Elevator Disconnect Requirements

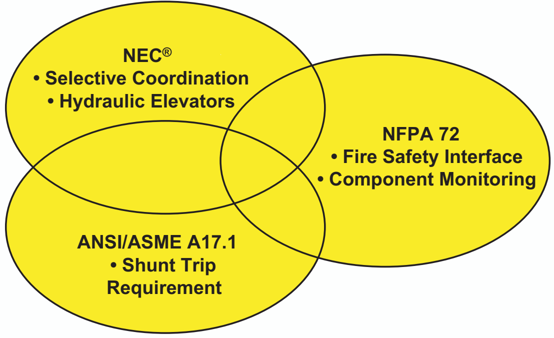
Elevator Circuits and Required Shunt Trip Disconnect — A Simple Solution.

When sprinklers are installed in elevator hoistways, machine rooms, or machinery spaces, ANSI/ASME A17.1 requires that the power be removed to the affected elevator upon or prior to the activation of these sprinklers. This is an elevator code requirement that affects the electrical installation. The electrical installation allows this requirement to be implemented at the disconnecting means for the elevator in NEC® 620.51(B). This requirement is most commonly accomplished through the use of a shunt trip disconnect and its own control power. To make this situation even more complicated, interface with the fire alarm system along with the monitoring of components required by NFPA 72 must be accomplished in order to activate the shunt trip action when appropriate and as well as making sure that the system is functional during normal operation. This requires the use of interposing relays that must be supplied in an additional enclosure. Other requirements that have to be met include selective coordination for multiple elevators (620.62) and hydraulic elevators with battery lowering [620.91(C)].

There is a simple solution available for engineering consultants, contractors, and inspectors to help comply with all of these requirements in one enclosure called the Bussmann® POWER MODULE™.

The POWER MODULE™ contains a shunt trip fusible switch together with the components necessary to comply with the fire alarm system requirements and shunt trip control power all in one package. For engineering consultants this means a simplified specification. For contractors this means a simplified installation because all that has to be done is connecting the appropriate wires. For inspectors this becomes simplified because everything is in one place with the same wiring every time. The fusible portion of the switch utilizes LOW-PEAK® LPJ-(amp)SP fuses that protect the elevator branch circuit from the damaging effects of short-circuit currents as well as helping to provide an easy method of selective coordination when supplied with an upstream LOW-PEAK fuse with at least a 2:1 amp rating ratio. More information about the Bussmann POWER MODULE™ can be found at www.bussmann.com.

POWER MODULE™ Elevator Disconnect
All-in-One Solution for Three Disciplines



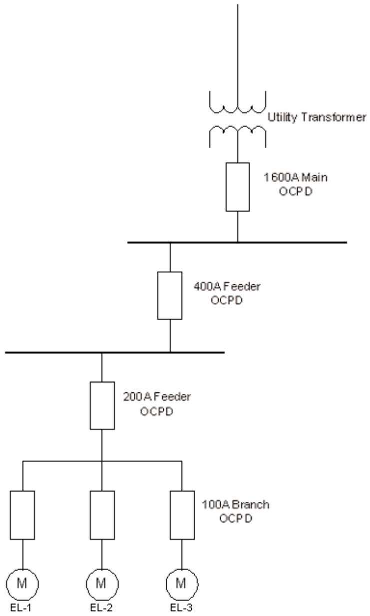
Elevator Selective Coordination Requirement

In the 2002 NEC®, 620.62 states:

> **Where more than one driving machine disconnecting means is supplied by a single feeder, the overcurrent protective devices in each disconnecting means shall be selectively coordinated with any other supply side overcurrent protective devices.**

A design engineer must specify and the contractor must install main, feeder, sub-feeder, and branch circuit protective devices that are selectively coordinated for all values of overloads and short-circuits.

To better understand how to assess if the overcurrent protective devices in an electrical system are selectively coordinated refer to the Selective Coordination Section of this booklet. Below is a brief coordination assessment of an elevator system in a circuit breaker system (example 1) and in a fuse system (example 2).



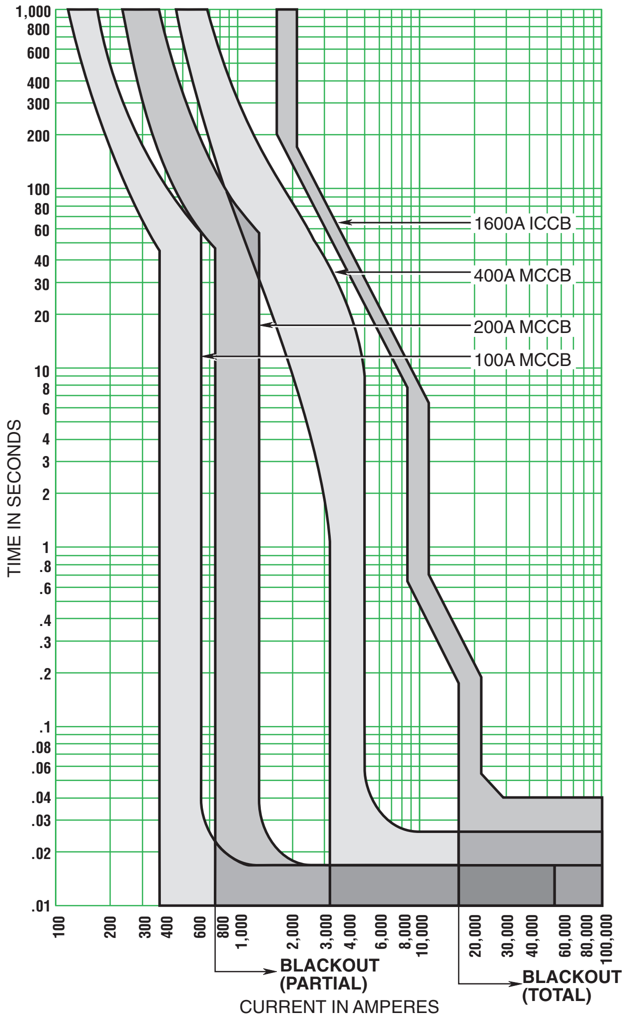
Using the one-line diagram above, a coordination study must be done to see that the system complies with the 620.62 selective coordination requirement if EL-1, EL-2, and EL-3 are elevator motors.

Go to the Selective Coordination section for a more indepth discussion on how to analyze systems to determine if selective coordination can be achieved.

Elevator Disconnect Requirements

Example 1 Circuit Breaker System

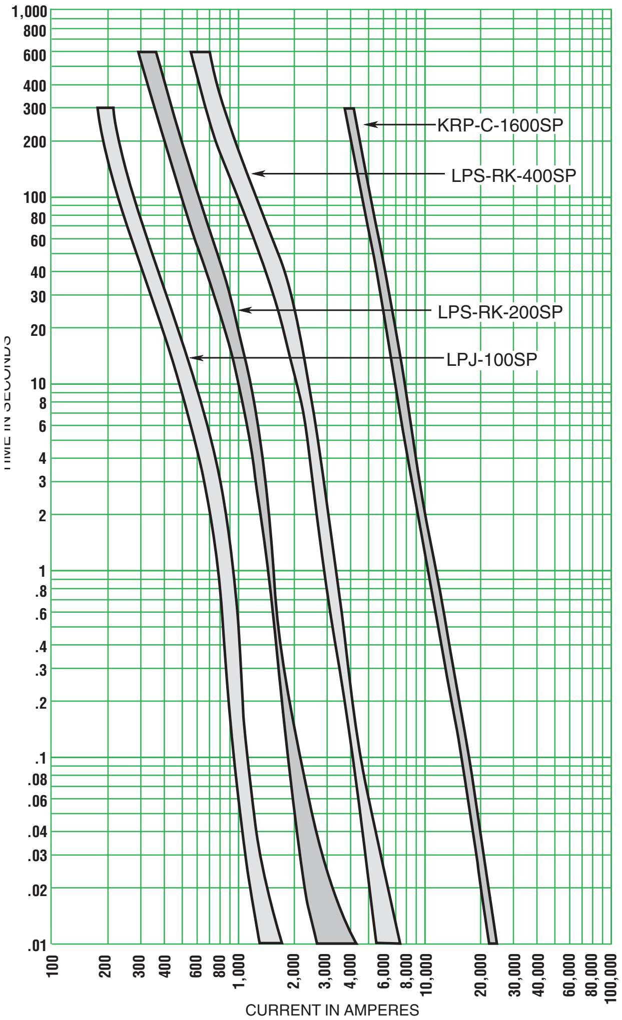
In this example, molded case circuit breakers (MCCB) will be used for the branch and feeder protective devices and an insulated case circuit breaker (ICCB) will be used for the main protective device.



Looking at the time current curves for the circuit breaker in the figure above, where any two circuit breaker curves overlap is a lack of selective coordination. The overlap indicates both devices open. If any fault current greater than 750 amps and less than 3100 amps occurs at EL-1, EL-2 or EL-3, the 200A circuit breaker will open as well as the 100A branch circuit breaker - this is not a selectively coordinated system and does not meet the requirements of 620.62. Fault currents above 3100 amps will open the 400A circuit breaker as well and faults above approximately 16,000 amperes will open the 1600 ampere circuit breaker - which further illustrates the lack of coordination. For a better understanding of how to assess circuit breaker coordination, see the section on Circuit Breaker Coordination in this book.

Example 2 Fusible System

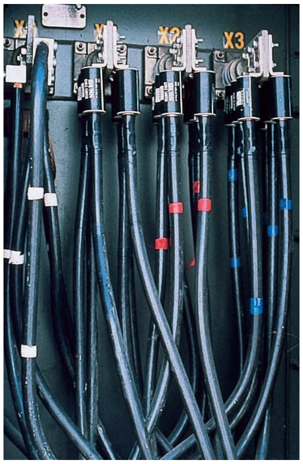
In our second example, LPJ-(amp)SP fuses will be used for the branch protection, LPS-RK-(amp)SP fuses will be used for the feeder protection, and KRP-C-(amp)SP fuses will be used for the main protection.



To verify selective coordination, go no further than the Fuse Selectivity Ratio Guide in the Fuse Selective Coordination section in this book. The LOW-PEAK® fuses just require a 2:1 ampere rating ratio to assure selective coordination. In this example, there is a 4:1 ratio between the main fuse (1600A) and the first level feeder fuse (400A) and a 2:1 ratio between the first level feeder fuse and the second level feeder fuse (200A). As well, there is a 2:1 ratio between the second level feeder fuse and the branch circuit fuse (100A). Since a minimum of a 2:1 ratio is satisfied at all levels for this system, selective coordination is achieved and 620.62 is met.

As just demonstrated in the prior paragraph, the fuse time current curves do not have to be drawn to assess selective coordination. For illustrative purposes, the time current curves for this example are shown above.

Cable Limiter Applications



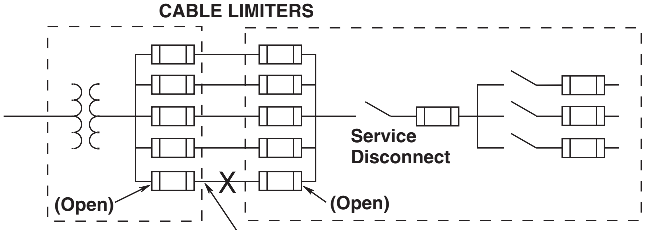
Cable Limiters

Cable limiters are distinguished from fuses by their intended purpose of providing only short-circuit response: they are not designed to provide overload protection. Typically, cable limiters are selected based on conductor size. They are available in a wide range of types to accommodate the many conductor sizes, copper or aluminum conductors, and a variety of termination methods. There are two broad categories of cable limiters:

1. *600V or less rated*-for large commercial, institutional and industrial applications.
2. *250V or less rated*-for residential and light commercial applications .

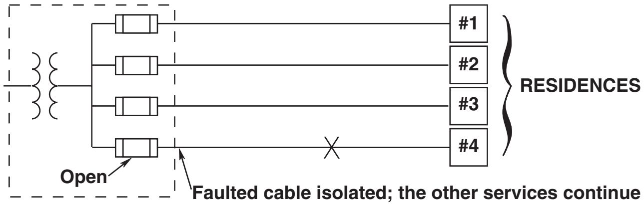
In institutional, commercial, and industrial systems, cable limiters are used at both ends of each cable on 3 or more cables per phase applications between the transformer and switchboard, as illustrated in the diagram and photographs.

COMMERCIAL/INDUSTRIAL SERVICE ENTRANCE (Multiple cables per phase)



Faulted cable isolated; only the cable limiters in faulted cable open; others remain in operation.

In residential systems, the cable limiters are normally installed on a single cable per phase basis at the source end of the lateral feeder to each residence.



Faulted cable isolated; the other services continue in operation without being disturbed

RESIDENTIAL SERVICE ENTRANCE (Single cables per phase)

Cable limiters may be located on the supply side of the service disconnecting means. The advantages of using cable limiters on the supply side of the service disconnect are multi-fold:

1. Isolation of one or more faulted cables. Only the affected cable(s) are removed from service by the cable limiters at each end opening, (assuming 3 or more cables per phase, with cable limiters on each end).
2. The isolation of a faulted cable permits the convenient scheduling of repair service.
3. The hazard of equipment burndown due to a fault on the line-side of the main overcurrent protective device is greatly reduced. Typically, without cable limiters, a fault between the transformer and service switchboard is given little or no protection.
4. Their current-limiting feature can be used to minimize arc flash hazards by reducing the magnitude of the arc flash current and the time of the arc flash exposure. There are many different cable limiters available for cables from 12 AWG to 1,000 kcmil and many different type terminations. Below is the listing of those most commonly used.

Copper Cable Limiter — 600V

Catalog Symbol	Cable Size	Catalog Symbol	Cable Size
KCY	4 AWG	**KCF**	4/0 AWG
KCZ	3 AWG	**KCH**	250 kcmil
KCA	2 AWG	**KCJ**	350 kcmil
KCB	1 AWG	**KCM**	500 kcmil
KCC	1/0 AWG	**KCV**	600 kcmil
KCD	2/0 AWG	**KCR**	750 kcmil
KCE	3/0 AWG	**KCS**	1000 kcmil
Tubular Terminal and Offset Bolt-Type Terminal			
KQV	12 AWG	**KDD**	2/0 AWG
KQT	10 AWG	**KDE**	3/0 AWG
KFZ	8 AWG	**KDF**	4/0 AWG
KIG	6 AWG	**KDH**	250 kcmil
KDY	4 AWG	**KDJ**	350 kcmil
KDA	2 AWG	**KDM**	500 kcmil
KDB	1 AWG	**KDU**	600 kcmil
KDC	1/0 AWG	**KDR**	750 kcmil
Compression Connector Rod Terminal and Tubular Terminal			
KEX	4/0 AWG	**KQO**	350 kcmil
KFH-A	250 kcmil	**KDT**	500 kcmil
***Center Bolt-Type Terminal and Off-Set Bolt-Type Terminal**			
KPF	4/0 AWG	**KDP**	500 kcmil
KFT	250 kcmil	**KFM**	750 kcmil
KEW	350 kcmil		

*Copper or aluminum cable; sizes of all other limiters pertain to copper only.

Cable Limiter Data Sheet No. 1042

3Ø Short-Circuit Calculations

Why Short-Circuit Calculations

Several sections of the National Electrical Code® relate to proper overcurrent protection. Safe and reliable application of overcurrent protective devices based on these sections mandate that a short-circuit study and a selective coordination study be conducted. These sections include, among others:

110.9 Interrupting Rating
110.10 Component Protection
240.1 Conductor Protection
250.95 Equipment Grounding Conductor Protection
517.17 Health Care Facilities - Selective Coordination
620.62 Selective Coordination for Elevator Circuits

Compliance with these code sections can best be accomplished by conducting a short-circuit study as a start to the analysis. The protection for an electrical system should not only be safe under all service conditions but, to insure continuity of service, it should be selectively coordinated as well. A coordinated system is one where only the faulted circuit is isolated without disturbing any other part of the system. Once the short-circuit levels are determined, the engineer can specify proper interrupting rating requirements, selectively coordinate the system and provide component protection. See the various sections of this book for further information on each topic.

Low voltage fuses have their interrupting rating expressed in terms of the symmetrical component of short-circuit current, I_S. They are given an RMS symmetrical interrupting rating at a specific power factor. This means that the fuse can interrupt the asymmetrical current associated with this rating. Thus only the symmetrical component of short-circuit current need be considered to determine the necessary interrupting rating of a low voltage fuse. For listed low voltage fuses, interrupting rating equals its interrupting capacity.

Low voltage molded case circuit breakers also have their interrupting rating expressed in terms of RMS symmetrical amperes at a specific power factor. However, it is necessary to determine a molded case circuit breaker's interrupting capacity in order to safely apply it. See the section Interrupting Rating vs. Interrupting Capacity in this book.

110.16 now requires arc-flash hazard warning labeling on certain equipment. A flash hazard analysis is required before a worker approaches electrical parts that have not been put into a safe work condition. To determine the incident energy and flash protection boundary for a flash hazard analysis the short-circuit current is typically the first step.

General Comments on Short-Circuit Calculations

Sources of short-circuit current that are normally taken under consideration include:

- Utility Generation
- Synchronous Motors
- Alternate Power Sources
- Local Generation
- Induction Motors

Short-circuit calculations should be done at all critical points in the system. These would include:

- Service Entrance
- Panel Boards
- Motor Control Centers
- Motor Starters
- Transfer Switches
- Load Centers
- Disconnects
- Motor Starters

Normally, short-circuit studies involve calculating a bolted 3-phase fault condition. This can be characterized as all 3-phases "bolted" together to create a zero impedance connection. This establishes a "worst case" (highest current) condition that results in maximum three phase thermal and mechanical stress in the system. From this calculation, other types of fault conditions can be approximated. This "worst case" condition should be used for interrupting rating, component protection and selective coordination. However, in doing an arc-flash hazard analysis it is recommended to do the arc flash hazard analysis at the highest bolted 3 phase short-circuit condition and at the "minimum" bolted three-phase short-circuit condition. There are several variables in a distribution system that affect calculated bolted 3-phase short-circuit currents. It is important to select the variable values applicable for the specific application analysis. In the Point-to-Point method presented in this section there are several adjustment factors given in Notes and footnotes that can be applied that will affect the outcomes. The variables are utility source short-circuit capabilities, motor contribution, transformer percent impedance tolerance, and voltage variance.

In most situations, the utility source(s) or on-site energy sources, such as on-site generation, are the major short-circuit current contributors. In the Point-to-Point method presented in the next few pages, the steps and example assume an infinite available short-circuit current from the utility source. Generally this is a good assumption for highest worst case conditions and since the property owner has no control over the utility system and future utility changes. And in many cases a large increase in the utility available does not increase the short-circuit currents a great deal for a building system on the secondary of the service transformer. However, there are cases where the actual utility medium voltage available provides a more accurate short-circuit assessment (minimum bolted short-circuit current conditions) that may be desired to assess the arc flash hazard.

When there are motors in the system, motor short-circuit contribution is also a very important factor that must be included in any short-circuit current analysis. When a short-circuit occurs, motor contribution adds to the magnitude of the short-circuit current; running motors contribute 4 to 6 times their normal full load current. In addition, series rated combinations can not be used in specific situations due to motor short-circuit contributions (see the section on Series Ratings in this book).

For capacitor discharge currents, which are of short time duration, certain IEEE (Institute of Electrical and Electronic Engineers) publications detail how to calculate these currents if they are substantial.

Procedures and Methods

To determine the fault current at any point in the system, first draw a one-line diagram showing all of the sources of short-circuit current feeding into the fault, as well as the impedances of the circuit components.

To begin the study, the system components, including those of the utility system, are represented as impedances in the diagram.

The impedance tables include three-phase and single-phase transformers, cable, and busway. These tables can be used if information from the manufacturers is not readily available.

It must be understood that short-circuit calculations are performed without current-limiting devices in the system. Calculations are done as though these devices are replaced with copper bars, to determine the maximum "available" short-circuit current. This is necessary to project how the system and the current-limiting devices will perform.

Also, multiple current-limiting devices do not operate in series to produce a "compounding" current-limiting effect. The downstream, or load side, fuse will operate alone under a short-circuit condition if properly coordinated.

The application of the point-to-point method permits the determination of available short-circuit currents with a reasonable degree of accuracy at various points for either 3Ø or 1Ø electrical distribution systems. This method can assume unlimited primary short-circuit current (infinite bus) or it can be used with limited primary available current.

3Ø Short-Circuit Calculations

Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amperes (F.L.A.) from either the nameplate, the following formulas or Table 1:

3Ø Transformer $$I_{F.L.A.} = \frac{KVA \times 1000}{E_{L-L} \times 1.732}$$

1Ø Transformer $$I_{F.L.A.} = \frac{KVA \times 1000}{E_{L-L}}$$

Step 2. Find the transformer multiplier. See Notes 1 and 2

$$\text{Multiplier} = \frac{100}{{}^{*}\%Z_{\text{transformer}}}$$

* **Note 1.** Get %Z from nameplate or Table 1. Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary. Transformer impedance is determined as follows: The transformer secondary is short circuited. Voltage is increased on the primary until full load current flows in the secondary. This applied voltage divided by the rated primary voltage (times 100) is the impedance of the transformer.

Example: For a 480 Volt rated primary, if 9.6 volts causes secondary full load current to flow through the shorted secondary, the transformer impedance is 9.6/480 = .02 = 2%Z.

* **Note 2.** In addition, UL (Std. 1561) listed transformers 25KVA and larger have a ± 10% impedance tolerance. Short circuit amperes can be affected by this tolerance. Therefore, for high end worst case, multiply %Z by .9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

Step 3. Determine by formula or Table 1 the transformer let-through short-circuit current. See Notes 3 and 4.

$$I_{S.C.} = \text{Transformer}_{F.L.A.} \times \text{Multiplier}$$

Note 3. Utility voltages may vary ±10% for power and ±5.8% for 120 Volt lighting services. Therefore, for highest short-circuit conditions, multiply values as calculated in step 3 by 1.1 or 1.058 respectively. To find the lower end worst case, multiply results in step 3 by .9 or .942 respectively.

Note 4. Motor short-circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short-circuit contribution is to multiply the total motor current in amperes by 4. Values of 4 to 6 are commonly accepted.

Step 4. Calculate the "f" factor.

3Ø Faults $$f = \frac{1.732 \times L \times I_{3Ø}}{C \times n \times E_{L-L}}$$

1Ø Line-to-Line (L-L) Faults
See Note 5 & Table 3 $$f = \frac{2 \times L \times I_{L-L}}{C \times n \times E_{L-L}}$$

1Ø Line-to-Neutral (L-N) Faults
See Note 5 & Table 3 $$f = \frac{2 \times L \times I_{L-N}^{\dagger}}{C \times n \times E_{L-N}}$$

Where:

L = length (feet) of conductor to the fault.
C = constant from Table 4 of "C" values for conductors and Table 5 of "C" values for busway.
n = Number of conductors per phase (adjusts C value for parallel runs)
I = available short-circuit current in amperes at beginning of circuit.

† **Note 5.** The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, **$I_{L-N} = 1.5 \times I_{L-L}$ at Transformer Terminals.**

At some distance from the terminals, depending upon wire size, the L-N fault current is lower than the L-L fault current. The 1.5 multiplier is an approximation and will theoretically vary from 1.33 to 1.67. These figures are based on change in turns ratio between primary and secondary, infinite source available, zero feet from terminals of transformer, and 1.2 x %X and 1.5 x %R for L-N vs. L-L resistance and reactance values. Begin L-N calculations at transformer secondary terminals, then proceed point-to-point.

Step 5. Calculate "M" (multiplier) or take from Table 2.

$$M = \frac{1}{1 + f}$$

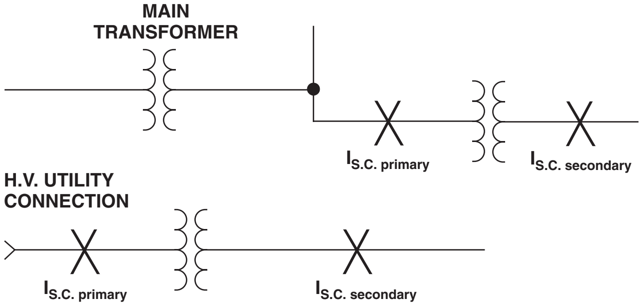
Step 6. Calculate the available short-circuit symmetrical RMS current at the point of fault. Add motor contribution, if applicable.

$$I_{S.C.\ sym\ RMS} = I_{S.C.} \times M$$

Step 6A. Motor short-circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short-circuit contribution is to multiply the total motor current in amperes by 4. Values of 4 to 6 are commonly accepted.

Calculation of Short-Circuit Currents at Second Transformer in System

Use the following procedure to calculate the level of fault current at the secondary of a second, downstream transformer in a system when the level of fault current at the transformer primary is known.



Procedure for Second Transformer in System

Step A. Calculate the "f" factor ($I_{S.C.\ primary}$ known)

3Ø Transformer
($I_{S.C.\ primary}$ and
$I_{S.C.\ secondary}$ are
3Ø fault values)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times 1.73\ (\%Z)}{100{,}000 \times KVA_{\ transformer}}$$

1Ø Transformer
($I_{S.C.\ primary}$ and
$I_{S.C.\ secondary}$ are
1Ø fault values:
$I_{S.C.\ secondary}$ is L-L)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times (\%Z)}{100{,}000 \times KVA_{transformer}}$$

Step B. Calculate "M" (multiplier).

$$M = \frac{1}{1 + f}$$

Step C. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)

$$I_{S.C.\ secondary} = \frac{V_{primary}}{V_{secondary}} \times M \times I_{S.C.\ primary}$$

3Ø Short-Circuit Calculations

System A

Available Utility
Infinite Assumption

1500 KVA Transformer,
480V, 3Ø, 3.5%Z,
3.45%X, .56%R

$I_{f.l.}$ =1804A

25' - 500kcmil
6 Per Phase
Service Entrance
Conductors in Steel Conduit

2000A Switch

KRP-C-2000SP Fuse

Fault X_1

400A Switch

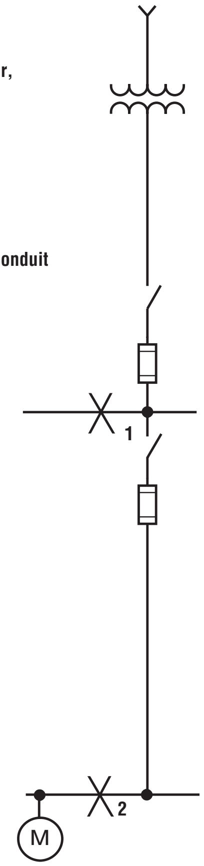
LPS-RK-400SP Fuse

50' - 500 kcmil
Feeder Cable
in Steel Conduit

Fault X_2

Motor Contribution

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \frac{1500 \times 1000}{480 \times 1.732} = 1804A$

Step 2. $\text{Multiplier} = \frac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1804 \times 28.57 = 51{,}540A$

$I_{S.C.\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS} = 51{,}504 + 7{,}216 = 58{,}720A$

Step 4. $f = \frac{1.732 \times 25 \times 51{,}540}{22{,}185 \times 6 \times 480} = 0.0349$

Step 5. $M = \frac{1}{1 + .0349} = .9663$

Step 6. $I_{S.C.sym\ RMS} = 51{,}540 \times .9663 = 49{,}803A$

$I_{S.C.motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$\underset{(fault\ X_1)}{I_{totalS.C.\ sym\ RMS}} = 49{,}803 + 7{,}216 = 57{,}019A$

Fault X_2

Step 4. Use $I_{S.C.sym\ RMS}$ @ Fault X_1 to calculate "f"

$f = \frac{1.732 \times 50 \times 49{,}803}{22{,}185 \times 480} = .4050$

Step 5. $M = \frac{1}{1 + .4050} = .7117$

Step 6. $I_{S.C.sym\ RMS} = 49{,}803 \times .7117 = 35{,}445A$

$I_{sym\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$\underset{(fault\ X_2)}{I_{total\ S.C.\ sym\ RMS}} = 35{,}445 + 7{,}216 = 42{,}661A$

*Assumes 100% motor load. If 50% of this load was from motors, $I_{S.C.}$ motor contrib. = 4 x 1,804 x .5 = 3608A

System B

Available Utility
Infinite Assumption

1000 KVA Transformer,
480V, 3Ø,
3.5%Z

$I_{f.l.}$= 1203A

30' - 500 kcmil
4 Per Phase
Copper in PVC Conduit

1600A Switch

KRP-C-1500SP Fuse

Fault X_1

400A Switch

LPS-RK-350SP Fuse

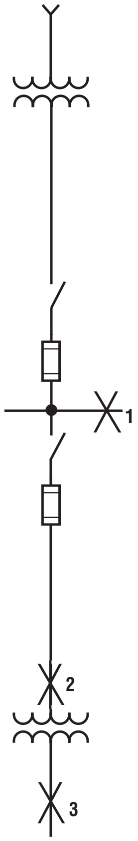
20' - 2/0
2 Per Phase
Copper in PVC Conduit

Fault X_2

225 KVA transformer,
208V, 3Ø
1.2%Z

Fault X_3

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \frac{1000 \times 1000}{480 \times 1.732} = 1203A$

Step 2. $\text{Multiplier} = \frac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1203 \times 28.57 = 34{,}370A$

Step 4. $f = \frac{1.732 \times 30 \times 34{,}370}{26{,}706 \times 4 \times 480} = .0348$

Step 5. $M = \frac{1}{1 + .0348} = .9664$

Step 6. $I_{S.C.sym\ RMS} = 34{,}370 \times .9664 = 33{,}215A$

Fault X_2

Step 4. $f = \frac{1.732 \times 20 \times 33{,}215}{2 \times 11{,}424 \times 480} = .1049$

Step 5. $M = \frac{1}{1 + .1049} = .905$

Step 6. $I_{S.C.sym\ RMS} = 33{,}215 \times .905 = 30{,}059A$

Fault X_3

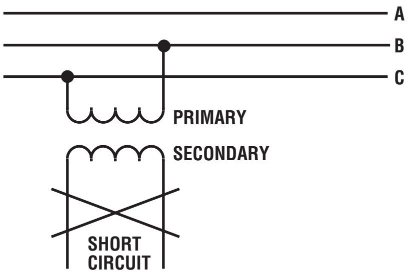
Step A. $f = \frac{30{,}059 \times 480 \times 1.732 \times 1.2}{100{,}000 \times 225} = 1.333$

Step B. $M = \frac{1}{1 + 1.333} = .4286$

Step C. $I_{S.C.\ sym\ RMS} = \frac{480 \times .4286 \times 30{,}059}{208} = 29{,}731A$

1Ø Short-Circuit Calculations

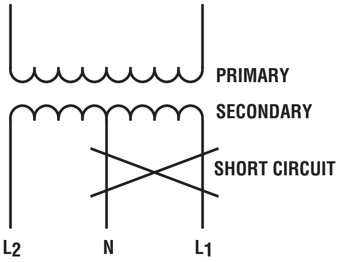
Short-circuit calculations on a single-phase center tapped transformer system require a slightly different procedure than 3Ø faults on 3Ø systems.



1. It is necessary that the proper impedance be used to represent the primary system. For 3Ø fault calculations, a single primary conductor impedance is only considered from the source to the transformer connection. This is compensated for in the 3Ø short-circuit formula by multiplying the single conductor or single-phase impedance by 1.73.

However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer and back to the source. This is compensated in the calculations by multiplying the 3Ø primary source impedance by two.

2. The impedance of the center-tapped transformer must be adjusted for the half-winding (generally line-to-neutral) fault condition.

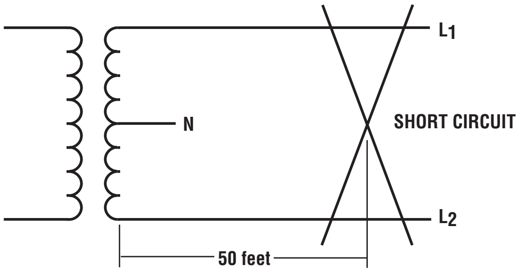


The diagram at the right illustrates that during line-to-neutral faults, the full primary winding is involved but, only the half-winding on the secondary is involved. Therefore, the actual transformer reactance and resistance of the half-winding condition is different than the actual transformer reactance and resistance of the full winding condition. Thus, adjustment to the %X and %R must be made when considering line-to-neutral faults. The adjustment multipliers generally used for this condition are as follows:

1.5 times full winding %R on full winding basis.
1.2 times full winding %X on full winding basis.

Note: %R and %X multipliers given in "Impedance Data for Single Phase Transformers" Table may be used, however, calculations must be adjusted to indicate transformer KVA/2.

3. The impedance of the cable and two-pole switches on the system must be considered "both-ways" since the current flows to the fault and then returns to the source. For instance, if a line-to-line fault occurs 50 feet from a transformer, then 100 feet of cable impedance must be included in the calculation.



The calculations on the following pages illustrate 1Ø fault calculations on a single-phase transformer system. Both line-to-line and line-to-neutral faults are considered.

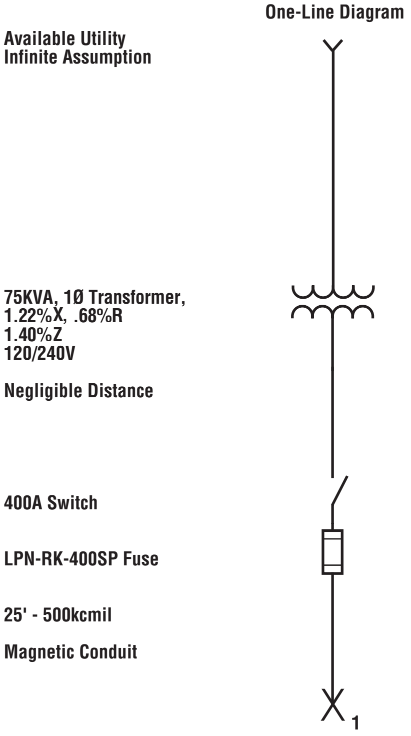
Note in these examples:

a. The multiplier of 2 for some electrical components to account for the single-phase fault current flow,

b. The half-winding transformer %X and %R multipliers for the line-to-neutral fault situation, and

1Ø Short-Circuit Calculations

Line-to-Line Fault @ 240V — Fault X_1



Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

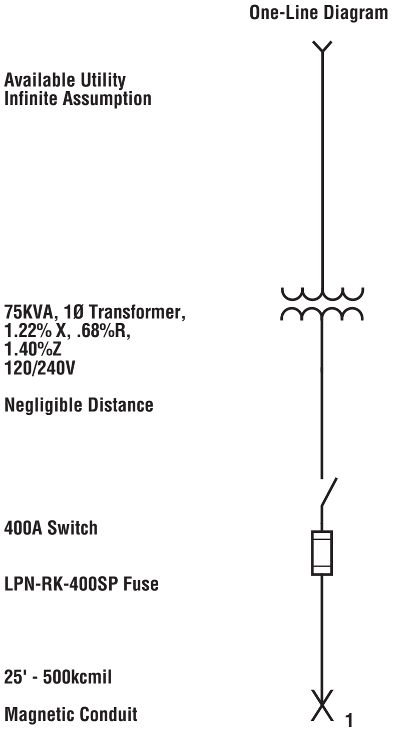
Step 3. $I_{S.C.} = 312.5 \times 71.43 = 22{,}322A$

Step 4. $f = \frac{2 \times 25 \times 22{,}322}{22{,}185 \times 240} = .2096$

Step 5. $M = \frac{1}{1 + .2096} = .8267$

Step 6. $I_{S.C.\ L\text{-}L\ (X_1)} = 22{,}322 \times .8267 = 18{,}453A$

Line-to-Neutral Fault @ 120V — Fault X_1



Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.\ (L\text{-}L)} = 312.5 \times 71.43 = 22{,}322A$

$I_{S.C.\ (L\text{-}N)} = 22{,}322 \times 1.5 = 33{,}483A$

Step 4. $f = \frac{2^{*} \times 25 \times 22{,}322 \times 1.5}{22{,}185 \times 120} = .6288$

Step 5. $M = \frac{1}{1 + .6288} = .6139$

Step 6. $I_{S.C.\ L\text{-}N\ (X_1)} = 33{,}483 \times .6139 = 20{,}555A$

* Assumes the neutral conductor and the line conductor are the same size.

Short-Circuit, Impedance and Reactance Data

TRANSFORMERS

Table 1. Short-Circuit Currents Available from Various Size Transformers

(Based Upon actual field nameplate data or from utility transformer worst case impedance)

Voltage and Phase	KVA	Full Load Amps	% Impedance†† (Nameplate)	Short Circuit Amps†
120/240 1 ph.*	25	104	1.5	12175
	37.5	156	1.5	18018
	50	208	1.5	23706
	75	313	1.5	34639
	100	417	1.6	42472
	167	696	1.6	66644
120/208 3 ph.**	45	125	1.0	13879
	75	208	1.0	23132
	112.5	312	1.11	31259
	150	416	1.07	43237
	225	625	1.12	61960
	300	833	1.11	83357
	500	1388	1.24	124364
	750	2082	3.50	66091
	1000	2776	3.50	88121
	1500	4164	3.50	132181
	2000	5552	4.00	154211
	2500	6940	4.00	192764
277/480 3 ph.**	75	90	1.00	10035
	112.5	135	1.00	15053
	150	181	1.20	16726
	225	271	1.20	25088
	300	361	1.20	33451
	500	602	1.30	51463
	750	903	3.50	28672
	1000	1204	3.50	38230
	1500	1806	3.50	57345
	2000	2408	4.00	66902
	2500	3011	4.00	83628

* Single-phase values are L-N values at transformer terminals. These figures are based on change in turns ratio between primary and secondary, 100,000 KVA primary, zero feet from terminals of transformer, 1.2 (%X) and 1.5 (%R) multipliers for L-N vs. L-L reactance and resistance values and transformer X/R ratio = 3.

** Three-phase short-circuit currents based on "infinite" primary.

†† UL listed transformers 25 KVA or greater have a ±10% impedance tolerance. Short-circuit amps shown in Table 1 reflect –10% condition. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

† Fluctuations in system voltage will affect the available short-circuit current. For example, a 10% increase in system voltage will result in a 10% greater available short-circuit currents than as shown in Table 1.

Impedance Data for Single-Phase Transformers

kVA 1Ø	Suggested X/R Ratio for Calculation	Normal Range of Percent Impedance (%Z)*	Impedance Multipliers** For Line-to-Neutral Faults for %X	for %R
25.0	1.1	1.2–6.0	0.6	0.75
37.5	1.4	1.2–6.5	0.6	0.75
50.0	1.6	1.2–6.4	0.6	0.75
75.0	1.8	1.2–6.6	0.6	0.75
100.0	2.0	1.3–5.7	0.6	0.75
167.0	2.5	1.4–6.1	1.0	0.75
250.0	3.6	1.9–6.8	1.0	0.75
333.0	4.7	2.4–6.0	1.0	0.75
500.0	5.5	2.2–5.4	1.0	0.75

* National standards do not specify %Z for single-phase transformers. Consult manufacturer for values to use in calculation.

** Based on rated current of the winding (one–half nameplate KVA divided by secondary line-to-neutral voltage).

Note: UL Listed transformers 25 KVA and greater have a ± 10% tolerance on their impedance nameplate.

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Impedance Data for Single-Phase and Three-Phase Transformers-Supplement†

kVA 1Ø	3Ø	%Z	Suggested X/R Ratio for Calculation
10	—	1.2	1.1
15	—	1.3	1.1
	75	1.11	1.5
	150	1.07	1.5
	225	1.12	1.5
	300	1.11	1.5
333	—	1.9	4.7
	500	1.24	1.5
500	—	2.1	5.5

†These represent actual transformer nameplate ratings taken from field installations.

Note: UL Listed transformers 25KVA and greater have a ±10% tolerance on their impedance nameplate.

Table 2. "M" (Multiplier) $M = \frac{1}{1+f}$

f	M	f	M	f	M
0.01	0.99	0.50	0.67	7.00	0.13
0.02	0.98	0.60	0.63	8.00	0.11
0.03	0.97	0.70	0.59	9.00	0.10
0.04	0.96	0.80	0.55	10.00	0.09
0.05	0.95	0.90	0.53	15.00	0.06
0.06	0.94	1.00	0.50	20.00	0.05
0.07	0.93	1.20	0.45	30.00	0.03
0.08	0.93	1.50	0.40	40.00	0.02
0.09	0.92	1.75	0.36	50.00	0.02
0.10	0.91	2.00	0.33	60.00	0.02
0.15	0.87	2.50	0.29	70.00	0.01
0.20	0.83	3.00	0.25	80.00	0.01
0.25	0.80	3.50	0.22	90.00	0.01
0.30	0.77	4.00	0.20	100.00	0.01
0.35	0.74	5.00	0.17		
0.40	0.71	6.00	0.14		

Table 3.
Various Types of Short Circuit Currents as a Percent of Three Phase Bolted Faults (Typical).

Three Phase Bolted Fault	100%
Line-to-Line Bolted Fault	87%
Line-to-Ground Bolted Fault	25-125%* (Use 100% near transformer, 50% otherwise)
Line-to-Neutral Bolted Fault	25-125% (Use 100% near tansformer, 50% otherwise)
Three Phase Arcing Fault	89% (maximum)
Line-to-Line Arcing Fault	74% (maximum)
Line-to-Ground Arcing Fault (minimum)	38% (minimum)

*Typically much lower but can actually exceed the Three Phase Bolted Fault if it is near the transformer terminals. Will normally be between 25% to 125% of three phase bolted fault value.

“C” Values for Conductors and Busway

Table 4. “C” Values for Conductors

Copper												
AWG or kcmil	Three Single Conductors						Three-Conductor Cable					
	Conduit						Conduit					
	Steel			Nonmagnetic			Steel			Nonmagnetic		
	600V	5kV	15kV	600V	5kV	15kV	600V	5kV	15kV	600V	5kV	15kV
14	389	-	-	389	-	-	389	-	-	389	-	-
12	617	-	-	617	-	-	617	-	-	617	-	-
10	981	-	-	982	-	-	982	-	-	982	-	-
8	1557	1551	-	1559	1555	-	1559	1557	-	1560	1558	-
6	2425	2406	2389	2430	2418	2407	2431	2425	2415	2433	2428	2421
4	3806	3751	3696	3826	3789	3753	3830	3812	3779	3838	3823	3798
3	4774	4674	4577	4811	4745	4679	4820	4785	4726	4833	4803	4762
2	5907	5736	5574	6044	5926	5809	5989	5930	5828	6087	6023	5958
1	7293	7029	6759	7493	7307	7109	7454	7365	7189	7579	7507	7364
1/0	8925	8544	7973	9317	9034	8590	9210	9086	8708	9473	9373	9053
2/0	10755	10062	9390	11424	10878	10319	11245	11045	10500	11703	11529	11053
3/0	12844	11804	11022	13923	13048	12360	13656	13333	12613	14410	14119	13462
4/0	15082	13606	12543	16673	15351	14347	16392	15890	14813	17483	17020	16013
250	16483	14925	13644	18594	17121	15866	18311	17851	16466	19779	19352	18001
300	18177	16293	14769	20868	18975	17409	20617	20052	18319	22525	21938	20163
350	19704	17385	15678	22737	20526	18672	22646	21914	19821	24904	24126	21982
400	20566	18235	16366	24297	21786	19731	24253	23372	21042	26916	26044	23518
500	22185	19172	17492	26706	23277	21330	26980	25449	23126	30096	28712	25916
600	22965	20567	17962	28033	25204	22097	28752	27975	24897	32154	31258	27766
750	24137	21387	18889	29735	26453	23408	31051	30024	26933	34605	33315	29735
1,000	25278	22539	19923	31491	28083	24887	33864	32689	29320	37197	35749	31959
Aluminum												
14	237	-	-	237	-	-	237	-	-	237	-	-
12	376	-	-	376	-	-	376	-	-	376	-	-
10	599	-	-	599	-	-	599	-	-	599	-	-
8	951	950	-	952	951	-	952	951	-	952	952	-
6	1481	1476	1472	1482	1479	1476	1482	1480	1478	1482	1481	1479
4	2346	2333	2319	2350	2342	2333	2351	2347	2339	2353	2350	2344
3	2952	2928	2904	2961	2945	2929	2963	2955	2941	2966	2959	2949
2	3713	3670	3626	3730	3702	3673	3734	3719	3693	3740	3725	3709
1	4645	4575	4498	4678	4632	4580	4686	4664	4618	4699	4682	4646
1/0	5777	5670	5493	5838	5766	5646	5852	5820	5717	5876	5852	5771
2/0	7187	6968	6733	7301	7153	6986	7327	7271	7109	7373	7329	7202
3/0	8826	8467	8163	9110	8851	8627	9077	8981	8751	9243	9164	8977
4/0	10741	10167	9700	11174	10749	10387	11185	11022	10642	11409	11277	10969
250	12122	11460	10849	12862	12343	11847	12797	12636	12115	13236	13106	12661
300	13910	13009	12193	14923	14183	13492	14917	14698	13973	15495	15300	14659
350	15484	14280	13288	16813	15858	14955	16795	16490	15541	17635	17352	16501
400	16671	15355	14188	18506	17321	16234	18462	18064	16921	19588	19244	18154
500	18756	16828	15657	21391	19503	18315	21395	20607	19314	23018	22381	20978
600	20093	18428	16484	23451	21718	19635	23633	23196	21349	25708	25244	23295
750	21766	19685	17686	25976	23702	21437	26432	25790	23750	29036	28262	25976
1,000	23478	21235	19006	28779	26109	23482	29865	29049	26608	32938	31920	29135

Note: These values are equal to one over the impedance per foot and based upon resistance and reactance values found in IEEE Std 241-1990 (Gray Book), IEEE Recommended Practice for Electric Power Systems in Commerical Buildings & IEEE Std 242-1986 (Buff Book), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. Where resistance and reactance values differ or are not available, the Buff Book values have been used. The values for reactance in determining the C Value at 5 KV & 15 KV are from the Gray Book only (Values for 14-10 AWG at 5 kV and 14-8 AWG at 15 kV are not available and values for 3 AWG have been approximated).

Table 5. “C” Values for Busway

Ampacity	Busway				
	Plug-In	Feeder		High Impedance	
	Copper	Aluminum	Copper	Aluminum	Copper
225	28700	23000	18700	12000	—
400	38900	34700	23900	21300	—
600	41000	38300	36500	31300	—
800	46100	57500	49300	44100	—
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	—	—	277800	256400	—

Note: These values are equal to one over the impedance per foot for impedance in a survey of industry.