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Quarterly Technical Progress Report

EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF

ULTRASONIC VIBRATIONS ON BURNOUT HEAT FLUX

WITH BOILING WATER

ATL Job 4116

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for

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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

Design of the test section and the flow system has been completed, and components are on hand. Assembly of the complete system is in progress, with completion and initial checkout expected during the latter part of April.

DISCUSSION OF PROGRAM

Flow System Description

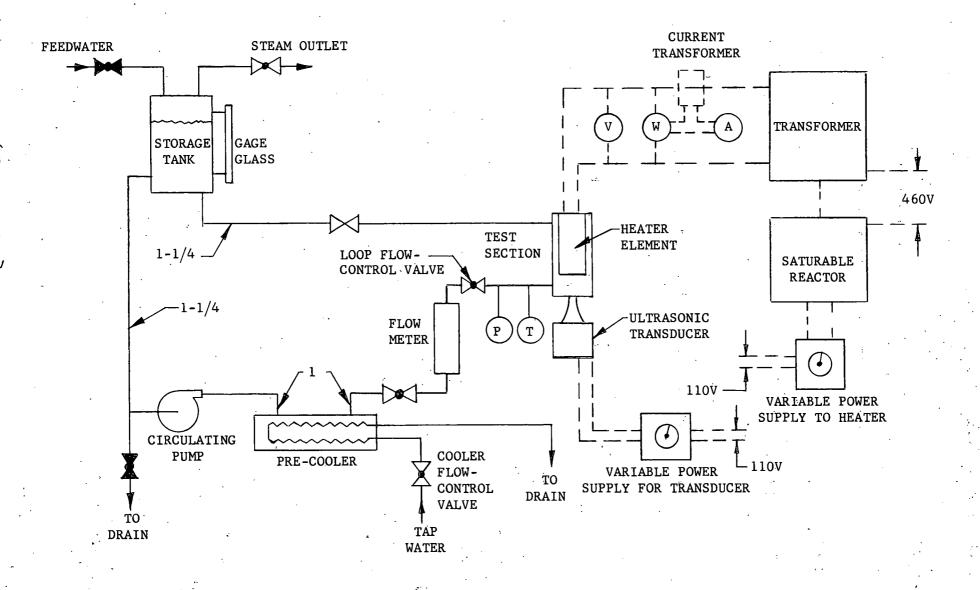
The flow system diagram is shown in Figure 1. The function of each component is described below in order of its appearance on the flow diagram, starting at the exit to the test section.

Storage Tank

The storage tank, a 42-gallon galvanized-steel tank fitted with a sight glass, is located at the high point of the system. Water and steam from the test section enter the bottom of the tank. With saturated water in the tank, the system water can be deaerated by bubbling steam from the test section through the tank water.

2. Pump

The centrifugal pump is driven by a $\frac{1}{4}$ -hp motor. In the range of use, 0 to 10 gpm, the head across the pump varies from 29 to 28 feet. The pump thus operates at essentially a constant head in this application.



PIPING AND INSTRUMENT DIAGRAM
ULTRASONIC - HEAT TRANSFER EXPERIMENT

FIGURE 1

3. Heat Exchanger

The degree of subcooling of water delivered to the test section is controlled by the heat exchanger.

4. Rotameter.

Flow to the test section is metered by a Rotameter. Rated accuracy is 2% of full scale. Two flow tubes and three floats for the Rotameter permit selection of six float-tube combinations having maximum scale readings corresponding to flow rates of 1.90, 2.52, 3.92, 5.12, 6.88, and 9.65 gpm. These flow rates correspond to liquid velocities in the annular test section (0.25 in. ID \times 0.75 in. OD) of 1.55, 2.06, 3.21, 4.19, 5.62, and 7.89 ft/sec, respectively.

5. Pressure Gage

Pressure is measured by means of a standard Bourdon tube gage with a scale range from 0 to 15 psig. Rated accuracy is 1% of full scale.

6. Temperature Gage

Temperature of water delivered to the test section is measured by means of a standard industrial thermometer. Scale range is 50 to 300°F. Rated accuracy is 1% of full scale.

7. Ultrasonic Transducer

The ultrasonic transducer operates at a nominal frequency of 25,000 cps and is supplied by a power supply variable from 0 to 300 watts. The circular radiating surface has a 3/4-inch diameter. The radiating surface is located at the end of a solid horn, the other end of which is roughly 3 inches in diameter. The latter end is welded to a steel cylinder which is attached to the driving crystal. The manufacturer claims an electrical-to-sonic efficiency of 90% for the transducer with the horn removed. The horn reduces this efficiency, but the amount of reduction is unknown. In any event, it is anticipated that cavitation of the hot water near the radiating surface will not permit good coupling between the water and the radiating surface in the higher ranges of power. Thus, the actual efficiency will be considerably less than 90%.

8. Test Section

A drawing of the test section is presented in Figure 2. Water enters the bottom (right side of drawing) of the test section and flows upward in the annular conduit formed on the outside by a precision-bore 3/4-in. ID glass tube and on the inside by the $\frac{1}{4}$ -in. OD heating element. In flowing from the inlet plenum to the annular flow conduit, the water passes through a wire screen provided to remove any swirling component of the flow.

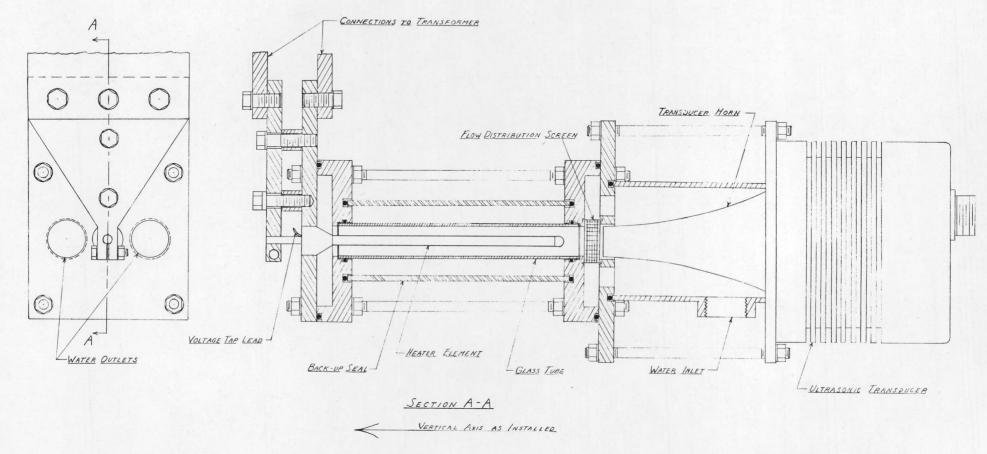
The $\frac{1}{4}$ -inch OD element is made of a 321 stainless steel tube with a 0.012-inch-thick wall and has a heated length of $5\frac{1}{2}$ inches. Electric resistance heating is provided by axial conduction of a 60-cycle current through the tube wall. Current is carried to the free end of the bayonet-type element by a central copper core of 0.202-inch diameter. Power generation in the copper core is about 1.1% of that generated in an equal length of the stainless steel heating tube. The annular electrical insulating gap between the copper core and the inside surface of the stainless steel tube is therefore filled with a silicone rubber in order to afford a low resistance thermal path from the core to the steel tube. The silicone rubber is suitable for continuous operation at 500°F and has a thermal conductivity of about 0.25 Btu/(hr-ft²-°F/ft).

An insulated nickel wire is attached to the inside surface of the heating tube 1 inch below the top of the active length of the heating element. The wire serves as a voltage tap for use in the bridge of the burnout detector described in the previous quarterly report.

9. Test-Section Power Supply

The electrical power supply consists of a saturable reactor in series with a low-impedance transformer required to match the low-impedance heating element. This combination will permit stepless variation of power from essentially zero to 50 kva with a maximum current of 2000 amperes. A power dissipation of 10 kw in the element corresponds to a heat flux of 1.14×10^6 Btu/(hr-ft²) at the surface of the element.

^{*} ATL-A-113, October - December 1960.



ASSEMBLY AND SECTIONS TEST SECTION ULTRASONIC - HEAT TRANSFER EXPERIMENT

FIGURE 2

10. Power Instrumentation

The measurement of electric power input to the test section is afforded by a wattmeter with $4\frac{1}{2}$ -inch scale and a range from 0 to 60 kw. Accuracy is 2% of full scale. The current terminals are connected to the secondary of the low-impedance transformer through a 2000-5 current transformer. Auxiliary measurements of heating-element voltage and current are made for monitoring purposes with a 0-30 volt voltmeter and a 0-2000amp ammeter, which is also connected through the current transformer.

PLANS FOR FUTURE WORK

During the next quarter, the program schedule calls for completion of the experimental program.

PRINCIPAL INVESTIGATOR

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



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