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EMPIRICAL METHOD FOR CALCULATING PIPE INTERSECTIONS CONTAINING FISSILE SOLUTIONS

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EMPIRICAL METHOD FOR CALCULATING PIPE INTERSECTIONS CONTAINING FISSILE SOLUTIONS

Bruce B. Ernst and C. L. Schuske

Abstract. An empirical method has been developed for calculating safe nuclear criticality parameters for complex arrays of intersecting cylinders (pipes or arms) containing enriched uranyl-nitrate solutions.

The critical parameters defined by this method include cylinder diameters, angles of intersection, cylinder spacings, and the total number of intersecting cylinders involved in arrays.

Discussed also are applications to typical problems encountered in fissile processing plants.

INTRODUCTION

Frequently, the designer of fissile processing plants and process equipment for such plants is confronted with the problem of complex piping systems. In the past because of lack of critical data, the criticality specialist circumvented such situations whenever possible, or made use of conservative approximations to pipe intersections.

A model has been developed by means of curve-fitting methods applied to the critical data reported recently by B. Ernst.[1] The critical data were obtained on intersecting cylindrical geometries and utilized aqueous solutions of uranyl nitrate at about 93 percent of uranium 235 (^{235}U) isotopic content. The aqueous solution had a density of 450.8 grams of ^{235}U per liter. The purpose of the model is to facilitate rapid analysis of intersection problems commonly found in the fissile process plant. In the formulation of the model, sufficient (but not over) conservatism is included to prevent penalizing designers of such equipment.

Two examples of use of the model are illustrated, together with experimental data as obtained.

[1]Bruce B. Ernst. *Critical Parameters of Bare Intersecting Pipes Containing Uranyl Nitrate Solution.* RFP-1196. Rocky Flats Division, The Dow Chemical Company, Golden, Colorado. (In Press.)

Definitions:

CENTRAL COLUMN – The main column or cylinder from which branching of arms occurs.

ARMS – Any pipe or cylinder intersecting the central column.

CONTACT AREA – The area subtended by an arm and another arm or an arm and the central column. (See Figure 1, where D = diameter; angles are theta (θ) and cosecant θ; and A = area.)

QUADRANT – Quadrant is a sector of a cylinder 18 inches long; where alpha (α) equals 90°. The quadrant is shown by the shaded area in Figure 2.

EXPERIMENTAL DATA

The critical parameters of aqueous uranyl nitrate filled cylindrical geometries reported by Ernst[2] are given in Tables I, II, and III. (Data shown have not been corrected for experimental error.)

Because of the complex nature of these geometries (arrays), a column of each Table identifies a specific illustration of that geometry in the text. For example, in Table I, note Figures 3 and 4; in Table II, Figures 4, 5, 6, 7, and 8; and in Table III, Figures 9, 10, and 11. The approach was used in place of providing a lengthy description of each array. In all arrays, the central column was made of a ⅛-inch thick stainless steel pipe of square cross section. The internal dimensions of the square column were 7.0 by 7.0 inches.

All experiments are considered to have minimal reflection because they were performed at least 4 feet above the concrete floor of the critical facility, and at least 10 feet from the nearest wall. No other reflecting surfaces of consequence were near, with the exception of the actual vessel walls. The

[2]*Ibid.*

TABLE I. Critical Parameters for Arrays of Arms Intersecting the Central Column [Theta (θ) = 90°].

Critical Vertical Edge-to-Edge Spacing of Arms along Central Column (inches)	Critical Number of Arms in the Array	Critical Solution Height (H_c) along Column and above Top Arm in Array (inches)	Identifying the Experimental Array (Figure No.)	*Value of (a) (inches)
(Inner Diameter Arms, 6.40 Inches; Wall Thickness 0.11 Inches.)				
0.00	5.8	Central Column Full	3	Not Applicable
5.19	8	45.94	3	Not Applicable
3.50	8	0.708	3	Not Applicable
4.00	8	1.97	3	Not Applicable
4.50	8	4.26	3	Not Applicable
6.63	12	Central Column Full	3	Not Applicable
6.63	∞	Central Column Full	4	6.63
(Inner Diameter Arms, 5.35 Inches; Wall Thickness 0.11 Inches.)				
0.00	7.95	Central Column Full	3	Not Applicable
0.25	8	49.59	3	Not Applicable
0.00	8	4.37	3	Not Applicable
2.00	12	3.02	3	Not Applicable
2.13	12	24.55	3	Not Applicable
3.00	16	31.34	3	Not Applicable
2.75	16	Central Column Full	4	4.19
1.75	12	Central Column Full	4	3.44
1.00	12	0.44	4	3.19
(Inner Diameter Arms, 4.34 Inches; Wall Thickness 0.078 Inches.)				
0.00	16.65	Central Column Full	3	Not Applicable

*D = Outer diameter of arms.
S = Surface to surface distance.

$a = \frac{(D + S)}{2}$; (See Figure 4).

FIGURE 1. Surface Area in Contact with Central Column.

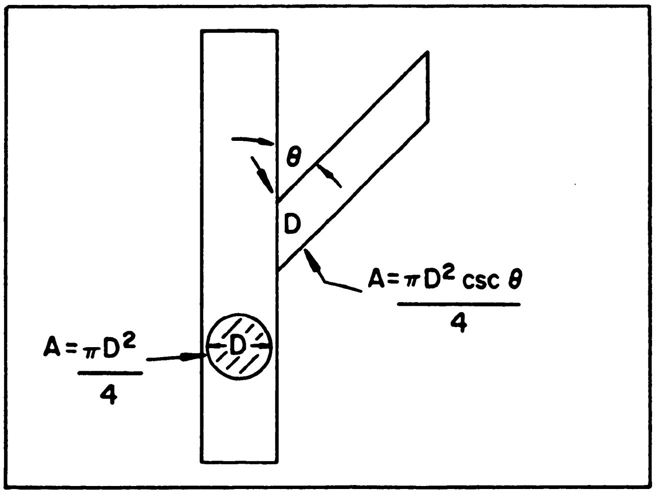

FIGURE 2. Typical Quadrant.

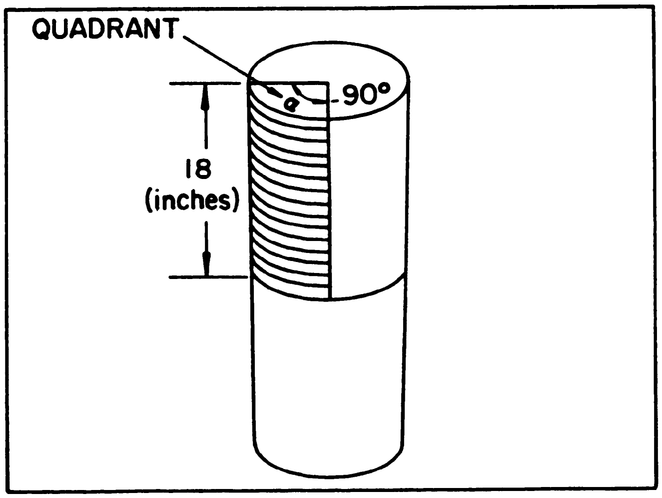

TABLE II. Critical Parameters for Arrays of Arms Intersecting the Central Column [Theta (θ) = 45°].

(Square Arms, 7.0 Inches; Wall Thickness, 0.125 Inches.)

Critical Solution

Empirical Analysis of Experimental Data:

In order to develop a calculational method for pipe intersections that will fit a wide range of cases,