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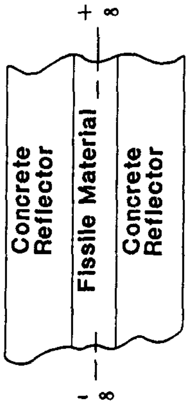
DATA AND ANALYSIS FOR CRITICALITY SAFETY—I

1. Effects of Concrete Composition in Nuclear Criticality Safety Calculations, *G. R. Handley, R. C. Robinson, J. C. Cline (MMES)*

Concrete must be specified for nuclear criticality safety calculations in many process situations. An exact characterization of concrete is difficult to obtain since the constituents vary as a function of mixture, aggregates, additives, thickness, surface protection, and exposure to temperature, humidity, time, and use. This paper reports the investigation of the k_{eff} results obtainable from choosing different concretes in a computational nuclear criticality safety analysis. It will be shown that generalizing on the reactivity effects of concrete can be extremely risky.

Eight concrete compositions were investigated calculationally as a reflector for a slab of U(100) metal or U(100)O_2F_2 solution and as an isolator/moderator between two concrete reflected slabs of U(100) metal or U(100)O_2F_2 solution. The hydrogen-to-^{235}U atom ratio of the uranyl fluoride solution was 50. All computations used the 16-group Hansen-Roach cross sections and the CSAS1X control sequence of SCALE-IV (Ref. 1). The CSAS1X control sequence activates the functional modules BONAMI-2, NITAWL, and XSDRNPM. A quadrature order of 16 was designated within XSDRNPM with a convergence criterion of 10^{-4}. The material atomic densities used are given in Table I, and Fig. 1 shows the computational models. Figure 2 graphically presents the k_{eff} result for each of these concretes as a reflector and as an isolator/moderator.

Concrete as a Reflector:



Concrete as an Isolator/Moderator:

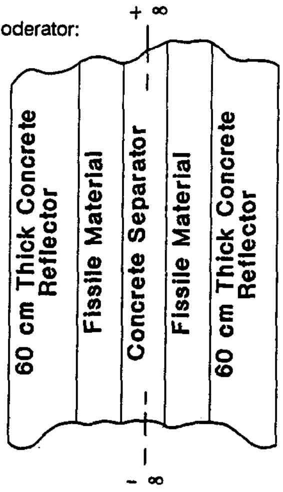


Fig. 1. Calculational models for infinite slabs.

The results shown in Fig. 2 illustrate several effects of concrete as a reflector:

1. Differences in k_{eff} as large as 12% occur, depending on the concrete selected.
2. Wet concrete (concrete with the highest hydrogen content) is a better reflector than dry concrete for reflector thicknesses of 20 cm or less.
3. Dry concrete is a better reflector than wet concrete for reflector thicknesses of >25 cm.
4. Approximately 45 cm may be considered an infinitely thick reflector for these concretes.

For concrete as a separator (isolator/moderator), the results shown in Fig. 2 illustrate the following effects:

1. Differences in k_{eff} as large as 24% occur, depending on the concrete selected.
2. For two reflected uranium metal slabs separated by concrete, the calculated k_{eff} is maximized between 10- and 20-cm separation thickness, depending on the concrete.
3. For two reflected uranyl fluoride solution slabs separated by concrete, the calculated k_{eff} is maximized at ~10-cm separation thickness.
4. Sixty centimetres of concrete between fuel slabs still permits a small amount of neutron interaction, as shown by the negative slope of the plotted data.
5. In general, concretes with high hydrogen content are more effective isolators.

It was shown that no one concrete composition can be assumed as the worst case in all nuclear criticality safety calculations. Clearly, there is no substitute for calculating reality, i.e., one must know the constituents of the concrete of interest. In studies of existing facilities, the analyst must obtain data on the existing concrete, preferably from physical and chemical analyses at various depths, or assume and verify that worst-case selections have been made. In studies of proposed future facilities, the mix, the drying rate, and other properties must be assumed in the calculations; therefore, a quality assurance plan is needed to assure that the designated concrete is actually used in the final facility.

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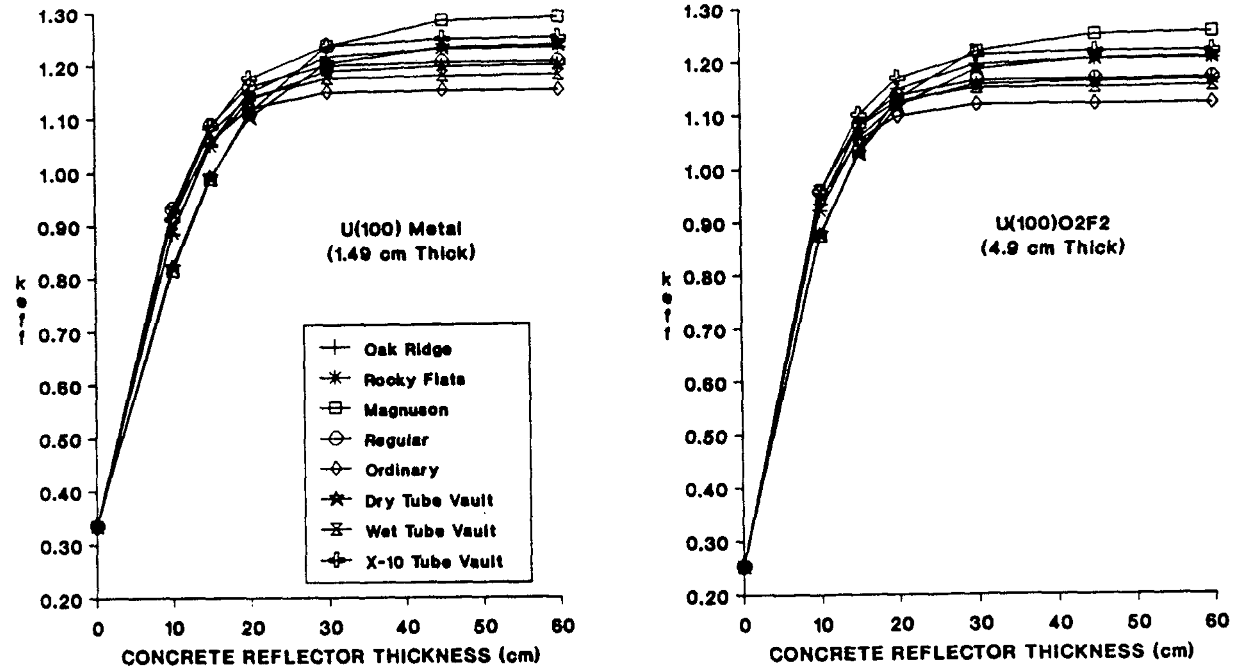
TABLE I

Material Atomic Densities

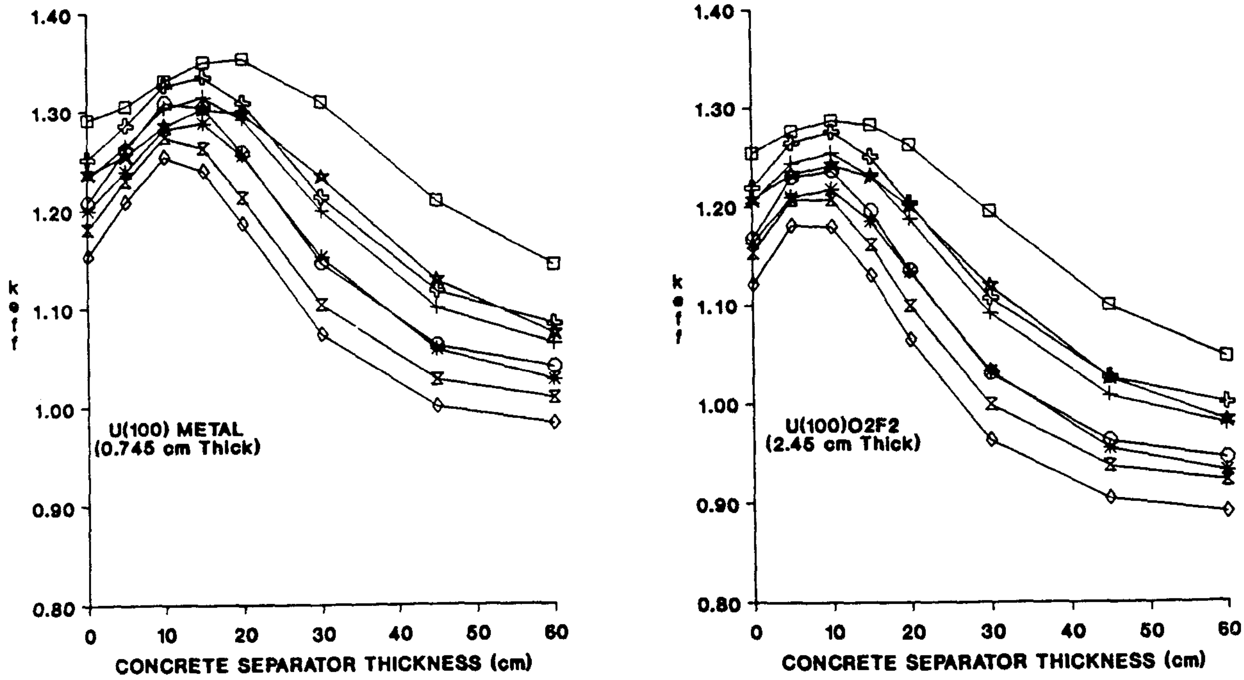
Atomic Densities (atom/b·cm)

Element	Oak Ridge[1] 2.299 g/cm^3	Rocky Flats[1] 2.321 g/cm^3	Magnuson[1] 2.147 g/cm^3	Regular[1] 2.300 g/cm^3	Ordinary[2] 2.370 g/cm^3	Dry Tube Vault[3] 2.304 g/cm^3	Wet Tube Vault[3] 2.413 g/cm^3	X-10 Tube Vault[4] 2.403 g/cm^3	U(100)O$_2$F$_2$	U(100) Metal
H	8.5010E-3[a]	1.0402E-2	4.2581E-3	1.3744E-2	1.4868E-2	5.9299E-3	1.3207E-2	9.4620E-3	6.0282E-2	
C	2.0217E-2	6.4296E-3	1.1348E-2		3.8140E-3	1.0869E-2	1.0869E-2	1.0517E-2		
N		1.9963E-5								
O	3.5511E-2	4.2372E-2	4.0370E-2	4.6068E-2	4.1519E-2	4.0787E-2	4.4426E-2	4.6078E-2	3.2552E-2	
F									2.4113E-3	
Na	1.6299E-5	3.8303E-4	7.9356E-5	1.7472E-3	3.0400E-4	1.2899E-5	1.2899E-5	1.2831E-5		
Mg	1.8602E-3	7.1885E-4	5.0111E-3		5.8700E-4	2.1006E-4	2.1006E-4	5.0950E-3		
Al	5.5580E-4	1.1241E-3	3.7660E-4	1.7454E-3	7.3500E-4	3.2163E-4	3.2163E-4	4.1696E-4		
Si	1.7000E-3	7.7140E-3	1.9382E-3	1.6620E-2	6.0370E-3	9.6143E-4	9.6143E-4	2.6750E-3		
S		8.2826E-5	1.0013E-4			6.0281E-5	6.0281E-5	9.6151E-5		
Cl			1.9074E-5							
K	4.0300E-5	4.8972E-4	3.1231E-4			8.2232E-6	8.2232E-6	1.2780E-5		
Ca	1.1101E-2	8.0209E-3	7.3008E-3	1.5206E-3	1.1588E-2	1.3665E-2	1.3665E-2	8.7644E-3		
Ti		2.9193E-5	4.0183E-5							
Mn			1.2050E-5							
Fe	1.9301E-4	2.5279E-4	1.2954E-4	3.4724E-4	1.9680E-4	8.3678E-5	8.3678E-5	1.3978E-4		
Zn								1.1178E-5		
^{235}U									1.2056E-3	4.8015E-2

[a] Read as 8.5010 × 10^{-3}.



Single Infinite Slabs



Two Fully Reflected Infinite Slabs

Fig. 2. Graphic presentation of results.

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