POWER SERVICE EQUIPMENT AND CALCULATIONS
EQUIPMENT DESIGN REQUIREMENTS
POWER SYSTEMS

1. GENERAL

Scope

1.01 This specification, together with the supplementary information listed herein, covers the equipment design requirements for commercial power service equipment and circuits in telephone and telegraph power plants and of power factor correction units. In some of the smaller plants the equipment has been established as standard by the design requirements for the plant and calculations are unnecessary.

1.02 This specification is reissued to incorporate previous appendix changes.

1.03 This specification varies from the former specification J86712 chiefly in the adoption of bus duct over the charging machines and limitation of drop in the main feeder to about 5% for all voltages because of the increasing use of electronic devices.

Description

1.04 Requirements and typical calculations are given herein for determining the size of commercial power service and associated equipment. Power service fused at the house service board is carried in conduit to the bus duct distribution or in small jobs to a small power service distributing cabinet. The charging units are connected by leads to the bus duct if furnished or otherwise to the power service distributing cabinet. Miscellaneous loads are connected to a small power service distributing cabinet which is supplied from the bus duct or house service board. Reserve alternators when provided will normally be connected by transfer switches located at the house service board or at the alternators.

1.05 Figs. 1 and 2 show the two general lead arrangements which will be used and the minimum voltages at various points in the distributing system. Fig. 3 shows maximum lengths of run which can be used without calculation of the voltage drop. Figs. 4 and 5 are included for convenience in calculating the sizes of fuses, feeders, capacitor or capacitor-reactor equipment, and the voltage drops when required.

1.06 Three-phase power systems usually have nominal ratings of 208, 230, or 240 volts. They are assumed to have a maximum voltage variation of ±5% at the entrance to the building. The 208-volt system is usually a 3-phase, 4-wire arrangement with 120 volts for lights, etc, being available from the neutral to any of the phase wires. The 230- and 240-volt systems will usually be furnished on a 3-wire basis although they are used with transformers to obtain 115 or 120 volts from any of the phases.

1.07 Charging motor generator sets will operate on voltages from 190 to 253 volts. Motor starters will not be suitable over the entire range and must be specified for 200- or 230-volt operation, both ±10%. Electronic equipment using vacuum tubes requires fairly close voltage regulation and the calculations shown herein provide for holding the voltage at the equipment within ±7.5%.

2. SUPPLEMENTARY INFORMATION

802-000-000 — Power Systems Index

AA128.002 — List of Equipment Design Requirements Section

AA128.006 — List of General Equipment Requirements Section

Floor Plan Data Book

Power Data Book

3. DRAWINGS

SD-80700-01 — Power Keysheet
SD-81185-01 — Power Service Circuit

4. EQUIPMENT

4.01 The size of the a-c power service equipment, including the main fusing, power service distributing cabinet, a-c distribution, power factor correction equipment, etc, depends on the power required by the connected motors, rectifiers, etc.

4.02 Where required, the fuse size; a-c watts input; the power factor; kva, or kvar (reactive kilovolt amperes or kilovars); and the current to be used for calculation purposes, may be obtained from the power data sheets. The kva rating at unity power factor of transformers for busy signal and idle indicating lamps shall be used in the calculations. In general, charging equipments with 500 watts or less input having no appreciable effect on the plant total may be disregarded in calculating service equipments with more than 50 kw input, and in calculating alternators, and capacitor-reactor units. This would include the small dry-disc rectifiers, a number of the tube rectifiers, some of the small ringing machines, etc. The full-load input of ringing machines and small motors over 500 watts for which other data is not given in the power data sheets, should be used for all load periods from night to busy hour when calculating average power factor for determining the size of capacitor or capacitor-reactor units.

4.03 The values for the 33-, 65-, and 165-volt machines operated at full rated d-c ampere output at 27.5, 55, or 135 volts, respectively, may be used for their normal full-load power requirements.

Size of Service Entrance Fuses

4.04 Where a total load of 50 kw or less (746 watts = one horse power) is connected to the service entrance fuses, these fuses shall be 115 per cent of the fusing of the largest motor plus the full-load running current of all other motors and other loads. Current drawn by power factor correction equipment, if furnished in the plant, may be disregarded.

4.05 Where a total load of more than 50 kw is connected to the service entrance fuses, these fuses shall be large enough to carry the maximum current. (Based on the maximum normal load kva of all units except the one which has the largest starting load plus the starting kva of this unit.)

Size of Service Entrance Leads

4.06 The leads between the house service board and the bus duct or power service cabinet shall be protected by fuses on a circuit breaker. These leads shall also meet the voltage limits of Fig. 1; that is, if the length exceeds the value allowed by Fig. 3, the lead size shall be increased, if necessary to give the minimum voltage allowed by Fig. 1 or 2 at the bus duct or power service cabinet under all conditions of voltage variation. If the values of Fig. 1 are not exceeded, no voltage drop calculation is necessary. The current value used for the voltage drop calculation for plants with the 50 kw or less of connected load shall be the same as that used for determining the service fuse size. The current value used for plants with more than 50 kw of connected load shall be the normal current (based on the normal load kva of all units). The calculation of normal current should be made by the vectorial addition of loads. The method is illustrated in parts 6 and 7.

4.07 Each lead of a single or polyphase circuit even though composed of multiple conductors will be referred to as a phase lead. The leads shall not be divided more than necessary. When the phase leads are divided, each phase lead shall be divided into the same number and size of conductors. A conductor of each phase lead shall be placed in each conduit or flexible steel-covered cable.

4.08 The resistance and reactance of leads are given in the power data sheets. When more than one conductor is used per phase lead, the current, resistance, and reactance of one conductor may be used for calculating the voltage drop. For example, if in a 3-phase, 3-wire circuit 1000 amperes are carried on nine 500,000 CM cables, (or three 500,000 CM cables per phase lead) the voltage drop may be calculated by using 333.3 amperes and one 500,000 CM cable per phase lead.

TABLE A — Summary of Requirements

Fuses and Leads

SERVICE ENTRANCE FUSES AND LEADS		DISTRIBUTION FUSES AND LEADS	
FUSES	LEADS (SERV ENTRANCE TO POWER SERV CAB OR BUS DUCT)	FUSES	LEADS (POWER SERV CAB. TO MOTORS, RECTIFIERS ETC)
Plants with 50 kw or less of connected load 115% fusing of largest unit plus full load current of other loads (par 4.04) Plants with more than 50 kw of connected load Maximum current, vectorial addition of loads (par 4.05)	Protected by fuse; meet voltage limits Fig. 1* (par 4.06)	Meet requirements of power data sheets, circuits, etc.	Meet requirements of power data sheets; circuits; etc; meet voltage limits Fig. 1*

* Calculation need not be made of voltage drop if the length of the leads does not exceed values shown in Fig. 1.

Distribution Arrangements

4.09 If there are three or fewer charging units or floor-mounted charging units in the ultimate, (trickle charge and power board mounted charge units excluded) the leads from the house service board will terminate in a power service cabinet located in the vicinity of the charging machines and in sight of all equipment connected to it (maximum 50 feet).

4.10 If there are four or more main charging units, the leads from the house service board will terminate at bus ducts located over the charging units. A separate duct shall be provided for each row of charging units as required on the power service circuit. A small distributing fuse cabinet shall be used for fusing power factor correction equipment, small power units, trickle charge rectifiers, and miscellaneous loads. While this cabinet will usually be connected to the bus duct by a switch and fuse unit, it will under some conditions be connected by its own feeder direct to the house service board or equivalent.

4.11 The fuses in the fuse cabinet for distribution to rectifiers and other miscellaneous loads shall be of the size specified on the power data sheets.

4.12 Leads between the switch and fuse units on the bus duct or power service distributing cabinet to motors, rectifiers, etc, shall be of the size specified by the power data sheets or circuits. A circuit from the switchboard or fuse cabinet in the power room feeding small distributing fuse cabinets on the same or other floors on which all circuits are 110-, 115-, or 120-volt, single-phase with one lead grounded, shall have a ground lead the same size as the associated ungrounded leads. If a part of the load consists of single-phase ungrounded circuits, the ground lead shall be able to carry the maximum unbalance of load.

4.13 The power service distribution cabinet associated with the power plant is primarily intended to supply equipments requiring 200 to 230 volts a-c. In some cases, equipment arrangements are available for operating from either 115- or 230-volt supply. In such instances, preference should be given to the use of the circuit operating on 200 to 230 volts a-c. When it is essential that 115-volt single-phase grounded supply be terminated at the power service distributing cabinet on installations using bus duct for the main charging units, a separate feeder should be provided between this point and the house service board.

4.14 In offices in which a-c busy and idle indicating lamps are furnished, the fuses at the house service board or power distributing fuse cabinet shall have a current rating of 115 per cent of the line current calculated by using kw or volt ampere rating and a power factor of 1.0 at the minimum allowable transformer voltage. The leads shall be large enough to be protected by the fuses.

Power Factor Correction

4.15 In offices where the power factor is low, it may be advisable to raise the power factor by the use of capacitor or capacitor-reactor equipment covered by J86413. The telephone company will decide whether power factor correction equipment is required, whether capacitors only will be satisfactory, or whether capacitor-reactor equipment is required and will select the size of units. In general, capacitors will be used without reactors if the power service is all underground between the generating or substation and the telephone building. Typical calculations are given in paragraph 8.

Frame-mounted Equipment

4.16 The 115-volt ac supplies to frame-mounted equipments not located in the power room, shall not be taken from the building lighting service panels. Instead, they shall be taken from the power service circuit and, unless otherwise specified, arranged to include engine reserve. The preferred distribution arrangement is to provide a small power service cabinet on each equipment floor to handle the distribution for that floor. These cabinets could be supplied from the power room service cabinet or directly from the telephone power service on the house service switchboard.

5. TYPICAL CALCULATON (SMALL OFFICE)

5.01 The following is a typical calculation of service equipment for a plant which has a total connected load on the feeder of 50 kw or less. The power service is assumed to be 230-volt, 3-phase with a voltage variation of ±5%. It is about 150 feet from the service entrance switch to the charging machines.

TABLE B

LOAD	FULL LOAD AMPS	CAPACITY OF FUSE-AMPS
1 — 200A — 65V MG Set	50	80
1 — 200A — 65V MG Set	50	80
1 — 200A — 65V MG Set	50	80
All other (Estimated)	5	15

Lead Arrangement

5.02 Since this office has only three major charge units in the ultimate, the distribution arrangement will be as shown on Figure 1.

Service Entrance Fuse

5.03 From paragraph 4.04 and Table B the fuse at the service entrance would be 92(115% × 80) + 50 + 50 + 5 = 197 amperes. Use 200 amperes.

5.04 000 cable will carry 200 amperes and the allowable length per figure 1 is 350 feet. Since the length of this cable is 150 feet the 000 cable will be satisfactory. If voltage drop calculations are required see illustration of method in paragraph 9.

Distribution Fuses and Leads

5.05 Distribution fuses shall be of the size given by the power data sheets and circuits. As an example, the fusing for the 200-ampere, 65-volt set is 80 amperes.

5.06 Distribution leads shall be of the size given by the power data sheets and circuits, unless the lengths in accordance with Fig. 3 are exceeded. As an example, the lead for the 200-ampere, 65-volt set is No. 4 (lead "B", Fig. 1) if the lead length does not exceed 100 feet. If longer, the leads should be increased in size, if necessary, to meet the voltage drop. Drop calculations are illustrated in paragraph 9.

6. TYPICAL CALCULATION (MEDIUM OFFICE)

6.01 The typical calculation following is for an office which is assumed to have a 48-volt busy hour load of 1900 amperes and a 24-volt load of 400 amperes. The service is 208 volts, 3-phase 4-wire. The machines are in two lines and the calculation will be arranged so that the requirements of each row are determined separately. In this manner it will be easy to determine whether the two rows can be combined in one power service and if they cannot be combined, the individual feeder calculations may be made readily.

TABLE C

ULTIMATE EQUIPMENT	MAX. LOAD FOR CALCULATION OF SERVICE FUSE SIZE			NORMAL LOAD FOR CALCULATION OF SERVICE CONDUCTOR VOLTAGE DROP		
	POWER KW		KVAR	POWER KW		KVAR
Row 1						
400A 65V MG	27.0		−16.0	27.0		−16.0
750A 65V MG	47.2	(starting)	−93.8	49.0	(running)	−30.0
750A 65V MG	49.0		−30.0	49.0		−30.0
750A 65V MG	49.0		−30.0	49.0		−30.0
Misc	5.0		− 1.0	5.0		− 1.0
Total	177.2		−170.8	179.0 (2)		−107.0 (4)
Row 2						
200A 33V MG	34.0	(starting)	−67.4	8.0	(running)	−5.0
200A 33V MG	8.0		− 5.0	8.0		−5.0
200A 33V MG	8.0		− 5.0	8.0		−5.0
Total	50.0 (1)		−77.4 (3)	24.0 (5)		−15.0 (6)

Calculate Service Fuse

From inspection it is obvious that the calculation using the 200A, 33-volt, MG set in the starting condition will require the largest fuse size.

$$\text{Tan}\ \theta = \frac{\text{Kvar}}{\text{Kw}} = \frac{(3) + (4)}{(1) + (2)} \quad \frac{77.4 + 107.0}{50.0 + 179.0} = \frac{184.4}{229.0} = .805$$

Power Factor = Cosine of angle whose tangent is .805 = .778

Minimum Voltage at Motor Terminals = 190

$$I = \frac{P}{\sqrt{3}\ E\ \text{Cos}\ \theta} = \frac{229{,}000}{\sqrt{3} \times 190 \times .778} = 894 \text{ Amperes}$$

Calculate Normal Load for Voltage Drop Purposes

$$\text{Tan}\ \theta = \frac{\text{Kvar}}{\text{Kw}} = \frac{(4) + (6)}{(2) + (5)} = \frac{107.0 + 15.0}{179.0 + 24} = \frac{122.0}{203.0} = .60$$

Power Factor = Cosine of angle whose tangent is .60 = .858

Minimum Voltage at Motor Terminals = 190

$$I = \frac{P}{\sqrt{3}\ E\ \text{Cos}\ \theta} = \frac{203{,}000}{\sqrt{3} \times 190 \times .858} = 718 \text{ Amperes} \quad (7)$$

6.02 From Table A the fuses and leads must have a capacity of at least 894 amperes. The next higher available switch size and lead combination may be used. The switch will be of 1000 amperes capacity. The leads will be two 700,000 CM cables per phase lead unless the length of run exceeds the value shown on Fig. 3, (275 feet) in which case the voltage drop calculation shall be made as shown in paragraph 9 and the lead size increased if required.

7. TYPICAL CALCULATION (LARGE OFFICE)

7.01 The typical calculation following is for an office which is assumed to have a 48-volt busy hour load of 6000 amperes, a 24-volt busy hour load of 3200 amperes and a 130-volt busy hour load of 600 amperes during power failure, 180 amperes normal. The machines are in three lines and the power service voltage is 208 volts, 3-phase 4-wire. It is known that the average power factor should be held to .85 and that the service leads will be from an underground distribution system so that capacitors will be used without reactors.

7.02 The first calculation to be made will be to determine what power factor connection will be required if any. This is shown in Paragraph 8 and the result of the calculation will be used in the following table.

TABLE D

ULTIMATE EQUIPMENT	MAX. LOAD FOR CALCULATION OF SERVICE FUSE SIZE			NORMAL LOAD FOR CALCULATION OF SERVICE CONDUCTOR VOLTAGE DROP	
	POWER KW		KVAR	POWER KW	KVAR
Row 1					
1200A 65V	77.0		−48.5	77.0	−48.5
1200A 65V	78.7	(starting)	−156.5	77.0	−48.5
1200A 65V	77.0		−48.5	77.0	−48.5
1200A 65V	77.0		−48.5	77.0	−48.5
1200A 65V	77.0		−48.5	77.0	−48.5
1200A 65V	77.0		−48.5	77.0	−48.5
Total	463.7(1)		−399.0(2)	462.0(7)	−291.0(8)
Row 2					
800A 33V	25.2	(starting)	−50.0	29.5	−16.5
800A 33V	29.5		−16.5	29.5	−16.5
800A 33V	29.5		−16.5	29.5	−16.5
800A 33V	29.5		−16.5	29.5	−16.5
800A 33V	29.5		−16.5	29.5	−16.5
Misc	5.0		− 1.0	5.0	− 1.0
Cap Unit	—		+20.0	—	+20.0
Total	148.2		−97.0	152.5(4)	−60.5(6)
Row 3					
300A 165V	47.2	(starting)	93.8	50.0	−30.0
300A 165V	50.0		30.0	50.0	−30.0
300A 165V	50.0		30.0	50.0	−30.0
Total	147.2(3)		153.8(5)	150.0(9)	−90.0(10)

TABLE D (Cont)

Calculate Service Fuse

Two feeders will be required for this office. From inspection, it is obvious that row 1 should be on a separate feeder and subsequent calculations will determine whether row 2 and row 3 can be on a common feeder.

Row 1

$$\text{Tan } \theta = \frac{\text{Kvar}}{\text{Kw}} = \frac{(2)}{(1)} = \frac{399}{463.7} = .862$$

Power Factor (Cosine of angle whose tangent is .862) = .757

Minimum Voltage at Motors = 190

$$I = \frac{P}{\sqrt{3}\ E \text{ Cos } \theta} = \frac{463{,}700}{1.73 \times 190 \times .757} = 1860 \text{ Amperes}$$

A 2000-ampere fuse is required and four 700,000 CM cables per phase lead unless the length exceeds the value shown on Fig. 3 in which case a voltage calculation similar to that shown in Par. 9 shall be made and the lead size increased if required.

Row 2 and Row 3

$$\text{Tan } \theta = \frac{(5) + (6)}{(3) + (4)} = \frac{153.8 + 60.5}{147.2 + 152.5} = \frac{214.3}{299.7} = .715$$

Power Factor = .812

$$I = \frac{299{,}700}{1.73 \times 190 \times .812} = 1120 \text{ Amperes.}$$

1120 Amperes can be carried on a 1200 ampere fuse and three 600,000 CM cables per phase lead so that both rows of bus duct may be fed from one feeder unless a voltage drop calculation requires the size to be increased.

Calculate Normal Load for Voltage Drop Purposes

Row 1

$$\text{Tan } \theta = \frac{(8)}{(7)} = \frac{291}{462} = .63$$

Power Factor = Cosine of angle whose tangent is .63 = .846

Minimum Voltage at Motor terminals 190

$$I = \frac{P}{\sqrt{3}\ E \text{ Cos } \theta} = \frac{462{,}000}{1.73 \times 190 \times .846} = 1660 \text{ Amperes}$$

TABLE D (Cont)

Row 2 and Row 3

$$\text{Tan } \theta = \frac{(6) + (10)}{(4) + (9)} = \frac{60.5 + 90}{152.5 + 150} = \frac{150.5}{302.5} = .497$$

Power Factor = Cosine of angle whose tangent is .497 = .894

Minimum Voltage at Motor terminals = 190

$$I = \frac{P}{\sqrt{3}\ E \text{ Cos } \theta} = \frac{302{,}500}{1.73 \times 190 \times .894} = 1030 \text{ Amperes.}$$

8. TYPICAL CALCULATION — POWER FACTOR CORRECTION EQUIPMENT

8.01 Capacitor-reactor or capacitor equipment for power factor correction is available in several sizes as shown on the power service circuit.

8.02 The amount of net corrective kvar to use in central office power plants for power factor correction depends upon the equipment used in the power plant and upon the power factor that it is desired to maintain.

8.03 Billing in some areas is on the basis of average power factor maintained over the 24-hour day. In other areas, the charge is made on the basis of the power factor during the peak or busy hour load period.

Power Factor — Average Loads

8.04 Average power factor is ordinarily billed on indicating power factor meter readings taken by a power company representative during a visit to the office or on the basis of kwhr and kvahr or kvarhr meter readings. Meters are usually ratcheted so that there is no advantage operating at a leading power factor.

8.05 In determining the proper net kvar corrective capacity to use in cases where the average power factor is the basis for billing, calculations may be made of the input to the charging units for each hour of the day and averaged. The office load curve permits determining the charging units in service and the load on them. The power data book gives information for motor input and power factor.

8.06 A typical calculation is shown in Table E. This is for the office which is illustrated by paragraph 7. For calculation purposes the load distribution will be assumed to be as follows: (see Table E)

	10 HOURS	8 HOURS	6 HOURS
48V	10%	50%	100%
24V	62%	85%	100%
130V	30%	30%	30%

Power Factor — Peak Loads

8.07 In case the billing is on the basis of the power factor at peak load, the readings for billing may be made on an indicating power factor meter at the time of the busy hour or peak load by a power company representative or on demand meters that read the peak kw and kva or kvar demand (usually averaged over 15 to 30 minute periods) during a given time, such as for a month. The calculations in this case may be based on the charging equipment in service during the busy hour, using the same general method of calculations illustrated for average power factor.

Building Load Correction

8.08 If the central office load and the building load are supplied through the same metering equipment, power factor correction for the entire building may be taken care of at the central office power service cabinet. However, if the building load is supplied through conductors, switches, and meters separate from the central office load, and it appears desirable to provide for correcting the power factor of the building load without arranging for a common metering point; capacitor or capacitor-reactor units may be connected at the building service panel, or other convenient point, of the capacity required to provide the necessary correction.

Fluorescent Lighting

8.09 If the connection for fluorescent lighting is made on the same meter as the central office supply, power factor correction for the fluorescent lighting may be taken care of if desired by the power factor correction equipment at the power service cabinet for central office power factor correction. However, if the fluorescent lighting is furnished through a separate meter, it may be desirable to provide separate correcting facilities. This may be done by the use of a capacitor or capacitor-reactor unit of suitable capacity for the fluorescent lighting load, or, if the load is small, by the use of the fluorescent lighting high power factor two-lamp auxiliary. This auxiliary, which serves two lamps and may be mounted close to the lamps, offers adequate correction in itself since one lamp operates with a leading and the other with a lagging power factor. If it is not necessary to correct for power factor at the lamp itself, either because power factor correction is not considered necessary or because a capacitor or capacitor-reactor unit cares for the correction, a single-lamp auxiliary (low power factor type) is used.

TABLE E

VOLTS	AMPERE RATING	AMP LOAD	KW	POWER FACTOR COS θ FIGS. 3 & 4	TAN θ	REACTIVE KILOVOLT AMPERES KVAR		KVAR WITH CAPACITOR UNIT
48	1200	600	42.0	—	—	−42.0		
24	800	800	29.5	—	—	−16.5		
24	800	800	29.5	—	—	−16.5		
24	800	500	20.0	—	—	−15.5		
130	300	180	34.0	—	—	−29.0		
Misc	—	—	5.0	—	—	− 1.0		
			160.0			−120.5		−120.5
								+ 20.0
								−100.5
	Hours 10			Hours 10				
	Kwhr		1600 (1)	Kvar Hr		—1205 (4)	Hours 10	
								−1005 (7)
48	1200	1200	77.0	—	—	−48.5		
48	1200	1200	77.0	—	—	−48.5		
48	1200	600	42.0	—	—	−42.0		
24	800	800	29.5	—	—	−16.5		
24	800	800	29.5	—	—	−16.5		
24	800	800	29.5	—	—	−16.5		
24	800	320	13.0	—	—	−15.0		
130	300	180	34.0	—	—	−29.0		
Misc			5.0			− 1.0		−233.5
			336.5				Cap	+ 20.0
							Unit	−213.5
	Hours 8			Hours 8		−233.5	Hours 8	
	Kwhr		2692.0 (2)	Kvar Hr		−1868.0 (5)		−1708.0 (8)

TABLE E (Cont)

VOLTS	AMPERE RATING	AMP LOAD	KW	POWER FACTOR COS θ FIGS. 3 & 4	TAN θ	REACTIVE KILOVOLT AMPERES KVAR		KVAR WITH CAPACITOR UNIT
48	1200	1200	77.0	—	—	−48.5		
48	1200	1200	77.0	—	—	−48.5		
48	1200	1200	77.0	—	—	−48.5		
48	1200	1200	77.0	—	—	−48.5		
48	1200	1200	77.0	—	—	−48.5		
24	800	800	29.5	—	—	−16.5		
24	800	800	29.5	—	—	−16.5		
24	800	800	29.5	—	—	−16.5		
24	800	800	29.5	—	—	−16.5		
130	300	180	34.0	—	—	−29.0		
Misc	—	—	5.0	—	—	− 1.0		
			542.0			−338.5		−338.5
							Cap Unit	+ 20.0
	Hours 6			Hours 6			Hours 6	318.5
	Kwhr		3252 (3)	Kvar Hr		2031 (6)		−1911.0 (9)

$$\text{Tan } \theta = \frac{(4) + (5) + (6)}{(1) + (2) + (3)} = \frac{1205 + 1868 + 2031}{1600 + 2692 + 3252} = \frac{5104}{7544} = .677$$

Average Power Factor (Cosine of angle whose tangent is .677 = .828)

Required Power Factor .85

Maximum allowable reactive kva

(Tangent of angle whose cosine is .85) = .62

$$\text{Tan } \theta = \frac{\text{Max allowable rkva hr}}{\text{Power kwhr}}$$

$$.62 = \frac{X}{7544} = 4675 \text{ rkva hr}$$

This office has 51C4 rkva hr

429 Capacitive rkva is required in 24 hours.

$$\text{Capacitor required is } \frac{429}{24} = 17.85 \text{ kva — Use 20}$$

Calculate Corrected Power Factor

If any of items (7), (8), or (9) are positive numbers substitute zero for the positive number in the following calculation.

$$\text{Tan } \theta = \frac{(7) + (8) + (9)}{(1) + (2) + (3)} = \frac{1005 + 1708 + 1911}{1600 + 2692 + 3252} = \frac{4624}{7544} = .613$$

Average Power Factor (Cosine of angle whose tangent is .613) = .852

9. TYPICAL CALCULATION VOLTAGE DROP

9.01 If the length of the four 700,000 CM cables per phase lead of the supply to row 1 in paragraph 7 does not exceed 275 feet (one way), no calculation is required. It is made in Table F, however to show the method. It will be satisfactory to use a current of 415 amperes and one 700,000 CM cable per phase in the calculations instead of 1660 amperes and four 700,000 CM cables as determined from Table D. When the calculation shows too much voltage drop the lead size shall be increased and the drop recalculated.

TABLE F

Voltage Drop Calculation

	LEAD F	REFERENCE
(1) Size of Lead	1-700,000 CM Cable	8.01
(2) Length of Leads	150 Feet	
(3) Resistance per Circuit (One-way length $\times \sqrt{3}$)	.00413 Ohm ($0.15 \times 0.0159 \times \sqrt{3}$)	4.08
(4) Reactance per Circuit (One-way length $\times \sqrt{3}$)	.0088 Ohm ($0.15 \times .034 \times \sqrt{3}$)	4.08
(5) Power Factor	.846 (Table D)	
(6) Minimum Voltage	197.6 Volts ($208 \pm 5\%$)	
(7) Current in Phase Lead $\frac{1660}{4} = 415$ amps	415 Amperes (Table D)	8.01
(8) In Phase Service Voltage (Min Voltage $\times \cos\theta$)	167 Volts ($197.6 \times .846$)	Fig. 5
(9) Reactive Service Voltage (Min Voltage $\times \sin\theta$)	104.8 Volts ($197.6 \times .53$)	Fig. 5
(10) In Phase Drop (7) × (3)	1.72 Volts	
(11) Reactive Drop (7) × (4)	3.66 Volts	
(12) Resultant In Phase Voltage (V_{1_p}) (8) − (10)	165.3 Volts	
(13) Resultant Reactive Voltage (V_r) (9) − (11)	101.1 Volts	

TABLE F (Cont)

	LEAD F	REFERENCE
(14) Resultant Voltage (V)	193.5 Volts (At Bus Duct)	Figs. 2 & 5

$$\text{Tan } \theta = \frac{101.1}{165.3} = .612$$

$$\text{Cos } \theta = .852$$

$$V = \frac{165.3}{.852} = 194$$

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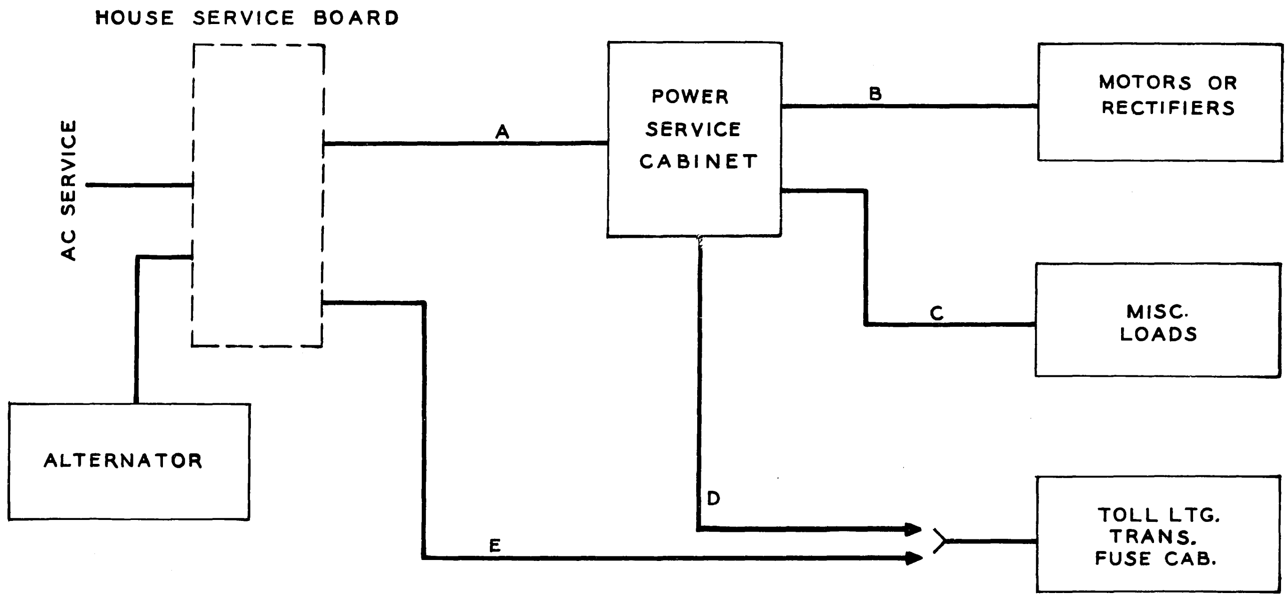
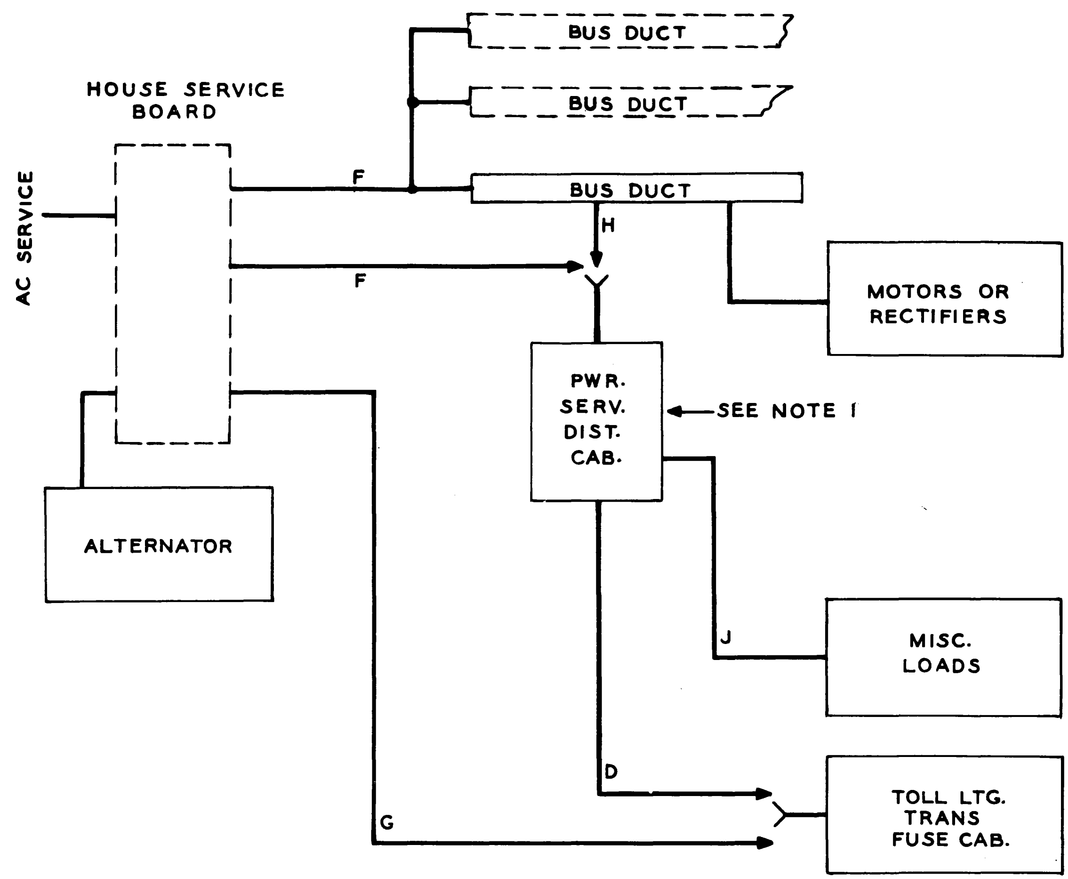
Attached: Figures 1 to 5 inclusive



NOMINAL PWR. SERV. VOLTAGE	MIN. PWR. SERV. VOLTAGE	MIN. VOLT. AT PWR. SERV. CABINET	MIN. VOLT. AT MOTOR OR RECT. MAIN CHG. UNITS	MIN. VOLT. AT MISC. LOADS	MIN VOLT. AT TOLL LTG. TRANS. FUSE CAB.	MIN. VOLT. AT TOLL LTG. TRANS.
240 ± 5%	228	219	216	216	214	210
230 ± 5%	218.5	210	207	207	205	201
220 ± 5%	209	201	198	198	196	192
208 ± 5%	197.6	192	190	187	187	183

Fig. 1 – Distribution Without Bus Duct



NOMINAL PWR.SERV. VOLT.	MIN. PWR.SERV. VOLT.	MIN.VOLT. AT BUS DUCT	MIN.VOLT. AT PWR. SERV. CAB	MIN.VOLT. AT MOTOR OR RECT MAIN CHG.UNITS	MIN VOLT. AT MISC. LOADS	MIN.VOLT. AT TOLL LTG. TRANS. FUSE CAB	MIN. VOLT. AT TOLL LTG. TRANS
240 ±5%	228	219	218	219	216	213	209
230 ±5%	218.5	210	209	210	207	204	200
220 ±5%	209	201	200	201	198	195	191
208 ±5%	197.6	190	189	190	187	184	180

NOTES:
1. USE "F" LEAD IF THERE ARE SINGLE PHASE GROUNDED CIRCUITS IN THIS CABINET.

Fig. 2 – Distribution With Bus Duct

VOLTAGE	LEADS								
	A	B	C	D	E	F	G	H	J
240	300′	100′	100′	225′	500′	350′	500′	35′	65′
230	275′	100′	100′	200′	500′	325′	500′	35′	65′
220	250′	100′	100′	200′	450′	300′	475′	35′	65′
208	200′	65′	150′	175′	350′	275′	450′	35′	65′

NOTES

LEADS A & F CALCULATED AT FULL LOAD 0.85 PF.

LEADS D, E & G CALCULATED AT 0.80 LOAD 1.0 PF.

Fig. 3 – Allowable Length of Leads

REACTIVE K.V.A. (KVAR)	IF POWER (K.W.) AND POWER FACTOR (COS. Θ) ARE KNOWN FIND TAN. Θ CORRESPONDING TO COS. Θ ON CURVE B AND MULTIPLY BY POWER (K.W.). KVAR = K.W. TAN. Θ.
K.V.A. OR POWER FACTOR (COS. Θ)	IF POWER (K.W.) AND REACTIVE K.V.A. (KVAR) ARE KNOWN. $\text{TAN. } \theta = \frac{\text{KVAR}}{\text{K.W.}}$. FIND COS Θ CORRESPONDING TO TAN. Θ ON CURVE B. $\text{K.V.A.} = \frac{\text{K.W.}}{\cos\theta}$.
IN PHASE VOLTAGE (E_{IP})	IF SERVICE VOLTAGE (E) AND POWER FACTOR (COS. Θ) ARE KNOWN. $E_{IP} = E \cos\theta$.
REACTIVE VOLTAGE (E_R)	IF SERVICE VOLTAGE (E) AND POWER FACTOR (COS. Θ) ARE KNOWN FIND SIN. Θ CORRESPONDING TO COS. Θ ON CURVE A AND MULTIPLY BY SERVICE VOLTAGE (E). $E_R = E. \sin\theta$
RESULTANT VOLTAGE (V)	IF RESULTANT IN PHASE VOLTAGE (V_{IP}) AND RESULTANT REACTIVE VOLTAGE (V_R) ARE KNOWN. $\text{TAN. } \theta = \frac{V_R}{V_{IP}}$ FIND COS. Θ CORRESPONDING TO TAN. Θ ON CURVE B. $V = \frac{V_{IP}}{\cos\theta}$.

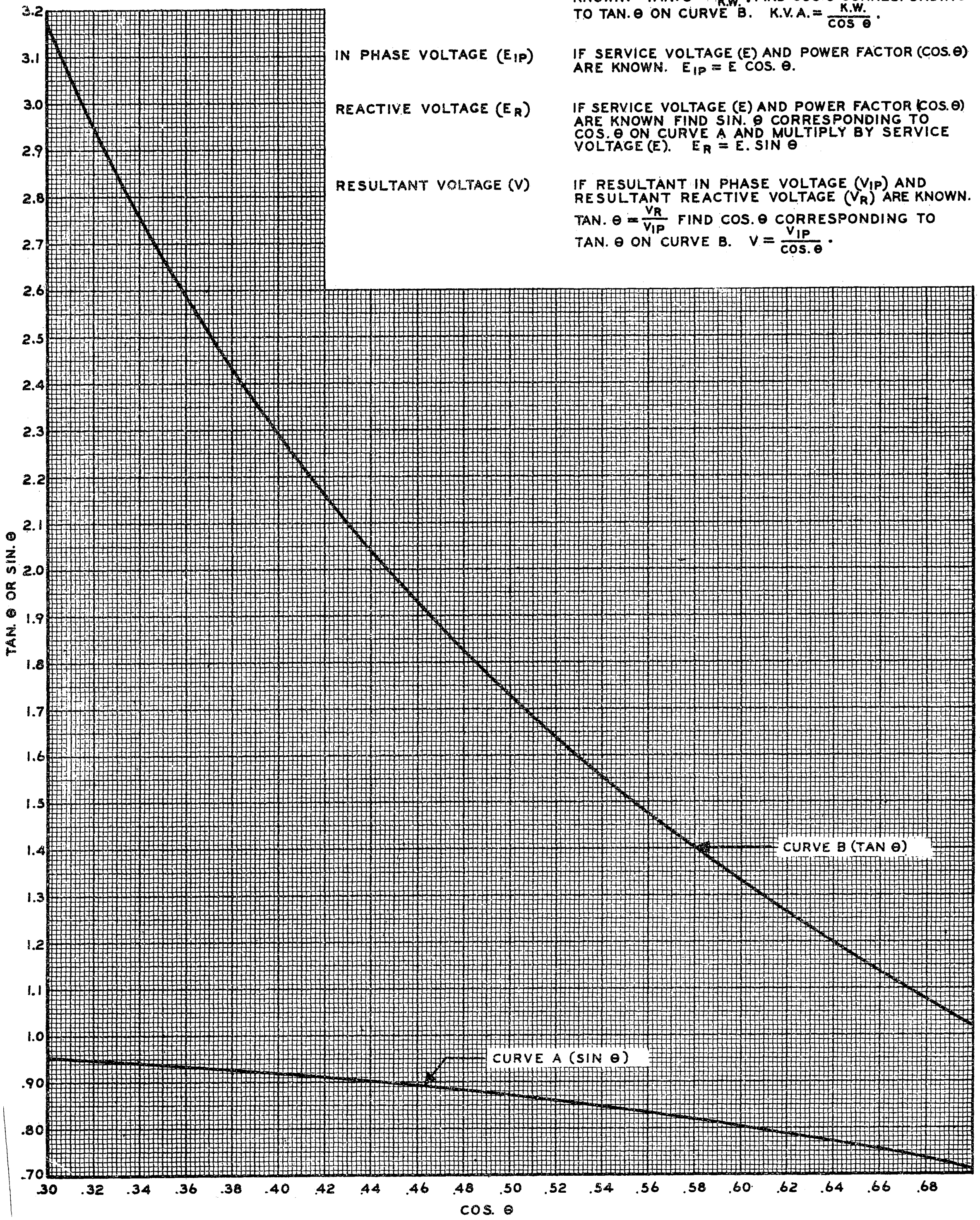


Fig. 4 – Calculation Chart

REACTIVE K.V.A. (KVAR)	IF POWER (K.W.) AND POWER FACTOR (COS. Θ) ARE KNOWN FIND TAN. Θ CORRESPONDING TO COS. Θ ON CURVE B AND MULTIPLY BY POWER (K.W.) KVAR = K.W. TAN. Θ
K.V.A. OR POWER FACTOR (COS. Θ)	IF POWER (K.W.) AND REACTIVE K.V.A. (KVAR) ARE KNOWN. $TAN.\ \theta = \frac{KVAR}{K.W.}$. FIND COS. Θ CORRESPONDING TO TAN. Θ ON CURVE B. $K.V.A. = \frac{K.W.}{COS.\ \theta}$.
IN PHASE VOLTAGE (E_{IP})	IF SERVICE VOLTAGE (E) AND POWER FACTOR (COS. Θ) ARE KNOWN. $E_{IP} = E\ COS.\ \theta$
REACTIVE VOLTAGE (E_R)	IF SERVICE VOLTAGE (E) AND POWER FACTOR (COS. Θ) ARE KNOWN FIND SIN. Θ CORRESPONDING TO COS. Θ ON CURVE A AND MULTIPLY BY SERVICE VOLTAGE (E). $E_R = E\ SIN.\ \theta$.
RESULTANT VOLTAGE (V)	IF RESULTANT IN PHASE VOLTAGE (V_{IP}) AND RESULTANT REACTIVE VOLTAGE (V_R) ARE KNOWN. $TAN.\ \theta = \frac{V_R}{V_{IP}}$ FIND COS. Θ CORRESPONDING TO TAN. Θ ON CURVE B. $V = \frac{V_{IP}}{COS.\ \theta}$.

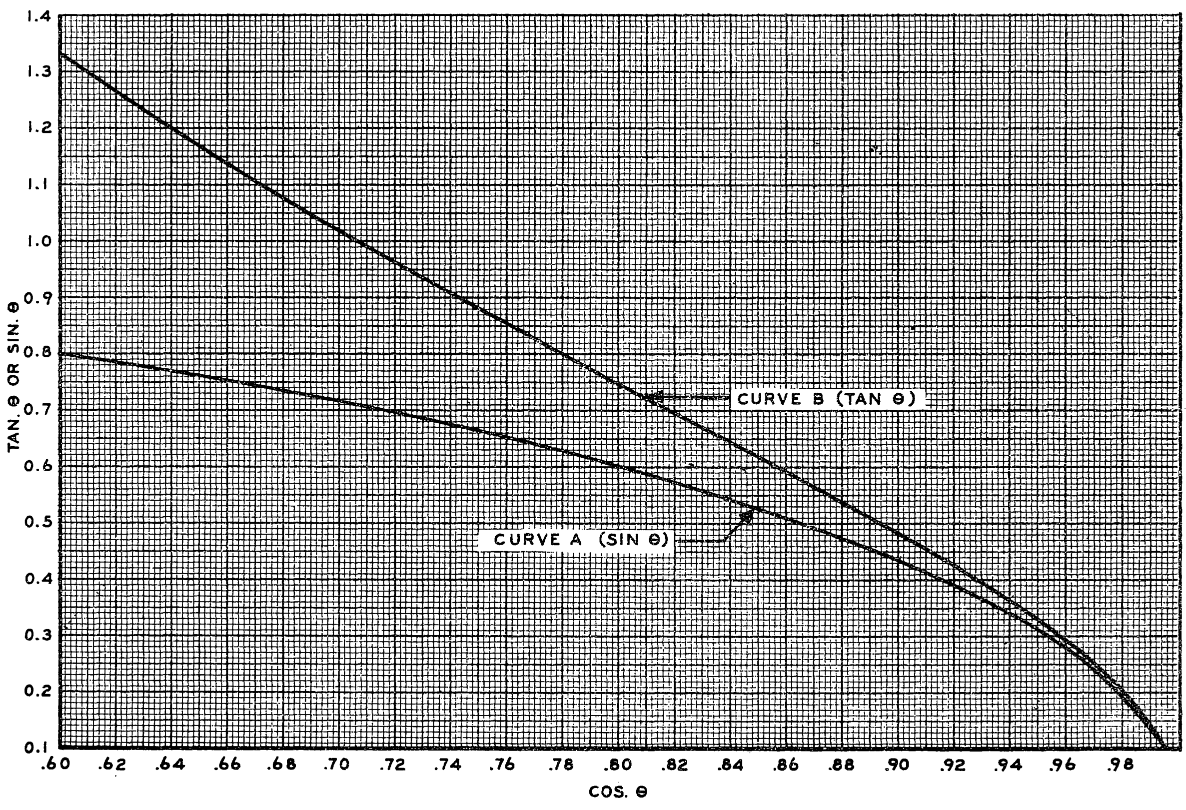


Fig. 5 — Calculation Chart