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This Week's Citation Classic

Scriven L E. On the dynamics of phase growth. *Chem. Eng. Sci.* **10**:1-13, 1959.
[Chemical Engineering Dept., Shell Develop. Co., Emeryville, CA]

This paper laid out fundamentals of convection and diffusion around a sphere of one phase growing from another, whether pure material or binary solution, e.g., bubbles in boiling. [The *SCI*® indicates that this paper has been cited over 125 times since 1961.]

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"Two papers on bubble growth in superheated liquids appeared in the April 1954 *Journal of Applied Physics,* one by H.K. Forster and graduate student Novak Zuber at UCLA, the other by Milt Plesset and graduate student S.A. Zwick at Caltech. Each was an approximate theory of spherically symmetric bubble growth, a reasonable model of the central events in ordinary boiling. Understanding for atomic power applications was lacking and scientific mechanical engineers were trying to unravel boiling. Chemical engineers were interested for distillation, etc.

"Differing somewhat, the two theories raised controversy. Each used more intuitive simplifications and mathematical approximations than I, a graduate student with Bob Pigford at Delaware, could rationalize. Two years later at Shell Development Company, my first problem was nucleation and growth of vapor bubbles in liquid drops that become superheated and blow apart into troublesome mist.

"Bubble growth in a drop is controlled by the mechanics of liquid motion, not the heat transport considered by Forster, Plesset, *et al.* The governing equation was too 'stiff for then available numerical methods and computers. But I learned convection, mastered the literature, and associated with Chuck Sternling, an engineer able to identify basic issues, link them to scientific principles, and devise attacks with weapons within reach.

"Data on boiling of solutions were rare, Sternling knew: if only boiling rates of *solutions* could be predicted from data on pure liquids! Reading the Plesset-Zwick and Forster-Zuber papers, he made his own approximate theory for *binary* solutions and hypothesized: *solution boiling rate* is to *pure fluid rate* as *rate of spherosymmetric bubble growth in solution* is to *the same in pure fluid.*

"At about that time I discovered how to solve exactly a distantly related convective diffusion problem[1] from my thesis research. And I had studied metallurgist F.C. Frank's[2] exact solution for spherosymmetric phase growth in the limit of no density change and hence no convection — a far cry from boiling. I decided to try for an exact solution for bubble growth in pure fluid, perhaps in mixtures. I also decided to assemble all the basic equations and boundary conditions and sort out earlier theories as logically as I could (some details took years[3]).That the outcome has been uncommonly useful to others is very pleasing news."

1. **Scriven L E & Pigford R L.** Fluid dynamics and diffusion calculations for laminar liquid jets. *Amer. Inst. Chem. Eng. J.* **5**:397-402, 1959.
2. **Frank F C.** Radially symmetric phase growth controlled by diffusion. *Proc. Roy. Soc. London* **A201**:586-99, 1950.
3. **Pignet T & Scriven L E.** On the dynamics of phase growth. *Chem. Eng. Sci.* **27**:1753-4, 1972.