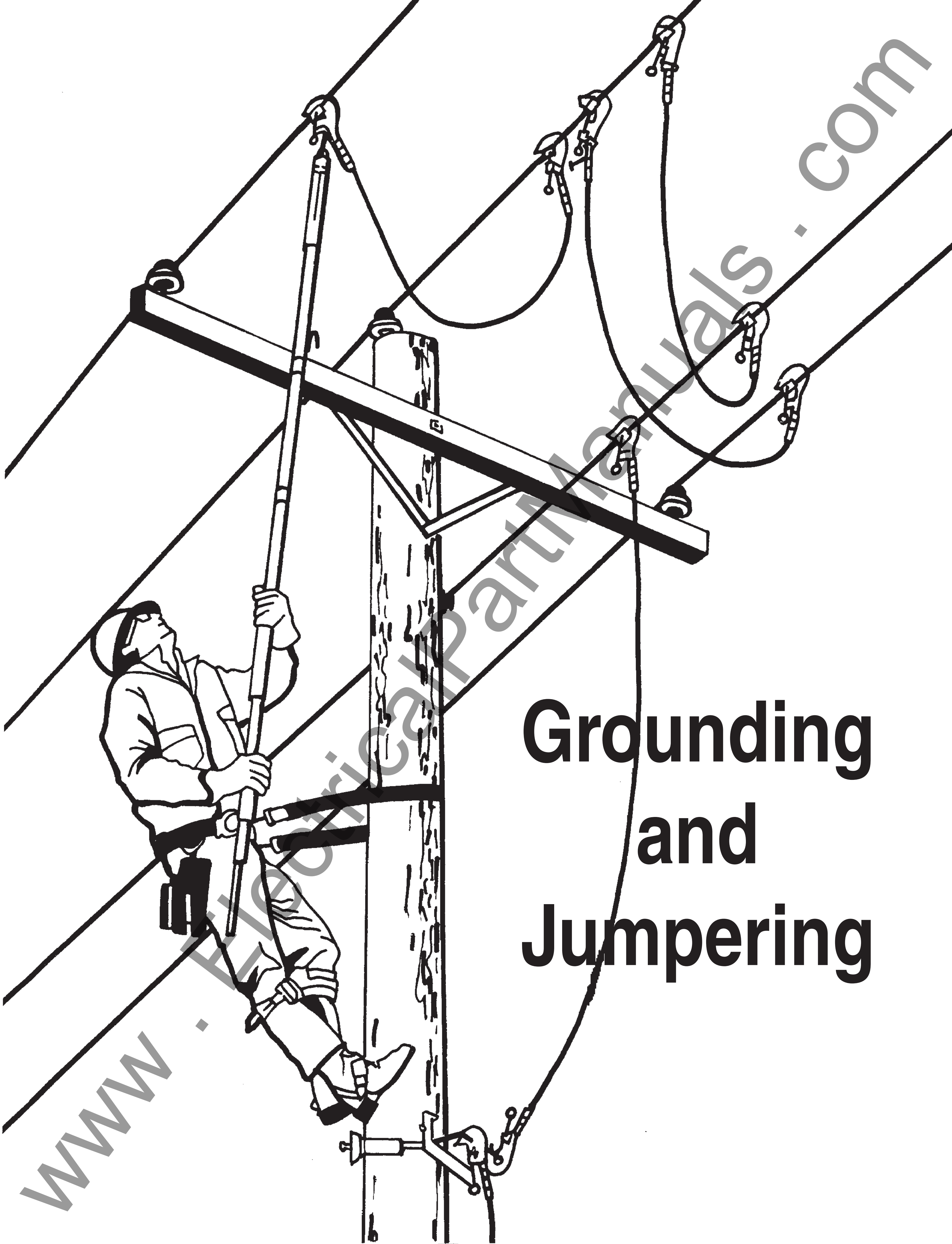

Grounding and Jumpering

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CHAPTER I

"GROUNDING AND JUMPERING" KEY TO SAFE WORK ON DE-ENERGIZED SYSTEMS

INTRODUCTION

Temporary grounding has received much attention from the application hardware and practice points of view. This chapter will deal with the subject primarily from the engineering and theoretical points of view. Not with the purpose of getting involved in deep drawn out formulations, but to show the basic theories which give sound foundations for proper grounding and jumpering practices.

Two major points will be emphasized throughout this chapter. First is the use of the terms "grounding" and "jumpering" as opposed to the classic terminology limited to grounding. Importance of the term "jumpering" will become more evident as you will see. Second is the emphasis on safety. Background, theory, details and application of safe grounding and jumpering will be a theme throughout this chapter. The information presented is equally applicable to distribution, transmission and substation work.

WHY IS TEMPORARY GROUNDING SO IMPORTANT?

This question has been asked and answered many times so we will only review the highlights. Definitely we want to keep safety of the work area as our prime requisite. On systems which are de-energized, many occurrences must be considered for continuous safety of the workman.

Induced voltage from adjacent energized lines is a constant consideration. Even though the system which is being worked has been "de-energized" there is electro magnetic feedover from adjacent systems which are energized. These may be systems on the same structure or on adjacent structures. The magnitude of feedover will vary with the proximity of the adjacent systems and with the magnitude of current on those systems. Major concern for this feedover is that it is of a continuous nature due to the continuous current flow on the adjacent systems. Therefore, induced voltages must be grounded to avoid possible electrical injury, discomfort and inadvertent reaction of the workman.

Fault currents on adjacent systems introduce a marked increase in the magnitude of feedover on the de-energized lines. While these fault currents will probably be of short duration, their magnitudes are such that the de-energized work area must be properly grounded and jumpered to avoid considerable danger to the work crew.

Although the de-energized work area may be bathed in bright sunlight, a storm on some other portion of the system could result in lightning striking the de-energized system and giving rise to transients which would render the work area extremely unsafe unless properly grounded and jumpered.

Another major consideration is accidental energizing of the system. Workmen will undoubtedly make certain that the system is de-energized before starting work, but through carelessness or misunderstanding, switches may be closed and energize the system in the work area. Accidents on adjacent systems, at crossovers or on overbuilds, could result in energized lines coming in contact with the de-energized system.

These situations all call for adequate grounding and jumpering procedures to ensure that a safe work area is maintained.

We have covered many of the known general factors which give rise to the need for safe grounding and jumpering; factors that support our contention that your grounding and jumpering practices should be given a thorough review.

Our electrical oriented world has increased the use of electrical power enormously during the past few years. As a result, increased generator capacities have been introduced. Along with this growth there have been marked increases in substation capacities, all of which means more power available in the case of mistake or fault with corresponding increases in resultant danger in the work area.

Increased congestion of current carrying systems due to increased system complexities and the need for better use of space and materials have given rise to considerably more system feedover. The increased number, size and complexity of substations are manifestations of these system growths. Increased numbers of conductors per structure have come about through the need for better utilization of each structure. Increased numbers of conductors per right-of-way are a necessity due to the need for better use of available land. These developments have brought increasing numbers of energized systems in close proximity with the de-energized line and have brought increased feedover probabilities.

Increases in currents carried on systems are evidenced by the increased conductor sizes and the increased use of bundled conductors. With these increased currents accompanying increases in feedover must be considered.

HOW GROUNDING AND JUMPERING HAS DEVELOPED

To appreciate the present grounding and jumpering practices and to see what considerations should be foremost in reviewing and upgrading these practices, we must look at grounding and jumpering progress over the years. Many papers have covered the practice of throwing a chain over the line or how tap clamps with No. 6 wire were used for grounding, so we will start a bit farther down the development path. The accompanying sketches will give some basics in the development of grounding and jumpering practices which apply to transmission, substation and distribution systems.

Figure 1 portrays the classic practice of connecting each conductor to a driven ground by means of quite long cables. This incorporates two points of interest which we will pursue in depth throughout our discussion. One point is the emphasis on cable length. The other is the location of cable connections in the work area. At first glance the workman on this structure may seem safe by grounding practices of this nature. To evaluate the workman's safety we will examine in detail just what the electrical situation actually is.

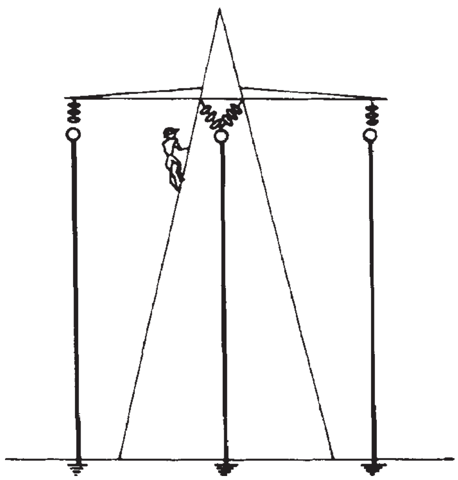


Fig. 1

The electrical equivalent of this structure is shown in Figure 2. R_j is the resistance of the jumper cable, R_m is the resistance of the workman and R_g is the ground resistance of the structure area. The important point of this circuit is that during current flow conditions R_j and R_g are in series and this combination of resistance is in parallel with R_m.

ELECTRICAL EQUIVALENT

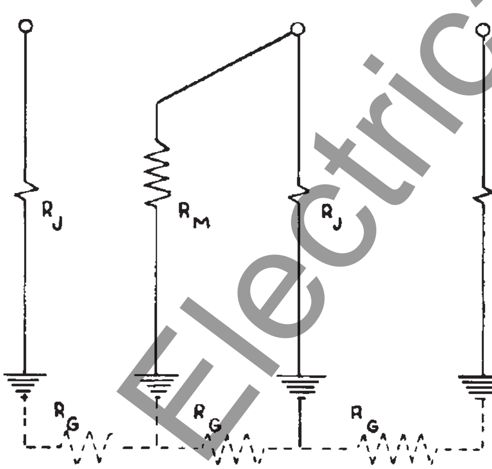


Fig. 2

The combined value of R_j and R_g will vary considerably from one work site to another. For purposes of this discussion a rather low combined value of 1 ohm will be considered. The value of R_m has been the subject of many papers and discussions. The combination of body resistance and contact resistance of a palm to conductor condition typical of a work position may be in the order of 5000 ohms but for purposes of this discussion a rather widely accepted body resistance value of 500 ohms will be considered.

If a current of 1000 amperes is encountered in the de-energized system, the voltage drop across R_j and R_g will be the product of 1,000 amperes times 1 ohm or 1,000 volts. I think we can all agree that the 1,000 ampere current is quite conservative on today's systems. The 1,000 volt drop is thus correspondingly conservative. This voltage drop of 1,000 volts is impressed across R_m, the workman, and results in a current flow through him of 1,000 volts divided by 500 ohms or 2 amperes. As we can readily see, there is a rather severe problem even with the conservative current flow of amperes on the grounded "de-energized" system. Much of this problem is caused by the excessive voltage drop incurred as a result of R_g.

A natural step toward improving grounding practices was to connect all three grounding cables to a common driven ground connection as shown in Figure 3. This reduced the R_g between phases so that the phase-to-phase resistance was virtually eliminated. This resulted in faster system reaction to clear the faulted line, however the practice still left the ground resistance in parallel with the work area and thus did not reduce the voltage drop across the workman.

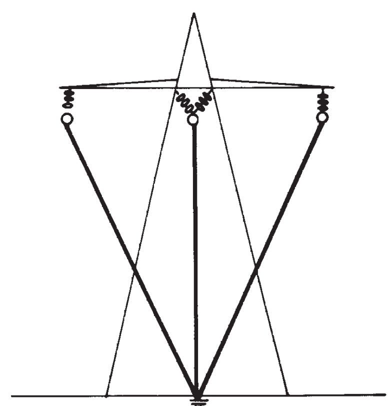


Fig. 3

A further step along this line of thinking was to run the cables close together for ease of handling as diagramed in Figure 4. The electromagnetic forces involved during fault currents on these closely located cables resulted in explosive results and discouraged further pursuit of this "convenience".

In an attempt to achieve work convenience while minimizing cable length and cable resistance between phases the practice of jumpering directly from phase-to-phase was instituted as shown in Figure 5. This reduced the number of lengthy leads to ground, reduced the violent action of multiple down leads during fault currents and achieved a minimum resistance between phases for rapid clearing of system faults. The method still utilized a single lead from one of the phases to a driven ground and thus left a high ground resistance and high voltage drop across the work area.

A natural evolution toward reducing the voltage drop across the work area is to run the "down lead" to the

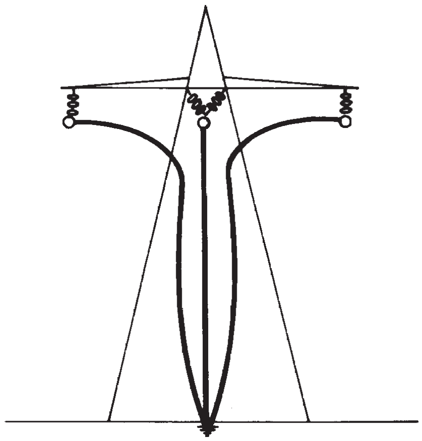


Fig. 4

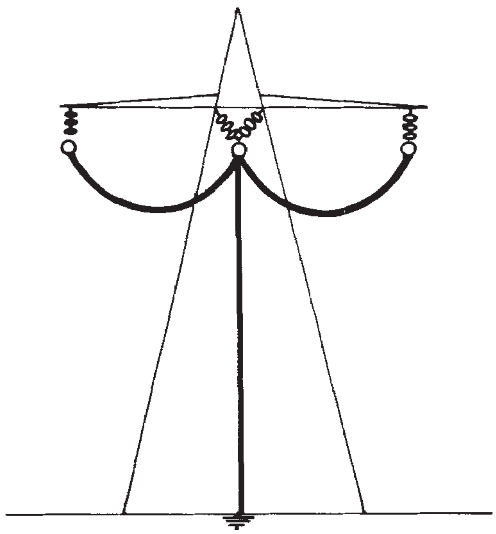


Fig. 5

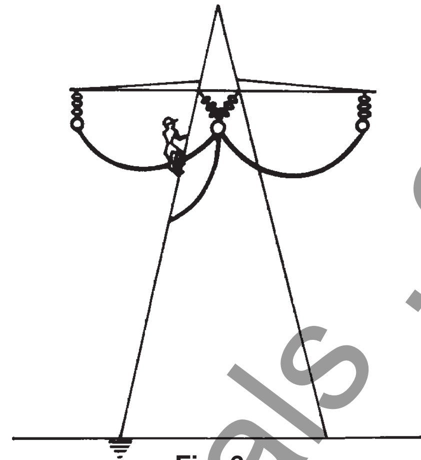


Fig. 6

ELECTRICAL EQUIVALENT

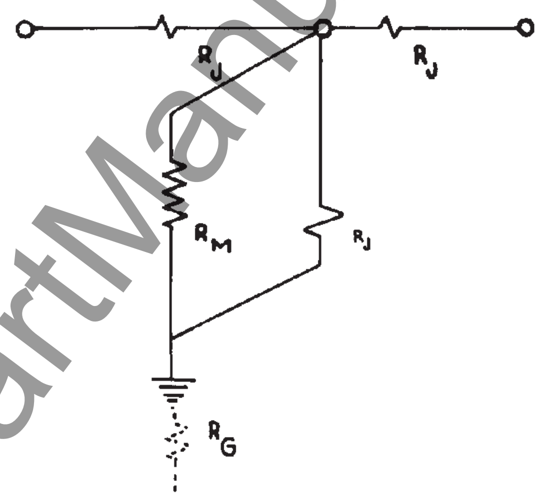


Fig. 7

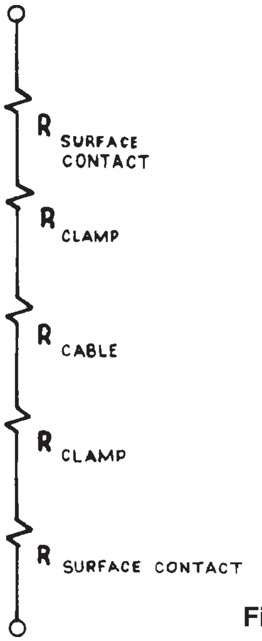
common ground of the structure. Further reduction of the voltage drop in the "down lead" is accomplished by shortening the lead length and connecting it to the structure just below the work area as shown in Figure 6. This practice gives short jumper lengths between phases to keep the resistance at a minimum. When a man is jumpered in this position, he is in parallel with a minimum of resistance and is subjected to a minimum voltage drop in case of current flow in the system. When there is a system neutral, a cable should also be connected to it for complete jumpering protection and to ensure lowest resistance in the ground return to the source.

The electrical equivalent of this system shown in Figure 7 readily discloses the advantages of having the man jumpered by only a cable resistance. This resistance could be in the order of 1 milliohm. The situation has now changed resistance and resultant voltage drop across the work area by a factor of 10^3, bringing a one volt impressed potential across the work area. This drastic reduction in voltage drop across the work area forms the basis for jumpering as a key to safe work practices. The markedly lower voltages also reduce likelihood of skin puncture and thus permit use of man-to-conductor resistances of considerably greater values than body resistance alone.

To further appreciate the importance of keeping the jumper resistance at a minimum, we should look at the series of components which are in parallel with the work area. The detailed electrical equivalent of the jumper resistance is shown in Figure 8. These resistances consist of the surface contact resistance between the clamp and the conductor, the resistance of the clamp itself, the resistance of the jumper cable, the resistance of the other clamp, and the resistance of the surface contact between the clamp and the structure. At the A. B. Chance Research Center, we have conducted extensive studies and tests relative to the factors which make up these resistances.

These factors combined with other items which should be thought of in optimizing the grounding and jumpering system are summarized in five major considerations.

Item No. 1 is "Choose adequate capacity clamps." This means choosing clamps for adequate mechanical size to fit the conductor (cable or bus). It also means choosing clamps which have adequate electrical capacity to withstand the maximum realizable system current for the full time duration over which that current may be encountered. Some examples of clamps with their particular mechanical and electrical capacities are shown in Figures 9 through 11. In addition to physical size and



DETAILED ELECTRICAL EQUIVALENT OF JUMPER

Fig. 8

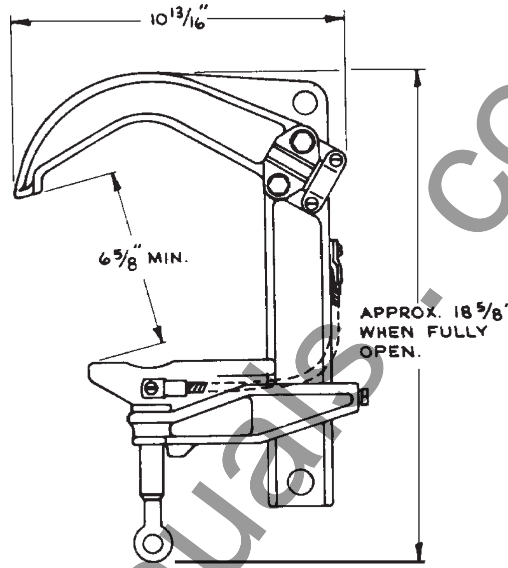


Fig. 9

C600-0337

MECHANICAL CAPACITY

Fig. 9-1

MAIN LINE		TAP
MAX.	MIN.	
6.62 O.D	4.50 O.D	(2) 4/0 Straight Stud Terminal

ELECTRICAL CAPACITY

Rated Current Capacity Outdoors with 4/0 Copper Tap		
CONTINUOUS CURRENT	FAULT CURRENT	
	15 CYCLES	30 CYCLES
550 AMPS	40,000 AMPS	30,000 AMPS

current rating, the clamp shown in Figure 11 offers another feature worthy of attention. It has the ability to swivel so that it can be connected readily in difficult areas such as on the conductor at the end of a string of deadend insulators.

Item No. 2 is "Choose adequate capacity cables." Three major considerations should be kept in mind when choosing the cable. One, the terminal capacity must be adequate. The terminals used on Chance grounding cables are designed and tested to ensure good mechanical and electrical interfaces between the cable and the clamp. The terminals are designed for strong, low resistance connection with the clamp by matching the terminal interface to the clamp. The design of machined ferrules provides intimate and solid mechanical and electrical crimping characteristics so that the cable is captivated to withstand the severe mechanical forces of short circuit current and to provide minimum voltage drop in the cable circuit.

The second consideration in choosing the cable is cable size. The electrical system characteristics which are used in choosing the proper size are magnitude on the greatest realizable current on the system and time duration of that current. The cable chosen must not fuse during this service since a fused jumper cable has a rather high resistance and resultant high voltage drop. Figure 12 shows fusing curves for various sizes of copper conductors as a function of current and time in cycles at 60 hertz. The maximum realizable system current can be located along the abscissa which is given in amperes times 1000. The number of cycles for which the cable will be subjected to the maximum system current is located on the right hand ordinate given in cycles at 60 hertz. As an example, a system with a maximum fault current of 20,000 amperes for 30 cycles duration would have an intersection near the 1/0 cable curve. To ensure against cable fusing during fault conditions a cable above the 1/0 size would be chosen.

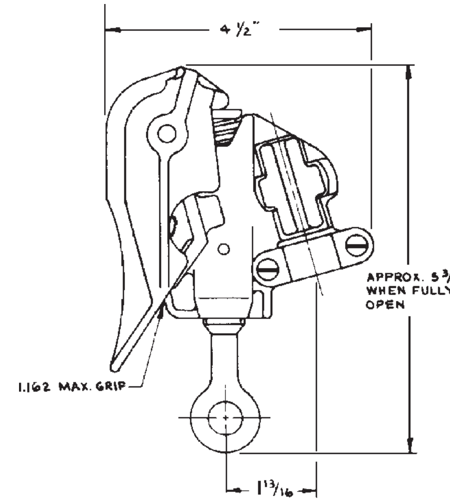


Fig. 10

C600-0434

MECHANICAL CAPACITY

Fig. 10-1

MAIN LINE		TAP
MAX.	MIN.	
1.162 O.D	.162 O.D	2 to 4/0 Ground Terminal

ELECTRICAL CAPACITY

Rated Current Capacity Outdoors with 4/0 Copper Tap		
CONTINUOUS CURRENT	FAULT CURRENT	
	15 CYCLES	30 CYCLES
400 AMPS	42,500 AMPS	30,000 AMPS

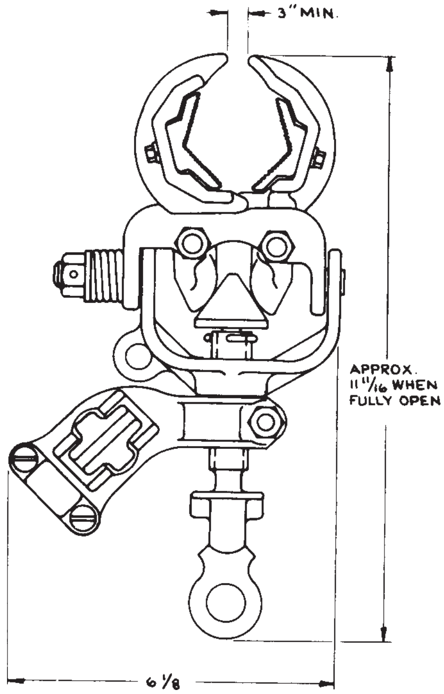


Fig. 11

G4228-10SJ

MECHANICAL CAPACITY

Fig. 11-1

MAIN LINE		TAP
MAX.	MIN.	
2.88 O.D	.258 O.D	2 to 4/0 Ground Cable

ELECTRICAL CAPACITY

Rated Current Capacity Outdoors with 4/0 Copper Tap		
CONTINUOUS CURRENT	FAULT CURRENT	
	15 CYCLES	30 CYCLES
400 AMPS	40,000 AMPS	30,000 AMPS

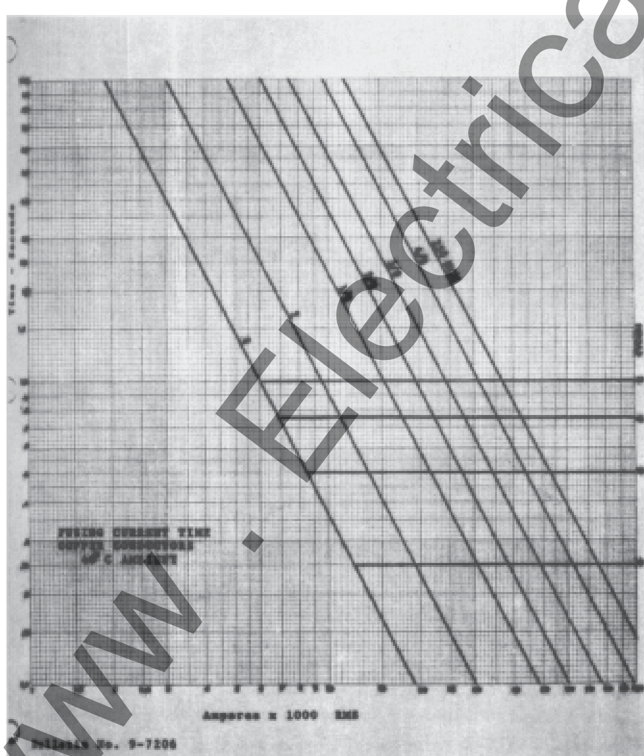


Fig. 12

The third consideration in choosing the cable is to relate the maximum system current, and the jumper resistance so that the voltage drop across the work area is ensured of being at a safe level. The work site will generally dictate jumper length. From the jumper length and the voltage drop which will be safely tolerable across the work site it then becomes necessary to choose a cable size offering low enough resistance. In some instances this may entail use of parallel jumpers to ensure that under maximum system currents the work area voltage drop is sufficiently low.

Item 3 is "Clean connections". The surface to which a clamp connects is generally corroded, contaminated or in the case of structure connections possibly even insulated by paint. This high resistance surface will add significant voltage drop to the jumper circuit. To get the surface clean and ensure a low voltage drop, the conductor should be wire brushed. Some structure surfaces may have to be filled and brushed before clamps are applied. From an operating standpoint it would be desirable to accomplish the cleaning without a separate brushing operation. At the A. B. Chance Research Center we have conducted extensive testing with clamps applied to contaminated conductors. While we are firm advocates of cleaning conductors prior to applying clamps, we have established that the serrated jaws of ground clamps such as pictured in Figure 13 do serve to penetrate surface corrosion and provide a satisfactory low resistance contact between the clamp and the conductor when a separate cleaning operation is impractical. The clamp should be lightly tightened in place, given a slight rotation on the conductor to allow cleaning action by the serrated jaws and the clamp should then be securely tightened in place.

In addition to the serrated jaws for aid in removing corrosion during clamp installation the flat face clamp shown in Figure 14 provides an extra margin of corrosion penetration. This is accomplished by means of a cone pointed setscrew. After the clamp has been lightly tightened, rotated and then securely tightened on the bus or tower structure, the setscrew is tightened to ensure penetration of any remaining surface contamination.

Item 4 is "Locate Clamps for Jumpering". The key to maintaining a safe work area is to keep the voltage drop across it at a minimum. The jumpering diagram shown in Figure 15 and its electrical equivalent shown in Figure 16 point out the key factors of phase-to-phase jumpering combined with jumpers connected to the system neutral and to the structure at a point immediately below the work area.

Item 5 is "Minimize cable slack". An obvious consideration is that shorter cables offer low resistance. However and of greater importance is the fact that tremendous forces are involved during fault currents. These forces result in severe and dangerous cable movements in the case of excessive cable slack. Words cannot begin to express the importance of proper cable routing to avoid

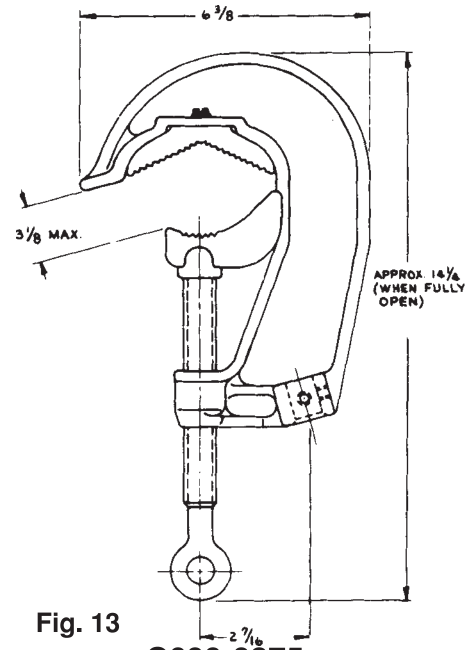


Fig. 13

C600-0375

MECHANICAL CAPACITY

Fig. 13-1

MAIN LINE		TAP
MAX.	MIN.	
3.00 O.D	.50 O.D	(2) 4/0 THREAD Stud Terminal

ELECTRICAL CAPACITY

Rated Current Capacity Outdoors with 4/0 Copper Tap		
CONTINUOUS CURRENT	FAULT CURRENT	
	15 CYCLES	30 CYCLES
400 AMPS	70,000 AMPS	70,000 AMPS

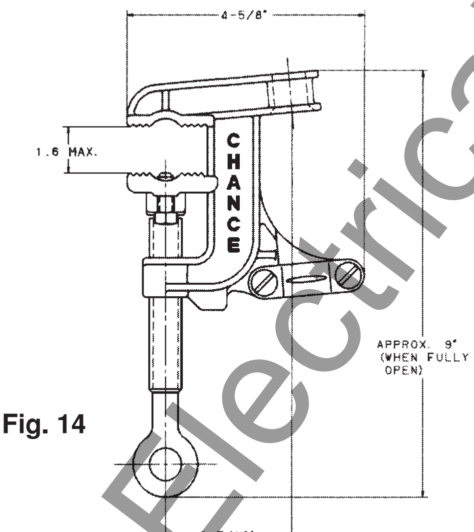


Fig. 14

C600-2332

MECHANICAL CAPACITY

Fig. 14-1

MAIN LINE		TAP
MAX.	MIN.	
1.5 O.D..	0.125 O.D.	2 TO 4/0 Ground Cable

ELECTRICAL CAPACITY

Rated Current Capacity Outdoors with 4/0 Copper Tap		
CONTINUOUS CURRENT	FAULT CURRENT	
	15 CYCLES	30 CYCLES
400 AMPS	43,000 AMPS	30,000 AMPS

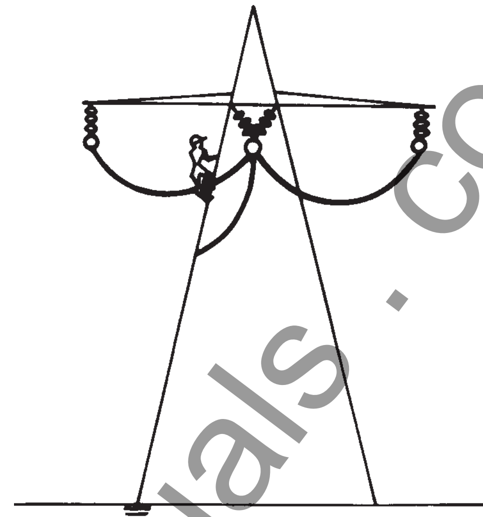


Fig. 15

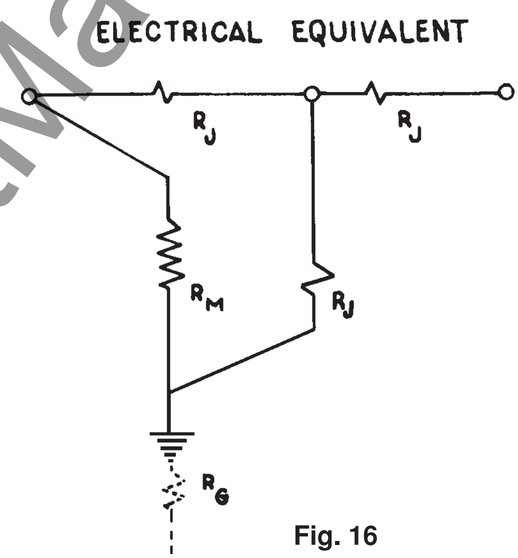


Fig. 16

excessive slack. A film including high speed movie footage taken during grounding and jumpering tests at the A. B. Chance Research Center vividly portrays the importance of minimizing cable slack as well as several other aspects of grounding and jumpering discussed in this chapter. Films (No. 25 and 52) are obtainable on loan from the Chance Advertising Department.

Therefore, this list of five major considerations is the basis for safe grounding and jumpering.

1. Choose adequate capacity clamps
2. Choose adequate capacity cable
3. Clean connections
4. Locate clamps for jumpering
5. Minimize cable slack

These are indeed the keys to safe work on de-energized systems.

Selecting ground clamps and cable

To serve your particular needs, the Chance grounding line comprises both ready-made sets and separate components for your specifications. Among the options and criteria to consider:

• Functional fit — Sizes of the clamp types in Chance Tool Catalog Section 3000, Grounding Equipment, appear in ascending order of maximum-main-line size. By design, many clamps serve a wide range for their conductor type (cable, bus or tower).

• Adequate capacity — Published ratings for both clamps and cable must withstand maximum-potential system fault-current magnitude and full-time duration. Certified test reports are available on request.

• Coordinated connectors — Terminal (either pressure-type or threaded-type) selected for clamps dictates the cable-ferrule type (either plain or threaded) to match.

• On-site handling — Application clearances and fit (for overhead conductors and ground wires, transmission tower shapes, URD apparatus or substation buswork) affect clamp and cable dimensions.

How to order a Grounding Set

In addition to the specifying criteria above, each part of a grounding set requires certain choices:

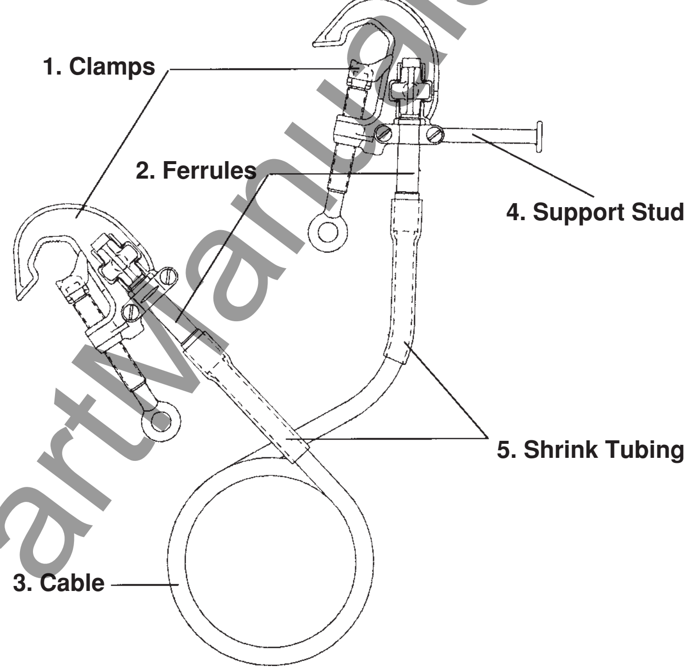
1. Clamps
•ASTM designations for Type, Class and Grade for clamps shown in Chance Tool Catalog Section 3000.

2. Ferrules
•Copper or aluminum. •Plain or threaded.

3. Cable
•Length required to reach application distances.
•ASTM Type I with black or yellow elastomer jackets for temperatures from -40°F (-40°C) through +94°F (+90°C).
•ASTM Type III with clear thermoplastic jacket for temperatures from +14°F (-10°C) through +140°F (+60°C) should be used only in well-ventilated areas.

4. Support Stud
•This option recommended on only one clamp to help control lifting the set to the first clamp attachment point.

5. Shrink Tubing
•This translucent option recommended for stress relief and inspection of cable strands between ferrule and jacket.



Reference:

Derived from ASTM F 855, Standard Specifications for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment

Grounding Set Ratings

Short Circuit Properties[A]								
Withstand Rating, Symmetrical kA RMS, 60 Hz			Ultimate Rating/Capacity,[B] Symmetrical kA RMS, 60 Hz				Continuous Current Rating, A RMS, 60 Hz	Minimum Cable Size with Ferrule Installed Equal or Larger Than
15 cycles (250 MS)	30 cycles (500 MS)	Copper Cable Size	6 cycles (100 MS)	15 cycles (250 MS)	30 cycles (500 MS)	60 cycles (1 S)		
14	10	#2	29	18	13	9	200	#2
21	15	1/0	48	30	21	15	250	1/0
27	20	2/0	61	38	27	19	300	2/0
34	25	3/0	76	48	34	24	350	3/0
43	30	4/0	96	60	43	30	400	4/0
54	39	250 kcmil or two 2/0	114	72	51	36	450	250 kcmil or two 2/0
74	54	350 kcmil or two 4/0	159	101	71	50	550	350 kcmil or two 4/0

[A] Withstand and ultimate short circuit properties are based on performance with surges not exceeding 20% asymmetry factor (see Appendices X3 and X4, ASTM F 855).
[B] Ultimate rating represents a symmetrical current which the clamp shall carry for the specified time.

Substation grounding — special considerations

As the ratio of inductive reactance to resistance (X_L/R) increases near and in substations, so also do fault currents become more asymmetrical. This increases heating and mechanical forces to levels beyond requirements for on-line applications. For these severe applications, special attention must be given to grounding-clamp selection. Working toward additional guidance in this regard are ASTM and IEEE. For a typical substation with an X_L/R of 14 — the IEC (International Electro-Technical Commission) grounding standard for this application — Chance has successfully tested at 43,000 amperes for 15 cycles these clamp catalog numbers: G3367-2, G4229-1SJ, C600-1743, C600-0065, C600-1733, C600-1783, T600-0658 and C600-0337. For specifics on each clamp, see Chance Tool Catalog Section 3000.

CHAPTER II

PROTECTIVE GROUNDING FOR LINE PERSONNEL

The three basic method of protecting linemen are to:

(1) Insulate the energized conductors and other energized parts.

(2) Isolate all energized conductors and energized parts from the work area.

(3) De-energize and place protective grounds on each side of the work area.

For Number (1), rubber and plastic cover equipment should be used through the distribution voltages designated as safe for the insulation method.

For Number (2), hot line tools should be used to detach and remove from their insulated supports, on the structures, the energized parts, thus isolating the work area by moving all energized parts beyond reach.

The third method is the one to be discussed today — de-energized lines by forces of nature, failure of parts, vandalism or a planned outage. Regardless of how the line becomes de-energized, a routine procedure has to be followed before the linemen can work safely. Remember, if you can't see both ends, it's hot. — If it isn't grounded, it isn't dead.

Since we can't see both ends, we have to get word from the load dispatcher or dispatchers at each end of the line to be sure there is no chance for possible back feed and that all switches have been opened and hold tags placed on them. The hold tags will be assigned to the supervisor in charge of the work and can only be removed when that supervisor, whose name is on the hold tag, calls in and reports all work completed, all grounds removed and all men in the clear.

On lower voltage lines coming from unattended stations, a troubleman or member of the line crew is told what circuit is to be de-energized by opening the recloser by number and the air break switch by number and placing the hold tag on the air break switch handle or on the lock.

In no case should anyone consider automatic switching devices, such as oil reclosers, as a switching clearance to de-energize the line for safety. On rural lines, if there is no visible air break on the circuit, the leads from the recloser to the section of line to be worked should be removed. Precautions will have to taken in removing the first two leads if there is an ungrounded transformer bank beyond the reclosers. The first two leads could be "hot" and provisions should be made to keep them away from men and any part of the structure until the last one is removed from the recloser.

With all the above, there is no guarantee to the linemen that the line is de-energized and safe to contact. Although infrequent, the wrong switches could have been opened through bad communications or human error. Today, two-way radios have eliminated some of the communication problems. There is also the possibility of accidental contact with an adjacent line or on crossovers. A car striking a pole or weather conditions have caused many accidental contacts. All of these possibilities make grounding absolutely necessary.

In 1954 Messrs. Harrington and Martin with Booneville Power Administration made tests to determine safe working conditions for linemen should the line they were on be accidentally energized. This information is contained in an A.I.E.E. Paper No. 54-206, dated July 9, 1954. They found the accepted rule, by most companies, of installing protective grounds on adjacent towers to the one being worked on, would not provide adequate protection should the lineman contact the tower or conductors during accidental energization of the line. They also determined that short circuiting and grounding all conductors at the work location, using leads and clamps of adequate current carrying capacity, would provide sufficient protection for the linemen. Their report caused many companies to reevaluate their grounding equipment and grounding practices. Many utilities made a complete study of their fault currents and found their equipment and practices to be inadequate to protect the linemen should the line be accidentally energized.

Their study revealed the size conductors used in ground leads were in some cases too large. Such excessively large size conductors were unnecessarily costly and the extra weight made the equipment difficult to use. In some cases, the diameter of leads were too small as fault currents were continually going up. They also found their clamps didn't have adequate current carrying capacity. In many instances, hot line clamps were being used instead of ground clamps. Hot line clamps were never designed and tested for ratings for continuous current and fault currents at 15 and 30 cycles. Since the Booneville test in 1954, Chance has joined forces with several operating companies conducting extensive study and test programs on grounding equipment in our laboratory. Some of the equipment tested was on the operating utilities line trucks, including weathered and corroded wire of various sizes, which was removed from service. Ground clamps in some cases were attached to a piece of corroded conductor. These burned the conductor in two at 3 to 5 cycles and 10,000 amps. After the conductor received minor cleaning, the same equipment withstood in excess of 11,000 amps for 25 cycles, which is required for a safe operation.

In over 200 field and laboratory tests in a joint program between Philadelphia Electric Company and Chance, six ground clamps were developed with replaceable serrated jaw inserts that clean both the ground and conductor during attachment. The serrations on the aluminum alloy inserts bite through enough of the corrosion to make a safe connection during normal clamp installation. Where the attachment is on a heavily corroded area, rotating or moving the clamp as it is tightened causes a scrubbing action that cleans away corrosion, making a low resistance contact.

With the high forces set up on short circuits, the clamps, cable and cable attachments must provide adequate mechanical strength. Periodic inspection for broken strands that can weaken the grounding leads, electrically and mechanically, is very important.

After the Philadelphia Electric — Chance grounding tests, Chance conducted other tests with other utilities on heavy distribution and subtransmission circuits to determine what would be needed in the way of cable sizes, clamps and ferrules to handle these higher fault conditions and provide protection to their line personnel. Along with these tests, different types of grounding procedures were studied to find safe and easier working methods.

Violent action on long leads on high current tests indicated that phase-to-phase jumpers would be the best method of reducing the violent action of ground leads coming down the pole in the lineman's working area.

When grounding on distribution systems, the common neutral or system ground should be considered for the ground end of one or more ground leads.

For ungrounded systems, a screw or driven ground rod should be employed to establish ground and a lead coming up the pole and attaching to a metal bracket or ground support below the work area should be used.

After the cable support has been grounded at ground, one cable lead or jumper should run from the ground support, attached to the pole, to one phase using that phase as the ground source for the jumpers for the other two phases.

The best procedure found for single pole distribution and subtransmission is to ground from the ground bracket on the pole to one of the outside phases. Then a jumper from the grounded outside phase to the middle phase and the third jumper from the middle phase to the other outside phase.

In some single pole structures it may be advisable to ground the two bottom phases through the metal bracket on the pole, then one of the bottom phases to the middle or top phase. This would be particularly true on two-arm construction.

Where shield wires are used, it is also a good idea to bond or jumper the nearest phase with another jumper from the shield wire to one of the bonded phases. The leads should be kept as short as possible and, in many cases where longer leads are used, they can be pushed farther away from the pole to shorten them and to get them out of the workman's way.

Some utilities have adopted what we believe to be the safest grounding procedure for transmission. They ground all three phases at each end of the area. This might involve several crews on a major job or perhaps several structures to be worked by a single crew. In addition to placing a ground at each end of the work area, they also require what may be considered a personal ground for the phase the crew is working on. This not only gives the lineman better protection, but also assures him that no mistake has been made in de-energizing the line when the personal ground is placed adjacent to the work area.

On ungrounded distribution circuits and subtransmission, guy wires should also be bonded to grounded phases. The safest position for a lineman on a pole where shield wires are available is to establish a ground below his feet and also a ground from the shield wire down to the grounded conductor.

Figure 1 shows a typical 69 kV 3-phase installation where the ground bar is placed below the lineman's feet with a jumper being installed from a screw ground rod to the grounding bar. The second ground jumper is placed from the grounding bar to the outside phase. The third jumper is installed from the bottom phase to the top phase. If a static wire is attached to the pole, this should be tied into one of the phase wires.

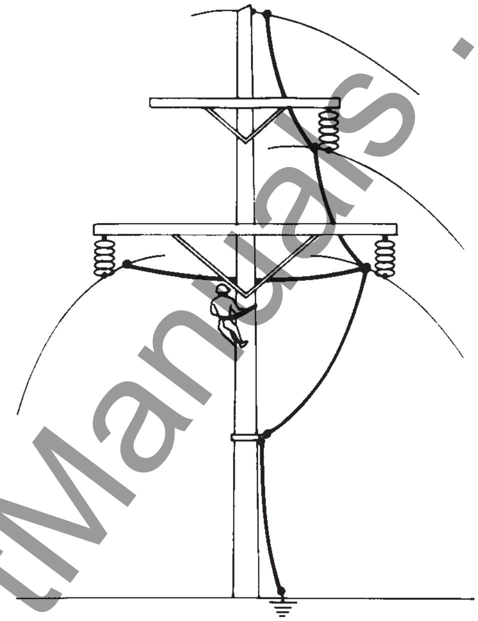


Fig. 1

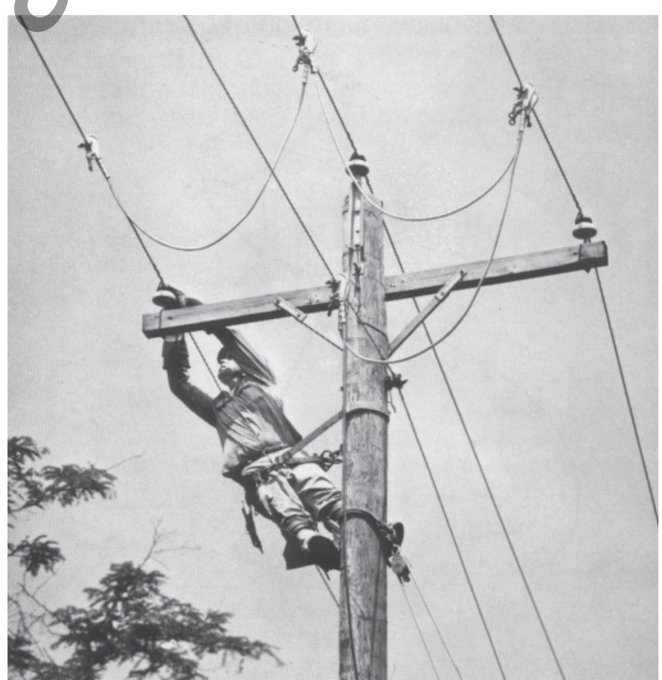


Fig. 2

A typical jumpering operation is shown on Figures 2 and 3 which are probably the most popular structures and consist of 3 phases and a neutral wire. You will note in all cases that we stress that the grounding bar be placed below the lineman's feet to keep him and the structure at the same potential.

This procedure calls for a jumper connected from the grounding bar to the neutral bar with a jumper running from the bar to the screw ground rod. A jumper is then placed from the grounding bar to the middle conductor with phase-to-phase grounding techniques used from this point.

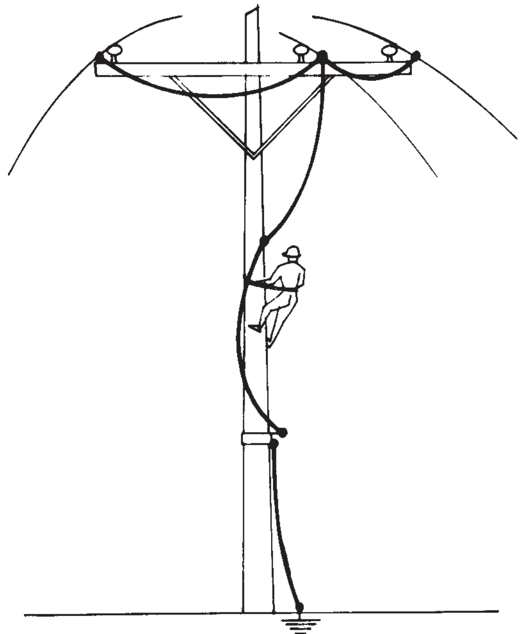


Fig. 3

Figure 4 – Grounding of Steel Poles. When jumpering conductors on steel poles, certain attachments are necessary for adequate grounding. This can be accomplished three ways:

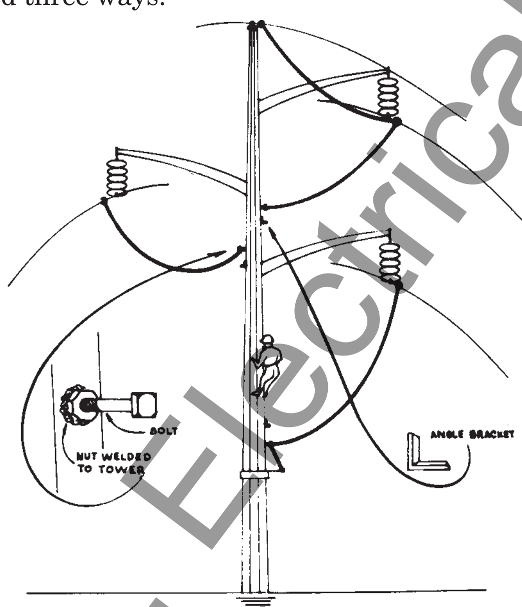


Fig. 4

a. Weld a nut on the pole for installation of a ground lug shown in Figure 4. When this nut is not in use, a plastic cap should be inserted in the nut to keep moisture and contamination out. Before inserting lug, make sure that the lug is clean and also that the threads on the nut welded to the pole are clean. A non-oxide should be placed on the threads of the nut and stud for a good electrical connection.

b. A small angle can be welded to the pole which will serve the same purpose as the lug.

c. A portable grounding bar can be placed on the pole with a screw tightener. The most important point in using this bar is that the two set screws located one on each side of the grounded bar be tightened so that the set screw point will penetrate the galvanizing or paint to insure a good electrical connection.

We realize that by tightening down on this set screw, it will damage the galvanizing or paint, but a suitable primer or paint can be applied to the damaged area to prevent rust. The most important thing is to have a good electrical connection to protect the lineman working on the structure.

You will note that the same jumpering procedure is used as Figure 1 except that the jumper going from the ground bar to the screw ground rod was eliminated. The pole is being used to replace this jumper.

Figure 5 – The H fixture is one of the most common structures on voltages from 69 kV through 345 kV single

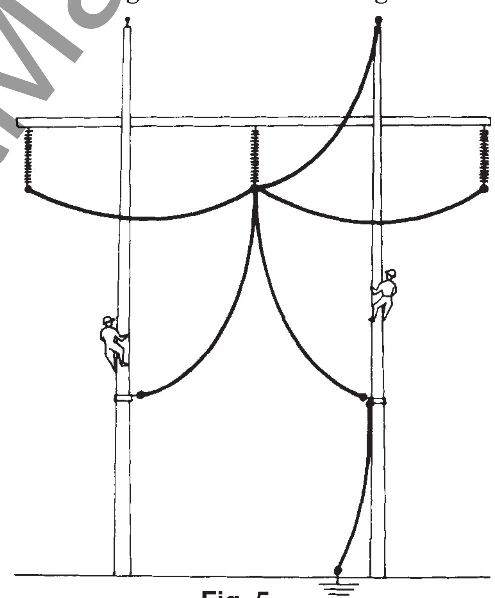


Fig. 5

and bundle conductor. Install a grounding bar below the lineman's feet, jumper from grounding bar to screw ground rod. If there is a pole ground on the pole, jumper this ground to the grounding bar. Step No. 1 – Jumper from the grounding bar to the middle phase. No. 2 – Jumper from the middle phase to one of the outside phases. No. 3 – Jumper from the middle phase to the other outside phase. No. 4 – If there is static wire on the pole, jumper from the static to the middle phase. No. 5 – In the case where there are two linemen required on the structure, a ground bar should be placed below the second lineman's feet and a jumper placed from the bar to the middle conductor.

Where you have long phase spacing, it may be difficult for one lineman to control the jumper leads, however, by using two linemen and tying a handline in the middle of the jumper to control the weight, the lineman will experience little difficulty in making the recommended

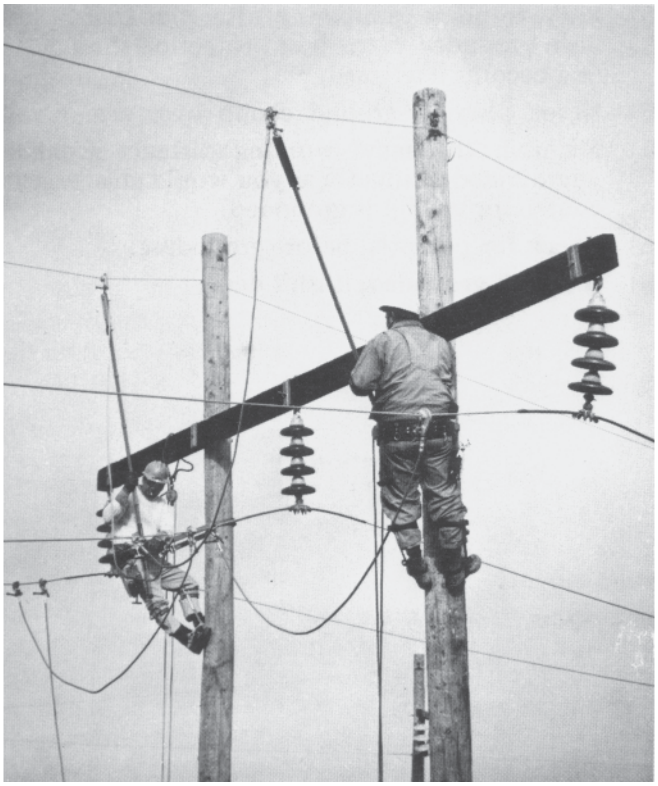


Fig. 5A

ground connections. In cases where there is bundle conductor, it is recommended that each conductor of the bundle be grounded.

GROUNDING ON STEEL TOWERS

Safety rules vary from utility to utility. Some companies allow their linemen to ground directly over the conductor while some require that they ground from below the conductor as shown in Figure 6.

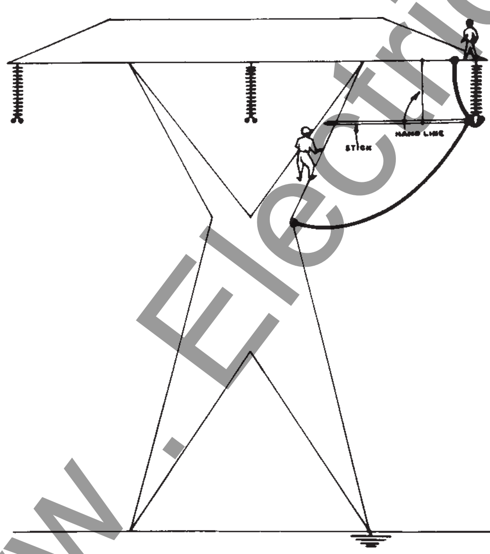


Fig. 6

One method for grounding directly over the conductor where bundle conductors are used is shown in Figure 7 – (grounding bar) using a single jumper attached to the tower and the middle of the grounding bar. This bar can be lowered into position with a handline or a gripall clamp-stick. After the grounding bar is positioned so that the clamps seat on the conductor, the eye screws can be tightened, thus giving a good jumpering attachment to the bundle conductor.

In the case where you cannot ground directly above the conductor, the handline can be placed approximately in the middle of the crossarm overhead. The tower end of the jumper should be attached firmly to the tower leg below the lineman's feet and the handline attached to the stick used to put the ground on the conductor end. By attaching the handline to the grounding stick, the lineman does not have to lift the weight of the jumper, but can guide the ground clamp onto the conductor and tighten it securely. It is recommended that all conductors of the bundle be jumpered. This can be accomplished by running separate leads from the tower to the bundle conductor or using a short jumper, grounding each conductor in the bundle.

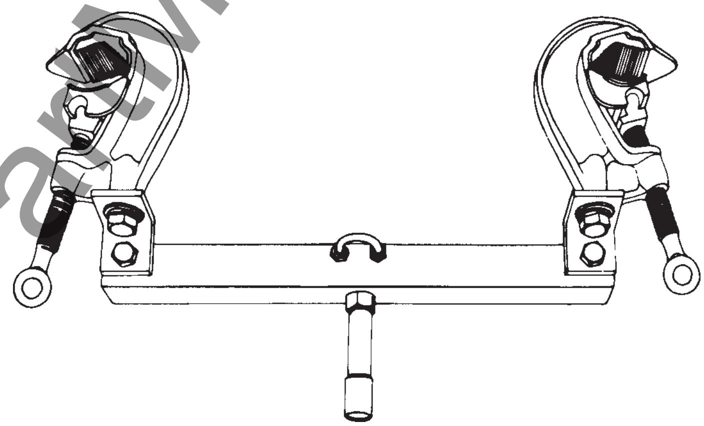


Fig. 7

We recommend phase-to-phase jumpering but with the larger phase spacing, it may seem quite difficult. In which case, the crossarm could be considered the phase-to-phase ground. However, serious consideration should be given regarding ground resistance between the connection points.

We have conducted tests on corten steel and found that with all the various connection points and the resistance built up in the corten at the connection points, an adequate ground is not obtainable. A separate jumper must be run down the tower and tied into the counterpose and static wire, if not insulated, to obtain a good ground connection.

For restricted-space applications and as a truck-grounding system, a compact ball and socket clamp design delivers a high-current rating usually associated with only large clamps. See Figure 8.

It applies to a wide range of switching equipment, including:

- Industrial metalclad gear,
- Substations — indoors and out,
- Distribution — overhead and underground.

For trucks, a ball stud permanently mounts on each body.

Two clamp styles and two ball-stud lengths adapt to many applications. Clamp bodies, eyescrews and ball-studs are bronze alloy. Tin-plated ball-studs have nominal 1"-diameter ball and stud to fit NEMA terminal pads. Lockwasher and nut are silicone bronze.

ASTM Designation of Type I, Class A, Grade 5.

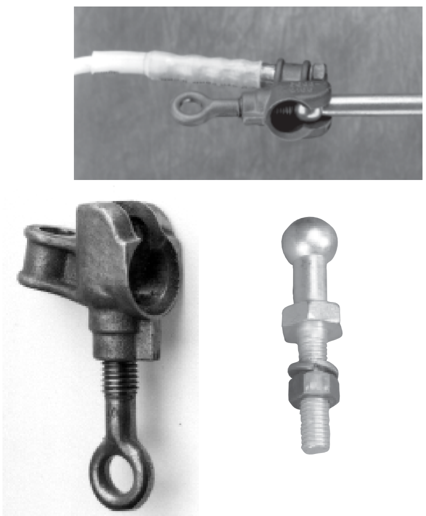


Fig. 8

For underground cables, penetrator ground sets are available wih chisel- and spike-point clamps. See Figure 9.

Chisel-point clamp main-line capacity is 1½". C-Type clamp in Chisel Sets fits conductors from #6 (0.162") to 636 kcmil ACSR (0.998").

Spike-point clamp main-line capacity is 2½". C-type clamp in Spike Set fits conductors from #6 (0.162") to 2" O.D. bus.

Each set includes 6-ft. of #2 copper clear-jacket ground cable and ferrules, a penetrator clamp (choice of hardened-steel ½"-wide chisel or conical spike) and C-type grounding clamp.

Screw-type copper-clad ground rod in sets indicated is 24" long for easy handling. The helix (spiral), handle and wing nut are bronze.

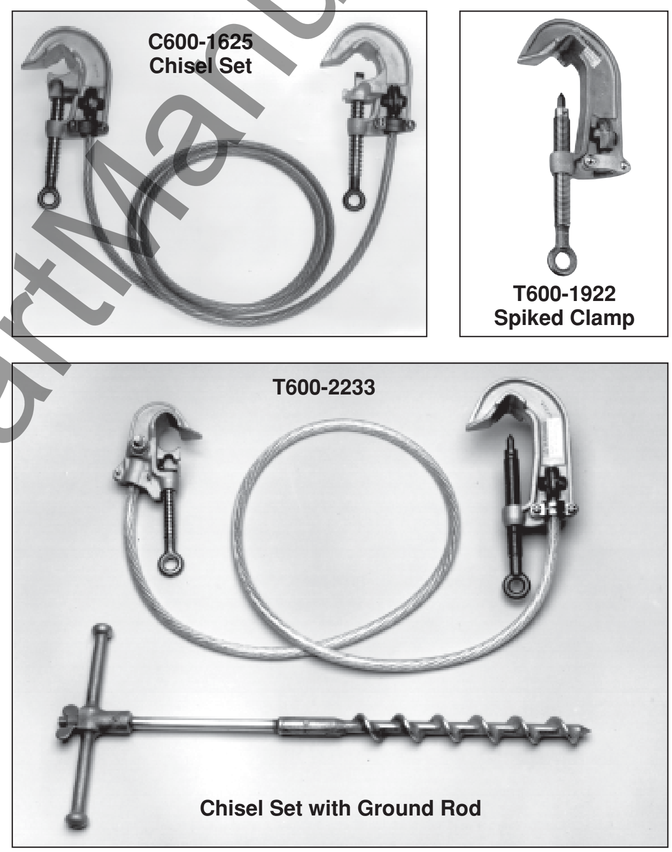


Fig. 9

Traveling grounds are required when stringing conductors in close proximity to energized conductors. There have been many accidents reported where conductors have inadvertently contacted an energized conductor causing serious injury. Also, the traveling ground will bleed off any static buildup due to inductance from energized conductors. See Figure 10.

A traveling ground is required on all conductors being strung. The jumper lead going from the traveling ground should be attached to the system neutral. The traveling ground should also be jumpered to the stringing or breaking rig.

When removing conductors from the stringing blocks for clipping in, the conductors should be adequately grounded before removal from the stringing sheave. Do not depend on the conductive liner on the sheave wheel as this liner does pick up residue from the conductor.

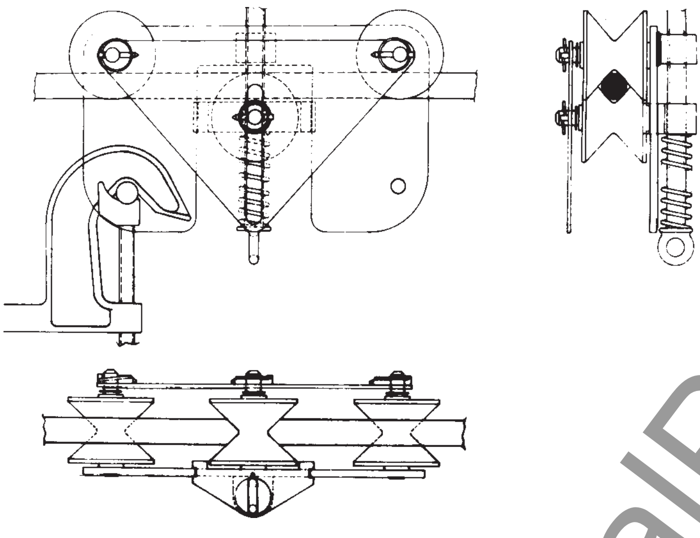


Fig. 10

A rotating ground tool is mounted on the arbor shaft adjacent to the reel of conductor. A ground conductor is installed in the non-rotating collar connector and to a suitable ground provision. The inner end of the reel conductor is then inserted into the ground connector located on the rotating flange. As the reel is turned, electrical ground continuity is assured. See Figure 11.

- The GR-27BS2 has been tested to 27 kA fault current level (2/0 Rating).
- The GR-43BS2 has been tested to 43 kA fault level (4/0 Rating).

Tested per ASTM F855 Standard.

GR-27BS2
GR-43BS2

Fig. 11

Catalog Number	Max. Pipe Dia. (D)	Connector Type	Connector Range
GR-27BS2 (27 kA Rating)	$2^{11}/_{16}$"	Two 1"-diameter Ball Studs	See Ball Stud Clamp on Chance Cat. page 3013 in Tool Catalog.
GR-43BS2 (43 kA Rating)			

SUMMARY

(1) Linemen's protective grounds are one of the most important parts of any line construction tool kit.

(2) Clamps should be selected with adequate continuous current carrying capacity, short circuit carrying capacity and mechanical strength.

(3) Cable and cable attachments to the ground clamps should have adequate current carrying capacity and mechanical strength.

(4) Install grounds as close to the work area as is possible. On transmission voltages, in addition to grounding all three phases at each end of the work area, a personal ground should be used at the work location on the phase being worked on.

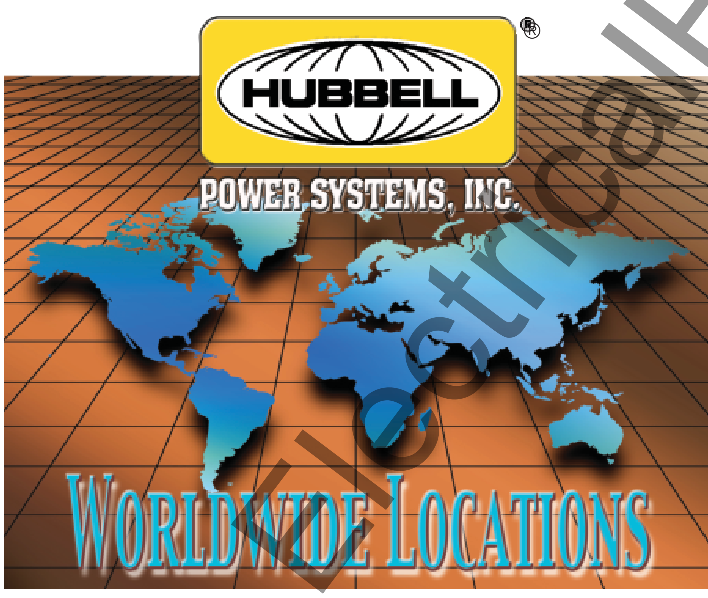
(5) Phase-to-phase jumpering after one phase has been grounded is the best protection should the line become energized.

(6) Never place a ground clamp over armor rod.

(7) Maintain the same working distance from an ungrounded conductor as you would an energized conductor until it is grounded.

(8) Check for potential before grounding.

(9) If it isn't grounded, it isn't dead.



UNITED STATES
HUBBELL POWER SYSTEMS, INC.
210 N. Allen
Centralia, Mo 65240-1395
Phone: 573-682-5521
Fax: 573-682-8714
e-mail: hpsliterature@hps.hubbell.com

MEXICO
HUBBELL DE MEXICO, S.A. DE. CV
Av. Coyoacan No. 1051
Col. Del Valle
03100 Mexico, D.F.
Phone: 52-55-9151-9999
Fax: 52-55-9151-9988
e-mail: vtasdf@hubbell.com.mx

CANADA
HUBBELL CANADA, INC.
870 Brock Road South
Pickering, Ontario L1W 1Z8
Phone: 905-839-1138
Fax: 905-831-6353
e-mail: infohps@hubbellonline.com

ASIA
HUBBELL S.E. ASIA PTE. LTD.
23 Tagore Lane #03-16
Tagore 23 Warehouse
Singapore 787601
Phone: 65-6454-4772
Fax: 65-6454-4775
e-mail: hpsliterature@hps.hubbell.com

Web: http://www.hubbellpowersystems.com
E-mail: hpsliterature@hps.hubbell.com

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