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Ms. Judith Ikle
California Public Utilities Commission
c/o Aspen Environmental Group
235 Montgomery Street, Suite 800
San Francisco, California 94104

Re: A.99-09-029 - Pacific Gas and Electric Company Northeast San Jose Transmission Reinforcement Project - Comments on the Draft EIR

Dear Ms. Ikle:

On behalf of Pacific Gas and Electric Company ("PG&E"), I write to comment on the draft Environmental Impact Report ("DEIR") for the Northeast San Jose Transmission Reinforcement Project (the "Project"). PG&E appreciates the opportunity to comment on the DEIR and we hope these comments will be useful. This letter has two main sections. The first contains PG&E's substantive general comments on the DEIR and its conclusions. The second contains PG&E's technical comments or corrections on the DEIR.

PART I: SUBSTANTIVE GENERAL COMMENTS

1. <u>The evidence in the DEIR does not support the conclusion that the combined 1-880-A/I-880-B alternative is environmentally superior; in fact, PG&E's proposed project is environmentally superior.</u>

The evidence and analysis in the DEIR does not support the conclusion that the I-880-A/I-880-B alternative is the "environmentally superior" alternative. Rather, that evidence demonstrates that either the proposed project or a hybrid of the proposed project and the I-880-A alternative, on balance, will result in fewer impacts than the I-880-A/I-880-B alternative. The DEIR's recommendation that the combined I-880-A / I-880 B alternative be considered environmentally superior is not justified, and is not supported by the analysis or facts in the DEIR. For example:

- The visual analysis does not support the recommendation. The visual impact of new power lines is similar at any location, and the EIR demonstrates this.

Adjacent to Interstate 880, however, this visual impact affects over 130,000 drivers per day, as opposed to a small number of trail users on a partially completed trail near the proposed route. The analysis also overstates the incompatibility of power lines and trails; in fact, local general plans specifically call for locating trails on power line easements.

- The selection of the environmentally superior alternative is based in part on findings that "bird strike" impacts will be significant with the proposed project. The EIR, however, overstates the potential for bird strikes, and more importantly, the selection of I-880-A/I-880-B as environmentally preferred ignores that fact that bird strike impacts can be mitigated.

- A complete consideration of the land use impacts of the I-880-B alternative demonstrates that it is not environmentally superior.

- Short-term construction impacts, although not significant, also support a determination that the I-880-B alternative is not environmentally superior.

- The separate comparison of the I-880-A and I-880-B alternatives with the proposed project understates the adverse impacts of those alternatives when combined, and a combined analysis considering all impacts will demonstrate that the proposed project is environmentally superior.

- Overall, considering the information contained in the PEA as well as the DEIRs own analysis, the proposed project is the best electrical solution and is also the environmentally preferred solution.

Each of these points is explained below.

a. <u>The evidence in the DEIR demonstrates that the visual impacts of the I-880-B alternative would be substantially more severe than those of the proposed project.</u>

The DEIR contains extensive analysis of the visual impacts of the preferred route. Despite the fact that visual impacts is one of the three impact areas considered to be of primary concern by the DEIR (DEIR page D-1),[1] however, the DEIR contains far less analysis of the visual impacts of the I-880-B alternative. Nonetheless, a primary

[1] All page references are to the June, 2000 DEIR, unless otherwise noted.

basis for the conclusion that the I-880-A/I-880-B combination is environmentally superior is the assertion that the alternative would substantially mitigate the visual impacts of the preferred route. (Tables D.3-2, D.3-3) That conclusion ignores new visual impact that portions of the I-880-B portion of the alternative would cause, adversely affecting visitors, workers and businesses in the City of Fremont and motorists along the I-880 corridor. More analysis is needed to provide a complete and accurate comparison with the impacts of the preferred route. Without this information and comparison, the determination of the environmentally superior route is not adequately supported. PG&E is now preparing and will submit a series of visual renderings of a 230 kV transmission line built along various sections of the I-880-B corridor so that these impacts can be better analyzed. Such additional information will further demonstrate either that the proposed project is environmentally superior, and that the combination of the proposed project and the I-880-A alternative is also superior to the DEIRs preferred route.

Although the DEIR concludes that the proposed project would be superior with regard to visual impacts, neither that fact nor the substantial visual impacts of the I-880-B alternative appear to have appropriately influenced the selection of the environmentally superior alternative. The DEIR's conclusions regarding visual impacts are purportedly based on the assumption that trail users have a higher visual "expectation" than workers, businesses and motorists along the I-880 corridor. The determination of visual impacts specifically includes the "number of viewers" and the "duration of view," yet the conclusion drawn is contrary to the facts presented. (C.12-2.) The DEIR determines that visual impacts on perhaps hundreds of yearly trail users would be more significant than visual impacts on perhaps millions of yearly motorists using I-880 and businesses along the I-880 corridor, yet there is no evidence to sustain such a conclusion. In fact, this determination fails to account for the dramatic difference in the duration of views between motorists and employees who would view the project day after day and throughout the day versus trail users who would likely see the project occasionally and for relatively short time periods.

The DEIR notes that the "[L]andscape visibility can be a function of presence or absence of screening features such as land forms, vegetation, and or built structures." (C.12-2.) Furthermore, the DEIR states that the proposed route would have "[g]reater visual consistency with existing uses (4 existing transmission lines)." (D-10.) Accordingly, the DEIR concludes that the proposed route would have lesser negative visual impacts than the I-880-B alternative. Despite this, however, the DEIR concludes that the I-880-B alternative is "clearly superior." (D-6.) Such a conclusion is contrary to the analysis in the DEIR and is not supported by substantial evidence in the record or in the document itself.

In fact, the analysis in the DEIR demonstrates that the I-880-B alternative should not be recommended as the environmentally superior alternative. The DEIR demonstrates that the visual impacts of the proposed project, the I-880-A alternative, and the I-880-B alternative are basically similar. For example, each of these alternatives is determined in the DEIR to be inconsistent with BCDC policies on visual impacts. The DEIRs recommendation of the I-880-B alternative fails to consider, however, the far greater number of users affected by this impact when it is located along Interstate 880. While the proposed project is located near the Bay Trail, this trail is not yet completed, which plainly reduces current use (in addition, the existing Bay Trail segment currently presents views of the Bay with existing power lines). Along Interstate 880, however, the project would affect the view of millions of motorists each year (based on average daily traffic of 130,000 to 136,000 vehicles, DEIR Figure C.11-1), and this impact would occur along a stretch of freeway that does not now include views of adjacent powerlines.

Moreover, the DEIR overstates the incompatibility of power lines with the Bay Trail. As the DEIR notes, both the Fremont and San Jose General Plans actually contain statements to the effect that utility easements provide opportunities to locate recreational trails. Specifically, the San Jose General Plan Parks and Recreation Policy 7 states that the City encourages the Santa Clara Valley Water District, school districts, PG&E and other public agencies and utilities to provide appropriate recreational uses of their respective properties and rights-of-way. (C.7-21.) The City of Fremont General Plan Open Space Element Policy OS 2.5.3 states that the City shall use a variety of resources in completing its trail system and work with other public agencies to develop paths on existing rights-of-way, such as creeks, flood control channels, Hetch Hetchy and South Bay Aqueduct rights-of-way, and PG&E power line easements. (C.7-16.)

The DEIR also fails to recognize the additional visual impacts caused by the circuitous and winding path of the I-880-B alternative route. Unlike the preferred route, which is essentially straight for the majority of its distance, the I-880-B route turns fourteen angles between the Newark-Metcalf 230 kV line and the end of Fremont Boulevard. Each of these turns would require an "angle structure," which is a larger, more substantial tower. By their nature, these angle towers have greater visual impacts. Moreover, a winding route requires more towers than a straight route. Also, the winding nature of the I-880-B route means that viewers at various vantage points, particularly those generally in parallel with the route, e.g. along I-880, would see many different sections of the line simultaneously, whereas viewers of the preferred route would view one, continuous line that would be less visually intrusive.

In sum, the visual impacts of the I-880-B alternative would be substantially worse than the impacts of the proposed project, or the impacts of the proposed project combined with the I-880A alternative. This should be reflected in the EIR's conclusion regarding the environmentally superior alternative.

b. The DEIR's conclusion that the proposed project would have an unavoidable significant impact by causing bird strikes fails to consider available, feasible mitigation measures, and that failure improperly skews the determination of the environmentally superior alternative.

The DEIR finds that the proposed project would have an unavoidable significant impact in that it would potentially cause bird mortality because it would place a relatively thin wire high in the air through a corridor heavily used by birds. The 230 kV conductors proposed are approximately 1.22 inches in diameter. Thus, they are easily visible to birds. The static wire, or shield wire, however, is a fairly thin wire strung across the top of the transmission towers. The DEIR concludes that wire would present a danger to birds and create a high probability of bird strikes resulting in bird mortality and creating a significant, unavoidable "Class I" impact. This conclusion is flawed for two reasons.

First, the DEIR classifies bird collision potential as significant because the "Loss of bird species protected by the Migratory Bird Treaty Act would be considered a significant and unavoidable impact (Class I)." (C.3-73) This interpretation incorrectly suggests that any bird strike would be a significant impact. A more appropriate criteria of significance is the standard developed by the Avian Power Line Interaction Committee, which has defined the biological significance of bird collision mortality as "the effect of collisions upon a bird population's ability to sustain or increase its numbers locally and throughout the range of the species." (APLIC 1994, p. II/8).

A bird hitting a power line is actually a rare event. In general, the risk that a bird flying across a powerline will collide with it is a small fraction of 1%. Where estimates have been made, collisions with powerlines account for far less than 1% of total bird mortality. This impact is difficult to predict given the life history data and collision numbers necessary to model the effect of collision mortality on a population. Generally, however, one would expect it to be significant only in a few cases where small populations of birds are particularly vulnerable.

Several factors can be used to predict bird mortality from a powerline. In order, they are:

1) Whether the line is in an existing powerline corridor. In this case, one would not expect an increase in mortality, because the transmission line is proposed to

parallel the existing transmission line. The new transmission line may make the corridor more visible, possibly decreasing total bird mortality in that corridor.

2) Bird movements across the proposed route. Birds fly and it can be expected that sooner or later a bird will hit anything that is put into the air - as they have been know to hit golf balls while in flight. In general, if more birds fly across the transmission line, more birds have the potential to hit it. Determining the rate of movement across a corridor requires a rigorous, multi-year study, because the factors influencing movements are so variable.

3) If such a study is lacking, then movements can be predicted by guessing where the birds are moving to and from within the study area. Shorebirds and gulls frequenting the edges of the Bay will move between feeding areas and roosting areas. These movements are greatest because their feeding areas are tidal - and they will move in and out of feeding areas with the tide, up to four times a day. Ducks will move from nighttime holding areas to open water to feed.

4) Characteristics of the birds moving across the corridor. Species, flight behavior, age, and migratory status have all been shown to influence birds' susceptibility to collisions with powerlines.

The DEIR's determination that bird mortality resulting from bird strikes is an unavoidable significant impact should be reviewed giving consideration to the biological significance definition set forth above. Evaluating bird mortality under this definition, and in combination with the bird strike mitigation, should demonstrate that this impact will be less than significant.

Second, this conclusion is not supported by the evidence in the DEIR. The second paragraph on C.3-63 starts by admitting that "[i]t is impossible to predict the magnitude of bird mortality from the transmission line without extensive information on bird species and movements in the project vicinity. These data are not available for the proposed transmission route." The third paragraph identifies the aquatic/natural resources that may attract birds to the area and states that the gulls are the most visible bird movements in the area. The DEIR then states "[g]ulls are not particularly susceptible to collisions with power lines. (Leitner, 1981)." The DEIR also states that, in the South San Francisco Bay, bird mortality is expected to be greatest where transmission lines cross tidal mudflats that are used extensively by feeding shorebirds (C.3-63). Figure C.3-1 demonstrates that the vast majority of the proposed route follows developed areas and grasslands, with a small area crossing salt ponds, but no mudflats. The obvious conclusion is that bird strikes are not a significant impact, yet the DEIR fails to make that finding.

On the same page the DEIR states, "[t]he proposed transmission line route parallels an existing PG&E Co. transmission line corridor." In general, several transmission lines within a single corridor are expected to be more visible to birds than single lines. (APLIC, 1994). Additional bird mortality is expected to be lower when a line is constructed within an existing corridor than when it crosses new areas." Again, it appears that no consideration has been given to this evidence, which supports the conclusion that impacts to bird mortality from the proposed project will be limited.

Third, the DEIR's conclusion fails to acknowledge or analyze a number of available, feasible and commonly used mitigation measures. PG&E proposed a number of such measures, but only one is included in the DEIR and that mitigation measure is not identified in detail or listed on the Mitigation Monitoring Program. The DEIR should identify the mitigation measures proposed by PG&E, and should discuss the feasibility and efficiency of these measures. If these measures are found infeasible or ineffective, the EIR should explain why. Both as part of its analysis and as part of the determination of the environmentally superior alternative, the DEIR should analyze the preferred project with these mitigation measures in place.

In fact, numerous studies have shown that marking wires significantly drops the mortality rate associated with bird strikes. The marking of power lines has been researched for a number years, with studies concluding that it is an effective way to reduce the impacts associated with bird strikes. The Netherlands now require that all overhead wires be marked in bird collision zones with 10-cm (4-in.) spirals and 5-m (16.4-ft) spacing. This effort has on average reduced the bird mortality rate associated with bird strikes by 90 percent. (Koops 1993, referenced in APLIC, 1994).

Two U.S. studies in the early 1990s also demonstrated the effectiveness of wire marking for bird strike reduction. A study completed by Morkill and Anderson (1991) evaluated yellow aviation marker balls (30 cm. or 12 in. in diameter) crossed with a black vertical stripe. The marked spans were associated with significantly lower (54%) bird mortality. (APLIC, 1994). The second study by Brown and Drewien (1995) compared the effectiveness of two new methods: yellow Spiral Vibration Dampers (SVD's) and yellow swinging fiberglass plates. Though both showed a reduction in mortality rates in the 60 percentile range, the plates were found to damage the transmission wires and were rejected. The study concluded that the SVD's were effective and reduced bird mortality rates by 61 percent, though this number could be improved if the horizontal aspects of the plates were introduced. (APLIC, 1994).

In short, this type of mitigation measure is commonly used and readily available. The following list provides a sample of available marking techniques that should be discussed in the DEIR. Additional information on these methods is found in Exhibit A. This list should not be considered exhaustive.

1. **Spiral Vibration Dampers (SVD)** - Preformed shape of high-impact PVC. Designed to grip a conductor tightly on one end and loosely on the other end to dampen vibration that is induced by low-velocity winds. Available in gray and yellow. Installation is moderately labor-intensive on lower-height distribution lines and requires high-reach equipment for the higher lines.

2. **Bird Flight Diverters (BFD)** - Preformed shape of high-impact PVC. Two designs of varying sizes are available. Have proven effective when installed on the overhead groundwires of transmission lines.

3. **Aerial Marker Sphere** - Spheres typically used to alert aircraft to power lines. Size ranges from 22.9 cm (9 in.) and 30.5 cm (12 in.) in diameter. Available in a variety of colors.

4. **Metal Bird Flight Diverters** - Made from several preformed aluminum alloy rods sized to fit steel overhead groundwires or aluminum conductors. Contains a number of spiral metal loops to aid in visibility.

5. **Avifaune Spiral** - Preformed shape of PVC produced in two colors. Has been used on both conductors and overhead groundwires with a recommended spacing of 7 to 10 cm (23 to 32.8 in.).

The DEIR's failure to analyze the proposed project with mitigation measures such as those described above in place is a substantial factor in the DEIR's unsupported determination that the I-880-B alternative is environmentally superior. When the EIR considers and evaluates this mitigation measure, the EIR will be able to provide a more accurate weighing of the potential impacts of the preferred project versus the I-880-B alternative. When considered in tandem with the dramatic visual impacts of the I-880-B alternative that the proposed project would avoid, the mitigation of potential bird strike impacts will demonstrate that the proposed project is environmentally superior to the I-880-B alternative.

c. <u>Full consideration of the potential land use impacts of the I-880-B alternative demonstrates that it is not environmentally superior.</u>

The comparison between the Land Use and Recreation impacts of the proposed project and the I-880-A/I-880-B alternative (Table D.3-2) is incongruous with the Visual Resources comparison on the next line of the table. (D-10.) Under Land Use and Recreation, the DEIR states that the proposed project would create more impacts because it would "degrade" the recreational trail experience for 2.7 miles, versus one mile for the I-880-A/I-880-B alternative. Under Visual Resources, however, the DEIR states that the proposed project would have "greater visual consistency with existing uses." The only existing public uses in the area of the proposed project are recreational trails. The only "degradation" of the recreational trail experience identified is through visual impacts. Thus, if the visual impacts of the proposed project are less, the land use and recreation impacts must also be less. The conclusion that the proposed project would have greater Land Use and Recreation Impacts, therefore, is not supported, and is in fact contradicted, by the statements in the DEIR.

Moreover, the DEIR's conclusion as to land use impacts completely ignores the potential land use impacts of the I-880-B alternative. The I-880-B alternative as proposed would run through a dense and developing commercial and industrial corridor along a major regional highway. (See, e.g., C.7-53, 54.) Additionally, development pressure on remaining vacant land in the area is tremendous. Hence, the potential for land use impacts from the I-880-B alternative is substantial. For example, "[t]ransmission lines would be placed along the sidewalk/lawn border of the businesses along the west side of Lakeview Boulevard" (C.11-24), and construction along the I-880-B segment would require the removal of approximately 321 mature trees. Yet the DEIR fails to account for the potential impacts of such impacts in selecting the I-880-B alternative as the environmentally superior alternative.

On the whole, the DEIR's recommendation of the I-880-B alternative does not sufficiently consider the economic, land use and employment impacts on the City of Fremont and existing businesses or businesses that may wish to locate on land adjacent to or near the proposed I-880-B alternative corridor. This is contrary to the DEIR's statement that land use impacts were considered very important in its analysis. (D-2) Accordingly, the EIR's conclusion regarding the environmentally superior alternative is not supported.

d. Short-term construction and traffic impacts on I-880 should be considered in determining which alternative is environmentally superior.

The DEIR concludes that "[n]o transportation impacts were found to be significant unavoidable impacts" of either the proposed project or any of the alternatives analyzed. (ES-19) The I-880-B alternative, however, could have substantial impacts on the I-880 freeway during construction. According to the DEIR, I-880 carries approximately 105,000 vehicles per day north of Montague Expressway. (C.11-2) The DEIR states that, nonetheless, because construction impacts are short-term impacts, they are not significant. Although PG&E agrees with the proposition that short-term construction impacts should not be considered significant due to their transient nature, these impacts should still factor into the analysis of which alternative is environmentally superior. In this case, these impacts provide further support for the conclusion that either the proposed route or a combined proposed I-880-A route are environmentally superior to the route favored in the DEIR.

e. <u>The comparison of the I-880-A and the I-880-B alternatives separately with the preferred project understates their combined impact and thus skews the analysis of the superior alternative.</u>

The separation of the I-880-A and the I-880-B alternatives for individual comparison with the preferred project results in an inaccurate conclusion regarding the environmentally superior alternative. The DEIR concludes that a combination of the I-880-A alternative and the I-880-B alternative comprises the environmentally superior project. Throughout the DEIR, however, these alternatives are separately compared against each other and against the preferred project. This separate analysis of these alternatives overstates the benefits of the I-880-B alternative, and understates the potential adverse impacts of that alternative.

The impact-maximizing effect of this compound analysis may be most obvious in the area of land use impacts. Analysis of the I-880-A alternative alone reveals that it would have substantial impacts on existing or planned commercial development in Fremont, such as the Lam Research "campus" at the north end of the Bayside Business Park. As demonstrated above, the I-880-B alternative would have tremendous economic, employment and land use impacts on properties in Fremont, including Catellus property, the Bayside Business Park, and particularly the dense and rapidly developing I-880 corridor. Separating these alternatives for analytical purposes, however, only accounts for these impacts individually, not on a comprehensive basis.

In addition, an alternative analyzed in an EIR should meet basic project objectives. It is clear that neither the I-880-A or I-880-B alternatives in themselves can satisfy basic project objectives, because neither one provides the complete transmission line that is required. Thus the realistic comparison of the alternatives should compare the proposed project with the combined I-880-A and I-880-B alternative. When the land use and other impacts of these combined alternatives are considered, the proposed project should be determined to be environmentally preferred.

f. The proposed project is the environmentally superior alternative.

Despite the apparent deficiencies in the alternatives analysis outlined above, the DEIR states that the "Table D.3-3 shows that along the central part of the route, the I-880-B Alternative is clearly environmentally superior to both the Underground Alternative and the proposed route segment." (D-6 (emphasis added).) Two pages later, the DEIR states that "determining a superior alternative is difficult because of the tradeoffs associated with different alternatives." These statements are difficult to reconcile. In any event, the analysis and discussion in the DEIR reveals that the environmental superiority of the I-880-A/I-880-B alternative over another or over the preferred project is anything but clear. (See e.g. D-10-15) On the contrary, a full consideration of the issues discussed above will show that the proposed route is superior with respect to, among other factors, visual impacts (fewer receptors, fewer impacts, more existing background "noise"), land use impacts (minimal impacts on economic, employment and commercial uses, and compatibility with recreational uses), construction impacts, and wildlife impacts (mitigation measures will reduce or avoid bird strike impacts).

Even now, the DEIR acknowledges that the comparison of the alternatives to the preferred project is a very close call. PG&E is confident that, after full consideration of the points raised above, the final EIR and the analysis and evidence contained therein will demonstrate that the proposed project is the overall environmentally superior alternative, and that the combination of the proposed project with the I-880-A alternative is also environmentally superior to the I-880-A/I-880-B alternative.

2. The suggested land use conflicts regarding the Los Esteros Substation are not a physical environmental impact, but a variant on the location of the substation should still be evaluated in the EIR.

US Dataport has suggested that the proposed location of the Los Esteros Substation conflicts with local land use plans, and that such a conflict necessarily constitutes a significant environmental impact under CEQA. US Dataport's argument is based on the fact that it is proposing a project that would also utilize the proposed Los Esteros Substation site. Due to that proposal, US Dataport has suggested that the Los Esteros Substation should be constructed instead on an adjacent parcel currently owned by the City of San Jose. The City of San Jose recently stated in their testimony in this matter that the use of the City's property for the substation would not be incompatible with existing general plan and zoning designations. The City had also stated in the past, however, that this site might be needed for water pollution control plant operations, which might prevent PG&E from being able to obtain this property through condemnation (thereby rendering US Dataport's proposal infeasible). Although PG&E is currently in on-going discussions with these parties, the City has neither approved the US Dataport development nor has it provided PG&E with assurance that PG&E will be able to acquire the necessary City parcel for relocating the substation.

Of course, the final determination of whether a conflict exists should be made by the CPUC. The DEIR states that a project such as a utility substation would be consistent with the Alviso Specific Plan and the San Jose General Plan and would be permitted on the site under current zoning regulations with a use permit. (C.7-27 - 28, C.7-31 - 32.) The DEIR therefore concludes that there is not a substantial conflict with existing land use plans in the area. PG&E concurs with that analysis. Generally, while fundamental conflicts with existing land use plans may indeed demonstrate a significant environmental impact, a difference between a proposed use and an existing use designation is not such a conflict. See, e.g., Families Unafraid to Uphold Rural El Dorado County v. County of El Dorado, 62 Cal. App. 4th 1332 (1998). Accordingly, the DEIR correctly concludes that construction of the Los Esteros Substation in the location proposed by PG&E would not, after mitigation, cause a significant land use impact. (C.7-45 - 47.)

In sum, PG&E supports the DEIR's conclusion that the proposed Los Esteros site is the environmentally superior site for the location of the substation. Nonetheless, because US Dataport's proposal could result in a slight variation on the project as it will be approved by the CPUC, PG&E recommends analyzing such a variant in the Final EIR if such analysis can be provided without a delay in the schedule for completion of the EIR. This analysis should include not only the substation but also the necessary adjustments to the transmission line routes heading into and out of the substation. Given the proximity and similarity of the sites, PG&E believes it is possible to add this analysis without delay.

3. The following variant on the I-880-A alternative would reduce the visual impacts of that alignment.

PG&E proposes an adjustment to the I-880-A alternative alignment, as shown on the attached map (Exhibit B), that improves Mitigation Measure V-3, subpart (a), and also reduces the probability of bird strikes south of Milepost ("MP") 1.7 because the I-880-A route would be adjusted to parallel the existing Newark-Trimble/Newark-Kifer 115 kV line rather than creating a new corridor across Salt Ponds A-22 and A-23. The placement of the new towers would be opposite or nearly opposite the existing sets of 115 kV towers, where the adjustment to the I-880-A route is parallel to the Newark-Trimble/Newark-Kifer 115 kV line. The placement of the new towers in opposite or nearly opposite positions to the existing towers and parallel to the existing lines would result in the most harmonious profile for the three sets of conductors, and this would further reduce the potential for bird strikes.

Mitigation Measure V-3(a) as currently drafted calls for paralleling the Newark-Montague 115 kV pole line. Under this current version of the mitigation measure, however, the new 230 kV tower line would be too far to the east to avoid a building in the northwest corner of the Bayside Business Park near MP 2.7. As such, under the mitigation measure as currently drafted, the alignment would have to make a sharp turn to the west along the southern boundary of the southerly Salt Pond A-23 in order to get far enough west to clear the building. The proposed change, on the other hand, parallels the westerly set of towers and is able to clear the building near MP 2.7.

PART II. TECHNICAL COMMENTS AND CORRECTIONS.

PG&E respectfully submits the following list of technical comments and corrections on the DEIR.

1. <u>General Comment on NRS Alternative</u>

The DEIR's description of the Northern Receiving Station ("NRS") Alternative is not clear as to whether certain existing 115 kV lines would remain, specifically those between the proposed Los Esteros Substation site and the NRS. This alternative would not eliminate any of the existing 115 kV circuits currently extending from Newark Substation to Scott and Kifer Substations. The NRS Alternative would require a 230 kV transmission line from the Newark Substation to the NRS site. That line would run along the same route as the PG&E preferred alternative from Newark to a location in the vicinity of the proposed Los Esteros Substation. The line would then pass south of Alviso to a location in the vicinity of Highway 237. From Highway 237 to the NRS location, the existing 115 kV line paralleling Lafayette Street would remain and be utilized for the new 230 kV conductors, since this portion of the line was originally constructed to 230 kV specifications at the request of the City of Santa Clara. The portion of the 115 kV line being replaced with 230 kV conductors would, however, have to be replaced with a new, additional 115 kV double circuit line paralleling the existing lines (that would be upgraded to 230 kV) from Hwy 237 to the NRS. Thus, while the existing 115 kV line would technically be replaced, it would not be eliminated because it would be rebuilt in tandem with, and parallel to, the proposed route for the NRS Alternative.

The cost for the 230 kV Transmission in Table ES-3 (page ES-24) for the NRS Substation (with transmission line) heading should be changed from $41.3 (million) to

$39.8 (million). The total cost under the same heading should be changed from $118.1 (million) to $116.6 (million).

2. Specific Comments and Corrections

Specific comments relating to text are noted below. In each case, the page number and relevant text has been identified. Recommended changes are noted in **BOLD**.

Executive Summary

The DEIR on page ES-11 makes an incorrect statement regarding the impacts to the California tiger salamander. The DEIR in the Alternatives section states: "A combination of the I-880-A and I-880-B alternatives is preferred to the comparable segment of the proposed transmission line route because it would reduce potential impacts to burrowing owls and California tiger salamanders, . . ." The reference to impacts to the California tiger salamander is simply not true. The proposed project does not impact the California tiger salamander and this statement should be revised to reflect that there are no impacts to the California tiger salamander caused by implementation of PG&E's preferred alternative.

A. Introduction/Overview

The DEIR on page A-1 incorrectly lists the date PG&E filed a new Application for a Certificate of Public Convenience and Necessity (CPCN) for the project as September 13, 1999. This date should be **September 9, 1999**

The DEIR on page A-6 should add in the description of Figure A.2-1 - blue and purple **solid lines.**

The DEIR on page A-10 states that "Under CEQA requirements, the CPUC will determine the adequacy of the Final EIR, and, if adequate, will certify the document as complying with CEQA." PG&E would like to note that CEQA does not bind the CPUC to accept the EIRs determination of the environmentally superior alternative, nor, if it does accept that determination, to choose the environmentally superior alternative as the project that it wishes to approve.

The chart shown on page A-12 incorrectly shows that an easement is required from the Bay Conservation and Development Commission. This chart should be corrected to show that no such easement is required.

B. Description Of Proposed Project, Alternatives And Scenario For Analysis Of Cumulative Impacts

The location of the Trimble Substation is incorrectly noted on Figure B.2-1 on page B-3. The correct location is southwest of the marked location.

The DEIR incorrectly references the 115 kV connections on page B-15. The first sentence of the last paragraph on the page should read: The **four** 115 kV connections listed above will occur in the immediate vicinity of the Los Esteros Substation. The fourth connection (Los Esteros to Montague Substation) would **include new construction** on Trimble Road and Montague Expressway.

The DEIR incorrectly identifies one of the privately owned staging areas as south of MP 5.4 of the proposed 230 kV transmission line route on page B-21. This sentence should read: south of MP 5.4 of the **westerly** 230 kV transmission line route.

The DEIR incorrectly shows on page B-23 that 23 acres of the substation site will be disturbed during construction. This should revised to **24** acres.

On page B-24 in the last paragraph, the first sentence should be revised to read: as well as to terminate **the** outgoing transmission lines.

The DEIR identifies tower locations in the second paragraph of page B-29. The identified locations do not match the existing 115 kV transmission lines. The Don Edwards San Francisco Bay National Wildlife Refuge Manager requests matching towers to reduce conductor differences between the existing lines and a new 2230 kV line.

The System Alternatives Eliminated discussion beginning on page B-47 needs minor revisions. The middle of the first paragraph of the section should be revised to read: . . .and includes applicant siting studies, application preparation, application review by the California Energy Commission (CEC, for power plants **and associated facilities**). In the second paragraph in the section on the same page the line should be revised to read: In addition to the separation of State agency oversight over transmission **line only projects** (CPUC) and power plants **(with associated transmission interconnections)** (CEC), an additional complication is the responsibility of the California Independent System Operator (ISO) to assure reliability of the transmission grid.

The DEIR on page B-50 bullet lists specific additional impacts that could occur. The following errors were noted. First, in the last sentence of the second bullet **addition** is misspelled. The second sentence in the third bullet should read: The proposed project includes a total of **14.6** circuit miles (one **7.3** mile double circuit tower line), . . .

The first paragraph on page B-53 should be revised to correctly reference the I-880-A Alternative. This section should be revised to read:

> . . .which crosses Auto Mall Parkway (in a **south**easterly to **north**westerly direction) at a point **immediately** west of I-880. The alternative would then follow the west side of I-880 along the edge of a business park and along the eastern edge of soon-to-be-created Pacific Commons Preserve for about **0.6** mile**s**, where a single angle structure would be located in the Preserve. The route would cross ~~the westerly edge of~~ an I-880 inspection and weigh station about one mile southeast of the auto Mall Parkway interchange….This alternative would require removal of **about 100** trees on the west side of the parking lots behind Northport Loop West.

Figure B.6-3 on page B-55 should be revised as shown in Exhibit C to reflect variants proposed in this comment letter in Section C.7 Land Use and Public Recreation.

The DEIR on page B-56 should be revised to correctly reference variants proposed in this comment letter in Section C.7 Land Use and Public Recreation in order to avoid land use conflicts and read:

> …side of the street (**about 62** existing trees would need to be removed and replaced with trees that don't grow so high) to the point where the Parkway ~~on-ramp~~ meets the **westerly edge of Fremont Blvd.** At that point, the route would turn south **along Fremont Blvd. for about 900 feet and then turn easterly along Dixon Landing Parkway, to a point** west of I-880. **At this point the line would turn southeasterly and parallel I-880 and Dixon Landing Parkway**. After crossing West Warren Avenue, the line would be located in **landscaped areas in front of** the building on Lakeview Drive. South of Gateway Blvd., Lakeview Drive runs immediately west of the freeway; in this segment, the transmission line would be located in the landscaped area just west of the street. Where Lakeview Drive turns west, the alternative route would **turn southwest** along **Lakeview Drive** to the **westerly edge of Fremont Blvd.,** then it would turn south, re-connecting with the proposed route at the pole at MP 4.3 **of the proposed route**.

The second sentence of the second full paragraph on the same page should be revised to read:

> The alternative would require removal of approximately **321** ornamental trees along Cushing Road and Interstate 880. **A number of** trees would require periodic trimming for electrical clearances.

The third full paragraph on the same page should be revised to read:

> A transmission line along the freeway would be a compatible land use. However, because development in the Caltrans right-of-way is discouraged, the right-of-way would ~~probably~~ have to be acquired from adjoining private property owners. ~~The line would also cross the Garden of Noah Cemetery (a small pet cemetery) south of West Warren Avenue and adjacent to the I-880. PG&E Co. has state that construction of towers could interfere with existing land uses (unless an easement can be voluntarily acquired, land rights cannot be obtained by eminent domain)~~.

The last full paragraph on the same page should be revised to reflect the correct mileage along the alternative route. The second sentence should read: This alternative is slightly shorter than the proposed route (about 7.0 miles versus **7.3** miles of 230 kV line), . . .

The DEIR should be revised at page B-57, as follow. The first paragraph, second sentence should read: South of that point, in this alternative, the overhead line would turn easterly and cross the westerly pair of 115 kV lines (the proposed route is going **in a southeasterly direction** at this point).

The fifth sentence of the second paragraph on page B-57 should be revised to add the following text: The corridor would then include two 115 kV overhead lines (Newark-Milpitas and Newark-Montague; see Figure B.2-7) and one underground 230 kV line, **double circuit line in two trenches**.

The last paragraph on page B-65 should be revised to reflect the correct transmission line lengths. The last sentence should read: This alternative would require a nearly 50 percent longer 230 kV transmission line (about **11.4** miles, whereas the proposed project would require **7.3** miles).

C.3 Biological Resources

The chart shown on page C.3-17 combines a number of plant community classifications. Ruderal salt marsh is not the same thing as northern coastal salt marsh, and ruderal upland is not the same as non-native annual grassland. These classifications should not be combined and the chart should be revised to reflect this.

The DEIR beginning at page C.3-25 misstates the species that could potentially occur along the proposed project route. This in turn lists many species that would never occur in the project area due to lack of habitat. This list should be reviewed and species that lack the requisite habitat should be removed.

Clarification is needed on page C.3-33 in the Western Snowy Plover discussion. The sentence states that "they have begun breeding in salt ponds around the bay this century." Please clarify which century, the twentieth or the twenty-first.

The DEIR at pages C.3-45 - C.3-46 references the CEQA definition of significance, the same definition that PG&E used in its PEA studies. However, the example given at C.3-47 suggests that the DEIR considers the disturbance of a single burrowing owl next site as significant, even if the nest is abandoned only for one season. This impact would not affect the population levels of burrowing owls by itself, and is not permanently reducing the species habitat available for the burrowing owl. Most biologists would consider this impact to the population as insignificant. Page C.3-47 should be revised to provide a more appropriate example of a significant impact to wildlife resources.

The DEIR at page C.3-53 incorrectly identifies the amount of habitat disturbed in the Wildlife Habitat Disturbance discussion. This sentence should be revised to read: The primary form of habitat disturbance would be the use of heavy equipment during stringing of the line, and use of off-road vehicles within the **100-130'** ROW (see Project Description).

The DEIR at page C.3-54 reads: "Most bird collisions with powerlines occur under two common conditions. . ." This paragraph does not accurately summarize Wendy Brown's 1993 paper at the 1993 Avian Interactions Workshop (Brown 1993). For example, this paper discusses a number of factors that can influence the rate of collision mortality. The paper also discusses biological significance and mitigation measures, but the EIR ignores these.

Table C.3-7, Avoidance and Buffer Requirements for Reducing Impacts to Special Status Species on page C.3-61, identifies various buffer distances for different species but fails to provide a source or rationale for these buffer zone distances. Moreover, the buffer zones are not consistent for the species designated as Special Status Species. The table should provide a reference for the buffer distances and should be revised to show consistent buffer distances for species under the same designation.

The DEIR at page C.3-63, the last paragraph incorrectly references the proposed project. The first sentence should be revised to read: The **westerly alternative** parallels an existing PG&E Co. transmission line corridor. Also, though the bird collision impact is considered significant even after implementation of PG&E's Applicant Proposed Measure 10.27a, there is no discussion of the basis of that conclusion. The paragraph should be revised to explain the proposed Mitigation Measure and discuss the reduction in number of bird collisions it will achieve. As discussed supra at page 7, there is ample evidence showing that Mitigation Measure 10.27a will reduce impacts to less than significant levels. If, after further analysis, the Energy Division disagrees, the basis for its position must be presented in the FEIR.

The DEIR at page C.3-66, the last sentence in the seventh paragraph states "In addition, staging areas required for conductor stringing equipment may impact shrew habitat at MP 4.1." It should be noted that staging areas in habitat suitable for sensitive species will be avoided as construction plans are developed and PG&E has not yet determined that it will utilize a staging area at MP 4.1.

The DEIR at page C.3-77 discusses the Westerly Route Alternative and concludes that this alternative would have a higher potential for bird collisions. This statement is incorrect. The Westerly Route Alternative calls for replacing the two 115 kV lines with two tubular steel tower lines with bundled 230 kV circuits. Because this alternative does not involve any new routes through the salt ponds, it would result in *no net increase* in bird mortality. On the contrary, because the proposed structures are more visible, this alternative would likely reduce current levels of bird collisions, if any. This section should be revised to illustrate that, in terms of bird collisions, this is the least impactful alternative.

C.5 Geology, Soils, and Paleontology

The first line of page C.5-2 should be revised to read: proposed 115 kV **power** lines generally follow established roadways.

The Helly and Wesling report referenced on page C.5-2 has a different date than the reference shown on page C.5-26. Please verify and provide the correct reference.

The discussion on page C.5-6 states that "Regionally damaging earthquakes may also occur on other known faults in northern California. In addition, it is important to note that earthquake activity from *unmapped* subsurface faults or surface faults, which are classified as being *potentially active*, is a possibility that is currently not predictable without detailed studies investigating each fault." (Emphasis added) This paragraph leads the reader to believe that there are a number of active faults that have yet to be mapped. This paragraph should be revised to explain this, although there are unmapped and undiscovered faults, due to the lack of studies available on the faults they cannot be classified at this time.

The second paragraph on page C.5-7 should be revised to read: The characteristics of significant local faults that **could** contribute to seismic shaking along the proposed project are listed in Table C.5-4, Fault Activity.

In the Liquefaction Potential discussion on page C.5-8, please clarify *how* the frequency of earthquakes in the surrounding region affects liquefaction potential. On the same page, the liquefaction related phenomena text should be revised to include a discussion of sand boils.

Table C.5-3, Applicant Proposed Measures for Geologic Impacts on page C.5-14, at Measure 6.2a there is a reference to mud mats. This term is not clear and should be clarified. Wood mats may be needed for construction access, but do not fall in the same foundation improvement category.

Mitigation Measure G-1 on page C.5-15 discusses the same issue identified above. The term mud mats should be clarified.

The DEIR at page C.5-20 states: "A site-specific assessment is necessary for each transmission tower along Coyote Creek and at the proposed substation site because of the high potential of liquefaction and the history of liquefaction at the site." Please clarify whether this includes a boring or CPT at each site.

In the Proposed Route, Underground through Business Park discussion at page C.5-20, please identify whether a level of risk is known for lateral spreading.

The DEIR at page C.5-21, the I-880-B Alternative discussion again references lateral spreading. The lateral spreading potential in this area should be discussed further.

Table C.5-4 on page C.5-24 again references mud mats in the G-1 Mitigation Measure discussion. Please clarify this term. Also, the Monitoring/Reporting Agency is identified as an *approved* engineer. Please define what an approved engineer is.

C.6 <u>Hydrology and Water Quality</u>

On page C.6-31, the H-10 heading and section should be revised to read:

> H-10 Tower footings along the I-880 B Alternative shall not encroach **within the right of way of** the Fremont Flood Control Channel.
>
> **The right-of-way limits of the channel have been set by the Flood Control Agency, so impacts caused by other projects do not affect**

> **the channel.** Construction of tower footings along the I-880-B Alternative route could generate sediment transport and contamination into the adjacent Fremont Flood Control Channel . . .

The second to last sentence on page C.6-33 should be revised to read: The potential for spilled or construction related contaminants to reach groundwater is greater for the Westerly Route because travel time will be less than **with** the proposed route.

Table C.6-3 on page C.6-40, Mitigation Measure H-10 should be rewritten because the 50 feet encroachment limit is an arbitrary figure with no basis in actual calculations. The measure should be revised to state that Tower Footings should not encroach within the Flood Control Channel right-of-way.

C.7 Land Use and Public Recreation

In order to mitigate or avoid potential impacts or conflicts, PG&E suggests that the FEIR should evaluate the variants shown on Exhibit C.

The DEIR at page C.7-2 incorrectly states the proposed project alignment from the existing transmission line corridor. The second sentence in the first full paragraph should be revised to read: The proposed project alignment would parallel this existing transmission line corridor for approximately 2 miles and would be located about **85** feet west of it.

The DEIR at page C.7-8 incorrectly states the direction when describing the Trimble-Montague 115 kV upgrade land uses. The first sentence in the first paragraph should read: Heading **southwesterly** along the alignment. . . The first sentence in the second paragraph should be revised to read: Continuing **southwesterly**, the alignment crosses Coyote Creek. . . On the same page, the first paragraph in the Recreational Uses discussion should be revised to read:

> . . . The Don Edwards San Francisco Bay National Wildlife Refuge also provides recreational opportunities in the vicinity of the transmission line alignment. The **federally owned** refuge is west of the proposed project alignment from about MP 0.9 to about MP 6.6. However, trails within the **federally owned** refuge are a considerable distance from the alignment - generally more than a mile. No other existing recreational facilities were identified in the vicinity of the 230 kV alignment.

The DEIR at page C.7-11 incorrectly states the location of Pinewood Park from the Montague Substation. This sentence should be revised to read: As noted above, Pinewood Park is also in this neighborhood, approximately **1,400** feet north of the substation.

We disagree with the statement regarding San Francisco Bay Conservation and Development Commission ("BCDC") jurisdiction as stated on page C.7-11. Salt ponds A-22 and A-23 were diked prior to 1966 and are therefore outside BCDC's jurisdiction. Since there is no project development in other areas of the salt ponds, and the salt ponds where the project is proposed is not within BCDC jurisdiction, this sentence should be removed.

Table C.7-1 Land Use Policy Consistency at page C.7-20 incorrectly states that the review is for the City of Fremont. The heading on this page should be for the City of San Jose.

The DEIR on page C.7-28 incorrectly references the City of Fremont. The last full paragraph on that page should be revised to read: . . .It should be noted that the zoning of the substation site is inconsistent with the City of **San Jose's** land use designation of the site as light industrial.

The DEIR on page C.7-35, the last two sentences in the paragraph before section C.7.2 should be revised to read: The segment of Bay Trail that parallels the proposed project from about MP 4.9 to MP 6.7 would be located on the east level of Coyote Creek, while the transmission line would be **west of the** west levee.

On page C.7-50 of the DEIR, the following sentence should be added to the first full paragraph: **The City of Milpitas plans to install a 36" diameter sewer line adjacent to the Proposed 230 kV route between MPs 5.3 and 7.0. Construction is expected to occur in 2000.** Based on the above analysis. . . Section C.7.3.1.1 should also be revised to read: . . The underground segment continues through the entire length of the business park, turning west at Lakeview Boulevard, then converting to **two** overhead structure**s** at the end of Fremont Boulevard.

The last paragraph on page C.7-53 should be revised to reference the full name of the automobile factory and read: . . .The New **United** Motor~~s~~ automobile factory is on the east side of the freeway.

The DEIR on page C.7-56 incorrectly states the parameters of the 230 kV line. This last paragraph on the page should be revised to read:

> This alternative involves two 230 kV lines that have different routes at the southern end, and a new 115 kV connector (approximately **2.3** miles long) as shown on Figure B.6-5. The first line ~~(the~~ follows the same alignment as the

> Westerly Route Alternative from MP 0.0 to the Los Esteros Substation; see Section C.7.3.4.1 for a discussion of the land jurisdiction and uses for along this line. . . would be connected to the Los Esteros Substation via a new **115 kV connector** and follow the first line back to the existing 115 kV transmission line fight-of-way.

The DEIR at page C.8-18, the first paragraph under section C.8.3.2 should be revised to read: . . .The north side of Auto Mall Parkway near the alignment is lined with office and light industrial development. **Part** of the alignment segment along the west side of the I-880 is through undeveloped open space.

The first full paragraph on page C.8-19 should be revised to add the full name of the automobile factory and read: As the alternative alignment veers southeast at I-880, it passes four hotels on the west side of the alignment. The New **United** Motors automobile factory is on the east side of the freeway.

C.9 <u>Public Health, Safety and Nuisance</u>

The DEIR discusses the results from the epidemiological study by Nancy Wertheimer and Ed Leeper on Page C.9-4. The report states "This study observed an association between the wiring configuration on transmission lines outside of homes in Denver and the incidence of childhood cancer." The study titled "Electrical Wiring Configurations and Childhood Cancer" published in the American Journal of Epidemiology in 1979 by Wertheimer and Leeper mainly looked at distribution primary and secondary voltage wiring configurations next to homes. On Page 278 in Table 3 the authors list the wiring configurations at the homes of cancer cases and controls used in the study. This table indicates that only one control and one case had ever lived in a home within 20 meters of a high tension (transmission) power line. The statement in the Draft Environmental Impact Report should be changed to read:

> "This study observed an association between the wiring configuration **of distribution power** lines outside of homes in Denver and the incidence of childhood cancer."

The DEIR discusses international EMF guidelines on Page C.9-7. The report references the International Radiation Protection Association's recommended guidelines published in 1990. A more recent version of the guidelines was published in April of 1998. Below is a table comparing the old and new power-frequency exposure guidelines:

	1998				1990	
	50 Hz		60 Hz		50/60 Hz	
	Public	Workers	Public	Workers	Public	Workers
ELECTRIC FIELD	5 kV/m	10 kV/m	4.2 kV/m	8.3 kV/m	5 kV/m (up to 24 hours)	10 kV/m (whole work day)
					10 kV/m (few hours)	> 30 kV/m (few hours)
MAGNETIC FIELD	0.1 mT [1 G]	0.5 mT [5 G]	0.083 mT [0.83 G]	0.42 mT [4.2 G]	0.1 mT [1 G] (up to 24 hours)	0.5 mT [5 G] (whole work day)
					1 mT [10 G] (few hours)	5 mT [50 G] (few hours) 25 mT [250 G] (for extremities)

International Commission on Non-Ionizing Radiation Protection. **Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 Hz).** *Health Physics* 1998 April; 74(4):494-522.

International Non-ionizing Radiation Committee of the International Radiation Protection Association. **Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields.** *Health Physics* 1990 January; 58(1):113-22.

The DEIR discusses PG&E Co.'s transmission and substation EMF design guidelines on Page C.9-14. The report states that the guidelines can be found at PG&E Co.'s website at: http://www.pge.com/customer_services/other/emf/index.html. This website provides a summary of PG&E Co.'s EMF policies and information about national and state programs on the issue of EMF. Copies of the "Transmission Line EMF Design Guidelines" and "Substation EMF Design Guidelines" were included in the application and can be requested by calling the project information line.

At page C.9-17, San Jose Bomb Disposal Facility, the project is referenced incorrectly and the text should be revised to read: ~~A number~~ **Two** of the alternative transmission line routes (Westerly Route Alternative **and the** Westerly Upgrade Alternative~~, and NRS Alternative~~) pass the general vicinity of a San Jose Police Department facility used for training and disposal of bombs and explosive devices. (The route for the 230 kV line that is part of the NRS alternative uses the easterly alternative that bypasses Los Esteros substation.) Exhibit D contains additional relevant information on this issue.

C.11 Transportation and Traffic

PG&E, as part of its daily business, does not enter into access agreements or acquire easements from governing agencies. Rather, it compiles with conditions of encroachment permits to do work in the public right-of-way. The word "encroachment permit" should be substituted for "access agreement easement throughout this section. At page C.11-12, the last sentence of Mitigation Measure T-1 should be revised to read: Said measures shall be incorporated in an **encroachment permit** with the applicable governing agency prior to construction.

PG&E in the course of normal business practice does not use registered Traffic Engineers to prepare traffic control plans. Traffic control plans are prepared by PG&E personnel familiar with utility operations. At page C.11-18, Mitigation Measure T-8 should be revised to remove the reference to preparation by a registered traffic engineer to read: PG&E Co. shall develop and implement detailed Traffic Control Plans (TCPs) for the entire route at all locations where construction activities would interact with the existing transpiration system.

The DEIR at page C.11-23 does not state the environmental setting for the I-880-A Alternative with specificity and the text should be revised to read:

> The I-880A alternative would replace the first 2.7 miles of the proposed route. Rather than starting at the Newark Substation, it would start about a mile east of the substation at a tap off PG&E Co.'s existing Newark-Metcalf 230 kV line, which crosses Auto Mall Parkway (in a northwest to southeast direction) at a point **immediately** west of I-880. This alternative would then follow the west side of I-880 (along **business parks and** the eastern edge of soon to-be-created Pacific Commons Preserve) for about 0.75 mile**s**. **N**orth of Cushing Parkway, the line would turn south **and enter the parking lots of commercial businesses located along the west side of Northport Loop west. Further south the alternative crosses salt ponds A-22 and A-23.** At MP 2.7. . .

The DEIR at page C.11-25, the Westerly Route Alternative Environmental Setting incorrectly describes the alternative alignment and should be revised to read: . . .There it would **parallel** an existing 115 kV route across the San Francisco Bay Natural Wildlife Refuge. . .

The DEIR at page C.11-26, the Northern Receiving Substation Alternative Environmental Setting states the current buildout by the City of Santa Clara and PG&E with limited specificity. This paragraph should be revised to read:

> Because the City of Santa Clara and PG&E Co. **has** over-built **one of** the two existing 115 kV **double circuit** lines between SR 237 and the substation location, **the overbuilt line south of SR 237** could be **used for a 230 kV line. This line would need to be replaced with another 115 kV double circuit line between SR 237 and the NRS Substation.**

The second paragraph in the Barber 115 kV Alternative, at page C.11-27, should be revised to add: This alternative would require more roadway crossings than the Trimble-Montague 115 kV upgrade (including an additional freeway crossing at SR 237 **and I-880**).

As identified supra, the Chart at page C.11-30 should be revised to delete the reference to *preparation by a registered traffic engineer* in Mitigation Measure T-8.

C.12 Visual Resources

Figures C.12-2 through C.12-4, C.12-6, C.12-9, C.12-11, C.12-12, C.12-14, C.12-15, C.12-17, C.12-18, C.12-19, C.12-21, and C.12-22 incorrectly show the crossarms on the proposed towers for the 230 kV line. This is not the type of crossarm proposed in PG&E's application. Please see Figure B.2-5 in the DEIR for the correct type of gull-winged crossarm that is proposed. These figures should be revised to reflect the crossarm referenced in PG&E's application.

The DEIR at page C.12-19, does not fully recognize the visual impacts caused by the transition structures required at either end of the underground segment of the Underground through Business Park alternative (two structures at each end). These structures are very large, contain many cross-arms and other accessories that contribute to a sense of visual clutter. Those structures will be located in proximity to one another and to the viewer, and will not be shielded from view by topography or other structures, and thus will have a moderately severe visual impact in the immediate vicinity of the structures.

# # #

PG&E appreciates the opportunity to comment on the DEIR. Should you have questions about these comments, please do not hesitate to contact me directly.

Very truly yours,

Michael H. Zischke

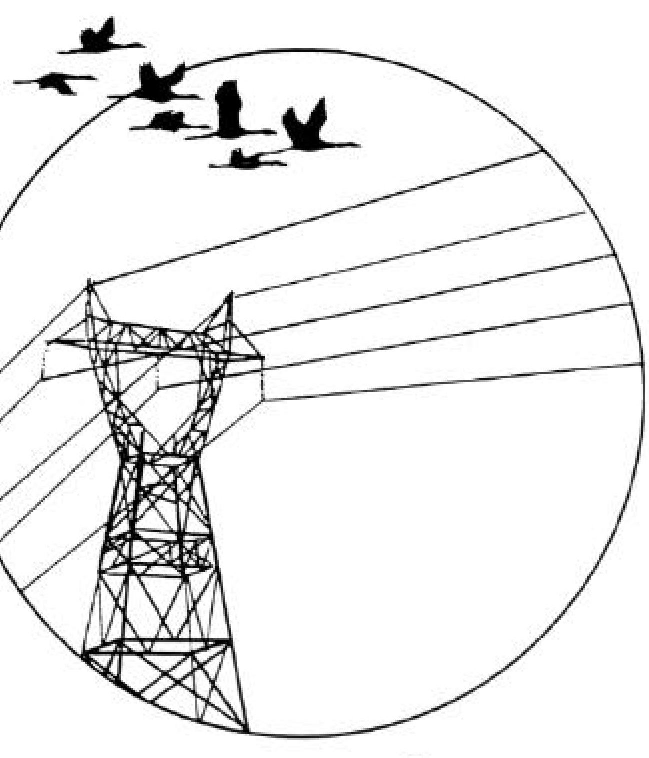
Enclosures

cc: Ms. Susan Lee

bcc: Mr. Tom Marki
Mr. Robert Bonderud
Ms. Sheila Byrne
Ms. Mary Boland
Mr. Craig Seltenreich
Michelle L. Wilson, Esq.
David T. Kraska, Esq.
David C. Levy, Esq.

EXHIBIT A

Mitigating Bird Collisions With Power Lines: The State Of The Art In 1994



Avian Power Line Interaction Committee (APLIC)

EDISON ELECTRIC INSTITUTE

Additional copies of this book may be obtained by calling the Edison Electric Institute publications number:

1-800-EEI-5453

and requesting Item #06-94-33.

This book should be cited as follows:

Avian Power Line Interaction Committee (APLIC). 1994. Mitigating Bird Collisions with Power Lines: The State of the Art in 1994. Edison Electric Institute. Washington, D.C.

Aerial Marker Spheres

In recent years, international orange aerial marker spheres, traditionally used to warn aircraft of power lines, have sometimes been installed in an attempt to reduce bird collisions. (See Figure 12.) The sizes most often used were 22.9 cm (9 in.) and 30.5 cm (12 in.) in diameter. Recommended spacing has varied, depending on the agency request and the line location. The distance between spheres generally ranges from 30.4 to 100 m (100 to 328 ft.).

Aerial marker spheres are available in a variety of colors, including international orange, yellow, and white. They are also available in a variety of diameters, such as: 22.9 cm (9 in.); 30.8 cm (12 in.); 50.8 cm (20 in.); 61 cm (24 in.); 91.4 cm (36 in.); and 137.2 cm (54 in.). Studies regarding the effectiveness of color for warning pilots have demonstrated that international orange is *not* the most effective color for all lighting conditions (*Electrical World* July 1986). The Federal Aviation Administration (FAA) is now suggesting a combination of international orange, white, and yellow for marking lines for aircraft. Yellow has been shown useful in collision marking system studies, because it reflects light longer on both ends of the day and does not blend in with background colors as readily as international orange.

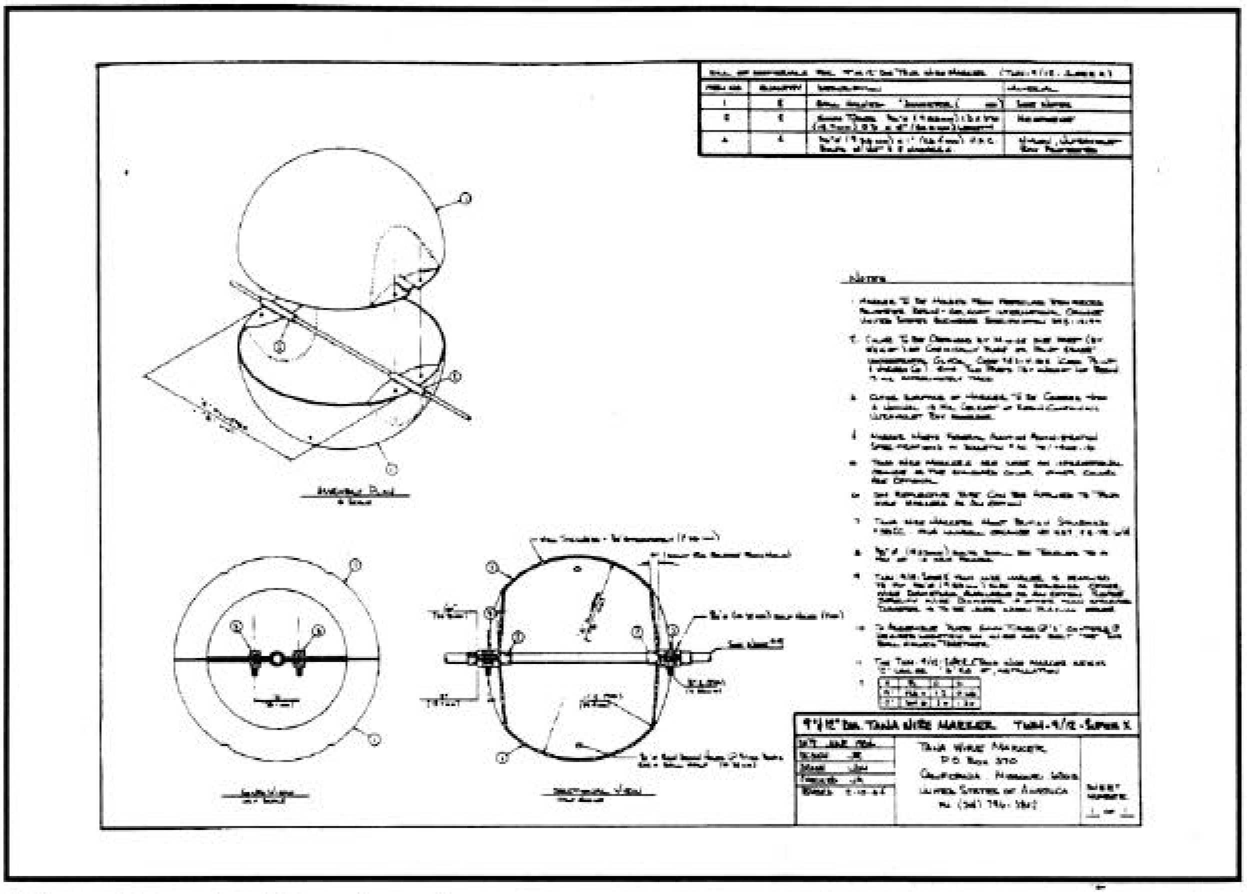


Figure 12 Aerial marker spheres

Spheres are moderately labor-intensive to install on an existing line, but less costly when added to a new line during the construction phase. (See Table 1 for specific product cost.) Costs for installation on a new line are estimated to be in the range of 120% to 150% of the cost of the sphere. Retrofitting of existing lines will vary dramatically in cost, depending on the number of spheres installed, line access for construction equipment, line voltage, and availability for maintenance, location, and other factors.

Benefits

- In Nebraska, Morkill and Anderson (1991) found that one to five spheres per span (numbers varied because of span length, voltage, and configuration) were effective in reducing collisions for the lesser sandhill crane by 54%.

- Aerial marker spheres 50 cm (20 in.) in diameter, when spaced 50 - 70 m (164 - 230 ft.) apart, showed a decrease of 40% in bird collision victims (Koops 1987).
- Although, per unit, aerial marker spheres are more costly than spiral vibration dampers (SVD's - see below), the overall cost of marking new or existing lines would be about the same because fewer spheres would be required.

Drawbacks

- The legal counsel of some utility companies object to the use of aerial marker spheres to prevent bird collisions. They prefer that the spheres be used only to mark hazards to air navigation, in compliance with FAA regulations.
- Improper design or installation of aerial marker spheres on conductors or overhead groundwires can cause spheres to work loose and slide into the bottom of the span. Conductor damage may create a forced outage.
- Adding aerial marker spheres can affect line tension and structure design, particularly in areas where heavy ice and wind loadings occur. The additional loading could affect initial cost of construction.
- Retrofitting an existing line with aerial marker spheres may require additional resources to modify structures and/or conductor tensions to comply with safety factors.
- Aerial marker spheres used in sparsely populated areas are enticing targets for irresponsible users of firearms.
- The size and number of aerial marker spheres used may result in visual degradation for environments where esthetics are important (tourist areas, scenic mountain views, historic areas, and so on).

A 91.4-cm (36-in.) illuminated aerial marker is available and adaptable to any power line of 69 kV or above. Because it must be installed on the energized conductors in order to have energy for the internal lighting system, it would therefore not be effectively located to reduce nocturnal collisions with the overhead groundwires or the energized conductors during an outage. Studies involving lighted towers or objects indicate that the lights attract the birds rather than repel them (Cochran and Graber 1958; Verheijen 1958); therefore, such a system is not recommended at this time.

Swinging Plates

An experimental swinging plate (Figure 13) was tested in the San Luis Valley study and, although it was effective in reducing sandhill crane and waterfowl collisions by 63%, the aerodynamic instability proved to be very damaging to the conductors (Miller 1990; Brown and Drewien 1995). Plate movement in high winds can lead to severe damage when clamps wear through the conductor. This is particularly a problem on aluminum conductors. Inquiries into the cost of wind tunnel studies to make the plates aerodynamically stable were conducted, but the study costs could not be justified. Therefore, until a swinging plate design can be made aerodynamically stable, swinging plates should not be used on power lines as marking devices.

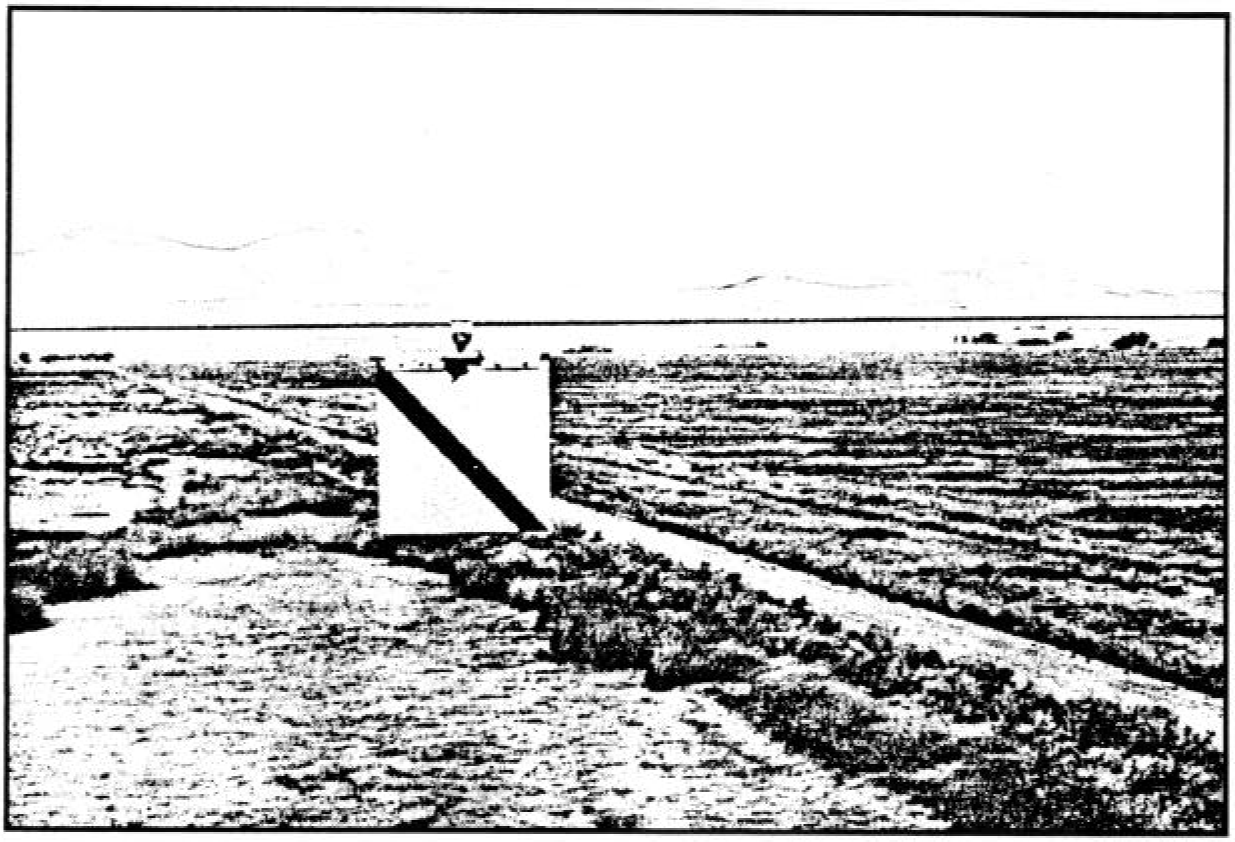
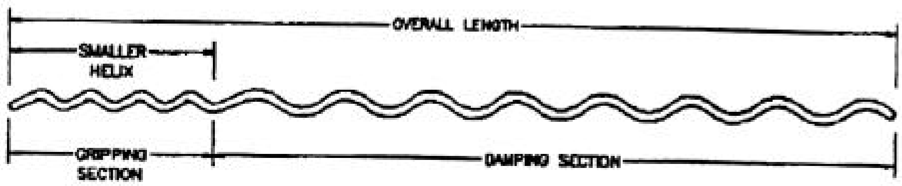


Figure 13 Swinging Plate

Spiral Vibration Dampers (SVD)

Spiral vibration dampers (Figure 14) are a preformed shape made of high-impact polyvinyl chloride (PVC), and possess excellent chemical and strength properties. They have been designed to grip a conductor tightly on one end and loosely on the other to dampen aeolian vibration that is induced by low-velocity winds of 4.8 - 12.9 kmph (3 - 8 mph). The length of the SVD depends on the conductor size.

SVD's can be purchased in the standard gray color with ultraviolet (UV) ray stabilizers that will help the devices retain color, flexibility, and service life when exposed to extreme sunlight and operating weather conditions. They are also available in a yellow, high-impact PVC that is not color-stabilized for long-term outdoor use; however, early testing indicates that, although their color will probably fade to white, SVD's should not become brittle or lose their basic elastic properties (Dulmison representative, pers. comm.). It is not known whether the fading will reduce the effectiveness of the SVD as a marking system. However, the additional silhouette of the device (not its color) appears to be the key to effectiveness (Koops, pers. comm.).



CATALOG NUMBER	CONDUCTOR RANGE	ROD DIA.	OVERALL LENGTH	GRIPPING SECTION	COLOR CODE
SVD 0441	0.174–0.249	0.5	49	8.5	RED
SVD 0635	0.250–0.326	0.5	51	8.5	BLUE
SVD 0830	0.327–0.461	0.5	53	10	WHITE
SVD 1173	0.462–0.563	0.5	53	10	YELLOW
SVD 1432	0.564–0.760	0.75	64	13	GREEN

NOTES:
1) Manufactured from grey or yellow high impact p.v.c.
2) Dimensions are in inches

DRAWING NUMBER DUL CAD 124-93 | TITLE SPIRAL VIBRATION DAMPERS | Dulmison

Figure 14 Spiral vibration damper

SVD installation is moderately labor-intensive on lower-height distribution lines, and more so on transmission lines that are more than 15.2 m (50 ft.) above ground. Higher lines reqqire more costly high-reach bucket equipment. When used to cover 27.5% of the span (30 per 140.2-m [460-ft.] span), the installed cost would be ± 244% of the cost of the SVD. (The reader will bear in mind that cost depends on access, line height, numbers of SVD's installed, line conditions (energized vs. un-energized), and so on.)

Benefits

- A study conducted in the San Luis Valley used yellow extruded SVD's, installed to cover 27.5% of the span (Brown and Drewien 1995). The SVD's retained their yellow color throughout the 3-year study period and proved effective in reducing collisions by 61%. Following the study, they eventually faded to white.
- SVD's help to control aeolian vibration associated with low-velocity winds that blow across the conductors.

- SVD's change the airfoil of the conductors under both normal and icing conditions to reduce galloping. (Icing conditions, wind velocity, and tension of the conductors are some of the factors that cause high-amplitude galloping.)
- Given the SVD's relatively light weight, and the rate of coverage on a single overhead groundwire, the tensions of conductors and design of associated structures are virtually unaffected.
- SVD's are a standard line attachment product; they are readily available from the manufacturers (see **Appendix B - Product Information**).

Drawbacks

- Costs of installation rise as the height of the line increases.
- When used on triangularly spaced distribution lines, SVD's should not be installed on the top, or ridge phase only. Otherwise, despite their light weight, they will cause the top phase to sag below the two outside phases on a horizontal configuration. This will expose the line to interphase contact during high wind conditions. SVD's should be staggered so that every third one is on an alternate conductor (see Figure 15). This prevents the chance of interphase contact and increases the visibility of SVD's.
- The SVD cannot be used on energized conductors with voltage levels above 230 kV.
- The bright color is not properly stabilized for UV exposure and begins to fade after a time. It is not clear whether this reduces effectiveness.

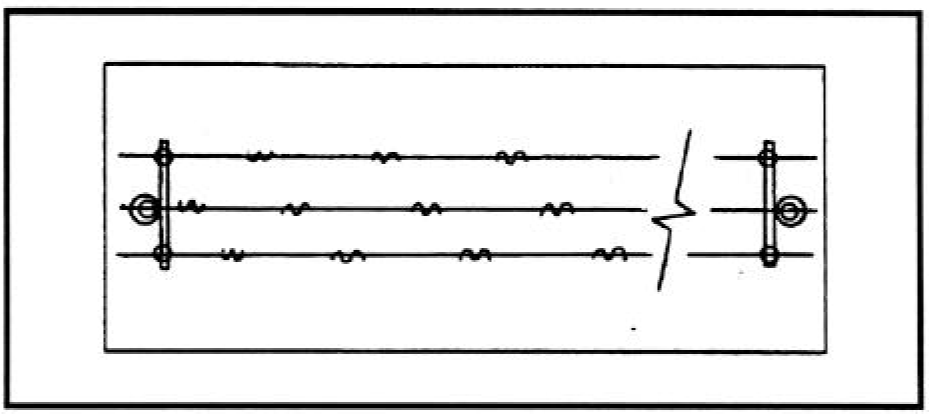


Figure 15 SVD positioning on conductors, every third conductor

Bird Flight Diverters (BFD)

Bird Flight Diverters were developed in Great Britain, and have been used in Europe since the early 1970's. One firm currently makes BFD's in the United States. Two manufacturers make the product for use in the European and South African market (one in Great Britain and one in Germany; see **Appendix B - Product Information**). BFD's are a preformed shape made of high-impact PVC which possesses excellent chemical and strength properties; they are very similar to the SVD's. The BFD's have generally been installed on the overhead groundwires, and, depending on the spacing, have reduced collisions in the range of 57% to 89% (Koops and De Jong 1982, Koops 1987).

There are two different BFD designs. The first is a device 17.8 - 39 cm (7 - 15 in.) long; it has two ± 10.2-cm (4-in.) spirals on one end (BFD-4). (See Figure 16.) The device is extruded in a gray color, with enough UV stabilizers to protect it when exposed to sunlight. It is also produced in a yellow, high-impact PVC with some UV stabilization; the color is expected to fade after long periods of exposure. Early testing of the yellow PVC does not

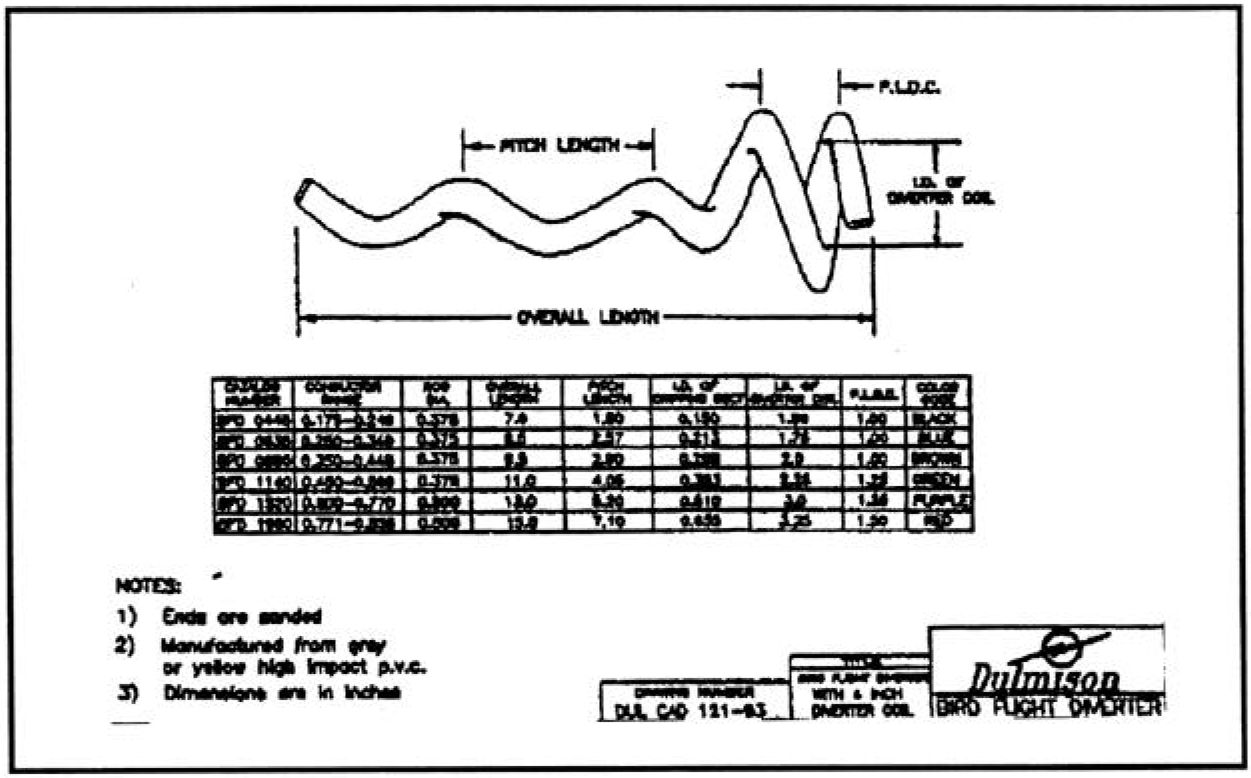


Figure 16 Bird flight diverter (BFD-4)

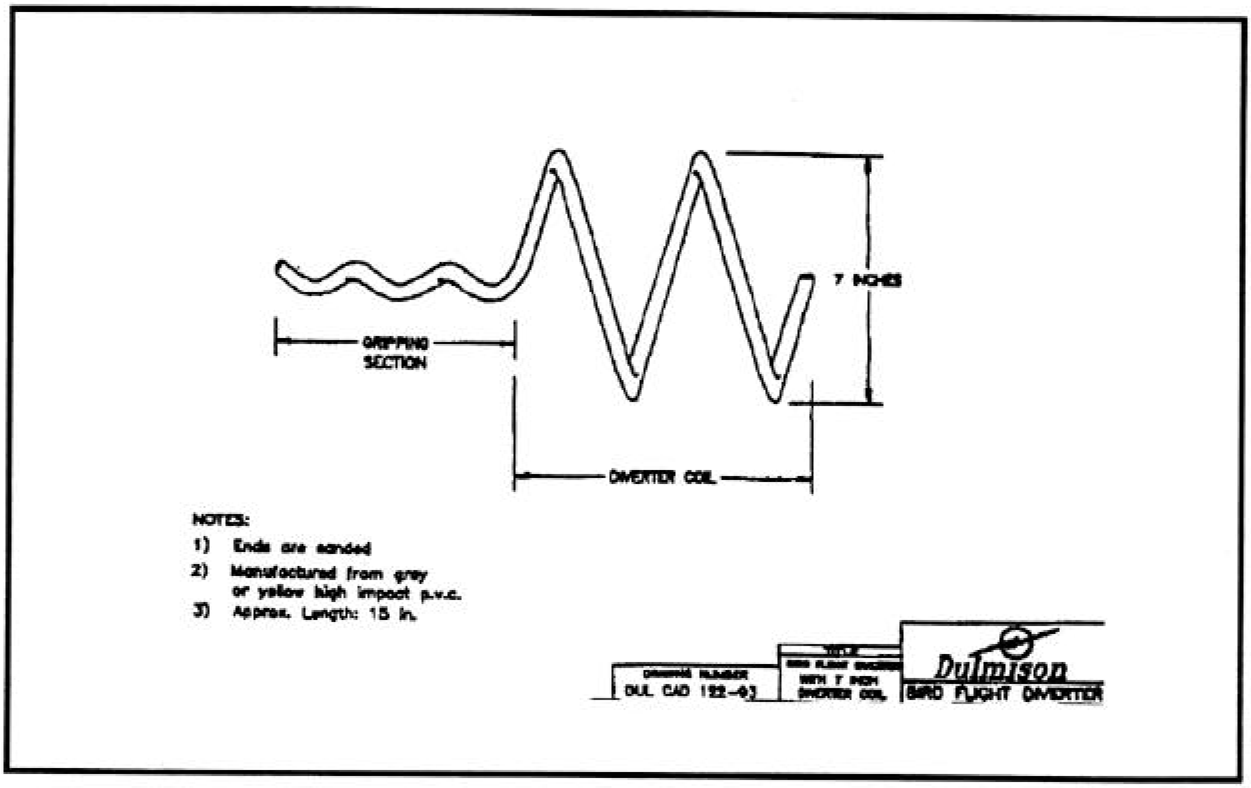
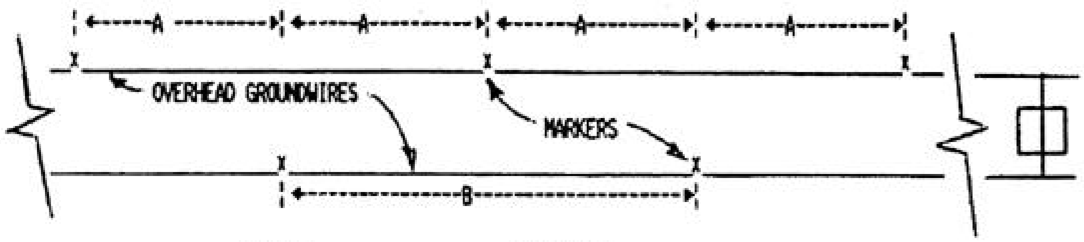


Figure 17 Bird flight diverter (BFD-7)

indicate loss of flexibility; long-term longevity is unknown at this time. A second device is the same length, but has two ± 17.8-cm (7-in.) spirals on one end (BFD-7; Figure 17). This device, spaced at 15 m, has reduced collisions in the 65% - 74% range. BFD's have also been used in South Africa (Ledger et al. 1993; Lawson and Wyndham 1993).

BFD's have proven effective when installed on the overhead groundwires of transmission lines in Europe. Studies conducted in the Netherlands have installed the markers staggered on opposite overhead groundwires so that the markers appear, on an approach to the line, to be 5 m (16.4 ft.) apart (Koops 1979, Koops and De Jong 1982, Koops 1987). On each individual overhead groundwire, however, they are 10 m (32.8 ft.) apart. Figure 18 shows how the 5-, 10- and 15-m spacing is accomplished, and shows that each overhead groundwire supports one-half of the markers.

A third device (Figure 19), the Swan Flight Diverter, has four 17.8-cm (7-in.) spirals between end-gripping sections, and is 62.2 cm (24.5 in.) long. It is extruded in a gray color, with enough UV stabilizers to protect it from high and prolonged sunlight exposure. As with SVD's and BFD's, it is also extruded in a yellow, high-impact PVC with some UV stabilization. There are no data on effectiveness of this device.



SPACING	DIMENSIONS A	DIMENSIONS B
5 METER	5 METER	10 METER
10 METER	10 METER	20 METER
15 METER	15 METER	30 METER

Figure 18 Marker spacing diagram for overhead groundwires

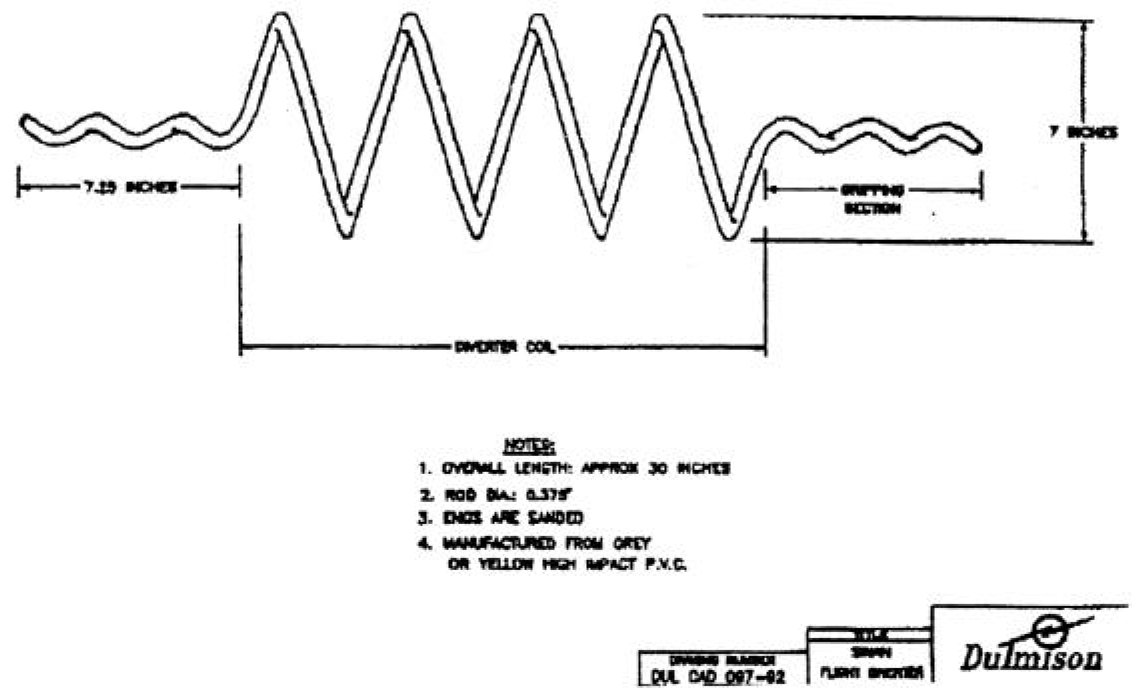


Figure 19 Swan flight diverter (SFD)

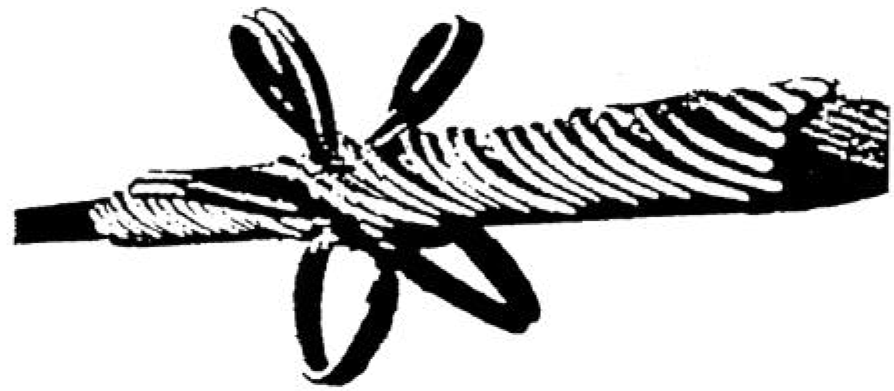


Figure 20 Metal bird flight diverter, comprised of a number of spiral loops. Also available for use on earth wires for high-voltage construction.

Data currently available from European research indicate that a greater number of the small BFD's are more effective than a lesser number of the large BFD's (Koops 1987); however, review of research data indicates that there may be situations where the larger silhouette of the BFD's and SFD's may have advantages over the smaller BFD's.

Another device (Figure 20) is made from several preformed aluminum alloy rods sized to fit steel overhead groundwires or aluminum conductors. It has a number of spiral loops protruding to increase visibility. This device is manufactured by Preformed Line Products-South Africa, and has been used on high-voltage lines in that country. At this time, no data are available on reduction of bird collisions. Pricing (see Table 1) and availability do not appear to make it economical for use in the United States.

Benefits

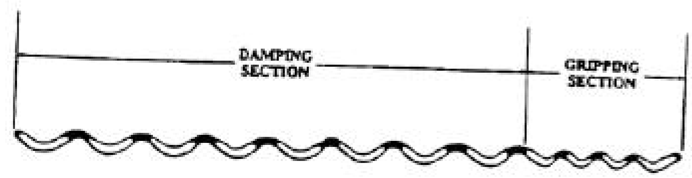
- BFD's on overhead groundwires have reduced collisions in the range of 57% to 89%. When spaced at 5 m (16.4 ft.) on the overhead groundwires, BFD-4's have reduced bird collisions by 89%; when spaced at 10 m (32.8 ft.), they have reduced collisions by 58% (Koops 1987). BFD-7's, spaced at 15 m, have reduced collisions in the 65-74% range.
- BFD's or SFD's on the conductor add a small aeolian vibration stabilizing effect, since the airflow over the conductor is changed by the added profile of the BFD. Required additional damping is accomplished by adding SVD's to overhead groundwires less than 1.3 cm (0.5 in.) in diameter, in accordance with good damping recommendations (see Figure 21). Larger overhead groundwires require Stockbridge-type dampers. (Damping

recommendations are readily available from the manufacturer, upon receipt of all sag-tension data, span lengths, conductor sizes, and other pertinent line design information.)

REF.
AP 011

SPIRAL VIBRATION DAMPERS

BY: [signature]
DATE: 1-4-93



SPAN LENGTH (FT.)	SVD'S PER SPAN	SVD'S PER SPAN END
0 – 300	1	–
301 – 600	2	1
601 – 1200	4	2
1201 – 1800	6	3

APPLICATION PROCEDURE

1. APPLY THE GRIPPING SECTION 4 INCHES TO 6 INCHES OUT FROM THE CLAMP OR THE END OF THE RODS.
2. WHEN MORE THAN ONE IS REQUIRED, THEY SHOULD BE APPLIED 4 INCHES TO 6 INCHES APART FOR FULL EFFICIENCY. FOR EASE OF INSTALLATION, THEY CAN BE LACED AND INSTALLED AT ONE LOCATION WITH A MINOR LOSS OF EFFECTIVENESS.
3. CHANGES IN TENSION AND/OR EXTREME WIND EXPOSURE WILL EFFECT THE PROTECTABLE SPAN LENGTH.

Dulmison

Figure 21 Dulmison spiral vibration damper recommendations

- Where SVD coverage is 27.5% in a 137.2-m (450-ft.) span, 31 SVD's would be required to achieve the effect of 27 BFD's. Labor costs are slightly less for the BFD's; however, the SVD installed cost would be about 38% less expensive than the BFD's. Although studies are not directly comparable, the BFD's have been shown to reduce collisions by up to 89%, versus 61% for the SVD's. The increased effectiveness and lesser labor cost favor the use of BFD's.

- BFD's and SFD's can be used on the overhead groundwires of all high-voltage lines.

Drawbacks

- BFD's have been extruded in bright colors in Europe, but, as with SVD's, the colors are not properly stabilized for UV exposure and begin to fade after a time. (However, it appears that the silhouette of the BFD is the key to effectiveness rather than the color.) (Koops, pers. comm.)
- BFD's, SFD's, and SVD's cannot be installed on the electrically energized conductors on lines with a voltage of more than 230 kV, since it would subject the PVC to ozone deterioration (destroying the chemical properties, making them brittle and reducing their service life); they could also be the cause of RI and TVI (radio and television interference) at the higher voltages (Dulmison representative, pers. comm.).

Avifaune Spiral (AS)

The French-made Avifaune Spiral (Figure 22) has been used in France and other European countries. It is a PVC, preformed device, similar in nature to the BFD's described above. The AS is 91.4 cm (36 in.) long and has two 35.6-cm (14-in.) spirals in the middle of attaching spirals, similar to the SFD discussed above. It is produced in two colors, red and white; French researchers recommend alternating the colors. They have been used on both conductors and overhead groundwires with a recommended spacing of 7 to 10 m (23 to 32.8 ft.). Data on the effectiveness, UV stability of the colors, price, and availability for the United States market has not been available from the French product representatives.

Others

Some visual frightening systems have been tried using silhouettes of raptors (e.g., goshawk (*Accipter gentilis*), peregrine falcon (*Falco peregrinus*), and owls). Generally attached to towers, these types of systems have not proven to be as effective as conductor or overhead groundwire attachment devices because the visual frightening systems cannot be used mid-span, where most collisions occur. Further, birds become accustomed to the objects and will no longer avoid them (Raevel and Tombal 1991; Brown 1993).

A limited study compared the use of an oversized overhead groundwire with a conventional overhead groundwire (Brown et al. 1987; Miller 1990). The oversized wire was 25.2 mm (1 in.) in diameter compared to the conventional 9.5 mm (0.4 in.) (or 2.6 times greater). Researchers concluded that there was no significant effect on bird response to the presence of the two different sized conductors.

Table 1, following, summarizes the foregoing discussion concerning the marking systems available today.

SPIRALES DE BALISAGE

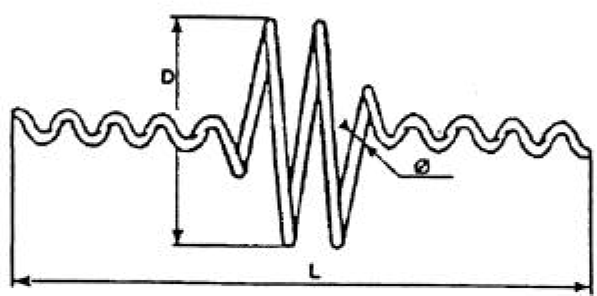
TYPE BAV

THE BALISAGE SPIRALS ARE UTILIZED FOR DIMINISHING THE RISK OF COLLISIONS FOR MIGRATING BIRD'S AGAINST CABLES OR LINES.

THE BALISAGE SPIRALS ARE MADE OF PLASTIC TREAD OF RED OR WHITE COLOR.

THE LINES ARE MADE SO THEY BECOME VISIBLE TO BIRDS SO THEY CAN MODIFY THEIR ALTITUDE.

WE RECOMMEND TO PLACE THE SPIRALS AT 7 TO 10 METERS IN THE ZONES WHERE THE BIRDS FLY AND ALTERNATE THE COLOR, RED-WHITE-RED-WHITE, ETC.



CARACTÉRISTIQUES

Référence (*)	Section conducteurs (mm^2)	L	D	Ø	Poids net (kg)
BAV 34	34,4	950	350	10	0,620
BAV 54	54,4	950	350	10	0,620
BAV 75	75,5	932	350	12	0,620
BAV 148	148	932	350	12	0,620
BAV 228	228	932	350	12	0,630
BAV 288	288	932	350	12	0,630
BAV 366	366	1047	350	12	0,640
BAV 412	412	1047	350	12	0,650
BAV 570 - 612	570 - 612	1162	350	12	0,660

(*) À la commande, compléter les références par la lettre R (Rouge) ou B (Blanche).

Figure 22 Avifaune spiral

TABLE 1. SUMMARY OF DATA ON AVAILABLE MARKING SYSTEMS

MARKER TYPE	SIZE cm (in.)	SPACING m (ft.)	UNIT COST[a] $	INSTALLED COST (% x unit cost)[b]	REPORTED REDUCTION IN COLLISIONS[c]
Aerial Marker Sphere	30.5 (12)	100 (328)	$59.00	120 - 150%	40 - 54%
Spiral Vibration Damper	124.5 (49)	2.8 (9)	$2.50	244%	61%[d]
Bird Flight Diverter (BFD-4)	10.2 (4)	5 (16.4)	$4.00	200%	86 - 89%
Bird Flight Diverter (BFD-4)	10.2 (4)	10 (32.8)	$4.00	185%	57 - 58%
Bird Flight Diverter (BFD-7)	17.8 (7)	5 (16.4)	$4.50	200%	No data
Bird Flight Diverter (BFD-7)	17.8 (7)	10 (32.8)	$4.50	185%	No data
Bird Flight Diverter (BFD-7)	17.8 (7)	15 (49.2)	$4.50	165%	65 - 74%
Swan Flight Diverter (SFD)	17.8 (7)	5 16.4	$8.00	250%	No data
Metal BFD	N/A	No data	No data	No data	No data
Avifaune Spiral	35.56 (14)	7 - 10 (22.9 - 32.8)	No data	No data	No data
Swinging Plate[e]	30.48 (12)	30.5 (100)	± $40.00	100%	63%

a Approximate prices as of September 1, 1994. Actual quoted prices depend on quantities and product color quoted.

b Costs will vary with number of markers, line voltage, access, new or existing construction, etc.

c Reported reduction in collision is derived from different studies with widely varying methodologies, environments, and species. Therefore, rates of reduction should not be directly compared and may not be replicable for future projects.

d When used to cover 27.5% of the span.

e Design not recommended for use because it is aerodynamically unstable, damaging the conductors.

EXHIBIT B

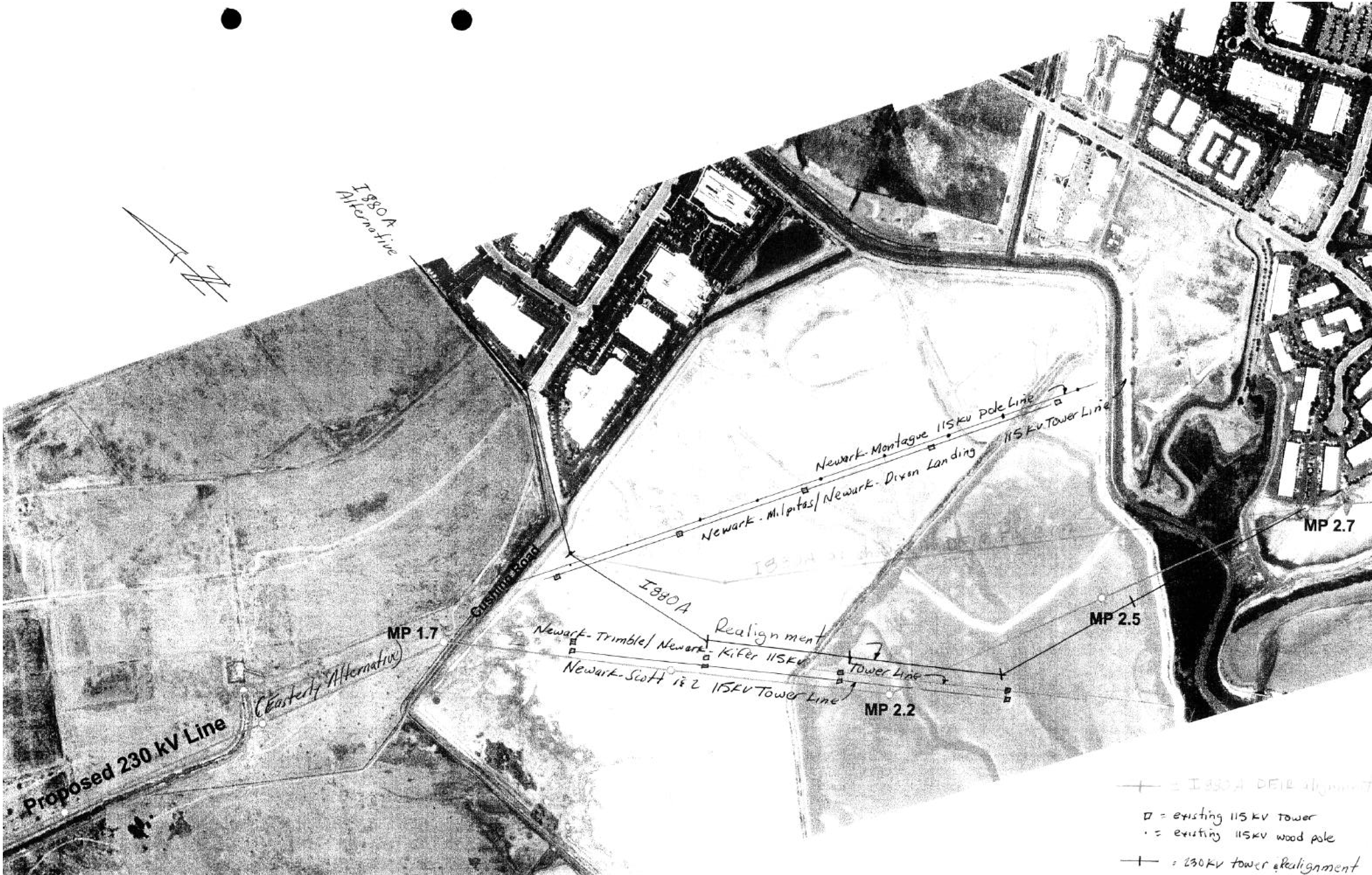

I880A Alternative
N
Newark-Montague 115kV Pole Line
Newark-Milpitas/Newark-Dixon Landing 115kV Tower Line
Cushing Road
I880A
Realignment
MP 1.7
Newark-Trimble/Newark-Kifer 115kV Tower Line
Newark-Scott 1&2 115kV Tower Line
(Easterly Alternative)
Proposed 230 kV Line
MP 2.2
MP 2.5
MP 2.7
□ = existing 115kV tower
• = existing 115kV wood pole
+ = 230kV tower & realignment

EXHIBIT C

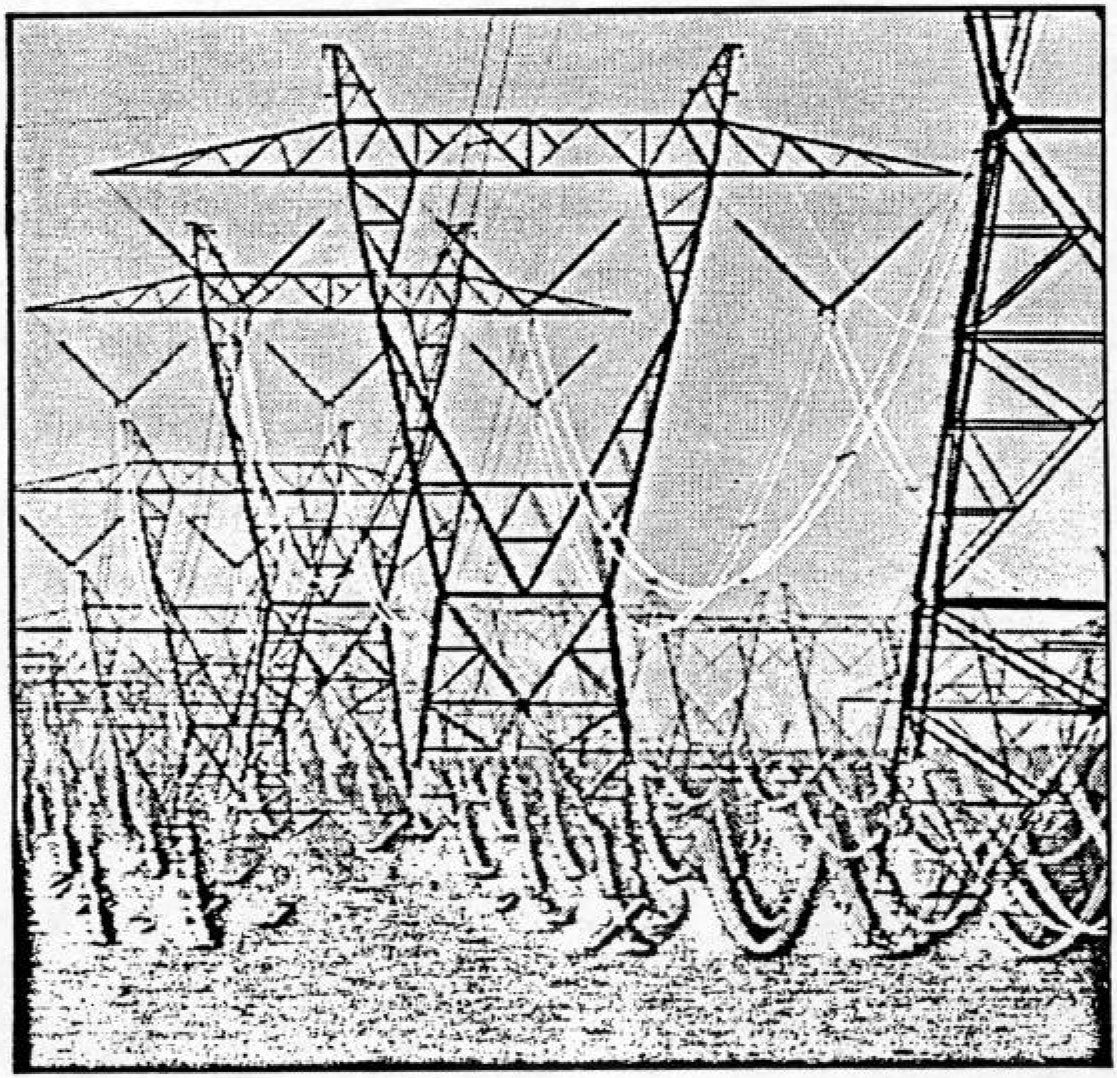
Figure B.6-3
I-880-B Route Alternative, Underground Alternative, and Proposed Route

EXHIBIT D

STAFF REPORT

HIGH-VOLTAGE TRANSMISSION LINES

Summary of Health Effects Studies

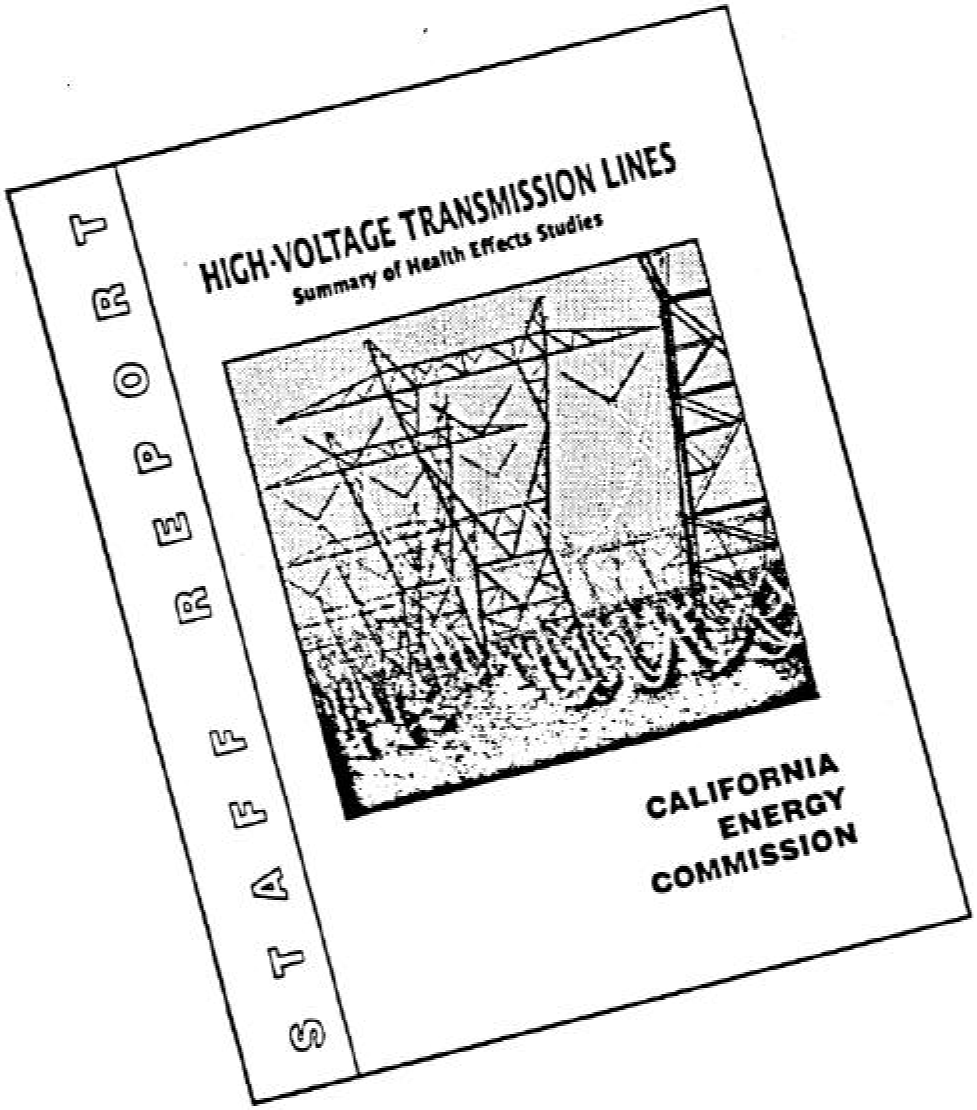


JULY 1992

CALIFORNIA ENERGY COMMISSION

Pete Wilson, *Governor*

P700-92-002



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B. B. Blevins, *Executive Director*

Abstract

Electromagnetic fields from high-voltage power lines and other sources are presently regulated indirectly, by limiting their intensities within levels necessary to protect against their known shock hazards. Such hazards result where electric charges accumulate to high levels in nearby large, ungrounded metal objects and are discharged as shock currents when people contact them. Because electromagnetic fields are too weak to directly produce large bodily currents, direct exposure to them has been considered as unlikely to pose any significant short-term or long-term hazards to humans or animals. At present, however, there is heightened public concern about living near high-voltage transmission lines because of the possibility of health effects from long-term exposures. The evidence of greatest concern has been reported from several laboratory animal and tissue studies and from studies of humans with presumed, long-term exposure to electromagnetic fields. However, because of the general difficulty in replicating these findings in studies by other research groups and a lack of understanding of the biological mechanisms that may underlie any effects of these weak fields, there is considerable uncertainty about the most appropriate interpretation of these findings. At this time, the staff of the California Energy Commission does not recommend additional regulatory limits on the strengths of electromagnetic fields from high-voltage transmission lines. The staff continues to investigate this issue and will provide appropriate regulatory guidance when and if it becomes necessary based on findings from further research efforts.

INTRODUCTION

The short-term shock hazards associated with high-voltage transmission lines are generally well understood and can be avoided or minimized through appropriate design, construction and operation. The present heightened public concern about living near high-voltage transmission lines stems mostly from questions about possible health effects from long-term exposure to the electric and magnetic fields which they produce. Exposure to both fields is often referred to as electromagnetic field **(EMF)** exposure because both fields always occur together when they originate from sources of electrical power.

The issue of possible EMF health effects is difficult to evaluate because conducting human or animal studies with electric and magnetic fields is complex and the results are difficult to interpret. This paper provides background information about: (1) the general nature of electromagnetic fields; (2) the levels at which they are usually encountered in the environment; (3) the types of biological effects that have been attributed to them from studies with humans, laboratory animals and biological tissue; (4) the possible magnitude of the human health risks that have been suggested by current findings; and (5) how this type of information is presently considered by the California Energy Commission and other permitting agencies when approving the design, construction and operation of high-voltage transmission lines.

THE NATURE OF ELECTRIC AND MAGNETIC FIELDS

Electric and magnetic fields are created by electric charges. Electric fields represent the forces that charges exert on other charges, while magnetic fields result from the additional forces that moving charges exert on other moving charges. **Voltage** is the term used for describing the electrical force that causes electric charges to move between two points along a conducting object. This directional movement of electric charges constitutes **current flow**.

The level of voltage is measured in **volts** (V) or **kilovolts**, (kV, 1,000 volts). Current is measured in **amperes** (Amps) or **milliamps** (mA, one thousandth of an ampere). The amount of **electric power** transmitted along a conductor, calculated by multiplying the voltage by the current, is measured in **watts** (W), **kilowatts** (kW, 1,000 watts), or megawatts (MW, 1,000,000 watts).

Types of Electric Currents

Charges in an electric current may move steadily without change in strength and direction, as **direct current** (dc). The fields that are produced by direct currents do not vary in strength and direction and are known as **direct-current fields** (dc fields). Current which changes strength and direction over time is called **alternating current** (ac), and produces **alternating-current fields** (ac fields).

Transmission lines can conduct either direct current or alternating current. Most high-voltage lines presently in use are ac lines. The frequency of change in the strength and direction of the current in ac lines is expressed in cycles per second or **hertz** (Hz). The ac electric power in North America is transmitted at 60 Hz. In Europe and other parts of the world electric power is transmitted at 50 Hz. The fields created by these power frequencies are within the extremely low-frequency (ELF) range (between 1 Hz and 300 Hz) of the natural electromagnetic spectrum and are often referred to as **ELF fields**. Within this frequency range, electric and magnetic fields exist as separate quantities and can be studied separately with regard to their potential biological effects.

Unlike the most energetic fields (such as Gamma-rays or X-rays), the energy carried by ELF fields is too small for exposure to produce biological effects through the breakdown of charged particles (ionization) or heat production. These fields are too weak to penetrate the exposed body to any significant degree and can therefore induce only microscopic internal fields and related currents. Such induced currents and fields are markedly lower than those that exist naturally in the body. Any significant biological effects of such field exposures must therefore be produced through mechanisms that do not involve ionization or heat production.

ELECTRIC POWER TRANSMISSION

Some electric power is lost as current flows along a transmission line. This loss is minimized when power is transmitted at high voltages and relatively low current levels. The voltage used for transmission depends on the amount of power transmitted and the distance over which it is to be transmitted.

Most high-voltage transmission lines in the United States are rated at 115, 230, 345, 500 and 765 kV. Those with voltages of less than 345 kV are the ordinary high-voltage lines, and those with voltages over 345 kV are the extra high-voltage (EHV) lines. These lines terminate at distribution substations from which the power is further transmitted at lower voltages until delivered at 120 V through service lines to individual homes and businesses. Although less power is lost from direct-current transmission, alternating current is more efficient than direct-current for power delivery because ac voltage and current levels can be reduced at less expense to distribution and service levels using a transformer. For this reason, most of the electricity in the United States is transmitted as ac power.

ELECTRIC FIELDS FROM HIGH-VOLTAGE POWER LINES

Electric field strengths are measured in units of **volts per meter** (V/m), or **kilovolts** (one thousand volts) **per meter** (kV/m) for stronger fields. For high-voltage transmission lines, field strengths are measured directly under the line at a fixed height of 1.0 meter (3.3 ft.) from the ground. Maximum values are approximately 1.6 kV/m per 100 kV of line voltage. Therefore, fields from typical 115 kV lines may be more than 1 kV/m and up to 8 kV/m for 500-kV lines. Because there are significantly more distribution and service lines than high-voltage lines, most humans are exposed to power lines with electric field intensities of much less than 8 kV/m.

The strengths of electric fields from a transmission line at any given distance depend on several factors, including line voltage, line arrangement (conductor configuration), and the height of the line above the ground. Field intensity diminishes rapidly with distance from lines. For example, an electric field of 8 kV/m directly under a 500-kV line drops off to about 0.1 kV/m at a distance of 300 feet from the line. By comparison, the earth's static (non-changing) electric field averages about 0.13 kV/m during fair weather and up to 5.0 kV/m during thunderstorms. The earth's electric field strength at the power frequencies of 50 Hz or 60 Hz is about 10^{-7} kV/m; therefore, power-frequency electric fields in the vicinity of high-voltage power lines may be up to 10^{8} times stronger than natural background levels.

Studies with human subjects show that power line electric fields of intensities as low as 1.0 kV/ can be perceived by some individuals under certain conditions due to slight vibration of the body hair. However, the perception threshold of the average individual is much higher (around 7 kV/m). Therefore, the electric fields encountered under most power lines are below the levels readily perceived by the average individual.

Electric Fields in Home and Workplace

Within the home or workplace, the fields produced by wall wiring or electrical equipment can range from 0.001 kV/m for common household appliances, up to 2.0 kV/m in the case of electric blankets. The strengths of these fields diminish rapidly with distance from their sources and range from less than 0.001 kV to about 0.01 kV/m depending on the distance from the source. They are much less intense than those encountered under high-voltage transmission lines. Because electric fields cannot penetrate most objects, trees, houses and other such structures can shield individuals from electric fields created by transmission lines. Therefore, outside power lines do not contribute significantly to average 60-Hz electric field levels within nearby buildings. Consequently, prolonged, involuntary exposure to electric fields usually occurs only outdoors in the vicinity of high-voltage lines.

Currents Induced by Electric Fields

Electric charges are induced in a conducting object exposed to an electric field as long as it is insulated from the ground. When it is grounded, these accumulated charges will be conducted to the ground. Contact with a charged, but ungrounded object, such as a car or bus, could pose a shock hazard. The magnitude of this shock depends on the amount of current involved. The current level depends, in turn, on the strength of the electric field, the size of the charged object and how well both the object and the individual are insulated from the ground. Such shocks also can occur when the individual with the induced charges is insulated from the ground but later makes contact with a grounded object. Just before such contact, a spark occurs, similar to one received from touching a grounded door knob after walking across a carpet. The continually recharging electric fields from the ac line will create the possibility of repeated sparks.

Spark discharges may produce instantaneous currents with peak values (at the point of contact) generally higher than the current that flows while contact is maintained with the charged object. Depending on the voltage and the energy involved, spark discharges can produce sensations ranging from just perceivable to painful. Since such sensations last only an instant, spark discharges are usually of only secondary concern. The potential magnitude of any such discharges will usually serve as a general guide to identifying the annoyance or comfort-based limits on electric field strengths in a variety of situations.

Existing Safety Limits on Currents Induced by Electric Fields from High-Voltage Lines

No health-based standards presently exist for limiting human exposures to 60-Hz electromagnetic fields. For high-voltage transmission lines and other sources, field strengths are minimized indirectly by limiting the level of the shock currents that may be associated with their electric fields. To this end, 5 milliamps (5 mA) has been specified in the National Electrical

Safety Code (NESC) as a limit on the steady-state current to which any individual should be exposed while maintaining contact with the largest charged object encountered under any power line in the United States. Currents above this limit can lead to involuntary muscle contractions that may prevent the individual from voluntarily letting go of the charged object to avoid further (and potentially life-threatening) current flow. In practice, all power lines are designed and constructed in a way that limits their electric field strengths to levels below those necessary to protect both adults and children from steady-state currents of this magnitude, even under the worst-case conditions that allow for induction of the maximum current possible. Such current induction could occur, for example, in connection with large vehicles where transmission lines cross over highways or in parking lots located under transmission lines.

Minimum conductor heights are required for all transmission lines in California to ensure that the actual ground clearance will be sufficient to protect against electrocution from direct contact with the energized line. The electric field strength-related and safety-based 5 mA limit is the only criterion specified for the design, construction and operation of high-voltage transmission lines in the United States. Standardized grounding procedures are usually employed to minimize shocks that may be associated with conducting objects in the transmission line environment. By contrast, the American National Standards Institute (ANSI) allows a leakage current of up to 0.5 mA from portable household appliances and up to 0.75 mA from fixed appliances. These appliance leakage currents are usually larger than those induced by fields from the typical high-voltage line.

The electric field component of power line fields is also responsible for other line-related environmental effects (corona effects) that may manifest as audible noise, ozone production and interference with radio or television signals. These types of effects became readily perceivable with the introduction of lines with voltages of 345 kV or higher in the 1950s. They have been considered since then (together with the potential for electric shocks) in the design, construction and operation of all transmission lines.

Although the minimum width of each power line corridor is influenced by the need for adequate service and maintenance space, the actual edge of each right-of-way is influenced by land availability and cost. It therefore varies from one power service area to another. In practice, the edge of each corridor is established in a way that seeks to maintain the electric field strength within the range (generally below 3.0 kV/m) necessary to minimize perceptible spark discharges and induced currents. Field strengths of between 1.0 and 3.0 kV/m have been identified from expert testimonies in past Energy Commission hearings (1977 and 1981) as appropriate limits on the strengths of the electric fields from 230- to 760-kV lines at the edge of their rights-of-way.

MAGNETIC FIELDS FROM HIGH-VOLTAGE POWER LINES

Magnetic fields are produced only when current flows in a conductor; and their magnitudes depend only on the amount of current that flows in a conductor, not the applied voltage. The magnitude of the magnetic field fluctuates as the current changes. The strength of the magnetic field to which an individual is exposed depends not only on the amount of current in the line, but also on the line configuration and its distance from the individual. For magnetic fields in general, field strengths within exposed objects are considered in terms of exposure per unit area and are commonly expressed in units of **gauss** (G) or **tesla** (T). One tesla equals 10,000 gauss. The **milligauss** (mG), which is one thousandth of a gauss, is normally used as a more practical unit for describing fields of relatively low intensities. As with electric fields, the magnetic field intensity diminishes rapidly with distance from the line. For some 500-kV lines, for example, the maximum magnetic field of about 140 mG directly under the line, will drop to about 3.0 mG at approximately 300 feet, depending on the amount of current in the line.

The average strength of 60-Hz magnetic fields encountered under transmission lines is up to one million times greater than the earth's natural magnetic field of the same frequency. The levels under a high-capacity line, however, may be comparable to the earth's static (non-ac) magnetic field which has an average value of about 500 mG. Most scientists believe that any comparison between this static natural magnetic field and the man-made 60-Hz alternating field is of little or no biological significance, since any biological effects of exposure to static magnetic fields will likely differ from those of their time-varying counterparts. Furthermore, all life forms have evolved in the presence of the earth's static electric and magnetic fields and are assumed to have adapted to them. Biological effects, as applied in the context of electromagnetic field studies, include all detectable disturbances of the biological system, whether or not they are readily identifiable as significant to the well-being of the animal or human in question.

Unlike electric fields, magnetic fields can penetrate most materials; therefore, trees, houses or other large objects cannot shield individuals from them. As a result, the ac magnetic fields from outside power lines can add to the average levels in nearby residences and contribute to the long-term residential magnetic field exposures that are not within the direct control of the building occupants.

Electric Currents Induced by Alternating-Current Magnetic Fields

The main difference between magnetic fields from ac power lines and the static fields from the earth or from dc lines is that magnetic fields from ac lines can induce voltages and currents within an exposed object while static fields cannot. The electric currents induced within an individual by ac magnetic fields are generally less than one-tenth of those induced by ac electric fields from the same source. These magnetically induced currents flow in loops within the body and are thus not conducted to the ground. The ac magnetic fields do not pose the same shock hazard associated with the presence of large, ungrounded objects in ac electric fields. Because of their unique mode of charge induction, ac powerline magnetic fields can, under certain conditions, induce strong currents in long, permanent conducting loops such as fences, wires and pipes that may run parallel to the line. The magnitude of the induced current will increase with the length of the conducting loop. The magnetic field component of powerline fields can induce currents that may be larger than those of the electric fields, although the induced voltages (in these conducting loops) would be lower than those induced in large objects by the electric field component. These magnetic field-related shock hazards can be minimized through standardized grounding practices.

Magnetic Fields in the Home and Workplace

Within the home and workplace, some common electrical appliances and devices can produce 60-Hz magnetic fields that may reach tens or hundreds of milligauss in their immediate vicinity. However, the intensity of magnetic fields decreases even more rapidly with distance from the source than that of electric fields. Average background 60-Hz magnetic field levels do not exceed 1.0 mG in the work or home environment. It is important to note that, while the individual may be exposed to high magnetic field levels during the short period the appliance or device is in use, these sources do not contribute significantly to the individual's long-term exposure. This means that most long-term involuntary exposures to 60-Hz magnetic fields above background levels are related to 60-Hz fields associated with power delivery systems. Therefore, any attempt to control involuntary long-term exposures to 60-Hz magnetic fields above background levels should be focused on the power delivery system.

ORIGIN OF CONCERN OVER HIGH-VOLTAGE TRANSMISSION

Before the introduction of extra high-voltage lines, which produce stronger electromagnetic fields, the most notable impacts of transmission lines (in addition to their well recognized shock hazards) were conflicts with other land uses and their impacts on the landscape's aesthetic appearance. Since their 60-Hz fields generally were assumed to be too weak to significantly affect biological tissue, relatively few people ever considered the possibility of health hazards from direct exposure to these fields.

A review of the available literature shows that public concern over the presence of these lines began to increase with the use of extra high-voltage transmission lines with stronger electric fields that produced the corona and other perceivable environmental effects.

Because of the low energy content of 60-Hz and other electromagnetic fields, scientists always have assumed that exposures would be unlikely to produce any immediate or acute effects. Any concern over exposures always has been related to possible health hazards from the cumulative effects of long-term field exposures, as usually happens with low-level exposures to toxic environmental agents. This concern was heightened in the mid-1960s by a report from Soviet scientists of health effects in humans with a history of long-term occupational exposure to the electromagnetic fields from power delivery systems. Since most of the perceivable effects of powerline fields have always been attributed to the influence of the electric field component, the reported symptoms in the exposed workers were attributed to electric field exposure. The most important of these symptoms included headaches, fatigue, sleep disorders, irritability and reduced sex drive. Because such symptoms normally are associated with effects on the nervous system, some scientists interpreted these findings as confirming the belief that the biological effects of exposure to 60-Hz and other ELF fields would most likely be produced in electrically sensitive tissues in the body.

In spite of significant flaws in the early Soviet studies, these findings were used as the basis for a Soviet 5 kV/m limit on some kinds of occupational exposure to electric fields. They also stimulated more human and animal studies by scientists throughout the world. Most of these studies have been based on the assumption that the biological effects of 60-Hz and other ELF fields would be produced through their common property of current induction. The most important of these studies can be grouped into three main categories, according to the types of information they were intended to provide: (1) Laboratory animal studies for indirect evidence of possible biological effects in exposed humans; (2) studies of humans exposed to ELF fields in the laboratory, home, workplace or from medical applications, for direct evidence of exposure-related symptoms; and (3) cell and tissue studies to identify mechanisms that may underlie any effects on humans or laboratory animals.

OVERVIEW OF LABORATORY ANIMAL STUDIES OF ELF FIELD EFFECTS

Well-controlled animal studies with weak 60-Hz and other ELF fields are complex and difficult to conduct reliably in laboratories. The complexity of these studies generally is recognized as the primary reason for their largely contradictory findings. Relating animal study results to possible effects in humans is also complicated in the case of ELF field studies by both the present inability to establish a basic unit of dose to the exposed animal and the inability to identify specific aspects or patterns of ELF electric or magnetic field exposures that might cause biological effects. Given these difficulties, the challenge to scientists has been to reliably detect the biological effects of field exposure and establish them as reliable evidence of a possible hazard to the health of the exposed animal. Such findings could then be used to establish the field strength limits deemed necessary for minimizing long-term human exposures to 60-Hz fields from all known sources.

Findings from Animal Experiments

Much of the early animal research on 60-Hz field effects was conducted with strong electric fields in order to improve the chances of detecting effects (as is usual for studies with harmful environmental agents). Unfortunately, the use of such strong electric fields often produced effects that were due to the animal's perception of the field, as well as its response to the microshocks, noise and vibration that the field produced. Many scientists believe that these secondary factors were largely responsible for early reports in the literature of 60-Hz field effects, including effects on behavior, cardiovascular function, fertility, growth and development, learning ability, hormone secretion, immune system and blood chemistry changes. As a result, most of the findings reported from these early experiments are considered unreliable for either establishing the possibility of ELF field effects at levels normally encountered by humans, or specifying health-protective limits on human exposures.

Using more advanced equipment and refined study procedures (mostly since 1979) scientists have established that weak power line fields, either electric or magnetic, can produce biological effects in exposed laboratory animals, when used alone or together. The most significant human health effects suggested by these findings are effects on biological rhythms, such as sleep-wake cycles, effects on the secretion of some hormones, and effects on learning ability and response to drugs. There presently is no agreement among scientists about how best to interpret these findings because they have generally been small, difficult to duplicate in other laboratories and are not generally associated with obvious injury to the exposed animal. The only agreement is that they are insufficient, at the present, for directly establishing long-term exposure to power line fields as capable of producing readily detectable signs of injury at the whole-animal level.

OVERVIEW OF TISSUE AND CELL STUDIES OF ELF FIELD EFFECTS

The nature of any molecular-level effects of ELF field exposure has been investigated in studies with isolated tissues and cells. Because of the difficulty in directly demonstrating the effects of ELF field exposure on the functioning of biological tissues, most tissue function studies with 60-Hz and other ELF fields have involved using strong fields to induce (or directly introduce) electric currents into the tissue in amounts comparable to normal physiological levels. These fields are much stronger than those from power lines, and were intended to produce demonstrable effects on electrically sensitive tissues, or effects that could be attributed to tissue heating in less electrically sensitive tissues.

The subtle effects of exposure to weak ELF fields were expected to be detected only by studying the effects of the applied weak field on the molecular-level charge movement that constitutes current flow. The most widely reported of these studies were conducted with brain and other electrically sensitive tissues. In these studies, field effects were monitored by watching for induced changes in the natural movement of calcium ions (current flow) across the cell membrane. ELF electric and magnetic field exposures were expected to produce the same types of effects on the molecular-level calcium ion movement that constitutes current flow.

Findings from Tissue Studies

Some of the 60-Hz field effects attributed to the induction of relatively large amounts of electric current in tissues include effects on the firing of individual neurons in nervous system tissue, effects on nerve signal transmission, muscle contraction and cell growth. These may result through the established mechanisms of electrical signalling or heat production associated with electric currents at normal physiological levels. It is reasonable to assume that the mechanisms underlying these strong field effects would differ from those that may be responsible for the effects of the weak power line fields. For these reasons, many scientists believe that the results of studies with strong fields are of limited value in predicting the possible health consequences of the subtle biological effects that could result from long-term exposures to weak fields.

Findings from Cell Membrane Studies

Detectable effects on trans-membrane calcium ion movement (calcium ion effects) have been reported by some scientists from exposure to both ELF electric and magnetic fields. Most of the studies have been conducted with ELF fields of frequencies other than 50-Hz or 60-Hz. The same types of effects, however, have also been obtained with 50- or 60-Hz electric and magnetic fields, when used alone or together. The results of these cellular-level studies are more controversial than those of studies with strong fields. This controversy is due primarily to the general difficulty in reproducing the same types of effects in other laboratories, even under what normally would seem like identical conditions in similar studies with harmful substances. This contributes to the present uncertainty about the reliability of such findings. Some scientists attribute this relative lack of reproducibility to the unusual sensitivity of these molecular-level effects to minor changes in experimental conditions. They believe that such findings would be easier to reproduce with a better understanding of the nature of the underlying mechanisms.

Implications of Results from Cell Membrane Studies

Many scientists have cited the calcium ion effects produced by ELF field exposures as evidence in support of the hypothesis that weak ELF fields can produce detectable biological effects. In the case of electric fields, the underlying mechanisms are thought to involve the magnification of field-induced electrical signals at the cell membrane. Such signal magnification is thought to allow for production of biological effects without tissue heating. For ELF magnetic fields, the magnification step has been proposed by some scientists as not involving electric fields but instead is thought to involve the ability of magnetic fields to directly interact with biological molecules in a way not assumed possible in the past. Many theories have been suggested to explain such direct magnetic field effects. At present, none have been generally accepted. Studies in this area are continuing.

If the concept of direct ELF magnetic field effects is proven true, it would mark a significant departure from all common assumptions about the nature of the physical mechanisms underlying the biological effects of electric and magnetic fields. It would also suggest the possibility that ELF magnetic fields can produce some types of biological effects that ELF electric fields cannot.

Of particular significance, with respect to the present heightened public concern, is the fact that these calcium ion effects were reported to have been produced with both ELF electric and magnetic fields of intensities that were lower, in some cases, than those from high-voltage lines and other common sources. Calcium ions have been shown to play important roles in bodily functions, including cell-to-cell communication at the molecular level, nerve impulse conduction, muscle contraction, hormone secretion and cell growth and control at the cellular level. Scientists believe that any agent that can disrupt calcium metabolism in a detectable way could pose a health hazard to humans. One of the most important of these diseases could be cancer, which involves the disruption of cell growth and control at the molecular level.

OVERVIEW OF STUDIES ON EFFECTS OF 60-HZ FIELDS ON HUMANS

All individuals are exposed to 60-Hz electric and magnetic fields to varying degrees. Studies of effects in humans should therefore be seen as an investigation of the effects of exposures above these "background" levels. A large number of the early human studies were of occupational exposure to strong fields. Others were conducted with human volunteers exposed to moderately strong 60-Hz fields for short periods of time. While the occupational exposure studies were intended to investigate the possible effects of long-term exposures, those short-term exposure studies with human volunteers were conducted to establish the differences in human response thresholds, in addition to the possibility of permanent effects from relatively intense, short-term exposures. The few epidemiological studies during this early period were conducted in countries outside the United States. In these surveys, investigators looked for increased complaints about general well-being as a sign of ill-effects from living near transmission lines.

Findings from Epidemiological Studies

The early occupational and human volunteer studies did not yield any evidence to support the earlier Soviet findings. The few residential study results published before 1979 also failed to produce any evidence of readily detectable field effects that could be reliably linked to living near high-voltage power lines. Many scientists have noted, however, that these early studies were not specialized enough to detect relatively rare diseases such as birth defects, reproductive effects and cancer. For this reason, new concern was raised when in 1979 cancer was reported from the first such epidemiological study in the United States deemed capable of detecting such rare diseases.

CHILDHOOD CANCERS AND 60-HZ MAGNETIC FIELD EXPOSURE

In the initial 1979 report, the increased cases of childhood cancers were attributed to elevated levels of exposure to magnetic fields, not from high-voltage lines, but from ordinary residential distribution and service lines. In these studies, actual magnetic field levels were not measured. Elevated or relatively low exposures were assumed from wiring code configurations as they relate to current (and therefore magnetic field) levels. Magnetic fields were implicated because only they could have penetrated the buildings in which the children lived.

The significance of these early findings lies mostly in their serving to establish 60-Hz magnetic field exposure as a potential factor in concern over high-voltage transmission lines, instead of the electric field component alone. Such a potential childhood cancer link was not found in many later studies conducted in the same way. Scientists, however, do not consider these negative findings as proof of a definite lack of such cancer-causing effects, since such studies are usually difficult to conduct satisfactorily. According to the present understanding of cancer development, any cancer resulting from specific exposure to a cancer-causing agent is expected to appear as the full-blown disease only long after the initiating exposure. The necessity for this long lag time accounts, in part, for the present difficulty in attributing specific cancers to exposure to any of the many carcinogens that an individual encounters during his or her lifetime.

Children were studied in these initiating surveys, not because of any expectation of their higher level of sensitivity to electro-magnetic field exposure, but because the incidence of cancer and several other diseases in children can be more readily identified from available medical records as unusual events, when compared to adults in whom these diseases are more common. The environmental consequences of any such observed diseases could then be explored further. It would be premature to conclude from these reported findings that children are more sensitive than adults to any cancer-causing or other health effects of 60-Hz magnetic field exposure. The magnetic field levels implicated in these early studies were less than 1.0 mG in some cases, and up to 7.0 mG in others. Some scientists, however, have interpreted results of the most complete of these early studies as suggesting that elevated risks of childhood leukemia could result from long-term exposures to magnetic field strengths of over 2.0 mG. Because of uncertainties about the correct interpretation of these survey findings, the accuracy of such conclusions cannot be established at the present, and must await clarifying studies.

Since the fields implicated in these cancer surveys were from ordinary distribution lines, it could mean that the present focus on high-voltage lines may be out of proportion to their contribution to the total human exposure to ELF magnetic fields at the reported levels. Findings from the most recent of these studies also have been interpreted by the authors as pointing to the possibility of the same link between childhood cancer and elevated 60-Hz magnetic field exposures, as assumed indirectly from residential wiring configurations. As expected, the same elevated childhood cancer risk was not found for electric field exposures from actual measurements of electric field levels. It also was not found when estimates of past magnetic field exposures were obtained from actual measurements of magnetic field levels in the environments of the children studied. This has been interpreted by scientists either as not supporting the initial assumption of a real cancer link or as pointing to the inability to assess possible effects of such magnetic field exposures in terms of their most biologically relevant features.

ADULT CANCERS AND 60-HZ MAGNETIC FIELD EXPOSURE

The evidence for a possible link between residential magnetic field exposures and adult cancer is much weaker than has been presented for childhood cancers, adding to the perception by some scientists and members of the public that children may be more susceptible than adults to the cancer-causing effects of exposure to power-line fields. In similar surveys of occupationally exposed adult individuals, past levels of 60-Hz field exposures were estimated, not from actual measurements, but from information about job categories. As with residential childhood exposure studies, adult exposures to 60-Hz fields have been most consistently linked with leukemia in the studies that found such effects. The link with brain cancer and the other relatively rare nervous system cancers has been reported to a lesser extent. Unlike the case with residential exposures, scientists have been unable to attribute any such occupational cancers to either 60-Hz electric or magnetic fields alone, because of the difficulty in estimating the types, magnitude and patterns of the past worker exposures that could have been responsible for the reported cancers. This and other uncertainties in these types of studies has limited the usefulness of their results for either establishing 60-Hz electric and magnetic fields as cancer-causing agents (acting alone or together) or estimating the magnitude of any such occupational cancer risks.

Magnitude of Cancer Risks Reported from Residential Cancer Surveys

A cancer-causing potential for 60-Hz magnetic field exposure cannot be reliably established or refuted on the strength of the available evidence. Some scientists have found it appropriate in the meantime to use preliminary estimates of the potential cancer risk as a way of defining the possible extent of any such cancer problem. Some of these scientists have interpreted results of the most complete of the early residential surveys as suggesting an approximate doubling of the risk of childhood leukemia in children assumed to have been exposed to elevated levels of powerline magnetic fields. However, these cancers are relatively rare and their incidence does not appear to have increased with the increasing use of electric power. The present concern should be seen as due partly to the fact that humans are commonly exposed to magnetic fields at some of the levels implicated in these cancer cases.

NEED FOR CAUTION IN ASSESSING CANCER-CAUSING POTENTIAL OF 60-HZ MAGNETIC FIELD EXPOSURE

Since powerline electric fields did not contribute to the involuntary, long-term, powerline field exposures in the studies already discussed, minimizing the effects of such long-term exposures would involve only the control of the magnetic field component. This would mark a major departure from the existing electric field-based approaches to field control. Given the extent of the measures necessary to maintain the low levels implicated in some of the cancer surveys, such changes in field control should be instituted only after establishing the cancer-causing effects of magnetic field exposure with a high level of certainty. Those scientists who have urged caution in assessing such a cancer potential have pointed to the difficulties in interpreting these survey results as well as the inability to establish such a cancer-causing potential from the results of animal and tissue experiments (as has been necessary in the past for most of the established human cancer-causing agents).

Even if a cancer-causing potential is suggested by results of animal cancer studies in the future, it still would be difficult to identify the biological mechanisms that might be responsible for such cancers. In seeking to identify a possible mechanism, some scientists have noted that ELF fields are generally recognized as too weak to damage genetic material and therefore unable to initiate cancer. This means that any cancers from magnetic field exposure would likely be due to the ability of magnetic fields to promote the development of cancers. The problem with this assumption is that the concept of promotion in cancer development is poorly understood. Furthermore, 60-Hz fields have not been established as cancer promoters from any of the cancer surveys or laboratory studies. At present, the relatively poor understanding of cancer development prevents scientists from regulating any of the established cancer-causing substances solely as cancer promoters. Until this concept is better understood and reliably established for the biological effects of 60-Hz magnetic fields, caution should be exercised in citing the potential for cancer promotion as the basis for modifying the existing electric field-based approach to electromagnetic field control.

As with findings from whole animal, tissue and cell studies of non-cancer ELF field effects in general, the reported cases of magnetic field-related childhood cancers did not increase with higher levels of exposure (as would be expected for all known carcinogens). This unusual pattern of effects could be interpreted either as support for the unique pattern of ELF field effects in general or as indicative of a lack of any real cancer-causing property. The appropriate conclusion must await the results of clarifying studies.

HOW FIELDS FROM TRANSMISSION LINES ARE PRESENTLY REGULATED AT THE CALIFORNIA ENERGY COMMISSION

Although significant health effects cannot be established for electric and magnetic exposure from the available information, it would be inappropriate to discount the potential for such effects on the strength of that evidence. The present California Energy Commission approach to 60-Hz field control, therefore, is to ensure that public exposures to fields from future transmission lines do not exceed those associated with the presence of existing lines. The strengths of these fields can be estimated, for any given line, using well established methods, and can be verified, as necessary, by actual measurements during operations. The present Energy Commission practice is intended to ensure that transmission lines are constructed and operated according to existing, technology-driven industry practices. Such practices have been established from experience as necessary for ensuring system safety and reliability while also minimizing its related shock hazards. The present 1.6 kV/m limit on the strength of the electric field at the edge of the line right-of-way is intended to maintain future exposures within existing levels.

When reviewing transmission line proposals, the Energy Commission staff evaluates the adequacy of the design criteria proposed for achieving this 1.6 kV/m field limit, while also ensuring system reliability and safety. The Energy Commission staff also assesses the adequacy of proposed grounding procedures as well as plans necessary for educating nearby residents on how to avoid the risks of electrocution and electric shocks.

Although the Energy Commission does not presently specify any limits on the strengths of magnetic fields from power lines, a typical Energy Commission Condition of Certification requires that actual magnetic field strengths be measured during operations. Measured values are required to be submitted, along with those of the electric field component, for comparison with design values. Average values have been less than 100 mG at the edge of the right-of-way for the 230-kV lines permitted by the Commission.

A few states (Montana, Minnesota, New Jersey, New York, North Dakota, Oregon and Florida) have sought to limit field exposure levels to those from existing lines by specifying limits on the strengths of electric fields, either within or at the edge of rights-of-way for new lines. In Florida and New York concern over potential health effects of magnetic field exposure has caused regulatory agencies to specify limits on the strengths of magnetic fields, in addition to the electric fields, from new lines. As with electric fields, these magnetic field limits were not based on established health effects but were intended mainly to limit magnetic fields from new lines to the lowest levels presently achievable with existing technology. These regulatory limits range from 150 mG to 250 mG at the edge of rights-of-way, depending on line voltage.

The Energy Commission staff believes the present available information does not justify establishing health-based limits on electric and magnetic fields from high-voltage power lines. Therefore, the staff recommends that the Energy Commission continue the use of the 1.6 kV/m safety-based limit for the electric field strength to minimize exposures in the vicinity of transmission lines. This value is within the range of 1.0 kV/m to 2.0 kV/m that has also been established for fields at the edge of rights-of-way in the few states with such requirements.

The line design and operating criteria necessary for achieving these electric field limits have proven adequate for protection against the shock and electrocution hazards associated with transmission lines. They also have been established in a way that minimizes other perceivable environmental effects of electric fields, such as noise and interference with radio and television reception. The Energy Commission staff believes that any future limits on magnetic fields from high-voltage lines should be established as part of an overall effort to minimize total public exposure to 60-Hz magnetic fields from transmission lines and other sources. Such control strategies should be based on a better understanding of the nature and magnitude of any health risks from exposure to these fields as they are presently encountered in the environment. This level of understanding does not exist at present.

While concerned individuals may act according to individual judgements to minimize both 60-Hz electric and magnetic field exposures that may be under their direct control, the steps necessary for such exposure reductions may not apply in the case of powerline fields exposure, which is largely beyond the control of the individual. If such actions are taken, they should be recognized as driven by the concern over the possibility of significant health effects. Because the probability of such effects has not been established from the available information, the appropriate extent of such reduction measures cannot be specified at the present.

Since the possibility of significant biological effects cannot be discounted for electric or magnetic field exposure at the present, staff recommends continued Energy Commission support for research on the potential health effects of electric and magnetic fields from all sources as a way of identifying the need for and the extent of any field reduction measures deemed necessary in the future. Staff also recommends the continuation of the present

Commission practice of siting power lines as far from populated areas as fiscally reasonable and that public concerns continue to be considered in the choice of line corridors.

RECOMMENDATIONS FOR FURTHER RESEARCH

Given that the present heightened concern is mainly over the potential for magnetic field-induced cancers, steps should be taken towards identifying the best ways to prevent exposures above existing levels without significant impacts on the existing power production and delivery system. As a preliminary step in this regard, staff recommends conducting surveys in California to establish typical strengths of both electric and magnetic fields from the existing classes of power lines. From such surveys, information should be obtained on the typical widths of line rights-of-way and the industry rationale for the choice of each line corridor. This should help identify line configurations that produce the lowest magnetic field levels while also minimizing field-related safety hazards. Given that the safety and reliability of such lines have been established from operating experience, these types of configurations could be recommended as an interim measure for future lines. Staff believes that any significant modifications to existing lines and related facilities would be premature at this time. Staff further recommends that the Energy Commission continue cooperating with other agencies and interested groups to promote public education about electromagnetic field effects in general. This should allow for an orderly citizen response to all concerns about electromagnetic field exposures within California.

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Electric and Magnetic Fields

UNDERSTANDING EMF

Electric and Magnetic Fields

Questions have been raised about the possible health effects of 60-Hertz (power frequency) electric and magnetic fields (EMF), which are found wherever you have electric power. This web site contains information that will help you understand the EMF issue, and the latest health studies.

- What is the US Government Doing?
- What Is California Doing?
- What Is Pacific Gas and Electric Company Doing?
- Pacific Gas and Electric Company Policies
- Q & A
- EMF Information on the Internet

Previous news items are also available for viewing.

ICNIRP EMF and RF Exposure Guidelines Published

3/31/98 - The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published its revised electric and magnetic field exposure guidelines for the general public and workers. They appear in the April issue of Health Physics. The revisions span frequencies from static to radio frequency fields and result from expert consultation worldwide.

Previous ICNIRP guidelines were issued in 1988 (RF), 1990 (50/60-Hz) and in 1994 (static fields). The 1998 guidelines supersede all of this earlier work. Their purpose is "to establish guidelines for limiting EMF exposure that will provide protection against known adverse health effects." They are not intended to protect against potential long-term health effects such as cancer, because "ICNIRP concluded that available data are insufficient to provide a basis for setting exposure restrictions."

The guidelines are based on two concepts: basic restrictions and reference levels. Basic restrictions are the restrictions on the effects of exposure. For power-frequency electric and magnetic fields, they correspond to induced current density. Reference levels correspond to the level of external fields applied. Usually, they are derived from the use of a mathematical model.

According to ICNIRP, "compliance to the reference level will ensure compliance with the basic restriction. However, whenever a reference level is exceeded, it is necessary to test compliance with the relevant basic restriction."

As in the 1990 guidelines, the basic restrictions at 50/60 Hz are:

- 10 mA/m^2, for workers
- 2 mA/m^2, for the general public.

Revisions to the 1990 power-frequency guidelines also entail notable differences:

- The reference levels are now frequency dependent, which means that they are different for 50 and 60 Hz.
- "Short term" and "For limbs" limits are no longer specified for occupational exposures; similarly, "Few hours per day" limits on public exposures are not specified in the new guidelines. For low-frequency range, ICNIRP now recommends that, "restrictions on current densities induced by transient or very-short term peak fields should be regarded as instantaneous values which should not be time-averaged."
- Guidelines for combined exposures are presented, as well as for contact current. For occupational exposure, the contact current maximum reference level is 1 mA and for the public, 0.5 mA. This is a factor of 10 below the generally-accepted "let-go" threshold".
- The new ICNIRP guidelines specifically "note" that "industries causing exposure to electric and magnetic fields are responsible for ensuring compliance with all aspects of the guidelines." For occupational exposures, "appropriate protective measures must be implemented when exposure in the workplace results in the basic restrictions being exceeded." For the general public, "the same measures [as for workers] can be applied whenever there is a possibility that the general reference levels might be exceeded."

The old and new power-frequency exposure guidelines are:

	1998				1990	
	50 Hz		60 Hz		50/60 Hz	
	Public	Workers	Public	Workers	Public	Workers
ELECTRIC FIELD	5 kV/m	10 kV/m	4.2 kV/m	8.3 kV/m	5 kV/m (up to 24 hours)	10 kV/m (whole work day)
					10 kV/m (few hours)	> 30 kV/m (few hours)
MAGNETIC FIELD	0.1 mT [1 G]	0.5 mT [5 G]	0.083 mT [0.83 G]	0.42 mT [4.2 G]	0.1 mT [1 G] (up to 24 hours)	0.5 mT [5 G] (whole work day)
					1 mT [10 G] (few hours)	5 mT [50 G] (few hours) 25 mT [250 G] (for extremities)

The 1990 power-frequency guidelines are in effect in various countries either by actions of national health agencies or by voluntary implementation by industries. A proposal is currently under development by the European Commission, and will be based on the ICNIRP guidelines.

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International Commission on Non-Ionizing Radiation Protection. **Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 Hz).** *Health Physics* 1998 April; 74 (4):494-522.

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Original Contributions

ELECTRICAL WIRING CONFIGURATIONS AND CHILDHOOD CANCER

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An excess of electrical wiring configurations suggestive of high current-flow was noted in Colorado in 1976–1977 near the homes of children who developed cancer, as compared to the homes of control children. The finding was strongest for children who had spent their entire lives at the same address, and it appeared to be dose-related. It did not seem to be an artifact of neighborhood, street congestion, social class, or family structure. The reason for the correlation is uncertain; possible effects of current in the water pipes or of AC magnetic fields are suggested.

electricity; electromagnetic fields; leukemia; neoplasms

Electrical power came into use many years before environmental impact studies were common, and today our domestic power lines are taken for granted and generally assumed to be harmless. However, this assumption has never been adequately tested. Low level harmful effects could be missed, yet they might be important for the population as a whole, since electric lines are so ubiquitous. In 1976–1977 we did a field study in the greater Denver area which suggested that, in fact, the homes of children who developed cancer were found unduly often near electric lines carrying high currents.

In our modern power delivery systems, high-tension wires carrying current at voltages up to several hundred kilovolts (kv) deliver power to distribution substations where the voltage is stepped down, resulting in proportionately higher current in the medium-voltage (usually 13 kv, wire-to-wire) primary lines. These latter radiate out from the substation to distribute power through a neighborhood. Then, at the local transformer, the voltage of the primaries is stepped down once more to produce the 240 volt current which is carried along the secondary wires to service drops which bring the power to the customer's house. The current flow will always be greatest in the wires directly issuing from the substation or the transformer. At these points the voltage has been stepped down and "transformed" into current. And it was particularly homes close to these transforming points that were over-represented among our cancer cases.

Because our findings appeared to relate to high current rather than voltage, we looked into the magnetic fields induced by current flow. Magnetic fields penetrate the human body (and buildings, etc.) readily. They are not easily shielded, but

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Abbreviations: AC, alternating current; HCC, high-current configuration; Hz, hertz; LCC, low-current configuration.

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TABLE 1

Daytime measurements of 60 Hz magnetic fields (in RMS gauss) in Colorado in 1976–1977

	75 cm above ground, under wires					75 cm above ground over buried plumbing which serves:	
	Large primaries (N = 64)*	High tension (N = 22)*	Thin primaries (N = 51)*	First span† secondaries (N = 84)*	Second span† secondaries (N = 73)*	First span† homes (N = 160)*	Second span† homes (N = 104)*
Maximum measurements	.035	.020	.008	.005	.004	.013	.008
Median measurements	.007	.0033	.0022	.0017	.0009	.0015	.0010
% > .0030 gauss	73.4%	54.5%	35.3%	20.2%	6.8%	22.5%	10.4%

* N = no. of sites studied.

† First span secondaries are those nearest the transformer; second span wires are further "down-stream" from the transformer (see text). First- and second-span homes are homes near the respective types of secondaries.

they can be cancelled by balancing the currents that produce them. Such cancellation occurs in electric wires, where the return current tends to balance the supply current. However, the cancellation is imperfect because the wires are often separated in space and, more importantly, because some of the return current does not flow through the wires at all, but returns instead through the ground, and particularly through the plumbing system to which most urban electrical systems are grounded at each house.

This results in a locally imbalanced current, both in the distribution wires and in the plumbing. That imbalanced current produces a 60 hertz (Hz) magnetic field which, though small (table 1), is nonetheless orders of magnitude larger than the 60 Hz field found in nature (about 10^{-8} gauss (1)). The ground-current flows not only in the street plumbing, but also through the pipes in the house. Current which enters the plumbing at one house can flow through several homes before it returns to the distribution wires, because the plumbing provides a continuous, low-resistance path between houses.

The ground-current produces a magnetic field within the house (localized near the plumbing) which appears to be related roughly to the types of wiring configurations nearby (see table 1). This relationship between wires and plumbing is to be expected because, other things being equal, the greatest unbalanced current tends to occur where the total current in the wires is greatest, and the unbalanced portion of the current must detour through ground paths such as the nearby earth and plumbing.

A number of household appliances and power tools also produce magnetic fields, but in comparing the fields from appliances with those from power lines, it is important to note that most appliances present approximately a magnetic dipole source, with fields falling off roughly as the inverse cube of the distance, while a wire with unbalanced current will have a field falling off only as the inverse of the distance. For instance:

	1 cm	15 cm	1 m	3 m	30 m
Electrical drill	13 gauss	.12	.001	<.0001	<.0001
Electrical range (4 burners on high)	1 gauss	.04	.0015	<.0001	<.0001
Wire carrying 15 amperes	3 gauss	.2	.03	.01	.001

In the literature there are listings of 60 Hz magnetic fields produced by appliances which appear quite high. These should not be misinterpreted: They are apparently due to the use of measurements taken "as close as possible" to the appliance. Our measurements indicate that magnetic-field exposure to the whole body from normal use of household appliances rarely exceeds .001 to .002 gauss for any extended period, while the ambient fields in a house due to nearby distribution wires or plumbing may sometimes reach those levels, or more, for hours or days at a time. If magnetic-field exposure is responsible for our finding, it may be that, above some minimum threshold, duration of continuous exposure is more important than strength of exposure *per se*. There is some precedent for such a threshold effect in the literature on direct current (DC) magnetic fields (2).

Our field measurements showed that, on the average, those types of wires associated with cancer in our study exhibited high magnetic fields (compare tables 1 and 3). However, the readings varied considerably over time; and because our observations were all made in good weather and during work-day hours when domestic current is minimal, because current-flow had most probably altered since the time of our subjects' residency, and because it was rarely feasible to go close to the house to take a measurement, no attempt was made to take systematic measurements at our study homes. Rather this study is based on the *potential* current flow suggested by different wiring configurations (nearness and size of wires, closeness to origin of current, etc.).

Experimental work on physiologic effects of low-level, extremely low frequency magnetic fields is limited. It has been recently reviewed (3). Among the positive reports are decreased mitosis in slime molds (4), decreased growth of seedlings (5) and chicks (6), decreased *in vitro* growth of embryonic tissue cells (7), and a number of behavioral and physiologic changes in rats (8). All these results are for fields considerably higher (.5−30 gauss) than the 60 Hz fields generally found near power lines; however, the findings reported often appear to be unrelated to dose over the range studied. Prolonged exposure to the .001−.1 gauss range most pertinent to wiring effects has not been explored experimentally.

Two studies suggest that a relatively strong AC (alternating current) field may interfere with growth of implanted tumors in animals (9, 10) except where the tumor tissue is exposed to the field *before* implantation. In this latter condition, tumor "takes" were increased (9).

To explore occupational exposure to AC magnetic fields, we analyzed data from a USPH publication on occupation by cause of death (11). All those occupational categories which seemed likely to include men frequently exposed to AC magnetic fields were grouped together and found to have, as a group, a cancer rate significantly higher than the total population. The "exposed" categories included: power station operators; stationary engineers; linemen and servicemen, telephone, telegraph and power; motor-men, street, subway and elevated railway; electricians; and welders and flame cutters. The standard mortality ratio for cancer for these categories combined was 115, a significant increase over the ratio of 100 for all occupations ($\chi^2 = 24.5, p < .0001$). For other "natural causes" of death this same group showed a standard mortality ratio of 102 ($\chi^2 = 1.8$, not significant). While this crude analysis in itself proves nothing, it underlines the fact that the harmlessness of AC magnetic fields is still unproven.

Methods

Our cases consisted of persons dying of cancer in Colorado before age 19 in the years 1950–1973, who also had a Colorado birth certificate. Only subjects with addresses occupied from 1946–1973 in the greater Denver area were used. Controls for these cases consisted of next Denver-area birth certificates, chosen both from the files organized by birth-month and county (*file 1 controls*), and from the alphabetical search-listings, which list all Colorado births alphabetically within several wide spans of years: 1939–1958, 1959–1969, and 1970–1974. These latter were called *file 2 controls*. If the next birth certificate was that of a sibling it was skipped.

Birth addresses were those listed on the birth certificates. "Death" addresses were obtained for both cases and controls by searching for parents in city directories for the two years just prior to diagnosis of the case. For cases who could not be traced, the address on the death certificate was used. For controls, if the *file 1 control* could not be traced, the *file 2 control* with most similar birth date who could be traced was used. There were no significant differences in the proportion of "high-current configurations" (HCC's as defined below) shown by the *file 1 controls* used (21 per cent HCC), the *file 2 controls* used (23 per cent HCC) and the unused extra controls (25 per cent HCC), so it seems unlikely that our method of selecting controls biased our findings.

In all, 344 cases met our criteria. Thirty-nine of these were born before 1946, and 33 had a birth address which was lost because it had been demolished or was not adequately specified. Only death addresses were analyzed for these 72 cases and their respective controls. Similarly, 16 cases had no usable death address, so only birth addresses were used for these cases and their controls. Table 2 gives a summary of how many persons and how many addresses were available for cases and controls.

The procedure was simply to visit the birth and "death" addresses of each case and each control, and to draw a small map of the electrical wires and transformers in the vicinity. Primary (13 kv) wires were categorized as either "large-gauge" (built

Table 2

Distribution of persons and addresses available for analysis, for cases and controls, in a study of electrical wiring configurations and childhood cancer in Colorado in 1976–1977

Residential status	Cases		Controls	
	Persons*	Addresses*	Persons	Addresses
Stable	109	109	128	128
Moved, birth and death addresses available	147	294	128	256
Only birth address	16	16	16	16
Only death address	72	72	72	72
Totals	344	491	344	472

* Tables 3, 4, and 9 present data on total addresses, tables 5, 6, 7, 8, and 10 present data on total persons. Tables presenting data on persons are generally broken into total persons with an available birth address ($N = 272$) and totals with an available death address ($N = 328$).

to carry high currents) or "thin" depending on whether they were clearly larger than the secondary wires. Distances were measured from the part of the house nearest the wires to the wires, with a rollatape.

Three types of homes, because of their proximity to high-current wires, were considered to have "high-current configurations" (HCC's): 1) homes less than 40 meters from large-gauge primaries or an array of six or more thin primaries; 2) homes less than 20 meters from an array of 3–5 thin primaries or from high-tension (50–230 kv) wires; and 3) homes less than 15 meters from "first span" secondary (240 volt) wires. *First span secondaries* were defined as those secondaries which issued directly from the transformer and had not yet lost any current through a service drop occurring beyond the transformer pole. The span of secondary wires separated from any transformer by at least one intervening service drop (ignoring those drops directly attached to the transformer pole) were called *second span secondaries*. First span wires will have more current running through them than second span wires because the first span must carry current for all the drops that mark its distal end *plus* whatever current the second span requires.

All other configurations were considered "low-current configurations" (LCC's). In addition, where first span wires could be seen to be carrying current to no more than two single family homes, on the average (on both sides of the block), those wires were called *short first span* wires and, because they carried current for so few homes, they were always considered LCC's, regardless of distance. Houses situated beyond the pole at the end of a secondary line ("end poles" in tables 3 and 4) were considered the extreme example of LCC homes, because they had no distribution wires at all running past them.

Since the Denver area has been growing fast, many new primary wires have been installed to accommodate increased power demands. Many of these new installations are of a style easily distinguished from older wires. For addresses occupied before 1956 (20 years prior to our field work) we noted that only 59 per cent of the primary wires found near our study homes were of the "old fashioned" types which had been in use at the time of our subjects' occupancy. (Actually 71 per cent of the primary wires observed near pre-1956 case addresses were "old fashioned," but only 49 per cent of the wires near pre-1956 control addresses were of the older types that could have been in use in those early years.) Where the more modern wiring was observed, we could not tell whether it represented new installations or replacement wiring, but we did know that it could not have been there in its present form in the pre-1956 years. Therefore, we decided to treat all primary wires seen near homes occupied before 1956 as unreliable, and to code such homes strictly according to their more stable secondary-wire configurations.

This adjustment did not critically affect our findings. Proximity to primary wires was most strongly associated with cancer for recent addresses, and the association (as expected) was weaker in the older data. But the association was still significant when all years were considered and no adjustments made: For birth addresses, 31 per cent of the 272 cases and 22 per cent of the 272 controls had homes near (unadjusted) primaries, a difference significant beyond the .025 level by Chi-square. For death addresses the figures were 29 per cent of 328 cases and 19 per cent of 328 controls, significant beyond the .01 level.

Results

General configurations. Table 3 shows how many cancer and control homes exhibited the various wiring configurations. It can be seen that the most striking difference between cases and controls was found for subjects who had only one address from birth to death. This might be because, for subjects who moved, the effects of configurations at one address were diluted by effects of configurations at other addresses.

Table 4 indicates that the greater the exposure to current expected from a given wiring configuration, the greater the excess of cancer found in homes where that configuration was observed.

Type of cancer. The breakdown according to type of cancer (table 5) shows a fairly similar excess of HCC's in cancer cases for all categories but one, the death addresses of cases with "other tumors." Such a wide association with different types of cancer is not characteristic of known carcinogens such as ionizing radiation; thus the broad association observed here suggests that the HCC-cancer relationship may not be a causal one. The most likely alternatives are that it is due to some artifact, or that it reflects some effect of HCC's on the body's general ability to resist cancer.

Onset age. As table 6 shows, the HCC-cancer relationship was observed in both young and older subjects. The fact that the relationship held for the birth as well as the death addresses of older subjects would seem to suggest that the effects of HCC exposure can be long delayed. However, a closer look at the data showed that

TABLE 3

Wiring configurations at the homes of cancer cases and controls, Colorado, 1976–1977

Type of configuration*	Stable residence: Case	Stable residence: Control	Moved residence: Birth address: Case	Birth address: Control	Death address: Case	Death address: Control
Substation <150 m†	2	0	2	0	2	0
Large primaries <40 m	14	6	14	13	38	17
High tension <20 m	0	0	0	1	1	0
Thin primaries <20 m	13	10	11	4	17	11
1st span secondaries <15 m	19	10	26	11	23	20
Total HCC's	48	26	53	29	81	48
1st span secondaries >15 m	33	43	53	57	66	51
"Short" first span wires	6	11	9	4	11	19
Second span secondaries	20	33	40	40	51	66
End poles	2	15	8	14	10	16
Total LCC's	61	102	110	115	138	152
(% HCC)	(44.0)	(20.3)	(32.5)	(20.1)	(37.0)	(24.0)
	$\chi^2 = 14.4$		$\chi^2 = 5.4$		$\chi^2 = 7.6$	
	$p < .001$		$p = .02$		$p < .01$	

† All six cases within 150 m of a substation were also less than 40 m from large primaries.
* HCC = high-current configuration; LCC = low-current configuration.

TABLE 4

Cancer related to the amount of current expected from different wiring configurations, Colorado, 1976–1977

Wiring configuration	Expected current	Total addresses: Case	Total addresses: Control	% cases
Substation	Very high	6	0	100.0
Other HCC	High	176	103	63.1
LCC except end poles	Low	289	324	47.1
End poles	Very low	20	45	30.8

23 (66 per cent) of the 35 older cases born at HCC's were also living at a HCC (usually the same address) within two years of their cancer onset. Only three (20 per cent) of the 15 older controls born at HCC's were living at a HCC within two years of the "death" date. Thus the HCC-cancer relationship observed in the birth addresses of older subjects can be largely attributed to a HCC residence near the time of cancer onset, and there is no need to posit a long-delayed effect of HCC's.

Urban-suburban differences. Since cancer may show a different incidence in urban and non-urban areas, it seemed important to rule out the possibility that a difference in urbanization between cases and controls was the significant variable in this study, and simply carried the HCC differences with it, spuriously. This seemed unlikely, intuitively, because the field work was done one neighborhood at a time, and on none of the 22 days of field work did the individual day's results fail to show a preponderance of HCC's in the case addresses.

A more formal survey shows that, although there was a slight excess of suburban addresses in the controls, it was not statistically significant. Furthermore, the cases showed more HCC's than the controls independently in three areas: in old Denver, in the more recently developed Denver areas (as estimated from a planning department publication (12)), and in the Denver suburbs (see table 7).

Socioeconomic class. The literature reports an excess of leukemia in families of higher socioeconomic class (13). Our data, dealing with all types of childhood cancer, show only an insignificant trend in this direction. It seemed possible that our method of choosing controls might have biased our control group against lower-class controls, since only controls who could be traced in directories were used. However, a check on the discarded controls showed that upper and lower

TABLE 5

Wiring configurations and type of cancer, Colorado, 1976–1977

Residence	Type of wiring configuration*	Leukemia Case	Leukemia Control	Lymphoma Case	Lymphoma Control	Nervous system tumors Case	Nervous system tumors Control	Other Case	Other Control
Birth address	HCC	52	29	10	5	22	12	17	9
	LCC	84	107	21	26	35	45	31	39
	(% HCC)	(38.2)	(21.3)	(32.3)	(16.1)	(38.6)	(21.1)	(35.4)	(18.7)
Death address	HCC	63	29	18	11	30	17	18	17
	LCC	92	126	26	33	36	49	45	46
	(% HCC)	(40.6)	(18.7)	(40.9)	(25.0)	(45.5)	(25.8)	(28.6)	(27.0)

* HCC = high-current configuration; LCC = low-current configuration.

class controls were discarded equally often, while Class III controls were somewhat disproportionately retained. There was no significant difference in the per cent of discarded and retained controls showing a HCC and, as table 8 shows, the association between HCC's and cancer was observed within each social-class group. It therefore seems unlikely that some spurious relationship to social class explains our findings.

Family pattern. The literature reports an excess of first siblings and older mothers among children with leukemia (14). In our total sample of childhood cancer cases, a trend towards both more first siblings and older mothers was noted, but neither was statistically significant. Furthermore, the HCC-cancer relationship holds to approximately the same degree within each maternal-age and sibling-order category tested, so we see no clue in these variables as to why the relationship between HCC's and cancer should exist.

Traffic congestion. A recent report (15) suggests that cancer may occur unduly often near heavy-traffic routes. Our data did show a mild excess of case-addresses near such routes; case-addresses were more likely than control-addresses to be found within 40 meters of streets having a daily traffic count of 5000 vehicles or more on the 1960 Department of Highways traffic map. However, once again, a significant excess of HCC's in cancer cases was found independently for addresses on heavy-traffic routes and for other addresses. (For heavy-traffic routes, 53 per cent of 74 case-addresses showed HCC's against 30 per cent of 48 control-addresses; for other locations, 35 per cent

TABLE 6
*Wiring configurations and cancer onset age, Colorado, 1976–1977**

Residence	Type of wiring configuration†	Cancer onset 0–5 years		Onset 6–18 years	
		Case	Control	Case	Control
Birth address	HCC	66	40	35	15
	LCC	103	129	68	88
	(% HCC)	(39.1)	(23.7)	(34.0)	(14.6)
Death address	HCC	68	37	61	37
	LCC	105	136	94	118
	(% HCC)	(39.3)	(21.4)	(39.4)	(23.9)

* Case-control differences are significant by Chi-square ($p < .01$) for each category in the table.
† HCC = high-current configuration; LCC = low-current configuration.

TABLE 7
*Wiring configurations in different neighborhoods of cancer cases and controls in Colorado in 1976–1977**

Residence	Type of wiring configuration†	Old Denver		Newer Denver		Suburban	
		Case	Control	Case	Control	Case	Control
Birth address	HCC	42	26	27	9	32	20
	LCC	77	91	40	44	54	82
	(% HCC)	(35.2)	(22.2)	(40.3)	(17.0)	(37.2)	(19.6)
Death address	HCC	49	24	35	19	45	31
	LCC	62	77	49	55	88	122
	(% HCC)	(44.1)	(23.8)	(41.7)	(25.7)	(33.8)	(20.3)

* Case-control differences are significant by χ^2 ($p < .05$ or better) for each category in the table.
† HCC = high-current configuration; LCC = low-current configuration.

TABLE 8

Father's occupational class at subject's birth, related to wiring configurations at birth residences of cancer cases and controls, Colorado, 1976–1977*

Type of wiring configuration†	Classes I and II		Class III		Classes IV and V	
	Case	Control	Case	Control	Case	Control
HCC	19	9	49	30	33	16
LCC	34	41	98	111	39	65
(% HCC)	(35.8)	(18.0)	(33.3)	(21.3)	(45.8)	(19.8)
	$\chi^2 = 3.2$		$\chi^2 = 4.7$		$\chi^2 = 10.8$	
	$p < .10$		$p < .05$		$p \cong .001$	

* Class categories follow the schema provided in "Mortality by Occupation Level and Cause of Death," Vital Statistics Special Reports 53, #5, 1963, and are as follows: Class I: Professional. Class II: Technical, Administrative and Managerial. Class III: Clerical, Sales, and Skilled Workers. Class IV: Semi-skilled Workers. Class V: Laborers.

† HCC = high-current configuration; LCC = low-current configuration.

TABLE 9

Increase of cancer cases within 40 meters of heavy-traffic routes, as related to the presence or absence of nearby primaries, Colorado, 1976–1977*

Type of subject	Near primary wires		Not near primaries	
	Traffic routes	Other locations	Traffic routes	Other locations
Cases	32	84	42	333
Controls	9	53	39	371
(% cases)	(78.0)	(61.3)	(51.9)	(47.3)
	$\chi^2 = 3.3$		$\chi^2 = 0.4$	
	$.05 < p < .10$		Not significant	

* "Nearby" primaries here means that the primaries were near enough to the house to qualify it as a high-current configuration (HCC).

of 417 case-addresses showed HCC's against 21 per cent of 424 control-addresses).

In fact, the excess cancer we found on heavy-traffic routes seems to be related to the frequent presence on such routes of primary wires carrying especially high currents. Table 9 shows that the excess of cancer cases on high-traffic routes occurred to a significant extent *only* where primary wires were nearby.

Sex distribution. Many cancers, including leukemia, occur more frequently in males than females. This is reflected in our data where 57 per cent of our cases were males, as compared to 49 per cent of the controls. The excess of HCC's among cases was significant for both males and females when the sexes were analyzed separately, but the trend was stronger in the males; 51 per cent of the 197 male cases had a HCC at their birth- or death-address, or both, while 45 per cent of the 147 female cases had such an address. This compares with only 28 per cent of the 168 control males and also 28 per cent of the 176 control females.

It is interesting that significant male excess among our cancer cases appeared to be confined to two categories: 1) cases whose birth address had a lower current configuration than the death address, and 2) cases with stable address who developed cancer after at least one year of postnatal life at a residence situated near primary wires (table 10).

Because these two categories were chosen from a number of ways we might have categorized the data, they must remain suspect until a replication confirms or

TABLE 10

Sex distribution of cancer cases in a study of electrical wiring configurations and childhood cancer in Colorado in 1976–1977

Type of address	Males	Females	% male	Significance*
Birth address had lower current configuration than death address	28	14	66.7	$\chi^2 = 4.0, p < .05$
Stable residence at HCC† involving primary wires	22	4	84.6	$\chi^2 = 11.1, p < .001$
Other cases with any HCC address	56	48	53.8	$\chi^2 = 0.5$, not significant
Other cases with no HCC address	91	81	52.9	$\chi^2 = 0.5$, not significant

* An expected value of 50 per cent male was used to calculate the chi-squares.
† HCC = high-current configuration.

disputes them. However, we chose these categories for a reason: We hypothesized that males might be excessively susceptible to HCC's at all ages, including prenatally. (It is of interest here that male rats appear especially susceptible to experimental magnetic fields (8, p. 182) (16), as do embryos (17).) If males are more susceptible, they might frequently be aborted when pregnancy occurs at a HCC, but pregnancy at a LCC would allow the most susceptible males to be born and then to develop cancer later when exposed to a situation with higher current nearby. This hypothesis is consistent with the male excess in category 1 above.

Category 2 is presumed to provide a potentially similar situation: Where primary wires are found running near a house (in 1976), it is always possible that these wires were first installed or were "beefed up" at some time *after* the subject's birth. Or if they were present all along, the current they carry may sometimes have increased with time. If any of these things happens, the postnatal current flow near the house will be increased over the prenatal flow, even without a change in residence. Should this happen, the susceptible male who escaped abortion during pregnancy might develop cancer, and this would explain the male excess in category 2.

Substations. Power carried at higher voltage is stepped down to produce increased current at two points in our electrical distribution system: at the distribution substation, and again at the neighborhood transformers. As indicated, cancer cases were found in excess close to the "first span" wires issuing from the transformers. An even stronger trend was found for substations.

None of the 702 control addresses visited (including our unused extra controls) was within 150 meters of a substation. This is to be expected since probably less than one home in 1000 in the Denver area is that near a substation. What is surprising is that six of 491 case addresses were found within 150 meters of a substation and, in each case, less than 40 meters from the large primary wires issuing from that substation. These six are shown in table 3. Each cancer case had lived at the substation address within three years or less of his illness. Although these numbers are small, they are striking.

Blind studies. It should be noted that our Denver-area study, being exploratory, was not done blind. This could lead to error, although our observations were reasonably unambiguous. To check just how reliable our coding was, an assistant observed and coded 70 case and 70 control addresses randomly chosen from those previously coded by the principal investigator. The assistant did not know the case-control status of the addresses she coded. Her coding agreed with ours in 128 (91 per cent) of the 140 instances. In five of the 12 instances of disagreement, the assistant's judgment favored the hypothesis of a HCC-cancer correlation, while ours did not. In seven instances, the reverse was true.

Also, a blind study was done (for birth addresses only) in Colorado Springs and Pueblo. This study showed the same correlation as the Denver study, similar in degree but less significant due to the smaller numbers; 32 per cent of the 65 cases and 18 per cent of the 65 controls showed HCC's. The correlation was strongest for cases with onset before six years of age, possibly because many of the older cases had been gone from their birth addresses for many years before their cancer onset.

Discussion

It is not clear *how* residence near a HCC might affect the development of cancer, but several possibilities should be considered:

1) Some association of both cancer and HCC's with a third factor may spuriously account for our correlation. Although we found no indication of such a third factor in our analyses of social class, neighborhood, congested streets, or family make-up, the possibilities have not been exhausted.

2) The magnetic fields produced by wire currents may somehow directly "cause" cancer. There is, however, no independent evidence or theoretical understanding which seems to support this possibility. The evidence concerning mutagenic effects of extremely low frequency magnetic fields, for instance, is ambiguous, but probably negative (18).

3) Carcinogenic activity may be associated with some *indirect* effect of the HCC's. For example, fields around power lines might change the distribution of some ambient environmental carcinogen, such as particles which emit ionizing radiation. (However, the fields near domestic wires are too weak to make this seem probable.) Or the increased current flowing in the plumbing might locally affect the drinking water. (There is often a small amount of lead in copper water pipes, for instance, due to imperfect soldering. And lead in the water supply is correlated with cancer, at least geographically (19). However, it is not clear that AC current in pipes could affect this small amount of lead enough to make a difference.)

4) AC magnetic fields might affect the development of cancer indirectly, through some effect on physiologic processes. It is conceivable, for instance, that contact-inhibition of cellular growth, or the basic immune reaction of recognizing "self" from "not self," involves electrical potentials occurring at cell surfaces. Against an electromagnetic background different from that provided during evolution, any such cell mechanism might be altered.

Whatever the basis for our observed correlation, it should be emphasized that, although the risk of cancer appears to be increased for children living near HCC's, it is rarely increased by a factor of more than two or three. Therefore, if in the general population one child in 1000 is likely to get cancer before age 19, no more than two or three in 1000 living near a HCC would be expected to get it. The practical significance of the correlation, if any, lies in the high prevalence of HCC's, not in any very high risk posed by most HCC's.

References

1. Polk C: Sources, propagation, amplitude and temporal variation of extremely low frequency (0–100 Hz) electromagnetic fields. *In* Biological and Clinical Effects of Low Frequency Magnetic and Electric Fields. Edited by JG Llaurado, A Sances Jr. Springfield, IL, Charles C Thomas, 1974, pp 21–48