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This Week's Citation Classic

Goodman T R. The heat-balance integral and its application to problems involving a change of phase. *Trans. ASME* 80:335-42, 1958.
[Allied Research Associates, Inc., Boston, MA]

An approximate mathematical technique utilizing the 'heat-balance integral' is presented for solving for the location of the melt line in heat conduction problems involving a change of phase. Several different boundary conditions are considered and comparisons with known solutions are made. [The SCI® indicates that this paper has been cited in over 100 publications since 1961.]

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"In 1956, I was the head of a small group in applied mathematics at Allied Research Associates, Inc. (now defunct), in Boston, Massachusetts. I was approached by our resident physicist and told that, in connection with a contract we had with the General Electric Company, it was necessary to examine the transient phase change of an ablating body, and also the phase change under certain other circumstances. I was also shown the published literature on the phase change problem and it was easy to see that the solutions that had been published did not correspond to the solutions that we required. Not to worry! It was clear to me that the phase change problem was a special case of a nonlinear transient diffusion problem. Borrowing from my knowledge of techniques used in boundary layer theory (which is also a nonlinear diffusion problem), I applied what had been known in boundary layer circles as the Karman-Pohlhausen method (now known more generally as the integral method) to the problem at hand.

"The integral method, although approximate, provides accuracy adequate for engineering purposes and has the distinct advantage of reducing the problem from one requiring the solution of a partial differential equation, which is relatively difficult, to one requiring the solution of an ordinary differential equation, which is relatively easy. Moreover, the concepts involved in applying the method are very simple to understand, so that today the method has become a standard one and is taught in many courses in heat transfer. It is undoubtedly these reasons, and also because of the flexibility of the method in accounting for a wide variety of boundary conditions, that account for the popularity of the paper. I consider this paper to be one of my best efforts, and although there are others of equal merit, this one, by opening doors for other investigators, will undoubtedly take the popularity prize.

"The paper was first presented publicly at the Heat Transfer and Fluid Mechanics Institute in Pasadena, California, in 1957, and subsequently disseminated to a larger audience in its present form. The phrase 'heat-balance integral' was introduced into the technical language with the presentation of the paper and has been universally accepted.

"Several years after publication of the paper I prepared a review article on the subject,[1] but in more recent years I have turned my attention to other matters."

1. **Goodman T R.** Application of integral methods to transient nonlinear heat transfer. (Irvine T F, Jr. & Hartnett J P, eds.) *Advances in heat transfer*. New York: Academic Press, 1964. Vol. I. p. 51-122.