Drifting Instability in Two-Phase Heat Transfer Systems

IT has long been recognized that two-phase heat and mass transfer systems are subject to various forms of instability. One such form has appropriately been called "drifting instability" and is characterized by the fact that the system drifts off from its initial set point to another of its own choosing. E. F. ADIUTORI* has analysed drifting instability and demonstrated that it is a particular form of what he calls "thermal instability".† The analysis demonstrates that drifting instability can result when the system does not satisfy the stability criterion:

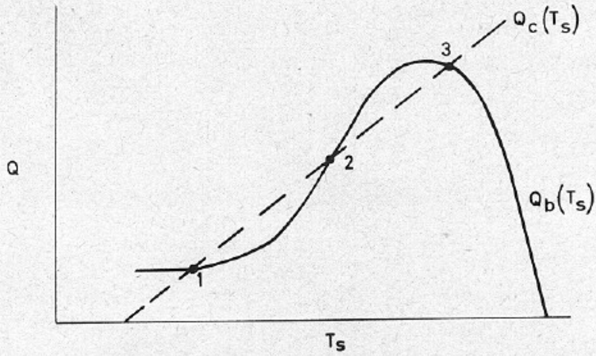
$$(dQ_b/dT_s - dQ_c/dT_s) <s\ 0 \quad . \quad . \quad . \quad (1)$$

It should be noted that, since (dQ_c/dT_s) is almost always positive, this type of instability can occur only when the boiler exhibits the rather odd behaviour required for (dQ_b/dT_s) to be greater than zero. Thus, this type of instability results from the non-linear behaviour of boilers whereby (dQ_b/dT_s) can be greater than zero, seeming to signify that the heat is flowing uphill (in a differential sense).

This type of stability can be appraised either graphically (see accompanying diagram) or analytically by rearranging Equation 1 in the following form:

$$[-U_b^* - U_c^* + (T_p - T_s)(dU_b^*/dT_s)] <s\ 0 \quad . \quad . \quad . \quad (2)$$

In utilizing Equation 2, one must be very careful not to make the unwarranted assumption that U_b^* is independent of T_s, since this is equivalent to assuming that the system is linear and results in the erroneous conclusion that the system is necessarily stable in this regard. It is also important to note



Key: 1 and 3: Stable with respect to drifting; 2: Unstable with respect to drifting — See Equation 1

that both the diagram and the equations are based on certain simplifying assumptions which must either be verified or accounted for in the analysis of an actual system.

The above may be used to demonstrate that this type of instability can be eliminated in the following ways:

(1) Install a controller to sense T_s and operate on the coolant flow rate to the condenser. In this way, it is possible to increase the "effective" value of (dQ_c/dT_s) as desired and so result in a system which is effectively stable in this respect. While the system would still be unstable in that it would continually "hunt", the amplitude of the hunting can be restricted to a tolerable level, by adjustment of the controller.

(2) Obtain a higher temperature heat sink for the condenser. (This would often require that the size of the condenser be increased in order to handle the same heat load.) Alternatively, a regenerative heat exchanger may be placed in series with the condenser coolant, thus providing a higher temperature sink as desired.

(3) Increase the linear resistance to heat transfer in the boiler—for instance, by increasing the thickness of the boiler tube walls. (This is generally an undesirable "fix" for obvious reasons.)

* Paper presented to the A.I.Ch.E. Las Vegas Meeting, September, 1964.

† "New Theory of Thermal Stability in Boiling Systems", E. F. ADIUTORI, *Nucleonics*, May, 1964.