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ATL-A-122

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UNITED STATES-EURATOM JOINT RESEARCH
AND DEVELOPMENT PROGRAM

Experimental Investigation of the Effects of Ultrasonic Vibrations on
Burnout Heat Flux with Boiling Water

Quarterly Report No. 3 (April - June 1961)

Advanced Technology Laboratories, A Division of American-Standard,
Mountain View, California

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Quarterly Technical Progress Report #3
EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF
ULTRASONIC VIBRATIONS ON BURNOUT HEAT FLUX
WITH BOILING WATER

ATL Job 4116

April - June 1961

for
The U. S. Atomic Energy Commission
Contract AT(04-3)-250
Project Agreement No. 9

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STATEMENT OF PROBLEM

The objective of the work is to establish experimentally the effect of an ultrasonic field on the maximum nucleate heat flux (i. e., burnout heat flux) that can be sustained by boiling water in a flow system. The water will flow in the direction of sound propagation within an annular flow channel bounded on the outside by a glass tube and on the inside by a $\frac{1}{4}$ -inch-OD electrically heated element. Experimental work will be carried out at or near atmospheric pressure, with provision for controlling the subcooling of the inlet water.

SUMMARY OF PROGRESS TO DATE

The heat-transfer loop has been completed and is operating satisfactorily. Difficulty has been experienced in obtaining a sufficiently strong connection between the burnout-detector voltage tap and the heating element. This problem and its potential solution is described. The lack of means for obtaining controlled burnout has thus far prevented collection of data on burnout effects of the ultrasonic field.

DISCUSSION OF PROGRAM

The loop as constructed is essentially identical to the description presented in the quarterly report for January-March 1961 (ATL-A-118). Various minor alterations and operating experience with system components are summarized below. Items not discussed are as previously described.

1. Temperature Measurement

Chromel-alumel thermocouples have been installed immediately upstream and downstream of the test section to supplement water-temperature measurements made with the standard industrial thermometer. The 6-mil-diameter thermocouple wires project into the water plenums formed by the flanges at the ends of the test section. Temperature measurements afforded by the thermocouples will permit heat-balance determinations under no-net-boiling conditions.

2. Pressure Gage

Provision has been made for relocating the pressure-gage tap in the entrance-water plenum of the test section. The new location will permit pressure (and thus saturation temperature) measurements without corrections required as a result of the pressure drop between the test-section entrance and the original tap location.

3. Test-Section Power Supply

During the initial weeks of power-supply operation, it became evident that the saturable reactor was not operating properly. An open-circuit voltage of from 4 to 6000 volts observed across the leads to the reactor dc control windings had made the burnout detector, which cuts power to the test section by opening the dc control circuit, inoperative. The reactor was sent to the manufacturer for repair and has operated satisfactorily since its return.

The minimum power input to the test section occurs when the dc control windings are open. This power input, 1.3 kw, corresponds to a heat flux from the element of about 146,000 Btu/hr-ft², which is well below burnout values and does not represent a limitation in achieving the objectives of the program.

The rate at which power to the test section decays following burnout-detector operation has not been directly measured. However, visual observation of the wattmeter during the decay leads to the estimate of a decay time constant of less than $\frac{1}{2}$ second.

4. Test Section

The $\frac{1}{4}$ -inch-OD test element has been altered so that the burnout-detector voltage tap is now welded to the external surface of the element rather than to the internal surface. This change was dictated by the difficulty in avoiding wire-caused short circuits between the copper core and the stainless steel tube. The voltage-tap wire is now brought out of the test section via the annular water channel.

5. Burnout Detector

The circuit diagram for the burnout detector is shown on Figure 1. The method of operation was described in the Quarterly Progress Report for October-December 1960 (ATL-A-113).

6. Power Instrumentation

The 0- to 60-kw wattmeter has been replaced with a 0- to 20-kw wattmeter that is otherwise identical. This power range is better suited to the power dissipation in the test element during burnout determinations.

AUTOMATIC POWER DISCONNECT SYSTEM

FIGURE 1

EXPERIMENTAL RESULTS

Problems in development of a successful burnout-detector voltage-tap connection to the test element have prevented the collection of data under burnout conditions. As noted above, the present tap is connected to the external surface of the element. To date, the connection has been made by electrically butt-welding the 9-mil wire to the tube surface. The strength of this weld has proved inadequate when subjected to the buffeting of the boiling water, and the taps have failed on the elements fabricated in this manner. Elements now being fabricated will have a lap-weld made by spot-welding a bent length of the wire to the tube.

One of the elements (with failed voltage tap) has been allowed to burn out. The experimental procedure consisted of setting a constant heat flux and flow rate and allowing the inlet water temperature to increase until burnout occurred. The burnout conditions obtained were as follows.

Inlet velocity:	8.51 ft/sec
Mass rate:	4530 lb/hr
Inlet temperature:	200°F
Heat flux:	1,020,000 Btu/hr-ft ²
Saturation temperature at inlet conditions:	~215°F

These conditions correspond to subcooled boiling along the entire length of the heating element. Rupture occurred 1-3/8 inches from the entrance end of the element.

Presumably, burnout occurred at this location rather than at the downstream end because of a local reduction in cross-sectional area of the stainless steel tube, with a consequent local increase in heat flux.

While the inlet water was increasing to the burnout condition (200°F), the ultrasonic transducer was occasionally turned on to full power (300 watts electrical). The ultrasonic field had no visible or otherwise detectable effect on the boiling phenomena. During survey runs, however, an effect of the ultrasonic field has been noted at low velocities and subcoolings. The effect appears to be an increase in the number of bubbles (or an increase in frequency of formation) and a reduction in bubble size.

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PLANS FOR FUTURE WORK

The program is scheduled for completion July 31, 1961.

PRINCIPAL INVESTIGATOR

The technical supervisor on the program is Dr. Fred E. Romie.

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