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ON-SITE WORKER-RISK CALCULATIONS USING MACCS

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ABSTRACT

We have revised the latest version of MACCS for use with the calculation of doses and health risks to on-site workers for postulated accidents at the Rocky Flats Plant (RFP) in Colorado. The modifications fall into two areas: (1) an improved estimate of shielding offered by buildings to workers that remain indoors; and, (2) an improved treatment of building-wake effects, which affects both indoor and outdoor workers. Because the postulated accident can be anywhere on plant site, user-friendly software has been developed to create those portions of the (revised) MACCS input data files that are specific to the accident site.

INTRODUCTION

Government authorization to operate any nuclear facility, such as RFP, is dependent upon the assurance of safe operations of the facility. Such an assurance is based, in part, upon the evaluations of the consequences and risks of postulated accidents that could release radionuclides into the atmosphere. Most calculations of the doses and health risks of such postulated accidents have been concerned with two groups of people: (1) off-site individuals, that is, individuals beyond the plant boundaries; and, (2) individuals located in the immediate vicinty of the accident site. More recently, attention has turned to collocated workers, that is, on-site workers exterior to the building or vehicle involved in the accident. These individuals would be either outdoors or in other buildings on plant site. This paper is concerned with the evaluation of doses and the corresponding health risks to those individuals.

At RFP, many methods have been used in the past to calculate doses to persons exposed to atmospheric releases of radionuclides from postulated accidents. In the future we plan to use an RFP-specific code called the Terrain Responsive Atmospheric Code for assessing the consequences of such accidents, once it has been validated and approved for use by the Department of Energy (DOE) and the Colorado Department of Health. In the meantime, the RFP standard has become the MELCOR Accident Consequence Code System (MACCS),[1] an NRC-sponsored code used for evaluating the consequences of accidents at nuclear power plants. This code was developed at the Sandia National Laboratories primarily for assessing consequences to individuals and populations outside of the plant boundaries. At RFP, we are using the latest version of MACCS, called MACCS2, for assessing consequences to on-site personnel, modifying it where necessary. (As of this writing, MACCS2 is still in the beta-testing stage. It may be released for dissemination by late 1993.) Two areas of usage are addressed in this paper: shielding by buildings and building wake effects.

SHIELDING

In order to calculate the doses to on-site workers, we need to know where they are and how well shielded they are by the building they occupy. The degree of shielding offered by a building depends upon its characteristics, its ventilation rate, and the weather, as discussed below.

Accidents involving radionuclides can conceivably occur in any of the plutonium processing or storage buildings at RFP. An accident can also occur <u>near</u> any building if we also consider transportation accidents. *Where* an accident occurs has a great influence on how many people are affected by it. In order to define where the people are relative to the accident site, MACCS makes use of the concept of a "population wheel", which divides the population into 16 azimuth sectors and up to 35 range intervals. For off-site populations, a single population wheel centered on the plant can be used. However, for on-site populations, the population wheel will be different for each potential accident site. Therefore, we have developed software for generating sets of population wheels for any arbitrary accident site. The input to this software is a file having the locations of all buildings on plant site and the populations of each building by work shift. Its output includes population wheels, in the format required by MACCS, specific to the postulated accident site. Three sets of three population wheels (nine in all) are produced for the specified accident site. Each set contains the population wheels for each of the three work shifts. One set is for persons in the production buildings, another for persons in office buildings, and the third set for persons outdoors. For the latter, a user-specified fraction of the population of each building is taken to be outdoors; they are assumed to normally be in the vicinity of the building to which they are assigned. To this is added the number of persons known to work outdoors permanently, these being spread uniformly over the populated portion of the plant site.

We have modified the way in which MACCS inputs and uses shielding factors. In earlier versions of MACCS, four sets of shielding factors were input; these were for inhalation, cloudshine, groundshine, and skin dose. Each set consisted of a triplet of values, one value for individuals being evacuated, one for individuals being sheltered, and one for individuals involved in normal activities. In MACCS2, shielding data sets can be assigned for up to three different populations. These could be used, for example, to specify a different off-site population for each emergency response scenario (evacuation, sheltering, and normal activities) and thus, once defined, these could be used for all accident scenarios. However, for on-site individuals we need to define the shielding values specific to the accident being evaluated. We know the populations, locations, and characteristics of the buildings occupied by the workers and thus we can make a dynamic estimate of the shielding offered to these individuals; the term dynamic is used here to mean that each weather sequence used by MACCS will have its own set of shielding factors.

In order to input and use the shielding factors, we employ the concept of the "sheltering wheel", which is parallel to that of the population wheel in that it uses the same azimuth and range divisions. A sheltering wheel contains the shielding factors for each spatial element (i.e., azimuth sector and range interval), as determined by the ventilation rate, building characteristics, and weather. Two sheltering wheels are needed for any given accident site: one for the persons in production buildings and one for persons in office buildings. (Persons outdoors, who are not shielded, do not need a sheltering wheel.) In practice, the sheltering wheel is computed partly within MACCS and partly outside of it. The reason for this will be evident below.

The degree of protection offered by a building depends upon the rate of exchange, R, of the inside and outside air. The total rate is the sum of the rate provided by the building's ventilation system and the rate provided by leaks through building cracks (such as around windows and doors):

$$R = R\ (\text{ventilation}) + R\ (\text{leaks})$$

Typically, R (ventilation) has values of 10 to 20 air exchanges per hour. On the other hand, R (leaks) is much smaller than this, usually less than one air exchange per hour for a well-constructed building, and thus can be ignored compared to R (ventilation). For some accident scenarios, however, the ventilation system is turned off and the only contribution to R is from R (leaks). We therefore need to compute the shielding factors for the ventilation systems being both turned off and turned on.

The shielding factor (SF) expresses the degree of protection offered by a building. It is a parameter having values between zero (total shielding) and one (no shielding) and is given by Englemann[2] as

$$SF = (fR/R')\{1 - (1/R'\tau) + (1/R'\tau)\exp(-R'\tau)\}$$

where τ is the duration of the plume passage, f is the filtration factor for the incoming air (f = 1 for no filtration), and

$$R' = R + v_d A/V$$

is the virtual air exchange rate, where V is the volume of the building, A is the surface area within the building (including walls, furniture, etc.), and v_d is the deposition velocity. From theoretical considerations, R (leaks) is expected to be proportional to the square of the wind speed, W, and to the absolute value of the temperature difference between inside and outside air, $|T_i - T_o|$. We have performed a least-squares fit to the data given by Englemann[2] for a well-constructed building and find

$$R\ (\text{leaks}) = 0.00881\ W^2 + 0.0135\ |T_i - T_o|$$

where W is in m/s and T_i and T_o are in °C. Typical values for R (leaks) range from 0.2 to 1.0 air exchanges per hour. This equation is illustrated in Figure 1.

The term $v_d A/V$ is perhaps the most uncertain of all the terms in the shielding factor equation. The deposition velocity depends upon the sizes of the particles, their chemical properties, and the nature of the surfaces (walls, furniture, etc.) within the building. The value recommended by Englemann[2] for v_d is 0.13 mm/s. It may be expected that this value may vary by a large amount depending upon the factors noted above. The term A/V may be easily estimated by assuming that a building consists of N rooms, each measuring *dxdxd*. The ratio A/V will then be 6/d, regardless of the number of rooms. An office building would have rooms on the order of 3 to 4 meters on a side whereas a production building may have rooms 10 to 20 meters on a side. If we allow an extra factor of two for A (to account for furniture, partitions, etc.) and use v_d = 0.13 mm/s we then get $v_d A/V$ to be about 0.3 - 0.6/hr for production buildings and 1.5 - 2.0/hr for office buildings. This is comparable to, or even larger than, R (leaks).

Plateout wheels, the distribution of building-weighted and population-weighted values of $v_d A/V$, are generated for any given accident site by the same software that generates the population wheels. Two such wheels are generated, one for persons in production buildings and one for persons in office buildings. Furthermore, this software also generates ventilation wheels, the distribution of building-weighted and population-weighted ventilation rates for use when the ventilation systems are running. Again, two such wheels are generated one for persons in production buildings and one for persons in office buildings. The plateout and ventilation wheels are read by MACCS2 (modified version) and combined within MACCS2 with the weather data for the weather sequence being processed to derive the sheltering wheels that are applied to the dose calculations.

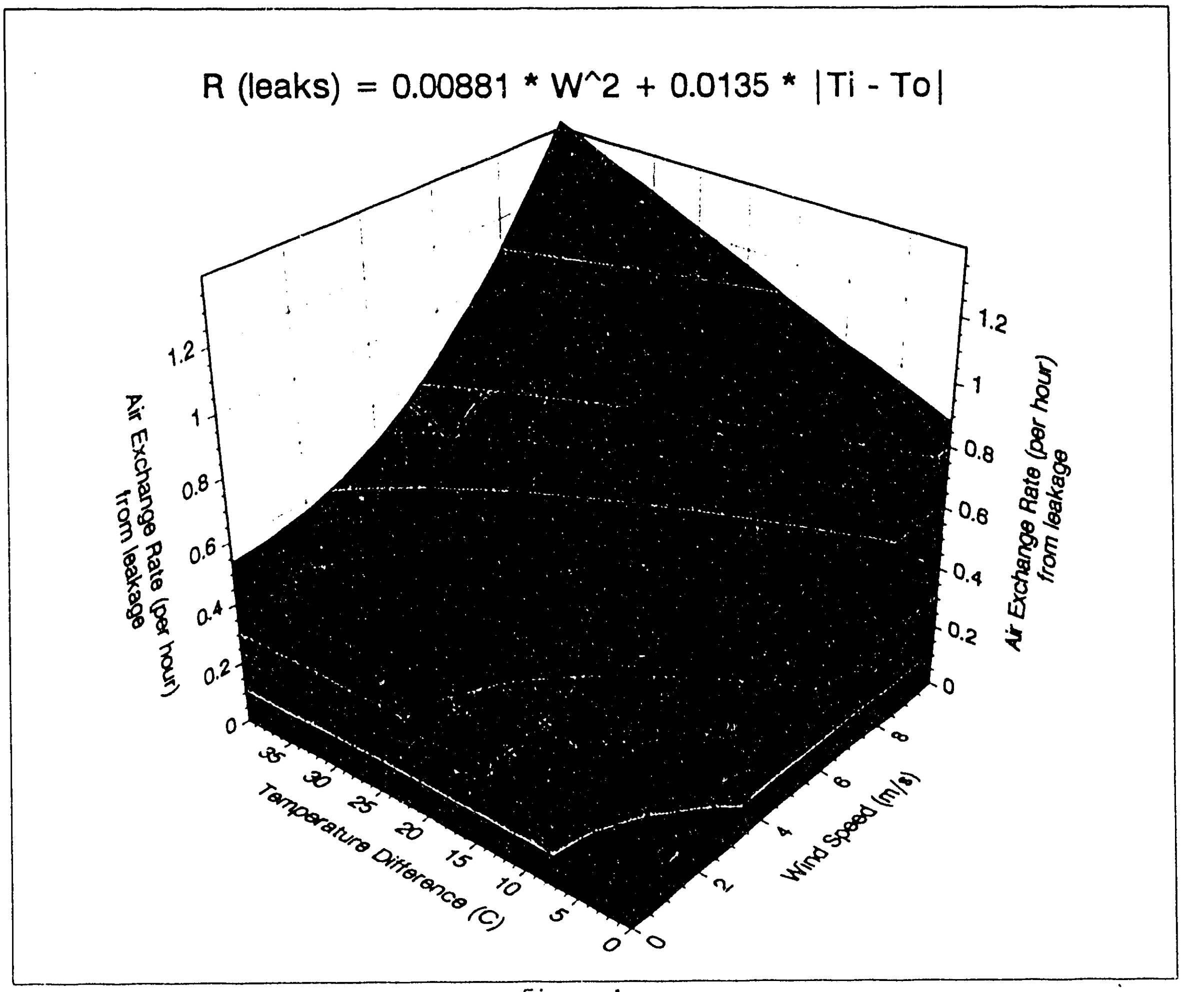

Figure 1

BUILDING WAKE EFFECTS

MACCS2 (unrevised) treats building wake effects in a simple way, one that is perhaps adequate for individuals distant from a nuclear power plant but is clearly inappropriate for on-site dose assessment at RFP. Many of the buildings at RFP are clustered together and the air movement between and downwind of them is highly complex and variable. The problem is extremely complex and an accurate evaluation of dose at a particular location may not be possible today, even using supercomputers. However, since MACCS2 is only intended to give average values within each spatial element an improvement to the manner in which MACCS2 handles building wake effects is possible for on-site individuals. Our approach is to create "building wake effects wheels", having the same azimuth sectors and range intervals as the population wheels, and generated by the same software that generates those wheels. The values assigned to each spatial element within the building-wake-effects wheel are correction factors to be applied to the dispersion factors (χ/Q) calculated within MACCS2. These correction factors can be generated from any appropriate model. Because they are generated outside of MACCS2, they can be modified when new and better wake-effects models become available without having the modify MACCS2 further. The model currently under development is dependent upon the "footprint" area of the buildings, and their heights. The presence of buildings forces the plumes to flow between and over them, thereby increasing the plume concentration for people between buildings and at ventilation inlets. Three sets of such wheels are generated, one for persons in production buildings, one for persons in office buildings, and one for person outdoors. The details of this model are still under development.

REFERENCES

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