Westinghouse

RAILROAD DATA

Westinghouse Electric & Manufacturing Co.

East Pittsburgh, Penna.

IN view of the increasing interest among steam railroad men in the various applications of electricity to railroad operation, we are pleased to present these pages of

Westinghouse Railroad Data

Special
Publication 1707

Westinghouse
Electric & Manufacturing Company
East Pittsburgh, Pa.

Traction Data

ELECTRIC LOCOMOTIVES

Electric locomotives are built in a variety of types and sizes, employing several kinds of motors and methods of drive between the motors and drive wheels. The proper system of electrification and the best type of locomotive have been the subjects of much controversy. Each of the systems has a field of application and it is now felt that no one type or system should supersede all others. So much discussion has centered around these subjects that the reader will not here be burdened with such matter.

Data on several locomotives which have been built for heavy railroad service is given in the following pages. The railroad man who has had long experience with steam locomotives sometimes has difficulty in obtaining a correct conception of the meaning of electric locomotive ratings. A steam locomotive has a definite maximum tractive effort rating which is fixed by the dimensions of the cylinders, the driver diameter, and the boiler pressure. A steam locomotive generates its own power and can deliver tractive power only within the capacity of its own power plant, that is, the boiler and fire box. An electric locomotive, on the other hand, has behind it the capacity of the power plant and distribution system which is very large. The maximum tractive effort which an electric freight locomotive can exert is usually limited only by the adhesion between the drive wheels and the rails. This is sometimes true with passenger locomotives also, but it often happens that the current capacity of the motors is not sufficient to slip the drive wheels.

However, if an electric locomotive were permitted to exert for any considerable length of time the large tractive effort it is capable of producing by virtue of the enormous power behind it, the electrical equipment would be injured by overheating. It is therefore necessary to apply to electric locomotives, ratings which must always be associated with time limits. The two ratings most commonly given are the hourly rating and the continuous rating. The first indicates the capacity of the locomotive for one hour, assuming that the electrical equipment is at the temperature of the surrounding air at the start of the run. The continuous rating shows what tractive effort can be produced continuously without injuring the equipment. The question of ratings and their meaning will be amplified further under the heading of Locomotive Selection.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

DATA

Weights—Total		600,000 Lb.
On Drivers		378,000 Lb.
Per Driving Axle		63,000 Lb.
Ratings—One Hour, Short Field, Forced Ventilation	T. E.	66,000 Lb.
	Speed	26.7 M.p.h.
	Hp.	4,680
Continuous, Short Field,	T. E.	40,800 Lb.
	Speed	31.2 M.p.h.
	Hp.	3,400
Maximum Tractive Effort, 40.4% Adhesion, Limited by Motor Capacity		153,000 Lb.
Tractive Effort, 25% Adhesion		94,500 Lb.
Maximum Speed		65 M.p.h.
Number & Nominal Rating of Motors—Six Twin		780 Hp.
Gear Ratio		24:89
Driver Diameter		68 In.
Trolley Voltage		3,000 D-C.
Road Nos.		10301-10309

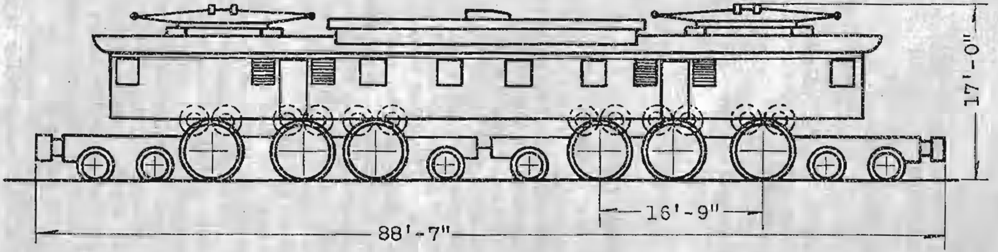
GENERAL INFORMATION

This locomotive was designed for heavy passenger service over mountain grades. It regularly hauls 960-ton passenger trains on a 440-mile run which includes 21 miles of grade averaging 1.72 percent with a maximum of 2 percent.

The locomotive consists of two Pacific type running gears coupled back to back and supporting a single cab which contains the control and auxiliary equipment. Each of the six driving axles is driven by a twin motor placed vertically above the axle. The drive between the motor and drive wheel is by single gearing and a quill which surrounds the axle but is connected to the wheels only by springs. The only non-spring borne weight is, therefore, the weight of the wheels and axles themselves. This gives a very flexible type of drive and a locomotive having very little damaging action on the track.

The control is arranged so that either twelve, six or four motor armatures can be connected in series between the trolley and rail. This gives three combinations of motors which, with two field shunt positions of the controller in each combination, makes a total of nine running speeds. The locomotive is equipped for regenerative braking. Two axle generators, one carried on each of the four-wheel engine trucks, supply excitation for the main motors when regenerating, and auxiliary power when motoring. In case of failure of the power supply, the axle generators can be used to furnish power for the air compressor and thus make it possible to descend a grade safely by air braking. An oil fired steam boiler is supplied for train heating.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.



CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

300-Ton Passenger Locomotive

PENNSYLVANIA RAILROAD
FF-1 TYPE LOCOMOTIVE

DATA

Weights—Total			516,000 Lb.
On Drivers			439,500 Lb.
Per Driving Axle			73,250 Lb.
Ratings—One Hour, Forced Vent.	T. E.		88,000 Lb.
	Speed		20.4 M.p.h.
	Hp.		4,800
Continuous	T. E.		73,000 Lb.
	Speed		20.5 M.p.h.
	Hp.		4,000
Maximum Tractive Effort, 31.8% Adhesion, Limited by Motor Capacity			140,000 Lb.
Tractive Effort, 25% Adhesion			109,875 Lb.
Maximum Speed			35 M.p.h.
Number & Nominal Rating of Motors			4—1,200 Hp.
Gear Ratio			21:106
Driver Diameter			72 In.
Trolley Voltage			11,000 A-C.
Road No.			3,931

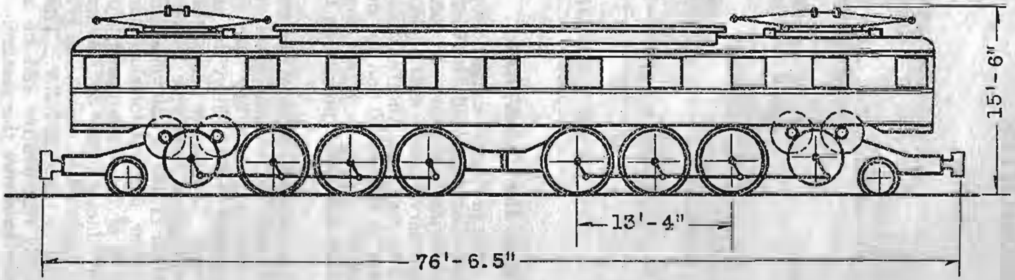
GENERAL INFORMATION

This locomotive is the product of a joint design by the Pennsylvania Railroad Company and the Westinghouse Electric and Manufacturing Company. It was laid out for heavy, drag-freight service, such as is encountered on the Pennsylvania's line over the Allegheny Mountains. The wheel arrangement is 260 + 062 and the drive is by geared jack shaft and side rods. Each jack shaft carries two flexible gears which mesh with pinions on the shafts of two motors.

The motors on this locomotive are of the three-phase induction type and run at constant speed regardless of the amount of tractive effort they are supplying. Single-phase 25-cycle power is collected by the pantagraph from the overhead wire. This power passes through the main transformer and phase converter which together reduce its potential from 11,000 to 850 volts and convert it into three-phase power, suitable for the main motors. The phase converter is of the synchronous type serving to maintain high power factor in the distribution system. The motors can be connected in cascade to give a half-speed running position on the controller. This type of locomotive is inherently regenerative and no additional equipment is necessary to secure this feature.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 4 6-24 Printed in U. S. A.



PENNSYLVANIA RAILROAD

FF-1 Type Locomotive

PENNSYLVANIA RAILROAD
L-5 TYPE LOCOMOTIVE

DATA

Weights—Total			408,000 Lb.
On Drivers			300,000 Lb.
Per Driving Axle			75,000 Lb.
Ratings—One Hour, Forced Vent.		T. E.	59,000 Lb.
335 Volts per Motor		Speed	21.0 M.p.h.
		Hp.	3,300
Continuous		T. E.	50,000 Lb.
		Speed	23.0 M.p.h.
		Hp.	3,070
Maximum Tractive Effort, 33⅓% Adhesion, Limited by Motor Capacity			100,000 Lb.
Tractive Effort, 25% Adhesion			75,000 Lb.
Maximum Speed			35 M.p.h.
Number & Nominal Rating of Motors			4—825 Hp.
Gear Ratio			30:118
Driver Diameter			80 In.
Trolley Voltage			11,000 A-C.
Road No.			3,930

GENERAL INFORMATION

This locomotive is the latest development in single-phase locomotives employing commutator type motors. It is intended to be used either in freight service or high speed passenger service, the change in speed being secured by changing the gear ratio. The data above applies to the locomotive when geared for freight service. With a 50:98 gear ratio, the locomotive has a continuous tractive effort rating of 25,000 lb. at 46 miles an hour and a maximum speed of 70 miles an hour.

The drive is by geared jack shaft and side rods, each jack shaft being driven by two motors. The jack shaft gear is of a new flexible type and two of the four pinions which mesh with each jack shaft are also flexible. The four driving wheels are in one rigid wheel base and the cab is rigidly mounted on the side frames.

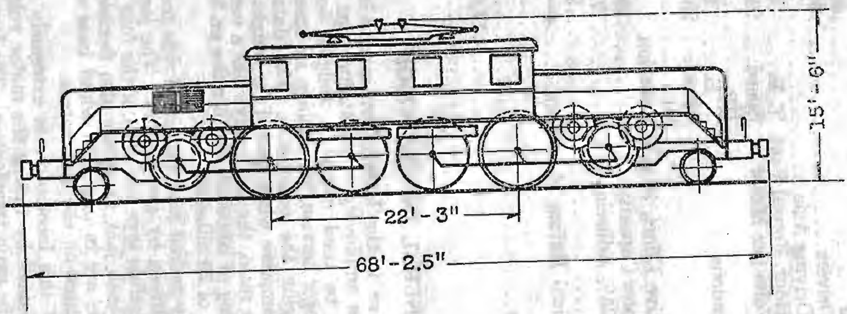
The control of this locomotive is extremely simple. Acceleration is obtained by raising the motor voltage by means of taps on the main transformer. The low voltage taps may also be used for running when reduced speed is desired. The transformer is of the oil insulated forced-cooled type.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 5

6-24

Printed in U. S. A.



PENNSYLVANIA RAILROAD

L-5 Type Locomotive

NORFOLK AND WESTERN RAILWAY

DATA

Weights—Total		828,000 Lb.
On Drivers		596,000 Lb.
Per Driving Axle		74,500 Lb.
Ratings—One Hour, 8 Pole, Forced Vent.	T. E.	108,000 Lb.
	Speed	14.1 M.p.h.
	Hp.	4,060
4 Pole,	T. E.	63,000 Lb.
	Speed	28.3 M.p.h.
	Hp.	4,750
Continuous 8 Pole,	T. E.	90,000 Lb.
	Speed	14.2 M.p.h.
	Hp.	3,400
4 Pole,	T. E.	52,500 Lb.
	Speed	28.4 M.p.h.
	Hp.	4,000

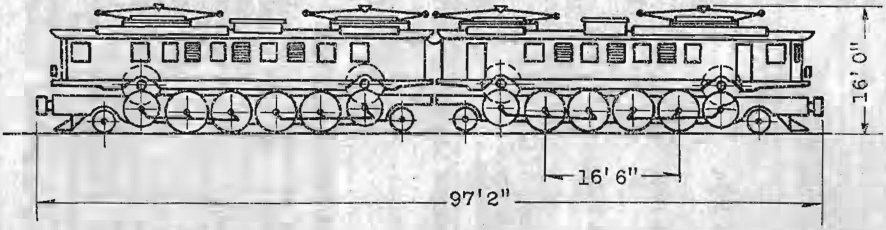
Maximum Tractive Effort, 31.1% Adhesion, Limited by Motor Capacity	185,000 Lb.
Tractive Effort, 25% Adhesion	149,000 Lb.
Maximum Speed	38 M.p.h.
Number & Nominal Rating of Motors	4—1,190 Hp. (4P)
Gear Ratio	21:100
Driver Diameter	62 In.
Trolley Voltage	11,000 A-C.
Road Nos.	2512-2515

GENERAL INFORMATION

This locomotive consists of two coupled cabs, each cab having four driving axles in one rigid wheel base. The cab structure is mounted rigidly on the locomotive side frames which are of massive vanadium steel construction. The heavier parts of the electrical equipment are mounted on the cross ties which connect the side frames.

The locomotive is of the so-called split-phase type and is driven by three-phase induction motors which receive their power from a phase converter and main transformer. The motors have two windings which give constant running speeds of approximately 14 and 28 m.p.h. Regenerative braking is automatic at either speed. Smooth acceleration is obtained with a liquid rheostat of an improved type.

These locomotives are used to haul heavy coal trains over a profile which includes 5.28 miles of 1.7 percent grade. Two locomotives handle a 4,200 ton coal train up the grade.



NORFOLK & WESTERN RAILWAY

414-Ton Freight Locomotive

NEW YORK, NEW HAVEN & HARTFORD RAILROAD PASSENGER LOCOMOTIVE

DATA

Weights—Total			350,000 Lb.
	On Drivers		233,000 Lb.
	Per Driving Axle		38, 830 Lb.
Ratings—One Hour, Forced Vent.		T. E.	18,000 Lb.
	335 Volts per Motor	Speed	51 M.p.h.
		Hp.	2,460
	Continuous	T. E.	12,540 Lb.
		Speed	61 M.p.h.
		Hp.	2,040
Maximum Tractive Effort, 20.4% Adhesion, Limited by Motor Capacity			47,520 Lb.
Maximum Speed			70 M.p.h.
Number & Nominal Rating of Motors			6 Twin 410 Hp.
Gear Ratio			27:87
Driver Diameter			63 In.
Trolley Voltage			11,000 A-C.
Road Nos.			0300-0304

GENERAL INFORMATION

Five of these locomotives have been in service since 1919 and twelve more have recently been delivered to the New Haven. These locomotives have six driving axles, each driven by a twin single-phase commutator type motor through gearing and a quill. They are used in fast passenger service between New York and New Haven and are capable of handling a 900-ton train in this service. Motors of the type used on these locomotives will run on either alternating or direct current and the control is arranged so that they can run into the Grand Central Station or over the Hell Gate Bridge, taking power from a third rail at 600 volts direct current. This increases the weight of the locomotive somewhat.

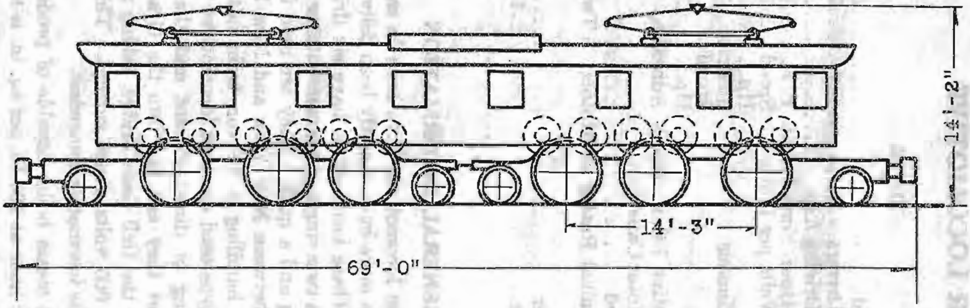
An oil fired steam boiler capable of producing 4,000 lb. of steam per hour at 100 lb. per sq. in. is supplied on all of the seventeen locomotives.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 7

6-24

Printed in U. S. A.



NEW YORK, NEW HAVEN & HARTFORD RAILROAD

175-Ton Passenger Locomotive

NEW YORK, NEW HAVEN & HARTFORD RAILROAD FREIGHT LOCOMOTIVE

DATA

Weights—Total			219,500 Lb.
On Drivers			165,000 Lb.
Per Driving Axle			41,250 Lb.
Ratings—One Hour, Forced Vent.		T. E.	21,200 Lb.
330 Volts per Motor		Speed	28.5 M.p.h.
		Hp.	1,610
Continuous		T. E.	14,760 Lb.
		Speed	34 M.p.h.
		Hp.	1,336

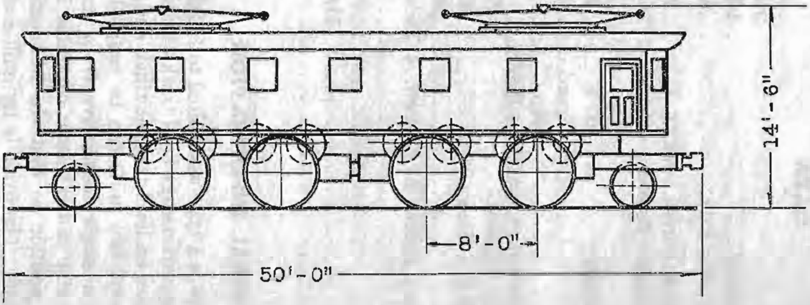
Maximum Tractive Effort, 34.0% Adhesion, Limited by Motor Capacity .... 56,000 Lb.
Tractive Effort, 25% Adhesion .... 41,250 Lb.
Maximum Speed .... 45 M.p.h.
Number & Nominal Rating of Motors .. 4 Twin 404 Hp.
Gear Ratio 17:97
Driver Diameter .... 63 In.
Trolley Voltage .... 11,000 A-C.
Road Nos. 076-0111

GENERAL INFORMATION

This locomotive is a type well suited to freight service on a line having approximately level track. It can handle fifty-five 45-ton cars on level tangent track and, if longer trains are necessary, two units can be coupled together and operated as a single locomotive from one master controller. Each step of the master controller is an economical running position so that the locomotive has a very flexible control. The drive is by quill and gearing, similar to other New Haven locomotives. Twin commutator type motors, mounted directly above the driving axles are used. Thirty-six of these locomotives have been in use on the New Haven since 1912.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 8 6 24 Printed in U. S. A.



NEW YORK, NEW HAVEN & HARTFORD RAILROAD

110-Ton Freight Locomotive

NEW YORK, NEW HAVEN & HARTFORD RAILROAD SWITCHER LOCOMOTIVE

DATA

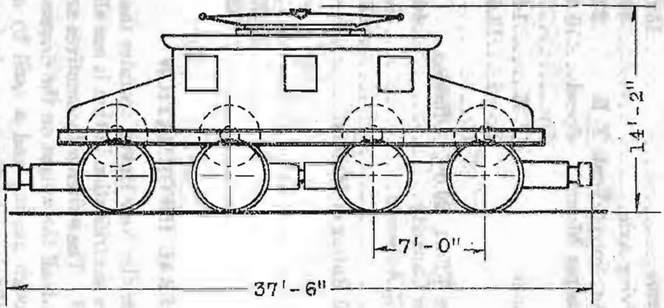
Weights—Total		159,200 Lb.
On Drivers		159,200 Lb.
Per Driving Axle		39,800 Lb.
Ratings—One Hour, Forced Vent.	T. E.	23,200 Lb.
228 Volts per Motor	Speed	10.5 M.p.h.
	Hp.	652
Continuous	T. E.	14,400 Lb.
	Speed	13.5 M.p.h.
	Hp.	520
Maximum Tractive Effort, 29.0% Adhesion, Limited by Motor Capacity		46,000 Lb.
Tractive Effort, 25% Adhesion		39,800 Lb.
Maximum Speed		25 M.p.h.
Number & Nominal Rating of Motors		4—163 Hp.
Gear Ratio		17:101
Driver Diameter		63 In.
Trolley Voltage		11,000 A-C.
Road Nos.		0201-0214

GENERAL INFORMATION

In many respects the New Haven operates the world's most comprehensive electrification in that it has all classes of service electrified. The switcher locomotives are of the steeple cab type with all the weight on the drivers. Each axle is driven through gearing and a quill by a single 25-cycle motor of the commutator type. It has double end control and low speed suitable for switching service. The two four-wheel trucks are articulated so that the tractive effort is transmitted through the truck frames rather than through the cab structure. This locomotive has proved in service to be a very satisfactory type.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 9 6-24 Printed in U. S. A.



NEW YORK, NEW HAVEN & HARTFORD RAILROAD

80-Ton Switcher Locomotive

STANDARD 50-TON LOCOMOTIVE

DATA

Weights—Total			100,000 Lb.
On Drivers			100,000 Lb.
Per Driving Axle			25,000 Lb.
Ratings—One Hour, Short Field, Natural Ventilation	T. E.		12,600 Lb.
	Speed		14.9 M.p.h.
	Hp.		500
Continuous, Short Field	T. E.		9,400 Lb.
	Speed		16.2 M.p.h.
	Hp.		400

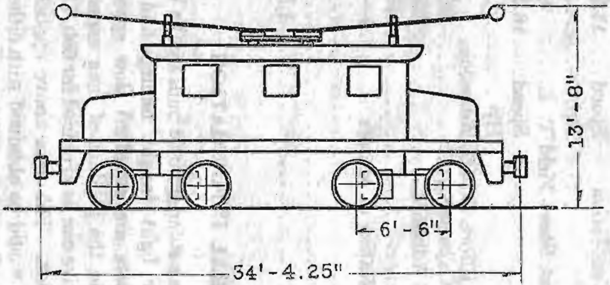
Maximum Tractive Effort, 36.4% Adhesion, Limited by Motor Capacity . . . . . 36,400 Lb.
Tractive Effort, 25% Adhesion . . . . . 25,000 Lb.
Maximum Speed . . . . . 47 M.p.h.
Number & Nominal Rating of Motors . . . . . 4—125 Hp.
Gear Ratio 17:60
Driver Diameter . . . . . 36 In.
Trolley Voltage . . . . . 1,500 D-C.

GENERAL INFORMATION

This locomotive is a standard unit built by the Westinghouse Company for light freight haulage and general purposes. The motors are standard slow speed direct current machines and the product of long experience in design. The locomotive can be arranged for 600, 750, 1,200 or 1,500-volt operation. The data above applies to 750 motor voltage which would be obtained with either 750 or 1,500 volts on the trolley wire. With operation on 600 or 1,200 volts, the speeds will be slightly less than 80 percent of the speed with 750 volts per motor. If higher speeds are desired, the locomotive can be supplied with different windings in the motors.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 10
6-24
Printed in U. S. A.



WESTINGHOUSE STANDARD 50-TON LOCOMOTIVE

Data on Representative Modern Steam Locomotives

DATA ON REPRESENTATIVE MODERN STEAM LOCOMOTIVES

Road	Manu-facturer	Wheel Arrange-ment	Cylinder Dimension		Total Evaporative Heating Surface Sq. Ft.	Tractive Effort 85%	Driver Diam. In.	Driving Wheel Base	Weight	
			Bore	Stroke					Total Eng. & Tend.	On Drivers
Virginian....	Am.	2-10-10-2	30 48	32	8606	147200	56	50′-0″	898300	617000
C. & O.......	Am.	2-8-8-2	23	32	6447	103500	57	......	774000	491000
P.R.R.......	P.R.R.	2-8-8-0	30½	21	6656	135000	62	......	794000	540000
Virginian....	Am.	2-8-8-2	25 39	32	6120	101300	57	42′-4″	740100	478000
N. & W......	Bald.	2-8-8-2	24.5 39	32	6308	104300	56	42′-1″	695000	470500
Reading.....	Bald.	2-8-8-2	26 40	32	5747	98000	55½	39′-8″	630000	435200
Southern....	Bald.	2-8-8-2	25 39	30	4993	84800	56	41′-1″	603000	374000
P.R.R.......	Bald.	0-8-8-0	26 40	28	5030	100000	51	40′-1½″	650000	458140
N. & W......	Bald.	2-6-6-2	22 35	32	4771	67500	56	30′-6″	571000	341000
P.R.R.....	P.R.R. Bald.	2-10-0	30½	32	4808	90400*	62	22′-8″	553400	341000
B. & O.......	Bald.	2-10-2	30	32	5270	84400	58	22′-4″	730000	347230
So. Pac......	Bald.	2-10-2	29½	32	5103	71150	63½	22′-10″	621000	306000
Can. Nat..	Mont. Loc.	2-8-2	27	30	3551	54600	63	16′-6″	499900	227600
D. L. & W...	Am.	2-8-2	28	32	4418	67700	63	17′-0″	574100	271500
L. V.........	Am.	2-8-2	27	32	4009	63000	63	16′-6″	489500	239000
L. V.........	Bald.	2-8-2	27	30	4110	59000	63	16′-6″	477000	237900
Nickel Plate.	Lima	2-8-2	26	30	3777	54700	63	16′-9″	506800	238100
Union Pacific.	Am.	4-8-2	29	28	4974	54800	73	19′-6″	582800	230000
St. L. & S. F.	Bald.	4-8-2	28	28	4382	54100	69	18′-0″	584500	232100
Can. Nat...	Can. Loc.	4-8-2	26	30	4079	49600	73	19′-6″	577000	226770
Great North.	Bald.	4-8-2	29	28	5025	54830	73	19′-0″	617000	272000
N. Y. C......	Am.	4-8-2	3 25	28	5155	64700	69	18′-0″	634800	241500
Can. Pac...	Mont. Loc.	4-6-2	25	30	3530	42600	75	13′-2″	489000	181500
P.R.R.......	P.R.R.	4-6-0	24	28	2862	41330	68	14′-3″	413500	178000
Maine Centr'l	Lima	4-6-0	20	28	2005	30200	63	15′-0″	319600	136000

*75%.

ELECTRIC LOCOMOTIVES OF NORTH AND SOUTH AMERICA

ELECTRIC LOCOMOTIVES OF NORTH & SOUTH AMERICA

Railroad	Key No.	Series No.	No. in Service	Year Placed in Service	Mfg Co.	Class of Service	Contact Conductor: Voltage	Contact Conductor: Type	Type of Loco.	Classification by Wheels	Driving Wheels: No.	Driving Wheels: Dia.	Truck Wheels: No.	Truck Wheels: Dia.	Articulated Trucks	Wheel Base: Rigid	Wheel Base: Total	Weights-Lbs.: Total	Weights-Lbs.: On Drivers	Weights-Lbs.: Av. per Driving Axle	Weights-Lbs.: Mech. Parts	Weights-Lbs.: Elect. Parts	Dimensions: Length over All	Dimensions: Width over All	Dimensions: Height to Top Rail to Highest Point Trolley Down	Regenerative Control	Motors: No.	Motors: Type	Motors: Method of Drive	Gear Ratio	Tractive Effort-Lbs.: One Hour Rating with Forced Ventilation	% Coef of Adhesion	Continuous Rating with Forced Ventilation	% Coef of Adhesion	Starting at 25% Coef of Adhesion	Limited by Motor Capacity	Speed M.P.H.: One Hour Rating	Speed M.P.H.: Continuous Rating	Speed M.P.H.: Max. Safe	Horse Power of Locomotive: One Hour Rating Forced Ventilation	Horse Power of Locomotive: Continuous Rating Forced Ventilation	Motor Volts per Arm.
Baltimore & Ohio	1a	6-9	4	1903-6	G.E.	Frt.	600	3rd Rail	D.C.	080	8	42"	0	—	—	14'-6¼	14'-6¼	160,000	160,000	40,000	116,000	44,000	29'-1"	9'-2"	13'-8"	No	4	GE 65B	Gear	19:81	56,000	22.5			40,000		8.0			800		600
	1b	11-12	2	1910	"	P+F.	600	"	"	040+040	8	50"	0	—	Yes	9'-6	27'-6"	185,000	185,000	46,250	119,000	66,000	39'-6"	10'-2½	14'-5"	No	4	GE 209A	Twin Gear	24:78	25,000	13.5	12,800	6.9	46,250		16.4	19.6	45	1100	670	600
	1c	13-14	2	1912	"	"	600	"	"	040+040	8	50"	0	—	Yes	9'-6	27'-6	200,000	200,000	50,000	135,000	65,000	39'-6"	10'-2½	14'-5"	No	4	GE 209A	"	24:78	25,000	12.5	12,800	6.4	50,000		16.4	19.6	45	1100	670	600
	1d	15-16	2	1923	"	"	600	"	"	040+040	8	50"	0	—	Yes	9'-6		240,000	240,000	60,000	175,000	65,000	39'-6"	10'-2½		No	4		"	24:78	25,000	10.4	12,800	5.3	60,000		16.4	19.6	45	1100	670	600
Bethlehem-Chile Iron Mines	2	6-8	3	1920	G.E.	Frt.	2400	3rd Rail Catenary	D.C.	040+040	8	52"	0	—	Yes	11'-0	35'-8"	239,000	239,000	59,750	120,600	118,400	49'-6"	10'-0¼	16'-7¾	Yes	4	GE 253A	Twin Gear	18:82	42,000	17.6	35,200	14.7	59,750		12.2	12.7	35	1370	1190	1200
Boston & Maine	3a	5000-4	5	1911	BLW West.	P+F	11,000	Catenary	A.C. 1φ	240+042	8	63"	4	42"	Yes	7'-0	38'-6"	260,000	204,000	51,000	141,800	118,200	48'-5"	10'-3"	14'-5"	No	4	W 403	Geared Quill	22:91	18,480	9.1	18,000	8.8	51,000	72,000	25.0	25.5	37.5	1232	1224	342
	3b	5005-6	2	1917	"	"	11,000	"	"	240+042	8	63"	4	42"	Yes	7'-0	38'-6"	265,500	217,000	54,250	147,500	118,000	48'-0"	10'-1"	14'-0½	No	4	W 403A	"	22:91	18,480	8.5	18,000	8.3	54,250	72,000	25.0	25.5	37.5	1232	1224	342
Butte, Anaconda & Pacific	4a	39-64	26	1913-1[illegible]	G.E.	Frt.	2400	Catenary	D.C.	040+040	8	46"	0	—	Yes	8'-8	26'-0"	160,000	160,000	40,000	100,000	60,000	37'-4"	10'-0"	15'-6"	No	4	GE 229A	Twin Gear	18:87	30,600	19.3	25,000	15.6	40,000		15.4	16.2	35	1280	1090	1200
	4b	65-6	2	1913	"	Pass.	2400	"	"	040+040	8	46"	0	—	Yes	8'-8	26'-0"	160,000	160,000	40,000	100,000	60,000	37'-4"	10'-0"	15'-6"	No	4	GE 229A	"	25:80	20,200	12.6	16,200	10.1	40,000		23.4	24.6	50	1280	1090	1200
Canadian Nat'l (Mt. Royal Tun.)	5	600-5	6	1918	G.E.	P+F	2400	Twin Catenary	D.C.	040+040	8	46"	0	—	Yes	8'-6	26'-0"	166,000	166,000	41,500	102,540	63,460	37'-4"	10'-0"	15'-6"	No	4	GE 229A	Twin Gear	25:80	20,200	12.2	16,200	9.8	41,500		23.4	24.6	50	1280	1090	1200
Chicago, Milwaukee & St. Paul	6a	10050-3	4	1917-8	G.E.	Switch	3000	Twin Catenary	D.C.	040-040	8	40"	0	—	No	8'-0	30'-4"	143,200	143,200	35,800	80,900	62,300	41'-5"	10'-1"	16'-8"	No	4	GE 255A	Gear	17:64	21,400	15.0	14,000	9.8	35,800		11.5	12.8	35	660	480	1500
	6b	10200-41	42	1916	"	Frt.	3000	"	"	2 Cabs 440+040+[illegible]	16	52"	8	36"	Yes	10'-6	102'-8"	576,000	450,000	56,250	328,000	248,000	112'-0"	10'-0"	16'-8"	Yes	8	GE 255	"	18:82	84,500	18.8	70,700	15.7	112,500		15.3	15.9	35	3440	3000	1500
	6c	10250-4	5	1920	"	Pass.	3000	"	"	240+480+080+042	24	44"	4	36"	Yes	13'-9	67'-0"	521,200	457,800	38,150	286,550	234,650	76'-0"	10'-0"	16'-8"	Yes	12	GE 100	Gearless	—	48,500	10.6	42,000	9.2	114,450		27.1	28.4	90	3500	3200	1000
	6d	10300	1	1920	BLW West.	Frt.	3000	"	"	462+264	12	68"	12	36"	Yes	16'-9	79'-10	600,000	378,000	63,000	367,200	232,800	88'-7"	11'-0¼	17'-0"	Yes	6 Twin	W 348	Geared Quill	21:92	78,000	20.6	48,100	12.7	94,500	180,600	22.6	26.4	55	4680	3400	750
	6e	10301-9	9	1920	"	Pass.	3000	"	"	462+264	12	68"	12	36"	Yes	16'-9	79'-10	600,000	378,000	63,000	367,200	232,800	88'-7"	11'-0¼	17'-0"	Yes	6 Twin	W 348	"	24:89	66,000	17.5	40,800	10.8	94,500	153,000	26.7	31.2	65	4680	3400	750
Chilean State	7a	2801-6	6	1923-4	BLW West	Ex. Pass.	3000	Catenary	D.C.	260-062	12	42"	4	30"	Yes	14'-5	48'-4"	259,800	210,000	35,000	155,600	104,200	58'-5"	10'-6¾	14'-4⁷⁄₁₆	Yes	6	W 354-A5	Flex Gear	21:56	25,800	12.3	19,800	9.4	52,500	70,800	36.0	39.7	63	2460	2040	1500
	7b	2501-11	11	1923-4	"	Loc. Pas.	3000	"	"	040+040	8	42"	0	—	Yes	8'-4	26'-0"	160,000	160,000	40,000	94,600	65,400	38'-9½	10'-7"	14'-2³⁄₁₆	No	4	W 354-A5	"	21:56	17,200	10.8	13,200	8.3	40,000	47,200	36.0	39.7	56	1640	1360	1500
	7c	2001-15	15	1923-4	"	Frt.	3000	"	"	060+060	12	42"	0	—	Yes	13'-9	37'-0"	230,000	230,000	38,300	140,000	90,000	49'-9½	10'-6¾	14'-4³⁄₁₆	Yes	6	W 350-D5	"	15:63	31,200	13.6	24,360	10.6	57,500	84,000	21.5	23.0	44	1800	1500	1500
	7d	2301-7	7	1923-4	"	Switch	3000	"	"	040-040	8	42"	0	—	No	8'-6	27'-4"	137,000	137,000	34,250	82,500	54,500	40'-0"	10'-6¾	14'-2³⁄₁₆	No	4	W 350-D2	Gear	16:63	23,000	16.8	11,000	8.0	34,250	56,000	10.5	12.8	35	640	380	1500
Grand Trunk (St. Clair Tunnel)	9	2655-60	3	1908	BLW West	P+F.	3300	Catenary	A.C. 1φ	2 Cabs 060-	12	62"	0	—	—	16'-0	45'-5½	264,000	264,000	44,000	147,300	116,700	58'-11"	9'-8"	15'-3"	No	6	W 137	Gear	16:85	37,800	14.3	24,600	9.3	66,000	96,000	16.2	19.4	30	1632	1272	280
Great Northern	10	5000-3	4	1909	G.E.	P+F.	6600	Direct Suspension	A.C. 3φ	040+040	8	60"	0	—	Yes	11'-0	31'-9"	230,000	230,000	57,500	121,000	109,000	44'-2"	10'-0"	15'-1"	Yes	4	GE 1506	Twin Gear	19:81	38,000	16.5	34,800	15.1	57,500		15.1	15.2	30	1500	1400	500
Long Island	12	323	1	1917	West.	Frt.	650	3rd Rail	D.C.	040-040	8	55"	0	—	No	7'-2	26'-1"	175,800	175,800	43,950	114,640	61,160	38'-8"	10'-1¾	13'-6"	No	4	W 98	Gear	22:70	23,200	13.2	15,440	8.8	44,800		21.2	26.7	56	1200	1000	650
Mexican	13	1001-10	10	1924	G.E.	P+F.	3000	Catenary	D.C.	040+040+040	12	46"	0	—	Yes	9'-2	40'-6	308,000	308,000	51,300	173,000	135,000	52'-11"	10'-1½	15'-2"	Yes	6	GE 278	Gear	18:90	54,000	17.6	48,500	15.8	77,000		19.0	19.5	39	2736	2520	1500
Michigan Central	14a	7500-5	6	1909	G.E.	P+F.	600	3rd Rail	D.C.	040+040	8	48"	0	–	Yes	9'-6	27'-6	200,000	200,000	40,000	135,000	65,000	39'-6"	10'-2½	14'-8"	No	4	GE 209A	Twin Gear	19:82	35,000	17.5	18,000	9.0	50,000		11.8	14.0	40	1100	670	600
	14b	7506-9	4	1914	"	"	600	"	"	040+040	8	48"	0	–	Yes	9'-6	27'-6	240,000	240,000	60,000	175,000	65,000	39'-6"	10'-2½	14'-8"	No	4	GE 209A	"	19:82	34,000	14.2	18,000	7.5	60,000		12.3	14.0	40	1100	670	600
New York Central	15a	1100-34	35	1906	GE	Pass.	600	3rd Rail	D.C.	484	8	44"	8	33"	—	13'-0	32'-6	227,700	140,900	35,225	167,700	60,000	38'-9	10'-1"	14'-9½	No	4	GE 84	Gearless	—	21,000	14.9	5,000	3.6	35,225		38.5	60.0	80	2200	800	600
	15b	1135-46	12	1906-9	"	"	600	"	"	484	8	44"	8	36½	—	13'-0	36'-0	244,500	148,500	37,125	184,500	60,000	43'-0½	10'-1"	14'-6"	No	4	GE 84	"	—	21,000	14.1	5,000	3.4	37,125		38.5	60.0	80	2200	800	600
	15c	1141-56	10	1913	"	"	600	"	"	040-040+040-040	16	36"	0	—	Yes	5'-0	45'-7	237,000	237,000	29,625	165,000	74,000	53'-2"	10'-1⅞	14'-6"	No	8	GE 92	"	—	17,200	7.3	11,400	4.8	59,250		50.5	57.5	85	2320	1760	600
	15d	1157-72	16	1914-8	"	"	600	"	"	040-040+040-040	16	36"	0	—	Yes	5'-0	46'-5	265,000	265,000	33,125	177,000	88,000	56'-10"	10'-1⅞	14'-6"	No	8	GE 91	"	—	20,000	7.6	14,000	5.3	66,250		49.0	56.3	85	2600	2000	600

(1) Without Forced Ventilation (2) Includes Steam Heating Equipment (3) Short Field Ratings (4) Motors Series Parallel 300V Ratings (5) Continuous Rating 120°C Rise

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 12

6-24

Printed in U. S. A.

Electric Locomotives of North and South America (Cont.)

ELECTRIC LOCOMOTIVES OF NORTH & SOUTH AMERICA

Railroad	Key No.	Series No.	No. in Service	Year Placed in Service	Mfg. Co.	Class of Service	Contact Conductor Volts	Contact Conductor Type	Type of Loco	Classification by Wheels	Driving Wheels No.	Driving Wheels Dia.	Truck Wheels No.	Truck Wheels Dia.	[illegible] Trucks	Wheelbase Rigid	Wheelbase Total
New York New Haven & Hartford	16a	01-041	41	1907	BLW West	Pass	[illegible]	[illegible]	[illegible]	240+042	8	62"	4	33"	No	8'-0"	30'-9"
	16b	068	1	1919	G.E.	[illegible]	11000	Catenary	AC 1φ	440+044	8	54"	8	36"	Yes	10'-0"	34'-10"
	16c	069	1	1910	BLW West	P & F	[illegible]	[illegible]	[illegible]	220+040+022	8	63"	4	36"	No	11'-0"	39'-0"
	16d	070	1	1910	"	[illegible]	11000	Catenary	AC 1φ	240+042	8	57"	4	36"	Yes	8'-0"	43'-6"
	16e	071	1	1910	"	Pass	[illegible]	[illegible]	[illegible]	240+042	8	63"	4	42"	Yes	7'-0"	38'-6"
	16f	072	1	1911	"	"	[illegible]	"	"	240+042	8	63"	4	36"	Yes	7'-0"	38'-6"
	16g	013-075	3	1912-3	"	"	[illegible]	"	"	240+042	8	63"	4	36"	Yes	8'-0"	40'-6"
	16h	076-0111	36	1912-3	"	Frt	11000	Catenary	AC 1φ	240+042	8	63"	4	36"	Yes	8'-0"	40'-6"
	16i	0200	1	1911	"	Switch	11000	"	"	040+040	8	63"	0	—	Yes	7'-0"	23'-6"
	16j	0201-14	14	1912	"	"	11000	"	"	040+040	8	63"	0	—	Yes	7'-0"	23'-6"
	16k	0215	1	1912	"	"	11000	"	"	040+040	8	63"	0	—	Yes	7'-0"	23'-6"
	16l	0300-4	5	1919	"	Pass	[illegible]	[illegible]	[illegible]	262+262	12	63"	8	36"	Yes	14'-3"	58'-6"
	16m	0305-16	12	1923-4	"	"	[illegible]	"	"	262+262	12	63"	8	36"	Yes	14'-3"	59'-6"
New York Westchester & Boston	17	301	1	1912	BLW West	Frt	11000	Catenary	AC 1φ	040+040	8	63"	0	—	Yes	7'-0"	23'-6"
Norfolk & Western	18a	2500-11	12	1915	BLW West	Frt	11000	Catenary	[illegible]	2 Cabs 240+042	16	62"	8	30"	Yes	11'-0"	94'-10"
	18b	2512-15	4	1924	ALCO West	"	11000	"	"	2 Cabs 282	16	62"	8	33"	—	16'-6"	83'-0"
Pennsylvania System	19a	3931	1	1917	PRR West	Frt	11000	Catenary	[illegible]	260+062	12	72"	4	36"	Yes	15'-4"	63'-11"
	19b	3930	1	1924	"	Frt Pass	11000	"	AC 1φ	282	8	80"	4	33"	—	22'-3"	54'-11"
	19c																
	19d	32-3	2	1910	"	Pass	600	3rd Rail	D.C	440+044	8	68"	8	36"	Yes	7'-2"	55'-11"
	19e	10-31	22	1910	"	"	600	"	"	440+044	8	72"	8	36"	Yes	7'-2"	55'-11"
	19f	34-42	9	1911	"	"	600	"	"	440+044	8	72"	8	36"	Yes	7'-2"	55'-11"
	19g	3951	1	1910	"	Switch	600	"	"	040+040	8	56"	0	—	Yes	8'-6"	26'-1"
Paulista (South America)	20a	208-11	4	1921	G.E.	Pass	3000	Catenary	D.C.	440+044	8	42"	8	36"	Yes	7'-9"	46'-0"
	20b	200-7	8	1921	"	Frt	3000	"	"	040+040	8	42"	0	—	Yes	8'-8"	26'-0"
	20c	212-5	2	1921	BLW West	Pass	3000	"	"	240+042	8	63"	4	36"	Yes	8'-4"	41'-2"
	20d	214-5	2	1921	"	Frt	3000	"	"	060+060	12	40"	0	—	Yes	14'-0"	37'-0"
	20e			1924	GE	Switch	3000	"	"	040+040	8	42"	0	—	No		

Key No.	Weights–Lbs. Total	On Drivers	Av. per Driving Axle	Mech. Parts	Elect. Parts	Length over All	Width over All	Height Top of Rail to Highest Point Trolley Down	Regenerative Control	Motors No.	Motors Type	Method of Drive	Gear Ratio	T.E. One Hour Rating with Forced Ventilation	% Coef of Adhesion	T.E. Continuous Rating with Forced Ventilation	% Coef of Adhesion	Starting at 25% Coef of Adhesion	Limited by Motor Capacity	Speed One Hour Rating	Speed Continuous Rating	Max. Safe	H.P. One Hour Rating Forced Ventilation	H.P. Continuous Rating Forced Ventilation	Motor Volts per Arm.
16a	217,600	167,600	41,900	105,600	(1) 112,000	37'-7½"	10'-2"	14'-3"	No	4	W130	Gearless Quill	—	8,000	4.8	5,200	3.1	—	19,600	59.0	73.0	88	1260	1016	284
16b	291,000	194,000	48,500	172,000	119,000	62'-0"	10'-0"	14'-5"	No	4	GE9614	Gear Siderod	55:71	27,000	13.9	22,200	11.5	48,500		23.0	26.4	45	1800	1600	
16c	252,000	176,000	44,000	111,500	(1) 120,500	46'-8"	10'-3"	14'-5"	No	8	W409B	Geared Quill	22:92	15,600	8.9	10,940	6.2	—	41,200	58.8	46.3	54	1616	1336	330
16d	210,000	192,000	48,000	138,000	132,000	52'-0"	10'-3"	14'-6"	No	2	W406	Siderod	—	16,800	8.7	12,000	6.2	—	36,000	29.0	34.3	61	1300	1100	310
16e	289,500	186,450	46,615	160,300	(1) 129,000	48'-0"	10'-3"	14'-5	No	4	W403	Geared Quill	34:79	10,400	5.6	10,120	5.4	—	40,400	51.5	53.0	67	1428	1432	380
16f	248,000	184,000	46,000	120,000	(1) 128,000	48'-0"	10'-3"	14'-5	No	4	W405B	"	34:79	10,400	5.7	10,120	5.5	—	40,400	45.0	46.0	67	1248	1240	342
16g	259,000	182,000	45,500	124,000	(1) 115,000	50'-0"	10'-3"	14'-6	No	8	W409C	"	22:92	15,600	8.6	10,840	6.0	—	41,200	38.8	46.3	62.5	1616	1336	330
16h	219,500	165,000	41,250	120,900	98,600	50'-0"	10'-5"	14'-6	No	8	W409C	"	17:97	21,200	12.9	14,760	8.9	41,250	56,000	28.5	34.0	45	1616	1336	330
16i	158,000	158,000	39,500	79,700	78,300	37'-0"	10'-1¼"	14'-2	No	4	W410	"	17:101	23,200	14.7	14,480	9.1	39,800	46,000	8.1	11.4	25	500	440	190
16j	159,200	159,200	39,800	83,400	75,800	37'-6"	10'-1¼"	14'-2	No	4	W410	"	17:101	23,200	14.6	14,400	9.1	39,800	46,000	10.5	13.5	25	652	520	228
16k	154,700	154,700	38,675	83,500	71,200	37'-6"	10'-1¼"	14'-2	No	4	W410	"	17:101	23,200	15.0	14,400	9.3	38,700	46,000	10.5	13.5	25	652	520	228
16l	330,000	233,000	38,835	176,900	(1) 173,100	69'-0"	10'-2	14'-2	No	12	W409CZ	"	27:81	18,000	7.7	12,540	5.4	—	47,520	51.0	61.0	70	2460	2040	335
16m	358,000	240,000	40,000	176,300	(1) 161,700	68'-6"	10'-2½"	14'-2	No	12	W409CZ	"	25:89	19,260	8.0	13,080	5.5	—	52,500	48.0	56.8	70	2508	2052	349
17	159,200	159,200	39,800	83,400	75,800	37'-6"	10'-0"	14'-2	No	4	W410	Geared Quill	17:101	23,200	14.6	14,400	9.1	39,800	46,000	10.5	13.5	25	652	520	228
18a	604,400	512,800	64,100	388,800	215,600	105'-8"	10'-9"	16'-0"	Yes	8	W450A	Gear Siderod	18:85	84,000 / 45,000	16.4 / 8.4	66,000 / 38,500	12.9 / 7.5	—	125,000	14.3 / 28.1	14.4 / 28.4	38	3200 / 3200	2520 / 2900	725
18b	828,000	596,000	74,500	530,000	307,000	97'-2"	10'-5"	16'-0"	Yes	4	W452	"	21:190	108,000 / 63,000	18.1 / 10.6	90,000 / 52,500	15.1 / 8.8	149,000	185,000	14.1 / 28.3	14.2 / 28.4	38	4060 / 4750	3400 / 4000	1150
19a	516,000	439,500	73,250	258,400	257,600	76'-6¼"	10'-1¼"	15'-6"	Yes	4	W451	Gear Siderod	21:106	88,000	20.0	73,000	16.6	110,000	140,000	20.4	20.5	35	4800	4000	850
19b	408,000	300,000	75,000	220,000	188,000	68'-2½"	10'-1"	15'-6"	No	4	W418	"	30:118 / 50:98	59,000 / 29,500	19.7 / 9.8	50,000 / 25,000	16.7 / 8.3	75,000 / —	100,000 / 54,000	21.0 / 42.0	23.0 / 46.0	35 / 70	3300	3070	335
19c																									
19d	332,000	208,000	52,000	205,000	127,000	64'-11"	10'-7¼"	14'-8¼"	No	2	W315	Jackshaft Siderod	—	(1,3) 11,700	8.5	(3) 10,150	5.2	52,000	52,300	(3) 45.1	(3) 54.8	80	(1,3) 2130	(1,3) 1570	600
19e	313,000	199,000	49,750	194,000	119,000	64'-11"	11'-2¼"	14'-8¾"	No	2	W315	"	—	(1,3) 16,700	8.4	(3) 10,150	5.1	—	49,400	(3) 47.8	(3) 58.0	80	(1,3) 2130	(1,3) 1570	600
19f	319,000	203,000	50,750	202,500	116,700	64'-11"	11'-2¼"	14'-8¾"	No	2	W315	"	—	(1,3) 16,700	8.2	(3) 10,150	5.0	—	49,400	(3) 47.8	(3) 58.0	80	(1,3) 2130	(1,3) 1570	600
19g	195,140	195,140	48,785	100,000	95,140	38'-9"	10'-7¼"	14'-6⅜"	No	2 / 2	W103 / W109	Gearless Quill	—	19,820	10.1	10,940	5.6	—	38,500	11.9	14.5	40	(4) 630	(4) 423	300
20a	240,000	160,000	40,000	158,900	81,100	55'-0"	10'-1¼"	14'-5"	Yes	4	GE267A	Twin Gear	30:70	(1) 15,680	9.8	(1,5) 14,720	9.2	40,000		40.5	41.3	62	(1) 1680	(1,5) 1600	1500
20b	200,000	200,000	50,000	118,800	81,200	39'-2"	10'-1¼"	14'-5"	Yes	4	GE267A	"	18:82	(1) 30,600	15.5	(1,5) 28,800	14.4	50,000		20.8	21.0	34	(1) 1680	(1,5) 1600	1500
20c	283,800	205,800	51,450	166,800	117,000	52'-11"	10'-7"	14'-10"	Yes	4 Twin	W351	Geared Quill	28:86	(1) 20,960	10.0	(1) 14,240	6.9	51,450	54,400	(1) 42.8	(1) 47.2	65	(1) 2400	(1) 1800	1500
20d	234,300	234,300	39,050	145,450	88,850	50'-2"	10'-6½"	14'-10"	Yes	6	W350	Gear	16:63	(1) 32,400	13.8	(1) 21,600	9.2	58,575	82,800	(1) 20.8	(1) 23.4	42	(1) 1800	(1) 1350	1500
20e	140,000	140,000	35,000						No	4								35,000							

(1) Without Forced Ventilation (2) Includes Steam Heating Equipment (3) Short Field Ratings (4) Motors Series Parallel 300V Ratings (5) Continuous Rating 120°C Rise

TRAIN RESISTANCE

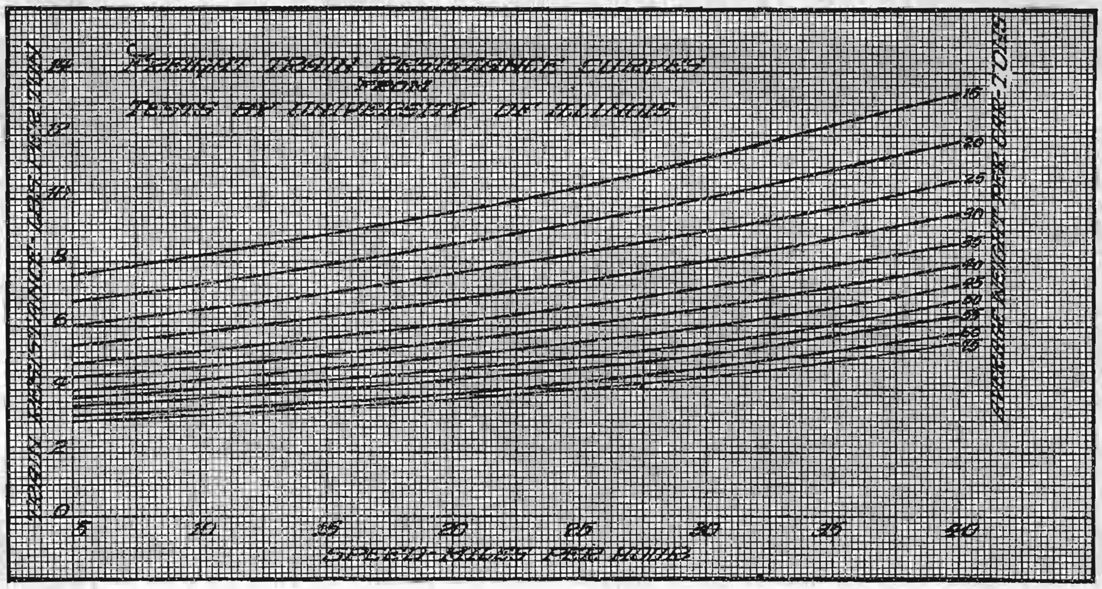
The summation of the forces opposed to the motion of a train at constant speed on straight level track is known as train resistance. It is usually expressed in pounds per ton of train weight. Train resistance includes all losses in bearings, losses due to rolling friction, bending rails, flange friction and wind resistance. All of these variables depend on the condition of bearings, design of trucks, condition of the road-bed, shape and cross section of the cars, so that tests to furnish accurate data must be sufficiently comprehensive to eliminate errors due to purely local conditions. Various tests have been made in the past to secure consistent and accurate data. The component parts of train resistance have been studied and formulas developed covering them as well as the whole. In general, it may be said that train resistance expressed in pounds per ton varies with the speed and with the weight of the rolling equipment.

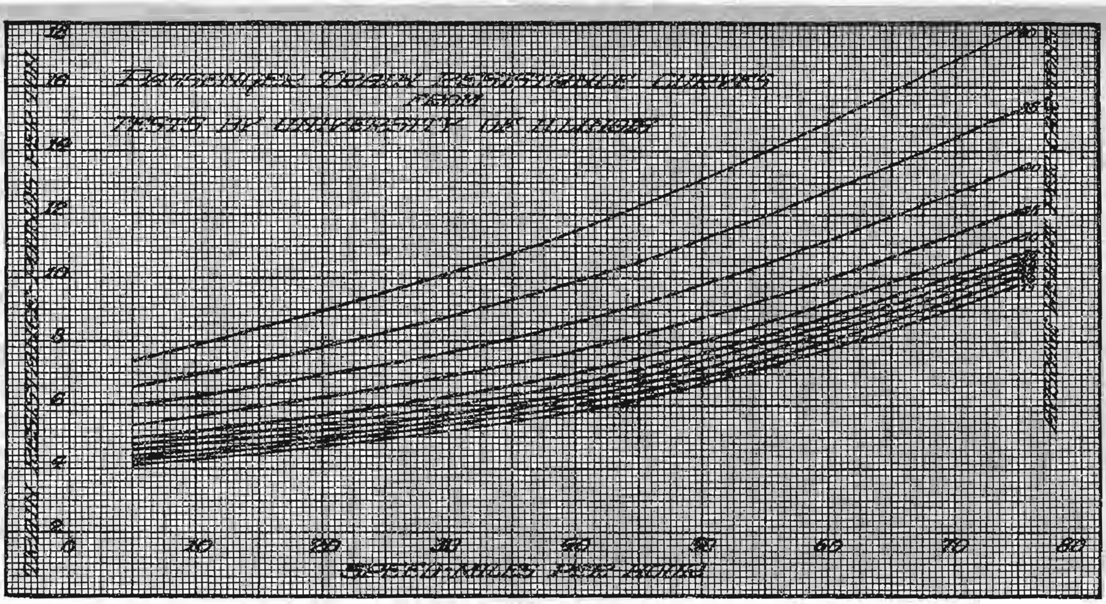
Although formulas for train resistance are available in a variety of forms, it is common practice to obtain train resistance values from curves. Very complete tests have been made by the University of Illinois on train resistance for both passenger and freight trains. These tests are fully described in bulletins Nos. 43 and 110. Inside are reprinted the curves which were drawn up as a result of these tests. These curves do not include locomotive resistance. A fair average value for this is 15 lb. per ton.

(See Tables Inside)

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 13 6-24 Printed in U. S. A.


FREIGHT TRAIN RESISTANCE CURVES
FROM
TESTS BY UNIVERSITY OF ILLINOIS
5
10
15
20
25
30
35
40
SPEED-MILES PER HOUR


PASSENGER TRAIN RESISTANCE CURVES
FROM
TESTS BY UNIVERSITY OF ILLINOIS
0
10
20
30
40
50
60
70
80
SPEED-MILES PER HOUR

Industrial Lighting Section

(Including Sheets 14 to 20)

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707 6-24 Printed in U. S. A.

INDUSTRIAL LIGHTING

The great progress made in industrial lighting during the last few years has been due not only to the demand for increased production, savings in operation and betterment of working conditions, but has been made possible by improvements in lamps and equipment and in methods of installation. Among the advantages of good factory lighting are:

1. Increased production for the same labor cost.
2. Greater accuracy in workmanship.
3. Decrease in spoilage.
4. Reduction of accidents.
5. Improved order and cleanliness in the plant.
6. Easier supervision of men.
7. Better working and living conditions.
8. Less eye strain and physical fatigue.
9. Greater contentment of men, reducing labor turn-over.
10. Lowered compensation insurance rates.

Requirements for Good Lighting

In the design of an adequate system for an industrial plant the following requirements must be met:

1. A steady light of sufficient intensity on all working surfaces.
2. A comparable intensity of light on adjacent areas and on the walls.
3. Light of a color and spectral character suited to the purpose for which it is employed.
4. Freedom from glare and from glaring reflections.
5. Light so directed and diffused as to avoid objectionable shadows or contrast of intensity.
6. A system which is simple, reliable, easy to maintain and reasonable in initial and operating costs.

Modern reflectors and Mazda C lamps are universally applicable to the vast diversity of conditions arising in the demand for good lighting of industrial plants.

Types of Factory Lighting

The principal types of illumination used in industrial plants are: (1) General lighting, secured by a system giving uniform intensity throughout a shop without regard to machines or work; it approaches more nearly "daylight" conditions than any other system. (2) Localized lighting, secured by single units suspended over individual working planes. (3) General and localized lighting, a combination of the first two types. (4) Modified lighting, secured by suspending lighting units so that the maximum amount of illumination will be received on the most important working planes.

ILLUMINATING CALCULATIONS

Although the installation of every lighting system involves individual problems which must be studied to obtain the best results, the procedure in designing a general lighting system has been very well standardized. It may be divided into the following steps:

1. **Selection of the desirable intensity of illumination on the working plane.** This depends upon the character of the work to be done. Table II gives recommended values for various classes of work. It should be remembered, however, that increased illumination will result in increased production. This holds true even above the figures given as desirable intensities.

2. **Determination of the utilization constant.** Part of the light emitted by the lamp does not reach the working plane but is absorbed by the reflecting surfaces, walls, and ceiling. The amount depends upon the type of fixture, the color of the surroundings, and the proportions of the room. The ratio between the effective lumens and the total lumens is called the utilization constant. The values for the various conditions are given in Tables III and IV.

3. **Determination of the total quantity of light to be supplied by the lamp.** Use the values found above with the following formula:

$$\text{Total lumens} = \frac{\text{Area of room in sq. ft.} \times \text{intensity in ft. candles} \times \text{depreciation factor}}{\text{Utilization constant}}$$

(Depreciation factor: Under ordinary conditions the light output from open reflectors diminishes from 10 to 25 per cent after about four weeks, due to the collection of dust and dirt on the reflecting surface. Therefore, in designing an installation it is well to include a depreciation factor of 1.1 to 1.4.)

4. **Selection of suitable lighting unit.** The choice of lighting equipment best suited for a proposed installation should be made with regard to the requirements of good lighting as covered on the preceding page. The data given under "Selection of Reflector" gives the relative values of the various types of units with respect to the more important criteria.

Industrial Lighting (Cont.)

5. **Determination of number of lamps to be used and their location.** The area to be lighted should be divided as nearly as possible into equal squares and a lighting unit placed at the center of each square. The size of the squares depends upon the ceiling height, the division of the room by columns or ceiling beams into bays, and the extent to which shadows will be objectionable. The higher the ceiling the greater will be the allowable spacing between lighting units, and generally speaking, fewer units of larger size are preferable to a large number of smaller units. Not only are the larger lamps more efficient, but the expenses of wiring and maintenance are reduced. On the other hand a few large lamps will produce deep shadows, and the intensity of these shadows is decreased as the number of units is increased. The ideal number is the smallest that will give reasonably uniform lighting. The distribution of light from a lamp may be controlled to produce the same results with different types of reflectors if the proper ratio between mounting height and outlet spacing is observed. This relation is as follows: With the R L M standard dome type the maximum spacing of outlets is 1⅔ times the mounting height; with the standard bowl type the maximum spacing of outlets is 1¼ times mounting height.

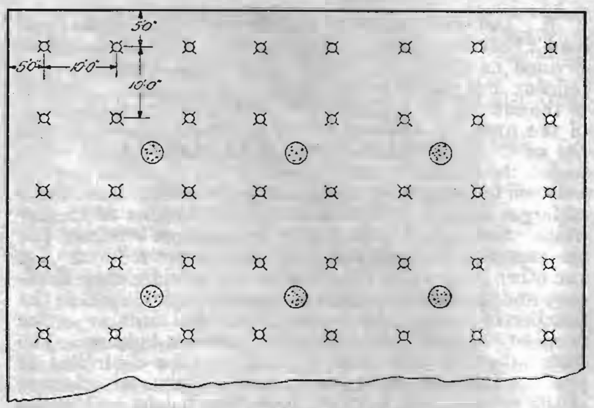
6. **Determination of size of lamps.** The total lumens required can now be divided by the number of outlets to obtain the lumens per lamp. From Table V, the lamp which gives nearest that amount of light may then be selected.

Planning a Specific Lighting Installation

Suppose the problem is to design a lighting system for a machine shop. The character of the work performed in the shop may be classified as medium grade, that is, there is no very fine work. Area of room 80 x 120 ft. or 9,600 sq. ft. with 12 ft. ceiling. Lower section of walls tan, ceiling and upper part of walls white.

1. The recommended foot-candle values for medium machine work vary from 6- to 12-foot candles, (Table II). Select 9-foot candles as an average.

2. Porcelain enameled steel reflectors are the most practical for factory lighting. In this particular case the R L M Standard Dome Reflector is recommended because of its sturdiness, medium cost and wide distribution of light. It will be desirable to use bowl enameled lamps because this coating reduces the apparent brightness of that portion of the bulb.



Correct layout for the problem

3. The Utilization Constant (Tables III & IV) for the R L M Standard Dome Reflector and bowl enameled lamp in a room with light ceilings and walls will be 0.54. An allowance of 15 percent must be made for depreciation in light output due to the unavoidable collection of dust between cleaning periods and gradual aging of the lamp. Assuming this allowance of 15 percent a depreciation factor of 0.85 should be used.

4. Total lumens necessary.

$$\frac{80 \text{ x } 120 \text{ (sq. ft.) x } 9}{.54 \text{ x } .85} = 188{,}235$$

5. From Table I, it will be seen that four outlets per bay are necessary with a 12-foot ceiling, if uniform illumination is to be obtained. With twenty-four bays there will be a total of ninety-six outlets.

6. Dividing the total numbers of lumens required by the number of outlets gives the lumens which each lamp must supply.

$$\frac{188{,}235}{96} = 1{,}960$$

Table V shows that a 150 watt Mazda C lamp generates 2,100 lumens and, therefore, is the proper size for this installation.

7. To determine the correct mounting height refer to Table I. Columns three and one show that for a spacing of 10 feet the unit should be mounted 7 feet 6 inches above the working plane or 10 feet above the floor.

Industrial Lighting (Cont.)

TABLE I
SPACING AND MOUNTING HEIGHT

Direct Lighting Units, Including Semi-enclosing and Totally Enclosing Units

Mounting Height of Unit		Recommended Spacing Between Outlets	Recommended Distance Between Outlets and Sidewalls	
Above Plane of Work	Above Floor*		In Usual Locations where Aisles and Storage are Next to Wall	In Office or Where Work Benches are Next to Wall
4	6½	6	3	2
6	8½	9	4½	3
8	10½	12	6	4
10	12½	15	7½	5
12	14½	18	9	6
14	16½	21	10½	7
16	18½	24	12	8
20	22½	30	15	10
24	26½	36	18	12
30	32½	45	22½	15
40	42½	60	30	20

Semi and Totally Indirect Lighting Units

Ceiling Height		Recommended Spacing Between Outlets	Recommended Distance Between Outlets and Sidewalls		Suspension Distance Ceiling to Top of Reflector †
Above Plane of Work	Above Floor*		In Usual Locations Where Aisles and Storage are Next to Wall	In Offices or Where Work Benches are Next to Wall	
5	7½	7½	3½	2½	1¼
7	9½	10½	5	3½	1¾
9	11½	13½	6½	4½	2¼
11	13½	16½	8	5½	2¾
13	15½	19½	9½	6½	3¼
15	17½	22½	11	7½	3¾
18	20½	27	13½	9	4½
24	26½	36	18	12	6
30	32½	45	22½	15	7½
40	42½	60	30	20	10

*Plane of work assumed to be 2½ feet above floor. When the plane of work is higher or lower than 2½ feet above floor, neglect this column and work from the first column.

†Suspension distances in table are based on best distribution of light and efficiency of utilization for standard units. In some installations other considerations may require a different suspension distance.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

TABLE II

Present Standards of Desirable Illumination for Various Classes of Service

Industries Classified Alphabetically

Industry or Place	Foot-candles Range
Aisles in Factories	1 – 2
Assembling of Manufactured Articles:	
Rough	3 – 6
Medium	5 – 10
Fine	8 – 16
Extra Fine	10 – 50
Boilers, Engine Rooms and Power Houses:	
Boilers, Coal and Ash Handling, Storage Battery Rooms	2 – 4
Auxiliary Equipment, Oil Switches and Transformers	3 – 6
Switchboards, Engines, Generators, Blowers and Compressors	4 – 8
Carpenter Shop (See Woodworking)	
Cars:	
Baggage	3 – 6
Day Coach, Subway	4 – 6
Dining	4 – 8
Mail	6 – 12
Pullman	4 – 8
Street Railway	4 – 8
Coal Breaking and Washing, Screening	2 – 4
Construction, General:	
Indoor	2 – 4
Outdoor (Rough)	0.5 – 2
Depot:	
Baggage Room	3 – 6
Train Sheds, Concourse	2 – 5
Waiting Room	3 – 6
Drafting	10 – 20
Electric Manufacturing:	
Storage Battery, Molding of Grids	4 – 8
Coil and Armature Winding, Mica Working, Insulating, Molding, Wire Insulating	8 – 16
Lamp Manufacturing (Exclusive of Mounting)	5 – 20
Erecting	2 – 6
Forge Shops and Welding:	
Rough Forging and Welding	4 – 8
Fine Welding	6 – 12

Industrial Lighting (Cont.)

TABLE II (Cont.)

Industry or Place	Foot-candles Range
Foundries:	
Charging Floor, Tumbling, Cleaning, Pouring and Shaking Out	3 – 6
Rough Molding and Core Making	4 – 8
Fine Molding and Core Making	6 – 12
Halls, Passageways in Interiors	1 – 3
Inspecting:	
Rough	4 – 8
Medium	6 – 12
Fine	10 – 20
Extra Fine	15 – 50
Lavatories	2 – 5
Locker Rooms	2 – 4
Machine Shops:	
Rough Bench and Machine Work	4 – 8
Medium Bench and Machine Work, Ordinary Automatic Machines, Rough Grinding, Medium Buffing and Polishing	6 – 12
Fine Bench and Machine Work, Fine Automatic Machines, Medium Grinding, Fine Buffing and Polishing	8 – 16
Extra Fine Bench and Machine Work, Small Instrument Assembling	10 – 50
Office:	
File Room	3 – 6
Desk	8 – 10
General	6 – 10
Vault (Safe)	4 – 6
Vault (Storage)	2 – 4
Paint Shops:	
Firing, Dipping and Spraying	3 – 6
Rubbing, Hand Painting and Finishing (Ordinary)	5 – 10
Hand Painting and Finishing (Fine)	8 – 16
Hand Painting and Finishing (Extra fine) (Automobile Bodies, Piano Cases, etc.)	10 – 50
Power House	4 – 6
Railway Station:	
Waiting Room	3 – 6
Ticket Offices, etc., (See Offices)	6 – 12
Rest Room, Smoking Room, etc.	3 – 6
Baggage Room	3 – 6
Concourse	3 – 6
Train Platform	2 – 4
Receiving and Shipping	3 – 6

Westinghouse Electric & Manufacturing Company
S. P. 1707 East Pittsburgh, Penna.
Sheet 17 6-24 Printed in U. S. A.

TABLE II (Cont.)

Industry or Place	Foot-candles Range
Roadways and Yard Thoroughfares	0.1 – 0.5
Shafting Pulleys and Mechanical Transmissions	1 – 3
Sheet Metal Works:	
Miscellaneous Machines, Ordinary Bench Work, Punch Presses, Shears, Stamps, Welders, Spinning, Fine Bench Work	5 – 12
Tin Plate Inspection	10 – 20
Steel and Iron Mills, Bar, Sheet and Wire Products:	
Soaking Pits and Reheating Furnaces	1 – 3
Charging and Casting Floors	3 – 6
Muck and Heavy Rolling, Shearing (Rough by Gauge), Pickling and Cleaning	3 – 6
Automatic Machines, Rod, Light and Cold Rolling, Wire Drawing, Shearing (Fine by Line)	5 – 10
Plate Inspection	10 – 20
Stone Crushing and Screening:	
Belt Conveyor Tubes, Main Line Shafting Spaces, Chute Rooms, Inside of Bins	1 – 2
Primary Breaker Room, Auxiliary Breakers under Bins	2 – 4
Screen Rooms	3 – 6
Storage and Stock Rooms:	
Rough, no Reading of Labels	1 – 3
Medium	3 – 6
Fine	4 – 8
Structural Steel Fabrication	4 – 8
Telegraph Operating	4 – 12
Telephone:	
Manual Exchanges	3 – 6
Automatic Exchanges	6 – 12
Warehouse	1 – 2
Wharf:	
Freight	1 – 3
Passenger	1 – 3
Woodworking:	
Rough Sawing (Saw Mills) Bench Work (Rough)	3 – 6
Sizing, Planing, Rough Sanding, Machine Woodworking (Medium), Bench Work (Medium), Gluing and Veneering, Cooperage	5 – 10
Machine Woodworking (Fine), Bench Work (Fine), Fine Sanding and Finishing	6 – 12

Industrial Lighting (Cont.)

SELECTION OF REFLECTOR

Various lighting units are rated in accordance with seven fundamentals, illustrated on the following page. The importance of these criteria is different for different classes of work. It must be emphasized that the relative importance of the various criteria should be carefully weighed with respect to the particular problem at hand. For instance, in an office the criteria would rank in importance: (1) direct glare; (2) reflected glare; (3) shadows; (4) efficiency based upon illumination on horizontal; (5) maintenance; (6) vertical illumination. On the other hand, where lamps are to be hung above a crane in a foundry, the order of importance would be: (1) efficiency based upon illumination on horizontal; (2) vertical illumination; (3) maintenance; (4) shadows; (5) direct glare; (6) reflected glare.

In the chart the best rating given is A, which denotes the highest degree of excellence, while D, the lowest, indicates that an installation of units so rated in any particular, will very likely prove unsatisfactory in an installation where this factor is important. The ratings B and C, while indicating a result not equal to A, are decidedly superior to rating D. In other words a rating B or C in certain respects does not disqualify a unit provided that in the essential requirements of a given location, the unit is rated A or B.

A+, A, A— —Excellent B+, B, B— —Good CW, C, C— —Fair D—Very Bad

No.	Lighting Unit	Efficiency: Horizontal	Efficiency: Vertical	Appearance of Room	Direct Glare	Reflected Glare	Shadows	Maintenance
1	R L M Dome Type with Clear Lamp	A+	B+	C+	C	D	C+	A+
2	R L M Dome Type with Bowl Enameled Lamp	A—	B	B	B+	B	B+	A—
3	Luminous Top R L M Dome Type with Clear Lamp	B	C+	A—	A—	B	B+	B
4	Standard Bowl Type with Clear Lamp	B+	B—	C	C+	D	C	A

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

Illumination on Horizontal Surfaces is a prime requisite in offices, drafting rooms and those shops where the problem is to provide the best illumination for sustained vision of flat surfaces on the horizontal or slightly oblique planes in which papers, books and other flat objects are usually examined.

Illumination on Vertical Surfaces of work or machine parts is fully as important as the lighting of the surface in the horizontal plane. In a consideration of the amount of light necessary for factory illumination, the criterion must be the intensity on all working surfaces whether vertical, horizontal or oblique.

Favorable Appearance of Lighted Room refers only to the general or casual effect produced by the complete system, and is not intended to rate the unit as to satisfaction from the standpoint of good vision or freedom from fatigue.

Direct Glare is the most frequent and serious cause of bad lighting. It results among other things from unshaded or inadequately shaded light sources located within the field of vision, or from too great a contrast between the bright light source and a dark background or adjacent surfaces. Glare should be avoided by the use of proper reflecting and diffusing equipment.

Reflected Glare from polished working surfaces is particularly annoying because of the necessity of directing the eyes toward those surfaces, and further, because the eyes are by nature especially sensitive to light rays from below. The harmful effects of this specular reflection can be minimized by properly shielding from below or diffusing the source.

Shadows, that is, difference in brightness of surfaces, are essential in observing objects in their three dimensions, but are of little or no value in the observation of flat surfaces. Where shadows are desirable, they should be soft and luminous, not so sharp and dense as to confuse the object with its shadow.

Maintenance depends upon the contour of the reflector, construction of fixture, and condition of ceiling. The rating is based upon the likelihood of breakage, the labor involved in maintaining the units at comparable degrees of efficiency, and indication given of need of cleaning.

Industrial Lighting (Cont.)

Utilization Constant

The Utilization Constant for a certain reflector is dependent upon the color of walls and ceilings and upon the proportions of the room, or room index.

The Room Index of a square room is equal to the width of the room divided by 2 times the mounting height above the working plane, i.e.:

$$\text{Room Index} = \frac{\text{width of room}}{2 \times \text{mounting height}}$$

For rooms of dimensions different from those in the table use the nearest available figure.

The utilization constant of rectangular rooms is equal to the constant for a square room of the narrow dimension plus one third of the difference between the constant for a square room of the long dimension and the constant for a square room of the narrow dimension.

For instance, to find the constant for an installation of R L M Dome Reflectors with Bowl Enameled lamps in a room 80 ft. x 160 ft., mounting height, 20 ft., light-colored ceiling, medium-light walls, follow the rule and you have:

For a room 80 ft. square. Room index = 2.0. From Table IV Utilization Constant = .50

For a room 160 ft. square. Room index = 4.0. From Table IV Utilization Constant = .58

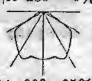
For a room 80 ft. x 60 ft. From above rule Utilization Constant = .50 + ⅓ (.58-.50) = .53

TABLE III
ROOM INDEX OF A SQUARE ROOM

Width of Room in Feet	Mounting Height Above Working Plane in Feet														
	4	5	6	7	8	9	10	12	14	16	18	20	24	30	40
8	1.0	.8	.6	.6	.6	.6									
10	1.25	1.0	.8	.8	.6	.6	.6								
12	1.5	1.25	1.0	.8	.8	.6	.6								
14	1.5	1.5	1.25	1.0	.8	.8	.6	.6							
16	2.0	1.5	1.25	1.25	1.0	.8	.8	.6	.6	.6	.6				
18	2.0	2.0	1.5	1.25	1.0	1.0	.8	.8	.6	.6	.6				
20	2.5	2.0	1.5	1.5	1.25	1.0	1.0	.8	.8	.6	.8	.6			
22	2.5	2.0	2.0	1.5	1.25	1.25	1.0	1.0	.8	.6	.8	.6			
24	3.0	2.5	2.0	1.5	1.5	1.25	1.25	1.0	.8	.8	.8	.6	.6		
26	3.0	3.0	2.0	2.0	1.5	1.5	1.25	1.0	.8	.8	1.0	.6	.6		
28	3.0	3.0	2.5	2.0	1.5	1.5	1.5	1.25	1.0	.8	1.0	.6	.6		
30	4.0	3.0	2.5	2.0	2.0	1.5	1.5	1.25	1.0	1.0	1.0	.8	.6	.6	
35	4.0	3.0	3.0	2.5	2.0	2.0	1.5	1.25	1.25	1.0	1.25	.8	.8	.6	
40	5.0	4.0	3.0	3.0	2.5	2.0	2.0	1.5	1.5	1.25	1.5	1.0	.8	.8	.6
45	5.0	4.0	4.0	3.0	3.0	2.5	2.0	2.0	1.5	1.5	1.5	1.0	1.0	.8	.6
50	5.0	5.0	4.0	4.0	3.0	3.0	2.5	2.0	2.0	2.5	2.0	1.25	1.0	.8	.6
60	5.0	5.0	5.0	4.0	4.0	3.0	3.0	2.5	2.0	2.0	2.0	1.5	1.25	1.0	.8
70	5.0	5.0	5.0	5.0	4.0	4.0	3.0	3.0	2.5	2.0	2.0	1.5	1.5	1.25	.8
80	5.0	5.0	5.0	5.0	5.0	4.0	4.0	3.0	3.0	2.5	3.0	2.0	1.5	1.25	1.0
100	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	3.0	4.0	2.5	2.0	1.5	1.25
120	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0	4.0	3.0	2.5	2.0	1.5

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

TABLE IV
Utilization Constants

Color Reflection Factor	Ceiling	Very Light (70%)			Medium (50%)			Fairly Dark (30%)	
	Walls	Fairly Light 50%	Fairly Dark 30%	Very Dark 10%	Fairly Light 50%	Fairly Dark 30%	Very Dark 10%	Fairly Dark 30%	Very Dark 10%
	Room Index	Utilization Constants							
R L M DOME  Clear Lamp 90 to 180°—0%	.6	.34	.29	.24	.34	.29	.24	.28	.24
	.8	.42	.38	.34	.42	.37	.33	.37	.33
	1.0	.46	.43	.39	.45	.42	.39	.42	.39
	1.25	.50	.47	.43	.49	.46	.43	.45	.42
	1.5	.53	.50	.46	.52	.49	.46	.48	.45
 0 to 90°—76%	2.	.58	.55	.51	.57	.54	.51	.53	.51
	2.5	.62	.59	.56	.61	.58	.56	.58	.56
	3.	.64	.61	.58	.63	.60	.58	.60	.58
	4.	.67	.65	.63	.66	.64	.62	.63	.61
	5.	.69	.67	.65	.67	.66	.64	.65	.63
R L M DOME  Bowl Enameled Lamp 90 to 180°—0%	.6	.32	.28	.23	.32	.28	.23	.27	.23
	.8	.40	.36	.34	.39	.35	.33	.35	.33
	1.0	.43	.39	.37	.42	.39	.37	.39	.37
	1.25	.46	.43	.41	.45	.43	.41	.43	.41
	1.5	.48	.45	.43	.47	.45	.43	.45	.43
 0 to 90°—66%	2.0	.52	.50	.48	.51	.49	.47	.49	.47
	2.5	.56	.54	.52	.55	.53	.51	.53	.51
	3.	.57	.55	.53	.56	.54	.52	.54	.52
	4.	.60	.58	.56	.59	.57	.55	.57	.55
	5.	.61	.59	.57	.60	.58	.57	.58	.56
Luminous Top R L M Dome  Bowl Enameled Lamp 90 to 180°—8%	.6	.28	.25	.22	.27	.24	.22	.23	.21
	.8	.34	.31	.29	.33	.30	.28	.30	.28
	1.0	.38	.35	.33	.36	.34	.32	.33	.32
	1.25	.41	.38	.36	.39	.37	.35	.36	.35
	1.5	.43	.40	.38	.41	.39	.37	.38	.37
 0 to 90°—55%	2.	.47	.44	.42	.45	.43	.41	.41	.40
	2.5	.50	.47	.45	.48	.46	.44	.44	.43
	3.	.51	.49	.47	.49	.47	.46	.46	.45
	4.	.53	.51	.50	.51	.49	.48	.48	.47
	5.	.55	.53	.51	.52	.50	.49	.49	.48
STD. BOWL  Clear Lamp 90 to 180°—0%	.6	.31	.26	.23	.30	.26	.23	.25	.23
	.8	.38	.34	.31	.37	.34	.31	.33	.31
	1.0	.41	.38	.35	.41	.38	.35	.37	.35
	1.25	.44	.41	.38	.44	.41	.38	.40	.38
	1.5	.47	.44	.41	.46	.43	.41	.43	.41
 0° to 90°—65%	2.	.51	.48	.45	.50	.47	.45	.47	.45
	2.5	.54	.51	.49	.53	.51	.49	.51	.49
	3.	.56	.54	.51	.55	.53	.51	.53	.51
	4.	.58	.56	.54	.57	.55	.54	.55	.53
	5.	.60	.58	.56	.58	.57	.55	.56	.55

Industrial Lighting (Cont.)
TABLE V
Total Lumens of Mazda Lamps for General Lighting Service

SIZE IN WATTS	110-120 Volts		Mazda C (Daylight)	220-250 Volts	
	Mazda B	Mazda C		Mazda B	Mazda C
10	82	....	....	...	....
15	131	....	....	...	....
25	238	....	....	195	....
40	404	....	....	...	....
50	510	500	....	455	....
60	612	....	....	...	....
75	...	885	602	...	....
100	...	1290	877	...	980
150	...	2145	1459	...	....
200	...	3060	2081	...	2460
300	...	4950	3366	...	4260
500	...	9050	6154	...	7850
750	...	14325	....	...	12525
1000	...	20000	....	...	17800

Diagram of Mounting Heights

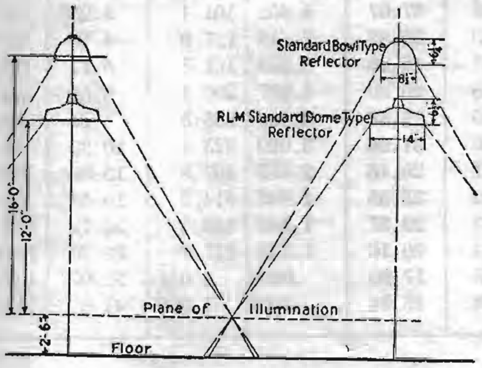


Diagram showing the proper mounting heights of different types of reflectors when the spacing between lamps is 20 feet. For other spacings the mounting heights will be different because it is necessary to maintain the proper ratio between mounting heights and spacings.

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

GENERAL DATA

Copper Wire Table

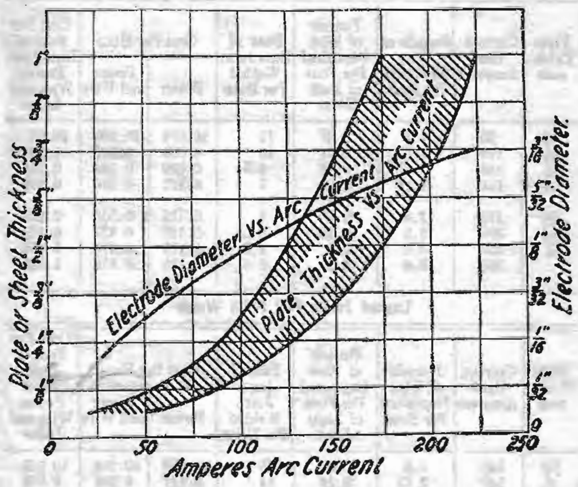
Size B & S Gauge	Diam. in Mils.	Lb. Per 1000 Ft.	Feet Per Lb.	Ohms Per 1000 Ft. 25° C	Ohms Per Mile 25° C
00	364.8	402.8	2.482	.0794	.419
0	324.9	319.5	3.130	.100	.528
1	289.3	253.3	3.947	.126	.665
2	257.6	200.9	4.977	.160	.845
3	229.4	159.3	6.276	.201	1.06
4	204.3	126.4	7.914	.254	1.34
5	181.9	100.2	9.980	.319	1.69
6	162.0	79.46	12.58	.403	2.13
7	144.3	63.02	15.87	.508	2.68
8	128.5	49.98	20.01	.640	3.38
9	114.4	39.63	25.23	.808	4.26
10	101.9	31.43	31.82	1.019	5.38
11	90.74	24.92	40.12	1.285	6.79
12	80.81	19.77	50.59	1.619	8.55
13	71.96	15.68	63.80	2.048	10.81
14	64.08	12.43	80.44	2.580	13.61
15	57.07	9.858	101.4	3.253	17.18
16	50.82	7.818	127.9	4.10	21.63
17	45.26	6.200	161.3	5.17	27.38
18	40.30	4.917	203.4	6.51	34.4
19	35.89	3.899	256.5	8.21	43.4
20	31.96	3.092	323.4	10.36	54.7
21	28.46	2.452	407.8	13.06	68.9
22	25.35	1.945	514.2	16.48	86.9
23	22.57	1.542	648.4	20.72	109.3
24	20.10	1.223	817.7	26.20	138.2
25	17.90	.9699	1.031	32.97	173.9
26	15.94	.7692	1.300	41.6	219.8

ARC WELDING AND CUTTING

For metallic electrode welding especially when portable equipment is desired the 200-ampere, single operator type is usually used.

When the welding work is brought to a central point multiple operator equipments may be used on account of the lesser cost of the equipment per welding circuit.

Multiple operator stationary or portable metallic or graphite electrode welding or graphite electrode cutting generators are available in capacities of 300, 500, 750 and 1000 amperes. One generator will serve power to a number of operators through suitable control panels depending upon the size of the generator and the amount of current to be used by each operator.



Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

COST AND APPLICATION DATA

Approximate Cost of Cutting Steel or Cast Iron

Material Thickness	Current in Amperes	Time		Kw. Hours Per Foot	Power Cost Per Foot	Power and Labor Cost Per Foot
		Minutes Per Foot	Feet Per Hour			
¼	400	.80	75	0.421	$0.0084	$0.0164
⅜	400	1.00	60	0.526	0.0105	0.0205
½	400	1.20	50	0.632	0.0126	0.0246
⅝	400	1.7	35	0.903	0.018	0.0351
¾	400	3.0	20	1.58	0.0316	0.0616
1	600	3.75	16	2.92	0.0584	0.0959
1⅜	600	4.3	14	3.34	0.0668	0.1096
2	600	6.7	9	5.2	0.1040	0.1706
4	600	17.0	3½	13.35	0.2670	0.4385
6	800	30.0	2	31.0	0.620	0.920
8	800	40.0	1½	41.3	0.827	1.227
10	800	60.0	1	62.0	1.240	1.840
12	800	80.0	¾	82.7	1.653	2.453

Power at 2 cents per Kw.-hr. Labor at 60 cents per hour.
Cost of cutting ¾ in. rivets approximately $1.10 per hundred.

Approximate Cost of Welding Steel Plate

Butt Joint Beveled 45°

Plate Thickness	Current Used Amperes	Pounds of Wire Deposited Per Hour	Pounds of Wire Deposited Per Foot of Butt Joint	Feet of Butt Joint Welded Per Hour	Cost Per Hour		Cost Per Foot of Butt Joint Power, Wire and Labor
					Power	Power and Wire	
⅛	90	1.3	0.07	19	$0.079	$0.199	$0.05
3/16	110	1.6	0.16	10	0.089	0.237	0.099
¼	125	1.8	0.28	6.5	0.098	0.264	0.156
5/16	150	2.15	0.44	5	0.117	0.315	0.213
⅜	175	2.5	0.63	4	0.138	0.368	0.279
½	200	2.8	1.10	2.5	0.163	0.421	0.468
¾	225	3.2	2.5	1.3	0.175	.0.470	0.938
1	250	3.6	4.5	0.8	0.186	0.518	1.580

Lapped Joints Full Fillet Welds

Plate Thickness	Current Used Amperes	Pounds of Wire Deposited Per Hour	Pounds of Wire Deposited Per Foot of Lapp Joint	Feet of Lapp Joint Welded Per Hour	Cost Per Hour		Cost Per Foot of Lapp Joint Power, Wire and Labor
					Power	Power and Wire	
⅛	125	1.8	0.07	25	$0.098	$0.264	$0.041
3/16	150	2.15	0.16	14	0.117	0.315	0.076
¼	175	2.5	0.28	9	0.138	0.368	0.124
5/16	200	2.8	0.44	6.5	0.163	0.421	0.180
⅜	225	3.2	0.63	5	0.175	0.469	0.244
½	250	3.6	1.1	3.25	0.186	0.517	0.389
¾	300	4.3	2.5	1.75	0.202	0.598	0.770
1	400	6.0	4.5	1.33	0.266	0.818	1.180

Power at 2 cents per Kw.-hr. Wire at 8 cents per pound. Labor at 75 cents per hour.

WHEEL LATHE EQUIPMENT

Direct current motors are as a rule, most satisfactory for wheel lathes because of their superior characteristics for speed adjustment, dynamic braking and rapid deceleration so desirable when hard spots are encountered. When direct current service is not available, alternating current motors equipped with wound rotors will give very satisfactory performance.

The modern control equipment for such service is a full magnetic type equipped with push buttons for starting, stopping and slowing down and a double throw knife switch for reversing the drive. When a D-C. motor is used a field rheostat is supplied for speed adjustment of the motor.

RECOMMENDED MOTOR RATINGS

Driving Wheel Lathes

SIZE OF MACHINE	HP. OF MOTORS	
	MAIN	TAIL STOCKS
51″ x 108″	15	5
69″ x 108″	20	8½
84″ x 108″	25	8½
90″ x 108″	35	8½
100″ x 108″	50	8½

Car Wheel Lathes, Open Centre

SWING IN INCHES	HP. OF MOTORS	
	MAIN	TAIL STOCK
47½	25	None
49½	35	5
55	50	8½

Car Wheel Lathe, Centre Drive

SWING IN INCHES	HP. OF MOTORS	
	MAIN	TAIL STOCK
42	50	5

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

DIRECT CURRENT REVERSING MOTOR PLANER EQUIPMENT

Constant Voltage

This equipment employs the use of an adjustable speed motor with range of adjustment from 250 to 1000 r.p.m. and a control panel to provide reversing and dynamic braking at the end of each stroke. The lower half of the range (250 to 500 r.p.m.) is used for the cutting stroke and the upper half (500 to 1000 r.p.m.) for the return stroke. All speed adjustment is obtained by means of field weakening resistance. These equipments are built in the following horsepower sizes, 230 volts only, 5-10-15-20-25-35-50-75.

Variable Voltage

This equipment is particularly adaptable where direct current is not available or where a wider range of speed is desired than is possible with the constant voltage equipment. It consists of a variable voltage motor generator furnishing power to an adjustable speed direct current motor. The total speed range is 200 to 1200 r.p.m., part of which is obtained by means of varying the generator voltage and the remainder by field control of the motor. These two variables are combined in order to obtain a cutting speed range of 200 to 800 r.p.m. and a return speed range of 500 to 1200 r.p.m. These equipments are built in the following horsepower sizes; 15-25-35-50-75. The driving motor of the motor generator can be supplied for connection to any commercial power circuit.

RECOMMENDED MOTOR RATINGS

Width of Planer Housing in Inches	Length of Planer in Feet	Motor HP.
36	8 to 16	5
36	18 to 24	10
42	8 to 16	15 to 20
42	18 to 24	20 to 25
48	8 to 12	20 to 25
48	14 to 24	25 to 35
60	10 to 12	20 to 25
60	16 to 20	25 to 35
72	14 to 20	35 to 50
84	14 to 20	35 to 50
96	18 to 24	50 to 75
120	18 to 24	50 to 75
Frog & Switch old type	....	35
Frog & Switch later than 1922	....	50

TURNTABLES AND TRANSFER TABLES

Modern turntables are of the continuous girder type, the girder being approximately 110 feet long, supported equally at the center and the two ends. The motors for driving the table are usually mounted directly on the trucks at each end of the girder and are geared directly to the table wheel shafts. Two motors are used and are operated by one duplex controller. The control circuits are usually carried through suitable disconnecting switches so that in the event of trouble with one motor, the table may be operated by the second motor.

The motors used on these tables are usually rated at 20 hp. to 25 hp. for intermittent duty. When direct current service is available, series type motors are used, and when only alternating current service is available, wound rotor motors are used.

The method of braking tables varies with the turntable manufacturers and the various railroads. Many tables are equipped with only mechanical brakes which are operated either by a hand lever or a foot pedal. On the other hand there now seems to be a marked tendency toward the application of magnetic electric brakes for this service. The principal reason for this is that when mechanical brakes are provided the table operators quickly discover that they can stop the tables with much less physical exertion by "plugging" or reversing the motors. However, this practice imposes on the motors additional duty for which they were not intended and results in damage to the equipment. This is obviated by providing magnetic brakes.

Some large tables are operated by motor driven tractors located at each end of the table in which case the motor and control equipment is the same as that described above. However, smaller tables, 75 feet, 85 feet and 100 feet long are usually operated by a single tractor located at one end of the table.

Where only one motor is used on a table it is usually rated at 25 hp. to 30 hp., and is of the same type as for double motor equipment. The controller, however, is somewhat smaller.

The turntable controllers supplied by the Westinghouse Company are of the cam operated contactor type and can be used with either A-C. or D-C. motors by making a few simple changes in the internal wiring. The contacts of the contactors are also interchangeable with those of the same capacity on other starters and controllers designed for general purpose motors. Both of these features greatly reduce the parts stock to be carried for replacement.

Transfer tables are usually equipped with but one motor which is used for propelling the table and also for pulling the rolling stock on and off the table. This is accomplished by suitable clutches to engage either the driving wheel gears or the drum gears.

The motor and control equipment used is of the same type as used for single motor equipped turn tables.

GENERAL MOTOR DATA (Cont.)

If true power is expressed in kilowatts (kw.) and apparent power as the product of kilovolts (1000 volts) and amperes or kv-a.

$$\text{Power factor (P.F.)} = \frac{\text{Kw.}}{\text{Kv-a.}}$$

Three-Phase Connections. Three-phase circuits may be connected in delta (△) or in star (Y) as illustrated. If three transformers are connected in delta, the voltage across each transformer is the same as the line voltage ($E_t = E$): the current in each line wire is the instantaneous sum of the currents through two transformers ($I = 1.7321\ I_t$). If three transformers are connected in star, $E = 1.732 \cdot E_t$ and $I = I_t$.

Measurement of A-C. Power. If W = watts, E = average volts between line terminals, I = average line current, and P.F. = power factor expressed as a decimal fraction, the following formula represent their relations:

Single-phase $W = EI \times P.F.$
Two-phase $W = 2EI \times P.F.$
Three-phase $W = 1.732\ EI \times P.F.$

From the above formula the current can be found as follows:

Single-phase $I = \frac{W}{E \times P.F.}$

Two-phase $I = \frac{W}{2\ E \times P.F.} = \frac{.5\ W}{E \times P.F.}$

Three-phase $I = \frac{W}{1.732\ E \times P.F.} = \frac{.578\ W}{E \times P.F.}$

Effect of Changes of Voltage and Frequency

The starting torque of an induction motor will vary as the square of the voltage applied to the primary: hence, the primary voltage required to produce a given starting torque can be determined by means of the formula:

$$V_1 = V \sqrt{\frac{T_1}{T}}$$

Where V_1 and T_1 signify required voltage and torque respectively, V, the full rated voltage, and T, the starting torque at full voltage. For example: if a squirrel cage induction motor is required to start with full load torque only, and if the starting torque at full voltage is 2.5 times full load torque (2.5 F.L.T.) the starting voltage should be:

$V_1 = V \sqrt{\frac{1}{2.5}} = .63\ V$; that is, the starting voltage should be 63% of full voltage.

The starting current of squirrel cage induction motors depends on the starting voltage applied and is independent of the torque required to start the load; the current falls almost immediately, however, to the value corresponding to the required torque and then decreases more gradually as the motor speed accelerates. From this, it follows that the starting voltage should not be greatly in excess of that required for the torque.

Wound rotor motors when started by means of resistance in the secondary circuits can usually be accelerated to full speed with full load torque with current very little in excess of full load current.

A variation in either voltage or frequency not exceeding 10% is generally permissible with any induction motor. Such variations are always accompanied by changes from normal performance with either the voltage or the frequency differing from normal; the following performance change will be obtained:

CHARACTER OF CHANGE	EFFECT ON			
	POWER FACTOR	TORQUE	SLIP	EFFICIENCY
Voltage higher	Decreased	Increased	Decreased	Decreased
Voltage lower	Increased	Decreased	Increased	Increased
Frequency higher	Increased	Decreased	% Slip unchanged	Increased
Frequency lower	Decreased	Increased	% Slip unchanged	Decreased

The voltage and frequency should not be varied simultaneously in opposite directions, that is, one increased and the other decreased. If an induction motor must operate on frequency other than standard, the performance will be better if the voltage is changed in proportion to the square root of the frequency. For example: a 220-volt, 60-cycle motor, operating on 50 cycles, will have very nearly its normal performance if the voltage is decreased to $220 \times \sqrt{\frac{50}{60}} = 200$.

GENERAL MOTOR DATA

Approximate Amperes per Terminal for Alternating-Current Induction Motors For Determining Size of Wire, Capacity of Fuse and Setting of Circuit-Breaker

Hp. of Motor	110 Volts		220 Volts		440 Volts		550 V.	1100 V.	2200 V.
	2-Ph.	3-Ph.	2-Ph.	3-Ph.	2-Ph.	3-Ph.	3-Ph.	3-Ph.	3-Ph.
½	3.3	3.7	1.7	1.8	.9	1	—	—	—
1	6	6.5	3	3.2	1.5	1.6	—	—	—
2	10.5	12	5	6	2.9	3	2.5	—	—
3	15	17	7.5	9	3.8	4.5	3.5	—	—
5	27	30	13	15	6.5	7.5	6	—	—
7½	—	—	20	22	10	11	9	—	—
10	—	—	25	29	12.5	14	11	—	—
15	—	—	35	41	18	20	16	—	—
20	—	—	48	55	24	27	22	—	—
25	—	—	54	62	27	31	25	—	—
30	—	—	70	81	35	40	32	16	8
40	—	—	95	109	47	54	44	22	11
50	—	—	110	127	55	64	52	27	13
75	—	—	165	192	83	96	77	39	20
100	—	—	215	248	108	124	100	50	25
150	—	—	320	366	160	183	147	80	40
200	—	—	410	475	205	237	192	98	49
250	—	—	510	590	250	290	237	125	62
300	—	—	600	700	300	350	287	150	74

For single-phase motors multiply the current per terminal for a two-phase motor by two.

Horsepower is a measure of the time rate of doing work and is defined as the equivalent of raising 33,000 pounds one foot in one minute. 1 hp. is equivalent to 746 watts.

Torque is the pull or turning moment required in applying power by rotation and varies inversely as the radius at which the power is applied. The torque T is expressed in pounds at one foot radius, sometimes called pound-feet.

Full Load Torque is the turning moment required to develop full rated output of a motor of given horsepower at a given speed.

The torque T of any motor at any output expressed in pounds at one foot radius can be found by means of the following formula:

$$T = \frac{5250 \times \text{Hp.}}{\text{R.p.m.}}$$

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 24 6-24 Printed in U. S. A.

Conversely if the torque in pounds at one foot radius is known, the horsepower at any given speed can be determined from the formula:

$$\text{Hp.} = \frac{T \times \text{R.p.m.}}{5250}$$

Starting Torque is the turning moment a motor will develop in starting with a given starting voltage impressed. Starting torque is expressed in terms of full load torque, as 1.5 times full load torque, and generally on the basis of full voltage regardless of whether this is actually used in starting or not.

Pull Out Torque, or maximum running torque is the maximum turning moment a motor will develop under running conditions with rated voltage applied.

Amperes for Direct Current Motors. The relation of the horsepower (Hp.), the volts (E), the amperes (I) and the efficiency in percent (e) of the electric motor is expressed by the formula:

$$\text{Hp.} = \frac{EIe}{746}$$

This formula contains four quantities indicated by letters; if any three are known or can be assumed, the other one can be found. Efficiencies of industrial motors can be assumed at from 80% to 90%, depending upon the size.

For example, to determine the current required by a 10 hp., 220-volt motor of which the efficiency is unknown, assume 85% as an approximate value and apply the formula:

$$10 = \frac{220 \times I \times .85}{746}$$

$$\text{Therefore } I = \frac{10 \times 746}{220 \times .8} = 40 \text{ Approx.}$$

A rough approximation in determining the current required by direct-current motors is as follows:

8 amperes per hp. for 110-115-volt motors.
4 amperes per hp. for 220-230-volt motors.
1¾ amperes per hp. for 500-volt motors.

Power Factor is the ratio of the true power (kw. or wattmeter reading) to the apparent power (kv-a. or product of voltmeter and ammeter readings). The ratio is usually expressed in percent and cannot be greater than 100%.

GENERAL MOTOR DATA (Cont.)

If true power is expressed in kilowatts (kw.) and apparent power as the product of kilovolts (1000 volts) and amperes or kv-a.

$$\text{Power factor (P.F.)} = \frac{\text{Kw.}}{\text{Kv-a.}}$$

Three-Phase Connections. Three-phase circuits may be connected in delta (△) or in star (Y) as illustrated. If three transformers are connected in delta, the voltage across each transformer is the same as the line voltage ($Et = E$): the current in each line wire is the instantaneous sum of the currents through two transformers ($I = 1.7321\ It$). If three transformers are connected in star, $E = 1.732\ Et$ and $I = It$.

Measurement of A-C. Power. If W = watts, E = average volts between line terminals, I = average line current, and P.F. = power factor expressed as a decimal fraction, the following formula represent their relations:

Single-phase $W = EI \times P.F.$
Two-phase $W = 2EI \times P.F.$
Three-phase $W = 1.732\ EI \times P.F.$

From the above formula the current can be found as follows:

Single-phase $I = \frac{W}{E \times P.F.}$

Two-phase $I = \frac{W}{2\ E \times P.F.} = \frac{.5\ W}{E \times P.F.}$

Three-phase $I = \frac{W}{1.732\ E \times P.F.} = \frac{.578\ W}{E \times P.F.}$

Effect of Changes of Voltage and Frequency

The starting torque of an induction motor will vary as the square of the voltage applied to the primary: hence, the primary voltage required to produce a given starting torque can be determined by means of the formula:

$$V^1 = V \sqrt{\frac{T^1}{T}}$$

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 24 6-24 Printed in U. S. A.

Where V^1 and T^1 signify required voltage and torque respectively, V, the full rated voltage, and T, the starting torque at full voltage. For example: if a squirrel cage induction motor is required to start with full load torque only, and if the starting torque at full voltage is 2.5 times full load torque (2.5 F.L.T.) the starting voltage should be:

$V^1 = V \sqrt{\frac{1}{2.5}} = .63\ V$; that is, the starting voltage should be 63% of full voltage.

The starting current of squirrel cage induction motors depends on the starting voltage applied and is independent of the torque required to start the load; the current falls almost immediately, however, to the value corresponding to the required torque and then decreases more gradually as the motor speed accelerates. From this, it follows that the starting voltage should not be greatly in excess of that required for the torque.

Wound rotor motors when started by means of resistance in the secondary circuits can usually be accelerated to full speed with full load torque with current very little in excess of full load current.

A variation in either voltage or frequency not exceeding 10% is generally permissible with any induction motor. Such variations are always accompanied by changes from normal performance with either the voltage or the frequency differing from normal; the following performance change will be obtained:

CHARACTER OF CHANGE	EFFECT ON			
	POWER FACTOR	TORQUE	SLIP	EFFICIENCY
Voltage higher	Decreased	Increased	Decreased	Decreased
Voltage lower	Increased	Decreased	Increased	Increased
Frequency higher	Increased	Decreased	% Slip unchanged	Increased
Frequency lower	Decreased	Increased	% Slip unchanged	Decreased

The voltage and frequency should not be varied simultaneously in opposite directions, that is, one increased and the other decreased. If an induction motor must operate on frequency other than standard, the performance will be better if the voltage is changed in proportion to the square root of the frequency. For example: a 220-volt, 60-cycle motor, operating on 50 cycles, will have very nearly its normal performance if the voltage is decreased to $220 \times \sqrt{\frac{50}{60}} = 200$.

POWER FACTOR CORRECTION

The question of power factor correction is obviously an economic one, the total of the monetary and capitalized advantages through correction being balanced against the total operating cost (not first cost alone) of the corrective equipment applied.

The synchronous motor furnishes a method of correction which should always be given consideration. In railway shops these motors may be advantageously applied to compressors, fans, blowers, centrifugal pumps and other constant speed loads. The service must be one in which the motor can be in operation continuously, as is particularly evident in connection with the large number of power factor penalty clauses which operate upon the maximum kv-a. plant demand over an interval of stated duration.

The synchronous condenser furnishes the most economical corrective method in many cases, although the entire operating cost of the equipment must be charged to power factor correction. It seldom proves economically preferable for ratings below 150 kv-a.

The static condenser often shows economies better than those of any of the other types, chiefly because of the low energy cost involved in operating this type of equipment.

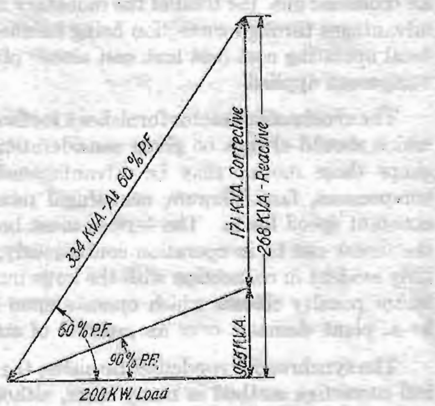
The following example shows the method of calculating the kv-a. capacity of a condenser needed to correct the power factor a definite amount for any given load. The kv-a. required to correct from a given initial to a given final power factor is entirely dependent on the load on the plant, as a condenser which would correct a 100 kw. load from 50 percent power factor to unity would increase the power factor to 76 percent if the load became 200 kw. at the same initial power factor.

(See over for example)

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 25 6-24 Printed in U. S. A.

Example—Plant whose average load is 200 kw. and average power factor 60. It is desired to correct the power factor to 90.



Present load = 200 kw. at 60 percent power factor.

Desired power factor = 90

Present kv-a. $= \frac{200}{.60} = 334$

Present reactive kv-a. $= \sqrt{334^2 - 200^2} = 268$

Kv-a. at desired power factor $= \frac{200}{.90} = 222$

Reactive kv-a. at desired power factor $= \sqrt{222^2 - 200^2} = 96.5$

Corrective effect needed = 268 − 96.5 = 171.5 kv-a.

Size of standard condenser: Static, 180 kv-a; Synchronous 200 kv-a.

GENERAL DATA

Weight and Specific Gravity of Various Materials

Material	Specific Gravity	Pounds Per Cubic Foot
Brick, fire	2.24–2.4	140–150
Brick, hard	2.0	125
Brick, soft	1.6	100
Brickwork in mortar	1.6	100
Brickwork in cement	1.79	112
Cement loose, Portland	1.25	78
Concrete	1.92–2.24	120–140
Earth, loose	1.15–1.28	72– 80
Earth, rammed	1.44–1.76	90–110
Gravel	1.6 –1.92	100–120
Lime, quick in bulk	.8 – .88	50– 55
Masonry	2.24–2.88	140–180
Mortar	1.44–1.6	90–100
Sand	1.44–1.76	90–110
Slate	2.72–2.88	170–180
Soapstone	2.65–2.8	166–175
Stone, various	2.16–3.4	135–200
Trap	2.72–3.4	170–200
Tile	1.76–1.92	110–120

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 26

6-24

Printed in U. S. A.

Resistances and Weights of Trolley, Feeder and Rail — Single Track, Single Trolley

Size of Trolley B & S	Size of Feeder B & S	Pounds Per Mile		Rail Lb. Per Yard	Size of Bonds		Ohms Per Mile			
		Trolley	Feeder		Length In.	B & S	Trolley	Feeder	Track	Total
000	......	2740	....	50	28	000	0.339	.....	0.066	0.405
000	0000	2740	3450	60	10	000	0.339	0.269	0.049	0.199
000	0000	2740	3450	70	10	0000	0.339	0.269	0.042	0.192
0000	0000	3450	3450	80	10	000	0.269	0.269	0.037	0.171
0000	0000	3450	3450	60	28	000	0.269	0.269	0.055	0.189
0000	300000	3450	4900	70	10	000	0.269	0.190	0.042	0.153
0000	500000	3450	8125	80	10	000	0.269	0.114	0.037	0.117
0000	750000	3450	12240	90	12	350m	0.269	0.076	0.032	0.091
0000	300000	3450	4900	70	28	0000	0.269	0.190	0.048	0.159
0000	400000	3450	6550	70	10	0000	0.269	0.142	0.042	0.135
0000	500000	3450	8125	70	10	0000	0.269	0.114	0.042	0.122
0000	600000	3450	9760	70	10	0000	0.269	0.0950	0.042	0.112
0000	790000	3450	11400	70	10	0000	0.269	0.0812	0.042	0.1044
0000	800000	3450	13040	70	10	0000	0.269	0.0712	0.042	0.0983
0000	900000	3450	15200	70	10	0000	0.269	0.0634	0.042	0.0933
000	1000000	3450	16320	70	10	0000	0.269	0.0570	0.042	0.0890
000	1250000	3450	20410	90	12	350m	0.269	0.0455	0.032	0.0709
000	1500000	3450	24430	90	12	350m	0.269	0.0379	0.032	0.0652
0000	1750000	3450	28550	90	12	350m	0.269	0.0325	0.032	0.0610
0000	2000000	3450	32610	90	12	350m	0.269	0.0279	0.032	0.0573

GENERAL DATA

Conversion Factors

MULTIPLY	BY	TO OBTAIN
Acres	43560	Square Feet
Acres	4047	Square Meters
Acres	1.562×10^{-3}	Square Miles
Acres	4840	Square Yards
Acre-Feet	43560	Cubic Feet
Acre-Feet	3.259×10^{-5}	Gallons
Atmospheres	76.0	Cms. of Mercury
Atmospheres	29.92	Inches of Mercury
Atmospheres	33.90	Feet of Water
Atmospheres	14.70	Pounds per Sq. In.
Board-Feet	144 Sq. In. x 1 In.	Cubic Inches
British Thermal Units	777.5	Foot-Pounds
British Thermal Units	2.928×10^{-4}	Kilowatt-Hours
Bushels	1.244	Cubic Feet
Bushels	2150	Cubic Inches
Centimeters	0.3937	Inches
Circular Mils	5.067×10^{-6}	Square Centimeters
Circular Mils	7.854×10^{-7}	Square Inches
Circular Mils	0.7854	Square Mils
Cubic Feet	2.832×10^{-4}	Cubic Cms.
Cubic Feet	1728	Cubic Inches
Cubic Feet	0.03704	Cubic Yards
Cubic Feet	7.481	Gallons
Cubic Feet Per Minute	0.1247	Gallons Per Sec.
Cubic Yards	27	Cubic Feet
Cubic Yards	46656	Cubic Inches
Cubic Yards	202.0	Gallons
Days	1440	Minutes
Days	86400	Seconds
Degrees (angle)	60	Minutes
Degrees (angle)	0.01745	Radians
Degrees Per Second	0.1667	Revolutions per Min.
Feet	0.3048	Meters
Feet Per Minute	0.01136	Miles Per Hour
Feet Per Second	0.6818	Miles Per Hour
Feet Per Sec. Per Sec.	0.6818	Miles per Hr. Per Sec.
Foot-Pounds	1.286×10^{-3}	British Thermal Units
Foot-Pounds	3.766×10^{-7}	Kilowatt-Hours
Foot-Pounds Per Min.	3.030×10^{-5}	Horsepower
Foot-Pounds Per Min.	2.260×10^{-5}	Kilowatts
Foot-Pounds Per Sec.	1.818×10^{-3}	Horsepower
Foot-Pounds Per Sec.	1.356×10^{-3}	Kilowatts

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Penna.

S. P. 1707
Sheet 27 6-24 Printed in U. S. A.

MULTIPLY	BY	TO OBTAIN
Furlongs	40	Rods
Gallons	0.1337	Cubic Feet
Gallons	231	Cubic Inches
Grams	980.7	Dynes
Grams	0.03527	Ounces
Gram Calories	3.968×10^{-3}	British Thermal Units
Horsepower	42.44	B. T. U. Per Min.
Horsepower	33000	Ft.-Lb. Per Min.
Horsepower	1.014	Metric Horsepower
Horsepower	0.7457	Kilowatts
Horsepower (boiler)	33520	B. T. U. Per Hour
Inches	2.540	Centimeters
Inches	10^{-3}	Mils
Kilograms	2.205	Pounds
Kilometers	0.6214	Miles
Kilometers Per Hour	0.6214	Miles Per Hour
Kilometers Per Hour	54.68	Feet Per Minute
Kilometers Per Hr. Per Sec.	0.6214	Miles Per Hr. Per Sec.
Knots	6080	Feet
Knots	1.152	Miles
Links (Surveyors)	7.92	Inches
Log_{10} N	2.303	Ln N
Meters	3.281	Feet
Meters	39.37	Inches
Meters	1.094	Yards
Miles	1.609	Kilometers
Miles	1760	Yards
Miles Per Hour	88	Feet Per Minute
Miles Per Hour	1.467	Feet Per Second
Miles Per Hr. Per Sec.	1.467	Feet Per Sec. Per Sec.
Miles Per Hr. Per Sec.	0.4470	Meters per Sec. Per Sec.
Ohms Per Mil.-Ft.	0.1662	Microhms Per Cm. Cube
Perches (masonry)	24.75	Cubic Feet
Pounds Per Ton	0.5	Kilograms Per Metric Ton
Rods	16.5	Feet
Square Centimeters	1.973×10^{-5}	Circular Mils
Temp. (degs. Fahr)-32	5/9	Temp (deg. Cent.)
Tons (long)	1016	Kilograms
Tons (long)	2240	Pounds
Tons (metric)	2205	Pounds
Years	8760	Hours