February 18, 2015

In reply refer to: FOIA #BPA-2015-00676-F

Reed Bartlett
Bodwell EnviroAcoustics
55 Ocean Drive
Brunswick, ME 04011

Dear Mr. Bartlett:

We have received your request for records under the Freedom of Information Act (5 U.S.C. § 552). Thank you for your interest in the Bonneville Power Administration (BPA). Your request was received in this office on February 13, 2015, and has been assigned control number BPA-2015-00676-F. Please use this number in any correspondence with the agency about your request.

You requested:

We have reviewed your request and have determined that it addresses all of the criteria of a proper request under the FOIA, DOE, and BPA regulation that implements the FOIA at Title 10, Code of Federal Regulations, Part 1004.

Final response:
BPA is releasing the requested files in their entirety on the enclosed CD.

There are no fees associated with this request.

Pursuant to Department of Energy FOIA regulations at 10 C.F.R. § 1004.8, you may administratively appeal this response in writing within 30 calendar days. If you choose to appeal, please include the following:

(1) The nature of your appeal - denial of records, partial denial of records, adequacy of search, or denial of fee waiver;
(2) Any legal authorities relied upon to support the appeal; and
(3) A copy of the determination letter.

Clearly mark both your letter and envelope with the words “FOIA Appeal,” and direct it to the following address:

Director, Office of Hearings and Appeals
Department of Energy
1000 Independence Avenue SW
Washington DC 20585-1615

Thank you for your interest in the Bonneville Power Administration. I appreciate the opportunity to assist you. If you have any questions about this letter, please contact Kim Winn, FOIA Public Liaison, at 503-230-5273.

Sincerely,

C. M. Frost
Freedom of Information Act Officer

Enclosure: CD
ABSTRACT:

Presented in this report are the analytical expressions that are presently recommended by the Branch of Laboratories for predicting audible noise, RI, TVI, and ozone. This report also describes the computer program that can be used to make these calculations. The computer program is the result of combining several existing individual computer programs. These analytical expressions and the resultant computer program give state-of-the-art calculations. The Laboratories have ongoing R&D programs to collect data for better understanding of the corona processes. As this data is collected it will be compared with predictions from the computer, therefore, the analytical expressions will be improved as the new and better data shows that such improvements are needed.
EMPIRICAL EXPRESSIONS FOR CALCULATING HIGH VOLTAGE TRANSMISSION CORONA PHENOMENA

BY

Vernon L. Chartier
Chief High Voltage Phenomena Engineer
Bonneville Power Administration
Division of Laboratories
Vancouver, Washington

Paper presented at the Engineering Seminar of Bonneville Power Administration's Technical Career Program for Professional Engineers

Portland, Oregon April 7, 1983
INTRODUCTION

The Bonneville Power Administration (BPA) engineers over the past 10 years have been developing empirical expressions for calculating corona phenomena associated with a-c and d-c high voltage transmission lines. The majority of these empirical expressions were developed from data obtained from BPA operating lines or test lines (The Dalles DC Test Line, Lyons 1200-kV Test Line) in conjunction with data that was in the technical literature, such as from the Apple Grove 750-kV Project and from Project UHV. Up until 1977, no single Division within BPA had the primary authority for developing these empirical expressions; therefore, such equations were being produced by System Engineering, Transmission Engineering, and the Laboratories. However, In 1977 the Chief Engineer assigned the responsibility for the development and maintenance of the empirical equations for calculating audible noise (AN), radio interference (RI), television interference (TVI), corona losses (CL), and ozone (O3) to the Division of Laboratories.

As a result of this directive from the Chief Engineer, in 1977 Bob Larson and Vern Chartier produced a report that not only described the recommended equations for calculating corona phenomena for a-c lines, but also described a computer program written for the CDC 6600 that could make calculations for any a-c line. The initial computer program was limited to a-c lines. In addition, the line(s) could have no more than six phases and four overhead ground wires. That original computer program and the associated equations are described in BPA Division of Laboratories’ Technical Report Number ERJ-77-167 [1].

Over the past 4 years the Laboratories has been updating that original computer program (called COMBINE) so that it could make all the corona phenomena calculations associated with both a-c and d-c lines. Subroutines for calculating electric and magnetic fields were also added. The original program was called COMBINE since it combined all the individual corona phenomena programs into one program and calculated the electric field at the surface of the conductor using a technique developed by Markt-Mengele [2, 3].

The purpose of this report is to describe the latest equations that are being used at BPA to make corona and field effect calculations. At this time, the program calculates the lateral profiles of AN, RT, TVI, electric field, and magnetic field. Lateral profile printouts of these sets of phenomena can be requested individually or collectively. If an individual printout is requested for audible noise and/or TVI, the noise contribution from each phase/pole plus the total is printed out. For RI, a frequency spectrum as a function of lateral distance is printed out. The individual printout for ozone gives both a vertical and a horizontal profile of O3 concentration. The individual printouts for electric and magnetic fields give the maximum field and its electrical angle, and the maximum horizontal and vertical component and their appropriate electrical angles. A separate printout for corona loss can be requested which gives the total corona losses, the corona loss for each phase/pole as a function of rain intensity, and the average rain and average fair weather losses.

The user has the option of inputting values for conductor surface voltage gradients (previously calculated from some other source), or he may have the program compute them using the equation developed by Markt-Mengele [2, 3].

The user has the option of inputting and outputting values in either Metric or English units.

The program can handle a combination of 50 phases or poles and overhead ground wires. At this time the program cannot make calculations for a hybrid line (a-c and d-c lines in close proximity).

All the analytical expressions in this program are state-of-the-art. The Division of Laboratories makes an attempt to conduct measurement programs on BPA’s existing transmission system and at the Lyons 1200-kV test facility to verify or update the analytical expressions. The Laboratories also tries to keep abreast of the R&D work being conducted all over the world on corona and field effects. Some of the data coming from other countries is sometimes used in conjunction with data from North America to update existing equations.

EFFECT OF ALTITUDE

Altitude has a very definite effect on the production of corona, as has been shown at the Leadville High Voltage Project operated by the Public Service Company of Colorado and Westinghouse in the 1950’s [4, 5]. Obviously, the development of empirical expressions for the effect of altitude is difficult, since the only data in the literature is either from lines at sea level or the test lines at Leadville (3400 m above sea level). Westinghouse engineers used the Leadville data to develop a term for correcting RI calculations made at sea level to

75
other altitudes [6]. Reference 6 also contains an Italian formula for the effect of altitude on RT. These two equations are compared in Figure 1. The agreement is quite good. The Westinghouse formula requires the user to know what the average relative air density is for each altitude, whereas the Italian formula only requires a knowledge of the altitude.

![Figure 1: Effect of Altitude on Corona Phenomena](image)

For calculating corona phenomena, the Italian correction term for altitude has been applied in the computer program for not only RI, but also for TVI, AN, and CL. It obviously has not been verified for either TVI or AN, and only partially verified for CL. However, it is better to have a correction term for all these corona phenomena rather than no term. After all, if RI and CL, which are the result of increased corona activity, increase with altitude so too must AN and TVI.

The use of this term for correcting CL needs further verification. A careful study of the Leadville [4] and Tidd [7] papers gives some indication that it might be valid for rain. However, the Leadville weather and the Tidd weather are very dissimilar. Foul weather at Leadville consists primarily of dry snow in the winter and very little rain, whereas foul weather at Tidd consists of mostly rain and wet snow; even the dry snow at Tidd is much wetter than Leadville snow. Heavy snow seems to produce higher corona losses than heavy rain or wet snow. This data indicates that dry snow produces a different type of corona (possibly ultra-corona) which may produce different levels of AN, RI, and TVI than either rain or wet snow.

Therefore, at this time, calculations using this altitude correction for determining corona loss should be made with a great deal of caution, especially for snowy weather.

**AUDIBLE NOISE**

The method of calculating A-weighted AN for a-c and d-c lines is based upon empirical expressions developed by V. L. Chartier and R. D. Stearns. Those equations and how they were developed are thoroughly described in an IEEE paper [8].

The equation for calculating the AN during rainy weather for each phase of an a-c line is:

$$ SLA = -170.46 + 120 \log E + 55 \log deq - 11.4 \log D $$

where:

- $E$ = average maximum surface gradient kVrms/cm
- $deq$ = equivalent diameter of the bundle from an AN standpoint
- $deq = d$ for $n < 3$
- $= (0.58d)n0.48$ for $n \geq 3$
- $d$ = subconductor diameter, mm
- $n$ = number of subconductors in the bundle
- $D$ = radial distance between conductor and microphone, m

The formula for calculating the $L_{50}$ A-weighted AN per positive pole for fair weather (the negative pole produces negligible AN) is:

$$ SLA = -133.4 + 86 \log E + 40 \log deq - 11.4 \log D $$

$deq = d$ for $n = 1,2$

- $= (0.66d)n0.64$ n $> 2$

The equations calculate the $L_{50}$ rainy weather AN for a-c lines and the $L_{50}$ fair weather AN for d-c lines. The $L_{50}$ fair weather AN for a-c lines is calculated by subtracting 25 dB from the $L_{50}$ rainy weather AN. The $L_{50}$ AN for rain for a-c lines is calculated by adding 3.5 dB to the $L_{50}$ rainy weather AN.

For d-c lines, the $L_5$ fair weather AN is calculated by adding 3.5 dB to the $L_{50}$ fair weather AN, whereas the $L_{50}$ AN during rainy weather is calculated by subtracting 6 dB from the $L_{50}$ fair weather AN. Only the positive pole produces measurable AN for d-c lines; therefore, -999.9 is printed out for the negative pole.

For the effect of altitude, the previously discussed term $AN - ALTITUDE$ is used. However, its use below 300 m is not recommended since the data used to develop the empirical formulas was taken at altitudes primarily between 0 and 300 m. There has been some question about how to use this term around 300 m. It is strongly recommended by the Laboratories that until further data is collected the equations be used just as they are written, but that 1 dB be added for each 300 m above sea level.

**RADIO NOISE**

The methods of calculating RI for both a-c and d-c lines over the frequency range of 100 KHz to 20 MHz has evolved over the last 10 years. There is no single reference which describes the equations that are used by BPA. Reference 9 describes the general a-c equation that is used in the AM broadcast band and at distances within 60 m of the outside phase of
Table I: Prediction Formulas - DC Lines

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPA</td>
<td>( E = 51 + 1.5(g - 20.9) + 10 \log \frac{d}{2} + 40 \log \frac{\frac{d}{2} \cdot \frac{d}{2}}{d} - 33 \log \frac{f}{0.83} - 40 \log \frac{d}{30.5} )</td>
</tr>
<tr>
<td>Reiner Gehrig [10]</td>
<td></td>
</tr>
<tr>
<td>BPA Capon [11]</td>
<td>( E = 214 \log \frac{d}{14} - 278 \left( \log \left( \frac{E}{14} \right) \right)^2 + 40 \log \frac{d}{2} - 27 \log \frac{\frac{d}{2} \cdot \frac{d}{2}}{d} - 40 \log \frac{d}{30.5} )</td>
</tr>
<tr>
<td>BPA Gehrig [12]</td>
<td>( E = 1.6 g + 40 \log \frac{d}{2} - 40 \log \frac{f}{30.5} )</td>
</tr>
<tr>
<td>BPA Perry [13]</td>
<td>( E = E_0 + 80 \log \frac{d}{2} + 10 \log \frac{n}{n_0} + 40 \log \frac{d}{d_0} + 40 \log \frac{D}{D_0} )</td>
</tr>
<tr>
<td>Germany [14]</td>
<td>( E = E_0 + K(g - g_0) + 40 \log \frac{d}{d_0} + 20 \log \frac{1+f}{1+f} + 29.4 \log \frac{D}{D_0} )</td>
</tr>
<tr>
<td>IREQ [15]</td>
<td>( \Gamma = \Gamma_0 + 1.71(g - g_0) + 40 \log \frac{d}{d_0} + 30.8 \frac{n}{n_0} )</td>
</tr>
<tr>
<td>Sweden [17]</td>
<td>( E = E_0 + 10 \log n + 20 \log r + 1.5(g - g_0) - 40 \log \frac{D}{D_0} )</td>
</tr>
</tbody>
</table>

The values of \( C_1 \) and \( C_2 \) are derived from the following equations:

\[
C = 10 \log (DW^2 + ESU^2 + EIND^2)
\]

where:

- \( DW \) is the direct wave component
- \( ESU \) is the surface wave component
- \( EIND \) is the induction field component

\[
DW = \frac{\lambda H_c}{2 \pi D} \frac{47.7 H_c}{fD}
\]

where:

- \( H_c \) is height of conductors, m
- \( D \) is radial distance between conductors and antenna, m
- \( f \) is frequency, MHz
- \( \lambda \) is wavelength, m
- \( H_a \) is height of antenna, m

when \( D < \frac{12 H_c H_a}{\lambda} \)

\[
DW = \frac{47.7 H_c}{(12 H_c H_a)} \frac{(fD)}{\lambda(D)}
\]

\[
= 1.908 \frac{(H_c f)}{H_a D^2}
\]

All the constants in this equation came from the Apple Grove A-line, where excellent long-term RI data was collected over several years [18]. The constants \( C_1 \) and \( C_2 \) adjust the RI calculated at 15 m to other lateral distances from the line. The equations for these terms are based upon the work of Pakala and Chartier [19]. \( C_1 \) is a constant for the reference line at the particular distance conductor height, antenna height, and frequency for which the RI is being calculated. Therefore, \( C_2 \) is based upon the input data. The difference between \( C_1 \) and \( C_2 \) is added to the RI/phase calculations at 15 m.
where:

\[ f(p) = \frac{2 + 0.3p}{2 + p + 0.6p^2} \]

\[ \rho = \frac{52.50}{\delta \lambda^2} \]

\[ \delta = \text{ground conductivity, mhos/m} \]

\[ E_{IND} = \frac{Hc}{(KD)^2} \]

The reference parameters for calculating \( C_1 \):

\[ D_{W1} = \frac{(47.75)(13.7)}{f(21.0)} = 31.2 \]

\[ E_{IND1} = \frac{13.7 + 70.5}{f^2} \]

\[ \rho_1 = \frac{(52.5)(21.0)}{52.5 + 21.0} = 276.16 \]

\[ f(p)_1 = \frac{2 + 0.3p_1}{2 + p_1 + 0.6p_1^2} \]

\[ ESU = f(p)_1 + \frac{31.1}{f} \]

DC EQUATION

The RI/positive pole at a horizontal distance of 15 m from the positive pole is given by:

\[ RI = 60.5 + 86 \log \frac{E}{27.5} + 40 \log \frac{d}{46.2} + 10(1-(\log(10f)^2) + \frac{8}{300} - C_1 + C_2 \]

This equation calculates the average fair weather. All the constants in this equation come from the most recent RI tests at The Dalles d-c test site [20].

Data from IREQ [16] suggests that for d-c lines RI during average rain conditions is 3 dB less than average fair weather levels; whereas heavy rain RI is 6 dB less.

TELEVISION INTERFERENCE

The method for calculating TVI for a-c lines during rainy weather is based upon an equation developed by V. L. Chartier. The empirical terms used for calculating the propagation of TVI were developed from data in References 21 and 22.

The per phase TVI level in dB \( \mu \text{V/m} \) is given by:

\[ TVI = 10.0 + 120 \log \frac{E}{16.3} + 30.0 \log \frac{D/30.4}{75.0/f} + C \]

where:

\[ E = \text{Conductor surface voltage gradient, kVrms/cm} \]
\[ D = \text{Diameter of a subconductor in the bundle, mm} \]
\[ f = \text{Frequency at which TVI is to be calculated} \]

The constants in this equation come from a 345-kV line in New York where excellent TVI during steady rain was obtained [22]. Measurements of TVI from APP lines have agreed quite well with calculated levels using this equation.

No significant TVI has ever been measured from d-c lines during fair or foul weather. As a result, no attempt has been made to develop equations for calculating TVI from d-c lines.

CORONA LOSS

There are a number of methods that exist for calculating corona losses for both a-c and d-c lines. Most of these methods are not very easy to understand or use; therefore, in the Laboratories we decided to develop empirical equations similar to the equations for other corona phenomena [23].

AC LINES

The CL/phase in dB above 1 w/m is calculated using the following equation:

\[ CL = 14.2 + 65 \log \frac{E}{27.5} + 40 \log \frac{d}{46.2} + 10(1-(\log(10f)^2) + \frac{4K_1 \log n + K_2 + \frac{4}{300}}{4} \]

where:

\[ n = \text{number of subconductors} \]
\[ K_1 = 13 \text{ for } n < 4 \]
\[ K_2 = 19 \text{ for } n > 4 \]
\[ K_2 \text{ is a term that adjusts corona loss for rain intensity.} \]

To calculate the losses in w/m or kW/km, the antilog of CL must be taken or:
CASE 1: \( D_0 < C \)  
\( A < C \)

Both the reference point and the measuring point lie on the 20 dB/decade slope of the curve.

The value of \( C \) is therefore determined by:

\[
C = 20 \log_{10}(D_0/A)
\]

CASE 2: \( D_0 < C \)  
\( A > C \)

If \( D_0 < C \) and \( A > C \), we must move from the reference point down to the measuring point. Therefore:

\[
C = 20.0 \log_{10}(D_0/C) + 40.0 \log_{10}(C/A)
\]

CASE 3: \( D_0 > C \)  
\( A < C \)

In this case we must move up from the reference point to the measuring point.

\[
C = 20.0 \log_{10}(C/A) + 40.0 \log_{10}(D_0/C)
\]

CASE 4: \( 61 > C \)  
\( A > C \)

In this case both points lie on the 40 dB/decade portion of the curve. Therefore:

\[
C = 40.0 \log_{10}(D_0/A)
\]

Table II
\[ CL (W/m) = \exp(-Ct(d8/10) \text{ antilog} \frac{CL (dB \ W/m)}{10}) \]

The total losses for a line, of course, are:

\[ CL (Total) = \frac{CL(i)}{w/m} \]

To calculate the average levels during rainy weather, the computer program assumes an average rain intensity of 1.676 mm/hr (this, of course, will vary from region to region). To calculate the average fair weather losses, the program subtracts 17 dB from the calculated average rainy weather losses. This difference of 17 dB was obtained from the Apple Grove test data where carefully controlled fair weather measurements were made.

**DC LINES**

IREQ has conducted the most extensive corona loss measurements in all kinds of fair, rainy, and snowy weather. Consequently, until a better analysis of all the available corona loss data can be conducted, the Division of Laboratories has adopted the IREQ corona loss formula. We have modified that formula so it calculates the average corona loss for each pole in rain, which assumes the corona losses are the same for the negative and positive poles of a d-c bipole line.

\[ CL = 16.9 + 0.73 (E - 25) + 20 \log \frac{d}{40.7} \]

\[ 8 \log \frac{n}{6} + K_2 + q/300 - 3.0 \]

To obtain average fair weather corona loss, 5 dB is subtracted from the average rainy weather calculation. At this time, we are assuming that the change in corona loss on d-c lines as a function of rain intensity is the same as for a-c lines; therefore, \( K_2 \) in the d-c formula is the same as for the a-c formula.

**OZONE CONCENTRATION**

The method of calculating theoretical estimates of ozone concentrations is based on a method developed by V. L. Chartier and J. F. Roach [24].

For the case of a wind normal to the line, the lateral profile is estimated by (MKS units):

\[ C(X,Z) = \sum_{t=1}^{3} \frac{S_i}{\sigma_z \sqrt{2\pi}} \left\{ \frac{e^{-\frac{(Z-H)^2}{2\sigma_z^2}}}{\sigma_z^2} \right\} \]

\[ + \exp\left\{ -\frac{(Z+H)^2}{2\sigma_z^2} \right\} \]

Where:

- \( S_i \) is the source strength of the \( i \)-th line
- \( U \) is the wind speed
- \( H \) is the average height of the line above ground
- \( Z \) is the ozone sensor height
- \( \sigma_z \) is the spreading coefficient in the \( Z \) direction

The spreading coefficient is approximated by (MKS units):

\[ x = 0.0315 \left[ \frac{23}{U} + 4.75 \left( \frac{100/H}{25} \right) \right] (X-X_1) \]

Where \( X_1 \) is the \( X \) coordinate of the \( i \)-th line source.

The source strength \( S_i \) for a-c lines is given by:

\[ S_i = 1.260 \times 10^{-7} \left( \frac{P_i}{G_i} \right) \]

and for d-c lines, it is:

\[ S_i = 1.260 \times 10^{-9} \frac{P_i}{G_i} \]

for the negative pole, and:

\[ S_i = 0.380 \times 10^{-9} \frac{P_i}{G_i} \]

for the positive pole.

**DISCUSSION**

1. Effect of altitude on corona phenomena is based upon radio noise and corona loss data obtained at Leadville, Colorado, in the 1950's. It is obvious that AN data is especially needed at higher altitudes, and it would be desirable to obtain additional RI and TVI data at higher altitudes. A test station will be installed on the Garrison-Hot Springs double-circuit 500-kV lines at an altitude of about 1800 m, which will provide some of this additional data.

2. The empirical expressions for calculating corona losses are primarily developed from rain data on both a-c and d-c lines. There is some indication that corona losses may be higher during dry snow conditions than during rainy weather. Dry snow being a sharp pointed object may be going into a form of ultra-corona which is known to be very lossy. The Leadville and other data needs to be examined in detail to determine if an additional correction factor for dry snow should be developed and added to existing CL formulas.

3. Most of the better radio noise formulas give about the same calculations for RI at the reference distance of 15 m from the outer phase. However, the agreement falls apart when a comparison of calculated lateral profiles is made. An example of this disagreement can be seen in Figure 2 where a comparison is shown between the calculated RI levels using the BPA empirical formula, and the General Electric analytical formula for the 500-kV base case delta-configurated line shown in Figure 5.4.22 of the "Red Book." Also shown on this curve is a calculated lateral profile, assuming the 1 MHz field produced by corona would have the same lateral profile as the 60 Hz field. Many analytical approaches have used this assumption for making RI calculations.
The difference between fair weather and foul weather AN is assumed to be 25 dB based upon data obtained on the Marlon-Alvey and Marion-Lane 500-kV lines. Data from other lines in and outside of EPA territory indicates that this difference is a function of conductor surface gradient and possibly other line parameters. Therefore, additional data is needed to verify this assumption.

The formula for calculating TVI for a-c lines is quite similar to the RI formula, and like the RI formula, it assumes the TVI is primarily generated by conductor corona. Some data from the Apple Grove 750-kV project and the Lyons 1200-kV test facility indicate that TVI is independent of conductor configuration. This data suggests the primary source of the TVI might be the corona off the Insulators or the tower hardware where the electric fields are stronger because of the proximity of the tower.

**REFERENCES**


V. L. Chartier was born in Fort Morgan, Colorado, on February 14, 1939. He received B.S. degrees in Electrical Engineering and Business from the University of Colorado in 1963. From 1963 to 1975 he was with the Advanced Systems Technology Department of the Westinghouse Electric Corporation, where he was engineer-in-charge of the Apple Grove 750-kV Project and was a principal consultant to the utility industry on the effects of corona and electric fields of high voltage transmission lines. In 1975 he joined the Bonneville Power Administration’s Division of Laboratories, where he has been associated with the Lyons 1200-kV Project and other high-voltage projects. He is presently BPA’s Chief High Voltage Phenomena Engineer.

Mr. Chartier is a member of the USNC of IEC; Technical Advisor to the USNC of IEC on matters pertaining to CISPR Subcommittee C on High-Voltage Lines and Traction Systems; past Chairman of the IEEE/PES Corona and Field Effects Subcommittee; past member of the Board of Directors of the IEEE Electromagnetic Compatibility Society; Secretary of IEEE/PES Transmission and Distribution Committee; member of ANSI C63 Committee (Radio Electrical Coordination); Chairman of Subcommittee 4 (High Voltage Apparatus and Power Lines) of ANSI C63; Expert Advisor to CIGRE Study Committee No. 36 (Interference); and member of the Acoustical Society of America.
1. INTRODUCTION

This computer program computes lateral profiles of audible noise, radio interference (RI), television interference (TVI), and ozone concentration. Lateral profile printouts of these sets of phenomena can be requested individually or collectively. If an individual printout is requested, audible noise, RI, or TVI will be presented on a noise per phase arrangement. A vertical as well as a horizontal profile of ozone concentration is available upon request.

Subroutines for audible noise, RI, and TVI are modified versions of programs originally developed and coded by V. L. Chartier of BPA. The subroutine for calculation of ozone production is a modified version of a program written by Dan Brackeg of BPA based on research by V. L. Chartier and J. F. Roach of Westinghouse. A subroutine for calculation of the conductor surface voltage gradient was based on Mangoldt's equation and was coded by R. H. Larson of BPA. Within the ozone subroutine is an empirical equation for calculating corona losses which was taken from a paper by T. Sugimoto of the Shiobara Test Project and coded by R. H. Larson.

The user has the option of inputting values for conductor surface voltage gradients (previously calculated from some other source) or he may have the program compute them using the equation developed by Mangoldt.

The user has the option of inputting and outputting values in either Metric or English units.

The program has a capability of performing calculations on either single or double circuit transmission line configurations where a maximum of four overhead ground wires are in existence.

It is possible to process multiple problems sequentially by stacking the data cards for each study sequentially.

This computer program is the result of combining existing programs for calculating these corona phenomena. All the analytical expressions are state-of-the-art. The Laboratories has on-going R&D projects for verifying and improving the accuracy of these analytical techniques; therefore, reports will be issued as new analytical expressions are developed.

2. AUDIBLE NOISE

The method of calculating A-weighted audible noise is based on an empirical equation developed by V. L. Chartier of BPA.

The audible noise per phase is given by:

\[ 120.0 \log_{10}(E) + 55.0 \log_{10}(\text{Deq}) - 11.4 \log_{10}(R) - 170.5 \]

where:

- \( E \) = maximum conductor surface voltage gradient, kVrms/cm
- \( \text{Deq} \) = \( 0.589(D) \times N^{0.482} \) for \( N \geq 4 \)
  - \( D \) if \( N < 4 \)
- \( N \) = Number of conductors in the bundle
- \( D \) = Diameter of a subconductor in the bundle, mm
- \( R \) = Radial distance from bundle center to calculating point, m
The total audible noise is the sum of the contribution of each of the three phases calculated in decibels.

3. RADIO NOISE

The method of calculating RI is based on an empirical equation developed by W. E. Pakala and V. L. Chartier:

The RI/phase in dB above one µV/m is given by:

for \( R \leq CH \):

\[
RI = 48.0 + 3.5 (E-17.5) + 30.0 \log_{10} \left( \frac{D}{35.1} \right) + 20.0 \log_{10} \left( \frac{30.7 \times Y/R^2}{B} \right) + 10.0(1-f)
\]

and for \( R > CH \):

\[
RI = 48.0 + 3.5 (E-17.5) + 30.0 \log_{10} \left( \frac{D}{35.1} \right) + 20.0 \log_{10} \left( \frac{30.7 \times Y/B}{R} \right) + 10.0(1-f)
\]

where:

\( \lambda/2\pi \) where \( \lambda \) is in m

\( E \) = Maximum conductor surface gradient, kVrms/cm

\( D \) = Diameter of subconductor in bundle, mm

\( Y \) = Midspan height of bundle, m

\( B = \left( \frac{\lambda}{2\pi} \right)^2 \)

\( R \) = Radial distance from transmission line to calculating point, m

\( f \) = Frequency at which RI is to be calculated, MHz

This equation is valid for frequencies between 0.2 and 1.6 MHz.

4. TVI

The method for calculating television interference is based on an equation developed by V. L. Chartier. The per phase TVI level in dB above one µV/m is given by:

\[
TVI = 10.0 + 3.5(E-16.3) + 30.0 \log_{10}(D/30.4) + 20 \log_{10}(75.0/f) + C
\]

where:

\( E \) = Conductor surface voltage gradient, kVrms/cm

\( D \) = Diameter of a subconductor in the bundle, mm

\( f \) = Frequency at which TVI is to be calculated

There are four distinct cases which need to be considered to determine the value of C:

1. \( 61.0 \leq CH \), \( A \leq CH \)
2. \( 61.0 \leq CH \), \( A > CH \)
3. \( 61.0 > CH \), \( A \leq CH \)
4. \( 61.0 > CH \), \( A > CH \)
where:

A is the radial distance from the conductor to the measuring point.
61.0 is the reference radial distance for which the empirical formula was developed.

CH is the "changeover" distance given by for formula: \[ CH = \frac{(12.0)(HA)(HC)}{\lambda} \]

where:
\( \lambda \) = Wavelength
\( f \) = TVI, measuring frequency
HA = Antenna height
HC = Conductor height

CASE 1: \( 61.0 < CH \)
\( A < CH \)

Both the reference point and the measuring point lie on the 20 dB/decade slope of the curve.
The value of C is therefore determined by:
\[ C = 20 \log_{10}(61.0/A) \]

CASE 2: \( 61.0 < CH \)
\( A > CH \)

If \( 61.0 < CH \) and \( A > CH \), we must move from the reference point down to the measuring point, therefore:
\[ C = 20.0 \log_{10}(61.0/CH) + 40.0 \log_{10}(CH/A) \]

CASE 3: \( 61.0 > CH \)
\( A < CH \)

In this case we must move up from the reference point to the measuring point.
\[ C = 20.0 \log_{10}(CH/A) + 40.0 \log_{10}(61.0/CH) \]
CASE 4: 61 > CH
A > CH

In this case both points lie on the 40 dB/decade portion of the curve, therefore:
\[ C = 40.0 \log_{10}(61.0/A) \]

5. OZONE CONCENTRATION

The method of calculating theoretical estimates of ozone concentrations is based on a method developed by V. L. Chartier and J. F. Roach. For the case of a wind normal to the line, the lateral profile is estimated by (MKS units):
\[
C(x, z) \approx \sum_{i=1}^{3} \frac{S_i}{U \sigma_z \sqrt{2 \pi}} \left\{ \exp \left[ -\frac{(z-H)^2}{2 \sigma_z^2} \right] + \exp \left[ -\frac{(z+H)^2}{2 \sigma_z^2} \right] \right\}
\]

where \( S_i \) is the source strength of the \( i \)-th line, \( U \) is the wind speed, \( H \) is the average height of the line above ground, \( Z \) is the ozone sensor height, and \( \sigma_z \) is the spreading coefficient in the \( Z \) direction.

The spreading coefficient is approximated by (MKS units):
\[
\sigma_z = 0.0315 \left[ \frac{23}{U} + 4.75(100/H)^{0.25} \right] \left( \frac{X-X_1}{(X-X_1)} \right)^{0.86}
\]

where \( X_1 \) is the \( X \) coordinate of the \( i \)-th line source.

The source strength \( S_i \) is given by:
\[
S_i = 1.260 \times 10^{-7} (P_i)(G_i)^2
\]

where \( P_i \), the corona loss per line source, is given by an empirical equation developed by Sugimoto of the Shiobara test station:
\[
P_i = \frac{0.021 r^2 N e^{-0.27E}}{R} e^{-0.22E} + 1.0 \text{ kW/km}
\]
where:

\[ r = \text{Radius of the subconductor} \]
\[ N = \text{Number of conductors} \]
\[ E = \text{Maximum potential gradient at the conductor surface (kV/cm)} \]
\[ R = \text{Precipitation rate (mm/hr)} \]

\[ G_i, \text{ the maximum surface gradient factor per phase, is given by:} \]
\[ G_i = \frac{E_i}{kV(\text{rms})} \]

6. CALCULATION OF CONDUCTOR SURFACE GRADIENT

The formula for calculating the gradient per phase was developed by Mangoldt. 7

\[ E = (18.0 \times 10^6) Q \left[ 1 + \frac{K_2}{N r} \right] \text{ kVrms/cm} \]

where:
\[ K_2 = 2(N-1)\sin \frac{\pi}{N} \]

\[ s = \text{Subconductor spacing} \]
\[ r = \text{Radius of a subconductor} \]
\[ N = \text{Number of subconductors in bundle} \]
\[ Q = \text{Total Charge on the bundle} \]

7. INPUT SPECIFICATIONS

CARDS 1, 2

BCD heading cards used for study identification
72 columns of each are used
Note that the first column is not used

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-73</td>
<td>Any BCD alphanumeric heading for study identification</td>
<td>12A6</td>
</tr>
</tbody>
</table>

CARD 3

Contains option flags and other miscellaneous input data

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Units option flag</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>Metric units = 0 or blank</td>
<td></td>
</tr>
<tr>
<td></td>
<td>English units = 1</td>
<td></td>
</tr>
</tbody>
</table>
### CARD 3 con't

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Gradient option flag &lt;br&gt;l = gradient to be inputted &lt;br&gt;0 = gradient will be computed by the program</td>
<td>I1</td>
</tr>
<tr>
<td>24</td>
<td>Number of phases (3 or 6)</td>
<td>I1</td>
</tr>
<tr>
<td>31-32</td>
<td>Total number of conductors (number of phases + number of earth wires)</td>
<td>I2</td>
</tr>
<tr>
<td>33-40</td>
<td>Line-line voltage in kV/rms</td>
<td>F8.0</td>
</tr>
<tr>
<td>41-48</td>
<td>Wind velocity in m/s or mi/hr. This is used in calculating spreading coefficients in the ozone subroutine</td>
<td>F8.0</td>
</tr>
<tr>
<td>49-56</td>
<td>Rain rate in mm/hr or in/hr (this is used in computing corona losses in the ozone subroutine)</td>
<td>F8.0</td>
</tr>
</tbody>
</table>

### CARD 4

Contains flags specifying which type of interference is to be computed: AN, RI, TVI, ozone, or a combination thereof.

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-4</td>
<td>If the combined printout of all four types of interference is desired, type in the word &quot;COMB&quot; in this field.</td>
<td>A4</td>
</tr>
<tr>
<td>7-8</td>
<td>For specifying individual printouts.</td>
<td>A2</td>
</tr>
<tr>
<td>11-12</td>
<td>In any of these fields type in the corresponding two character name of the type of individual printout desired</td>
<td>A2</td>
</tr>
<tr>
<td>15-16</td>
<td></td>
<td>A2</td>
</tr>
<tr>
<td>19-20</td>
<td></td>
<td>A2</td>
</tr>
</tbody>
</table>

- AN = audible noise
- RI = radio noise
- TV = television interference
- OZ = ozone concentrations

Any or all of these names may be used in any order.

### CARD 5

Antenna (or sensor) heights and standard frequency specification card

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-8</td>
<td>Vertical height of audible noise microphone</td>
<td>F8.0</td>
</tr>
</tbody>
</table>
CARD 5 con't

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-16</td>
<td>Vertical height of RI antenna</td>
<td>F8.0</td>
</tr>
<tr>
<td>17-24</td>
<td>Vertical height of TVI antenna</td>
<td>F8.0</td>
</tr>
<tr>
<td>25-32</td>
<td>Vertical height of ozone sensor</td>
<td>F8.0</td>
</tr>
<tr>
<td>33-40</td>
<td>Frequency at which RI values are to be calculated.</td>
<td>F8.0</td>
</tr>
<tr>
<td></td>
<td>(EPA uses .834 MHz, IEEE uses 1.0 MHz)</td>
<td></td>
</tr>
<tr>
<td>41-48</td>
<td>Frequency at which TVI values are to be calculated.</td>
<td>F8.0</td>
</tr>
<tr>
<td></td>
<td>(usually around 75 MHz)</td>
<td></td>
</tr>
</tbody>
</table>

CARDS 6 to (number of conductors +5)

Phase information cards. There must be one for each phase (and one for each earth wire if gradients are to be calculated).

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-8</td>
<td>An eight character alphanumeric identification name for each conductor group</td>
<td>A8</td>
</tr>
<tr>
<td>9-16</td>
<td>Horizontal distance of conductor bundle center from reference axis (meters or feet)</td>
<td>F8.0</td>
</tr>
<tr>
<td>17-24</td>
<td>Bundle center midspan height (meters or feet)</td>
<td>F8.0</td>
</tr>
<tr>
<td>25-32</td>
<td>Number of subconductors in the group or bundle</td>
<td>F8.0</td>
</tr>
<tr>
<td>33-40</td>
<td>Subconductor diameter (mm or in)</td>
<td>F8.0</td>
</tr>
<tr>
<td>41-48</td>
<td>Bundle subconductor spacing (cm or in)</td>
<td>F8.0</td>
</tr>
<tr>
<td>49-56</td>
<td>Line to neutral voltage kV(rms) for the bundle</td>
<td>F8.0</td>
</tr>
<tr>
<td>57-64</td>
<td>Electrical phase angle in degrees of the conductor voltage with respect to any arbitrary synchronous reference</td>
<td>F8.0</td>
</tr>
<tr>
<td>65-72</td>
<td>The value of the conductor gradient is entered in this field (only if col. 16 on CARD 3 is a 1, i.e., the user would rather input his own value for the gradient)</td>
<td>F8.0</td>
</tr>
</tbody>
</table>
Lateral Profile Distance CARDS

After the phase information cards come the cards specifying the lateral distances from the reference axis at which points the calculations are to be made. Several of these cards can be used as desired if varying distance increments are preferred over different distance ranges (a maximum of 50 points can be used)

<table>
<thead>
<tr>
<th>Columns</th>
<th>Field Contents</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-8</td>
<td>The number of points corresponding to the starting distance and the distance increment designated respectively by the next two data fields</td>
<td>I2</td>
</tr>
<tr>
<td>9-16</td>
<td>Location of the horizontal starting point for a set of calculating points</td>
<td>F8.0</td>
</tr>
<tr>
<td>17-24</td>
<td>The distance increment for a set of calculating points</td>
<td>F8.0</td>
</tr>
</tbody>
</table>

Blank CARD

Each case study should be followed by a blank card.

8. DATA ORDER

The order of the data cards is the same as they are listed in the input specifications section with heading cards coming first and distance card(s) last followed by a blank card.

A blank card indicates the end of a study. If there is another sequential study to follow, its heading cards will immediately follow the blank card.

When there are no more studies to be processed, a card with an asterisk(*) punched in column 1 should follow the blank card of the last data set.

An example of a listing of input data for two studies run consecutively is shown in Table I.
9. DATA OUTPUT

An example of the data output for Case 1 shown in Table I is shown in the following pages.
AUDIBLE NOISE CALCULATIONS EQUIVALENT DIAMETER FORMULA

OREGON CITY - KEELER 3-3.989 CY AAAC
16.21 M PHASE, SPACING, 15.24 M COND HT

<table>
<thead>
<tr>
<th>Dist. From Center of Tower (Meters)</th>
<th>Maximum Height (Meters)</th>
<th>Gradient (KV/M)</th>
<th>Diameter (MM)</th>
<th>No. of Subcon.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE A</td>
<td>-16.21</td>
<td>15.24</td>
<td>16.46</td>
<td>30.89</td>
</tr>
<tr>
<td>PHASE B</td>
<td>-6.30</td>
<td>15.24</td>
<td>17.88</td>
<td>30.39</td>
</tr>
<tr>
<td>PHASE C</td>
<td>10.21</td>
<td>15.24</td>
<td>16.86</td>
<td>30.89</td>
</tr>
</tbody>
</table>

Microphone HT. = 1.5 Meters

<table>
<thead>
<tr>
<th>Dist from Centerline (Meters)</th>
<th>Totals (RAI) L5 (OBA)</th>
<th>L50 (OBA)</th>
<th>PHASE A L50 (OBA)</th>
<th>PHASE B L50 (OBA)</th>
<th>PHASE C L50 (OBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>54.2</td>
<td>53.7</td>
<td>43.4</td>
<td>48.7</td>
<td>43.4</td>
</tr>
<tr>
<td>5.0</td>
<td>54.0</td>
<td>50.5</td>
<td>42.5</td>
<td>48.4</td>
<td>44.1</td>
</tr>
<tr>
<td>10.0</td>
<td>53.4</td>
<td>46.3</td>
<td>41.6</td>
<td>47.6</td>
<td>44.4</td>
</tr>
<tr>
<td>15.0</td>
<td>52.3</td>
<td>41.8</td>
<td>40.8</td>
<td>46.3</td>
<td>44.2</td>
</tr>
<tr>
<td>20.0</td>
<td>52.1</td>
<td>41.4</td>
<td>40.1</td>
<td>45.9</td>
<td>43.4</td>
</tr>
<tr>
<td>25.0</td>
<td>51.2</td>
<td>41.1</td>
<td>39.4</td>
<td>45.1</td>
<td>42.5</td>
</tr>
<tr>
<td>30.0</td>
<td>50.4</td>
<td>39.3</td>
<td>38.9</td>
<td>44.4</td>
<td>41.7</td>
</tr>
<tr>
<td>35.0</td>
<td>49.3</td>
<td>39.3</td>
<td>39.3</td>
<td>43.7</td>
<td>43.9</td>
</tr>
<tr>
<td>40.0</td>
<td>49.2</td>
<td>37.8</td>
<td>37.8</td>
<td>43.1</td>
<td>40.1</td>
</tr>
<tr>
<td>45.0</td>
<td>43.5</td>
<td>37.4</td>
<td>37.4</td>
<td>42.5</td>
<td>39.5</td>
</tr>
<tr>
<td>50.0</td>
<td>43.1</td>
<td>37.0</td>
<td>37.0</td>
<td>42.1</td>
<td>38.9</td>
</tr>
<tr>
<td>55.0</td>
<td>47.7</td>
<td>41.7</td>
<td>36.6</td>
<td>41.7</td>
<td>38.4</td>
</tr>
<tr>
<td>60.0</td>
<td>47.3</td>
<td>41.3</td>
<td>36.3</td>
<td>41.3</td>
<td>37.9</td>
</tr>
<tr>
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<td>46.9</td>
<td>35.9</td>
<td>36.3</td>
<td>40.9</td>
<td>37.4</td>
</tr>
<tr>
<td>70.0</td>
<td>45.5</td>
<td>41.2</td>
<td>35.6</td>
<td>42.5</td>
<td>37.0</td>
</tr>
<tr>
<td>75.0</td>
<td>45.2</td>
<td>41.1</td>
<td>35.3</td>
<td>45.2</td>
<td>36.7</td>
</tr>
<tr>
<td>80.0</td>
<td>43.9</td>
<td>42.4</td>
<td>35.1</td>
<td>39.9</td>
<td>36.3</td>
</tr>
<tr>
<td>85.0</td>
<td>43.5</td>
<td>41.6</td>
<td>34.4</td>
<td>39.6</td>
<td>36.0</td>
</tr>
<tr>
<td>90.0</td>
<td>45.3</td>
<td>41.8</td>
<td>34.6</td>
<td>39.3</td>
<td>35.7</td>
</tr>
<tr>
<td>95.0</td>
<td>45.3</td>
<td>41.5</td>
<td>34.3</td>
<td>39.1</td>
<td>35.4</td>
</tr>
</tbody>
</table>
## RADIO NOISE CALCULATIONS

WESTINGHOUSE SIMPLE FORMULA

**OREGON CITY - KEELER 3-3.089 CM AAAC**

10.21 M PHASE SPACING, 15.24 M CONO HT

<table>
<thead>
<tr>
<th>PHASE</th>
<th>DIST. FROM CENTER OF TOWER (METERS)</th>
<th>MAXIMUM RISE (METERS)</th>
<th>SUBCON. DIA. (MM)</th>
<th>NO. OF SUBCON.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-10.21</td>
<td>15.24</td>
<td>16.45</td>
<td>33.39</td>
</tr>
<tr>
<td>B</td>
<td>0.30</td>
<td>15.24</td>
<td>17.86</td>
<td>33.39</td>
</tr>
<tr>
<td>C</td>
<td>10.21</td>
<td>15.24</td>
<td>16.45</td>
<td>33.39</td>
</tr>
</tbody>
</table>

**ANTENNA HT. = 1.0 METERS, FREQ. = .834 MHz**

<table>
<thead>
<tr>
<th>DIST FROM CENTERLINE (METERS)</th>
<th>HEAVY RAIN (D9)</th>
<th>FAIR WEATHER (D9)</th>
<th>PHASE A RI (D9)</th>
<th>PHASE B RI (D9)</th>
<th>PHASE C RI (D9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>32.5</td>
<td>56.5</td>
<td>48.1</td>
<td>56.3</td>
<td>48.1</td>
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<tr>
<td>5</td>
<td>79.5</td>
<td>59.5</td>
<td>45.0</td>
<td>55.5</td>
<td>50.5</td>
</tr>
<tr>
<td>10</td>
<td>77.6</td>
<td>53.0</td>
<td>42.0</td>
<td>53.3</td>
<td>51.6</td>
</tr>
<tr>
<td>15</td>
<td>74.7</td>
<td>50.7</td>
<td>39.3</td>
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<tr>
<td>20</td>
<td>72.3</td>
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<td>36.9</td>
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</tr>
<tr>
<td>25</td>
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<tr>
<td>30</td>
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<td>27.5</td>
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<td>34.0</td>
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<td>24.9</td>
<td>31.0</td>
<td>27.6</td>
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<td>70</td>
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<td>23.4</td>
<td>29.3</td>
<td>25.6</td>
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<td>85</td>
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<td>22.9</td>
<td>28.8</td>
<td>25.0</td>
</tr>
<tr>
<td>90</td>
<td>52.3</td>
<td>28.3</td>
<td>22.5</td>
<td>28.3</td>
<td>24.4</td>
</tr>
<tr>
<td>95</td>
<td>51.9</td>
<td>27.9</td>
<td>22.1</td>
<td>27.9</td>
<td>23.9</td>
</tr>
</tbody>
</table>
## TVI Calculations, QP Detector, Stoddart NM30A Meter

**Oregon City - Keeler 3-3.089 cm AAAG**
**10.21 m Phase Spacing, 15.24 m Cond. HT**

<table>
<thead>
<tr>
<th>Dist. From Center of Tower (Meters)</th>
<th>Maximum Subcon. (Meters)</th>
<th>Gradient (KV/M)</th>
<th>No. of Cond. Subcon.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase A</td>
<td>15.24</td>
<td>16.46</td>
<td>3.89</td>
</tr>
<tr>
<td>Phase B</td>
<td>15.24</td>
<td>17.36</td>
<td>3.89</td>
</tr>
<tr>
<td>Phase C</td>
<td>15.24</td>
<td>16.45</td>
<td>3.89</td>
</tr>
</tbody>
</table>

**Antenna HT. = 3.0 Meters, Freq. = 75.0 kHz**

<table>
<thead>
<tr>
<th>Dist From Centerline (Meters)</th>
<th>Totals (Rain) Quasi-Peak</th>
<th>Phase A QP</th>
<th>Phase B QP</th>
<th>Phase C QP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DBU/M</td>
<td>DBU/M</td>
<td>DBU/M</td>
<td>DBU/M</td>
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<tr>
<td>0.0</td>
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<td>22.4</td>
<td>29.6</td>
<td>22.4</td>
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<tr>
<td>5.0</td>
<td>26.4</td>
<td>20.7</td>
<td>26.4</td>
<td>20.7</td>
</tr>
<tr>
<td>10.0</td>
<td>27.4</td>
<td>19.8</td>
<td>27.4</td>
<td>19.8</td>
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<tr>
<td>15.0</td>
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<td>17.5</td>
<td>23.6</td>
<td>17.5</td>
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<tr>
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<td>16.2</td>
<td>24.0</td>
<td>16.2</td>
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<td>22.5</td>
<td>15.0</td>
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<td>14.0</td>
<td>21.2</td>
<td>14.0</td>
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<td>13.1</td>
<td>20.0</td>
<td>13.1</td>
</tr>
<tr>
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<td>12.2</td>
<td>19.3</td>
<td>12.2</td>
</tr>
<tr>
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<td>18.0</td>
<td>11.4</td>
<td>18.0</td>
<td>11.4</td>
</tr>
<tr>
<td>50.0</td>
<td>17.1</td>
<td>10.7</td>
<td>17.1</td>
<td>10.7</td>
</tr>
<tr>
<td>55.0</td>
<td>16.4</td>
<td>10.3</td>
<td>16.4</td>
<td>10.3</td>
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<tr>
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<td>15.6</td>
<td>9.4</td>
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<td>8.3</td>
<td>15.0</td>
<td>8.3</td>
</tr>
<tr>
<td>70.0</td>
<td>14.3</td>
<td>7.3</td>
<td>14.3</td>
<td>7.3</td>
</tr>
<tr>
<td>75.0</td>
<td>13.3</td>
<td>6.3</td>
<td>13.3</td>
<td>6.3</td>
</tr>
<tr>
<td>80.0</td>
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<td>12.7</td>
<td>5.8</td>
</tr>
<tr>
<td>85.0</td>
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<td>5.6</td>
<td>12.2</td>
<td>5.6</td>
</tr>
<tr>
<td>90.0</td>
<td>11.8</td>
<td>6.0</td>
<td>11.3</td>
<td>7.6</td>
</tr>
<tr>
<td>95.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
OREGON CITY = KFELD  3-3.069 CM AAAC
16.21 M PHASE SPACING,15.24 M CORD HT

\[ X(11) = -10.2 \text{ METERS}, \quad Y(11) = 15.2 \text{ METERS}, \quad S(11) = 4.269E-09 \text{ KG/M/SEC}. \]
\[ X(21) = 6.6 \text{ METERS}, \quad Y(21) = 15.2 \text{ METERS}, \quad S(21) = 7.463E-09 \text{ KG/M/SEC}. \]
\[ X(31) = 16.2 \text{ METERS}, \quad Y(31) = 15.2 \text{ METERS}, \quad S(31) = 4.269E-09 \text{ KG/M/SEC}. \]

RAIN = 25 M4/HR,

WIND VELOCITY = 0.224 METERS/SEC, S(MEAN) = 5.294E-09 KG/H/SEC.

<table>
<thead>
<tr>
<th>OZONE CONCENTRATION IN PPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEIGHT</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
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<tr>
<td>25</td>
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<tr>
<td>35</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>45</td>
</tr>
<tr>
<td>50</td>
</tr>
</tbody>
</table>
## Combined Output of Audible Noise, Radio Noise, TVI, and Ozone Concentration

**Oregon City - Keeler 3-3.689 CM AAAC**  
**10.21 M Phase Spacing, 15.24 M Cond. HT**

### 525 KV

<table>
<thead>
<tr>
<th></th>
<th>Dist. From Center of Tower (Meters)</th>
<th>Height (Meters)</th>
<th>Maximum Gradient (KV/CM)</th>
<th>Subcon. Diam. (M)</th>
<th>No. of Subcon.</th>
<th>Subcon. Spacing (CM)</th>
<th>Voltage L-N (KV)</th>
<th>Phase Angle (Degrees)</th>
<th>Corona Losses (KW/KM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase A</td>
<td>-10.21</td>
<td>15.24</td>
<td>16.45</td>
<td>30.89</td>
<td>3,3</td>
<td>45.72</td>
<td>303.11</td>
<td>-0.00</td>
<td>11.33</td>
</tr>
<tr>
<td>Phase B</td>
<td>0.30</td>
<td>15.24</td>
<td>17.86</td>
<td>30.89</td>
<td>3</td>
<td>45.72</td>
<td>303.11</td>
<td>-126.00</td>
<td>17.06</td>
</tr>
<tr>
<td>Phase C</td>
<td>10.21</td>
<td>15.24</td>
<td>16.46</td>
<td>30.89</td>
<td>3</td>
<td>45.72</td>
<td>303.11</td>
<td>126.00</td>
<td>11.33</td>
</tr>
</tbody>
</table>

An Microphone HT. = 1.5 M, Ant. HT. = 1.0 M, TV Antenna HT. = 3.0 M  
RI Freq. = 0.634 MHz, TV Freq. = 75.000 MHz, Wind Vel. (03) = 0.224 M/SEC

### Lateral Dist. from Centerline (Meters)

<table>
<thead>
<tr>
<th>Lateral Dist. from Centerline (Meters)</th>
<th>Audible Noise Totals (Rain)</th>
<th>Radio Interference Rain</th>
<th>TVI Total for Rain 25.40 MM/HR at 0 M Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>54.2 DBA 50.7 DBA</td>
<td>Heavy L50 DBUV/M</td>
<td>29.6 Ozone 0.628 PPM</td>
</tr>
<tr>
<td>5.0</td>
<td>54.0 DBA 50.5 DBA</td>
<td>Light L50 DBUV/M</td>
<td>29.0 Ozone 0.570 PPM</td>
</tr>
<tr>
<td>10.0</td>
<td>53.5 DBA 50.6 DBA</td>
<td>Light L50 DBUV/M</td>
<td>27.4 Ozone 0.472 PPM</td>
</tr>
<tr>
<td>15.0</td>
<td>52.8 DBA 49.3 DBA</td>
<td>Light L50 DBUV/M</td>
<td>25.6 Ozone 0.721 PPM</td>
</tr>
<tr>
<td>20.0</td>
<td>52.0 DBA 49.5 DBA</td>
<td>Light L50 DBUV/M</td>
<td>24.0 Ozone 0.663 PPM</td>
</tr>
<tr>
<td>25.0</td>
<td>51.2 DBA 47.7 DBA</td>
<td>Light L50 DBUV/M</td>
<td>22.5 Ozone 0.647 PPM</td>
</tr>
<tr>
<td>30.0</td>
<td>51.0 DBA 47.6 DBA</td>
<td>Light L50 DBUV/M</td>
<td>21.2 Ozone 0.642 PPM</td>
</tr>
<tr>
<td>35.0</td>
<td>49.8 DBA 46.3 DBA</td>
<td>Light L50 DBUV/M</td>
<td>20.0 Ozone 0.366 PPM</td>
</tr>
<tr>
<td>40.0</td>
<td>49.2 DBA 45.7 DBA</td>
<td>Light L50 DBUV/M</td>
<td>19.0 Ozone 0.032 PPM</td>
</tr>
<tr>
<td>45.0</td>
<td>48.6 DBA 45.1 DBA</td>
<td>Light L50 DBUV/M</td>
<td>18.0 Ozone 0.024 PPM</td>
</tr>
<tr>
<td>50.0</td>
<td>48.1 DBA 44.6 DBA</td>
<td>Light L50 DBUV/M</td>
<td>17.1 Ozone 0.026 PPM</td>
</tr>
<tr>
<td>55.0</td>
<td>47.7 DBA 44.2 DBA</td>
<td>Light L50 DBUV/M</td>
<td>16.4 Ozone 0.024 PPM</td>
</tr>
<tr>
<td>60.0</td>
<td>47.3 DBA 43.8 DBA</td>
<td>Light L50 DBUV/M</td>
<td>15.6 Ozone 0.026 PPM</td>
</tr>
<tr>
<td>65.0</td>
<td>46.9 DBA 43.4 DBA</td>
<td>Light L50 DBUV/M</td>
<td>15.0 Ozone 0.021 PPM</td>
</tr>
<tr>
<td>70.0</td>
<td>46.5 DBA 43.0 DBA</td>
<td>Light L50 DBUV/M</td>
<td>14.3 Ozone 0.019 PPM</td>
</tr>
<tr>
<td>75.0</td>
<td>46.2 DBA 42.7 DBA</td>
<td>Light L50 DBUV/M</td>
<td>13.8 Ozone 0.016 PPM</td>
</tr>
<tr>
<td>80.0</td>
<td>45.9 DBA 42.2 DBA</td>
<td>Light L50 DBUV/M</td>
<td>13.2 Ozone 0.017 PPM</td>
</tr>
<tr>
<td>85.0</td>
<td>45.6 DBA 42.1 DBA</td>
<td>Light L50 DBUV/M</td>
<td>12.7 Ozone 0.016 PPM</td>
</tr>
<tr>
<td>90.0</td>
<td>45.3 DBA 41.8 DBA</td>
<td>Light L50 DBUV/M</td>
<td>12.2 Ozone 0.015 PPM</td>
</tr>
<tr>
<td>95.0</td>
<td>45.0 DBA 41.5 DBA</td>
<td>Light L50 DBUV/M</td>
<td>11.8 Ozone 0.015 PPM</td>
</tr>
</tbody>
</table>
10. FORTRAN LISTING

The following pages are the FORTRAN listing for the computer program.
PROGRAM COMBINE (INOUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT)

COMMON /AREA/NEH,FREQI,FRETV,X(11),Y(11),GRAD(10),DIAM(10),ANR(10)
       ,ACOMB,NET,SO,DI,NPIF,TITLE(2,12),DIS(50),UNITS,
2   FAZNUH(10)
   DIMENSION SPECTM(4),SALU(150),SALU(131),TVMAX(50),RIFAIR(50)
1   ,HRAIN(50),ARAIN(50),SUBSEC(12),V(10),PH(10),UZURE(50)
2   ,F(A)

INTEGER UNITS

19 DC SL.L=1,2
22 FORMAT (A1,12AE)
1F (COLL.EQ.1) 2 GO TO 150
33 CONTINUE
23 FORMAT (A1,12AE)
   FORMAT (T6.,T2MHS.,THUtLLS A.
13 FORMAT (A4,4(2X,A2))
600 CONTINUE

READ (5,34000) VERTAN, VERTAI, VERTIV, VERTAU, FREQI, FRETV

C SUBCONDUCTOR SPACING IN CM, DIAM IN MM IF METRIC UNITS ARE USED

DO 110 I=1,NC

READ 36071, FAZNUH(I), X(I), Y(I), ANR(I), DIAM(I), SUBSEC(I), V(I), PH(I)
1   , GRAD(I)
   F(I) = 0.0
111 CONTINUE
501 FORMAT (A5,35COO) NET, , SC, DI
34000 FORMAT (5E6,0)
35103 FORMAT (AX,12,2FE,0)
35611 FORMAT (AS,32E)
6 IF (NET.EQ.0) GO TO 530
NPTI = NPTF
NPTF = NPT + NPTI
NPTI = NPTI * 1
DO 650 I = NPTI, NPTF
DIS(I) = SD
SD = SD + DI
651 CONTINUE
GO TO 511
675 IF (UNITS.EQ.1) GO TO 730
628 CONTINUE

IF (ISRAD, EQ. 1) GO TO 523
CALL MANSC (X,Y,DIAM,V,PH, ANR, SUBSEC, GRAD, EQ.)

523 CONTINUE
GO TO 615 I=1, 4
IF (SPECTM(I), EQ. 2HAN) CALL RAN (SLAB, SLAE1, VERTAN)
IF (SPECTM(I), EQ. 2HR1) CALL RAN (HR, RAF, KIF, VERH, ARAIN)
IF (SPECTM(I), EQ. 2HTV) CALL TVI (TV, MAX, VERTIV)
IF (SPECTM(I), EQ. 2HO7) CALL OZ (WIND, EAIN, VOLML, OZONE, VERTOZ, P)

615 CONTINUE
IF (CMNS, EQ. 4, HOOMS) GO TO 610
GO TO 19

CALL AN (SLAB, SLAE1, VERTAN)
CALL RAN (HR, RAF, KIF, VERH, ARAIN)
CALL TVI (TV, MAX, VERTIV)
CALL OZ (WIND, EAIN, VOLML, OZONE, VERTOZ, P)
PRINT 2000
2001 FORMAT (1HM)
2002 FORMAT (A,F10.2)
2102 FORMAT(* COMBINED OUTPUT OF AUDIBLE NOISE, RADIO NOISE, TVI*
                   I*, AND OZONE CONCENTRATION */)
DO 22 L=1,2
22 PRINT 2001, (TITLE(L,K), K=1,12)
231 FORMAT (X, 136)
PRINT 2020, VOLML
2621 FORMAT (LH, F5, KX 1)
PRINT 2003
PRINT 13303
PRINT 13317
IF (UNITS.EQ.1) PRINT 10710
IF (UNITS.EQ.1) GO TO 903
PRINT 10109
13305 FORMAT (15X,* (KME) * (METERS) * 4X * (METERS) * 2X * (KV/C4) * 3X * (MM) * 13X
1 * (C) * (KU) * (DEGREES) * (KW/KM) * *)
13310 FORMAT (15X,* (FEET) * (FEET) * 2X * (KV/C4) * 3X * (IN) * 13X
1 * (IN) * (KU) * (DEGREES) * (KW/FT) *)
13308 FORMAT (15X,* DIST FROM *13X,* MAXIMUM_SUBCON * NG CF_SUBCON* 
1 * VOLTAGE_PHASE_CORONA *)
13307 FORMAT (15X,* CENTER OF TOWER_HEIGHT_GRADIENT * DIAM_SUBCON * 
1 * SPACING L-N ANGLE_LOSSES *)
13315 FORMAT (15X,* *4X,F2.2,4X,F2.2,4X,F2.2,F9.2,F9.2,4X,F2)
317 CO.3E I = 1,NC 
WRITE (6,13325) FAZNUM(I),X(I),Y(I),GRAD(I),DIAM(I),ANG(I)
1 SUBSEC(I),V(I),PH(I),P(I)
35 CONTINUE
IF (UNITS.EQ.1) PRINT 10011,VERTAN,VERTRI,VERTIV,FREQ1,FRETV,R
1,WIND
IF (UNITS.EQ.1) GO TO 360
PRINT 10011,VERTAN,VERTRI,VERTIV,FREQ1,FRETV,WIND
13011 FORMAT (1H0,* an MICROPHONE_HT=**F3.1** M, RI HT=**F3.1**
1 * H, TV ANTENNA HT=**F3.1**, M * /
2 * F1_FREQ=**F7.3** MHZ, *3X*T V_FREQ= **F7.3** MHZ, *
3 * WIND Vel.(G0) = **F6.3** MPH * *)
13011 FORMAT (1H0,* an MICROPHONE_HT=**F3.1**, FT, RI ANT_HT=**F3.1**
1 * FT, TV ANTENNA HT=**F3.1**, FT * /
2 * F1_FREQ=**F7.3** MHZ, *2X*T V_FREQ= **F7.3** MHZ, *
1 * WIND Vel.(G0) = **F6.3** MPH * *)
350 PRINT 2006
PRINT 2006
IF (UNITS.EQ.1) PRINT 2007,RAIN,VERTOZ
IF (UNITS.EQ.1) GO TO 363
PRINT 3007,RAIN,VERTOZ
PRINT 2005
2005 FORMAT (* LATERAL DIST AUDIBLE NOISE RADIO INTERFERENCE 
1 * TVI OZONE *)
2006 FORMAT (* FROM TOTALS (RAIN) RAIN总 RAIN *
1 * FOR RAIN RATE OF )
2007 FORMAT (* CENTERLINE LS LSO HEAVY LSO *
CONVERT METRIC TO ENGLISH

243 VERTEAN = VERTEAN*3.28
244 VERTR = VERTR*R3.28
245 VERTIV = VERTIV*3.28
246 VERTOZ = VERTOZ*3.28
247 WIND = WIND/0.47
248 RAIN = RAIN/25.4
249 SEG I = 1, NC
250 SUBSEC(I) = SUBSEC(I)/2.54
251 X(I) = X(I)*3.28
252 Y(I) = Y(I)*3.28
253 CO(I) = P(I)*1.0934
254 DIAM(I) = DIAM(I)/25.4
255 SEG I = 1, NEXT
256 DIS(I) = DIS(I)*3.28
257 GO TO 330
198 STOP
END
SUBCLINE AN (SCALE,SCALE1,VERTAAH)
COM-H/AREA/TH,FREQ1,FREQ2,X(10),Y(10),GRD(10),DIAM(10),ANR(10)
1),ICNA3,NET,SL,CI,NETE,TITLE(1,12),DIS(50),UNITS,
1,FAZNUM (10)
DIMENSION SL=6,SLACON(6),RHL(6),KSC(6),R(6),DEQ(6)
1,SLAE(50),SLAE1(50)
INTEGER UNITS
23.FORMAT (1HI)
691 FORMAT (F10.1, F10.1, 2X, F10.1)
599 FORMAT (1HO)
2018 FORMAT (IX,* MICROWAVE HT.*F6.1, *METERS.//)
2016 FORMAT (IX,* MICROWAVE HT.*F6.1, * FEET.//)
13202 FORMAT (* DIST FROM TOTALS (RAINF) PHASE A. PHASE B. PHAS
1E-9)
1E-9)
1504 FORMAT (* (METERS) (OBA) (OBA) (OBA) (OBA) (OBA)
1E-9)
2013 FORMAT (* (FEET) (OBA) (OBA) (OBA) (OBA) (OBA)
1E-9)
15035 FORMAT (* DIST FROM TOTALS (RAINF) PHASE A1. PHASE B1. PHAS
1E-9)
1603 FORMAT (IX,* CENTER OF TOWER. HEIGHT. DIAM. SUBCON.*
1E-9)
1602 FORMAT (IX,* DIST FROM MAXIMUM SUCON. NC. CR.*
1E-9)
1503 FORMAT (IX,* (METERS) *4X *(METERS) *2X *(K\% DRM)*3X *(IN).*
1E-9)
2009 FORMAT (IX,* (FEET) *4X *(FEET) *2X *(K\% DRM)*3X *(IN).*
1E-9)
1E-9)
15011 FORMAT (* (METERS) (OBA) (OBA) (OBA) (OBA)
1E-9)
2011 FORMAT (* (FEET) (OBA) (OBA) (OBA) (OBA)
1E-9)
1E-9)
1E-9)
VERTAAH
IF(NCOMA.EQ.0) GO TO 139
WRITE(6,23)
WRITE(6,31202)
20 WRITE(5,2) TITLE(L,K), K=1,12)
21 FORMAT (IX,124)
WRITE(6,999)
WRITE(6,1000)
WRITE(6,1000)
IF(UNITS.EQ.1) PRINT 2009
IF(UNITS.EQ.1) GO TO 202
WRITE(6,10000)
DO 35 I=1,NPH
WRITE(6,10001)FAZNUM(I),X(I),Y(I),GRAD(I),DIAM(I),ANR(I)
35 CONTINUE
PRINT 959
PRINT 201E,VERT
35 CONTINUE
IF(NPH.EQ.5) GO TO 185
WRITE(6,10002)
WRITE(6,10003)
IF(UNITS.EQ.1) PRINT 2034
IF(UNITS.EQ.1) GO TO 188
WRITE(6,10104)
GO TO 188
201 DO 235 I=1,NPH
X(I)=X(I)-3.25
Y(I)=Y(I)+3.25
DIAM(I)=DIAM(I)/25.4
PRINT 1010,FAZNUM(I),X(I),Y(I),GRAD(I),DIAM(I),ANR(I)
X(I)=X(I)/3.25
Y(I)=Y(I)/3.25
DIAM(I)=DIAM(I)*25.4
235 CONTINUE
PRINT 959
VERT=VERT+3.25
PRINT 201E,VERT
VERT=VERT+3.25
GO TO 36
185 WRITE(6,10004)
WRITE(6,10005)
IF(UNITS.EQ.1) PRINT 2011
IF(UNITS.EQ.1) GO TO 188
WRITE(6,10111)
184 CONTINUE
NPT=NPT+1
GO 360 M = 1,NPT
GO = 0 I = 1,NPH
D=DIFS(H)
RSQ(I) = (Y(I)-VERT)**2+(D-X(I))**2
R(I) = SQRT(RSQ(I))
XX = ANR(I)
IF(XX.LT.99) GO TO 78
DEQ(I) = 0.589*DIAM(I)*ANR(I)**0.482
GO TO 70
70 DEQ(I) = DIAM(I)
75 FHL(I) = -16.4 + 122.4*ALOG10(GRAD(I)) + 33.0*ALOG10(DEG(I))
    $\text{SLA}(I)$ = FHL(I) - 11.4*ALOG10(R(I)) - 5.8
80 $\text{SLACON}(I)$ = 10.**($\text{SLA}(I)$/10.)
 $\text{SLATOT}$ = $\text{SLA}$
DO 96 I = 1, NEH
94 $\text{SLATOT}$ = $\text{SLATOT}$ + $\text{SLACON}(I)$
 $\text{SLAEQ}(M)$ = 18.6*ALOG10($\text{SLATOT}$)
 $\text{SLAEQ}(M)$ = $\text{SLAEQ}(M)$ + 3.5
IF (NGORNE EQ. 1) GO TO 990
IF (UNITS EQ. 1) GO TO 228
WRITE (6, 228) $\text{SLAEQ}(M)$, $\text{SLAEQ}(M)$, ($\text{SLACON}(I)$, I=1,NEH)
END CONTINUE
195 RETURN
END
SUBROUTINE RI (PRAIN, RFAIR, RCTRL, ARAIN)
COMMON/AREA/NEH, FREQI, FREQT, X(11), Y(11), GRAD(11), DIAM(10), ANX(10)
1, RCOC, RNET, SCQ, DI, RNET, TITLE(2,12), DIS(50), UNITS,
2 RAZUM(10)
DIMENSION HEAN(50), RIFAIR(51, R(6), E(6), RSC(6), EPHTH(6), ACCAIN(S)
1)
INTEGER UNITS
23 FORMAT (1HI)
200 FORMAT (1EI, 1F10.1, 2E13.1)
339 FORMAT (1HI)
12001 FORMAT (14H ANTEI, H*METERS, FH, FREQ$, F7.3, 4H. MHZ, )
1)
2001 FORMAT (14H ANTEI, H*METERS, FH, FREQ$, F7.3, 4H. MHZ, )
1)
1202 FORMAT (*) DIST FROM HEAVY FAIR PHA, PHASE A PHASE B PHASE C
1 G C C)
1203 FORMAT (*) CENTERLINE RAIN WEATHER R1 R1 R1
1)
1204 FORMAT (*) (METERS) (DB) (DB) (DB) (DB)
1)
2004 FORMAT (*) (FEET) (DB) (DB) (DB) (DB)
1)
1208 FORMAT (*) DIST FROM HEAVY FAIR PHASE A1 PHASE B1 PHASE C C*
1E C1 PHASE A2 PHASE B2 PHASE C2 *
1207 FORMAT (1X, *CENTER OF TOWER HEIGHT GRADIENT DIAM. SUBCON.")
1208 FORMAT (14X, *DIST. FROM*, 13X, *MAXIMUM SUBCON. NC. CE")
1209 FORMAT (1SX, * (METERS) *X* (METERS) *X* (KI/CA) *X* (KH) *)
2009 FORMAT (15X, * (FEET) *X* (FEET) *X* (KI/CA) *X* (KH) *)
1210 FORMAT (*) CENTERLINE RAIN WEATHER R1 R1 R1
1)
1211 FORMAT (*) (METERS) (DB) (DB) (DB) (DB)
1)
2011 FORMAT (*) (FEET) (DB) (DB) (DB) (DB)
1)
1212 FORMAT (*) (METERS) (DB) (DB) (DB) (DB)
1)
3001 FORMAT (*) RADIO NOISE CALCULATIONS WES TINGHOUSE SIMPLE FORMULA*x/z*
1)
VETR=VETR
IF(NOFF2, E7.1) GO TO 188
WRITE(6, 23)
WRITE(6, 1000)
GO TO 21, L=12
21 WRITE(6, 21)(TITLE(L,K), K=1, 12)
21 FORMAT (1X, 18E)
PRINT 599
WRITE(6,10003)
WRITE(6,10002)
IF(UNIT.EQ.1) PRINT 2039
IF(UNIT.EQ.1) GO TO 207
WRITE(6,10003)
GO 33 I=1,NPH
WRITE(6,10302) FINUM(I), X(I), Y(I), GRAD(I), DIAM(I), ANK(I)
33 CONTINUE
WRITE(6,99)
WRITE (6,10001) VERT, FREORI
250 CONTINUE
IF(NPH.EQ.6) GO TO 125
WRITE(6,10002)
WRITE(6,10003)
IF(UNIT.EQ.1) PRINT 2044
IF(UNIT.EQ.1) GO TO 125
WRITE(6,10003)
GO TO 125
211 GO 235 I=1,NPH
Y(I)=Y(I)*3.28
X(I)=X(I)*3.28
DIAM(I)=DIAM(I)/25.4
PRINT (2305, FINUM(I), X(I), Y(I), GRAD(I), DIAM(I), ANK(I)
X(I)=X(I)/3.28
Y(I)=Y(I)/3.28
DIAM(I)=DIAM(I)*25.4
235 CONTINUE
PRINT 999
VERT=VERT*3.28
PRINT 2301, VERT, FREORI
VERT=VERT/3.28
GO TO 253
135 WRITE(6,10005)
WRITE(6,10006)
IF(UNIT.EQ.1) PRINT 2011
IF(UNIT.EQ.1) GO TO 131
WRITE(6,10011)
131 HL = 306 / FREORI
CH = HL/5.283185308
P = CH**2
NP1=NP1
DC E03_1 = 1, NP1
CO 40_1 = 1, NPH
T = DIS(M)
RES(I)=(Y(I)-VERT)**2 + (0.-X(I))**2
!

.(1) = .SQR(RESQ(1))
: = 1(1)

IF (ACT CH) 38,39

\( E(1) = 1.3 + 3.5 \times (\text{GRAD}(1) - 17.3) + 3.2 \times \text{ALOGIC}((
\text{DIAM}(1))/35.1) \)

\( 1 + 2.1 \times \text{ALOGIC}(3.7 \times Y(1))/3 + 26 \times \text{ALOGIC}(CH/\pi(1)) + 10 \times (1 - \text{ECEF}) \)

GO TO 39

\( E(1) = 48.7 + 3.5 \times (\text{GRAD}(1) - 17.3) + 3.2 \times \text{ALOGIC}((
\text{DIAM}(1))/35.1) \)

\( 1 + 21 \times \text{ALOGIC}(3.7 \times Y(1))/10(1 - \text{FREG}) \)

GO TO 39

\( E(1) = 2.7 + 2.4 \times (\text{GRAD}(1) - 17.3) + 3.2 \times \text{ALOGIC}((
\text{DIAM}(1))/35.1) \)

\( 1 + 21 \times \text{ALOGIC}(3.7 \times Y(1))/10(1 - \text{FREG}) \)

99 EPHASE(I) = E(I)

99 CONTINUE

EMAX = AMAX1(E(1),E(2),E(3))

IF (NSEG = EQ. 3) GO TO 355

EMAX = AMAX1(E(4),E(5),E(6))

EMAX = AMAX1(EMAX,FMAX)

733 HRAIN(M) = EMAX + 24.0

FIFTH(M) = EMAX

ARAIN(M) = EMAX + 17.0

IF (NGM = EQ. 1) GO TO 533

IF (UNITS = EQ. 1) P = 0 - 3.28

WRITE(E, SGO) E, HRAIN(M), EMAX, (EPHASE(J), J = 1, NPH)

F00 CONTINUE

133 RETURN

END
SUBROUTINE TVI (TVMAX, VERTIV)
COMMON/AREA, X(NH), FREQL, FREQV, X(13), Y(13), GRAD(10), DIAM(10), ANR(10),
& NCORE, NEI, SG, DI, CPR, TITLE(L2, L2), DIS(50), UNITS,
& F8.1, T, E(6), VMAX(50)
INTEGER UNITS
2 FORMAT (10)
DIMENSION FS(50), R(6), E(6), EHASE(6), TVMAX(50)
1 FORMAT (100)
6 FORMAT (F8.1, 5X, F8.1, 5X, IF10.1, 2X, IR10.1)
9 FORMAT (100)
1301 FORMAT (14H ANTENNA HT. = F5.1, 7H METERS, 6H, FREC. = F7.3, 4H MHZ, //)
1302 FORMAT (* DIST FROM TOTALS (RAIN) PHASE A PHASE B PHAS
& EF C *)
1303 FORMAT (* CENTERLINE QUASI-PEAK GP GP GP
& GP *)
1304 FORMAT (*) (METERS), DBUV/MDBUV/MDBUV/MDBUV
& I/M  * )
1305 FORMAT (*) (FEET), DBUV/MDBUV/MDBUV/MDBUV
& I/M  * )
1306 FORMAT (*) DIST FROM TOTALS (RAIN) PHASE A1 PHASE B1 PHAS
& EF C *)
1307 FORMAT (14X, CENTER OF TOWER HEIGHT GRADIENT DIAM. SUBCON. *)
1308 FORMAT (14X, DIST. FROM*, 13X, MAXIMUM SUBCON. NG. CF*)
1309 FORMAT (15X, METERS) 4X (METERS) 2X (KV/CH) 3X (MH) */
2229 FORMAT (15X, (FEET) 4X (FEET) 2X (KV/CH) 3X (MH) */
1310 FORMAT (*) CENTERLINE QUASI-PEAK GP GP GP
& GP  * )
1311 FORMAT (*) (METERS), DBUV/MDBUV/MDBUV/MDBUV
& I/M  * )
1312 FORMAT (*) (FEET), DBUV/MDBUV/MDBUV/MDBUV
& I/M  * )
1313 FORMAT (14H TVI CALCULATIONS, GP DETECTOR, STOCART N433A METER *
& I //)
   VERT=VERTIV
IF(NCORE.EQ.1) GO TO 169
WRITE(6, 23)
PRINT 10212
DO 21 L=1, 2
21 WRITE(6, 21) (TITLE(L, K), K=1, 12)
   WRITE(6, 22)
   WRITE(6, 959)
WRITE(6,10006)
WRITE(6,10007)
IF(UNITS.EQ.,1) PRINT 2009
IF(UNITS.EQ.,1) GO TO 200
WRITE(6,10009)
DO 35 I=1,NFH
WRITE(6,10006)FAZNUM(I),X(I),Y(I),SHAD(I),DIAM(I), ANR(I)
35 CONTINUE
WRITE(6,999)
WRITE (6,10001) VERT,FREOTV
25A CONTINUE
IF(UNIT.EQ.,6) GO TO 155
WRITE(6,10002)
WRITE(6,10003)
IF(UNITS.EQ.,1) PRINT 2004
IF(UNITS.EQ.,1) GO TO 168
WRITE(6,10004)
GO TO 188
232 DO 235 I=1,NFH
X(I)=X(I)*Z28
Y(I)=Y(I)*Z28
DIAM(I)=DIAM(I)/25.4
PRINT 10006,FAZNUM(I),X(I),Y(I),GRAC(I),DIAM(I),ANR(I)
X(I)=X(I)*Z28
Y(I)=Y(I)/Z28
DIAM(I)=DIAM(I)*25.4
235 CONTINUE
PRINT 999
VERT=VERT*Z28
PRINT 22011,VERT,FREOTV
VERT=VERT/Z28
GO TO 251
135 WRITE(6,10005)
WRITE(6,10010)
IF(UNITS.EQ.,1) PRINT 2011
IF(UNITS.EQ.,1) GO TO 188
WRITE(6,10011)
135 CONTINUE
NPT=NPT
DO 300 K=1,NPT
DO 46 I=1,NFH
C=DIS(I)
R5Q(I) = (Y(I)-VERT)**2 + (O-X(I))**2
R5Q(I) = SQRT(R5Q(I))
CH=12.1*VERT*Y(I)*FREOTV*Z28          \ 984.2344
E(I) = 16.3 + 3.3 * (GFD(I) = 16.3 + 33 * ALOG10(U1AM(I)/30.4)
1 25 * ALOG10(ZR/ZEFOTV)

E = E(I)

IF(E1, LT, CH AND A, LT, CH) E(I) = E(I) + 20.3 * ALOG10(E1.C/A)

IF(E1, LT, CH AND A, GT, CH) E(I) = E(I) + 20.3 * ALOG10(E1.C/CH) + 100

IF(E1, GT, CH AND A, LT, CH) E(I) = E(I) + 40.0 + ALOG10(E1.C/CH) + 20.3 * ALOG10

1 (CH/A)

IF(E1, GT, CH AND A, GT, CH) E(I) = E(I) + 40.0 + ALOG10(E1.C/CH) + 20.3 * ALOG10

39 IFPHASE(I) = E(I)

40 CONTINUE

E.MAX = MAX1(E(1), E(2), E(3))

IF(NEH, EQ. 3) GO TO 390

EMAX = AIMAX1(E(4), E(5), E(6))

EMAX = AIMAX1(EMAX, EMAX)

390 TMAX(4) = E MAX

IF(KOC(4), EQ. 4) GO TO 390

IF(WR1ES.EQ. 1) D#0 = 3.22

WRITE(E, EQ) E, EMAX, (IFPHASE(J), J=1, NEH)

500 CONTINUE

199 RETURN

END
SUBROUTINE OZ(WIND, RAIN, VOLTL, OZONE, VELOC, P,)
COMMON AREA, N, E, S, E, F,(10), T, OZONE, VOLTL, RAIN, VELOC, P,)
DIMENSION S(6), P(6), OZONE, E(10), T(10), VELOC(10),
INTEGER UNITS
VOLTL = VOLTL/SORT(1, 0)
DATA PI/3.14159265/
PRINT 1, WIND
SSAR = 0.0
IF(INCOME.EQ.1) GO TO 40
PRINT 100
100 FORMAT (1HI)
PRINT 23, (TITL(L, K), K=1, 12, L=1, 2)
PRINT 400
40 CONTINUE
CO 10, K=
RN(I) = D(I) / 20.0
10 CONTINUE
CO 9 I=1, NPH
P(I) = (112) * ANB(I) * EXP(0.27 * GRAD(I)) /
1 123 + EXP(-0.22 * GRAD(I)) / RAIN + 1.0)
GG(I) = GRAD(I) / VCLITN
S(I) = F(I) * GG(I) * GG(I) + 1.250E-07
I=1
5 SSAR = SSAR + S(I)
SSAR = SSAR / MY
IF(INCOME.EQ.1) GO TO 100
CO 30, K=1, NPH
30 PRINT 211, I, T(I), Y(I), T(I), S(I), GRAD(I), F(I), ANB(I)
PRINT 200, RAIN
200 FORMAT (10, PAIN = -F6.0, -MM/HR, -)
PRINT 402
WRITE(6, 202) WIND, SSAR
202 FORMAT (IX, 12A6)
999 FORMAT (+, -)
211 FORMAT (IX, 12X) = 06.1* METERS, Y(*12*) = 06.1* METERS, S(*12*-
1) = 09.3* KG/M/SEC.*, 3F6.3)
212 FORMAT (1X, WIND VELOCITY = *
FT.3* METERS/SEC, 3F6.3)
I(N) = 09.3* KG/M/SEC. / 31X*OZONE_CONCENTRATION_IN_PPM /*
)
PRINT 300
PRINT 308
300 FORMAT (HEIGHT = 38X* LATERAL DISTANCE FROM CENTERLINE (METERS))
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335 FORMAT (14H0, 15X, 2*10X, 5X, 12A9X, 15X, 25X, 3X, 50A, 8X, 7F*)
   1  (X*(1.0 + 2X + 8X + 1E0 *))
   DO 10 J=3,25,5
   J=J+5
   G=G+12
   DO 12 I=1,J,11
   12 C(I)=0.0
   h=6
   DO 14 I=1,2
   KK2=KK1*KK3=3
   KK=32
   IF(I=20,1128,19)
   18 KK1=E0
   KK1=0
   KK2=120
   KK3=25
   21 CONTINUE
   DO 14 KK=KK1, KK2, KK3
   M=KK-KK1
   M=M+1
   CO 14 L=E, NPH
   XL=X(L)
   IF (X(L,LT,.25)) 14, 13
   13 SIG=(23.15*(23./HINC+4.5*(1CQ./Y(L))**.25)* (H-Y(L))**.33
   A=(A* ((G=Y(L))**2.)/(2.*SIG**2.))
   B=(G+Y(L))**2.)/(2.*SIG**2.))
   C=(SEFY* (HINC*SIG*SORT(2.*PI))
   C(M)=C(M)+C1*(1./EXP(A)+1./EXP(B))
   14 CONTINUE
   DO 16 I=1,11
   16 C(I)=C(I)*CFACT
   WRITE (5,205) I1, (C(I), I=1,11)
   215 FORMAT (14G, 121, 12X, 11F, 11, 14)
   19 CONTINUE
   IF(NCOMB.NE.1) GO TO 25
   120 CONTINUE
   CO 105 M=1, NTF
   C(M)=0.0
   CO 109 L=1, NPH
   XL=DIG(M) = X(L)
   IF (X(L,LT,.25)) GO TO 105
   SIG=(23.15*(23./HINC+4.5*(1CQ./Y(L))**.25)* (XL)**.33
   A=(Y(L)-VERTOZ) * (Y(L)-VERTOZ) / (2.0 * SIG * SIG)
   S=(Y(L)+VERTOZ) * (Y(L)+VERTOZ) / (2.0 * SIG * SIG)
   C1=(SEFY* (HINC*SIG*SORT(2.*PI)))
C(N) = C(N) + C1 * (1.0 / EXP(A) + 1.0 / EXP(B))

110  CONTINUE
100   I = I + 1
2(I) = C(I) + OFACT
CZNECE(I) = C(I)
110  CONTINUE
25  RETURN
END
SUBROUTINE HANKO (X,Y,DIAM,V,P,ANR,SUBSPC,ERG,NG)

DIMENSION X(L),Y(L),DIAM(L),BUNCIA(L),ANR(L),SUBSPC(L)

1 X(I) = Y(I) = DIAM(I) = BUNCIA(I)

2 
EPS = (1.0 / (2.0 * PI)) * (I-1) * PI - EPS
EPSI = 1.0 / (2.0 * PI)

3 F(I) = 1.0, NC
VEAL(I) = V(I) * COS(FH(I) * PT / 180.0) * 1.000
VIMAG(I) = V(I) * SIN(FH(I) * PT / 180.0) * 1.000

4 DIA(I) = DIAM(I) / 10.0
ANG(I) = ANR(I) / 10.0

5 IF (ANG(I) = 0.0) GOTO 10

6 IF (ANG(I) < 0.0) GOTO 10

7 
SUNP(I) = BUNCIA(I) / SIN(P/ANG(I))

8 
COS(I) = BUNCIA(I) * (ANG(I) * DIA(I)) / SUNP(I)

9 
/ 100.0

10 CONTINUE

11 F(I) = EPSI * ALOGH (SQR ((X(I) - X(J)) ** 2 + (Y(I) - Y(J)) ** 2))

12 
/ 10.

13 CONTINUE

CALL MATRIX (10,NC,NC,12,P,10,DET)

CALL MATRIX (22,NC,NC,12,E,12,VEAL,12,QREAL,12)

CALL MATRIX (22,NC,NC,12,P,12,VIMAG,12,QIMAG,12)

14 I = 1, NC

15 D(I) = SQRH (QREAL(I) * QREAL(I) + QIMAG(I) * QIMAG(I))

16 
SUNP(I) = 2.0 * ANR(I) - 1.0 + SIN (PI/ANG(I))

17 CONTINUE

18 
F(I) = (D(I) * (1.0 + CK2(I) / (SUBSPC(I) / RAD(I)))) * (1.0 - EPSI)

19 CONTINUE

RETURN

END
11. REFERENCES


