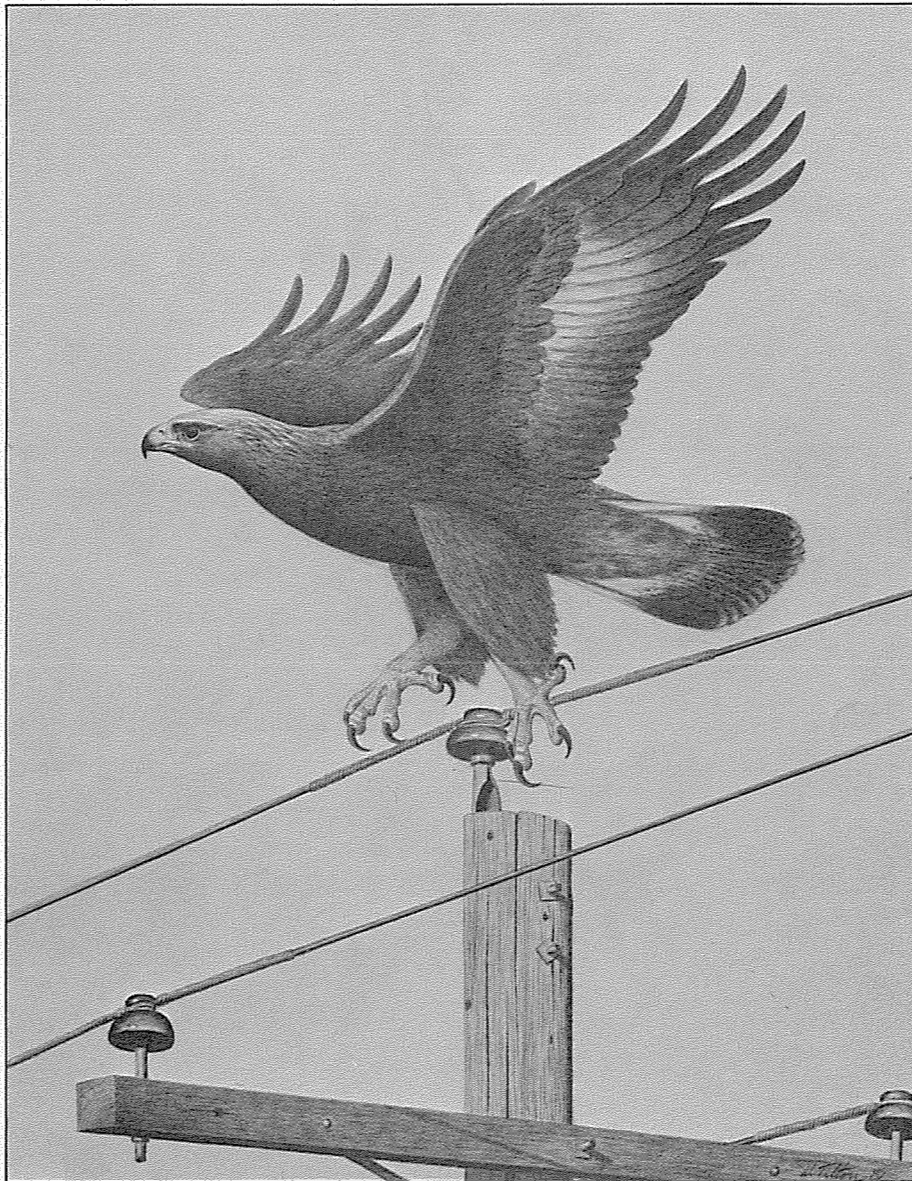


# SUGGESTED PRACTICES FOR RAPTOR PROTECTION ON POWER LINES

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## THE STATE OF THE ART IN 1981



Raptor Research Report No. 4  
Raptor Research Foundation, Inc.  
1981

# **Suggested Practices for Raptor Protection on Power Lines**

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## **The State of the Art in 1981**

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## HOW TO USE THIS PUBLICATION

"Suggested Practices for Raptor Protection on Power Lines...The State of the Art in 1981" is organized to provide rapid access for a variety of readers to a thorough but lengthy synthesis of all available information on the subject. The six parts have different values depending on a reader's objective and prior knowledge.

"PART ONE: THE IDENTIFICATION AND RESOLUTION OF AN ISSUE" is a lesson for everyone in successful coordination between conservationists; industry biologists, engineers, and executives; and government staff biologists, land managers, and species managers.

"PART TWO: THE BIOLOGICAL ASPECTS OF RAPTOR ELECTROCUTION" presents the land manager or power line design engineer with a thorough discussion of the biological reasons for raptor susceptibility to electrocution. A better understanding of the biological and ecological relationships involved has been an important stimulus to the development of mutual respect and communication between those interested in solving the electrocution problem.

"PART THREE: POWER LINE DESIGN AND MODIFICATION FOR RAPTOR SAFETY" switches the emphasis toward teaching biologists and conservationists about the electric industry, particularly about the design constraints which do not allow implementation of every conceivable modification or new configuration of power lines that would be safe for eagles. The suggested practices presented in PART THREE have been field tested, for the most part, and are widely applicable, where needed. However, because of the vast diversity of line designs and voltages used by different power companies, across-the-board standards are impractical. Everyone is cautioned not to pull pages from this report and insist that designs be precisely as shown or that suggested practices be implemented unnecessarily.

"PART FOUR: OTHER SELECTED MITIGATION METHODS" concerns techniques for mitigating power line construction, maintenance, and operation impacts -- other than electrocution -- on raptors. Land-use planners and those who develop environmental assessments will benefit from reading PART FOUR even if they need not be concerned with PARTS ONE through THREE.

Those who seek even more information may facilitate their acquisition of the original literature on the subject by using "PART FIVE: LITERATURE CITED AND ANNOTATED BIBLIOGRAPHY." For quick reference to specific points use "PART SIX: INDEX."

Land managers and industry executives who wish only a general overview of the contents of this publication, or any part of it, may read the EXECUTIVE SUMMARY beginning on the following page.

## EXECUTIVE SUMMARY

PART ONE: THE IDENTIFICATION AND RESOLUTION OF AN ISSUE. Birds of prey (raptors) are one of the most politically sensitive groups of birds with which industry, governmental agencies, and conservation organizations must be concerned. As end-of-the-food-chain organisms, raptors are both biologically important and environmentally sensitive. Such sensitivities have created considerable academic interest in these birds and their problems (such as electrocution by power lines) and have generated great public demand for better protection and management of raptor populations and habitats.

A new dawn for the raptor conservation movement and for the concept of raptor management occurred during the winter of 1970-1971 in Wyoming and Colorado. During that winter and the subsequent spring, nearly 1,200 eagle deaths resulting from poisoning (30+), shooting from aircraft (800+), and electrocution or shooting along power lines (300+) were documented in agency reports and court testimonies. Continuing discoveries of dead raptors, primarily immature and subadult Golden Eagles, led to certain healthy alliances between industry, government, and conservation organizations dedicated to solving the raptor electrocution problem.

In 1972 the U.S. Rural Electrification Administration published the first definitive guidance on how to minimize raptor electrocution problems on power lines. Between 1972 and 1975, knowledge concerning this subject increased, and a second-generation handbook was produced entitled "Suggested Practices for Raptor Protection on Powerlines." This publication is still widely used by industry and government, but will be replaced by the present report.

Since 1975 several carefully designed research projects involving both the biological and power line design aspects of the raptor electrocution issue have been completed. At the same time, the pertinent literature grew to over 225 references. The following new assessment of this issue and its solutions 1) reflects what was learned between 1975 and 1981 and 2) synthesizes relevant information from all available sources.

PART TWO: THE BIOLOGICAL ASPECTS OF RAPTOR ELECTROCUTION. Raptors are electrocuted by power lines because of two seemingly unrelated yet interactive factors: 1) the distribution, size, behavior, and other biological aspects of raptors, and 2) designs of electric industry hardware which place electrical wires close enough together that raptors can simultaneously touch two or more of them with their wings or other parts of their bodies. The corrective measures that have been developed as a result of recent studies can make both old and new power line configurations safe for eagles. However, to minimize the biological impacts of various land uses as well as the constraints placed on power line design engineers, it is necessary that both industrial and governmental planners, managers, and developers understand the ecological relationships involved.



Large size is by far the most crucial factor which predisposes certain raptors to electrocution. Between 70 and 90 percent of all raptor mortalities along electric distribution lines are eagles. Of all such eagle mortalities, less than 10 percent are Bald Eagles; the others are Golden Eagles.

There are an estimated 63,000 Golden Eagles in the United States south of Canada during the winter months when most electrocution and shooting problems occur (Table 1). Clearly, the Golden Eagle is neither rare, threatened, nor endangered. However, the impact of power lines is not the only factor impinging on Golden Eagle populations. Thus, public demand, industry image, power line reliability, and Federal law all require consideration of Golden Eagles regardless of their current abundance.

The major concentrations of both nesting and wintering Golden Eagles are in the intermountain West, particularly in western shrub and grassland habitats, in combinations of these habitats, and in ecotones between shrub, grassland, and forest habitats. In particular, greater numbers of Golden Eagles are electrocuted where rabbits occur than where only rodents and birds are found.

Raptors are basically opportunistic and thus utilize power lines and support structures for a number of purposes, especially perching and nesting. The heaviest use is as hunting perches. "Still" hunting from a perch is an energetically conservative way to find prey provided good prey habitat is within an eagle's view from the perch. Some power poles are "preferred" by the eagles because they provide considerable elevation above the surrounding terrain, thereby providing the birds a wide range of vision, easy takeoff, and greater attack speed when hunting. Seeking out these "preferred" poles by land managers and industry personnel facilitates the resolution of some local electrocution problems, but in homogeneous habitats one pole would not offer any advantage over another to a hunting eagle; therefore, corrective measures must be applied more widely.

Studies have shown that most Golden Eagle mortalities along power lines (up to 98 percent of identifiable carcasses) are immature or subadult birds, even though the general population is only about 30 to 35 percent younger birds. This disproportionate susceptibility of immatures and subadults to electrocution involves several factors, but none is more important than flying and hunting experience. The fact that immature eagles are generally less adept at maneuvering than adults, especially when landing and taking off from electric distribution lines, has been demonstrated by considerable research. Hundreds of hours of actual observations and analysis of slow-motion 16-mm movies of Morlan W. Nelson's trained immature eagles landing on dummy power poles clearly demonstrated the problems and led to methods for modifying old power line designs and planning new construction to maximize eagle safety.

#### PART THREE: POWER LINE DESIGN AND MODIFICATION FOR RAPTOR SAFETY.

The basic problems of all power lines which electrocute eagles are: 1) the distance between wires is less than the wingspread of the bird landing or perching on them; and 2) design practices dictate the grounding of particular parts of the equipment to prevent damage from lightning (ground wire placement also decreases effective separation of wires).

Most lines that electrocute raptors are distribution lines (Figure 2) that carry between 12,000 and 69,000 volts. Higher voltage transmission lines (Figure 1) pose little electrocution hazard because wire separation is adequate.

The two main considerations for making electric power poles safe for eagles are: 1) modifications of existing problem lines (Figures 3 and 4) and 2) proper design of new facilities. Both approaches are still vitally necessary, but because of the vast diversity of line designs and voltages used by different power companies, across-the-board standards and guidelines are impractical. Nonetheless, specific problems can be attacked on a broad front including: 1) design and modification of poles, crossarms, and wire placements to effect adequate separation of energized hardware; 2) insulation of wires and other hardware where sufficient separation cannot be attained; and 3) management of eagle perching.

Adequate separation of energized wires, ground wires, and other metal hardware is the most important factor in preventing raptor electrocutions. The objective is a 60-inch (152-cm) minimum separation of conductors. This can be accomplished in retrofitting old three-phase lines by lowering the existing crossarm (Figure 8) or by raising the center wire on a pole-top extension (Figure 7).

Another useful technique is to put 4-inch (10.2-cm) gaps (Figure 9) in ground wires near energized conductors. Lightning will discharge across these gaps, but day-to-day safety is provided to the birds because a gapped ground wire is not actually connected to ground. Leaving the top 20 to 30 inches (50.8 to 76.2 cm) of poles free of wires so that eagles can perch safely is also effective. In addition, the use of grounded steel crossarm braces should be avoided (Figure 11). As a general rule, the less grounded metal that is placed near energized wires, the less the hazard of raptor electrocution.

Armless configurations (Figure 13) and underground placement of wires present special problems involving reliability and/or cost that in some circumstances decrease their attractiveness to the industry. However, new analyses of armless configurations have increased their usefulness in heavy eagle use areas.

Where adequate separation of conductors and potential conductors cannot be attained, insulation of wires and other metal equipment may be the only solution short of redesigning and extensively modifying the line. On three-phase problem configurations center conductor insulation should extend a minimum of 3 feet (0.9 m) on either side of the pole-top insulator (Figure 14).

Two simple and economical methods of making existing problem lines safe for eagles involve encouraging eagles and other birds to perch on less dangerous parts of power line support structures. One method is to install wooden perches 14 to 16 inches (46 to 51 cm) above any energized wire or object so that raptors can sit out of danger (Figure 15). The second technique is to encourage eagles to perch in non-lethal positions on power line structures by placing perch guards (Figure 16) in dangerous

areas. Inverted "V" perch guards made of wood, fiberglass, or PVC rod have shown considerable promise as an economical and effective solution to many raptor electrocution problems, though tests of these guards are continuing.

PART FOUR: OTHER SELECTED MITIGATION METHODS. Direct impacts of power lines on raptors, other than electrocution, are commonly identified as line construction activities, maintenance impacts, increased vulnerability of perching and nesting raptors to harassment and persecution (e.g., shooting), increased chances of collisions between raptors and power lines, entanglement, noise disturbance, and field and corona effects.

The direct impacts of power line construction include: 1) loss of habitat through right-of-way clearing (where it is done), construction of access roads, and actual placement of poles, towers, and conductor pulling sites; and 2) disturbance of raptors through interference with courtship, nest building, incubation, and foraging activities which leads to desertion of nearby natural nests and roosts. When necessary, mitigation of these impacts may require preconstruction environmental assessment and planning, seasonal restrictions on the timing of construction, on-site analysis of raptor behavior at the time of construction in problem areas, salvaging deserted eggs or young birds by fostering them to other pairs away from the impacted area, making maximum use of existing roads and trails during line construction, and constructing lines with the aid of helicopters rather than building new access roads in previously undisturbed areas.

The principal impact of line maintenance on raptors is the destruction, primarily to prevent power outages and electrical fires, of nests built on poles and towers. Pursuant to the Bald Eagle Protection Act, the Migratory Bird Treaty Act, and many State wildlife laws, it is illegal simply to destroy such nests. The most exciting successes in mitigating the effects of raptor nests on power line support structures involve: 1) moving problem nests to less dangerous places on the structures and 2) placing artificial nesting platforms in safe places on transmission towers or on dummy poles adjacent to energized lines.

Increased accessibility by man to previously undisturbed areas is usually the greatest long-term impact of power line construction on wildlife. This leads directly to shooting by indiscriminant hunters of perching and nesting raptors. Electrocution is highly selective (over 90 percent) against younger non-breeders; shooting, which is directed more at the general wintering population, does not discriminate to the same degree between adult breeders and subadult or immature non-breeders.

Both raptors and industry hardware (e.g., porcelain insulators) would suffer less shooting damage if power line corridors and roads were separated, where practicable, particularly in remote, otherwise undisturbed areas. If maintenance roads must be built underneath new power lines in previously inaccessible areas, road or trail closures should be implemented to minimize the access.

Collision of raptors with power lines is not a major problem, although where endangered species occur, some mitigation may be appropriate. Likewise, no significant impacts of electric or magnetic fields, or corona (e.g., noise, ozone) on perching and nesting raptors have been found.

The habitat enhancement value of power lines must be evaluated on a number of levels including: 1) local versus regional benefits to raptor populations; 2) direct versus indirect impacts (both negative and positive); 3) habitat diversity versus species abundance; and 4) aesthetics versus functionality. For example, functionally, a new power line may provide raptors with hunting perches and nesting places thereby increasing habitat diversity and raptor abundance; but, if it also increases the number of raptors that are shot, then the true habitat enhancement value may be lessened.

Most raptors which nest on power poles or transmission towers are species which inhabit open plains, prairies, or savannahs where trees and cliffs are absent and do not provide nest sites (Table 2). The Osprey is a notable exception. The success of power line nests varies from area to area and between species. Some have speculated that nesting on power poles and transmission towers is actually extending the breeding range of some raptors, but more often the result is a local increase of raptor density within a species' general range.

In any case, interest in artificial nesting platforms as habitat enhancement for raptors is very high. Actual installation of artificial nesting structures on power poles and transmission towers has been limited (Table 3), but the success of nest structure programs in general is promising.

An artificial nest structure design by Morlan W. Nelson (Figure 17) is of particular importance in that it was developed primarily for installation on power transmission towers. The design is intended to minimize construction time, use of materials, and, thus, cost per structure. Also, with features to protect nestlings from strong winds and intense sun, the structures could easily be modified into release stations for raptors for reintroducing them into areas where they have been extirpated.

## PROLOGUE

Whereas cooperation between the electric utility industry, conservation organizations, and Federal agencies has reduced the occurrence of raptor electrocutions by power lines; and  
whereas this cooperation illustrates the effectiveness of coordinated efforts in conserving an important wildlife resource;  
Be it resolved that the participants of the 1975 Annual Meeting of the Raptor Research Foundation commend the electric utility industry for its collective efforts on behalf of raptors; further, the participants recommend that the industry continue this work.

Resolution passed at the 1975 Annual Meeting of the Raptor Research Foundation, Inc., Boise, Idaho.

**PART ONE**

**THE IDENTIFICATION**

**AND**

**RESOLUTION OF AN ISSUE**

## PART ONE:

### THE IDENTIFICATION AND RESOLUTION OF AN ISSUE

Birds of prey (raptors) are one of the most politically sensitive groups of animals with which industry, governmental agencies, and conservation organizations must be concerned. As end-of-the-food-chain organisms, raptors are both biologically important and environmentally sensitive. Such sensitivities have created considerable academic interest in these birds and their problems and have generated great public demand for better protection and management of their populations and habitats. This has also served to forge certain healthy alliances between industry, government, and conservation organizations for the direct benefit of raptors and other wildlife.

A new dawn for the raptor conservation movement and for the concept of raptor management occurred during the winter of 1970-1971 in Wyoming and Colorado. During that winter and the subsequent spring, nearly 1,200 eagle deaths resulting from poisoning, shooting from aircraft, and electrocution were documented in agency reports and court testimonies (Turner 1971, Laycock 1973). A poisoning incident in Jackson Canyon near Casper, Wyoming, set in motion the sequence of events that has led to this state-of-the-art follow-up to "Suggested Practices for Raptor Protection on Powerlines" (Miller et al. 1975).

Jackson Canyon is a secluded area with many large trees partially sheltered by precipitous canyon walls. It has undoubtedly been a winter roosting place for both Golden Eagles (Aquila chrysaetos) and Bald Eagles (Haliaeetus leucocephalus) for centuries, primarily due to the shelter provided and the close proximity to uncountable acres of prairie containing small mammals and carrion which serve as a prey base.

During early May, 1971, the carcasses of 11 Bald Eagles and 4 Golden Eagles were discovered in Jackson Canyon. The toll later 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. Subsequent analyses of the carcasses revealed that thallium sulfate, then a widely used predator control poison, was the cause of the eagle deaths. The individual responsible for lacing several antelope carcasses with the poison was apprehended and subsequently fined less than \$700. More importantly, however, the incident sent conservationists by the scores into the field to scour the West for additional poisoned eagles.

What they found were over 300 dead eagles and other raptors near power lines. While many had been shot, many others unquestionably had been electrocuted by lines not designed with eagle protection in mind. For instance, seventeen dead Golden Eagles, one Red-tailed Hawk (Buteo jamaicensis), and one Great Horned Owl (Bubo virginianus) were found, all apparently electrocuted, along 3.5 miles (5.6 km) of pole lines in northeastern Colorado (Glendorff 1972a). Five Golden Eagles and four Bald Eagles were located under a power line in Tooele County, Utah, and another

47 eagles died along a line in Beaver County, Utah (Smith and Murphy 1972, Richardson [1972]). In June of 1974, Benson (1977, 1980) discovered 37 dead Golden Eagles and one Short-eared Owl (Asio flammeus) under a line southwest of Delta, Millard County, Utah. Similar problems were also noted in New Mexico (Denver Post 1974), Idaho (Peacock 1980), Oregon (White 1974), Louisiana (Pendleton 1978), Nevada (U.S. Fish and Wildlife Service 1975b), and several other states.

Much of the information from the early 1970s 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. Although the electrocution problem had been noted earlier (Hallinan 1922, Marshall 1940, Dickinson 1957, Benton and Dickinson 1966, Edwards 1969, Coon et al. 1970), its magnitude was not known until the 1970s.

A simultaneous increase in the attention given to this problem also occurred in other countries. Markus (1972) found 148 Cape Vultures (Gyps coprotheres) electrocuted by an 88 kV power line in South Africa. Ledger and Annegarn (1981) report 284 electrocuted Cape Vultures along lines in the same area. Garzon (1977) documented the electrocution of several species of raptors in Spain. Switzer (1977) mentions that about 100 hawks and owls are electrocuted by power lines in Saskatchewan each year. Bijleveld and Goeldlin (1976) note the electrocution of several hawks in Switzerland.

More recently, Benson (1981) found 416 raptor carcasses and skeletons along 24 five-mile (8-km) sections of power lines in six western states. In Utah U.S. Fish and Wildlife Service employees found remains of 594 raptors (some dead up to 5 years) under 36 different distribution lines (about 250 miles (402 km) total). Sixty-four of these carcasses were fresh enough to determine the cause of death; 54 (87.5 percent) had been electrocuted (Joseph In Prep.).

Looking at the magnitude of the problem in a different way, Gillard (1977) reports from Saskatchewan that 13 of 207 (6.3 percent) banded and recovered Great Horned Owls had been electrocuted. Meyer (1980) reviewed Bald Eagle mortality data for 1960 through 1974; 4 percent of the eagle deaths were attributed to electrocution (total sample size not given). Kochert (pers. comm. in Snow 1973) reported that 55 percent of 60 autopsied Golden Eagles from Idaho had been electrocuted.

It is impossible to relate these figures to the overall population dynamics of eagles, because several other direct and indirect mortality factors must be considered. Habitat alteration, shooting, and, in the case of the Bald Eagle, organochlorine pesticides are probably all more detrimental than electrocution by power lines. For example, the search for dead eagles in Wyoming and Colorado during the spring and summer of 1971 also revealed a major shooting campaign. During August, 1971, a Wyoming helicopter pilot told the Senate Environmental Appropriations Subcommittee that he had piloted several eagle hunts during the preceding seven months during which roughly 560 eagles were killed. The shooting was commissioned by the father-in-law of the Casper, Wyoming, sheep



rancher who had set the thallium sulfate baits that resulted in the Jackson Canyon incident. Further testimony by the helicopter pilot revised the estimate of eagle kills to nearly 800 and implicated at least 12 other Wyoming ranching companies.

The alliances between industry, government, and conservation organizations that grew out of these adverse circumstances have been instrumental in identifying solutions to the eagle electrocution issue. Formal reaction by the electric industry to its share of the problem was initiated in response to a January, 1972, letter from Robert K. Turner, Rocky Mountain Regional Representative of the National Audubon Society, to Thomas Riley of the Pacific Gas and Electric Company. This letter, which drew attention to the situations in Colorado and Wyoming, especially the electrocution problem, was forwarded to Richard S. Thorsell of the Edison Electric Institute in New York City (now located in Washington, D.C.). Edison Electric Institute is the association of electric utility companies in the United States. It provides a committee structure and coordination for the industry. Through the Institute, Thorsell has coordinated most of the meetings, fund raising, and publications (including the present one), which have resulted in significant progress toward decreasing the hazard of power lines to eagles.

About the same time, several Federal agencies were alerted. A meeting to discuss the electrocution problem was held in Washington, D.C., on January 19, 1972 (U.S. Fish and Wildlife Service 1972). In attendance were representatives of the Rural Electrification Administration, Forest Service, Bureau of Land Management, Fish and Wildlife Service, National Park Service, and Bureau of Indian Affairs. The position of each agency was presented, and it was agreed that the Fish and Wildlife Service would coordinate the search for lethal lines and that the Rural Electrification Administration would begin developing proposed line modifications to minimize eagle electrocutions.

An early assumption by everyone seriously committed to solving the raptor electrocution problem was that eagle mortalities along power lines were directly related to the presence of the line, irrespective of whether the birds were shot or electrocuted. In addition, most segments of the electric industry recognized that solving or at least minimizing the problem was good business, both from technical as well as political viewpoints.

One of the most important aspects of power line design is reliability. Anything that can cause an outage, particularly if it is a common problem, can cost an electric company hundreds of thousands of dollars annually in lost revenues and repair costs. Raptors and other birds cause a significant number of outages. For example, when birds are electrocuted or shot, they 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 (an insignificant mortality factor according to Baldrige 1977; Pinkowski 1977; Kroodsma 1978; and Meyer 1979, 1980), dropping prey or nesting material onto energized wires, and building nests on power poles in positions that jeopardize the reliability of the lines (see below).

The first Edison Electric Institute workshop concerning eagle electrocution and its relationship to power outages and other related issues was held in Denver, Colorado, on April 6, 1972 (Olendorff 1972c). It was attended by representatives of western power companies, the U.S. Rural Electrification Administration, state and Federal wildlife agencies, and major conservation organizations. Three results of this meeting were: 1) striking an accord between the participants to seek modifications and restrictions that would be both biologically and economically feasible; 2) establishment of a raptor mortality reporting system to be administered by the U.S. Fish and Wildlife Service; and 3) distribution of the first definitive document concerning the prevention of eagle electrocution (i.e., U.S. Rural Electrification Administration 1972).

The Rural Electrification Administration (REA) is an agency of the Department of Agriculture that lends money to cooperatives which supply electricity primarily to customers in rural areas. While basically a bank, REA also sets minimum standards for power line design as part of the loan conditions. Before the April 6, 1972, meeting in Denver, it had already been determined that early three-phase and single-phase REA-designed power lines presented the most serious electrocution problems to eagles (see below). REA Bulletin 61-10 entitled "Powerline Contacts by Eagles and Other Large Birds" dealt with the causes of raptor electrocutions resulting from certain grounding practices and conductor spacing (U.S. Rural Electrification Administration 1972). Suggestions were made as to how member companies could correct existing problem lines or design new lines that were safe for eagles. The consensus of the participants at the Denver meeting was that REA Bulletin 61-10 was an excellent starting place for further action.

The U.S. Fish and Wildlife Service raptor electrocution reporting system was instituted in 1973. After initial documentation of about 300 eagle carcasses and skeletons that had accumulated during 1972 and two or three previous years, the number of reported eagle mortalities along power lines dropped from 123 in 1973, to 88 in 1974, and to 65 in 1975. While these data are suggestive, no conclusions can be drawn from them. Too many variables were involved to ensure reliability of the figures. For example, during the same period, the trend in mid-winter Golden Eagle populations was downward in response to a steep jackrabbit population decline one to two years earlier. In response, the number of Golden Eagles electrocuted in Idaho declined during those years (Kochert 1980) when fewer young Golden Eagles were fledged. Also, the figures yielded by the reporting system are contradicted by recent findings of substantial numbers of eagle mortalities along power lines in several western states (Benson 1981, Joseph In Prep.).

Thus, while national summary data concerning the magnitude of the electrocution problem are of interest, the standardization of data collection is difficult. Management action to correct lines is of greater importance. A sharp downward trend in eagle electrocutions throughout the West remains a goal, but to reach it emphasis must be on proper design and corrections in problem areas, not on counting dead eagles.

As data were gathered on the magnitude of raptor electrocutions during the early 1970s, several regional meetings were held to familiarize more industry and agency personnel with the problem. Meetings in Ontario, Oregon (April 16, 1974) (U.S. Bureau of Land Management 1974d), and Reno, Nevada (October 3, 1974), are 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, together with the technical and biological analyses of several other industry and agency personnel, formed the basis for the second definitive work on this subject: "Suggested Practices for Raptor Protection on Powerlines" (Miller et al. 1975). This publication has been widely circulated and utilized effectively by both industry and government (Damon 1975, Edison Electric Institute 1975). For example, on U.S. Bureau of Land Management administered lands, new power lines proposed by the electric industry require rights-of-way permits. When application is made to construct a new line, the Bureau must decide 1) whether to grant the permit and 2) 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 U.S. Bureau of Land Management directives, as well as those of other agencies, require similar clearances and explicitly stipulate that such actions be consistent with the suggested practices of Miller et al. (1975).

Thus, the state of the knowledge of raptor electrocution problems and their solutions was well documented in 1975. Electrocution had been identified as a definite mortality factor of raptors, particularly Golden Eagles; but it was also recognized early on by agency biologists, conservationists, and industry personnel alike as a situation that could be largely corrected by design modifications. More importantly, however, raptor protection became an issue of the people as indicated by the attention given to the subject in newspaper articles (Denver Post 1974; Gilliland 1975 (Idaho Statesman); New York Times 1972, 1976; Simison 1973 (Wall Street Journal); St. Paul Pioneer Press 1976), conservation organization publications (Conservation News 1973, 1976 (National Wildlife Federation); Denver Audubon Society Newsletter 1971; Laycock 1973 (National Audubon Society); Pendleton 1978 (Defenders of Wildlife); Raptor Research Foundation 1975; Society for the Preservation of Birds of Prey 1976; Wyoming Wildlife News 1977), and power company newsletters (Consumers Power Company 1972; Hutchinson 1973 (Public Service Company of Colorado); Illinois Power Company 1972; Northwest Electric Light and Power Association News 1977; Public Service Company of Colorado 1973).

Eagle electrocution is a classic, "clinical ornithology" problem which involves intervention in and change of "an unhealthy relationship that has arisen between an organism and its human influenced natural environment" (Zimmerman 1975). We continue to discover new problem areas which require such intervention to prevent electrocution hazards to eagles (Benson 1981, Joseph In Prep.), but with each discovery more is learned. The following new assessment of the problem and its solutions reflects what was learned between 1975 and 1981.

**PART TWO**

**THE BIOLOGICAL**

**ASPECTS OF**

**RAPTOR ELECTROCUTION**

## PART TWO:

### THE BIOLOGICAL ASPECTS OF RAPTOR ELECTROCUTION

Raptors are electrocuted by power lines because of two seemingly unrelated yet interactive factors: 1) the distribution, size, behavior, and other biological aspects of raptors, and 2) designs of electric industry hardware which place phase and ground wires (see PART THREE for definitions) close enough together that raptors can simultaneously touch them with their wings or other parts of their bodies. Considerable research has been conducted since the early 1970s to provide a better understanding of these interactions and why some raptors are more susceptible to electrocution than others. The research and analyses of Erwin L. Boeker (Boeker and Ray 1971; Boeker [1972], 1974; U.S. Fish and Wildlife Service 1972; and Boeker and Nickerson 1975), Morlan W. Nelson (Nelson and Nelson 1976, 1977; Nelson 1974, 1975, 1976, 1977, 1978, 1979a, 1979b, 1980a, 1980b, 1980c 1980d; Hjortsberg 1979; Anderson 1975), and Patrick C. Benson (1977, 1980, 1981) are particularly noteworthy in this regard. Their work has effectively bridged the gap between the biological and engineering disciplines involved in the raptor electrocution issue. The corrective measures that have resulted both for new and old designs can now make nearly all power lines safe for eagles. However, to minimize biological impacts, planners, land managers, and developers must also understand the ecological relationships involved.

#### Susceptibility of Raptors to Electrocution

The major groups of raptors are susceptible to electrocution in different ways and to varying degrees. Forest-dwelling accipiters -- the Sharp-shinned Hawk (Accipiter striatus), Cooper's Hawk (Accipiter cooperii), and Goshawk (Accipiter gentilis) -- rarely perch on power lines and poles. The seclusion and shelter of trees are used more by these species than are the relatively exposed perches provided by electric transmission and distribution facilities. Ground-oriented raptors, such as the Marsh Hawk (Circus cyaneus), Short-eared Owl, and Burrowing Owl (Athene cunicularia), are rarely electrocuted, although some records do exist (Benson 1980, 1981; Pendleton 1978). Small species, such as the American Kestrel (Falco sparverius) and Screech Owl (Otus asio), simply cannot span the distance between two electric conductors, even with outstretched wings, except on rare occasions.

Electrocution of smaller raptors is probably underestimated by the existing data, since they are not as noticeable to investigators and since mammalian predators may carry off or consume small raptors before they are found. According to ranchers who have taken notice, larger eagles generally are not carried off by foxes, coyotes, and other predators. A higher frequency of electrocution of smaller raptors is also suggested by the electrocution of twenty or more hawks and falcons used in falconry during the past decade, primarily near transformers where conductor spacing is commonly only a few inches or centimeters. This problem is increased by the telemetry antennas that many falconers attach to their birds to help in locating them should they fly away (Chindgren 1980, 1981).

Nonetheless, large size is by far the most crucial factor which predisposes certain raptors to electrocution. One of this continent's largest owls, the Great Horned Owl, is the most commonly electrocuted nocturnal raptor, though less than one percent of the 416 avian mortalities found by Benson (1981) along electric distribution lines carrying less than 64 kV were of this species. Ansell and Smith (1980) reported that 4 of 113 (3.5 percent) of such mortalities in Idaho between 1972 and 1979 were Great Horned Owls. Gillard (1977) also reports noteworthy Great Horned Owl electrocution mortality in Saskatchewan.

Wild large falcons, such as Peregrine Falcons (Falco peregrinus) and Prairie Falcons (Falco mexicanus), are rarely electrocuted, although Benson (1981) reports the deaths of three immature Prairie Falcons along electric distribution lines.

Buteos or soaring hawks make up the largest non-eagle group of power line mortalities. About 8 to 12 percent of all raptor mortalities along power lines are Red-tailed Hawks, Rough-legged Hawks (Buteo lagopus), Ferruginous Hawks (Buteo regalis), and Swainson's Hawks (Buteo swainsoni) (Benson 1981, Ansell and Smith 1980, Peacock 1980, Joseph in Prep.). With the exception of the Swainson's Hawk, these are species that winter extensively in the Great Basin, prairies, or cold deserts of western North America and commonly perch on power poles and transmission towers. All but the Rough-legged Hawk also nest there.

Between 70 and 90 percent of all raptor mortalities along electric distribution lines are eagles. Corroborating data can be found in Benson (1981), Boeker and Nickerson (1975), Peacock (1980), Ansell and Smith (1980), Olendorff (1972a), and Joseph (In Prep.). Boeker [1972] reports that 5 percent of 300 eagle deaths along power lines between 1970 and 1972 were threatened or endangered Bald Eagles. The numbers of Bald Eagle deaths vary from area to area as indicated by the following studies: Ansell and Smith (1980)--1.7 percent of all (N=91) eagle mortalities; Peacock (1980)--4.6 percent (N=133); Benson (1981)--0.0 percent (N=343); and Joseph (In Prep.)--9.9 percent (N=111). Willard (1978) reports that 6 to 8 percent of Bald Eagle mortality is due to transmission lines.

The overall level of Bald Eagle loss may be underestimated by these studies because Ansell and Smith (1980) and Peacock (1980) worked where there were few large concentrations of Bald Eagles. Platt (1976) mentions seeing 24 Bald Eagles sitting on a series of 35 power poles in a nearly treeless prairie in Utah. Joseph (In Prep.) studied lines where up to 300 Bald Eagles have been seen near Vernon, Utah. The area used has many power lines, but most have been corrected. If this type of concentration occurred where lines had not been corrected, e.g., in Nevada or other similar "cold desert" habitats, Bald Eagles could suffer greater losses, particularly as the numbers of Bald Eagles increase following the DDT ban.

The threatened or endangered status makes the loss of each Bald Eagle potentially significant. However, throughout most of its range the Bald Eagle perches mainly on trees, not on power line supports (e.g., see Meyer 1979). It is unrealistic to expect to prevent every Bald Eagle electrocution because of the unpredictability and infrequency of such occurrences. Moreover, most Bald Eagle electrocutions occur in the same areas where

Golden Eagles encounter problems (Smith and Murphy 1972, Joseph In Prep.). Because efforts to minimize electrocution of Golden Eagles will also benefit Bald Eagles and most other raptors, the remainder of this discussion will center on the biology of Golden Eagles and on preventing their electrocution. In any case, based on existing information, raptor electrocution in North America is mainly a problem of Golden Eagles.

### Golden Eagle Distribution

Geographical Distribution. Much of the Golden Eagle's success in North America comes from the species' adaptability to numerous nesting habitats. Only a few nest in the forested regions of the eastern United States, but western North America supports tens of thousands of Golden Eagles. The Golden Eagle population which winters in the western United States (but nests throughout western North America) is estimated at about 63,000 birds (Table 1). A few hundred (or thousand) additional birds probably winter in southern Canada and northern Mexico. Estimates of the percentages of each state in which Golden Eagles winter (Table 1) were based on personal experience, personal communications, reference to vegetation (habitat) maps, and extrapolations from published literature. Estimates of the number of Golden Eagles per 100 square miles (259.8 sq km) in each state were derived from 1974-1978 winter aerial transects conducted and/or coordinated by E.L. Boeker of the U.S. Fish and Wildlife Service. These transects also showed that about 64.4 percent of the observed Golden Eagles were adults. This is corroborated by transect data collected by the U.S. Bureau of Land Management in Idaho as part of the Snake River Birds of Prey Research Project (U.S. Bureau of Land Management 1980, M.N. Kochert pers. comm.). Data from 16 transects flown on the Snake River Floodplain between October, 1972, and January, 1981, indicate that 222 adults and 113 immatures (i.e., 66.3 percent adults) were seen.

Using a figure of 65 percent adults, the 63,242 total estimate (Table 1) represents about 41,000 adults or a potential of 20,500 pairs. Clearly, the Golden Eagle is neither rare, threatened, nor endangered on this continent, though local concern may be warranted where loss of habitat, human disturbance, and persecution campaigns are significant problems.

The conclusion that Golden Eagles are not rare, threatened, or endangered can also be reached by analyzing nesting data. Boeker and Ray (1971) found 147 nests sites along the front range of the Rocky Mountains in New Mexico, Colorado, and Wyoming. About one-third of these sites were active each year. For the most part, this did not include 12 pairs found in 1,000 square miles (2,598 sq km) of shortgrass prairie and winter wheatlands in northeastern Colorado (Olendorff 1975). This study area represents about one-fiftieth of the similar habitat in eastern Colorado.

The Texas to North Dakota corridor of states does not have nearly as many nesting Golden Eagles, but nesting densities are much greater in the intermountain areas of Wyoming, Montana, Idaho, Utah, Nevada, Arizona, New Mexico, and western Colorado. Reynolds (1969) followed up on earlier work by McGahan (1965) in south central Montana where the Rocky Mountain foothills meet the plains. Twenty-three pairs were found in 1967 in 1,260

Table 1. Estimated wintering Golden Eagle numbers in the western United States.

State	Sq Mi <u>1/</u>	Percent Habitat <u>2/</u>	Habitat (Sq Mi)	Eagles per 100 Sq Mi <u>4/</u>	Total Eagles
Arizona	113,909	85	96,800	0.9	871
California	158,693	60	95,200	5.3 <u>5/</u>	5,046
Colorado	104,247	70	73,000	9.7 <u>6/</u>	7,081
Idaho	83,557	50	41,800	6.7 <u>7/</u>	2,801
Kansas	82,264	10	8,200	7.2 <u>8/</u>	590
Montana	147,138	75	110,400	11.9	13,138
Nebraska	77,227	10	7,700	7.2 <u>8/</u>	554
Nevada	110,540	80	88,400	5.3	4,685
North Dakota	70,665	15	10,600	2.1	223
New Mexico	121,666	85	103,400	8.5	8,789
Oregon	96,981	45	43,600	0.9	392
South Dakota	77,047	20	15,400	7.2	1,109
Texas	267,338	35	93,600	1.7	1,591
Utah	84,916	85	72,200	8.3	5,993
Washington	68,192	50	34,100	0.9 <u>9/</u>	307
Wyoming	97,914	80	78,300	<u>3/</u> 12.9	10,072 <u>3/</u>
	<u>1,762,294</u>		<u>972,700</u>		<u>63,242</u>

1/ From BLM Public Land Statistics.

2/ Estimated from personal experience, personal communications, study of vegetation maps, and published literature.

3/ From Wrakestraw 1973. If U.S. Fish and Wildlife Service aerial transect data were used (i.e., 34.2 eagles per 100 square miles) the estimate would be 16,707 birds higher. Wrakestraw's data were more systematically collected over broader areas of the State.

4/ Primarily from unpublished U.S. Fish and Wildlife Service aerial transect data (used with permission of the Director, Denver Wildlife Research Center) for 1974-1978 (average of the 5 years where available), unless otherwise noted. See Boeker et al. 1978.

5/ Extrapolated from data collected in Nevada.

6/ Colorado data vary from 1.8 eagles per 100 square miles in southeast Colorado in 1974 to 21.3 per 100 square miles in northwestern Colorado, also in 1974.

7/ From U.S. Bureau of Land Management (1980) and M.N. Kochert (pers. comm.) as also reported by Boeker et al. 1978.

8/ Extrapolated from data collected in South Dakota.

9/ Extrapolated from data collected in Oregon.



square miles (3,273 sq km) -- a density one and one-half times that reported by Olendorff (1975) on the shortgrass prairie in northeastern Colorado.

Kochert (1972), in continuing work on Beecham's (1970) study area, reported 56 breeding pairs in a 1,422-square-mile (3,694-sq-km) study area along 150 linear miles (241 km) of the Snake River in southwestern Idaho. The density of this Upper Sonoran life zone population is three and one-third times greater than in the 1,000-square-mile (2,598-sq-km) Colorado study area. Page and Seibert (1973) and Seibert et al. (1976) found Golden Eagle nesting densities in the sagebrush dominated country in Elko County, Nevada, to be about the same as in northeastern Colorado -- 88 active pairs in about 8,500 square miles (22,083 sq km). About twice that density was noted by Edwards (1969) in western Utah (24 pairs in 1,100 square miles (2,858 sq km)).

The Pacific Coast States appear to have varying numbers of Golden Eagles -- more in the south than in the north. Thelander (1974) estimated that about 500 pairs nest in California each year. Eastern Oregon and eastern Washington have moderate numbers of Golden Eagles, of the order of 100-150 pairs each (possibly twice that in Oregon (Morlan W. Nelson pers. comm.)).

Ecological Distribution. As the above data indicate, the major concentrations of both nesting and wintering Golden Eagles are in the intermountain West, particularly in western shrub and grassland habitats, in combinations of these habitats, and in ecotones between shrub, grassland, and forest habitats.

Forested areas, where many natural perches are available, generally have fewer reported raptor electrocutions than parklands, shrublands, and grasslands (Benson 1981), although Yager (1978) reports that 6 of 20 Ospreys (Pandion haliaetus) found dead on Long Island and in the Adirondak Mountains of New York apparently had been electrocuted. Switzer (1977) reports that the heavily wooded areas of Saskatchewan average three electrocuted hawks and owls per year per superintendency (a political unit similar to a county in the United States). In parkland areas the average is six per year. In the more open grasslands of southern Saskatchewan electrocutions average twelve per year per superintendency.

Benson (1981) found a highly significant difference both in raptor use and in raptor mortalities along electric distribution lines in agricultural versus non-agricultural areas. There was much more use and many more mortalities in native shrublands. This difference was attributed primarily to variations in rabbit distribution and availability.

In particular, greater numbers of Golden Eagles were electrocuted where cottontail rabbits (Sylvilagus sp.) were present than where only jackrabbits (Lepus sp.) occurred (Benson 1981). Where only jackrabbits occurred, about 14 percent of the poles had raptor carcasses under them, compared to nearly 37 percent where only cottontails were found. Where both cottontails and jackrabbits were present, about 22 percent of the poles had raptor carcasses under them. The most lethal 25 percent of the

lines studied by Benson (1981) were in sagebrush dominated areas where rabbits frequently occurred in large numbers. No correlation was found between rodent population densities and the incidence of raptor electrocutions.

The attraction of eagles to areas of high rabbit populations and the relationship of this to electrocution and other power line mortalities (e.g., shooting) was also noted by Olendorff (1972a) in the particular area near the Pawnee National Grassland where 17 electrocuted eagles were found. Kochert (1980) concluded that the incidence of eagle electrocutions in Idaho was a function of the mid-winter eagle density which in turn was strongly related to the density of jackrabbits in the Snake River Birds of Prey Study Area. Clearly, habitat use by eagles coincides with the habitat use of their prey. Their prey occurs in native shrublands and grasslands, and, accordingly, more raptors are electrocuted in such habitats.

Seasonal Patterns. Most Golden Eagle mortalities (80.6 percent) along power lines (primarily electrocutions) occur during the winter, while most non-eagle mortalities (e.g., Red-tailed Hawks) occur during courtship and nesting (45.8 percent) (mostly adults) and fledging (29.2 percent) (mostly fledglings) (Benson 1981). Inclement weather (particularly rain, snow, and wind) during the winter increases the susceptibility of raptors to electrocution because of feather wetting (increased conductivity) and ineptness of immatures and subadults in landing on power poles in the wind (Nelson and Nelson 1976, 1977). Other factors, such as the attraction of eagles to high prey concentrations which coincidentally occur near dangerous lines are also involved, as is the energetic benefit of "still hunting" from poles compared to hunting from a soar. These factors will be discussed in greater detail in other sections of this report.

#### Physical Characteristics of Golden Eagles.

Size. The maximum wingspread of a female Golden Eagle is about 90 inches (229 cm); the wingspread of a male is about 12 inches (30.5 cm) less (Brown and Amadon 1968). Their tails are up to 13 inches (33.0 cm) long and extend about 10 inches (25.4 cm) below the top of their perch. The fleshy parts of their bodies which can make direct contact with electric wires include their feet, mouth and beak area, and the ends of their "hands" to which the primary feathers are attached. A perched eagle can reach out only about 7 inches (17.8 cm) and touch a wire or grounded crossarm brace at perch level with its beak. The effective reach from the fleshy tip of one "hand" to the tip of the other for a large female is about 4 1/2 feet or 54 inches (137 cm), i.e., about 36 inches (91.4 cm) 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 either rain-soaked or dry eagles to electrocution.

Electrical Qualities of Feathers and Skin. Nelson (1979b, 1980c) undertook extensive conductivity studies on eagle feathers and live birds to illustrate the electrocution risks of wet versus dry eagles. His major conclusions were as follows: 1) for voltages up to 70,000 volts and with

electrodes separated at least seven inches, there is no measurable current flow (no conductivity) through a dry feather (a dry feather is almost as good an insulator as air); 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; and 4) the hazard to wet birds is on the order of ten times greater than to dry ones and is exacerbated by a loss of some flight capability and control. It should be noted that the amount of current conducted through wet feathers is dependent upon the amount of salts and minerals present in the water.

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 (including ground wires, lightning arrestors, grounded metal crossarm braces, etc.). 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, 1980c). While lethal voltages and currents were not determined, these experiments demonstrated that at 280 volts, with a current of 6.3 milliamperes, the eagle's respiration increased; at over 400 volts with a current range of 9 to 12 milliamperes, the eagle convulsed. These trials, summarized below, indicate that skin-to-skin contacts are 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.

<u>Dry Feathers</u>	<u>Wet Feathers</u>	<u>Skin-to-Skin</u>
Negligible Effect At 70,000 V (no measurable currents, electrodes spaced 7 in.)	Burned at 5,000- 7,000 V (current off scale, not measurable)	Bird Convulsed at 400-500 V (current 9-12 milliamperes)

It is important to note that eagles are not likely to make skin-to-skin contacts with their wings unless take-offs and landings are stressed by wind, dampness, or general inexperience (young birds).

#### Golden Eagle Behavior

Raptor Use of Power Lines and Related Structures. One of the most important characteristics of raptors is that they are opportunistic. Use of power poles and towers by raptors for a variety of purposes is no exception. These uses include the following: perches from which the birds can find strong air currents, broadcast territorial boundaries, guard nests, and hunt prey; perches for the birds to rest, get shade (for smaller species), feed, and sun themselves; and substrates on which to build nests. In fact, some would argue that once a power transmission or distribution line is in place, the presence of the line itself mitigates any construction impacts to local raptor populations because of the opportunity for perching and/or nesting it provides. The use of power line structures as nest substrates and the potential for raptor management through providing artificial nesting platforms along transmission lines are discussed in greater detail in Part Four of this publication.

The degree of benefit that raptors derive from power lines depends on the size and behavioral versatility of the species, the habitats through which the lines run, the design of the lines and supporting structures, and the richness and vulnerability to predation of the prey resources in the area. In a before-and-after study of a newly constructed transmission line in eastcentral Colorado, Stahlecker (1975, 1978) found that although the transmission towers represented only 1.5 percent of the available perches in the area, 81 percent of the raptors were observed perched on them. Also, raptor use of the area along the line was greater after construction than before. In southeastern Idaho, Craig (1978) found that 77.6 percent of all perched raptors observed along a 116-mile (187-km) car survey route were on power poles or wires. Marion and Ryder (1975) found extensive use of power poles by perched raptors along a 45-mile (72.4-km) raptor census route in northeastern Colorado. Other notable studies which indicate high levels of raptor use of power poles and lines as perches have been conducted by Meents and Delesantro (1979), Pinkowski (1977), the Bureau of Land Management (1974e), and the Pacific Gas and Electric Company (in Edison Electric Institute [1980a]).

Preferred Poles. Of particular interest in analyzing electrocution problems is the use of power poles as hunting perches. "Still" hunting is an energetically conservative way to find prey, provided good prey habitat is within an eagle's view from the perch. This is often the case, and raptors tend to utilize "preferred poles" which apparently facilitate hunting success. When "preferred poles" are not safe for eagles, researchers have found up to six or eight eagle carcasses or skeletons under a single pole (Olendorff 1972a; Dickinson 1957; Edwards 1969; Benton and Dickinson 1966; Nelson and Nelson 1976, 1977).

One of the most important aspects of a preferred pole is that it provides considerable elevation of a perched bird above the surrounding terrain and thereby provides the eagle with a wide range of vision, easy take-off, and greater attack speed when hunting (Benson 1981; Boeker [1972]; Boeker and Nickerson 1975; Nelson and Nelson 1976, 1977). An incident involving six electrocuted Golden Eagles under a single pole near the Pawnee National Grassland in northeastern Colorado (Olendorff 1972a) is particularly instructive. From this pole an eagle can command a view of a wide, dry streambed filled with good stands of saltbush and sage, but no trees. To the south, on the opposite side of the streambed, the land rises slowly for a mile or more, thereby affording a view of even a larger hunting area to the eagle sitting on this pole.

Pearson (1979) stresses that in addition to perch height, high habitat diversity below a power line is also an important factor which leads to high raptor use of an area.

Actually, the increased habitat diversity is only an indirect cause for increased utilization. A more direct reason for increased utilization is the increased diversity and density of prey that is concomitant with the increased habitat diversity. It is normal to expect the raptors to spend more time hunting (perched) in areas that offer a greater potential for successful prey obtainment. (Pearson 1979: 4)

Benson (1981) statistically confirmed the predictions of earlier workers as to the relationship between perch height above the surrounding terrain and the occurrence of eagle electrocution. Actual height of electric distribution poles on which eagles were electrocuted was not much different from those on which they were not. (Pole height generally varies only 4 to 10 feet (1.2 to 3.0 m).) However, poles which gave eagles the greatest height advantage above the terrain (which may effectively vary 100 to 200 feet (30.5 to 61.0 m)) had a higher probability of mortalities occurring on them (i.e., the birds select for the best view of suitable surrounding hunting habitat).

The direction of the prevailing wind relative to the crossarm is also an important characteristic of poles which receive a great deal of raptor use. Boeker [1972] and Nelson and Nelson (1976, 1977) indicated that poles with crossarms perpendicular to the prevailing winds produced fewer raptor mortalities. Benson's (1981) statistics revealed that about half as many birds were found below poles with crossarms perpendicular to the wind compared to poles with crossarms diagonal or parallel to it. This difference is presumed to be related to the effect of wind on the ability of immature and subadult eagles to land on poles without touching wires or other energized parts (see below).

The capacity of the habitat adjacent to power lines to carry high prey populations is also important in determining which poles are used by eagles. In flat, homogeneous habitat where prey is uniformly distributed, one pole may receive no more use than the next, because neither offers any advantage to an eagle in locating prey (Ansell and Smith 1980). In the northeastern Colorado example (see above), however, the rabbit population was high. For the preceding several years the local landowners had posted their extensive land holdings with "no hunting" signs. Thus, very little rabbit hunting occurred. Cottontails, especially, but also jackrabbits, scattered in every direction as one drove through the area during the spring of 1971. A similar situation north of Thermopolis, Wyoming, in 1977 and 1978 resulted from a natural rabbit population "high" (Nelson 1979b).

Thus, because raptors are opportunists in seeking out concentrations of prey, as well as perches from which to hunt, their susceptibility to electrocution on improperly designed power lines is high. This biological predisposition to electrocution coupled with overall size maximizes the danger to larger raptors, such as the Golden Eagle, particularly on poles with crossarms perpendicular to the prevailing wind and which command a broad view of surrounding habitat that supports large concentrations of prey.

Adult vs. Immature Eagle Susceptibility to Electrocution. Studies have shown that most Golden Eagle mortalities (up to 98 percent of identifiable carcasses) along power lines are immature or subadult birds: Boeker and Nickerson (1975)--90.0 percent immatures or subadults (N=419); Joseph (In Prep.)--98.0 percent (N=101); and Benson (1981)--94.2 percent (N=52). The number of live immature or subadult Golden Eagles observed using electric distribution lines is considerably lower: Benson (1981)--79.5 percent immatures or subadults (N=156). In the general wintering

population, however, as determined by aerial transects, immatures and subadults usually do not predominate: Boeker and Ray (1971)--33.7 percent immatures or subadults; Wrakestraw (1973)--29.7 percent (N=6,383); Boeker (1974 unpubl. notes)--35.6 percent; and U.S. Bureau of Land Management (1980) and M.N. Kochert (pers. comm.)--33.7 percent (N=335). The ground surveys of Edwards (1969) over three winters (1966-1969) showed the population in western Utah to be 39.4 percent immatures or subadults (N=450).

Thus, there are actually more adults in the population than there are immatures and subadults combined, but the susceptibility of adults to electrocution is lower than one might expect in light of their preponderance in the general population. Conversely, immatures and subadults appear to be more prone to electrocution than adults, though there are fewer of them.

Susceptibility of immature as opposed to adult Golden Eagles to electrocution involves several factors, but none is more important than flying and hunting experience. All Golden Eagles are opportunistic in using high concentrations of rabbits whenever they are encountered. However, immatures and adults hunt their prey in different manners. Adults will sometimes "still" hunt from a power pole, but they are more likely than immatures to hunt from a soar. In doing so, they are not exposed to the hazard of electrocution as often.

Immatures, on the other hand, are supplied with food by their parents for the first several months after fledging. During that time they learn to fly and hunt. This involves frequent short flights from perch to perch to develop their flight capabilities. When they finally become interested in pursuing their own prey, they generally begin by "still" hunting from stationary perches, such as power poles, rather than hunting from a soar. This is particularly true in flat country where updrafts are less common. These first attempts to kill from perches involve continued frequent changes of perches following numerous unsuccessful chases. Benson (1981) observed one immature Golden Eagle make over 20, unsuccessful hunting sorties after cottontails from a distribution line. Had the line been unsafe for eagles and had the weather conditions been poor, that eagle could easily have fallen victim to electrocution.

Benson (1981) also found that fewer electrocutions occurred and there were fewer poles with multiple eagle kills under them in areas with only jackrabbits. He speculates that this is because aerial hunting (as opposed to "still" hunting) was the principal tactic used there. Catching jackrabbits with any consistency requires experience and tenacity in long, crosscountry chases initiated in flight. Adults or older subadults have this experience. Immatures find more success in pouncing on cottontails (which are restricted to smaller home ranges) from stationary perches such as power poles. Thus, they are strongly predisposed to electrocution.

The fact that immature eagles are generally less adept at maneuvering than adults, especially when landing and taking off from electric distribution lines, has been demonstrated by considerable research. The studies of Nelson (1979b, 1980c) and Nelson and Nelson (1976, 1977), where trained immature eagles were photographed landing on "dummy" power poles, were landmarks in resolving many raptor electrocution problems.

These studies, funded primarily by the electric industry, were inspired by the need for careful analyses of the many ways raptors are electrocuted. The research strategy was to film eagles landing on mockups of numerous configurations of power lines, approaching from several different angles, and in calm as well as inclement weather.

Eagles seldom perch on wires (conductors) and do not normally perch on pole-top porcelain insulators which tend to be too small or too smooth and slick for comfortable gripping. Instead, the firmer footing of pole tops and crossarms are used. Most often, when an adult eagle approaches a power pole crossarm with several (usually three) wires, it comes in under the outside wire, swings up between wires with wings folded, and virtually stalls out onto the perch. The landing, when made into a head wind rather than a crosswind, is skilled and graceful with very little flailing of wings.

Immature Golden Eagles often try to settle onto a crossarm from above, using their outstretched wings to brake their descent. They sometimes approach diagonally and go to the highest point -- usually an insulator -- then slip off or change to the crossarm. When there is awkwardness or lack of coordination, a crosswind, or if the bird is wet, the imbalance of stopping quickly often causes the bird to lean forward. This is corrected by more wing flapping near the wires and other energized parts of the structure, thereby increasing the chance of electrocution. Sometimes immature birds begin corrective action at some distance from the poles, particularly when the in-run is too swift or at the wrong angle. If they are coming in parallel to the lines, they can settle down across two of them or fly up under two of them and be electrocuted.

Hundreds of hours of actual observations and analysis of slow-motion 16-mm movies of Morlan W. Nelson's trained immature eagles clearly demonstrated that during landing the birds caught the wires of the dummy poles between their outer primaries deep enough to make skin-to-skin contact near the tips of each "hand." 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. Using different structural arrangements of dummy lines and supports, researchers determined exactly which lines were dangerous and which were not (Nelson and Nelson 1976, 1977; Hannum et al. 1974; Miller et al. 1975). From these analyses, methods to modify old designs and to plan new construction were conceived to maximize eagle safety. This effort is documented in the movie "Silver Wires, Golden Wings" coordinated by the power industry through the Edison Electric Institute (1980b).

Other Behavioral Factors. When raptors nest near problem lines, their fledglings may be more vulnerable to electrocution. Fitzner (1978) found a young Swainson's Hawk electrocuted in southcentral Washington State soon after it fledged. Gillard (1977) reported two fledgling Great Horned Owls electrocuted near nests in Saskatchewan. Several young Peregrine Falcons being introduced to the wild in the Eastern United States (with trailing telemetry antennas) have also been electrocuted (Cade and Dague 1977). Nelson and Nelson (1976, 1977) found numerous Golden Eagle bones and



feathers beneath a few poles near an active eyrie. However, the mitigation of these situations is difficult, because the experience level of an immature raptor will still be low when it encounters power lines at considerable distances from its nest during the first month or so after fledging. There is no evidence that electrocution is more common in nesting areas. To the contrary, most eagles are electrocuted on their wintering grounds.

Encounters between wintering immature or subadult Golden Eagles may result in lethal movements of birds perched on power poles. Any random, vigorous movement near inadequately separated conductors increases the chance of electrocution considerably. Benson (1981) reports finding one pair of electrocuted eagles below a pole with the talons of each bird imbedded in the breast of the other. While 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. Four other instances of pairs of freshly electrocuted immatures found below power lines were also noted.

Several instances of electrocution of birds carrying prey or nest material have been reported. Fitzner (1978) and Switzer (1977) speculate that a dangling snake or rabbit could help span the gap between conductors or between a conductor and a ground, thereby allowing sufficient current to flow to electrocute the bird. Gillard (1977) found a young Great Horned Owl electrocuted; it had been carrying a freshly killed snowshoe hare (Lepus americanus) which apparently touched a grounded wire while the bird touched a conductor. Similar incidents are noted by Brady (1969) and Hardy (1970). Nest building is also a critical period, particularly for smaller raptors. Benson (1981) found that most non-eagle electrocutions occur during the nesting phase. If the nest is built on the power pole itself, the problem is extremely critical. Two adult Red-tailed Hawks were electrocuted at separate nests in Wyoming (Benson 1981), and Ospreys have been electrocuted when carrying seaweed (New York Times 1951) and barbed wire (Electric Meter 1953) to their nests.

Rain not only increases the conductivity of feathers, but also elicits a spread-wing, drying behavior in raptors and many other birds. This behavior increases the chance of electrocution. While most nesting eagles do not typically perch on electric distribution poles at night, wintering eagles do; and they are frequently soaked by nighttime rain or snow storms. When the storm is over, or at the first sun of the morning, a wet eagle will extend its wings and let them droop in a relaxed manner below the level of its perch.

The hazard of this behavior was verified by Nelson (1979b) on the dummy poles. A trained eagle was soaked with a garden hose and placed on the mockup crossarm in the sun. "The eagle immediately spread its wings to dry and touched both wing tips and the skin of the wing joints to the conductors." (Nelson 1979b: 4). Bathing may also increase the risk of electrocution, primarily to wintering birds. Wintering birds often dry on the poles where their lives are centered during that period. Nesting adults normally would dry in the trees or on the cliff near their nest or their bath.



**PART THREE**

**POWER LINE DESIGN**

**AND MODIFICATION**

**FOR RAPTOR SAFETY**

## PART THREE:

### POWER LINE DESIGN AND MODIFICATION FOR RAPTOR SAFETY

#### Background and Terminology

The design of new power line configurations and the modification of existing lines to be safe for eagles must be based on biological considerations as well as the fundamental physics of electric current, the reliability of electric service, numerous economic and political factors, and safety of both the public and operating personnel. Reliability is particularly important because power outages frequently occur when birds are electrocuted. Restoration of service requires a lengthy search for the cause of the outage and expensive on-site inspection and resolution.

Thus, while the biologist and the engineer can individually advocate sound technical solutions to the eagle electrocution problem, they collectively must consider all factors before making recommendations to their managers or corporate executives. Line changes requested by biologists cannot completely compromise other optimum design criteria, and economics must be factored into the solution.

Before prescribing solutions, however, it is important to understand precisely why lines electrocute birds, which general designs are especially lethal to raptors, and which are safe. Factors such as voltage (e.g., of transmission versus distribution lines), conductor spacing, and ground wire placement are of particular concern; but so, too, are the more general constraints on the electric power industry, such as public safety and other environmental considerations.

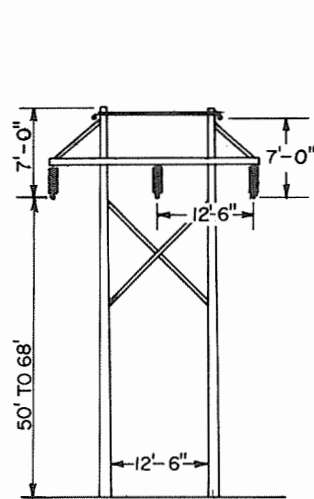
The increasing need for electrical energy has been precipitated by development and growth of communities, towns, and cities throughout the United States. Environmental pressures and concerns have forced the utility industry to construct power plants away from urban centers. This has made high voltage lines necessary to transmit the power from the generating stations to the areas of load for residential and industrial consumption.

High voltage power lines are referred to as transmission lines (Figure 1). Transmission lines are energized at voltages of 115,000 volts or higher, including 230,000, 345,000, 500,000, and even 765,000 volts. (Note: Some electric companies consider 69,000 volt lines as transmission lines. The separation is arbitrary and of little importance here.) Industry standards use kilovolt (kV) for each 1,000 volts; hence the terminology used would be 115 kV, 230 kV, 345 kV, 500 kV, or 765 kV, respectively. The electrical conductors (wires) comprising transmission lines are suspended 35 to 100 feet (10.7 to 30.5 m) above the ground (depending on voltage, topography, and landscape details) from wood or steel tower structures. These electrical conductors (termed "phases") are separated 12 to 30 feet (3.7 to 9.1 m) from each other depending on voltages. Most

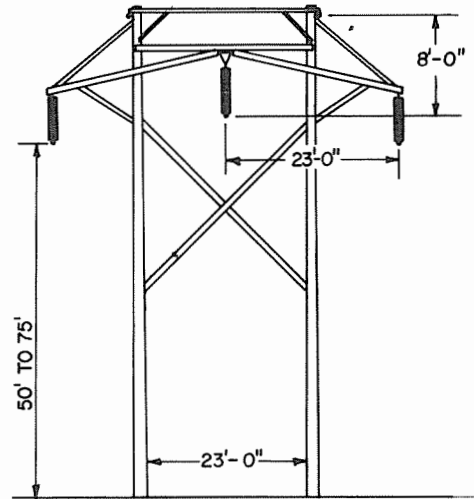
FIGURE I

# HIGH VOLTAGE TRANSMISSION STRUCTURES

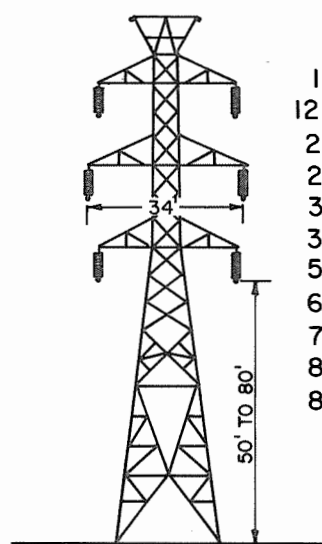
(SUFFICIENT CONDUCTOR SPACING PREVENTS  
PHASE-TO-PHASE OR PHASE-TO-GROUND CONTACT.)



TYPICAL 115KV WOOD H-FRAME

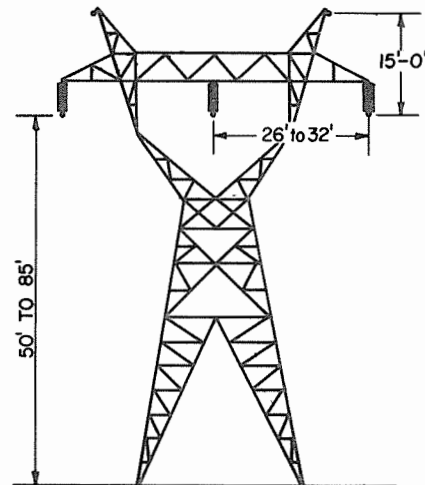


TYPICAL 230KV WOOD K-FRAME



TYPICAL 115KV  
DOUBLE CIRCUIT TOWER

7'	= 02.13 m.
8'	= 02.44 m.
15'	= 04.57 m.
12 1/2'	= 03.81 m.
23'	= 07.01 m.
26'	= 07.93 m.
32'	= 09.76 m.
34'	= 10.37 m.
50'	= 15.25 m.
68'	= 20.74 m.
75'	= 22.87 m.
80'	= 24.40 m.
85'	= 25.92 m.



TYPICAL 345/500KV  
TOWER CONFIGURATION

transmission lines will have two overhead ground wires for lightning protection in addition to the three phases of electrical conductors. Each transmission circuit utilizes three separate phases to transmit electrical energy.

A three-phase system, rather than a single-phase system, is used because the capacity of single-phase systems is only about one-third of the capacity of three-phase systems. Also, single-phase systems are not adaptable for general power purposes, because single-phase motors are limited to ten horsepower or less due to design and manufacturing limitations. Of all the alternating current methods of transmission, the three-phase (three-wires plus a neutral wire) requires the least conductor material and is therefore the most economical and efficient.

Transmission lines are terminated at substations where the voltages are transformed or reduced to lower voltages for distribution to industrial and residential loads. Distribution lines carry voltages ranging anywhere from 4 kV to 13 kV, 23 kV, 34 kV, or 69 kV (Figure 2). Conductors of distribution lines (usually three energized conductors and one neutral conductor (see below)) are commonly carried 26 to 30 feet (7.6 to 9.1 m) off the ground on wooden poles. Conductor spacing is sometimes only 2 to 4 feet (0.6 to 1.2 m), not sufficient to prevent electrocution of birds with 6 1/2- to 7 1/2-foot (2.0- to 2.3-m) wingspans.

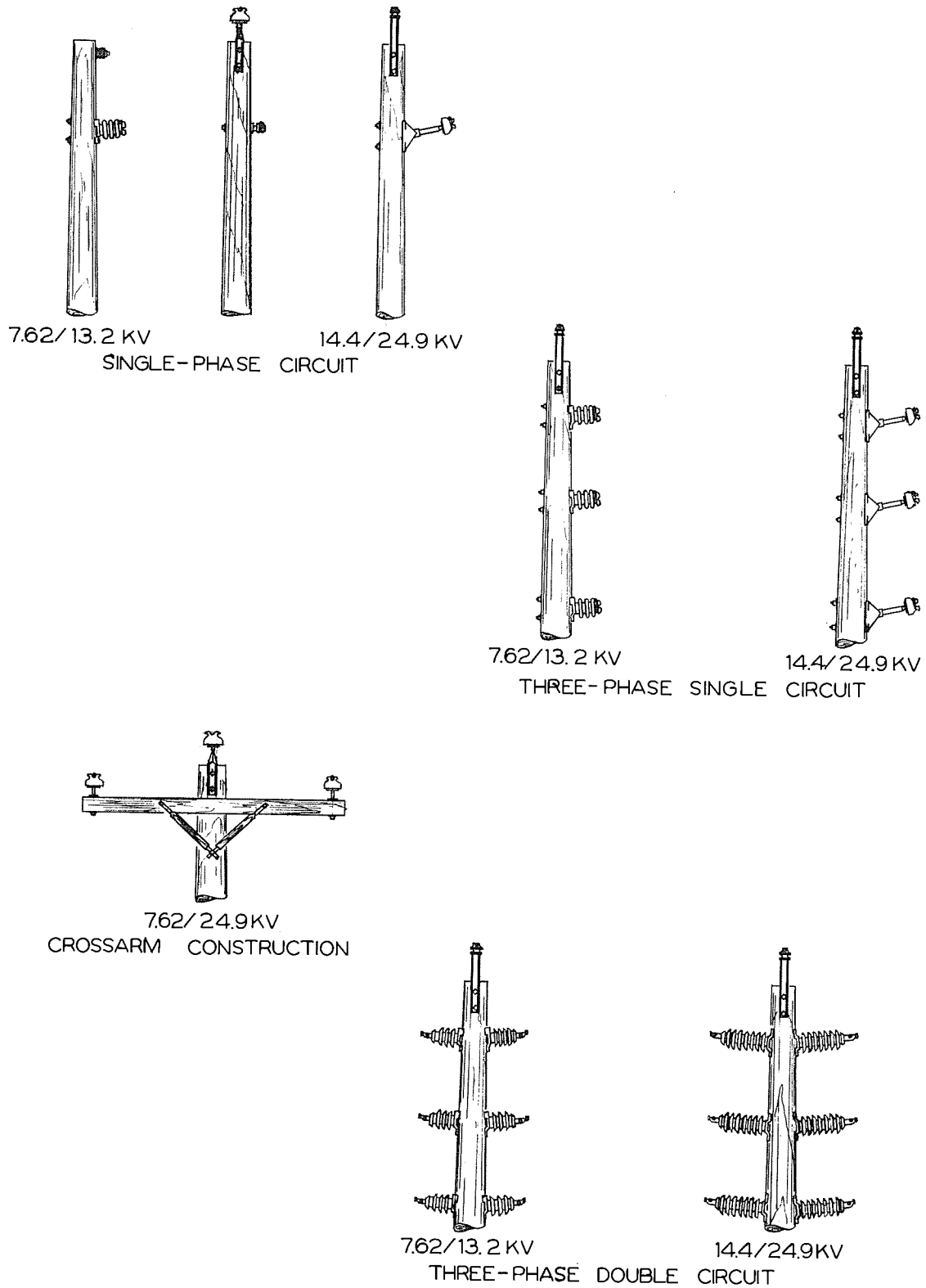
Most lines that electrocute raptors carry between 12 and 69 kV. Benson (1981) found that there was no significant difference in the number of raptor mortalities along lines which carry voltages in the lower portion of this range (12 to 23 kV) compared to the higher portion (34.5 to 69 kV).

Lines carrying 69 kV do not pose much of a hazard to dry eagles, because the birds can only make wingtip contact with the wires, and feathers are good insulation (see above). Nelson (1979b) cites an excellent example of the relative safety of 69 kV lines. An eagle used in falconry for two years was released along such a line near the Snake River Canyon where it subsequently nested on a cliff. Almost daily this bird (it had the remnant of the falconer's jess) perched and hunted from this line as documented by radiotelemetry (Dunstan et al. 1978). No electrocuted eagle has ever been found under this line, though several have been found under nearby distribution lines carrying lower voltages.

There is also a lower limit under which distribution lines rarely kill eagles. The principal examples are numerous 480-volt lines which generally supply farming and oil industry equipment in Wyoming. No electrocuted birds have been found under these lines, and Nelson (1979b, 1980c) demonstrated the non-lethal nature of such voltages during his conductivity studies. Also, the 480-volt lines are usually lower in elevation (pole height and terrain) than higher voltage feeder lines.

All electrical equipment must have certain protection from people and the elements. The terms used for protective equipment are similar to what we find in the normal residence today (e.g., fuses, switches, and circuit breakers). Lightning arresters are used extensively to protect transformers or residential meters from harm from lightning strikes. Fused

FIGURE 2  
TYPICAL DISTRIBUTION CONFIGURATION



cutouts are merely switches with fuses that burn out under certain conditions. This opens a switch as soon as the current through the fuse exceeds a certain limit, very similar to the common residential circuit breaker.

Other terms used in the following section which may need additional definition include the following. Insulators are usually porcelain objects used to separate conductors (wires) from crossarms or towers. Fiberglass, a new insulating medium, is being used more and more. Wood also has certain insulating qualities, especially when dry, which explains its wide use for crossarms, line supports (poles), and braces. Guy wires and anchors are used to reinforce poles in situations where poles cannot support loads by themselves. Transformers are coils of wire immersed in oil in a metal container. They are used to convert from one voltage level to another. The term energized is used whenever a conductor or piece of equipment is at a potential or voltage. A neutral conductor is normally at ground potential (0 volts). However, under certain operating conditions, such as during lightning conditions, current does flow in the neutral conductors. The same situation exists in the overhead ground wires (lightning protection wires) on transmission lines.

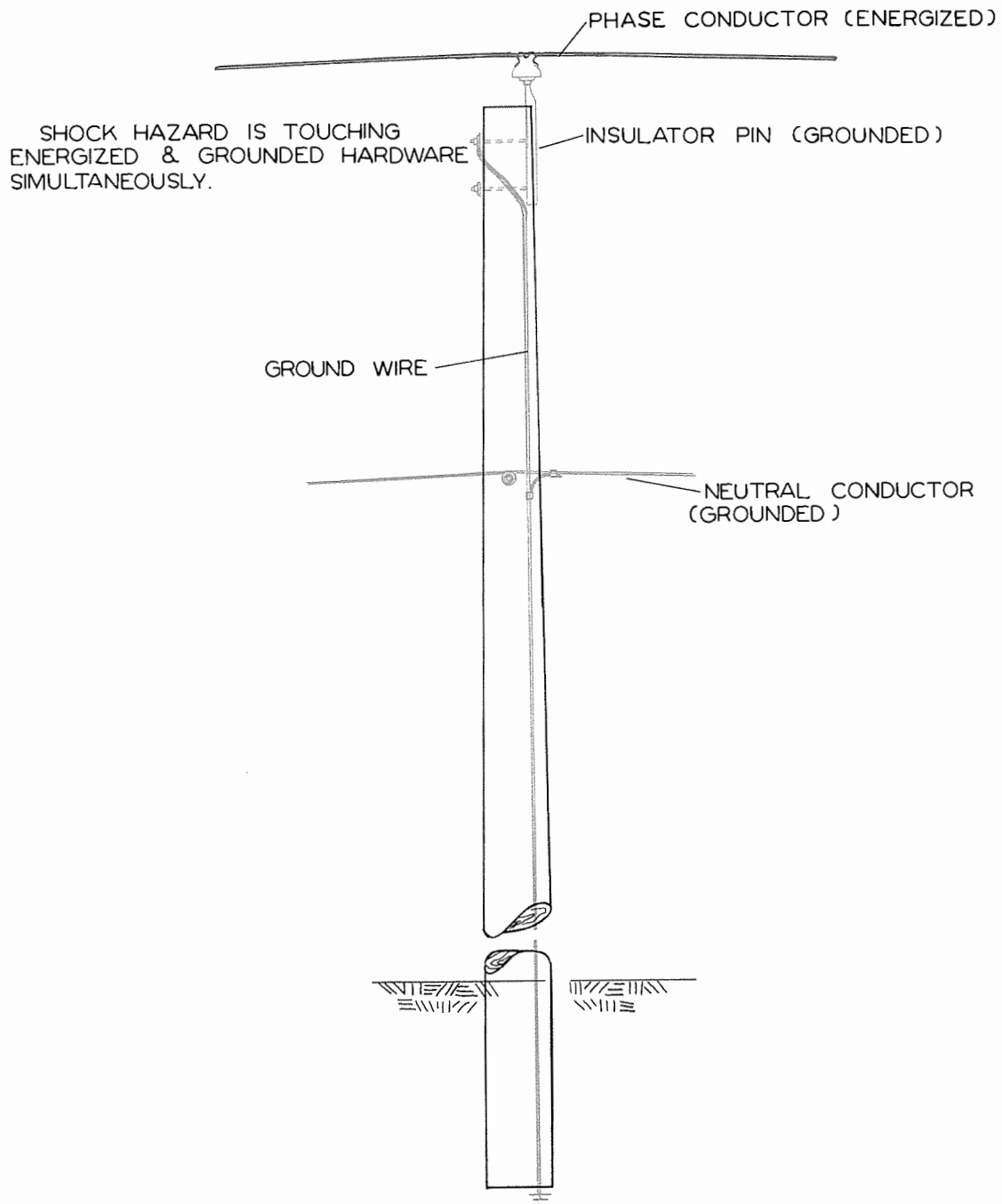
All electrical equipment must have certain portions connected to ground to drain off electrical charges which occur because of wind, insulation contamination, moisture, or other circumstances (very similar to the charge one builds up when walking on a thick carpet). Thus, ground wires are run down the sides of poles to drain charges from transformer cases, crossarm braces, insulator pins, or other metal equipment. Some grounding practices cause problems to raptors, humans, or other animals when the air gap is bridged between a ground potential and an energized conductor by a metallic object, human extremity, or the wings of a bird. Any time the gap is bridged an electrical conductive path is established, and the voltage is shunted to ground. As a result, electric current, measured in amperes, flows through the conducting medium to ground. It is the combination and magnitude of current and voltage that causes electrocution of raptors and humans.

### Specific Design Problems

The basic problems of all power lines which electrocute eagles are: 1) the distance between phase conductors is less than the wingspread of the bird landing or perching on them; and 2) design practices dictate the grounding of particular parts of the equipment to prevent damage from lightning. A variety of configurations of conductors and guy wires are necessary to change direction of the line or to connect equipment, switches, and safety devices to the lines. Each configuration may present a slightly different problem to biologists, engineers, and eagles.

Most electrocuted eagles found during the early 1970s were along two general types of pole lines. The first type, single-phase poles with the phase conductor carried on an insulator mounted on top of the pole and with a ground wire extending to near the top of the pole to ground the insulator pin (Figure 3), has been particularly lethal. With this design a perched bird can be electrocuted (even without opening its wings) by

FIGURE 3  
SINGLE-PHASE PROBLEM DESIGN



touching its breast to the conductor and its tail or foot to the grounded pin or ground wire. The specifications for this common Rural Electrification Administration design used for supplying power to rural ranches was changed in 1972 with wire gapping as shown in Figure 9 (see below). This was the design of the 7,240-volt line that killed 17 eagles in north-eastern Colorado (Olendorff 1972a).

The second extremely hazardous design is three-phase, single pole construction where a 6- or 8-foot (1.8- or 2.4-m) crossarm provides excellent perching opportunities to birds, but conductor spacing is insufficient (about 3 to 4 feet (0.9 to 1.2 m.)) to prevent their electrocution (Figure 4). Grounded steel crossarm braces add to the hazard of this design. Although its specifications were changed in 1962, this design remained very much in evidence in the field during the 1970s. Two variations of this design are common; one has the center phase carried on an insulator atop the pole, and the other has the center phase on an insulator mounted on the crossarm beside the pole top and closer to one of the outside phase wires (Figure 4). In the latter case, conductors are forced closer together, and the hazard increases proportionately.

Poles with transformers, corner poles, and other designs which include jumpers, other extra wires, or metal equipment mounted on the poles may require special consideration. Single-phase transformers or transformer banks for three-phase systems (Figure 5), have far more wires which eagles can touch than do poles which merely support conductors. Eagles and other raptors occasionally try to sit on top of transformer tanks rather than on top of the pole or on the crossarm. Corner poles require special guy wires and jumpers (Figure 6) because of the different forces placed on the poles and crossarms by changing line direction. When six to eight eagles are found under a single pole, it nearly always has extra equipment mounted on it and/or is a heavily used hunting perch.

### Suggested Practices

The two main considerations for making electric power line poles safe for eagles are: 1) modification of existing lines and 2) proper design of new facilities. Both activities are still vitally necessary in the effort to minimize raptor electrocutions. Experience has borne out, however, that because of the vast diversity of line designs and voltages used by different power companies, across-the-board standards and guidelines are impractical. The following suggested practices relate primarily to distribution lines carrying between 4 and 69 kV.

One factor which can minimize the number of modifications to existing structures is the "preferred pole" concept discussed above. It has often been stated (Simison 1973; White 1974; Anderson 1975; Nelson and Nelson 1976, 1977) that 95 percent of all eagle electrocutions could be eliminated by correcting 2 percent of the poles. While these percentages may be somewhat optimistic, it is still cost effective to initially approach the solution for a problem line by correcting particularly lethal poles. These usually are "preferred poles," but there are often complicating factors, such as extra wires for transformer leads, jumpers on corner poles, and grounded wires for controlling lightning damage. Biologists and engineers must be prepared, however, to abandon the "preferred pole"



FIGURE 4  
THREE-PHASE PROBLEM DESIGN

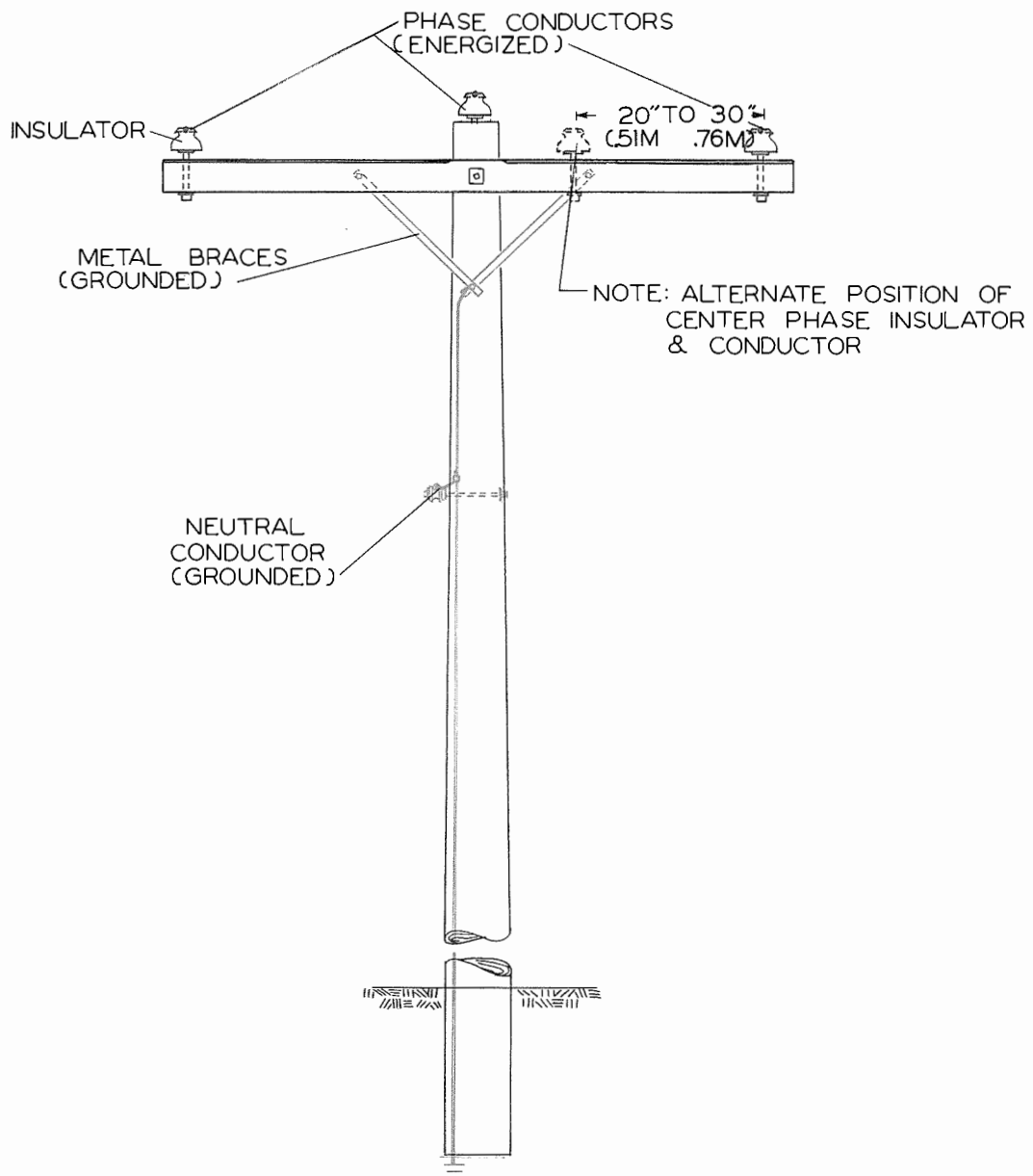


FIGURE 5  
COMMON TRANSFORMER CONFIGURATIONS

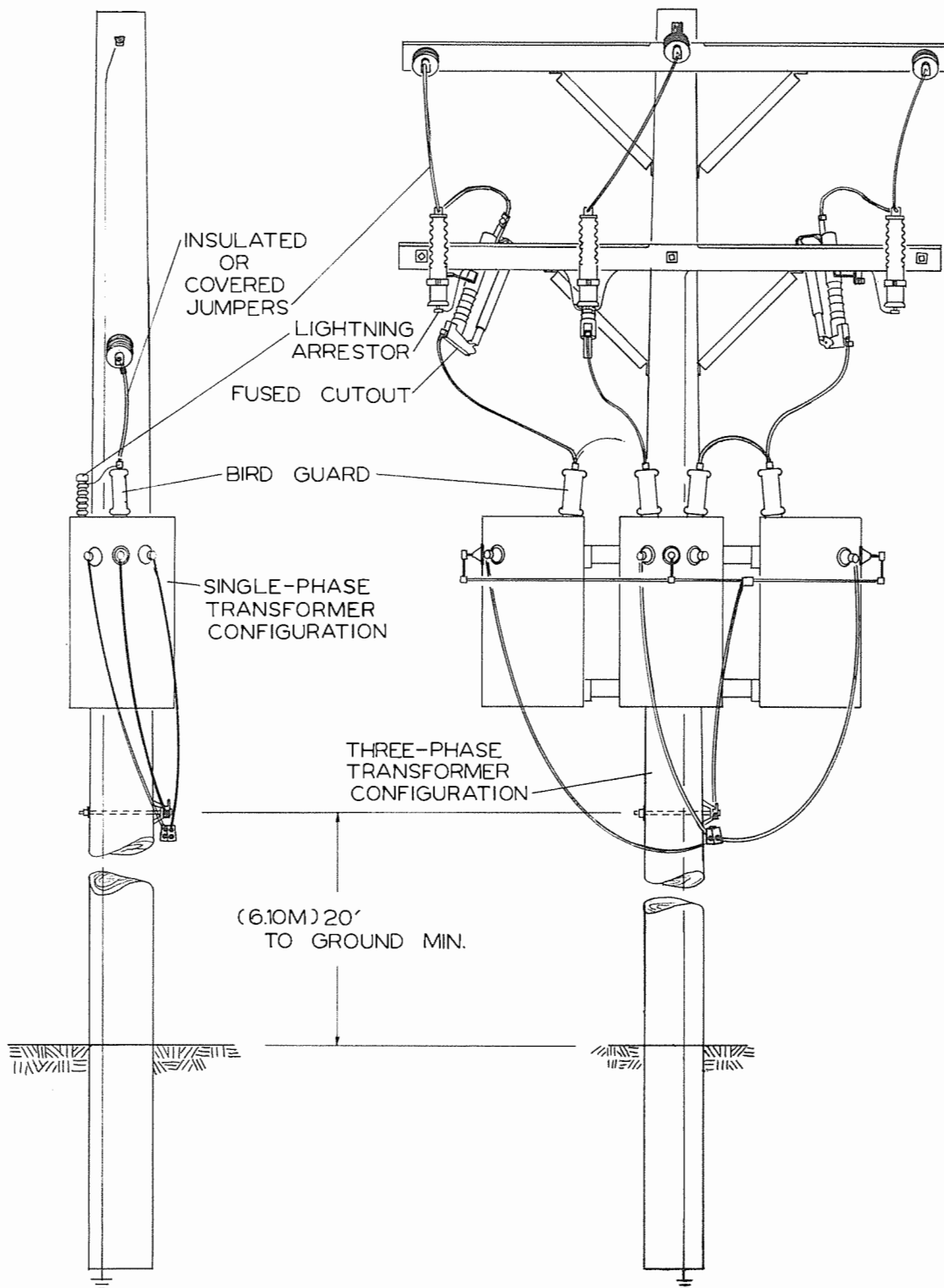
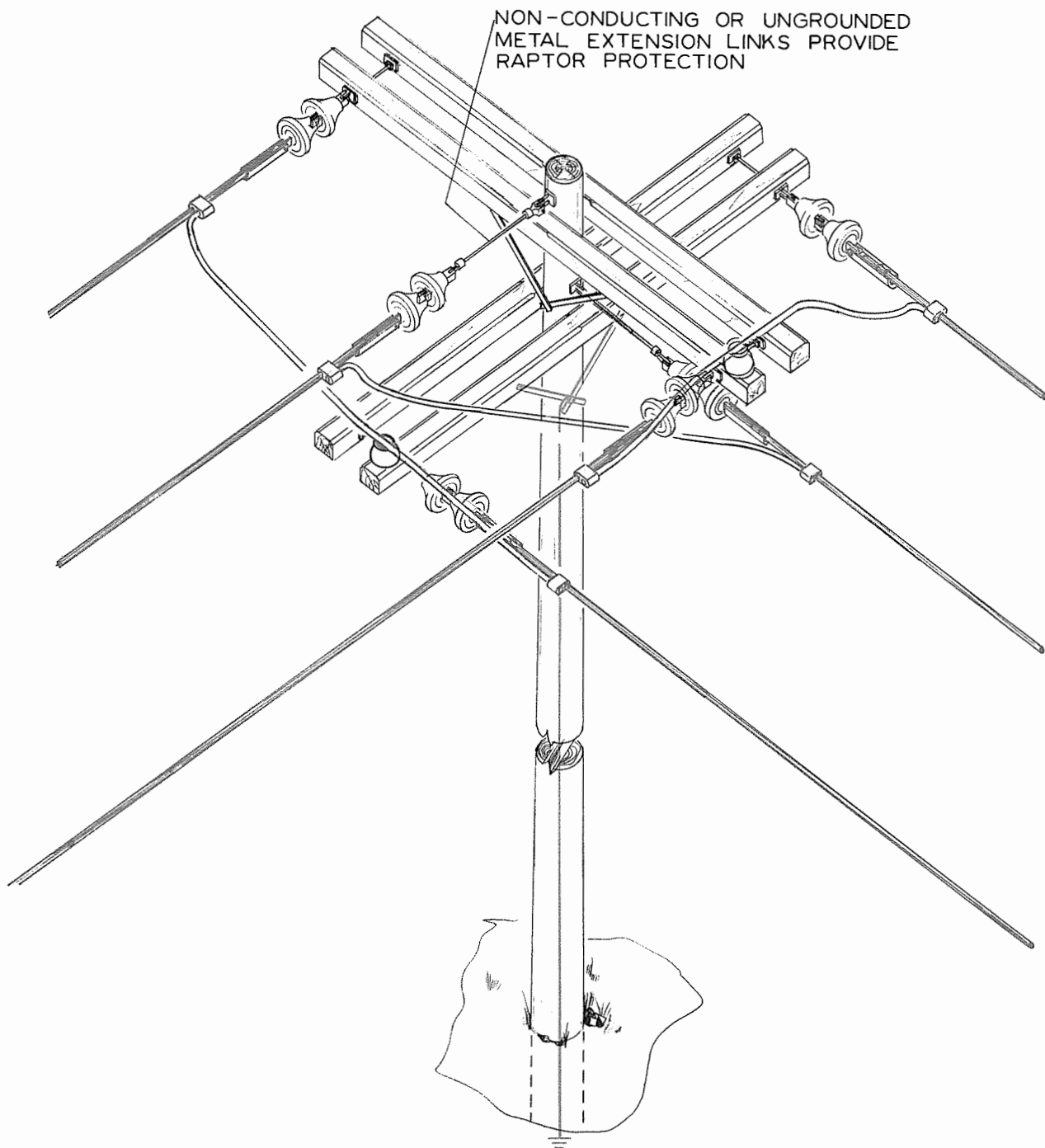


FIGURE 6  
TYPICAL THREE-PHASE CORNER CONFIGURATION



concept along long, linear stretches of lines through relatively homogeneous habitats. The technical solution may be the same in both cases, but in the latter instance modification of the poles may need to be more widespread and, therefore, more expensive.

As with the frequency of raptor electrocution, the cost of modifying existing problem lines decreases with the size of the raptor involved. If a line is electrocuting Red-tailed Hawks, Prairie Falcons, or other small raptors near their nests, the solution should be rather inexpensive compared to correcting lines for Bald or Golden Eagle protection. While protection of smaller raptors from electrocution may only require the application of insulation on certain wires, eagle protection frequently involves the rearrangement of wires to provide adequate spacing.

Because many of the methods for modifying old lines may be helpful in the design of new facilities, suggested practices are discussed below under the following three categories: 1) design and modification of poles, crossarms, and conductor placements to effect adequate separation of energized hardware; 2) insulation of wires and other hardware where sufficient separation cannot be attained; and 3) management of eagle perching.

Pole, Crossarm, and Conductor Configurations. Adequate separation of energized conductors, ground wires, and other metal hardware is the most important factor in preventing raptor electrocutions. The basic concepts necessary to prevent problems from arising from insufficient conductor spacing are the same whether one is designing new lines or modifying old ones.

On the lethal three-phase designs (Figure 4) where conductors are placed nearly horizontally, risk of electrocution can be reduced by providing vertical separation (and thus actual separation) of conductors by raising the center phase on a poletop extension (Figure 7) or by lowering the two outside phases (i.e., by lowering the crossarm if the center phase insulator is on top of the pole) (Figure 8) (Hannum et al. 1974, Dodge 1975, Miller et al. 1975). The objective in either case is a 60-inch (152-cm) minimum separation of conductors (Figures 7 and 8). There is no chance of skin-to-skin contact by Golden Eagles with this separation. Wing-tip to wing-tip contact with conductors is possible, but the likelihood of such contact under precisely the wrong wing position and weather conditions is minimal.

Vertical separation is more easily accomplished when designing new lines than when retrofitting existing lines. Lowering the crossarm (Figure 8) is possible only if there is sufficient ground clearance to maintain adequate public safety and line reliability. It is also very expensive unless the number of poles to be modified can be reduced through biological analysis, such as applying the "preferred pole" concept.

A more popular option has been to raise the center conductor further above the outside conductors using a pole-top extension (Figure 7) (Nelson and Nelson 1976, 1977; Benson 1981; Miller et al. 1975). These extensions are costly, yet when a solution is necessary, this may be the least expensive method.

FIGURE 7  
POLE-TOP EXTENSION

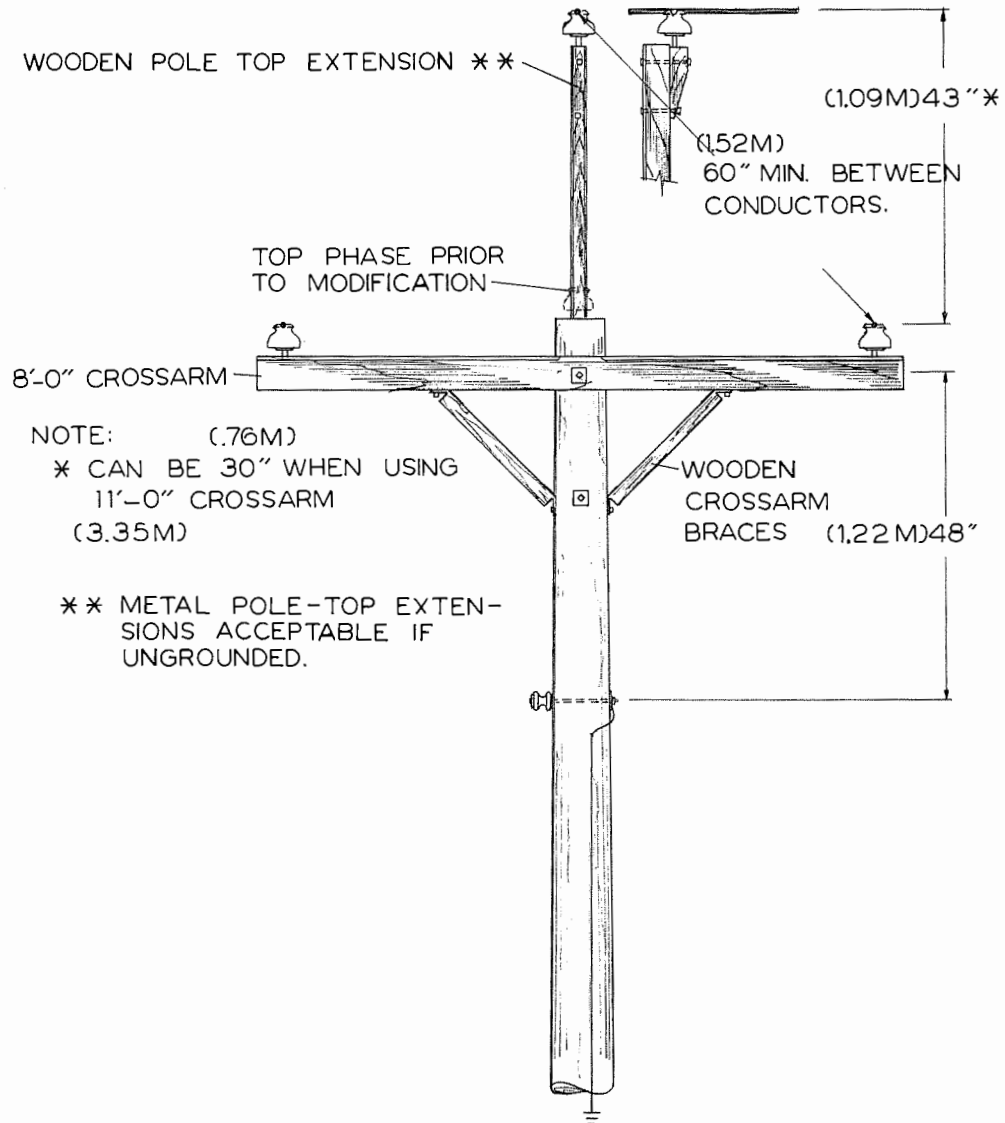
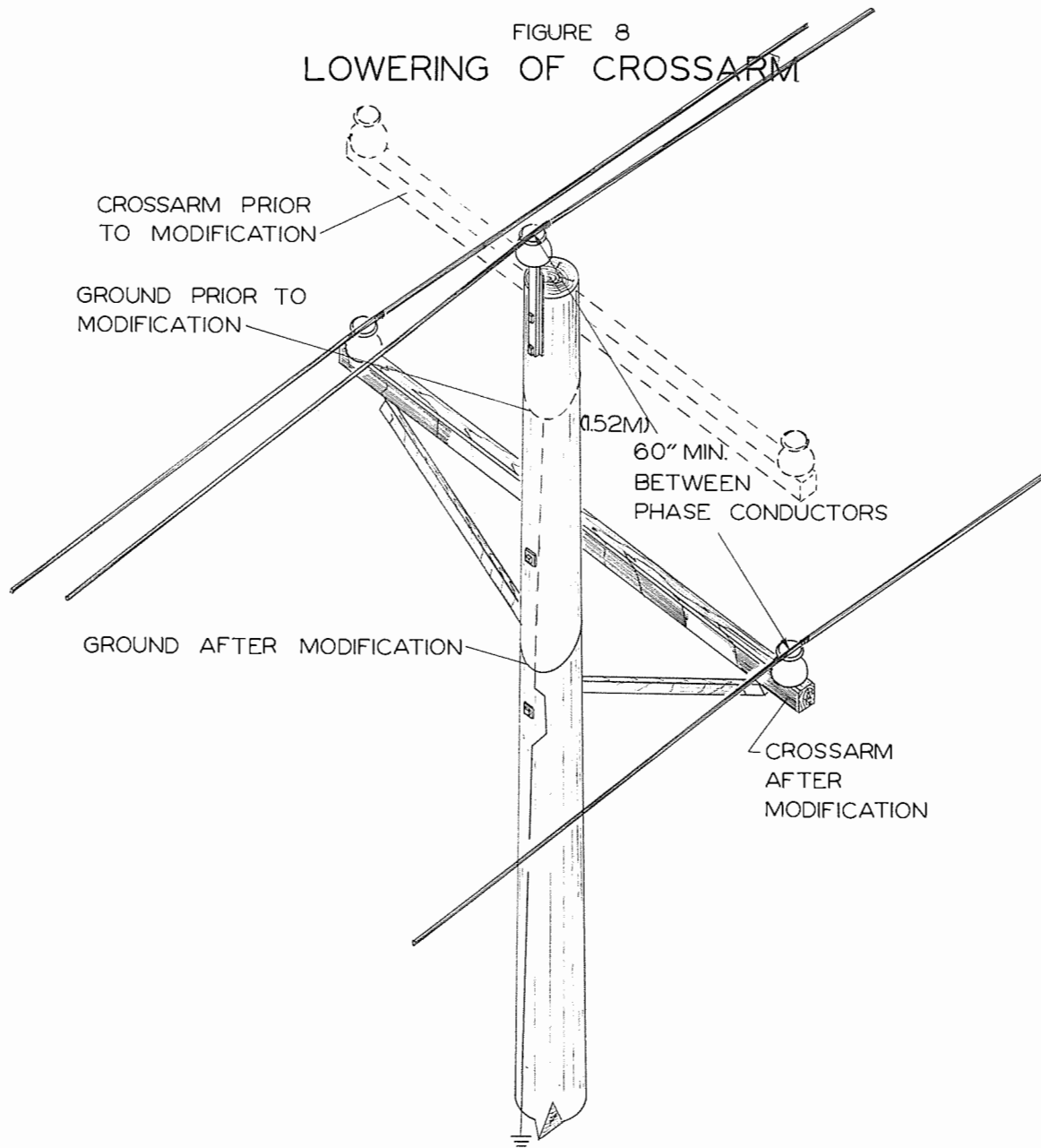


FIGURE 8  
LOWERING OF CROSSARM



In certain parts of the West, lightning occurs so frequently that extra precautions must be taken to prevent serious damage to power lines, transformers, and their support structures. Extensive grounding of all metal parts on certain poles has frequently resulted in very small separations of phase and ground wires and other grounded metal equipment. Of particular concern is the placement of lightning arrestors near to or above the tops of poles, use of metal rather than wooden crossarm braces, and mounting of transformers and other related electrical equipment on the poles.

Because an eagle's tail feathers may reach 10 inches (25.4 cm) below its perch, the end of the pole ground wire (usually a lightning arrestor) should end at least 12 inches (30.5 cm) below the top of the pole. Single phase, no crossarm structures with the insulator mounted on top of the pole may be modified so that the ground wire is placed directly under the bracket on which the insulator is mounted. It is then nearly impossible for the eagle to touch it with its tail. A 4-inch (10.2-cm) gap between the end of the ground wire and the insulator mounting bracket and another 4-inch (10.2-cm) gap just above the neutral wire (Figure 9) will effectively keep grounded wires out of reach of perched eagles (U.S. Rural Electrification Administration 1972). Lightning will spark over these gaps, but day-to-day safety of the birds is ensured. It has also been recommended that the gapped wires be bent away from the poles so that arcing occurs through air rather than along the pole to prevent a pole fire (Nelson 1978).

A better solution for single-phase configurations in heavily used eagle habitat is not to install the phase wire insulator on top of the pole, but to leave the top 20 to 30 inches (50.8 to 76.2 cm) free of wires and other equipment as a perch that might be used by birds (Figure 10). Insulators should be installed on the side of the pole to carry the phase wire at least 24 to 48 inches (61.0 to 122 cm) above the accompanying neutral wire. In this way the possibility of a raptor simultaneously touching two conductors is virtually eliminated. This configuration would be very expensive for a long series of poles because the poles are not being used in an optimal manner. However, it would be ideal as a modification in problem areas or as an acceptable new design in known eagle use areas.

Steel crossarm braces were widely used by U.S. Rural Electrification Administration cooperatives prior to 1962. These braces were frequently grounded and often reduced effective conductor-to-ground separation in half. Use of wooden or other non-conductive braces significantly decreases the likelihood of raptor electrocutions (Figure 11). As a general rule, the less grounded metal that is placed near conductors, the less the hazard of raptor electrocution. Ungrounded metal braces on wooden crossarms present no hazard to raptors.

As mentioned above, transformers pose especially serious problems to raptors, even the smaller species. One solution has been to install all equipment and protective devices (lightning arrestors, fused cutouts, etc.) on a second, lower crossarm which leaves the top crossarm for perching (Figure 12). This still may not be sufficient, since birds will sometimes perch atop the transformer tanks. Thus, mounting of equipment on

FIGURE 9  
GROUND WIRE GAPPING

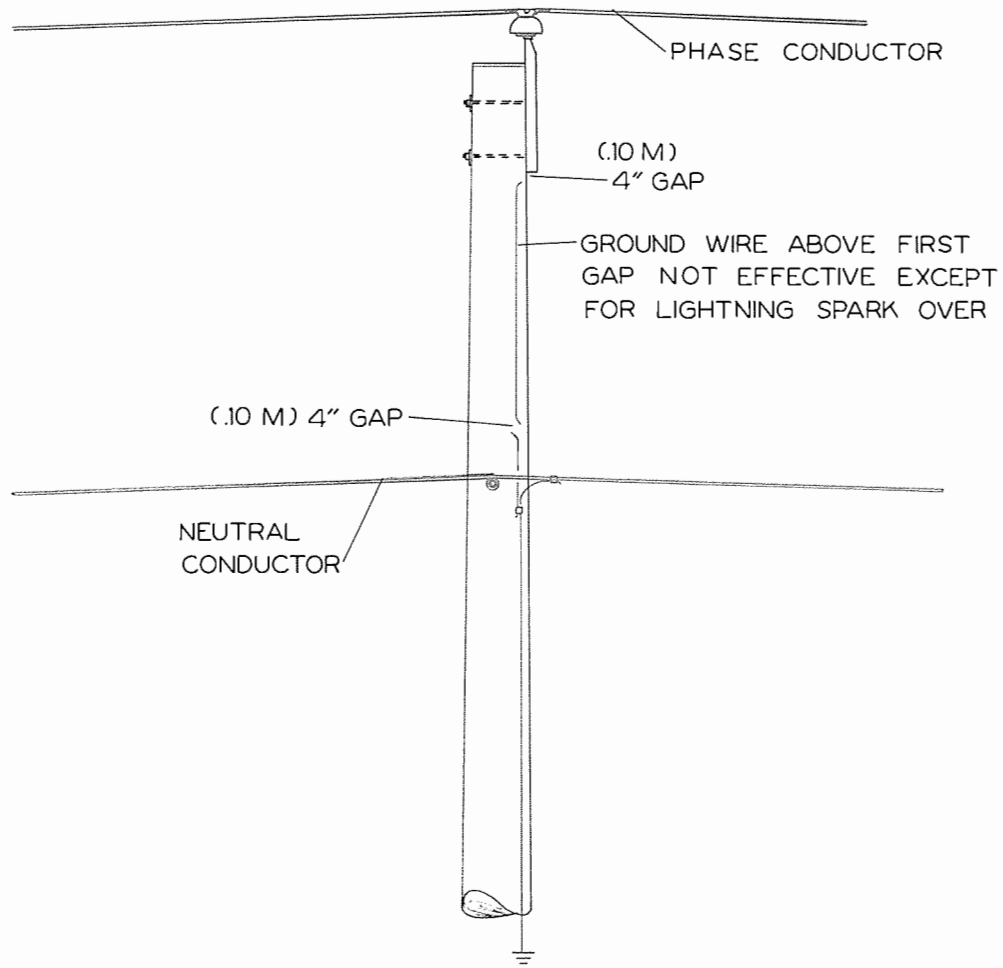




FIGURE 10  
SINGLE-PHASE SIDE-MOUNTING CONFIGURATION

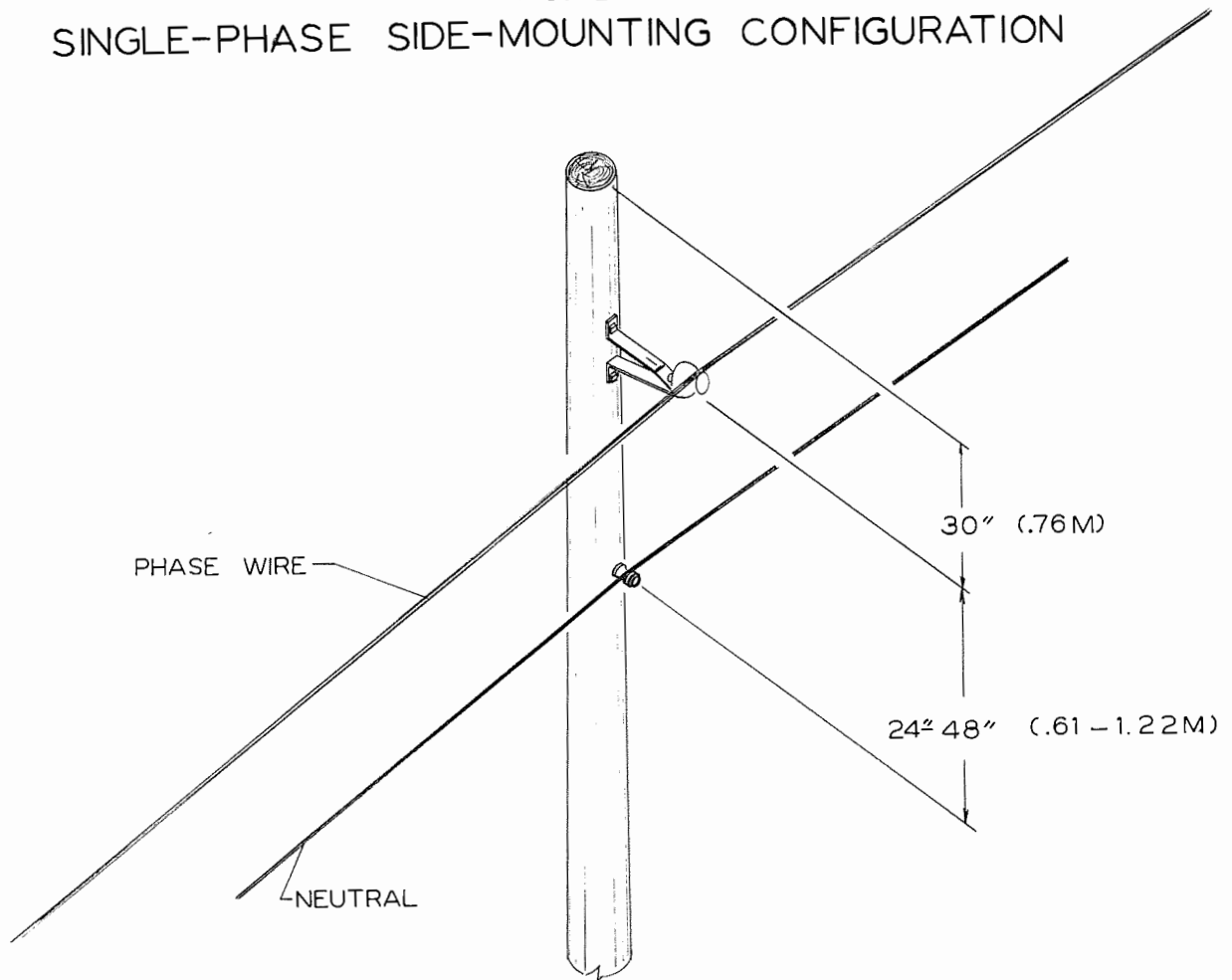


FIGURE 11  
USE OF NON-CONDUCTIVE CROSSARM BRACES  
IN LIEU OF GROUNDED METAL BRACES

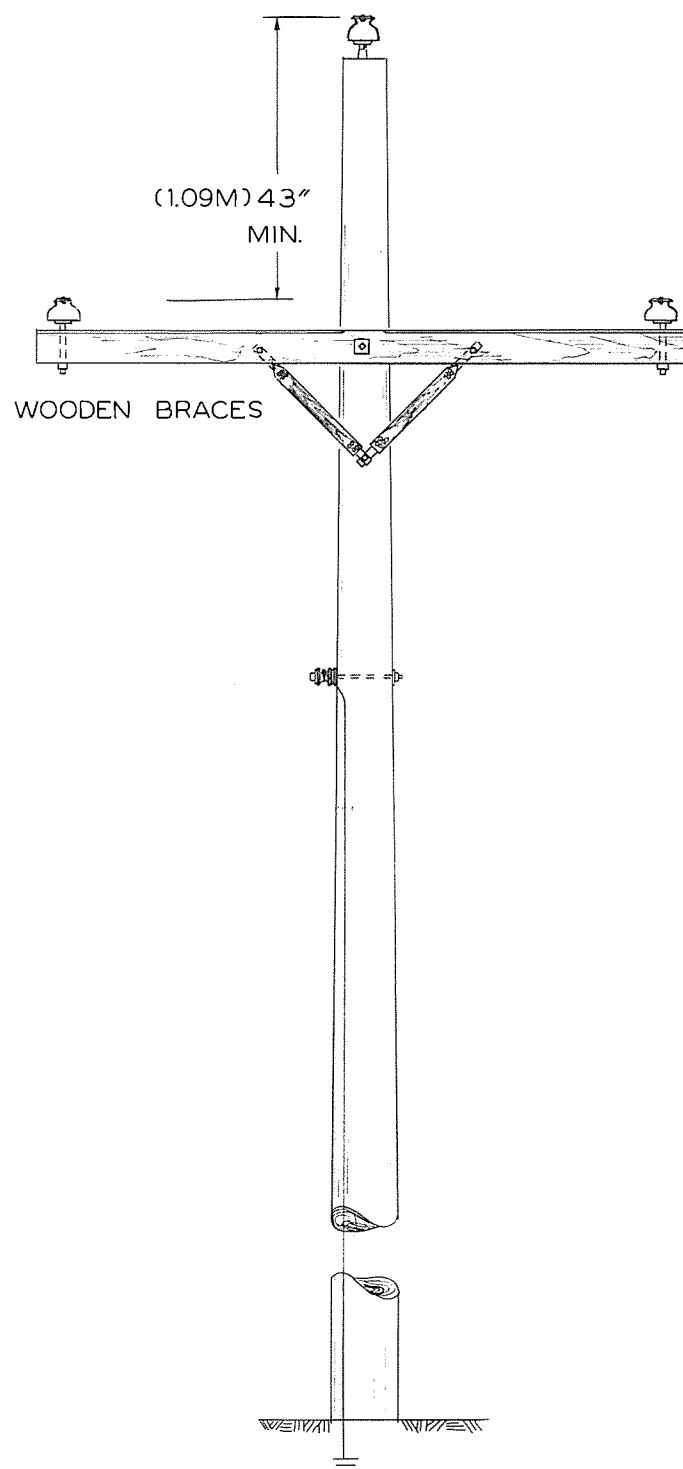
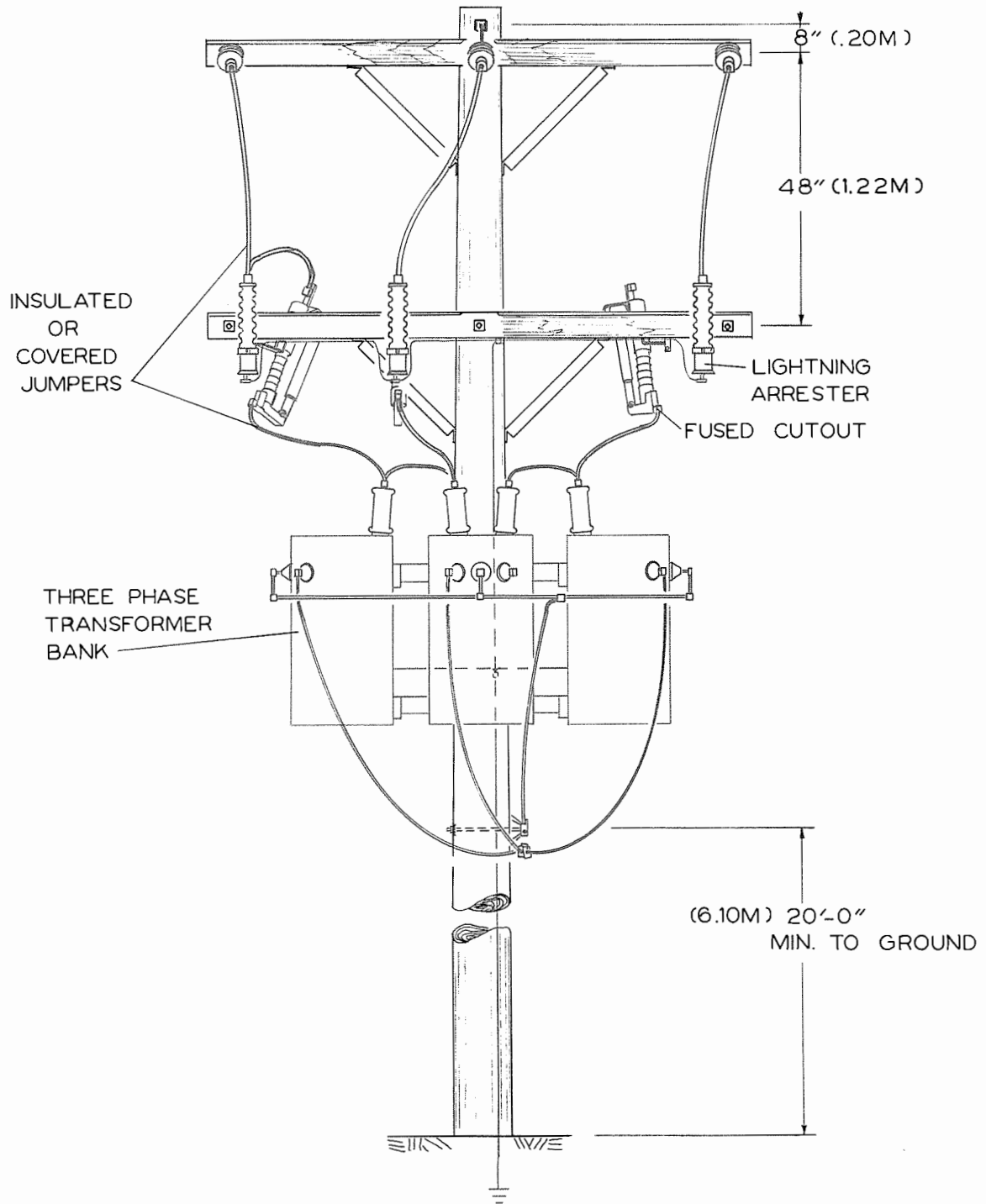


FIGURE 12  
INSTALLATION OF TRANSFORMER EQUIPMENT  
TO PROVIDE FOR RAPTOR PERCHING



the second crossarm must often be done in combination with insulation of transformer risers and jumpers and with artificial perches to provide higher and safer places for the birds to sit (see below).

Armless Construction. Armless construction is an alternative to the pole/crossarm configuration and to underground placement of wires (see below). Raptor electrocution by armless configurations is minimized by limiting raptor perching primarily to the top of insulators and/or by placement of conductors alternately on one side of the pole and then the other (Figure 13). However, there have been continuing problems with some of the early armless designs depicted in Miller et al. (1975), particularly those without adequate separation between the top conductor and the next lower one. This has led to the suggestion that these conductors be at least 55 inches (140 cm) apart, which may require some lines built since 1975 to be corrected. The 55-inch (140-cm) conductor spacing for armless construction is less than the 60 inches (152 cm) suggested for pole/crossarm configurations because of the more limited mobility of eagles perched on the insulators of armless configurations.

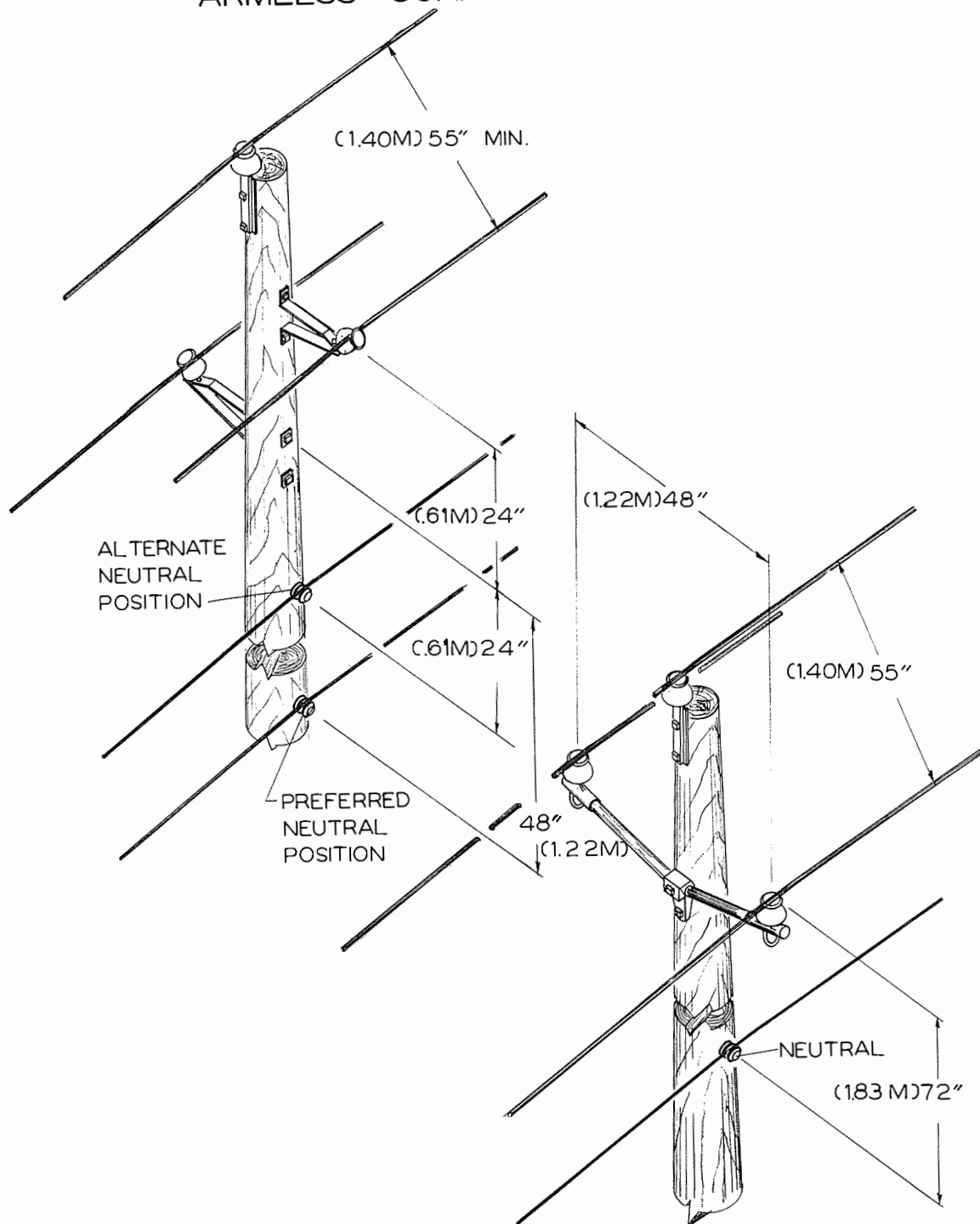
Armless construction does have other disadvantages. Ansell and Smith (1980: 59-60) summarize the experiences of Idaho Power Company as follows:

Beginning in 1974, it has been the Idaho Power Company's policy to utilize only "armless" distribution configurations in areas of heavy raptor use. Although these structures are quite beneficial in preventing electrocution of birds of prey they do pose some problems to the utility and create extra hazard to maintenance crews working on the modified lines. Because the phases, or conductors, are closer together when the armless configuration is used, it is necessary to place the poles nearer to one another than with standard crossarm configurations. This means that more structures are needed per mile of distribution line. On the average, an armless structure costs about the same as structures utilizing crossarms; however, approximately three to four more poles are required per mile of line. This results in an additional cost of about \$1000-1200 per mile of construction.

Undergrounding. One obvious solution to all raptor electrocution problems of new construction is the placement of power lines underground. Unfortunately, this practice generally is too expensive for widespread application in rural areas. Underground lines sometimes present design problems, particularly for high voltage transmission lines. Thus, the overwhelming industry preference both from the economic and engineering standpoints is to suspend electric power lines aboveground on poles and towers. Thompson (1978) briefly dismisses undergrounding as a cost ineffective method of preventing bird collisions with power lines.

Insulation. Where adequate separation of conductors and potential conductors cannot be attained, insulation of wires and other metal equipment may be the only solution short of redesigning and extensively modifying the line. Where the center phase of a three-phase system cannot be raised and the crossarm cannot be lowered, an alternative is to install conductor insulation extending a minimum of 3 feet (0.9 m) on either side

FIGURE 13  
ARMLESS CONFIGURATIONS



of the pole-top insulator (Figure 14). This assembly (commonly PVC tubing) can be installed with a hot stick in a few minutes per pole, provided access is readily available to the poles. When using this type of system, wooden crossarm braces should also be employed, or, if metal braces are present, the grounding of the braces should be gapped as discussed previously.

Where primary deadends occur, such as on corner poles, non-conducting extension links can be installed to keep the phase wires further away from the pole and crossarms (Figure 6). By running any necessary jumpers underneath the crossarms, phase-to-phase contacts can be minimized. An eagle can then safely perch on top of the pole or on the crossarm. Metal extension links can be used if they are not grounded.

Management of Eagle Perching. Two simple and economical methods of making existing problem lines safe for eagles involve encouraging eagles and other birds to perch on less dangerous parts of power line support structures. One method is to install perches, usually of 2-inch by 4-inch (5.1-cm by 10.2-cm) wooden construction, a safe distance above any energized wire or object (Miller et al. 1975) (Figure 15). This solution is not new, however, since in 1946 the Pacific Gas and Electric Company solved a severe outage problem in the Sierra Mountains by installing 2-inch (5.1-cm) wooden dowel perches on top of each of the towers in the problem area (Dickinson 1957, Benton and Dickinson 1966). The perches were high enough to allow the eagles to clear the wires on take-off.

Artificial perches are particularly useful where multiple bird kills have occurred on poles which receive high raptor use. Commonly this occurs whenever there are transformers or jumpers, or where it is difficult to insulate or change the position of conductors (Anderson 1975). One problem which may be encountered with the design shown in Figure 15 is that defecations may cause flashovers. However, raptors generally do not defecate straight down, so this problem is minimized on most distribution configurations.

The original suggested practice for artificial perches was to install perches a minimum of 2 feet (61 cm) above the conductor (Miller et al. 1975, Dodge 1975). Others have suggested a 3-foot (91-cm) vertical rise (Nelson and Nelson 1976, 1977). Benson (1981), however, found electrocuted eagles under poles with artificial perches, and others have reported eagles sitting on crossarms under such perches. Thus, the perches must be low enough so that birds cannot sit underneath them, but high enough to prevent casual touching of conductors with the bird's tail or a wing stretched downward. An eagle's tail will reach about 10 inches (25.4 cm) below its perch, and the top of its head is 18 to 20 inches (46 to 51 cm) above the perch. Thus, a vertical rise for perches of 14 to 16 inches (36 to 41 cm) would be most appropriate. Touching two conductors simultaneously when both are below the perch is not likely, except on take-off. If greater vertical separation is necessary for some reason, perching on the crossarm might be prevented by installing an extra crosspiece as part of the perch assembly halfway between the crossarm and the perch. Installation of perch guards on the crossarm (see below) is another practical method of filling excess space in this situation.

FIGURE 14  
CONDUCTOR INSULATION ALTERNATIVE

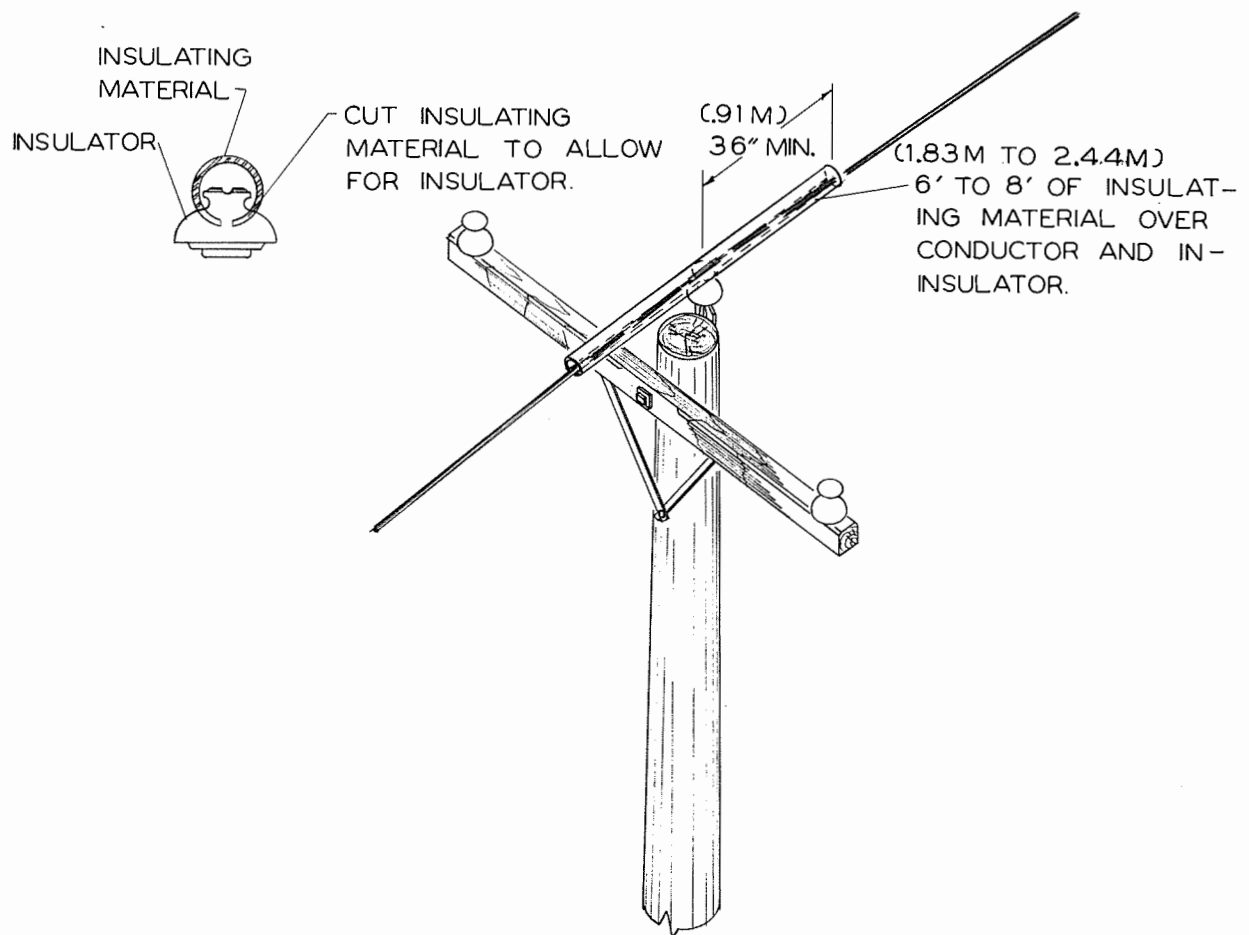
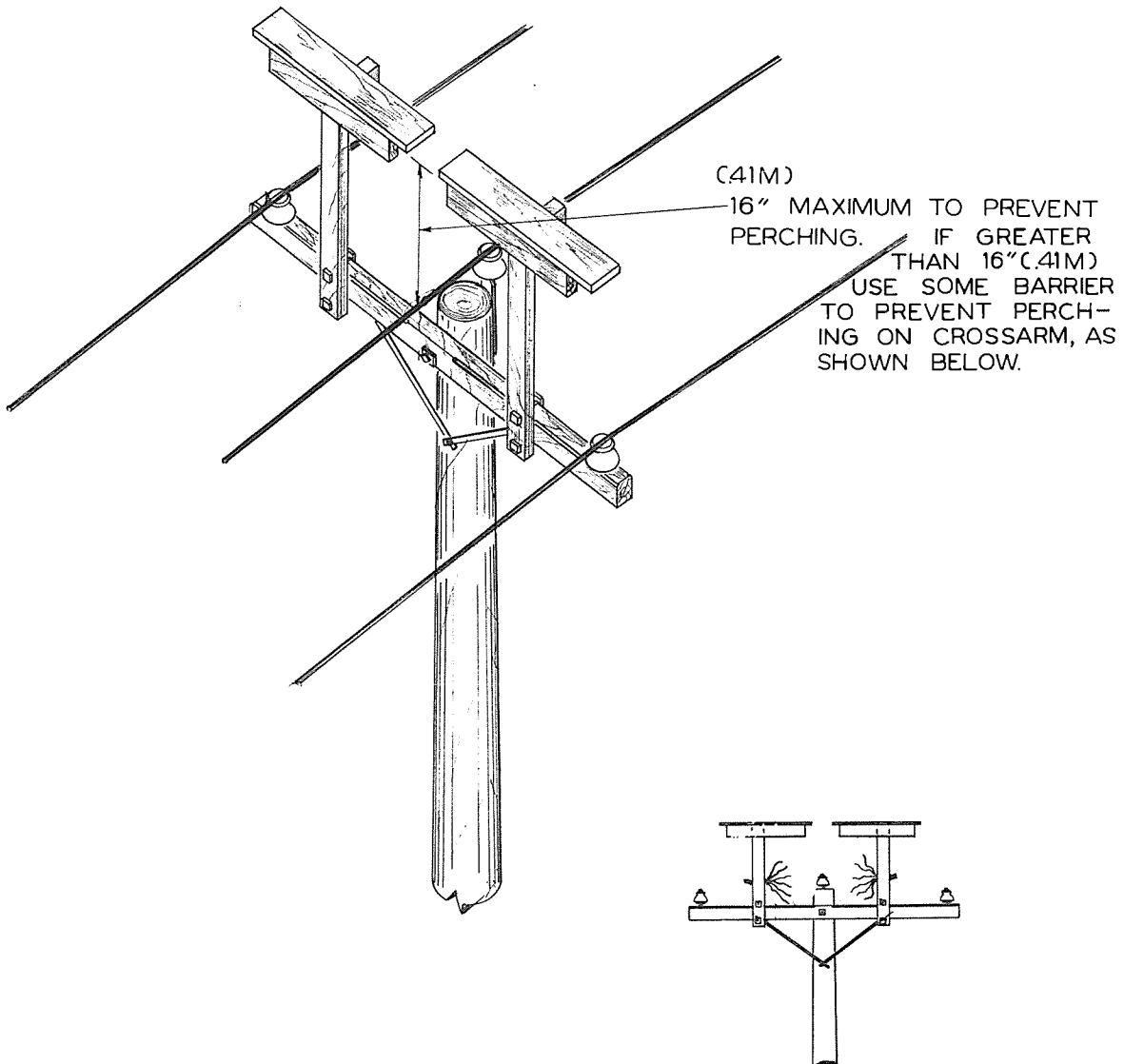


FIGURE 15  
**ELEVATED PERCH CONSTRUCTION**





One other factor to consider when erecting raptor perches is the orientation of the perch relative to the crossarm and to the prevailing wind. If a perch runs perpendicular to the crossarm, access is still provided to the crossarm. Perches must run parallel to the crossarm to prevent birds from getting under them. Perches should also be placed perpendicular to the prevailing wind (Benson 1981), though this may not be possible without changing the orientation of the crossarm or the entire pole. Such a change in orientation would simply be infeasible in most situations. When in doubt, the perch should be oriented parallel to the existing crossarm (Figure 15).

The second method of encouraging eagles to perch in less lethal positions on power line structures is the installation of perch guards. The first documented perch guards that prevented raptor electrocution were actually designed to keep birds from perching above insulators on transmission towers (Michener 1928). The transmission line was plagued with power outages apparently caused by birds defecating on strings of suspended insulators and causing flashovers. Michener (1928) describes the extensive and expensive measures to prevent the problem, including the use of inverted "V" structures (see below) on some tower members where the birds perched, iron pans on the cross members above the center insulators to catch the excrement, and saw-tooth guards on horizontal tower members near insulators. The efforts did solve the problem, but at great expense.

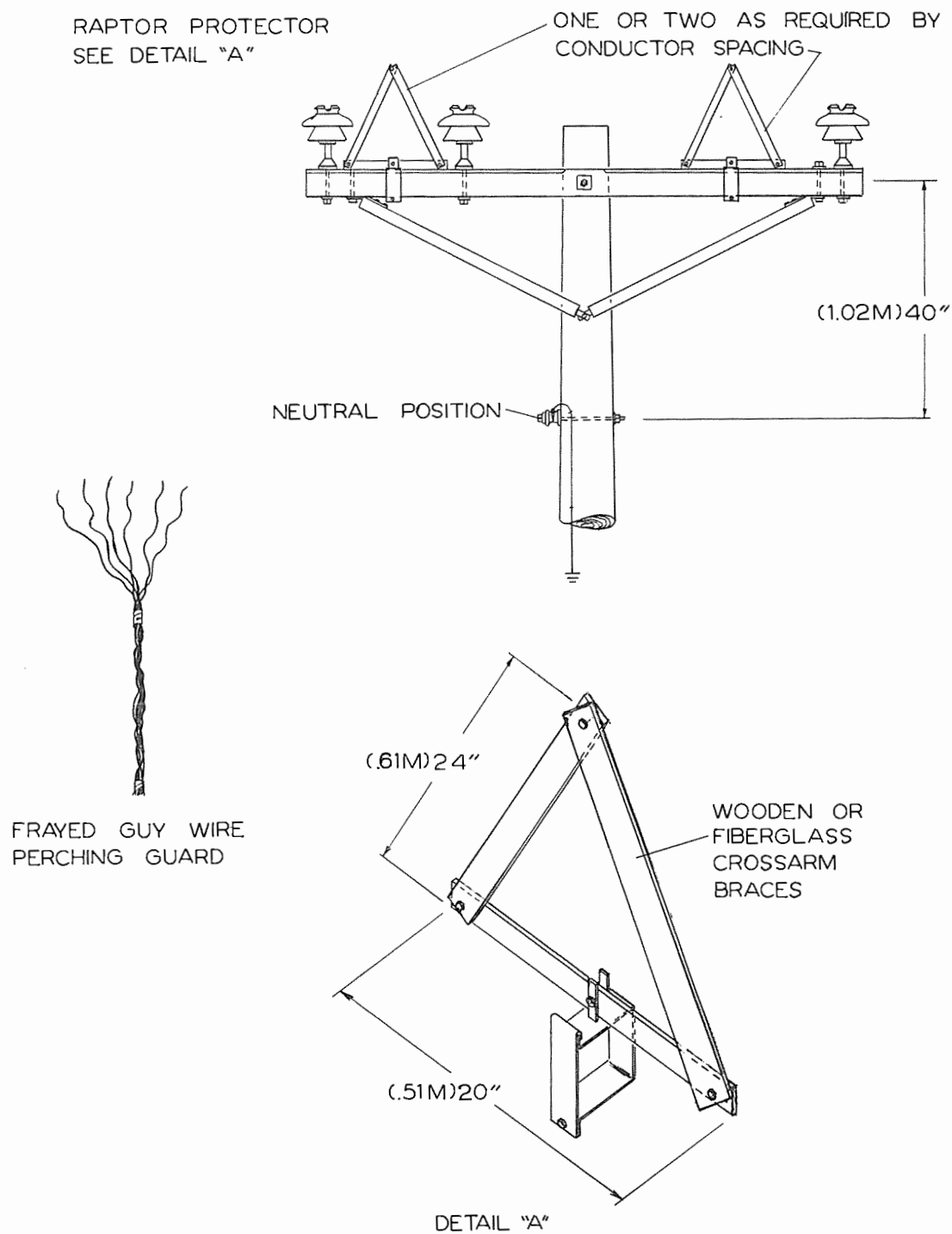
Another early "eagle guard" was designed in the late 1930s by the Idaho Power Company for installation on a 20,000-volt line which was plagued with about 50 outages a year, primarily from eagle electrocutions (Marshall 1940). About 3,000 wooden triangles were installed on the crossarms on both sides of the poles so that the birds would not have a level place to perch. The number of outages dropped almost to zero in subsequent years to the benefit of both the industry and the eagles.

Another perch guard design consisted of short pieces of large diameter standard wire with one end mounted on a base plate and the other end unraveled so that many stiff wire strands stuck out like a porcupine (Benton and Dickinson 1966, Lee 1980) (Figure 16). Nelson (1980c) tested similar devices in his "dummy pole" experiments and found them to be extremely effective.

In 1945 the Bonneville Power Administration installed these "metal porcupines" on a 230-kV transmission line and successfully eliminated a serious bird problem (West et al. 1971). In 1971 the same agency placed similar bird guards over insulators on about 154 miles (248 km) of 500-kV lines with a history of outages (Lee 1980). In some cases raptors used these perch guards as a substrate on which to build nests. In any event, the guards were not effective in reducing the outages. It was concluded in 1978 that raptors were not the cause of the outages, and the perch guard program was discontinued.

More recently, attention has turned to an inverted "V" perch guard configuration which has been tested by Nelson (1979b, 1980c) and is currently being field tested in several forms: wood, fiberglass, and PVC rod. Specifications for the wooden and fiberglass versions are shown in Figure 16. Larger "V's" or more than one "V" may be effective for wider

FIGURE 16  
PERCH GUARDS



perching areas on higher voltage lines, though at some point the problem disappears because of adequate phase separation. The inverted "V" perch guard has been endorsed by several power companies as an economical and effective means of protecting birds of prey (Solt 1980), particularly on structures where two conductors are carried on one side of the crossarm (Nelson 1979b, 1980c; Benson 1981). The materials are relatively inexpensive, and the units can be installed while the line is energized.

**PART FOUR**

**OTHER**

**SELECTED**

**MITIGATION MEASURES**

## PART FOUR:

### OTHER SELECTED MITIGATION METHODS

#### Introduction

Man is destined to urbanize, to grow industrially, and, in doing so, to require more agriculture. This creates new demands for electricity which -- by law in many countries -- must be served by power companies. Thus, the impacts of electric transmission and distribution lines are in reality by-products of cosmopolitan demands by consuming publics for energy of all kinds. Mitigation of today's vast use of global environments -- for living space, to create work, and to feed a burgeoning population -- is beyond the influence of this paper; yet, mitigation of the direct effects of each type of impact will certainly ameliorate the local effects of habitat degradation. In this local context, and in some cases from a regional perspective, the identification of power line impacts and their mitigation have both meaning and merit.

Besides electrocution, the direct impacts of power lines are commonly identified as line construction activities, maintenance impacts, increased vulnerability of perching and nesting raptors to harassment and persecution (e.g., shooting), increased chances of collisions of raptors with power lines, entanglement of birds in lines, noise disturbance, and electric field and corona effects. The following discussion seeks to differentiate between which of these impacts are legitimate concerns and which are not.

Construction Impacts. While the impacts of constructing electric power plants are part of this general issue, only the impacts of line construction are considered here. The significance of most power line construction impacts generally is not quantified in the literature (published or unpublished), though several excellent consultant reports and other documents raise the important considerations (e.g., Nelson 1979a; Meyer 1979; Thomas Reid Associates 1980; Baldrige 1977; Pinkowski 1977; Stahlecker 1975, 1978; Rowell 1976; Zitney and Boyle 1976). However, until basic research on raptor tolerances of different types of human disturbances is completed, most new construction projects need to be evaluated on a site-by-site or line-by-line basis, and suggested mitigation measures will remain somewhat speculative (though not necessarily over-reactive or ineffective).

The direct impacts of power line construction include: 1) loss of habitat through right-of-way clearing (where it is done), construction of access roads, and actual placement of poles, towers, and conductor pulling sites; and 2) disturbance of raptors through interference with courtship, nest building, incubation, and foraging activities which leads to desertion of nearby natural nests and roosts. Generally, wildlife activity will cease in the immediate construction area, and nests that are close to the construction will often be deserted (Stahlecker 1975).

Mitigation of Construction Impacts. Benson (1981: 81) suggests that prior to construction of a line, "surveys should be made of (a) small mammal populations, (b) populations of raptors, particularly wintering eagles and (c) human activity." In many situations covered by state and/or federal environmental laws it is necessary to do such studies or else to acquire the information from available sources. On federally owned lands it is generally the responsibility of the land management agency to do the necessary studies prior to granting a right-of-way permit. Arrangements can often be worked out, however, for a utility company to do the studies in a manner acceptable to the government agency.

Inventories conducted prior to route approval not only provide useful information for minimizing the effects of line placement on raptors, but also allow segment-by-segment analysis of the impacts of construction and maintenance. Meyer (1979) and Nelson (1979a) identify the possible impacts of new transmission lines on various raptors and cite several areas of concern (e.g., river crossings) in each case. Their segment-by-segment analyses permitted suggestion of alternate routes and specific seasonal restrictions on construction activities. Basically, impacts can be more easily mitigated or avoided if planners, developers, and land managers understand the ecological relationships and animal behaviors involved. Trade-offs can also be analyzed more thoroughly with adequate inventory data.

For example, considerably more disturbance can be tolerated by wintering raptors, which can move to another area, than by nesting birds, which are tied to the nest site and the immediate area for several months. Thus, seasonal construction restrictions to protect raptors can be applied to minimize interference with courtship, nest building, and incubation. Such restrictions should not be applied as a general mitigation measure; rather, good justification based on analyses such as those of Meyer (1979) and Nelson (1979a) must be present.

Fyfe and Olendorff (1976: 5) itemize the dangers of human disturbance to nesting raptors as follows:

- 1) The parent birds may become so disturbed that they desert their eggs or young completely; 2) the incidence of egg breakage or trampling of young by parent birds may be increased, as may the chances of cooling, overheating, loss of humidity, and avian predation of eggs; 3) newly hatched birds may be chilled or overheated, and may die in the absence of brooding;...

Desertion of nests after eggs are laid is the most serious concern during construction, although the effect (loss of one year's productivity) may only be short termed. Low levels of disturbance late in the nesting cycle often are not a problem, since desertion is less likely to occur the longer incubation is allowed to progress. Also, it is uncommon for raptors to desert a nest after the young hatch, provided they are given at least some consideration. For example, Nelson (1979a: 4) indicates that:

Under most conditions,...working [construction] hours between 7:00 a.m. and 6:00 p.m. give the nesting birds an opportunity to follow their normal procedures of feeding rather early in the

morning or rather late in the evening....experience has shown where there has been some interference, that these birds seem to work around the problems when they have a chance because of the long daylight hours during the nesting season.

Thus, construction crews might be directed to refrain from working either very early (before 7:00 a.m.) or very late (after 6:00 p.m.) when in the vicinity (ca. one-fourth mile line of sight) of nesting raptors.

As construction nears an active nesting site, evaluation of raptor behaviors by a qualified biologist may be appropriate. On-site analysis of factors such as stage of reproduction, distance from the line, and tolerance of the pair of birds involved probably would allow more construction to occur than would "armchair" analyses during the environmental assessment process.

Other benefits of this approach would include: 1) the opportunity to study the reactions of the birds to the impacts (a critical need at this time); and 2) the opportunity to salvage deserted eggs or young birds by fostering them to other pairs of the same species which nest further from the new line. The outstanding success of efforts to augment clutches of eggs or broods of young raptors in wild nests, both in North America and abroad, is reviewed by Olendorff et al. (1980).

Nelson (1979a) suggests another technique for consideration in efforts to minimize construction impacts. Many raptor nesting territories, most notably those of Golden Eagles, contain several nests which are used sporadically through the years. While the most heavily used site may be near a new power line right-of-way, others would probably be farther away. Nelson (1979a: 9) suggests that, "We might even precede the courtship period with a certain amount of human activity in the area for the purpose of making the birds take up an alternate site for that individual year." This is not yet an operational technique, though research of this type in conjunction with the construction of several (not all) new power lines would be useful. Any such studies would need to be coordinated with the appropriate state and federal wildlife agencies and should also be fully documented and publicized.

With this "early disturbance" technique, as with many other mitigation measures, construction timing is extremely important (Meyer 1980, Nelson 1979a). One method of creating flexibility of timing is to build lines in smaller sections so that critical areas could be avoided at the most sensitive times, but construction of the line could continue in other areas. For example, "...impacts to the wintering eagle population can be prevented by adjusting construction schedules to avoid high eagle concentrations in the months in which they are present" (Thomas Reid Associates 1980: 24). This is already a common practice (Consumers Power Company 1972, Edison Electric Institute [1980a]), and it has been suggested in many consultant reports and other documents (Baldrige 1977, U.S. Bureau of Land Management 1976a, Meyer 1979, Nelson 1979a, Thomas Reid Associates 1980, etc.).

Habitat destruction during power line construction is another concern which can be largely mitigated by sound planning and development of proper stipulations to be placed on rights-of-way permits from land managing agencies. The possible types of surface disturbance which may result from construction of a new line were summarized by Lee (1978b: 2) as follows:

Transmission line construction usually involves vegetation clearing, access road construction, tower footing installation, tower assembly and erection, conductor stringing, and site restoration. The environmental impact of these activities varies widely depending on such factors as size and length of line, topography, and vegetation types encountered, weather, and time of year during which construction occurs.

The effects of clearing vegetation in rights-of-way through forested areas where this is necessary, can be minimized by selective clearing of the overstory and leaving the understory intact to the extent practical. Right-of-way clearing can be particularly detrimental in Bald Eagle wintering habitat along lake or reservoir shorelines or in riparian areas if large numbers of trees are removed (Meyer 1980). Impacts to vegetation can also be limited by making maximum use of existing roads and trails and constructing lines with the aid of helicopters rather than building new access roads.

The need for such mitigation should be thoroughly evaluated by land managers and the power companies prior to line construction. Frequently, the direct impacts of long, linear rights-of-way on raptor populations are not significant except at the time of construction. In some cases the beneficial effects of new lines (see above, "Golden Eagle Behavior") may even outweigh the effects of construction. For example, placement of long-term electrocution hazard to nesting adults, because of their perching experience. However, young birds will perch on them extensively, especially during the immediate post-fledging period when they are least experienced. Precautions for lines near nests include proper design and construction during the non-nesting season (approximately August through December), but one need not be overly concerned with the distance between the line and the nest. Young birds will still be nearly as inexperienced when they disperse to a line five miles (8 km) from the nest as when they find power poles to perch on within a few hundred yards or meters of their nests. Proper "eagle-safe" design, even if it requires extra measures (greater crossarm length, insulation, etc.), should be used to ensure the safety of eagles on power lines over the long term.

Direct Impacts of Line Maintenance. Maintenance of power lines and their supporting structures has both positive and negative effects on raptors. The amount of raptor research being conducted by power company biologists who accompany line maintenance crews on their routine patrols increases each year. In many cases the use of helicopters and fixed-wing aircraft allows an analysis of raptor behavior that cannot be justified (because of cost) in itself. Power companies are encouraged to maximize the benefit of their maintenance patrols in this way, and government agencies should utilize the excellent data that are being collected in this manner.



The principal negative effect of power line maintenance is the destruction of nests built on poles and towers, primarily to prevent power outages and electrical fires. Raptor nests are commonly very bulky structures which can engulf the top of a pole and crossarm of a distribution line. On transmission towers longer sticks may sometimes span the distance between the tower and a conductor and cause flashovers, particularly in wet weather, if a nest is built over a suspended insulator.

As a result, many power companies routinely remove raptor nests from poles and towers to ensure line reliability (Ellis et al. 1978; Stoczek 1972; Stahlecker 1979; Pendleton 1978; Anderson 1975; Garber 1972; Nelson and Nelson 1976, 1977; Lee 1977, 1980; Fitzner 1980b). Often, however, the birds simply rebuild their nests in precisely the same locations (see above references). Stoczek (1972) reports that Ospreys in New Brunswick rebuilt nests up to six times in the same year after they were repeatedly removed by line maintenance crews. However, "...the later in the season the nests are disturbed, the less persistent are the osprey in renewing their building efforts." (Stoczek 1972: 25)

Mitigation of Line Maintenance Impacts. The most useful mitigation of line maintenance impacts on raptors would be a better understanding of when to destroy or not to destroy raptor nests on power poles and transmission towers. Too often, these decisions are left to individual maintenance crews that may not be aware of the public and biological sensitivities involved -- sensitivities that may or may not be justified.

While it can be argued that the birds would not be nesting at all in many habitats if power lines were not present, it is still illegal simply to search and destroy such nests according to provisions of the Bald Eagle Protection Act, Migratory Bird Treaty Act, Endangered Species Act, and many state wildlife laws. Also, destruction of raptor nests poses a continuing higher risk in that the birds will attempt to rebuild their nests and, in doing so, increase the chance of sticks being dropped across wires, of defecations which can cause flashovers, and of the birds themselves being electrocuted. In addition, it is very costly to have linemen repeatedly removing raptor nests. Thus, the following techniques could be used by line maintenance crews to the mutual benefit of both raptors and the industry.

On transmission towers the main objective should be to prevent raptors from nesting directly over insulators (Lee 1980). Michener (1928) describes rather extensive methods to prevent raptors from perching directly over suspended insulators, some of which are applicable to raptors attempting to nest (see also "Management of Eagle Perching" elsewhere in this report). Stoczek (1972) reports success in preventing Osprey nesting on power poles in New Brunswick with a bird repellent grease. It is doubtful that anything that fouls birds' feathers would be acceptable today, at least in the United States, following the worldwide problems with the effects of oil spills on birds. Another technique is simply to trim longer sticks which hang down from raptor nests toward conductors, thereby minimizing the chances of flashovers (Anderson 1975; Nelson and Nelson 1976, 1977), although in many cases this requires de-energizing the line. Van Daele (1980) suggests that problem nests be removed after the

fall migration when the birds are not present (September through December) and that some device be constructed in place of the nest to discourage nesting in subsequent years.

The most exciting successes both from raptor management and line maintenance standpoints involve 1) moving problem nests to less dangerous places on transmission towers (Lee 1977, 1980) and 2) placing artificial nesting platforms in safe places on towers (see below) or on dummy poles adjacent to energized lines (Electric Reporter 1946; Investment Dealers' Digest 1950; Electric Meter 1951, 1953; New York Times 1951; Benton and Dickinson 1966; and Stocck 1972). The erection of dummy poles and artificial nest structures for Ospreys during the late 1940s and early 1950s by several power companies in the northeastern United States is particularly noteworthy. In one case, energized conductors were moved to a new set of crossarms several feet below the original crossarms on which a nest was built (Oregon Wildlife 1976).

The significance of implementing one or a combination of the suggested practices for mitigating line maintenance impacts is illustrated by the work of Fitzner (1980b: 16):

During the early 1970s local power companies removed nests from utility poles and towers on the Hanford Site [southcentral Washington], believing them to be fire hazards. In 1974 when this policy was discovered by researchers studying Hanford raptors, power company officials were requested to stop the practice, which they did. The result of this decision was a near three-fold increase in the population of red-tailed hawks [from 9 pairs to about 25 pairs] within three nesting seasons.

Harassment and Persecution Impacts. Increased accessibility by man to previously undisturbed areas is usually the greatest long-term impact of power line construction on wildlife. This leads directly to the most serious raptor persecution problem associated with power lines in most areas: shooting by indiscriminant hunters of roosting and nesting birds. Coon et al. (1970) found that of "...55 bald eagles which died of injuries, 45 had been shot, seven had impact injuries, two were trapped, and one was electrocuted." These birds came from throughout North America, and not necessarily associated with power lines. Kroodsma (1978) showed a similar relationship after combining data from Coon et al. (1970), Mulhern et al. (1970), Belisle et al. (1972), and Cromartie et al. (1975). Of 221 Bald Eagle mortalities between 1960 and 1972, shooting accounted for 104 deaths (47 percent), while only 3 birds (1 percent) were electrocuted. On the other hand, in Idaho, 123 Golden Eagle mortalities were reported between 1972 and 1979 (Peacock 1980). Eighty-four birds (68 percent) were electrocuted, while only 17 (14 percent) were shot. Likewise in Utah, of 64 Golden Eagle mortalities of known cause, 56 (88 percent) were electrocuted, and 8 (12 percent) were shot (Joseph In Prep.).

While the latter two studies, as well as Benson (1981), show electrocution to be more important than shooting as a mortality factor of Golden Eagles, it must be remembered that these studies were, by design, searches of power line rights-of-way for electrocuted birds. They do not reflect,

for example, the hundreds of eagle shootings during the early 1970s alluded to in the opening paragraphs of this report.

Thus, considering overall mortality of Golden Eagles, shooting probably has a greater negative effect than electrocution. The person behind a rifle does not discriminate between adult breeders and subadult or immature non-breeders. Electrocution, on the other hand, is highly selective (over 90 percent) against younger non-breeders. The chance encounters of aerial gunners and weekend "plinkers" are directed more at the general wintering population which includes more adults (long-term average about 65 percent (see above section on "Adult vs. Immature Eagle Susceptibility to Electrocution")).

Mitigation of Shooting Impacts. The frequency with which raptors are shot off of power lines and their support structures is related to the distance between the lines and the nearest road. The same must certainly be true of the incidence of shot insulators which is the industry side of this problem. Thus, both raptors and industry hardware would suffer less shooting damage if power lines and roads were separated, but this frequently is not possible. Land managing agencies and utility companies generally try to concentrate facilities (roads, pipelines, power lines) in corridors.

In remote, previously undisturbed areas, where raptor activity is concentrated, a thorough analysis of all competing factors should be made prior to line placement. The trade-offs between placing a new line near an existing road and building a new maintenance road and line must be considered. New maintenance roads soon become virtual highways for off-road vehicle users and major sources of general wildlife harassment that comes with free public access. Increased levels of camping, hiking, game hunting, fishing, nature photography, and other recreational pursuits provided by power line maintenance roads elevate the number of incidents involving those who would harm both raptors and industry hardware. Thus, access may more than offset any benefit to raptors provided by the power line (e.g., more perching and nesting opportunities), as well as any savings to the power company (e.g., ease of maintenance). Good planning and environmental assessment are vitally necessary in such cases.

Raptor Collisions with Power Lines. Research as well as anecdotal literature have shown that raptors do collide with power lines (e.g., Fitzner 1975, Brunetti 1965, Dawson 1974, Glue 1971, Beecham and Kochert 1975, Belisle et al. 1972, Coon et al. 1970, Cromartie et al. 1975, Lee 1978a, Mulhern et al. 1970, Kroodsma 1978). However, raptor collision is not a major problem with either distribution lines or transmission lines (Pinkowski 1977, Thomas Reid Associates 1980, Kroodsma 1978). This is generally attributed to the high visual acuity of raptors and the large size of transmission line conductors. It follows, then, that a few more collisions might occur in foggy weather (Kochert in Baldrige 1977, Thompson 1978, Thomas Reid Associates 1980), at night in the case of owls (Glue 1971, Anderson-Harild and Block 1973, Fitzner 1975, Herren 1969), or when the birds are distracted in some way (e.g., when chasing prey) (McKernan in Baldrige 1977, Engerson and Kirven 1979). But even these instances are uncommon.

Mitigation of Collision Impacts. Although efforts to portray raptor power line collisions as a serious problem (Baldrige 1977, Stahlecker 1975) have not been convincing, it is possible that when endangered species are involved some mitigation may be appropriate. Slow-flying raptors (buteos, eagles, condors) generally are not collision-prone, but swifter flying large falcons may be more susceptible (Olsen and Olsen 1980--Peregrines and Australian Hobbies; Brown 1976--Merlins). The participants of the workshop on Impacts of Transmission Lines on Birds in Flight (Avery 1978: 106) concluded that:

Raptors that actively pursue prey in flight [e.g., the Peregrine Falcon] are probably more vulnerable to a collision with transmission lines than those that do not, but factors such as size of bird, wing span, and maneuverability (erratic or straight flight) are also important. The group agreed that when birds pursue prey, engage in courtship flights, defend a territory, or escape from a predator, they are particularly prone to collide with a power line, because they are preoccupied and not very alert to the hazards that transmission lines pose.

For example, power line collisions are suspected in the severe injuries or deaths of seven Peregrine Falcons in California during the period 1973-1980 (Brian Walton pers. comm.). In Australia five Peregrines were found below wires and were suspected to have collided with them (C.M. White pers. comm.). These incidents prompted Enderson and Kirven (1979) to suggest that power transmission lines within 12 km (7.5 miles) of a Peregrine Falcon nest in northwestern California should be routed in certain drainages that the birds did not use much. Ridgetops should also be avoided for reasons other than just falcon safety (e.g., to minimize visual impacts).

Likewise, placement of transmission lines near winter Bald Eagle roosts deserves thorough analysis. Steenhof (1977) suggests that construction of transmission lines within 1 mile (1.6 km) of communal roosts be prohibited because of collision possibilities in strong winds or poor light conditions. Meyer (1979) suggests specific electric circuit designs and alternate route selections to reduce the potential for Bald Eagle collisions at river crossings of a proposed transmission line. However, Meyer (1979) also noted that Bald Eagles which approached transmission lines below line height would always increase their flight height to cross above the lines -- a deliberate avoidance behavior.

In summary, collision with power lines is not a significant mortality factor of raptors. However, in the proximity of nest sites, communal roosts, and other high use areas of endangered species, mitigation techniques should be evaluated and, if appropriate, implemented. It is difficult, however, to justify expensive rerouting of lines on the basis of possible collisions of raptors outside of concentration areas or other extremely high use areas.

Entanglement. Gretz (1981) notes that some raptors which appear to have been electrocuted may have first become entangled in power lines. In his report Gretz identifies two Golden Eagles and a Ferruginous Hawk that

apparently became entangled by their talons when they attempted to perch on insulators. He speculates that they were electrocuted in their struggle to free themselves from the entanglement. The problem is caused by the wire wrapping (tie-wire) that holds the conductor to the insulator. If this tie-wire is loose, it allows a raptor's talon to get caught between the wire wrap and the conductor, thereby trapping the bird to the power line. Entanglement has not been previously recognized or studied since the problem may be disguised by electrocution. Accordingly, it is important to accurately identify the initial problem of entanglement where it occurs in order to make appropriate modifications for eliminating this hazard.

However, many biologists who have found raptors below power lines believe that entanglement is a very rare occurrence (e.g., M.W. Nelson, P.C. Benson, R.A. Joseph, and R.P. Howard pers. comm.). This is substantiated by the fact that no other reference to entanglement was found during the extensive literature search made for the present publication. Olendorff (unpubl.) has a photograph of an eagle foot apparently entangled in a wire running about 8 inches (20.3 cm) above a transformer tank. In at least one of Gretz's (1981) photographs the entangled eagle foot is on a structure with extra jumpers, metal extension links, and a lightning arrester running within 2 inches (5 cm) of the top of the pole. Both of these designs are potential eagle electrocution hazards.

Thus, an equally plausible explanation for entanglement is that in the convulsion of being electrocuted, a sustained severe contraction of muscles controlling the raptor's toes either locks the foot around a wire or drives a claw underneath the tie-wire. In any case, entanglement is a small problem that can be dealt with only where it occurs repeatedly along the same line. Corrections can be made by rewinding the tie-wires or else by covering the insulators as shown in Figure 14.

Field and Corona Effects: Impacts and Mitigation. To date, no significant impacts of electric and magnetic fields and corona (e.g., noise, and ozone) have been identified on perching and nesting raptors (Lee 1980). Only a few studies of power lines have specifically addressed these factors (e.g., Ellis et al. 1978, Lee and Griffith 1978). However, these studies along with results of laboratory research indicate a low probability for adverse effects (Lee et al. 1979).

Several anecdotal references to this subject also suggest that electric field strength effects are not debilitating. Ellis et al. (1978) discuss the removal of two 4-week-old Red-tailed Hawks from a nest on a 500 kV transmission line. The birds were reared to fledging in captivity and then released; neither bird showed any signs of impairment, behaviorally or physiologically. Morlan W. Nelson (in Lee 1980) conducted a similar experiment with a young Red-tailed Hawk hatched in a nest situated in an electric field which measured 15 kV/m. The only abnormality was a "slight misalignment of feathers in the first and second primaries of both wings. This did not appear to cause any problems in flying, however." (Lee 1980: 6)

Because of the data gaps concerning electric field strength effects on raptors and the documented success of hundreds, if not thousands, of nests on power poles and transmission towers, no measures to mitigate these effects seem necessary at this time. Efforts to minimize raptor electrocution and to prevent flashovers across suspended insulators should also minimize field strength effects.

### Habitat Enhancement

Habitat Diversity Versus Raptor Density. Power line construction in many areas is an important type of perch management for raptorial birds, but whether a new power line actually enhances or detracts from raptor habitat depends a lot on terrain and other characteristics that influence habitat diversity (Pearson 1979). In topographically diverse habitats one might wish to discourage raptor perching on power lines to minimize any possible direct impacts on raptors. This can be done, as Benson (1981: 81) suggests, by placing power poles or transmission lines "such that natural roosting sites, (e.g., rock outcrops, cliffs) will be chosen over power poles. This requires that poles be placed in lower positions, avoiding ridgelines and hills."

On the other hand, in large expanses of homogeneous habitats power lines may provide the diversity necessary for nesting and more effective foraging by raptors.

In either case the benefit of power lines to raptors must be considered in a context of habitat diversity and not necessarily raptor abundance. Fitzner (1980b: 31) suggests that we:

create a variety of different nesting [or perching] options which would provide an equal opportunity for nesting of those raptors which typically nest within the impact area of any planned energy facility. Striking a balance of different species which manifest differing behavioral or physiological needs should be a goal....

Snyder and Snyder (1975) also caution against intensive raptor management programs that place greater emphasis on raptor abundance than on raptor habitat diversity.

Thus the true habitat enhancement value of new power lines must be considered on a number of levels including: 1) local versus regional benefits to raptor populations; 2) direct versus indirect impacts (both positive and negative); 3) habitat diversity versus species abundance; and 4) aesthetics versus functionality. In the latter case it may be functional for raptors to perch or nest on power lines, but it is not aesthetically acceptable to many people. For, as Segnestam in Chancellor (1977: 406) laments, "What if we end up with birds of prey inhabiting power line towers but which have lost their original habitat?" While this is not likely in the foreseeable future, the aesthetic argument is a valid one to many people, and it must be considered.

However, debating these points should not interfere with management research or the implementation of proven management techniques. Just as we should stop emphasizing the counting of electrocuted raptors at the expense of modifying existing lines and designing new lines to be safe for eagles, so, too, we should not argue long about the largest philosophical issues before proceeding with research and project implementation to maximize the habitat management potential of both existing and new power lines on a case-by-case basis, where appropriate.

Raptor Use of Power Line Support Structures as Nest Substrates. Most raptors which nest on power poles or transmission towers are species which inhabit open plains, prairies, or savannahs where trees and cliffs are absent and do not provide nest sites (Table 2). The one notable exception is the Osprey, the most prodigious user, among raptors, of many types of man-made objects as nest substrates. For example, in northern California Henny et al. (1978) found that about 2 percent of all Ospreys (7 of 355) nest on transmission towers and power poles, but at Shasta Lake Detrich (1978) found the level to be 25 percent (4 of 16 nests). The level of nesting on utility poles in northern Idaho and northeastern Washington is variously recorded as from 4 to 6 percent by Melquist (1974) (23 of 556 nests), Melquist and Johnson (1975) (11 of 267 nests), and Schroeder and Johnson (1977) (10 of 221 nests). It is not known how much overlap there is in these data.

Use of power line structures as nest substrates is often a local phenomenon. Stoeck's (1972) Osprey study area in New Brunswick is one example. Others include 1) the U.S. Department of Energy Hanford Site where Fitzner (1980b) found 52 percent (12 of 23) of all Red-tailed Hawks nesting on transmission towers, and 2) central North Dakota where 47 percent (21 of 45) of all Ferruginous Hawks nested on transmission towers (Gilmer and Wiehe 1977).

The net advantage or disadvantage of nesting on power line support structures is still open for debate. Van Daele (1980: 107) believes that overall, "Osprey productivity and success is probably not affected by the type of nest support." However, Melquist (1974) reports that Ospreys nesting on utility poles in Idaho and Washington fledged at least one young 50 percent of the time, compared to 68 percent for the entire sample of nests (N=556). Likewise, Gilmer and Wiehe (1977: 8) found that tower nesting Ferruginous Hawks laid slightly larger clutches than birds using other nest substrates, but because of nest loss during windstorms and overcrowding in some nests, "the number of young fledged per tower nest was lower (2.5 young fledged/nest) than in other nests (2.8)."

The advantages of nesting on power poles and transmission towers (primarily the latter) have been noted by several researchers and industry biologists. Anderson (1975) and Nelson and Nelson (1976, 1977) point out that tower nests are certainly superior to natural cliff eyries with southern exposures because of the shading that the birds get from the tower beams and cross braces. Also, because of the height of the nests and their openness to the air (compared to a heat absorbing cliff), maximum circulation of air and cooling is attained. Van Daele (1980) adds that nests on poles and towers provide unique opportunities for research and public education.

Table 2. Species of raptors that have nested on power poles or transmission towers. Minimum numbers of nestings documented in the cited papers are given in parentheses under the species' names.

Species	Reference	Pole or Tower?
Osprey (N=195)	Benton and Dickinson 1966	P
	Bogener 1979	P
	Detrich 1978	T
	Dunstan 1968	P
	Edison Electric Institute [1980a]	T
	Electric Meter 1949, 1951, 1953	P
	Electric Reporter 1946	P
	Frier 1978	T, P
	Garber 1972	P
	Henny et al. 1978	T, P
	Lee 1980	T
	MacCarter and MacCarter 1979	P
	Melquist 1974	P
	Melquist and Johnson 1975	P
	Nelson and Nelson 1976, 1977	T
	Pendleton 1978	P
	Public Service Electric and Gas Company 1977	T
	Rhode Island Division of Fish and Wildlife 1980	P
	Saurola 1978	P
	Schroeder and Johnson 1977	P
	Stocek 1972	P
	Stone 1937	P
	Van Daele 1980	P
Harris' Hawk (N=2)	Arizona Game and Fish Department 1976	T
	Ellis et al. 1978	P
Swainson's Hawk (N=10)	Edison Electric Institute 1980a	T
	Fitzner 1978	P
	Olendorff and Stoddart 1974	P
	Meentz and Delesantro 1979	T
Red-tailed Hawk (N=66)	Arizona Game and Fish Department 1976	T, P
	Baldrige 1977	T
	Ellis et al 1978	T
	Fitzner 1980b	T
	Gilmer and Wiehe 1977	T
	Lee 1978b, 1980	T
	Lee and Griffith 1978	T
	Nelson and Nelson 1976, 1977	T
	Olendorff and Stoddart 1974	T
	Rue 1957	T
	Stoner 1939	T
	U.S. Bureau of Land Management 1979c	T



Table 2. Continued

Species	Reference	Pole or Tower?
Ferruginous Hawk (N=24)	Gilmer and Wiehe 1977 Howard 1975 Nelson and Nelson 1976, 1977 North Dakota Outdoors 1976 Olendorff and Stoddart 1974	T P T T, P P
Tawny Eagle (N=1)	Dean 1975	T
Golden Eagle (N=20)	Anderson 1975 Baldridge 1977 Lee 1978b, 1980 Lee and Griffith 1978 Nelson and Nelson 1976, 1977 U.S. Bureau of Land Management 1979c	T T T T T T
Martial Eagle (N=6)	Dean 1975	T
American Kestrel (N=1)	Illinois Power Company 1972	T
Great Horned Owl (N=4)	Fitzner 1980b Gilmer and Wiehe 1977	T T

Others even speculate that nesting on power line support structures is actually extending the breeding range of some raptors (Maslowski and Maslowski 1974; Nelson and Nelson 1976, 1977; U.S. Bureau of Land Management 1979c). More likely, by affording raptors additional choices of nest sites (particularly subadult or first-time nesters) (Van Daele 1980), power line structures lead to locally higher raptor densities within a species' general range. Meentz and Delesantro (1979) believe this to be the case for Swainson's Hawks nesting on transmission towers in southern New Mexico. Eisenmann (in Benton 1954: 66) indicates "that certain hawks in Panama, once considered rare in that locality, have increased in numbers as transmission lines have provided nesting sites, and are now common in some of the more settled areas." At least, nesting on power line structures allows more uniform habitat utilization by spreading raptors into areas where availability of nest sites is a limiting factor.

Artificial Nest Structures for Raptors. Interest in artificial nest structures as habitat enhancement for raptors was very high as the decade of the 1980s began. In a review of the literature concerning raptor management, Olendorff et al. (1980) discussed four types of artificial structures: nestboxes, platforms, wire and wicker baskets, and artificial

nests (i.e., nests carefully built by man to resemble natural nests). Only nestboxes and platforms are generally applicable to use on power poles and transmission towers, although the mounting of oak barrels or similar artificial nesting cavities on transmission towers for raptor use has also been suggested (Olendorff 1973, Olendorff and Stoddart 1974).

Actual installation of artificial nesting structures on power poles and transmission towers has been limited (Table 3). Several consultant reports have recommended further use of artificial platforms as mitigation for new transmission lines (Zitney and Boyle 1976, Baldrige 1977, Meyer 1979, Nelson 1979a), and several power companies have installed artificial structures adjacent to power poles and towers to attract birds away from energized lines (see above). However, the following discussion concerns only the use of power poles and transmission towers as supports for artificial nesting platforms. Documentation of the huge success of nestbox programs (primarily for kestrels) can be found elsewhere (Stahlecker 1979, Olendorff et al. 1980).

Nest Structure Project Planning. The information needed to design a successful and acceptable raptor nesting structure project is much the same as that required for routing and construction of a new line:

(a) an evaluation of both need and feasibility, (b) past and present knowledge of population levels and local distributions of the critical [target] species, including competitors of the species in need of management, (c) habitat and nest substrate preferences and (d) some indication that the prey base is sufficient for a larger raptor population. (Olendorff and Stoddart 1974: 61)

Several other workers have suggested additional items for this list. Howard and Hilliard (1980) and Howard (1980) point out that the possible occurrence of rare, threatened, or endangered species (e.g., prey) in areas to receive artificial nest structures should be evaluated. Following from a suggestion from Snyder and Snyder (1975) that critical limiting factors of raptor populations should be determined wherever management practices are to be implemented, Stahlecker (1979) cautions against overutilization of available prey. For example, if an area is important for winter foraging, will a higher nesting raptor population deplete prey resources prematurely? Van Daele (1980) poses two additional questions for consideration: 1) Are there specific pairs of birds for which artificial structures should be constructed to protect them from electrocution hazards? 2) Is the number of natural nest sites in the area adequate? Stahlecker (1979) attributes the lack of use of artificial platforms in his study area to a combination of poor placement on the individual towers and the presence of adequate numbers of natural nest sites. Detrich (1978) reported that the low usage of artificial nest platforms by Osprey (1 of 15 used) was due either to the high availability of natural nesting sites or to an unsuitable platform design. Bogener (1979) subsequently implemented Detrich's recommendation to trim branches from around the platforms and found an increase in Osprey use (6 of 15 used).

Table 3. The success of artificial nesting structures installed on power poles and transmission towers.

Reference	Location	Type and No. of Structures	*No. Occupied (and species)
Illinois Power Co. 1972	Illinois	1 Wooden Nestbox	1 (Kestrel)
Sietke (In Saurola 1978)	East Germany	30 Iron Platforms on Poles	Almost All Used Each Year (Ospreys)
Stahlecker 1975, 1979	Colorado	12 Wooden Platforms 1975 25 Nestboxes 1976 25 Nestboxes 1977 25 Nestboxes	None 12 (Kestrel) 19 (Kestrel) 24 (Kestrel)
Nelson 1978, 1979a, 1980b	Idaho	6 Wooden Platforms (2 to 4 Years Each)	4 (Golden Eagle) 1 (Red-tailed Hawk) 1 (Osprey) **1 (Bald Eagle)
Nelson 1980a, 1980b	Idaho Oregon	40 Steel Platforms on Towers	Too Early for Results
Bridges 1980	North Dakota	20 Wooden or Wire Mesh Platforms	Too Early for Results
Lee 1980	Oregon, Washington, Montana	1977 4 Wooden/ Fiberglass Platforms  1978 5 Wooden/ Fiberglass Platforms 1979 5 Wooden/ Fiberglass Platforms	1 (Red-tailed Hawk) 1 (Osprey) 1 (Osprey)  1 (Osprey)

\* Minimum number of times used in time periods specified.

\*\* A pair occupied a platform early one season, but did not nest successfully.

Other advantages and disadvantages of artificial nest structure projects must also be considered. If a project has research application or public education potential, its merit is increased (Van Daele 1980). However, if the public will react negatively to such a program, the initiating company or agency may want to reconsider. Negative reactions might come from people for which "the sight of a golden eagle nesting atop a man-made tower does not compare to the sight of one at a cliffside eyrie." (Snyder and Snyder 1975: 191) Likewise, an increase in raptor numbers

from artificial structures may aggravate raptor conflicts with man (e.g., Golden Eagle conflicts with the sheep industry (Stahlecker 1979) or Osprey depredation problems at fish hatcheries or private fishing ponds (Van Daele 1980)).

The following recommendations will also assist in project planning:

- 1) To maximize the success of artificial structures, place them on or near poles and towers which have been used previously by nesting raptors (Lee 1977). While this will not increase raptor density, it may increase line reliability (by moving the nests to safer positions) and nesting success (by minimizing wind damage to nests and heat prostration of unshaded young raptors).

- 2) Place artificial structures below or horizontally removed from conductors to keep energized hardware from being fouled by dropped nest material or excrement (Nelson 1980b), but do not place them so low that they are unattractive to the target species (Stahlecker 1979).

- 3) Since raptors (particularly eagles) seek out and use updrafts to save energy when hunting and when bringing prey to their nests, place artificial structures on poles or towers near the face of a rolling hill or escarpment which deflects winds upward (Nelson 1980b). However, do not put structures near escarpments or gallery forests along streams where adequate natural nest sites exist (Nelson 1979a).

- 4) Use discretion in placing artificial nesting platforms where ground nesting raptors occur, because such raptors are generally smaller and more vulnerable to predation than the buteos and eagles which can be attracted to the platforms. This is especially important to Burrowing Owls (Fitzner 1980b), which are preyed upon by a number of larger diurnal raptors.

- 5) Place all artificial nesting structures away from intensive human disturbance (e.g., away from roads and trails) (Stahlecker 1975, 1979; Baldrige 1977). Nelson (1980b: 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." It should be added that it must also be free of continued, day-to-day harassment. Thus, where disturbance can be avoided, it should be; the overall success of the project will probably be enhanced by doing so.

- 6) Keep in mind that artificial nesting structures may not be needed on all types of transmission towers, because the metal lattice work of some steel towers and the double crossarms of H-type wooden construction provide adequate nest substrates (Lee 1980). However, to prevent wind damage it may be desirable to wire existing nests to the towers or cross-arms, particularly to stabilize them in places where they will not disrupt operation of the lines.

- 7) While there is considerable enthusiasm about placing artificial nesting platforms on transmission structures, a study is needed to evaluate the effectiveness of a large-scale program. The limited success to

date is in part attributable to the fact that platforms have been installed primarily in previously used raptor territories.

The Morlan Nelson Nest Structure Design (Figure 17). The following discussion is summarized from Nelson (1974, 1980b), Nelson and Nelson (1976, 1977), and Sandeen (1975). The use and success of this structure are outlined in Table 3 under Nelson (1978, 1979a, 1980a, 1980b), Bridges (1980), and Lee (1980).

The basic design is intended to minimize construction time, use of materials, and, thus, cost per structure (\$125.00 according to Bridges (1980) and \$265.00 if covered with fiberglass according to Lee (1980)). A 4-foot by 8-foot (1.2-m by 2.4-m) sheet of plywood is cut as shown in Figure 17. Wooden dowels are set into the base at 45 degree angles to stabilize the nest materials in heavy winds.

Placement of the structures on steel towers or H-type wooden configurations (Figure 17) is done to provide the most open route to the platform by the parent birds and the maximum degree of shading during the hottest portions of summer days. Thus, the angle of the sunshade should be pointed due south to allow morning sun to hit the nest, but to provide shade in the afternoon. Since the open end must then face north, the structure should be mounted on the north side of the tower (or the north end of the double crossarm) whenever possible.

Future use of this artificial structure, which is designed to last up to 100 years, will certainly increase. Nelson's own enthusiasm is indicative of the level of support given by industry personnel, agency biologists, and conservationists alike:

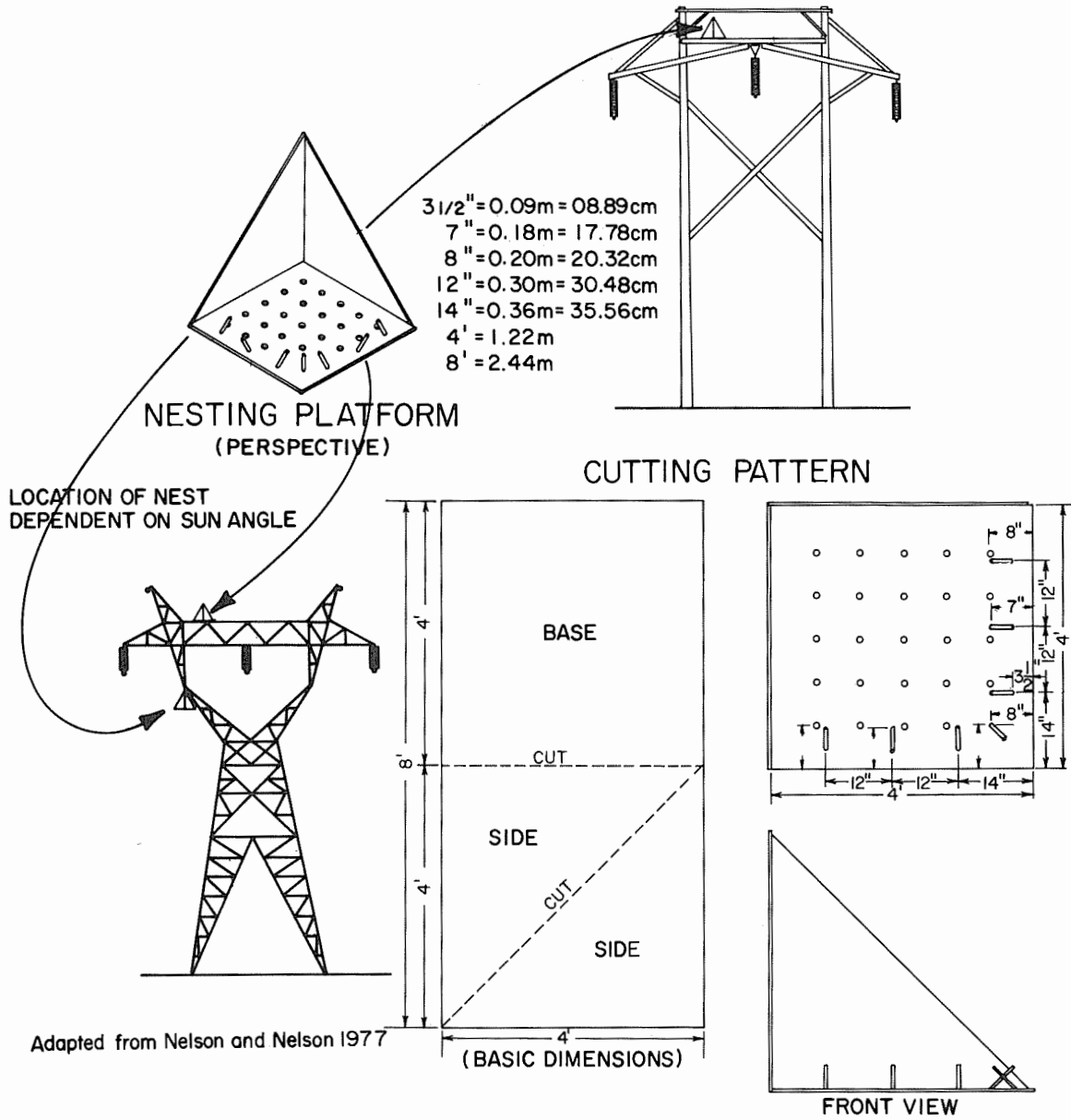
The great nesting potential in high voltage lines throughout the world will be a significant factor in the future in maintaining populations of birds of prey as we see them today. These high voltage lines offer high, safe nesting sites in prey areas without natural nesting sites.

The forty platforms [actually 38 by final count] in over 500 miles of line in Idaho and Oregon being constructed now [1980] by the Pacific Power and Light Company, offer an excellent opportunity for evaluation [of the platform] in several life zones and definitive determinations of impact and potential value to the birds of prey. (Nelson 1980b: 4)

Other Types of Habitat Enhancement. One of the most promising recent advancements in the development of raptor management techniques is the cross-fostering and hacking (controlled releasing) of raptors to areas where they have been extirpated or where a range extension of a species is desirable. Cross-fostering involves the fostering of young of one species to wild parents of another (e.g., Prairie Falcons to Red-tailed Hawks nesting on steel transmission towers). Hacking, which was developed by falconers to provide their birds with a degree of natural experience before being taken into captivity for falconry training, in the raptor

FIGURE 17

# EAGLE NESTING PLATFORMS



management sense involves allowing birds to go completely wild in a pre-determined place by supplying them with food at a hack station until they are capable of killing for themselves. The success of these two introduction techniques is summarized by Olendorff et al. (1980).

Many of the hacking efforts to introduce Peregrine Falcons and Bald Eagles to the eastern United States are done at hacking towers that resemble steel transmission towers and H-type wooden configurations currently used by the power industry. The behavior of cliff-nesting Peregrine Falcons is being modified to the point that birds released two to five years earlier are now returning to breed on the hacking towers.

The potential for hacking Peregrine Falcons from power lines running close to historical eyries is noteworthy. As Nelson (1980b) indicates, it would be simple to redesign his artificial nest structure into a hacking station for use on transmission structures by industry and government. Again, the philosophical merit of doing so is open for debate, but this should not preclude management research to clarify the feasibility, merit, and legalities involved.

**PART FIVE**

**LITERATURE CITED**

**AND**

**ANNOTATED**

**BIBLIOGRAPHY**



## PART FIVE:

### LITERATURE CITED AND ANNOTATED BIBLIOGRAPHY

In order to present a thorough list of references concerning raptor protection on power lines, the following citations and annotations include not only references cited in the present paper (indicated by an asterisk), but also all other available references. Annotations include only information pertinent to this review, even though the contents of a particular paper may have other significant merit. Several papers listed here were cited in support of ancillary sections of this report (e.g. "Golden Eagle Distribution"), but do not contain information on raptor/power line interactions. The senior author would appreciate receiving copies of all papers concerning raptors and power lines which are not listed here in case this publication is ever updated again. Unless otherwise noted, all papers listed below are on file in the Raptor Management Information System. Contact the senior author for access to this system.

Allen, B.A. 1979. Determination of status and management of the Golden Eagle. Unpubl. rep. New York Department of Environmental Conservation, Division of Fish and Wildlife, Albany. 4 pp.

A single immature Golden Eagle was electrocuted in Niagra County, New York, in 1979.

\*Anderson, W.W. 1975. Pole changes keep eagles flying. Transmission and Distribution. November, 1975. pp. 28-31. (Idaho Power Company.)

An excellent summary of efforts spearheaded by the Idaho Power Company to minimize eagle electrocutions. Several photographs add to the descriptions of research begun in 1972 by Morlan W. Nelson and reported later by Nelson and Nelson (1976, 1977) and Nelson (1978). The extent to which Golden Eagles use nests built on transmission lines is also discussed. Instead of destroying such nests, Idaho Power Company linemen just trim the longer sticks to clear the conductors.

\*Anderson-Harild, P., and D. Bloch. 1973. Birds killed by overhead wires on some locations in Denmark. (In Danish with English summary). Dan. Ornithol. Foren. Tidsskr. 67: 15-23.

Forty percent of total bird losses along power lines at 4 locations in Denmark were night migrants (including owls).

\*Ansell, A.R., and W.E. Smith. 1980. Raptor protection activities of the Idaho Power Company. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 56-70.

"A brief history of the electrocution of birds-of-prey within the Idaho Power Company service area is given, including a brief discussion of the ecological interrelationships which culminate in the electrocution of large raptorial [sic] birds. Ongoing raptor protection activities and associated costs are summarized. A useful appendix is attached illustrating recommended modification techniques of "hazard poles" and a form to be used by interested individuals to notify the company of suspected electrocutions." (Authors' abstract.)

\*Arizona Game and Fish Department. 1976. Wildlife surveys and investigations [raptors]. Spec. Performance Rep. Proj. No. W-53-R-26. 77 pp.

Mentions that a Harris' Hawk nest in Maricopa County in 1975 was located on a power pole.

Arizona Republic. 1976. 60-foot towers for birds of prey being created along Verde River. Newspaper article. December 24, 1976. p. A-3.

Sixty-foot (18.3-m) towers erected as raptor perches along the Verde River are very similar to electric utility poles. No follow-up information is available.

\*Avery, M.L. (ed.). 1978. Impacts of transmission lines on birds in flight: proceedings of a workshop. U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. 151 pp. (U.S. Government Printing Office Stock No. 024-010-00481-9.)

See Lee 1978, Kroodsma 1978, Thompson 1978, and Willard 1978.

Baglien, J.W. 1975. Biology and habitat requirements of the nesting Golden Eagle in southwestern Montana. Master's Thesis. Montana State University, Bozeman. 53 pp.

Includes a comment about one Bald Eagle and one Golden Eagle which were electrocuted on power lines in the Madison River Basin of southwestern Montana.

\*Baldrige, F.A. 1977. Raptor nesting survey of southern San Diego County, Spring 1977; with an analysis of impacts of powerlines. Unpubl. rep. U.S. Bureau of Land Management, Riverside, California. 29 pp.

During the nesting period, May-June, 1977, a study was conducted along the proposed Sundesert Nuclear Project transmission line corridors in southern San Diego County, California, to determine numbers, species, and nesting areas of raptorial birds near the proposed corridors. Discussion topics include electrocution, collisions, indirect impacts, and mitigating factors.

\*Beecham, J.J., Jr. 1970. Nesting ecology of the Golden Eagle in southwestern Idaho. Master's Thesis. University of Idaho, Moscow. 48 pp.

Golden eagle population data.

\*Beecham, J.J., and M.N. Kochert. 1975. Breeding biology of the Golden Eagle in southwestern Idaho. Wilson Bull. 87: 506-513.

Electrocution was the leading cause of mortality of immature Golden Eagles.

\*Belisle, A.A., W.L. Reichel, L.N. Locke, T.G. Lamont, B.M. Mulhern, R.M. Prouty, R.B. DeWolf, and E. Cromartie. 1972. Residues of organochlorine pesticides, polychlorinated biphenyls, and mercury and autopsy data for Bald Eagles, 1969 and 1970. Pestic. Monit. J. 6(3): 133-138.

Bald Eagle mortality data.

\*Benson, P.C. 1977. Study of powerline utilization and electrocution of large raptors in four western states. Research proposal submitted to the National Audubon Society. Brigham Young University, Provo, Utah. 7 pp.

Most aspects of this research proposal were subsequently carried out (see Benson 1981). The initial objectives of the study were: 1) determine and gather data on high raptor electrocution areas; 2) analyze significance of high nesting density to electrocution mortality rates; 3) analyze hunting and wintering territorial effects on electrocution mortality rates; 4) gather data on the use of power poles by raptors for hunting perches and nesting structures; 5) provide data on the apparent impact on breeding populations with a reduced recruitment potential; 6) provide data and suggest impact on migrant populations; and 7) document and bring to the attention of the general public, power companies, scientists, and conservationists the magnitude of this problem.

\*Benson, P.C. 1980. Study of large raptor electrocution and powerpole utilization in six western states. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 34-40.

"In an attempt to determine the ecological factors influencing the majority of raptor electrocution mortalities in the West, data from 24 five mile sections of powerline were collected. Soil and vegetation types, topographic relief, weather patterns and prey base were all considered to isolate the ecological types where the problem most often occurred. Human disturbance both active and passive were considered, attempting to eliminate bias due to shooting. Age was determined, when possible, to assess the impacts upon breeding and subadult populations. Construction and power output of the poles were measured to determine the safest types

available for use. These data will hopefully be used by power companies and state and federal management agencies to determine modification needs and the most practical solutions to eliminate raptor electrocutions." (Author's abstract.)

\*Benson, P.C. 1981. Large raptor electrocution and powerpole utilization: a study in six western states. Ph.D. Dissertation. Brigham Young University, Provo, Utah. 98 pp.

An extensive report on raptor/power pole relationships in the deserts of the western United States where low vegetation and flat terrain make power poles attractive to raptors as hunting and roosting perches. The Golden Eagle was the most commonly electrocuted raptor, particularly young eagles inexperienced in flight. More electrocutions occurred in native shrub areas than in cultivated areas. Most new power lines are designed to be safe to raptors; however, older configurations with only horizontal separation of conductors are particularly dangerous and represent the majority of western power lines. Recommendations include placement of poles such that natural roosting sites will be chosen over poles; compromising when placing power lines near roads such that they are near enough for easy maintenance and far enough away to avoid shooting; insulating wires on corner and transformer poles; and positioning safety features (such as perches) perpendicular to the wind and low enough so that raptors cannot sit beneath them. This is the most thorough study to date of the biological aspects of the raptor electrocution problem.

\*Benton, A.H. 1954. Relationship of birds to power and communication lines. Kingbird 4(3): 65-66.

Mentions that "certain hawks in Panama...have increased in numbers as transmission lines have provided nest sites,..."

\*Benton, A.H., and L.E. Dickinson. 1966. Wires, poles, and birds. In: Birds in our lives. A. Stefferud (ed.). U.S. Bureau of Sport Fisheries and Wildlife, Washington, D.C. pp. 390-395.

A general description of power poles and lines and their beneficial as well as adverse effects on birds. Briefly describes the causes of eagle electrocution and techniques utilized to remedy the situation, including the erection of duplicate poles with platforms for nesting Ospreys.

\*Bijleveld, M.F.I.J., and P. Goeldin. 1976. Electrocution d'un couple de Buses Buteo buteo a Jongny (VD). Nos Oiseaux 33(6): 280-281.

A pair of Common Buzzards was electrocuted at a 17-kV power line in Switzerland.

\*Boeker, E.L. [1972.] Powerlines and bird electrocutions. Unpubl. rep. U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Denver, Colorado. 8 pp.

An early summary of the raptor electrocution problem in the western United States, where most documented losses were associated with Rural Electrification Administration power distribution lines. Three-phase lines with spacing less than six feet (1.8 m) between the phase conductors and ground wires were found to be particularly lethal. Boeker proposed action on two fronts to eliminate or reduce the electrocution problem: 1) that existing lethal lines be modified to prevent further losses; and 2) that specifications for future line construction include safeguards against electrocution. Specific recommendations are given for facilitating communications between responsible agencies and interested parties, for modifying the lines, and for monitoring the lines before and after modification.

\*Boeker, E.L. 1974. Status of Golden Eagle surveys in the western states. Wildl. Soc. Bull. 2: 46-49.

Gives a brief account of the provisions of the Bald Eagle Protection Act which concern Golden Eagles, and discusses early efforts to minimize raptor electrocutions on power lines. Reports primarily on the wintering and nesting status of the species.

\*Boeker, E.L., M.A. Jenkins, and L.D. Crowley. 1978. Golden Eagle population studies in the Western States. In: U.S. Fish and Wildlife Service Annual Progress Reports -- 1978. Denver Wildlife Research Center, Denver, Colorado. pp. 38-42.

Golden Eagle population data.

\*Boeker, E.L., and P.R. Nickerson. 1975. Raptor electrocutions. Wildl. Soc. Bull. 3: 79-81.

An accumulation of information on raptor electrocution beginning in 1971 that provides insight into the "where and why" of this phenomenon. Electrocutions were most frequent in states with the largest eagle populations. In the lower 48 states, documented electrocution losses of raptors totaled 153 in 1972 and 128 in 1973.

\*Boeker, E.L., and T.D. Ray. 1971. Golden Eagle population studies in the Southwest. Condor 73: 463-467.

Golden Eagle population data.

\*Bogener, D.J. 1979. Osprey inventory and management study for Shasta Lake Ranger District (1979). Unpubl. rep. U.S. Forest Service, Redding, California. 13 pp.

Mentions that 4 of 16 Osprey nests at which incubation occurred were on steel power transmission towers. Also includes a discussion of Osprey use of artificial nest structures. Based on a recommendation from Detrich

(1978), Bogener trimmed branches from around the nest structures to increase visibility from the platforms. Osprey use of the nest structures subsequently increased from 1 used in 1978 to 6 used in 1979.

\*Brady, A. 1969. Electrocuted Great Horned Owl. *Cassinia* 51: 57.

Presumably this occurred when the prey item held by the owl touched a conductor.

\*Bridges, J.M. 1980. Raptor nesting platforms and the need for further studies. In: *Proceedings of a workshop on raptors and energy developments*. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 113-116.

"Artificial nesting structures have been placed in 400 kV d.c. transmission towers in central North Dakota to provide additional nesting habitat for raptor species in that area. Three different types of nesting platforms were regularly spaced over approximately 80 miles of the line. One type is wooden and follows the designs suggested by Morlan W. Nelson for Idaho Power Company. The other two are experimental designs developed by Commonwealth Associates in conjunction with the United Power Association. The latter two designs are somewhat less expensive to construct and should realize a greater longevity. Additional studies are recommended which might enhance the few positive aspects of transmission line - raptor interactions." (Author's abstract.)

Bromby, R. 1981. Killer lines in Colorado present an electrocution hazard to raptors. *Wildlife News* 6(3): 2-3. (Colorado Division of Wildlife, Denver).

A brief review of the electrocution problem in Colorado. The cooperative efforts of government and industry which resulted in the correction of many hazardous lines are discussed, and the recently identified problem of entanglement is mentioned.

\*Brown, L. 1976. *British birds of prey*. William Collins Sons and Co., Ltd., London. 400 pp.

Mentions on page 223 that "the most common single cause of accidental death [of Merlins] is by collision against wires."

\*Brown, L., and D. Amadon. 1968. *Eagles, hawks and falcons of the world*. McGraw-Hill Book Company, New York, New York. 945 pp.

A brief paragraph recognizes the electrocution problem, but this book was written before the true magnitude of the electrocution issue was identified during the 1970s. Also gives physical measurements of Golden Eagles used in this publication.

\*Brunetti, O.A. 1965. Report on the cause of death of a [the Pinehurst] California Condor. Unpubl. rep. California Department of Fish and Game, Sacramento. 11 pp. & 2 pp. supplement.

An investigation into the cause of death of a California Condor led to the conclusion that the bird struck some object, possibly a power line, which stunned it so that it fell to the road below and was killed.

\*Cade, T.J., and P.R. Dague (eds.). 1977. Peregrine Fund Newsletter No. 5. 12 pp.

Passing mention is made of three hacked (released) Peregrine Falcons being electrocuted in separate incidents in the northeastern United States. All had telemetry antennas which probably helped span the distances between electric conductors.

Call, M. 1979. Habitat management guides for birds of prey. U.S. Bureau of Land Management Tech. Note No. T/N-338. Denver, Colorado. 70 pp.

Provides descriptions and photographs of raptor nests on power poles and transmission towers, and gives specifications for artificial nest structures on power lines, primarily those developed by Nelson (1974, 1978, 1980b).

\*Chancellor, R.D. (ed.). 1977. World conference on birds of prey, report of proceedings. International Council for Bird Preservation. 442 pp.

Of interest here is discussion of the wisdom of encouraging raptors to nest on man-made nest sites and/or artificial structures. See pp. 399-408.

\*Chindgren, S.[R.] 1980. Mixing it up. Hawk Chalk 19(2): 50-53.

Documents in a short paragraph the electrocution of a trained Gyrfalcon.

\*Chindgren, S.R. 1981. Trained raptor electrocution -- a request for information. Hawk Chalk 20(1): 59.

Author seeks information in order to quantify the extent of electrocution of falconers' birds.

\*Conservation News. 1973. Eagle electrocution study undertaken. 38(10): 10-11. May 15, 1973.

Brief review of Morlan Nelson's photographic work using mock-up poles and trained eagles to solve specific raptor electrocution problems.

\*Conservation News. 1976. Power line electrocution -- hazards made safer. 41(21): 8-10. November 15, 1976.

Reports on the progress made in preventing power line electrocution of raptors, particularly Golden Eagles. Power line mortality could be significantly reduced with the use of corrective insulation, pole modifications, and wider wire spacing.

\*Consumers Power Company. 1972. Construction awaits birth of eagles at utility line project. News release dated April 27, 1972. Jackson, Michigan. 1 p.

Power line construction by Consumers Power Company near Mio, Michigan, was delayed until August 1 due to the proximity of an active Bald Eagle nest.

\*Coon, N.C., L.N. Locke, E. Cromartie, and W.L. Reichel. 1970. Causes of Bald Eagle mortality, 1960-1965. J. Wildl. Dis. 6(1): 72-76.

The greatest cause of mortality (45 of 76 documented deaths) were shootings. One bird was electrocuted.

\*Craig, T.H. 1978. Car survey of raptors in southeastern Idaho 1974-1976. Raptor Res. 12(1/2): 40-45.

Reports significant use of power poles and lines as perches by raptors.

Crawford, J.E., and L.A. Dunkeson. 1974. Powerline standards to reduce raptor losses on the National Resource Lands. (Abstract only.) In: Management of raptors. F.N. Hamerstrom, Jr., B.E. Harrell, and R. R. Olendorff (eds.). Raptor Res. Rep. No. 2: 124.

In 1971 field reconnaissance of power lines crossing the National Resource Lands (public domain) in the eleven Western States revealed annual electrocution losses of over 200 eagles. Since these were extensive field surveys, actual annual losses were considered to be much higher. (See U.S. Bureau of Land Management (1971b)).

\*Cromartie, E., W.L. Reichel, L.N. Locke, A.A. Belisle, T.E. Kaiser, T.G. Lamont, B.M. Mulhern, R.M. Prouty, and D.M. Swineford. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for Bald Eagles, 1971-72. Pestic. Monit. J. 9: 11-14.

Bald Eagle mortality data.

\*Damon, J.D. 1975. Report suggests ways to protect eagles perched on power lines. News release dated August 20, 1975. Edison Electric Institute, New York, New York. 3 pp.



Announces the release of the first edition of "Suggested Practices for Raptor Protection on Powerlines" (see Miller et al. 1975).

\*Dawson, B. 1974. Letting them go -- Great Horned Owls go to school. Museum Talk 48(2): 45-48. (Santa Barbara Museum of Natural History, Santa Barbara, California.)

Mentions two Golden Eagles which lost wings due to power line collisions.

\*Dean, W.R.J. 1975. Martial Eagles nesting on high tension pylons. Ostrich 46: 116-117.

In the Kimberly area of the Cape Province, South Africa, Martial Eagles (Polemaetus bellicosus) were recorded nesting on transmission towers. The observed nests were all in woodland habitats, though there were numerous trees that were considered to be available to the eagles. In the Ottoshoap area of the western Transvaal, a Tawny Eagle (Aquila rapax) was recorded nesting on a transmission tower.

\*Denver Audubon Society Newsletter. 1971. Action taken on eagle electrocutions. 3(7): 1.

Brief documentation of the electrocution of 54 Golden Eagles in Weld and Moffat Counties, Colorado, and the efforts to correct the lines involved.

\*Denver Post. 1974. Power lines menacing eagles. Newspaper article. March 24, 1974.

Announces several aerial surveys of power lines for electrocuted eagles in New Mexico. Mentions that 19 eagle mortalities occurred along 14 miles (22.5 km) of lines near Roswell between March, 1971, and April, 1974.

\*Detrich, P.J. 1978. Osprey inventory and management study for Shasta Lake Ranger District. Unpubl. rep. U.S. Forest Service, Redding, California. 17 pp.

A thorough report on a California Osprey population. Four of 16 nests at which incubation occurred were on steel power transmission towers. One pair nested on one of 15 available artificial platforms. Another platform had evidence of use prior to the incubation period in 1977. Pruning of branches around artificial platforms is recommended to increase platform use (see Bogener (1979)). Various human impacts are also discussed.

\*Dickinson, L.E. 1957. Utilities and birds. Audubon Mag. 59: 54-55, 86-87.

Describes a 1946 modification of power transmission towers in the Sierra Nevada Mountains of California by the Pacific Gas and Electric Company. The modification involved placing a 2-inch (5.1 cm) wooden dowel perch on the top of each tower. The diameter of the perch was considered important in that it had to be large enough to be readily grasped by the eagle.

\*Dodge, G. 1975. Engineers' forum: protection against problems of wildlife. Elec. World, April 1, 1975. p. 48.

Briefly describes measures proposed by Morlan W. Nelson to prevent electrocution of eagles by electric distribution lines. (See Nelson and Nelson (1976, 1977) and Nelson (1978) for details.)

Dunkeson, L. 1973. Minimum standards for electric distribution lines relating to protection of raptors [draft]. Source? 7 pp.

A detailed stepdown outline of how to correct existing lines or design new lines to minimize raptor electrocution. No evidence was found that this draft was ever finalized.

Dunstan, T.C. 1967. Study of Osprey in Itasca County, Minnesota. Master's Thesis. University of South Dakota, Vermillion.

Two of 24 Osprey nests located in Itasca County, Minnesota, were on double crossbar type power poles. A nestling from one of these nests was probably electrocuted.

\*Dunstan, T.C. 1968. Breeding success of Osprey in Minnesota from 1963 to 1968. Loon 40: 109-112.

Mentions that Ospreys in Minnesota sometimes nest on the double crossbars of telephone or power line poles. Also mentions two known cases of Osprey electrocution: one case of an adult being electrocuted and another case of a nestling being electrocuted.

\*Dunstan, T.C., J.H. Harper, and K.B. Phipps. 1978. Habitat use and hunting strategies of Prairie Falcons, Red-tailed Hawks, and Golden Eagles. U.S. Bureau of Land Management, Denver, Colorado, and Boise, Idaho. 177 pp.

Illustrates several home ranges of each species in relation to power lines.

Edison Electric Institute. 1973. [Raptor electrocutions.] Letter to the Associate Director of the Bureau of Land Management dated July 16, 1973. 3 pp.

Discusses the early awareness of the electric power industry of the raptor electrocution problem and the willingness of the industry to effect a solution.

\*Edison Electric Institute. 1975. [Distribution of "Suggested Practices for Raptor Protection on Powerlines."] Letter from the Institute to the Assistant Secretary of the Interior for Fish and Wildlife and Parks dated September 24, 1975. 2 pp.

Details the distribution of over 3,000 copies of Miller et al. (1975).

\*Edison Electric Institute. [1980a.] Compatibility of fish, wildlife, and floral resources with electric power facilities and lands: an industry survey analysis. Prepared by Urban Wildlife Research Center, Inc., Ellicott City, Maryland (Daniel L. Leedy, Research Director) for EEI, Washington, D.C. (Richard S. Thorsell, Environmental Project Manager). 130 pp.

An excellent review of the manner and extent to which the electric utility industry's facilities and activities impact fish, wildlife, and floral resources both positively and negatively. Whereas much of the literature on this subject focuses largely upon negative impacts, the main thrust here concerns 1) positive impacts and 2) voluntary efforts by the industry to mitigate negative impacts and to manage, protect, and enhance associated resources. Many examples involving raptors are cited. Also included is a partial annotated bibliography summarizing completed research.

\*Edison Electric Institute. 1980b. [Silver Wires, Golden Wings.] News release dated June 17, 1980. EEI, Washington, D.C. 2 pp.

Brief news release about a 25-minute, 16 mm movie that outlines the efforts of western electric utilities to prevent the electrocution of birds of prey on power lines. Other movie segments show the installation of artificial nesting platforms on electric transmission towers. The movie is distributed by Modern Talking Picture Service, 5000 Park Street North, St. Petersburg, Florida 33709.

Edison Electric Institute. [1980c.] Studies/management for raptors. Unpubl. rep. Washington, D. C. 9 pp.

A brief listing of private electric company activities in the study and management of raptors on or near their facilities.

\*Edwards, C.C. 1969. Winter behavior and population dynamics of American Eagles in Utah. Ph.D. Thesis. Brigham Young University, Provo, Utah. 142 pp.

A section on mortality documents the deaths of eight eagles (presumably Golden Eagles) under a single power pole on the Desert Chemical Depot in north-central Utah. Also documents the death by shooting of 37 raptors, 21 of which were Golden Eagles, along a road which paralleled a power line.

\*Electric Meter. 1949. Pampered bird. March, 1949. p. 3.

Dummy poles were erected near certain power poles to lure nesting Ospreys away from activated lines.

\*Electric Meter. 1951. Homeless hawk happy with rebuilt roost. May, 1951. p. 1.

Osprey carried a burning stick to its nest on a dummy power pole and destroyed it. Line crews rebuilt the crossarm and nest, and the birds returned.

\*Electric Meter. 1953. South Jersey nemesis. November, 1953.

Discusses the problems that electric companies in southern New Jersey were having with outages caused by nesting Ospreys. Many poles with crossarms convenient for nesting were erected in an effort to lure the Ospreys away from energized lines.

\*Electric Reporter. 1946. Short circuit is isolated. October, 1946.

Brief note about Ospreys nesting on power poles and shorting out electric distribution facilities in New Jersey. Dummy poles were erected adjacent to the power poles as alternate nest sites for the birds. In some cases the birds switched their nests to the dummy poles.

Electricity Supply Commission of South Africa. 1980. Plea to save Africa's birds from electrocution. Megawatt 63: 11-13.

An informative summary of the electrocution problem in South Africa. The lattice steel towers of 132-, 275-, and 400-kV lines are used safely by raptors, since the conductors are widely spaced; but lines of 88 kV or less, especially those of the so-called Kite construction, are extremely dangerous. The higher voltage lines are used extensively as roost sites by Cape Vultures and as nesting sites by Martial Eagles, Tawny Eagles, Rock Kestrels, Greater Kestrels, and Lanner Falcons. Between 1970 and 1977, however, over 300 vultures were electrocuted on the lower voltage lines. There is reason to believe that the Cape Vulture is the only bird in Africa on which electrocution is having a direct effect. The loss of these slow-reproducing birds, many of them adults, to an unnatural cause is possibly hastening the decline.

Electric World. 1981. 500 kV towers are for the birds. July, 1981.

Pacific Power and Light Company installed artificial nest platforms on 38 transmission towers on its new 534-mile (859-km) 500-kV AC line, which extends from Medford, Oregon, to the Mid-Point Substation near Twin Falls, Idaho. The steel platforms, designed according to specifications from Morlan W. Nelson, were placed at the waists of the towers, about two-thirds of the way up from the ground to the conductors. The platforms were installed to prevent birds from nesting on the lattice members of the crossarm, above the triple-bundles of the three-phase line, where excrement from the birds could cause flashovers. Of a dozen or so units installed in Idaho, six have been occupied, one by a predatory bird, the others by Common Ravens.

\*Ellis, D.H., J.G. Goodwin, Jr., and J.R. Hunt. 1978. Wildlife and electric power transmission. In: Effects of noise on wildlife. Academic Press, Inc. pp. 81-104.

This paper emphasizes three related topics: 1) the major areas of wildlife/power line interactions; 2) the degree of wildlife utilization of power line corridors and power towers; and 3) the physical environment on and around high voltage power towers. Many of the examples given involve raptors.

\*Enderson, J.H., and M. N. Kirven. 1979. Peregrine Falcon foraging study in the Geysers-Calistoga Known Geothermal Resource Area, Sonoma County, California -- 1979. Unpubl. rep. U.S. Bureau of Land Management, Sacramento, California. 82 pp.

Includes comments regarding Peregrine collisions with power lines in California and Colorado.

\*Fitzner, R.E. 1975. Owl mortality on fences and utility lines. Raptor Res. 9: 55-57.

Describes the deaths of two Short-eared Owls on power lines in southeastern Washington and Idaho during the winter of 1973-74. Entanglement, rather than electrocution, was cited as the cause of both deaths.

\*Fitzner, R.E. 1978. Behavioral ecology of the Swainson's Hawk (Buteo swainsoni) in southeastern Washington. Ph.D. Dissertation. Washington State University, Pullman. 194 pp.

A complete life history of the Swainson's Hawk. Of interest here is the report of one Swainson's Hawk being electrocuted during its immediate post-fledging period. Also mentions that two of 90 nests were located in the crossarms of wooden utility poles.

Fitzner, R.E. 1980a. Behavioral ecology of the Swainson's Hawk in southeastern Washington. Battelle Pacific Northwest Laboratory Tech. Rep. No. PNL-2754. Richland, Washington. 65 pp.

Mentions that a young Swainson's Hawk was apparently electrocuted when it landed on a wooden power pole with a prey item which may have contacted two conductors. Power poles near the nest tree at this particular site were used extensively for perching by young hawks. Also mentions that a pair of Swainson's Hawks nested on a wooden utility pole. The author suggests that, though artificial nest structures could be placed on utility poles to attract more nesting pairs, the placement of elevated platforms in situations other than on power poles may better merit the effort, since power poles are generally near roads where the potential of disturbance is greater.

\*Fitzner, R.E. 1980b. Impacts of a nuclear energy facility on raptorial birds. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 9-33.

"In summary, the long-term ecological studies of birds of prey at the Hanford Site in southeastern Washington reveal that: 1) A wide variety of raptorial birds and the raven nest on the site primarily due to the no-trespass policies and buffer zone requirements at a nuclear energy facility. 2) Several raptor species and ravens have adapted to nesting on or in manmade structures, particularly transmission towers. 3) Artificial nest sites appear to be preferred by only a select group of birds and thus may be causing an increase in these few species, having no impact on some, and negatively impacting others. The negative impacts could result when species preferring artificial structures move into an area already being used for nesting by those species not preferring artificial structures. 4) Management of raptors and ravens at energy facilities should consider the overall natural species makeup of the raptor community in the impact area and manmade structures should be equipped with a variety of artificial nests suitable as nest sites for these raptors. Care must be taken not to disturb or alter naturally existing raptor nest sites." (Author's summary.)

Fitzner, R.E., W.H. Rickard, L.L. Cadwell, and L.E. Rogers. 1981. Raptors of the Hanford Site and nearby areas of southcentral Washington. Battelle Pacific Northwest Laboratory Tech. Rep. No. PNL-3212. Richland, Washington. 61 pp.

Mentions that on the Hanford Site Red-tailed Hawks nest principally on utility towers.

Frier, J.A. 1977. Research and management of endangered birds in New Jersey (Ospreys). Unpubl. rep. New Jersey Department of Environmental Protection, Division of Fish, Game, and Wildlife, Trenton. 13 pp.

Mentions that a nesting pole was installed near a channel marker on which a nest was obstructing the light. The birds returned and immediately constructed a nest on the pole.

\*Frier, J.A. 1978. Research and management of endangered birds in New Jersey (Ospreys). Unpubl. rep. New Jersey Department of Environmental Protection, Division of Fish, Game, and Wildlife, Trenton. 14 pp.

Includes a breakdown of the types of man-made structures used as nest sites by Ospreys in New Jersey. Of 104 nests, eight occurred on high tension towers, nine on telephone poles, and four on other types of power line poles. Also mentions that 31 nests were on poles erected specifically for Ospreys.

\*Fyfe, R.W., and R.R. Olendorff. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service, Occas. Pap. No. 23. 17 pp.

Itemizes specific dangers of human disturbance to nesting raptors. As cited in the present paper these dangers must be considered during construction of power lines near active raptor nest sites.

\*Garber, D.P. 1972. Osprey study, Lassen and Plumas Counties, California, 1970-1971. California Department of Fish and Game, Wildlife Management Branch Admin. Rep. No. 72-1, Sacramento. 33 pp.

Mentions that 1 of 60 Osprey nests in northern California in 1970 and 1971 was on a power pole.

\*Garzon, J. 1977. Birds of prey in Spain, the present situation. In: World conference on birds of prey, report of proceedings. R.D. Chancellor (ed.). International Council for Bird Preservation. pp. 159-170.

Included in this summary of the status of birds of prey in Spain is a review of significant threats and mortality factors. One of the greatest threats to such large raptors as Aquila heliaca, Aegypius monachus, and Bubo bubo is posed by overhead cables (power lines). A great many raptors are killed by collisions with or by electrocution on power lines.

\*Gillard, R. 1977. Unnecessary electrocution of owls. Blue Jay 35: 259.

Mentions the recovery of two Great Horned Owls electrocuted on power poles. At least 13 of 207 other banding recoveries were by this means.

\*Gilliland, J. 1975. Eagle-safe poles praised. Newspaper article. Idaho Statesman, Boise, Idaho. October 22, 1975.

Briefly describes the use of motion pictures by Morlan W. Nelson to document the design of eagle-safe power poles.

\*Gilmer, D.S., and J.M. Wiehe. 1977. Nesting by Ferruginous Hawks and other raptors on high voltage powerline towers. *Prairie Natur.* 9(1): 1-10.

Based on one year of data (1976), tower nesting Ferruginous Hawks (21 nests) laid slightly larger clutches (3.7 eggs/nest) than birds nesting in trees and on haystacks and the ground (24 nests collectively) (3.2 eggs/nest). Because of nest loss during windstorms and loss of young due to crowding conditions encountered as the nestlings grew older, the number of young fledged per tower nest (2.5) was lower than in other nests (2.8). Also notes that raptor electrocution is a problem on some power lines; however, no electrocutions were verified on the 230-kV lines studied in this investigation.

\*Glue, D.E. 1971. Ringing recovery circumstances of small birds of prey. *Bird Study* 18(3): 137-146.

Kestrels and Sparrow Hawks were more prone to collisions with overhead wires and cables than were Barn, Tawny, and Little Owls (Kestrels were more prone than Sparrow Hawks, and Barn Owls were more prone than Tawny and Little Owls). These differences were explained primarily by the modes of hunting of each species; for example, Kestrels and Barn Owls tend to hunt over fields and open country 20-30 feet (6.1-9.1 m) up; hence, they are more prone to striking overhead wires and cables.

\*Gretz, D.I. 1981. Power line entanglement hazard to raptors. Unpubl. rep. U.S. Fish and Wildlife Service, Denver, Colorado. 9 pp.

Calls attention to an additional hazard to raptors associated with power lines (besides electrocution, collision, shooting, etc.): entanglement of the talons in the loose wire wrappings which hold conductors to insulators. Gretz suggests that some raptors thought to have been electrocuted outright may in fact have been electrocuted during the struggle to free their talons from entanglement. Possible solutions include: 1) tightly rewinding the wire which holds the conductor to the insulator, or 2) covering the wire wrapping with a split plastic tube.

Haas, D. 1980. Endangerment of our large birds by electrocution--a documentation. In: *Ökologie der Vögel [Ecology of Birds]*. Vol. 2. Deutscher Bund für Vogelschutz, Stuttgart. pp. 7-57.

Mentions that 14 diurnal raptor species (530 individuals) and 5 nocturnal species (62 individuals) were found beneath power lines in the Federal



Republic of Germany during this study, all apparent victims of electrocution. Electrocution of Eagle Owls is so serious a problem that the population is acutely jeopardized. The danger arising from different pylon types is discussed and remedial measures are suggested.

\*Hallinan, T. 1922. Bird interference on high tension electric transmission lines. Auk 39: 573.

Describes how Turkey Vultures are electrocuted on a three-phase 13,000-volt line while sitting on metal crossarms.

\*Hannum, G., W. Anderson, and M. [W.] Nelson. 1974. Powerlines and birds of prey. Report presented to Northwest Electric Light and Power Association, Yakima, Washington, April 22, 1974. 23 pp.

A brief introduction discusses a directive given to Idaho Power Company employees and consultant Morlan W. Nelson concerning the company's effort to study several aspects of the eagle electrocution issue. This is followed by a nearly verbatim version of Nelson and Nelson (1976, 1977) which was presented at the 1975 World Conference on Birds of Prey in Vienna, Austria.

\*Hardy, N. 1970. Fatal dinner. Thunder Bay Field Natur. Club Newslett. 24(1): 11.

A Great Horned Owl perched on a utility pole insulator with a prey item. In trying to obtain better footing, the owl touched a 4160-volt conductor and was electrocuted. (Citation and summary from Wildl. Rev. 138: 73.)

Heijnis, R. 1980. Bird mortality from collision with conductors for maximum tension. In: Ökologie der Vögel [Ecology of Birds]. Vol. 2. Deutscher Bund für Vogelschutz, Stuttgart. pp. 111-129.

Three of 73 bird species found under a 150-kV power line in the Westzijderveld and de Reef Nature Reserves, Polder Westzaan, Holland, were raptors. In all cases the cause of mortality was by collision with conductors. Raptor silhouettes made of red or silver-gray colored plastic proved more successful in reducing the number of non-raptor wire strikes than were strips or plastic spirals placed on the conductors.

\*Henny, C.J., D.J. Dunaway, R.D. Mallette, and J.R. Koplin. 1978. Osprey distribution, abundance, and status in western North America: I. The northern California population. Northwest Sci. 52(3): 261-271.

Mentions that an estimated 2 percent of all Osprey nests in northern California in 1975 were on power transmission poles or towers, and that 5 percent were on man-made Osprey nesting platforms.

\*Herren, H. 1969. Status of the Peregrine Falcon in Switzerland. In: Peregrine Falcon populations: their biology and decline. J.J. Hickey (ed.). University of Wisconsin Press, Madison. pp. 231-238.

Of interest here is the following parenthetical comment: "Wires of various sorts are the main cause of eagle owl [Bubo bubo] fatalities and have resulted in extirpations of these owls in the greater part of their former range in Switzerland." Also mentions that between 1952 and 1965 five Peregrine Falcons were killed or wounded in collisions with wires.

\*Hjortsberg, W. 1979. Morlan Nelson among the raptors. Rocky Mountain Mag. May, 1979. pp. 58-67.

A semi-popular, personal account of the accomplishments of Morlan W. Nelson in preventing raptor/power line problems, assisting in the establishment of the Snake River Birds of Prey Natural Area, and in theorizing about the decline of the Peregrine Falcon in the western states.

\*Howard, R.P. 1975. Breeding ecology of the Ferruginous Hawk in northern Utah and southern Idaho. Master's Thesis. Utah State University, Logan. 59 pp.

This excellent life history of the Ferruginous Hawk deals with population dynamics, food habits, growth, mortality factors, and habitat preferences. One nest out of 97 was on the crossarm of a utility pole.

\*Howard, R.P. 1980. Artificial nest structures and grassland raptors. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 117-123.

Discusses the use of artificial nest structures by Ferruginous Hawks in the Snake River Birds of Prey National Conservation Area, Idaho. Of special interest is the listing of five factors which should be evaluated before a nest platform program is implemented, including a recommendation that the introduction of nest structures should not displace or affect resident threatened and endangered species.

Howard, R.R., and J.F. Gore (eds.). 1980. Proceedings of a workshop on raptors and energy developments. Idaho Chapter, The Wildlife Society, Boise, Idaho. 125 pp.

Eleven papers are included, primarily concerning the relationship between raptors and the electric power industry. According to the editors, this publication represents "a compendium of information on raptors and energy developments. It is not a definitive statement on the subject since many studies are not yet completed. Rather this symposium serves as a mid-stream review of where we are and what directions we want to explore."

See Peacock 1980, Nelson 1980a, Fitzner 1980, Benson 1980, Lee 1980, Ansell and Smith 1980, Kochert 1980, Meyer 1980, Van Daele 1980, Bridges 1980, and Howard 1980.

\*Howard, R.P., and M. Hilliard. 1980. Artificial nest structures and grassland raptors. Raptor Res. 14: 41-45.

A nearly verbatim republication of Howard (1980).

\*Hutchinson, E. 1973. "...where eagles dare to perch." Lines. March, 1973. pp. 9-11. (Public Service Company of Colorado.)

A popular article concerning the electrocution problem and the way in which private and government cooperators united to solve the problem. Morlan W. Nelson's work with a trained eagle and mockup power poles is described, and the corrective measures developed for reducing electrocutions are discussed. See Nelson and Nelson (1976, 1977) and Nelson (1978) for details.

\*Illinois Power Company. 1972. IP helps maintain Sparrow Hawks. Hi-Lines November, 1972. p. 14.

When three young American Kestrels were discovered in a nest in a partially damaged power line crossarm in July, 1971, near Belleville, Illinois, the Illinois Power Company let the young birds fledge before repairs were made. A nestbox was then placed on the crossarm and was occupied by American Kestrels the following year.

\*Investment Dealers' Digest. 1950. One for Ripley. June 5, 1950.

Brief note about Ospreys nesting on power poles and shorting out electric distribution facilities in New Jersey. Dummy poles were erected adjacent to the power poles as alternate nest sites for the birds. In some cases the birds switched their nests to the dummy poles.

Jarvis, M.J.F. 1974. High tension power lines as a hazard to large birds. Ostrich 45: 262.

Author notes that at least 30 Cape Vultures were killed in 10 years on 1 km (0.6 mile) of power lines near Seymour, Cape Province, South Africa. Ledger and Annegarn (1981) reevaluated this incident and report the true figures to be three vultures actually known to have been killed on 8 km (5 miles) of 11-kV lines.

\*Joseph, R.A. In Prep. Eagle electrocutions in Utah and Colorado. U.S. Fish and Wildlife Service, Salt Lake City, Utah.

See U.S. Fish and Wildlife Service 1980a, 1980b, and 1980c for much of the raw data which will be included in this paper.

Kingery, H.E. 1971. The spring migration: Great Basin-Central Rocky Mountain region. *Amer. Birds* 25: 774-780.

In Wyoming and Colorado over 78 Bald and Golden Eagles were electrocuted by power lines in spring, 1971.

\*Kochert, M.N. 1972. Population status and chemical contamination in Golden Eagles in southwestern Idaho. Master's Thesis. University of Idaho, Moscow. 102 pp.

Mentions the electrocution of 9 immature Golden Eagles in 1970 and 1971 by power lines in southern Idaho.

\*Kochert, M.N. 1980. Golden Eagle reproduction and population changes in relation to jackrabbit cycles: implications to eagle electrocutions. In: *Proceedings of a workshop on raptors and energy developments*. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 71-86.

Golden Eagle reproductive performance and relative black-tailed jackrabbit densities were assessed in the Snake River Birds of Prey Area from 1970-1978. Mid-winter Golden Eagle densities were related to jackrabbit densities. The incidence of eagle electrocutions was correlated with the mid-winter eagle density. A possible relationship among Golden Eagle winter density and reproductive performance, the incidence of Golden Eagle electrocutions, and jackrabbit density is established. The incidence of Golden Eagle electrocutions may be cyclic with jackrabbit fluctuations.

\*Kroodsma, R.L. 1978. Evaluation of a proposed transmission line's impacts on waterfowl and eagles. In: *Impacts of transmission lines on birds in flight*. M.L. Avery (ed.). U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. pp. 69-76.

Argues that the potential for Bald Eagle collisions with electric transmission lines is minimal because of the eagle's keen eyesight, relatively slow flight, and maneuverability, although the potential increases with poor visibility (due to fog, or at dusk) and during pursuit of prey when the birds may be distracted.

Lafferty, M.B. 1981. Biologists optimistic: eagle population higher. Newspaper article. *The Courier*, Findlay, Ohio. June 4, 1981.

Mentions that six Bald Eagles have flown into power lines in Ohio over the last ten years.

\*Laycock, G. 1973. Saving western eagles from traps and zaps: bobcat baits and poles take heavy tolls. Audubon 75(5): 133.

Briefly reviews the electrocution problem and its solutions. Mentions that utility poles in areas where eagle electrocution is frequent can be made safe at a cost of \$135 each. Solutions include wider spacing of wires, providing safe perches, or designing poles to discourage eagles from landing on them.

\*Ledger, J.A., and H.J. Annegarn. 1981. Electrocution hazards to the Cape Vulture Gyps coprotheres in South Africa. Biol. Conserv. 20: 15-24.

"Electrocution of Cape Vultures in South Africa is reviewed. Data from the ranching areas of the western Transvaal is presented, with details of more than 300 birds known to have been electrocuted between 1970 and 1977. Most birds were electrocuted on 88 kV suspension towers. Surveys with a light aircraft revealed that towers carrying voltages of 132, 275, and 400 kV provided safe perches for vultures, and were regularly used by numbers of birds for roosting in the flat treeless survey area." (Authors' abstract.)

\*Lee, J.M., Jr. 1977. Transmission lines and their effects on wildlife: a status report of research on the BPA system. Paper presented at the annual meeting of the Oregon Chapter of the Wildlife Society, January 19-21, 1977. 25 pp.

Included is a discussion of Bonneville Power Administration's efforts to reduce the negative effects of transmission lines on raptors (and, vice-versa, to reduce the negative effects of raptors on transmission lines). Also discusses the ways in which transmission lines enhance the suitability of an area for raptors. Chief negative effects of transmission lines on raptors are collisions with conductors, electrocution, and shooting. The chief negative effect of raptors on transmission lines is the interruption of service due to "flashouts" -- power failures caused by nest material or excrement contacting conductors. Transmission lines often provide substrates for nesting where other substrates are nonexistent.

\*Lee, J.M., Jr. 1978a. Effects of transmission lines on bird flights: studies of Bonneville Power Administration lines. In: Impacts of transmission lines on birds in flight. M.L. Avery (ed.). U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. pp. 53-68.

Primarily a discussion of waterfowl collisions with power lines. Mentions non-disabling collisions of a Turkey Vulture and a Golden Eagle with transmission lines.

\*Lee, J.M., Jr. 1978b. A status report on the BPA Biological Studies Program. Bonneville Power Administration, Portland, Oregon. 9 pp.

Of interest here is a review of several ongoing studies by the Bonneville Power Administration to determine the long-term effects of transmission lines on raptors. The effects of audible noise and electric and magnetic fields, and the extent of utilization of BPA lines by raptors are under investigation.

\*Lee, J.M., Jr. 1980. Raptors and the BPA transmission system. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 41-55.

Bonneville Power Administration maintenance policy regarding birds and power lines is discussed. In 1977 a BPA transmission maintenance standard on bird nests was adopted, directing that nests on transmission structures over insulators be moved to another location on the structure rather than being removed or destroyed. Also included are: 1) a discussion of nest surveys conducted by BPA along its power line corridors; 2) a discussion of the raptor nest platforms installed on some BPA lines; and 3) a discussion of the effects of electric and magnetic fields on raptors using power lines for perching and nesting.

\*Lee, J.M., Jr., T.C. Bracken, and L.E. Rogers. 1979. Electric and magnetic fields as considerations in environmental studies of transmission lines. In: Biological effects of extremely low frequency electromagnetic fields. R.D. Phillips et al. (eds.). CONF-78106. National Technical Information Service, Springfield, Virginia. pp. 55-73.

Includes an excellent review of the effects of electric and magnetic fields on birds. Although birds show an avoidance for perching on energized transmission conductors, they regularly nest and produce young in transmission towers with no apparent ill effects. Based on several recent studies, it also appears unlikely that transmission line fields interfere with egg hatchability, chick growth and development, or navigation and orientation.

\*Lee, J.M., Jr., and D.B. Griffith. 1978. Transmission line audible noise and wildlife. Paper presented at the Ninth International Congress on Acoustics, Madrid, Spain, July 3-9, 1977.

Includes a brief discussion of the effects of audible noise from transmission lines on raptors. Mentions a case where an American Kestrel attempted to land on one of the energized conductors of a prototype 1100/1120 kV line. The bird approached the conductor, but after a few attempts at landing it flew off. Later it landed on an energized conductor. The possible long-term effects of audible noise on raptors has yet to be determined.

\*MacCarter, D.L., and D.S. MacCarter. 1979. Ten-year nesting status of Osprey at Flathead Lake, Montana. Murrelet 60: 42-49.

An 80 percent increase in this population since 1967 is documented. Ospreys nested on Canada Goose nestboxes (number unspecified), and five nestings occurred on power and utility poles. Most nests were in snags or in the tops of live Douglas-fir.

Males, R. 1980. Effects of power lines and poles on birds. EPRI J. March, 1980. pp. 49-50. (Electric Power Research Institute.)

Two Electric Power Research Institute projects are seeking answers to questions regarding the impact of power lines and poles on birds. The first study is aimed at identifying criteria for classifying those power poles which present a high risk of electrocution to raptors (see Benson 1981). The second study has as its purposes the development of methodologies for studying bird behavior in relation to transmission lines and assessment of collision mortalities.

\*Marion, W.R., and R.A. Ryder. 1975. Perch-site preferences of four diurnal raptors in northeastern Colorado. Condor 77: 350-352.

Six kinds of above-ground perch sites were used by large diurnal raptors wintering on the shortgrass prairie in northeastern Colorado. Golden Eagles, the most abundant raptor observed, perched on a wide variety of sites, but apparently preferred haystacks and trees. Haystacks may attract eagles because of the abundance of rabbits nearby. None of the other raptors observed during this study were perched on haystacks. Although use of fenceposts was common, Rough-legged Hawks preferred trees and U.S. Rural Electrification Administration poles as perch sites. Ferruginous Hawks perched on fenceposts in proportion to the availability of these perch sites.

\*Markus, M.B. 1972. Mortality of vultures caused by electrocution. Nature 238: 228.

One hundred forty-eight carcasses of the Cape Vulture (Gyps coprotheres) were found in one area of the Transvaal Province of South Africa over a period of 14 months. Cause of death: electrocution. Ledger and Annegarn (1981) report that the actual time period was 27 months.

\*Marshall, W. 1940. "Eagle guard" developed in Idaho. Condor 42: 166.

Describes the construction and placement of "eagle guards" which prevent birds from alighting on the crossarms of power poles. Braces are made of two pieces of one-half by two-inch (1.3 by 5.1-cm) boards cut to a standard size and nailed together at the peak. The installation is done without interrupting service. Approximately 3,000 of these guards were placed on the 20,000-volt line running from near Hagerman to Boise, Idaho, a distance of about 100 miles (161 km). Outages decreased significantly.

Maser, C.J., J.W. Thomas, I.D. Luman, and R. Anderson. 1979. Wildlife habitats in managed rangelands -- the Great Basin of southeastern Oregon. Manmade habitats. U.S. Forest Service, LaGrande, Oregon. 40 pp.

Includes a brief outline of the use of power lines, poles, and towers by birds (including raptors) and possible techniques for the management of rights-of-way to minimize impacts on wildlife.

\*Maslowski, K., and S. Maslowski. 1974. Power firm acts to save birds from electrocution. Newspaper article. Cincinnati Enquirer. October 13, 1974.

Lauds the Idaho Power Company for its efforts to learn about and minimize raptor electrocutions on power lines.

\*McGahan, J. 1965. Ecology of the Golden Eagle. Master's Thesis. University of Montana, Missoula. 78 pp.

Golden Eagle population data.

\*Meents, J.K., and M.C. Delesantro. 1979. Use of a 345 kV transmission line by raptors. Unpubl. rep. Public Service Company of New Mexico, Albuquerque. 13 pp.

A 15-mile section of the El Paso Electric 345-kV transmission line in Dona Ana County, New Mexico, is examined in terms of its use by raptors. Included are discussions of the intensity of use by various species, activities of raptors while on the line, portion of structures used, and relationships to habitat. Special emphasis is placed on breeding of Swainson's Hawks in the summer of 1978.

\*Melquist, W.E. 1974. Nesting success and chemical contamination in northern Idaho and northeastern Washington Ospreys. Master's Thesis. University of Idaho, Moscow. 105 pp.

Twenty-three (4%) of 556 Osprey nests were on utility poles in 1972 and 1973 in northern Idaho and northeastern Washington. Nests on utility poles were less successful than most other types of nests.

\*Melquist, W.E., and D.R. Johnson. 1975. Osprey population status in northern Idaho and northeastern Washington -- 1972. In: Population status of raptors. J.R. Murphy, C.M. White, and B.E. Harrell (eds.). Raptor Res. Rep. No. 3. pp. 121-123.

Eleven (4%) of 267 Osprey nesting locations in northern Idaho and northeastern Washington in 1972 were on utility poles.



\*Meyer, J.R. 1979. Northwest Montana/North Idaho transmission corridor Bald Eagle study. Bonneville Power Administration, Portland, Oregon. 90 pp.

Habitat use by Bald Eagles was studied along a proposed transmission line corridor between Libby, Montana, and Rathdrum, Idaho. Formal Endangered Species Act section 7 consultation was conducted on the project. Findings include: the distance between perch trees and the nearest road appears to be more a reflection of road distance from the river, not eagle preference to perch away from roads; Bald Eagles were seen perched on an electric transmission line only once out of 399 observations; and Bald Eagles will gain altitude to fly over a transmission line rather than pass under it. The major potential impacts of transmission line construction and operation on Bald Eagles include habitat loss, human disturbance, electrocution, and collision mortality. Habitat loss can be minimized by rerouting the line or by leaving the maximum number of possible perch trees. Human disturbance can be minimized by constructing the line between April and September when wintering Bald Eagles are not present.

\*Meyer, J.R. 1980. Study of wintering Bald Eagles to assess potential impacts from a proposed 230 kV transmission line. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 87-103.

"A biological study of the northern Bald Eagle was conducted from November 1978 through April 1979 to assess the potential impacts from Bonneville Power Administration's proposed 230-kV transmission line project in northwestern Montana and northern Idaho. Bald Eagle use of wintering habitat was investigated on the Pend Oreille and Kootenai Rivers. The overall impact of the proposed project was considered to be minor and not likely to jeopardize the continued existence of the Bald Eagle." (Author's abstract.)

\*Michener, H. 1928. Where engineer and ornithologist meet: transmission line troubles caused by birds. Condor 30: 169-175.

An early review of the problems associated with raptor/power line interactions. Included is a discussion of the various causes of flashovers and related power outages. Streams of excrement from roosting or nesting raptors were most often blamed for the flashovers. Efforts to reduce flashovers concentrated mostly on measures to prevent the birds from nesting or roosting above insulators. Such measures included the attachment of heavy wires and inverted "V" grills on some tower members where the birds perched, the installation of galvanized iron pans on the crossarms above center insulators, and the installation of saw-toothed guards on horizontal tower members near insulators.

\*Miller, D., E.L. Boeker, R.S. Thorsell, and R.R. Olendorff. 1975.  
Suggested practices for raptor protection on powerlines. Raptor  
Research Foundation, Provo, Utah. 21 pp.

Describes a number of power pole designs to minimize the electrocution of  
raptors. Illustrations of the suggested modifications are included. This  
report defined the state-of-the-art of resolving the electrocution problem  
as of June, 1975, and served as the starting point for the current paper.

\*Mulhern, B.M., W.L. Reichel, L.N. Locke, T.G. Lamont, A.A. Belisle,  
E. Cromartie, G.E. Bagley, and R.M. Prouty. 1970. Organochlorine  
residues and autopsy data from Bald Eagles 1966-68. Pestic. Monit. J.  
4(3): 141-144.

Bald Eagle mortality data.

Murphy, J.R. 1977. Status of eagle populations in the western United  
States. In: World conference on birds of prey, report of proceed-  
ings. R.D. Chancellor (ed.). International Council for Bird Preser-  
vation. pp. 57-63.

Mentions electrocution as one of the more overt types of human impact on  
Golden Eagles which has received priority in research and management  
efforts, and contends that more emphasis needs to be given to some of the  
subtler kinds of impacts, such as habitat loss and the decline of prey  
populations in some areas.

Murphy, J.R. 1978. Management considerations for some western hawks.  
Transactions of the 43rd North American Wildlife and Natural Resources  
Conference. pp. 241-251.

A summary of threats to and management recommendations for nine species of  
North American hawks and eagles. The dangers of governmental interagency  
rivalry and the importance of conservation organization involvement are  
discussed. Included is a brief summary of efforts to reduce electrocu-  
tions of Golden Eagles.

\*Nelson, M.W. 1974. Eagle nest structure. Personal letter to Mr. Dave  
Luman (Bureau of Land Management, Portland, Oregon) dated December 20,  
1974. 3 pp.

Gives specific directions for placement of artificial nest platforms on  
steel transmission towers.

\*Nelson, M.[W.] 1975. Powerlines and birds of prey. Aware Mag. 51: 9-12.

Paper not seen.

\*Nelson, M.[W.] 1976. Constructing electric distribution lines for raptor protection. In: Proceedings of the American power conference, Chicago, Illinois, April 20-22, 1976. R.E. Armington (ed.). Illinois Institute of Technology, Chicago, Illinois.

Paper not seen.

Nelson, M.W. 1977. Preventing electrocution deaths and the use of nesting platforms on power poles. Hawk Trust Annual Rep. 8: 30-33.

Paper not seen.

\*Nelson, M.W. 1978. Preventing electrocution deaths and the use of nesting platforms on power lines. In: Bird of prey management techniques. T.A. Geer (ed.). British Falconers' Club. pp. 42-46.

A brief summary of the causes of raptor electrocutions on power lines and the preventative measures adopted by the Idaho Power Company and the Bonneville Power Administration to reduce electrocutions. Also discussed is the use of nesting platforms to reduce problems associated with raptors nesting on power lines, i.e., the problem of power outages caused by nest material contacting conductors and the problem of nests blowing out in high winds. The platform design used included a large wind and shade screen which proved to be important to raptors which used the platforms, especially to Red-tailed Hawks and Golden Eagles which took maximum advantage of the screens by placing nest cups such that eggs or young would remain shaded during the hottest times of the day.

\*Nelson, M.[W.] 1979a. Impact of Pacific Power and Light Company's 500 kV line construction on raptors. Unpubl. rep. Pacific Power and Light Company, Portland, Oregon. 14 pp.

Discusses the natural stresses on raptors and the impacts expected from construction of a power transmission line from Twin Falls, Idaho, to Medford, Oregon. Interesting comments include the following: 1) birds can better tolerate problems associated with construction projects if work is done during normal work hours (7:00 a.m. to 6:00 p.m.) during the summer when the daylight period is much longer; 2) work on top of a cliff or well back from the edge poses little threat to raptors nesting on the cliff (there are conflicting reports elsewhere); and 3) it may be possible to induce birds to take up an alternate site during a particular year by preceding the courtship period with a certain amount of human activity. The paper ends with a discussion of the virtues of placing artificial platforms on transmission towers and recommendations for placement along the line in question.

\*Nelson, M.W. 1979b. Power lines progress report on eagle protection research. Unpubl. rep. Boise, Idaho. 13 pp.

The natural capacity of eagles to avoid electrocution under various voltages, contact types, and climatic conditions was determined. Dry feathers were found to be almost as good an insulator as air. The electrocution hazard to a wet eagle is roughly ten times greater than under dry conditions. Even when wet, eagles generally are not in danger when lines carry less than 5,000 volts. Perch guards were shown to be the most economical method of discouraging eagles from landing in dangerous situations.

\*Nelson, M.[W.] 1980a. Historic overview of raptor-powerline problems and raptor management priorities. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 6-8.

Historic overview of government and industry cooperation and public interest in solving the eagle electrocution problem is presented. The author stresses that the future of both species of eagle in the United States at this time seems secure, and argues that raptor management priorities should now shift toward a greater effort on behalf of the endangered Peregrine Falcon and other raptors.

\*Nelson, M.W. 1980b. Location of nesting platforms on power lines. Unpubl. rep. Boise, Idaho. 4 pp.

Factors affecting the placement of raptor nesting platforms on the towers of high voltage power lines are discussed. Power lines appropriate for platform placement are located in high prey base areas and near escarpments, ridges, etc., which face prevailing winds. The platforms should be placed on the north side of the towers with the sun shade facing south to maximize available shade during the hottest times of the day. Platforms should be placed below the conductors, where practicable.

\*Nelson, M.W. 1980c. Update on eagle protection practices. Unpubl. rep. Boise, Idaho. 14 pp.

Summarizes new research on eagle feather conductivity and the use of wooden or metal perch guards to discourage eagles from landing in dangerous places on power poles. A dry feather is almost as good an insulator as air. Wet feathers, however, will conduct dangerous current starting at 5,000 volts. The threat of numerous 480-volt power lines in Wyoming is dismissed as insignificant because of the insulating effects of feathers, even when wet. Perch guards, regardless of design, proved to be an effective and inexpensive deterrent to eagle perching.

\*Nelson, M.W. [1980d.] Utah Power and Light Company -- six hazardous structures to eagles. Unpubl. rep. Tundra Films, Boise, Idaho. 10 pp.

Results of research done with six different configurations of mockup poles and lines. Discusses the safety of each design and recommends modifications for those which were not safe for eagles. Excellent design drawings of each structure are included.

\*Nelson, M.W., and P. Nelson. 1976. Power lines and birds of prey. Idaho Wildl. Rev. 28(5): 3-7.

The Nelsons summarize their work on the eagle electrocution problem beginning in 1972 when the issue was first confronted by private organizations, government, and industry. A chronological account is presented in which the causes of electrocution, the extent of the problem, and the corrective measures implemented are discussed. An estimated 95 percent of all electrocutions could be prevented by correcting only 2 percent of existing power poles, those which are habitually selected by Golden Eagles over all others as hunting perches.

\*Nelson, M.W., and P. Nelson. 1977. Power lines and birds of prey. In: World conference on birds of prey, report of proceedings. R.D. Chancellor (ed.). International Council for Bird Preservation. pp. 228-242.

A nearly verbatim republication of Nelson and Nelson (1976).

Nesbitt, S.A., and D.T. Gilbert. 1976. Powerlines and fences -- hazards to birds. Florida Natur. 49(2): 23.

Mentions in passing that raptors seem to be especially vulnerable to collision with power lines, but primarily concerns a Sandhill Crane which was killed by such a collision.

\*Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota. 399 pp.

Citing Nelson and Nelson (1977), Cade and Dague (1977), Markus (1972), Belisle et al. (1972), Cromartie et al. (1975), Mulhern et al. (1970), and others, Newton presents a brief account of the extent of the electrocution problem and the measures taken to reduce raptor electrocutions.

\*New York Times. 1951. Ospreys flourish on Long Island after quitting nests in Scotland. Newspaper article. August 16, 1951.

Repeated short circuits caused by Ospreys building nests on power poles forced Long Island and New York electric companies to put up special poles nearby to accommodate the birds. A company official estimated that the eastern Long Island Osprey population increased four-fold during the 15 years after the lines were built. The number of such dummy nesting poles certainly exceeded 50 and may have been nearer 100 during the early 1950s.

\*New York Times. 1972. Hundreds of eagles are killed in west by electric lines. Newspaper article. October 11, 1972.

A brief review of the eagle electrocution problem which includes comments on the number of losses reported, the reasons raptors utilize power poles, and the initial measures taken to reduce the problem.

\*New York Times. 1976. Curb of danger to eagles noted. Newspaper article. September 5, 1976.

An optimistic review of the eagle electrocution problem which cites a decrease in the number of eagles electrocuted each year in western states. This decrease is attributed to action by government and industry which resulted in appropriate modifications of existing power lines.

\*North Dakota Outdoors. 1976. Ferruginous Hawk. 39(2): Inside Front Cover.

Includes a photograph of a nest on an electric transmission tower. Also mentions Ferruginous Hawks nesting on telephone poles.

\*Northwest Electric Light and Power Association News. 1977. Idaho Power helps save the eagles. Volume and issue number unknown. pp. 2-3.

A popular article briefly summarizing Morlan W. Nelson's work on the eagle electrocution problem. Of special interest is a discussion of nesting platforms installed for Golden Eagles by the Idaho Power Company on some of its towers, according to Nelson's specifications.

\*Olendorff, R.R. 1972a. Eagles, sheep and power lines. Colo. Outdoors 21(1): 3-11.

Briefly describes the natural history of Golden Eagles as it relates to depredation on sheep and to electrocution. Methods for the prevention of eagle electrocution via power pole modification are discussed.

Olendorff, R.R. [1972b.] Ecological impact of the electric industry in northern Colorado -- a research proposal. Unpubl. proposal. The American Museum of Natural History, New York, New York. 8 pp.

Summarizes research efforts which would assess the biological assets and liabilities of the electric industry. Recommends that such research be conducted by independent researchers, but as a cooperative effort between conservation groups, government, and industry, thereby promoting mutual understanding and equitable solutions.

\*Olendorff, R.R. 1972c. Edison Electric Institute eagle workshop, April 6, 1972. Unpubl. rep. The American Museum of Natural History, New York, New York. 4 pp. plus appendices.

Minutes of the subject meeting which include discussions of 1) the objectives of the Edison Electric Institute and the U.S. Rural Electrification Administration, 2) the willingness of the industry to help solve the eagle electrocution problem, and 3) the U.S. Bureau of Sport Fisheries and Wildlife system for reporting eagle deaths.

\*Olendorff, R.R. 1973. Raptorial birds of the U.S.A.E.C. Hanford Reservation, south-central Washington. Battelle Pacific Northwest Laboratory Tech. Rep. No. BNWL-1790 VC-11. Richland, Washington. 45 pp.

Includes a discussion of various types of artificial nest substrates for raptors. Suggests that cliff nesting raptors, such as Prairie Falcons, might be induced, as a means of expanding their nesting range, to nest in oak barrels mounted on power poles.

\*Olendorff, R.R. 1975. Population status of large raptors in north-eastern Colorado, 1971-1972. In: Population status of raptors. J.R. Murphy, C.M. White, and B.E. Harrell (eds.). Raptor Res. Rep. No. 3. pp. 185-205.

Golden Eagle population data.

\*Olendorff, R.R., and M.N. Kochert. 1977. Land management for the conservation of birds of prey. In: World conference on birds of prey, report of proceedings. R.D. Chancellor (ed.). International Council for Bird Preservation. pp. 294-307.

Included in this summary of the U.S. Bureau of Land Management's involvement in raptor management and protection is a discussion of the Bureau's efforts to implement "Suggested Practices for Raptor Protection on Powerlines" (Miller et al. (1975).

\*Olendorff, R.R., R.S. Motroni, and M.W. Call. 1980. U.S. Bureau of Land Management Tech. Rep. No. T/N-345. Denver, Colorado. 56 pp.

An extensive review paper summarizing all aspects of raptor management. Of interest here are 1) a brief discussion of the electrocution issue, 2) a discussion of hacking and cross-fostering as a means of augmenting raptor populations (cited in the present paper in reference to range extension by cross-fostering on or hacking from transmission towers), and 3) a complete summary of the use of all types of artificial nest structures and/or artificial nests (see Table 3 in the present paper).

\*Olendorff, R.R., and J.W. Stoddart, Jr. 1974. Potential for management of raptor populations in western grasslands. In: Management of raptors. F.N. Hamerstrom, Jr., B.E. Harrell, and R.R. Olendorff (eds.). Raptor Res. Rep. No. 2. pp. 47-88.

A wide-ranging discussion of the potential benefits of and techniques to be used for managing grassland raptor populations. Mentions that Swainson's Hawks, Red-tailed Hawks, and Ferruginous Hawks are known to nest on utility towers and poles, and that oak barrels mounted on power poles might induce Prairie Falcons to nest where cliff cavities are limiting. Also includes a five-point discussion of factors which should be evaluated prior to implementation of an acceptable raptor nesting structure project.

\*Olsen, J., and P. Olsen. 1980. Alleviating the impact of human disturbance on the breeding Peregrine Falcon. II. Public and recreational lands. Corella 4: 54-57.

Citing Bijleveld (1974), Herren (1969), and Brown (1976), the Olsen's mention the problem of raptors (particularly falcons) striking overhead wires. Also mentioned is the fact that no work on the electrocution problem similar to that done in the United States has been done in Australia.

Olsen, V. 1958. Dispersal, migration, longevity, and death causes of Strix aluco, Buteo buteo, Ardea cinerea, Larus argentatus. Acta Vertebr. 1(2): 91-189.

Recoveries of birds ringed in Sweden, Norway, and Finland showed that "found dead under powerline" was the cause of death given for 30 of 371 Tawny Owls and 11 of 473 Common Buzzards. In the latter species, "shot" was the most common cause of death.

\*Oregon Wildlife. 1976. Osprey nest "unwired". 31(4): Page number unknown.

A new crossarm was placed under an existing nest on an electric power pole. The lines were moved to the new crossarm leaving the nest intact.

\*Page, J.L., and D.J. Seibert. 1973. Inventory of Golden Eagle nests in Elko County, Nevada. Cal-Neva Wildlife 1973. Transactions of the Western Section of the Wildlife Society, February, 1973. pp. 1-8.

Golden Eagle population data.

\*Peacock, E. 1980. Powerline electrocution of raptors. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 2-5.



Summarizes the involvement of the U.S. Fish and Wildlife Service's Division of Wildlife Services in the raptor electrocution problem. In 1972 the Division was assigned the responsibilities of identifying problem areas and alleviating the problems through cooperation with the power industry.

\*Pearson, D.C. 1979. Raptor protection study, Lanfair Valley - report of findings and recommendations. Company memorandum to files. Southern California Edison Company, Rosemead, California. 7 pp.

Southern California Edison Company conducted a study on a distribution line in southern California to determine which of the 296 poles in the line needed modification to prevent raptor electrocutions. Of the 296 poles, 252 (85%) showed some evidence of raptor utilization, but only 42 (14%) showed evidence of significant use. The higher intensity of utilization of these poles was shown to be correlated with greater habitat diversity of these sites, with a corresponding increase in the diversity and density of prey. Two groups of poles were shown to receive especially heavy use, though within each group individual poles were utilized inconsistently. Thus, it was concluded that identifying groups of poles, as opposed to individual poles, is a more efficient means for effecting modifications.

\*Pendleton, E. 1978. To save raptors from electrocution. Defenders 53(1): 18-21.

Included in this popular article is a wide-ranging discussion of the problems associated with raptors on power lines. From across the country numerous examples are cited of raptors nesting on power poles and causing fires and power outages. The persistence of certain raptors, such as Ospreys, in rebuilding their destroyed nests in the same location and the measures undertaken by the utility companies to reduce repeated outages are discussed. Morlan W. Nelson's work in reducing electrocution of Golden Eagles in Idaho is also mentioned.

\*Pinkowski, B.C. 1977. Powerline and Bald Eagle interactions in the upper Mississippi River Valley. Report for the Northern States Power Company by Ecological Science Division, NUS Corporation, Pittsburgh, Pennsylvania. 20 pp.

Though collisions with and electrocution by power lines are recognized sources of Bald Eagle mortality, there was no evidence that power lines pose a hazard to Bald Eagles in the Mississippi River Valley.

\*Platt, J.B. 1976. Bald Eagles wintering in a Utah Desert. Amer. Birds 30: 783-788.

Mentions a situation where 24 Bald Eagles were observed perched on 35 power poles along a 56.8-mile (91.4 km) survey transect through Cedar

Valley and Rush Valley near Cedar Fort and Faust, Utah. No reason for the concentration was determined, however. Also mentions that eagles are commonly observed perched on telephone poles while feeding.

Potter, J.K., and J.J. Murray. 1949. Fall migration: middle Atlantic coast region. Audubon Field Notes 3(1): 8-10.

Two Barn Owls were among the casualties in collisions with telegraph wires and radio towers at Cape May, New Jersey, in September and October, 1949.

\*Public Service Company of Colorado. 1973. Eagles and us. Newspaper advertisement. Denver Post, January 28, 1973. Denver, Colorado. p. 7.

An effective advertisement which calls upon the public to join industry efforts to reduce eagle mortalities on power lines by preventing or reporting irresponsible shooting.

\*Public Service Electric and Gas Company News. 1977. Ospreys nestle up to power towers. 56(10): 1, 4-5, Nov. 15, 1977. Newark, New Jersey.

Discusses the inhabitation of Artificial Island, a man-made strip of land three miles long and a mile wide on the Delaware River, by seven pairs of Ospreys which nest on 500-kV transmission towers.

\*Raptor Research Foundation. 1975. Resolution No. 2 [pertaining to cooperation between the power industry, conservation organizations, and Federal agencies in reducing raptor electrocutions on power lines]. Provo, Utah. 1 p.

A resolution adopted by the Raptor Research Foundation at its 1975 annual meeting in Boise, Idaho, commending the electric utility industry for its cooperation with government and conservation groups in reducing the problem of raptor electrocution on power lines.

\*Reynolds, H.V., III. 1969. Population status of the Golden Eagle in south-central Montana. Master's Thesis. University of Montana, Missoula. 61 pp.

Golden Eagle population data.

\*Rhode Island Division of Fish and Wildlife. 1980. Osprey Newslett. No. 7. 3 pp.

Almost one-half of Rhode Island's Ospreys nest on power poles. To prevent electrocution and increase line reliability, the Narragansett Electric Company has constructed alternate nesting platforms and widened conductor spacing in certain areas.

\*Richardson, G.H. [1972.] Raptors and powerlines. Unpubl. rep. U.S. Forest Service, Salt Lake City, Utah. 8 pp.

Discusses electrocution problems and their solutions on National Forest lands in Utah. Mentions that approximately 45 Bald and Golden Eagles and a large number of hawks were electrocuted on a 44,000-volt transmission line in the Beaver-Milford area in the southern part of the State.

\*Rowell, C.H. 1976. Land use and environmental impacts associated with the development of high, extra high, and ultra high voltage transmission lines. Cornell Univ. Natur. Resource Res. and Ext. Ser. 6: 1-42.

Paper not seen.

\*Rue, L.L., II. 1957. High-tension redtails. Audubon Mag. 59: 178-181.

An account of Red-tailed Hawks utilizing a transmission line tower as a nest site in New Jersey.

Ryder, R.A. 1969. Diurnal raptors on the Pawnee Site. U.S. International Biological Program, Grassland Biome Tech. Rep. No. 26. Colorado State University, Fort Collins. 16 pp.

Mentions two Golden Eagles which were found dead in northeastern Colorado, apparently electrocuted by wires going to a pump.

\*Sandeem, R. 1975. Boisean's power line design may save eagles worldwide. Newspaper article. Idaho Statesman, Boise, Idaho. Sept. 9, 1975.

Briefly describes the modification of power poles to protect eagles from electrocution and the construction of Golden Eagle nesting platforms for placement on power poles. Discussion centers on Morlan W. Nelson's work.

\*Saurola, P. 1978. Artificial nest construction in Europe. In: Bird of prey management techniques. T.A. Geer (ed.). British Falconers' Club. pp. 72-80.

Briefly reviews the extent to which artificial nest structures have been constructed for and used by raptors in 11 European countries, with special emphasis on Finland. Mentions that 25-30 iron platforms were installed on "power-line poles" in the German Democratic Republic for Osprey, and "almost all of them have been annually in use."

Schmidt, E. 1973. Ecological affects of electrical lines and their poles and accessories on birds. Beitr. Vogelkd. 19(5): 342-362.

Paper not seen.

\*Schroeder, G.J., and D.R. Johnson. 1977. Productivity of northern Idaho Osprey populations. In: Transactions of the North American Osprey research conference. J.C. Ogden (ed.). National Park Service. pp. 199-203.

Ten (4.5%) of 221 Osprey nests in northern Idaho were located on utility poles in 1970 and 1971.

\*Seibert, D.J., R.J. Oakleaf, J.W. Laughlin, and J.L. Page. 1976. Nesting ecology of Golden Eagles in Elko County, Nevada. U.S. Bureau of Land Management Tech. Note No. T/N-281. Denver, Colorado. 17 pp.

Cites electrocution on transmission lines as an unquantified, but probably important mortality factor of Golden Eagles in Nevada.

Serr, E.M. 1976. The spring migration: northern Great Plains. Amer. Birds 30(4): 855-858.

Mention is made of a "wire-killed" Peregrine Falcon in Montana.

\*Simison, R.L. 1973. Some natural enemies join forces to curb electrocution of eagles. Wall Street J. 89(7): 1, 12. July 11, 1973.

An excellent example of investigative writing concerning the issues and solutions to the problems pertaining to eagle electrocutions. The theme of the paper is that industry personnel and conservationists can and should get together to solve conservation problems.

\*Smith, D.G., and J.R. Murphy. 1972. Unusual causes of raptor mortality. Raptor Res. 6: 4-5.

Brief documentation of apparent electrocutions of 52 Golden and 4 Bald Eagles in Utah.

\*Snow, C. 1973. Golden Eagle (Aquila chrysaetos). U.S. Bureau of Land Management Tech. Rep. No. T/N-239. Denver, Colo. 52 pp.

Includes a two-page review of what was known about the raptor electrocution problem in 1973. Discussion focuses on the cause of electrocution and the methods proposed by Boeker (1972) and Nelson (1973) to mitigate the problem.

\*Snyder, N.F.R., and H.A. Snyder. 1975. Raptors in range habitat. In: Proceedings of the symposium on management of forest and range habitats for non-game birds. D.R. Smith (ed.). U.S. Forest Service, Tucson, Arizona. pp. 190-209.

Citing Olendorff (1972), Boeker ([1972], 1974), Weir (1971), Glue (1971), and Herren (1969), the Snyders briefly summarize what was known of the electrocution problem in 1975.

Soars, D. 1981. Inter-agency cooperation saves raptors. *Wildlife Journal* 4(3): 1. (Wildlife Rehabilitation Council, Walnut Creek, California.)

After the February, 1981, discovery of an injured Bald Eagle and two dead Prairie Falcons under a power pole near Merced, California (apparent victims of electrocution), the Pacific Gas and Electric Company modified the pole to make it safe for perching raptors.

\*Society for the Preservation of Birds of Prey. 1976. Eagle electrocution reduced. *Raptor Rep.* 4(3): 13.

A brief review of the electric utility industry's efforts to reduce eagle electrocutions on power lines.

\*Solt, V. 1980. Raptor mortalities from powerlines studied. *Fish and Wildl. News.* August-September, 1980. pp. 2, 16.

A popular article which briefly reviews ongoing efforts by government, industry, and the private sector to reduce Golden Eagle electrocutions on power lines.

\*Stahlecker, D.W. 1975. Impacts of a 230 kV transmission line on Great Plains wildlife. Master's Thesis. Colorado State University, Fort Collins. 67 pp.

Raptor censuses were conducted along a new 230-kV transmission line in southeastern Colorado before, during, and after its construction. Construction activities may have caused abandonment of two Swainson's Hawk nests. The winter raptor population after construction was significantly greater than the pre-construction population (this may have been due to greater visibility of tower-perched birds). Twelve nestboxes and 10 artificial nest platforms were installed on towers to increase potential raptor breeding sites. All twelve nestboxes were occupied by Kestrels, but none of the nest platforms were used. This work was expanded in subsequent years (see Stahlecker (1979)).

\*Stahlecker, D.W. 1978. Effect of a new transmission line on wintering prairie raptors. *Condor* 80: 444-446.

Discusses beneficial aspects of a transmission line on the local distribution and numbers of wintering diurnal raptors. An increase in raptors utilizing the area was noted. However, it is not known if the increase in numbers was localized and a result of the construction of the line, or whether there was an influx of raptors into east-central Colorado.

\*Stahlecker, D.W. 1979. Raptor use of nest boxes and platforms on transmission towers. Wildl. Soc. Bull. 7: 59-62.

Summarizes raptor use of 25 nestboxes and 12 nest platforms on transmission towers in east-central Colorado. The boxes were installed 3-4 meters (3.3-4.4 yards) high on the transmission line poles, while the platforms were installed at 7-9 meters (7.7-9.9 yards) in height. Nestboxes increased the local breeding population of American Kestrels from a minimum of 6 pairs to at least 25 pairs in three years. No raptors utilized the nest platforms, probably because they were placed too low on the towers.

\*Steenhof, K. 1977. Management of wintering Bald Eagles. U.S. Fish and Wildlife Service, Columbia, Missouri. 59 pp.

Includes a general discussion of the causes of electrocution. Cites Coon et al. (1970) and Vian (1971) to illustrate that occasional Bald Eagle mortalities are attributable to electrocutions on and collisions with power lines.

\*Stocek, R.F. 1972. Occurrence of Osprey on electric power lines in New Brunswick. New Brunswick Natur. 3(2): 19-27.

Summarizes the occurrence of Osprey nests on electric power lines in New Brunswick over a 15-year period, 1957-1971. An estimated total of 87 pairs of Ospreys engaged in nest building on nine power lines during this period; 51 of these were on a single line near the Bay of Fundy. Most nests were destroyed by line maintenance crews, a policy adopted by the New Brunswick Electric Power Commission to avoid power outages and service interruptions caused by the nests. Many Ospreys attempted to renest after their nests were destroyed -- four, five, even six times; however, this persistence decreased as the nesting period progressed.

\*Stone, W. 1937. Birds of Old Cape May. Delaware Valley Ornithological Club, Philadelphia, Pennsylvania. 520 pp.

Includes a photograph of an Osprey nest constructed on a telegraph pole in Seagirt, New Jersey. Also documents the use of wagon wheels mounted on poles to attract nesting Ospreys.

\*Stoner, E.A. 1939. Western Red-tailed Hawk nests on high voltage tower. Condor 41: 215.

Red-tailed Hawks nested in a high voltage tower near Benicia, California, approximately 75 feet (22.9 m) from the ground.

\*St. Paul Pioneer Press. 1976. [Picture of electrocuted Snowy Owl.] March 11, 1976.

A photographer for the St. Paul Pioneer Press photographed a Snowy Owl perched on a power pole near St. Cloud, Minnesota, but returned the next day to find the same owl electrocuted.

\*Switzer, F. 1977. Saskatchewan Power's experience. Blue Jay 35: 259-260.

Summarizes briefly the extent of the electrocution problem in Saskatchewan. An average of 100 raptors are killed by electrocution on power lines each year.

\*Thelander, C.G. 1974. Nesting territory utilization by Golden Eagles (Aquila chrysaetos) in California during 1974. California Department of Fish and Game, Wildlife Management Branch Admin. Rep. No. 74-7. 19 pp.

Golden Eagle population data.

\*Thomas Reid Associates. 1980. Biological assessment for endangered species: Cottonwood-Elverta #3 transmission line rehabilitation project, Shasta, Tehama, and Butte Counties, California. Unpubl. rep. Prepared for Western Area Power Administration, Sacramento, California. 32 pp.

Assesses the potential impact of a new transmission line on Bald Eagles and Peregrine Falcons. The greatest risk of mortality was assumed to be collision with the line rather than electrocution.

\*Thompson, L.S. 1978. Transmission line wire strikes: mitigation through engineering design and habitat modification. In: Impacts of transmission lines on bird flight. M.L. Avery (ed.). U.S. Fish and Wildlife Service, Biological Services Program, Washington, D.C. pp. 27-52.

Of interest here is a table which lists the 80 species of birds representing 13 orders (including 4 species in the Order Falconiformes) which have been documented as victims of wire strikes or electrocutions in the United States.

Turek, F.J. 1960. On damage by birds to power and communication lines. Bird Study 7: 231-236.

Paper not seen.

\*Turner, J. 1971. Eagles: vanishing Americans? Sierra Club Bull. 56(9): 14-19.

Illegal shooting, poisoning, and power line electrocutions cause considerable eagle mortality in western states. Sixteen eagle deaths were attributed to power lines near Worland, Wyo. in 1971. In the Escalante Desert, Utah, forty dead eagles (10 with "white heads") were found beneath a 12-mile (19.3-km) stretch of power line. An additional 54 eagles were reported killed by power lines in Colorado's Pawnee National Grasslands and Moffat County. Eagles using utility wires and poles as perch sites are sometimes shot.

U.S. Bureau of Land Management. 1971a. Raptor losses on power lines.

Agency memorandum from the State Director, Wyoming, to the Director, Denver Service Center, dated October 20, 1971. 3 pp.

Minutes of a September 29, 1971, meeting held in Casper, Wyoming. Participants were from several power companies, the U.S. Rural Electrification Administration, and the U.S. Bureau of Land Management. Discusses: 1) the relative safety of newer single-phase lines with the neutral wire below the live wire; 2) the problems with and economics of perch construction to alleviate electrocutions; and 3) the feasibility and economics of burying new lines.

U.S. Bureau of Land Management. 1971b. Raptor mortality assessment.

Agency memorandum from the Director, Denver Service Center, to all BLM State Directors dated October 19, 1971. 7 pp.

Over 200 eagles are electrocuted annually on power line rights-of-way crossing BLM-administered lands. Eight suggestions on how to minimize raptor electrocutions are given.

U.S. Bureau of Land Management. 1974a. Information on guidelines for power line rights-of-way to benefit raptors. Agency memorandum from the State Director, New Mexico, to the Director dated August 12, 1974. 3 pp.

Includes a set of standard right-of-way stipulations for electric distribution lines in the BLM Roswell District. Pole specifications are given to minimize raptor electrocutions.

U.S. Bureau of Land Management. 1974b. Possession of dead eagles. Agency memorandum from the State Director, Oregon, to the Director, Washington, D.C., dated July 19, 1974. 2 pp.

Stresses that the U.S. Fish and Wildlife Service wishes to have all eagle carcasses brought in from the field and is willing to issue other Federal agencies blanket permits for their personnel to do so.



U.S. Bureau of Land Management. 1974c. Power line construction and modifications to prevent raptor losses through electrocution. Agency memorandum from the State Director, Oregon, to the District Managers in that State dated August 13, 1974. 3 pp.

Gives Bureau policy for minimizing raptor electrocutions on newly constructed lines as well as existing problem lines.

\*U.S. Bureau of Land Management. 1974d. Raptor loss coordination meeting. Agency memorandum from State Director, Oregon, to the Director, Washington, D.C., dated May 2, 1974. 8 pp.

Includes minutes of an April 16, 1974, meeting at Ontario, Oregon, attended by 54 agency and company personnel. Electrocution is said to be the third most important decimating factor of eagle populations behind post-fledging accidents and shooting.

\*U.S. Bureau of Land Management. 1974e. Study of the influence of power transmission lines upon birds of prey habitat. Appendix F to Greenlee County, Arizona, to El Paso, Texas, 345 kV transmission line, Final Environmental Statement. New Mexico State Office, Albuquerque. pp. 333-343.

A study of raptor use of electric transmission lines and towers based on observations made in conjunction with helicopter line patrol by the Public Service Company of New Mexico. Over 200 observations of perched raptors are analyzed according to habitat type. No nesting occurred on the transmission towers studied.

U.S. Bureau of Land Management. 1975. Powerline rights-of-way and bird electrocutions: interim guidelines. Agency memorandum from the State Director, Wyoming, to the Director, Washington, D.C., dated January 21, 1975. 2 pp.

Gives detailed stipulations for power line rights-of-way permits which will protect raptors from electrocution. These stipulations are standards oriented, rather than design oriented, because of the variety of designs that can be used without endangering raptors.

\*U.S. Bureau of Land Management. 1976a. Raptor protection on powerlines. Agency memorandum from the State Director, Colorado, to District Managers and Division Chiefs in that State dated February 10, 1976. 1 p.

Reaffirms the Bureau's commitment to using "Suggested Practices for Raptor Protection on Powerlines" (Miller et. al. 1975). Also requires specificity in stipulations placed on power line construction.

U.S. Bureau of Land Management. 1976b. "Suggested Practices for Raptor Protection on Powerlines." Agency memorandum from the Associate Director, Washington, D.C., to all BLM Field Officials dated January 23, 1976. 3 pp.

BLM policy limits new construction of power lines to those designs specified in the subject document (Miller et al. 1975). Power pole designs not so specified shall be proved "eagle safe" at industry expense and be subject to approval by the appropriate State Director in consultation with the Washington Office Staff. Also discusses the intent and applicability of laws pertinent to the eagle electrocution issue.

U.S. Bureau of Land Management. 1979a. Guidelines for prevention of raptor electrocution on powerlines. BLM Manual Section 2851, Arizona Supplement. Phoenix, Arizona. 116 pp.

Presents BLM responsibilities, policies, and procedures relating to minimizing the potential for electrocutions of raptors on power lines. Appendices include a copy of REA Bulletin 61-10, a copy of "Suggested Practices for Raptor Protection on Powerlines," and 80 pages of design specifications (drawings) for eagle-safe poles and lines.

U.S. Bureau of Land Management. 1979b. Powerline construction -- raptor protection. Agency memorandum from State Director, Colorado, to the Director, Washington, D.C., dated March 22, 1979. 2 pp.

Notes that U.S. Rural Electrification Administration personnel were still using REA Bulletin 61-10 (March 27, 1972) instead of "Suggested Practices for Raptor Protection on Powerlines" (Miller et al. 1975). Also mentions confusion arising from "Suggested Practices" concerning which set of line/crossarm measurements to be applied on a case-by-case basis.

\*U.S. Bureau of Land Management. 1979c. Transmission line impact paper. Unpubl. rep. Desert Planning Staff, Riverside, Calif. 12 pp.

Includes comments on the negative and positive impacts of power line construction and maintenance on raptors. In general, negative impacts include: initial habitat loss due to construction activities; increased accessibility on maintenance roads; potential of electrocution (on low voltage lines) and collision with conductors; and the effects of corona and audible noise. Impacts of audible noise and corona may be negligible, but more research is needed to assess their actual impact. Disturbance at existing nests due to construction activities may be a problem in some areas. The chief positive impact of transmission lines on raptors is the extension of the ranges of some species which utilize transmission towers as perching and nesting sites in areas lacking natural sites.

\*U.S. Bureau of Land Management. 1980. Snake River Birds of Prey Research Project annual report 1980. Boise, Idaho. 47 pp.

Golden Eagle population data.

\*U.S. Fish and Wildlife Service. 1972. Eagle electrocution problems. Agency memorandum from the Acting Deputy Director of the Bureau of Sport Fisheries and Wildlife to the Director of the Bureau of Land Management dated February 28, 1972. 7 pp.

Includes minutes of a January 19, 1972, working conference on eagle electrocution in Washington, D.C., involving only Federal agency personnel. The roles of the participating agencies were discussed, and corrective measures to minimize raptor electrocution were recommended by Erwin L. Boeker. The group recommended that suggested modifications and restrictions be economically and biologically feasible, that the U.S. Fish and Wildlife Service coordinate the location of killer poles and lines, and that the U.S. Rural Electrification Administration furnish land management agencies with guidelines and drawings of proposed modifications.

\*U.S. Fish and Wildlife Service. 1974. [Reno raptor electrocution workshop.] Letter from Portland Regional Office to the Bureau of Land Management Washington Office dated August 30, 1974.

Announces an October 3, 1974, eagle electrocution workshop in Reno, Nevada.

U.S. Fish and Wildlife Service. 1975a. [Collection of eagle carcasses.] Letter from the Acting Regional Director (Denver, Colorado) to the Colorado State Director of the U.S. Bureau of Land Management dated January 31, 1975. 2 pp.

Authorizes two BLM employees to receive, temporarily possess, and transport dead eagles, live injured eagles, and other raptors in an effort to get them to FWS Special Agents in Colorado.

\*U.S. Fish and Wildlife Service. 1975b. Eagle studies helping prevent electrocution of eagles in Nevada. Agency news release. Portland, Oregon. January 13, 1975. 3 pp.

Illustrates the importance of eagle inventory data during negotiations with electric companies concerning the construction of new power lines which are safe for perching eagles.

U.S. Fish and Wildlife Service. 1980a. Eagle electrocution monitoring program. Agency memorandum from Raptor Biologist and Team Leader, Endangered Species Team, to Area Manager, Salt Lake City, Utah, dated February 6, 1980. 3 pp.

Objectives of an eagle electrocution monitoring program for Utah and Colorado are stated. Methods to be used in achieving those objectives include employing temporary biological technicians to locate hazardous distribution lines, holding workshops to educate agency and company personnel, meeting with industry representatives, and educating the public through the media.

U.S. Fish and Wildlife Service. 1980b. Eagle electrocution study in Utah. Agency memorandum from Area Manager, Salt Lake City, Utah, to Regional Director, Portland, Oregon, dated December 15, 1980. 5 pp.

Data gathered by surveying under 36 distribution lines comprising an estimated 250 miles (402 km) of line resulted in the finding of 529 eagle remains. Of this number, 98 identifiable Golden Eagle carcasses were found with 61 being fresh enough that cause of death could be determined. Fifty-four of the 61 were electrocuted.

U.S. Fish and Wildlife Service. 1980c. Raptor mortality data for Utah -- July 1, 1970 to May 5, 1980. Unpubl. table. Salt Lake City, Utah. 1 p.

A one-page table that updates the data from the preceding citation to the following: 548 eagle remains; 101 identifiable Golden Eagle carcasses; 64 fresh enough to determine the cause of death; 54 (or 87.5 percent) were electrocuted.

U.S. Fish and Wildlife Service. 1981. Eagle electrocutions -- powerline surveys. Agency memorandum from the State Supervisor to the Area Manager, Boise, Idaho, dated January 16, 1981. 2 pp.

Describes excellent cooperation between FWS, various land management agencies, and power companies to minimize raptor mortalities. Gives raptor mortality data for Idaho for the period 1972-1980.

\*U.S. Rural Electrification Administration. 1972. Powerline contacts by eagles and other large birds. U.S. Department of Agriculture. REA Bulletin 61-10. March 27, 1972. 6 pp.

This bulletin was transmitted to REA borrowers on September 14, 1973, under the title: "Protection of Bald and Golden Eagles from Powerlines." This has caused some confusion as to proper referencing. REA requests that all borrowers cooperate to the fullest extent with State and Federal agencies to minimize accidental electrocution of eagles. The report discusses the causes of electrocution on distribution lines built to REA standards, and offers suggestions for modifying existing structures and for constructing new lines in areas where eagle electrocutions have occurred.

U.S. Rural Electrification Administration. 1974. Raptor electrocution.  
Letter to Bureau of Land Management dated July 5, 1974. 5 pp.

Concerns the importance of physical separation of conductors and the use of insulation and perch guards to minimize raptor electrocutions.

\*Van Daele, L.J. 1980. Osprey and power poles in Idaho. In: Proceedings of a workshop on raptors and energy developments. R.P. Howard and J.F. Gore (eds.). Idaho Chapter, The Wildlife Society, Boise, Idaho. pp. 104-112.

"Throughout their range, Ospreys frequently nest on power poles. This habit is advantageous because it provides the birds with good nest sites, increases public exposure to a large raptor, and facilitates scientific research. Disadvantages of these sites are an increased susceptibility of the Osprey to human disturbance, more chances for Osprey electrocutions, and power interruptions caused by hanging nest material. Management practices which can be used to minimize the adverse effects of power pole nests include the construction of artificial nesting platforms and/or nesting discouragement devices. All management activities should be coupled with a public education program for a better understanding of the Osprey and the managing agency's activities." (Author's abstract.)

Vian, W.E. 1971. Wintering Bald Eagle (Haliaeetus leucocephalus) on the Platte River in southcentral Nebraska. Master's Thesis. Kearney State College, Kearney, Nebraska. 60 pp.

Mentions a banded Bald Eagle which was recovered as a result of striking a "high tension wire" about 8 miles (12.9 km) east of Louisville, Cass County, Nebraska.

Walker, L., and M. Walker. 1940. Headlines on eagles. Nature Mag. 33(6): 321-323.

Contains an anecdotal account of the electrocution of a single Golden Eagle.

Weir, D.N. 1971. Mortality of hawks and owls in Speyside. Bird Study 18(3): 147-154.

Forty percent of all raptor casualties in Speyside, England, were attributed to collision with man-made objects. Three birds were found near overhead wires suggesting that they were killed in collisions with the wires.

\*West, H.J., J.E. Brown, and A.L. Kinyon. 1971. Simulation of EHV transmission line flashovers initiated by bird excretion. IEEE Transactions on Power Apparatus and Systems PAS-90(4): 1627-1630.

"During the past two years, unexplained flashovers have caused 32 outages on the Bonneville Power Administration 500 kV ac [alternating current] transmission lines. Tests reported in this paper indicate that some of these unexplained flashovers may have been caused by large birds and leave little or no evidence of the cause. It is also shown that this mechanism may cause flashovers on ehv dc [extra high voltage direct current] transmission lines." (Authors' abstract.)

\*White, C.M. 1974. Current problems and techniques in raptor management and conservation. Transactions of the 39th North American Wildlife and Natural Resources Conference. pp. 301-311.

Recognizes in a paragraph that electrocution of large raptors is a frequent problem in the West.

Wilcox, J.R. 1979. Florida Power and Light Company and endangered species: examples of coexistence. In: The mitigation symposium: a national workshop on mitigating losses of fish and wildlife habitats. U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. General Tech. Rep. RM-65. pp. 451-454.

Includes a comment regarding an active Bald Eagle nest located 50 meters (45.7 yards) from a 240-kV transmission line near Florida Power and Light's Sanford Plant in central Florida.

\*Willard, D.E. 1978. Impact of transmission lines on birds (and vice versa). In: Impacts of transmission lines on birds in flight. M.L. Avery (ed.). U.S. Fish and Wildlife Service, Biological Services Program. Washington, D.C. pp. 3-7.

Includes a comment to the effect that 6-8 percent of Bald Eagle mortality is due to transmission lines.

\*Wrakestraw, G.F. 1973. 1973 Wyoming Bald and Golden Eagle survey. Amer. Birds 27: 716-718.

Golden Eagle population data.

\*Wyoming Wildlife News. 1977. Power line electrocution hazards made safer through engineering. February, 1977. p. 12.

Nearly verbatim republication of Conservation News (1976) by approximately the same title. Abstract is with the cross-referenced paper.

\*Yager, L. 1978. Factors affecting reproduction of Ospreys. Unpubl. rep. New York Department of Environmental Conservation, Division of Wildlife, Albany. 8 pp.

Six of 20 Osprey carcasses collected on Long Island and in the Adirondak Mountains of New York showed signs of electrocution.

\*Zimmerman, D.R. 1975. To save a bird in peril. Coward, McCann and Geoghegan, Inc., New York. 286 pp.

Documents the "clinical ornithology" approach to the conservation of endangered birds.

Zimmerman, D.R. 1976. Bald Eagle bicentennial blues. Natur. Hist. 85: 8-16.

Mentions two cases in which Bald Eagle mortality was associated with power lines. In one case an eagle was shot apparently while perched on a power line near Brigham, Utah. During its fall it made contact with two conductors which singed its feathers. In another case, an eagle carried the carcass of a filetted 36-inch (91-cm) long Kingfish (which it apparently stole from a fisherman) across two conductors of a power line in Florida and was electrocuted.

\*Zitney, G.R., and G.L. Boyle. 1976. Vegetation and wildlife survey, Sonora Area Distribution Project. Prepared for Pacific Gas and Electric Company, San Francisco, California, by Biosystems Associates, Larkspur, California. 94 pp.

Discusses potential impacts to raptors of the proposed Sonora Area 115-kV transmission system and distribution substations near the New Melones Reservoir in California. Mitigation to reduce impacts include the construction of artificial perches on power lines to avoid raptor electrocutions and the avoidance of known raptor nest sites during construction.

# **PART SIX**

## **INDEX**



## PART SIX

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