APPENDIX H

ELECTROMAGNETIC FIELD MODELING

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APPENDIX H-1

ELECTROMAGNETIC FIELDS BACKGROUND INFORMATION

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ELECTROMAGNETIC FIELDS BACKGROUND INFORMATION

Electromagnetic fields (EMFs) are electric and magnetic fields naturally created by electric charges. Electric fields result from the strength of the electrical charge, its voltage, while magnetic fields result from the motion of the charge, its current. Electric fields are easily shielded and may be weakened, distorted, or blocked by objects such as earth, trees, and buildings. Magnetic fields are not as easily blocked. The intensity or strength of an electric field in a location is measured in volts per meter (V/m) or in kilovolts per meter (kV/m). The intensity of a magnetic field is measured in gauss (G) or tesla (T). Both electric and magnetic fields decrease as the distance from the source increases. (California Department of Health Services, Frequently asked questions, 2012)

Public concern over EMFs began in the 1970s and 1980s, after published epidemiological studies showed a slight increase in the incidence of cancer in groups of people living or working near low-voltage, high-current electrical distribution and telephone lines. These studies related the increase to high magnetic fields created by the lines. Additional studies to measure the effects of EMFs on public health conducted by industry, federal and state governments produced sometimes conflicting and inconclusive results.

Transmission and distribution lines, electrical wiring, motors, appliances, and other electrical devices produce low-frequency (60 Hertz in North America) EMFs in the immediate vicinity of power lines and all other electrical devices. Magnetic fields generally fall to background strengths at distances of 50-300 meters from high voltage power lines (IARC 2002). Table 1 shows the strength of magnetic fields from common household appliances at distances of 1 to 3 feet from the appliance. (California Electric and Magnetic Fields Program, 1999)

Research on Potential Health Impacts

In the 1990s, the California Public Utilities Commission (CPUC) began to examine the potential harmful health effects of EMFs caused by electric utility power systems. The CPUC and California Department of Health Services (DHS) reviewed studies concerning EMF exposure from power lines, appliances, and other sources. The CPUC established the California EMF Research, Education, and Technical Assistance Program under the guidance of the DHS to provide technical information and assistance to public policy-makers. The CPUC currently advocates a "low cost" approach to managing EMF, which minimizes EMF exposure when it is practical and inexpensive to do so. One example of a low cost measure to manage EMF is transposed phasing, the arrangement of the multiple bundles of wire carried on transmission poles in opposite order on either side of the pole. This arrangement results in a magnetic field that decreases quickly with greater distance from the line (IARC 2002). Due to the lack of conclusive evidence on EMF as carcinogenic, the State of California has no current regulations governing EMF exposure. (California Electric and Magnetic Fields Program, 1999) Appendix H-1-2 contains a short factsheet on EMF radiation prepared by the California Electric and Magnetic Fields Program.

Table 1
EXAMPLES OF MAGNETIC FIELDS AT SPECIFIED DISTANCES FROM APPLIANCE SURFACES

	Magnetic Fields in Milligauss (mG)	
Household Appliance	**1-foot Distance**	**3-foot Distance**
Coffee Machine	0.09-7.30	0-0.61
Vacuum	7.06-22.62	0.51-1.28
Dishwasher	4.98-8.91	0.84-1.63
Microwave oven	0.59-54.33	0.11-4.66
Mixer	0.49-41.21	0.09-3.93
Computer Monitor	0.20-134.7	0.01-9.37
Hairdryer	0.1-70	0.1-2.8
Printer	0.74-43.11	0.18-2.45
Toaster	0.29-4.63	0.01-0.47
Portable Heater	0.11-19.60	0-1.38
Refrigerator	0.12-2.99	0-0.01-0.60

Source: California Electric and Magnetic Fields Program, DHS 1999

In 1998, a work group formed by a federal program that studied this issue classified EMF as a "possible human carcinogen" for childhood leukemia, meaning that the group believed that EMF might increase the risk of childhood leukemia but was not sure. That program's final report states that "[power frequency] ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard." (California Electric and Magnetic Fields Program, 1999)

In 2002, the International Agency for Research on Cancer (IARC), part of the World Health Organization, conducted a comprehensive review of the evidence for harmful health effects of EMFs, both from power lines and other sources. The IARC found "limited evidence in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation to childhood leukemia" and inadequate evidence for any other carcinogenic effects. IARC reached this conclusion after evaluating two pooled studies which combined data from multiple other published studies. The pooled studies indicated an increase in risk of childhood leukemia at exposure levels above 4 mG and 3 mG respectively (IARC 2002).

In 2007 the World Health Organization prepared a monograph building on the work by the IARC (WHO 2007). The monograph also identified EMFs as a "possible health risk based on epidemiological studies demonstrating a consistent pattern of an increased risk of childhood leukemia," but found no evidence to establish a casual link. While the monograph recommended that policy makers establish guidelines for EMF exposure, it also states that "given the small estimated effect resulting from [the risk of childhood leukemia], the rarity of childhood leukemia, the rarity of average exposures higher than 0.4 μT and the uncertainty in determining the relevant exposure metric, it is unlikely that the implementation of an exposure limit based on the childhood leukemia data and aimed at reducing average exposure to ELF magnetic fields to below 0.4 μT, would be of overall benefit to society." (WHO 2007)

Existing Regulations

Although there are no federal regulations governing chronic EMF exposure, several states and local communities have regulations designed to limit public exposure. Florida limits EMF exposure at the edge of a transmission line right of way to between 15 and 25 μT, depending on the line voltage and Irvine, California has set a limit of 0.2-0.4 μT (WHO 2007). Other government organizations have limited new construction near sources of EMFs to limit exposure. The California Department of Education restricts the siting of new schools near transmission lines. Ireland and the Netherlands have similar policies to that govern proximity of lines to schools and daycare centers. Despite the World Health Organization's conclusion that exposure limits based on epidemiological data were not necessary, they also concluded that "Local authorities should improve planning of ELF EMF-emitting facilities, including better consultation between industry, local government, and citizens when siting major ELF EMF-emitting sources." (WHO 2007)

EMF Hazards from Proposed MID Facilities

Alternating current (AC) flowing through a conductor generates an asymmetric magnetic field that varies in intensity and direction over time. Flow of AC current through other wires, appliances, and electrical equipment produces similar fields. The magnetic fields generated by each conductor in a power line can be modeled to predict the combined vertical and horizontal fields produced by the power line. The intensity of the magnetic field decreases rapidly with distance from the conductor. Unlike electric fields that induce a charge in other conductors and can be shielded, magnetic fields pass through air, water, and solid objects unobstructed.

Point Impact Analysis modeled three EMF configurations for the proposed 115-kV transmission lines with two 21-kV distribution lines, using Southern California Edison Co. FIELDS program Version 1.0. Model inputs consist of conductor height, conductor diameter and bundling, operating conditions (voltage, amperage, phase), and ground wire configuration. The proposed Merced 115-kV transmission lines were modeled with a typical load of 377 amps, while the two 21-kV distribution lines had a loading of 300 amps. The maximum rated amp capacity of PG&E conductors was used to estimate the highest potentials fields along the route. Appendix H-1-3 provides the modeling assumptions and output data for each configuration modeled.

All three modeling configurations used the pole design and conductor spacing for the proposed double-circuit 115-kV transmission lines with two 21-kV distribution circuits underbuild as shown in Figure 3.3-4, Typical Profile of MID 230 kV Pole in the Project Description of this EIR. The three configurations modeled were:

Case 1 – Proposed project with optimized 115-kV phasing
Case 2 – Case 1 plus parallel PG&E distribution lines 45 feet from the centerline
Case 3 – Proposed project without optimized phasing

In Case 1, the three phases of the two 115-kV circuits are arranged so that the field strengths on either side of the poles partially cancel each other when combined, reducing ground level exposure to EMF. Case 2 models the magnetic field strength with the PG&E poles 45-feet away from the center of the proposed MID poles. For comparison, Case 3 shows the field strength without phase rotation.

Table 2 shows the magnetic field strengths of the three modeled configurations at a height of three feet above the ground.

Table 2
MAXIMUM MAGNETIC FIELDS IN MILIGAUSS (mG)

	0 ft Distance (centerline)	**20 ft Distance (from MID centerline)**	**100 ft Distance (from MID centerline)**
Case 1	11.9	9.4/10.0	1.8/2.2
Case 2	10.8	8.4/9.2	1.5/1.3
Case 3	26.8	25.5/21.2	7.0/5.9

The calculated magnetic field at the houses closest to the alignment along Reilly Road is 8.4 mG, approximately 20 feet away from the centerline of the proposed project. For comparison, magnetic fields around household appliances, at a three-foot distance, range from zero to 9.4 mG. (California Electric and Magnetic Fields Program, 1999)

Based on the lack of conclusive data from decades of scientific studies, EMFs may be considered a possible health hazard with a low risk of adverse public health effects. Given the predicted field strengths for the proposed line, the potential risks are little different from the risks due to common exposures to household appliances.

References

California Department of Health Services. Frequently asked questions, 2012.

California Electric and Magnetic Fields Program. Short Factsheet on EMF. 1999.

International Agency for Research on Cancer (IARC). Monographs on the Evaluation of Carcinogenic Risk to Humans. Volume 80: Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. World Health Organization. 2002.

Kheifets, Leeka and Riti Shimkhada. Childhood Leukemia and EMF: Review of the Epidemiologic Evidence. Bioelectromagnetics Supplement 7: S51-S59. 2005.

National Institute of Environmental Health Sciences. Electric and Magnetic Fields Associated with the Use of Electric Power: Questions and Answers. Electric and Magnetic Fields Research and Public Information Dissemination Program (EMF RAPID). June 2002.

World Health Organization (WHO). Environmental Health Criteria 238: Extremely Low Frequency Fields. 2007.

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APPENDIX H-2

CA DEPARTMENT OF HEALTH SERVICES SHORT FACTSHEET ON EMF

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SHORT FACTSHEET ON EMF

The use of electricity is taken for granted, but people are still concerned about whether powerlines and appliances are safe or unsafe. Here are answers to some common questions about electric and magnetic fields. See also our Web site at http://www.dhs.ca.gov/ps/deodc/ehib/.

What are electric and magnetic fields and why are people concerned about them?

Electric and magnetic fields are a basic force of nature (like gravity), generated by electricity. They are found almost everywhere. Electric and magnetic fields are found in nature, where they are created by such things as lightning and static electricity. Man-made fields are found wherever people use electricity, such as near powerlines and electrical appliances. Like sound, electric and magnetic fields are made of a mixture of components and so can be described in many different ways. Both have wave-like properties such as strength and "frequency" (how often they cycle back and forth). Sound can be loud (strong) or soft (weak), high or low pitched (different frequencies), suddenly loud or constant in tone, and pure or jarring. Similarly, electric and magnetic fields are a mixture of components. They can be strong or weak, have a high or low frequency, have sudden increases in strength ("transients") or a constant strength, and consist of one pure frequency or several (called "harmonics"). For example, the *strength* of a field can be weak and constant, as in most nighttime home environments, or it can be strong and vary from high to low every few seconds, as from an electric blanket set on high.

Powerlines and wiring in buildings and appliances generate 50 and 60 Hertz fields, sometimes referred to as "power frequency" fields. Hertz is the unit for measuring the frequency of fields in the number of wave cycles each second. The lower the frequency of a field, the lower its energy. Power frequency fields are low frequency fields and have low energy levels. Microwave and x-ray fields are high frequency fields and have high energy levels.

Early scientific studies found a link between increased rates of cancer and closeness to certain kinds of powerlines that can cause strong magnetic fields. Over the last two decades concern about the health effects of electric and magnetic fields has increased.

Where does EMF come from?

We are exposed to EMF from many sources, including high voltage transmission lines (usually on metal towers) carrying electricity from generating plants to communities, and distribution lines (usually on wooden telephone poles) that bring electricity to our homes, schools and workplaces. We are also exposed to magnetic fields from wiring in buildings and from all our electric appliances, like TV sets, radios, hair dryers, electric blankets and electric tools.

Most of the fields we experience in a day come from sources other than powerlines, such as wiring and appliances in homes or workplaces. The strength of both electric and magnetic fields decreases as you move away from their source, just as the heat from a campfire decreases with distance. For both electric and magnetic fields strength decreases more quickly with distance from "point" sources like appliances than from "line"

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Department of Health Services

sources such as powerlines. For example, the magnetic field is down to "background levels" (the naturally occurring amounts) at 3 or 4 feet away from an appliance (*table 1*). It reaches background levels around 60 to 200 feet from a distribution line and about 300 to 1000 feet from a transmission line.

In spite of these similarities, electric fields and magnetic fields have somewhat different properties and possibly different ways of influencing our bodies. Electric fields can be shielded or weakened by trees, buildings and even human skin, but magnetic fields are not so easily blocked. Most recent studies have focused on the health effects of magnetic fields because they are not readily shielded and are easier to measure than electric fields.

Table 1. Examples of magnetic fields at particular distances from appliance surfaces.

	MILLIGAUSS (mG) at 1 foot	at 3 feet
aquarium pump	0.35-18.21	0.01-1.17
band saw	0.51-14.24	0.05-0.75
can opener	7.19-163.02	1.30-6.44
clock	0.34-13.18	0.03-0.68
clothes iron	1.66-2.93	0.25-0.37
coffee machine	0.09-7.30	0-0.61
computer monitor	0.20-134.7	0.01-9.37
copier	0.05-18.38	0-2.39
desktop light	32.81	1.21
dishwasher	4.98-8.91	0.84-1.63
drill press	0.21-33.33	0.03-8.35
fax machine	0.16	0.03
food processor	6.19	0.35
garbage disposal	2.72-7.79	0.19-1.51
hairdryer	0.1-70	0.1-2.8*
microwave oven	0.59-54.33	0.11-4.66
mixer	0.49-41.21	0.09-3.93
portable heater	0.11-19.60	0-1.38
printer	0.74-43.11	0.18-2.45
portable fan	0.04-85.64	0.03-3.12
radio	0.43-4.07	0.03-0.98
range	0.60-35.93	0.05-2.83
refrigerator	0.12-2.99	0.01-0.60
scanner	2.18-26.91	0.09-3.48
sewing machine	3.79-7.70	0.35-0.45
tape player	0.13-6.01	0.01-1.66
television	1.80-12.99	0.07-1.11
toaster	0.29-4.63	0.01-0.47
vacuum	7.06-22.62	0.51-1.28
VCR	0.19-4.63	0.01-0.41
vending machine	0.46-5.05	0.02-0.59

L. Zaffanella, School Exposure Assessment Survey, California EMF Program, interim results, Nov. 1997.

What kind of scientific studies have been done?

Nobody knows for sure whether exposure to 50 and 60 Hertz fields is a health risk. Three kinds of studies have been done to explore this:
1) laboratory studies that expose human or animal cells or organs to fields, looking for biological changes
2) laboratory studies that expose animals to fields, looking for changes in body function, chemistry, behavior or general health
3) "epidemiological" studies that observe people's health and evaluate whether groups that have high or unusual EMF exposure have a greater chance for developing a disease like cancer than groups with "normal" or usual exposures

What do these studies show?

First, *these studies do not show a clear pattern of health hazards*. Some but not all animal and cell studies have shown biological changes linked with *magnetic field* exposure. However, it is not clear whether these biological changes would be the same in humans. Second, it is not clear which component (frequency, strength, harmonics, etc.) of magnetic field exposure might be hazardous.

Concern about possible health hazards from electric power use is supported by results of some scientific studies, but the evidence they provide is still incomplete and inconclusive and even, in some cases, contradictory. A good deal of research is underway to help resolve these questions and uncertainties. Most but not all epidemiological studies show an association between leukemia (a type of cancer) and an "indirect" estimate of high magnetic field exposure such as living very near a type of powerline that could cause of high magnetic fields or working where there is high electrical exposure. These estimates may not really represent a person's true exposure at the critical time period when they may have started developing an illness. Also, these studies show that some estimates of magnetic field exposure might be *related* to cancer, but this does not necessarily mean that magnetic fields *cause* cancer. Indirect ways of estimating exposure may unintentionally include other risk factors like chemicals used at work or living in a particular neighborhood.

How would magnetic field measurements taken in my house compare to others?

The California Department of Health Services measured the strength of magnetic fields in the bedroom, family room, and kitchen and at the front door of some San Francisco Bay Area houses. Any appliances or electrical devices that were on at the time were left on. As shown in *table 2*, about half of the houses had an average magnetic field level below 0.71 milligauss (mG, the basic unit for measuring magnetic field strength), and 90% of homes had levels below 1.58 mG.

These are measures of the average strength of the 60 Hertz frequency magnetic field at a particular day and time. Field strengths vary with time, day and season depending on electricity use. For example,

Table 2. Distribution of average magnetic field strength of San Francisco Bay Area homes.

homes below average field strength	736 homes measured [1]
10%	0.43 mG
25%	0.54 mG
50%	0.71 mG
75%	0.98 mG
90%	1.58 mG

[1]Lee, G., California Exposure Assessment study (preliminary findings). California EMF Program. 1996.

dinnertime readings are often higher than the middle of the night because appliances are in use. The other magnetic field components (like harmonics of other frequencies and short bursts of stronger fields called transients) are not included in these measurements, so they do not describe other aspects of the fields or other frequencies. Also, the field strength may change over time or distance depending on the location and type of its source.

Fairly simple measurements made by a trained technician can show the main indoor or outdoor sources of elevated magnetic fields in a home. Many utility companies and several private businesses can take these measurements. Taking measurements at different distances from powerlines can help show if the lines are sources for elevated magnetic fields inside a home. Turning off the house's main power switch will rule out sources caused by power use inside. In most cases it is possible to find and correct the source of elevated fields if they are due to faulty wiring, grounding problems or choice of lighting fixtures.

What are current government initiatives on EMF?

The State of California

The California Department of Education enacted regulations that require minimum distances between a *new school* and the edge of a transmission line "right-of-way," or the area immediately surrounding lines that utility companies need to access the lines for maintenance and repairs. The setback distances are 100 feet for 50-133 kV lines, 150 feet for 220-230 kV lines, and 350 feet for 500-550 kV lines. These distances were not based on specific biological evidence, but on the known fact that the strength of electric fields from powerlines drops to near background levels at the specified distances, given that no other major sources are present.

In 1993, the California Public Utilities Commission (CPUC) authorized the state's investor-owned utilities to carry out "no and low cost EMF avoidance and measures" in construction of new and upgraded utility projects. The CPUC also established our California EMF research, education, and technical assistance program under the guidance of the Department of Health Services. This program will provide information to assist those responsible for making public policy. However, at present the state of California has no formal rules or guidelines, but advocates "no and low cost" of EMF. This means minimizing EMF exposure when it is easy and inexpensive to do so. Right now there is not enough evidence to justify making regulations governing EMF.

The Federal Government

At the Federal level, the Federal Energy Policy Act of 1992 included a five-year program of electric and magnetic field (EMF) Research and Public Information Dissemination (EMF-RAPID). The EMF-RAPID Program asked these questions: Does exposure to EMF produced by power generation, transmission, and use of electric energy pose a risk to human health? If so, how significant is the risk, who is at risk, and how can the risk be reduced?

In 1998, a working group of experts gathered by the EMF-RAPID Program met to review the research that has been done on the possible health risks associated with EMF. This group reviewed the studies that have been done on the subject, and then voted on whether they believed that exposure to EMF might be a health risk. They then published a report describing their findings. A majority of the scientists on this working group voted that the epidemiology studies of childhood leukemia provide enough evidence to classify EMF as a “possible human carcinogen.” This means that, based on the evidence, these researchers believe that it is possible that EMF causes cancer, but they are not sure. They also decided that they did not have enough evidence to determine whether EMF exposure might cause other diseases.

The EMF-RAPID Program released its final report to Congress in 1999. This report explains the program’s findings, including the results of its working group and many research projects. The final report states that “the NIEHS believes that there is weak evidence for possible health effects from [power frequency] ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions should be encouraged.” (page 38) For more information on the EMF-RAPID program, or to look at these reports, contact the EMF-RAPID Program, National Institute of Environmental Health Sciences, National Institutes of Health, P.O. Box 12233, Research Triangle Park, North Carolina 27709, or visit their Web site at http://www.niehs.nih.gov/emfrapid. When ordering a copy of the final report, refer to the NIH publication number 99-4493.

Conclusion

Until we have more information, some communities and individuals are adopting the “no and low cost” avoidance strategy. It’s easy to move an electric clock a few feet away from a bedside table, and it’s simple to sit further away from the computer monitor. Table 1 above shows how quickly EMF decreases as you move away from an appliance. It almost disappears at distances of 3 to 5 feet. It is possible to take measurements in your home to identify sources of EMF, including faulty electrical wiring that can produce elevated magnetic fields and electrical shock. In California, the Public Utilities Commission requires investor-owned utilities to provide magnetic field measurements at no charge to their customers.

Contact us for a more detailed long factsheet. Please send us your questions and comments, too.

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APPENDIX H-3

ANALYSIS OF EMF DUE TO PROPOSED MID FACILITIES

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Main Title: MID South 115kV Line w/ 21kV Underbuild
Subtitle: Base Case Not-Optimized
Input File: MIDBCNO.FLD
Frequency (Hertz): 60
Soil Resistivity (Ohm-meter): 100
Maximum Horizontal Distance From Reference (ft): 100
Step Size (ft): 5
Height For Field Calculation (ft): 3
Left Coordinate of Right of Way (ft): -20
Right Coordinate of Right of Way (ft): 20

Phase Conductor Data

Number of Phases (<=25): 12

Phase ID No.	Phase ID Name	Phase Coordinates X(ft)	Phase Coordinates Y(ft)	SubConds. Per Bundle	Cond. Diam. (in.)	Bund. Diam. (in.)	Phase-Phase kV	Phase Curr. (Amp)	Phase Angle (deg)
1	A	6.50	75.00	1	1.12	1.12	115.00	377.00	0.00
2	B	6.50	65.00	1	1.12	1.12	115.00	377.00	120.00
3	C	6.50	55.00	1	1.12	1.12	115.00	377.00	240.00
4	AA	-6.50	75.00	1	1.12	1.12	115.00	377.00	0.00
5	BB	-6.50	65.00	1	1.12	1.12	115.00	377.00	120.00
6	CC	-6.50	55.00	1	1.12	1.12	115.00	377.00	240.00
7	a	5.50	47.75	1	0.56	0.56	21.00	300.00	30.00
8	b	2.50	47.75	1	0.56	0.56	21.00	300.00	150.00
9	c	-2.50	47.75	1	0.56	0.56	21.00	300.00	270.00
10	aa	5.50	43.75	1	0.56	0.56	21.00	300.00	30.00
11	bb	2.50	43.75	1	0.56	0.56	21.00	300.00	150.00
12	cc	-2.50	43.75	1	0.56	0.56	21.00	300.00	270.00

Ground Wire Data

Number of Ground Wires (<=10): 3

Ground Wire No.	Ground Wire Name	Ground Wire Coordinates X(ft)	Ground Wire Coordinates Y(ft)	GW Diam. (in.)	GW Curr. (Amp)	GW Phase Angle (deg)
1	g1	0.00	80.00	1.12	0.00	0.00
2	g2	-5.50	47.75	0.56	0.00	0.00
3	g3	-5.50	43.75	0.56	0.00	0.00

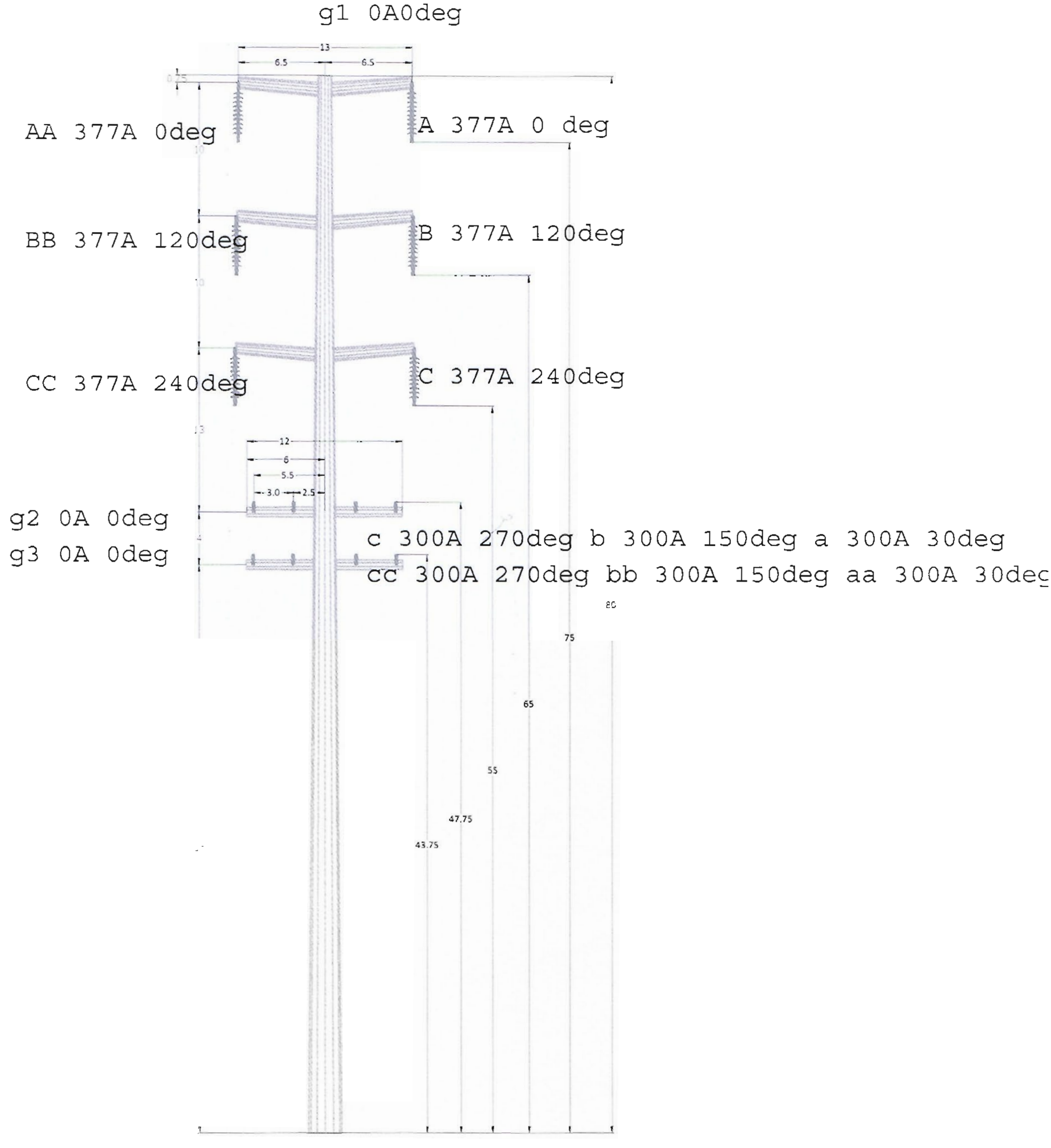
Input File: MIDBCNO.FLD

MID South 115kV Line w/ 21kV Underbuild
Base Case Not-Optimized

MAGNETIC FIELD VALUES

DISTANCE (Feet)	B in X (mG)	B in Y (mG)	B Product (mG)	B Max (mG)
-100	1.661	6.870	7.068	7.006
-95	1.510	7.485	7.636	7.570
-90	1.347	8.155	8.266	8.195
-85	1.229	8.880	8.964	8.888
-80	1.284	9.655	9.740	9.657
-75	1.645	10.473	10.602	10.511
-70	2.341	11.318	11.557	11.457
-65	3.349	12.163	12.615	12.504
-60	4.672	12.968	13.784	13.659
-55	6.329	13.673	15.067	14.925
-50	8.343	14.195	16.465	16.303
-45	10.722	14.425	17.974	17.784
-40	13.446	14.228	19.576	19.351
-35	16.436	13.453	21.240	20.970
-30	19.537	11.976	22.916	22.588
-25	22.495	9.777	24.528	24.127
-20	24.958	7.197	25.975	25.484
-15	26.527	5.723	27.137	26.537
-10	26.848	7.536	27.886	27.165
-5	25.759	11.276	28.119	27.271
0	23.387	15.004	27.787	26.822
5	20.149	17.853	26.920	25.860
10	16.600	19.521	25.625	24.504
15	13.242	20.077	24.051	22.910
20	10.394	19.784	22.348	21.226
25	8.186	18.942	20.635	19.564
30	6.621	17.797	18.989	17.990
35	5.633	16.511	17.446	16.532
40	5.112	15.183	16.020	15.194
45	4.911	13.869	14.713	13.973
50	4.888	12.604	13.519	12.859
55	4.937	11.408	12.430	11.843
60	4.992	10.292	11.439	10.917
65	5.022	9.264	10.538	10.073
70	5.015	8.326	9.720	9.305
75	4.970	7.475	8.976	8.606
80	4.891	6.708	8.302	7.970
85	4.783	6.021	7.690	7.391
90	4.654	5.406	7.134	6.865
95	4.509	4.859	6.629	6.385
100	4.354	4.371	6.170	5.949

MID 115 not-optimized configuration



TYPICAL DOUBLE CIRCUIT TRANSMISSION STRUCTURE WITH DOUBLE 21-kV UNDERBUILD CIRCUITS

Main Title: MID South 115kV Line w/ 21kV Underbuild
Subtitle: Base Case Optimized
Input File: MIDBCO.FLD
Frequency (Hertz): 60
Soil Resistivity (Ohm-meter): 100
Maximum Horizontal Distance From Reference (ft): 100
Step Size (ft): 5
Height For Field Calculation (ft): 3
Left Coordinate of Right of Way (ft): -20
Right Coordinate of Right of Way (ft): 20

Phase Conductor Data

Number of Phases (<=25): 12

Phase ID No.	Phase ID Name	Phase Coordinates X(ft)	Phase Coordinates Y(ft)	SubConds. Per Bundle	Cond. Diam. (in.)	Bund. Diam. (in.)	Phase-Phase kV	Phase Curr. (Amp)	Phase Angle (deg)
1	A	6.50	75.00	1	1.12	1.12	115.00	377.00	0.00
2	B	6.50	65.00	1	1.12	1.12	115.00	377.00	120.00
3	C	6.50	55.00	1	1.12	1.12	115.00	377.00	240.00
4	CC	-6.50	75.00	1	1.12	1.12	115.00	377.00	240.00
5	BB	-6.50	65.00	1	1.12	1.12	115.00	377.00	120.00
6	AA	-6.50	55.00	1	1.12	1.12	115.00	377.00	0.00
7	a	5.50	47.75	1	0.56	0.56	21.00	300.00	30.00
8	b	2.50	47.75	1	0.56	0.56	21.00	300.00	150.00
9	c	-2.50	47.75	1	0.56	0.56	21.00	300.00	270.00
10	aa	5.50	43.75	1	0.56	0.56	21.00	300.00	30.00
11	bb	2.50	43.75	1	0.56	0.56	21.00	300.00	150.00
12	cc	-2.50	43.75	1	0.56	0.56	21.00	300.00	270.00

Ground Wire Data

Number of Ground Wires (<=10): 3

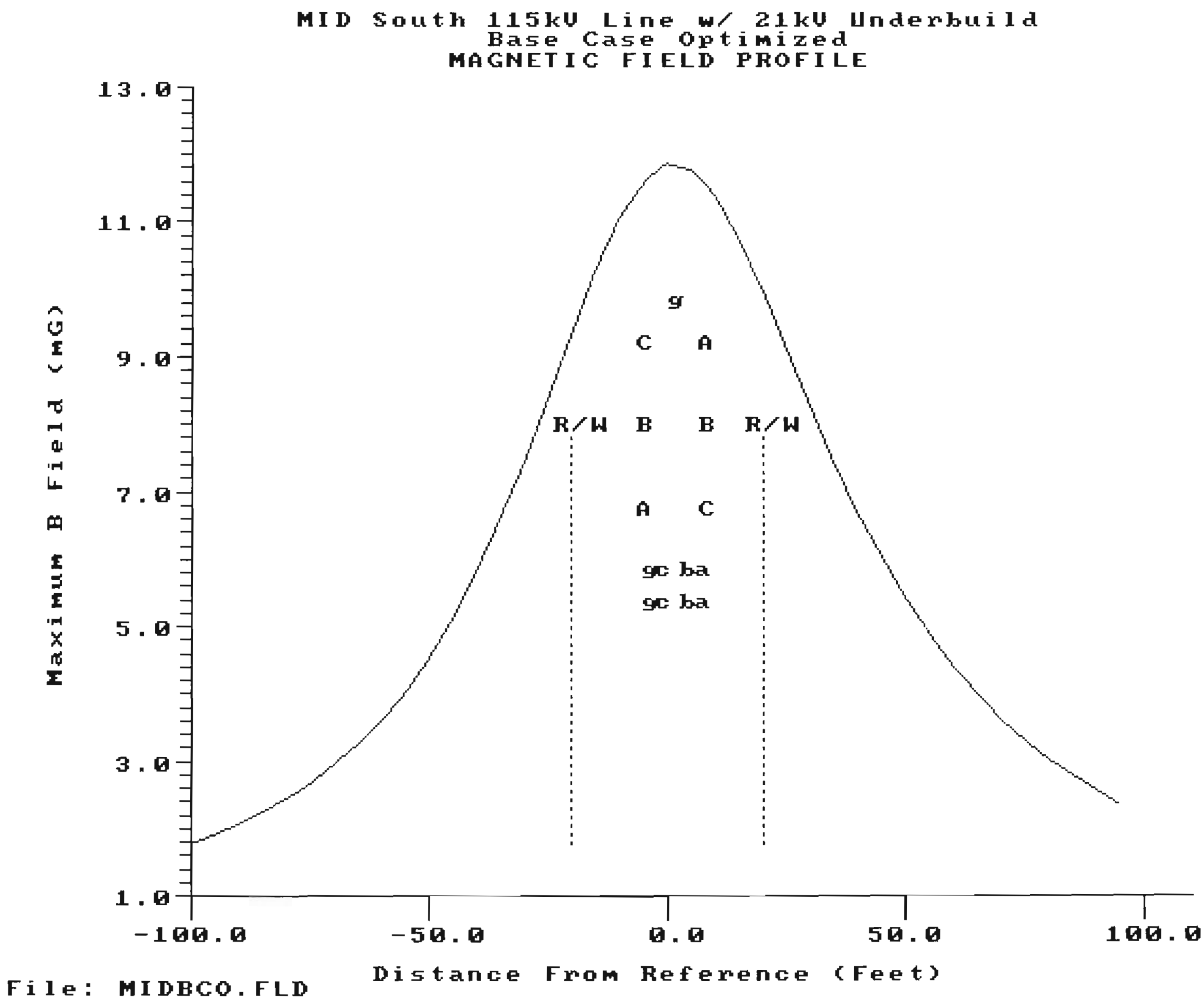
Ground Wire No.	Ground Wire Name	Ground Wire Coordinates X(ft)	Ground Wire Coordinates Y(ft)	GW Diam. (in.)	GW Curr. (Amp)	GW Phase Angle (deg)
1	g1	0.00	80.00	1.12	0.00	0.00
2	g2	-5.50	47.75	0.56	0.00	0.00
3	g3	-5.50	43.75	0.56	0.00	0.00

Input File: MIDBCO.FLD

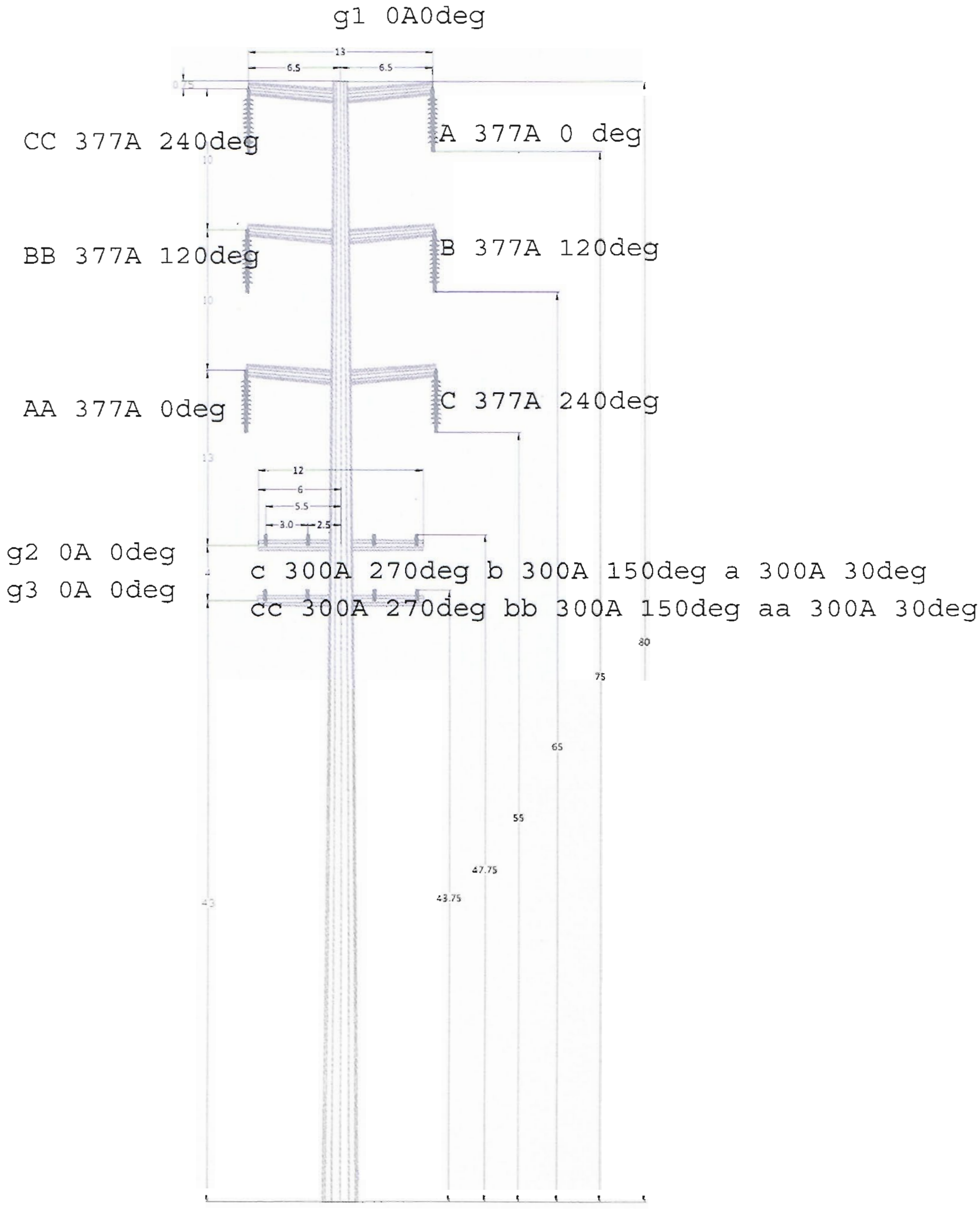
MID South 115kV Line w/ 21kV Underbuild
Base Case Optimized

MAGNETIC FIELD VALUES

DISTANCE (Feet)	B in X (mG)	B in Y (mG)	B Product (mG)	B Max (mG)
-100	1.407	1.170	1.830	1.771
-95	1.547	1.229	1.976	1.909
-90	1.705	1.292	2.139	2.064
-85	1.885	1.357	2.323	2.241
-80	2.094	1.424	2.532	2.442
-75	2.336	1.490	2.771	2.673
-70	2.620	1.551	3.045	2.941
-65	2.957	1.598	3.361	3.253
-60	3.358	1.619	3.728	3.618
-55	3.836	1.595	4.155	4.048
-50	4.403	1.502	4.652	4.551
-45	5.063	1.314	5.231	5.140
-40	5.806	1.046	5.900	5.822
-35	6.594	0.948	6.662	6.600
-30	7.348	1.565	7.513	7.467
-25	7.933	2.857	8.432	8.400
-20	8.158	4.623	9.377	9.357
-15	7.806	6.691	10.281	10.270
-10	6.701	8.795	11.057	11.051
-5	4.812	10.567	11.611	11.608
0	2.324	11.636	11.866	11.864
5	0.437	11.780	11.788	11.787
10	2.909	11.020	11.397	11.396
15	4.866	9.599	10.762	10.761
20	6.146	7.851	9.971	9.970
25	6.793	6.074	9.112	9.112
30	6.946	4.460	8.254	8.254
35	6.767	3.096	7.441	7.441
40	6.391	1.998	6.696	6.695
45	5.917	1.147	6.027	6.025
50	5.408	0.518	5.432	5.429
55	4.902	0.225	4.907	4.902
60	4.422	0.449	4.444	4.438
65	3.977	0.689	4.036	4.028
70	3.571	0.867	3.675	3.666
75	3.206	0.991	3.356	3.346
80	2.880	1.072	3.072	3.062
85	2.588	1.120	2.820	2.810
90	2.329	1.144	2.595	2.584
95	2.100	1.150	2.394	2.383
100	1.896	1.142	2.213	2.203


MID South 115kV Line w/ 21kV Underbuild
Base Case Optimized
MAGNETIC FIELD PROFILE
13.0
11.0
9.0
7.0
5.0
3.0
1.0
Maximum B Field (mG)
g
C A
R/W B B R/W
A C
gc ba
gc ba
-100.0
-50.0
0.0
50.0
100.0
Distance From Reference (Feet)
File: MIDBCO.FLD

MID 115 optimized configuration



TYPICAL DOUBLE CIRCUIT TRANSMISSION STRUCTURE WITH DOUBLE 21-kV UNDERBUILD CIRCUITS

Main Title: MID South 115kV Line w/ 21kV Underbuild
Subtitle: Reilly Rd Parallel
Input File: MIDRRD.FLD
Frequency (Hertz): 60
Soil Resistivity (Ohm-meter): 100
Maximum Horizontal Distance From Reference (ft): 100
Step Size (ft): 5
Height For Field Calculation (ft): 3
Left Coordinate of Right of Way (ft): -20
Right Coordinate of Right of Way (ft): 20

Phase Conductor Data

Number of Phases (<=25): 15

Phase ID No.	Phase ID Name	Phase Coordinates X(ft)	Phase Coordinates Y(ft)	SubConds. Per Bundle	Cond. Diam. (in.)	Bund. Diam. (in.)	Phase-Phase kV	Phase Curr. (Amp)	Phase Angle (deg)
1	A	6.50	75.00	1	1.12	1.12	115.00	377.00	0.00
2	B	6.50	65.00	1	1.12	1.12	115.00	377.00	120.00
3	C	6.50	55.00	1	1.12	1.12	115.00	377.00	240.00
4	CC	-6.50	75.00	1	1.12	1.12	115.00	377.00	240.00
5	BB	-6.50	65.00	1	1.12	1.12	115.00	377.00	120.00
6	AA	-6.50	55.00	1	1.12	1.12	115.00	377.00	0.00
7	a	5.50	47.75	1	0.56	0.56	21.00	300.00	30.00
8	b	2.50	47.75	1	0.56	0.56	21.00	300.00	150.00
9	c	-2.50	47.75	1	0.56	0.56	21.00	300.00	270.00
10	cc	5.50	43.75	1	0.56	0.56	21.00	300.00	30.00
11	bb	2.50	43.75	1	0.56	0.56	21.00	300.00	150.00
12	aa	-2.50	43.75	1	0.56	0.56	21.00	300.00	270.00
13	R1	45.00	65.00	1	0.26	0.26	12.00	183.00	30.00
14	R2	41.00	60.00	1	0.26	0.26	12.00	183.00	150.00
15	R3	49.00	60.00	1	0.26	0.26	12.00	183.00	270.00

Ground Wire Data

Number of Ground Wires (<=10): 3

Ground Wire No.	Ground Wire Name	Ground Wire Coordinates X(ft)	Ground Wire Coordinates Y(ft)	GW Diam. (in.)	GW Curr. (Amp)	GW Phase Angle (deg)
1	g1	0.00	80.00	1.12	0.00	0.00
2	g2	-5.50	47.75	0.56	0.00	0.00
3	g3	-5.50	43.75	0.56	0.00	0.00

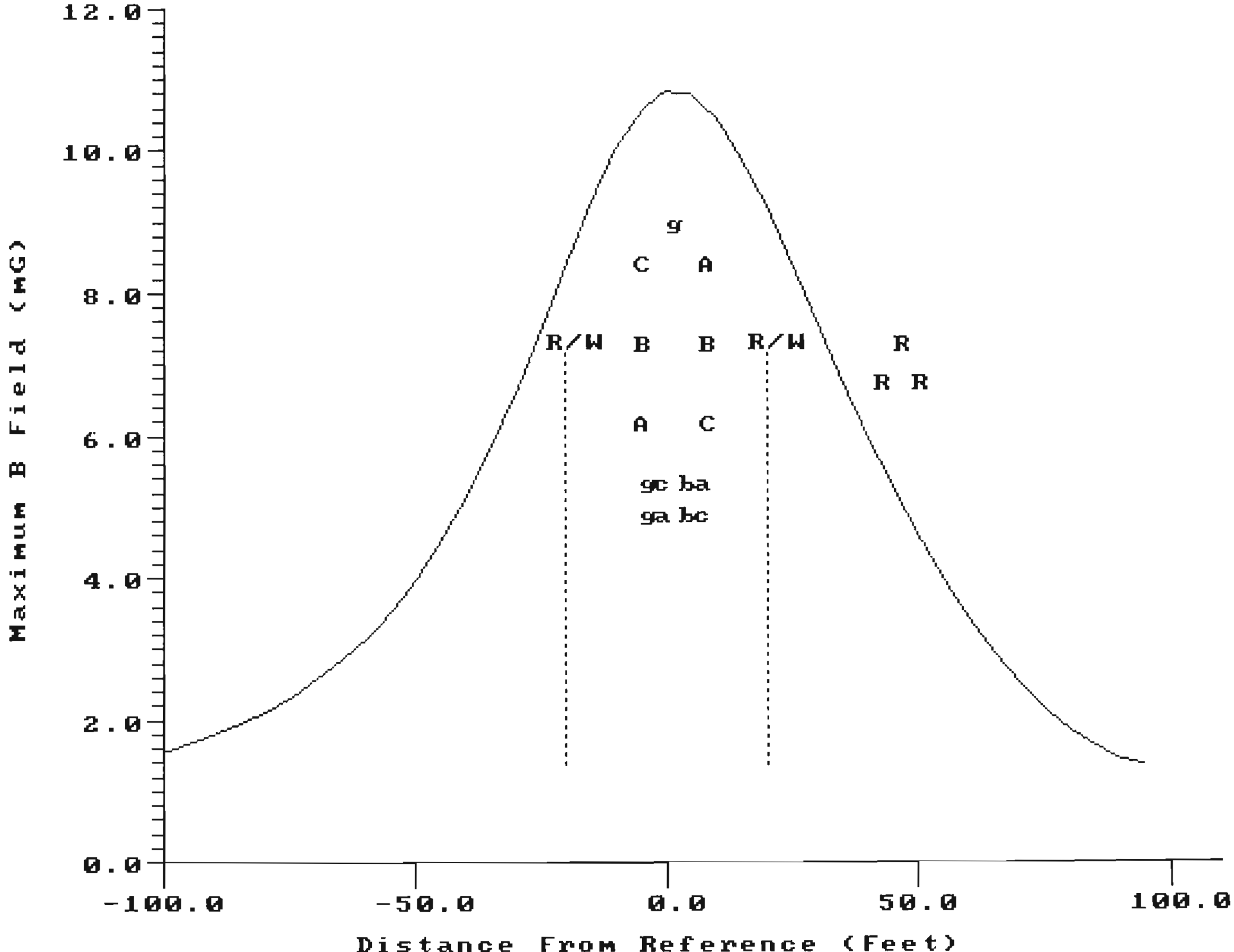
Input File: MIDRRD.FLD

MID South 115kV Line w/ 21kV Underbuild
Reilly Rd Parallel

MAGNETIC FIELD VALUES

DISTANCE (Feet)	B in X (mG)	B in Y (mG)	B Product (mG)	B Max (mG)
-100	1.146	1.069	1.567	1.542
-95	1.267	1.117	1.689	1.661
-90	1.405	1.168	1.827	1.794
-85	1.563	1.220	1.982	1.946
-80	1.745	1.272	2.160	2.119
-75	1.958	1.322	2.363	2.320
-70	2.210	1.366	2.598	2.552
-65	2.509	1.395	2.871	2.825
-60	2.869	1.396	3.191	3.147
-55	3.301	1.350	3.567	3.528
-50	3.817	1.226	4.010	3.978
-45	4.422	0.985	4.531	4.508
-40	5.106	0.588	5.140	5.126
-35	5.832	0.341	5.842	5.836
-30	6.523	1.212	6.634	6.633
-25	7.045	2.567	7.498	7.498
-20	7.214	4.297	8.397	8.392
-15	6.817	6.279	9.268	9.254
-10	5.689	8.259	10.029	10.004
-5	3.825	9.876	10.591	10.554
0	1.582	10.764	10.879	10.833
5	1.829	10.704	10.859	10.805
10	4.078	9.726	10.546	10.487
15	5.888	8.078	9.997	9.933
20	6.995	6.114	9.290	9.220
25	7.416	4.161	8.504	8.424
30	7.284	2.485	7.696	7.602
35	6.760	1.417	6.907	6.793
40	5.997	1.406	6.159	6.018
45	5.119	1.912	5.464	5.291
50	4.228	2.334	4.829	4.619
55	3.401	2.561	4.257	4.006
60	2.695	2.609	3.751	3.456
65	2.142	2.523	3.309	2.970
70	1.753	2.348	2.930	2.548
75	1.513	2.125	2.609	2.189
80	1.385	1.885	2.339	1.891
85	1.323	1.647	2.113	1.654
90	1.291	1.425	1.923	1.486
95	1.266	1.225	1.762	1.380
100	1.240	1.051	1.625	1.305

MID South 115kV Line w/ 21kV Underbuild
Reilly Rd Parallel
MAGNETIC FIELD PROFILE



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