

CONTENTS

CHAPTER 1 – <i>Lighting & Lamps</i>	1-1
Quality Lighting Measures	1-4
Quantity Lighting Measures	1-4
Primary Lighting Terms and Units of Measurement.	1-5
Inverse Square Law	1-6
Lumen and Foot-Candle Formulas.	1-7
Calculating Maintained Light Level.	1-8
Common Units of Brightness	1-9
Conversion Factors for Units of Illumination.	1-9
Recommended Illumination Ranges	1-10
Recommended Light Levels.	1-12
Reflectance Values of Various Materials and Colors	1-13
Light Source Characteristics	1-14
Light Source Efficacies.	1-15
Lumens, Life, and Efficacy for Various Lamps	1-16
CRI Values for Selected Light Sources	1-18
Brightness	1-19
Contrast	1-19
Light Fixture Spacing (Foot-Candles)	1-20
Typical Lighting Distribution Curve.	1-21
Vertical, Perpendicular and Horizontal Planes.	1-22
Lamp Advantages and Disadvantages.	1-23
Lamp Ratings	1-23
Lamp Characteristics	1-24
Lamp Lumen Depreciation	1-28
Lamp Energy Distribution Curves	1-29
Measuring Savings from Dimming Controls.	1-30
Dimming Circuit for Series-Connected Cold-Cathode Lamps	1-30
Energy Savings Potential with Occupancy Sensors	1-31
Typical Lighting Control System.	1-32

CHAPTER 2 – <i>HIDs</i>	2-1
Basic Characteristics of HID Lamps	2-2
Specific HID Lamp Information	2-3
Common HID Lamp Bases with ANSI Designations	2-5
HID Ballast Selection Factors.	2-8
Ballast Loss	2-9
Recommended Ballast Output Voltage Limits	2-10
Recommended Short-Circuit Current Test Limits.	2-11
Ballast Sound Rating	2-12
Typical Radio Interference Filter for HID Ballast	2-12
HID Lamp Troubleshooting Guide	2-13
Outdoor Luminaires	2-14
Cutoff Classifications	2-14
General Mounting Guidelines for HID Lamp Poles	2-15
Low-Pressure Sodium	2-17
Low-Pressure Sodium Lamps	2-18
Low-Pressure Sodium Ballasts	2-18
Low-Pressure Sodium Lamp Fixtures	2-19
Typical Performance Values for Low-Pressure Sodium Systems.	2-20
LPS Watts Rise Over Life Hours	2-21
Mortality Curves for Typical Low-Pressure Sodium Lamps	2-22
Spectral Power Distribution for Low-Pressure Sodium Lamps	2-23
High-Pressure Sodium	2-24
High-Pressure Sodium Lamps	2-25
High-Pressure Sodium Ballasts	2-25
250 W High-Pressure Sodium Lamp Currents.	2-26
High-Pressure Sodium Lamp Lumens Data	2-26
Typical Performance Values for High-Pressure Sodium Systems.	2-27
High-Pressure Sodium Lamp Lumen Depreciation	2-28
Mortality of Typical High-Pressure Sodium Lamps	2-28

Spectral Power Distribution for High-Pressure Sodium Lamps	2-29
Metal-Halide	2-30
Metal-Halide Lamps	2-31
Metal-Halide Ballasts	2-31
Metal-Halide Lamp Characteristics	2-32
Typical Performance Values for Metal-Halide Systems	2-33
Lamp Lumen Depreciation for Typical 400-Watt Metal-Halide Lamps	2-34
Mortality Curves for Typical 400-Watt Metal-Halide Lamps	2-34
Spectral Power Distributions for Clear Metal-Halide Lamps	2-35
Spectral Power Distributions for Phosphor-Coated Metal-Halide Lamps	2-35
Mercury-Vapor	2-36
Mercury-Vapor Lamps	2-36
Mercury-Vapor Ballasts	2-37
Typical Performance Values for Mercury-Vapor Systems	2-39
Approx. Lumen Maintenance of Color-Improved Mercury Lamps Operating Vertically	2-40
Mortality Curves for Typical Mercury-Vapor Lamps	2-40
Spectral Power Distribution for Clear Mercury-Vapor Lamps	2-41
Spectral Power Distribution for Deluxe Mercury-Vapor Lamps	2-42

CHAPTER 3 – *Fluorescents* 3-1

Fluorescent Lamp Identification	3-2
Common Fluorescent Types	3-3
Common Shape Identifiers	3-3
Fluorescent Lamp Data	3-4

Fluorescent Lamp Output	3-5
Mortality Curve for Fluorescent Lamps	3-5
Fluorescent Lamp Lumen Depreciation	3-6
Fluorescent Lamp Characteristics	3-7
2-Foot x 4-Foot Troffer Shielding Media	3-10
U.S. EPACT Fluorescent Lamp Standard Levels	3-10
Compact Fluorescent Fixture Data	3-11
Typical Performance Values for 2-Foot Systems	3-12 & 3-13
Typical Performance Values for 2-Lamp 4-Foot Systems	3-14 – 3-17
Typical Performance Values for 3-Lamp 4-Foot Systems	3-18 – 3-21
Typical Performance Values for 4-Lamp 4-Foot Systems	3-22 – 3-25
Typical Performance Values for 2-Lamp 8-Foot Systems	3-26 – 3-29
Preheat Circuits	3-30
Ballast.	3-30
Rapid-Start Circuits	3-31
Instant-Start Circuits.	3-32
Characteristics of Common Ballasts	3-33
U.S. and Canadian Standards for Ballast Efficacy Factor	3-34
Typical Magnetic Ballast Watts.	3-34
Approximate ANSI Thermal Correction Factors: Wattage	3-35
Approximate ANSI Thermal Correction Factors: Lumens	3-35
Fluorescent Lamp Bases	3-36
Typical Fluorescent Bases with ANSI Designations	3-37
Typical CFL Bases with ANSI Designations.	3-38
Fluorescent Lamp Troubleshooting Guide	3-41

CHAPTER 4 – <i>Incandescents</i>	4-1
Incandescent Lamp Data	4-2
Type A Incandescent Bulb Ratings	4-2
Efficacy of Common Incandescent Lamps	4-3
Incandescent Lamps Operated Below Rated Voltage	4-4
U.S. EPACT Incandescent Reflector Lamp	
Standard Levels	4-4
Type T Tungsten-Halogen Bulb Ratings	4-5
Tungsten-Halogen Lamps	4-5
Incandescent Lamp Characteristics	4-6
Reductions in Light Output and Power Consumption	
of a Typical Incandescent Lamp Over Life	4-7
Mortality Curve for Typical Incandescent Lamps	4-7
Spectral Energy Distribution for a Typical	
Incandescent Lamp Operating at a Filament	
Temperature of 3000° K	4-8
Relative Energy Radiated as Light from Incandescent	
Lamps at Various Temperatures	4-8
Incandescent Bases with ANSI Designations	4-9
Halogen Bases with ANSI Designations	4-11
Typical Bulb Shapes and Their ANSI Designations	4-14
ANSI Bulb Shape Descriptions	4-17
Typical Performance Values for Compact Sources	4-18
Typical Performance Values for Directional Lamps	4-21
Floodlight Beam Spreads	4-24
Incandescent Lamp Troubleshooting Guide	4-24
 CHAPTER 5 – <i>Lamp Disposal</i>	 5-1
Decision Chart	5-10
Informational Resources	5-11
U.S. EPA Headquarters	5-11
U.S. EPA Regional Offices	5-11
Solid and Hazardous Waste Agencies per State	5-13

TSCA, RCRA, and CERCLA	
Information Phone Lines	5-22
EPA-Approved Disposal Locations	5-23
Recycling Resources (Lamp)	5-24
Recycling Resources (Ballast)	5-27

CHAPTER 6 – *Lighting Terms* 6-1

CHAPTER 7 – *Electrical Maintenance* 7-1

Basic Electrical Safety Guidelines	7-1
OSHA Safety Color Codes	7-2
Lockout/Tagout Guidelines	7-3
Minimum Cover Requirements 0-600 Volts, Nominal	7-4
Volume Required per Conductor	7-4
Vertical Conductor Supports	7-4
Minimum Depth Working Clearances	7-5
Elevation of Unguarded Live Parts Above	
Working Space	7-5
Minimum Clearance – Live Parts	7-6
Effect of Electric Current on Human Body	7-7
Grounding	7-7
Grounding Electrode Conductors – AC Systems	7-8
Minimum Size Conductors – Grounding	
Raceway and Equipment	7-9
Grounding Methods	7-10
Grounding Different Types of Circuits	7-11
Voltage Relationship on Grounded 4-Wire Systems	7-13
Grounding an Existing Circuit	7-14
Grounding a Screw-Shellbase	7-14
Decibel Levels of Sounds	7-15
Maximum Average Sound Levels for Transformers	
in Decibels	7-16
Hearing Protection Levels	7-16
Types of Fire Extinguishers	7-17

Electrical Cable Class Ratings	7-18
Cable Insulation Moisture Ratings	7-18
Conductor Prefix Codes	7-18
Types of Conductors	7-19
Cable Jacket Materials	7-22
Size of Extension Cords for Portable Electric Tools for 115-Volt	7-25
Amcapacity of Lamp and Extension Cords (A.W.G.) – Types S, SJ, SJT, SP, SPT, ST	7-26
Enclosures	7-26
Hazardous Locations	7-26
Enclosure Types	7-27
Non-Locking Wiring Devices	7-29
Locking Wiring Devices	7-32
Sizing Single-Phase Transformers	7-35
Sizing Three-Phase Transformers	7-36
Transformer Deratings	7-37
Derated KVA Capacity	7-37
Transformer Overloading	7-38
Permissible Overloading	7-38
Transformer and Regulator Inspection Checklist	7-39
Generator Sizing Form	7-42 & 7-43
Calculating Amperes, Horsepower, Kilowatts & Kilovolt Amperes	7-44

CHAPTER 8 – Meters and Testing . . . 8-1

Meter Troubleshooting Basics	8-1
Basic Meter Types and Uses	8-2
Meter Functions and Options	8-3
Meter Specifications	8-3
Meter Terms	8-4
Meter Abbreviations	8-7
Meter Symbols	8-8
High Voltage Field Acceptance Test	8-10

Connections for a Belted Core-Loss and Friction Test . . .	8-11
Connections for Kapp's Loading-Back Test	8-12
Connections for Hopkinson's Loading-Back Test	8-13
An Ammeter and Voltmeter Connected into a Circuit . . .	8-14
Meter and How It Is Used With a 2 or 3 Wire Supply . . .	8-15
Measuring Power	8-16
Measuring Current	8-23
Measuring Voltage	8-24
Voltage Measurements of a 2-Lamp, Rapid-Start, Series-Type, Electromagnetic Fluorescent Ballast . . .	8-26

CHAPTER 9 – Motor Maintenance . . . 9-1

Locating Circuits	9-2
Checking Capacitors	9-3
Unmarked 3 ϕ Induction Motors	9-4
Wye or Delta Connection	9-4
Wye-Connected Motor	9-5
Delta-Connected Motor	9-5
DC Motor Performance Characteristics	9-6
Maximum Acceleration Time	9-6
AC Voltage Variation Characteristics	9-7
AC Frequency Variation Characteristics	9-7
Phase Unbalance and Temperature Rise	9-8
Phase Unbalance Derating Factor	9-9
Single-Phasing Condition	9-10
Improper Phase Sequence (Phase Reversal)	9-11
Voltage Surge	9-11
Voltage Problems	9-12
Voltage Variance	9-13
Acceptable AC Load Voltage Ranges (60Hz)	9-13
Voltage Unbalance	9-14
Finding Voltage Unbalance	9-15
Calculating Voltage Unbalance	9-16
Motor Overcycling	9-17

Improper Ventilation	9-17
Excessive Heat.	9-18
Motor Overloads.	9-19
Megohmmeter Connections	9-20
Ohmmeter Connections	9-21
Insulation Spot Testing	9-22
Dielectric Absorption Testing	9-23
Polarization Index Values	9-24
Insulation Step Voltage Testing	9-25
Contactors and Motor Starter Troubleshooting Guide	9-26
Direct Current Motor Troubleshooting Guide	9-28
Shaded Pole Motor Troubleshooting Guide	9-30
Split-Phase Motor Troubleshooting Guide	9-31
Three-Phase Motor Troubleshooting Guide	9-34
Motor Repair and Service Record	9-36
Semiannual Motor Maintenance Checklist.	9-37
Annual Motor Maintenance Checklist.	9-38

CHAPTER 10 – Power Transmission 10-1

Method of Aligning Pulleys.	10-1
Calculating Pulley Diameter	10-2
Pulley and Gear Calculations.	10-3
Formulas for Finding Pulley Sizes	10-4
Formulas for Finding Gear Sizes	10-4
Formula to Determine Shaft Diameter	10-5
Formula to Determine Belt Length.	10-5
Adjusting Belt Tension	10-6
V-Belts	10-7
V-Belt/Motor Size	10-7
Standard “V” Belt Lengths	10-8
Horsepower Capacities of Light 4-Ply Nylon-Stitched Belts	10-10
Horsepower Capacities of Medium 4-Ply Nylon-Stitched Belts	10-10

Horsepower Capacities of Heavy 4-Ply Nylon-Stitched Belts	10-11
Horsepower Capacities of Medium 4-Ply Woven Endless Cotton Belts	10-11
Horsepower Capacities per Inch of Width of Regular Single-Ply Dacron Belts	10-12
Horsepower Capacities per Inch of Width of Medium Single-Ply Dacron Belts	10-13
Horsepower Capacities per Inch of Width of Light Single-Ply Dacron Belts	10-14
Horsepower Capacities of $\frac{3}{8}$ " Diameter Wound Endless Round Belts	10-15
Correction Factors for Small Pulley Angles of Contact Less Than 180°	10-16
Correction Factors for Belt Variations	10-17
Horsepower Capacities of $\frac{1}{4}$ " Diameter Braided Endless Round Belts	10-18
Horsepower Capacities of $\frac{3}{8}$ " Diameter Braided Endless Round Belts	10-19
Horsepower Capacities of $\frac{9}{16}$ " Diameter Wound Endless Round Belts	10-20

CHAPTER 11 – *Communication Systems* . . 11-1

Telephone Circuit Operation	11-1
Rating Paired Copper Building Cables	11-1
Horizontal Four-Pair Cat 5 Cabling	11-1
Traditional Telephone Network	11-2
Common Telephone Connections	11-3
Color Coding of Cables	11-3
Twisted-Pair Plugs and Jacks	11-4
Standard Phone Jacks	11-4
Pin Connectors	11-5
Cross Connections	11-5
Category Cabling	11-5

Installation Requirements	11-5
Conductors Entering Buildings	11-6
Circuit Protection	11-6
Interior Communications Conductors	11-7
Standard Telecom Color Coding	11-8
Modular Jack Styles	11-9
Common Wiring Configurations	11-9
Telephone Connections	11-11
Separation and Physical Protection for Premises Wiring	11-12
Ethernet 10Base-T Straight Thru Patch Cord	11-13
Ethernet 10Base-T Crossover Patch Cord	11-13
Digital Patch Cable (DPC) Coding	11-13
Distance Limits for Horizontal Cabling	11-14
Standard Materials for Structured Cabling (568) Systems	11-15
Ethernet Failures	11-15
Computer Circuits	11-16
Data Signal Transmission	11-16
Cable Colors	11-17
Separation from Sources of Interference	11-17
Minimum Bending Radii	11-18

CHAPTER 12 – Conversion Factors, Measurements, Tools & Materials. 12-1

Commonly Used Conversion Factors	12-1
Electrical Prefixes	12-6
Common Prefixes	12-6
Common Electrical Quantities	12-6
Conversion Table	12-6
Decimal Equivalents of Fractions	12-7
Common Engineering Units and Their Relationship	12-8

Trigonometric Formulas – Right Triangle	12-9
Trigonometric Formulas – Oblique Triangles	12-10
Trigonometric Formulas – Shapes	12-11
Sheet Metal Screw Characteristics	12-13
Allen Head and Machine Screw Bolt & Torque Characteristics.	12-14
Hex Head Bolt & Torque Characteristics	12-15
Whitworth Hex Head Bolt & Torque Characteristics.	12-17
Metric Hex Head Bolt & Torque Characteristics.	12-18
Tightening Torque in Pound-Feet-Screw Fit.	12-19
Screw Torques	12-19
Standard Taps and Dies (in inches)	12-20
Taps & Dies – Metric Conversions	12-21
Recommended Drilling Speeds (RPMs)	12-22
Torque Lubrication Effects in Foot-Pounds	12-23
Metalworking Lubricants	12-23
Types of Soldering Flux	12-24
Hard Solder Alloys	12-24
Soft Solder Alloys	12-24
Properties of Welding Gases	12-25
Welding Rods – 36" Long	12-25
Strength Gain vs. Pull Angle	12-26
Length of Wire Cable per Reel.	12-26
Steel Wire Diameters	12-27
Wire Rope Characteristics for 6 Strand	12-29
Cable Clamps per Wire Rope Size	12-30
Rope Characteristics	12-31
Chain Characteristics	12-32
Steel Sheet Measurements	12-33
Steel Plate Weights & Sizes.	12-35

COMMON UNITS OF BRIGHTNESS

1 Candle per square inch	= 452 footlamberts = 0.487 lamberts = 487 millilamberts
1 Footlambert	= 1 lumen per sq. foot reflected or emitted = 0.00221 candles per sq. in. = 1.076 millilamberts
1 Lambert	= 1 lumen per sq. centimeter reflected or emitted = 1000 millilamberts = 929 footlamberts = 2.054 candles per sq. in.
1 Millilambert	= 0.929 footlamberts = 0.002054 candles per sq. in.

CONVERSION FACTORS FOR UNITS OF ILLUMINATION

Given	Multiply By	To Obtain
Illuminance (E) in lux	0.0929	foot-candles
Illuminance (E) in foot-candles	10.764	lux
Luminance (L) in cd/sq. m	0.2919	footlamberts
Luminance (L) in footlamberts	3.4263	cd/sq. m
Intensity (I) candelas	1.0	candlepower

METAL-HALIDE LAMP CHARACTERISTICS

Lamp Wattage (W)	Voltage Rating (V)	Fuse Rating (A)	Starting Current (A)	Operational Current (A)
50	120	3	.60	.65
	277	3	.25	.30
100	120	8	1.15	1.15
	208	5	.66	.66
	240	3	.58	.58
	277	3	.50	.50
175	120	5	1.30	1.80
	208	3	.75	1.05
	240	3	.65	.90
	277	3	.55	.80
	480	3	.35	.45
250	120	8	2.10	2.50
	208	5	1.40	1.45
	240	5	1.10	1.25
	277	3	1.00	1.10
	480	3	.60	.60
1000	120	20	8.0	9.0
	208	15	4.6	5.2
	240	10	4.0	4.5
	277	10	3.5	3.9
	480	10	2.0	2.3

FLUORESCENT LAMP CHARACTERISTICS *(cont.)*

Lamp Type & Description	Normal Length (mm) (in.)	Min. Req. RMS Voltage (V) Reliable Starting	Operating Current (mA)
F32T8	1200 47.25	200	265
FT36W/2G11RS	419 16.49	1 = 230	430
CFL26	169 6.65	198	325
T5	1200 47.25	375	210
T5/H0	830 32.6	425	400
40T12/SS	1200 47.25	1 = 200 2 = 256	460
96T12/SS (Slimline)	2400 94.48	565	440
96T12/H0/SS (Rapid start)	2400 94.48	2 = 296	830