830 Power Building
TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401

August 22, 1977

Regulatory File Cy.

Director of Nuclear Reactor Regulation
Attention: Mr. S. A. Varga, Chief
Light Water Reactors, Branch No. 4
Division of Project Management
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Varga:

In the Matter of the Application of	)	Docket Nos. 50-327
Tennessee Valley Authority	)	50-328
		50-390
		50-391

In a letter to D. B. Vassallo from J. E. Gilleland dated August 11, 1976, TVA submitted for review a revised scoping document for an RHR sump vortex test utilizing a physical model of the Sequoyah and Watts Bar sump. Enclosed for your review is the detailed test plan for an RHR sump vortex test. The test will be conducted at TVA's Norris Engineering Laboratories using a scale model of the RHR sump and reactor cavity equipment located near the sump.

Very truly yours,

J. E. Gilleland
Assistant Manager of Power

Enclosure (3)

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Tennessee Valley Authority
Division of Water Management
Water Systems Development Branch

MODEL STUDY FOR SEQUOYAH AND WATTS BAR NUCLEAR PLANT CONTAINMENT SUMP PERFORMANCE

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Sequoyah Nuclear Plant

Advance Report No. 11

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Prepared by
Theodoric G. Fain
Norris, Tennessee
August 1977

Report No. 72-27

MODEL STUDY FOR SEQUOYAH AND WATTS BAR NUCLEAR PLANT CONTAINMENT SUMP PERFORMANCE

INTRODUCTION

In the event of a loss of coolant accident, the emergency core cooling system is designed to protect the fuel cladding by providing a supply of borated water to the reactor coolant system and, ultimately, the reactor core. This water is initially supplied from the Refueling Water Storage Tank (RWST). After the injection of water from the RWST, water accumulating in the containment area is continuously withdrawn by way of the containment sump, cooled, and recirculated to remove heat from the reactor core and from containment.

The containment sump, shown in Figure 1, is protected at entry by a coarse steel screen supported within a substantial frame and angled in such a manner to allow gravity to aid in cleaning. Water flowing into the sump passes through a 1/2 inch mesh screen, through a 1/4 inch mesh screen, and enters the twin discharge pipes connecting the sump to the residual heat removal (RHR) and containment spray pumps. The two screens, the solid top cover plate, and the internal deflector plate were designed to suppress the formation of air drawing vortices which could impair system performance.

Sequoyah and Watts Bar Nuclear Plants were not designed for a full-scale prototype test of the containment sump; alterations for such a test at the present stage of construction would be prohibitively expensive and cause major delays in construction. For this reason, TVA plans to verify the effectiveness of the containment sump vortex suppression design by constructing and testing two 1:4 scale physical models at the Engineering Laboratory, Norris. A model for Sequoyah will be constructed and tested first. After the Sequoyah model tests have been completed and the results accepted, a model for Watts Bar will be constructed and tested. Both models will utilize the same test facility, pumps, and equipment, and be tested according to the same procedures. The separate Watts Bar model is necessary because details of the flow boundaries near the sump entrance are different from those at Sequoyah. This report describes (1) physical characteristics, (2) parameters, (3) instrumentation, (4) test procedure, and (5) acceptance criteria for the planned model studies.

PHYSICAL CHARACTERISTICS

Model Limits

The Sequoyah model will have the orientation of Unit No. 1 (Units 1 and 2 are opposite hand but otherwise identical) and will include the containment sump, the sump intake structure, the two discharge pipes leading from the sump, and a portion of the containment area between the crane wall and reactor shield wall. The portion of containment floor included (El 679.78) will extend from the centerline of the refueling canal (Azimuth 270.0°) clockwise to recirculating pump No. 1 (Azimuth 52.3°), as shown in Figure 2. Within this floor area, the reactor shield wall, crane wall, and all obstructions to flow (piping, equipment, supports, etc.) up to El 700.0 will be modeled (maximum water level is El 693.0). The model limits for the Watts Bar model will be selected on a similar basis and will be described in the final report of the Watts Bar test. Preliminary tests will be conducted on both the Sequoyah model and the Watts Bar model to verify that flow obstructions outside the model limits have no significant effect on flow patterns at the sump.

Material

The sump and discharge pipes will be made of clear acrylic plastic for flow visualization. The remainder of the containment, equipment, and flow passages will be mostly of wood, with other materials (plastic, steel, non-ferrous metals, epoxy) as needed for dimensional stability.

Model Similitude

Dynamic similarity between model and prototype will be attained primarily by equating Froude numbers. It is known that viscous forces are relatively important within the vortex core and that the Reynolds number in a Froudian model is always smaller than that of the prototype. To insure that model results are conservative, a large scale (1:4) is chosen which results in a model Reynolds number near the same order of magnitude as that of the prototype. Based on maximum design flow and discharge pipe diameter, these values are 1.49×10^6 for prototype and 1.86×10^5 for model. Also the model will have a capacity of up to twice the scaled maximum design flow for sensitivity tests.

PARAMETERS TO BE EVALUATED

The ability of the sump to pass the designed amount of water will be indicated by the discharge coefficient, defined as

$$C_D = \frac{Q}{A\sqrt{2gH}}$$

where Q = total discharge through sump
A = discharge pipe cross-sectional area
H - static head on discharge pipe

The formation of a vortex strong enough to impair effectiveness of the sump will cause a reduction in C_D.

Large-scale turbulence intensity within the sump will be indicated by the pressure coefficient, defined as

$$C_p = \frac{\sqrt{\overline{\Delta P^2}}}{V^2/2g}$$

where ΔP = magnitude of pressure fluctuations in the sump
V = mean velocity in discharge pipes

Such pressure pulsations may effect entrance conditions of the discharge pipes.

The amount of entrained free air in the discharge pipes will be indicated by the air-water ratio, defined as

$$R_A = \frac{Q_A}{Q_W}$$

where Q_A = flow rate of entrained free air
Q_W = water flow rate

Ideally, this ratio will always equal zero.

The extent of rotation or swirling flow in the discharge pipes will be indicated by the circulation number, defined as

$$\Gamma = 2\pi R V_t$$

where R = radius of discharge pipe
V_t = tangential velocity near pipe wall

Additionally, flow patterns at the free water surface and throughout the model will be outlined with injected dye, visually observed, and photographed.

INSTRUMENTATION

Evaluation of the parameters listed will require measurements of (1) all inflows and outflows, (2) water surface elevations in containment, (3) wave heights in containment, (4) pressure fluctuations in the sump, (5) pressure distribution in the discharge pipe, (6) tangential velocities in the discharge pipe, (7) entrained air in the discharge pipe, and (8) water temperature.

(1) All inflows to the containment, along with outflows from the two discharge pipes, will be measured with calibrated rotameters and/or orifice meters connected to manometers. Sizes of these meters will be selected for the range of flows expected in each case.

(2) Water surface elevation in containment will be inferred from a measurement of hydrostatic pressure. This pressure will be sensed by a variable reluctance pressure transducer and an a.c. bridge-carrier amplifier system and recorded on an analog magnetic tape recorder.

(3) Concurrently, wave heights on the water surface in containment will be sensed with a variable capacitance wave height probe and an a.c. bridge-carrier amplifier system and recorded on an analog magnetic tape recorder. These transducer outputs will be checked and calibrated with a hook gage in a stilling well readable to nearest one-thousandths of a foot.

(4) Pressure fluctuations in the sump will be measured at the locations shown in Figure 1 by means of two flush mount, diaphragm-actuated, strain gage type pressure transducers connected in a d.c. bridge-amplifier system. The amplified outputs will be recorded on an analog magnetic tape recorder.

(5) In the discharge pipes, pressure distribution will be measured with a series of piezometer taps located as shown in Figure 1, connected to manometers.

(6) Tangential velocities will be computed from measured deflections of a series of thin strings mounted on a circumference inside the pipe.

(7) The volume of free air collected by the air trap shown in Figure 1 will be measured by a manometer mounted on one side.

(8) Water temperature will be measured with a thermistor sensor located near the bottom of the sump. This thermistor will be connected to a bridge-amplifier whose output will be recorded by an analog magnetic tape recorder.

TEST PROCEDURE

The studies will proceed in the following manner:

1. Design of model and generation of detailed drawings for the shop (in progress).
2. Construction of the model parts in the shop (in progress).
3. Assembly of the model (in progress).
   Steps 1, 2, and 3 are taking place simultaneously.
4. Installation of instrumentation.
5. Preliminary operation, shake down, alterations, calibrations. (After this, the facility is operable.)
6. Sensitivity tests: Looking for circulation at the sump for different approach flow conditions, water depths and single, dual and alternating suction line operation over a range of flows in the neighborhood of the flow rate based on Froude scaling.

7. Possible alteration in or near the sump to break up possible excessive circulation.
8. A set of final verification tests.
9. Report.

ACCEPTANCE CRITERIA

Performance of the sump shall be considered acceptable if the sump causes withdrawal of the expected amount of water for all postulated failure modes and for operating conditions without <u>any</u> entrainment of air at any time due to a discrete vortex near the sump. Furthermore, the intensity of circulation near the sump in the 1:4 scale Froude model shall never exceed that which gives rise to a discrete vortex with persistent, continuous dye tube from the water surface into the pipe entrance and with a clearly discernable depression in the free water surface. Smaller, less intense, and transient circulations and vortices seen in the model shall be acceptable as long as these vortices do not in any way alter the flow to the RHR pumps as indicated by measured values of discharge and head-loss coefficients.

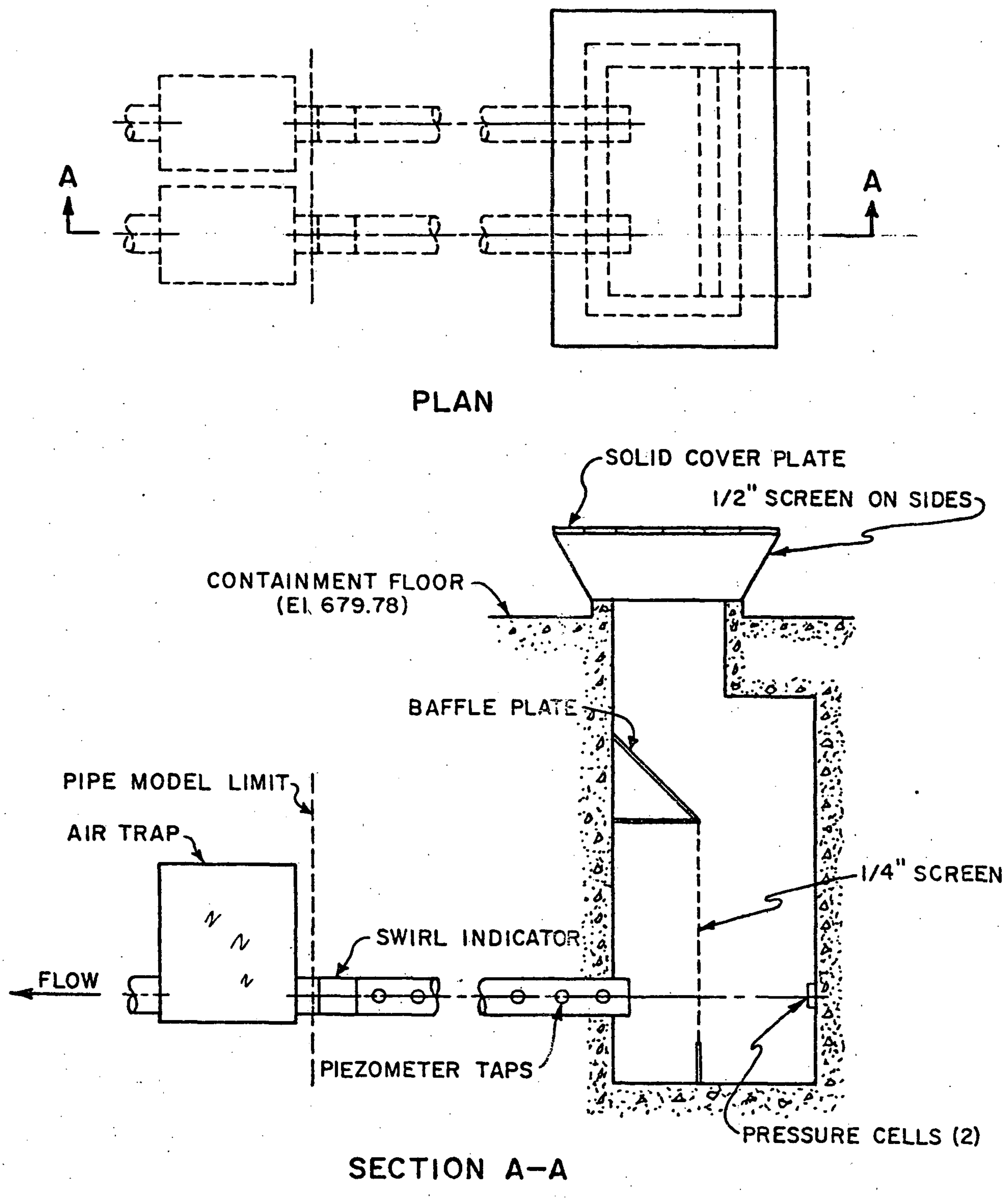

Figure 1 : Containment Sump
(Units 1 and 2 Identical)

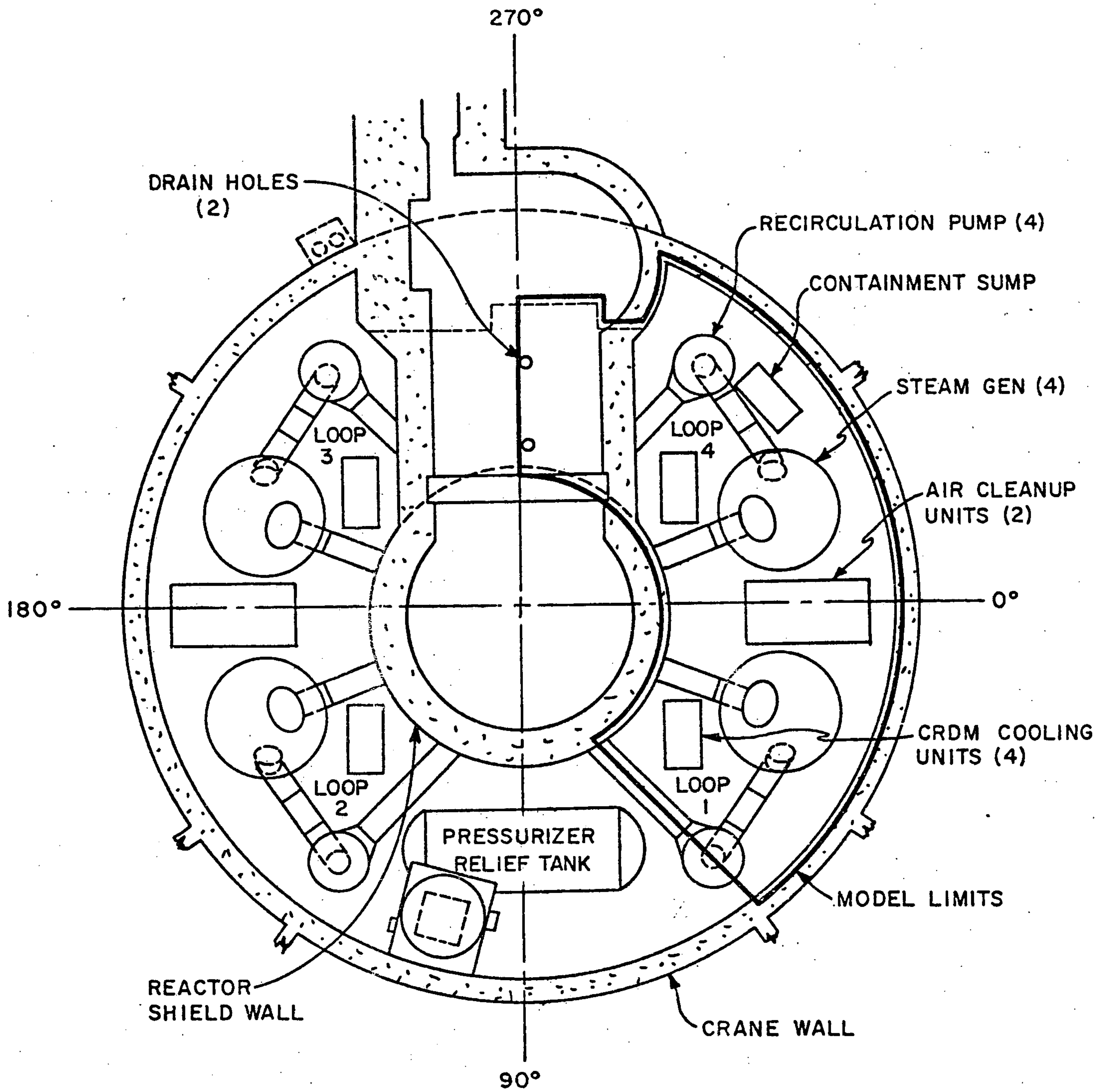

Figure 2: Model Limits
(Sequoyah Unit I)