

CONTENTS

	Page
PART I – GENERAL METALLURGY	
CHAPTER I	
Ores and Their Treatment:	
Definition and Classification of Ores	3
Methods of Treatment	4
Properties of Solids and Gases	6
The Refining of Metals	7
Molding and Casting Metals	7
CHAPTER II	
Fuels:	
Fuels	11
The Natural Solid Fuels	12
The Artificial Fuels	16
The By-product Oven and its Product	22
Producer-gas	25
Gas-producers	26
Pulverized Coal	29
Fuel Economy at Iron and Steel Works	32
CHAPTER III	
Refractories:	
Refractory Materials and Their Properties	33
Acid Refractories	34
Neutral and Basic Refractories	36
Basic Refractories	38
CHAPTER IV	
The Sampling and Valuation of Ores:	
Principles of Sampling	41
Receiving, Sampling, Crushing, Bedding and Storing Ores	42
Sampling-mill	47
Sampling Metals	49
Valuation or Price of Ores	51
CHAPTER V	
Crushing and Sizing:	
Crushing	52
Breaking	53
Secondary Grinding	57
Grinding (pulverizing)	60
Sliming	65
Factors that Influence grinding	67
Screening	69
Classifying	72
Hydraulic Classifiers	72
Mechanical Classifiers	73

	CHAPTER VI	
Metallurgical Furnaces:		
Shaft Furnace		76
Reverberatory Furnace		77
	CHAPTER VII	
Combustion:		
Principles of Combustion		79
Combustion in the Air and in the Blast-furnace		80
Temperature of Combustion		83
	CHAPTER VIII	
Metallurgical Thermo-Chemistry:		
Methods of Determining Thermic Values		87
Calorimetry		88
Heats of Formation of Chemical Elements		89
	CHAPTER IX	
Roasting:		
Kinds of Roasting		92
Chemistry of Roasting		93
Roasting Ores in Lump Form; Heap-roasting		97
Roasting of Ores in Pulverized condition		99
The Long-hearth Reverberatory Roaster		100
Mechanically Operated Roasting Furnaces		102
Multiple-hearth Furnace Type		106
Roasting of Mette		112
Capacity of Furnaces and Cost of Roasting		113
Sinter-roasting		114
Blast or Pot-roasting of Ores		114
Multiple Roasting		118
Trend of Roasting		118
Dust Losses in Roasting		119
	CHAPTER X	
Concentration of Ores and Tonnage Calculations:		
Concentration		120
Flotation		121
Treatment of Concentrates		123
Tonnage and Capacity Calculations		124
Ratios of Concentration and Recoveries		125
Dust Losses and Dust-Catchers		126
	PART II – GOLD	
	CHAPTER XI	
Gold Ores, Also Their Classification for Milling:		
Occurrence		129
Classification of Milling Methods		130
	CHAPTER XII	
Amalgamation of Gold Ores:		
Amalgamation Methods and Costs		132
Stamp-Milling with Plate Amalgamation		133
General Arrangement of a Gold Stamp-mill		139
Concentration in Stamp-milling		140
	CHAPTER XIII	
Hydrometallurgy of Gold Ores:		
Milling Ores in Aqueous Solution		142

CHAPTER XIV

Chlorination of Gold Ores:	
Ores Suited to Chlorination	144
The Goldfield Chlorine Mill Co., Goldfield, Nev	145
Barrel Chlorination	145

CHAPTER XV

Cyaniding of Gold Ores:	
Outline of the Process of Cyaniding	146
Gravity Concentration Prior to Cyaniding	146
Ores Suited to Cyanidation	148
Chemistry of the Cyanide Process for Gold Ores	149
The Standard Systems of Cyanidation	153
Development of Cyaniding on the Rand	153
The Separation of Sand from Slime	155
Description of Vats	155
Double Treatment	157
Slime Treatment (decantation)	160
Slime-agitation	161
The Air-compressor	162
Pneumatic Agitators	162
Mechanical Agitators	164
Combined Mechanical and Pneumatic Agitators	164
Comparative Agitator Data (1912)	166
Agitation Treatment	166
Thickening	167
The Dorr Thickener	168
The Golden Cycle Super-thickener	169
Continuous Counter-current Decantation	170
Main System of Filtration	171
Intermittent Vacuum Filters	171
Continuous Vacuum Filters	173
Pressure Filters	175
General Remarks on Filters	180
Clarifying	181
Filter-press Operation	182
The Crowe Vacuum Process	184
The Precipitation of Gold from Cyanide solutions	185
The merrill Precipitation Process	185
The Zinc or Extractor Box	188
Drying and Refining the Gold Precipitate	191

CHAPTER XVI

Typical Gold-mill Cyanide Practice:	
Free-milling Porous Ores	193
The Wasp No. 2 Mill, Black hills, South Dakota	193
Treatment of Clayey Ores	195
The Victorious Mill, Western Australia	195
The City-deep Mill, Rand District, South Africa	196
Trend of Practice in the Witwatersrand, South Africa	199
The Golden Cycle Mill, Colorado Springs, Colo	200
Kalgoorlie Destrict, Western Australis	203
The Hollinger Mill, Porcupine District, Ontario	203
The united Eastern Mill, Oatman, Ariz	206
The Wright-Hargreaves 200-ton Mill, Ontario District, Canada	210

CHAPTER XVII

Treatment of Gold-Bearing Concentrates:	
General Outline of Treatment	215
The Alaska-tradwell Concentrate Plant	216

Concentrate Treatment Plant, Goldfield Cons. Co., Goldfield, Nev	220
Other Methods of Concentrate Treatment	222
Gold-milling costs	222
CHAPTER XVIII	
Smelting of Gold Ores:	
Blast-furnace-smelting vs. Cyaniding of Gold Ores	224
The Price of Gold Ores and of Gold	225
Summary of Costs in Cyaniding	225
PART III – SILVER	
CHAPTER XIX	
Silver its Ores and Their Treatment:	
Characteristics of Silver Ores	229
Extraction of Silver from Ores	230
Treatment of Silver Ores	230
CHAPTER XX	
Amalgamation of Silver Ores:	
The Washoe Process of Wet Silver Stamp-milling	232
Concentration and Amalgamation of Silver Ores	235
The Boss Process of Silver-milling	241
The High-grade Nipissing Mill, Cobalt, Ontario	242
Chloridizing Roasting	244
Dry Silver Milling (Reese River Process)	246
The Patio Process	247
The Holt-Christensen Process	247
CHAPTER XXI	
Hydrometallurgy of Silver:	
Principles of the Hydrometallurgy of Silver	248
The Ziervogel Process	249
The Hyposulphite lixiviation of Silver Ore (Von Patera Process)	249
The Russell Process	250
CHAPTER XXII	
Cyanidation of Silver Ores:	
Principles of Cyanidation of Silver Ores	251
Chemistry of the Cyanide Process for Silver Ores	252
Chemistry of the Process for Silver Ores	252
Precipitation of Silver from Cyanide Solution	253
Precipitation on Zinc shavings	253
The Santa Gertrudis, Mexico, precipitating and Melting Plant	253
Precipitation by Aluminum Dust	256
Treatment of Silver Precipitate	257
Melting and Refining Silver Precipitate	258
Typical Silver Mills	260
The Tonopah-Belmont Development Co.'s Mill, Tonopah, Nev	261
Cyanidation of Mixed Silver Ores at the San Francisco Mill, Pachuca, Mex	264
The 50-ton Elko-Prince Mill, Nevada	266
Practice at Nipissing Co.'s Mill, Cobalt, Ontario	268
“Low-grade” Ore Mill	269
Cyanidation of Silver-bearing Concentrates	272
Cyanidation of Silver-bearing Concentrates (Belmont-Shawmut Mill)	273
Cost of Silver-milling	274
CHAPTER XXIII	
Refining Silver-Gold Bullion:	
Parting Silver-gold Ingots of Bars with acids	275
Electrolytic Parting of Gold from Silver	277

PART IV – IRON AND STEEL
CHAPTER XXIV

Iron Ores and Their Smelting:	
Classification and Occurrence of Iron Ores	283
Roasting Iron Ores	286
The Agglomeration of Fine Ores	287
Smelting for Crude Iron	287
Iron Blast-furnace and Plant	288
Gas-cleaning	294
The Hot-blast Stoves	295
Blast-furnace and Accessories	297
Operation of the Blast-furnace	298
Irregularities of Furnace Operation	300
Disposal of Slag or Cinder	301
Disposal of Pig Iron	302
The Gayley Dry-air Blast	304
Chemical Reactions of the Blast-furnace	305
The Heat Balance of the Blast-furnace	308
Burdening the blast-furnace	309
General Arrangement of the Blast-furnace Plant	311
Pig Iron	312
Classification of Pig Iron	313
Influence of the Contained Elements on the Character of the Pig Iron	314

CHAPTER XXV

Wrought Iron and Steel:	
The Manufacture of Wrought Iron by the Puddling Process	316
Steel-making	319
Steel-making by the Bessemer Process	319
Bessemer Processes	320
The Acid Bessemer Process	322
The Basic Bessemer Process	325
The Converter and Mixer Building	326
Steel-making in the Open-hearth Furnace	328
The open-hearth Furnace	329
The Acid Open-hearth Process	333
The Basic Open-hearth Process	335
The Open-hearth Plant	339
The Duplex Process of Steel-making	340
The Triplex Process	342
Electric steel-making	342
Duplex and Electric-furnace plant	344
Varieties of Steel	346
Pig Iron, Steel and Iron Ore Prices	348

PART V – COPPER
CHAPTER XXVI

Copper Ores and Their Treatment:	
Characteristics of Copper Ores	353
Extraction of Copper from its Ores	256
The Roasting of Copper-bearing Sulphides	357

CHAPTER XXVII

Copper Blast-furnace Smelting of Oxidized Ores:	
Blast-furnace Plant for Oxidized Ores	359
Lake Superior Copper Country Blast-furnace Smelting of Copper Slag	261
Smelting to Black Copper by the Union Miniere du Haut katanga	363

CHAPTER XXVIII

Blast-furnace Smelting of Sulphide Ores:	
Matte Smelting	364
Storage of Bedding of Ores	365
The Messiter System of Bedding	366
Unloading and Bedding of Ore	368
The Unloading Pocket	368
Ore-bedding Bins	368
The Copper-matting Blast-Furnace	369
Accessories of the Blast-furnace	372
Blast-furnace Conditions	374
Large Copper-smelting Blast –furnaces	374
Regular Operation of the Copper Blast-Furnace	376
Copper Matte	378
Copper-furnace Slags	379
Calculation of Charge for Matte-smelting	379
Pyrite Matte-smelting	382
Reactions in Pyrite Matte-smelting	383
Calculation of Charge in Pyrite-smelting	386
Disposal of the Slag	389
Copper Blast-furnace Costs	391

CHAPTER XXIX

Reverberatory Smelting:	
The Welsh Process of Reverberatory Smelting	392
Large-scale Reverberatory Matte-smelting	369
The Direct Coal-fired Furnace	396
Furnaces Fired by Pulverized Coal	398
The Oil-fired Furnaces	400
Reverberatory Smelting	404
Reactions and Calculation of the Charge	404
Schedule of Copper Ore Prices	406

CHAPTER XXX

Converting Copper-matte:	
The Copper Converter	407
The Converter Lining	409
Operation of a 20-ft. Great Falls Upright Converter	411
Operation of a Pierce-Smith Horizontal Converter	411
Chemical Reactions of the Converter	412
Smelting Concentrates and Fine Ore in a Converter	414
Blast-furnace Smelting and Converting Plant	415
Description and Costs of a Blast-furnace and Converting Plant	418
Reverberatory Smelting Works	419
Costs of a Proposed Reverberatory and Converter Plant and Its Operation	423

CHAPTER XXXI

The Hydrometallurgy of Copper:	
Principles of the hydrometallurgy of Copper	426
Extraction of Copper by Natural Leaching Methods	427
The Rio Tinto Process	427
The Shannon Copper Co. Process (Heap-roasting and Scrap-iron Precipitation)	431
Extraction of Copper as a Chloride	432
The Longmaid –Henderson Process	432
Sulphuric Acid Leaching with Electrolytic Precipitation	435
The Butte-Duluth Process	436
The Ajo Process of the new Cornelia Copper Co	438
Ammonia Leaching	444
Ammonia Leaching at Kennicott	445
Sulphur Dioxide Leaching	448

CHAPTER XXXII

Reverberatory Refining of Blister-Copper:	
Copper-refining	449
Melting and Refining Lake Copper	451
Refining Furnaces of the Electrolytic Plant	453

CHAPTER XXXIII

Electrolytic Copper-Refining:	
Electrolytic Copper-refining Plant	457
The Refinery	457
Capital Requirements	465
Cost of Refinery and Operating Costs in 1916	465
Commercial Copper	467
Copper-refining Contracts	468

PART VI – LEAD
CHAPTER XXXIV

Properties of Lead and its Ores:	
Characteristics of Lead Ores	471
The Smelting of Lead Ores on the Ore-hearth	473
The Newnam Hearth	475

CHAPTER XXXV

Silver-lead Smelting:	
Silver-lead Blast-furnace Smelting	477
Receiving, Sampling and Storing of Lead Ores	477
Bedding Ores at a Custom Works	478
Roasting	479
The Dwight-Lloyd Sintering Plant	479
General Arrangement of a Small Silver-lead Smelting Works	482
The Silver-lead Blast-furnace	483
Open and Closed-top Blast –furnace	486
Operating the Blast-furnace	488
Chemical Reactions and Physical Changes of the Blast-furnace	492
Action of Various Bases in Slags	494
Fuel and Fluxed in Silver –lead Smelting	497
Calculation of a Blast-furnace Charge	498
Products of the Blast-furnace	500
Flue-dust	500
The Bag-House	501
Volatilization Plant of the Chief Consolidated Mining Co., Eureka, Utah	504
Electrical Precipitation of Flue-dust by the Cottrell Process	504
Briquetting Flue-dust	510
Sintering flue-dust	512
Lead-copper Matte	512
Speiss	514
Arsenic Fume	514
Cadmium Recovery	515

CHAPTER XXXVI

Smelting of Zinc-Plant Residue:	
Outline of Processes	516

CHAPTER XXXVII

Smelting of Lead Ores – Costs and Prices:	
Costs of Lead Ores	520
Ore Prices; Mississippi Valley Lead Smelting Works	521
Ore Prices; Colorado and Utah Silver-lead Smelteries	521
Selling Price of Matte	525

CHAPTER XXXVIII

Refining of Lead and Base Bullion:	
Primary or Commercial Pig Lead	526
Refining Base-Bullion	526
The Parkes Process	530
Treatment of the Rich Lead	535
The Pattinson Process	539
Cost of Refining Base-bullion	540
Selling Price of Base-bullion	540
The Betts Process for the Electrolytic Refining of Lead	540
Silver-lead Smelting Works and Refinery	542

PART VII – ZINC CHAPTER XXXIX

Zinc and its Ores:	
Properties of Zinc	547
Zinc Ores	547

CHAPTER XL

The Roasting and Smelting of Zinc Ores:	
Roasting Zinc Ores and Concentrates	549
Roasting Furnaces	550
The Wedge Mechanical Blende-Roasting Furnace	551
The Hegeler Furnace	551
The Ridge Furnace	554
Blast-roasting	556
Sulphuric Acid	556
The Smelting or Distillation of Zinc Ores	557
Operating the Furnace	563
Manufacture of Retorts and Condensers	565
Losses in the process	566
Cost of Smelting	567
Price of Zinc Ores and Zinc Concentrates in 1922	568
Spelter or Zinc	569

CHAPTER XLI

Refining of Spelter:	
Grades of Commercial Zinc	571
Redistillation of Spelter	571
Equalizing or Refining Spelter in the Setting Tank or Remelting Furnace	573

CHAPTER XLII

The Hydrometallurgy of Zinc:	
Outline of the Process	575
Electrolytic Zinc	575
The Coolbaugh Process	579

PART VIII – PLANT AND EQUIPMENT AND THEIR COSTS

CHAPTER XLIII

Accessory Equipment of Plants:	
The Handling of Materials	583
Intermittent Handling of Materials	583
Industrial Cars and Hoists	585
Steam Shovels and locomotive Cranes	587
Continuous Handling of Materials	588
Relative Merits of Conveying Systems and of Pumps	594

CHAPTER XLIV

Ore Storage and Supply:	
Provision for Supply	595

Feeders	595
Pumps and Air-lifts	598
Compressors, Vacuum Pumps and Fans	601
CHAPTER XLV	
Location, Equipment and Erection:	
Location of Works	603
Controlling Factors in Choice of a Site	604
Design of Plant	607
Cost of Plant	608
Costs of Metallurgical Plants	610
Unit Costs in 1914	611
PART IX – THE BUSINESS OF METALLURGY	
CHAPTER XLVI	
The General Economic Situation:	
Distribution of Wealth	617
The National Income	617
Economics of Engineering	619
The Labor Situation	620
CHAPTER XLVII	
Organization and Operating:	
Organization of a Metallurgical Company	623
General Administration	623
The Operating Department	624
Elimination of Waste	626
Rules of Works	626
Plant Operation	627
Labor Turnover	627
Modes of Payment	629
Wages and Welfare	630
Capital and its Requirements	631
The Accounting Department	632
Typical Operating Department	635
The Purchasing and Selling Departments	635
CHAPTER XLVIII	
Profits and Costs:	
Profits	637