CC/NUMBER 19
MAY 7, 1979

This Week's Citation Classic

Danckwerts P V. Continuous flow systems. Distribution of residence times. *Chem. Eng. Sci.* **2**:1-13, 1953. [University of Cambridge, Department of Chemical Engineering, Cambridge, England]

When material flows through a vessel or a chemical plant at constant rate, some of it spends more and some less than the average residence time in the system. If the system is, for instance, a blender, a chemical reactor or a drier, this spread of residence times may have an important effect on the performance of the plant. This paper describes methods for the quantitative description and measurement of residence-time distributions, and their use in calculating the performance of chemical plant items. [The *SCI*® indicates that this paper has been cited over 335 times since 1961.]

P. V. Danckwerts
Department of Chemical Engineering
University of Cambridge
Cambridge, England

July 6, 1978

"In 1952 there was a general recognition among chemical engineers and others of the facts described in the first two sentences of the abstract. One or two people had actually measured residence-time distributions in an *ad hoc* manner. What was lacking was a comprehensive analysis of the subject setting out clearly what we were talking about, how we could describe the behaviour of a particular flow system in quantitative terms and determine it by simple experiments, and how we could use the information so obtained to explain or predict the performance of a plant. 'We' refers mainly to chemical engineers, although many other people, from hydrologists to physiologists, are interested in the same kind of problem; it is a pity that — as an analysis of the citations would probably demonstrate — practitioners of different disciplines tend to re-invent concepts and their analysis in isolation and mutual ignorance. The outcome was a new tool for use in the design of chemical and allied plants, which has been widely applied.

"I had been revolving the subject in my mind for some time, and one day the solution crystallised almost instantaneously. I remember saying to my colleague E. S. Sellers, during our morning tea-break at Cambridge, 'I see it all now, Stan.' It was an experience similar(on a minor scale) to Kekule's vision of the benzene ring while riding on the top of a tram.

"I attribute the inception and success of the idea first of all to the fact that chemical engineering was at that time a wide-open field, to which a limited (although very fruitful) amount of analytical thought had been applied. It was relatively easy to open up a far-reaching new topic, whereas nowadays we have pointed ourselves into corners and serious third-degree sophistication has set in. Secondly, it is an illustration of the value of academic idleness, which alas is almost lost to us now. I had no research students to supervise and no administrative burdens. In the words of P. G. Wodehouse, I was a young man with life and all its boundless opportunities opening before me and could stuff my pipe in my mouth, put my feet on the stove and ruminate. We should do more of this in universities — people in industry are too busy and we are ill-advised to emulate them."