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SUGGESTED PRACTICES FOR RAPTOR PROTECTION ON POWER LINES:

THE STATE OF THE ART IN 1996

EXECUTIVE SUMMARY

Purpose and Use of the Publication. An investigation into eagle mortalities in the early 1970's revealed evidence of a relationship between power lines and the electrocution of eagles. Since that time, engineers, wildlife biologists, utility planners, and the utility industry have worked to address the problem. This publication presents the history and relative success of more than two decades of work to develop and implement solutions to the problem; it also represents a major update and revision for organizations seeking to preserve and enhance raptor populations, while maintaining the integrity and reliability of electric power networks worldwide. It explores the background of the interaction from biological and electrical perspectives, and provides specific guidance for reducing bird mortalities through cooperative utility, federal, state, and agency actions. It includes an extended, current bibliography. The goals of *Suggested Practices* are to minimize electrocutions so that avian resources are not adversely affected, and to reduce the number of and potential for electrical outages.

The Issue. Discoveries of large numbers of electrocuted raptors in the early 1970's spurred utilities and government agencies to work together to identify causes and develop solutions to the electrocution problem. Beginning in 1972, agencies such as the Edison Electric Institute (EEI), U.S. Fish and Wildlife Service (USFWS), National Audubon Society, Rural Electrification Administration (REA; now Rural Utilities Service[RUS]), and the Bureau of Land Management (BLM) began concerted efforts to address the problem. The results of their efforts were documented in the first edition of *Suggested Practices* (Miller et al. 1975); it recommended minimum phase spacing, elevated perches, gapping of groundwires, and other measures to make power-line structures safer for raptors. A few years later, the widely used report was expanded to incorporate new findings and recommendations (Olendorff et al. 1981).

Literature accounts of raptor power-line interactions since 1981 indicate that raptor electrocution remains a widespread problem in North American and throughout the world. In North America, all species known to be at risk at the time of the 1981 edition of *Suggested Practices* continue to appear in electrocution records. These include threatened and endangered species such as the bald eagle (*Haliaeetus leucocephalus*) and peregrine falcon (*Falco peregrinus*). Species that did not appear previously in electrocution records are now known to be at risk. In other parts of the world, electrocution may be the primary factor causing declines in some species. However, much progress has been made in documenting the problem, in retrofitting particularly hazardous power lines, and in implementing raptor-safe engineering of new lines. For example, raptor protection measures are now mandated as part of permitting and licensing requirements by most federal agencies in the U.S.

Biological Aspects of Raptor Electrocution. Raptors are attracted to power lines. They use power poles and towers as perches from which to establish territorial boundaries, hunt, rest, find shade, feed, and sun themselves. Power-line structures are also used by many species as nesting substrates.

Raptors vary widely in their susceptibility to electrocution. Forest-dwelling raptors rarely perch on power lines and poles, and ground-nesting raptors are rarely electrocuted. Smaller species (e.g., merlin [*Falco columbarius*] and screech-owls [*Otus* spp.]) generally cannot span the distance between two electric conductors to complete a circuit. Larger birds, such as the ferruginous hawk (*Buteo regalis*) or red-tailed hawk (*B. jamaicensis*), are more likely to be electrocuted.

Golden eagles (*Aquila chrysaetos*) are particularly vulnerable to electrocution because of their size (wingspans up to 2.3 meters or 7.5 feet). Many eagle electrocutions are caused by simultaneous skin-to-skin, foot-to-skin, and beak-to-skin contacts with two phase wires or a phase and a ground. Risks increase in weather that hampers controlled flight, or when feathers are wet, increasing conductivity. Immatures and subadults, less adept in flight skills and at landing on power poles, are also at greater risk. Other factors that affect susceptibility to electrocution include choice of prey, method of pursuit, the attraction of eagles to high seasonal or local prey concentrations, habitat diversity, the direction of the prevailing wind, and topography. Risks also occur from excreta streams and from nesting activities where nest materials may complete a circuit.

Suggested Practices: Power-Line Design and Raptor Safety. Electrocution of raptors occurs most often on distribution lines of 69,000-volts (69-kV) or less. Mortality is directly related to the spacing between elements that can comprise a phase-to-phase or phase-to-ground contact. Two design factors make a line hazardous for raptors: (1) phase conductors separated by less than the wingspread (flesh-to-flesh distance) of the bird that is landing, perching, or taking off; and (2) a distance between grounded hardware (e.g., groundwires, metal braces) and an energized conductor (phase) that is less than the wingspread or the distance from the tip of the bill to the tip of the tail.

Problem designs occur on both single-phase and three-phase lines. Such problems include grounded insulator pins or jumper wires set too close to the phase conductor, use of metal crossarm braces, and reduced spacing between an energized conductor and the groundwire used for lightning protection.

The key to remedying lethal combinations is to modify problem structures or to use new construction designs with proper spacing of design elements. Modification measures are used to correct existing problems; raptor-safe construction provides appropriate designs for new or rebuilt lines in areas of more concentrated raptor use. The key objective for raptor protection is to provide a 152.4-centimeter (60-inch) minimum separation between conductors and/or grounded hardware, or to insulate hardware or conductors against simultaneous contact if such separation is not possible.

These recommendations are based on several assumptions:

- a need has been demonstrated for such modification;
- cost and other factors will play a part in determining the appropriate action;
- the focus should be on those poles that present the greatest problem;

- in areas heavily used by raptors, a series of poles may require action; and
- older lines (with more cramped spacing) may need most attention.

Recommendations include use of insulating materials; gapping groundwires; adding pole-top extensions; lowering crossarms; installing perch guards or longer crossarms; and addition of elevated perches, depending on the nature of the pole and the problem.

Perching, Roosting, and Nesting by Raptors on Power Lines. Power lines may also offer nesting and other opportunities for raptors. In open plains, prairies, or savannahs where trees and cliffs are scarce, power poles often provide the vertical structures necessary for nesting, roosting, and more effective foraging. Numerous species nest successfully on power-line structures. Power lines may allow for population increases of some raptors in areas where natural nesting substrate is limiting.

Raptor nests, however, can interfere with line maintenance and cause electrical outages. Generally, current practice is to accommodate nesting behavior, rather than to discourage it. Nesting platforms have been provided on the poles themselves or on "dummy" poles placed near those poles where nests have been built. Nest platforms are generally more necessary on distribution poles (with their closely spaced conductors) than on transmission structures. Various designs are available, and may be deployed after a problem has been documented or where raptors are likely to make heavy use of poles.

Platforms are best placed on or near preferred poles and towers, and located so that dropped nest material or excreta will not interfere with operation of the line. Raptors should not be encouraged to nest in areas that would adversely affect other desirable wildlife species (prey).

Cooperative Management of the Electrocution Issue. Much of the success in reducing raptor mortalities can be attributed to the concerted, joint efforts by utilities, conservation groups, government agencies, and other affected parties since the 1970's. Successful management of this issue often depends on continuing cooperation and integration of efforts. Prioritizing poles and high-use raptor areas for modification is the key to success in reducing raptor mortalities.

Mortalities can be reported through existing utility company procedures (e.g., outage reporting systems), both to identify areas that should receive priority and to monitor the effect of management actions. Bird mortalities should be identified, even when they are not associated with an actual outage.

Several management options offer effective possibilities for cooperative action. A company/agency working agreement translates their respective mandates and desires, including legal and economic constraints, into guidelines for action. With a framework that includes reporting procedures for specially protected species or for banded or injured birds, action does not have to be deferred while individual requests for direction are made. Standard operating procedures also contribute to effectiveness, especially if backed up by company employee training. Awareness and interest provides better understanding, more thorough data collection, and more effective results. Heightened awareness, however, must begin with management personnel.

Finally, research suggests that utility and agency files contain a great amount of unpublished data that could contribute greatly to understanding of problems and effective solutions. Efforts should be made to summarize and disseminate this information. Additional studies are needed to evaluate new remedial actions and improve raptor-safe standards. The use of raptor-safe construction techniques can be encouraged through the influence of international funding agencies and consultants involved in the economic development of Third World countries. The tools described in this document can be used worldwide to reduce raptor electrocutions, while still providing reliable electrical service.

FOREWORD

Public perceptions of raptors have changed dramatically in recent years. Only a few decades ago, raptors were considered "vermin" and in conflict with humans. As recently as the 1950's, some states even offered bounties on raptors. Today, however, birds of prey are valued as powerful and impressive birds that form an integral component of ecosystems.

As our perceptions about raptors have changed, so has our concern for their welfare. For centuries, humans have changed Earth's natural landscapes, to the detriment of its wildlife. Human developments have eliminated and altered habitat, and direct human actions have added to the natural mortality factors of raptors. The additive effects of human-caused losses in the latter half of this century have turned the tide against some raptors. In North America, many species became endangered during this period, and others declined significantly. Pressures on raptor populations are increasing throughout the world. Thus, it is imperative that we take steps to reduce raptor mortality where there is a possibility of success, as in the raptor electrocution problem.

Environmental issues often are resolved with conflict and confrontation. The history of the raptor electrocution problem, however, is an encouraging exception. From the beginning, efforts to reduce raptor electrocutions on power lines were marked by a spirit of cooperation. In the 1970's, biologists, engineers, and government officials began working together to solve the problem. That effort led to the development of the two earlier editions of this document: the 1975 *Suggested Practices for Raptor Protection on Powerlines*, and the subsequent *Suggested Practices for Raptor Protection on Power Lines--the State of the Art in 1981*, published by the Edison Electric Institute and distributed by the Raptor Research Foundation. This cooperative spirit was due in no small part to Butch Olendorff, to whom the current edition is dedicated. Butch had an extraordinary ability to bring people of opposing viewpoints together to work towards common goals. Equally important was the resolve on the part of Richard Thorsell, Edison Electric Institute (retired), to organize and fund all three editions of *Suggested Practices*. It was Richard who first envisioned an electric industry manual for raptor protection on power lines.

Demands for electricity are increasing, and new engineering approaches to distribute electricity are constantly being developed. Before his untimely death in 1994, Butch felt that *Suggested Practices* should be updated to acquaint biologists and industry personnel with the latest developments in resolving raptor electrocution issues. This publication is the result. The Edison Electric Institute and Raptor Research Foundation are very pleased to present *Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996.*

Michael N. Kochert
Vice President
Raptor Research Foundation, Inc.

DEDICATION

This publication is dedicated to the memory of its senior author:

Richard R. (Butch) Olendorff

(1943 - 1994)

Butch devoted his life to the conservation of raptors, setting standards that guided the development of raptor research and management through the early years. A charter member of the Raptor Research Foundation (RRF), Butch served as RRF's editor from 1971 to 1976, its secretary from 1975 to 1976, and its president from 1977 to 1981. From 1975 to 1977, he served on RRF's Board of Directors. At the time of his death, he was the Technical Assistance Leader and past Director of the Raptor Research and Technical Assistance Center, Boise, Idaho.

Butch worked for the Bureau of Land Management (BLM) for 19 years, and for the newly established National Biological Survey (now Service) from 1993 until his death in February 1994. During that time, Butch produced over 35 publications and scientific papers, and developed a computerized raptor management bibliography with over 10,000 references. In 1985, Butch conceived and organized one of the largest raptor conservation events ever organized, the 10-day World Raptor Meetings in Sacramento, California. Butch's dedication and hard work remain a shining example of the tremendous difference one person can make toward the wise stewardship of wildlife.

The BLM periodically gives the Richard R. "Butch" Olendorff Conservation Award to individuals who make significant contributions toward raptor conservation.

A Richard R. Olendorff Memorial Fund has also been established: it will provide for the development of the Richard R. Olendorff Memorial Library at Boise State University. Contributions may be sent to:

The Richard R. Olendorff Memorial Fund
West One Bank
P.O. Box 7159
2730 Airport Way
Boise, Idaho 83707.

About the Authors

RICHARD R. OLENDORFF was a raptor biologist for the National Biological Survey (now Service). He received his Bachelor of Science Degree in zoology at the University of Washington in 1967, and completed his doctorate at Colorado State University in 1971. He was a Post-doctoral Fellow and Research Associate at the American Museum of Natural History in New York before becoming the Endangered Species Liaison Officer in Washington D.C. for the BLM. In 1989, Butch moved to Boise, Idaho, to establish the Raptor Research and Technical Assistance Center. Butch died in February 1994; this publication is dedicated to his memory. Butch was the senior author of the 1981 edition of *Suggested Practices.*

ALLAN R. ANSELL is the environmental supervisor for Idaho Power Company in Boise, Idaho. Allan received a Bachelor of Arts degree in botany and environmental biology from the University of Montana in 1974, and has worked for Idaho Power Company since 1975. He has worked extensively with raptor/powerline issues for over 20 years, and also oversees a broad range of environmental studies related to power plant licensing and permitting.

MONTE G. GARRETT is a senior wildlife biologist for PacifiCorp in Portland, Oregon. He received his Master's Degree in wildlife biology in 1982, and assisted in waterfowl research with the U.S. Fish and Wildlife Service until 1984. From 1984 to 1986, Monte conducted research on bald eagle habitat selection, home range, and environmental contaminants within the lower Columbia River Estuary, Oregon and Washington. Since 1986, he has worked within PacifiCorp to identify and remediate power lines for raptor safety in seven western states.

ROBERT N. LEHMAN is a wildlife biologist for the National Biological Service, Raptor Research and Technical Assistance Center, Boise, Idaho. He has worked with raptors for nearly 20 years. Since 1990, he has coordinated the monitoring of raptors in the Snake River Birds of Prey National Conservation Area in southwestern Idaho. Bob received a Bachelor of Science degree in wildlife management from Humboldt State University in 1979, and a Master's degree in raptor biology from Boise State University in 1996. He was a co-author of the 1981 edition of *Suggested Practices.*

A. DEAN MILLER is a retired electrical engineer with 40 years of experience with the Public Service Company of Colorado in transmission engineering design and construction. He is a registered Professional Engineer and Land Surveyor in the state of Colorado. He co-authored the 1975 and 1981 editions of *Suggested Practices*, as well as the companion publication to this book, *Mitigating Bird Collisions with Power Lines: The State of the Art in 1994.* He is currently the engineering consultant to the Avian Power Line Interaction Committee.

The authors may be contacted through **Edison Electric Institute, 701 Pennsylvania Avenue, N.W., Washington D.C. 20004-2696. Attention: Environmental Programs Manager.**

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Valuable review of drafts and suggestions for improvements have been provided by Karen Steenhof, National Biological Service, Raptor Research and Technical Assistance Center; Dr. James Bednarz of Arkansas State University; Dr. Daniel Varland of Rayonier Northwest Forest Resources; and by the Raptor Research Foundation, as well as by the current members of the Avian Power Line Interaction Committee (APLIC), and the companies or agencies that support them. Their efforts were crucial to creating a true "state of the art" document for 1996.

Bonneville Power Administration	Phillip Havens
Central and South West Services	David Bouchard
Edison Electric Institute	Joel Mazelis
Florida Power & Light Company	Peter Quincy
Idaho Power Company	Allan Ansell
Nebraska Public Power District	Mark Czaplewski
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U.S. Fish and Wildlife Service	Jim Lewis
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Finally, we acknowledge those who pioneered this effort, especially Richard S. Thorsell, Edison Electric Institute Environmental Program Manager (retired); Thomas Riley, Pacific Gas and Electric (retired); Irv Boeker, U.S. Fish and Wildlife Service (retired); Ralph Sargent, Jr., Vice-President, Public Service Company of Colorado (deceased); Robert Turner, National Audubon Society; and Morlan Nelson, raptor expert. A host of supporters, industry and government leaders who allowed this program to develop also deserve recognition: they cared

about a problem and sought a solution to it, without regard to politics or glory. Their dedication set the stage for the success of the program and became the model for industry cooperation.

SUGGESTED PRACTICES FOR RAPTOR PROTECTION ON POWER LINES:

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CHAPTER I

INTRODUCTION

This book presents engineers, biologists, utility planners, and the public with a comprehensive portrait of progress in documenting and addressing the issue of raptor electrocution at electric power facilities.[1] It outlines the importance of the issue, and focuses on opportunities in the U.S. and throughout the world for avoidance or mitigation of electrocution problems, highlighting management options.

PURPOSE AND SCOPE

In the early 1970's, an investigation into reported killings and poisonings of eagles in Wyoming and other western states provided substantial evidence that power lines electrocuted eagles (Olendorff et al. 1981). Since then, engineers, wildlife biologists, utility planners, and the utility industry have worked together to understand the causes of raptor electrocution, and to develop and implement engineering solutions to the problem. Over the last 25 years, those efforts have led to a detailed understanding of the biological factors that attract raptors to power lines, and those harmful interactions that lead to electrocution.

This publication, *Suggested Practices for Raptor Protection on Power Lines: The State of the Art in 1996*, summarizes the history and relative success of more than two decades of work on the electrocution problem. It springs from two previous editions, and represents a major update and revision for organizations concerned with enhancing raptor populations while maintaining the reliability of electric power networks worldwide. Early attempts to understand the engineering aspects of raptor electrocutions led to the first edition of *Suggested Practices* (Miller et al. 1975). The 1975 edition summarized early findings and recommendations; it was then succeeded by the 1981 edition (Olendorff et al. 1981), which contained more research results and practical experience, as well as a comprehensive annotated bibliography.

Fifteen years of additional experience, design development, and research have produced new findings and refined recommendations for power-line structure modification and design to protect raptors. The current volume incorporates and builds from earlier material. It explores the background of the interaction from biological and electrical perspectives, and provides

[1] The focus is on electrocutions, not on collisions. Readers seeking information on the collision of raptors with power lines may consult *Mitigating Bird Collisions with Power Lines: The State of the Art in 1994 (APLIC 1994).*

guidance for reducing bird mortalities through cooperative actions. Goals are to minimize electrocutions, and to reduce the number of and potential for electrical outages.

This edition of *Suggested Practices* offers the reader an expanded range of solutions to hazardous power-line designs. Additional designs for which corrective measures are provided include bayonet, kite, switch pole, wishbone, horizontal post, compact, and suspension designs, as well as designs with jumper wires. Measures for modifying existing lines and for constructing new lines are now treated separately. Also included are the following:

- examples of transmission line hazards not identified in 1981;
- cross-referenced figures of problem designs and solutions;
- an updated bibliography with more than 100 new references;
- expanded treatment of the electrocution problem outside North America, giving the document a global perspective;
- a chapter on cooperative management to promote cooperation among industry, government, and private sectors;
- a glossary of terms;
- an appendix detailing the history of the raptor electrocution problem and individual and agency efforts to address it; and
- an appendix of commercially available products for managing raptor perching on power poles and for insulating conductors.

Not considered in the 1996 edition of *Suggested Practices* are discussions of other power-line-related impacts on raptors, including construction and maintenance impacts, impacts of shooting along power lines, and impacts of collision with power lines. These subjects were discussed in Part 4 of the 1981 edition and in the 1994 Collision Mitigation manual published by the Avian Power Line Interaction Committee (APLIC). The authors felt that these topics were beyond the scope of this document, or were addressed elsewhere. Given the addition of many literature citations since 1981 (and consequent length of the citations section), the annotations contained in the 1981 edition have been eliminated.

ORGANIZATION OF THIS DOCUMENT

This book is intended for use by scientists, managers, and engineers, and across national borders. International literature is included, but the primary focus is on North America. The sequence of chapters and a brief synopsis of their contents are listed below.

CHAPTER II	**THE ISSUE.** Defines the problem; traces its history; reviews the literature and latest research on raptor electrocution and its prevention.

CHAPTER III	**BIOLOGICAL ASPECTS OF RAPTOR ELECTROCUTION.** Identifies the causes of raptor electrocution on power lines and focuses on biological and environmental factors that predispose raptors to electrocution.
CHAPTER IV	**SUGGESTED PRACTICES: POWER-LINE DESIGN AND RAPTOR SAFETY.** Presents the reader with the background necessary to understand raptor electrocution from an engineering perspective: the construction and design of power facilities. Suggests ways to retrofit existing facilities and design new facilities to prevent or minimize raptor electrocution.
CHAPTER V	**PERCHING, ROOSTING, AND NESTING BY RAPTORS ON POWER LINES.** Explores the benefits of power lines to raptors and proposes strategies for repositioning nests or providing alternative nesting (perching, roosting) sites to minimize danger to raptors while maintaining electrical service.
CHAPTER VI	**COOPERATIVE MANAGEMENT OF THE ELECTROCUTION ISSUE.** Presents a cooperative, multi-disciplinary approach to managing the bird electrocution problem.

For literature citations from the text and additional useful references, see the **Literature Cited and Bibliography** section (pages 101-125). **Appendix A** contains a glossary; **Appendix B** a history of early agency actions addressing the electrocution issue; **Appendix C** information on specific products and sources for modifying power lines.

CHAPTER II

THE ISSUE

This chapter defines the issue and traces its history, provides a review of the literature, introduces the latest research on electrocution, and discusses approaches to addressing the problem. Particular emphasis is placed on studies since the previous edition of *Suggested Practices* (1981), including an overview of the issue outside the United States.

Raptors (birds of prey) are both ecologically important (high trophic level) and biologically sensitive to toxic substances, habitat destruction, and direct human persecution. Inadvertent destruction of raptors also occurs wherever humans and raptors interact. Electrocution on power lines is only one of many human-caused mortality factors that in combination may limit raptor populations. The biological importance and environmental sensitivity of raptors have led to considerable academic and public interest in the birds and the problem of electrocution, and to considerable demand for better protection and management of raptor populations and habitats.

In the U.S., the federal government provides protection for birds of prey through several laws. Prominent among these are The Bald and Golden Eagle Protection Act (16 U.S.C. 668-668C), The Migratory Bird Treaty Act (16 U.S.C. 703-712), and The Endangered Species Act (16 U.S.C. 1531-1543). Also, most states provide some form of legal protection. Violation of federal laws can result in fine and/or imprisonment. Misdemeanor violations may result in fines of up to $100,000 for individuals and $250,000 for organizations, and up to 2 years' imprisonment. Fines of up to $250,000 and $500,000 for individuals and organizations, respectively, may result from felony violations, depending on the statute.

Another major impetus for action is the impact of raptor electrocution on the electric power network. Raptors and other birds cause a significant number of power outages. PacifiCorp (unpubl. data)[2] documented 346 outages annually between 1986 and 1995, caused by large perching birds. In addition, an average of 13 nest-related outages occurred each year. When they are electrocuted or shot, birds may fall across conductors or into transformer banks. Other associated line problems include birds defecating onto and shorting out transformers or other equipment (Michener 1928, Benton and Dickinson 1966, West et al. 1971), colliding with wires (a less significant mortality factor for raptors, according to Baldridge 1977; Pinkowski 1977; Kroodsma 1978; Meyer 1979, 1980; Olendorff and Lehman 1986), dropping prey or nesting material onto energized wires (see Chapter II), and building nests on

[2] "Unpublished data" is used in this text to indicate information available from the authors and their respective organizations. "Pers. comm." is used to indicate information available from other researchers, as named in the text.

power poles in positions that jeopardize the reliability of the lines (PacifiCorp, unpubl. data) (see Chapter V). Stocek (1981) estimated that the annual cost of bird-related damage to Canadian utilities was $374,600.

Much less is known about the mortality of raptors than about most other aspects of their ecology. Thus, little is known about the effects of electrocution on raptor populations. Newton (1979:212) summarizes the difficulties of addressing the issue:

> The importance of different mortality causes is also poorly understood, partly because it is hard to find a sample that is representative of the whole population, and partly because of the operation of pre-disposing causes. Starvation, predation and disease are all recorded as causing deaths of raptors, as are various accidents and collisions, electrocution, shooting, trapping and poisoning. The [banding] recoveries and post-mortem analyses which provide most information are inevitably biased towards deaths that occur from human action or around human habitation.

Both direct and indirect mortality factors must be considered in studying the overall population dynamics of birds of prey. In addition to electrocution from power facilities, Postivit and Postivit (1987) identified eight other human activities that affect birds of prey: persecution[3], pesticide use and pollution, agricultural development, logging, dam construction and water management, energy and mineral development, urbanization, and recreation.

The growth of human populations and associated natural resource development (e.g., logging, mining, energy, or agricultural development) are a more pervasive threat to global raptor populations than all other threats combined (Newton 1991). Habitat destruction has been credited for greater reductions in raptor and other wildlife populations than any other factor, and is still the most serious long-term threat (Newton 1979). Howard (1980), for example, postulated the likely decline of local raptor populations due to agricultural development of lands surrounding the Snake River Canyon in southern Idaho. For the bald eagle (*Haliaeetus leucocephalus*), organochlorine pesticides are certainly more detrimental than electrocution by power lines (Anthony et al. 1994).

Nevertheless, electrocution at power facilities remains a legitimate concern. Such mortalities can be addressed by a variety of mitigation measures, through design and retrofitting of existing lines. It is in the interest of utility planners, biologists, and engineers to familiarize themselves with the issue and its dimensions, and to plan for and implement steps to identify potential electrocution problems and to rectify them.

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[3] Persecution was used here to mean shooting. We would include poisoning and direct trapping as well. Deaths from persecution are a much-debated topic: one study found that some researchers argue that persecution has caused local declines in raptor numbers, while others contend that no long-term impacts have resulted (Postivit and Postivit 1987).

EARLY REPORTS

Before the 1970's, raptor electrocution had been noted by several researchers (Hallinan 1922, Marshall 1940, Dickinson 1957, Benton and Dickinson 1966, Edwards 1969, Coon et al. 1970). However, until the 1970's, its magnitude was not known. In May 1971, the carcasses of 11 bald eagles and 4 golden eagles (*Aquila chrysaetos*) were discovered in Jackson Canyon, near Casper, Wyoming, a traditional roosting place for both species. The toll eventually reached 24 birds. External examinations revealed no gunshot wounds, and there were no power lines in the area on which the birds could have been electrocuted. It was determined that several antelope carcasses had been laced with thallium sulfate (then a widely used predator control poison), and left as bait.

Subsequent surveys in Wyoming and Colorado found nearly 1,200 eagle mortalities due to poisoning, shooting from aircraft, and electrocution. That death toll was documented both in agency reports and court testimonies (Turner 1971, Laycock 1973). The surveys uncovered a major shooting campaign. During August 1971, a Wyoming helicopter pilot told the Senate Environmental Appropriations Subcommittee that he had piloted several eagle hunts in the preceding 7 months; roughly 560 eagles had been killed. The shooting was commissioned by the father-in-law of the sheep rancher who had poisoned the eagles in Jackson Canyon. Revised testimony by the helicopter pilot set the estimate of eagle kills at nearly 800, and implicated at least 12 other Wyoming ranching companies.

During the surveys in Wyoming and Colorado, more than 300 eagles were found dead near power lines (Turner 1971, Laycock 1973). Although many had been shot, many others had been electrocuted by contact with lines not designed with eagle protection in mind. In addition, 17 golden eagles, one red-tailed hawk (*Buteo jamaicensis*), and one great horned owl (*Bubo virginianus*) were found dead, all probably electrocuted, along 5.6 kilometers (km) (3.5 miles [mi]) of lines in northeastern Colorado (Olendorff 1972a). Five golden eagles and 4 bald eagles were found dead under a power line in Tooele County, Utah, and another 47 dead eagles (electrocuted) were found along a line in Beaver County, Utah (Richardson 1972, Smith and Murphy 1972). Of 60 autopsied golden eagles in Idaho, 55% had been electrocuted (M. Kochert, pers. comm. in Snow 1973). In June of 1974, 37 golden eagles and one short-eared owl (*Asio flammeus*) were found dead under a line southwest of Delta, Millard County, Utah (Benson 1977, 1980). In a review of bald eagle mortality data for 1960 through 1974, 4% of the eagle deaths were attributed to electrocution (total sample size not given) (Meyer 1980). Similar problems were also noted in New Mexico (Denver Post 1974), Oregon (White 1974), Nevada (U.S. Fish and Wildl. Serv. 1975a), Louisiana (Pendleton 1978), and Idaho (Peacock 1980). A problem had clearly been identified.

Much of the information from the early 1970's was summarized by Boeker and Nickerson (1975), including documentation of 37 golden eagle deaths along a power line of just 88 poles in Moffat County, Colorado, in 1971. Four-hundred-sixteen raptor carcasses and skeletons were found along 24 8-km (5-mi.) sections of power lines in 6 western states (Benson 1981). In Utah, U.S. Fish and Wildlife Service (USFWS) employees found the remains of 594 raptors (some dead up to 5 years) under 36 different distribution lines (approximately 402 km or 250 mi. total). Sixty-four of these carcasses were fresh enough to determine the cause of death: 54 (87.5%) had been electrocuted (R. Joseph, U.S. Fish and Wildl. Serv., pers. comm.).

SUGGESTED PRACTICES: 1975 AND 1981

The evidence compiled after the Jackson Canyon incident caused serious concern about raptors and electric power facilities. Industry, government, and conservation organizations began to work together to identify and implement solutions to the problem of raptor electrocution. Agencies involved included the Rural Electrification Administration (REA; now the Rural Utilities Service [RUS]), U.S. Forest Service (USFS), Bureau of Land Management (BLM), the USFWS, National Park Service (NPS), and Bureau of Indian Affairs (BIA). The USFWS began searching for lethal lines, while the REA began developing proposed line modifications to minimize eagle electrocutions. The National Audubon Society and the Edison Electric Institute (EEI) initiated workshops, sought utility company participation, raised funds, and began to develop ways to address the problem. An REA bulletin described causes of raptor electrocution resulting from certain grounding practices and conductor spacing (U.S. Rural Electrification Administration 1972), and the USFWS initiated a raptor mortality data bank to track patterns in electrocution. (Appendix B presents a history of individual and agency contributions.)

As data were gathered on the magnitude of raptor electrocutions during the early 1970's, several regional meetings were held to familiarize industry and agency personnel with the problem. Meetings in Ontario, Oregon (16 April 1974) (U.S. Bur. of Land Manage. 1974a), and Reno, Nevada (3 October 1974), were particularly noteworthy. By then, several electric companies, most notably Idaho Power Company, had retained Morlan W. Nelson of Boise, Idaho, to begin testing the safety of new power-line designs and to propose modifications of existing lines.

These tests were instrumental in forming the basis for the first definitive work on the subject: *Suggested Practices for Raptor Protection on Powerlines* (Miller et al. 1975). This publication was widely circulated and used by both industry and government (Damon 1975, Edison Electric Institute 1975). For example, new power lines proposed by the electric industry required applications for rights-of-way permits across BLM-administered land. This agency then decided whether to grant the permit, and what restrictions, if any, should be placed on the design and placement of the lines to minimize environmental impacts, including eagle electrocutions (Olendorff and Kochert 1977). Many BLM directives (as well as those of other agencies) required similar clearances and explicitly stipulated that such actions be consistent with the suggested practices.

Field testing of the suggested practices in the mid-to-late 1970's led to a need for further documentation and evaluation. Some of the suggested practices and dimensions were found inadequate. For instance, the suggested 61.0-centimeter (cm) or 24-inch (in.) height of the overhead perch was too high, and needed to be reduced to 40.6 cm (16 in.) to keep the birds from landing beneath the perch. New insulation material and conductor support schemes were also developed. In the 1981 edition (Olendorff et al. 1981), earlier suggested practices were corrected and updated, and a complete literature review and annotated bibliography was provided.

THE CONTINUING PROBLEM

ELECTROCUTION ISSUES IN NORTH AMERICA

Despite the publication of *Suggested Practices* in 1981, and efforts on the part of the electric industry to correct many problem power lines, researchers have continued to report raptor use of power lines, raptor electrocution deaths, and solutions to the problem. During a literature review conducted for the 1996 *Suggested Practices*, over 100 new references were found documenting electrocution problems and their solutions worldwide since 1981 (see Literature Cited, pages 101-125). Of these, nearly 70 percent were from the North American continent.

Literature accounts from North America since 1981 indicate that the raptor electrocution problem is still widespread and continues to involve threatened and endangered species. The U.S.'s National Wildlife Health Laboratory (1985) reported that 130 (9.1%) of 1,429 dead bald eagles examined from 1963-1984 were electrocuted. Fifty-five percent of the eagles examined died in the last 6 years of the sampling period (1978-1984). Electrocution incidents occurred in 23 states, but were most common in Alaska, Kansas, Wisconsin, and Florida. In a more recent summary of bald eagle mortalities, 12% of deaths with known causes were due to electrocution (Franson et al. 1995).

Electrocution deaths of bald eagles have also been documented by Frenzel (1984), Pennsylvania State Game Commission (1984), California Bald Eagle Working Team (1985), Brett (1987), California Department of Fish and Game (1987), Jurek (1988), and Garrett (1993). Wood et al. (1990) summarized bald eagle deaths by electrocution in the southeastern United States using the National Wildlife Health Laboratory's 1985 data. In the Southeast, shooting was the leading cause of bald eagle mortality, followed by emaciation, poisoning, and electrocution.

Bald eagle losses to electrocution were probably underestimated in the 1970's and early 1980's because studies were not conducted in areas with bald eagle concentrations. During the winter, bald eagles often congregate in large numbers (Stalmaster 1987). Some of these concentrations involve hundreds of birds and occur in predominantly treeless areas where the only available perches are power poles. Over 1,000 bald eagles and a variety of other raptor species gather each winter in the Klamath Basin of southern Oregon and northern California (Keister et al. 1987). In Butte Valley, an area of the Klamath Basin used extensively by raptors for foraging, 90 electrocuted eagles were found between 1986 and 1992. Of these, 24 (27%) were bald eagles (PacifiCorp, unpubl. data).

Since 1981, electrocution deaths have also been documented for other threatened and endangered species. At least two peregrine falcons (*Falco peregrinus*) released as part of the Peregrine Fund's Rocky Mountain recovery program were electrocuted after fledging from release sites (Burnham 1982). Also, a peregrine falcon was electrocuted and two were suspected to have been electrocuted during a release in Ottawa, Canada (McDonnell and Levesque 1987). An Andean condor (*Vulture gryphus*), released in the former range of the California condor (*Gymnogyps californianus*) in 1989 as part of the California condor recovery effort, was electrocuted soon after its release (Rees 1989, U.S. Fish and Wildl. Serv. 1989). The species is listed as endangered in its native South America.

At least 11 North American raptor species that were not previously reported as electrocution victims are now known to be vulnerable to the hazard. Among diurnal species, these include the turkey vulture (*Cathartes aura*) (Harness 1996), northern goshawk (*Accipiter gentilis*) (O'Neil 1988, Harness 1996), Cooper's hawk (*Accipiter cooperii*) (O'Neil 1988), common black-hawk (*Buteogallus anthracinus*) (Schnell 1980), Harris' hawk (*Parabuteo unicinctus;* discussed below), and the American kestrel (*Falco sparverius*) (Harness 1996; Idaho Power Co., unpubl. data).

The number of owl species known to be vulnerable to electrocution has more than tripled since 1981. Records are now available for the long-eared owl (*Asio otus*) (Idaho Power Co., unpubl. data), eastern screech-owl (*Otus asio*) (Idaho Power Co., unpubl. data), western screech-owl (*Otus kennicottii*) (Harness 1996), barn owl (*Tyto alba*) (Williams and Colson 1989), and the great gray owl (*Strix nebulosa*) (Harness 1996).

The species listed above appeared in electrocution records in low numbers (generally less than five records each). However, the Harris' hawk appears to be electrocuted in surprisingly high numbers. Eight cases of electrocution were reported by Whaley (1986) in the Sonoran Desert of southern Arizona, but the author felt that many additional electrocutions probably were unreported. A higher incidence of electrocution in Harris' hawks was confirmed by Dawson and Mannan (1994). In an urban population in and near Tucson, Arizona, 112 (63%) of 177 mortalities with known causes were due to electrocution between 1990 and 1993. An additional 44 deaths were probably due to electrocution. Electrocutions typically occurred on residential power lines and transformers.

During the 1980's and early 1990's, additional electrocution records were found for many species that were known in 1981 to be vulnerable. In the Klamath Basin of Oregon and California (mentioned above), 66 golden eagles were found electrocuted between 1986 and 1992 (PacifiCorp, unpubl. data). In Montana, 32 golden eagle mortalities were confirmed from 1980 to 1985 (O'Neil 1988). In Nebraska, an estimated 500 raptors, mostly eagles, died of electrocution each year during a 6-year study (U.S. Fish and Wildl. Serv. 1988).

Buteos have also continued to appear in electrocution records during the 1980's and 1990's. In California, Estep (1989) reported that 28 unidentified raptors found electrocuted on wind energy farms in central California between 1984-1988 were probably Buteos. These birds represented 78% of the electrocution mortalities confirmed during that study. However, most raptor mortalities in that study were due to collisions with wind turbine blades (see also Orloff and Flannery 1993). Southern California Edison records indicate that red-tailed hawks constitute about 90% of electrocuted raptors found along their distribution lines (D. Pearson, Southern California Edison, pers. comm.).

ELECTROCUTION ISSUES OUTSIDE NORTH AMERICA

The raptor electrocution problem has received close attention in North America for 25 years, and a great deal of information is available on the subject. For this reason, the 1996 *Suggested Practices* focuses on raptor electrocution problems on this continent. Information about raptor electrocution elsewhere in the world was more difficult to obtain. During the 1995-1996 literature review, extensive information about electrocution of raptors and raptor use of power lines was found only for South Africa and a few countries in Europe. Scattered references were found for Russia, other parts of Africa, and South America. Evidence from this literature suggests that electrocution is a limiting factor in some raptor populations, and has been an important factor in some population declines.

South Africa has been aware of the electrocution problem since at least 1970. Markus (1972) found 148 Cape vultures (*Gyps coprotheres*) electrocuted by a single 88-kV power line in the eastern Cape Province over a 2-year period. Five years later, over 300 electrocuted Cape vultures had been found below this line (Ledger and Annegarn 1981). The Cape vulture is electrocuted probably more than any other raptor species in South Africa, and is now considered to be a threatened species in that country. Ledger (1980) argued that electrocution, along with a variety of other human-caused factors, has caused the species' decline. Ledger et al. (1993) also discussed increasing concerns about electrocutions of other species, including the Martial eagle (*Polemactus bellicosus*) and black eagle (*Aquila vereauxii*). These species are highly vulnerable to electrocution on farms in rural areas where terminal power poles supply electricity to water pumps and other farm equipment. Also in Africa, Nikolaus (1984) suggested that electrocutions of the Egyptian vulture (*Neophron pernopterus*) along a single electrical line over a 20-year period may be responsible for the decline of that species near Khartoum, Sudan.

Extensive work has also been done on the electrocution problem in Spain since Garzon (1977) reported that electrocution is a primary source of raptor mortality in that country. Fernandez and Insausti (1990) report that electrocution and shooting are the main causes of mortality in Bonnelli's eagle (*Hieraaetus fasciatus*) in the northeastern part of the country. Numerous studies have identified electrocution as the primary cause of mortality (up to 69% of known deaths) for the Spanish imperial eagle (*Aquila heliaca*) in Doñana National Park in Spain (Ferrer and de la Riva 1987; Meyburg 1989; Ferrar et al. 1991; Ferrer and Hiraldo 1991, 1992). The park is one of the last strongholds for this critically endangered species. Ferrar et al. (1991) also estimated that over 400 raptors of 13 species were electrocuted each year (1982 and 1983) along a single 100-km (62.5-mi.) power line that passes through the park. The line in question runs for 300 km (187.5 mi.) through southwestern Spain. Approximately 70% of the mortalities were adults electrocuted during the breeding period. The authors concluded that electrocutions were seriously affecting these raptor populations.

Elsewhere in Europe, 14 diurnal raptor species (530 individuals) and 5 nocturnal raptor species (62 individuals) were found beneath power lines in West Germany, all apparent victims of electrocution (Haas 1980). Electrocution of eagle owls (*Bubo bubo*) was such a serious problem that the population was considered jeopardized. Herren (1969) made similar comments regarding eagle owls in Switzerland, and felt that utility lines were responsible for extirpations of these owls from the greater part of their range. A survey of 175 Norwegian power companies conducted by Bevanger (1994) indicated that 73% of the respondents believed that their systems contained installations that caused particularly frequent raptor electrocutions. The World Working Group on Birds of Prey (1991) suggested that electrocution was the second greatest threat to raptor conservation in Czechoslovakia, next to nest robbing. Kaiser (1970) found that all but a few single-pole breakdowns with unknown causes throughout Europe could be traced to the excrement streams of common buzzards (*Buteo buteo*) perched on the poles, but did not discuss the proportions that were electrocuted or the potential impacts on buzzard populations.

THE OUTLOOK

In 1996, it is important to recognize that progress has been made in the effort to reduce raptor electrocution on power lines. For example, many electric utility companies in the United States have adopted or participated in raptor enhancement or protection programs. Fifty-eight of 88 respondents to a mail survey of electric utilities indicated that their organizations worked cooperatively on raptor enhancement programs (Blue 1996). Today, raptor protection measures are mandated as part of permitting and licensing requirements by most federal agencies in the U.S. In 1982, the BLM incorporated requirements for raptor protection on power lines into the Bureau's operations manual (Olendorff et al. 1989, Olendorff and Kochert 1992). The manual covers both modifications of existing lines and proposed lines on public lands administered by the BLM. The Federal Energy Regulatory Commission (FERC) routinely includes special articles mandating raptor protection in its licenses for the construction and operation of hydroelectric projects (Federal Energy Regulatory Commission 1992).

Nevertheless, raptor electrocutions continue today. Thousands of kilometers of new power lines will inevitably be built in the future, and many more kilometers of existing lines will continue to electrocute raptors. In the future, electrocution problems probably will be most severe on those continents that contain large, expanding human populations (Africa, South America, and Asia) (Bevanger 1994). Given the serious social, environmental, and economic crises facing much of Africa, it is unlikely that the prevention of electrocutions of birds of prey will be a high priority for utility managers on that continent (Ledger et al. 1993). This will likely be the case in the remainder of the developing world.

The challenge facing raptor conservation efforts in 1981 remains today: that of raising global awareness of the raptor electrocution problem and its solutions. Of particular importance is the incorporation of raptor-safe construction techniques (see Chapter IV) during the design phase of future distribution systems. Much work also remains to be completed in retrofitting existing lines, both inside and outside the U.S. The authors hope that the 1996 *Suggested Practices* will promote an awareness of the electrocution problem throughout the world.

CHAPTER III

BIOLOGICAL ASPECTS OF RAPTOR ELECTROCUTION

This chapter identifies the causes of raptor electrocution on power lines, and focuses on biological factors that predispose raptors to electrocution. Minimizing electrocution risks requires some understanding of raptor biology and the environmental factors that increase risk behavior.

Raptors are electrocuted by power lines because of two principal factors. First, raptors are opportunistic, and are attracted to power lines for many reasons. Power poles and towers provide perches for hunting, resting, feeding, and territorial defense. Raptors use power-line structures to sun themselves, find shade, and sense air currents. Many species also use power-line structures as nesting substrates, and in many areas power lines have provided benefits to raptors where they did not previously exist (see Chapter V). Second, many designs of electric industry hardware place conductors and groundwires close enough together that raptors can touch them simultaneously with their wings or other body parts, causing electrocution (see Chapter IV).

Of the 31 species of diurnal raptors and 19 species of owls that regularly breed in North America (Johnsgard 1988, 1990), 26 have been reported as electrocution victims. Electrocution risk depends on the specific habitat requirements, behavioral patterns, and prey of each species. Some species are more prone to electrocution because they are large and can easily span the distance between conductors; others because they live in areas lacking natural perches. Age, experience, weather, and time of year also affect the susceptibility of raptors to electrocution.

SUSCEPTIBILITY OF RAPTORS TO ELECTROCUTION: SPECIES DIFFERENCES

Forest-dwelling raptors (accipiters)--the sharp-shinned hawk (*Accipiter striatus*), Cooper's hawk, and northern goshawk--are rarely found in electrocution records. Of 971 combined electrocution records from 3 studies in the western U.S. (O'Neil 1988; Harness 1996; Idaho Power Co., unpubl. data), only 3 were northern goshawks, and one was a Cooper's hawk. Forested areas generally have fewer reported raptor electrocutions than parklands, shrublands, and grasslands (Switzer 1977, Benson 1981). Because natural perches are abundant in forested areas, accipiters are more likely to perch in trees than on the relatively exposed perches provided by electric transmission and distribution facilities.

Ground-nesting raptors such as the northern harrier (*Circus cyaneus)* and short-eared owl also are electrocuted infrequently, but a few records exist (Pendleton 1978; Benson 1980, 1981; Harness 1996; Idaho Power Co., unpubl. data). There are no known electrocution records for the burrowing owl (*Athene cunicularia*). These raptors typically hunt while in flight and perch on or near the ground (Johnsgard 1988, 1990); thus, they are less exposed to electrocution risks than other species.

Other owl species appear in electrocution records in low numbers. The great horned owl is the most commonly electrocuted nocturnal raptor, though numbers usually are low in comparison to many diurnal species. Only 2 great horned owl electrocution deaths were found out of 207 known electrocution mortalities in Saskatchewan (Gillard 1977); 4 of 113 mortalities in Idaho between 1972 and 1979 were great horned owls (Ansell and Smith 1980). Low numbers of this species in electrocution records were also reported by Stewart (1969), Houston (1978), Benson (1981), and Harmata (1991). O'Neil (1988) reported the highest incidence of great horned owl electrocutions in Montana: 12 (24%) of 50 records. Harness (1996) reported that 32 (18%) of 173 electrocution records identified to species were great horned owls.

No records were found for most forest-dwelling owls such as the spotted owl (*Strix occidentalis*) and barred owl (*Strix varia*), and only 2 of 301 electrocution records reported for 4 western states were great gray owls (Harness 1996). Records for the snowy owls (*Nyctea scandiaca*) were also uncommon (Parmalee 1972, Gillard 1977). This species is found primarily in remote arctic regions lacking power-line structures. Only one record was found for the barn owl (Williams and Colson 1989).

Small species (e.g., the American kestrel, merlin, screech-owls, and most kites) with wingspans below 100 cm (39+ in.) (Clark and Wheeler 1987) generally cannot span the distance between two electric conductors, even with outstretched wings (see Figure 1 for an illustration of raptor wingspans).[4] However, electrocution of smaller raptors is probably underestimated because they are not as noticeable and because mammalian predators may carry off or consume small raptors before they are found. Small raptors probably are more at risk on poles with transformers where element spacing is commonly only centimeters or inches (Idaho Power Co., unpubl data).

Large size is by far the most crucial factor that makes certain raptor species susceptible to electrocution. The likelihood of spanning conductors with outstretched wings or other body parts is much greater for large birds. However, large size alone cannot account for the high incidence of electrocution among some species. Only one electrocution death has been recorded for the California condor, the largest North American raptor (R. Mesta, U.S. Fish and Wildl. Serv., pers. comm.), and few records are available for the large falcons--gyrfalcon (*Falco rusticolus*), peregrine falcon, and prairie falcon (*Falco mexicanus*). Only one case was found of an electrocuted gyrfalcon: a trained bird belonging to a falconer (Chindgren 1980).

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[4] See Clark and Wheeler (1987) for comprehensive data on wing spans of all species.

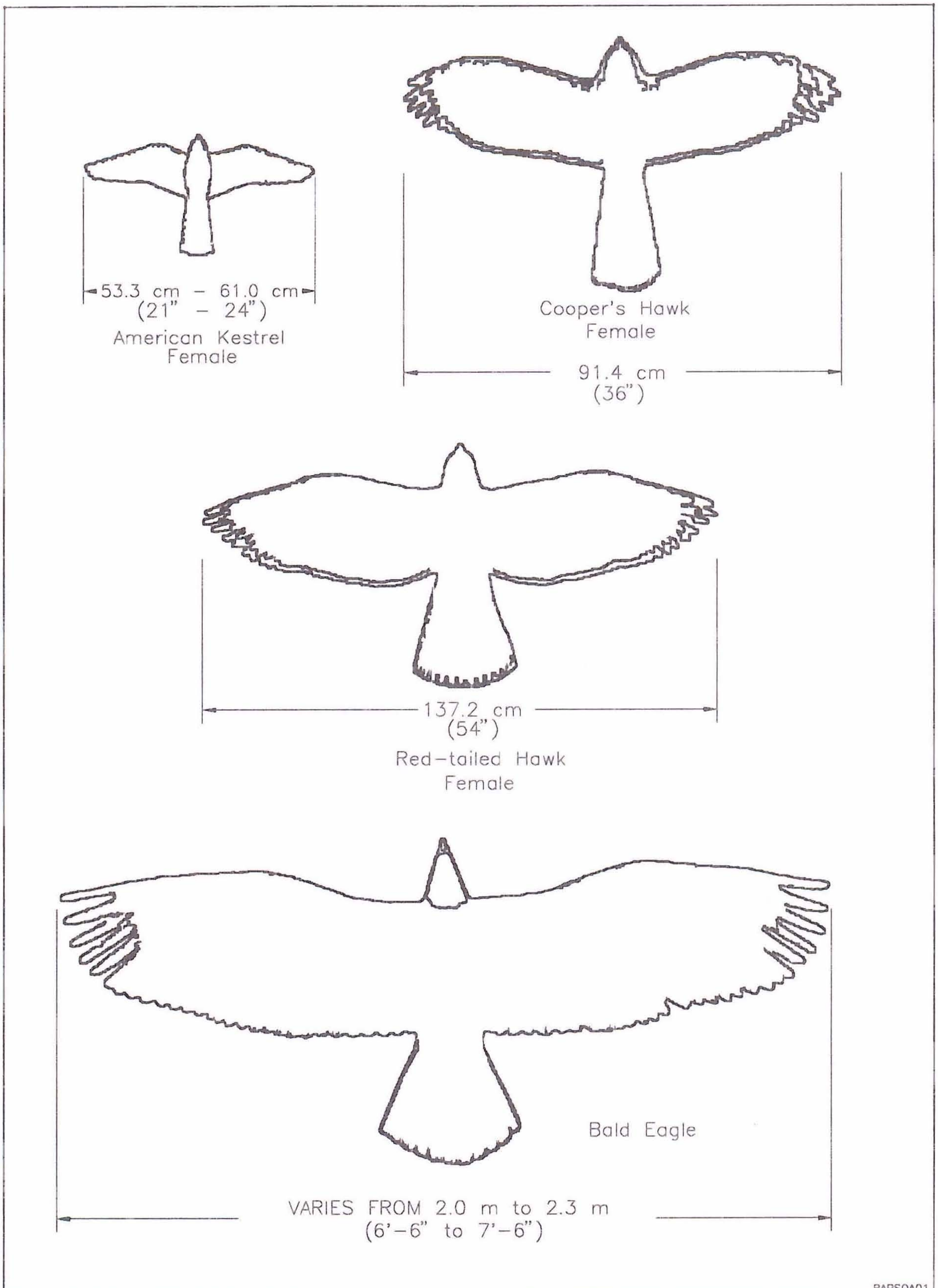


Figure 1. Wingspans of selected birds of prey. (Drawings not to scale.)

As mentioned previously, peregrine falcon electrocutions near North American release sites have occurred on a few occasions (Cade and Dague 1977, Burnham 1982, McDonnell and Levesque 1987). Benson (1981), Harmata (1991), Harness (1996), and Idaho Power Company (unpubl. data) have reported a total of seven electrocution deaths of prairie falcons.

Records of osprey (*Pandion haliaetus*) electrocutions are also surprisingly rare, considering how often the species nests on power poles (see Chapter V). Poole and Agler (1987) reported that less than 4% of 451 banded ospreys recovered between 1972-1984 died of electrocution, in collisions with power lines and TV/radio towers, and in entanglements with fishing nets. Additional electrocution mortalities of osprey have been documented by Dunstan (1967, 1968), Yager (1978), Fulton (1984), Harness (1996), and the Idaho Power Company (unpubl. data) (a total of 28 deaths).

Buteos (large soaring hawks) make up the largest non-eagle group of power-line electrocutions. Combined electrocution mortality of the red-tailed hawk, rough-legged hawk (*Buteo lagopus*), ferruginous hawk (*Buteo regalis*), and Swainson's hawk (*Buteo swainsonii*) has ranged between 8 and 15% of reported electrocutions in a number of studies (e.g., Ansell and Smith 1980, Peacock 1980, Benson 1981, O'Neil 1988). Except for the Swainson's hawk, these species winter extensively in open prairies and shrub-steppe deserts of western North America and commonly perch on power poles and transmission towers. All but the rough-legged hawk also nest in the region. Records of electrocution for southwestern Buteos and related species are rare. Only one record was found for the common black-hawk (Schnell 1980).

In the majority of studies conducted in the western United States, most reported raptor mortalities were eagles (e.g., Olendorff 1972a, Boeker and Nickerson 1975, Ansell and Smith 1980, Peacock 1980, Benson 1981). The relative proportion of bald eagle deaths among all species reported typically has ranged from about 1 to 10%:

- U.S. Fish and Wildl. Serv. (1983) 9.9% (*n*=754)
- Wood et al. (1990) 9.1% (*n*=1,428)
- Boeker (1972) 5.0% (*n*=300)
- Peacock (1980) 4.6% (*n*=133)
- Ansell and Smith (1980) 1.7% (*n*=91)
- Idaho Power Co. (unpubl. data) 1.2% (*n*=620).

Golden eagles are electrocuted more often than any other North American raptor. The proportion of golden eagles electrocuted among all species reported has ranged in a variety of studies from 51-93%:

- Smith and Murphy (1972) 93% (*n*=56)
- Boeker and Nickerson (1975) 90% (*n*=419)

- Olendorff (1972a) 89% (n=19)
- O'Neil (1988) 55% (n=58)
- Idaho Power Co. (unpubl. data) 51% (n=620).

Clearly, electrocution is a major cause of mortality for golden eagles. Of 375 golden eagle mortalities (with known causes) found between 1980 and 1984 along power lines in the western United States, 300 (80%) were caused by electrocution (Phillips 1986). Kochert (1973) reported that 65% of 26 mortalities with known causes in the Snake River Birds of Prey Natural Area in southern Idaho were due to electrocution. Other mortality factors included shooting, impact injuries, and disease. The preponderance of golden eagle deaths in electrocution studies suggests that we can learn a great deal about the biological aspects of electrocution from this one species.

GOLDEN EAGLES AND ELECTROCUTION

SIZE

Golden eagles are very large birds (Figure 2). The maximum wingspan of a female golden eagle is 2.3 meters (m) (7.5 feet [ft.]); that of a male 1.8 m (6 ft.) (Brown and Amadon 1968, Clark and Wheeler 1987). Tails are up to 33.0 cm (13 in.) long, and extend 25.4 cm (10 in.) below the top of a perch.

The fleshy parts of the body that can make direct contact with electric wires include the feet, mouth, beak, and the wrists (flesh end of wings) to which the primary feathers are attached (Figure 2). A perched eagle can reach out 17.8 cm (7 in.) with its beak and touch a wire or grounded crossarm brace at perch level. For a large female, the effective reach from the fleshy tip of one wrist to the tip of the other is 137.2 cm (54 in.): i.e., 91.4 cm (36 in.) less than the total wingspread, including the primary feathers. These distances are important when considering phase-to-phase or phase-to-ground separations of power lines and the susceptibility of eagles to electrocution (see Chapter IV).

DISTRIBUTION AND HABITAT USE

The golden eagle is one of the most widely distributed eagles in the world (Brown and Amadon 1968). The species' success is a result of its adaptability to numerous nesting habitats. In North America, only a few eagles nest in the forested regions of the East, but the West supports thousands of golden eagles (Harlow and Bloom 1989). The species is most common in the shrub-steppe habitats and prairies of the Intermountain West, but also occurs in tundra, desert, and mountainous settings from Alaska to Mexico. A characteristic of many of these landscapes is the lack of natural perches. Not surprisingly, golden eagle mortalities are reported most frequently from western states in the Great Basin or on the Great Plains, where forests and natural perches are lacking (Benson 1981).

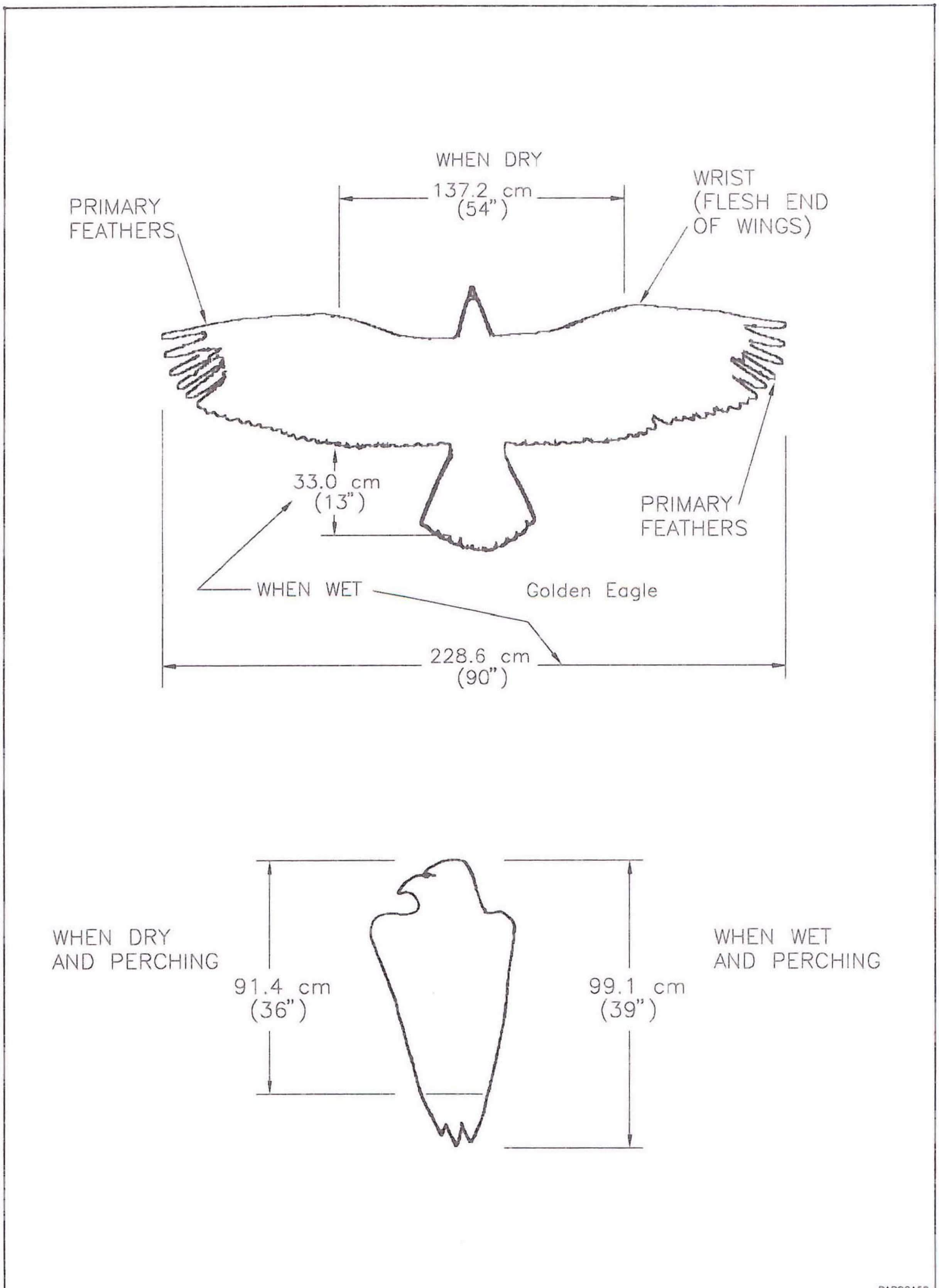


Figure 2. Critical dimensions of the golden eagle.

SEASONAL PATTERNS AND WEATHER EFFECTS

Electrocution risk of golden eagles also varies with season. Many golden eagle mortalities along power lines (nearly 80% in the Benson 1981 study) occur during the winter. Inclement winter weather (particularly rain, snow, and wind) increases the susceptibility of raptors to electrocution: wet feathers increase conductivity, and immatures and subadults are less adept at landing on power poles in the wind. Other factors are also involved: e.g., the attraction of eagles to high seasonal prey concentrations (which may, coincidentally, occur near dangerous lines) and the hunting strategy of "still hunting" from poles, compared to hunting in flight. Adults probably hunt from perches more during the winter than at other times of the year (because energy demands are greater); thus, they are at greater risk of electrocution during this period.

Most eagle electrocutions are caused by simultaneous skin-to-skin, foot-to-skin, and beak-to-skin contacts with two conductors or a conductor and a ground (e.g., groundwires, lightning arrestors, and grounded metal crossarm braces; see Chapter IV and the Glossary). Experiments to determine the conductivity of a live eagle by attaching electrodes to the skin of the wing joints and the toes were conducted by Nelson (1979b, 1980b). Although lethal voltages and currents were not determined, these experiments demonstrated that, at 280 volts and a current of 6.3 milliamperes, the eagle's respiration increased. At 400 to 500 volts and a current range of 9 to 12 milliamperes, the eagle convulsed. Wet feathers burned at 5,000 to 7,000 volts, but there was no measurable current through a dry feather at 70,000 volts. Skin-to-skin contacts were on the order of ten times more dangerous than contacts between a wet eagle and two conductors, and about 100 times more dangerous than contacts between conductors and dry feathers.

Thus, feather-wetting is a critical factor in raptor electrocutions. A dry feather is almost as good an insulator as air, but a wet feather demonstrably increases conductivity. Major conclusions from Nelson (1979b, 1980b) were as follows:

1) For voltages of up to 70,000 volts and with electrodes at least 17.8 cm (7 in.), apart, there is no measurable current flow (no conductivity) through a dry feather.
2) There is little or no possibility of electrocution of dry eagles from wing-tip contacts with two electric conductors.
3) Wet feathers conduct current more readily than dry ones, and become capable of conducting amperages dangerous to eagles starting at about 5,000 volts.
4) The hazard to wet birds is much greater than that to dry ones, and is increased even more because, when wet, the birds lose some flight capability and control.

The amount of current conducted through wet feathers also depended on the concentration of salts and minerals in the water: increased electrolyte content resulted in increased conductivity. Feather-wetting further increased danger because it elicited wing-spreading behavior in the birds studied (Nelson 1979b), presumably to dry the feathers. Thus, if wet eagles roost on distribution poles at night, or fly to poles after leaving other roost sites, electrocution risk is acute.

Finally, the direction of the prevailing wind relative to the crossarm is also an important factor. Poles with crossarms perpendicular to the prevailing winds produced fewer eagle mortalities (Boeker 1972; Nelson and Nelson 1976, 1977). About half as many birds were found below poles with crossarms perpendicular to the wind, as under poles with crossarms diagonal or parallel to the wind (Benson 1981). This difference was probably related to the effect of wind on the ability of immature and subadult eagles to land on poles without touching energized parts.

SUSCEPTIBILITY OF ADULTS VS. IMMATURES

In the following studies, most golden eagle mortalities along power lines were immature or subadult birds:

- Benson (1981) 94.2% (*n*=52)
- Boeker and Nickerson (1975) 90.0% (*n*=419).

The proportion of immature and subadult eagles in the general population, however, is usually below 40%:

- Edwards (1969) 39.4% (*n*=450)
- Boeker and Ray (1971) 33.7% (*n*=799)
- U.S. Bur. Land Manage. (1980) 33.7% (*n*=335)
- Wrakestraw (1973) 29.7% (*n*=6,383).

Susceptibility of immature golden eagles to electrocution involves several factors, but none seems more important than flying and hunting experience. Inexperienced birds may be less adept at landings and take-offs, and thus at greater risk. Inexperience also may affect how immature birds hunt. Immatures generally learn to fly and to hunt from a perch, particularly in flat country, where updrafts are less common. Learning to fly involves frequent short flights from perch to perch. The first attempts to kill involve frequent changes of perches following unsuccessful chases. One immature golden eagle was observed making over 20 unsuccessful hunting sorties after cottontails (*Sylvilagus* spp.) from a distribution line (Benson 1981). Had the line been unsafe for eagles and weather conditions poor, that eagle could easily have been electrocuted.

Hundreds of hours of actual observations and analysis of slow-motion, 16-mm movies made by Morlan Nelson in the early 1970's demonstrated that immature eagles are less adept at maneuvering than adults, especially when landing and taking off from electric distribution lines (Nelson 1979b, 1980b; Nelson and Nelson 1976, 1977). Trained golden eagles were filmed landing on unenergized, mockup power poles of various configurations in both calm and inclement weather. The eagles did not perch on wires (conductors) and seldom perched on pole-top porcelain insulators, which tend to be too small or too smooth and slick for comfortable gripping. Instead, they used the firmer footing of pole tops and crossarms. When an adult eagle approached a three-wire power pole crossarm, for instance, the bird usually came in under the outside wire, swung up between wires with wings folded, and stalled out onto the perch. The landing, when made into a headwind, was skilled and graceful, with very little wing flapping.

Immatures, by contrast, often tried to settle onto a crossarm from above, using outstretched wings to brake their descent. They sometimes approached diagonally, flew to the highest point--perhaps an insulator--and tried to land. The birds often slipped off the insulator or tried in midflight to change to the crossarm, maneuvers accomplished by much wing flapping. The risk of electrocution under these circumstances is clear. Sometimes, immature birds began corrective action at some distance from the poles, particularly when the approach was too swift or at the wrong angle. If they came in parallel to the lines, they often settled down across two conductors or tried to fly up between the conductors. Again, the risk is acute.

During landing, immature birds caught the wires of the dummy poles between their outer primaries deep enough to make skin-to-skin contact near the wrist. Contact also occurred occasionally on downward wing beats during take-offs. On energized lines, touching any two phase wires or a phase and a ground with fleshy parts of the body or with wet feathers can result in electrocution.

HABITAT USE, PREY TYPE, AND PREFERRED POLES OR AREAS

Golden eagles use power poles as hunting perches, a key factor increasing vulnerability to electrocution. Still-hunting conserves energy, provided good prey habitat is within an eagle's view from the perch. Eagles tend to use particular "preferred poles" that apparently facilitate hunting success. These typically provide good elevation above the surrounding terrain, a wide field of vision, and easy take-off (Boeker 1972; Boeker and Nickerson 1975; Nelson and Nelson 1976, 1977; Benson 1981). When the design of preferred poles is not safe for eagles, many electrocutions can occur. Researchers have found up to eight eagle carcasses or skeletons under a single pole (Dickinson 1957; Benton and Dickinson 1966; Edwards 1969; Olendorff 1972a; Nelson and Nelson 1976, 1977).

Benson (1981) confirmed that perch height above the surrounding terrain was important to the frequency of eagle electrocution. Actual height-above-ground of electric distribution poles on which eagles were electrocuted did not differ much from those on which they were not: pole height generally varies only 1.2 to 3.0 m (4 to 10 ft). However, poles that provided the greatest height above the surrounding terrain, e.g., those on bluffs and knolls, had a higher probability of causing electrocutions.

Habitat diversity plays an important part in pole preference. In one study (Pearson 1979), raptors used poles in heterogeneous environments more often than those in homogeneous environments. In fact, increased habitat diversity is only an indirect cause of increased use. A more direct reason is the increase in prey types and density of prey typical of greater habitat diversity. It is reasonable to expect that eagles will spend more time hunting in areas that offer a greater chance of a successful capture. It is also reasonable to expect that one pole will receive no more use than the next in uniform habitats, other factors notwithstanding (Ansell and Smith 1980). The "preferred pole" concept therefore may not apply when addressing an electrocution problem in homogeneous habitats ("preferred areas"). All poles should be considered in terms of proximity to prey.

Choice of prey can also influence electrocution risk. Benson (1981) found highly significant differences both in eagle use and eagle mortalities along electric distribution lines in agricultural versus non-agricultural areas in six western states. More use and many more mortalities occurred in native shrublands, primarily because of variations in rabbit distribution and availability. In particular, more golden eagles were electrocuted where cottontails occurred than where only jack rabbits (*Lepus* spp.) occurred. In jack rabbit habitat, about 14% of poles had raptor carcasses under them, compared to nearly 37% in cottontail habitat. Where both cottontails and jack rabbits were present, about 22% of poles had raptor carcasses under them. The most lethal 25% of the lines studied were in sagebrush-dominated areas where both types of rabbits occurred in large numbers. No correlation was found between rodent population densities and the incidence of raptor electrocutions.

Benson (1981) attributed differences in electrocution risk of adult and immature birds to the fact that aerial hunting (as opposed to still-hunting from a perch) was the principal tactic used by adults to capture for jack rabbits. Catching jack rabbits with any consistency requires experience and tenacity in long, cross-country chases initiated in flight. Adults generally have such experience. Young birds, by contrast, find more success in pouncing on cottontails or other prey from stationary perches such as power poles. Thus, they are more exposed to electrocution risk.

The attraction of eagles to areas of high rabbit populations and associated electrocution risk was also noted by Olendorff (1972a) near the Pawnee National Grassland in Colorado. Kochert (1980) concluded that the incidence of eagle electrocutions in the Snake River Birds of Prey Area in southwestern Idaho was a function of mid-winter eagle density, strongly related in turn to the density of jack rabbits. Jack rabbits in southwestern Idaho occur at highest densities in native shrublands (Smith and Nydegger 1985); accordingly, more eagles are electrocuted in such habitats when power lines are present.

NESTING AND ELECTROCUTION

Several additional factors make raptors susceptible to electrocution. Because many raptor species inhabit shrublands and plains where natural substrates such as trees and cliffs are limited, the birds exploit power poles and transmission towers as nest sites. (Chapter V presents solutions to this potential problem.) Nesting along power lines can place adults and fledglings, which are the same size as adults, at risk. For instance, Benson (1981) found that nearly 46% of red-tailed hawk electrocutions occurred during courtship and nesting. Most of these birds were adults. Benson also noted that nearly 30% of the hawks electrocuted during the late spring and early summer were fledglings. Dawson and Mannon (1994) reported that 41 (37%) of 112 electrocuted Harris' hawks in southern Arizona were birds that had recently fledged. A young Swainson's hawk was found electrocuted in south-central Washington soon after it fledged (Fitzner 1978), and two fledgling great horned owls were found electrocuted near nests in Saskatchewan (Gillard 1977).

Several instances of electrocution of birds carrying prey or nest material have been reported. A dangling prey item can help span the gap between conductors or between a conductor and a groundwire, electrocuting a bird returning to the nest (Switzer 1977, Fitzner 1978). A young great horned owl was found electrocuted, with a freshly killed snowshoe hare (*Lepus americanus*) lying nearby (Gillard 1977). Similar incidents were noted by Brady (1969) and Hardy (1970). Two adult red-tailed hawks were electrocuted at separate nests in Wyoming, possibly while carrying nesting material (Benson 1981), and ospreys have been electrocuted when carrying seaweed (New York Times 1951) and barbed wire (Electric Meter 1953) to their nests. Nests and nestlings can also be destroyed if nesting material lies across conductors, resulting in a flashover and fire (Vanderburgh 1993).

During the nesting period, birds often engage in courtship and territorial defense. During such displays, raptors often link together talon to talon, greatly increasing their effective wingspans. If these activities take place near a power line, the birds may be electrocuted. For example, a pair of electrocuted eagles was found below a pole, the talons of each bird imbedded in the breast of the other (Benson 1981). Although this may have been caused by convulsive action at the time of electrocution, it is likely that a territorial encounter or an attempted food theft initiated the incident.

In summary, golden eagles and other raptors are opportunists and seek prey concentrations as well as perches from which to hunt. Their susceptibility to electrocution on improperly designed power lines is correspondingly high. This biological susceptibility to electrocution, coupled with overall size, maximizes the danger, particularly on those poles with crossarms parallel to the prevailing wind, with a broad view of surrounding habitat, during inclement weather. Electrocution risk also occurs during nesting activities and from the nesting materials themselves, when they come into contact with energized surfaces.

CHAPTER IV

SUGGESTED PRACTICES: POWER-LINE DESIGN AND RAPTOR SAFETY

This chapter provides the reader with the background necessary to understand raptor electrocution from the engineering perspective: the construction and design of power facilities. It suggests alternative ways to retrofit existing facilities and to design new or rebuilt "raptor-safe" facilities to minimize or eliminate raptor electrocution.

As communities grow, the demand for electric energy increases. More lines must be built to bring power to those populated areas. The more miles of line, the greater the potential for interaction with raptors.

Biologists and planners must have a basic understanding of power systems, power-line designs, and related terminology to identify and implement solutions to the raptor electrocution problem. The sections below provide some necessary background about North American power lines, their designs, and the characteristics that make them raptor-hazardous or raptor-safe. A glossary of terms is also provided in Appendix A.

TERMINOLOGY

DISTINCTIONS BETWEEN TRANSMISSION AND DISTRIBUTION LINES

Power lines are rated and categorized by the voltage levels at which they are energized. Industry standards use kilovolt (kV) for each 1000 volts. Lines of greater than 69,000 volts (69-kV) are designed to transmit large blocks of energy long distances to load centers for distribution to various customers. In this report, these are called *transmission lines*. However, the distinction between transmission and distribution lines varies from company to company and country to country. In the United States, voltages between 69-kV and 115-kV are practically nonexistent, while in South Africa, transmission voltages of 88-kV are frequently used.

The *voltage rating* of a transmission line depends on the utility's existing transmission system voltages, interconnections with other utilities, potential delivery points, and the amount of power that must be transmitted to meet a specific load requirement. As voltages increase, the amount of power that can be transmitted increases rapidly. Various line design parameters
(such as conductor size and configuration, spacing, and the number of conductors per phase ["bundling" of conductors]) allow for different levels of power capacity.

Lines of 69 kV or less are used to serve residential customers, offices, industrial complexes, and agricultural developments. In this report, they are referred to as *distribution lines*. Once the lines reach the residential or industrial complexes, voltage is reduced to 115 volts, 208 volts, 220 volts, and 480 volts.

SINGLE- AND THREE-PHASE SYSTEMS

The term "phase" technically describes the mathematical relationship between the electrical characteristics of different electrical systems. In electrical engineering, the term "phase" has several significant meanings; however, for this report, it is used to mean an energized electrical conductor.

Alternating current (AC) is used for the distribution and transmission of electrical energy because it can be generated and transformed at significantly lower costs than if direct current (DC) were used. Although there are some high-voltage DC lines in existence, the termination and transformation equipment needed is massive and very expensive. This report, therefore, focuses exclusively on AC systems.

Single-phase systems are used for distribution lines only. They are built with two conductors, one energized (phase) and one neutral (grounded) conductor. Single-phase systems offer about one-third the capacity of three-phase systems, and are not adaptable for general power purposes because single-phase motors have design and manufacturing limitations that keep the motors at 10 horsepower or less.

Three-phase systems are used for both distribution and transmission lines. Transmission lines are always three-phase systems; they have three energized conductors (more if bundled), and may have one or two overhead groundwires for lightning protection. Distribution lines can have three or four conductors, with three phases only or three phases and one neutral (grounded) conductor. The neutral conductor can be placed on the top of the pole and used for lightning protection, or it can be placed below the three phases for the neutral connections needed to complete the electrical configuration.

All transmission and distribution lines and the associated electrical equipment must have certain protection from people and the elements. The terms used for protective equipment are similar to those used for equipment in the normal residence today (e.g., switches, lightning arresters, and circuit breakers). See Appendix A (Glossary) for more information.

RAPTOR ELECTROCUTIONS AND POWER-LINE DESIGN

Raptor electrocution by power lines is a combination of factors: biological (Chapter III) and electrical/design, primarily as a consequence of the physical spacing of components. With an understanding of how power lines electrocute birds, the utility can select designs that are raptor-safe, and avoid or mitigate those lines that are hazardous. Voltage, conductor spacing, and grounding practices are a particular concern; but so too are the more general constraints of the electric power industry, such as public safety, governed throughout the United States by the National Electrical Safety Code (NESC) (1993). The NESC sets forth in detail the minimum clearances for various voltage levels; safety factors for design of structures, conductors, and other power-line equipment; and safety factors to use in designing for maximum weather loading conditions (i.e., ice and wind loading) that could be experienced in certain areas around the United States. State and local governments also may have codes that govern power-line design and construction. Continued reference to NESC will imply compliance with such applicable safety and environmental regulations.

Two design factors govern the relative safety of a line for raptors:

1) phase conductors separated by less than the wingspread (flesh-to-flesh distance) of the bird that is landing, perching, or taking off; and

2) a distance between grounded hardware (e.g., groundwires, metal braces, etc.) and an energized conductor (phase) that is less than the wingspread or the distance from the tip of the bill to the tip of the tail.

A bird is electrocuted when it contacts two energized phases at the same time, or when it simultaneously contacts grounded hardware and an energized conductor.

VOLTAGE

Most lines that electrocute raptors are energized at voltage levels between 1 kV and 69 kV. Benson (1981) found no significant difference in the number of raptor mortalities along lines carrying voltages in the lower portion of this range (12 to 23 kV) compared with the higher portion (34 to 69 kV). In South Africa, for example, Lawson and Wyndham (1993) found the following:

- 80.4% of recorded events were electrocutions on 11-kV through 400-kV lines.
- 82.6% of those events occurred on the 11-kV through 22-kV lines.
- 17.4% of those events were recorded on the 66-kV to 400-kV lines.

Total miles of line in existence at various kV ratings were not reported. Only in isolated cases have transmission lines (greater than 69-kV) electrocuted raptors (Electricity Supply Commission of South Africa 1980; E. Colson, Colson and Associates, pers. comm.). A review of 558 Idaho Power Company electrocution records from 1972 - 1991 indicated only one incident, occurring on a 138-kV transmission line. The likelihood of electrocution is more closely related to line configuration than to voltage rating.

Very low voltage lines are not known to electrocute raptors. Principal examples of such lines are the numerous 480-volt lines that generally supply farming and oil industry equipment in Wyoming and other western states. The 480-volt lines are usually constructed below the higher-voltage distribution lines (underbuilt), and conductors are generally insulated with a covering that prevents contact with two bare conductors at the same time. No electrocuted birds have been found under these lines, and Nelson (1979b, 1980b) demonstrated the non-lethal nature of such voltages during his conductivity studies.

SPACING

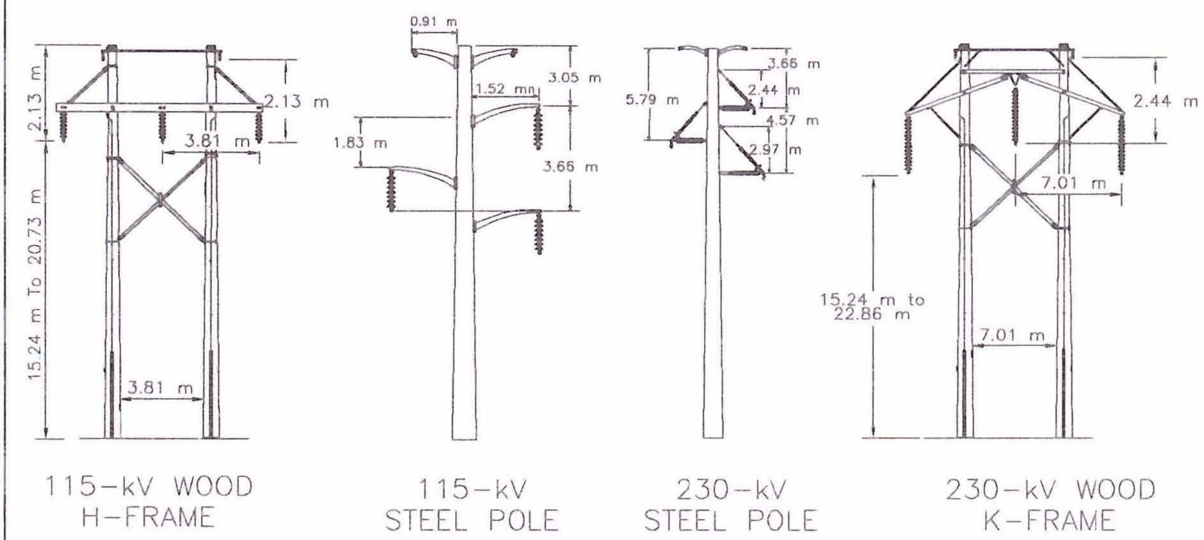
The voltage rating of a power line dictates conductor spacing and the clearance above ground. In accordance with the NESC, both the distance between conductors and the distance that the wires are hung above ground must be increased as voltages increase. With their lower voltages, distribution lines will therefore have shorter (and potentially more hazardous) distances between conductors and above ground than will transmission lines.

Transmission conductors are generally spaced 2.1 to 9.1 m (7 to 30 ft.) apart, and are supported on poles or towers (structures) that range from 15.2 m to 36.6 m (50 ft. to 120 ft.) in height (Figure 3). The conductors will generally be kept at least 6.4 m (21 ft.) above ground at the lowest point of sag. Where a circuit is one three-phase system, one tower can accommodate more than one circuit (see the double-circuit tower in Figure 3).

Distribution line conductors are generally spaced 0.6 to 1.8 m (2 to 6 ft.) apart, and are supported on 9.1- to 19.8-m (30- to 65-ft.) poles so that the conductors will be 7.6 to 10.7 m (25 to 35 ft.) above ground. As with transmission lines, distribution poles can accommodate more than one circuit for both single-phase and three-phase configurations (see Figures 4A and 4B). Because distribution spacings are less and are potentially more hazardous to raptors, the addition of wires, jumper wires, transformers, switches, grounding and other protective devices increases the potential for electrocution.

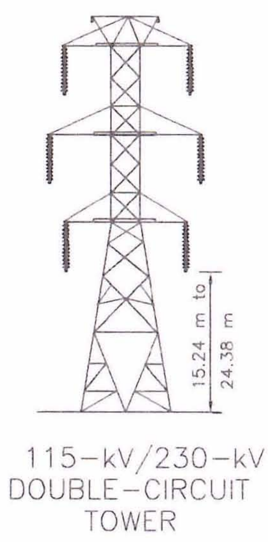
BONDING AND GROUNDING

Bonding is a practice of physically connecting all bolts, washers, insulator attachment connections, braces, and other hardware to a groundwire. The bonding drains off the leakage currents that are always present over insulators. Bonding is particularly necessary in contaminated areas (industrial or coastal cities with salt in the air) where excessive leakage currents cause burning around bolts from moisture inherent in the center of the poles. Pole groundwires (often referred to as downwires) are normally installed at each pole for worker and public safety, as well as to drain off leakage currents and static charges that are wind- and



DIMENSION CONVERSION

METRIC		ENGLISH
0.91 m	=	3'
1.52 m	=	5'
1.83 m	=	6'
2.13 m	=	7'
2.44 m	=	8'
2.97 m	=	9'-9"
3.05 m	=	10'
3.66 m	=	12'
3.81 m	=	12-6'
4.57 m	=	15'
5.79 m	=	19'
7.01 m	=	23'
7.92 m	=	26'
9.75 m	=	32'
10.36 m	=	34'
15.24 m	=	50'
20.73 m	=	68'
22.86 m	=	75'
24.38 m	=	80'
25.91 m	=	85'



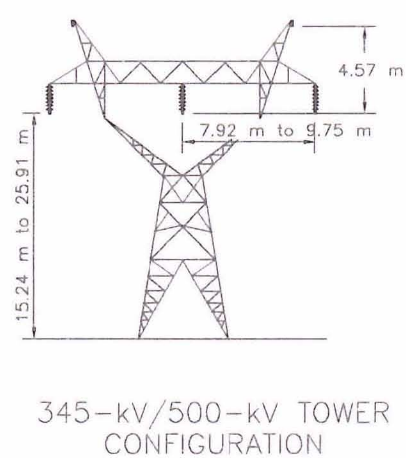


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Figure 3. Examples of high-voltage transmission structures. Dimensions will vary with utility's specifications.

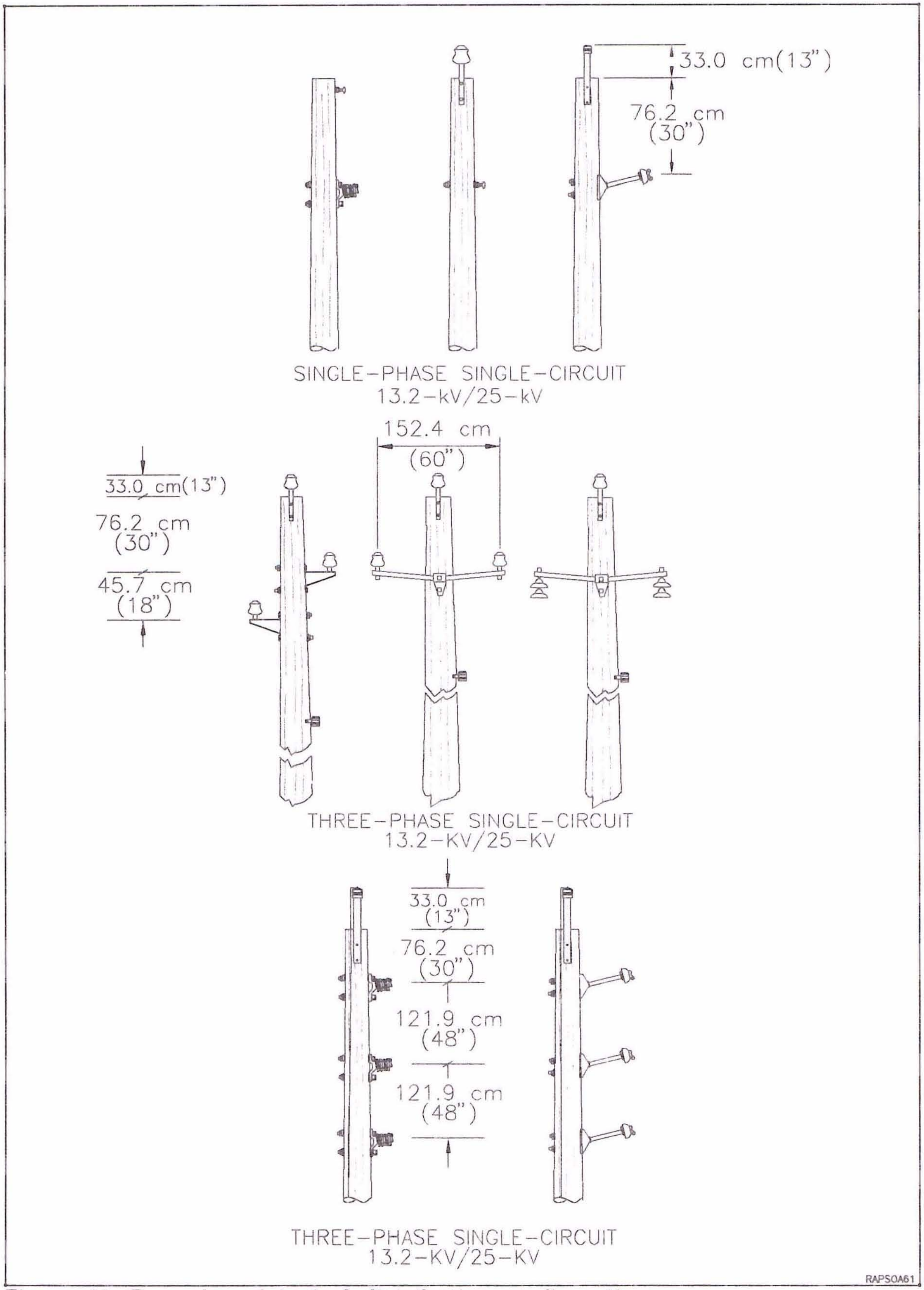

Figure 4A. Examples of typical distribution configurations.

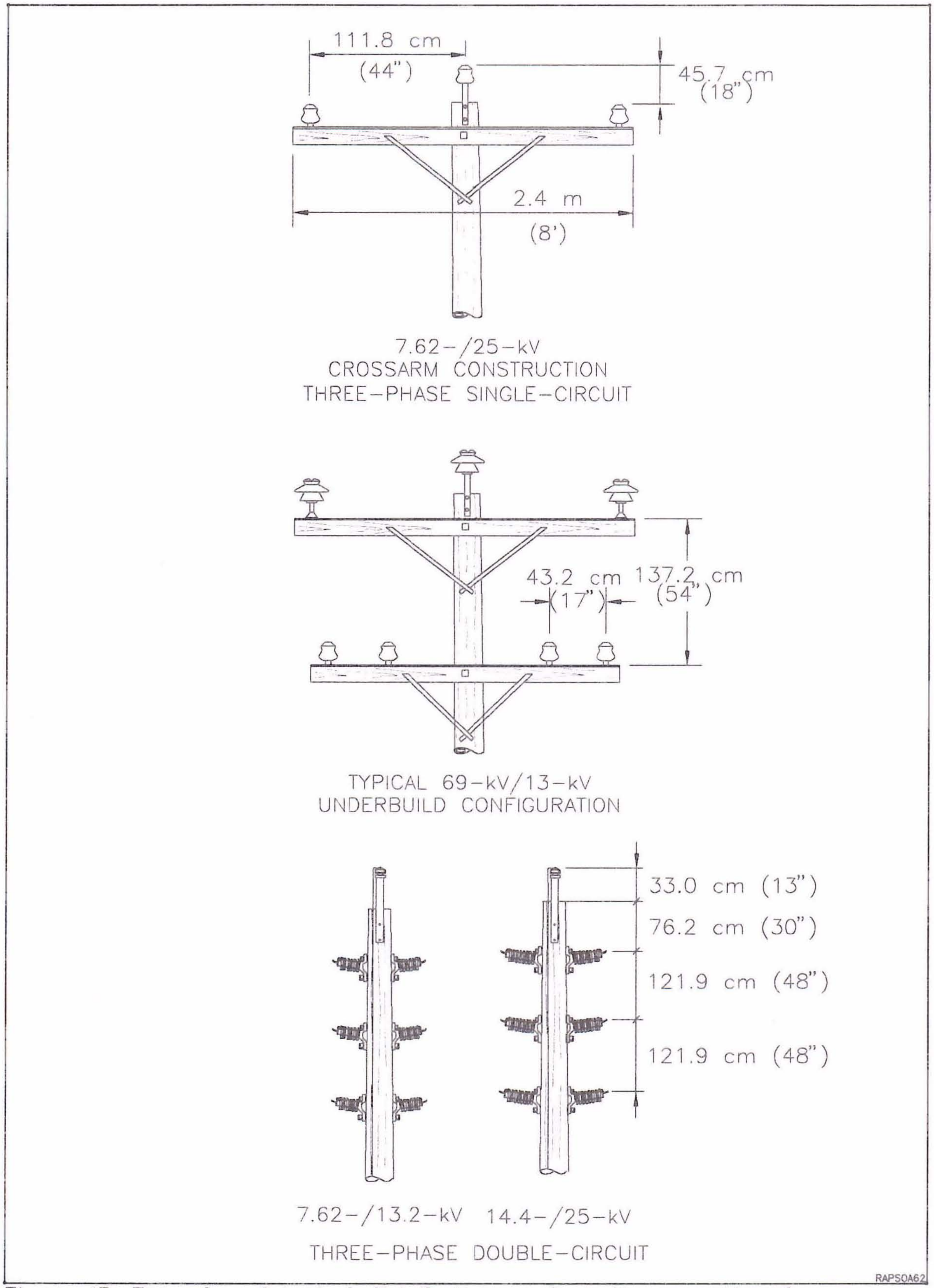

Figure 4B. Examples of typical distribution configurations, continued.

weather-induced on conductors. For raptors, however, bonding provides another ground source that can lead to electrocution.

SPECIFIC DESIGN PROBLEMS

SINGLE-PHASE LINES

In the early 1970's, most electrocuted eagles were found along two general types of pole lines: single-phase or three-phase (Olendorff et al. 1981). Figure 5 shows the first type, a single-phase line. (Note that in this and subsequent figures, *ground wires* are shown in green, and *energized wires* in red.) With this configuration, the tail feathers of an eagle perching on the pole top could touch the groundwire or grounded insulator pin, while the eagle's breast or other body parts contact the phase conductor. Either tail feathers or feet could contact the grounded insulator pin, and the breast the phase conductor. An eagle's tail feathers may reach more than 25.4 cm (10 in.) below its perch, spanning the distance. The design in Figure 5 killed 17 eagles in northeastern Colorado (Olendorff 1972a).

Figure 6 shows another single-phase power line, where the overhead groundwire was mounted on top of the pole, while the energized conductor was supported on a 121.9-cm (48-in.) crossarm, 61.0 cm (24 in.) below the top of the pole. When the raptor tried to perch on the conductor end of the crossarm, the distance between the phase conductor and the ground was less than the wingspread, and the bird was electrocuted. Seventeen dead eagles were also found below such a configuration along a 24-km (15-mi.) stretch of distribution line in central Wyoming in 1992 (PacifiCorp, unpubl. data). In both designs, phase-to-ground contact caused electrocutions.

THREE-PHASE LINES

The second hazardous design was a single-pole three-phase configuration (Figure 7). Crossarms of 1.8 or 2.4 m (6 or 8 ft.) are typically used for this configuration. They provide excellent perching opportunities on the crossarm between phases, but the phase spacing is insufficient (91.4 to 121.9 cm, or 36 to 48 in.) to prevent electrocution. Utility use of steel crossarm braces (grounded to prevent pole fires resulting from insulator leakage currents) increased hazards of electrocution. The practice resulted in a reduced ground-to-conductor separation. Although the REA specifications were changed in 1972 to increase conductor separation (REA Bulletin 61-10; see Appendix B), this design remains common today on poles constructed before 1972. As seen in Figure 7, the center phase is supported either with a pin attached to the pole top or on a pin next to the pole. In the latter case, the phases are closer together, and the hazard to raptors increases. Three-phase lines proportionately kill more eagles than other raptor species (Harness 1996; PacifiCorp, Idaho Power Co., unpubl. data).

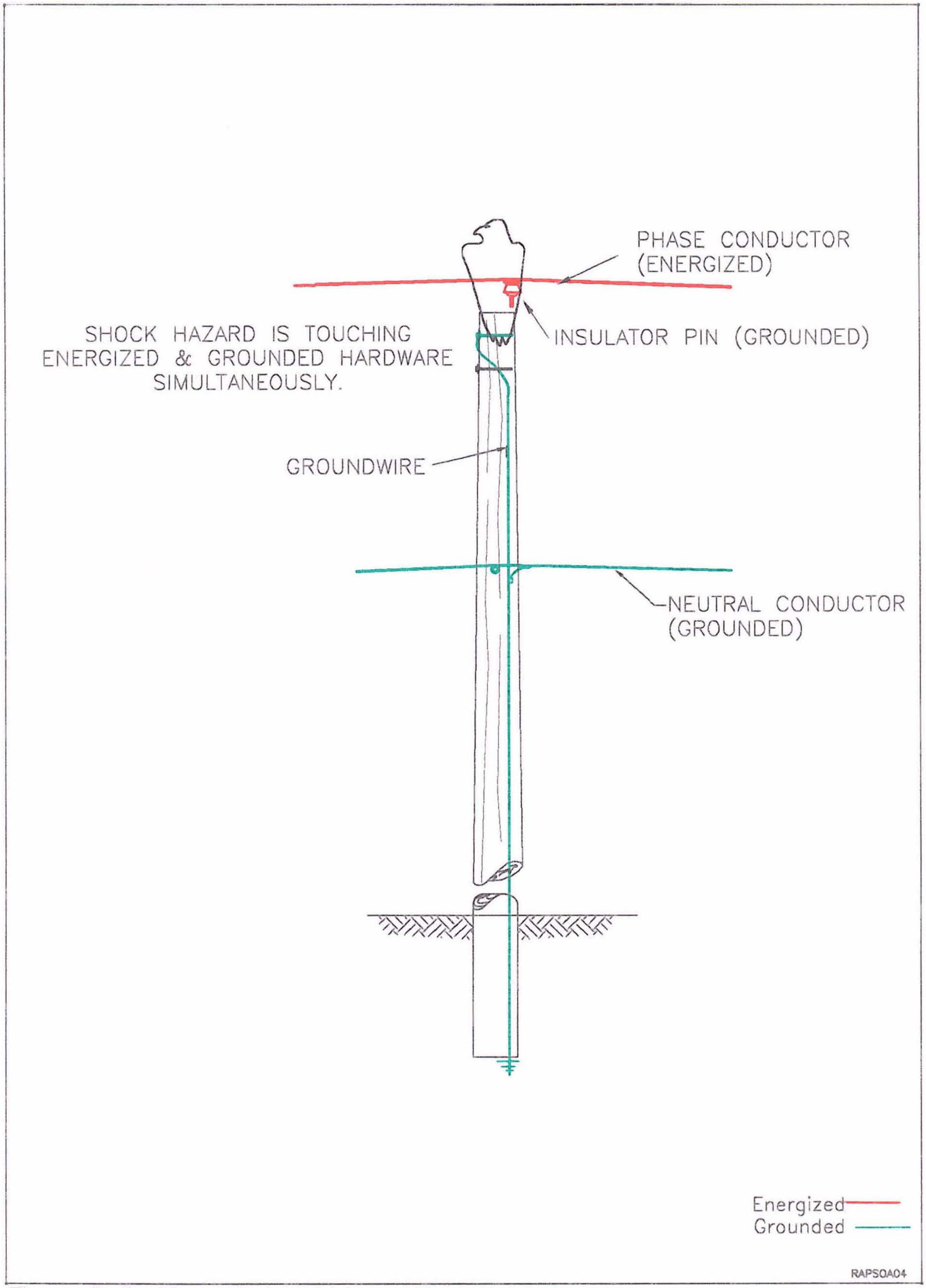

Figure 5. Problem single-phase configuration.
(Refer to Figure 17 for recommended solution.)

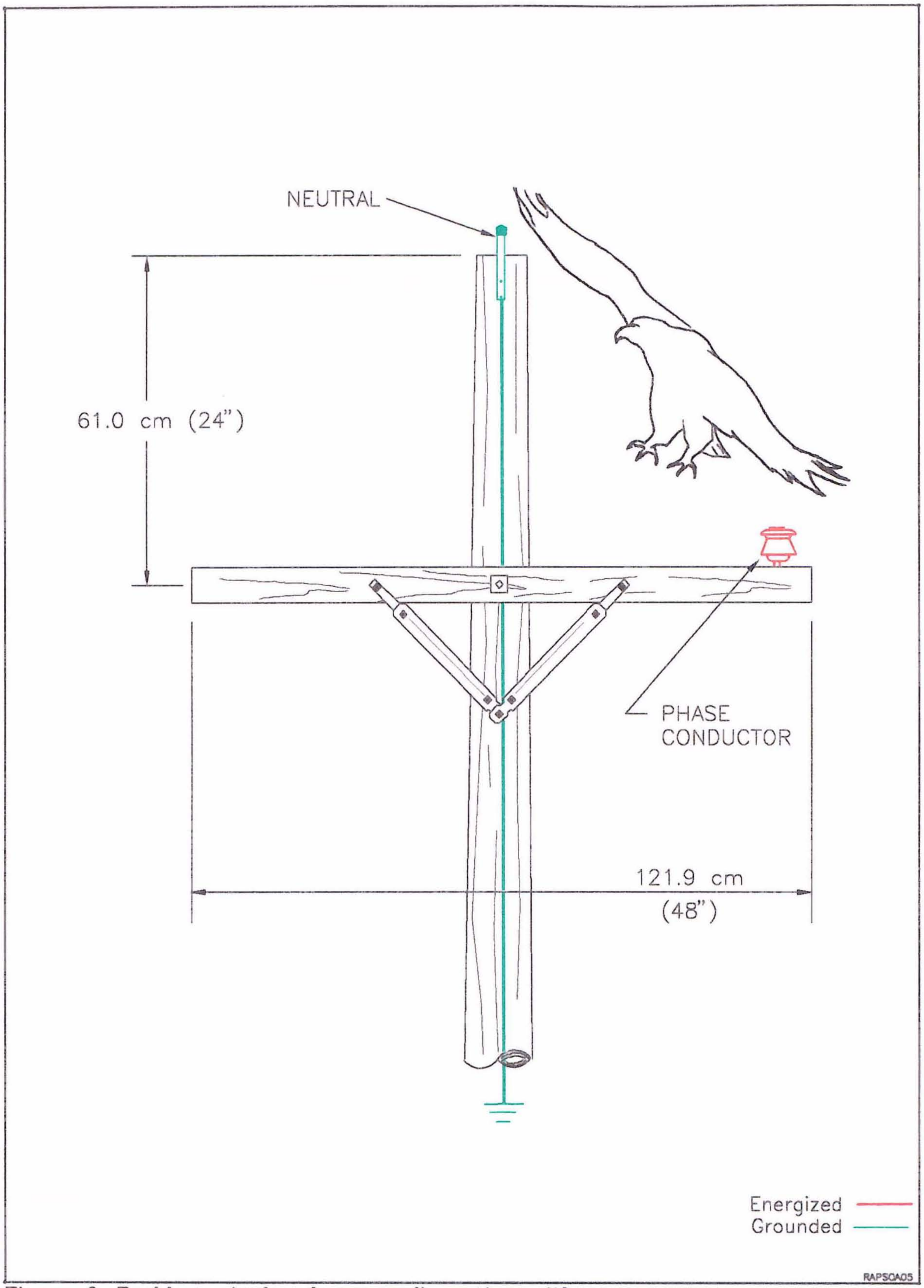

Figure 6. Problem single-phase configuration with crossarm.
(Refer to Figure 18 for recommended solution.)

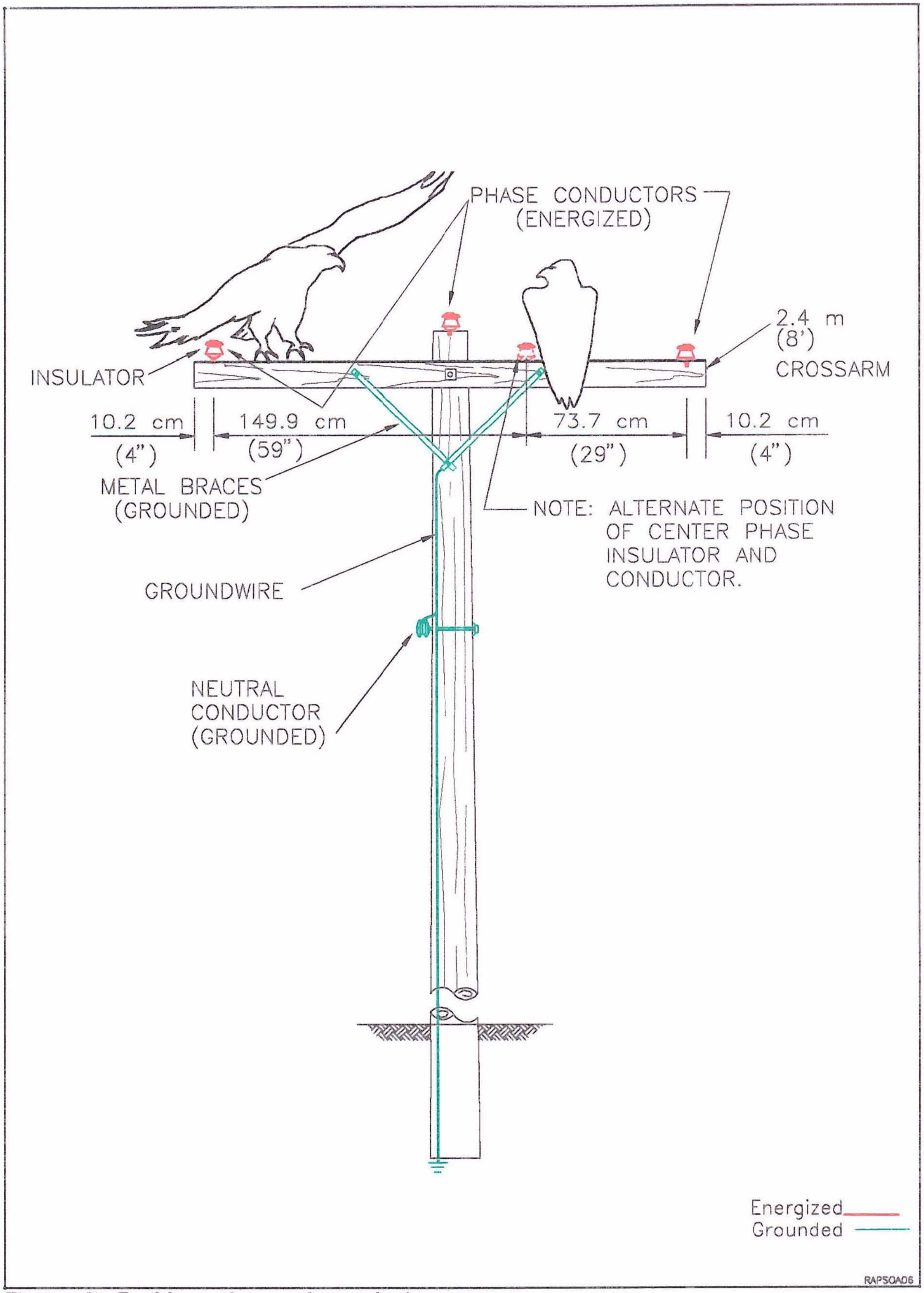

Figure 7. Problem three-phase design.
(Refer to Figures 19, 20, 21, 22, 23, & 34 for recommended solutions.)

Other three-phase designs have also been found hazardous. The three-phase design shown in Figure 8 is generally safe for raptor perching (Olendorff et al. 1981). However, recent field observations (PacifiCorp, unpubl. data) have indicated that larger raptors may be electrocuted when flying in to perch on the short fiberglass arms that support the phase conductors.

Ferrer et al. (1991), in a study in Doñana National Park in southwestern Spain, estimated that more than 400 raptors were electrocuted each year along a section of 16-kV line. The most hazardous configuration was a steel crossarm structure with the jumper wire supported on top of the arm, thus exposing the raptors to a lethal phase-to-ground condition (Figure 9).

Figure 10 shows a three-phase design with a steel bayonet added as a lightning rod. This rod is grounded, but does not support an overhead groundwire between poles. Many raptors were electrocuted (phase-to-ground) when they attempted to land or perch on the crossarms. In one year, 69 raptor carcasses were recovered from a line of this configuration in southern Idaho (Idaho Power Co., unpubl. data).

CORNER POLES

Poles designed to accommodate directional changes in power lines (Figure 11) create hazards for perching raptors. On such poles, jumper wires are normally required to complete electrical connections, and the 106.7-cm (42-in.) or less spacing between conductors is insufficient to prevent electrocution. Grounded metal crossarm braces, guying attachments, and possible bonding wires also add to electrocution hazards.

HORIZONTAL POST DESIGN

This armless configuration is commonly used for 44-kV and 69-kV power lines (Figure 12). Conductors are mounted on horizontal post insulators that are usually 50.8 to 68.7 cm (20 to 27 in.) long. In utility service areas subject to high lightning levels (isokeraunic levels, or lightning storm days), reliability of service is jeopardized. If lightning protection is justified, the power line must be designed with proper grounding and overhead groundwire protection. It is common practice to bond the bases of the post insulators with the groundwire. A raptor perching on the insulator will be electrocuted when it comes in contact with the energized conductor and either the grounded insulator base or the bonding groundwire. From 1991 through 1993, more than 30 golden eagles were electrocuted along approximately 32 km (20 mi.) of this type of line in central Wyoming (PacifiCorp, unpubl. data).

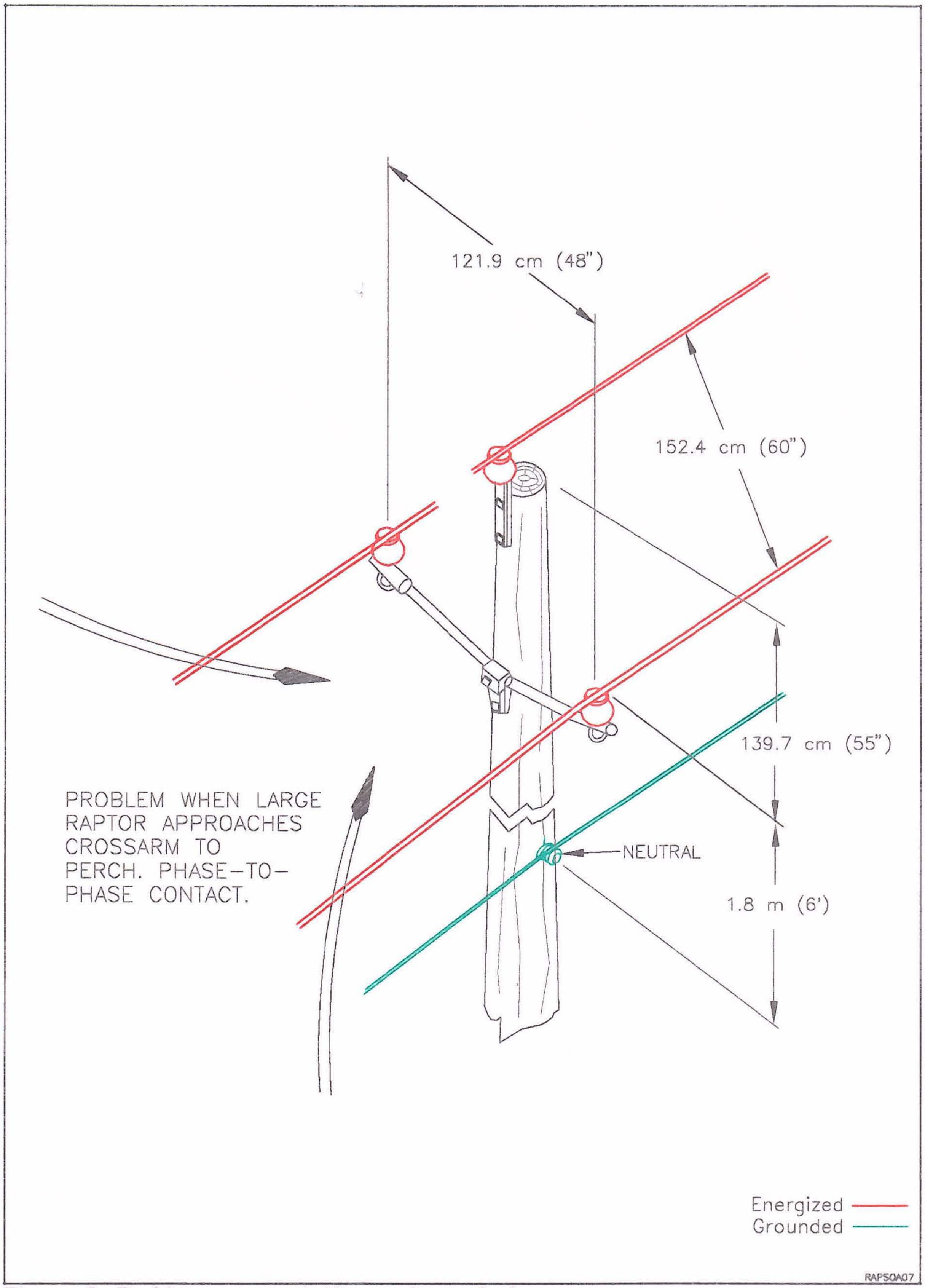

Figure 8. Problem compact three-phase design.
(Refer to Figures 33 & 34 for recommended increase in phase spacing.)

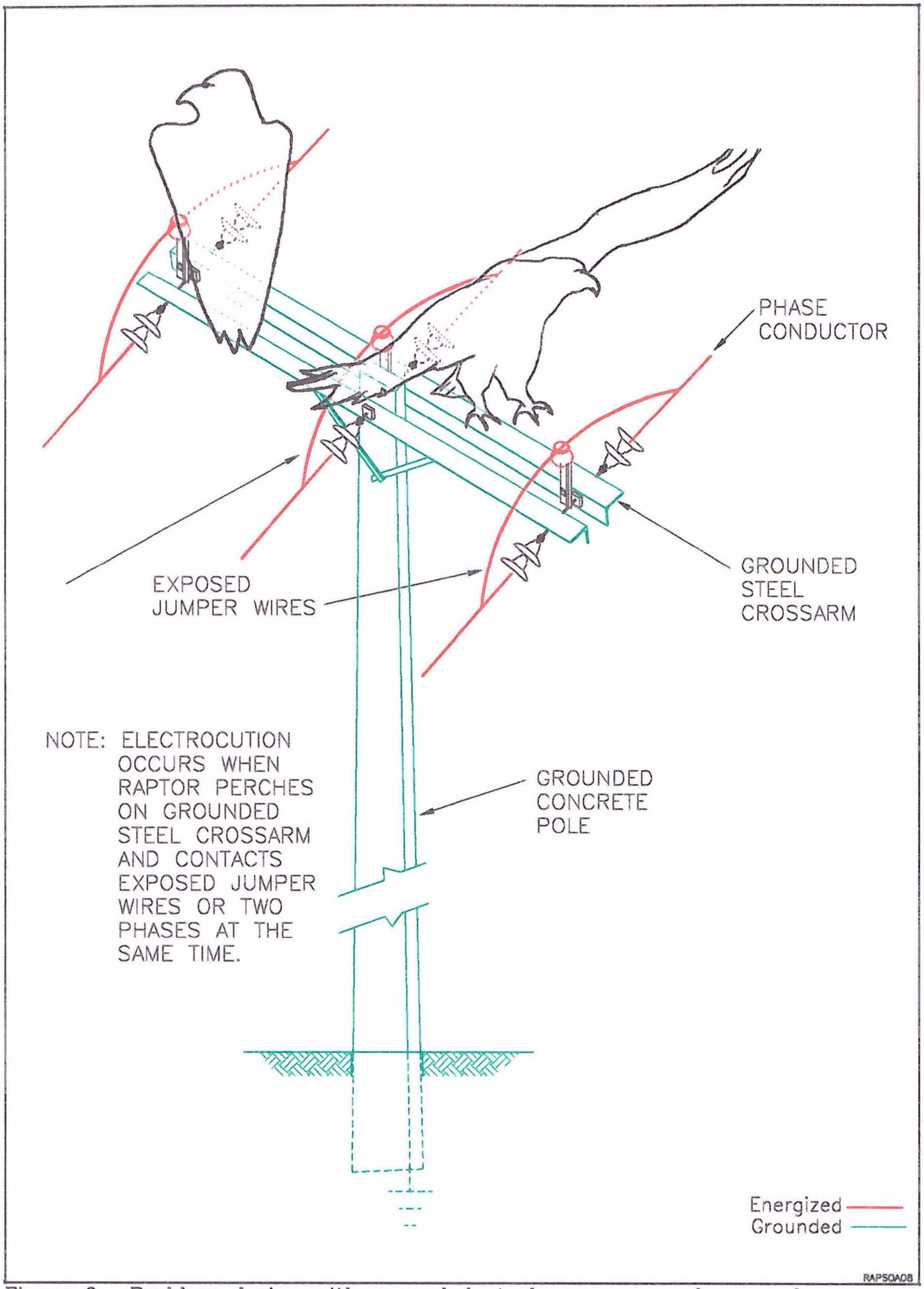

Figure 9. Problem design with grounded steel crossarm and exposed jumper wires used in Spain (see Ferrer et al. 1991).
(Refer to Figure 25 for recommended solution.)

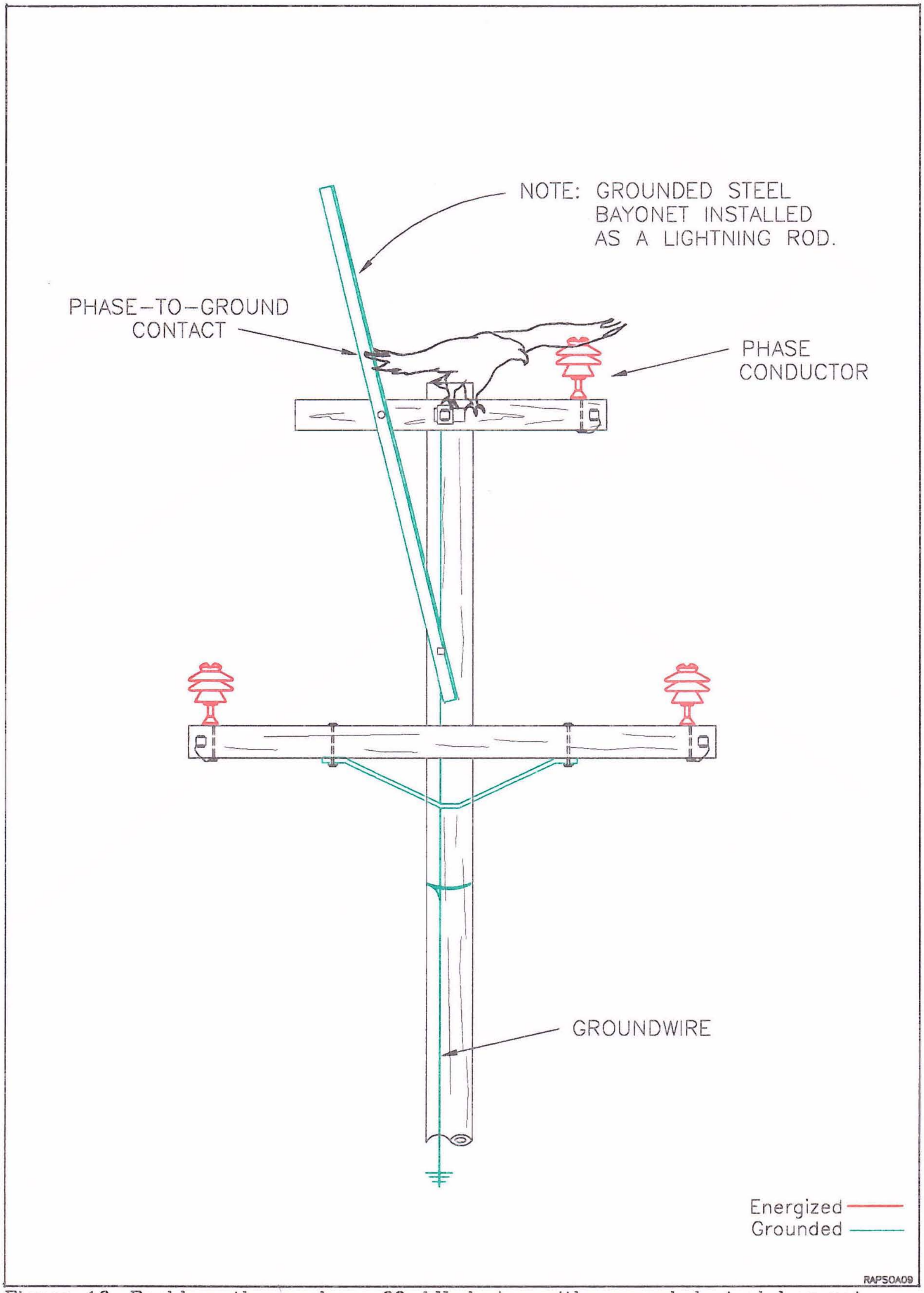

Figure 10. Problem three-phase 69-kV design with grounded steel bayonet. (Refer to Figure 24 for recommended solution.)

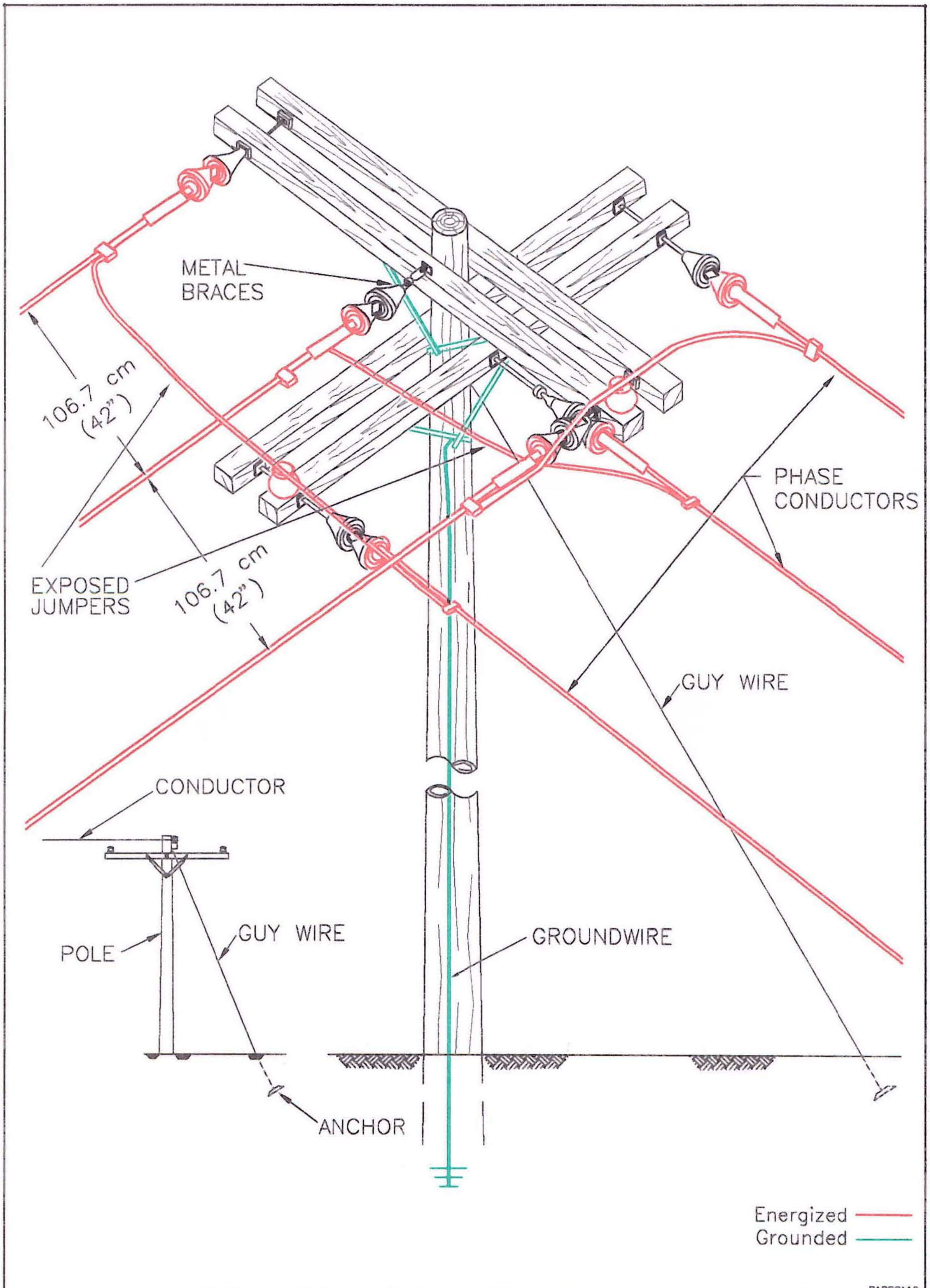

Figure 11. Problem three-phase distribution corner configuration. (Refer to Figures 26, 35, & 36 for recommended solutions.)

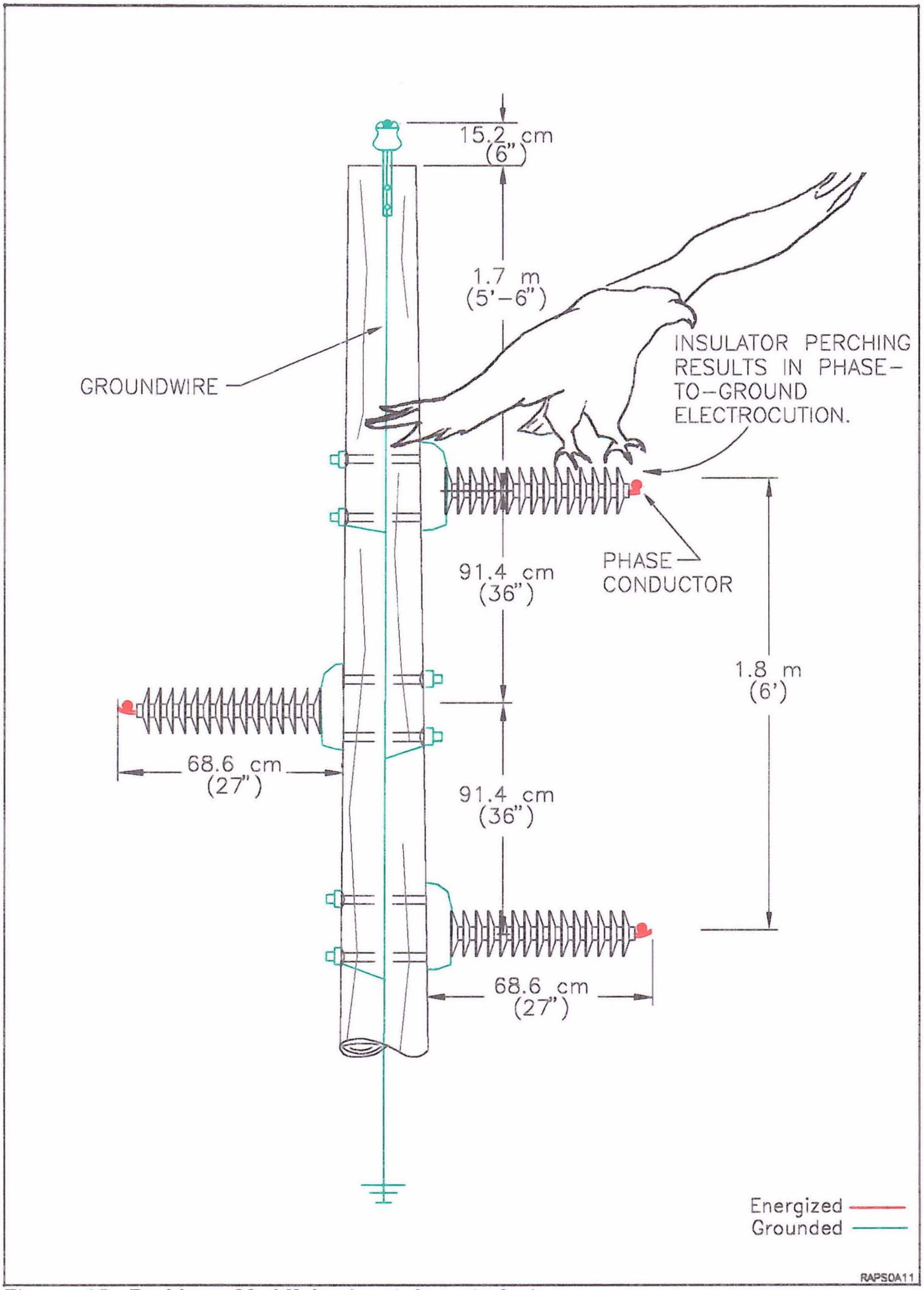

Figure 12. Problem 69-kV horizontal post design.
(Refer to Figure 27 for recommended solutions.)

WISHBONE CONFIGURATION

The wishbone configuration (Figure 13) is commonly used for 34-kV to 69-kV distribution lines. The distance from the top phase to the lower arm can be less than 91.4 cm (36 in.), and presents an electrocution hazard when perching raptors touch their heads to the energized conductor while their feet are in contact with bonding (grounded) hardware. Two conductors on one side of an underbuilt circuit may further increase the hazards of phase-to-phase contact for perching raptors.

PROBLEM TRANSMISSION DESIGNS

Although transmission lines rarely electrocute raptors, there are a few exceptions. Figure 14 illustrates a "kite" design (the metal frame used to support the conductors is shaped like a kite) used in South Africa. This design has killed Cape vultures because of insufficient clearance between the groundwire on the crossarm and the center phase (Electricity Supply Commission of South Africa 1980).

Two other cases of raptor deaths have occurred on double-circuit transmission tower designs with insufficient clearance for perching raptors from the grounded center crossarm brace to the top phase (E. Colson, Colson and Associates, pers. comm.). This configuration is also shown in Figure 14.

TRANSFORMERS AND OTHER EQUIPMENT

Poles with transformers, jumper wires, and other protective equipment (Figure 15) require special consideration because they are responsible for a disproportionate number of electrocutions. The wires, grounded hardware, switches, and lightning arresters on such poles are spaced closely together and create hazards for perching raptors. Lightning arresters are frequently used in conjunction with transformers for protection against lightning strikes. Fused cutouts are switches with fuses that burn out when current ratings are exceeded.

If the line is located in an area of high lightning activity, an overhead groundwire is required. All electrical equipment such as transformers, switches, lightning arresters, and so on must have sufficient grounding to protect the equipment from damage. Protective equipment is installed at all substations and on distribution lines to assure compliance with NESC requirements, and to protect all power system components (as well as the general public). Sufficient grounding usually reduces the spacing of phase and groundwires and other grounded metal hardware or equipment. When raptors try to perch or land on this equipment, and phase-to-ground or phase-to-phase contact is made, they are electrocuted. Harness (1996) conducted a review of raptor electrocutions of REA utilities in four states between 1986 and 1995. Fifty-seven percent of confirmed electrocutions (n=240) were associated with transformers, while only 13-24% of the total poles in these areas were transformer poles. Less than 21% of these transformers were three-phase banks (see Figure 15), but they accounted for 50% of all

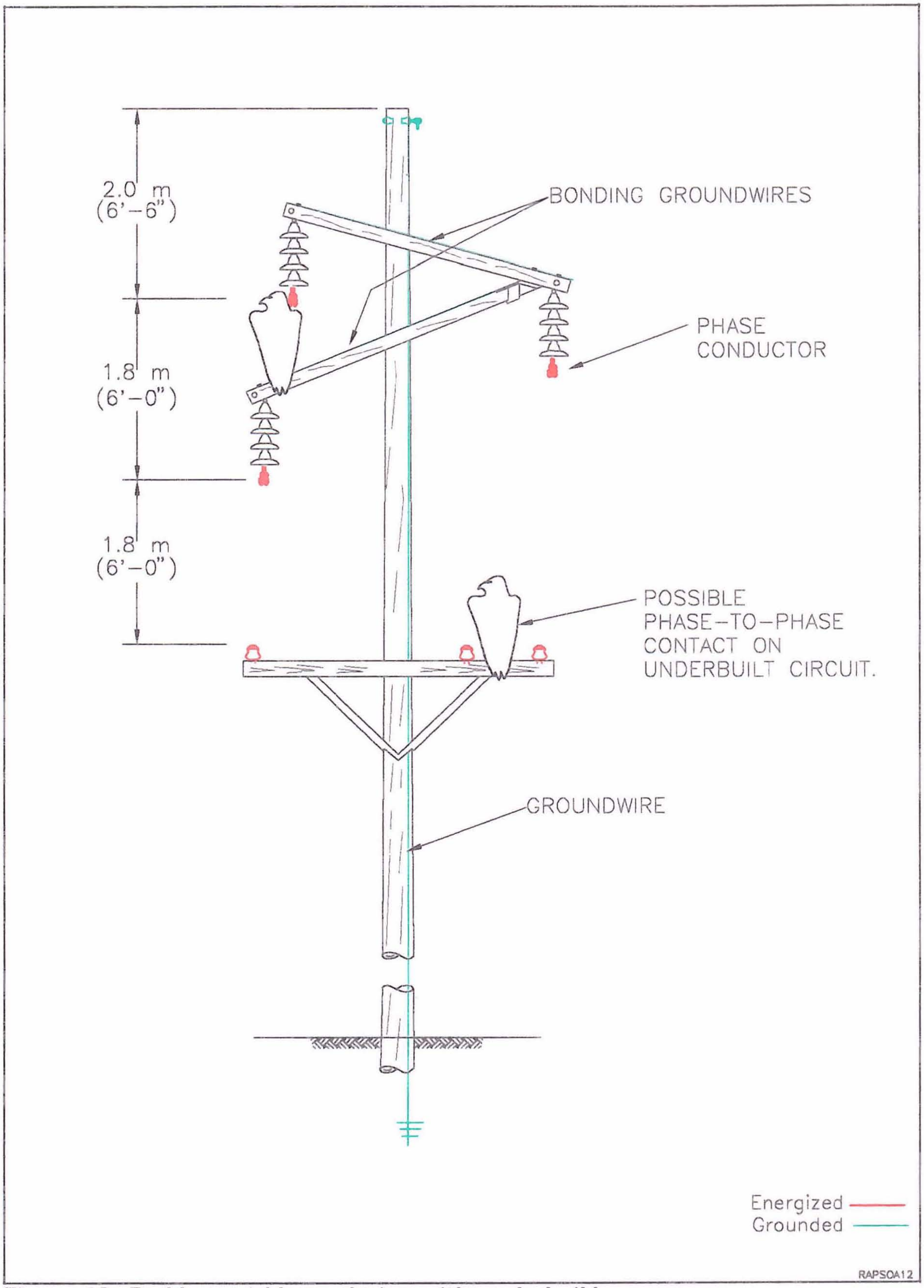

Figure 13. Problem wishbone design with underbuild.
(Refer to Figure 28 for recommended solution.)

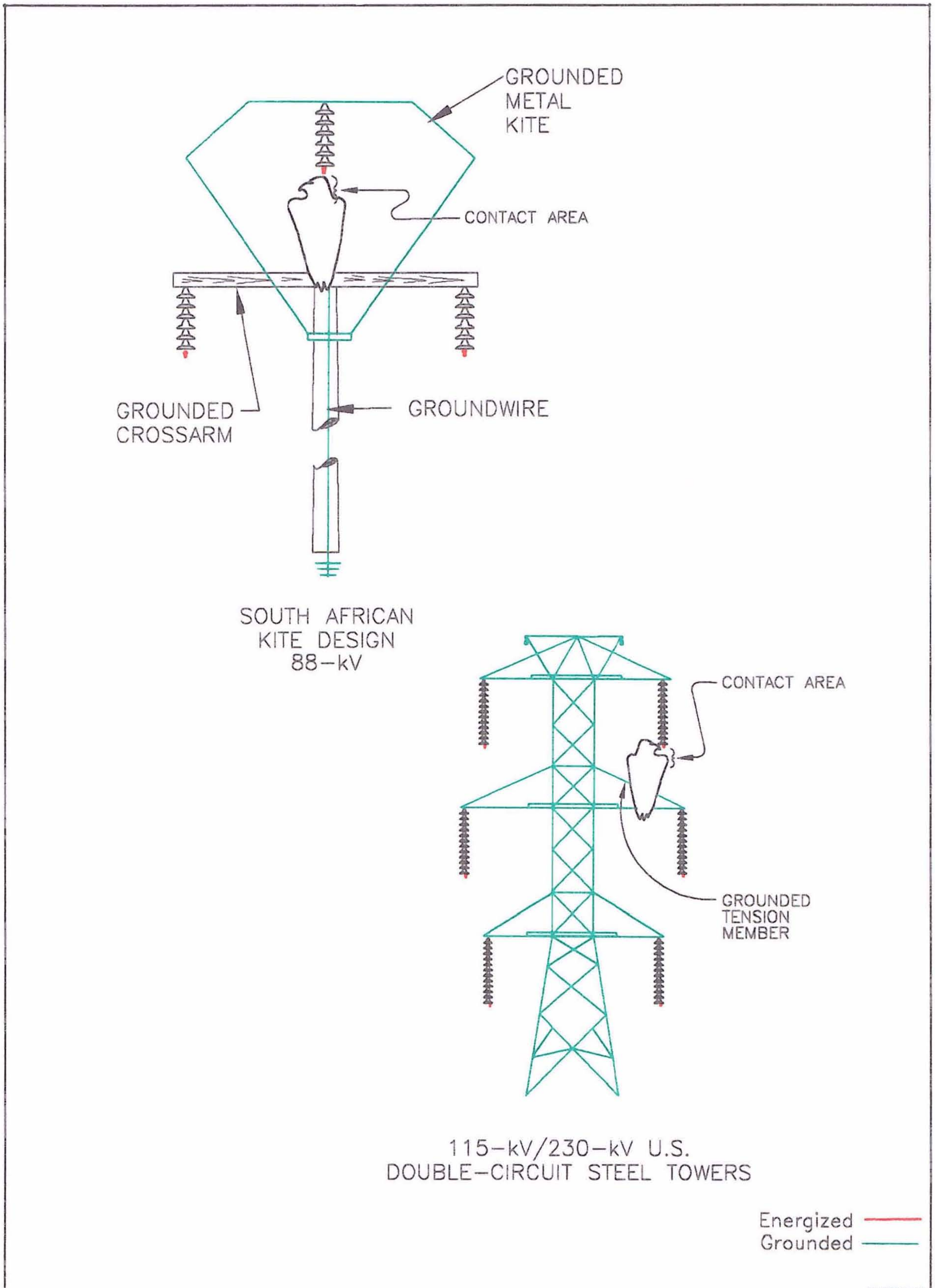

Figure 14. Problem transmission designs.
(Refer to Figure 29 for recommended solution.)

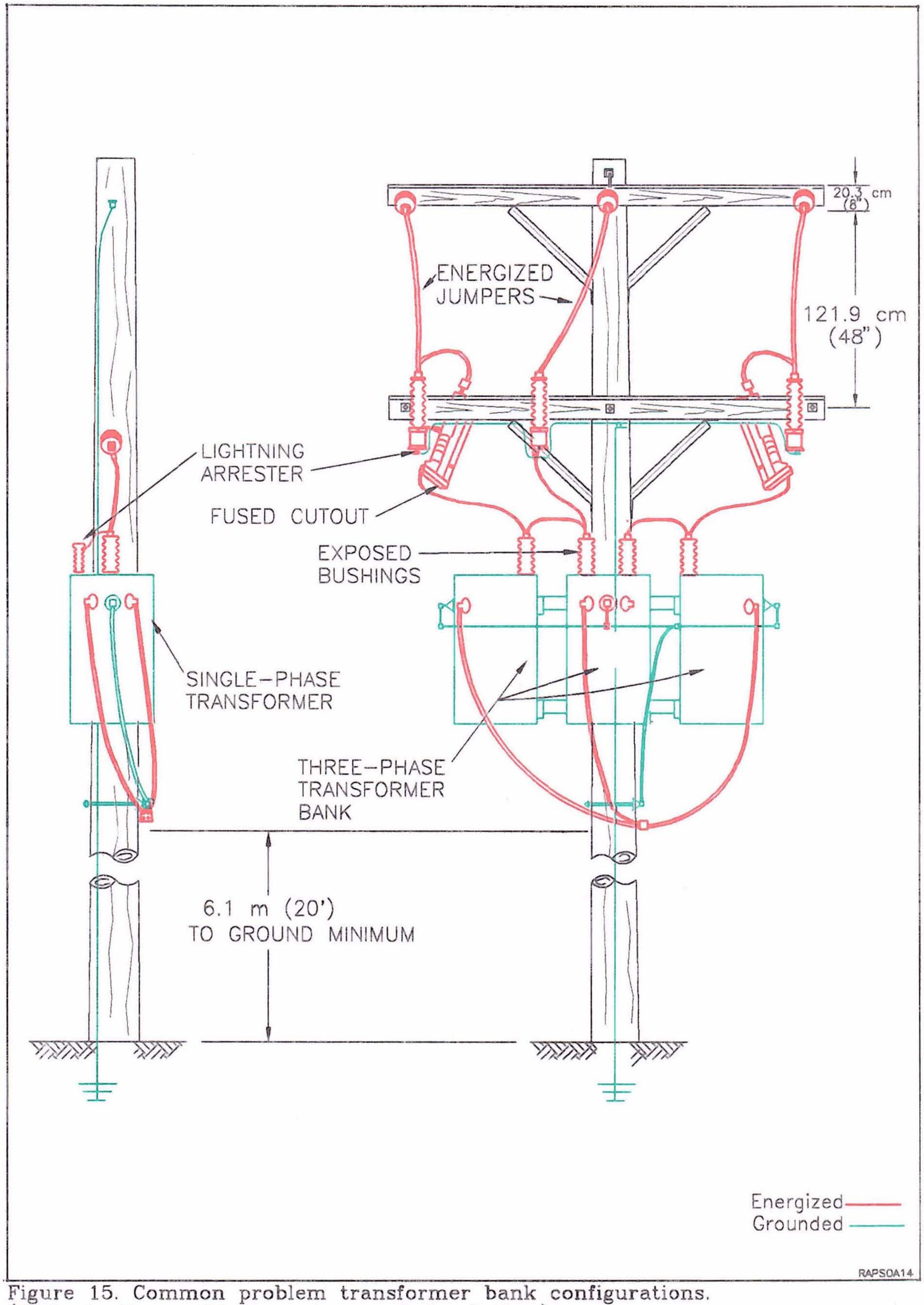

Figure 15. Common problem transformer bank configurations.
(Refer to Figure 30 for recommended solution.)

transformer electrocutions (n=138). PacifiCorp (unpubl. data) reported that 33% of all eagle electrocutions (n=165) between 1986 and 1994 were associated with transformers. Smaller raptors seemed even more vulnerable to transformers: 55% of hawk (n=64) and 64% of owl (n=50) electrocutions were associated with transformers.

Many types of switches are used to sectionalize equipment for maintenance and also to separate the distribution system into segments during storms or emergency conditions (Figure 16). A report from Germany (DIN VDE 0210/12.85, 1991) indicates multiple raptor deaths (exact numbers not reported) on those energized lines and switches between 1 kV and 60 kV. Solutions to the problems encountered in Germany are very similar to those discussed below and involve guards, perches, conductor coverings, and the use of crossarms with the insulators in suspension so that the raptors can perch safely on the arm.

SUGGESTED PRACTICES

Suggested practices are discussed below as they apply to modification of existing facilities, and raptor-safe design of new facilities. *Modification measures* are methods of retrofitting existing lines to make the structure safer for raptors. *Raptor-safe* construction involves engineering designs for new or rebuilt lines

Both standards are based on a required minimum spacing of 152.4 cm (60 in.) between phases or between phase and groundwires. This minimum was suggested by Morlan Nelson, based on filming and research in 1974. These dimensions are adequate to protect most birds under most conditions (Miller et al. 1975, Olendorff et al. 1981). However, there is still a greater chance of electrocution for wet birds.

Both modification and raptor-safe construction approaches must be employed if raptor electrocutions are to be minimized. It is important to note that raptor-safe construction reduces the chance of raptor electrocution more effectively than retrofitting. We recommend that any new line construction in areas heavily used by raptors employ raptor-safe standards. We recognize, however, that, given the diversity of line designs and voltages used by power companies, across-the-board standards and guidelines are not practical. It is not realistic to expect to eliminate all hazards to perching birds; however, it is realistic to work proactively to reduce known and potential hazards.

The following suggested practices relate primarily to distribution lines with 1-kV to 69-kV ratings, because lower-voltage lines (e.g., 480-V) are not known to electrocute raptors. Table 1 (page 78) provides a comprehensive list of measures and situations under which they most likely apply.

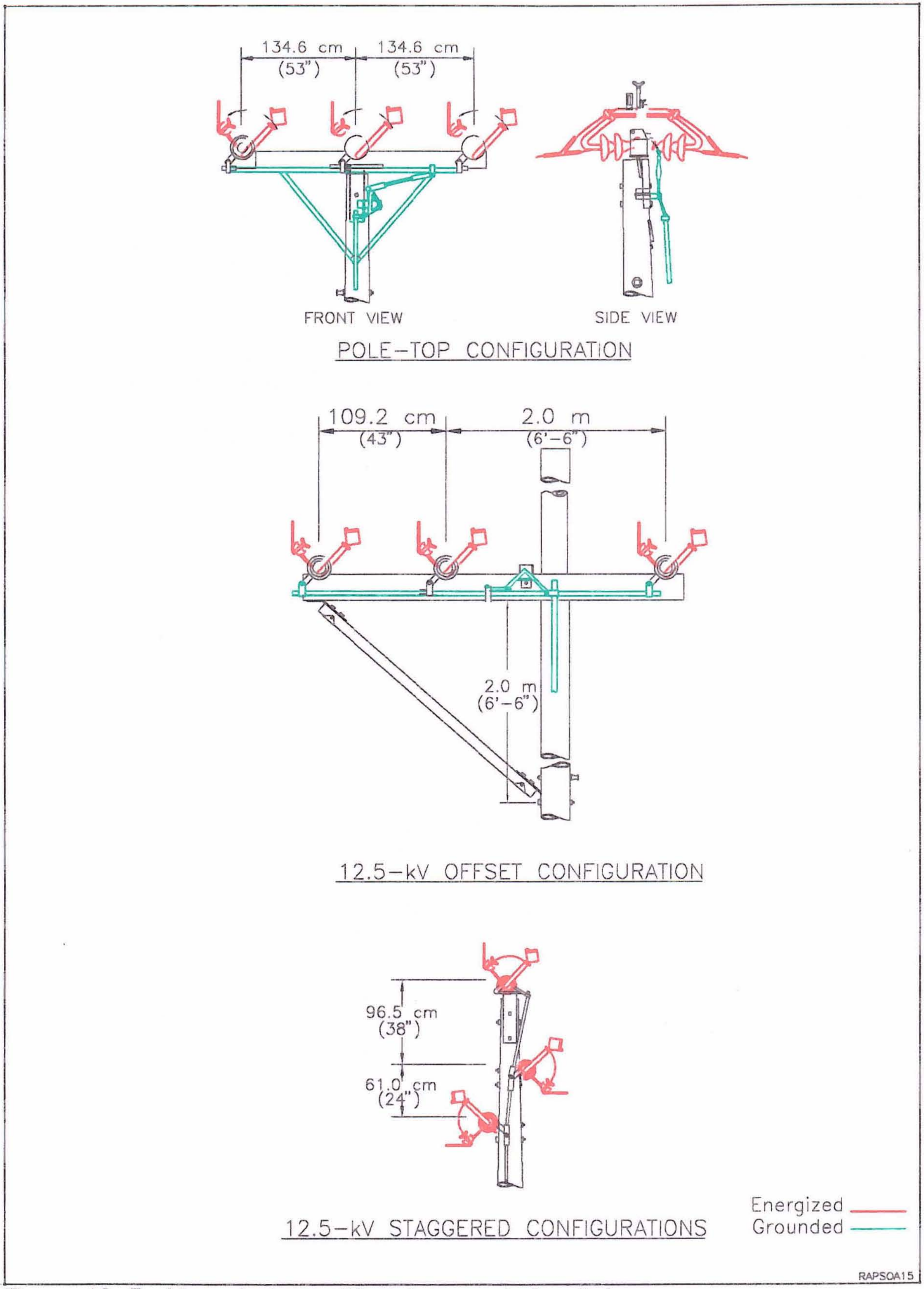

Figure 16. Problem designs with pole-mounted switches.
(Refer to page 68 for recommended solutions.)

MODIFICATION OF EXISTING FACILITIES[5]

In recommending the most appropriate remedial action for a particular problem, the following generalizations can be made:

1) Older power lines built to past construction standards may represent serious threats to perching raptors. Such lines are generally characterized by unusually short crossarms, placement of groundwires near energized phases, and metal crossarm braces.

2) The likelihood of electrocutions occurring at voltages greater than 69 kV is extremely low. Electrocution is a problem associated with *distribution lines.*

3) Poles that are (1) preferred by raptors (see Chapter III) and (2) prove particularly lethal to raptors should be corrected first.

4) Raptors may use all poles located in homogenous, high-density raptor habitat. In such a preferred area, all poles are possible threats. These areas should be monitored to determine appropriate actions.

5) Reports of electrocutions on distribution lines with standard crossarm construction should be evaluated closely to determine the need for modification. Modifications are generally not recommended as a response to single electrocutions, which may be isolated events. Biologists should determine whether multiple electrocutions are likely on a given pole or structure. Criteria could include documented findings of electrocuted birds near a pole, natural factors such as prey availability, terrain advantage, and/or consistent use of preferred poles for perching or still-hunting. If evidence of frequent use exists, the pole should be modified. If there is no such evidence, the pole should first be monitored (see Olendorff et al. 1981).

6) Poles supporting additional electrical hardware (transformers, switches, etc.) in raptor use areas are more likely to cause electrocution (Olendorff et al. 1981; Idaho Power Co., PacifiCorp, unpubl. data).

7) The cost of modifying problem lines does not decrease for smaller raptors. Modification for small raptors such as red-tailed hawks or prairie falcons costs the same as that for golden eagles because the largest modification expense is travel and labor.

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[5] **Note**: The suggested practices for modifying existing lines reference a variety of equipment and materials (e.g., elevated perches, perch guards, and conductor covers) developed since 1981 and found successful. Appendix C lists representative sources for such equipment.

Single-Phase Lines

Armless single-phase lines may be a problem when a groundwire extends close to the top of the pole. The best solution is to cover the groundwire with insulating material to prevent simultaneous phase-to-ground contact. Alternatively, if the groundwire is gapped, it will end at least 30.5 cm (12 in.) below the pole top (Figure 17). Lightning will spark over these gaps, but the safety of the birds is ensured. To prevent a pole fire, gapped wires should be bent away from the poles so that any arcing will occur in the air rather than along the pole surface (Nelson 1978).

For the single-phase crossarm configuration, the phase can be insulated with a conductor cover (Figure 18). Rather than modifying the structure with a longer crossarm or revising the grounding, the simplest and most economical solution is to cover the phase conductor with one of the products available (see Appendix C). Alternatively, the crossarm may be removed to convert to an armless configuration with an insulator or gapped groundwire.

Three-Phase Lines

Three-phase lines become a hazard when conductor spacing is insufficient (less than 152.4 cm or 60 in.), or when bonded hardware and grounded metal crossarm braces are too close to energized conductors, so that phase-to-ground contact may result. Use of wood or other non-conductive braces significantly decreases the likelihood of electrocution. Several remedial measures are available to correct the conductor spacing problem.

- Pole-top extensions can be added (Figure 19). This measure can achieve the 152.4-cm (60-in.) spacing (Miller et al. 1975; Nelson and Nelson 1976, 1977; Benson 1981; Olendorff et al. 1981).
- The crossarm can be lowered (Figure 20) if sufficient ground clearance is available to meet NESC requirements.
- The center phase can be covered with conductor insulation (Figure 21). This measure has been tested successfully on several power lines in Wyoming and Utah (PacifiCorp, unpubl. data).

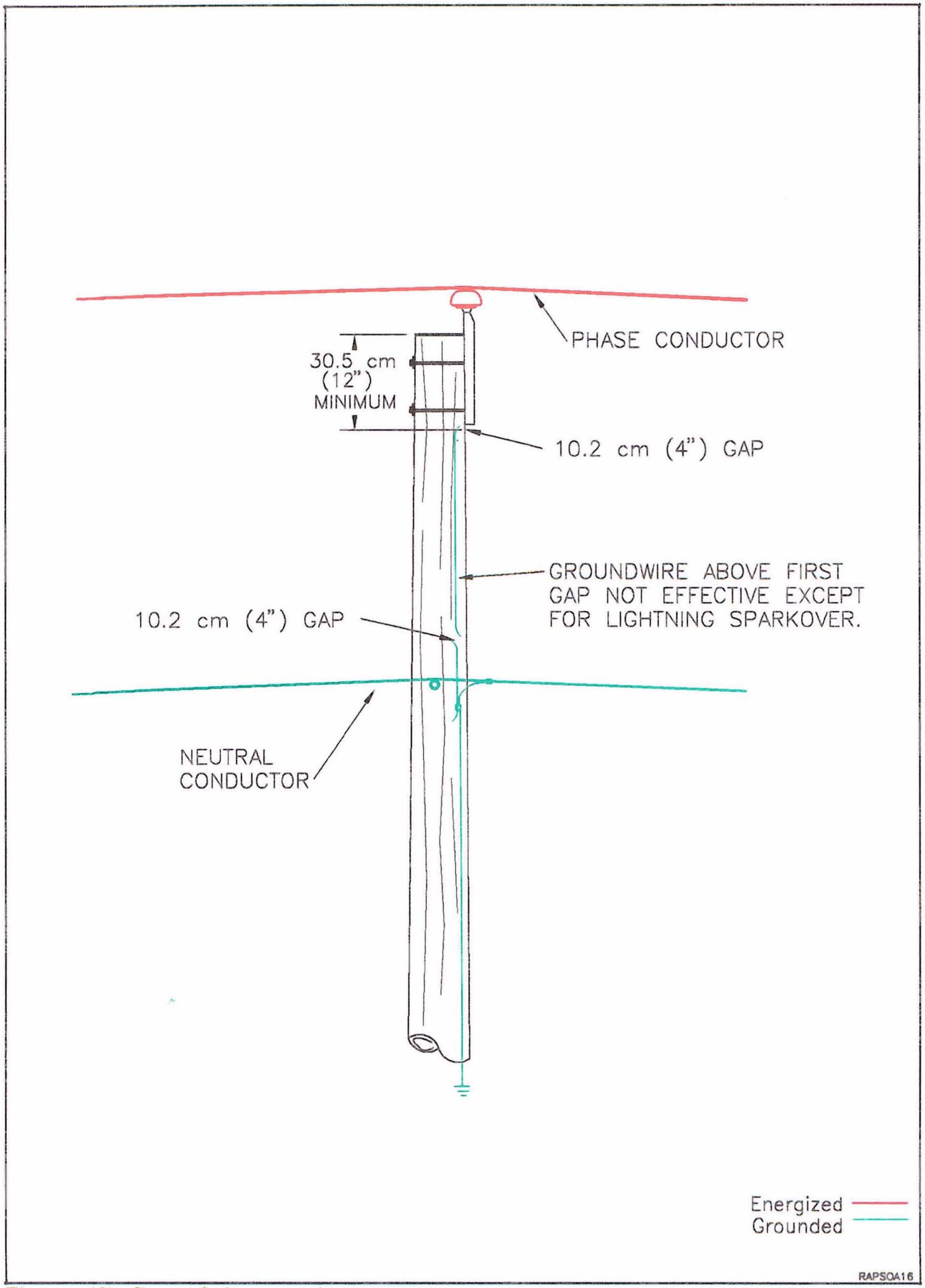

Figure 17. Groundwire gapping.
(Solution to Figure 5.)

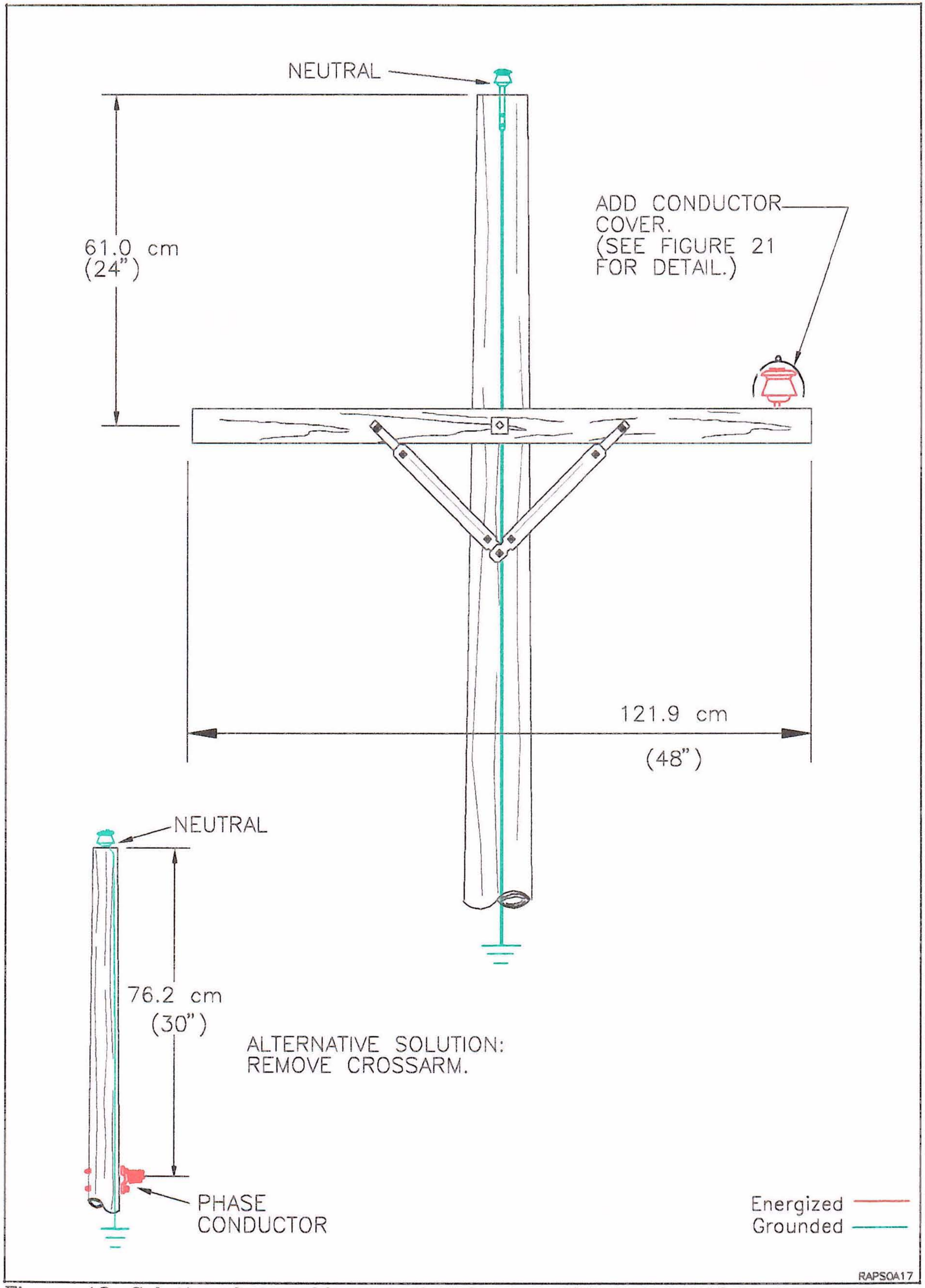

Figure 18. Solution for problem single-phase configuration with crossarm. (Refer to Figure 6.)

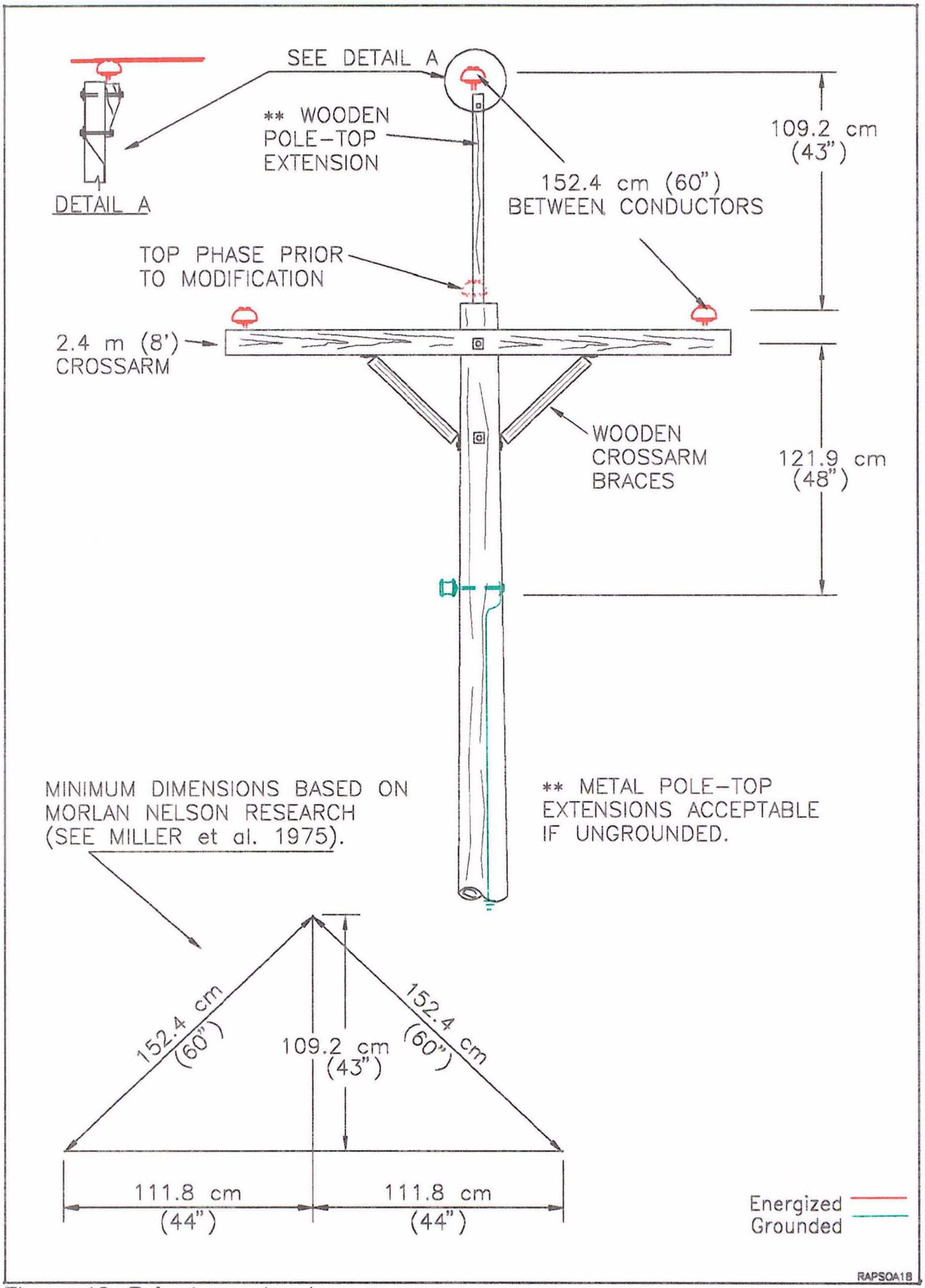

Figure 19. Pole-top extension.
(Refer to Figure 7.)

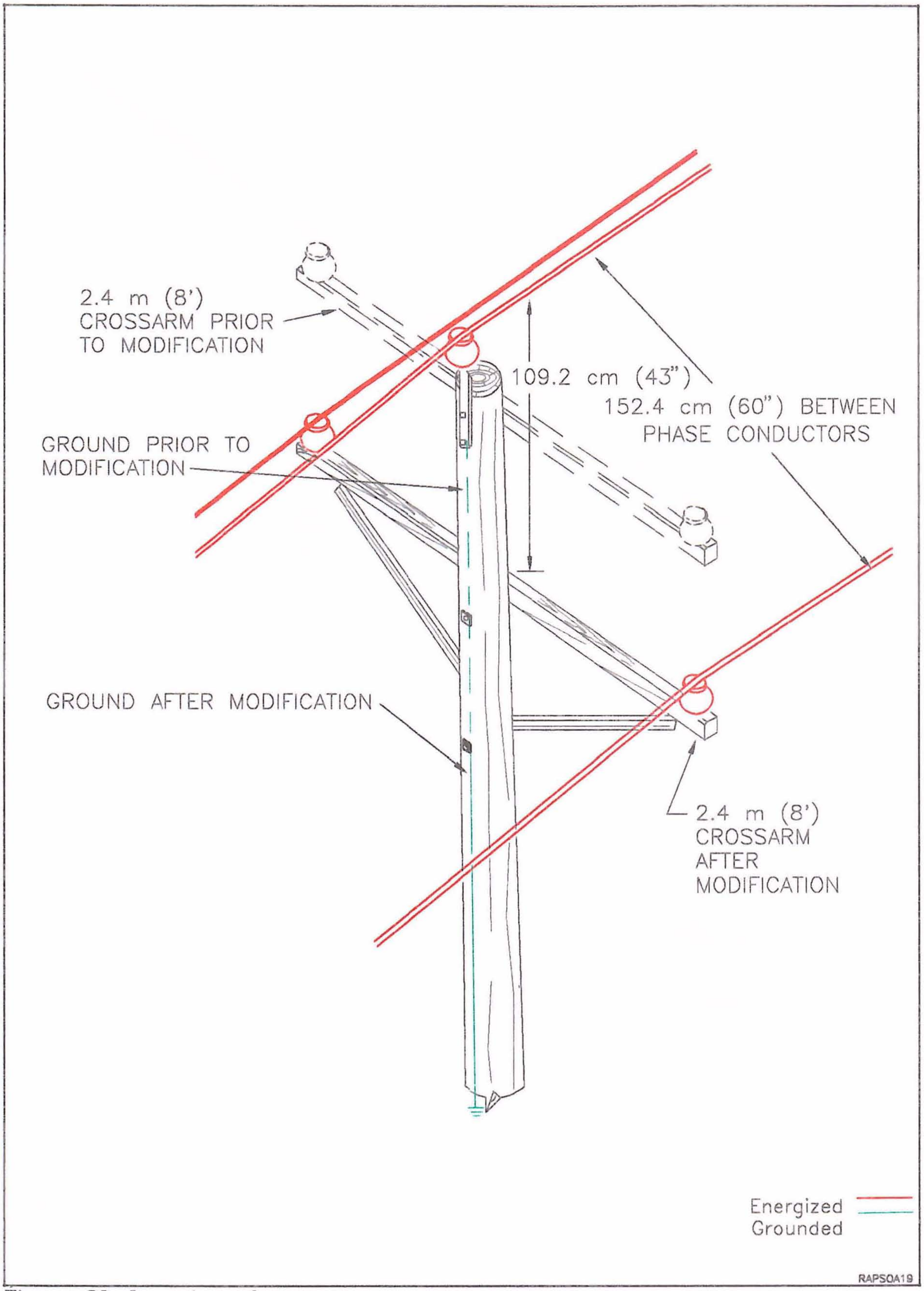

Figure 20. Lowering of crossarm.
(Refer to Figure 7.)

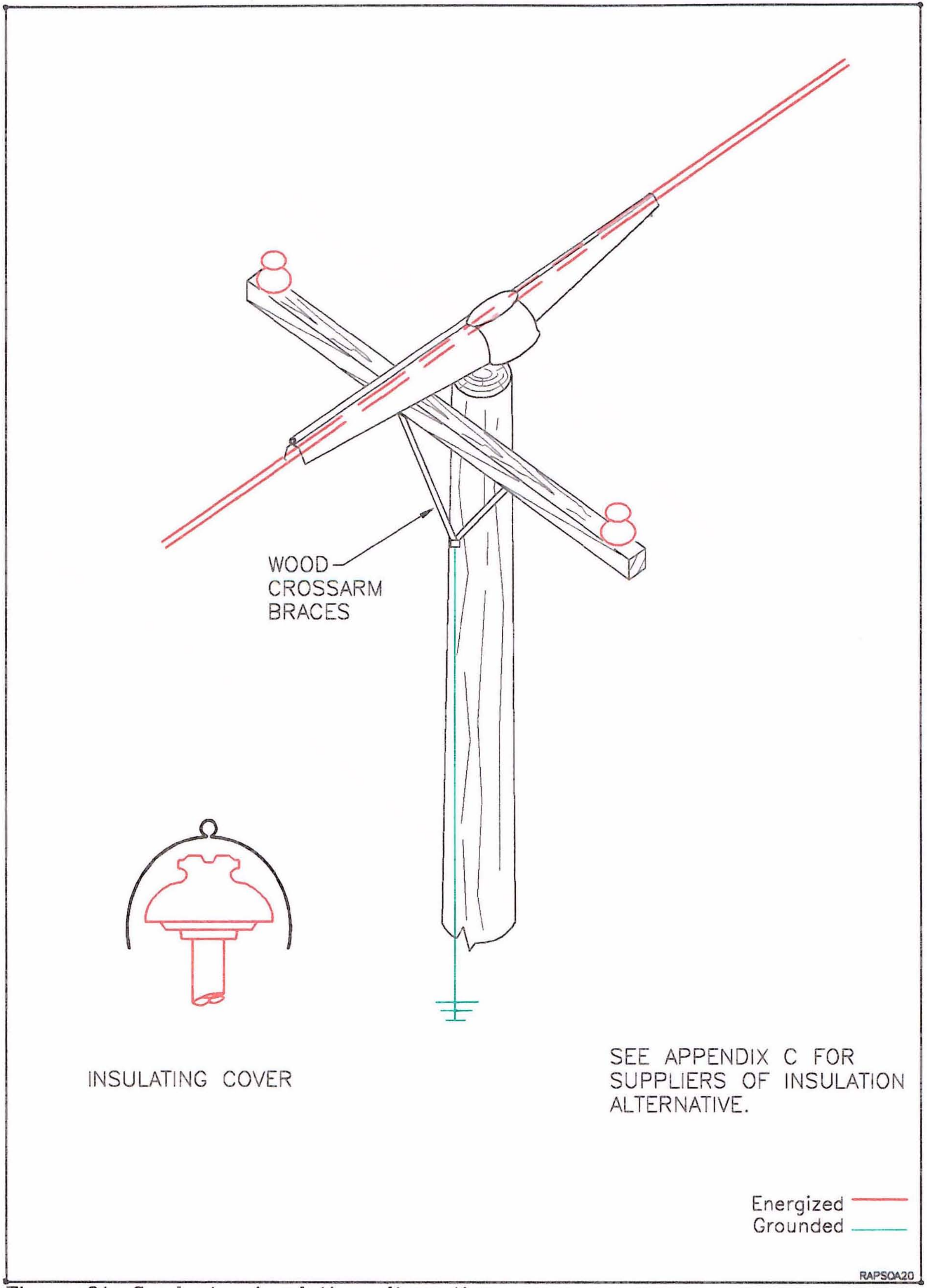

Figure 21. Conductor insulation alternative.
(Refer to Figure 7.)

- Perch guards may be installed to discourage perching between closely spaced phases (Figure 22). A variation of this measure is the elevated perch (Figure 23), which provides the bird with an alternate perching site. However, because raptors may try to land below the elevated perch, possibly for shade (Olendorff et al. 1981; PacifiCorp, unpubl. data), a 35.6- to 40.6-cm (14- to 16-in.) maximum height from the overhead perch to the crossarm is recommended. Perching below the elevated perch will be further discouraged with the use of the combination perch guard/ overhead perch (Figure 23), and is the recommended practice.

- A longer crossarm may be installed. Most three-phase lines mount conductors on 2.4-m (8-ft) crossarms. If adequate ground clearance is available, a 3-m (10-ft) crossarm mounted 61.0 cm (24 in.) below the top of the pole, with a pole-mounted middle phase, provides 152.4 cm (60 in.) of perching space.

- The groundwire can be gapped to eliminate electrocution (Figure 24).

- Jumper wires can be supported under the crossarm (Figure 25) to reduce the problem shown in Figure 9, but phase spacing and grounding must be carefully evaluated, to determine whether they are also contributing to the problem.

Corner Poles

Poles installed to accommodate changes in line direction are hazardous because of their closely spaced phases and jumper wires. On such poles, the center phase can be affixed to the top set of crossarms with a non-conducting extension link to prevent contact by a bird. Jumper wires should be insulated (Figure 26). The addition of an elevated perch could provide raptors with a hunting perch above the energized area. See also the suggestions for corner poles under Raptor-Safe Design of New Facilities (pages 69-79) and in Figures 35 and 36 (pages 74 and 75).

Horizontal Post Design

This design is not safe for raptors because a bird may make simultaneous contact with the phase and either the pole groundwire or the grounded base of the post insulator. Suggested options (Figure 27) to increase safe perching include the following:

- insulating the insulator bases, bolts, and groundwire with heat-shrink or other kinds of insulating material (insulating blankets, etc). Wood and plastic moldings are available to cover pole groundwires (Appendix C);

- installing perch guards on the post insulators to discourage perching on the insulators (perch guards completely eliminated eagle mortalities following installation on a line in central Wyoming in 1993 [PacifiCorp, unpubl. data]);

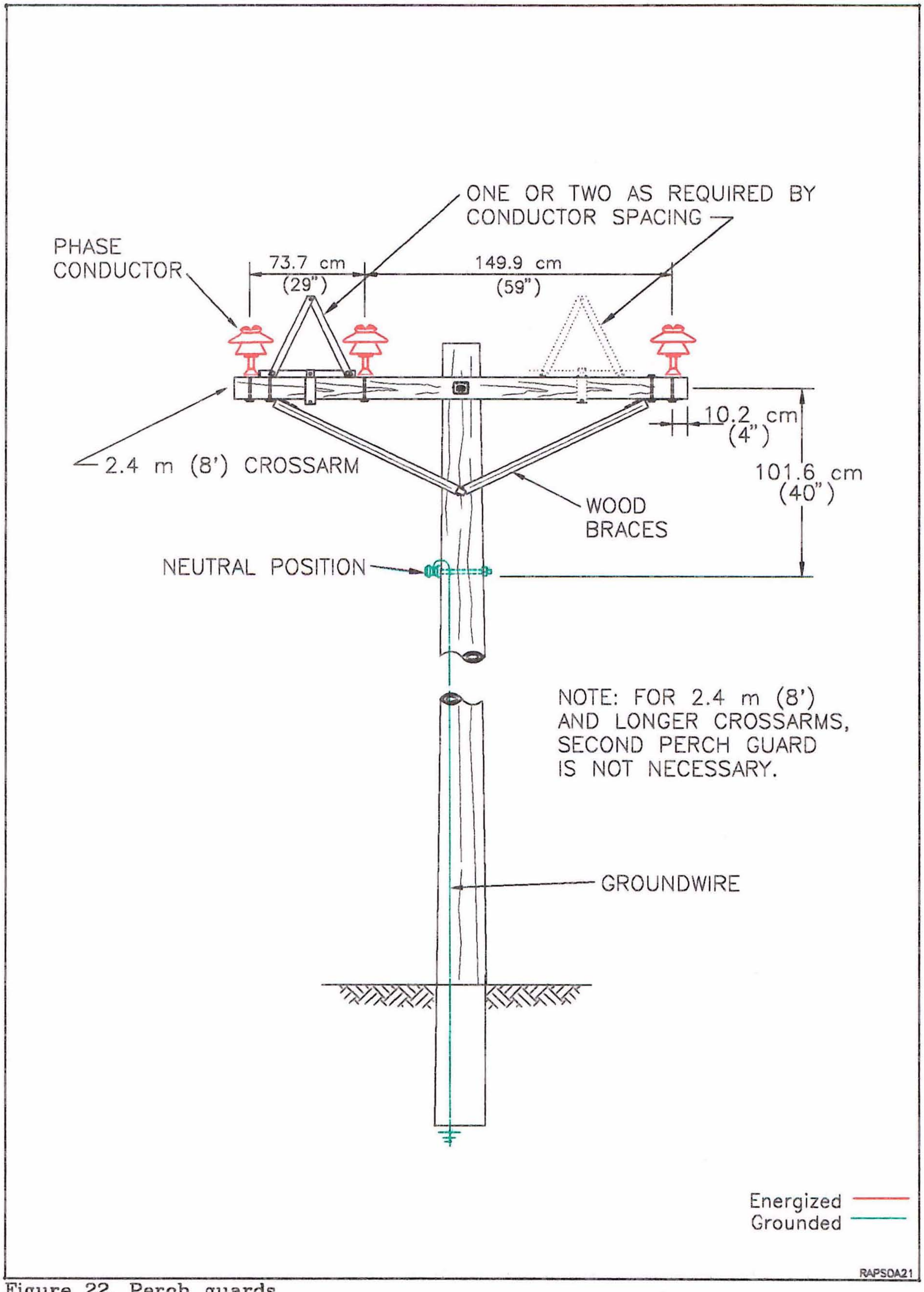

Figure 22. Perch guards.
(Refer to Figure 7.)

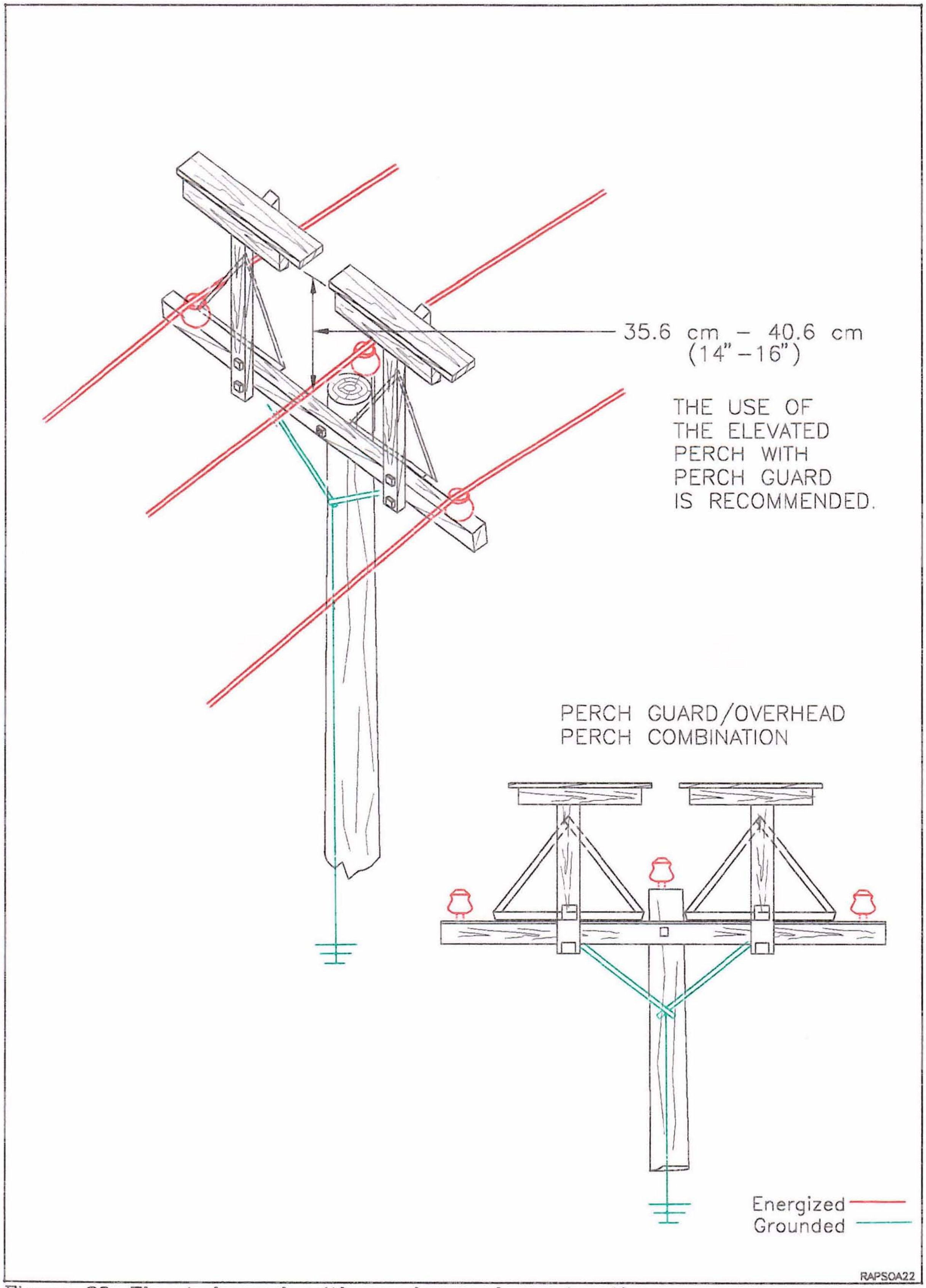

Figure 23. Elevated perch with perch guard construction.
(Refer to Figure 7.)

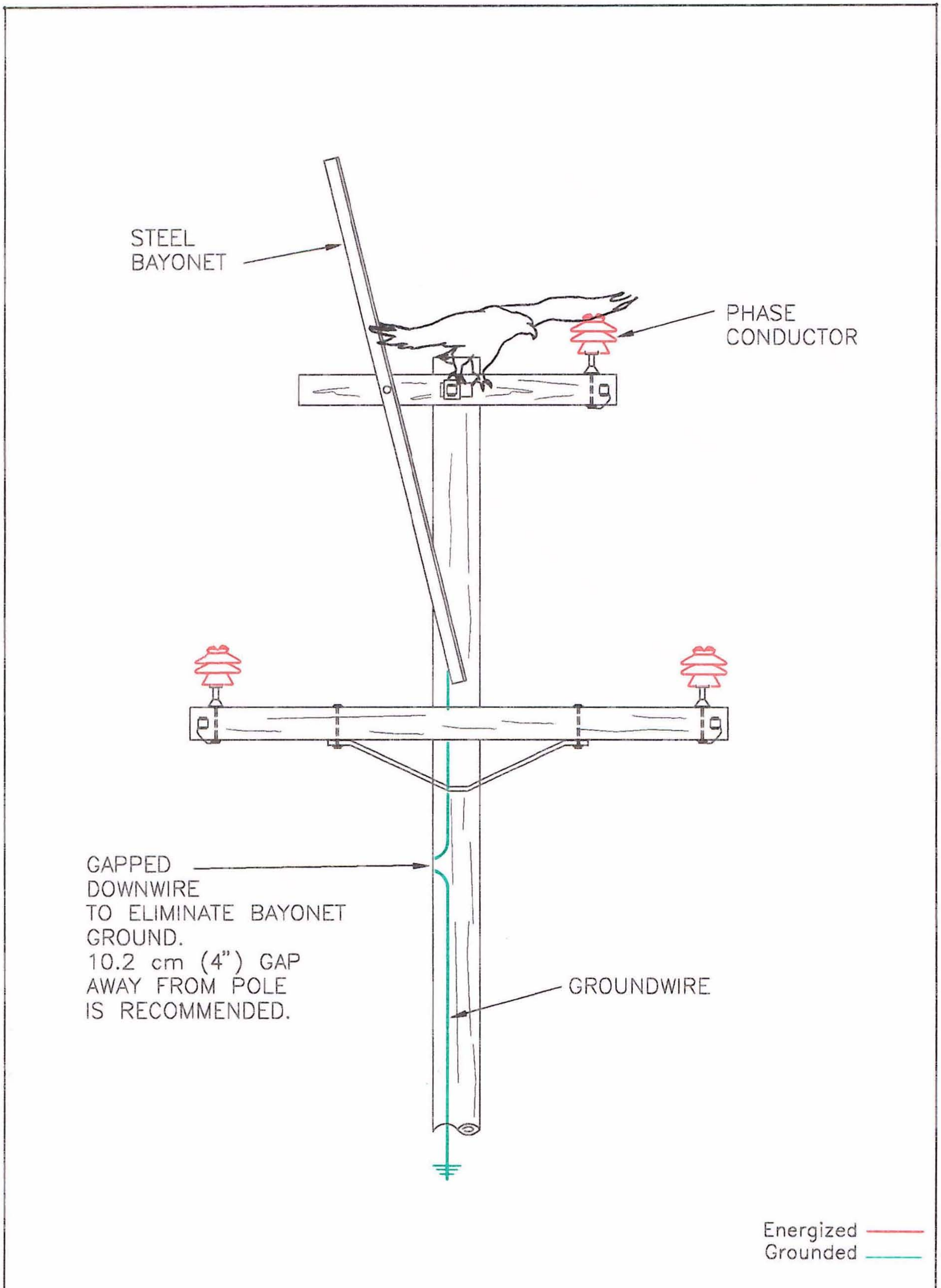

Figure 24. Solution for problem three-phase 69-kV design with steel bayonet. (Refer to Figure 10.)

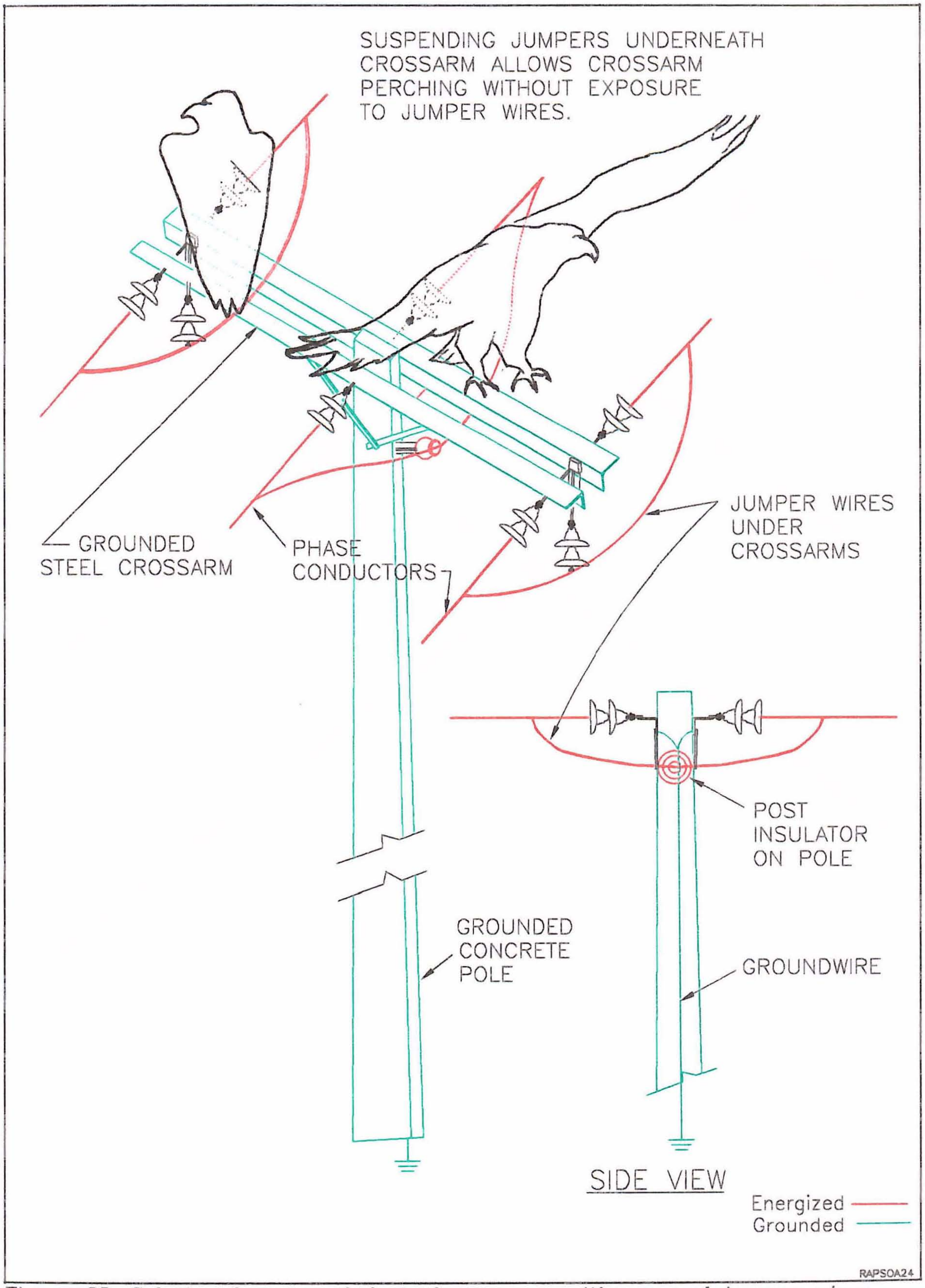

Figure 25. Solution for grounded steel crossarm with exposed jumper wires used in Spain (Ferrer et al. 1991). (Refer to Figure 9.)

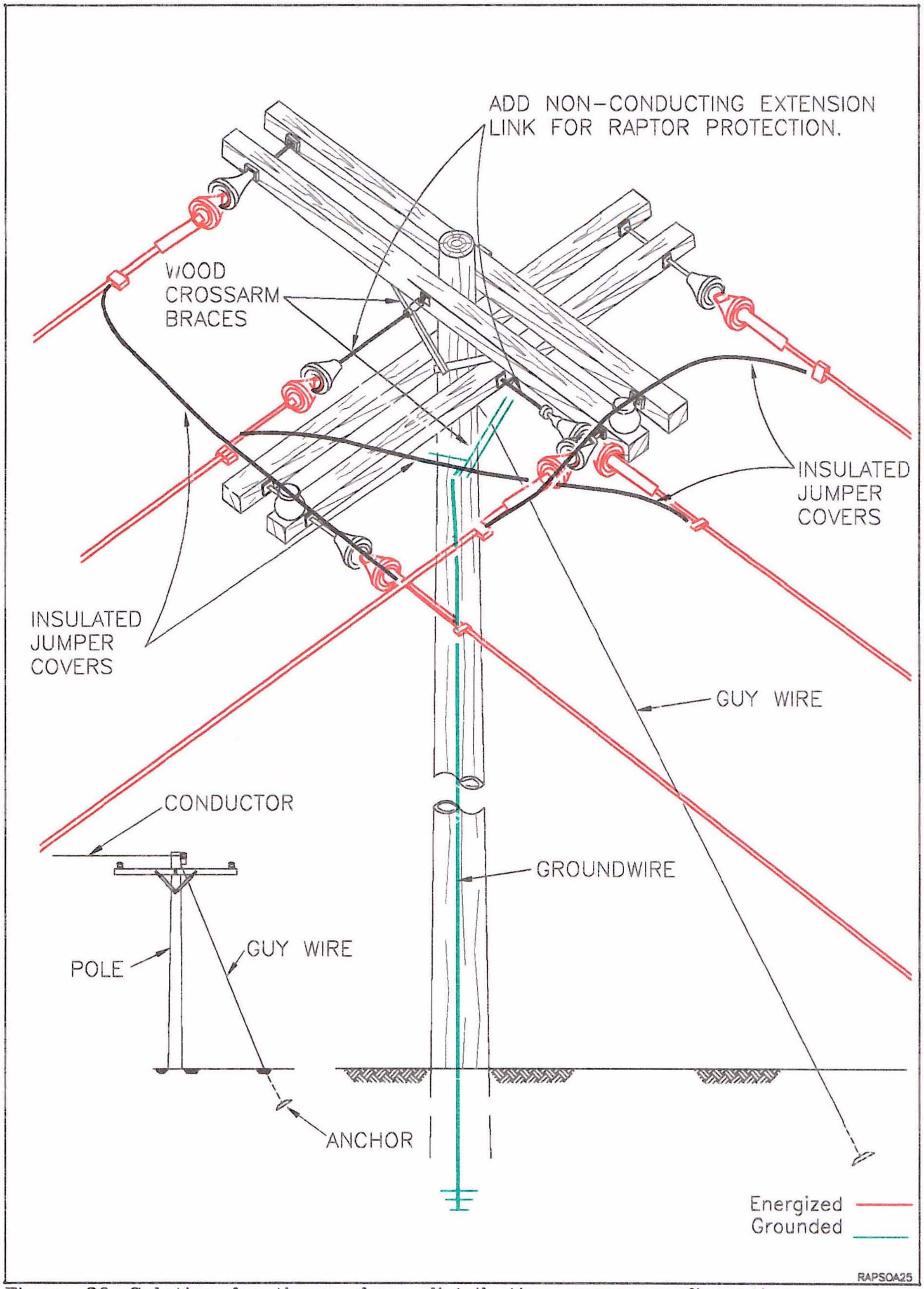

Figure 26. Solution for three-phase distribution corner configuration. (Refer to Figure 11.)

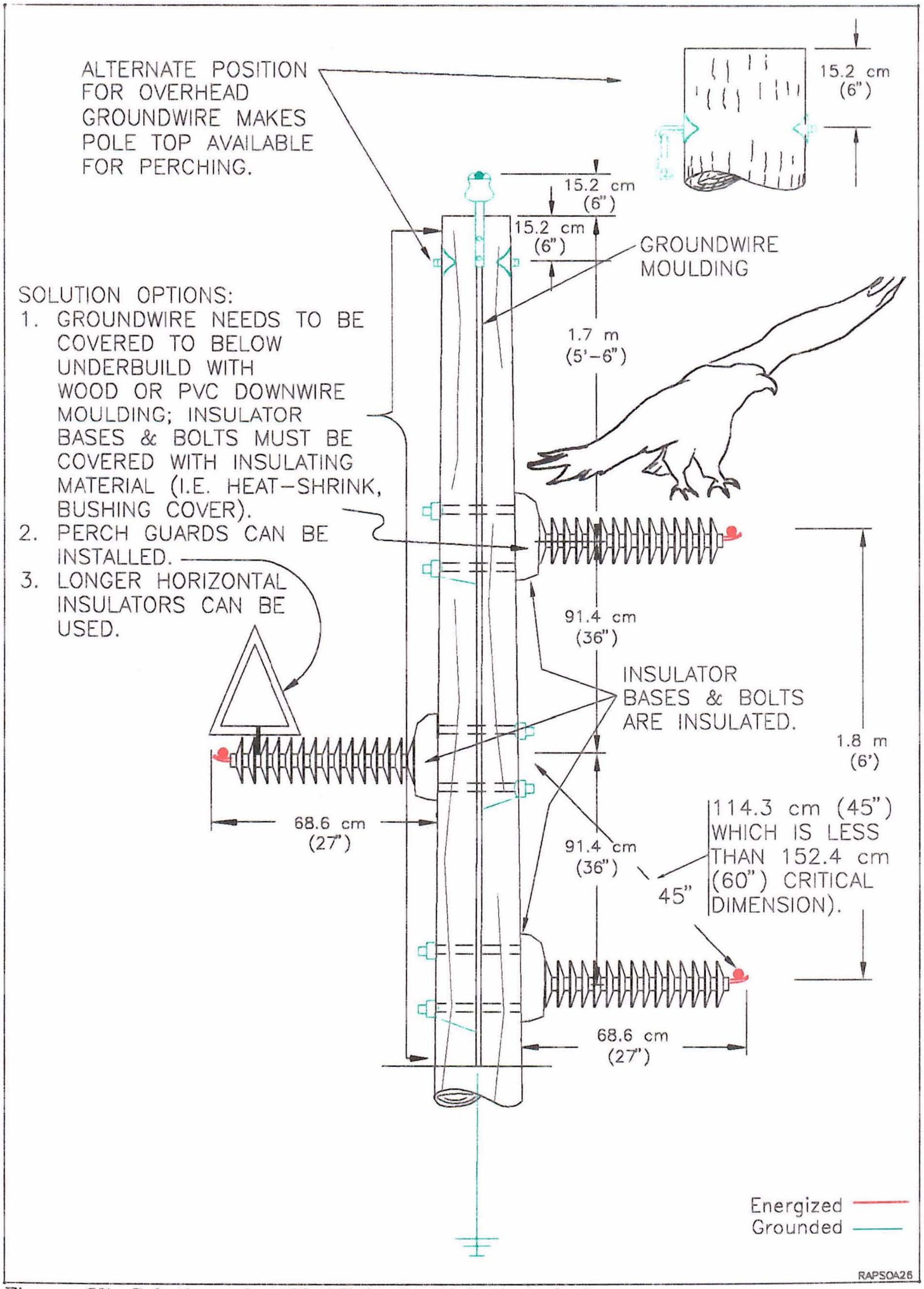

Figure 27. Solutions for 69-kV horizontal post design. (Refer to Figure 12.)

- replacing the standard post insulators with longer insulators to provide the necessary 152.4-cm (60-in.) spacing; and

- suspending the overhead groundwire on the side instead of on a ridge pin. This clears the pole top for perching.

Wishbone Design

Eagles or other large raptors may be electrocuted by perching on the lower crossarm of this design. Perch guards may be installed, but clearance distances may be difficult to maintain. Alternatively, the groundwire may be insulated, or a Swan Flight Diverter (SFD) may be installed on the phase conductor to prevent physical contact with the bird's head (Figure 28). (Use of both a perch guard and an SFD may be determined by actual dimensions and the physical size of the raptor involved.) The SFD was designed to wrap on a conductor, increasing conductor silhouette to reduce or eliminate bird collisions (Ledger et al. 1993, Avian Power Line Interaction Committee 1994). Because the device is made of an insulating polyvinyl chloride (PVC) material, it may be applied in this situation so that the head of the raptor does not get too close to the energized conductor. Note that, on the underbuilt circuit below the wishbone, a perch guard is recommended between the close phases to encourage perching on the other side of the pole.

Transmission Line Designs

Transmission structures that cause electrocutions because there is insufficient clearance between the grounded perching substrate and the phase conductor may be remedied by installing SFDs or perch guards in appropriate locations (Figure 29). It may also be possible to replace the tension member on the center arm of the double-circuit structure with a non-conducting material (e.g., fiberglass) or to cover it with an insulating material. Safe perching substrate on the "kite" design was provided by installing a perch on top of the "kite," and perch guards under the center phase conductor (Ledger 1984). SFDs may also be used on the conductor for this problem.

Transformers and Other Equipment

Poles with transformers and other equipment necessary for NESC compliance and safety considerations are particularly hazardous to perching raptors, given the close spacing of energized wires and grounded hardware. When bird mortalities are noted on such poles, safety can be provided by insulating jumper wires to prevent simultaneous contact (Figure 30). A variety of molding, insulator, conductor, and jumper-wire cover insulating materials are available to prevent contact with groundwires and other hardware (see Appendix C). In addition, insulation can be installed on exposed connections of transformer banks to protect birds that tend to perch on such equipment (e.g., owls; PacifiCorp, Idaho Power Co., unpubl. data).

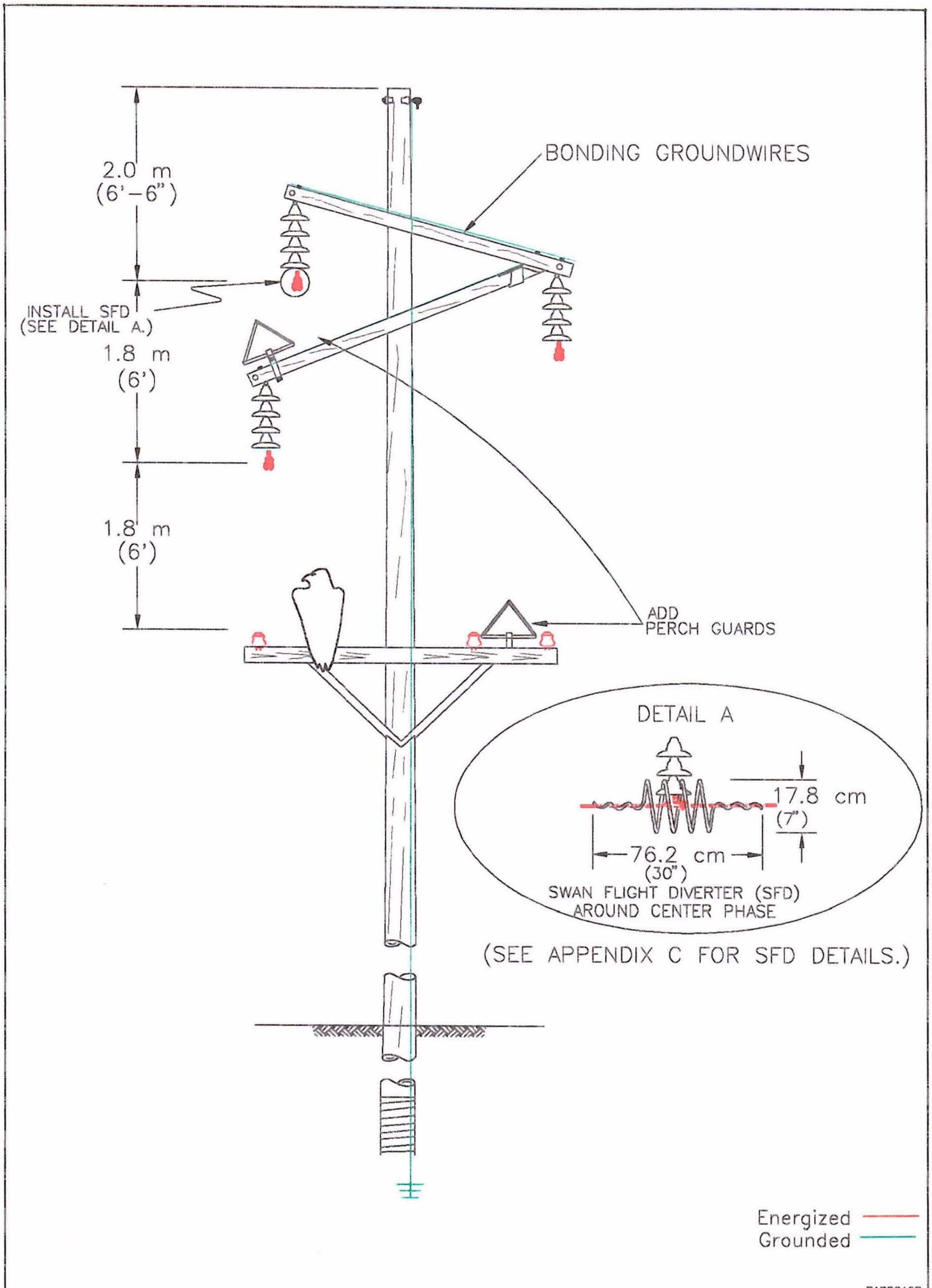

Figure 28. Solutions for the wishbone design.
(Refer to Figure 13.)

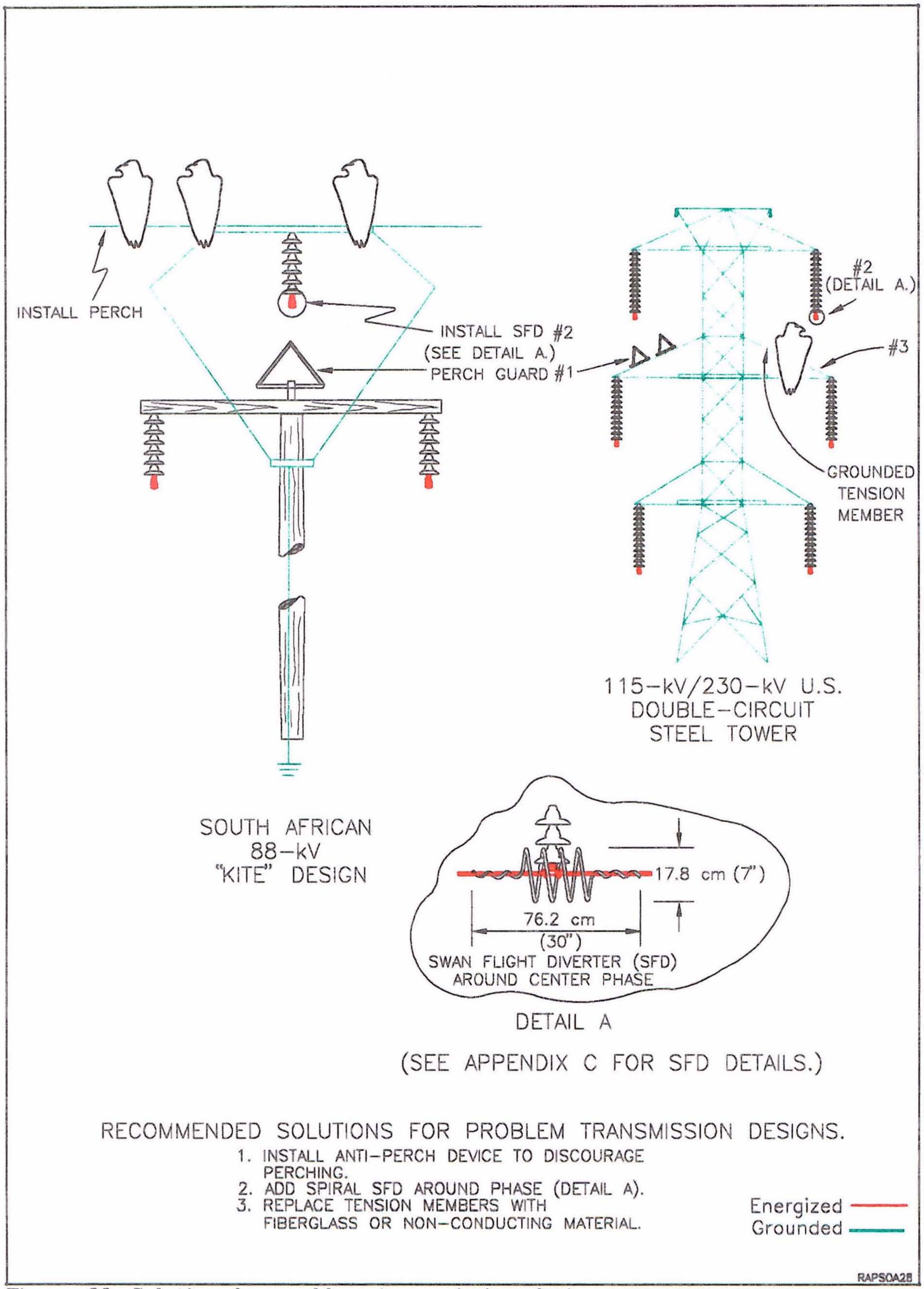

Figure 29. Solution for problem transmission designs. (Refer to Figure 14.)

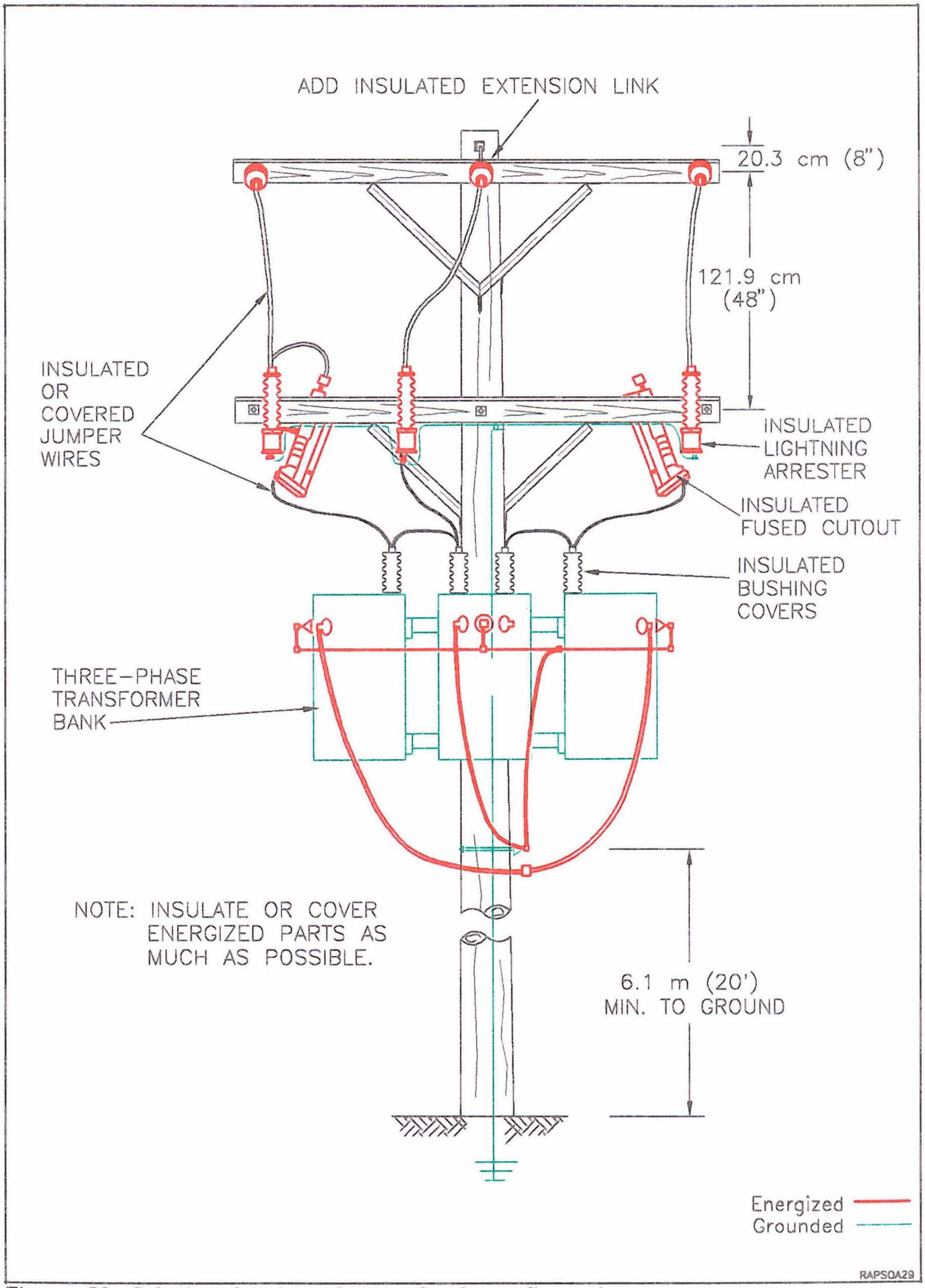

Figure 30. Solution for transformer bank configuration.
(Refer to Figure 15.)

These are relatively inexpensive remedial actions. Adding an elevated perch with a perch guard above the pole top or a non-conducting link on the center phase are other possible actions.

Switches used to sectionalize distribution systems (Figure 16, page 49) expose raptors to several electrocution risks. When switches are installed in an area with high populations of eagles or other raptors, offset or staggered switch configurations, along with greater pole height, may provide safer perching for raptors. This arrangement provides perches that should protect raptors from switch-related electrocutions. Spacing is the key to making these structures safe for raptors. Elevated perches with perch guards can also be added. The key factor is to equip the switch pole with a safe perching position above the energized switch blades. Insulation coverings should be used on as much of the energized portions as possible, to reduce the risk of phase-to-phase or phase-to-ground contact.

RAPTOR-SAFE DESIGN OF NEW FACILITIES

When designing or rebuilding power lines in raptor habitat, those concepts used to modify existing power lines also apply to new construction. Again, two basic considerations are *conductor spacing* and *grounding procedures*. As with retrofitting, the objective is to provide 152.4 cm (60 in.) between energized conductors or between energized conductors and grounded hardware. Because raptor-safe construction results in very little chance of raptor electrocution, any new line construction in areas used heavily by raptors should employ raptor-safe standards rather than the modification measures discussed above.

When planning the construction of new power lines, biological considerations, service reliability, other economic and political factors, and the safety of both the public and operating personnel must be considered. Although biological significance cannot be overlooked, it may not be possible to site lines outside high-quality raptor habitat. Biologists and engineers must cooperatively consider all factors before making recommendations to solve a raptor mortality problem.

Single-Phase Lines

Armless single-phase poles should be designed to prevent contact between the phase and groundwire. When groundwires are necessary on these poles, insulation or non-conductive molding must be installed over the groundwire to at least 30.5 cm (12 in.) below the top of the pole. This eliminates the possibility of simultaneous contact between the raptor's body on the phase and its tail on the groundwire. A good alternative to armless construction for single-phase lines is a side-mounting configuration that not only prevents phase-to-ground contact, but also makes the top of the pole a safe perch (Figure 31).

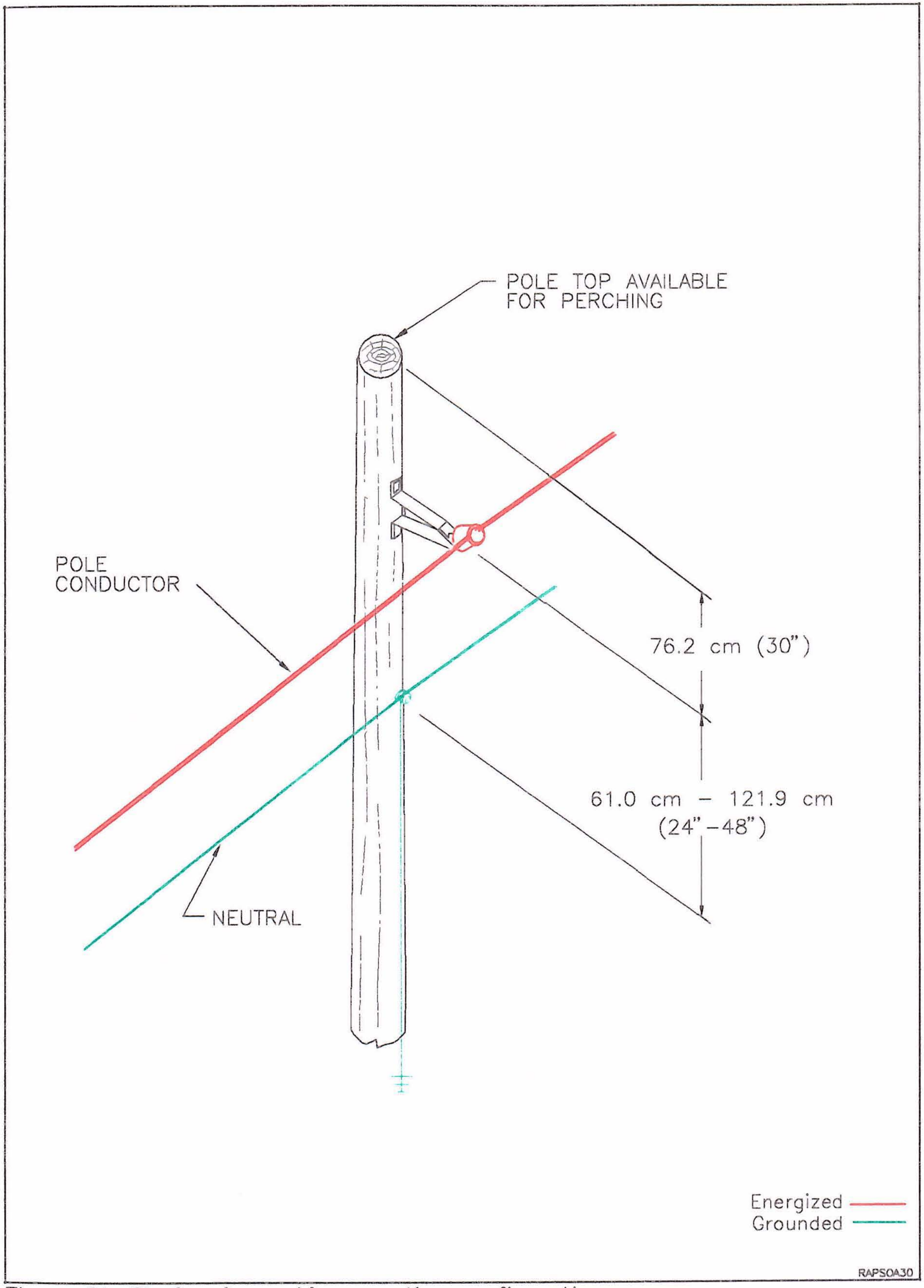

Figure 31. Single-phase side-mounting configuration.
(Solution for Figure 5.)

Three-Phase Lines

Raptor-safe construction for the three-phase crossarm design involves a pole tall enough to allow 109.2 cm (43 in.) from the top of the pole to the 2.4-m (8-ft) minimum length crossarm. Crossarm braces should be made of wood or other non-conductive material (Figure 32). If a groundwire is necessary, it should be insulated or covered with non-conductive material. This technique leaves little chance of raptor electrocution.

There are also several alternative raptor-safe compact designs for three-phase lines (Figure 33). Achieving a 152.4-cm (60-in.) spacing between conductors remains the key factor. The position of the neutral depends on the area's isokeraunic level. The neutral often serves as an overhead groundwire. However, if it is used on the top of the structure, the designer should make every effort to provide at least 152.4 cm (60 in.) for perching. Conductors can be suspended below the crossarm rather than above it in the conventional manner (Figure 34). As voltages increase, it is advantageous to suspend conductors to increase phase spacing.

Corner Poles

Poles that accommodate directional changes in power lines can be constructed in the conventional manner, if jumper wires are insulated and center phase non-conducting extension links are used (Figure 26, page 62). An alternative is the vertical design (Figures 35 and 36), which prevents simultaneous contact by a perching raptor. Longer poles are required, but crossarms and unwieldy jumper-wire arrangements are eliminated, overhead groundwires are easily accommodated, and guying and jumper-wire arrangements make this a raptor-safe design.

Horizontal Post Design

This configuration, typical of many 69-kV power lines, may be made raptor-safe if longer post insulators are used or the bolts and bases of the insulators and all groundwires are covered with an insulating material (Figure 27, page 63). The raptor-safe suspension configuration, which can also be used as an alternative to the wishbone design, not only provides adequate spacing between phases, but also accommodates perching on the davit arms and on the pole top (Figure 37). The ridge pin overhead groundwire attachment may be replaced with a side-mounted suspension arrangement so that the pole top is available for raptor perching.

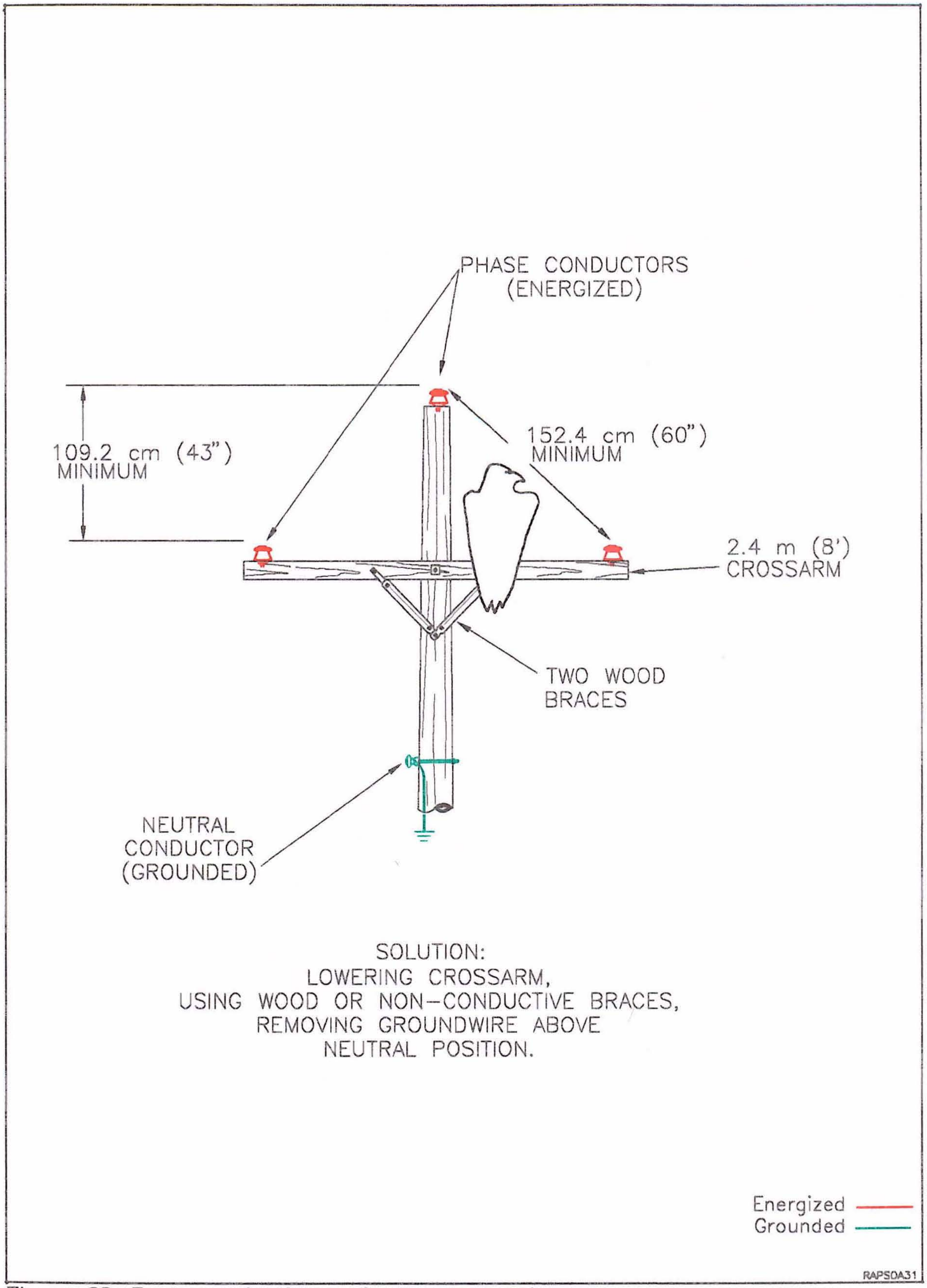

Figure 32. Raptor-safe three-phase construction.

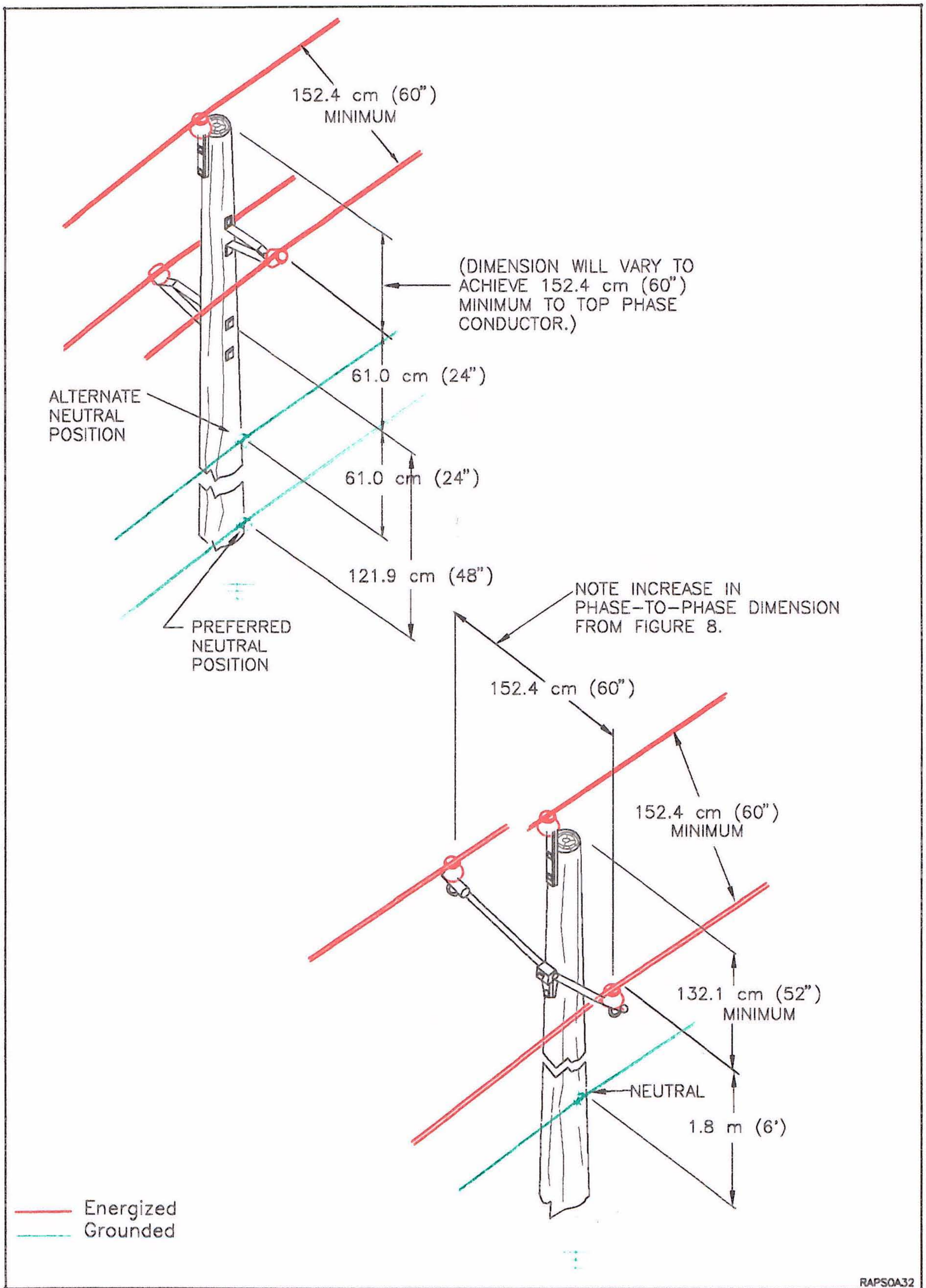

Figure 33. Raptor-safe compact designs. (See Figure 8.)

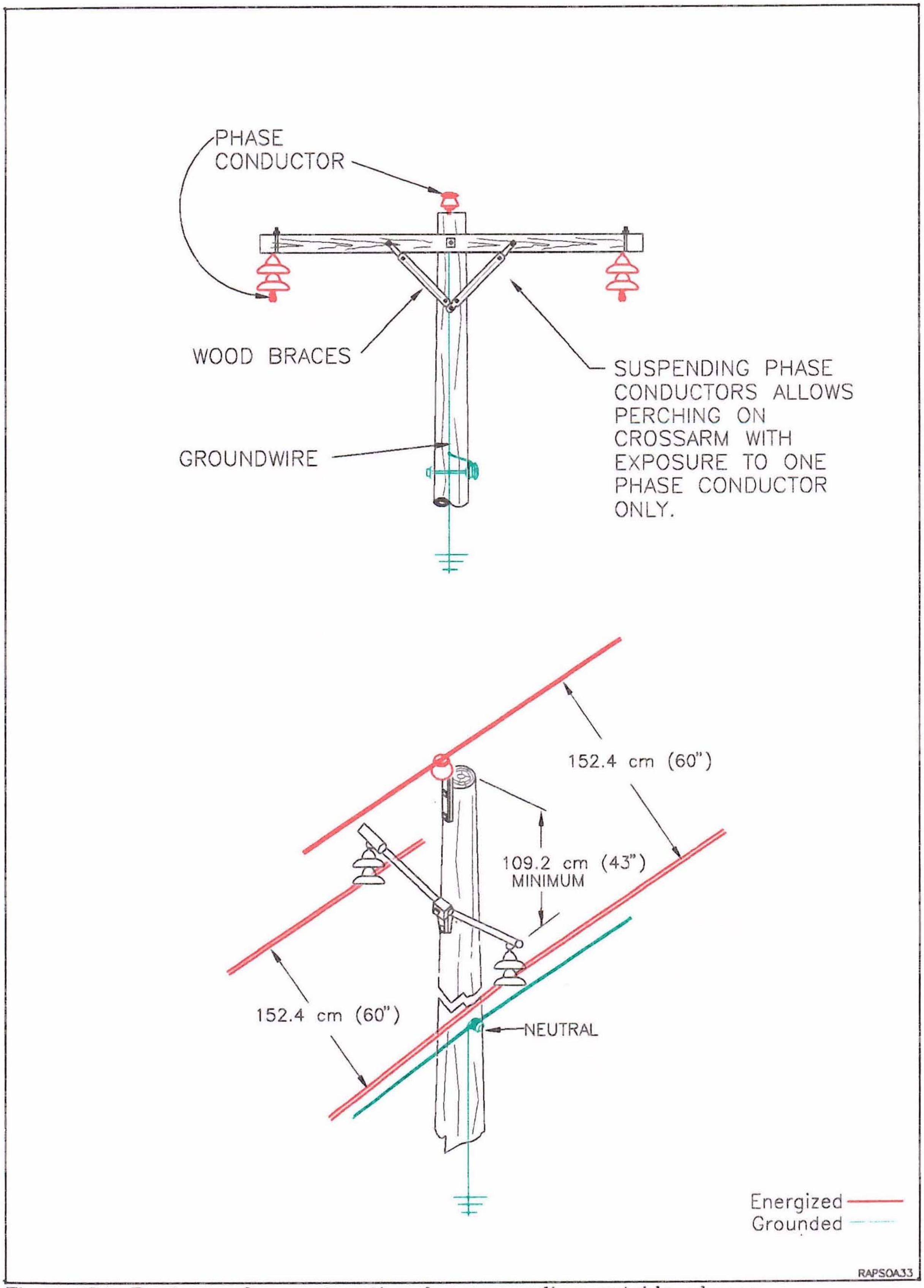

Figure 34. Raptor–safe construction by suspending outside phases. (Refer to Figures 7 & 8.)

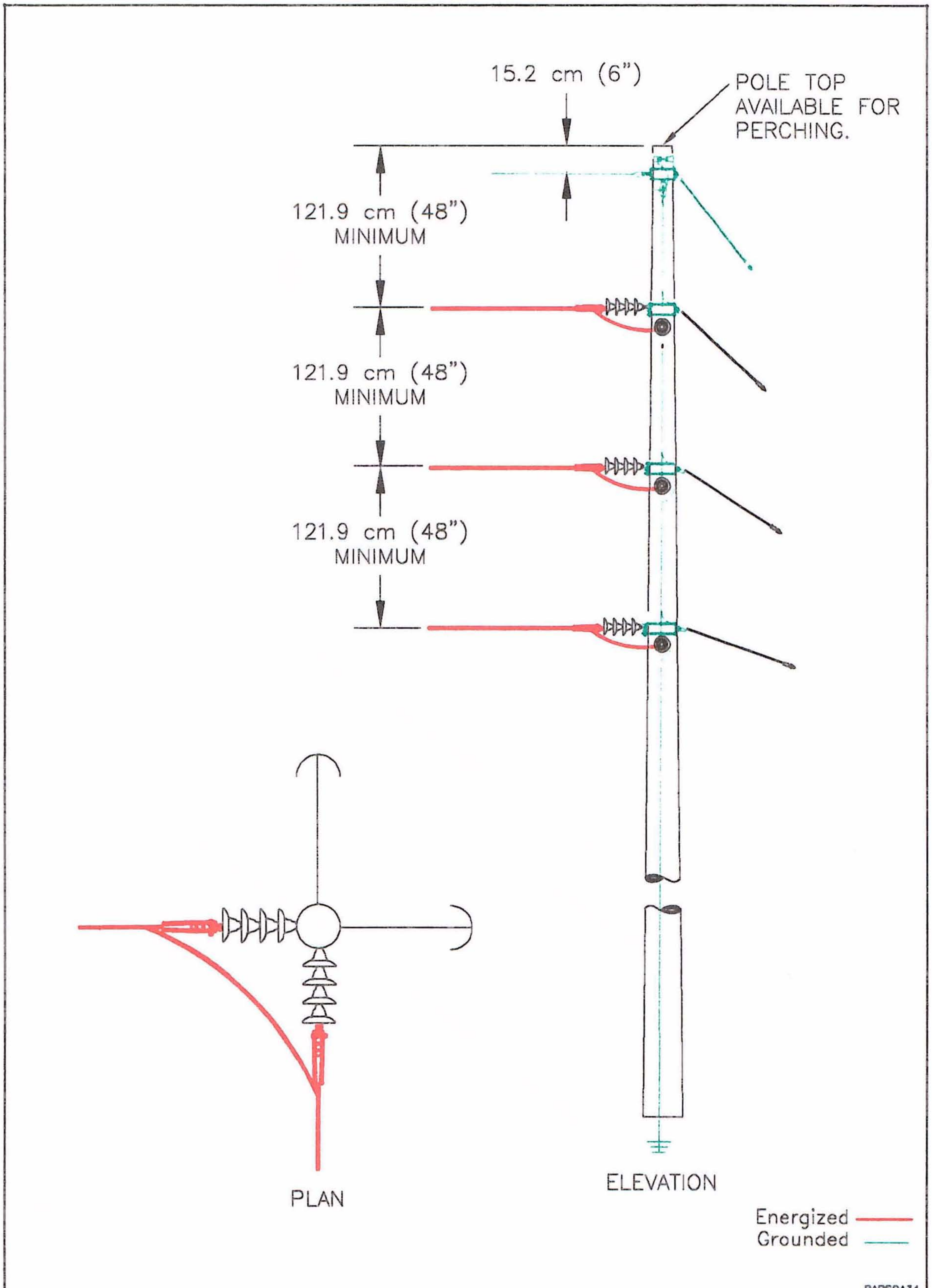

Figure 35. Three-phase vertical corner configuration/overhead groundwire on top. (Allows for pole-top perching and eliminates hazardous jumper wires shown in Figure 11.)

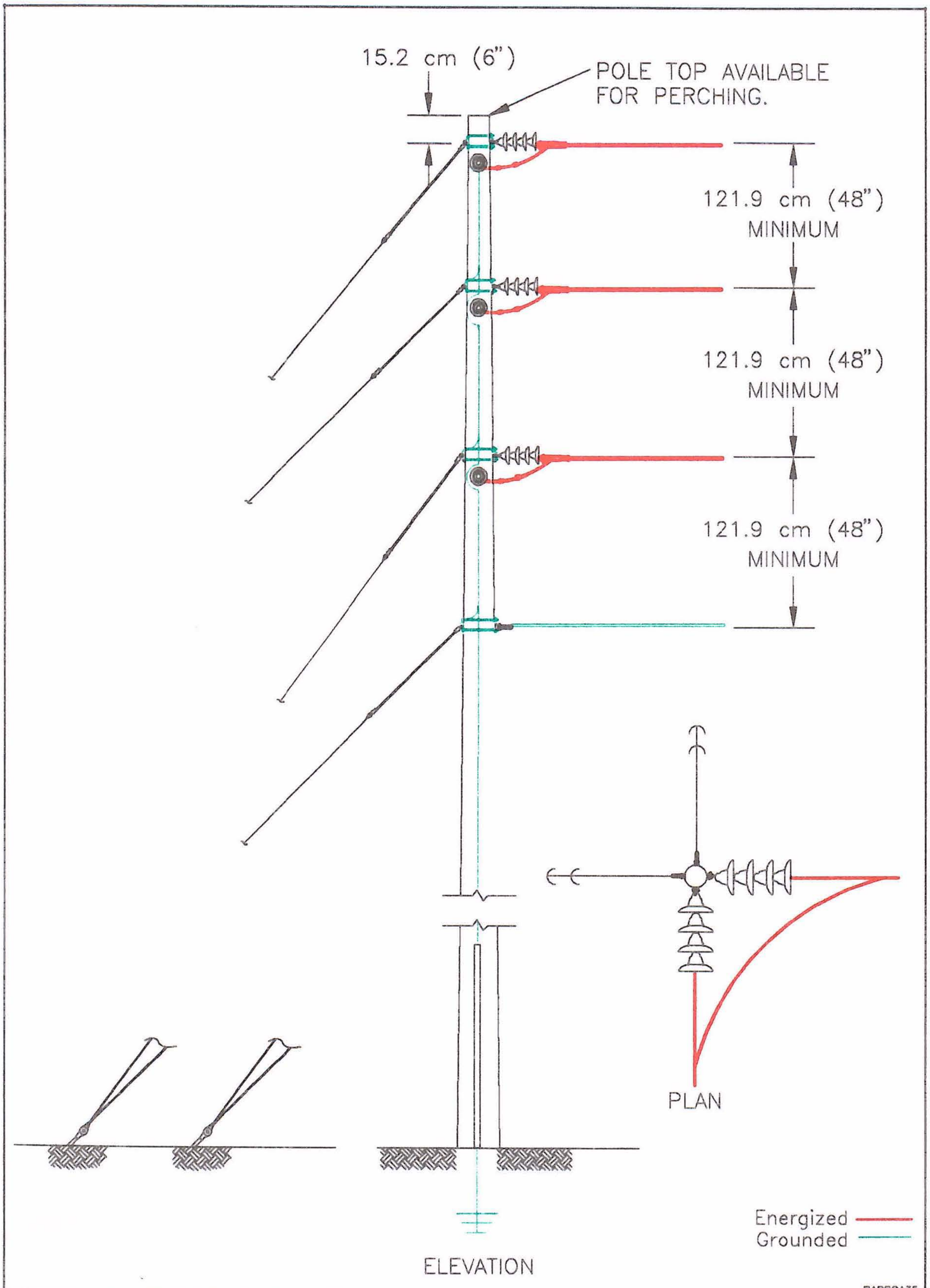

Figure 36. Three-phase vertical corner configuration/neutral on bottom. (Allows for pole-top perching and eliminates hazardous jumper wires shown in Figure 11.)

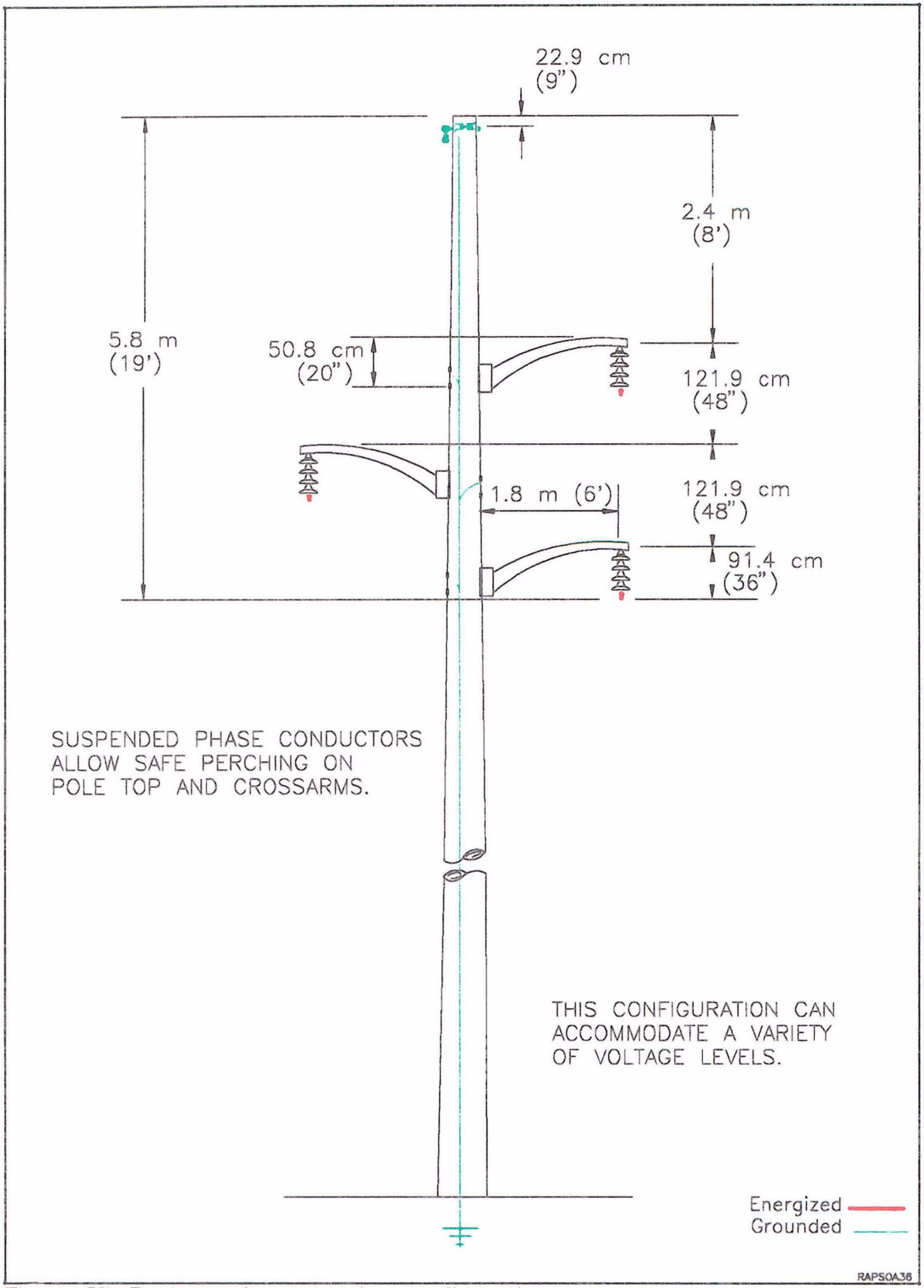

Figure 37. Raptor-safe suspension configuration.
(Allows for perching on poletop and all crossarms.)

Transformers and Other Equipment

For transformer banks and other associated equipment, designs should provide adequate spacing between jumper wires and other electrical connections (e.g., transformer bushings). In most cases it will be necessary to insulate such wires during new construction to ensure safe perching.

Table 1 presents a summary of the suggested practices for modifying existing facilities and for properly designing new facilities. This table offers guidelines; judgment is necessary to address specific problems and needs.

SUBSTATION MODIFICATION AND DESIGN

Substations are enclosed areas that terminate transmission and distribution lines. Electrocution of raptors at substations is rare, but may occur during pursuit of prey species that are attracted to substations (e.g., squirrels, passerine birds). David Stephenson (Ecologistics, pers. comm.) indicated that only 2 of 312 bird-caused substation outages recorded by Ontario Hydro between 1969 and 1990 were caused by raptors (owls). In one instance, a golden eagle caused an outage at a substation (PacifiCorp, unpubl. data); great horned owls also have caused substation outages, perhaps when using the buswork as roosting or feeding sites (D. Pearson, Southern California Edison, pers comm.; P. Quincy, Florida Power and Light, pers. comm.). Approximately 10-18% of similar wildlife electrocution and outage problems at substations have been caused by small birds (Stephenson 1991; E. Colson, Colson and Associates, pers. comm.; P. Quincy, Florida Power & Light, pers. comm.).

Preventive methods, dispersal methods, and physical removal may be used to eliminate animal species that attract raptors to substations (Lucid and Slack 1980). *Preventive* methods generally include altering the habitat surrounding the substation, modifying the substation design, or excluding entry of the animals (e.g., netting, enclosures). Some of these methods may be cost-prohibitive or impractical for most substations, but some equipment modifications (e.g., heat-shrink insulation, perch guards) may be as effective in substations as they are on distribution poles. (See Appendix C.)

Dispersal methods include auditory, olfactory, and pyrotechnic devices, or mock predators to discourage use of the facility by animals. Such approaches, however, are usually temporary: the animals become accustomed to the deterrents (Erickson et al. 1992). In addition, techniques such as playing recorded distress calls may be interpreted as harassment, and cannot be used on protected species without consultation and permission from the appropriate regulatory agency. *Physical removal* of animals that may attract raptors generally includes the use of chemical repellents, pesticides, or trapping. These methods may also require a permitting process, are frequently labor-intensive, and may be socially unacceptable.

Table 1. Summary of suggested practices.

Select appropriate options for modification or raptor-safe construction.

SUGGESTED PRACTICES	Single-Phase	Three-Phase	Corner Poles	Hori-zontal Post	Wish-bone	Trans Lines	Transf. & Other Equip-ment	Raptor-Safe Design
Set 152.4-cm (60-in.) minimum be- tween phases or phase-to-ground.	✓	✓		✓	✓		✓	✓
Cover groundwire with molding or insulation.	✓	✓		✓	✓			✓
Gap groundwire.	✓							
Cover phase conductor.	✓	✓		✓	✓			
Replace steel crossarm braces with wood braces.	✓	✓						✓
Add pole-top extension to achieve 152.4-cm (60-in.) minimum phase spacing.		✓						✓
Lower crossarm to achieve the 152.4-cm (60-in.) phase spacing.		✓						
Add perch guards to discourage perching.		✓	✓	✓	✓	✓	✓	
Add elevated perch with perch guards.		✓	✓	✓	✓	✓	✓	
Use longer crossarm for 152.4-cm (60-in.) minimum phase spacing.		✓	✓					✓
Add insulated extension link and cover all jumpers.			✓					
Insulate horizontal post insulator bases.				✓				
Insulate or cover bonding wires.		✓	✓	✓				
Add SFD to conductor.					✓	✓		
Insulate tension members on transmission tower arms.						✓		
Add bushing covers and insulate energized parts.							✓	
Add additional pole height.							✓	✓
Redesign to raptor-safe standards.	✓	✓	✓	✓	✓			✓
Change to vertical configuration on corner poles.			✓					
Use armless construction.	✓	✓						✓
Suspend conductors below crossarm.			✓	✓	✓	✓		✓
Increase length of horizontal post insulator.				✓				
Stagger or offset switches.							✓	
Increase phase spacing or phase-to-ground distance, to provide for raptor perching.	✓	✓	✓				✓	

The most successful program will integrate pest management with substation equipment protection (Pacific Gas and Electric 1994). A program focused merely on eliminating small birds and other wildlife may be an expensive (or even futile) approach to reducing hazards to raptors at substations. By contrast, using techniques suggested in this book to prevent perching or roosting in hazardous locations in substations may be the most cost-efficient approach for providing raptor protection.

RELATED ISSUES

Radio Interference (RI) and Television Interference (TVI)

Raptor protection modifications that affect conductor surfaces, or that place additional hardware close to conductors, may cause a noise problem for nearby radio and TV reception. Loose hardware (i.e., bolts, nuts, and washers that are not tightened), improper grounding or gaps between metal parts, improper tension on suspension-type insulators, and conductor surface imperfections (scratches, nicks, or protrusions) are common causes of RI and TVI on power lines. Any attachments to or modifications of the conductor-supporting hardware (braces, grounding attachments, crossarms, insulators, conductor coverings) should be selected carefully and discussed with design engineers to prevent RI and TVI.

Compact Designs and the Relationship to Raptor Protection

In responding to environmental concerns, utilities now often up-rate power lines on existing rights-of-way to meet increased power transfer capability of the lines, rather than build new lines on new rights-of-way. To cope with the need for higher voltages, design engineers have begun to use improved insulating materials and to reduce clearances and phase spacing (Electric Power Research Institute 1978). Compact designs are useful and often necessary. Characteristically they allow the following: (1) doubling or, in some cases, tripling voltage by reconfiguring existing lines, (2) increasing ground clearances by extending pole or tower height, (3) restricting conductor motion beyond certain limits in high winds, and (4) transmitting higher voltages while meeting NESC requirements and other safety requirements.

However, in using compact designs, clearances and phase spacing are necessarily reduced. If a line traverses a high raptor-use area, compact designs could cause raptor electrocutions because the phase spacing and grounding practices are less than those recommended above. The frequently used horizontal post-type insulators, for instance, have been shown to electrocute raptors (Figure 11, page 42). The authors therefore suggest examining carefully the need for compact designs when a line must be modified or constructed in a high raptor-use area. Inventories of raptors, food source, preferred poles, available alternative configurations, electrical reliability requirements, and other data must be obtained before determining the final design.

CHAPTER V

PERCHING, ROOSTING, AND NESTING BY RAPTORS ON POWER LINES

This chapter considers the benefits of power-line structures to raptors. Distribution poles and transmission structures are readily used for perching, roosting and nesting, and may increase the distribution and numbers of these species into areas lacking sufficient substrate for these purposes. Nest platforms may be installed on power-line structures to enhance populations of raptors while minimizing the risk to service.

Power lines may also provide *benefits* to raptor populations in the form of perching, roosting, and nesting substrate (U.S. Bur. Land Manage. 1974a, Marion and Ryder 1975, Pinkowski 1977, Craig 1978, Meents and Delesantro 1979, Edison Electric Institute 1980a, Ledger 1980, Hobbs and Ledger 1986, Postovit and Postovit 1987, Williams and Colson 1989, Steenhof et al. 1993). Following construction of a 230-kV transmission line in Colorado in 1974, raptor density increased near the line from 4-13 raptors/km^2 (before construction) to 21-32 raptors/km^2 (after construction) (Stahlecker 1978). Power-line structures were selected as perch sites for raptors because the elevated position provided an expansive view of the surrounding terrain (Olendorff et al. 1981). Golden eagles and red-tailed hawks used transmission towers as though they were natural substrates: the upper portions of the towers were used for resting and perching during the day, while the lower portions provided what little cover there was in the area for roosting at night (Smith 1985).

The extent to which a power line enhances or detracts from raptor habitat depends on habitat diversity (Pearson 1979). Topographically diverse habitats provide a wider array of prey choices and attract greater numbers of raptors. It may be prudent to modify existing distribution poles that are not built to the raptor-safe construction standards described in Chapter IV. Benson (1981) suggested that new lines in such habitat be located to encourage birds to take advantage of rock outcrops, cliffs, or other natural nesting sites, rather than power poles. This can be accomplished by locating poles away from the higher elevations offered by ridgelines and hills.

Many studies have documented raptor nesting on power-line structures (Table 2). Distribution poles and transmission towers are by far the most common types of artificial nest substrates used by raptors (Nelson 1982). Peregrine falcons have also nested successfully on

Table 2. Published accounts of raptor species nesting on transmission structures (T) and distribution poles (D). [Note that some studies refer only to nesting on power-line structures (P).]

Species	Structure	Reference
African hawk-eagle (*Hieraaetus faciatus*)	T	Tarboton and Allan 1984
	T	Allan 1988
American kestrel (*Falco sparverius*)	T	Illinois Power Company 1972
	P	Blue 1996
Aplomado falcon (*Falco femoralis*)	T	The Peregrine Fund 1995
Bald eagle (*Haliaeetus leucocephalus*)	T	Keran 1986
	T	Bohm 1988
	T	Hanson 1988
	T	Marion et al. 1992
Black eagle (*Aquila verreauxii*)	T	Boshoff and Fabricus 1986
	T	Ledger et al. 1987
Brown snake eagle (*Circaetus cinereus*)	T	Brown and Lawson 1989
Black-breasted snake eagle (*Circaetus gallicus*)	T	Brown and Lawson 1989
Ferruginous hawk (*Buteo regalis*)	T	Nelson and Nelson 1976
	T	Gilbertson 1982
	T	Gilmer and Stewart 1983
	T	Gaines 1985
	T	Electric Power Research Institute 1988
	T	Fitzner and Newell 1989
	T	Steenhof et al. 1993
	P	Blue 1996
Golden eagle (*Aquila chrysaetos*)	T	Anderson 1975
	T	Nelson and Nelson 1976
	T	Herron et al. 1980
	T	Electric Power Research Institute 1988
	T	Steenhof et al. 1993
	T	Blue 1996
Great horned owl (*Bubo virginianus*)	T	Gilmer and Wiehe 1977
	T	Steenhof et al. 1993
	P	Blue 1996
Greater kestrel (*Falco rupicoloides*)	T	Kemp 1984
Harris' hawk (*Parabuteo unicinctus*)	D	Ellis et al. 1978
	T	Whaley 1986
	P	Blue 1996
Lanner falcon (*Falco biarmicus*)	T	Tarboton and Allan 1984

Species	Structure	Reference
Martial eagle (*Polemaetus bellicosus*)	T T T	Dean 1975 Boshoff and Fabricus 1986 Hobbs and Ledger 1986
Mountain caracara (*Phalcoboenus megalopterus*)	P	White and Boyce 1987
Osprey (*Pandion haliaetus*)	D T T,D T D D D T T T T D P	Melquist 1974 Detrich 1978 Henny et al. 1978 Prevost et al. 1978 Henny and Anderson 1979 Van Daele et al. 1980 Jamieson et al. 1982 Austin-Smith and Rhodenizer 1983 Fulton 1984 Keran 1986 Hanson 1988 Vanderburgh 1993 Blue 1996
Pale chanting goshawk (*Melierax canorus*)	T	Brown and Lawson 1989
Prairie falcon (*Falco mexicanus*)	T P	Roppe et al. 1989 Blue 1996
Red-tailed hawk (*Buteo jamaicensis*)	T T T T T T T T P	Nelson and Nelson 1976 Ellis et al. 1978 Fitzner 1980a Gilbertson 1982 Brett 1987 Electric Power Research Institute 1988 Fitzner and Newell 1989 Steenhof et al. 1993 Blue 1996
Eurasian kestrel (*Falco tinnunculus*)	T	Boshoff et al. 1983
Swainson's hawk (*Buteo swainsonii*)	D D T P	Olendorff and Stoddart 1974 Fitzner 1978 Fitzner and Newell 1989 Blue 1996
Tawny eagle (*Aquila rapax*)	T T	Dean 1975 Tarboton and Allan 1984
White-backed vulture (*Gyps africanus*)	T	Ledger and Hobbs 1985
Zone-tailed hawk (*Bureo albonotatus*)	P	Blue 1996

a transmission structure in northern Utah in 1994 (D. Bunnell, Utah Division of Wildl. Res., pers. comm.). Although most species that nest on power-line structures inhabit open, arid habitats, one notable exception is the osprey. In a mail survey of utility companies, respondents most frequently named ospreys as nesting on power-line structures, followed closely by red-tailed hawks (Blue 1996).

Red-tailed hawk nests (n=142) were found in all but the lowest tower sections of a transmission line in Oregon and Idaho (Steenhof et al. 1993). Common raven (*Corvus corax*) seemed the least versatile, with 98% (n=408) of the nests found at the uppermost part of the towers. Seventy-two percent (n=29) of golden eagle nests and 48% (n=52) of the ferruginous hawk nests were located on nesting platforms installed on the towers. The Electric Power Research Institute (1988) reported that all hawk and eagle nests were located in the latticework in the central section of the transmission towers.

Non-raptorial birds also use power-line structures. Engel et al. (1992a) documented the largest known communal roosting congregations of common ravens in the world on structures of a 500-kV transmission line in southwestern Idaho. As many as 2,103 ravens were counted in a single roost of adjoining transmission towers 3 years after construction of the power line in 1981. The towers appeared to present an attractive alternative to natural roost sites, offering increased safety from predation and close proximity to local food sources.

BENEFITS TO RAPTORS

Some reports document drawbacks to power-pole nesting, such as nests blown away by wind, due to the openness of distribution-pole nest locations (Gilmer and Wiehe 1977, Postovit and Postovit 1987). Some investigators have reported electrocutions of raptors as a result of nesting activities on poles or towers (Ledger et al. 1987, Harmata 1991). These usually involved young inexperienced birds, which seem particularly vulnerable shortly after leaving their nests (Benson 1980, Meyburg 1989). However, most researchers and industry biologists noted advantages to raptor nesting on power poles and, primarily, transmission towers. Unlike nests on cliff eyries with southern exposures, tower nests on beams and cross-braces offer shading for the birds (Anderson 1975, Nelson and Nelson 1976, Steenhof et al. 1993). In addition, the height of the nests and their openness (compared to a heat-absorbing cliff) provide air circulation for cooling. Tower-nesting raptors may also benefit by increased protection from ground predators and range fires (Steenhof et al. 1993). Perching and nesting opportunities on power lines result in population increases of some raptors in areas where natural substrates are limited (Stahlecker 1978, Newton 1979, Yoakum et al. 1980, Fitzner and Newell 1989, Steenhof et al. 1993). Examples of population enhancement include the following:

- Fitzner and Newell (1989) monitored new 230-kV and 500-kV lines on the Hanford Site (south-central Washington) between 1979 and 1988. In 1979, soon after completion of the lines, only a single red-tailed hawk pair nested on these lines. By 1988, 19 red-tailed hawk, ferruginous hawk, and Swainson's hawk pairs were nesting on the lines.

- Within 10 years of construction of a 500-kV transmission line in 1980 across eastern Oregon and southern Idaho, 133 pairs of raptors and ravens were nesting on the line (Steenhof et al. 1993). In 1989, nests included golden eagles (n=8), ferruginous hawks (n=11), red-tailed hawks (n=33), and common ravens (n=81). A great horned owl nest was also found in 1987. Nest densities of these species on surrounding natural substrate remained as high as pre-construction levels, but nest success on the towers was similar to or higher than that of natural substrates.

- While the number of ospreys nesting on natural substrates remained constant in the Willamette Valley, Oregon (13 pairs in 1976, 12 pairs in 1993), the number of pairs nesting on power-line structures increased from 1 in 1977 to 66 in 1993, suggesting that nesting on power poles is a learned response (Henny and Kaiser 1996).

Other studies also report high productivity for raptor species nesting on power-line structures, compared to the productivity of raptors nesting on surrounding natural substrate (Van Daele et al. 1980, Gaines 1985, Olendorff 1993a).

DISADVANTAGES FOR LINE MAINTENANCE

Raptor use of power-line facilities presents problems for line maintenance. Raptor perching and nesting have caused electrical outages. As noted in earlier chapters, several investigators reported flashovers from excretions on conductor insulators (Ledger 1980, Gilbertson 1982, Smith 1983). Raptor nests may also cause outages and pole fires when nest material contacts energized hardware (Nelson and Nelson 1976, Stocek 1981, Hobbs and Ledger 1986, Shank 1988, Vanderburgh 1993).

Utility companies have attempted to deal with this problem in a number of ways. Shields affixed below the latticework on transmission towers prevent the accumulation of feces from roosting ravens (Engel et al. 1992b). Nest removal was a common practice (Stocek 1972, 1981; Fitzner 1980a; Toner and Bancroft 1986). Other solutions included trimming the nest material away from the conductors (Hobbs and Ledger 1986, Toner and Bancroft 1986) and installing perch guards or other devices to prevent nesting (Van Daele et al. 1980, Stocek 1981). These approaches are labor-intensive and often unsuccessful: many raptors are tenacious in rebuilding their nests (Hobbs and Ledger 1986).

Consequently, a number of utilities concluded that *accommodating* the birds' nesting behavior offered more advantages, including work efficiency and positive publicity associated with providing nesting opportunities for these species. Local utility companies removed nests from utility poles and towers on the Hanford Site in south-central Washington during the

1970's, believing that they were fire hazards. When this practice was discontinued in 1974, the population of red-tailed hawks increased 3-fold (from 9 pairs to about 25 pairs) within 3 nesting seasons (Fitzner 1980a). In 1977, the Bonneville Power Administration directed its employees to move nests to less dangerous places on transmission structures (Lee 1980). Other companies began leaving nests in place on distribution poles, but reduced the likelihood of outages by installing additional crossarms and lowering the conductors to safer positions below nests (Oregon Wildlife 1976, Stocek 1981, Toner and Bancroft 1986, Conn. Dep. of Env. Protect. Wildl. Bur. 1987). It is the policy in South Africa that no raptor nest may be removed at any time unless it is actually a threat to the power supply (Ledger et al. 1993). As a result, many kinds of raptors now regularly nest on transmission towers in South Africa.

NESTING PLATFORMS

The most successful raptor management/line maintenance technique has been the installation of nesting platforms in safe places on towers or poles. Dummy poles and artificial nest structures for ospreys were successfully installed during the late 1940's and early 1950's by several power companies in the northeastern United States (Electric Reporter 1946; Electric Meter 1949, 1953; Investment Dealers' Digest 1950). Some investigators reported poor use of platforms because they were inappropriately placed on transmission towers (Stahlecker 1979) or because natural sites were readily available (Detrich 1978). However, most published reports documented success by raptors using nest platforms (Nelson 1978, Stocek 1981, Ledger et al. 1987, Hanson 1988, Shank 1988, Steenhof et al. 1993, Vanderburgh 1993). Platforms on dummy poles reduced nesting on power poles, while maintaining productivity of osprey in the local breeding population (Austin-Smith and Rhodenizer 1983). Steenhof et al. (1993) reported that nesting success for ferruginous hawks on platforms (89%, n=19) was higher than nesting success on cliffs (58%, n=38) or other natural substrates (20%, n=5). Nest platform installation was reported as the most common form of enhancement by utility companies in recent years (Blue 1996).

NEST PLATFORMS ON DISTRIBUTION POLES

Nest platforms are generally more necessary on distribution poles (with their closely spaced conductors) than on transmission structures. Platforms provide for the needs of the birds, while preventing electrocutions and electrical outages. Artificial nesting substrate in a variety of designs is accepted by nesting raptors, especially ospreys. In November 1979, crews erected eight platforms made from discarded wooden cable spools near existing power-pole nests along the Indian Path power-line corridor in Lunenburg County, Nova Scotia; osprey subsequently used the platforms (Austin-Smith and Rhodenizer 1983). PacifiCorp routinely installs nest platforms above energized conductors on poles where problem nests of osprey and Buteo hawks are found (Figure 38) (PacifiCorp, unpubl. data). Florida Power Corporation solved its osprey nesting problem on double-crossarm constructions by installing fiberglass nesting platforms above the conductors (Figure 39). Excreta accumulation on insulators

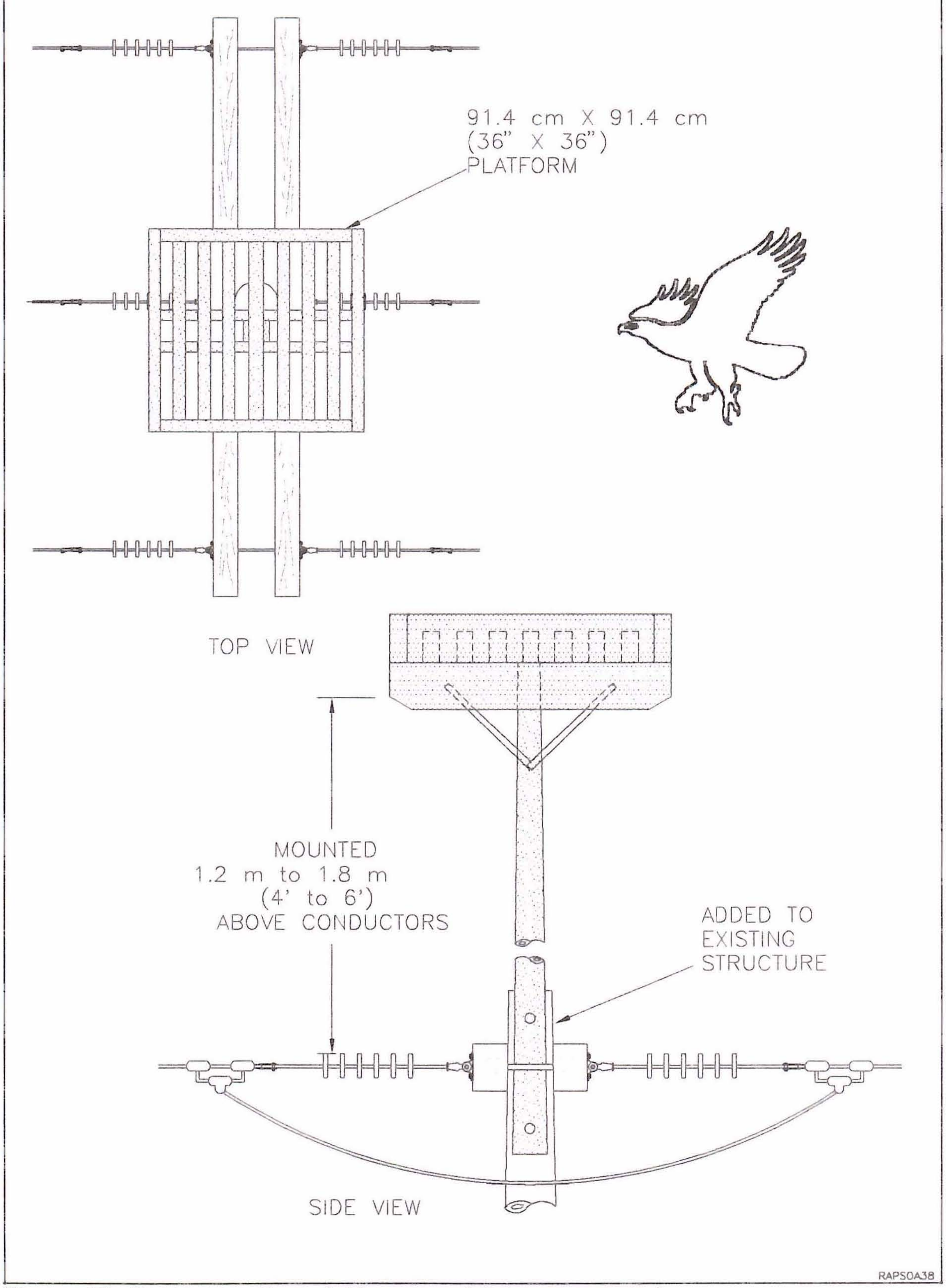

Figure 38. Raptor nesting platform used by ospreys and Buteo hawks (PacifiCorp).

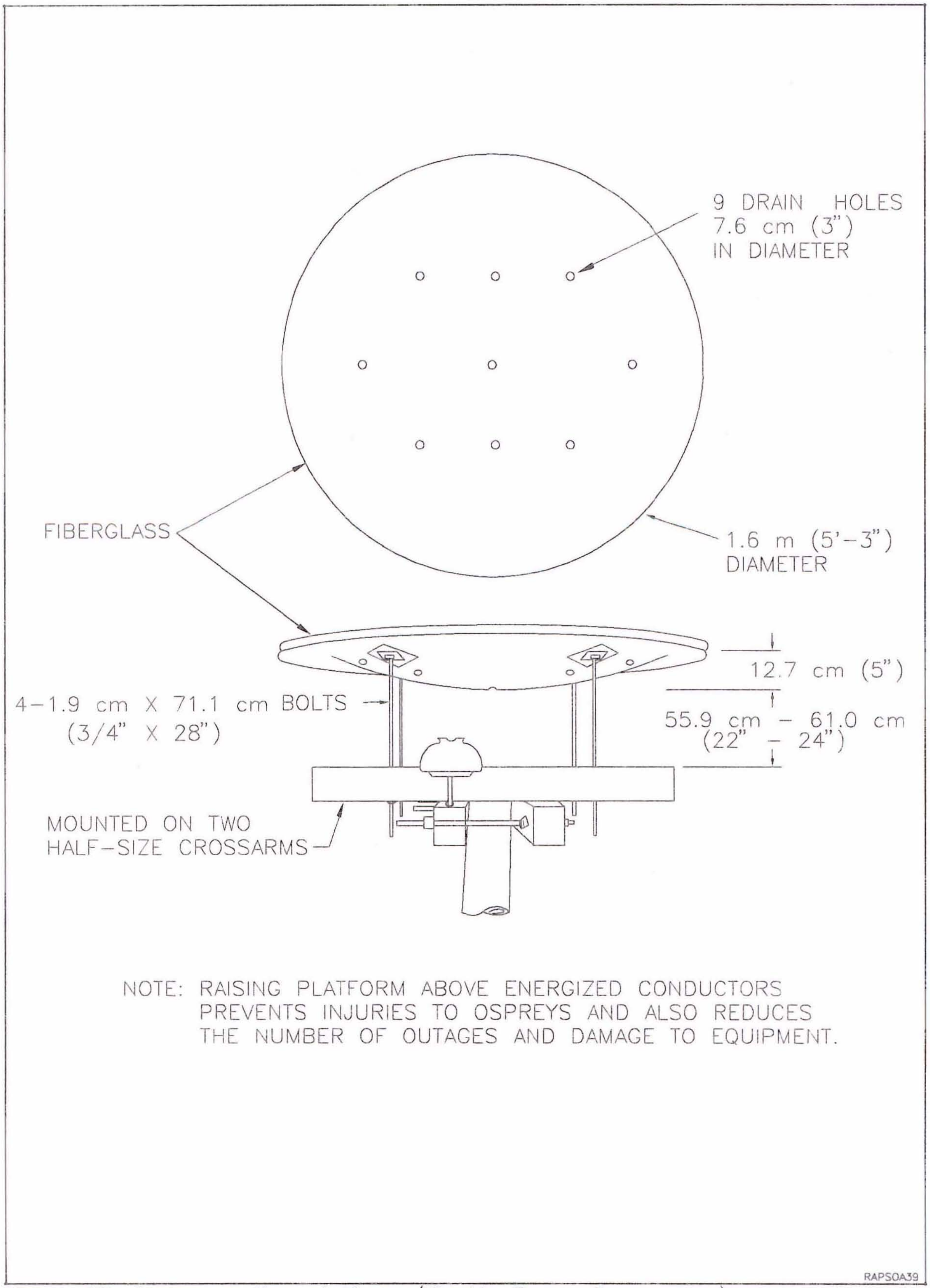

Figure 39. Osprey nesting platform (Florida Power Corporation).

through the drain holes in the platforms was apparently not a problem with this design (D. Voights, Florida Power Corporation, pers. comm.). Idaho Power Company has developed another platform design that is placed directly on the problem pole or on a pole set adjacent to the line near the location of a problem nest (Figure 40) (Idaho Power Co., unpubl. data). The platform must be placed close to the original nest location and at a height that is attractive to raptors. The placement of sticks (or part of the original nest) on the platform serves to entice the birds to the new nesting location. Additional nesting platform designs are used by other utility companies throughout the United States.

There may be times, however, when nesting must be discouraged. For example, an osprey nest on top of a transmission structure in Portland, Oregon, began to block the strobe light required by Federal Aviation Administration (FAA) regulations. PVC material banded to the crossbraces adjacent to the light prevented the placement of nest material. The birds eventually rebuilt their nest on a platform provided on the side of the tower (PacifiCorp, unpubl. data). A similar approach has been used successfully on distribution poles (Van Daele et al. 1980). Nest construction was discouraged by installing half of a large PVC tube over the crossarm position (Figure 41). The tube prevented nest material from accumulating on top of the crossarms during initial nest construction.

NEST PLATFORMS ON TRANSMISSION STRUCTURES

The wide spacing of conductors on transmission lines generally allows for raptor nesting without problems for electric operations (e.g., Hobbs and Ledger 1986). Furthermore, the latticework of steel transmission towers provides abundant opportunities for raptor nesting without the aid of nesting platforms.

Appropriately placed platforms on transmission structures are excellent mitigation for construction of new lines, and may increase populations of some raptors in areas lacking suitable nesting substrate. For example, in 1980 and 1981, the PacifiCorp Malin-to-Midpoint 500-kV transmission line was constructed across eastern Oregon and southern Idaho (Steenhof et al. 1993). In cooperation with the BLM, PacifiCorp installed 37 nesting platforms designed by Morlan W. Nelson of Boise, Idaho (Figure 42) (Nelson and Nelson 1976, Olendorff et al. 1981, Nelson 1982). Raptors and ravens began nesting on the transmission structures within one year of construction. Although only 2% of the towers had platforms, 72% (n=29) of the golden eagle and 48% (n=52) of the ferruginous hawk nesting attempts were on the artificial platforms from 1981 until 1989. Nineteen (51%) of the platforms were used at least once. Steenhof et al. (1993) suggested that nesting by raptors should be considered in certain habitats during the construction of transmission lines. Specifically, where the line traverses miles of treeless habitat, the use of artificial structures can enhance raptor populations.

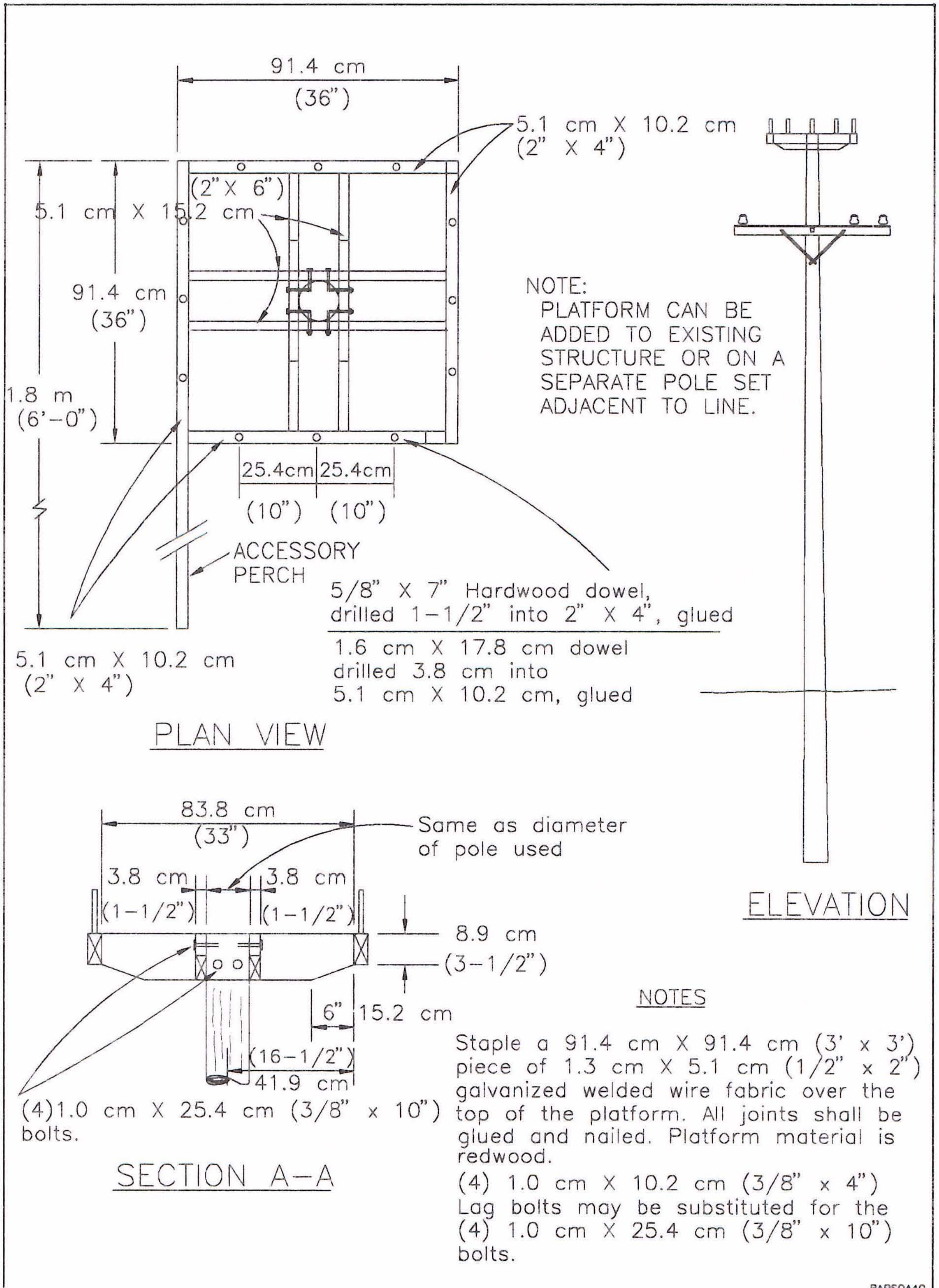

Figure 40. Osprey nesting platform details (Idaho Power Company).

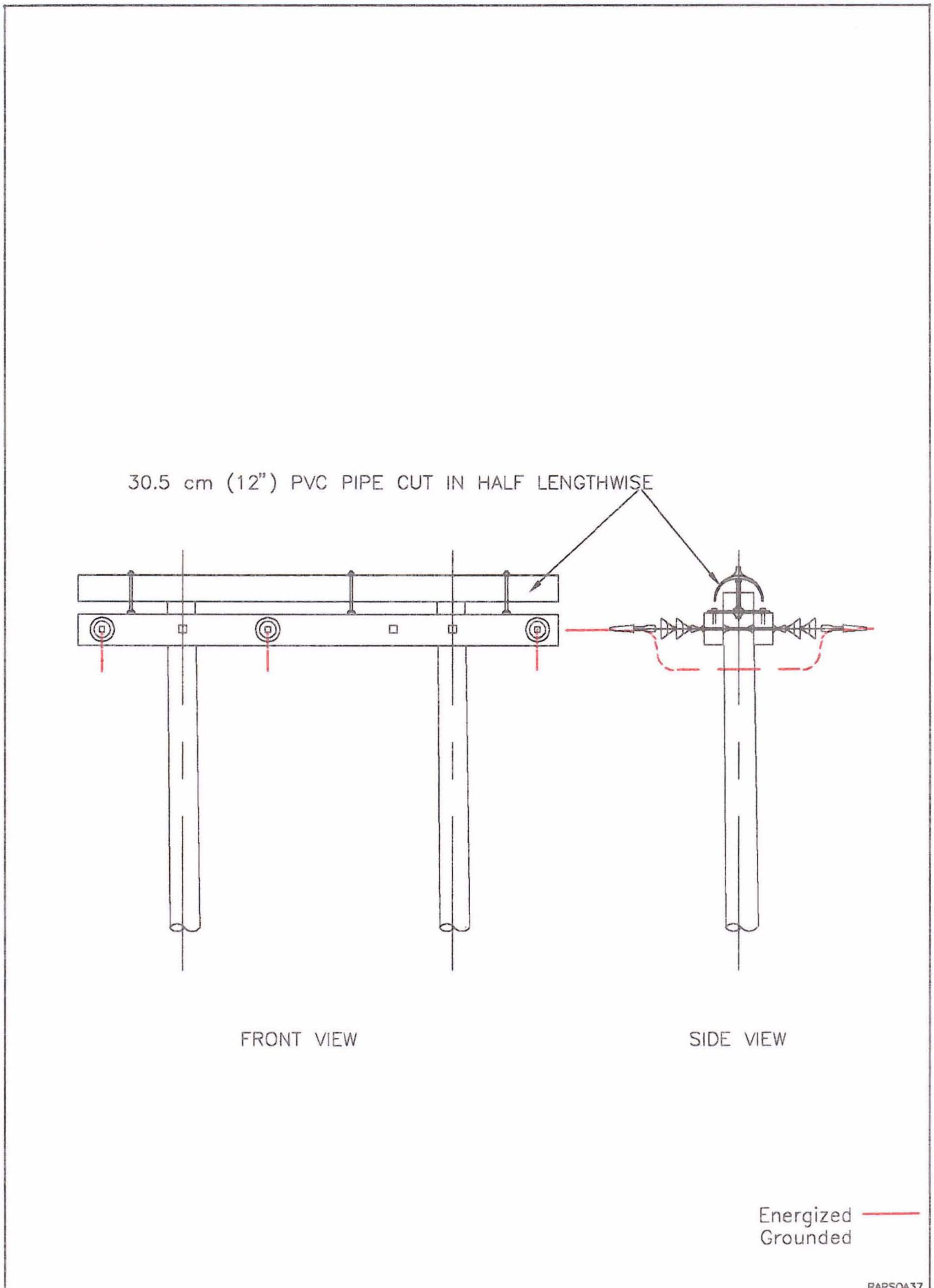

Figure 41. Nesting deterrent device (PacifiCorp).

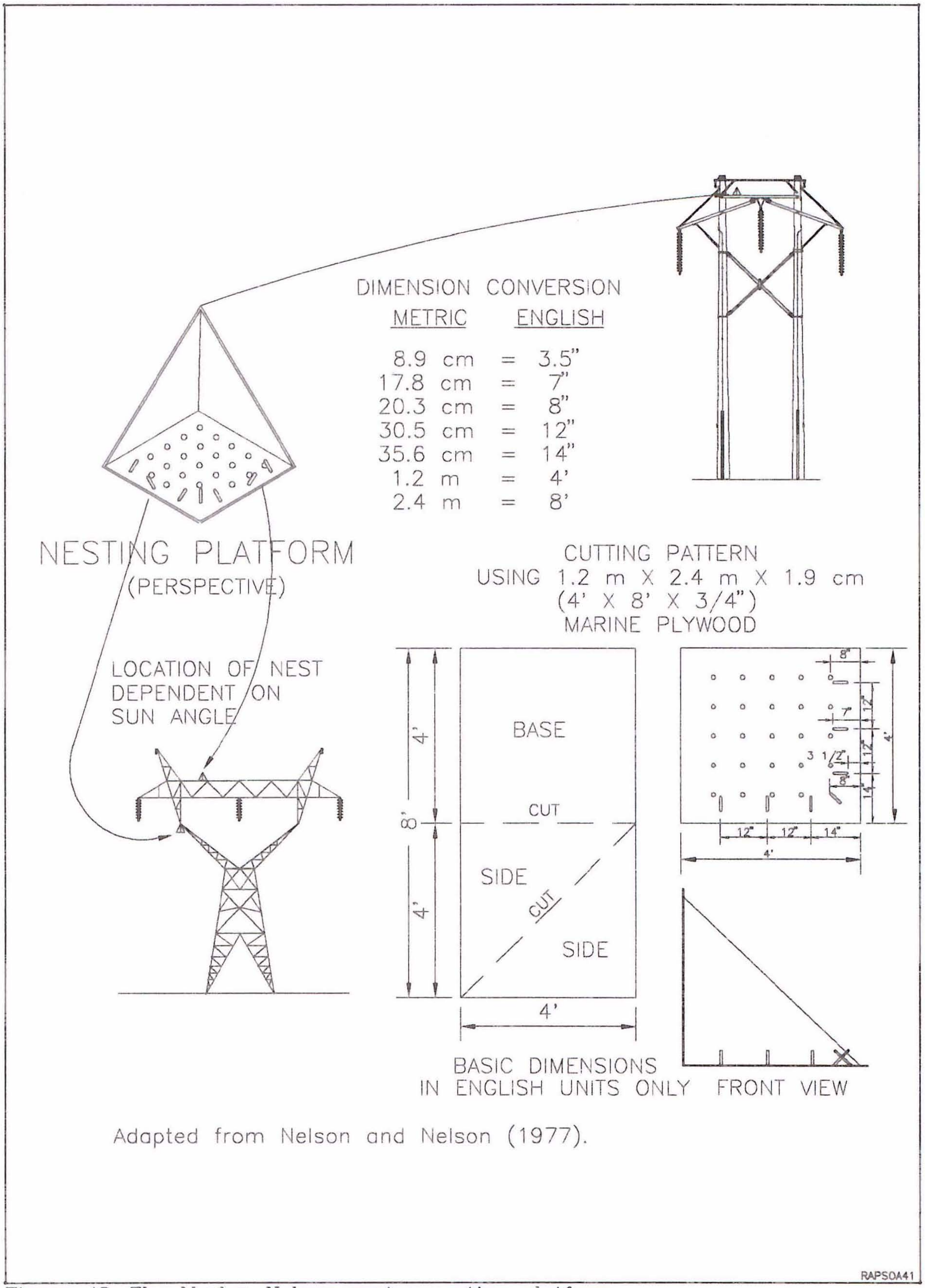

Figure 42. The Morlan Nelson raptor nesting platform.

DESIGNING AND INSTALLING NESTING PLATFORMS

In planning the use of nesting platforms, the biologist and engineer should bear in mind the following considerations.

1) Nest platforms should be placed on or near poles and towers that have been used previously by nesting raptors (Lee 1977). Although this may not increase raptor density, it may increase line reliability (by moving the nests to safer positions) and nesting success (by minimizing wind damage and heat prostration of unshaded young raptors).

2) Biologists should provide guidance, based on species' needs, on where to locate platforms (e.g., ravens prefer higher locations than Buteos; Steenhof et al. 1993).

3) Platforms should be placed where conductors and energized hardware will not be fouled by dropped nest material or excrement (Nelson 1980a). Nest platforms erected 121.9 cm (48 in.) above distribution conductors have not been known to cause electrical outages (PacifiCorp, unpubl. data).

4) Because raptors (particularly eagles) use updrafts to save energy when hunting and bringing prey to nests, nest platforms should be placed on poles or towers near the face of a rolling hill or escarpment that deflects winds upward (Nelson 1980a). However, platforms are not needed near escarpments or forests along waterways where adequate natural nest sites exist (Nelson 1979a).

5) Discretion should be used when placing nesting platforms near sensitive wildlife sites (e.g., grouse leks, colonies of burrowing owls). Wildlife using such sites might fall prey to eagles and other raptors that nest on the platforms. For example, ground-nesting burrowing owls are preyed upon by larger diurnal raptors (Fitzner 1980a).

6) In most cases, it is prudent to locate platforms away from intensive human activity (e.g., away from roads and trails) (Stahlecker 1975, Baldridge 1977). The site should be free from chronic harassment. However, Nelson (1980a: 1) states that "It is obvious under current situations that . . . birds [raptors] will nest very close to human activity, from 50 to 250 yards, if the site has the proper prey base." Disturbance should be avoided, where possible.

7) Nest platforms may not be needed on all types of transmission towers, because the metal latticework of some steel towers and the double crossarms of H-frame wooden construction provide adequate nest substrates (Lee 1980, Steenhof et al. 1993).

8) More study is needed to evaluate the success and productivity of raptors using nest platforms on transmission structures. The success reported to date (e.g., Steenhof et al. 1993) is in part attributable to the fact that the platforms used by raptors were

located near very high-density raptor areas. Further, more study of the influence of artificial platforms on raptor nesting density is needed.

9) Birds should be monitored as they select nesting locations. Monitoring after line construction may provide clues to the most appropriate locations for nest platforms and, ultimately, increase the chances of success. It may also be possible to provide platforms that keep birds from selecting inappropriate locations for nests.

CHAPTER VI

COOPERATIVE MANAGEMENT OF THE ELECTROCUTION ISSUE

To manage the electrocution issue effectively, utility companies and resource management agencies should work together to integrate their efforts. The goal is to document bird mortalities so that appropriate remedial actions may be taken and follow-up studies done to assess effectiveness. In this chapter, options for cooperative management are described.

Since the issue of raptor electrocution was identified in the early 1970's, many poles have been modified, and many new power lines in non-urban areas have been built to raptor-safe construction standards (PacifiCorp, Idaho Power Co., unpubl. data). However, as human populations grow, so will electric power distribution networks. Given the continued occurrence of electrocution, particularly outside the United States, efforts to solve the problem must continue (Ledger et al. 1987, U.S. Fish and Wildl. Serv. 1988, Meyburg 1989, Ferrer et al. 1991, Harmata 1991, Garrett 1993).

In the United States, this need continues, in part because distribution poles last for 30-60 years, depending on site conditions. Many were erected long before the extent of the raptor electrocution problem was understood or before raptor-safe construction techniques were known, and these poles may remain in service for years to come. A conservative estimate of total circuit miles of distribution lines in the United States in 1993 (22-kV to 70-kV lines only) exceeded 483,000 km (300,000 mi.) (Edison Electric Institute 1993: 97). Despite the positive steps made to reduce electrocution hazards over the past 25 years, there are probably millions of distribution poles throughout the United States and the world that could electrocute large birds. Retrofitting such a large number of poles is prohibitively expensive. Therefore, management efforts should continue to concentrate on those poles responsible for most electrocutions.

PRIORITIZING AND COOPERATING

It would be convenient to be able to predict accurately which poles present the most significant hazards, so that management actions could be planned. Some pole configurations are clearly more hazardous (see Chapter IV); therefore, poles must be prioritized for remedial action. Factors such as topography, prey populations, traditional migration pathways, and habitat influence the use of particular poles and are helpful predictors. However, it is difficult to anticipate events that might affect raptor use of poles in an area: e.g., drought, natural population cycles, changing land use practices, and changes in the numbers and distribution of prey. Such variations may increase or decrease use of existing power poles and the probability of electrocution.

To manage this issue most effectively, utility companies and resource management agencies should integrate their efforts (Hobbs and Ledger 1986, Colson 1993, Gauthreaux 1993). Resource agencies are mandated to manage the public's natural resources effectively and to enforce laws enacted to protect these resources. Utility companies are charged with providing cost-effective, reliable electric power to their customers. Together, they can document problems, identify needs, and undertake solutions. Action must respond to real-world constraints, including utility economics, time, and personnel commitments, as well as the public concerns for natural resources and the goals of the resource agencies. Through cooperation, agencies can benefit from the bird mortality data collected by utilities. Actions taken by utility companies to reduce bird mortalities will comply with laws protecting avian resources, promote good public relations, and reduce electrical outages (Stocek 1981, Hobbs and Ledger 1986, Williams and Colson 1989, Lewis 1993, Nobel 1995).

ISSUE MANAGEMENT

MORTALITY REPORTS

The first step in cooperative management is to identify a problem, usually through bird mortality data. Reports of bird mortalities near electrical facilities are essential for planning actions needed to reduce future electrocutions. Recorded mortalities can help to identify dangerous poles or lines; and they may be used to document success of modifications in reducing electrocutions.

Power lines in need of action, however, are frequently difficult to identify. Records collected over 10 years indicate that only 14% of eagle mortalities resulted in sustained electrical outages (PacifiCorp, unpubl. data). Most bird electrocutions result in only momentary outages that do not require a service call to restore power. Momentary outages are often attributed to unknown causes, and many mortalities may therefore go unnoticed. Carcasses typically are found by company personnel during routine patrols and line maintenance activities, or occasionally by landowners and other individuals during recreational activities. Many power lines are located in remote areas where carcasses may be carried off by scavengers.

Since the early 1970's, some utility companies have adopted internal procedures that include standardized reporting of bird mortalities, both to identify areas to prioritize management and to monitor the effect of management actions. A generic raptor electrocution reporting form was distributed by the RUS to public utilities in 1985. An EEI questionnaire distributed to member utilities in the fall of 1994 indicated that nearly 40% of respondents provided some mechanism within their companies for reporting bird mortalities (Blue 1996).

For utility companies with established reporting procedures, methods generally fall into two categories:

1) a systematic approach that incorporates reporting of bird mortalities into an existing company data collection system, or

2) an opportunistic approach in which information on mortalities is recorded incidentally during other work-related activities.

Many utility companies employ the latter approach; that is, employees are asked to record information on bird mortalities as they are found, usually related to electrical outages, or during routine maintenance surveys. Records may also include reports received from the agencies and the public. A reporting form may be used for data collection. Pertinent data includes the location of the dead bird, habitat conditions of the site, visual signs of death, and the type of pole configuration. These reports are generally submitted to the utility company's environmental services department. Some companies keep this information in a database to facilitate data analysis and retrieval. At least one company is using a geographic information system (GIS) to document patterns of mortalities and facilitate decision-making on pole modification, likelihood of future mortalities in particular areas, and siting of new lines (T. Nobel, Salt River Project, pers. comm.).

A systematic method of data collection integrates bird mortality reporting with other reporting systems in the company. For example, PacifiCorp includes bird mortality reports in the company's outage reporting system (Garrett 1993). Personnel input bird mortality data into this system, whether the data are related to an electrical outage or not. Mortalities are categorized into types (e.g., eagles, hawks, owls, waterbirds, etc.), and data recorded for subsequent computer entry. Frequencies of bird mortalities for specific time periods, regions, power lines, or even particular poles may then be reviewed as needed. Entry of data into an existing company record system promotes employee acceptance, thorough data collection, and efficient data review.

OPTIONS FOR MANAGEMENT ACTION

To address this problem adequately, utility companies and resource agencies will be most effective in addressing the problem(s) when they collaborate to take appropriate action. Several options are available, including working agreements, standard operating procedures, training, and site-specific prescriptions. The discussion below centers on those useful approaches for moving from reporting mortalities to remediating poles and preventing future electrocutions.

Working Agreements Between Agencies and Utilities

A cooperative working agreement is key to translating company and agency desires, including legal and economic constraints, into action (Nobel 1995). It is most useful to establish an informal written framework for cooperation, ideally with enough detail to assure both compliance with the law and applicability in the field. (Where formal requirements must be met, a more formal written document may be appropriate.) The agreement may describe steps to manage an electrocution problem, or to manage specific nests that may affect service reliability or result in electrocutions. The agreement may stipulate differences for reporting information on eagles or other species that receive special management consideration. Additional requirements may be necessary for banded or injured birds, as well as procedures for carcass disposal of different species. Requirements for nest management may differ for occupied and unoccupied nests, and for eagles and other birds. There should also be provisions for immediate action in emergency situations without prior agency approval.

Agencies and utility companies may see the issue from different points of view; thus the agreement may be a negotiated understanding that represents the best interests of all parties. Interpretation of laws, regulations, and agency goals may vary, for instance, between state wildlife agencies and regions of the USFWS. Therefore, if a company's service territory includes more than one state, separate agreements may be necessary to reflect local priorities. PacifiCorp has developed seven separate agreements, one for each state in its service territory (Garrett 1993). Each is different in detail but similar in overall purpose.

Standard Operating Procedures and Training

Standard operating procedures (SOPs), guided by company policy and working agreements with agencies, translate goals into action in the field. SOPs may include specific procedures for data collection and entry into a data base, and discussion of remedial action and hardware available for retrofitting problem poles.

The key to acceptance and use of SOPs by company employees is training (Nobel 1995). A training program may include written information such as fliers or pamphlets, a prepared video, or even a formal presentation to employees. The presentation may include a discussion of background issues, a detailed description of the SOP, bird identification, and remedial actions. A question-and-answer session should also be included to increase participation and to clear up areas of confusion. Personnel most likely to find bird mortalities (linemen, line patrolmen, meter readers, line construction personnel) should receive SOP training, but a heightened awareness must begin with management personnel. Employee compliance begins only with a conscientious management commitment to address this issue.

Utility company employees trained in procedures for reporting mortalities and remedial action contribute more to an understanding of this issue. Following implementation of a bird mortality reporting program, for instance, the mean number of mortalities reported annually by employees of one company increased from 12 between 1972 and 1984 to 39 between 1985 and 1991 (Idaho Power Co., unpubl. data). PacifiCorp personnel in southern Oregon have undergone extensive office and field training because of the high-density eagle population in their service area. Heightened awareness is reflected in the number of eagle carcasses found that are not related to sustained electrical outages. As noted above, most bird electrocutions do not cause sustained electrical outages. Although company-wide data indicated that 14% of eagle mortalities were found when responding to a sustained outage, only 5% of eagle mortalities reported by this company's personnel in southern California were outage-related. Employees, made more aware by training, reported more eagle mortalities not related to outages.

Site-Specific Prescriptions

Factors that cause electrocution hazards are complex and may be site-specific. As Ledger (1984) suggested, field observations contribute substantially to effective decision-making. When a problem area is identified, a site visit may be necessary to determine the best course of action. Such a visit not only allows for an assessment of site conditions, but also provides a format for interested parties to reconcile their points of view. The utility may be most concerned with finding an engineering solution that is cost-effective and assures reliable electrical service--all within a reasonable timeframe. The top priority of the resource agency may be to eliminate future mortalities as soon as possible. The goal of the site meeting is to find common ground. The value of a working agreement comes to bear at this point, because appropriate contacts among state, federal, and utility representatives will already have been established.

Site meeting attendees should first agree on the severity of the problem, based on the company's and agency's data, and then establish a timeframe for action. Utility engineering and operations personnel can provide guidance on line modifications, and biologists can provide input on the affected species. The timeframe for action should be based on budget and staffing constraints, as well as on biological considerations that affect species vulnerability to electrocution (e.g., time of migration, distribution of prey). In this way, necessary action and a work schedule may be agreed upon in a spirit of cooperation. Thereafter, mortality reporting provides a mechanism for monitoring the effectiveness of the remedial action.

1996 AND BEYOND

Agencies, utilities, and individuals concerned with reducing electrical hazards to birds must recognize two basic principles: that electricity is essential in human society, and that there will continue to be a mandate to protect avian resources. Because overhead power lines are a component of raptor habitat, and because any large bird perching on power-line structures faces some degree of risk, electrocutions will occur in the future. The goals are to minimize electrocutions, and to reduce the number of and potential for electrical outages.

Integrating the efforts of resource management agencies, land use planners, utility companies, and the concerned public can provide the means to move from crisis management to proactive planning. Mortality reports allow managers and technical specialists to prioritize sites that need action; they also increase our knowledge of effective pole modifications. Communication among agencies, companies, and the public facilitates decision-making and accomplishes mutual goals. Research conducted during the preparation of this document suggests that there is a great amount of unpublished data available in utility and agency files. This information, though at present largely unavailable for review, could contribute significantly to our understanding of the effectiveness of various remedial actions (i.e., power-line modifications) as power lines continue to affect raptor populations. Efforts should be made to summarize and disseminate this information. Additional studies are needed to evaluate new remedial actions and improve raptor-safe standards.

As for the future, raptor-safe construction standards will be critical in the developing world where some raptor populations appear to be declining as a result of interactions with power lines. The use of raptor-safe construction techniques can be encouraged through the influence of international funding agencies and consultants involved in the economic development of Third World countries (Ledger et al. 1993). In all areas of the world where electrocutions occur, increased knowledge of the biological factors related to raptor electrocution may allow modeling to anticipate electrocution problems. These models may then be incorporated into site planning for new power lines (M. Dedon, Pacific Gas and Electric, pers. comm.) The tools described in this document can be used worldwide, today and into the future, to reduce chances of raptor electrocution, while still providing reliable electrical service.

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APPENDIX A
GLOSSARY

adult- used properly of a bird only after it has assumed its final plumage.

ampere- unit of measure of the current strength in a conductor with a resistance of one ohm and an electromotive force of one volt.

amperage- the strength of electrical current in amperes.

breakdown insulation level has been exceeded.

bundling- an assembly of two or more conductors, used as a single conductor and employing spacers to maintain a predetermined configuration. The individual conductors of the assembly are called subconductors.

bushing (transformers)- a lining inserted in the top of a transformer tank to insulate the electrical leads of the transformer winding from the tank. Bushings are usually made of porcelain, and are used on many types of electrical equipment, i.e., transformers, circuit breakers, and capacitor banks.

bushing connectors- the devices used to make the necessary electrical connections to both ends of the bushing.

buswork- normally copper or aluminum bars used in substations to complete the electrical connections between circuits.

capacitance- the property of a circuit or body that permits it to store an electrical charge, equal to the accumulated charge divided by the voltage; measured in farads. Capacitance affects the efficiency of a circuit and is purposely added or subtracted to make energy use more efficient.

capacitor- a device consisting of conductors isolated in a dielectric medium; each capacitor is attached to one side of a circuit only. It is used to increase the capacitance of a circuit. Capacitors are constructed in metal tanks and have bushings.

capacitor banks- a series of capacitors connected together and inserted into an electrical circuit to change the efficiency of the energy use.

circuit (single)- a conductor or system of conductors through which an electric current is intended to flow. The circuit will be energized at a specified voltage.

circuit (double)- distribution poles or transmission towers can be designed to support more than one circuit. A double circuit would be a configuration that supports two circuits.

conductivity- the capacity to transmit electrical energy.

conductor- a material, usually in the form of a wire, cable or bus bar, suitable for carrying an electric current.

configuration- the arrangement of parts. A distribution configuration would include the necessary arrangement of crossarms, braces, insulators, etc. to support one or two electrical circuits.

crossarm- a piece of wood cut to specified dimensions (example: 8.9 cm x 11.4 cm x 2.8 m [8/3-1/2" x 4-1/2" x 8'-0"]) and bolted to a wood pole; used to support electrical conductors for the purpose of distributing electrical energy. Usually made of Douglas fir, and supplied in various lengths.

current- a movement or flow of electricity passing through a conductor. In electrical circuits, the current can be compared to the volume in a water pipe (gallons), since it is the measure of how much energy is being transmitted. Current is measured in amperes.

current rating- conductive materials such as wires, busbars, or conductors are limited by their substance and cross-section as to how many amperes of current can efficiently pass through them. The current rating will be based on the material's resistance and the ambient temperature surrounding the material.

davit arm- a formed, laminated wood or steel crossarm attached to wood or steel poles and used to support electrical conductors or overhead groundwires.

de-energized- any electrical conducting device not energized with a voltage or other source of potential.

distribution line- a circuit of low-voltage wires, energized at voltages from 0 to 69 kV, and used to distribute energy to residential, industrial and commercial customers. Distribution lines are normally constructed on wood poles with various types of crossarms that are attached to support the necessary electrical conductors.

downwire- (see **groundwire).**

electrode- any terminal connecting a conventional conductor, such as copper wire, with a non-conventional one, such as an electrolyte. In the case of checking the conductivity of an eagle feather, electrodes were attached to both ends of the feather, and electrical current was passed through the feather.

energized- electrically connected to a source of potential difference, or electrically charged so as to have a potential significantly different from that of earth in the vicinity.

escarpment- a long cliff or steep slope.

farad- the unit of capacitance; the capacitance of a condenser that retains one coulomb of charge with one volt difference of potential.

feather-wetting- the condition where weather or behavior (e.g., taking prey in water) results in the wetting of feathers, thereby rendering the bird potentially more susceptible to electrocution.

flashover- occurs when the value of insulation has been exceeded, as in the case of a lightning stroke, causing an interruption in service.

fledglings a bird that has left the nest and that still depends upon its parents for food.

fused cutouts- electrical switches fitted with a fuse, so that the switch will open when the current rating of the fuse is exceeded. Fused cutouts are used to protect electrical equipment and circuits from lightning and occurrences when conductors might be short-circuited by wires, wind, and conductive equipment of all kinds.

gapping (groundwire)- technique used to insert a physical gap in the pole groundwire. As used in this document, a space of 10.2 centimeters or 4 inches.

ground rod- normally a copper-clad rod, driven into the ground so that groundwires can be physically connected to the ground potential.

groundwire- a wire used to bond all of the bolts and other pole line hardware to ground. Groundwires are normally copper-clad or stranded galvanized wire and are attached to poles with staples. Sometimes also called *downwire.*

guy- secures the upright position of a pole (of wood or other material) and offset physical loads imposed by the use of conductors, wind, ice, etc. Guys are normally attached to anchors that are securely placed in the ground to withstand loads within various limits.

immature- a bird in an intermediate plumage, between that of its natal down and adult plumage. Not an adult bird, but usually fully grown.

insulators- insulating materials in a form designed to support a conductor physically and electrically separate it from another conductor or object. Insulators are normally made of porcelain. Polymer insulators make use of fiberglass rods that are covered with polymer sheds.

isokeraunic level- refers to the average number of thunder storm (lightning) days per year that are present in a region. Electric lines in areas of high levels normally have overhead groundwires installed so that lightning charges on the line can be grounded.

jumper wire- a conductive wire, normally copper, used to connect various types of electrical equipment. Jumper wires are also used to make electrical conductors on lines continuous when it becomes necessary to change direction of the line, i.e., angle poles, dead-end poles, etc.

kilovolt- 1000 volts, abbreviated kV. A 13,000 volt line expressed as 13 kV.

latticework- the combination of steel members connected together to make complete structures, such as transmission towers or substation structures.

leks (grouse)- a communal courtship area on which several grouse males hold courtship territories to attract and mate with females; sometimes called an arena.

lightning arrester- an electrical device used to connect lightning charges to ground. Lightning arresters are normally made of porcelain, which surrounds the necessary electrical connections to achieve the grounding results.

lightning days- lightning or thunderstorm days. Several lightning storms in the same day would be classed as a lightning day.

load centers- those areas that consume electrical energy. Residential communities, industrial and commercial complexes are load centers. An individual home or office can be a load center.

nesting substrate- the base upon which a nest is built, e.g. cliffs, trees, and power poles.

nestlings- young birds that have not yet reached sufficient size and maturity to leave the nest.

neutral (ground)- a conductor or wire that is at ground potential.

ohm- unit of electrical resistance equal to the resistance of a conductor carrying a current of one ampere at a potential difference (electromotive force) of one volt between terminals.

outage- event that occurs when the energy source is cut off from the load. Outages can occur when raptors short-circuit two conductors (phases) or connect one phase to ground through the fleshy (conductive) portion of their body.

phase- for purposes of this document, an energized electrical conductor. Single-phase refers to one energized conductor and one neutral; three-phase refers to a three- or four-conductor configuration, the fourth conductor of which will always be a neutral or ground potential conductor.

phase-to-ground- the contact of an energized wire (phase) to ground potential. Raptors will cause phase-to-ground faults when their feet are grounded and a fleshy part of their body contacts an energized phase.

phase-to-phase- the contact of two energized wires, more normally called a short-circuit. Raptors will cause phase-to-phase faults when the fleshy part of their wings contact two energized conductors (phases) at the same time.

pole- a wood pole used to support power lines. Poles are also artificially made of concrete, fiberglass, and steel. The pole made from trees is the most common pole used by the utility industry.

power line- a combination of conductors used to transmit or distribute electrical energy, normally supported by wood or steel poles. Power lines can be low-voltage (0 - 69 kV) single-phase or three-phase, or they can be high-voltage lines (in excess of 115 kV).

preferred pole- poles that facilitate hunting success and will normally give the raptor the highest location along a line, from which to observe prey over a large area. Used by raptors for perching or still-hunting for prey.

primary- also **primary feather.** One of the flight feathers attached to the hand (of the wing).

problem pole- a pole used by raptors for perching or still hunting, but shown to electrocute birds.

raptor- bird of prey. Members of the orders Falconiformes and Strigiformes. A type of bird with a sharp hooked beak modified for tearing of flesh and sharp talons used for holding and killing prey.

raptor-safe- a power line configuration designed to eliminate raptor electrocution by having 152.-centimeter (60-inch) minimum spacing between phases and phase to ground, and by providing for safe perching areas on the pole.

retrofitting- the modification of a power line configuration to make it raptor-safe.

ridge pin the insulator supporting pin that is attached to the top of a pole with two or more bolts and that supports energized or grounded conductors, depending on the power line design.

right-of-way- the strip of land that has been acquired by the power company or agency for the sole purpose of constructing and maintaining a power line. Rights-of-way are maintained for highways, pipe lines, waterways, etc.

sag- the distance measured vertically, at the midpoint of a span, from a conductor to a straight line joining the two points of support. Sag is necessary in conductors to allow for the expansion and contraction of the conductor material under different temperatures and weather conditions.

sectionalize- refers to the practice of isolating an energy source from a load. It is sometimes necessary to isolate electric systems (using switches) from load centers because of storms, floods, accidents, etc.

spacing (conductor)- the physical separation of phases or conductors from one another in order to eliminate physical contact.

still-hunt- the practice of hunting from a perch, as opposed to hunting in flight.

structure- the wood pole and crossarm system or the transmission tower being used to support a distribution or transmission line circuit.

subadult- a young bird that has not reached its adult plumage. See **immature.**

substation- an enclosed area (fenced for public safety) that terminates transmission and distribution lines, and includes the transformation and protective equipment necessary to serve the electric loads in an area and ensure public safety.

substrate- see **nesting substrate**.

switch- an electrical device used to sectionalize electrical energy sources.

tension member- the tower member on lattice steel towers that supports the crossarm from the top side. Because of its location above the crossarm, and the conductor load on the outer end of the crossarm, this member is in constant tension.

tower- the supporting structure on transmission and distribution power lines. Structures can be made of steel members bolted together, or of fabricated steel sheets welded into poles. Wood structures are also called towers.

transformer- a device used to transform voltages to acceptable levels. Transformers will have the electrical windings placed inside a steel tank and surrounded with clear insulating oil. Transformers are manufactured in all sizes, from pole-mounted distribution types to the large power transformers used in high voltage substations.

transmission - those poles or towers used to support the various conductors needed to transmit large blocks of energy.

transmission line- power lines designed and constructed to support voltages from 115 kV and up.

trophic level- functional classification of organisms in a community according to feeding relationships (energy transfer steps). The first level includes green plants; the second, herbivores. Predators occupy the highest trophic levels.

underbuild- refers to a circuit of lower voltage that is placed on the same pole but underneath another circuit of a higher voltage. The lower circuit is often referred to as the ‰underbuilt circuit.Â

unenergized- see de-energized

volt- the measure of electrical pressure. More specifically, it is the unit of electromotive force, or that difference of potential that, when steadily applied against a resistance of one ohm, will produce a current of one ampere.

voltage- electromotive force expressed in volts.

voltage rating- the rating of a power line in volts.

weather loading- the loading used during the design phase of a power line to accommodate those forces of nature that the line will normally have to withstand. These would include, but not be limited to, wind, ice, temperature, snow, flooding (for foundations), etc.

wire- a slender rod, strand or thread of ductile metal, usually having a circular cross section of a specified diameter. For purposes of this document, it is the copper or aluminum wire used for the construction of power lines.

APPENDIX B

EARLY HISTORY OF AGENCY ACTION

Chapter II provides a brief history of initial agency and individual response to the raptor electrocution problems identified after a systematic campaign to kill eagles was uncovered in the early 1970's. The material below provides additional detail for those interested in the process and people involved in this first, cooperative response.

When the Jackson Canyon incident and subsequent investigation revealed a close connection between raptor deaths and power lines, individuals, agencies, and concerned groups pulled together to study the problem and begin corrective action. On 19 January 1972, agency representatives met in Washington, D.C. to discuss the electrocution problem (U.S. Fish and Wildl. Serv. 1972). Agencies included the Rural Electrification Administration (REA; now the Rural Utilities Service), U.S. Forest Service (USFS), Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), and Bureau of Indian Affairs (BIA). The USFWS was designated to coordinate the search for lethal lines, while the REA would begin developing proposed line modifications to minimize eagle electrocutions.

In January 1972, Robert K. Turner, Rocky Mountain Regional Representative of the National Audubon Society, wrote to Thomas Riley of the Pacific Gas & Electric Company, drawing attention to the raptor electrocutions in Colorado and Wyoming (R. Turner, National Audubon Society, pers. comm.). The letter, forwarded to Richard S. Thorsell of the Edison Electric Institute (EEI)[1] in New York City, became the impetus for utility company participation, fund-raising, and publications aimed at decreasing power line hazard to eagles. Thorsell coordinated representatives of a group of western utilities[2] to assess the problem. They determined that grounding practices on 4-kV through 69-kV distribution lines (along with certain configurations of transformer banks, fused cutouts, lightning arresters, and conductor phase spacings) could be a substantial cause of raptor deaths. Engineering solutions were then to be developed in a cooperative public/private effort to solve the problem of raptor electrocutions.

On 6 April 1972, EEI hosted a meeting in Denver, Colorado, the first of several workshops on eagle electrocutions and its relationship to power outages and other related issues (Olendorff 1972c). It was attended by representatives of western power

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[1] Now located in Washington, D.C. Edison Electric Institute, the association of electric utility companies in the United States, provides a committee structure and coordination for the industry.

[2] Idaho Power Company, Pacific Gas and Electric Company, Pacific Power & Light Company (PacifiCorp) , Public Service Company of Colorado, Tucson Gas & Electric, and Utah Power & Light Company.

companies, the REA, state and federal wildlife agencies, and major conservation organizations[3]. Three concrete actions results:

1) An accord was struck among the participants to seek and implement power line modifications and restrictions that would be biologically and economically feasible and that would reduce raptor electrocutions.

2) A raptor mortality reporting system was established, to be administered by the USFWS.

3) Participants would work to document modifications with drawings and suggestions that could be used by private and public entities.

The REA, an agency of the U.S. Department of Agriculture, lends money to cooperatives that supply electricity primarily to customers in rural areas. As part of the loan conditions, the REA sets minimum standards for power line design. Even before the Denver meeting, it had been determined that older three-phase and single-phase REA-designed power lines presented the most serious electrocution problems for eagles. REA Bulletin 61-10, *Powerline Contacts by Eagles and Other Large Birds*, described causes of raptor electrocutions resulting from certain grounding practices and conductor spacing (U.S. Rural Electrification Administration 1972). The bulletin included suggestions on how member companies could correct existing problem lines or design new lines that would be safe for eagles.

The USFWS raptor electrocution reporting system was instituted in 1973. About 300 eagle carcasses and skeletons were found between 1969 and 1972. Subsequently, the number of reported eagle mortalities along power lines dropped: to 123 in 1973, to 88 in 1974, and to 65 in 1975.

No conclusions can be drawn from these figures, however, because other variables were involved that affect reliability of the figures. For example, during the same period, mid-winter golden eagle populations trended downward in response to a steep jack rabbit (*Lepus* spp.) population decline 1 to 2 years earlier. The number of golden eagles electrocuted in Idaho declined during those years (Kochert 1980) when fewer young golden eagles fledged. Additionally, reporting system figures are contradicted by findings of substantial numbers of eagle mortalities along power lines in several western states (Benson 1981; PacifiCorp, Idaho Power, unpubl. data). The USFWS reporting system is still in effect, and data indicate that eagle electrocution continues to be a pressing concern for utilities and agencies interested in conserving avian resources (Terry Grosz, USFWS, pers. comm.).

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[3] Colorado Division of Wildlife, National Audubon Society, National Wildlife Federation, USFWS.

APPENDIX C

PRODUCT INFORMATION

ALUMA-FORM
P.O. BOX 18555
MEMPHIS, TN 38181-0555
(901) 362-0100 * FAX (901) 794-9515

ALUMA-FORM produces:

- Wood raptor perches, several designs.
- Wood crossarms and wood braces of all designs.
- Wood and metal equipment mounting brackets for use with all types of electrical equipment.

BR&W COMPANY
37030 SW LUKAS ROAD
HILLSBORO, OR 97123
(503) 628-7812 * FAX (503) 329-6306

BR&W produces:

- Inverted V Raptor Guard.
- Raptor Perch/ Guard Combination.

CANUSA-EMI
7820 PALACE DRIVE
CINCINNATI, OH 45249
IN USA - 1-800-422-6872 IN CANADA - 1-800-845-6808
(513) 247-8800 * FAX (513) 247-8806

CANUSA-EMI produces:

- Heat-shrink materials of all kinds, including, but not limited to: sheets, tubing, connectors, insulation, splicing, tapes, sealing, and repair materials.

CONTINENTAL ELECTRIC COMPANY
P.O. BOX 835 - 6655 HIWAY 11 NORTH
TRUSSVILLE, AL 35173
(205) 655-7400 * FAX (205)655-3530

CONTINENTAL ELECTRIC COMPANY produces:

- Fiberglass perch guards of various designs and sizes.
- Scavenger guard (anti-perch device) for high-voltage lines.

DULMISON, INC.
1725 PURCELL ROAD
LAWRENCEVILLE, GA 30243
1-800-521-5230 * (770) 339-3362 * FAX (770) 339-3770

DULMISON, INC. produces:

- Spiral vibration dampers (SVD).
- Bird flight diverters (BFD).*
- Swan flight diverters (SFD).*

  * In standard gray PVC or yellow, high-impact PVC. Dulmison can also provide damping recommendations and related engineering information upon request.

HUGHES BROTHERS

210 N. 13TH ST. - P.O. BOX 159

SEWARD, NE 68434

(402) 643-2991 * FAX (402) 643-2149

HUGHES BROTHERS produces:

- Wood crossarms, wood braces, wood moldings for groundwires, and a variety of other wood products used for construction of transmission and distribution lines.
- Elevated wood perches and perch guards.
- Fiberglass extension links, fiberglass guy strains, and other related fiberglass products.
- Metal bands, bolts, and other transmission and distribution line materials.

KADDAS ENTERPRISES, INC.

151 WEST ANGELO AVENUE - P.O. BOX 65931

SALT LAKE CITY, UT 84115-0931

1-800-658-5003 * (801) 943-0607 * FAX (801) 486-4621

KADDAS ENTERPRISES, INC. produces:

- Conductor coverings named Bird Guard (various sizes available on request)

3 M ELECTRICAL PRODUCTS DIVISION
6801 RIVER PLACE BLVD.
AUSTIN, TX 78726-9000
1-800-245-3573 * FAX 1-800-245-0329

3 M ELECTRICAL PRODUCTS DIVISION* produces:

- Heat shrink products in various forms and sizes.
- Electrical tapes, splices, terminating devices, etc.

  * 3M markets their products through distributors and agents. Contact the above numbers for information on the nearest representative.

PACER INDUSTRIES
3203 EAST 3225 NORTH
TWIN FALLS, ID 83301-0507
(208) 733-8074 * FAX (208) 733-8074

PACER INDUSTRIES produces:

- Elevated perches, perch guards, anti-perch devices, etc. made of PVC materials, spring-loaded for installation with hot sticks.

PREFORMED LINE PRODUCTS COMPANY
P.O. BOX 91129
CLEVELAND, OH 44101
(216) 461-5200 * FAX (216) 442-8816

PREFORMED LINE PRODUCTS COMPANY produces:

- Wildlife protectors such as bushing and jumper covers, conduit riser caps, heat shrink tubing, groundwire molding and other products that can be used for insulating electrical equipment.
- Spiral vibration dampers, and a complete line of preformed line products.

RAYCHEM CORPORATION ELECTRICAL PRODUCTS DIVISION	
EASTERN CUSTOMER SERVICE CENTER	WESTERN CUSTOMER SERVICE CENTER
220 LAKE DRIVE	300 CONSTITUTION DRIVE
NEWARK, DE 19702	MENLO PARK, CA 94025-1164
(302) 453-1414 * FAX (302) 453-7574	(415) 361-3136 * FAX (415) 361-5043

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- Heat shrink materials in various forms and sizes.
- Electrical tapes, terminations, connectors, etc.

  * Raychem Corporation sells products through distributors and agents. Check the Customer Service Center nearest you for information on the distributor in your area.

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7520 NORTH LONG AVENUE - BOX 1060
SKOKIE, IL 60077
(847) 679-6700 * FAX (847) 679-2401

W.H. SALISBURY & CO.* produces:

- Insulating covers for all areas of distribution lines, including but not limited to jumper covers, insulating blankets, rubber goods of all descriptions, squirrel guards for transformers, human protective equipment, bushing covers of various sizes and shapes, and many other kinds of protective and insulating materials.

  * W.H. Salisbury & Co. sells through agents in cities throughout the U. S. Contact the company in Skokie or the agent nearest you.

VIRGINIA PLASTICS, INC.

P.O. BOX 4577

ROANOKE, VA 24015-0577

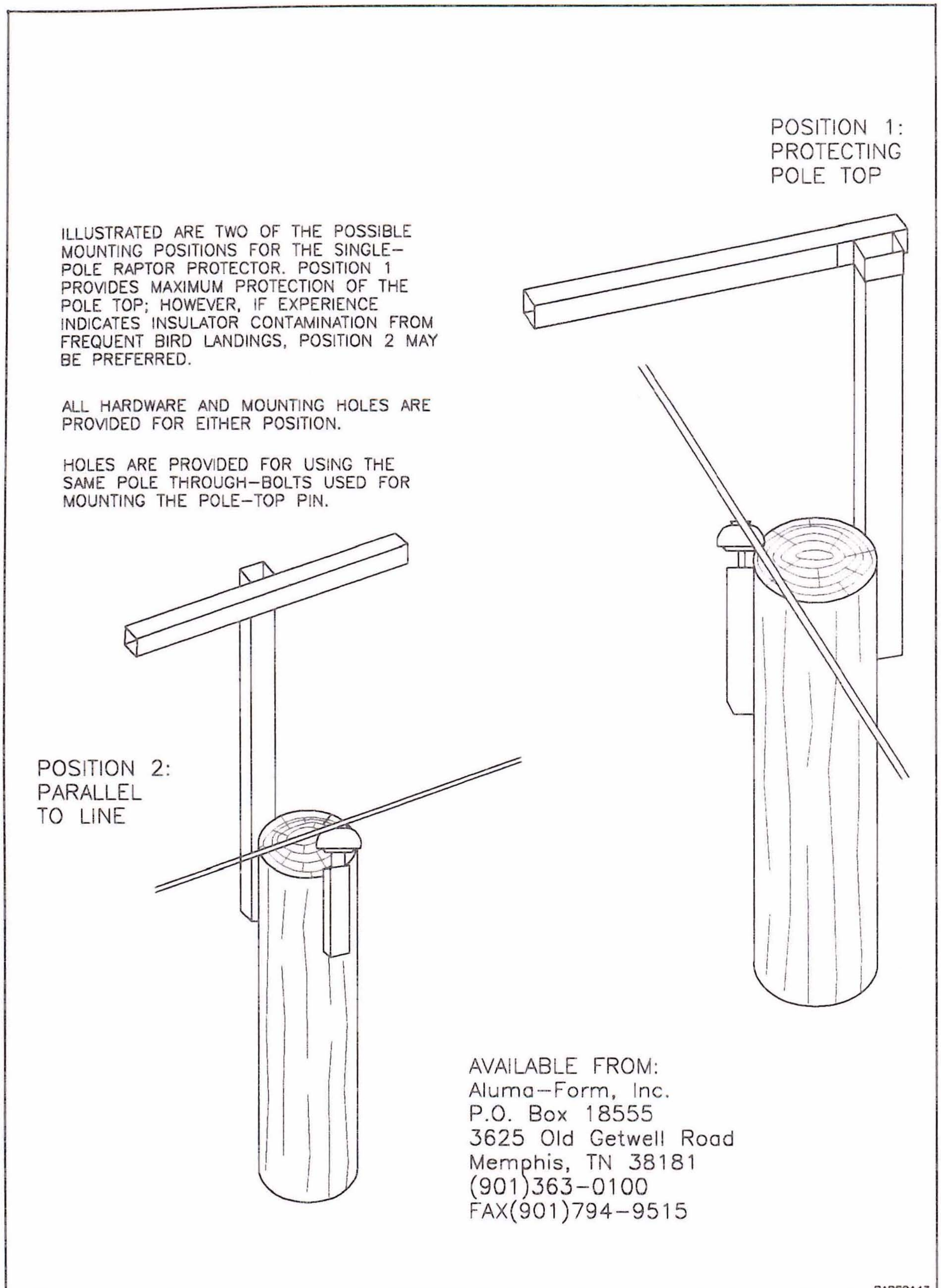
(540) 375-0100 * FAX (540) 375-0135

UTILITY CUSTOMER SERVICE (540) 375-0121

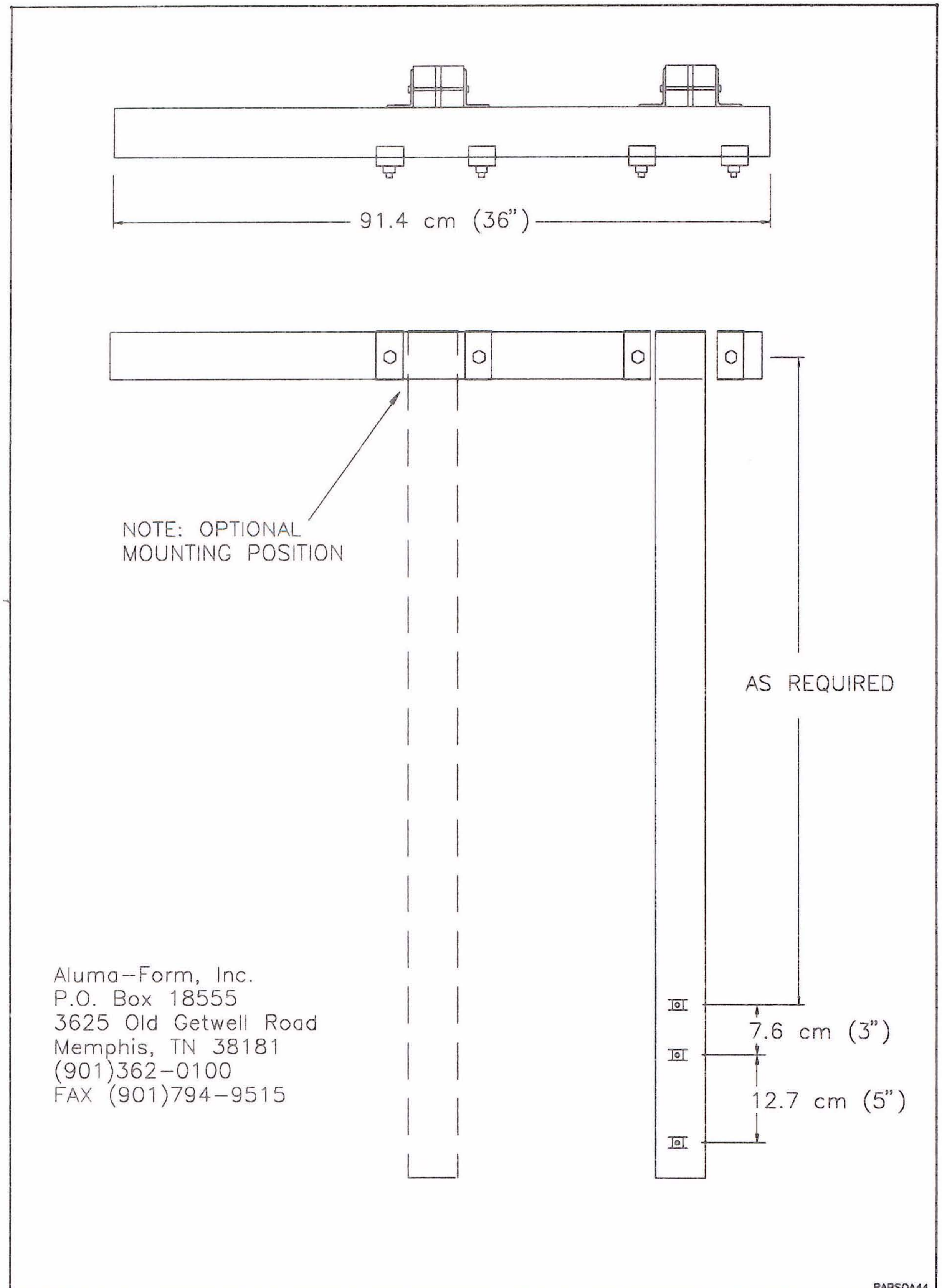
VIRGINIA PLASTICS, INC.* produces:

- Formed polymer equipment covers and barriers to discourage raptor contact.
- Guy guards, ground wire molding, between-phase barriers for crossarm installation.

  * Virginia Plastics, Inc. has plastic molding capabilities and can provide raptor-safe products such as barriers, perches, perch-guards, and covers for energized conductors and equipment.

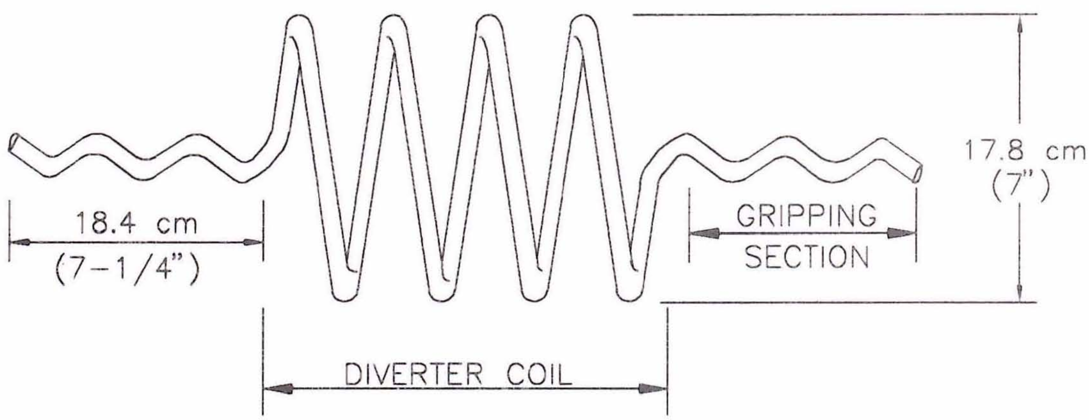


Appendix C. Product information - Aluma-Form, Inc./Raptor Protectorn.



Appendix C. Product Information - Aluma-Form, Inc/Raptor Protectorn.

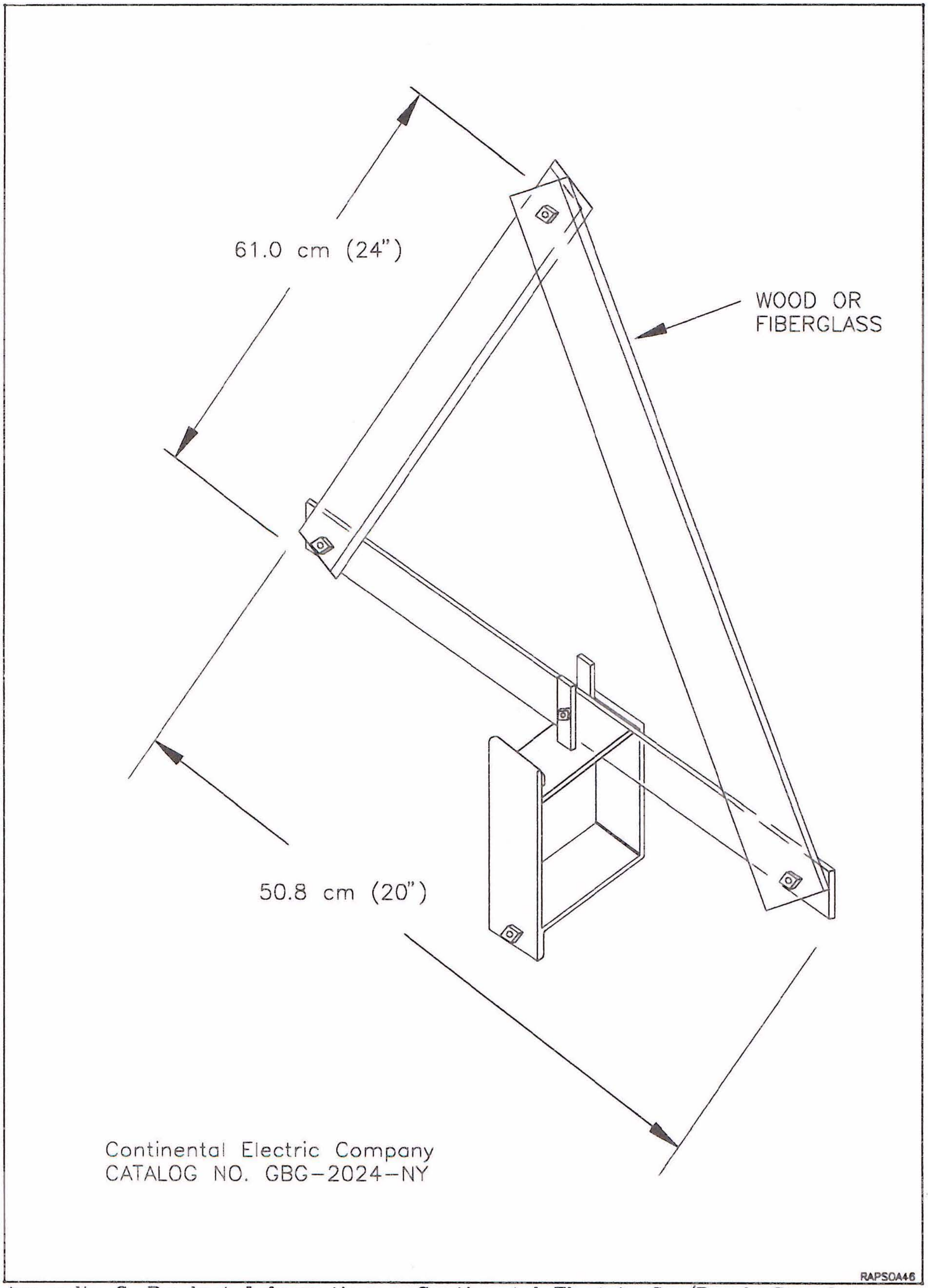
DULMISON SWAN FLIGHT DIVERTER



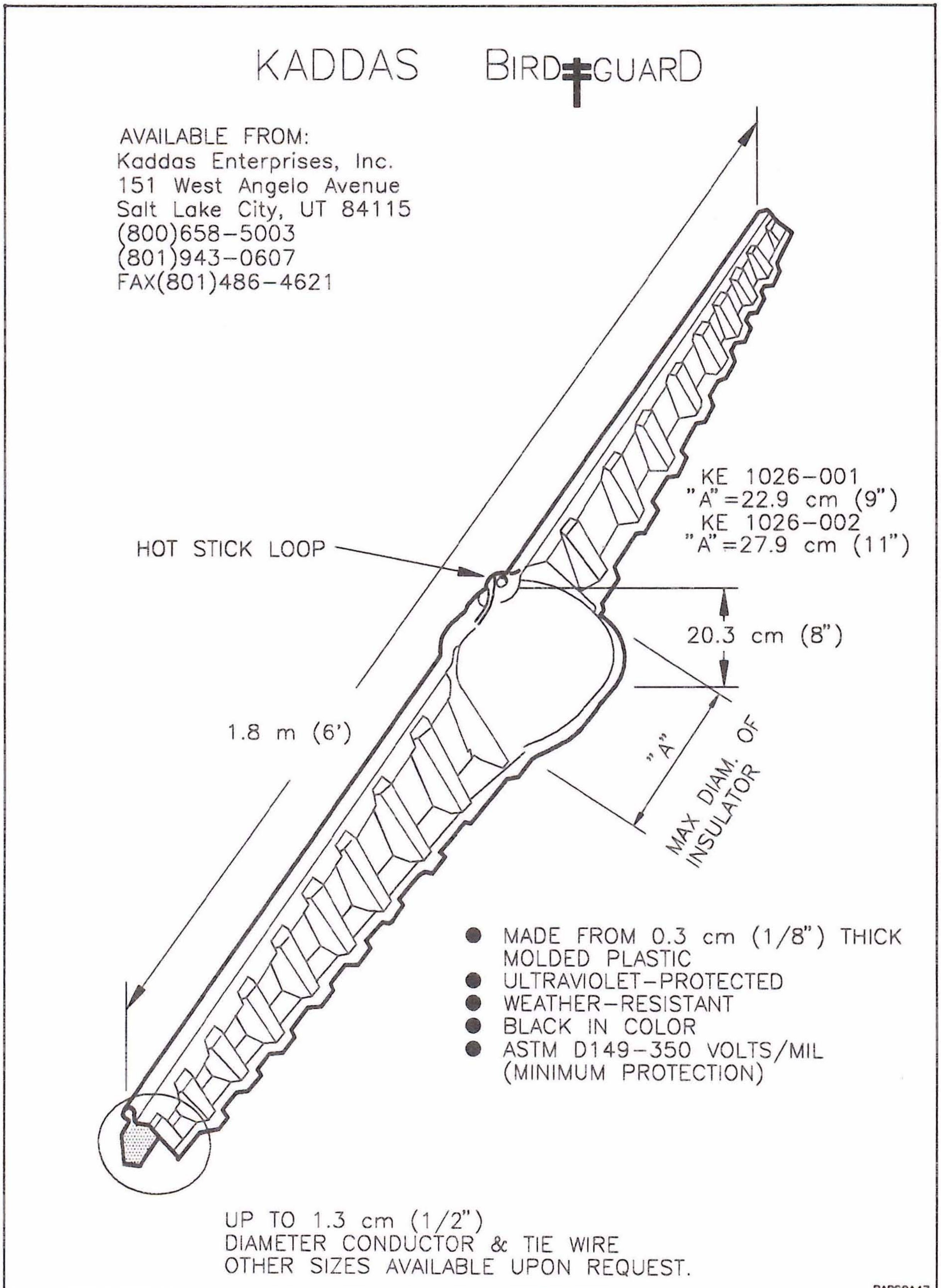
NOTES:
1. OVERALL LENGTH: APPROX 17.8 cm (7")
2. ROD DIA: 1.0 cm (0.375")
3. ENDS ARE SANDED.
4. MANUFACTURED FROM GREY
   OR YELLOW HIGH IMPACT P.V.C.

RAPS0A45

Appendix C. Product Information - Dulmison/Swan Flight Diverter.



Appendix C. Product Information – Continental Electric Co./Perch Guard.

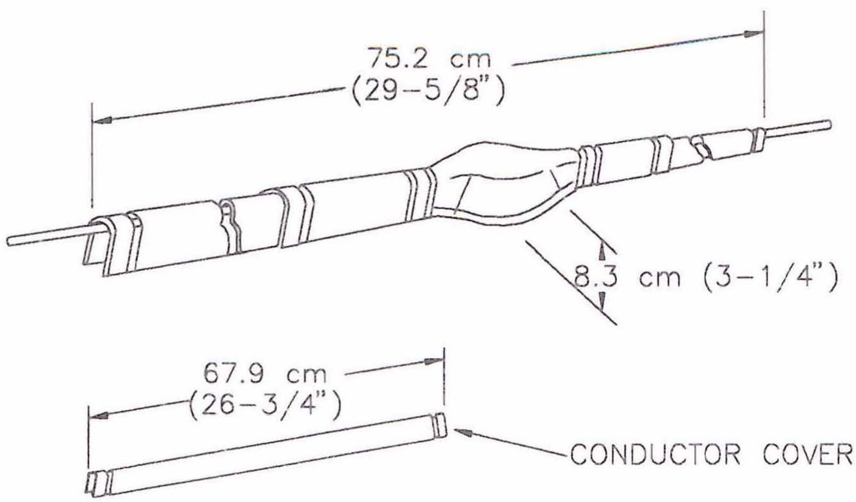


Appendix C. Product Information – Kaddas/BirdGuard.

Preformed Line Products (SOUTH AFRICA) (PTY) Limited

RAPTOR™ PROTECTOR

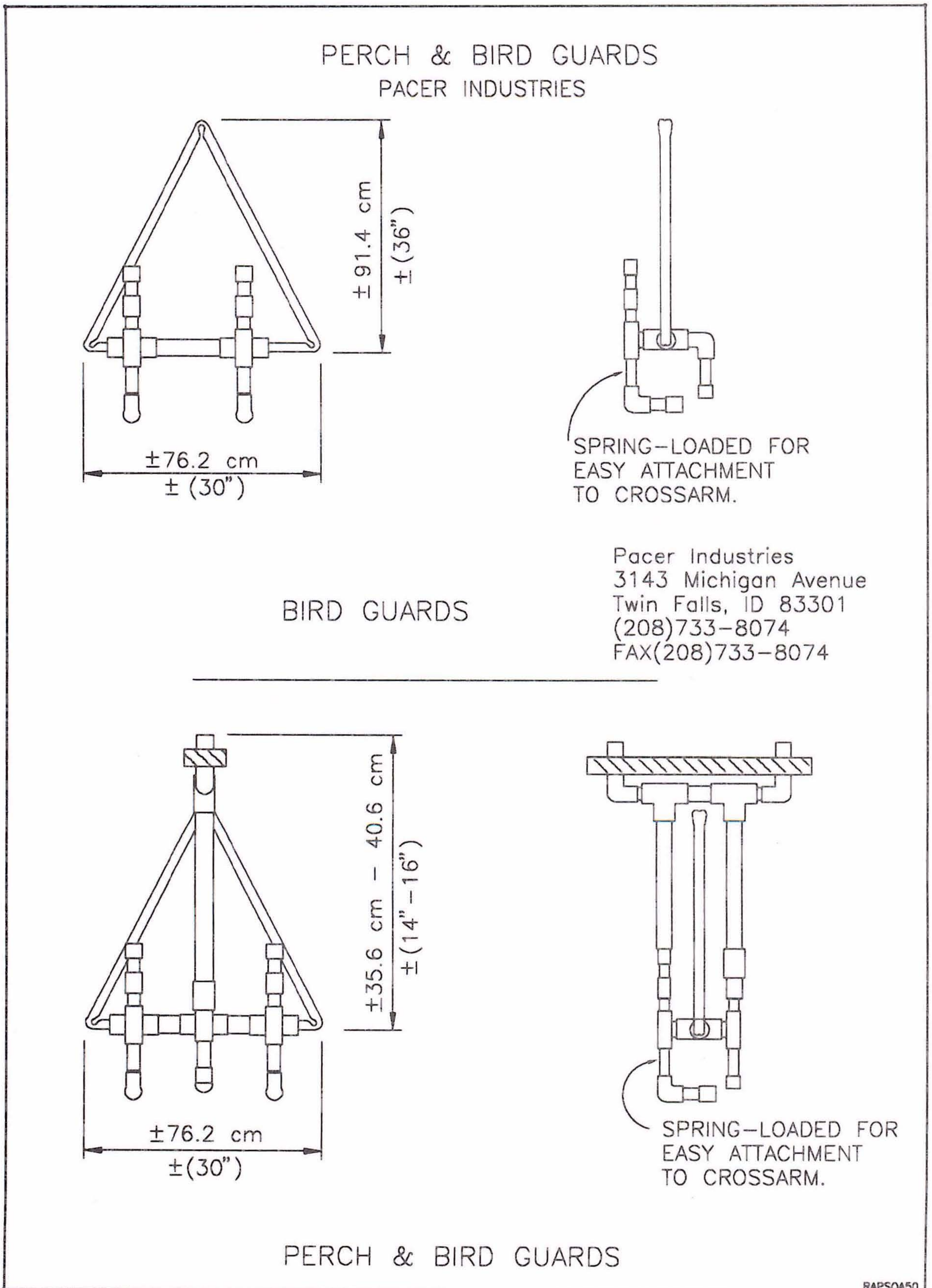
SA PATENT APPLIC NO 92/3660



AVAILABLE FROM:
Preformed Line Products Company
P.O. Box 91129
Cleveland, OH 44101
(216)461-5200
FAX(216)442-8816

RAPSOA48

Appendix C. Product Information - Preformed Line Products Co./Raptor Protector.

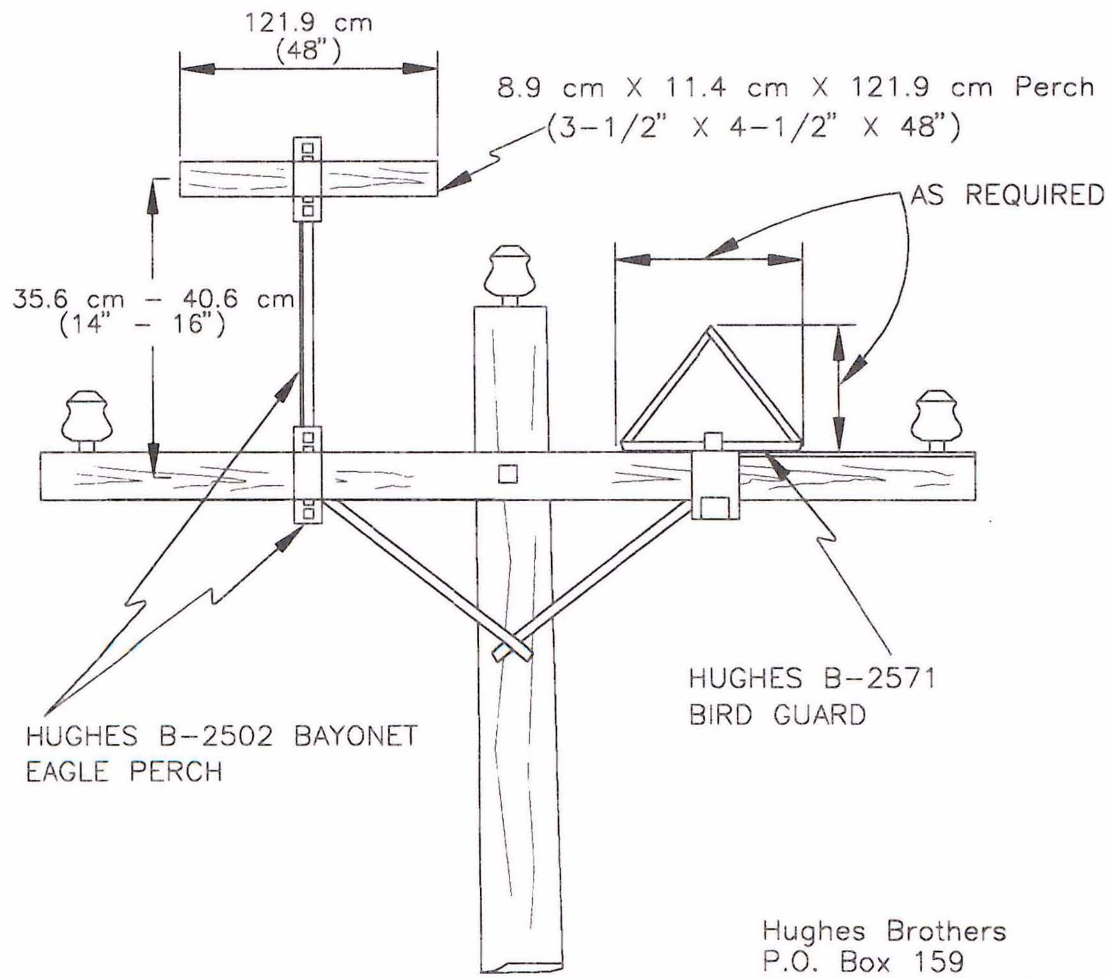


Appendix C. Product Information - Pacer Industries/Perch and Bird Guards.

ELEVATED PERCH AND BIRD GUARD CONSTRUCTION

BY HUGHES BROTHERS

COMBINE FOR RECOMMENDED PROTECTION
OF ELEVATED PERCH



Hughes Brothers
P.O. Box 159
210 North 13th Street
Seward, NE 68434
(402)643-2991
Fax(402)643-2149

Bayonet Eagle Perches provide
a safe place for eagles and other
raptors to land on single-pole structures.

RAPS0A49

Appendix C. Product Information.
Hughes Brothers/Elevated Perch/Perch Guard.