# RAILROAD ELECTRIFICATION

# AND THE

# ELECTRIC LOCOMOTIVE

Outline of Principles Involved in Railroad Electrification. A Comparison of Steam and Electric Locomotives. History of Electrification in United States. Data on Electrification in America, Europe and Australia.

ΒY

ARTHUR J. MANSON WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY. MANAGER, TRANSPORTATION DIVISION-NEW YORK.

> GRADUATE ELECTRICAL ENGINEER, MASSACHUSETTS INSTITUTE OF TECHNOLOGY. MEMBER OF: THE ASSOCIATION OF RAILWAY ELECTRICAL ENGINEERS; AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS; AMERICAN ELECTRIC RAILWAY ASSOCIATION.

> > PUBLISHED AND PRINTED IN U. S. A.

BY

# SIMMONS-BOARDMAN PUBLISHING COMPANY

30 CHURCH STREET, NEW YORK, N. Y.

CLEVELAND, OHIO. CINCINNATI, OHIO. NEW ORLEANS, LA. CHICAGO, ILL. WASHINGTON, D. C.

34 VICTORIA ST., WESTMINSTER, LONDON, S. W. I., ENGLAND.

# CHAPTER I

ADVANTAGES OF ELECTRIFICATION .- Terminals, Switching, Tunnels, Freight Haulage, Reliability of Service, Flexibility of Opera-tion, Increase of Track Capacity

#### CHAPTER II

ELECTRICAL TERMS AND THEIR RELATION TO MECHANICS.-Electricity, Static Electricity, Conductors and Insulators, The Magnet, Current Electricity, The Volt, The Ohm, The Ampere, The Watt, Electricity by Chemical Action, Relation to Mechanics, Centimeter – Gramme – Second System – The Dyne, Mechanical Equivalents

# CHAPTER III

OHM'S LAW.-Simple Circuit, Series Circuit, Parallel Circuits, Conductance, Solution of Problems Involving Use of Formulae 15 - 18

# CHAPTER IV

INDUCTANCE AND CAPACITY .- Discoveries of Faraday, Induction Due to Alternating Current, The Transformer, Self-Induction, Capacity, The Condenser, Effects of Inductance and Capacity 19-26

#### CHAPTER V

THE GENERATION OF THE ELECTRIC CURRENT.—Faraday's Discovery,	
Fleming's Rule, Magnetic Lines of Force, The Simple Genera-	
tor. The Necessity for a Commutator, The Direct-Current Gen-	
erator, The Alternating-Current Generator	27-32

# CHAPTER VI

THE ELECTRIC MOTOR.—Principle of the Electric Motor, Types of Motors Used, The Series Motor, The Torque of a Series Motor, The Speed of a Series Motor, The Induction Motor . . . 33 - 38

#### CHAPTER VII

THE ALTERNATING-CURRENT SINGLE-PHASE MOTOR .- The Series Commutator Type, Interpoles, The Alternating-Current Doubly-Fed Motor, The Alternating-Current Interpole Motor . . . 39 - 48

#### CHAPTER VIII

THE THREE-PHASE MOTOR	Principle of Opera	tion, Stator Wind-	
ing, Formula for Spee	d, Method of Speed	Variation	49–52
	v		

PAGE

1 - 6

7 - 14

# CHAPTER IX

#### RAILWAY MOTOR CHARACTERISTIC CURVES .- How to Read Them .-Direct-Current Motor Curves, Single-Phase Series Motor Curves, Single-Phase Doubly-Fed Motor Curves, Three-Phase 53-58 and Split-Phase Motor Curves . . . . . . . . . . .

# CHAPTER X

Mo	tor Comb	INA	TIONS F	OR S	peed Control.—	-S	eries-l	Para	llel	Co	nne	ec-	
	tions, Fi	eld	Control	I. Al	ternating-Curre	nt	Moto	r C	omt	oina	tion	ns.	
	Cascade	Co	nnection	i or	Concatenation								59-64

# CHAPTER XI

GENERAL PRINCIPLES RELATING TO THE OPERATION OF TRAINS .----· Tractive Effort, Train Resistance, Acceleration, Grade Resistance, Curve Resistance, Speed-Time Curve, Examples . . 65-74

#### CHAPTER XII

COMPARISON OF THE OPERATING CHARACTERISTICS OF STEAM AND ELECTRIC LOCOMOTIVES .- Equated Tonnage Rating, Tractive Effort Formula-Steam Locomotive, Tractive Effort-Electric Locomotive, Torque, Continuous and Hourly Rating, Compari-

#### CHAPTER XIII

METHODS USED FOR ACCELERATING ELECTRIC LOCOMOTIVES .- Direct-Current Locomotive Control, Rheostatic Control-Series Resistance, Rheostatic Control-Parallel Resistance, Rheostatic Control—Combination Resistance, Motor Combinations, Tran-sition Methods, Open-Circuit Transition, Shunted-Motor Transition, Bridging Transition, High-Voltage Direct-Current Locomotive Control, Alternating-Current Locomotive Control. Single-Phase Arrangement, Preventive Coils, Three-Phase and Split-Phase Arrangement . . .

#### 89-102

# CHAPTER XIV

ENERGY LOSSES INCURRED BY THE VARIOUS METHODS OF ACCELERA-TION.-Rheostatic Control, Series-Parallel Control, Series, Series-Parallel, Parallel Control, Energy Consumption and Re-sistance Losses, Formulas, Notching Diagram, Field Control, Energy Losses—High Voltage, Direct Current, Energy Losses 

#### CHAPTER XV

REGENERATIVE BRAKING WITH ELECTRIC LOCOMOTIVES .- Available Energy on Grades, Direct-Current Regeneration, Single-Phase Regeneration, Regeneration with Three-Phase Motors, Advan-

# CHAPTER XVI

Double Cut-Out Cock, Regenerative Interlock Valve, The Air Compressor, Electric Compressor Governor, Operation of the 

PAGE

# CHAPTER XVII

PAGE

ELECTRIC LOCOMOTIVE DESIGN.—Electrical Systems, Electric Locomotive Classification, Overhead Working Conductors, Third-Rail Conductors

### CHAPTER XVIII

THE PANTAGRAPH.—General Design and Construction, Pantagraph Insulators, Pantagraph Framework, Pantagraph Shoe for Alternating Current, Pantagraph Shoe for High-Voltage Direct Current, Pantagraph Insulator for 3000-Volts Direct Current, Methods of Pantagraph Operation, The Oil Circuit Breaker . 149–162

# CHAPTER XIX

THE THIRD-RAIL SHOE.—Design and Construction of the Stationary Shoe and the Folding Shoe, Relation to Third-Rail Position, Arrangement of Fuse Boxes

# CHAPTER XX

#### CHAPTER XXI

#### CHAPTER XXII

CONSTRUCTION OF THE MODERN RAILWAY MOTOR.—The Frame, Pole Pieces and Field Coils, The Housings, The Armature, The Commutator, The Armature Winding, The Brush Holder . 201-214

#### CHAPTER XXIII

18

# CHAPTER XXIV

INSPECTION AND	MAIN	TENAN	CEI	fileag	e B	etwee	n I	nspe	ctions,	
Light Inspec	tion, I	Heavy	Inspe	ction	and	Ove	rhau	ling,	Trip	-
Inspection .										231-234

# CHAPTER XXV

#### CHAPTER XXVI

PAGE

# CHAPTER XXVII

GEAR	RATIO	AND	V	Vн	EEL	D	IAN	ΜE	TER	-R	lela	tion	ı t	0	Sp	eed	aı	nd	
Т	ractive	Effor	t,	R	elat	ion	to	С	Mot	tor	Cl	lara	acte	eris	tic	Cu	rve	es,	
F	ormulae																		265-268

# CHAPTER XXVIII

# CHAPTER XXIX

#### CHAPTER XXX

# APPENDIX

V111