IN BOTH PHASES	27
1.12 DISPERSION, COALESCENCE AND CONTACTORS.....	27
1.13 SCALE-UP DECISIONS	33
1.14 SMALL SCALE CONTINUOUS TESTING	34
1.15 PILOT PLANT OPERATIONS	40
1.16 SOLVENT LOSS	45
1.16.1 Introduction	45
1.16.2 Soluble Losses	46
1.17 ENVIRONMENTAL CONSIDERATIONS	63
1.18 ECONOMICS.....	64
1.18.1 Capital Investments	65
1.18.2 Operating Costs	66
1.19 OPTIMIZATION OF THE SOLVENT EXTRACTION PROCESS	67
1.20 SOLVENT IN PULP PROCESSING	72
1.21 PLANT SCALE-UP AND OPERATION	72
1.22 NOTES	74
1.23 REFERENCES	74

CHAPTER 2

PLANT DESIGN AND MATERIALS OF CONSTRUCTION..... 81

2.1 INTRODUCTION	81
2.2 SELECTION OF SITE	83
2.3 BUILDINGS	83
2.4 SAFETY	84

2.5	FIRE HAZARDS.....	86
2.5.1	Introduction	86
2.5.2	Flammable Atmospheres.....	87
2.5.3	Electrostatic Charging.....	91
2.5.4	Ignition by Electrostatic Discharges	94
2.5.5	Applicability to Solvent Extraction Plants.....	96
2.5.6	Summary	102
2.6	AUTOMATION AND CONTROL	102
2.7	MATERIALS OF CONSTRUCTION	103
2.8	CORROSION	110
2.9	PAINTING	116
2.10	REFERENCES	118

CHAPTER 3 PROCESSES 121

3.1	INTRODUCTION	122
3.2	ALUMINUM.....	124
3.3	BERYLLIUM.....	129
3.4	CADMIUM	133
3.5	CESIUM	138
3.6	CHROMIUM.....	143
3.7	COPPER	149
3.8	GALLIUM AND INDIUM	239
3.9	GERMANIUM	246
3.10	IRON	248
3.11	LITHIUM	263
3.12	MANGANESE	264
3.13	MERCURY	269
3.14	MOLYBDENUM	270
3.15	NICKEL AND COBALT	279
3.16	NIOBIUM (COLUMBIUM) AND TANTALUM.....	393
3.17	NOBLE METALS.....	402
3.18	RARE EARTHS AND YTTRIUM	423
3.19	RHENIUM	456
3.20	SCANDIUM.....	459
3.21	SILVER	464
3.22	THORIUM	467
3.23	TITANIUM	496
3.24	TUNGSTEN	498
3.25	URANIUM	505
3.26	VANADIUM	573
3.27	ZINC AND CADMIUM	583
3.28	ZIRCONIUM AND HAFNIUM	599
3.29	ACID RECOVERY FROM PROCESS SOLUTIONS.....	613
3.30	MISCELLANEOUS METALS.....	639

CHAPTER 4
SOLVENT-IN-PULP PROCESSING 643

4.1	INTRODUCTION	643
4.2	SOLVENT-IN-PULP PROCESSES	644
4.3	REVIEW OF OPERATING EXPERIENCE	646
4.4	SOLVENT LOSSES	650
4.4.1	Adsorption of Solvent on Ore Particles	650
4.4.2	Crud Formation	653
4.4.3	Prevention of Solvent Losses and Crud Formation	655
4.4.4	Pulse Conditions.....	656
4.5	COST OF THE PROCESSES	656
4.6	DISCUSSION.....	659
4.7	REFERENCES	662

CHAPTER 5
SUMMARY OF PLANTS AND PROCESSES 665

5.1	INTRODUCTION	665
5.2	PROCESS SUMMARY	666
5.3	CHARACTERISTICS AND PERFORMANCE OF SOME EXTRACTANTS IN VARIOUS SYSTEMS.....	670
5.3.1	Anionic Systems.....	670
5.3.2	Cationic Systems.....	672
5.3.3	Chelating Systems.....	677
5.3.4	Solvating Systems	680
5.3.5	Solvent-in-Pulp	682
5.4	REFERENCES	682

CHAPTER 6
EFFLUENT TREATMENT 685

6.1	INTRODUCTION	685
6.2	CONCERN.....	687
6.3	PAST PRACTICE	688
6.4	PLANT PROCESSES	688
6.4.1	Recovery of Metals from Wastes.....	688
6.4.2	Processing of Smelter Dusts and other Solids	690
6.4.3	Recovery of metals and acids from wastes	692
6.4.4	Extraction of oils	696
6.5	SOME RECENT PROCESSES FOR ENVIRONMENTAL AND SECONDARY RECOVERY.....	696
6.6	FUTURE.....	697
6.7	REFERENCES	699

CHAPTER 7	
ECONOMIC CONSIDERATIONS	705
7.1 INTRODUCTION	705
7.2 GENERAL CONSIDERATIONS	708
7.2.1 Capital Investments.....	708
7.2.2 Operating Costs.....	709
7.3 COST COMPARISON OF SOME SELECTED SYSTEMS	714
7.4 OPTIMIZATION OF THE SOLVENT EXTRACTION PROCESS	714
7.5 EQUIPMENT, COALESCENCE AND SOLVENT LOSSES.....	722
7.6 SOLVENT REMOVAL AND RECOVERY	727
7.7 PLANT COST ESTIMATES	733
7.7.1 Copper	733
7.7.2 Uranium.....	741
7.7.3 Solvent-in-Pulp	746
7.8 SOLVENT EXTRACTION AS COMPARED TO OTHER PROCESS ROUTES	748
7.9 EXTRACTION AND SEPARATION OF METALS.....	755
7.10 BY-PRODUCT RECOVERY	760
7.11 RECOVERY OF METAL POWDERS	770
7.12 CONCLUSIONS	771
7.13 REFERENCES	772
APPENDICES	778
Appendix I – The Nomenclature of Solvent Extraction	778
Appendix II – Conversion Units	781
INDEX.....	782