PRESENTATION

William Kaune
EM Factors
Richland, WA

In introducing his presentation, William Kaune referenced Bracken's synopsis, recommending it to the participants, and then presented material on modeling exposures that centered on Kaune's own research, primarily in the area of residential exposures. The material below, prepared from the transcript of the proceedings and the slides from Kaune's presentation, reflects the substance of his presentation: Modeling Exposure to Electric Fields. This summary has been reviewed by the presenter for accuracy.

Kaune began with a conceptual discussion of exposure. He defined exposure as follows: the experience of a person moving through an environment in which there is a magnetic field, B, which is a function of position X, Y, and Z, and time (during which the person may move and/or the field may change). In mathematical terms, the cumulative exposure of a person moving through the field is the integral of the magnetic field at a position on the body over time, represented as:

$$X = \int_o^T B[x_B(t), y_B(t), z_B(t), t]\, dt$$

Determining exposure is also subject to time. For contemporaneous exposure, the researcher may place a meter at a given point on the subject's body and let it "move around" with the body, making a PE measurement, a true measure of the exposure at that point in space.

However, in many cases, such a technique is not practical or too costly, or it may be that the researcher's concern is with past (historical) exposure. Such research requires a "modeling step" to execute. For example, in modeling residential exposure, one might use wire-code category as a surrogate for exposure. Other approaches are time-activity-location modeling and modeling of historical fields from power lines. (Occupational exposure research may also use time-activity-task models or JEMs.)

Kaune focused on two residential-exposure research projects where he modeled magnetic field: a project that modeled females' contemporary exposure to household appliance magnetic fields in Western England and a second that modeled exposures based on historic load data for transmission lines in Sweden. The conceptual framework of the exposure integral described above was used in both cases to compute exposure.

The subjects of the English study were 50 mothers of young children; the women were already participants in a larger study of children's health. The study was conducted by Kaune and colleagues at the University of Bristol under partial sponsorship of the RAPID program. Trained technicians visited the residences, administered an extensive questionnaire on appliance usage (including time spent in proximity of operating appliances) in the home, and equipped the women with PE meters for a 24-hour data-capture period and a diary to record activities. The technicians also systematically measured the fields at 5, 30, 60, and 100 centimeters from the operating appliances. The measured appliance fields at a distance of 50 centimeters were multiplied times the time spent within 1 m of appliances and summed to arrive at an estimate of the TWA average magnetic field.

Results suggested that, although predicted and measured exposures were comparable in magnitude, there was essentially no relationship between the predicted and measured values of exposure. Kaune thinks it likely that one factor contributing to the result was overestimates of time near appliances by respondents to the questionnaire. This would lead to over-estimates of appliance exposures, making them comparable with measured TWA exposure. In fact, Kaune referred to other calculations that suggest that the contribution of appliances to TWA or cumulative exposure is relatively small. That small contribution is consistent with the nature of appliance fields, which fall off quickly with distance. A PE meter at the waist, presumably at some distance from most appliances, would not measure increases in TWA exposure from appliances.

Given that appliances produce close, relatively intense fields, it makes sense that appliance contributions to exposure would be apparent in the peak levels of exposure. When peak exposure defined in terms of time near certain appliances was compared with PE, they discovered that the modeled high-exposure category was associated with higher measured peak exposures than the defined low-exposure category. Thus, appliances do appear to contribute to peak exposure, but not in a measurable way to long-time cumulative or TWA exposure. (Any such work, of course, needs to be validated by independent research.

The Swedish Childhood Leukemia Study offers information from another aspect of modeling PE. This project involved calculating historic magnetic fields produced by transmission lines from loading data provided by utilities for some years in the past. Kaune was interested in how much fields from transmission lines at a residence changed over time. The geometry does not change, nor does the distance from the line; however, loading does. The question is: how strongly does the magnetic field at a residence depend on each of these parameters? Kaune examined calculated historical fields at residences as a function of distance and found that distance from the line explained 66% of the between-home variability in historic fields. With inclusion of line loading, 96% of the between-house variability was explained. Thus, geometry of the lines was relatively unimportant, while line loading accounted for about 30% of the variability.

Kaune then addressed the issue of how line currents vary over time by examining the correlation between annual average currents as a function of the interval between the annual period. He concluded that, over periods of five to ten years or less, transmission-line load currents may be sufficiently stable to ignore historical changes. That is: for periods of less than 10 years, contemporaneous measurements may be sufficient to estimate historical exposure. For longer periods, the loading seems to be important and would need to be included in a model. This result also raises some doubt as to the validity of extrapolation over longer periods of time.

In summing up his assessment of exposure models, Kaune stated that the only really satisfying model, in his opinion, was the type of model that computes historical fields by using the kind of historical data that is available for transmission lines. Models that may work, but are not yet proved, are the residential and occupational time-location-activity models. He felt that JEMs were insufficiently proven, in particular because they may not be able to identify those workers within jobs that are particularly highly exposed. From his previously described study, the model of appliance exposure based on questionnaires did not seem to work for TWA exposure.

Finally, he expressed uncertainty about historical residential exposure assesment and particularly about whether wire-code categories or spot measurements provided the best approach in this case.

SUMMARY OF DISCUSSION

Discussion centered on the two studies described in the presentation by Dr. William Kaune: the University of Bristol study of the contribution of appliance use to total exposure among housewives, and the modeling of exposure (via historical reconstruction of transmission-line fields) that was used in a Swedish epidemiology study of childhood cancer. The summary below was prepared from the symposium transcript.

Bristol Study of Appliance Contribution to Exposure

Both discussants and Kaune pointed out apparent ambiguities in the comparisons between predicted exposure based on questionnaire data and the actual PE measurements. The predicted exposures were both lower and higher than measured values. Kaune expected them to be lower than measured values, and was surprised that the predicted values were of the same order of magnitude as the actual measurements. Because, compared to the US, the UK has relatively low background residential exposures, it seemed to Kaune a likely place to be able to detect contributions of appliances to exposure. Apparently, the precision of the questionnaire data was not sufficient to allow prediction of TWA exposures for appliances. According to Kaune, respondents probably over-estimated time spent near appliances.

In response to a question about field levels from appliances in the UK where the operating voltage is twice (and the current consequently one-half) that in the US, Kaune indicated that a simple doubling of the appliance fields observed in the UK would not be appropriate for the US because of different motor designs and leakage. Similarly, background fields in the US cannot necessarily be halved to obtain those in the UK because of different wiring schemes. Fluorescent reading lamps were identified as a possible strong source in homes. However, Kaune noted that fluorescent lamps were not present in the Bristol study, except in the kitchen.

There was discussion of "recall bias" in the questionnaires used to estimate time for appliance use in the Bristol study. This type of bias is important to understand because of the consistent use of questionnaires in epidemiological studies and the possibility of a correlation between disease and recalled exposure, and not with actual exposure. Kaune indicated that respondents may have over-estimated the time spent using or near appliances. Corresponding questions were raised by discussants as to whether appliance contribution to TWA (or lack thereof) was significantly affected by subjects' poor recollection of time spent (rather than contributions to average exposure being generally so small they were at the noise level). In response to a question on identification of over-reporting, Kaune indicated that there was no way to determine which households had over-estimated time near appliances.

Also discussed was the possibility of recall bias associated with a participant's erroneous perception of some appliances as having higher fields than others. Kaune indicated that in the National Cancer Institute (NCI) childhood cancer study, this possibility was controlled for by including and testing responses for "red herring" appliances (those widely but erroneously perceived to have high fields). Kaune reported that this type of recall bias was apparently not strongly present in the NCI study.

Another suggested means to investigate time-of-use for appliances was data from appliance manufacturers that could bound the time spent using their products. Other sources of time-activity information identified as possibly being useful were the California Air Pollution Board studies of time-activity patterns for adults and children. Another suggested approach was to identify low-field homes and "stage" activities, while measuring fields at various body locations and videotaping subjects.

Zaffanella suggested a model of residential exposure based on the background field measured in the center of a room, with an upward adjustment for movement around the residence, plus a small component (0.06-0.86 mG) associated with appliance use. This approach is suggested by the fact that PE measurements are generally higher than area measurements. Based on measured data from US studies (RAPID 6, the EMDEX Project Residential study, and the 1000-home study), the all-room average field is consistently 1.3 to 1.45 times higher than the center-of-room value, and the contribution from appliances is quite small, as shown in Figure 9-1, below. He also pointed out that in the 1000-home study, which used survey measurements, the lowest homes had zero field. In the 1000-person study, with PE measurements, the lowest exposures were not zero. He attributed the non-zero PE, in this latter case, to appliance fields.

One discussant raised the recurring issue of what the appropriate field measure is for appliances or other sources: what is the appropriate length of time for TWA—one hour, one day, one week, one year? Does the relatively short high exposure near an appliance mean that your day is now an "exposed day"?

Center of Rooms Average Magnetic Field = Bs
Personal Exposure Average Magnetic Field = Bp

Model derived from EMDEX Project: **Bp = 1.45 Bs + 0.06**
Model derived from DOE RAPID: **Bp = 1.3 Bs + 0.085**

The models are consistent with the assumptions that:

Center-of-room fields are 1.3 ~ 1.45 times lower than room averages
Contribution of appliances to TWA is 0.06 ~ 0.085 mG

Zaffanella, 1998

Figure 9-1. Relation between residential measurements in the center of rooms and residential personal exposure.

Historical Reconstruction of Fields from Transmission Lines

Questions were raised about the precision of historical transmission-line current data in the Swedish childhood cancer study and about the stability of the Swedish transmission system. Kaune reported that line currents were given to the nearest 100 A for each line and that the power system in Sweden was quite stable, with hydro-power in the North supplying load centers in the South. During the period of interest, there was a small annual load growth rate: about 1.3% annually averaged over all 112 lines. For individual lines, there was a variety of load patterns: 30 lines had a trend of increasing loads, 30 lines had a trend of decreasing loads, and the remainder exhibited no trend. There was considerable random variation in the loads for individual lines.

A discussant raised a question about the difficulty of interpreting data on modeled exposure, when the variability of the exposures was less than the precision of the input data. For example, the average load current is 300 A with a precision of 100 A, while the annual load growth over time was 1.3 %. The inter-year variability calculations were also below the 33% uncertainty seen in current values. Extending this concern to exposure classification, the discussant noted that, in the contemporary time period, a change of 100 A in load current could affect the exposure category.

Kaune responded that the data are not very precise on a line-by-line basis, but that by averaging across lines (in this case, 112 lines), analysis made the estimates more precise. He also indicated that the issue of precision in exposure categories is discussed in the publication for the Swedish study. Kaune also expected that predicted exposure values would echo the load results vis-a-vis correlation: that is, there would be a decreasing relationship between the predicted exposures for one year versus another as the intervening interval between years increased.

In response to a point about the failure to include local sources in transmission-line models, Kaune noted that the average magnetic-field of residences in Sweden is about 0.05 μT about one-half that of US residences. The dominant sources in Swedish houses in the high-exposure category are transmission lines. Errors that one makes by neglecting local sources for these houses are not important. But farther from lines, local sources are more important. There is pretty good correlation of spot measurements with predicted levels for high categories but not for low categories. One discussant suggested that the data were available to provide an answer to this concern about local sources through additional analysis.

Discussants pointed out the need to include changes in line configurations and the addition of new lines to a corridor in the reconstruction models.

In response to a question about the variability and uncertainty associated with the use of calculations for historical exposures in a large Swedish epidemiology study, Kaune (see presentation and discussion of Topic 8) noted that his analysis was carried out for a group of lines and not just one line; this meant that the uncertainties would be averaged out.

Submitted written comments on this topic are found in Appendix C.