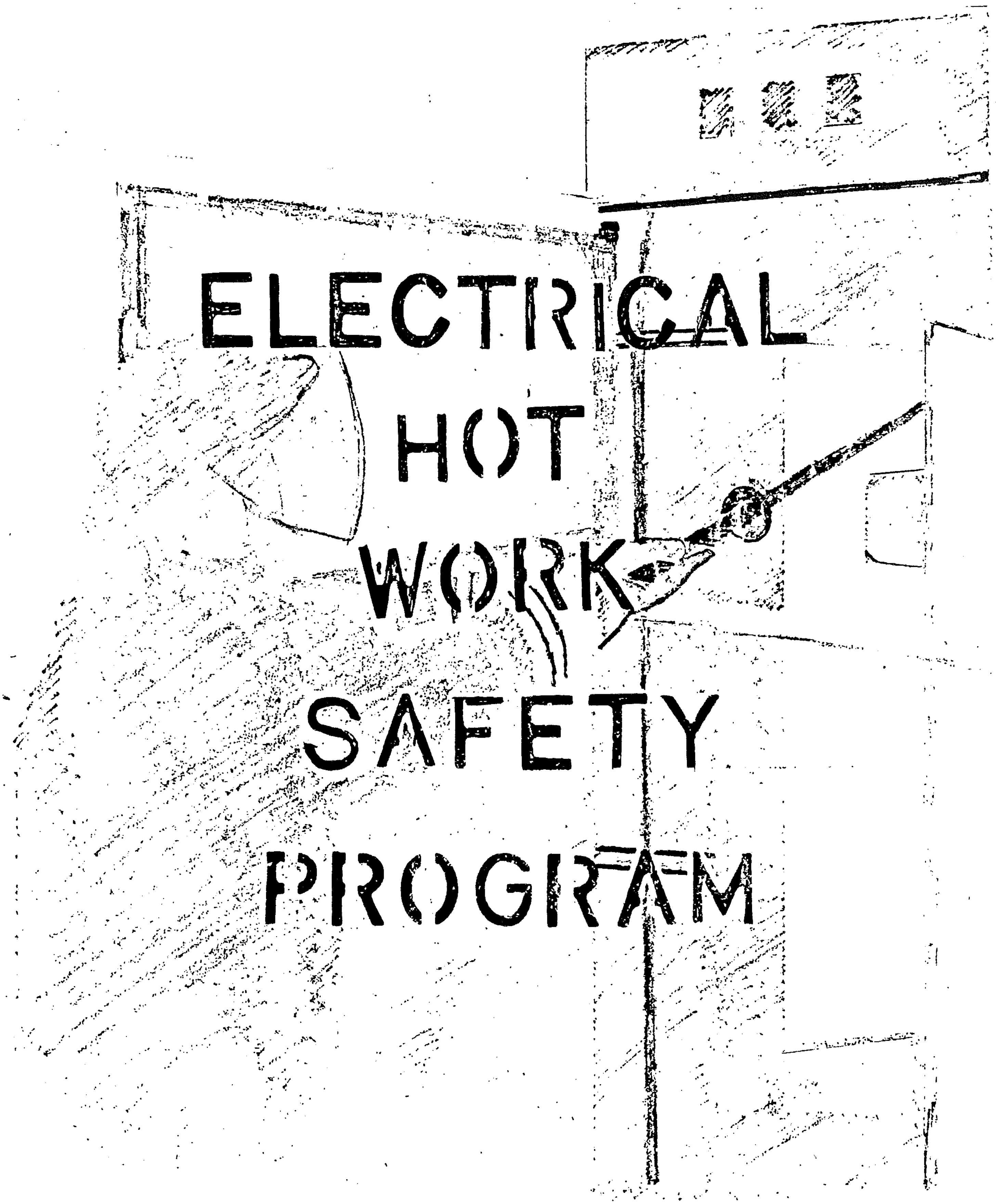
ELECTRICAL HOT WORK SAFETY PROGRAM



J.M.GALLAGHER
L.B.McCLUNG

TITLE

ELECTRICAL HOT WORK SAFETY PROGRAM

AUTHORS

J.M.GALLAGHER. 711 FROST COURT, SARNIA. ONTARIO. N7S 4H2.

L.B.McCLUNG. 631 JANE STREET, CHARLESTON. W.V. 25302.

This book represents information assembled from respected sources on electrical safety. A wide variety of references from which excerpts were taken are listed. Every reasonable effort has been made to give reliable data and information, but the authors cannot assume responsibility for the validity of all materials or for the consequences of their use.

First Edition, First Printing, October 1987. $ U.S.

ACKNOWLEDGEMENTS

The policies being expounded upon herein are those being developed and promoted by the authors. While the authors are employed full time in heavy industry and have drawn upon their experience and those experiences of their co-workers, the policies are seperately derived.

Grateful thanks are due to Andy Freed, Ted Vale, Ernie Gelinas, George Kingston, and Ron Lobb for use of illustrative photographs containing their pictures, to Bob Deaton for use of the BASIC program for calculation of distances associated with arc flash burns during electrical hot work procedures, and to Sarah Gallagher for cover page and other artwork. Special support was given by Ian Blackwood and Tom Raby who shared the enthusiasm of the authors from the start.

Love and indebtedness is expressed to Linda Gallagher for her typing the manuscript, and to Sue McClung for her editorial work. Without their patience, understanding and encouragement this work would still be a hoped for document.

Finally, having made it through the writing it is dedicated to our deep and mutual friendship.

J.M. "John" Gallagher.

L.B. "Bruce" McClung.

PREFACE

We have learned much about electrical hot work safety in the course of writing this book. An attempt has been made to describe the most recent information while at the same time set out tried and proven practical concepts. Situations taken from individual experiences are described. Details of an established, successful electrical hot work safety program that has been developed for all personnel who work in an area influenced by the presence of energized electrical equipment are presented. A focus is directed toward general features of philosophy and controls that when practiced on a regular basis will lead proponents into the awareness and discipline needed to safely perform the electrical hot work.

Although the expected prime readership will be plant electrical engineers, electrical specialists and those safety and health engineers interested in electrical hot work safety, the book will also be useful to production and management supervisors who must set policy and audit performance of work under potentially hazardous electrical work conditions. We must emphasize that an overall electrical hot work safety program for industrial concerns is not designed for any bare hands live line work. It is the intent to study alternatives such as planned de-energization for repair and replacement. However any electrical equipment should be considered "hot" until proven otherwise. The process of switching out of service, tagging and locking out, checking and testing for isolation, and de-energizing by application of temporary grounds should be handled as electrical hot work.

INDEX

CHAPTER 1

INTRODUCTION

The Electric Hot Work Safety Program was initially designed for all persons working in or on electrical equipment in a world scale polyethlene plant. It was developed to provide those people with an awareness of the potential hazards from touching exposed electrically energized components and to instill discipline of safe work practices in those people who are required to occasionally perform electrical hot work. The program has since been successfully applied to numerous industrial facilities both in the United States and Canada.

The Electical Hot Work Safety Program brings existing standards, electrical codes, regulations and good work practices together with basic safety principals and interprets them in a practical way. The program shows that through the use of electrical hot work standards and specific electrical hot work procedures, electrical shock and electric arc flash hazards can be eliminated or controlled. It stresses that only qualified personnel, wearing approved personal protective equipment and using approved test equipment and live line tools perform electrical hot work.

The Electrical Hot Work Safety Program is not designed for hands on live line work, it is designed for an intergrated electrical system in a continous process facility where every alternative is investigated before electrical hot work is authorized; ie: electrical circuits are switched out of service, tagged and locked open, are checked and tested for isolation and are de - energized by the application of temporary grounds.

The majority of electrical hot work performed in the world scale polyethlene plant used as an example in this program is from the testing of circuits for isolation, using approved tools to check for isolation, and from the application of temporary grounds on the isolated circuits.

Using the program, all circuits are considered hot until:

* THE CIRCUT HAS BEEN SWITCHED OUT OF SERVICE;
* TAGGED AND LOCKED OPEN;
* CHECKED FOR ISOLATION;
* TESTED FOR ISOLATION;
* DE-ENERGIZED BY THE APPLICATION OF TEMPORARY GROUNDS ON THE ISOLATED CIRCUITS.

CHAPTER 2

INSULATION BREAKDOWN

Most electrical systems rely on multigrade series insulating systems to maintain their electrical integrity.[1] Changes in the characteristics of one or more of the insulating mediums often lead to a deterioration which can result in arcing and/or flashover between phases or between phase and ground.

Most insulation failures are contained within the equipment, with the failed component being quickly removed from the system by circuit protection; ie: fuses, relays and/or circuit breakers. The failures we are primarily concerned with are those directly involving personnel that have the potential of electrical shock or electrical arc flashburn. e.g.:

a) Failure involving personnel in the fault current path or in close proximity to the arcing fault when they are working on or near exposed electrically energized components:

Summary of Incident

Electrical arc flash generated during 15 kv phase check.

Details of Investigation

In 1983 during a " routine " phasing check on a 15 kv service in a petro-chemical complex in Ontario, one man was fatally burned and three men were severely burned. The phasing check was made across an open 15 kv fuse disconnect switch by electrical personnel highly respected in their field of work. The tool used to perform the check was a Phasing Voltmeter/Potential Indicator for use on semi-conductor shield/or capacitive test voltage points, and was clearly marked "DO NOT USE ON ENERGIZED PARTS". The application of this phasing tool was misunderstood. When the tool contacted the live terminals inside the cell the lead between the two probes vapourized and a three phase fault developed.

b) Failure during switching, operation:

Summary of Incident

Switchgear flashed when disconnect was closed.

Details of Investigation

A plant operator was in the process of closing a disconnect switch on a 480 volt motor starter when it faulted and flashed. The operator who was wearing ALL the required protective equipment stood to one side of the switch and turned his face away from the starter during the switching operation. The energy released by the fault blew the starter door open. The electric arc flash released by the open door burned the equipment facing the faulted starter and scorched the operators protective gloves with molten metal. The operator was not injured.

The changes that effect the electrical integrity of an insulation system can be the result of many causes. For example mechanical failure, contamination, thermal failure or, as in the case of an air insulating medium, by a reduction of the air gap between phase and ground. Air is used extensively as an insulating medium. Dry air has better insulating qualities than moist air. Typically, dry air, at 20° degrees Celcius (68°F) and 760 mm (29.92 inches) Hg, atmospheric pressure between small diameter (2 centimeters, .79 inches) electrodes spaced 1 centimeter (.395 inches) apart will break down at approximately 5000 Volts. Moist air will reduce the level of breakdown voltage. Increasing the Volts/CM, Volts/Inches ratio by either increasing the voltage across the electrodes or reducing the air gap between the electrodes will stress the air insulating medium and accelerate the breakdown to the point the air is ionized and arcing occurs between the electrodes.

[2]

The National Electric Safety Code NESC Edition 1984, Page 92 gives a minimum clearance for a guard zone from live parts plus a practical method of calculating air breakdown for voltages above 8,700 volts of 4/10th (0.4) inches per 1000 Volts RMS for outdoor phase to phase spacing.

Electrical systems using air as an insulating medium are designed so that the conductors and components have sufficient clearance between phases and between phase and ground such that the intervening air is not stressed. However, when the ground plane is brought closer to the conductor or component by reducing the effective air gap by parts of a persons body or by tools used as an extension of the persons body, there is always the danger of overstressing the intervening air medium to the point flashover or arcing is produced from the conductor to the tool and/or person.

Personnel exposed to the insulation breakdown while operating the equipment, e.g. switching, racking in circuit breakers or by repairing and testing equipment, can be injured from electric shock or from electric arc flash without touching the exposed electrically energized component.

In Ontario, Canada during the years 1983, 1984 and 1985 the Workmens Compensation Board recorded 794 near electrocutions, 43 of these resulted in death. During a Five Year period 1980 to 1985, 13 Electrical Tradesmen were killed and 91 were severely injured in electrical accidents in Ontario.

CHAPTER 3

THE HAZARDS OF ELECTIC SHOCK

This Chapter is designed to provide a basic understanding of the effects of current flow through the human body. The variables that effect that current flow and the electrical source - human body - ground contact that provides the circuit for the current flow.

The data presented will provide an awareness of the circumstances that produce electric shock accidents and the resultant effects different current magnitudes and shock duration will have upon the human body.

Most industrial electricians, who from time to time may be required to perform electrical hot work, are aware that providing distance between their body or between tools and equipment used as an extension of their body and exposed energized components can eliminate electrical shock hazard. This safe distance in the program is referred to as THE MINIMUM CLEARANCE ZONE. For a current to flow through the human body, a person has to first penetrate the minimum clearance zone and bridge two points of Voltage Potential difference. Some typical simplified examples are. e.g.:

a) Direct physical contact with an exposed electrically energized component is shown in Figure 1.

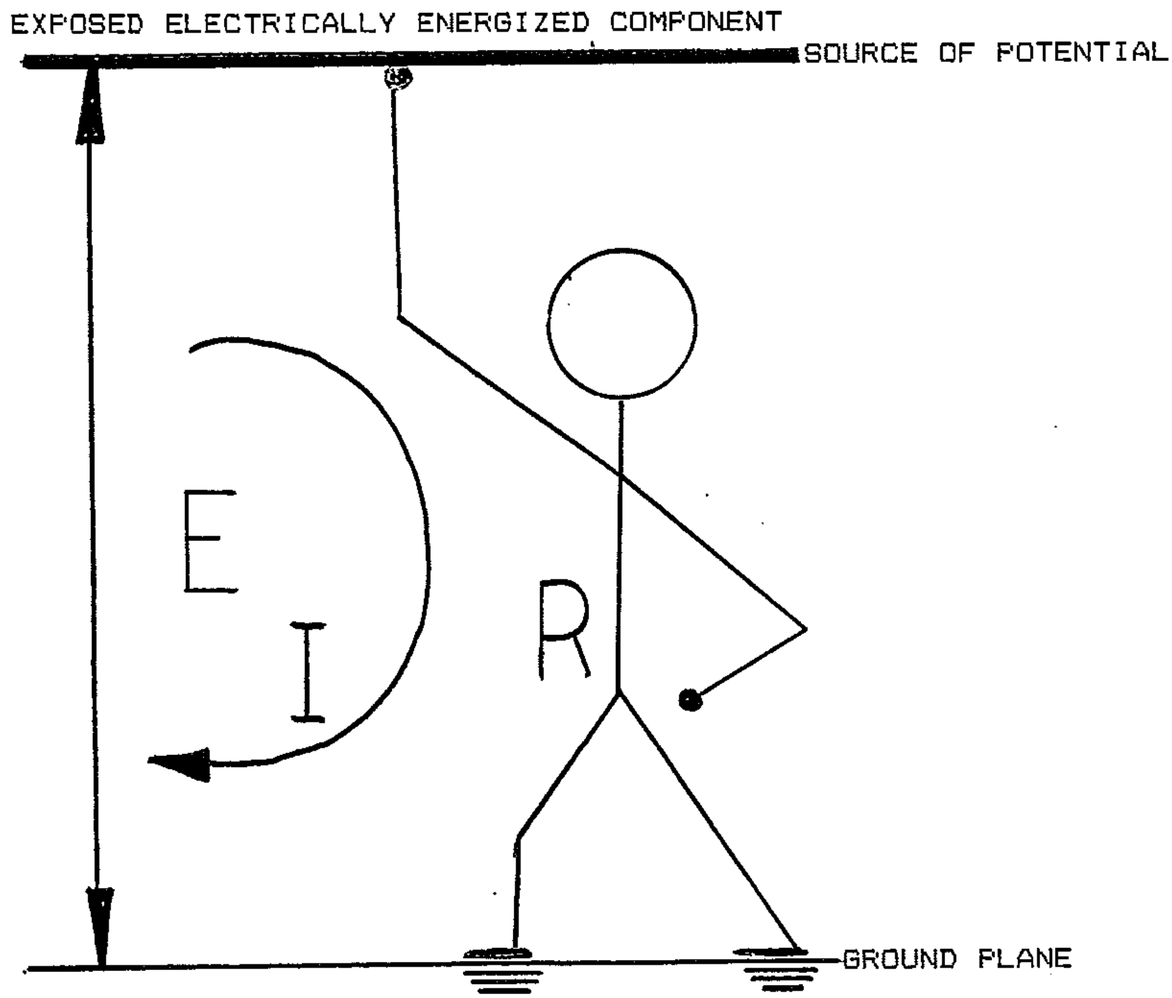


FIGURE 1

The equivalent basic circuit illustrating the direct physical contact while neglecting the contact resistance to the hands and feet is shown in Figure 2.

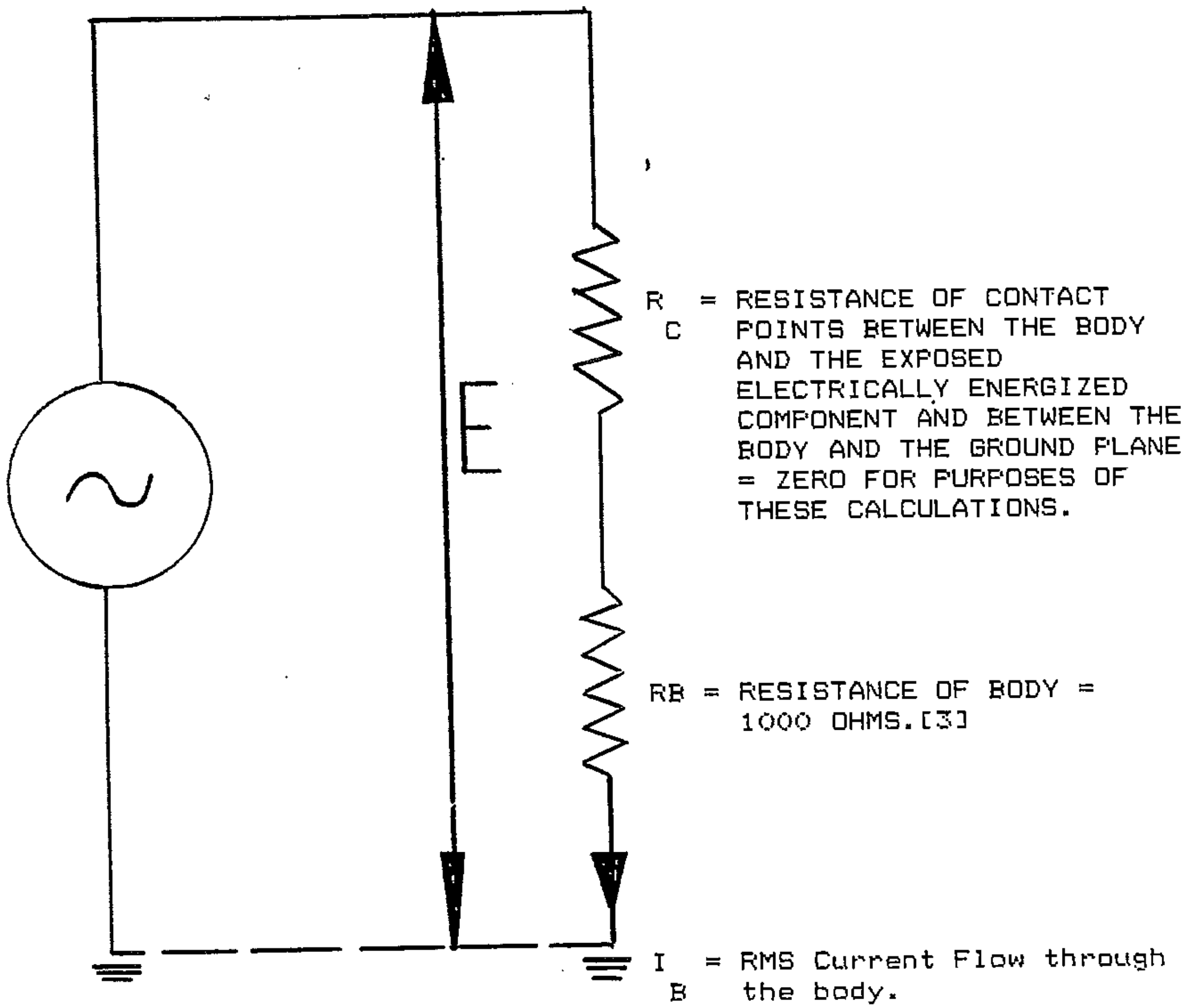
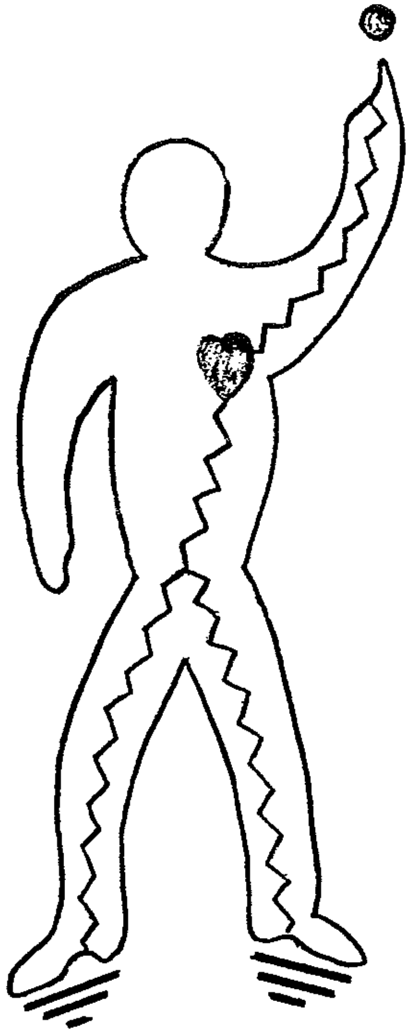


FIGURE 2

The total resistance of a persons body across a potential difference varies with weight, gender and physical condition of the contact surface with the electrically energized component(s) and ground plane. This value of resistance can vary for a 50 Kg.(120 lb.) man between 500 Ohms and a few thousand Ohms.
The resistance will be lowered considerably if the body contact is moist from perspiration or from blisters that form during high voltage contact.
The resistance will increase considerably if the contact area of a persons hand is heavily calloused or very dry. Touch Potential is illustrated in Figure 3.
Damp leather shoes or shoes with nailed soles offer a low resistance contact. Step Potential is illustrated in Figure 4.
For calculation purposes, a value of 1000 Ohms is often used for the resistance of a typical body. This level assumes relatively low resistance contact points.

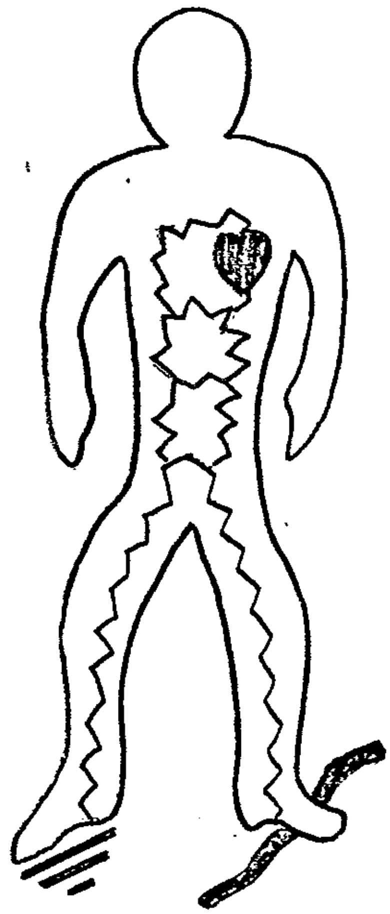


EXPOSED ELECTRICALLY ENERGIZED COMPONENT

TOUCH POTENTIAL

FIGURE 3

Most often involves an exposed electrically energized component as the source of the voltage potential difference: However, the voltage potential difference may be induced as by an electrical short in a lighting fixture.



ELECTRICALLY ELEVATED GROUND PLANE

STEP POTENTIAL

FIGURE 4

Most often involves an electrically elevated ground plane as the source of the voltage potential difference

b) Indirect physical contact via a conductive tool or component used as an extension of the body. The air insulating medium is overstressed to the point of breakdown and flashover results as shown in Figure 5.

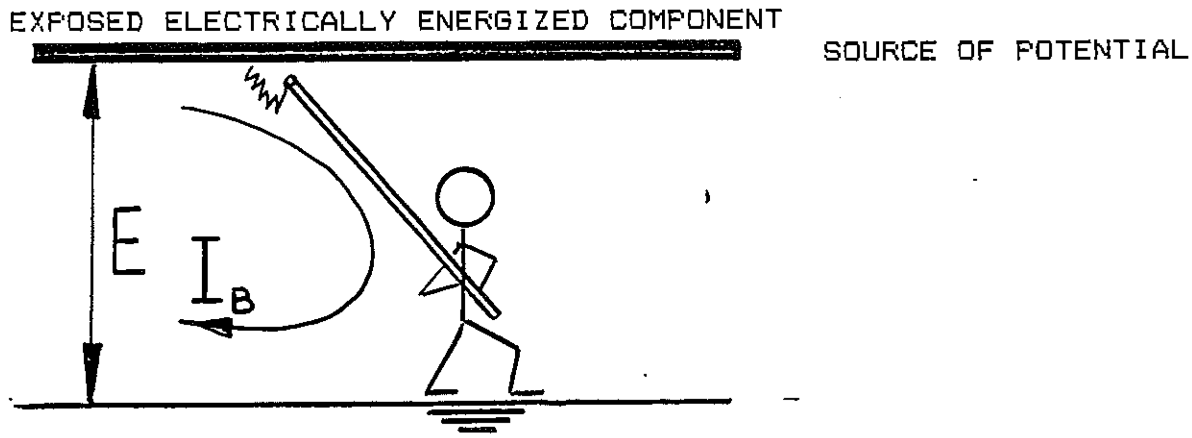
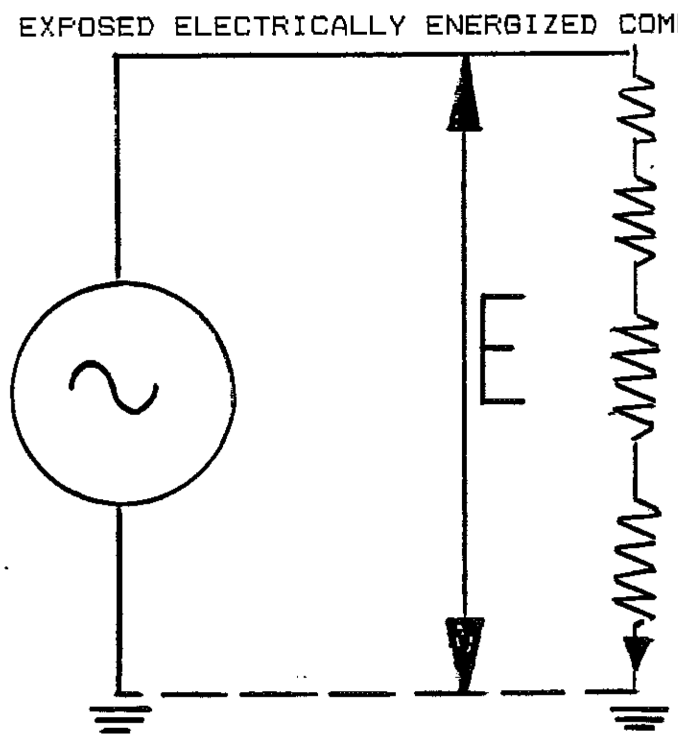


FIGURE 5

The equivalent basic circuit showing the flashover condition and neglecting the contact resistance of the tool, hands and feet is shown in Figure 6.



R_{ARC} = Resistance of arc

R_{TOOL} = Resistance of conducting tool

R_C = Resistance of contact points between the conductive tool and the body and between the body and the ground plane = Zero for the purpose of these calculations.

R_B = Resistance of body = 1000 Ohms

I_B = RMS current flow through body.

FIGURE 6

CHAPTER 4

CURRENT FLOW THROUGH THE HUMAN BODY

The basic hazardous effects of current flow through or near the human body are :

a). Involuntary movement or reflex action of the muscles from low values of current can cause rebound bumps and /or falls.

b). Physical damage to the body at the point of contact with the current source and at the point of current exit to ground.

c). Damage or cessation of the functioning of vital organs caused by the passage of a low level of current through the vital organ.

d). Muscular contractions resulting in asphyxiation. The muscular contractions often can cause a person to grip an energized component and not let go.

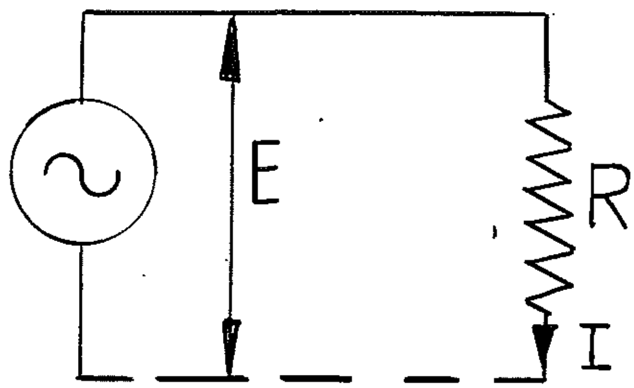
e). Internal damage to the body caused by the heat generated from a high level of current flow through the body.

f). Arc burns to the skin caused by the intense ultraviolet light and infra red heat from an electrical flash.

g). Hearing loss caused by the high pressure blast of an intense high energy electrical discharge.

Ohms Law can be applied to the basic circuit that is formed by a person who bridges two points of voltage potential difference:

e.g. when a conductor of resistance (R) connects two points of different potential (E) a current (I) will flow in the conductor as illustrated in Figure 7.

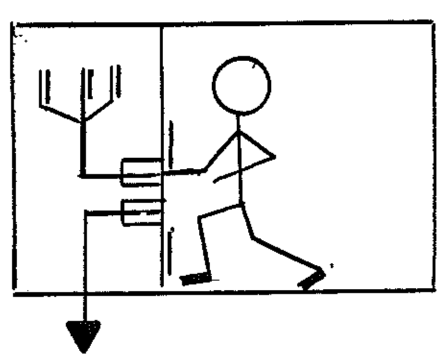


$$E = IR \qquad (1)$$

FIGURE 7

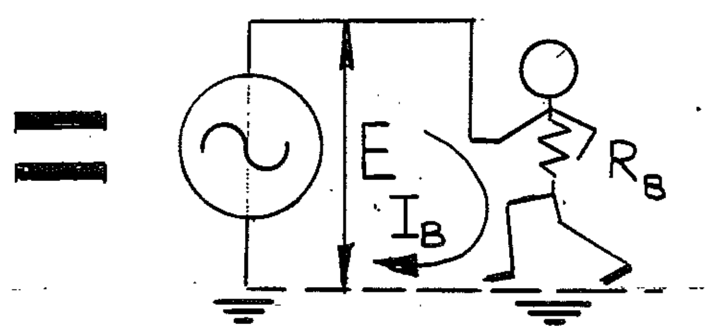
The accident that best illustrates this hazard is when a person touches an electrically energized component while standing on the ground plane and a voltage is impressed across the persons body as shown in Figure 8.

The equivalent circuit formed when a persons body is substituted for the resistance is shown in Figure 9.



SIDE ELEVATION OF 5 KV SWITCHGEAR CELL WITH CIRCUIT BREAKER REMOVED AND SHUTTERS OPEN

FIGURE 8



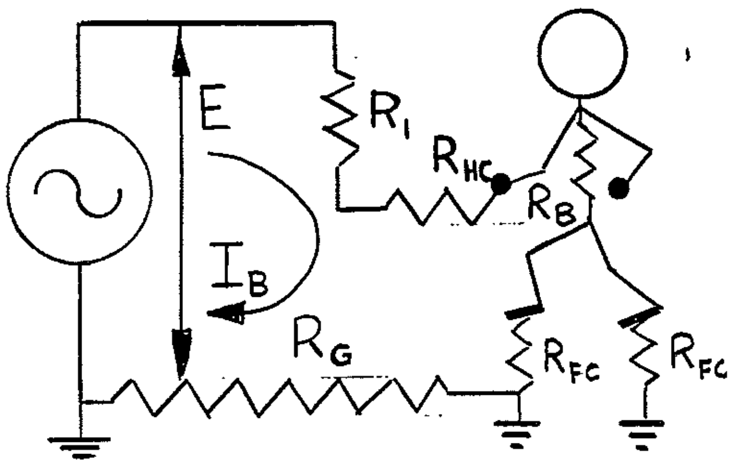
THE BASIC EQUIVALENT CIRCUIT

FIGURE 9

From Figure 9 the magnitude of current flow is dependent on the voltage source and resistance of the body.

$$I_B = \frac{E}{R_B} \quad \text{- - - - - - - - - - - - - - - - (2)}$$

The total equivalent circuit of Figure 8 is more complex because of the additional circuit resistance that must be taken into account as shown in Figure 10.



R_1 = Circuit Resistance.

R_{HC} = Hand Contact Resistance.

R_B = Body Resistance.

R_{FC} = Foot Contact Resistance.

R_G = Ground Resistance.

FIGURE 10

The equation to determine the current flow becomes :

$$I_B = \frac{E}{R_1 + R_{HC} + R_B + \frac{R_{FC} \times R_{FC}}{R_{FC} + R_{FC}} + R_G} \quad \text{- - - - - - - (3)}$$

$$I_B = \frac{E}{R_1 + R_{HC} + R_B + \frac{R_{FC}}{2} + R_G} \quad \text{- - - - - - - (4)}$$

The magnitude of current flow does not determine the extent of injury to a person. High current can have a less damaging effect on the body if the duration of shock is very small, than can a relatively low current applied for a long time.

All authorities agree that much higher currents can be tolerated without causing Ventricular Fibrillation if the duration is short. One study, [4] shows that 99.5 percent of all persons could withstand, without Ventricular Fibrillation, currents determined by the equation :

$$I_B^2 t = 0.0135 \quad (5)$$

from which

$$I_B = \frac{0.0116}{\sqrt{t}} \quad (6)$$

where I_B = The RMS current through the body in ampres.

t = The time duration shock in seconds.

0.0135 = An empiracally derived " Energy Constant "

NOTE : THE IMPORTANCE OF FAST CLEARING FAULTS CANNOT BE OVER EMPHASIZED FOR PERSONNEL PROTECTION.

EFFECTS OF ELECTRIC CURRENT ON THE BODY

The effects of electric current at 50 or 60 HZ on the human body are identified using a shock duration within the range of 0.03 to 3 seconds.

[5]

It should be noted, authorities generally agree the body can tolerate slightly higher currents at 25 HZ and up to 5 times as much at direct currents than those listed below.

1milliamp	Generally considered to be the threshold of perception.
5milliamp	Trip setting of ground fault circuit interrupter.
8milliamp	Mild shock.
9milliamp	TYPICAL LIMIT OF LET GO CURRENT.
9milliamp - 25milliamp	Currents in this range may be quite painful and may result in the lack of muscular control sufficient to make it difficult or impossible to let go of an electrically energized object grasped by hand.
25milliamp - 50milliamp	Muscular contractions will be experienced that will make breathing difficult. For shock duration of up to 3 seconds the effects will not be permanent and will disappear when the fault is removed.
50milliamp - 100milliamp	The threshold of Ventricular Fibrillation has been determined to be in this current range. For example, using equation (6) for a shock duration of 3 seconds

$$I_B = \frac{0.116}{\sqrt{t}} \quad (6)$$

$$I_B = \frac{0.116}{\sqrt{3}}$$

$$= 66\text{milliamp}$$

The uncontrolled twitching of the walls of the heart muscles will result in death unless a controlled countershock is applied during a short period of time in which it would be effective.

The type of equipment required to apply the countershock is almost never available in the field.

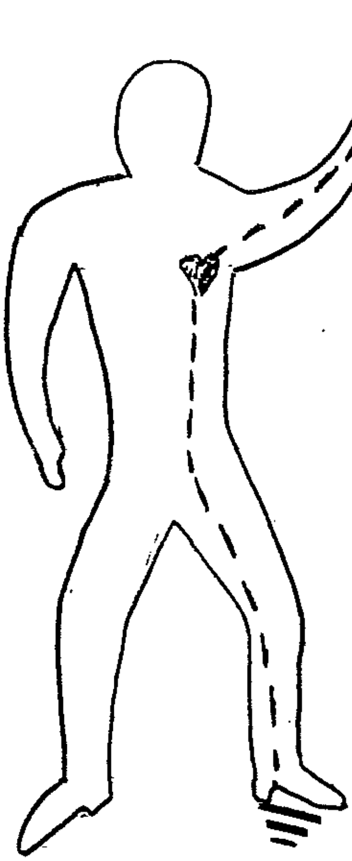
100milliamp and Up

Above the current magnitude of 100milliamp the heart may stop, inhibition of breathing or serious burns may be experienced that could result in serious injury or death.

The inhibition of breathing caused by currents flowing through the nerve systems controlling the respiratory system can continue long after the current has been removed.

Touch potential illustrated by Figure 11 as opposed to Step potential illustrated by Figure 12 is considered to be the worst case condition because during a touch potential condition the current flows from hand to foot through vital body organs. The current flow experienced during a Step potential condition passes from foot to foot. During this condition the ground resistance beneath the two feet are calculated in parallel and are effective in limiting body current flow.

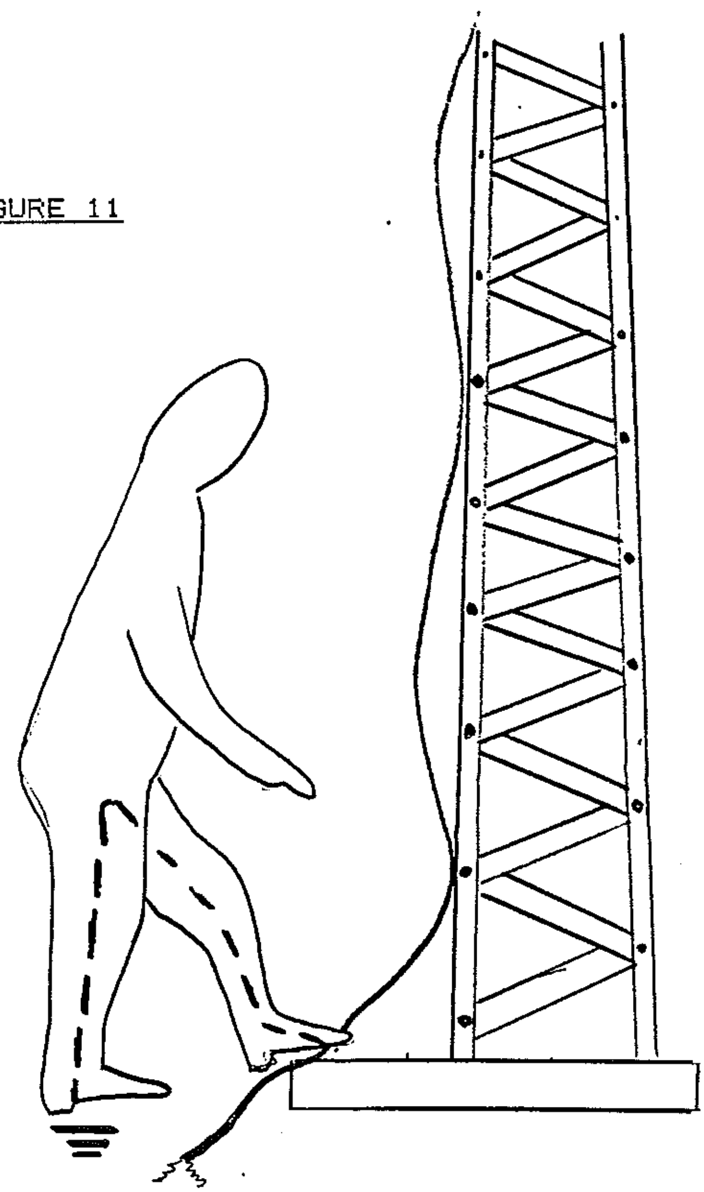
Because of the absence of vital organs as shown in Figure 13 in the current flow path the body can tolerate higher currents through a foot to foot path. Values of between 10 to 25 times the value of Touch potential currents are estimated to be required to cause Fibrillation of the heart as computed by equation (6).



TOUCH POTENTIAL

CURRENT PATH FROM ONE HAND TO FOOT PASSES THROUGH VITAL ORGANS OF THE BODY

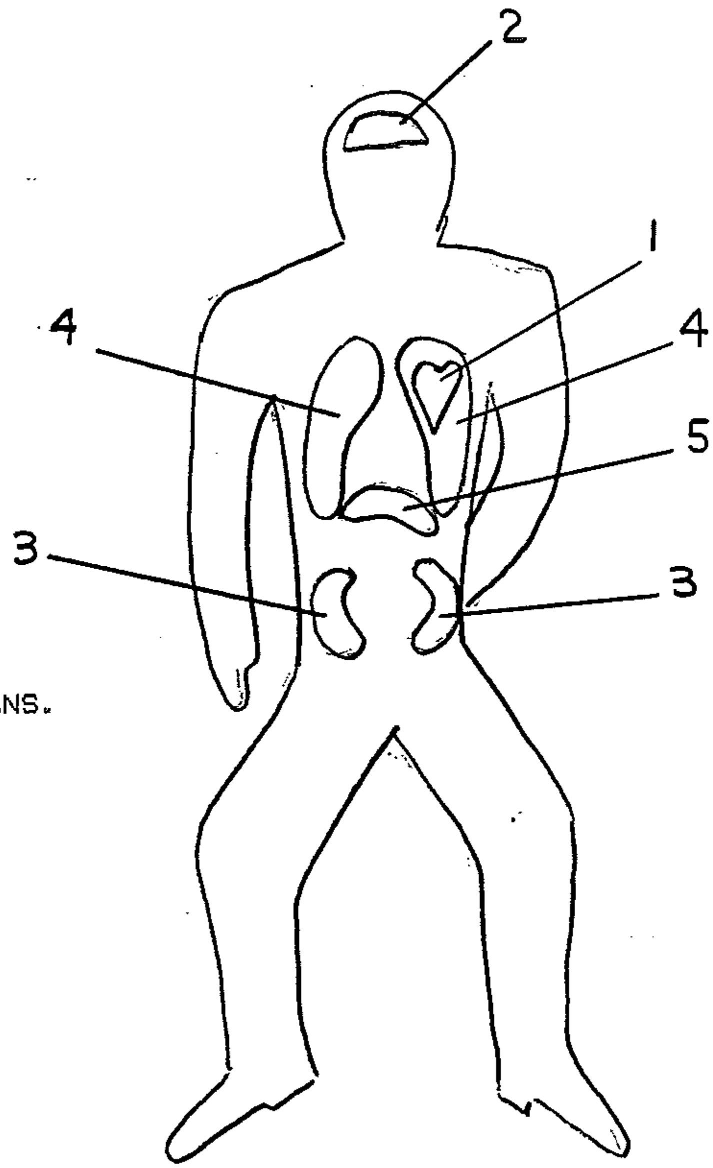
FIGURE 11



STEP POTENTIAL

CURRENT PATH FROM FOOT TO FOOT CAN BYPASS THE VITAL ORGANS OF THE BODY

FIGURE 12



HUMAN BODY

SHOWING VITAL ORGANS.

1. HEART.

2. BRAIN.

3. KIDNEYS.

4. LUNGS.

5. LIVER.

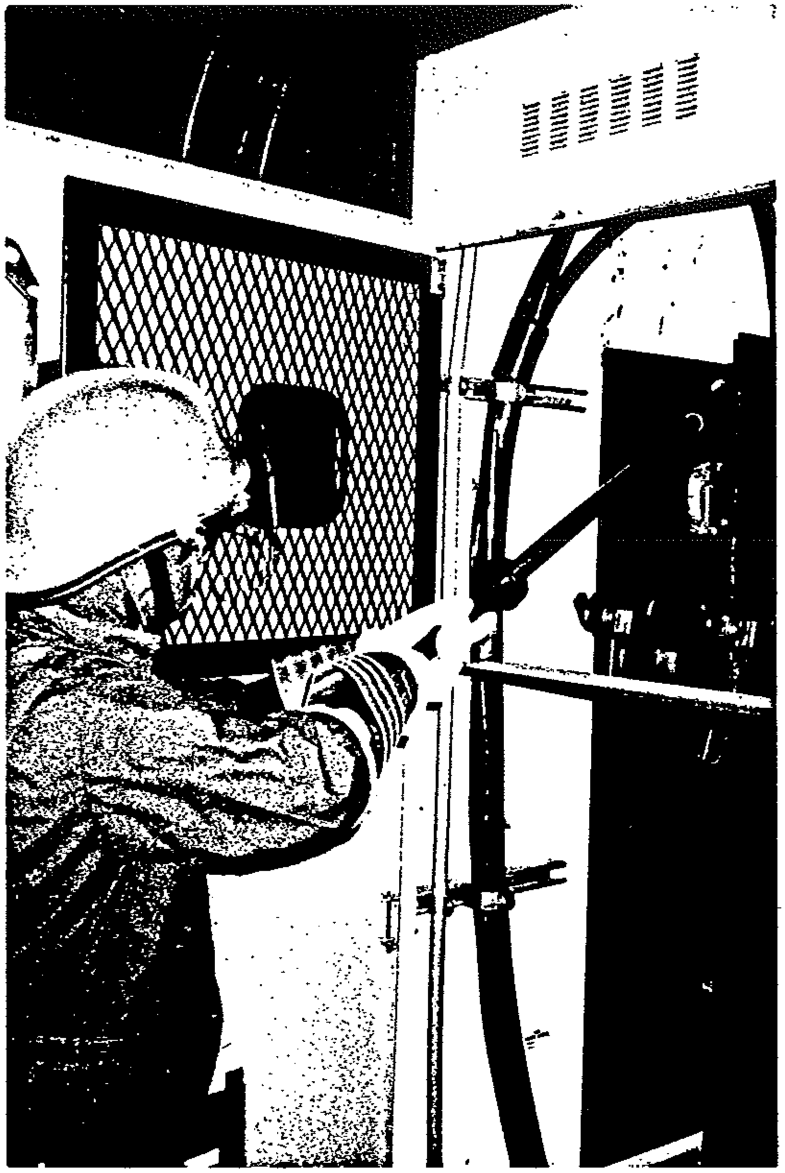


PLATE # 1

QUALIFIED LIMIT III ELECTRICIAN CHECKING FOR ISOLATION AT A 15 KV FUSE DISCONNECT SWITCH USING A VOLTAGE SENSOR AND WEARING FULL PERSONAL PROTECTIVE EQUIPMENT.

CHAPTER 5

MINIMUM CLEARANCE ZONE AND IMMEDIATE VICINITY ZONE

An Electrical Hot Work Safety Program should make all persons aware of their limitations when working in an environment influenced by electrical energy.

The minimum clearance zone that surrounds an exposed energized part is the absolute limit of approach in the program for the highest qualified electricians.

MINIMUM CLEARANCE ZONE is defined as the area around any exposed and energized electrical part that is detailed in Figure 14 and Table 1.

NOTE: IN THE PROGRAM THE 0 - 750 VOLTS RANGE HAS NO LIMITATIONS FOR PROPERLY TRAINED AND KNOWLEDGEABLE PEOPLE WORKING WITH APPROVED PROTECTIVE EQUIPMENT

No employee shall penetrate the minimum clearance zone with any part of his body or operate any unapproved object as an extension of his body within the minimum clearance zone.

The use of approved test equipment suitably insulated for the voltage class being worked on and operated to the manufacturer's instructions shall be permitted as an extension of the employees body within the minimum clearance zone. The approved equipment shall be operated by the employee from outside the minimum clearance zone at all times. In addition the use of suitable grounding devices that are designed to connect to an electrically isolated bus connection inside metal clad or metal enclosed switchgear in conformance with requirements for de-energization shall be permitted.

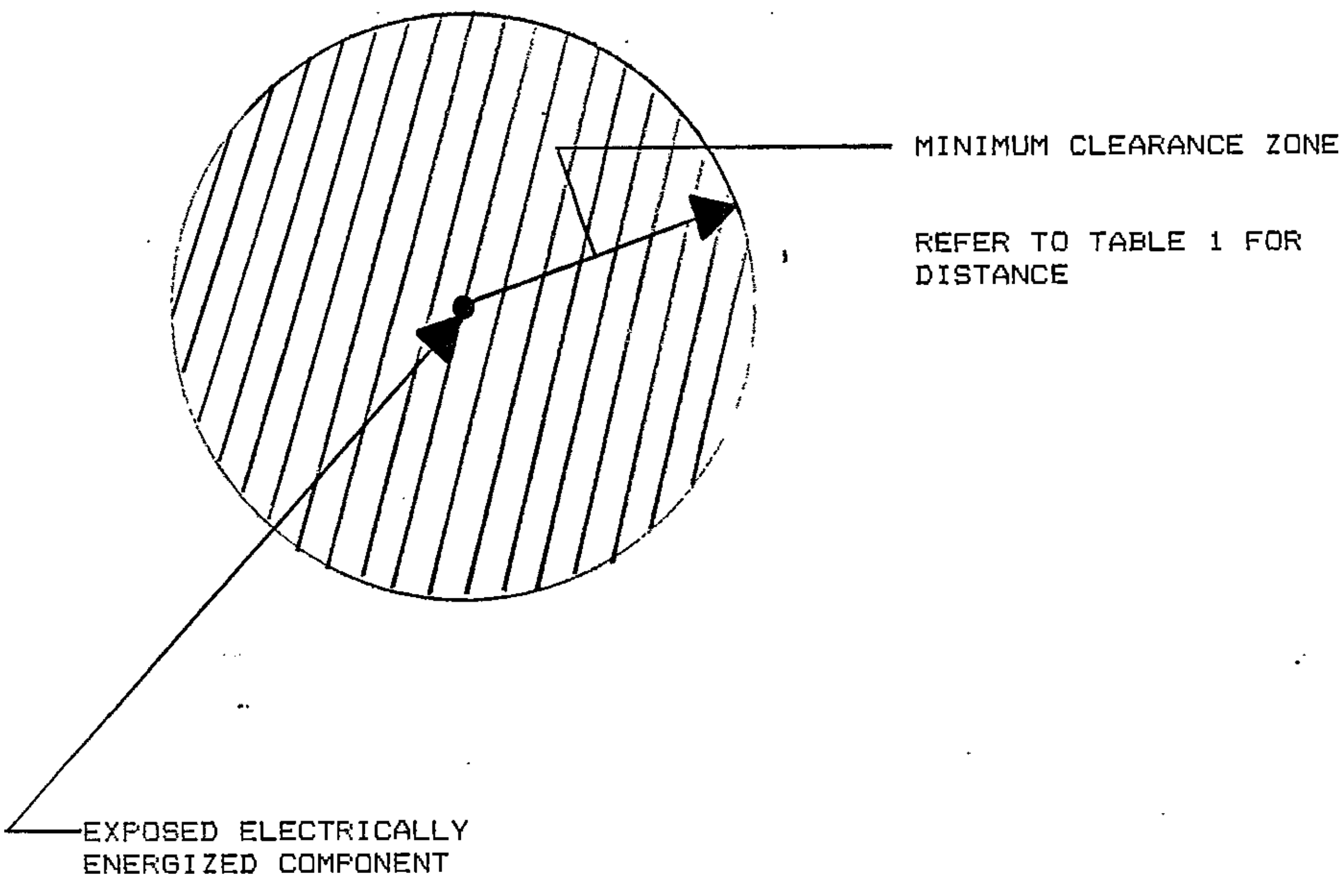


FIGURE 14

MINIMUM CLEARANCE ZONE

TABLE 1

MIMIMUM CLEARANCE ZONE

PHASE - PHASE VOLTS	DISTANCE IN FEET - PHASE TO EMPLOYEE
750 - 15,000	2
15,001 - 35,000	3
35,001 - 50,000	4
50,001 - 150,000	5
150,001 - 350,000	7
350,001 - 550,000	12

ONTARIO CANADA

BASED ON THE ELECTRICAL UTILITY SAFETY ASSOCATION OF ONTARIO.
[6]

VOLTS	DISTANCE IN FEET - PHASE TO EMPLOYEE
1,000 - 34,500 *	2
46,000	2'6"
69,000	3'
115,000 *	3'
138,000	3'6"
161,000 *	3'6"
230,000	4

UNITED STATES

BASED ON ANSI C2 NESC 1984 SECTION 422.1
[7]

* OSHA 1926 950 specifies minimum clearance's slightly greater than ANSI C2.

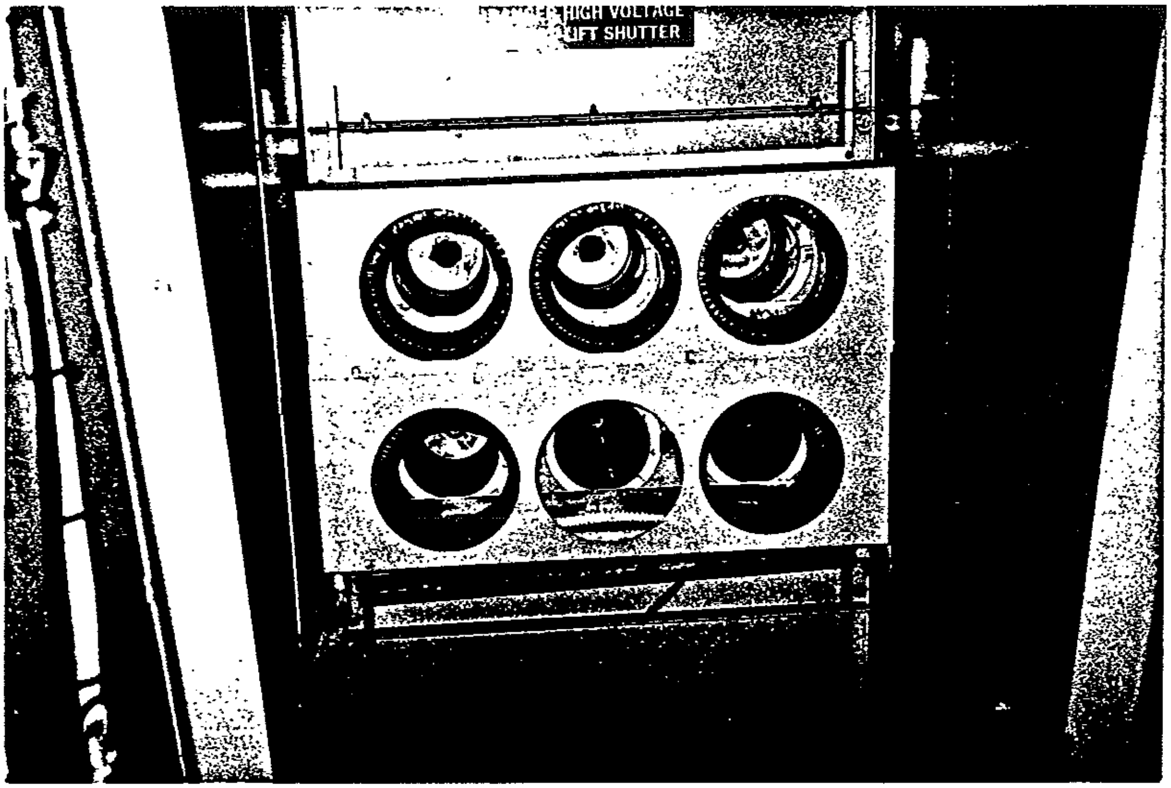


PLATE # 2

EXPOSED ELECTRICALLY ENERGIZED 15 KV BUS TERMINALS
(TOP)

MINIMUM CLEARANCE ZONE DISTANCE AT 15 KV PHASE - PHASE IS 0.6 METERS (2'0").

IMMEDIATE VICINITY ZONE is defined in the program as the area around the minimum clearance zone, detailed in Figure 15, that will allow an employee the opportunity to accidently penetrate the minimum clearance zone by any part of an employee's body or by tools, test equipment or vehicles operated by an employee. A person in the immediate vicinity zone is subject to inadvertantly penetrating the minimum clearance zone unless extreme care is exercised.

The perimeter of the immediate vicinity zone can vary and depends on the voltage class of the system, the length of the handles of the approved test equipment, or the dimensions of grounding/test devices being used to penetrate the minumum clearance zone, the fault level available at the exposed component and the time required to clear the fault (safe working distance from arc source). In the Electrical Hot Work Safety Program physical dimensions of the immediate vicinity zone are detailed by the location Electrical Hot Work Procedures.

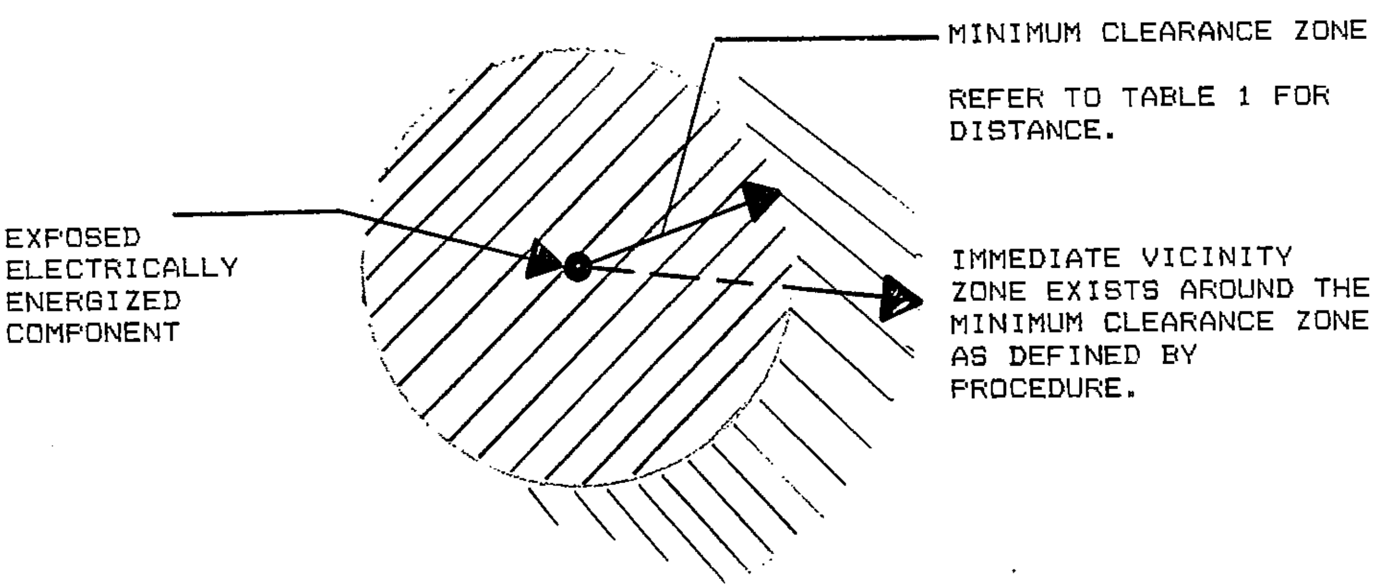


FIGURE 15
IMMEDIATE VICINITY ZONE

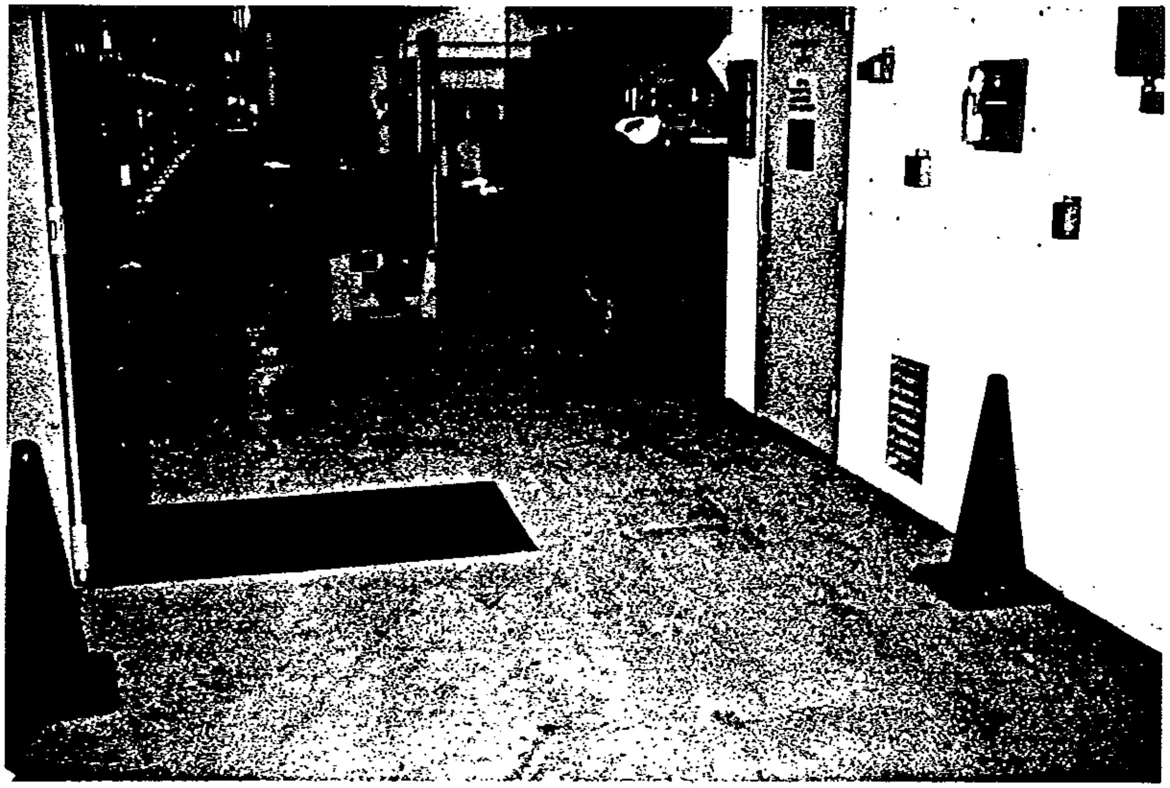


PLATE # 3

IMMEDIATE VICINITY ZONE ESTABLISHED IN FRONT OF A 15 KV METAL CLAD SWITCHGEAR CUBICLE.

CHAPTER 6

THE HAZARDS OF ELECTRIC ARC FLASH

The hazards of electric arc flash burn are often neglected compared to the precautions taken and the protection given to personnel to guard against electric shock. Burns from high current arcs can be fatal to personnel standing several feet away from the arc source.[8] Serious damaging burns to personnel standing up to ten feet away from high current arcs are not uncommon. Clothing can be ignited several feet away from the source of a high current arc and can lead to fatality because of the skin area that is exposed to burns and the time involved in removing the burning clothes from the body.

Electric arcing is the passage of electrical current through what had previously been an air insulating medium. The current passage through the air medium is the result of concentrated ionized gases or conductor materials vaporizing. The resulting electric arc between metals can produce temperatures of 20,000 degrees kelvin or 35,000°F.[8]

The damaging effect upon human skin is determined from the temperature rise on the skin the arc flash can produce, and the duration of the arc flash. Fast clearing time of the fault greatly reduces the damaging effect of the temperature.

Electrical personnel often expose themselves to the dangers of electrical arc burn when performing electrical hot work on exposed electrically energized parts. It is only the relative infrequency of high current arcs that really prevents more injuries than now occur.

The high current produced in an electrical arc is a result of Electrical "Stiffness" of the arc source. A typical Industrial plant distribution system has high fault levels available at all the different voltage levels. A typical petro-chemical complex electrical distribution system is illustrated by FIGURE 15. TABLE 2 identifies the fault levels and arc flash energy available at various locations on this distribution system. The corresponding safe working distances from the arc source in this distribution system is also detailed in TABLE 2. This safe working distance is used to determine the outer perimeter of the immediate vicinity zone.

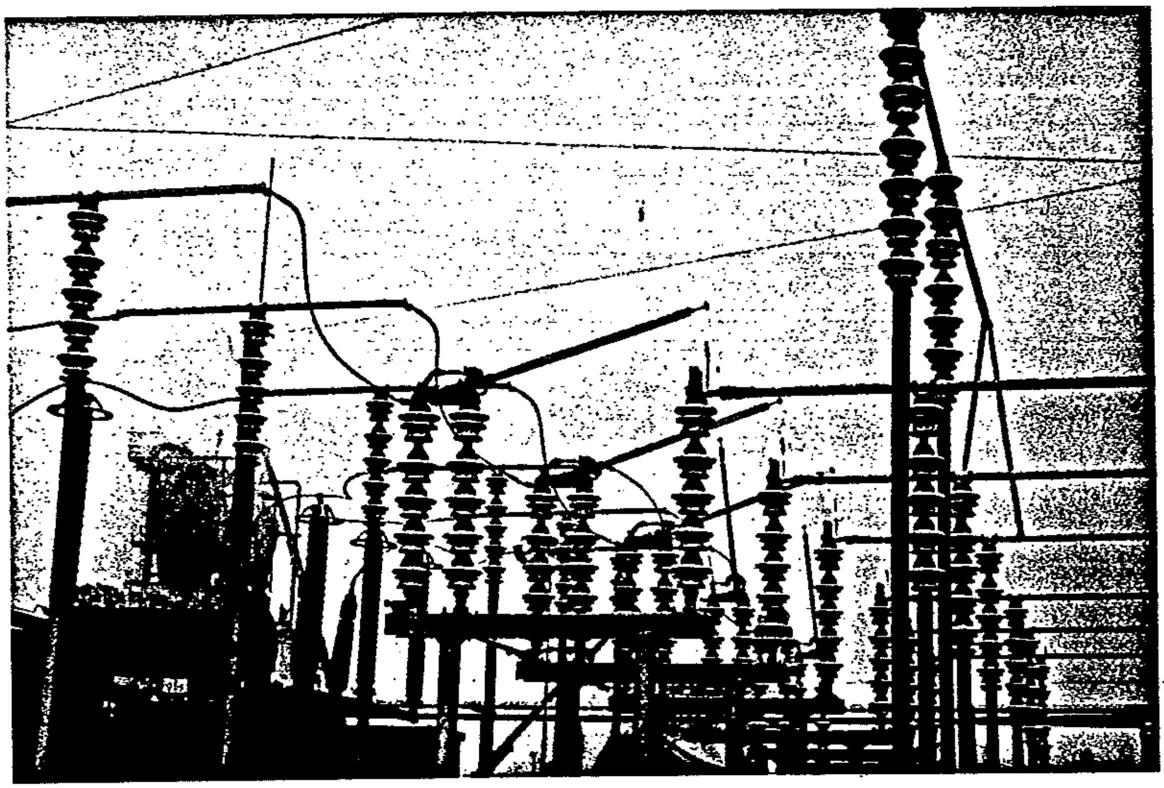


PLATE # 4

ELECTRIC ARC CAUSED BY CLOSING ACTION OF A 230 KV AIR BREAK SWITCH ON THE MAGNETIZING CURRENT (APPROX.1 AMPER) OF THE TRANSFORMER.
APPROX. ENERGY DISSIPATED IN THE ARC =

$$\sqrt{3}V.I.\ \cos C$$
$$= \sqrt{3} \times 230{,}000 \times 1 \times .18$$
$$= 71{,}700 \text{ WATTS.}$$

PLATE # 5

QUALIFIED LIMIT III ELECTRICIAN CHECKING FOR ISOLATION USING A VOLTAGE SENSOR AND WEARING FULL PERSONAL PROTECTIVE EQUIPMENT IN A 15 KV CELL.

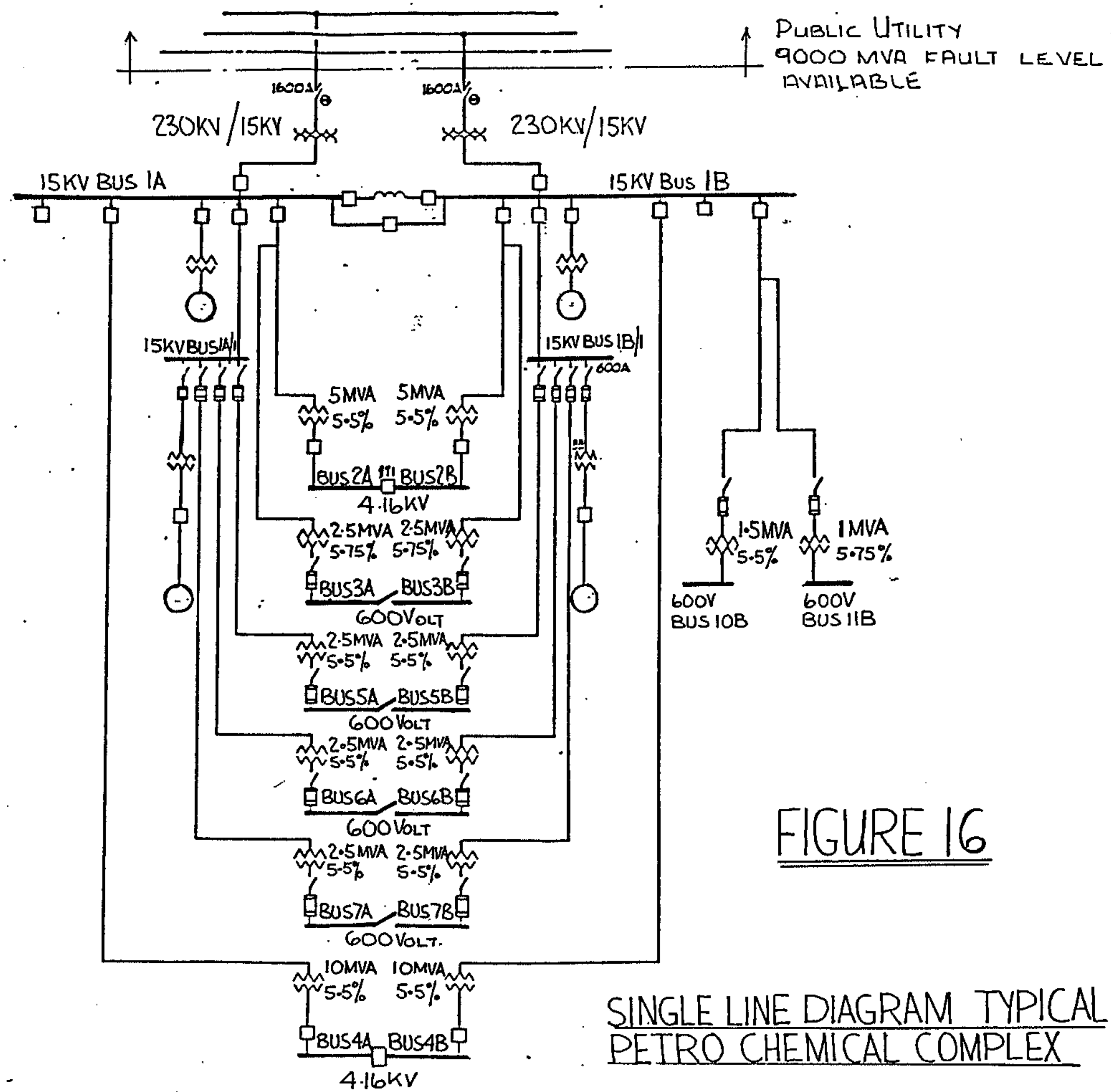


FIGURE 16

SINGLE LINE DIAGRAM TYPICAL PETRO CHEMICAL COMPLEX

TABLE 2

FLASH BURN HAZARD AT VARIOUS LEVELS IN A LARGE PETROCHEMICAL PLANT

BUS (1)	TRANF MVA (2)	% Z	I_{SC} AMPS (4)	ARC MW (5)	DISTANCE FROM ARC FOR SKIN TEMPERATURE		CLEARING TIME OF FAULT CYCLES (8)
					LIMIT OF CURABLE SKIN BURN < 80°C (6) FEET	LIMIT OF INCURABLE SKIN BURN > 96°C (7) FEET	
230 kV	9000	1.11	23,000	4,000	46	39	6 Cycles
13.8 kV	750(3)	9.4	31,300	374	14.1	12.1	6 Cycles
Load Side of All 13.8 kV Fuses	750(3)	9.4	31,300	374	5.8	5	1 Cycle
4.16 K	10	5.5	25,000	91	7.3	6.3	6 Cycles
4.16 kV	5	5.5	12,600	45	5.5	4.4	6 Cycles
Line Side of Incoming 600 V Fuse	2.5	5.5	44,000	23	3.7	3.2	6 Cycles
600 V Bus	2.5	5.5	44,000	23	0.74	0.64	1/4 Cycle
600 V Bus	1.5	5.5	26,000	27	2.8	2.5	6 Cycles
600 V Bus	1	5.75	17,000	17	2.3	2.0	6 Cycles

EXPLANATION OF (1),(2),(3),(4),(5),(6),(7) and (8) from TABLE 2

(1) This column lists electrical buses in a typical industrial Plant. The source of the arc was taken from a point on the bus.

(2) The base MVA of the transformers.

(3) Interrupting rating of the main bus vacuum circuit breakers.

(4) Short circuit symmetrical amps calculated from bolted 3 Ø fault at transformer terminals which will give maximum fault value.

$$I_{sc} = \frac{\text{MVA Base}}{\sqrt{3} \times V} \times \frac{100}{\% Z} \text{ - - - - - - - - - - - - - (7)}$$

(5) [9].Maximum power in 3 Ø arc at the identified bus calculated from $.707^2$ x maximum bolted fault (MVA_{bf}).

$$P = \sqrt{3} \times I_{SC} \times V \times .707^2 \text{ - - - - - - - - - - (8)}$$

(6) [9].Distance of personnel from arc source for a curable burn i.e. skin temperature <80° C as calculated from...

$$D_c = \sqrt{2.65 \times MVA_{bf} \times t} \text{ - - - - - - - - - - (9)}$$

$$= \sqrt{53 \times MVA \times t}$$

D = Distance for a just curable burn, feet.

MVA_{bf} = Bolted fault MVA at point involved.

MVA = Transformer rated MVA, 0.75 MVA and over, for smaller ratings multiply by 1.25

t = Time of exposure in seconds

(7) [9].Distance of personnel from arc source for an incurable burn i.e. skin temperature > 96° C as calculated from...

$$D_f = \sqrt{1.96 \times MVA_{bf} \times t} \text{ - - - - - - - - - - (10)}$$

$$= \sqrt{39 \times MVA \times t}$$

D_f = Distance for a just fatal burn, feet.

MVA_{bf} = Bolted fault MVA at point involved.

MVA = Transformer rated MVA, 0.75 MVA and over, for smaller ratings multiply by 1.25

t = Time of exposure, seconds.

(8) Clearing time of current limiting fuse .008 seconds or 1/2 cycles. Clearing time of 15kv breaker .1 seconds or 6 cycles (actual breaker 1.74 cycles, relay approx. 2 cycles, 1.74 + 2 + 2 for safety = 6 cycles).Clearing time of 5kv breaker .1 seconds or 6 cycles.

TYPICAL CALCULATION FROM TABLE 2

BUS 4E

TRANSFORMER BASE MVA = 10

SYSTEM VOLTS PHASE TO PHASE = 4.16KV

% Z TRANSFORMER = 5.5

CIRCUIT BREAKER CLEARING TIME = APPROX. 6 CYCLES.

I_{SC} Symmetrical Amps from A 3 phase bolted fault at the transformer terminals.

$$I_{SC} = \frac{\text{MVA Base}}{\sqrt{3} \times V} \times \frac{100}{\% Z} \qquad \text{-------------(7)}$$

$$= \frac{10}{\sqrt{3} \times 4160} \times \frac{100}{5.5}$$

$$= \underline{25{,}000 \text{ amps.}}$$

Maximum Power in 3 phase fault at the transformer terminals.

$$= \sqrt{3} \times I_{SC} \times V \times .707^2 \qquad \text{---------(8)}$$

$$= \sqrt{3} \times I_{SC} \times 4.16\text{kv} \times .707^2$$

$$= \underline{91 \text{ MW.}}$$

Distance of personnel from the source for a curable burn, ie: Actual skin temperature rise < 80°C.

$$\text{Distance curable} = Dc = \sqrt{53 \times \text{MVA} \times t} \qquad \text{-------(9)}$$

$$= \sqrt{53 \times 10 \times .1}$$

$$= \underline{7.28 \text{ feet.}}$$

Distance of personnel from arc source for an incurable burn, ie:

Actual skin temperature rise > 96^{o} C.

$$\text{Distance Incurable} = D_f = \sqrt{39 \times MVA \times t} \quad \text{------} \quad (10)$$

$$= \sqrt{39 \times 10 \times .1}$$

$$= \underline{6.24 \text{ feet.}}$$

BASIC Program for Calculation of Distances Associated With Arc Flash Burns During Electrical Hot Work Procedures

This program will facilitate use of most PC's to calculate minimum distances for curable burns and maximum distances for incurable burns resulting from electrical flashover. The program uses calculation methods described by Ralph H. Lee [9] and assumes a worst case for arc impedance. The program prompts the user for all data required, and an attempt was made to keep the BASIC fairly generic to reduce software compatibility problems.

```
10 REM FLASH BURN PROGRAM BASED ON A TECHNICAL PAPER BY RALPH H. LEE.
20 REM VERSION 1.0, ISSUED MAY 22, 1987.
30 CLS: PRINT "SELECT BASIS FOR FAULT CURRENT"
40 PRINT " (A) ACTUAL FAULT AMPS"
50 PRINT " (B) ACTUAL FAULT MVA"
60 PRINT " (C) SWITCHGEAR RATING IN AMPS"
70 PRINT " (D) SWITCHGEAR RATING IN MVA"
80 PRINT " (E) MVA BASED ON XFMR KVA & IMPEDANCE"
90 PRINT " (F) MVA FROM XFMR KVA & LEE'S FORMULA"
100 A$=INKEY$: IF A$="" THEN GOTO 100
110 IF A$="A" OR A$="a" THEN GOTO 180
120 IF A$="B" OR A$="b" THEN GOTO 240
130 IF A$="C" OR A$="c" THEN GOTO 180
140 IF A$="D" OR A$="d" THEN GOTO 240
150 IF A$="E" OR A$="e" THEN GOTO 280
160 IF A$="F" OR A$="f" THEN GOTO 360
170 GOTO 100
180 CLS: PRINT "ENTER FAULT AMPS IN KA"
190 INPUT KA
200 PRINT "ENTER SYSTEM L-L VOLTAGE IN KV"
210 INPUT KV
220 VA = KV * KA * (3^.5): LF = 0
230 GOTO 430
240 CLS: PRINT "ENTER MVA"
250 INPUT VA
260 LF = 0
270 GOTO 430
280 CLS: PRINT "ENTER TRANSFORMER BASE KVA"
290 INPUT BK: BK = BK / 1000
300 PRINT "ENTER IMPEDANCE IN % AT BASE KVA"
310 INPUT ZB: ZB = ZB / 100
320 PRINT "HOW MANY TRANSFORMERS IN PARALLEL"
330 INPUT ZU
340 VA = BK * ZU / ZB: LF = 0
350 GOTO 430
360 CLS: PRINT "ENTER TRANSFORMER BASE KVA"
370 INPUT BK
380 PRINT "HOW MANY TRANSFORMERS IN PARALLEL"
390 INPUT ZU
400 IF BK<750 THEN BK=BK*1.25
410 VA = ZU * BK / 1000
420 LF = 1
430 CLS: PRINT "SELECT UPSTREAM PROTECTIVE DEVICE"
440 PRINT " (A) CURRENT-LIMITING FUSE"
450 PRINT " (B) ORDINARY FUSE
460 PRINT " (C) CURRENT-LIMITING CIRCUIT BREAKER"
470 PRINT " (D) BREAKER WITH INST/DIFF RELAYS"
480 PRINT " (E) BREAKER WITH TIME DELAY TRIPPING"
490 A$=INKEY$: IF A$="" THEN GOTO 490
500 IF A$="A" OR A$="a" THEN T=8.000001E-03: GOTO 560
510 IF A$="B" OR A$="b" THEN T=.017: GOTO 560
520 IF A$="C" OR A$="c" THEN T=8.000001E-03: GOTO 560
530 IF A$="D" OR A$="d" THEN T=.1: GOTO 560
```

```
540 IF A$="E" OR A$="e" THEN CLS: PRINT "INPUT CLEARING TIME IN SECONDS":
    INPUT T: GOTO 560
550 GOTO 430
560 IF LF=0 THEN GOTO 600
570 DC = (53 * VA * T) ^ .5
580 DF = (39 * VA * T) ^ .5
590 GOTO 620
600 DC = (2.65 * VA * T) ^ .5
610 DF = (1.96 * VA * T) ^ .5
620 CLS: PRINT "FLASH BURN HAZARD DISTANCES"
640 PRINT "MINIMUM DISTANCE FOR CURABLE BURN IS ";
650 PRINT USING"###.## FEET."; DC
670 PRINT "MAXIMUM DISTANCE FOR INCURABLE BURN IS ";
680 PRINT USING"###.## FEET."; DF
690 PRINT "ANOTHER CASE (Y/N)?"
700 A$=INKEY$: IF A$="" THEN GOTO 700
710 IF A$="Y" OR A$="y" THEN GOTO 30
720 END
```

> Demonstration of flash burn calculation program. The areas in blocked areas (like this one) are comments and do not appear when the program is actually run. The first case will be for a 13.8 kV bus with 500 MVA switchgear. Like many such busses, differential relays are used to protect the zone where the hot work is being done.

```
SELECT BASIS FOR FAULT CURRENT
 (A) ACTUAL FAULT AMPS
 (B) ACTUAL FAULT MVA
 (C) SWITCHGEAR RATING IN AMPS
 (D) SWITCHGEAR RATING IN MVA
 (E) MVA BASED ON XFMR KVA AND IMPEDANCE
 (F) MVA FROM XFMR KVA AND LEE'S FORMULA
```

> This is the Main Menu. The most accurate calculations are produced by using actual data from a short-circuit study (A, B), and option E and F will give close results for most applications. Do NOT use E or F if there is generation or large motors connected to the electrical system at the same voltage as the point in question. Options C and D will always give conservative answers, if the system is properly designed.

> Press "D" since the only fault information given is 500 MVA rating of the switchgear. The Main Menu will disappear.

```
ENTER MVA
? 500
```

> Type "500" and press the <ENTER> key.

```
SELECT UPSTREAM PROTECTIVE DEVICE
 (A) CURRENT-LIMITING FUSE
 (B) ORDINARY FUSE
 (C) CURRENT-LIMITING CIRCUIT BREAKER
 (D) BREAKER WITH INST/DIFF RELAYS
 (E) BREAKER WITH TIME DELAY TRIPPING
```

> Select existing device. If in doubt, don't use current-limiting options. Most feeder breakers have instantaneous relaying. Press "D" since differential are used to protect the bus where work is being performed.

```
FLASH BURN HAZARD DISTANCES
MINIMUM DISTANCE FOR CURABLE BURN IS  11.51 FEET.
MAXIMUM DISTANCE FOR INCURABLE BURN IS  9.90 FEET.
ANOTHER CASE (Y/N)?
```

> Read results - worst case fault, resistance of arc are assumed. Press "Y" for next case.

Pressing "Y" returns to the Main Menu. The second case conditions are a 480 volt MCC, with 55,000 amps short-circuit current. The upstream protective device is a current-limiting fuse.

SELECT BASIS FOR FAULT CURRENT
(A) ACTUAL FAULT AMPS
(B) ACTUAL FAULT MVA
(C) SWITCHGEAR RATING IN AMPS
(D) SWITCHGEAR RATING IN MVA
(E) MVA BASED ON XFMR KVA AND IMPEDANCE
(F) MVA BASED ON XFMR KVA AND LEE'S FORMULA

Select item "A" since 55,000 amps fault is a known quantity.

ENTER FAULT AMPS IN KA
? 55

Enter fault current in kilo-amps symmetrical subtransient. Type "55" and <ENTER>.

ENTER SYSTEM L-L VOLTAGE IN KV
? .48

Line-to-line voltage in kiovolts. Type ".48" and press <ENTER>.

SELECT UPSTREAM PROTECTIVE DEVICE
(A) CURRENT-LIMITING FUSE
(B) ORDINARY FUSE
(C) CURRENT-LIMITING CIRCUIT BREAKER
(D) BREAKER WITH INST/DIFF RELAYS
(E) BREAKER WITH TIME DELAY TRIPPING

Current-limiting fuses installed, Press "A".

FLASH BURN HAZARD DISTANCES
MINIMUM DISTANCE FOR CURABLE BURN IS 0.98 FEET.
MAXIMUM DISTANCE FOR INCURABLE BURN IS 0.85 FEET.
ANOTHER CASE (Y/N)?

Read results and press "N" to quit program. All results assume that the workers bare skin is in direct line of sight with the arc and do NOT take into account the benefits which are available from using personal protective equipment (gloves, reflective garments, etc.

The hazards of electric flash burn can be minimized or eliminated by applying the following precautions :

a) <u>PERSONAL PROTECTIVE EQUIPMENT.</u>

Personal Protective Equipment to be worn during the performance of electrical hot work :

i. Flame resistant protective clothing.

ii. Fire resistant helmet and flame resistant neck cover.

iii. Full face shield.

iv. Leather gauntlet gloves.

b) <u>FAST CLEARING OF FAULTS.</u>

Minimizing the duration of the arc flash by fast clearing time of the fault that produces the electric arc flash greatly reduces the time the human skin is exposed to the high temperature. Reducing the exposure time of the human skin to the arc flash greatly reduces the damage to the skin. Again as is shown in the case of electric shock hazard the importance of fast clearing faults cannot be over emphasized for personnel safety. Figure 16 shows the fast clearing action of current limiting fuses.

c) <u>DISTANCE BETWEEN BODY AND HAZARD.</u>

Establish an Immediate Vicinity Zone around the minimum clearance zone and restrict the number of personnel in the zone to the people conducting the electrical hot work. The outer perimeter of the zone should be positioned so that the heat absorbed by personnel outside the zone will not raise the skin temperature past the threshold of injury. Refer to TABLE 2.

PLATE # 6

LIMIT III QUALIFIED ELECTRICIANS IN FULL PERSONAL PROTECTIVE EQUIPMENT REVIEWING THE ELECTRICAL HOT WORK PROCEDURE WITH LIMIT 1 QUALIFIED SUPERVISOR.

Fuse clearing characteristics

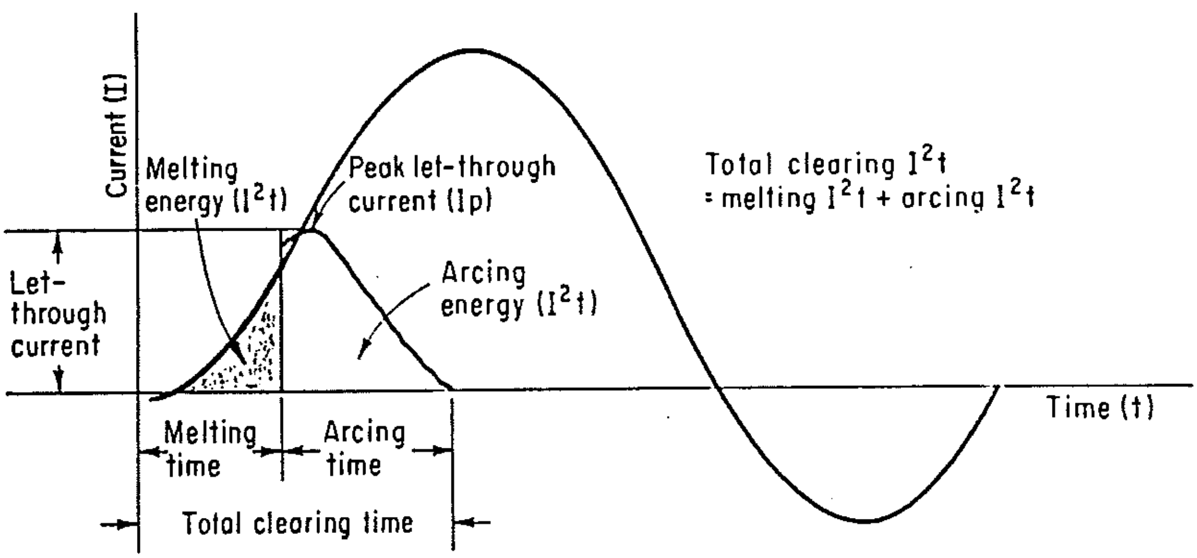


FIGURE 17

TYPICAL LET THROUGH ENERGY OF CURRENT LIMITING FUSE. THE FAST CLEARING OF FAULTS GREATLY REDUCES THE EXPOSURE TIME DURING ARC FLASH FAULTS.

CHAPTER 7

WORKING SAFELY IN AN ELECTRICAL ENVIRONMENT

The operation and maintenance of an integrated electrical system in a 24 hour continous process world scale petro-chemical complex requires that its personnel from time to time work in an environment influenced by the presence of electrical energy. This source of electrical energy could originate from installed electrical equipment or test equipment. The potential hazard to personnel required to work in this environment can be eliminated or minimized through the use of the Electrical Hot Work Safety Program.

The program is designed to provide an awareness of the potential electrical hazards to all the people who work in the electrical environment and has been developed to give the discipline to the people who occasionally are required to carry out the electrical hot work.

The program provides the required awareness and discipline by developing a philosophy, and by controls.

Awareness

Discipline

CHAPTER 8

PHILISOPHY OF ELECTRICAL HOT WORK SAFETY PROGRAM

THE ELECTRICAL HOT WORK SAFETY PROGRAM meets its goals by embracing as its philosophy the following five well known and tried basic safety principles : [10]

SAFETY PRINCIPLES

* IDENTIFY the Hazards

* ELIMINATE the Hazard whenever possible

* CONTROL the Hazard when it cannot be eliminated

* MINIMIZE SEVERITY OF INJURIES when a Hazard is out of control

* MINIMIZE SEVERITY OF INJURY after the injury has occured

IDENTIFY THE HAZARDS

The plant electrical hot work program shall identify all the electrical hot work performed in the plant.

All the identified electrical hot work shall be reviewed against the plant electrical hot work standard. e.g.:

a) What electrical work hazard classification does the electrical hot work fall into ?

b) How close can LIMIT 1 and unqualified personnel approach exposed electrically energized components and legally comply with Government Health and Safety Act regulations for Industrial Establishments and Construction Projects in Ontario, Canada ?

c) What tools, test equipment, and temporary grounds will be required to do the work ?

d) Are the tools, test equipment, and temporary grounds approved for use and have the correct voltage or current rating ?

e) Has the electrical integrity of the tools, test equipment and temporary grounds been maintained ?

f) Have the temporary grounds and connectors been sized correctly for the fault current levels available at the point of use ?

ELIMINATE THE HAZARDS

A) All the identified electrical hot work shall be reviewed to determine if the hazard can be removed by using a well defined electrical hot work procedure. e.g.:

1) The fuse replacement in a 13.8 kv metal enclosed fuse switch cubicle was potentially hazardous when the fuses were replaced by an electrician standing inside the fuse switch cubicle ; thereby positioning himself within the 2'0 space of the minimum clearance zone of 2'0" established for 15 kv. The potential hazard was eliminated by replacing the fuses from outside the switch enclosure using a fuse clamp stick designed by the manufacturer of the equipment ; thereby positioning the electrician outside the minimum clearance zone and away from the hazard source.

2) Relamping of High Pressure Sodium lighting fixtures in General Purpose and Hazardous areas is potentially hazardous if the circuit remains energized when the lamp is removed, or if with the lamp removed an electrician checks for voltage at the lamp socket.

The potential hazard exists from the continous high voltage, high frequency pulse required to ignite or strike a sodium arc in the lamp. The high voltage high frequency pulse is always present at the lamp base when the ballast is energized and the ballast secondary circuit is unloaded.

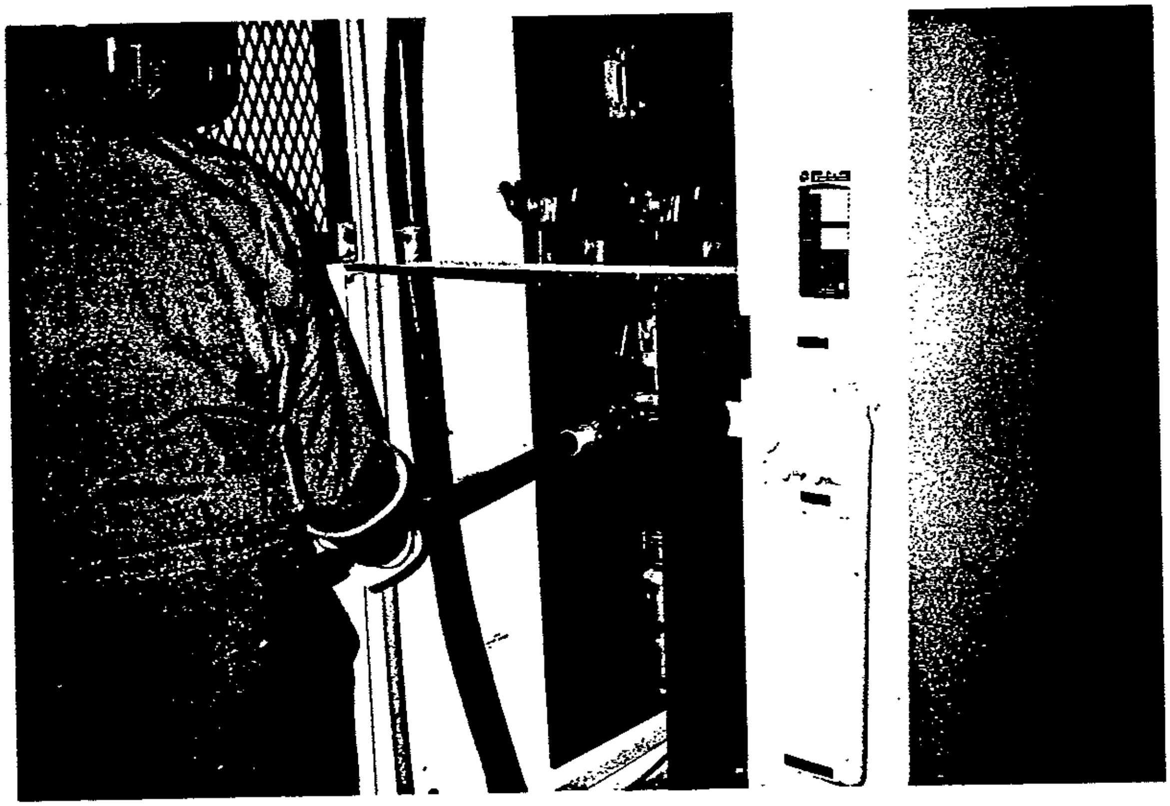


PLATE # 7

15KV FUSE REMOVAL ON AN ISOLATED 15KV FUSE DISCONNECT SWITCH. THE FUSE IS BEING REMOVED USING AN INSULATED FUSE CLAMP FROM OUTSIDE THE CUBICLE BY A QUALIFIED LIMIT III ELECTRICIAN WEARING FULL PERSONAL PROTECTIVE EQUIPMENT.

ie : The lamp is burnt out or removed from the circuit.

In standard High Pressure Sodium fixtures the Voltage Pulse can be in the region of 2,300 Volts - 4,000 Volts, 200milliamp at a 2×10^{-3} second pulse. In Instant restrike or Rapid restrike fixtures, the Voltage Pulse can be in the region of 6,000 Volts - 12,000 Volts, 200milliamp at a 2×10^{-3} second pulse.

The resultant potential shock energy of the Standard Fixture is approximately 0.92 - 1.6 joules and of the Instant or Rapid restrike fixture is approximately 2.4 - 4.8 joules.

The potential hazard is eliminated by switching off and tagging out or locking out the lamp circuit prior to relamping and by use of proper procedures, approved test equipment and protective clothing when the electrician checks for voltage at the lamp socket.

B) All the identified electrical hot work that could develop into a hazardous task if not controlled by procedure shall be identified. For example :

All electrical circuits shall be considered "HOT" until proven otherwise by :

visibly checking that the circuit is switched out of service; tagging and locking the circuit open; checking and testing the circuit for isolation using a voltage sensor approved for the voltage level being worked on ; and de-energizing the circuit by applying temporary grounds,

PLATE # 8

QUALIFIED LIMIT III ELECTRICIANS CHECKING THE POSITION OF THE LINE AND BUS TERMINALS IN A 15KV CELL WITH THE AID OF THE OPERATOR SINGLE LINE DIAGRAM. THE LOCATION WILL DETERMINE THE POSITION OF THE GROUND CARRIAGE CONNECTIONS THAT ARE INTERCHANGEABLE IN THE BUS OR LOAD CONNECTION POSITION.

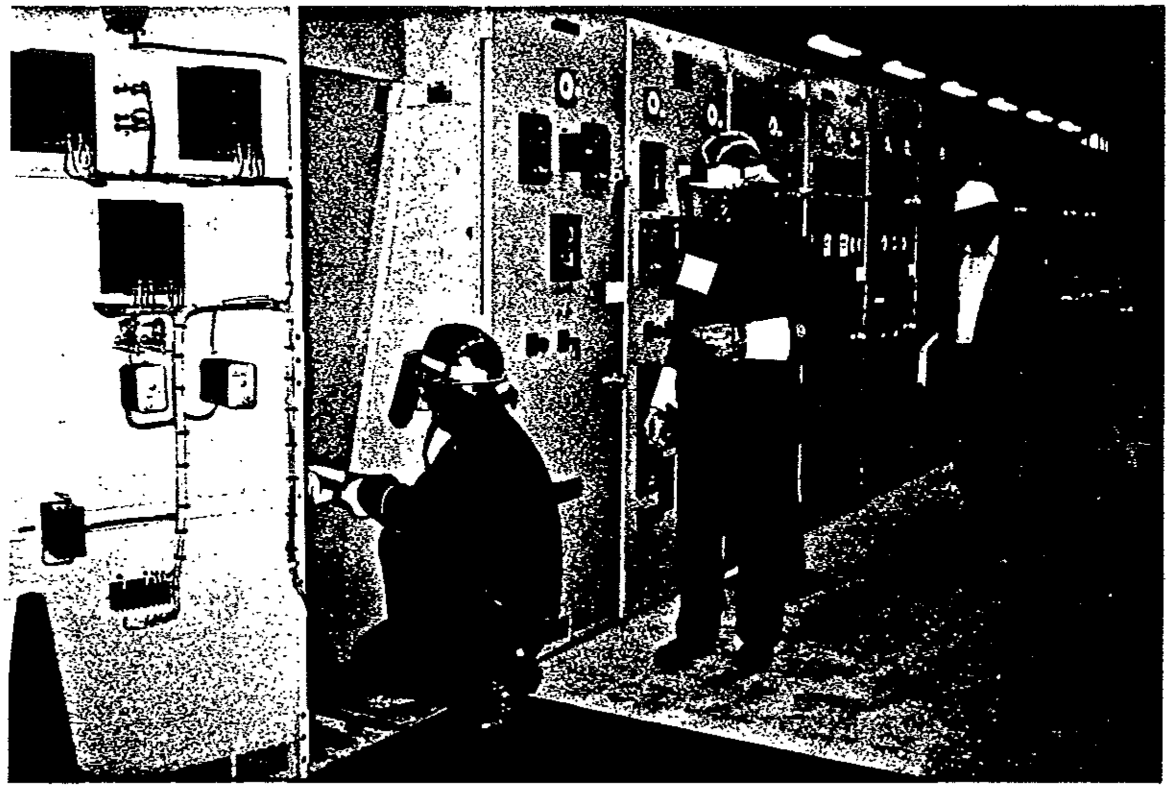


PLATE # 9

QUALIFIED LIMIT III ELECTRICIAN CHECKING FOR POTENTIAL OF THE PREVIOUSLY IDENTIFIED 15KV LOAD CONNECTION. THE QUALIFIED LIMIT III STANDBY MAN IS POSITIONED OUTSIDE THE POTENTIAL DIRECT ARC FLASH PATH.
A LIMIT I SUPERVISOR IS POSITIONED OUTSIDE THE ESTABLISHED AREA OF IMMEDIATE VICINITY.

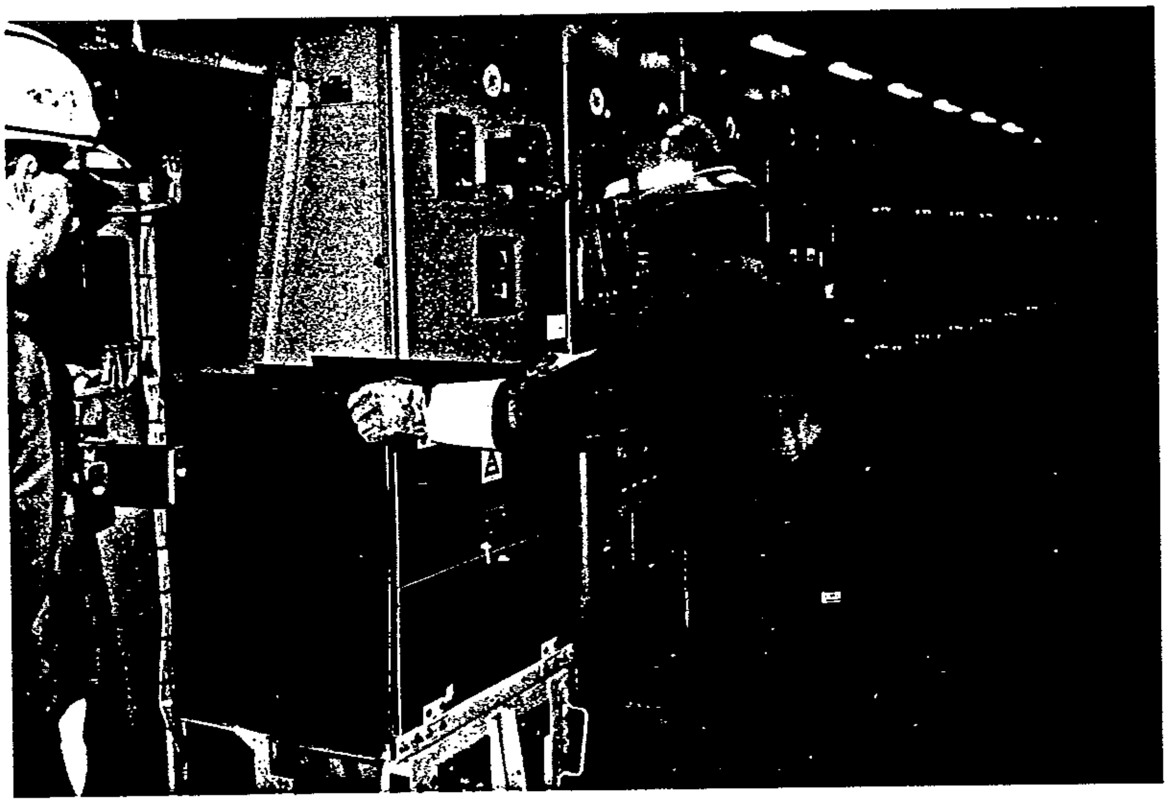


PLATE # 10

THE QUALIFIED LIMIT III ELECTRICIAN POSITIONS THE GROUND TEST DEVICE IN THE 15KV CELL PRIOR TO RACKING THE DEVICE ONTO THE ISOLATED LOAD SIDE TERMINALS TO DE-ENERGIZE THE 15KV CIRCUIT.

sized for the available fault current levels at the point of connection, to the isolated circuit.

The task of de-energizing a circuit making it safe to work on is in itself a hazardous task. Procedures are required for the correct use and care of high voltage sensing tools that are used to test a circuit for isolation, and for the application and care of temporary grounds used to de-energize a circuit. Testing a circuit for isolation should always be conducted using a voltage sensor approved for the voltage level being worked on and operated to the manufacturers instructions. The worker using the voltage sensor and the designated standby person should wear full protective clothing while performing this task. The integrity of the tool should be checked on a known voltage source before and after the circuit isolation check.

"Teasing" a circuit with the metallic end of a live line tool should not be used to test for isolation because:

a) the presence of low voltage on the circuit may not be seen or heard ;

b) sparking may be an indication of charging currents from induction and may be mistaken for line potential.

Throwing a chain over busbars to test for isolation should <u>never</u> be used to test for circuit isolation. The potential for personal injury and equipment damage from this uncontrolled action is extremely high and is unneccessary with todays test equipment.

Switching a circuit open including all sources of backfeed, locking and tagging the circuit open, and checking/testing for isolation effectively isolates that circuit from the distribution system. i.e. what can be seen on the Electrical Single Line Diagram.

Isolating a circuit will not remove and maintain induced voltages from the circuit, or offer protection to a worker in the event the circuit is accidently energized.

De-energizing the ciruit by the correct application of temporary grounds will connect and maintain the isolated circuit at earth potential and will:

a) maintain the circuit in a de-energized state by draining induced voltage to earth potential around the worker through a low impedance connection to ground;

b) provide a low impedance path to earth potential that will minimize the voltage potential gradient in the work area.

CONTROL THE HAZARDS

A) GENERAL WORK

The electrical hot work program will control the potential hazards involved in performing the identified electrical hot work through the use of well defined electrical hot work procedures. The electrical hot work procedures follow a standard format and shall be specific for the task. The procedures identify the equipment being worked on, the tools required to do the work, and the qualification of all personnel involved in the work.

B) SPECIAL WORK

With the Electrical Hot Work Procedures established to deal with the "General Work", personnel will have the hazard AWARENESS and DISCIPLINE necessary to take care of the special work. ie. Work not presently identified as electrical hot work or presently being conducted in the plant. For example :

A requirement developed to inspect and clean the porcelain insulators on a 230,000 Volt low profile busbar system in a double ended substation connected to the power utility. The inspection and cleaning were to be conducted by a contractor who met all the government regulations for performing live line insulator washing. The plant did not have a procedure that would allow the work to be conducted inside the plant.

Through the use of the Electrical Hot Work Program a qualified electrician quickly developed a procedure that incorporated the contractors procedure. The procedure was reviewed by the power utility, the contractor and the Plant Electrical Hot Work Committee before being approved for use.

MINIMIZE THE SEVERITY of injuries when the hazard is out of control

The program will minimize the severity of injuries when a potential hazard gets out of control during the execution of electrical hot work by :

A) Identifying the correct personal protective equipment to be worn.

B) Restricting the personnel exposed to the hazard by establishing an immediate vicinity zone and :

   1) Keeping all personnel not involved in the electrical hot work outside the area and;

   2) Minimizing the number of qualified personnel performing the work inside the area.

The immediate vicinity zone is developed from the Electrical Arc Flash Hazard Table 2 developed in the program for all the electrical distribution levels in the plant. The immediate vicinity zone is identified by electrical hot work procedure and is usually illustrated by a sketch in the procedure.

MINIMIZE THE SEVERITY of injury after the injury has occurred

The Electrical Hot Work Program will minimize the severity of an injury after it has got out of control by the assignment of a qualified standby person during the execution of the electrical hot work who is trained to provide :

A) Artificial resuscitaion.

B) Assistance or basic first aid to personnel who may have received electrical shock, arc flash burns or physical injury.

C) Assistance to remove the injured personnel from the hazard source.

CHAPTER 9

CONTROLS OF THE ELECTRICAL HOT WORK SAFETY PROGRAM

The Electrical Hot Work Program provides the necessary controls to enable personnel to effectively perform electrical hot work safely within the Philosophy of the five basic principles by the use of the following :

* A well defined Electrical Hot Work Standard.
* A Plant Electrical Hot Work Committee.
* Electrical Hot Work Procedures specific to the task, equipment being worked on, tools used to conduct the work and qualification of personnel performing the work.
* Training which leads to qualification of all personnel working in the environment influenced by electrical energy.
* Restricting access of personnel into the immediate vicinity zone.

PLANT ELECTRICAL HOT WORK STANDARD

The Plant Electrical Hot Work Standard forms the basis of all electrical hot work performed in the plant. There are no exceptions to the application of this standard except by a properly executed variance procedure signed by the appropriate Plant Management following the review by the Electrical Hot Work Committee.

Typically the Plant Electrical Hot Work Standard is based on a corporate standard and incorporates all the applicable government regulations. The standard must include a comprehensive list of definitions of electrical hot work terms that include the minimum clearance zone and immediate vicinity zone. The standard also provides for the audit of all electrical hot work in the plant.

CLASS A. Repair work to exposed and energized electrical systems over 150 Volts to 600 Volts inclusive, or repair work in the immediate vicinity to exposed and energized systems above 600 Volts ; or troubleshooting work performed on or in the immediate vicinity to exposed energized systems above 600 Volts.

Class A electrical hot work requires a hazardous work permit with full-time continous supervision by an electrical supervisor or qualified delegate specifically authorized for that job by Plant Management. No repair work shall be performed above 600 Volts.

<u>CLASS B.</u> Repair work to exposed and energized systems over 50 Volts to 150 Volts inclusive.

Class B electrical hot work requires that the Supervisor responsible for the exposed workers and Supervisor responsible for the equipment or their qualified delegate authorized by Plant Management, jointly review the work with the exposed worker immediately prior to its initiation if it is a first time job or a non-routine job. Routine practices will be covered by standard procedure and reviewed by periodic training. A Hazardous work permit may be required by the location when special work conditions exist.

<u>CLASS C</u> Troubleshooting work performed on any system over 50 Volts to 600 Volts inclusive, and all megohmeter or direct current high-potential testing.

Class C electrical hot work requires that the Supervisor responsible for the equipment be notified prior to the initiation of work. A Hazardous work permit may be required by the location when special work conditions exist.

<u>CLASS D</u> Installation of temporary ground cables or grounding devices on electrical systems rated above 600 Volts for de - energization purposes.

Class D electrical hot work requires that the Supervisor responsible for the exposed worker and the Supervisor responsible for the equipment, jointly review the work prior to its initiation, and prior to re - energization after the work is complete. A Hazardous work permit may be required by the location when special work conditions exist.

PLANT ELECTRICAL HOT WORK COMMITTEE

The administration of a comprehensive Electrical Hot Work Safety Program requires special attention within the framework of the plant line organization. Special consideration must be given to include the expertise of the people who are required to conduct the work, the resource of Electrical Engineers or Electrical Specialists and the authority and responsibility of supervision.

A team approach can best provide this administration role and fits in well with todays progressive plant management style. A typical Electrical Hot Work Team would consist of personnel from all the above disciplines, for example :

One Electrical Supervisor,Chairman	LIMIT I Qualification
One Electrical Engineer/Specialist	LIMIT II Qualification
One Electrician	LIMIT III Qualification

The position of one LIMIT III qualified Electrician could be rotated annually to give all plant LIMIT III qualified Electricians access to the committee.

The Electrical Hot Work Committee would provide controls to the program by performing the following duties :

A) Review the Electrical Hot Work Procedures against the plant Electrical Hot Work Standard.

B) Review modifications to the Electrical Single Line Diagrams and The Operator Single Line Diagrams.

C) Review modifications to the Electrical Distribution System.

D) Review all electrical test and live line equipment and personal protective equipment used in the Electrical Hot Work Procedures.

ELECTRICAL HOT WORK PROCEDURES

The Electrical Hot Work Procedures form the nucleus of the Electrical Hot Work Safety Program. They are specific to the task, the equipment involved, the tools required to perform the job and the qualification of the personnel involved in the work.

A typical plant would have approximately 8 electrical hot work procedures for work on voltage classes below 750 Volts, and approximately 26 electrical hot work procedures for work involving classes 750 Volts up to and including 230,000 Volts.

A typical list of the Electrical Hot Work Procedures including the Electrical Hot Work Standards would be :

SECTION	TITLE
STANDARDS	
XXX XX X	Corporate Electrical Hot Work Standard.
XXX XX XX	Division Electrical Hot Work Standard.
XXX XX XXX	Plant Electrical Hot Work Standard.
PROCEDURES BELOW 750 VOLTS	
EHWP 200	600 Volt Motor Control Centers Module Changeout.
EHWP 201	600 Volt Automatic Transfer Switch Trouble Shooting.
EHWP 202	120/208/240/ Volt Power Panel Troubleshooting and Repair.
EHWP 203	600 Volt Bolted Pressure Switch Fuse Changeout.

SECTION	TITLE
EHWP 204	Troubleshooting Inside An Energized 600 Volt Motor Control Center.
EHWP 205	Battery Charger and Battery Safety.
EHWP 206	Emergency Generator and Reliable Power System
EHWP 207	Thermovision Check on 600 Volt Motor Control Centers

PROCEDURES ABOVE 750 VOLTS

EHWP 100	Electrical Hot Work Committee.
EHWP 101	230 kv Switchyard - General Work.
EHWP 102	230 kv Switchyard - Temporary Ground 230 kv Line.
EHWP 103	230 kv Switchyard - Temporary Ground Transformer Bank.
EHWP 104	230 kv Switchyard - Temporary Ground 15 kv Reactor.
EHWP 105	15 kv Grounding Device.
EHWP 106	15 kv Fuse Removal Potential Transformers Bus 1A, Bus 1B.
EHWP 107	15 kv Fuse Removal.
EHWP 108	15 kv Metal Enclosed Switchgear Fuse Removal.
EHWP 109	15 kv Metal Enclosed Switchgear Temporary Grounds Load Side Circuit.
EHWP 110	15 kv Metal Enclosed Switchgear Temporary Grounds Line Side Circuit.
EHWP 111	5 kv Grounding Device.
EHWP 112	5 kv Temporary Grounds - 5 kv Motor Starter Circuit.
EHWP 113	5 kv Fuse Removal.
EHWP 114	5 kv Fuse Removal.

SECTION	TITLE
EHWP 115	5 kv H.R.G. Operation.
EHWP 116	Specification for Live LIne Tools.
EHWP 117	230 kv Switchyard - Energized Insulator Water Washing.
EHWP 118	Cable Trays General Work.
EHWP 119	Glowtector Operation.
EHWP 120	Phasing Stick Operation.
EHWP 121	Rubber Insulating Gloves for Electrical Hot Work.
EHWP 122	Temporary Grounds Identification.
EHWP 123	High Pressure Sodium Ballasts.
XXXX XXX	Operation of Cranes Near Electrical Power Lines.
EHWP 125	D.C. Hipot Testing.
EHWP 126	Trouble Shooting Energized 5 kv Motor Terminal Boxes for Ground Faults using H.R.G. Unit.

An Electrical Hot Work Procedure is provided for ALL the identified electrical hot work performed in the plant. The procedures are specific to particular tasks, the equipment being worked on, the live line tools required, and the qualification of the personnel performing the work. A procedure cannot be used for anything but the task identified.

Electrical hot work that may develop, that is not identified by established procedure shall have a procedure written against the plant Electrical Hot Work Standard and approved by the Electrical Hot Work Committee prior to performing the work.

Electrical hot work procedures allow for an instant audit of what is required to perform the electrical hot work.

Quote from an Operating Unit Department Head :

> "Being a Chemical Engineer and Department Head who had the responsibility to authorize Electrical Hot Work in my Operating Unit, I used to dread an Electrician walking into my office with a Hazardous Work Permit asking for my approval to perform Electrical Hot Work. I had no idea of what was required to do the work safely. Now through the Electrical Hot Work Safety Program the specific approved Electrical Hot Work Procedure is part of the Hazardous Work Permit. The procedure identifies who is qualified to perform the work, the tools required to do the work, the personal protective equipment, etc,etc. I can now knowledgeably authorize the Electrical Hot Work and Audit the work in progress. In fact, anyone in the plant can audit the work because the Electrical Hot Work Procedure and Hazardous Work Permit are posted at the job site."

All procedures follow a standard format that addresses the controls of Electrical Hot Work Program.

PLATE # 11

THE LARGE NUMBER OF PERSONNEL INVOLVED IN MOST ELECTRICAL HOT WORK TASKS DEMAND A COMMON WORKING LANGUAGE. THE ELECTRICAL HOT WORK PROGRAM CAN PROVIDE THAT LANGUAGE. THE SUPERVISOR OF THE PROCESS OPERATOR AND EQUIPMENT IS SHOWN FILLING IN THE HAZARDOUS WORK PERMIT WHILE THE ELECTRICIANS (2) IN FULL PROTECTIVE EQUIPMENT, THE OPERATOR WHO WILL PERFORM THE SWITCHING, AND THE SUPERVISOR OF THE ELECTRICIANS LOOK ON.

TYPICAL ELECTRICAL HOT WORK PROCEDURE OUTLINE

Title

1.0 Purpose

2.0 Qualification

3.0 Hazard Classification

4.0 Minimum Clearance Zone

5.0 Immediate Vicinity Zone

6.0 Limit of Approach

7.0 Unique Hazards

8.0 Safety

9.0 Personal Protective Equipment

10.0 Equipment

11.0 Reference Data

12.0 Procedure

13.0 Sketches

Title

Identifies the major equipment or device involved. e.g.:

PROCEDURE EHWP 105
Operation of 15 kv ground/test device for Allis Chalmers 15 kv Switchgear Bus 1A,1B Main Substation.

Purpose

The purpose identifies the task to be performed. e.g.:

1.0 Purpose.

To describe a procedure for the operation of the Allis Chalmers 15 kv ground/test inside the Allis Chalmers 15 kv Switchgear Bus 1A,1B Main Substation to facilitate the de-energization of a circuit or the testing of a circuit.

Qualification

Identifies the minimum qualification and number of persons required to perform the work. e.g.:

2.0 Qualification.

LIMIT III Ground Device Installer.
LIMIT II Minimum Helper.

Hazard Classification

The Hazard Classification identifies the class of Electrical Hot Work as defined by the Electrical Hot Work Standard for the particular task to be performed. The supervisory control and the requirements of a Hazardous Work Permit are identified in this section of the procedure. e.g.:

3.0 Hazard Classification.

Class D (For Ground/Test Device) requires a Hazardous Work Permit. The Supervisor responsible for the exposed worker and the Supervisor responsible for the equipment shall jointly review the work with the exposed worker prior to its initiation, and prior to re-energization of the equipment after the work is complete.

Class A (For the operation of the 15 kv Voltage Sensor only, refer to EHWP 119) requires a Hazardous Work Permit with full time continous supervision by an Electrical Supervisor specifically authorized for that job by Plant Management.

Minimum Clearance Zone

The Minimum Clearance Zone is the area around the exposed and energized electrical part detailed in FIGURE 14 and TABLE 1. The minimum clearance zone is established to provide a recognizable absolute limit of approach for LIMIT II and LIMIT III qualified personnel to exposed electrically energized components. No employee shall penetrate the minimum clearance zone with any part of his body, or approach with or operate any object as an extension of his body within the minimum clearance zone.

The use of approved test equipment or live line tools insulated for the voltage class being worked on and operated to the manufacturers instructions, shall be permitted as an extension of the employees body within the minimum clearance zone. The approved equipment shall be operated by the employee from outside the minimum clearance zone at all times. In addition, the use of grounding devices that are designed to connect to an electrically isolated bus connection inside metal enclosed switchgear in conformance with requirements for de-energization shall be permitted. e.g.:

4.0 Minimum Clearance Zone

The Minimum Clearance Zone for 15 kv phase to phase from TABLE 1 Electrical Hot Work Standard for LIMIT III and LIMIT II qualified persons is .6 meters (2 feet).

Immediate Vicinity Zone

The Immediate Vicinity Zone is the area around the Minimum Clearance Zone that will allow an employee the opportunity to penetrate the Minimum Clearance Zone by any part of his body, or by tools, test equipment or vehicles operated by the employee. A person in the Immediate Vicinity Zone is subject to inadvertently penetrating the Minimum Clearance Zone unless extreme care is experienced. All work in the Immediate Vicinity Zone is classed as Electrical Hot Work. Personnel working in the Immediate Vicinity Zone must wear the protective equipment identified by procedure at all times.

The perimeter of the Immediate Vicinity Zone can vary and depends on three basic requirements :

A) The voltage class of the exposed energized part.

B) The length of the tools being used by a person that could inadvertently penetrate the Minimum Clearance Zone unless extreme caution is used. e.g.:

If a person is conducting work 10 feet away from an exposed energized component rated 4,200 Volts, and is handling a 10 foot long conducting component (Steel or Aluminum Conduit) while performing the work, the person could accidently penetrate the Minimum Clearance Zone of 2'0" by using the tool as an extension of his body. This contributes to the determination of the outer perimeter boundary of the Immediate Vicinity Zone.

C) The fault level available at the point of the exposed energized part and the time required to clear that fault.

The fault level available at the point of exposure of the energized component determines the temperature personnel will be exposed to at a fixed distance from the part if an electrical arc/flash occurs. The temperature will be minimized by limiting the let through energy at the point of the fault by fast clearing action of the current limiting fuses or relay protective devices/circuit breakers. The temperature will decrease by increasing the distance between personnel and the source of the arc. This contributes to the determination of the outer boundary of the Immediate Vicinity Zone.

The Immediate Vicinity Zone is restricted to the personnel performing the electrical hot work and who are wearing the personal protective equipment identified by procedure. The outer perimeter of the Immediate Vicinity Zone is also designed to minimize the effects of electrical flash hazard to personnel not directly involved in the electrical hot work.

Persons qualified to the LIMIT I level may approach the distance specified in the Minimum Clearance Zone Tables by invitation and direct continous supervision of a qualified LIMIT II of III level person. e.g.:

5.0 Immediate Vicinity Zone

A clear unobstructed area in front of the 15 kv Allis Chalmers cubicle to be worked on shall be marked using "Traffic" cones. The area shall allow for the unobstructed use of the voltage sensors, ground/test device and hydraulic shutter lifting device. The area is designed to minimize the effects from electric arc flash burn. The outside perimeter shall be approximately 15'0" from the live 15 kv bus stubs.

Access to the immediate vicinity zone during the removal and installation of the grounding/test device shall be limited to the two qualified personnel assigned to the job. The approximate immediate vicinity zone is shown in Figure 1 of this procedure.(EHWP-105)

Limits of Approach

Ontario, Canada sets forth specific limits of approach for personnel to exposed energized electrical parts through the regulations for Industrial Establishments and Construction Projects. These limits of approach affect all personnel in Industrial Plants in Ontario. All plant employees must be aware of the limitations imposed by this Act and that any encroachment on these limitations will require special training in the activity in which the worker is engaged.e.g :

6.0 Limit of Approach.

The Limit of Approach for LIMIT I qualified personnel for this procedure shall be:

6.1 The area outside the immediate vicinity zone during testing and application of grounding device.

6.2 3 meters (10feet) from the exposed energized 15 kv bus when there is no established immediate vicinity zone.

Unique Hazards

This section of the Electrical Hot Work Procedure highlights the hazards that were identified during the development of the procedure. The hazards are those that may not be at first obvious to personnel who will be performing the hot work. e.g.:

7.0 Unique Hazards 15kv Grounding/Test Device.

7.1 The grouonding/test device is equipped with three (3) stubs that can be interchanged to either the line or bus position. Refer to FIGURE 2 Procedure EHWP 105

The grounding/test device is designed to connect to the isolated circuit to be de-energized (grounding device) or tested (test device).

IT IS IMPERATIVE THAT THE POSITION OF THE STUBS MATCH THE POSITION OF THE ISOLATED BUS STABS IN THE SWITCHGEAR CELL WHERE WORK IS TO BE PERFORMED.

The isolated bus stabs in the switchgear cell must be checked for potential using the voltage sensor before the grounding/test device is inserted in the cell.

7.2 The switchgear cell shutters are designed to open when the circuit breaker or grounding/test device is racked into the cell to the connect position. A manual operation of the shutters is required by this procedure to allow for a potential check on the isolated bus using the voltage sensor.Refer to Appendix B-8. (Electrical Hot Work Program).

The shutters must be securely blocked in the open position before the voltage sensor is used. Opening the shutters exposes both the line and bus terminals.

The minimum clearance zone around the exposed energized bus when the shutters are open is detailed in FIGURE 1.

7.3 The operation of the grounding/test device to the connect position in the cell will penetrate the minimum clearance zone.

The operator of the grounding/test device will penetrate the minimum clearance zone using the grounding/test device as an extension of his/her body. Refer to Electrical Hot Work Safety Standard XXX XX XXX.

The operation of the grounding/test device will be handled by a LIMIT III qualified person only.

7.4 Two types of grounding/test device are located in the Main Substation:

1) 1200 Amp.
2) 2000 Amp.

The electrical single line diagram must be consulted to determine the Ampere rating of the switchgear cell being worked on before the job starts.

7.5 Bus insulation in metal clad switchgear is not designed to prevent shock. Contact with this insulated energized bus could result in shock, burns or possibly death. Refer to Allis Chalmers Maintenance and Insulation Manual and Safety Standard MS-IV-5 Definition 8.

Safety

This section identifies or re-emphasises controls that must be in place prior to or during the performance of the electrical hot work. e.g.:

8.0 Safety.

8.1 A Hazardous Work Permit shall be required for this procedure.

8.2 All electrical conductors shall be considered energized until temporary grounds have been securely applied to the circuit after isolation.

8.3 The qualified persons shall both identify the 15 kv Allis Chalmers cell to be worked in from the operator single line diagram and electrical single line diagram. All possible sources of feedback and all points of isolation shall be identified on the operator single line diagram and electrical line diagram.

8.4 The qualified persons applying the temporary grounds shall both wear protective equipment identified in the Section on "Personal Protective Equipment" of this procedure.

8.5 The immediate vicinity zone shall be established before the job starts.

8.6 The master tag and lockout procedure shall be used to isolate the circuit before the job starts.

8.7 The temporary 15 kv grounding/test device applied by this procedure must be checked each time work is started after an absence from the job.

8.8 All insulated hand-held equipment penetrating the minimum clearance zone shall be tested and inspected prior to use as detailed in EHWP-116.

8.9 The temporary 15 kv grounding/test device applied by this procedure must be identified on the Master Card.

8.10 The temporary 15 kv grounding/test device must be removed before the qualified persons sign off the Master Card.

8.11 The qualified persons performing the work shall be familiar with the manufacturer's instructions on the equipment identified in this procedure.

8.12 The supervisor responsible for the qualified persons and the supervisor responsible for the equipment jointly review the work prior to its initiation and prior to re-energization.

8.13 Continous supervision by an Electrical Supervisor specifically authorized to observe the operation of the voltage sensor shall be provided when the LIMIT III person uses the voltage sensor on the 15 kv cell.

Personal Protective Equipment

The minimum personal protective equipment required by personnel to conduct the electrical hot work is listed in this section. The quantity of equipment and a cross reference to the equipment specification or manufacturer's data is identified in this section.

Personnel performing electrical hot work must wear the protective equipment at all times as identified by the specific procedure. Substitutions for the identified equipment must be approved by the Electrical Hot Work Committee. e.g.:

9.0 Personal Protective Equipment.

2 Pairs of Nomex III Flame-resistant Coveralls	Appendix A-1
2 Face Shields	Appendix A-2
2 Chieftain Citation Firefighters' Helmets complete with Nomex Liner and Clear Polycarbonate Faceshield	Appendix A-2
2 Pairs Class II Rubber Insulating Gloves with Leather Protective Covers	EHWP-121
1 Rubber Insulating Mat	Appendix A-2

Equipment

All the equipment that is required to perform the Electrical Hot Work is listed under this section of the Electrical Hot Work Procedure. The equipment identified is specific to the particular procedure and must not be substituted with unlisted equipment.

A cross reference is provided to equipment specifications and/or manufacturer's equipment data. The equipment must be used in accordance with the equipment specification and/or manufacturer's instructions and this data must be consulted by personnel performing the Electrical Hot Work.

All temporary grounds required by procedure are identified in this section. The grounds are identified by Master Tag Number and are sized to take into account the available fault level at the point the Electrical Hot Work is being performed. e.g.:

10.0 Equipment.

15 kv Grounding/Test Device	Appendix B-5
Voltage Sensor	EHWP-119
Shutter Lifting Mechanism	Appendix B-8

Reference Data

The reference data used to develop the Electrical Hot Work Procedure is listed in this section. The data includes Electrical Single Line diagrams, Operator Single Line diagrams and Equipment Manufacturer's Data.

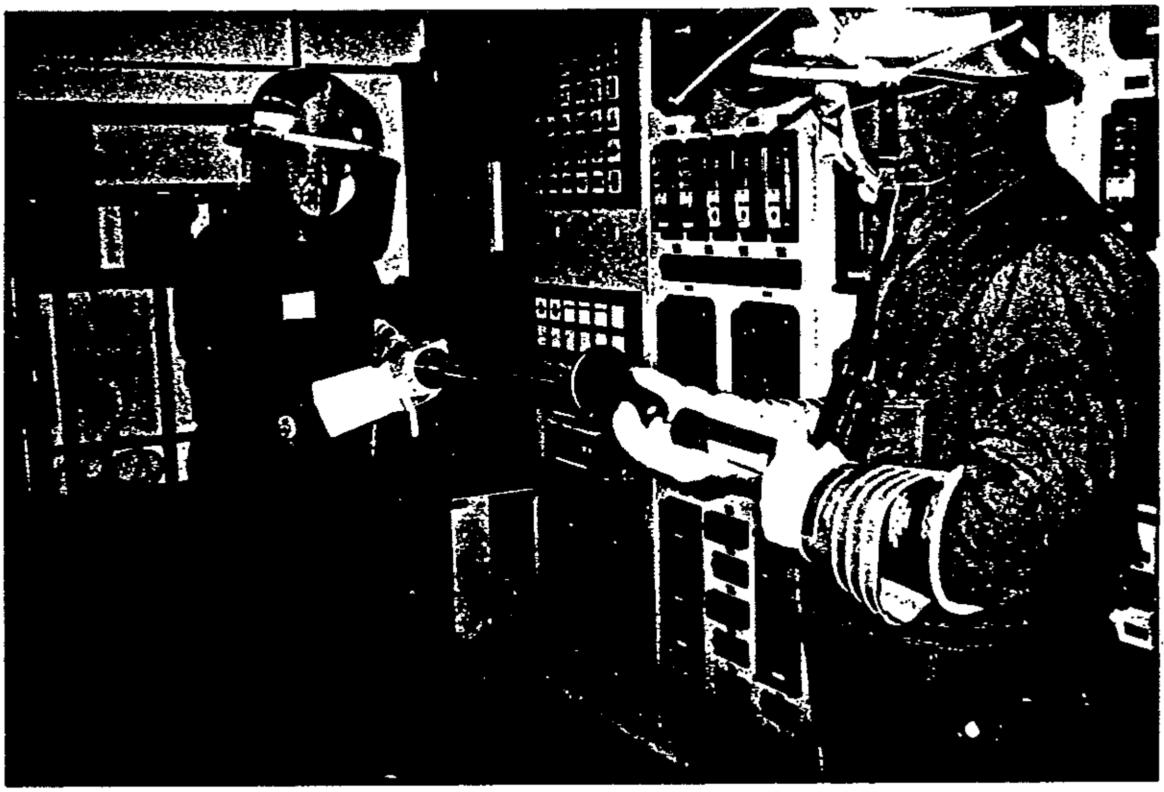


PLATE # 12

ELECTRICIANS CHECKING THE INTEGRITY OF THE VOLTAGE SENSING TOOL PRIOR TO USE.

NOTE: THE INTEGRITY OF THE TOOL WILL BE FURTHER CHECKED ON A KNOWN LIVE SOURCE USUALLY THE BUS CONNECTIONS IN A CELL AT THE TIME THE LOAD CONNECTIONS ARE BEING CHECKED FOR ISOLATION.

Personnel involved in the Electrical Hot Work must be familiar with the data referenced in this section. e.g.:

11.0 Reference Data.

3050300	Electrical One Line Diagram
3050300X	Operator Single Line Diagram
SG 3218	Siemens-Allis Installation, Operation, Maintenance, Parts, Instructions
SG 3386	Siemens-Allis Maintenance Guide for Switchgear Periodic Maintenance Program

Procedure

The procedure section of the Electrical Hot Work Procedure identifies all the steps required by qualified personnel wearing personal protective equipment using the specific tools or the specific pieces of equipment to complete a specific task of electrical hot work. e.g.:

12.0 Procedure.

12.1 The qualified persons doing the work shall both identify the points of isolation and lock out and check them against the operator single line diagram, the electrical single line diagram and Master Card.

12.2 The qualified persons doing the work shall apply their own locks to the points of isolation and sign on the Master Card.

12.3 The qualified persons shall discuss the job to be done and have a complete understanding of the equipment and this procedure.

12.4 The immediate vicinity zone markings shall be in place and the qualified persons shall be wearing the protective equipment described in this procedure when working in the immediate vicinity zone.

12.5 The qualified persons shall identify the exposed energized electrical equipment inside the Allis Chalmers cubicle and visibly determine the minimum clearance zone .6 meters (2 feet) for 15 kv and establish the immediate vicinity zone and limits of approach for LIMIT I qualified persons.

12.6 The qualified persons shall confirm that the position of the stubs on the grounding/test device matches the position of the isolated bus stabs in the switchgear cell where work is to be performed.

12.7 Install the shutter lifting device securely under the shutter lifting arm mechanism as detailed in Appendix B-8.

12.8 Open the shutters using the shutter lifting device from outside the switchgear cell.

12.9 <u>ENSURE THE SHUTTERS WHEN OPEN ARE BLOCKED OPEN.</u>

12.10 Check for potential on the isolated switchgear stabs using the voltage sensor and voltage sensor operation procedure EHWP-119.

12.11 Close the shutters after the voltage sensor potential check using the shutter lifting device and remove the device from the cell.

12.12 Confirm the isolated switchgear stabs match the position of the ground/test device to be inserted in the cell.

12.13 Confirm the Amper rating of the switchgear stabs match the rating of the ground/test device stubs, i.e.:

1) 1200 AMP. or
2) 2000 AMP.

12.14 <u>15 KV GROUND DEVICE</u>:

This procedure is for the application of the 15 kv ground and test device as a 15 kv grounding device only.

12.14.1 Securely ground the ground device back to the station ground using the 2/0 AWG copper cable.

<u>NOTE</u>: The switchgear sliding ground connection from the switchgear floor mounted ground bar to the grounding device carriage shall not be relied on for a positive ground connection.

12.14.2 Check that the bonding jumpers from the common ground bar on the grounding device to the grounding device stubs are secure.

12.14.3 Check the station ground bonding cable is securely connected to the grounding device common ground bar.

12.14.4 Close and secure using a nut and bolt the swing access door to the empty stub compartment. The swing access door to the grounded stub connections shall be left unlocked to facilitate inspection of the bonding jumpers.

12.14.5 Insert the ground device in the cell and rack into the connect position.

12.14.6 Check the ground device is secure in the connect position by pulling back on the handles attached to the front of the device.

12.14.7 When work is complete, remove the ground device by releasing the interlock release foot lever and rack the device out of cell.

12.14.8 Remove the grounding device from the master tag

12.15 <u>15 KV TEST DEVICE</u>:

This procedure is for the application of the 15 kv ground and test device as a 15 kv test device only.

The device shall be limited to a maximum Hipot test voltage of 38KV DC for 1 minute or a megger test up to 5,000 Volts.

12.15.1 Securely ground the ground device back to the station ground using the 2/0 AWG copper cable.

12.15.2 Disconnect the bonding jumpers between the common ground bar on the grounding device and the grounding/test device stubs.

12.15.3. Check the station ground bonding cable is securely connected to the grounding/test device common ground bar.

12.15.4. Close and secure using a nut and bolt, the swing access door to the empty stub compartment. The swing access door to the compartment containing the stub connection shall be left unlocked to facilitate test connections.

12.15.5 Insert the test device in the cell and rack into the connect position.

12.15.6 Check the test device is secure in the connect position by pulling back on the handles attached to the front of the device.

12.15.7 When work is complete, remove the ground device by releasing the interlock release foot lever and rack device out of cell.

12.15.8 Remove the test device from the master tag.

NOTE: Reconnect the bonding jumpers identified in Section 12.15.2.

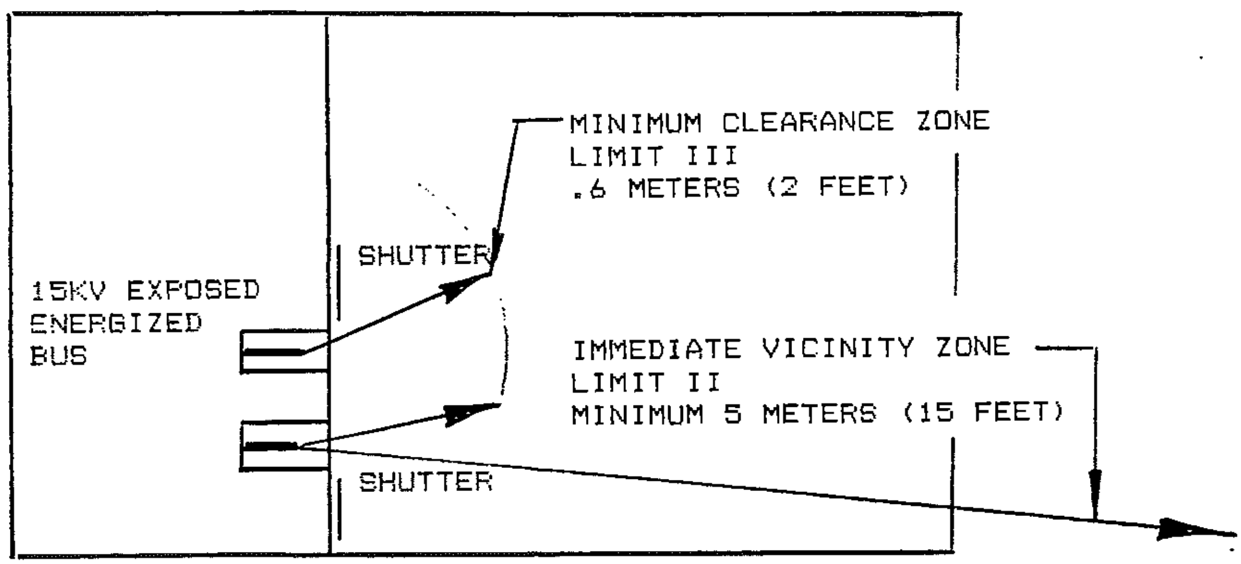
<u>Sketches</u>

Sketches are provided in certain Electrical Hot Work Procedures to illustrate and further explain various aspects of the procedure e.g.:

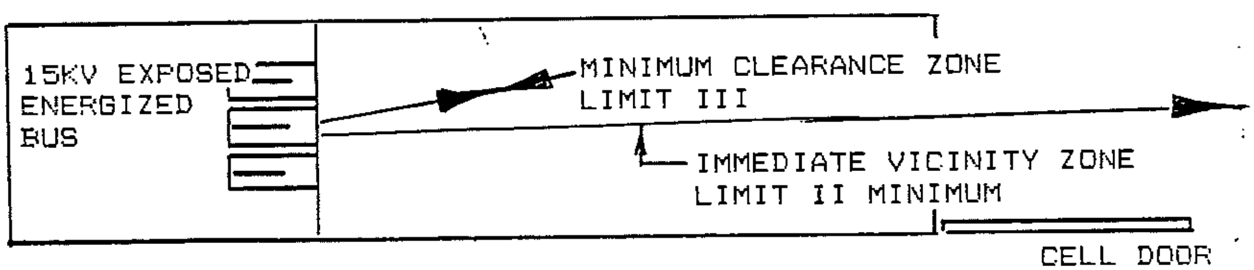
13.0 Sketches.

FIGURE 1	EHWP 105	Minimum Clearance Zone and Immediate Vicinity Zone 15 kv switchgear cell.
FIGURE 2	EHWP 105	Ground Test Device.

EHWP 105



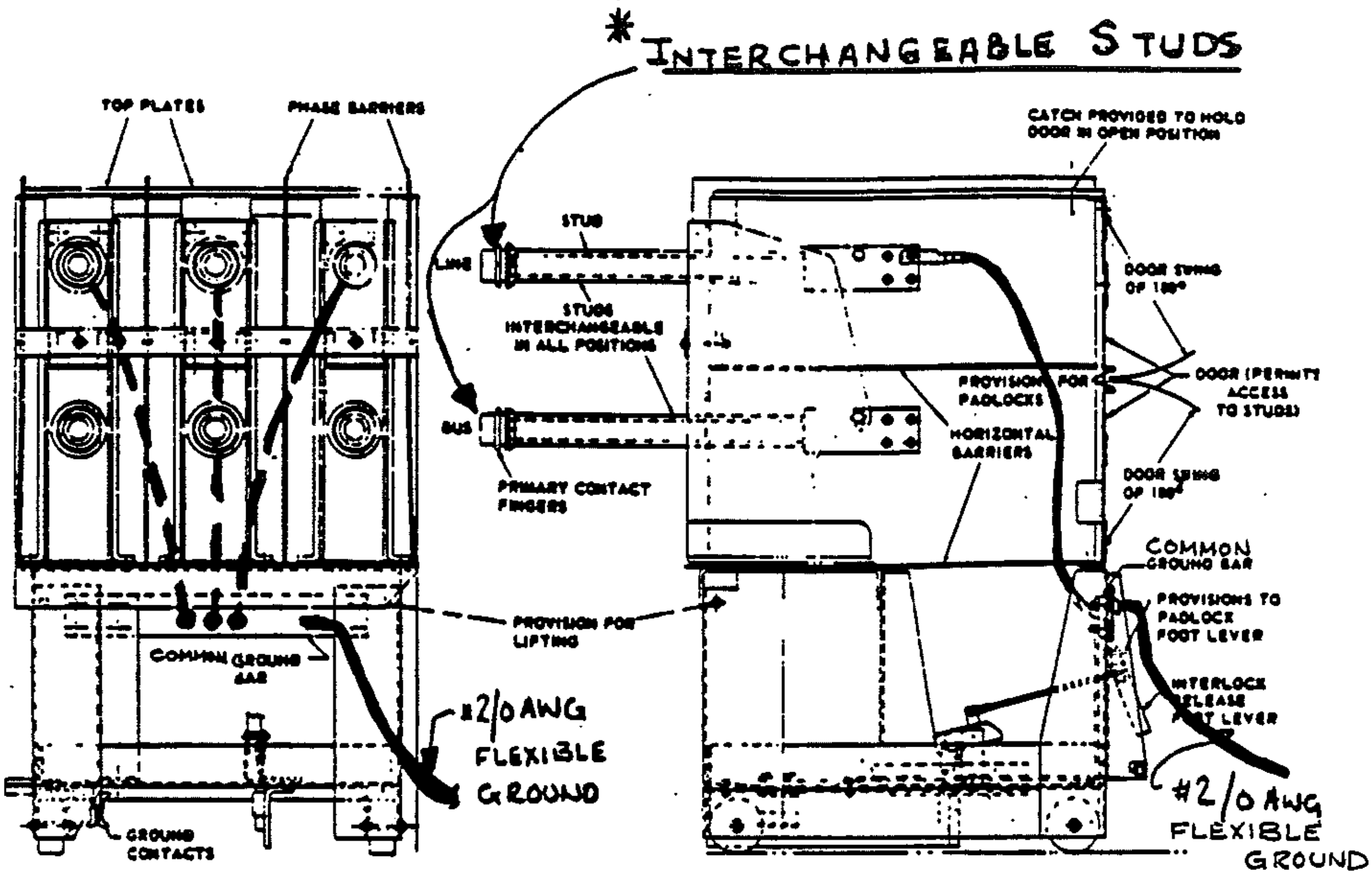
SIDE ELEVATION



PLAN VIEW

15KV SWITCHGEAR CELL WITH CIRCUIT BREAKER REMOVED AND SHUTTERS OPEN

FIGURE 1 (EHWP 105)



15KV GROUND TEST DEVICE

FIGURE 2 (EHWP 105)

TRAINING THAT LEADS TO QUALIFICATION

All personnel who work in the electrical environment in the plant are required to be classified to one of the three qualification levels :

LIMIT I

LIMIT II

LIMIT III

The term LIMIT is derived from the term Limit of approach universally used in the electrical industry to describe how close a "qualified" person is safely allowed to approach energized electrical equipment. See FIGURE 18.

The typical qualification requirements and classifications for personnel who work in an electrical environment are shown in TABLE 3.

CLASSIFICATION	QUALIFICATION REQUIREMENT
LIMIT I	Training Level 1
LIMIT II	Training Level 2
LIMIT III	Training Level 3

TABLE 3

Training Level 1

This is an instructional training module designed for LIMIT I employees who from time to time work within an environment influenced by electrical energy, but who have no need to approach exposed energized electrical equipment any closer than the limits defined in Government regulations. For example, the limits of approach detailed in TABLE 4 for the Occupational Health and Safety Act 1978 Regulations for Industrial Establishments and Construction Projects in Ontario.[11]

Training Level 1 is designed to educate and instruct personnel in the hazards of Electric Shock, Arc Flash Burns, Arc Pressures, Basic First Aid methods, and the Limits of safe approach to exposed electrically energized components.

LIMIT I qualified personnel shall have training to obtain an understanding of the following :

A) Electrical Hot Work Safety Program.

1) Working safely in an electrical environment.

a) Philosophy.

b) Controls.

c) Qualification.

d) Simplified Safe Work Practices.

e) Operator Single Line Diagram.

2) Electric Shock and Arc Flash.

a) Hazards of Electric Shock.

b) Mechanism of Electric Shock.

c) The Effects of Electric Current on the Human Body.

d) The Hazards of Electric Arc Flash Burn.

e) The Hazards of High Pressure Arcs.

f) First Aid Basics.

B) Government Regulations.

Limits of approach to exposed electrically energized components.

C) Personal Protective Equipment.

The Training Level I will provide instruction in electric hazard awareness to personnel who will be required to operate electrical equipment.

Training Level 2

Training Level 2 contains the training and instruction leading to qualification through a written test and instructor assessment. The Training Level 2 qualification allows personnel to work within the limits of approach defined in Training Level 1 and upto the minimum clearance zone as defined by TABLE 1 and FIGURE 14.

Training Level 2 consists of all of Training Level 1 plus knowledge obtained from electrical trade training programs and plant safety modules.

LIMIT II qualified personnel shall have training to obtain an understanding of the following :

A) Fundamentals of Electricity.

1) OHMS LAW.
2) Series Circuit.
3) Parallel Circuit.
4) Step Voltage.
5) Touch Voltage.
6) Grounding.

B) The Effects of Electric Shock on the Body.

1) Touch Potential.
2) Step Potential.
3) Clearing Fault Time.

C) The Effects of Electric Arc Flash on the Body.

1) Review of Energy Level available in Plant.

2) Immediate Vicinity Zone.

3) Clearing Fault Time.

D) Personnel Protective Equipment.

1) Temporary Grounds.

2) Fire Resistant Clothing.

3) Face Shields.

4) Rubber Insulating Gloves.

5) Rubber Mats.

6) Care and Testing of Personnel Protective Equipment.

E) Live Line Tools.

1) Voltmeters.

2) Clip on Ammeters.

3) Phasing Sticks.

4) Voltage Sensing Tools.

5) Care and Testing of Live Line Tools.

F) Safe Work Practices.

1) Master Tag and Lock Out.

2) Hazardous Work Permit.

3) Government Regulations.

4) Electrical Hot Work Standard.

5) Power Utility Work Protection Code.

(Items 1–5: LIMIT I)

6) Electrical Hot Work Procedures.

7) Equipment Manufacturers Instruction Manuals.

(Items 1–7: LIMIT II)

G) Electrical System Concept

1) Operator Single Diagram	LIMIT I	LIMIT II
2) Electrical One Line Diagram.		

H) Maintenance And Inspection Of Electrical Equipment.

The Training Level 2 will provide the electrical safety awareness for personnel to work within the immediate vicinity zone and up to the minimum clearance zone. This training level forms the basis for qualification for LIMIT II and LIMIT III personnel.

<u>Training Level 3</u>

Training Level 3 will allow qualified Electricians to work within the immediate vicinity zone and up to the minimum clearance zone. This qualification allows personnel who are wearing proper personal protective equipment to penetrate the minimum clearance zone with test equipment and live line tools approved for the voltage level being worked on, and operate them from outside the minimum clearance zone.

Training Level 3 consists of Training Level 1 and Training Level 2 plus knowledge obtained from electrical trade training programs, plant safety modules and job experience.

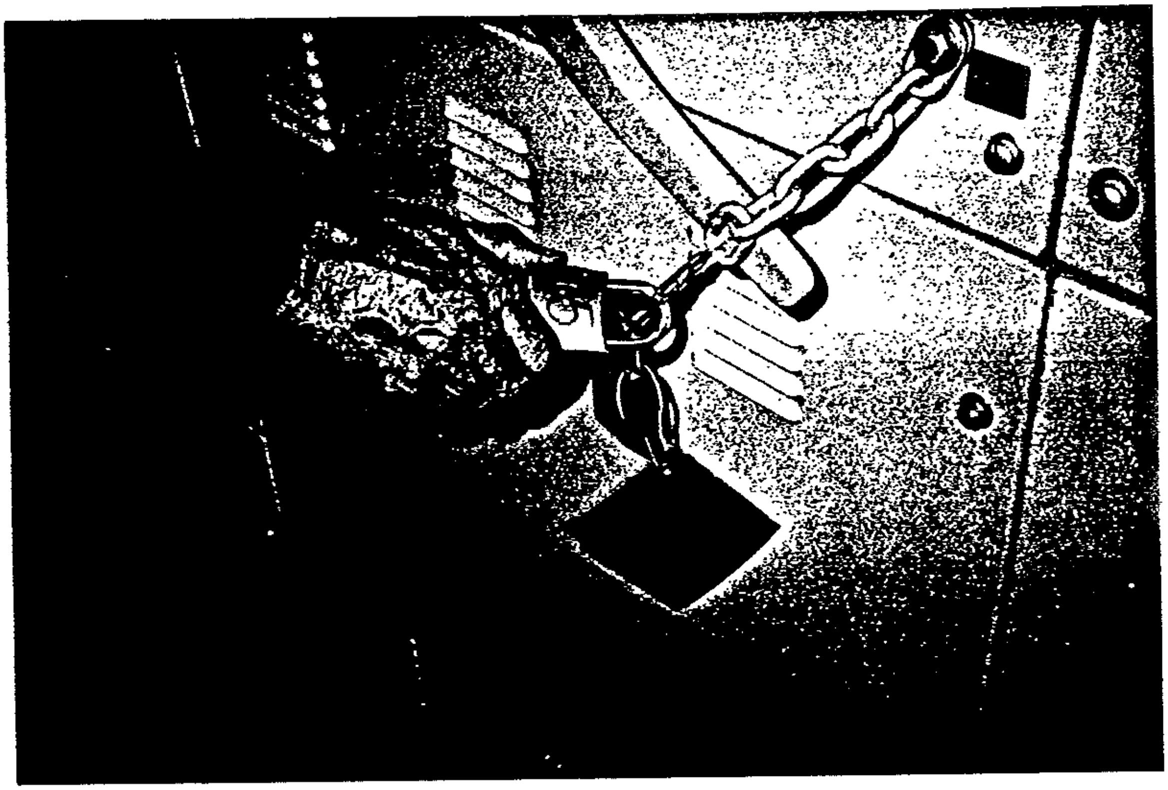


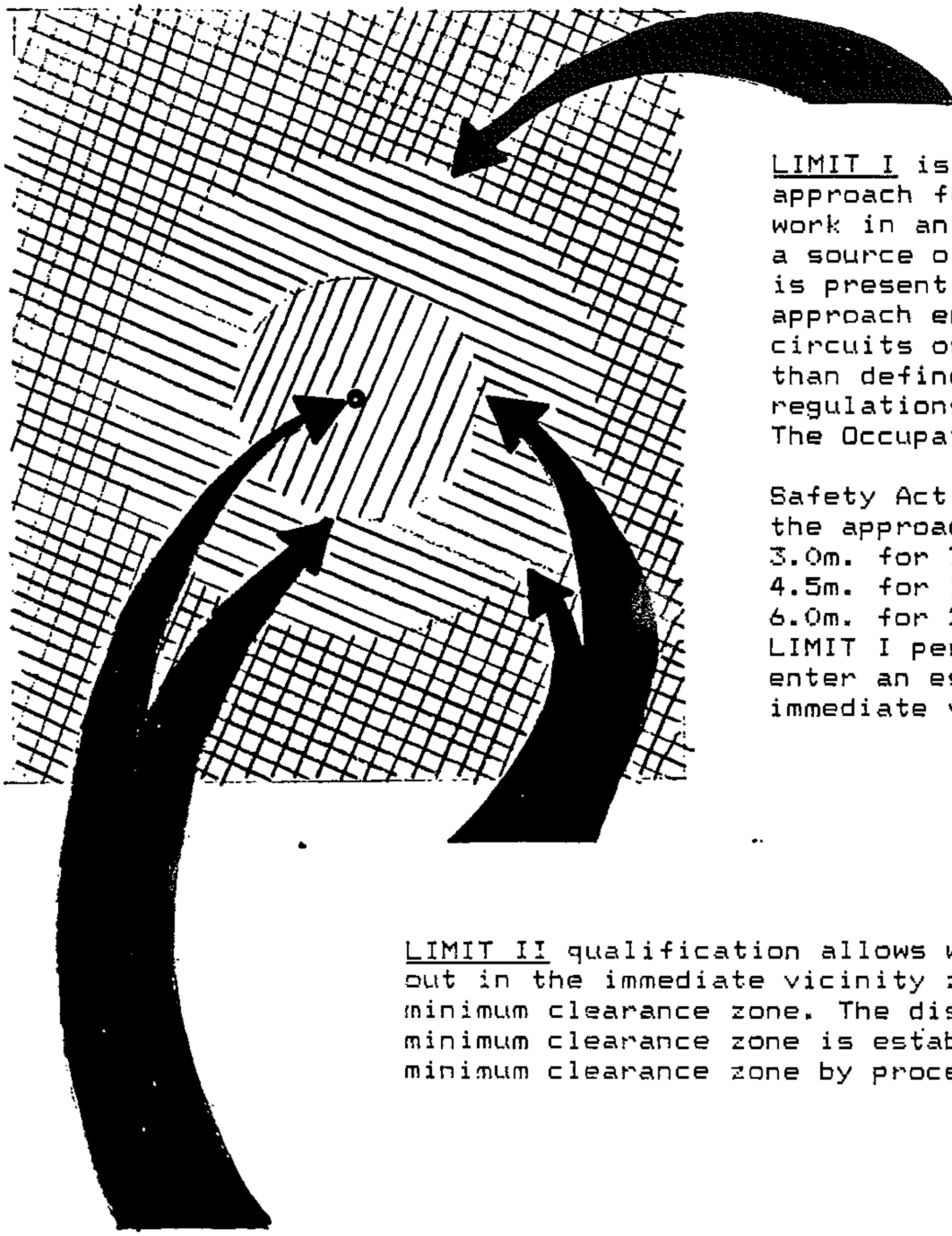
PLATE # 13

MASTER TAG AND LOCK OUT ON 600 VOLT SWITCH.

LOCK # 4. OPERATIONS UNIT LOCK.

LOCK # 5. ELECTRICIANS LOCK.

RESTRICTING ACCESS OF PERSONNEL INTO THE IMMEDIATE VICINITY ZONE



LIMIT I is the limit of approach for personnel who work in an environment where a source of electrical energy is present but do not need to approach energized electrical circuits or apparatus closer than defined by government regulations. e.g.:
The Occupational Health and Safety Act of Ontario[11] limits the approach of personnel to:
3.0m. for 750V - 150,000V
4.5m. for 150,000V - 250,000V
6.0m. for 250,000V and above.
LIMIT I personnel cannot enter an established immediate vicinity zone.

LIMIT II qualification allows work to be carried out in the immediate vicinity zone around the minimum clearance zone. The distance from the minimum clearance zone is established around the minimum clearance zone by procedure.

LIMIT III qualification allows work to be carried out in the immediate vicinity zone around the minimum clearance zone plus allows penetration of minimum clearance zone using approved test equipment suitably insulated for the voltage class being worked on and operated using the manufacturer's instructions.

FIGURE 18

LIMIT I Qualification.

The LIMIT I qualification is for personnel who work in an environment where a source of electrical energy could be present but who do not need to approach exposed energized electrical circuits or apparatus closer than that defined in Government regulations. For example, The Occupational Health and Safety Act 1978 Regulations for Industrial Establishments and Construction Projects in Ontario. [11]

The distance from an exposed electrically energized part a LIMIT I person must maintain is termed LIMIT OF APPROACH. Personnel qualified to the LIMIT I level are not allowed to enter an established immediate vicinity zone on their own.

LIMIT OF APPROACH. In all cases the worker requires specific qualification to ensure that he is at all times aware of the electrical hazards that exist within these limits. Unqualified persons and persons qualified to the level LIMIT I shall not be allowed to approach, or work, or allow any material or equipment to approach closer to exposed energized electrical equipment than the distance given in TABLE 4. [11]

Nominal Phase to Phase Voltage Range	Distance
750 to 150,000	3.05m. (10 feet)
150,000 to 250,000	4.58m. (15 feet)
250,000 to 550,000	6.10m. (20 feet)

TABLE 4

TABLE 5

LIMIT III

Qualified electricians who perform Electrical Hot Work 750 volts and above.

LIMIT II

Electrical engineers, electrical specialists, electricians in training, and control systems supervisors. These people may be required to get inside the Immediate Vicinity Zone to observe or act as standby. Limit II persons may be required to set conditions of Electrical Hot Work.

LIMIT I	LIMIT I A	LIMIT I B	LIMIT I C	LIMIT I D	LIMIT I E
Qualification for personnel who work in an electrical environment	Energy Systems Technicians	Process Technicians	Supervisors	Control Systems Technicians	Electrical Engineers, Electrical Specialists
	Switching Functions	Switching Functions	Supervision	Repair Work Troubleshoot	Troubleshoot
				< 750 V	120 V
				250 V	
				120 V	

Electrical Hot Work Committee Members

Limit III	Qualified Electricians
Limit II	Electrical Engineers and Electrical Specialists who are required to set conditions and act as standby
Limit I	Process Operating Staff and [illegible]

CHAPTER 10

SAFE WORK PRACTICES

An understanding of all safe work practices are necessary to make plant personnel aware of the rules and responsibilities for working in an electrical environment. In most plants these practices are usually already established and form part of a persons training.

Master Tag and Lock Out Procedure.

The Master Tag and Lock out procedure is the establishment of a policy for Tag and Lock out that assures the equipment is isolated before work begins, and that equipment upon which work is in progress is maintained isolated until maintenance/construction work is complete.

The review of this procedure and test for qualification under Safe Work Practices shall be a mandatory training standard for all LIMIT I,II,and III personnel.

Hazardous Work Permit.

The Hazardous Work Permit is one that is designed to protect personnel and equipment whenever potential hazardous work is to be performed. The review of the Hazardous Work Permit and test for qualification under Safe Work Practices shall be a mandatory training standard for all LIMIT I,II, and III personnel.

Plant Electrical Hot Work Standard.

The Plant Electrical Hot Work Standard forms the basis of all electrical hot work performed in the plant. In the larger organizations, the Plant Standard is usually written against a Divisional or Corporate Standard.

The review of the standard, test and qualification under Safe Work Practices shall be a mandatory training standard for all LIMIT I,II, and III personnel.

Plant Electrical Hot Work Procedures.

The Plant Electrical Hot Work Procedures are established procedures for specific electrical hot work tasks and are written against the Electrical Hot Work Standard.

The specific Electrical Hot Work Procedures contain a great deal of information necessary to safely perform the identified electrical hot work. Personnel qualified to LIMIT I,II, and III shall have a working knowledge and understanding of the Electrical Hot Work Procedures prior to use. A review of the identified Electrical Hot Work Procedures with test and qualification under Safe Work Practices will provide a valuable on-going training tool for all LIMIT I,II and III qualified personnel.

Power Utility Work Protection Codes.

Work in Plant Main Substations that connect directly to power utilities often require co-operation and communication between Plant Operators/Electricians and Power Utility Operators/ Electricians. In some cases plant personnel are required to work under the rules of the Power Utility. Personnel qualified to LIMIT I who are required to interface with the Power Utility personnel, and LIMIT II and LIMIT III personnel, should have a working knowledge and understanding of the Power Utility Work Protection Codes.

Operator Single Line Diagram.

The Operator Single Line Diagram can prove to be an invaluable safety tool for Operators and Electricians charged with switching and master tag and lock out duties. The Operator Single Line Diagram should not be confused with the Electrical Single Line Diagram.

The Operator Single Line Diagram is a scale representation of metal enclosed switchgear that puts the basic information found on the Electrical Single Line Diagram in physical perspective. The diagram is a physical scale representation of metal enclosed switchgear found on the Electrical Single Line Diagram. Each cubicle or cell outline of the switchgear is drawn to a minimum scale of 1 inch equals 1 foot.

The bus configuration and physical and electrical location of the high voltage components is then overlaid on the switchgear outline. The diagram shows all possible sources of voltage potential to the installation under normal and emergency conditions, and the location of devices for isolating such power supplies. Interlocks and a narrative of their function are identified on each diagram. The nomenclature of each component cell or cubicle is identified exactly on the diagram.

The information shown on the Operator Single Line Diagram allows the operator to identify the location of all power

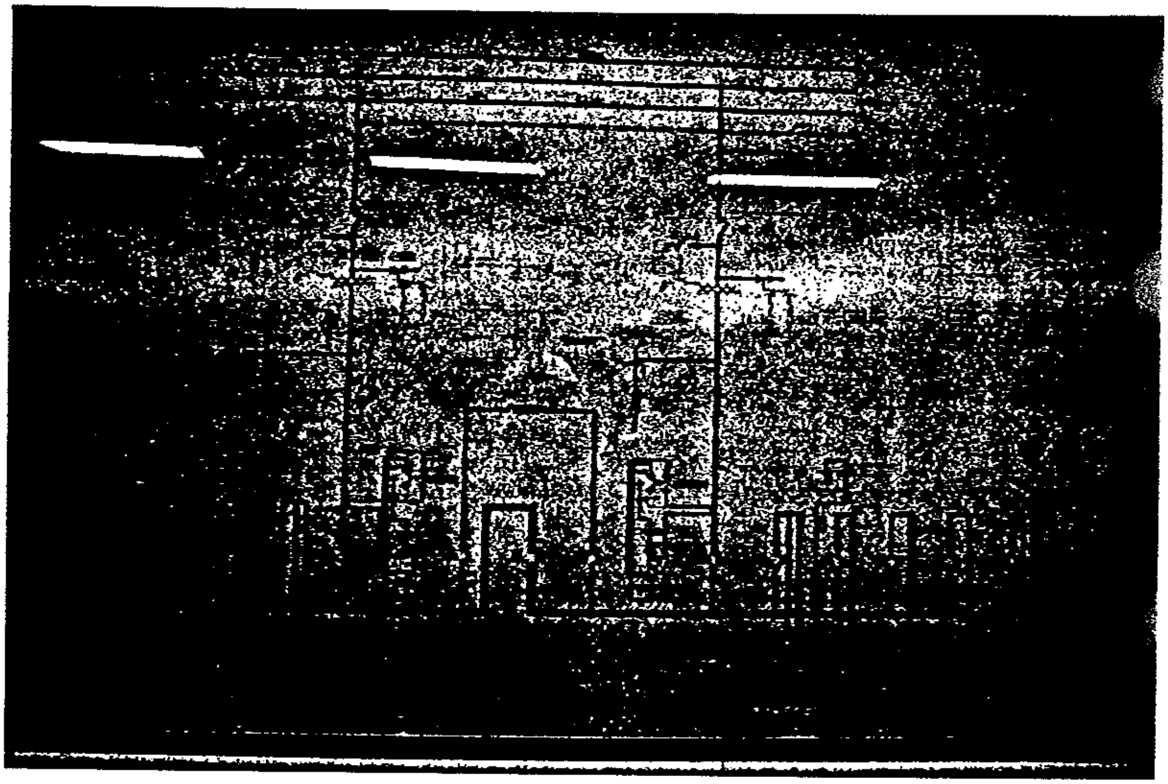


PLATE # 14

OPERATOR SINGLE LINE DIAGRAM

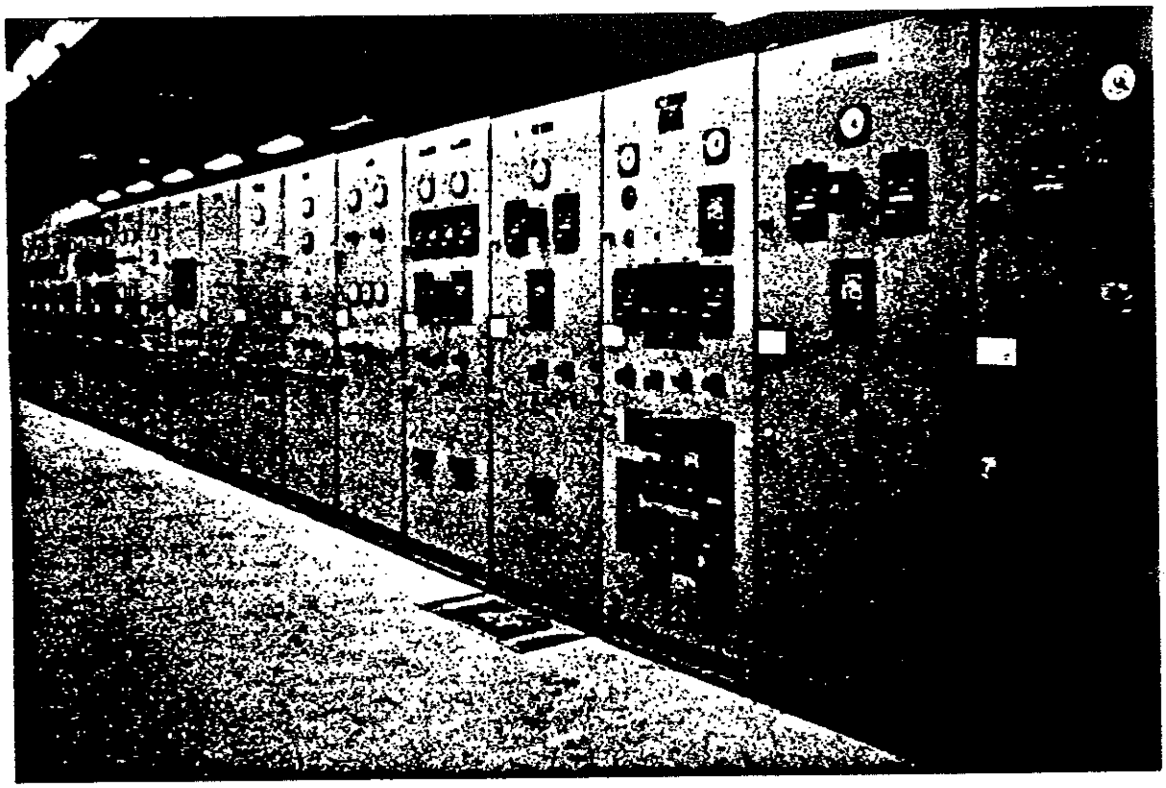


PLATE # 15

SLIDE OF 15KV SWITCHGEAR LINE UP THAT MATCHES THE OPERATOR SINGLE LINE DIAGRAM.

PLATE # 16

CHECKING MASTER TAG AGAINST THE OPERATOR SINGLE LINE DIAGRAM.

components involved in switching operations including sources of back feed prior to performing the actual switching operation. Electricians are able to identify and cross check points of isolation, eg, the location of load terminals or feeder terminals in a switchgear cell prior to testing for isolation using voltage sensing tools.

The Operator Single Line Diagram has been a requirement in Ontario since 1960. Each metal enclosed switchgear assembly must have an Operator Single Line Diagram. The diagram is required to be hung in the Substation in a well lighted area.

Electrical One Line Diagram.

The Electrical One Line Diagram or Single Line Diagram provides an overview of the Plant Electrical Power Distribution System. The Diagram is used for short circuit analysis, protective relay co-ordination studies and planning electrical switching functions.

The Diagram is a schematic representation of all the elctrical power components and their ratings as well as all the protective devices with their input signals and output functions.

A Single Line Diagram of the Plant Power Distribution System should be hung behind "Glass" in a well illuminated area of each Substation

Maintenance and Inspection of Electrical Equipment.

Poorly maintained electrical equipment can be a hazard. Harsh environmental factors such as high temperatures, excess moisture, conductive dust and other contaminates all contribute to loss of integrity of electrical insulation. Hard service conditions such as overloads, even full load on marginally designed components, deep cycling and vibration can result in circuit breakers and switches that "freeze" in the closed position or in protective devices that stick and fail to initiate tripping when needed. During long term neglect people are subject to forget features of design, details of construction, procedure of operation and idioynchrasies of complex integrated process electrical equipment.

The best way to minimize these detrimental effects is to recognize the inevitability of their presence or occurrance and act to detect the deterioration before breakdown or malfunction occurs.

Regular inspection and maintenance will allow the LIMIT II and LIMIT III electricians as well as the utility operating switch person to maintain familiarity with the electrical equipment and to determine the overall status of its condition. The inspection should consist of visual examination as well as other non-contact data collection such as infra-red detection of hot spots.

Regular inspection and maintenance can detect impending problems so corrective action can be scheduled and performed in time to prevent unwarranted failures. The switching activities associated with planned preventative maintenance provides the exercise that circuit breakers and switches need to help keep them operating freely. Regular bench test and calibration of protective devices will enhance their capability to respond to overcurrent or fault current signals and activate tripping of associated circuit breakers.

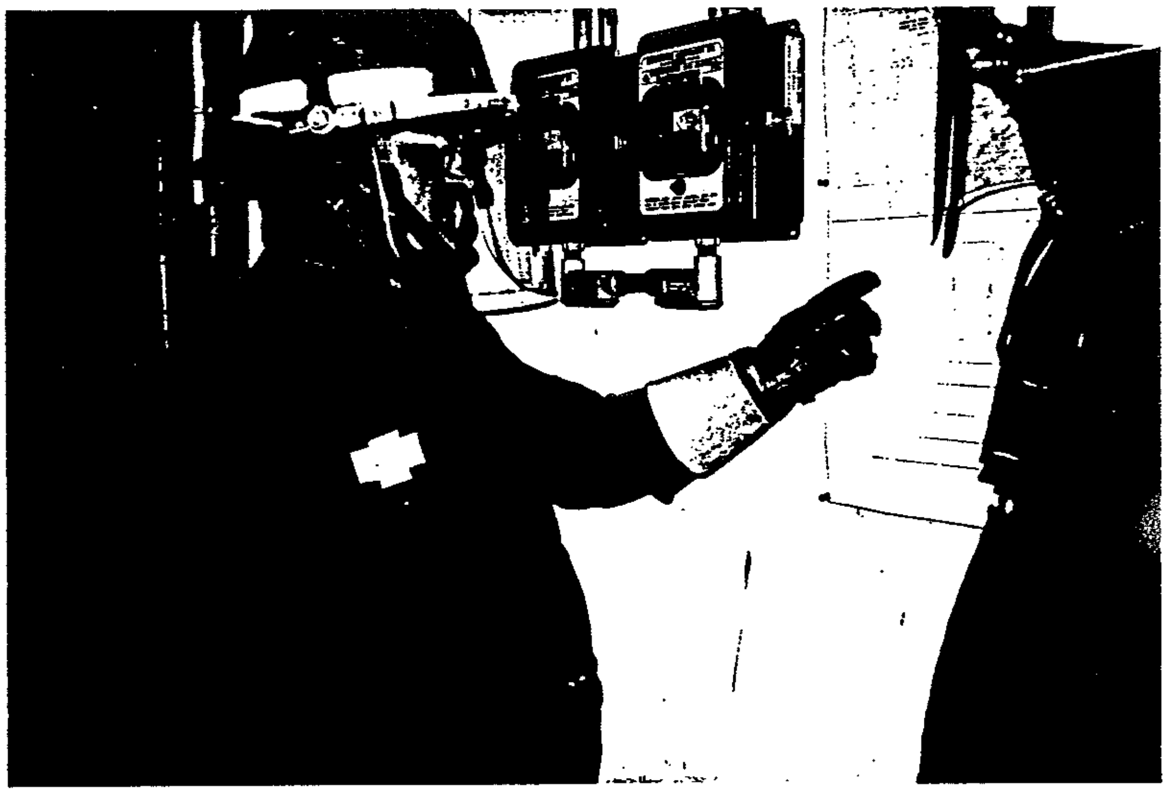


PLATE # 17

QUALIFIED LIMIT III ELECTRICIANS CHECKING THE SWITCHING SEQUENCE AND THE ELECTRICAL SINGLE LINE DIAGRAM.

CHAPTER 11

TEMPORARY GROUNDING

All circuits are considered hot until :

* The circuit has been switched out of service;
* Tagged and Locked open;
* Checked for isolation;
* Tested for isolation; and
* DE-ENERGIZED BY THE APPLICATION OF TEMPORARY GROUNDS ON THE ISOLATED CIRCUITS

DEFINITIONS

ISOLATED - A part is considered electrically isolated when it has been disconnected from energized parts by switching action, locked out and tagged, and is checked to ensure absence of voltage.

Isolating a circuit ensures that the circuit is not connected to any known source of potential, including potential backfeed as identified from the Electrical Single Line Diagram. It does not ensure that the circuit will be maintained at earth potential.

DE-ENERGIZED - (Dead) - means free from any electrical connection to a source of potential difference and from electrical charge; not having a voltage potential different from that of the earth potential.

Isolated circuits can become hazardous to a worker from many sources if they are not grounded to earth potential. e.g.:

INDUCTION.

Energized circuits adjacent to the isolated circuit can induce voltages on to the isolated circuit. The magnitude of the induced voltage varies with the proximity, voltage level and current loading of the adjacent circuits. In some cases the induced voltage will be of a continous nature.

ACCIDENTAL.

Energizing an isolated circuit by operator error should never occur when using an established Tagout and Lockout procedure. Failure to identify a source of backfeed during the isolation stage however could happen and the isolated circuit could become energized through this backfeed.

WIND.

Air movement over long isolated transmission lines becomes in itself an electro-static generator and induces voltages in the isolated line.

LIGHTNING.

"If you don't like the weather stick around for an hour" is an often heard saying. To the unsuspecting line man lightning storms may be creating havoc on distant parts of the isolated electrical system while he is bathing in sunshine. Lightning striking another part of the system could result in transient voltages which would make his work area unsafe if not properly grounded.

De-energizing a circuit through the application of temporary ground's connected from the isolated circuit to earth potential will maintain the work area in the vicinity of the grounds at earth potential. The correctly applied temporary ground's will also provide a low impedance path to ground that will facilitate fast clearing of the circuit by protective relay action in the event the circuit accidently becomes energized.

The low impedance path connection to earth potential provided by the temporary ground's will also minimize the voltage gradient in the work area. Minimizing this voltage gradient will in turn minimize the voltage and damaging current shunted across the worker who will be connected in parallel to the temporary ground. For example, by adding temporary ground's to FIGURE # 10, it can be shown the current flow shunted through the worker under fault conditions will be minimized substancially, see FIGURE'S # 19A and 19B.

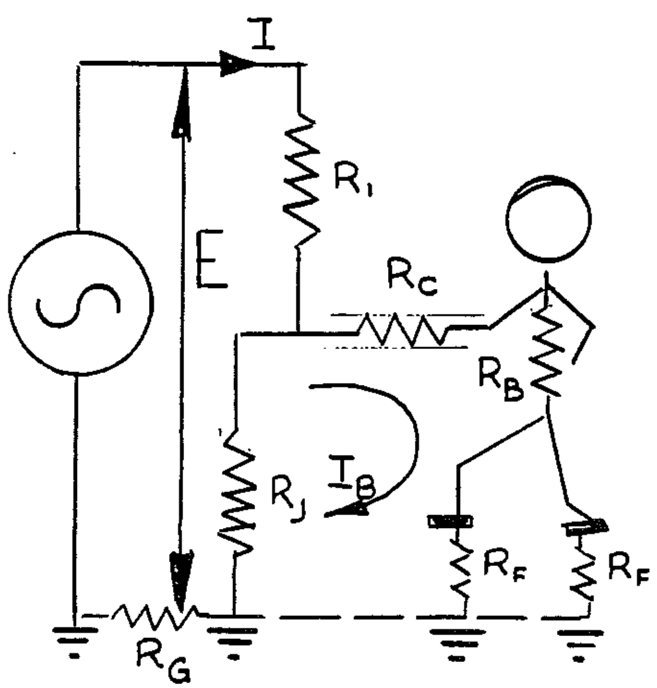


FIGURE 19A

R_J = GROUND JUMPER OF 0.001 OHMS RESISTANCE

R_B = RESISTANCE OF WORKERS BODY APPROX.1000 OHMS

R_G = GROUND RESISTANCE APPROX. 10 OHMS

R_C = CONTACT RESISTANCE AT WORKERS HAND = 0 OHMS FOR CALCULATION PURPOSE

R_F = CONTACT RESISTANCE AT WORKERS FEET = 0 OHMS FOR CALCULATION PURPOSE

E = 15,000VOLTS 3ϕ, 60HZ SYSTEM VOLTS

R_1 = CIRCUIT RESISTANCE = 0 OHMS FOR CALCULATION PURPOSE

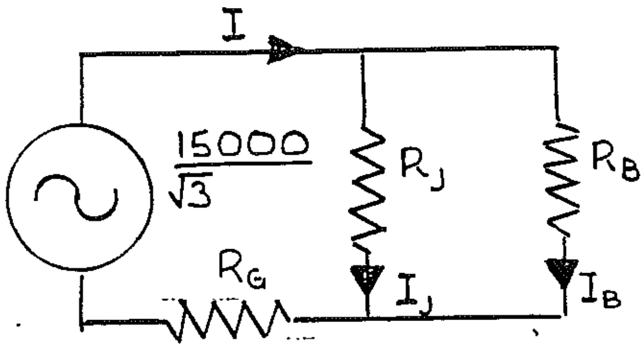


FIGURE 19B

$$I = \frac{E}{R_G + \frac{R_J R_C}{R_J + R_C}}$$

$$= \frac{8660}{10 + \frac{1 \times 10^{-3} \times 10 \times 10^{-3}}{1000 + 0.001}}$$

$$= \underline{865 \text{ AMPS}}$$

EQUIVALENT CIRCUIT

$R_J = 0.001$ OHMS

$R_B = 1000$ OHMS

$R_G = 10$ OHMS

$E = 8660$ VOLTS

$$I_J = 865 \times \frac{R_B}{R_J + R_B} = 865 \times \frac{1000}{1000.001}$$

$I = 864.999$ AMPS = CURRENT OF JUMPER

I_B = CURRENT FLOW THROUGH WORKERS SHUNTED BODY

= 865 − 864.999 = <u>1 milliamp</u>

= THRESHOLD OF PERCEPTION

Temporary ground's should be considered as an integral part of every electrical distribution system. The size of the temporary ground conductor and clamps must match the available short circuit currents where they are to be applied. The exact same considerations that are given to permanently installed electrical components must be given to the application of temporary ground's.

The procurement of temporary ground's for one Industry needed to accomodate the de-energization requirements of an annual outage on the 230kv incoming power lines shared with The Power Utility and other local industries, used to mean a foot race between the Industries to the local Electrical Equipment Distributor Store. The winning Industry got the pick of the temporary ground's. The loser scrambled around and usually made do with less than satisfactory ground's.

It is important to note that a good set of temporary ground's with adaquately sized clamps and conductors indicates knowledge and competency and sets the tone of the job to be done. Consequently, good grounding procedures are more likely to be followed.

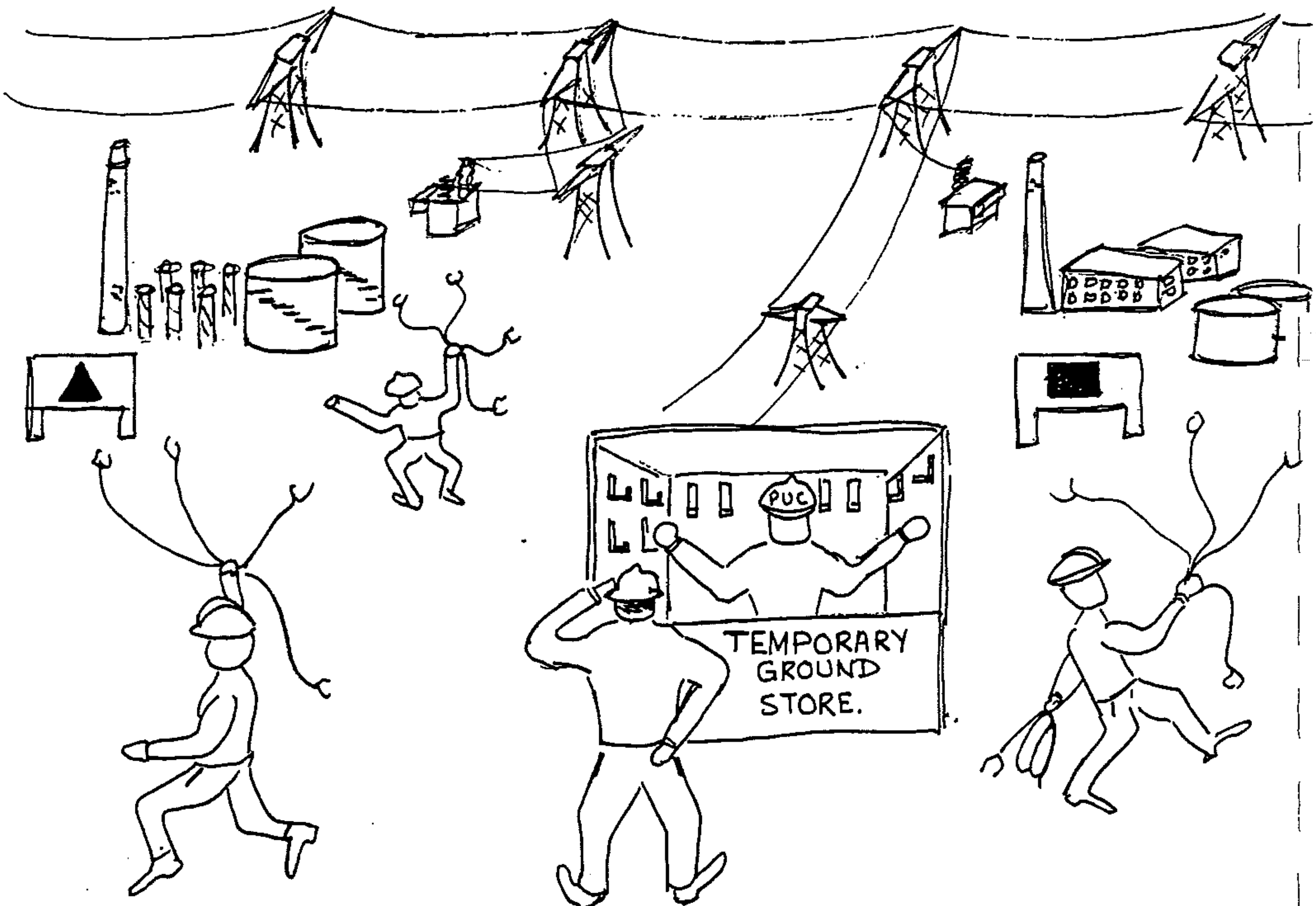


FIGURE 20

The Electrical Hot Work Safety Program ensures that ground sets are correctly sized and identified for use. Each procedure in the program that requires temporary ground's identifies the ground's by Tag #, See PLATE # 18. The temporary ground identified are specifically built for the isolated circuit to be de-energized.

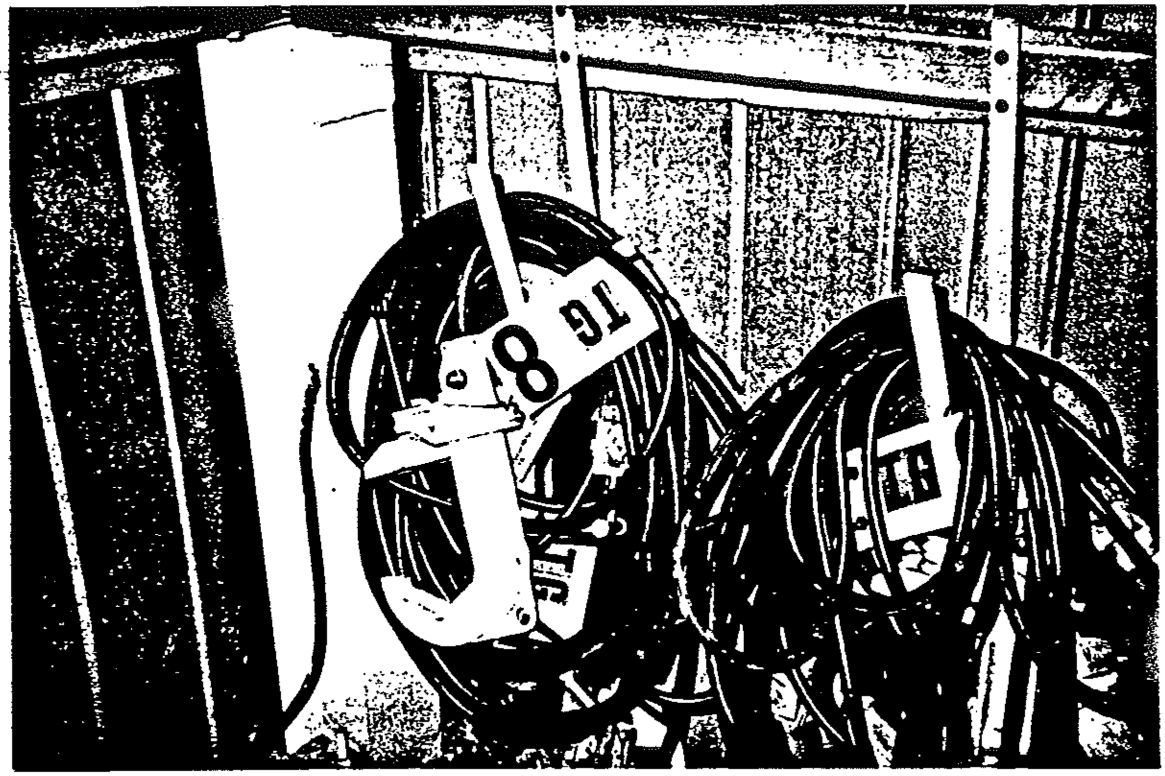


PLATE # 18

Fault Currents Available.

The temporary grounding procedure identifies the fault levels available at all the distribution buses in the Plant Electrical System. The ground conductors and associated clamps are sized to match the available fault currents where they will be connected.

Cables.

The temporary ground cables as shown on TABLE 6 are sized to match the available fault current and clearing times of the fault by relay protective devices/circuit breaker or current limiting fuses.

Shorter grounding cables offer lower resistance. Tremendous forces are involved during faults which result in severe and dangerous cable movement if there is excessive slack in the grounding cable. Long leads should be lashed at some intermediate point to reduce the hazard to personnel and dislocation of grounding connection.

MAXIMUM FAULT CURRENTS OF GROUNDING CABLES

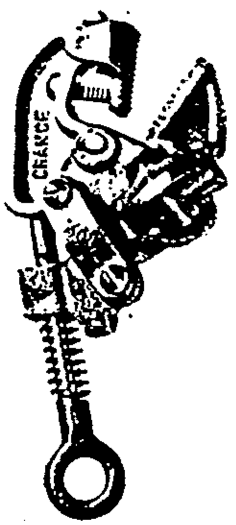
COPPER CABLE SIZE AWG	FAULT TIME CYCLES	RMS AMPERES
2	6 15 30 60	16,800 12,000 8,600 5,300
1/0	6 15 30 60	25,300 18,500 13,000 8,000
2/0	6 15 30 60	31,000 21,000 15,000 10,000
3/0	6 15 30 60	41,000 29,000 21,000 13,000
4/0	6 15 30 60	47,000 37,000 26,000 15,000

TABLE 6

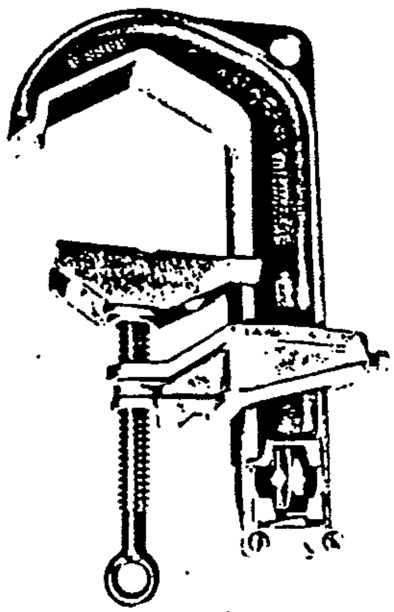
Clamps.

The temporary ground clamps are sized to match the available fault current and clearing time, of the fault, by protective devices.

It is important to select clamps that will securely fasten to the point of contact with the isolated circuit.



C600-1615



G3369

G3363-1

Catalog Number	G3367-2	G3369	G3363-1
ELECTRICAL RATINGS			
Continuous Current (AMPS)	400	400	400
Fault Current - 15 Cycles (AMPS)	40,000	40,000	35,000
Fault Current - 30 Cycles (AMPS)	30,000	30,000	25,000

FIGURE 21

A.B. CHANCE GROUND CLAMPS AND ELECTRICAL RATING TABLE

Temporary ground's should be applied where possible with live line tools that will put distance between the isolated circuit and the workman. The live line tool or GRIP-ALL should be identified in the Electrical Hot Work Procedure.

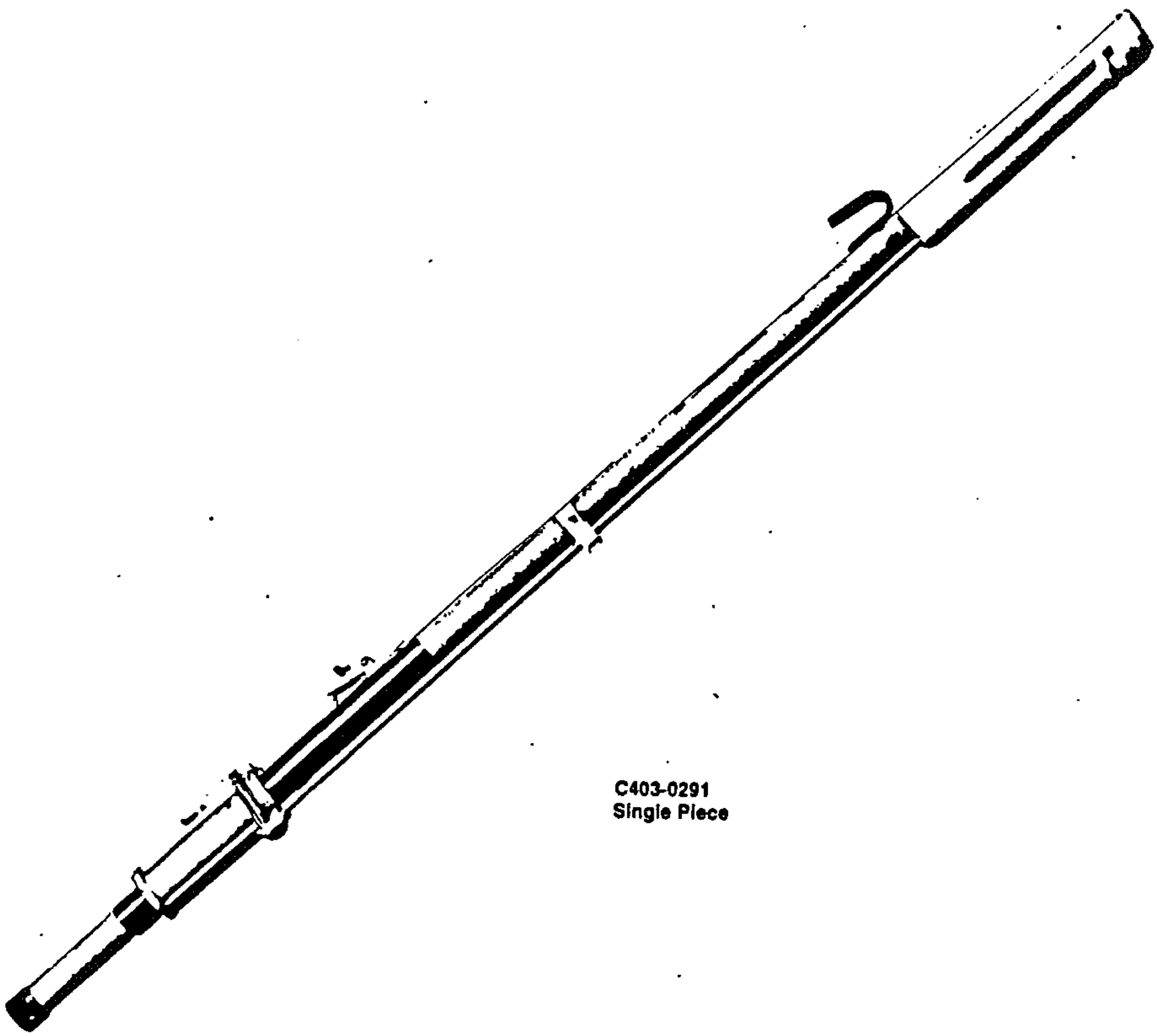


FIGURE 22

A.B. CHANCE GRIP-ALL (R) LIVE LINE TOOL

(R) GRIP-ALL IS A REGISTERED TRADEMARK OF A.B.CHANCE

Touch Grounding.

Many large industries now connect directly to Power Utility Bulk Power Systems. The growth in plant distribution systems has brought a corresponding increase in the fault levels available at the point of connection with Power Utilities.

It is not unusual to have a fault level in the region of 9,000 MVA available from the Power Utility.

The calculated values of touch and step potentials at these fault conditions can be potentially hazardous or fatal to personnel working in an improperly grounded switchyard.

The 230kv main switchyard in our example was designed to limit touch potential to a value below 50 Volts and 25 milliampers.

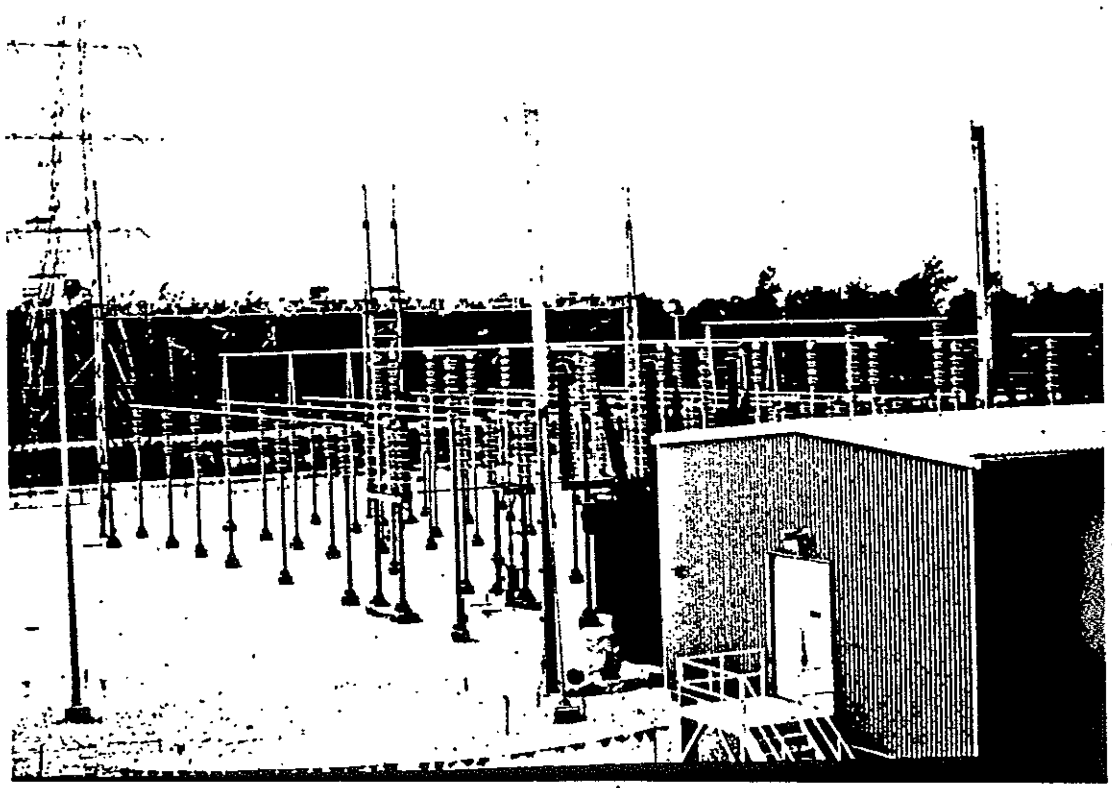


PLATE # 19

230 KV MAIN SWITCHYARD

The touch potential was calculated using an estimated future fault level value from the Power Utility of 18,000 MVA symmetrical.

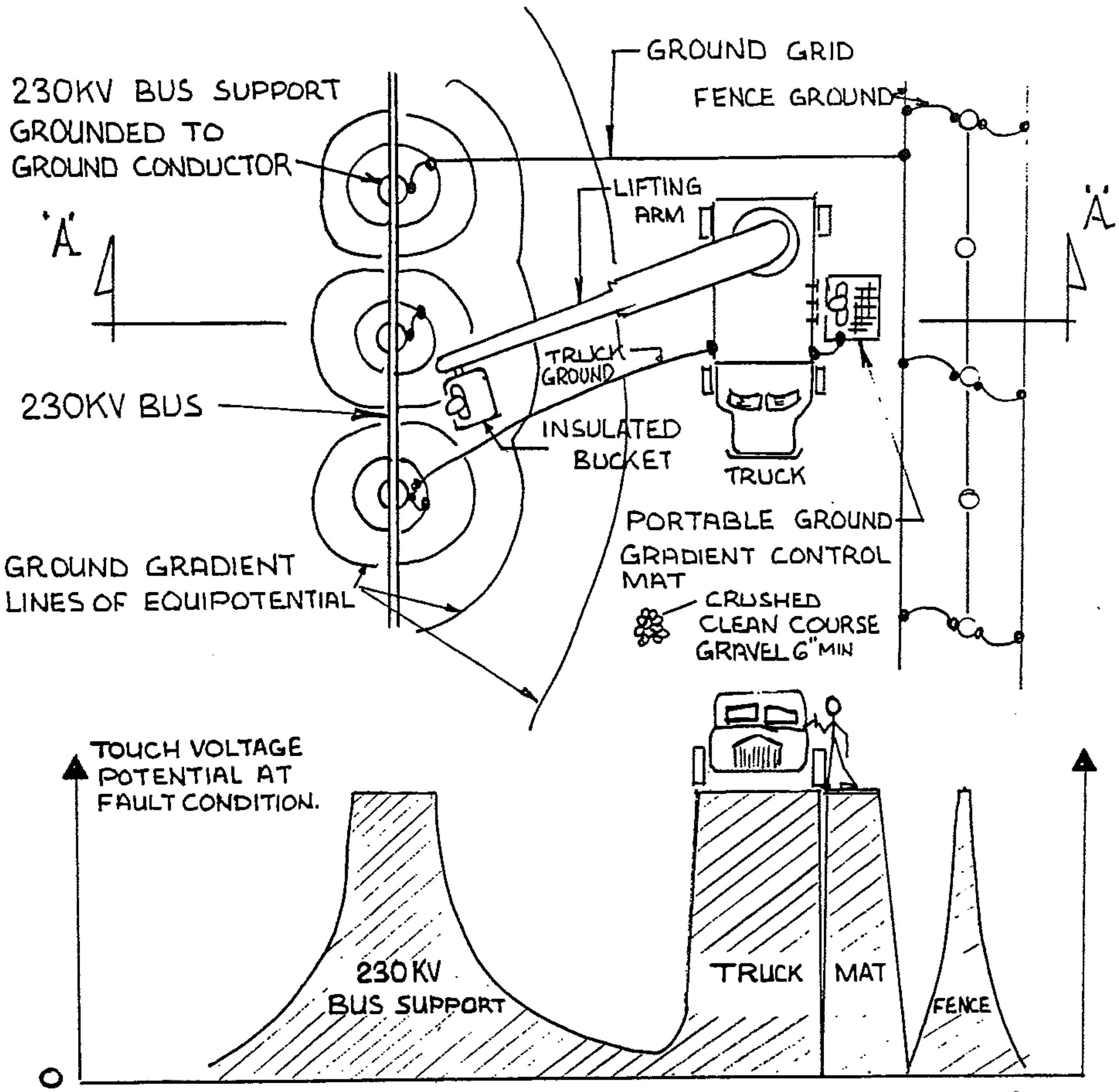
These calculated values of Touch Potential were developed under fault conditions with a person standing on top of a ground conductor buried under 6 inches of course clean gravel 1 Metre from and touching a grounded metal structure.

Touch Potentials as opposed to Step Potentials are determined to be the worst case condition because during a Touch Potential condition the current flows from hand to foot through vital body organs. The current flow experienced during a Step Potential passes from foot through lower body to foot.

Trucks operating in switchyards or near exposed energized lines need special consideration. Grounding the trucks to the ground grid can elevate the voltage gradient at the truck under fault conditions. These high levels of voltage gradient will be hazardous to passersby or workers standing on grade touching the truck.

The potential hazard exists even though the truck is connected back to the ground grid. Under fault conditions the voltage gradient rise of the truck will correspond to that of the ground grid. The area under and adjacent to the truck may be at a lower potential because of its relationship with the ground grid. The difference in potential between the truck body and grade may cause heavy currents to flow through a person who bridges the gap with his body. FIGURE # 23 illustrates the voltage gradient rise differences.

230KV MAIN SWITCHYARD PLAN VIEW



VOLTAGE PROFILE OF SWITCHYARD UNDER FAULT CONDITION
SECTION "A"-"A"

FIGURE 23

The potential hazard can be eliminated by providing the worker who is required to touch the truck a work area that will have a corresponding rise in potential with that of the truck under fault conditions. This can be achieved by :

a) Making the truck work area an intergral part of the truck; or

b) By providing a portable ground gradient control mat that is connected to the truck at the areas the worker is required to come in contact with the truck.

Portable ground gradient control mats that are connected to the associated equipment provide the same function as a ground gradient mat at an outdoor high voltage switch operating handle.

Portable ground gradient control mats are relatively easy to fabricate, FIGURE # 24 shows a typical design.

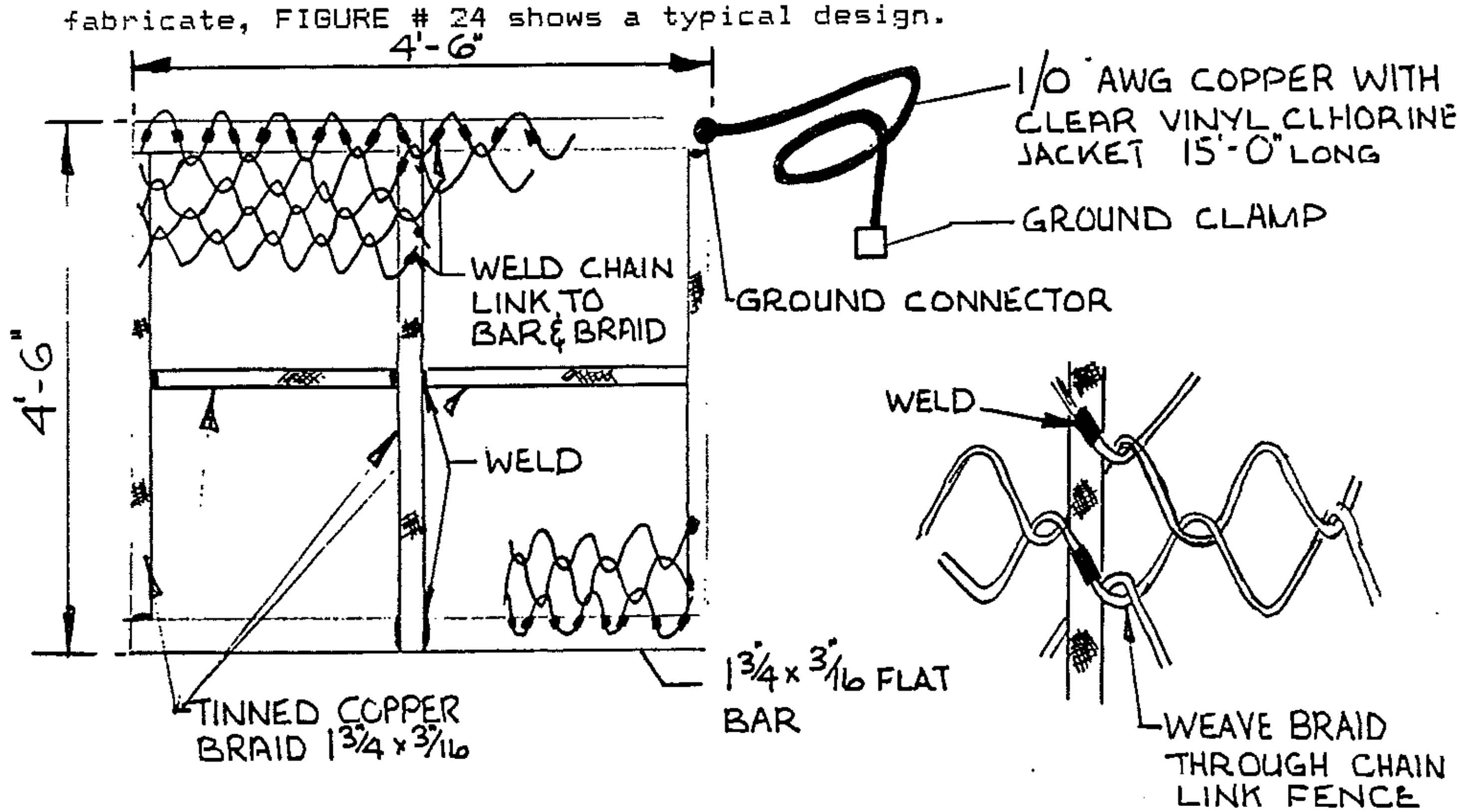


FIGURE 24

PORTABLE GROUNDGRADIENT CONTROL MAT

Portable ground gradient control mats should be stored in a clean place preferably a substation.

It should be noted that stepping off the mat during fault conditions would be hazardous to the worker. However, the exposure time to the hazard when the worker steps off the mat is very small when compared to the exposure time of the worker operating the controls of the truck while standing on the ground gradient control mat. It does however highlight the need for a worker to minimize his exposed time to the effects of Touch and Step Potential in a high voltage switchyard.

i) Minimize their time in the yard.

ii) Avoid unneccessary contact of grounded conducting equipment /structure and temporary equipment.

iii) When walking take smaller than normal steps, and when standing keep both feet together.

Typical Electrical Hot Work Procedure For Temporary Ground Identification And Storage

PROCEDURE : EHWP - 122 (Page 1 of 3)
DATE :
REVISION : 1

TITLE:

TEMPORARY GROUNDS IDENTIFICATION AND STORAGE

1.0 PURPOSE:

To describe a procedure for the storage and identification of temporary grounds used in the Electrical Hot Work Procedures.

2.0 SAFETY:

2.1 The temporary grounds shall be kept clean, dry and free from damage at all times.

2.2 The grounds identified by procedure shall not be substituted with grounds of a reduced electrical rating.

2.3 All grounds listed in this procedure and new grounds added to this procedure shall be approved for use by the Electrical Hot Work Committee.

3.0 HAZARD CLASSIFICATION:

CLASS D (For Temporary Grounds). The supervisor responsible for the exposed worker and the supervisor responsible for the equipment jointly review the work with the exposed worker prior to its initiation and prior to re-energization of the equipment after the work is complete.

4.0 PROCEDURE:

4.1 The temporary grounds shall be stored neatly on racks in the following Substations:
i) Main Substation
ii) Substation 2 and 3
iii) Combined Substation 4

4.2 All grounds applied to equipment shall be listed on the Master Card used to isolate the equipment.

4.3 All grounds shall be removed from the equipment and master tag before the qualified person responsible for the grounds signs off the Master Card.

PROCEDURE : EHWP -122 (Page 2 of 3)
DATE :
REVISION : 1

TEMPORARY GROUND IDENTIFICATION	WHERE USED	AVAILABLE FAULT LEVELS SYMMETRICAL AMPS	APPROX. CLEARING TIME OF FAULT	STORAGE LOCATION	PROCEDURE
TG-1 to TG-6	Main Sub 230KV Bus	23,000	6 Cycles	Main Sub	EHWP-102
TG-1 to TG-3	230KV/15KV	23,000	6 Cycles	Main Sub	EHWP-103
TG-7	15KV Current Limiting Reactor	31,000	6 Cycles	Main Sub	EHWP-104
TG-8	S & C 15KV Metal Encl. Switchgear Load Side	31,000	1 Cycle	Combined Sub 4	EHWP-109
TG-9	P.C.G. 600V Bus	45,000	6 Cycles	Combined Sub 4	EHWP-109
TG-8	S & C 15KV Metal Encl. Switchgear Load Side	45,000	1 Cycle	Combined Sub 4	EHWP-110
TG-10	S & C 15KV Metal Encl. Switchgear Line Side	45,000	6 Cycles	Combined Sub 4	EHWP-110
TG-11	Allis Chalmers 5KV Motor Starter	25,000	6 Cycles	Combined Sub 4	EHWP-112
TG-12, 13, 14	Main Sub 230KV Bus	23,000	6 Cycles	Main Sub	Spare

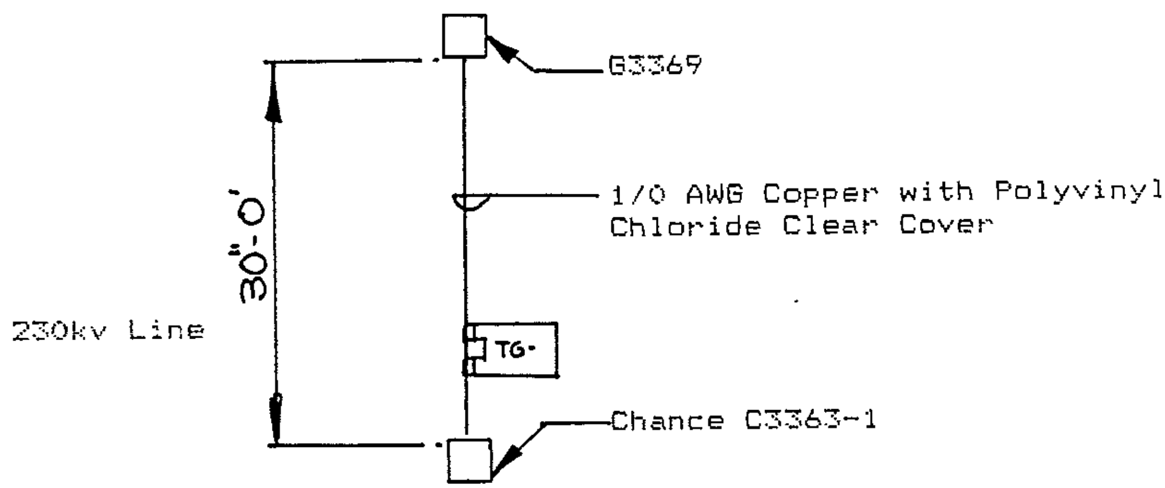
TEMPORARY GROUND IDENTIFICATION	WHERE USED	AVAILABLE FAULT LEVELS SYMMETRICAL AMPS	APPROX. CLEARING TIME OF FAULT	STORAGE LOCATION	PROCEDURE
TG-15	S & C 15KV Metal Encl. Switchgear Load Side	32,000	1 Cycle	Combined Sub 4	Spare
TG-16	P.C.G. 600V Bus	45,000	6 Cycles	Combined Sub 4	Spare
TG-17	230KV Main Sub Yard	23,000	6 Cycles	Main Sub	EHWP-102
TG-18	230Kv Main Sub Yard	23,000	6 Cycles	Main Sub	EHWP-102

TEMPORARY GROUND CABLE

EHWP-122

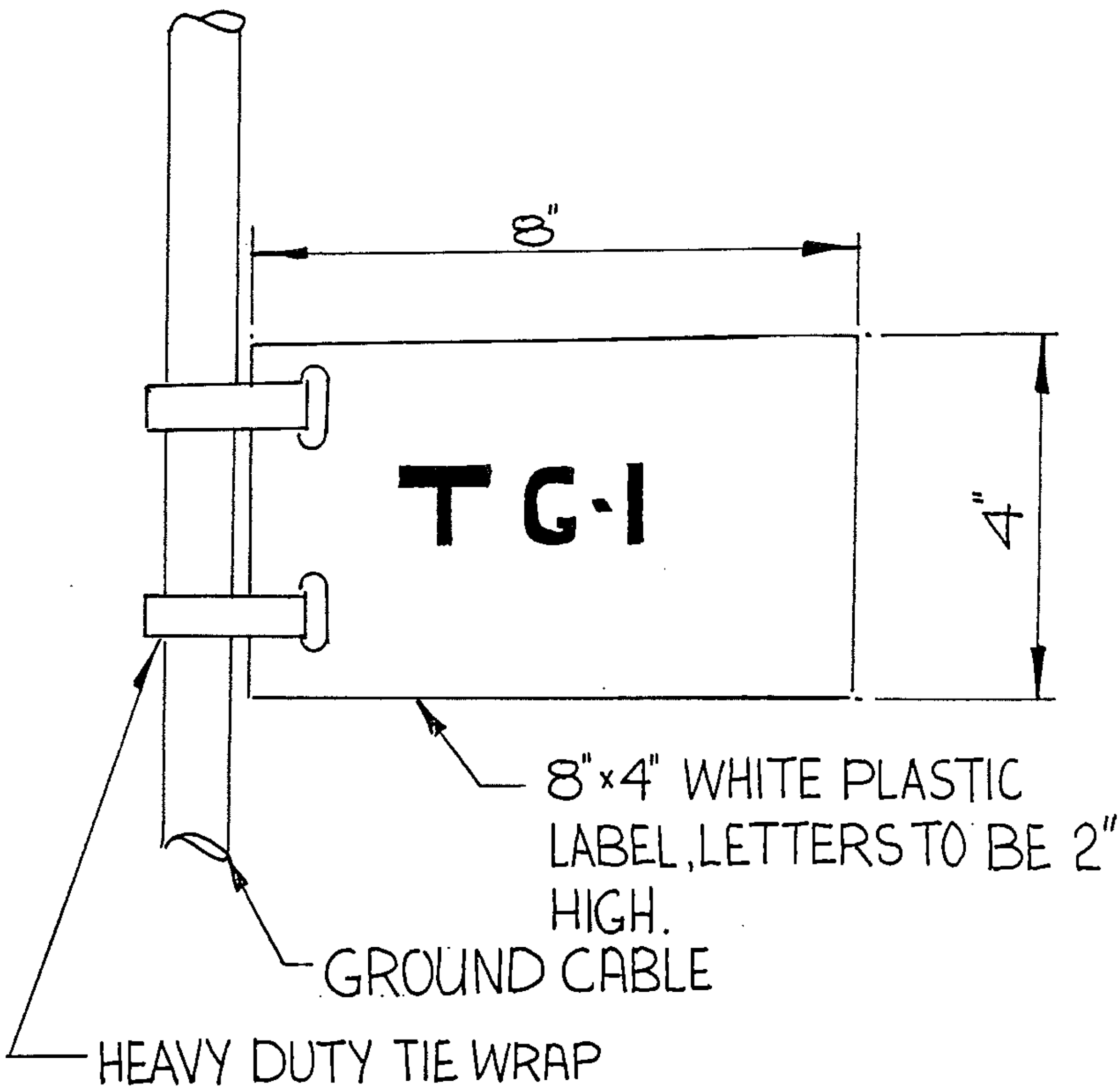
IDENTIFICATION	Storage Location
T.G. -1	Main Substation
T.G. -2	" "
T.G. -3	" "
T.G. -4	" "
T.G. -5	" "
T.G. -6	" "
T.G. -12	" "
T.G. -13	" "
T.G. -14	" "

USE GROUND CLAMP STICK CHANCE
CATALOGUE NUMBER C600-0617,20,21 AND



ELECTRICAL RATING

CABLE	FAULT TIME	FAULT AMPS. SYMMETRICAL
1/0 AWG Copper	6 cycles	25,300 Amps
	15 cycles	18,500 Amps
	30 cycles	13,000 Amps
	60 cycles	8,000 Amps
Clamp G3369	6 cycles	- Amp
	15 cycles	40,000 Amps
	30 cycles	30,000 Amps
Clamp C3363-1	6 cycles	- Amp
	15 cycles	25,000 Amps
	30 cycles	25,000 Amps



TYPICAL GROUND TAG

FIGURE 1

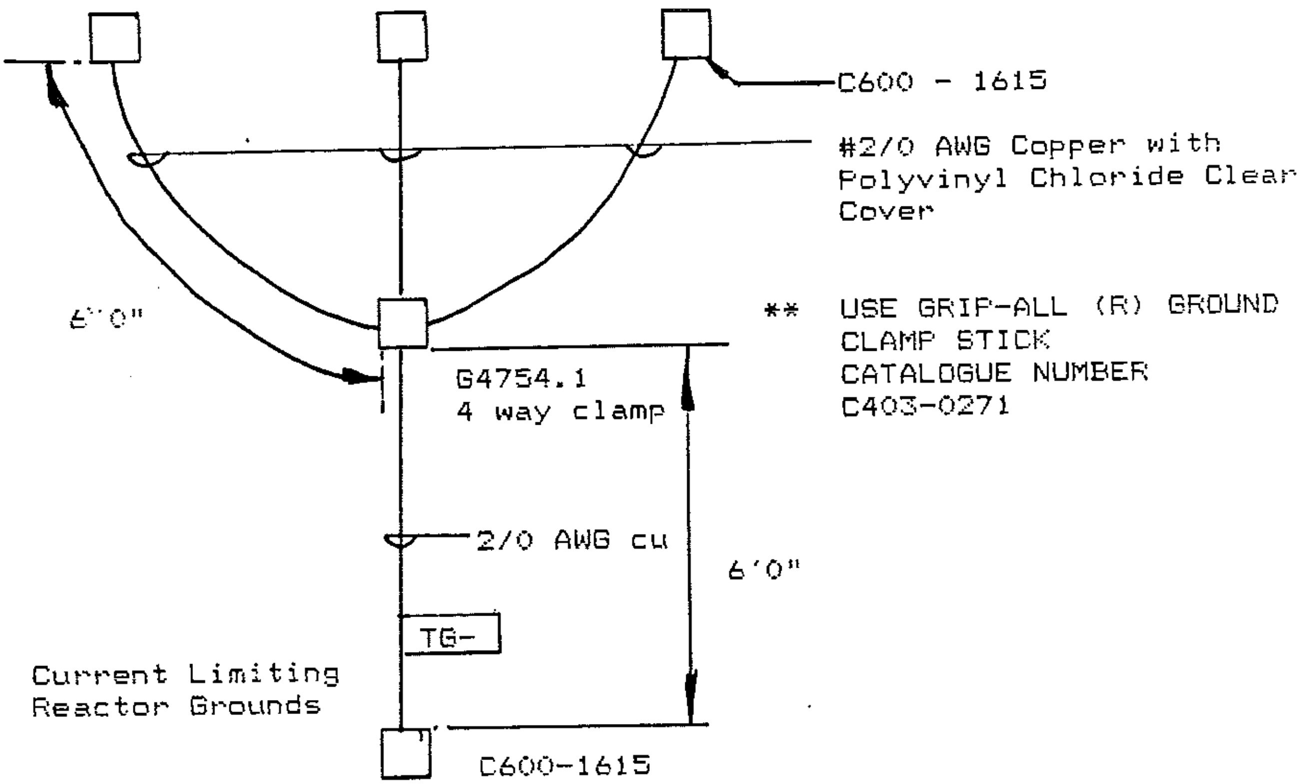
TEMPORARY GROUND CABLE

EHWP-122

Storage Location

IDENTIFICATION T.G. -7

Main Substation



ELECTRICAL RATING

CABLE	FAULT TIME	FAULT AMPS. SYMMETRICAL
2/0 AWG Copper	6 cycles	31,000 Amps
	15 cycles	21,000 Amps
	30 cycles	15,000 Amps
	60 cycles	10,000 Amps
Clamp C600-1615	6 cycles	- Amp
	15 cycles	40,000 Amps
	30 cycles	30,000 Amps

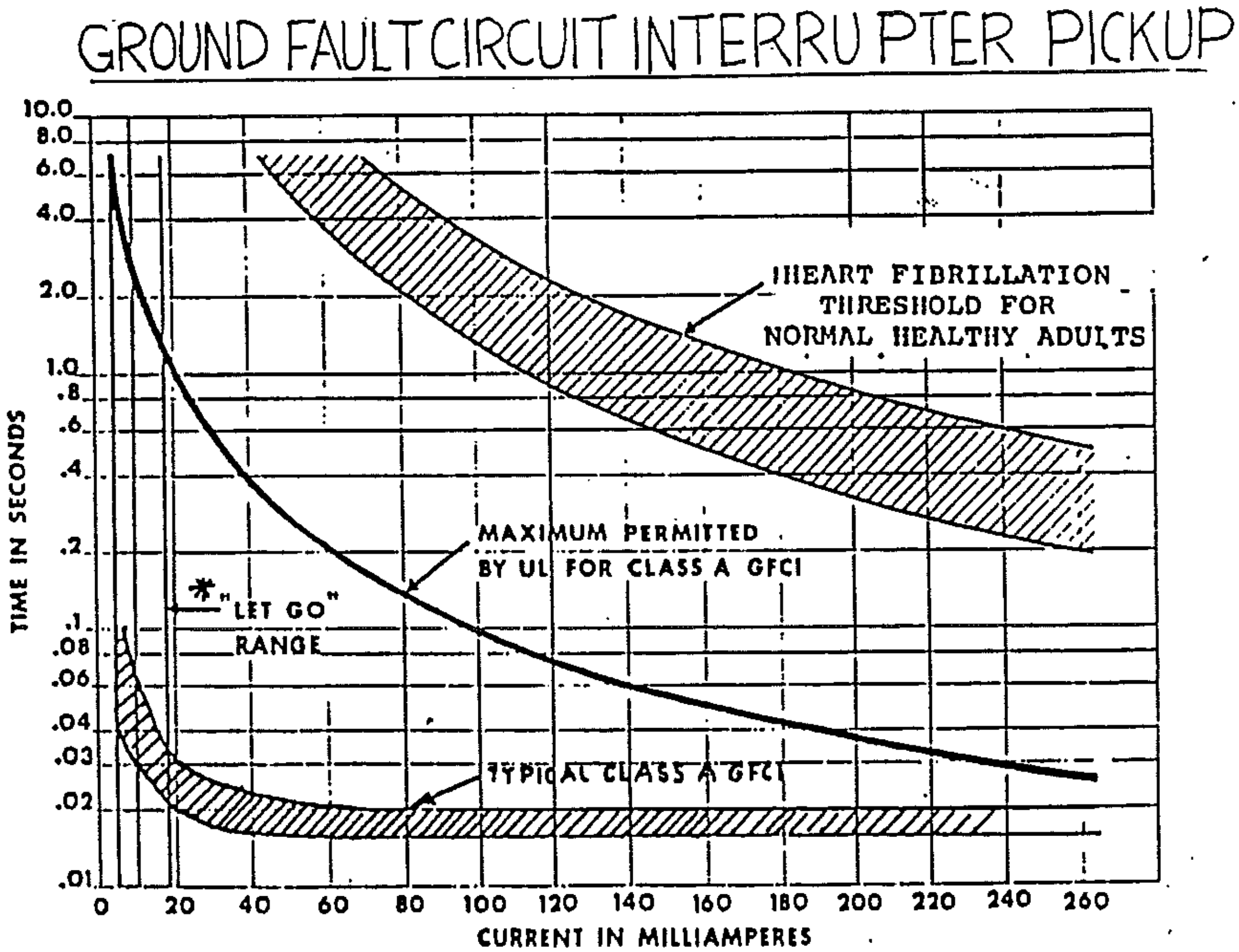
** GRIP-ALL is a Registered Trademark of A.B.Chance.

Ground Fault Circuit Interrupter and Assured Grounding

The use of ground fault circuit interrupters is not a substitute for assured grounding nor is assured grounding a total protection for personnel using portable electrical tools, lighting and test equipment. In confined spaces and moist locations both are required.

Listed or labelled portable tools protected by an approved system of double insulation may be used and the tool itself need not be grounded. Such equipment shall be distinctively marked to indicate that the tools utilize an approved system of double insulation. All portable equipment not double insulated that is utilized above 50 Volts must also be protected by ground fault circuit interrupters. Where used for personnel protection with portable equipment the ground fault circuit interrupters must be of the type that trip at 5 milliamp ± 1 milliamp in 7.26 seconds as shown by Figure 25. They must be tested for pickup level and tripping prior to each use.

Assured grounding must be regularly checked as part of an "Assured Equipment Grounding Conductor Program". For single grounds in small electrical systems the check can be by a three point ground test method. It becomes more complex for large electrical systems where multiple ground paths exist. In addition to using a three point ground test method to verify the low resistance of earth ground, the integrity and continuity of various ground paths must be confirmed by visual inspections and by ohmmeter test across



$$T = \left(\frac{20}{I}\right)^{1.43}$$

T = SECONDS

I = MILLIAMPS RMS

FIGURE 25

joints. To be "effectively grounded" the path from circuits, equipment, structures, and conduits or enclosures to ground shall be permanent and continous, have ample capacity to safely conduct the currents liable to be imposed on it, and have sufficiently low impedance to limit the potential above ground and to result in the effective operation of the overcurrent devices in the circuit.

CHAPTER 12

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment required for electrical workers performing electrical hot work tasks is a growth industry. The need for protective clothing specifically designed and tested for electrical shock and arc flash hazard is only now being recognized and standards developed.

Today, electrical workers who are exposed to potential electrical hazards are wearing an assortment of protective clothing. The clothing varies and could include coveralls made from synthetic Aramid fibers originally developed for chemical workers, race car drivers, and army, navy and air-force pilots, or could include protective flash suits originally designed for foundry workers.[12]

The philosophy of the Electrical Hot Work Safety Program is to provide clothing that maximizes worker protection while encouraging worker participation through the provision of comfortable, practical clothing. For example, personal protective clothing added on top of street clothing for workers in a Canadian winter could be a welcome relief. However, personal protective clothing added on top of street clothing for workers in a Gulf Coast summer could be burdensome, hot and not at all welcome. Personal protective clothing such as flame resistant coveralls required by the Electrical Hot Work Safety Program can be integrated with normal work wear and can be worn in place of normal work coveralls.

For many years the emphasis on personal protective clothing has been to provide worker protection against electrical shock hazard. Public Electric Utilities and electrical lineman contractors have led the field in protecting against this hazard by establishing standards for rubber insulating gloves, rubber blankets and tinted eye protection.[6] The protection has primarily been designed for use on and around electrical equipment in open places. For example, pole lines. The protection against arc flash burns with the exception of tinted eye protection has been secondary to that of electrical shock.

The growth in Industrial plant power distribution systems has in recent years resulted in a corresponding growth in the awareness of potential electrical safety hazards. Industrial electricians are just now taking the knowledge and developments in electrical safety from the Public Electrical Utilities etc. and adapting them to the Industrial plant environment which is typically more confined and has greater need for continuity of operation. Modern industrial electrical hot work safety programs should give equal attention to electrical shock and electrical arc flash burn hazard.[9]

The use of personal protective clothing in the Electrical Hot Work Safety Program is designed to minimize the severity of injuries that may occur when the hazard is out of control. The program combines commercially available apparel that protects against a variety of potential electrical hazards. e.g.:

a) Electrical Shock

b) Electrical Arc Flash Burn

c) Ultraviolet Radiation

d) Blue Light Radiation

e) Infrared Radiation

f) Molten Metal Splatter

g) Pressures developed by Arcs

The personal protective clothing required to protect against these potential electrical hazards must cover all parts of the body while giving unrestricted movement and visibility. The clothing should consist of the following :

A) Head, Face, Neck and Chin Protection

B) Eye Protection

C) Face Protection

D) Body Protection

E) Ear Protection

F) Hand Protection

G) Foot Protection

A) <u>Head, Face, Neck and Chin Protection</u>

The head, face, neck and chin protection required by the program is provided by a flame resistant Fireman's helmet that combines the following features :

1) Six (6) inch clear polycarbonate face shield attached to the helmet. The face shield will protect the face from molten metal splatter and will eliminate up to 99.997% of Ultraviolet radiation.

2) A synthetic aramid fiber flame resistant liner that attaches to the inside of the helmet and covers the neck, ears and chin of the worker.

3) The helmet absorbs shocks.

4) LIGHT WEIGHT CONSTRUCTION.

The flame resistant Fireman's helmet while slightly heavier than the regular hard hat duplicates the latter in appearance and maintenance.

Some industries have selected a full flame resistant hood with integrated face shield for head, neck, face and chin protection as an alternative to the flame resistant Fireman's helmet.[12]

B) Eye Protection

All persons performing electrical hot work shall wear eye protection. The radiation emission on an electric arc is illustrated in Figure 26. For complete protection, the eye protection should eliminate/reduce the following harmful radiation emissions detailed in Table 7.[17]

REGION	RANGE	EYE DAMAGE
ULTRAVIOLET	200 - 400 NANOMETERS	CORNEA AND LENS
BLUE LIGHT	430 - 440 NANOMETERS	RETINA
INFRARED	770 - 1400 NANOMETERS	RETINA
	1440 - 2000 NANOMETERS	CORNEA

TABLE 7

EMISSION OF AN ELECTRIC ARC

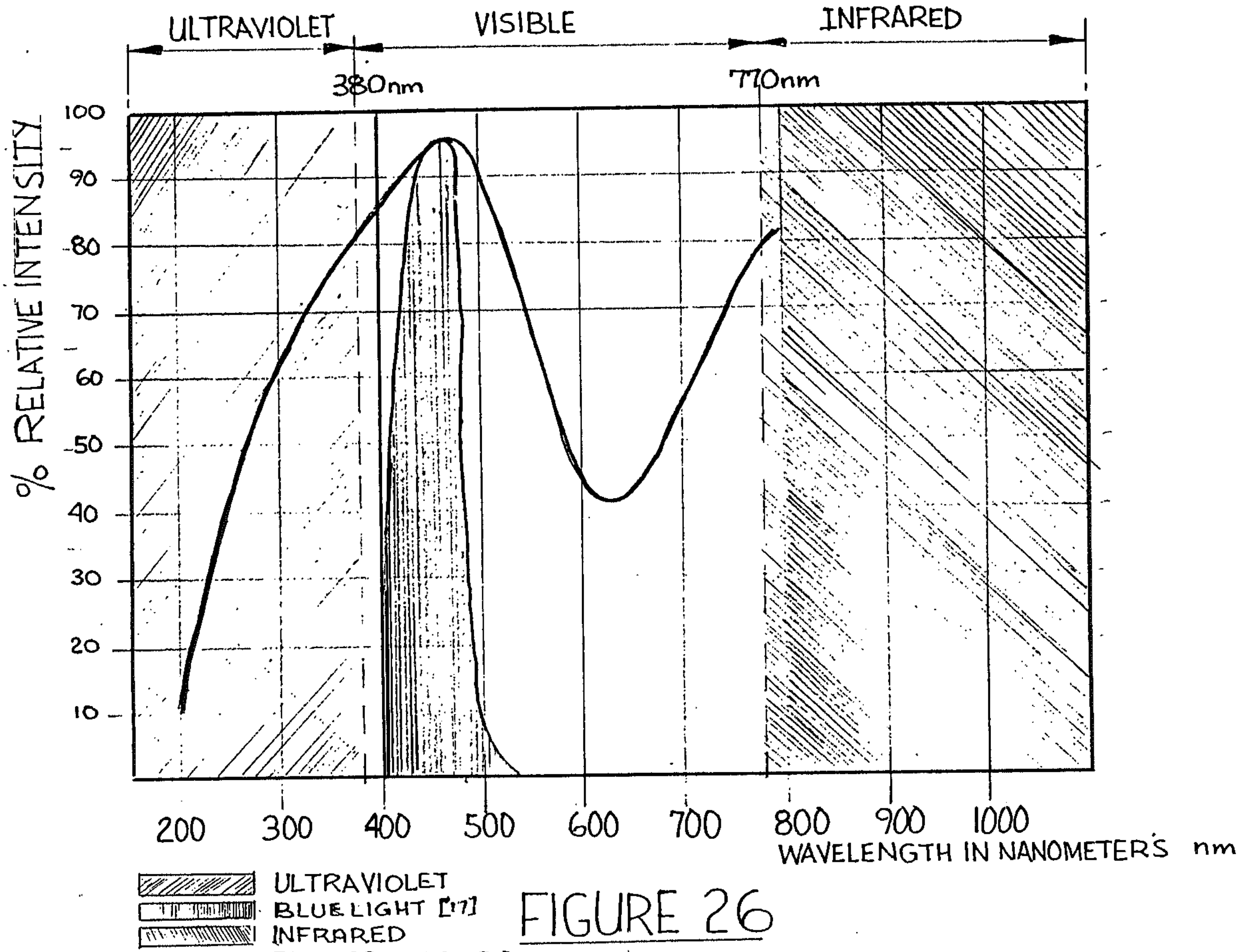


FIGURE 26

Clear glass lenses offer little protection from the Ultraviolet, Blue Light or Infrared radiation emissions of an electrical arc flash.

Clear Polycarbonated lenses while filtering out 99.9997% of Ultraviolet radiation emissions from an electrical arc flash, offer marginal improvement over clear glass when filtering out Blue Light and Infrared radiation.

Colour tinted Polycarbonated lenses can be obtained[19] with 1.7, 2.0, 2.5 and 3.0 density ratings. In all density ratings of Polycarbonated lenses, Ultraviolet arc emission radiation is virtually (99.997%) filtered. Increasing the density rating also increases the filtering effects from Blue Light and Infrared arc emission radiation. At the 1.7 density rating 50% of Blue Light and 90% of Infrared arc emission radiation is filtered. At the 3.0 density rating 88% of Blue Light and 95% of Infrared arc emission radiation is filtered.

For electrical hot work a Polycarbonated impact resistant lens of 1.7 density rating is recommended for normal daylight hours. Clear Polycarbonated impact resistant lenses are permitted where visibility is limited. In all instances the eye protection should be worn under a full face shield of clear Polycarbonate.

Polycarbonated lenses also provide superior protection against molten metal splatter when compared to the clear glass lens.[20]

When the molten metal touches a glass lens the rapid heating causes the glass to expand unevenly and the lens could crack or shatter. Heat treated glass safety lenses while capable of withstanding severe impacts offer little protection against the thermal shock of molten metal splatter.

The safety lens is constructed by first heating the glass lens to a near molten state then cooling rapidly. This heat treatment process freezes the outer surface in its expanded state thereby placing the outer surface in compression and the inner core in tension.

The balance of inner core tension and outer surface compression forces is altered by the thermal shock of molten splatter and the glass lens could shatter.

Polycarbonate maintains its impact resistance when scratched, pitted or exposed to molten metal splatter because of its tight molecular cohesion.

C) <u>Face Protection</u>

Clear Polycarbonate face shields that can attach to the flame resistant Fireman's helmet and cover the face provide the eyes a first line of defense against weld splatter and Ultraviolet radiation emissions of an electrical arc flash.

D) <u>Body Protection</u>

Flame resistant coveralls.

Selecting the correct flame resistant coveralls for an electrical hotwork program is as important as getting the electrical workers to wear them.

The program recommends light weight coveralls that duplicate normal work wear in appearance and maintenance. The coveralls must be capable of being cleaned regularly without loosing their fire resistant qualities. The coveralls should cover all the workers body not covered by flame resistant head, neck and chin protection, face shield, rubber insulating gloves and foot protection. Long button down sleeves and high button collars should be a standard feature of the coveralls.

Flame retardant treated (FRT) cotton is superior to polyester/cotton fabric, and man made Aramid flame resistant garments offer far superior protection than FRT cotton.

One leading Manufacturer of synthetic Aramid fibers has conducted extensive tests that demonstrate the superior flame resistant qualities of synthetic Aramid fibers compared to FRT cotton suits. The tests show the body burn area consisting of 2nd and 3rd degree burns can be reduced considerably when 6.7 oz/yd synthetic Aramid fiber is used in place of 10 oz/yd FRT cotton.

E) Ear Protection

Considerable pressures are developed during electrical arc faults. These pressures have been known to blow equipment doors open, cause structural damage in electrical rooms and forcibly project people backwards away from the source of arc. Needless to say, these pressures are also damaging to the human ears.[13]

The use of ear protection in the Electrical Hot Work Safety Program is limited to the protection from electrical arc pressures.

Ear protection during normal switching functions (excluding 115kv and above air blast breakers) has been considered but dismissed because of the importance of hearing the latching "CLICKS" and/or Trip/Closing actions of circuit breakers etc.

A variety of ear protection is usually readily available in most Industrial locations and most can be adapted for wear with the required head protection for electrical hot work.

F) Hand Protection

The use of rubber insulating gloves is mandatory in the Electrical Hot Work Safety Program for each person performing electrical hot work. The use of rubber insulating gloves in the program will provide additional protection for people performing electrical hot work and are not intended for direct use on exposed energized components.

There are two types of rubber insulating gloves and four classifications within each of the two types.

Type 1 are non resistant to ozone and are made from vulcanized natural or synthetic polyisoprene rubber.

Type 2 are resistant to ozone and are made from eleastomer or elastomeric compounds.

The class of glove identifies the maximum voltage system the gloves are designed for. The maximum voltage system is determined from the wall thickness of the glove and the corresponding voltage proof-test.

Type II are resistant to either one or a combination of ozone, flame and oil and are made from elastomer or elastomeric compounds.

The class of mat identifies the maximum voltage system the mats are designed for. The maximum voltage system is determined from the thickness of the mat and the corresponding voltage proof-test.

The mats are available in various standard 24, 30, 36, and 48 inch widths. Each piece of matting should be permanently marked at a maximum interval of 3 feet with manufacturer, type, class and standard of manufacture.

Table 10 [15] identifies the Classes and Voltage Levels for Rubber Insulating Mats.

TYPE I TYPE II	CLASS 0 *(RED)	CLASS 1 *(WHITE)	CLASS 2 *(YELLOW)	CLASS 3 *(GREEN)	CLASS 4 *(ORANGE)
Proof test Voltage RMS KV	5	10	20	30	40
Proof test Voltage DC KV	20	40	50	60	70
Nominal Max. use Voltage KV	1**	7.5	17	26.5	36

TABLE 10

* Marking of mat can be permanent moulding running the length of the mat or colour coded labels.

** The maximum use voltage for Class 0 type mats is based on the following:

Maximum use voltage = 0.95 a-c proof test voltage - 200.

Rubber insulating mats shall be laboratory tested every 12 months. If the integrity of the mat is suspected at any time because of cracks, stretching or punctures, the mat shall be withdrawn from service and laboratory tested.

CHAPTER 13

INSULATED TEST INSTRUMENTS, NON-CONDUCTIVE TOOLS AND LIVE LINE TOOLS

Qualified electricians are aware that providing distance between their body and exposed electrically energized components is the safest way to avoid electrical shock or flash burn hazard. However, situations involving troubleshooting, repair, maintenance and some operations cannot be performed without some method of contact for manipulation of test equipment, moving parts or removing and installing components. Many specific electrical hot work safety procedures stipulate the insulated test equipment, non-conductive tools and live line tools needed to perform certain tasks.

Employees shall not contact exposed electrically energized components unless they utilize adequate personal protective equipment, position themselves outside the minimum clearance zone and work with approved and suitably insulated test equipment, non-conductive tools and live line tools for the voltage class upon which work is to be performed. Employees shall not attempt use of insulated test equipment, non-conductive tools and live line tools on exposed electrically energized components until they have been instructed or are under training in there proper use.

The insulating integrity of insulated test equipment, non-conductive tools and live line tools is of paramount importance and not to be compromised. They shall be stored, handled, maintained and operated in a manner to preserve their insulating qualities.

Manufacturer's instructions are to be carefully followed in these regards. They shall be carefully wiped clean with a silicone impregnated non-conductive lint free cloth prior to and after each use. They should never be laid on the ground. A clean dry tarpaulin should be kept at the job site on which to lay the tools and to cover them when they are not in use. Prior to each use the overall condition of the insulated test equipment, non-conductive tools and live line tools should be inspected. If there is any doubt about its adequacy the tool must be tested before use. Otherwise they are to be tested as follows :

* Insulated test instruments shall be electrically tested at least every 12 months.
* Non-conductive tools shall be electrically tested at least every 12 months.
* Wooden live line tools shall be electrically tested at least every 12 months.
* Man mad fiber live line tools shall be electrically tested at least every 36 months.

Insulated Test Equipment

Potential indicating devices are the most frequently used type of insulated test equipment. These include :

* Voltage detection and phasing sticks
* Voltmeters
* Clip-on Ammeters
* Wattmeter

Voltage Detection and Phasing Stick

A number of potential indicators of various types and voltage ranges are marketed for use in obtaining a reliable indication of primary potential. Most will show presence of voltage on a line or equipment component but will not give an actual reading. The lighted potential indicators such as James G. Biddle's "DETEX" shown in Figure 27 may be suitable for testing a piece of equipment just to determine energized or de-energized conditions or to determine indication of two conductors in phase. For equipment that is normally energized a metered type potential indicator such as A.B. Chance's "PHASING TESTER" shown in Figure 28 may be desirable.

When using these voltage detectors and phasing sticks a voltage verifier or cross check should always be performed to assure the device is operating and/or reading correctly. A good solid contact between the indicator and the test point is needed. A check should always be made to determine that the indicator has the proper phase to ground rating for the voltage to be applied to it. An isolated line or component having a voltage induced from the energized equipment may give a positive reading with these indicators. If an assumed isolated line gives an indication of voltage potential all points of isolation should be re-checked to determine the cause of the indication.

Voltmeters

Voltmeters measure potential difference between two points and require a direct connection using meter leads. The leads should be properly insulated for the highest voltage on which they may be applied and fused to provide some protection should the meter or leads become defective. Meter leads should be connected negative to negative and positive to positive. If multimeters are used they must be set for the proper function. When making unknown measurements the meter should be set to the highest scale prior to making contact with the leads and the leads should be removed from the circuit under test while changing scales. The meter indicator should be "zeroed" before a connection is made in order to obtain more accurate readings. Overall the use of multimeters should be discouraged. Voltmeters that have the following features are preferred [16]:

* A meter to read volts AC or DC.
* Auto ranging - one scale fits all.
* High resistance probes - 1 megaohm in each probe.
* Retractable tips for probes.
* Compact - no larger than a wiggy.
* Read up to 600 volts.
* Three foot lead length.
* Low battery indicator.

Clip-On Ammeters

Clip-on ammeters measure alternating current without interrupting the circuit. They can be used on either covered or bare wire but should not be used over a concentric neutral shield. To avoid damage to the meter mechanism, set the scale to the highest position before using the meter. Remove the meter from the conductor and drop to a lower scale then reapply the meter until an accurate range is found. Current readings on circuits above 600 volts may be taken using an approved live line tools such as A.B. Chance's "AMERTONGS" shown in Figure 29 to hold the clip-on ammeter.

Wattmeter

The wattmeter is a combination of the voltmeter and clip-on ammeter with an iron core dynamometer. In order to facilitate connections the properly insulated leads should be equipped with insulated clips and spring loaded probes that can be installed or removed as required. Protective fuses should also be available in the leads.

Nonconductive Tools

Electricians have prided themselves in hand taping or hand dipping their favourite screwdrivers, pliers, wrench or wire cutters to make them "safe" for use in possible contact with low voltage electrically energized components. Only recently have non-conductive tools designed specifically for work on potentially energized equipment up to 1000 volts been made available. One such full line of nonconductive tools shown in Figure 30 are now available from Asplundh - Sibille. When new and/or just after being successfully voltage tested they may provide adequate protection when used on 1000 volts or lower rated equipment. However, they are subject to considerable abuse and continued use of rubber gloves is recommended. They should not be relied upon as the primary means of protection or isolation, but they can reduce the risk of damage or injury caused by accidental contact by uninsulated metal shank tools and they can serve as a secondary means of personal protective features.

Live Line Tools

Many designs of live line tools exist for performing specific tasks. They range from the short disconnect stick used on cutouts through universal poles with interlocking tools to hinged, extension model finger grip or clamp grip sticks. Various adaptors and end fittings are available to facilitate tasks from picking up and moving wires to tightening nuts.

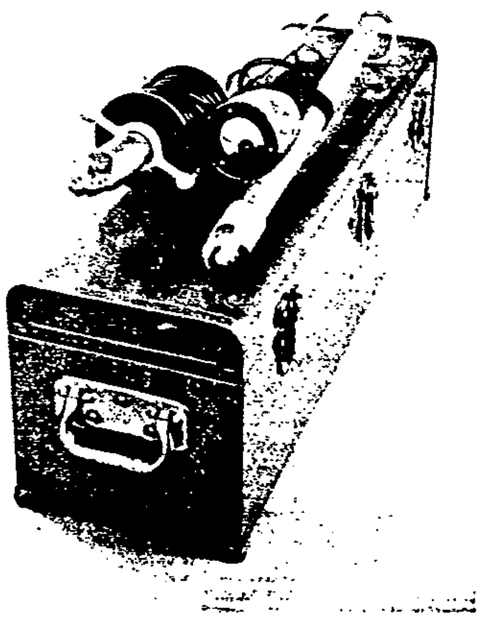
When employees must use live line tools as an extension of their bodies to reach inside the minimum clearance zone at least two qualified employees shall be assigned to do the work and no other work shall be in progress in the same area.

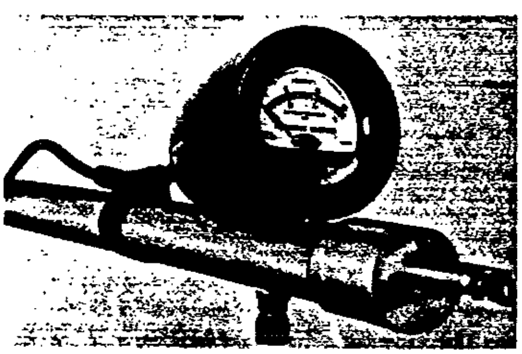
FIGURE 27

PHASING TESTER

16 kV Model

Checking Phase Connections





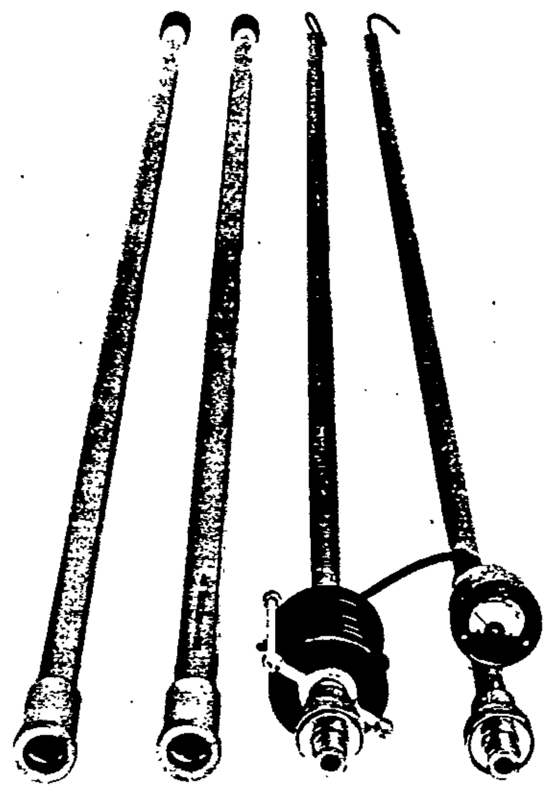


FIGURE 28

CHANGE

AMERTONGS

One Tool Adjusts To Fit Popular Ammeters:

- Amprobe A6
- Columbia AC-1
- Columbia AC-DC
- Ferranti 7-Range
- G.E. Snapper 150, 350, 1,000 Series
- Weston 633

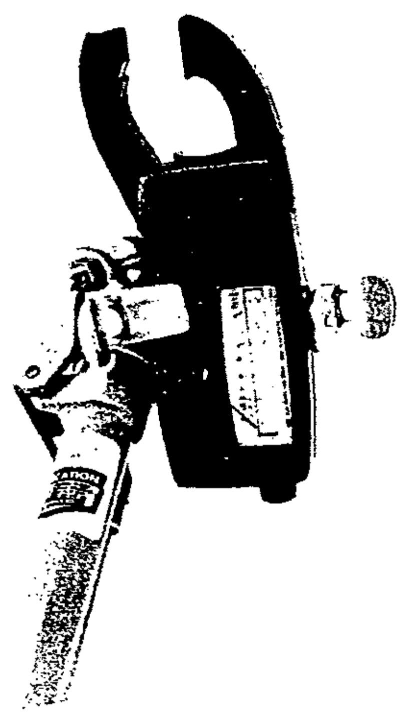
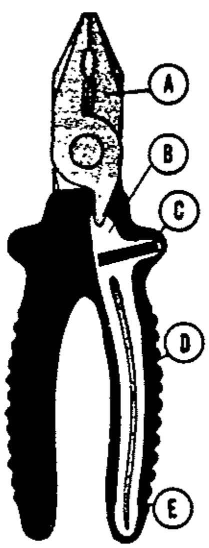


FIGURE 29

USER BENEFITS

- Provide additional worker protection against electrical shock, burns and flashover.
- Reduce the risk of damage to electrical equipment caused by accidental contact of uncoated metal tools with energized parts.
- Meet or exceed all applicable U.S. and international standards.
- Eliminate unsafe practices, such as wrapping metal tools in electrical tape, and the false sense of protection provided by soft-coated tools.
- Unmatched performance guarantee.

FEATURES



- The base tool (A) is manufactured from the highest quality chrome-vanadium alloy.
- The virtually indestructible, shock-resistant white inner coating (B) is positively bonded to the tool.
- The stops (C) on pliers are of specially treated nylon, providing 15,000 volts insulation.
- The ribbed handles (D) insure positive grip, even with oily gloves.
- (E) The orange PVC outer coating is fully bonded to the tool. It is self-extinguishing and non-corrosive.
- Insulation is guaranteed to 10,000 volts over a temperature range of −4°F to +160°F (−20°C to +70°C).

FIGURE 30

CHAPTER 14

DEFINITIONS

Authorized Person - One who has been appointed by the employer to have access to controlled areas or to have charge of hazardous working conditions.

Charged - Isolated but not de-energized - containing stored energy - at a potential different from earth or ground.

Conductor - That part of electrical equipment, apparatus, or wire intended to conduct the flow of electrical energy.

De-energized (Dead) - means free from any electric connection to a source of potential difference and from electric charge; not having a potential different from that of earth.

Electrical Hot Work - Any work on or in the immediate vicinity of the minimum clearance zone of an exposed and electrically energized alternating or direct current electrical system.

Exposed - as applied to live parts means that a live part is capable of being accidently touched or approached nearer than a safe distance by a person. An exposed part is one that is not suitably guarded, physically isolated, or insulated.

Grounded - Metallically connected to ground

Guarded - A part is considered guarded when it is covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms so as to remove the likelihood of dangerous contact or approach by persons or objects.

Guard Zone - Space around an exposed electrically energized component normally protected against intrusion by guards sufficiently strong and supported rigidly enough to prevent them from being displaced by a person falling against them.

Immediate Vicinity Zone - is the area around the Minimum Clearance Zone that will allow an employee the opportunity to penetrate the Minimum Clearance Zone by any part of an employees body or by tools, test equipment, or vehicles operated by an employee. A person in the Immediate Vicinity Zone is subject to inadvertantly penetrating the Minimum Clearance Zone unless extreme care is excercised. The Immediate Vicinity Zone can vary and depends on the voltage class of the system, the length of the approved test equipment, the dimensions of the grounding device being used to penetrate the Minimum Clearance Zone, the fault level available at the exposed part, and the time required to clear the fault.

Insulated - For conductors and parts less than 5000 volts to ground, barriers, enclosures, or insulation suitable for the voltage conditions involved may be used. For conductors and parts exceeding 5000 volts to ground, non-shielded insulating covering shall not be considered adequate.

Isolated - A part is considered electrically isolated when it has been disconnected from energized parts by switching action, locked out, tagged, and checked to ensure absence of voltage. A A part is considered physically isolated when access to the part is barricaded or roped off, etc., and warning signs are posted at the entrances; or when special means are required to access the part.

Minimum Clearance Zone - is the area around any exposed and energized electrical part. No employee shall penetrate the Minimum Clearance Zone with any part of his body. The use of approved test equipment suitably insulated for the voltage class being worked on and operated to the Manufacturer's instructions shall be permitted as an extension of the employee's body within the Minimum Clearance zone. The approved equipment shall be operated by the employee from outside the Minimum Clearance Zone at all times.

Owner/Employer - The Company, Corporation or entity that has prime ownership of facilities and equipment and that provides overall direction for working conditions.

Qualified Person - One who is competent by knowledge, training and experience to perform assigned work.

Repair Work - The act of removing, installing, modifying or repairing electrical components or wiring.

Troubleshooting - Work performed on an energized system to permit determining the cause and location of a problem or condition of the electrical system. Work done under this heading must be performed only with test instruments. During troubleshooting, mechanical connections may be made only to check circuit integrity and only if the voltage does not exceed 150 volts to ground.

Worker/Employee - A person who performs work or supplies services for monatary compensation or to gain work experience.

Working Space - is a Minimum Working Space that must be clear of obstructions when an employee approaches an energized part.

FIGURES

TABLES

PLATES

REFERENCES

[1] J.M.Gallagher and L.B.McClung, "Weak Chain Link Breakdown Phenomena of Multigrade Insulating Materials". IEEE 0090-3507/81/0000-0155. 1981.

[2] National Electrical Safety Code(NESC) ANSI C2-1984, Page 92.

[3] IEEE Guide For Safety In Substation Grounding.

[4] C.F.Dalziel, "Electric Shock Hazard", IEEE Spectrum pp. 41-50, Feb 1972. and "Dangerous Electric Currents" AIEE Transaction, Vol.65, pp.579-585 and 1123-1124, 1945.

[5] IEEE Guide For Safety In Substation Grounding, plus K.S. Geiges "Electric Shock Hazard Analysis" AIEE Transaction, Vol.76, pp.1329-31, 1957. and C.F.Dalziel and F.P. Massoglia, "Let Go Currents And Voltages" AIEE Transaction, Vol.75, Part II, pp.49-56, 1956.

[6] Electrical Utilities Safety Association of Ontario, Incorporated(EUSA) Rule Book 15M 3.85.BFL.

[7] National Electrical Safety Code(NESC) ANSI C2-1984, Page 348.

[8] R.H.Lee "The Other Electrical Hazard Electric Arc Blast Burns" IEEE 0197-2618/81/0000-0401. 1981. pp.401.

[9] R.H.Lee "The Other Electrical Hazard Electric Arc Blast Burns" IEEE 0197-2618/81/0000-0401. 1981. pp.405.

[10] Electrical Safety Awareness published by Ontario Hydro Utility Commission.

[11] The Occupational Health and Safety Act 1978 Regulations for Industrial Establishments and Construction Projects in Ontario.

[12] W.C.Gordon, "The Use of Protective Flash equipment" IEEE CH2207-9/85/0000-1729.

[13] R.H.Lee "Pressures Developed by Arcs" IEEE 0093-9994/87/0700-0760.

[14] ASTM Standards for Electrical Protective Equipment for Workers Rubber Insulating Gloves D120, Sixth Edition 1985.

[15] ASTM Standards for Electrical Protective Equipment for Workers Rubber Insulating Matting D178, Sixth Edition 1985.

[16] W. C. Jordon, "The Alternate to the VOM for Measuring Voltage on 250 Volts through 600 Volts" IEEE CH2272-3/86/0000-0819.

[17] W. T. Hamm, Jr., et al., "Sensitivity of the Retina to Rediation Damage as a Function of Wavelength Photochem, Photobiol, 29:735-743, 1979.

[18] American Conference of Government and Industrial Hygienist

[19] ANSI Z 87.1-1979 Standards.

[20] Thermal Shock Effect on Glass Safety Lenses, January 7, 1980, Industrial Safety Equipment Association, John R. Liataud, Chairman of Eye and Face Protection

[General] J. M. Gallagher and L. B. McClung, "Electrical Hot Work Safety Program", IEEE CH2272-3/86/0000-0921, 1986.