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DEVELOPMENT OF BNL HEAT TRANSFER FACILITY 1: FLASHING EXPERIMENTS*

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A major area of interest to reactor safety technology is the prediction of actual vapor generation rates under conditions of thermal nonequilibrium as would be encountered during a loss-of-coolant accident (LOCA) in a light water reactor. In support of the development of advanced codes dealing with LOCA induced flashing, analytical models of the nonequilibrium vapor generation processes of interest have been formulated, and an experimental facility has been constructed to provide data to verify these models. This facility is known as BNL Heat Transfer Facility 1.

The experimental facility consists of a flow loop, test section and the data acquisition and analysis system, and a schematic of the flow loop is shown in Figure 1. The main portion of the flow loop is constructed from "three inch" nominal (7.6 cm) stainless steel pipe. High purity water is circulated through the loop using a centrifugal pump rated 1500 ℓ/min at 600 kPa. Very close and stable control of all loop parameters is required since flashing is sensitive to very small changes in such parameters as flow rate, subcooling, and pressure. For this reason, all major facility parameters are continuously controlled using 3-mode automatic controllers and continuous control elements.

Starting from the pump, the fluid is circulated through a flow control station where the flow rate can be controlled from 3 to 950 ℓ/min and then measured with an accuracy of 1/2 percent of full scale flow rate. Excess flow from the pump is directed to secondary loops for cooling, purification, and simple bypass flow routing. After the flow rate is set and measured, the fluid passes through the heater system where up to 520 kW of heat can be added to the flow, and the outlet temperature can be controlled to $\pm$ 0.3^{o}C over the entire controlled flow range.

After leaving the heater system, the fluid passes through the test section. A pressurizer utilizes a 20 kw heating element continuously controlled with reference to an RTD in the steam volume above a fixed liquid level. This pressurizer is connected to the main loop between the heater system and the test section and, when valved in, the pressurizer fixes the inlet pressure to the test section, thus allowing two modes of operation: pressure controlled and flow rate controlled. Once the fluid has passed through the test section, it enters a condensing tank where a cooling spray is utilized to condense any vapor and to fix the tank temperature. Since the pressure in the tank is essentially the same as in the test section exit, the condensing tank and pressurizer can be used together to fix the pressure drop across the test section.

The fluid travels, after leaving the condensing tank, back to the pump, and depending on conditions, cooling water can be added to this flow to prevent cavitation in the pump. Cooling water is provided from pump excess flow and is cooled by shell and tube heat exchangers tied to a 730 kW cooling tower.

Purification of the test fluid is accomplished during initial filling of the test loop. The water is deoxidized, deionized and passed through

0.22 micron filters. In addition, about 40 ℓ/min of excess pump flow is continually passed through the purification station as a polishing procedure during flow loop operation. Loop pH is controlled via resin beds to 7.0 with a resistivity greater than 18 MΩ • cm.

The test section is a stainless steel tube, 78.7 cm long, and has a portion which forms a venturi. This converging/diverging portion is 55.9 cm long and has inside diameters of 5.1 cm at the ends and 2.5 cm at the throat. The wall thickness varies only from 0.57 mm to 0.60 mm over the entire tube length.

Three discrete levels of construction, each adding more complex instrumentation, are evident in the test section fabrication. In the first level, 49 pressure taps are installed on 1.3 cm centers along the length of the tube, and the second level adds a ten beam (two banks of five) gamma densitometer which can be traversed to measure virtually everywhere within the tube and yield the cordal averaged void fraction. A traveling probe containing several sets of either optical or r-f sensors, which will be inserted into the test section, is the third level of construction and is designed to provide both local void fraction and local phase velocity data. Test section instrumentation is summarized in Table I.

The centralized Data Acquisition and Data Analysis System (DADAS) was designed as a real time digital data system with multiterminal multitasking capability. The system was constructed around a Hewlett Packard 9640 system consisting of a 21MX minicomputer with 112 kilowords of central memory, 7.5 megaword cartridge disc and 9 track magnetic tape transport. Control of the system is accomplished with CRT and Silent 700 terminals. Tabular and graphical presentation of data is achieved with a Varian electrostatic printer/plotter.

Three levels of ADC speed and resolution are incorporated within DADAS. The slow speed, high resolution system employs an integrating digital voltmeter with microvolt resolution and 300 channel guarded crossbar scanner. The through-put rate of this system is up to 18 measurements per second with high common mode voltage rejection capability. The intermediate speed system is a 15 bit multiplexed ADC with a 50 kHz through-put rate. The system employs a single programmable gain amplifier and a signal conditioning amplifier and filter per channel. The system has high common mode voltage rejection capability and can be connected directly to experiments. The high speed system is also a 15 bit multiplexed ADC with a 500 kHz through-put rate. The system has eight input channels with simultaneous sample and hold amplifiers. The latter two systems are expandable to 2048 channels each.

Fabrication of the flow loop has been completed, and the system has been operated successfully over the designed temperatures, pressures and flow rates of 175°C, 1 MPa, and 750 ℓ/min. Pressure distribution data have been taken in the test section, and calibration of the gamma densitometer is being accomplished. Incorporation of optical or r-f sensors is awaiting successful development of a suitable probe seal.

The flexibility in the design high precision measurement capability and wide range of operating parameters, both hydrodynamic and thermodynamic, inherent in this flow loop make it a valuable research facility for investigation of a wide range of phenomena related to safety analysis of both LWRs and LMFBRs.

TABLE I

TEST SECTION INSTRUMENTATION

QUALITY MEASURED	TYPE OF SENSOR	RANGE	ACCURACY
Temperature	Resistance Temp. Detector (RTD)	-200 to 500°C	1.2% @ 200°C
Differential Pressure	Strain Gage Δp Transducer	4 to 500 kPa	1% of Reading
Flow Rate	Turbine Meter	3 to 950 ℓ/min	0.5% Full Scale
Void Fraction	Gamma Densitometer (Thulium/Cad-Telluride)	0 to 1	5% Steady State (Future 5% per 1 ms)

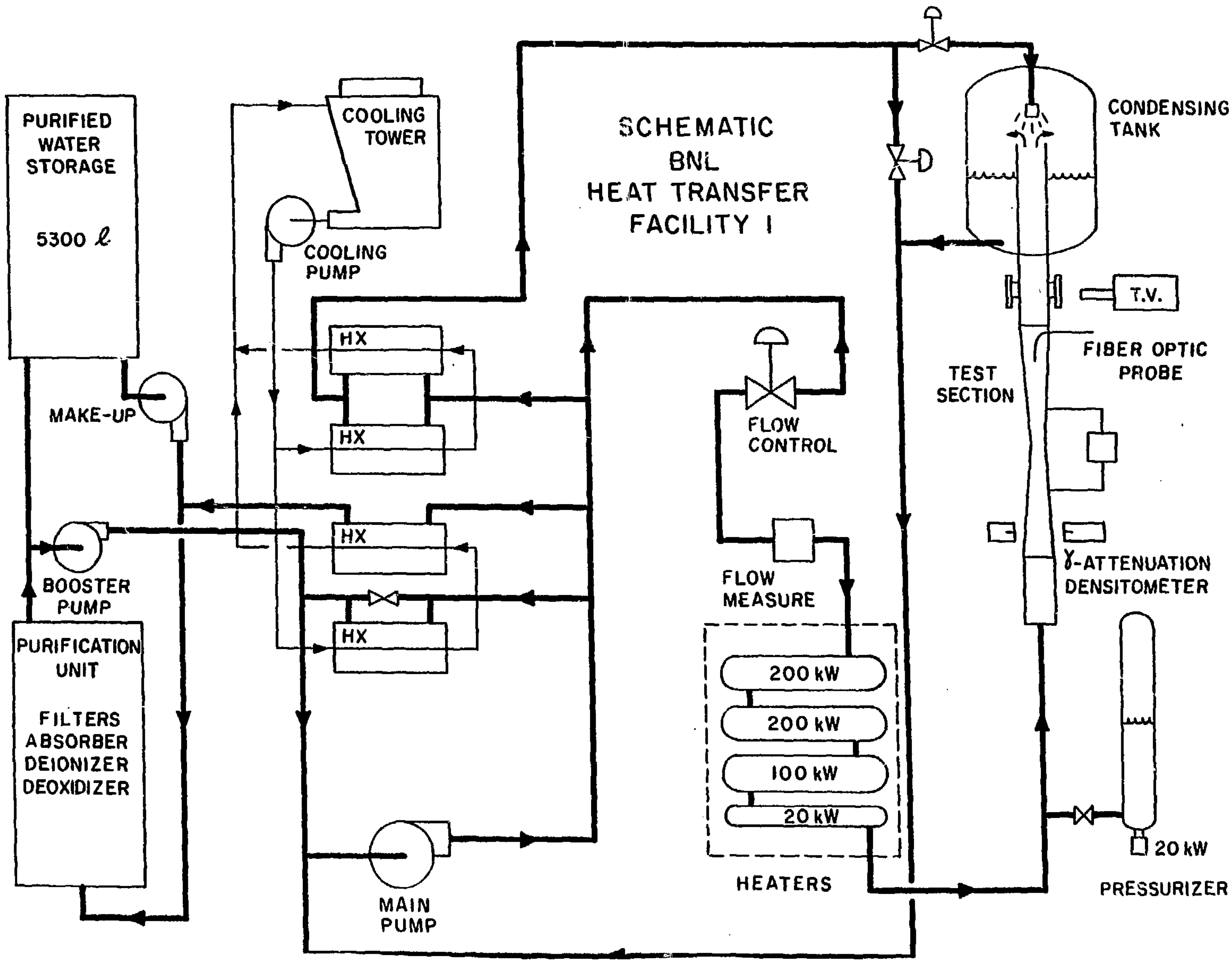

Figure 1 - Schematic of BNL Heat Transfer Facility 1 (BNL Neg. No 1-1246-79)