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EXPERIMENTAL PLANS FOR LMFBR CAVITY LINER SODIUM SPILL TEST LT-1

by

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INTRODUCTION

Reinforced concrete is an important material of construction in LMFBR cavities and cells. Steel liners are often installed on the concrete surfaces to provide a gastight seal for minimizing air inleakage to inerted cell atmospheres and to protect the concrete from direct contact with sodium in the event of a sodium spill. In making safety assessment analyses, it is of interest to determine the adequacy of the liners to maintain their leaktightness during postulated accidents involving large sodium spills. However, data for basing analytical assessments of cell liners are very meager and an experimental program is underway at HEDL to provide some of the needed information. The HEDL cell liner evaluation program consists of both bench-scale feature tests and large-scale sodium spill demonstration tests. The plans for the first large-scale sodium spill test (LT-1) are the subject of this paper.

TEST OBJECTIVES

The overall objective of Test LT-1 is to demonstrate that existing and proposed LMFBR cell liner systems can withstand a major sodium spill without leaking. Specific objectives are:

1. Demonstrate the capability of liner systems to withstand a large sodium spill.
2. Demonstrate the capability of liner systems to withstand long-term sodium exposure at high temperatures (third level thermal margin enhancement).
3. Determine water and gas release rates from concrete behind liners (vent requirements).
4. Determine thermal response of concrete behind liner.
5. Determine structural strength of concrete and embeds (pull-out) after spill.

DESCRIPTION OF THE TEST ARTICLE

General Description

The test will be performed in the Large Sodium Fire Facility (LSFF) using the arrangement shown in Figure 1. The lined concrete test article will be fabricated within an existing 10-ft x 15-ft x 18-ft sheetmetal cell which in turn is located within a ventilated concrete room. Sodium will be heated to 1100°F in the 900-gallon batch tank in an adjacent room. The test article cavity and sheetmetal cell will be inerted with nitrogen gas prior to the spill. When all preparations are complete, the sodium batch tank will be pressurized with argon and a 3-inch valve opened to allow the pre-weighed 3400 pounds of sodium to flow into the test article. An average flow rate of 300 gal/min is expected, requiring 1.7 minutes to complete the spill.

Sketches of the test article are shown in Figures 2, 3, and 4. The test article is essentially a U-shaped section of concrete with two vertical walls and a common floor. One wall is curved and has FFTF-type liner features and FFTF high-density (magnetite) concrete. The opposing wall is flat and has features which are being proposed for the CRBR. The floor is similar to that proposed for CRBR cells. The space separating the two walls will contain the sodium to a depth of approximately 4.2 feet at 1100°F. The ends of the sodium space are steel plates insulated with thermal insulation. External electrical heaters are on each end wall. One of these walls has a low concrete retaining wall to provide rigidity so that a CRBR triplanar corner can be incorporated in the test. Figure 3 shows a detail of the triplanar corner.

A steel lid is provided to enclose the sodium space. An open-ended, 4-inch pipe extends above the lid to serve as a vent and also to act as an air-cooled condenser to limit the loss of sodium vapors. Also provided are a 3-inch sodium spill pipe, a nitrogen gas inlet, a gas sample line, steam vent lines, thermocouple leads, pressure leads, and electrical immersion heaters. A 1/2-inch pipe is located near the bottom of the west steel wall to provide a means for draining off the sodium after cooldown.

A summary of the test conditions is given in Table I.

CRBR LINER FEATURES

The general features of the CRBR-type liner, corners, and floor are shown in Figures 2 through 5. All CRBR liner plates are 3/8-inch thick steel, of ASTM A-516 Grade 55. All structural shapes are of ASTM A-36 material. The studs are ASTM A-108. Procedures for installing the CRBR liner features will follow the specifications provided by Burns & Roe. No painting or surface treatment will be performed.

The vertical CRBR wall utilizes a pre-cast form wall consisting of a 4-inch thick layer of lightweight insulating concrete poured onto the 3/8-inch liner plate, with a 1/4-inch sheet of Ethafoam (expanded polyethylene) between the plate and the concrete. Nelson studs are welded to the plate, as shown in Figure 6.

Lightweight insulating aggregate will be placed under the CRBR floor plates to a thickness of 4 inches, as shown in Figure 4. Procurement and placing of the aggregate will be in accordance with Burns & Roe technical specifications.

FFTF-Type Liner Features

Two liner concepts patterned after those used in the FFTF are provided in the test article. The "Bechtel" liners are steel plates welded on all edges to 3-inch I-beams which are embedded in the concrete with one flange flush with the surface. Since the plates are welded on after removing the concrete forms, a thin air gap exists between the liner and concrete systems. Two, 2-ft x 2-ft test panels and several transition panels are provided, including both inside and outside corners.

The second FFTF-type of liner is the "EFCO" panels. In this type, the liner plate serves as the concrete form wall and is stiffened by welding horizontal 3-inch angles and vertical 3-inch deep bars which also act as embeds. Three EFCO panels are provided, two approximately 1-ft by 4-ft and a top EFCO-type panel measuring 1-ft by 6-ft. Because concrete is poured directly against the steel liner plate, there is no inherent air gap.

TABLE I

SUMMARY OF LT-1 TEST CONDITIONS

- 6-ft wide x 7-ft high flat CRBR wall, CRBR floor, and CRBR bi-planar and tri-planar corners
- 6-ft wide x 7-ft high curved FFTF-type wall with Bechtel and EFCO panels and embeds
- Magnetite concrete on FFTF wall, CRBR limestone-type concrete on floor and CRBR wall
- Pre-cast insulating concrete CRBR wall
- Concrete aged 60-day minimum
- Inert atmosphere (99+% nitrogen)
- Test article initially at nominal room temperature
- 3400 pounds of sodium spilled (to about 4-ft depth)
- 1100°F sodium spill temperature
- Deluge spill of sodium against CRBR wall at approximately 300 GPM
- Electrical heaters to increase sodium temperature to 1600°F within 24 hours and maintain at 1600°F for an additional five days
- All lined concrete provided with a vent for releasing evolved water and gases
- Artificial back-pressure on one FFTF panel.

All FFTF liner plates are 1/4-inch thick steel, of ASTM A-516, Grade 55. All embedments and structural shapes are ASTM A-36 material. Procedures for installing the FFTF-type liners will follow the specifications used in fabricating the FFTF cavity liners. No painting or surface treatment will be performed.

Welding and Weld Inspection

All welding and weld inspection of the liner plates, side walls, studs, and interfaces will be performed in accordance with specifications provided by Burns & Roe. In addition, ultrasonic and radiographic testing will be performed, where possible.

Concrete Description

High-density magnetite concrete, FFTF-type M-225-C, will be poured for the FFTF wall. The floor and CRBR wall will be a limestone type, mixed according to Burns and Roe specifications. All CRBR-type concrete materials except the water are supplied by Burns and Roe from Tennessee. The mix formulae are shown in Table II.

TABLE II
CONCRETE MIX PROPORTIONS

	lb/yd^3	
	FFTF M-225-C	CRBR Type
Portland Cement Type II	625	470
Fly ash	-	80
Magnetite sand	2273	--
Magnetite aggregate, 3/4"	2907	--
Limestone sand	-	1301
Limestone aggregate, 3/4"	-	1821
Water	314	245
Air entraining agent	-	14 oz
Water reducing agent	24 oz	14 oz
	6120	3919

The 4-in. thick, lightweight insulating concrete used in the CRBR pre-cast form wall is a perlite concrete with air-dried density of 65 lb/ft^3. Specifications for materials and mixing are furnished by Burns and Roe.

All the concrete will be aged for a minimum of 60 days prior to the time of the sodium spill. Prior experience with water release and sodium-concrete reaction tests has indicated that curing time is not a prime parameter as long as the concrete is approximately 80% hydrated. This occurs at approximately 28 days for Type II cement.

Steam and Gas Vents

For the FFTF wall, the boundary of each liner panel is defined by either the seal-welded 3-in. embeds (I-beams or angles) or by the test article end walls. Each FFTF-type panel is provided with a separate vent system which consists of a 0.75-in. hole drilled through the liner plate and a 3/4-in. schedule 40 pipe welded over the hole leading from the test article to a vent gas monitoring station. Ten vent lines and monitoring stations are provided for the FFTF wall. Vent details are shown in Figure 7.

For the CRBR side, steam and gas released from the floor concrete will pass through the crushed lightweight insulating aggregate and through holes in the 8-in. I-beam embeds to the air gap along the bottom horizontal bi-planar corner. From there, the steam and gas can flow up the vertical bi-planar gap or through the 1/4-in. gap between the vertical steel liner and lightweight insulating concrete. This gap is formed when the 1/4-in. thick Ethafoam sheet melts. Tests have shown that Ethafoam melts at about 200°F, reducing to approximately 5% of its original volume. A 3-in. x 4-in. x 6-ft. long plenum is provided at the top of the insulating concrete for collection of any steam flowing vertically. This plenum opens into the gap created by the vertical bi-planar corner and both regions are vented by a 1.5-in. pipe to a collection and monitoring station. The back (unheated) side of the concrete is also provided with a liner and vent. Vent details are shown in Figure 7.

TEST MEASUREMENTS

The measurements which will be made during the test are summarized in Table III. The applicability and cost/schedule impact of strain and concrete-liner gap dimensional measurements is being assessed.

TABLE III

TEST MEASUREMENTS

- Post-test deformation of liner plates and embeds (gage marks, deflection, plate thickness)
- On-line analysis of cell atmosphere (presence of hydrogen indicates liner leak)
- Water and gas release rates from various concrete surfaces as f(t) (flow rates and composition)
- Temperature of liner surfaces, embeds and concrete as f(t) at various locations
- Pre- and post-test concrete compressive strength
- Pre- and post-test water content of concrete at various locations
- Post-test embed anchoring strength
- Liner-concrete gap as f(t) at selected locations
- Liner strains as f(t) at selected locations*

*Applicability of strain gages and gap proximity sensors being assessed - not in current test plan.

The instrumentation is enumerated in Table IV.

TABLE IV

INSTRUMENTATION*

	No. of Locations
Thermocouples	72
Liner gap pressure gauges	7
Steam and gas vent monitoring stations	12
Cell gas analyzer systems	2
Sodium aerosol sample stations	5
Cell inert gas (N_2) flow rate	2
Cell differential pressure transducer	1

*Applicability of strain gages and liner gap proximity sensors being assessed.

ANALYSES

Pre-test stress analyses are being performed on the CRBR and FFTF liners and their interfaces for the LT-1 operating conditions. These analyses will assure that the test article design will withstand the test conditions and will provide a basis for evaluating test results. Preliminary results indicate that the design is capable of withstanding the test conditions.

A CACECO computer code case has been run to predict steam release and sodium poool temperatures. Figure 8 shows the CACECO output for the sodium pool temperature for the case of a constant 44-kW input of electrical heat applied immediately after the spill. The sodium temperature is reduced from an initial 1100°F to 870°F by heat exchange with the steel and concrete. After 9 hours, the 1100°F value is regained and 1600°F is attained in approximately 26 hours. The temperature passes the 1100°F level fairly slowly, being 1100 ± 20°F for a period of 1.2 hours.

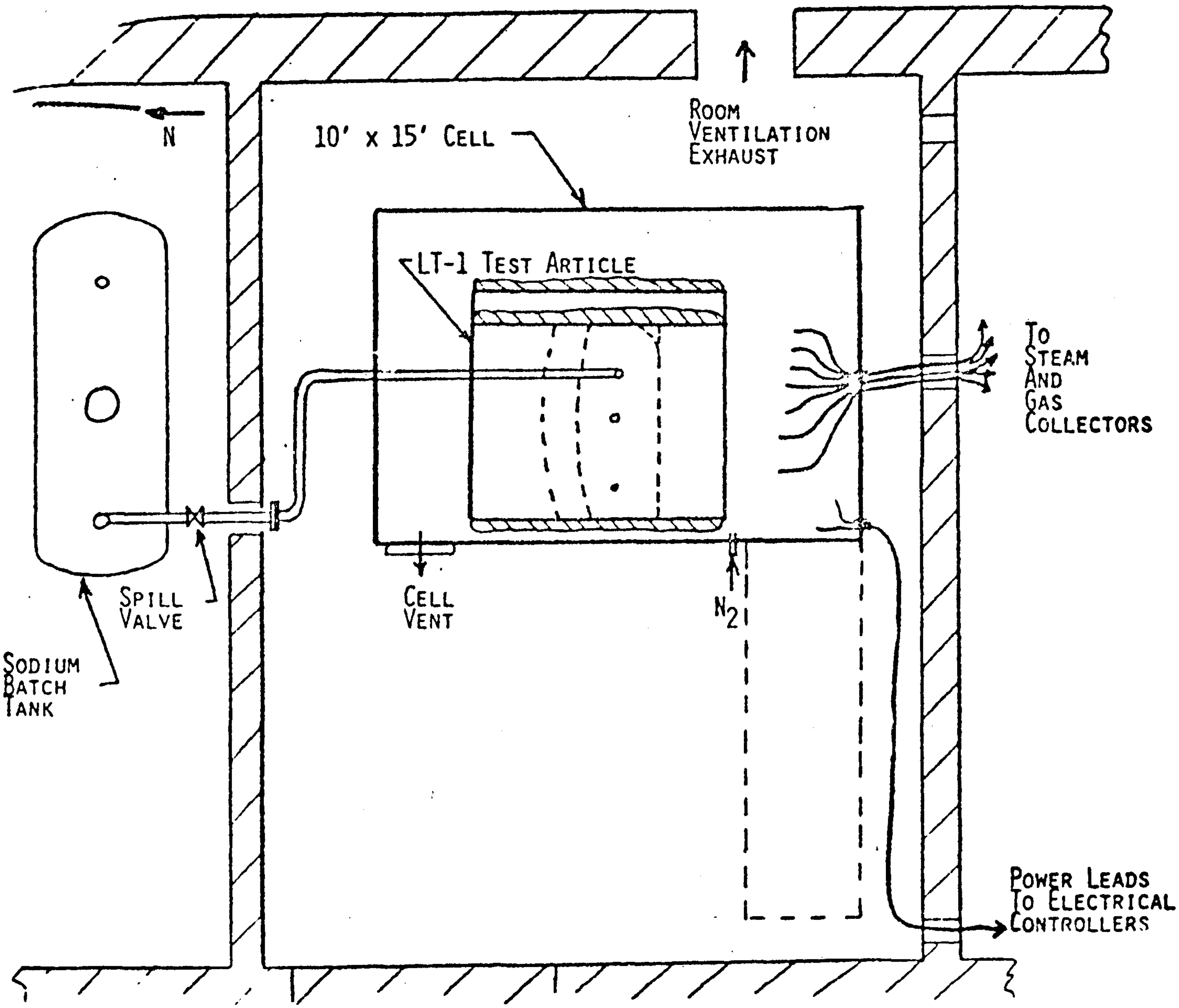

FIGURE 1. Arrangement of LT-1 Test Article Within LSFF.

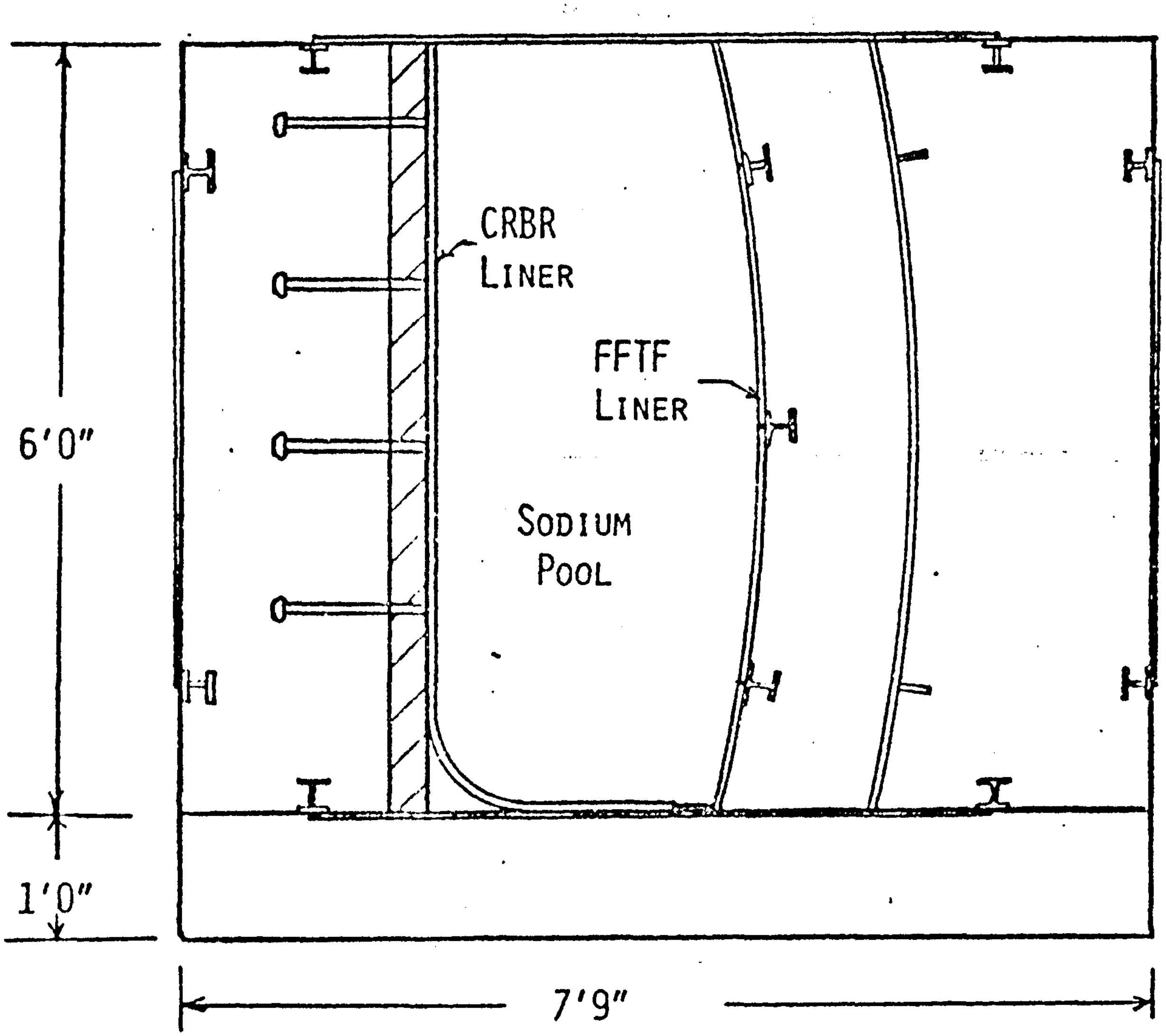

FIGURE 2. Liner Test LT-1 - Plan View.

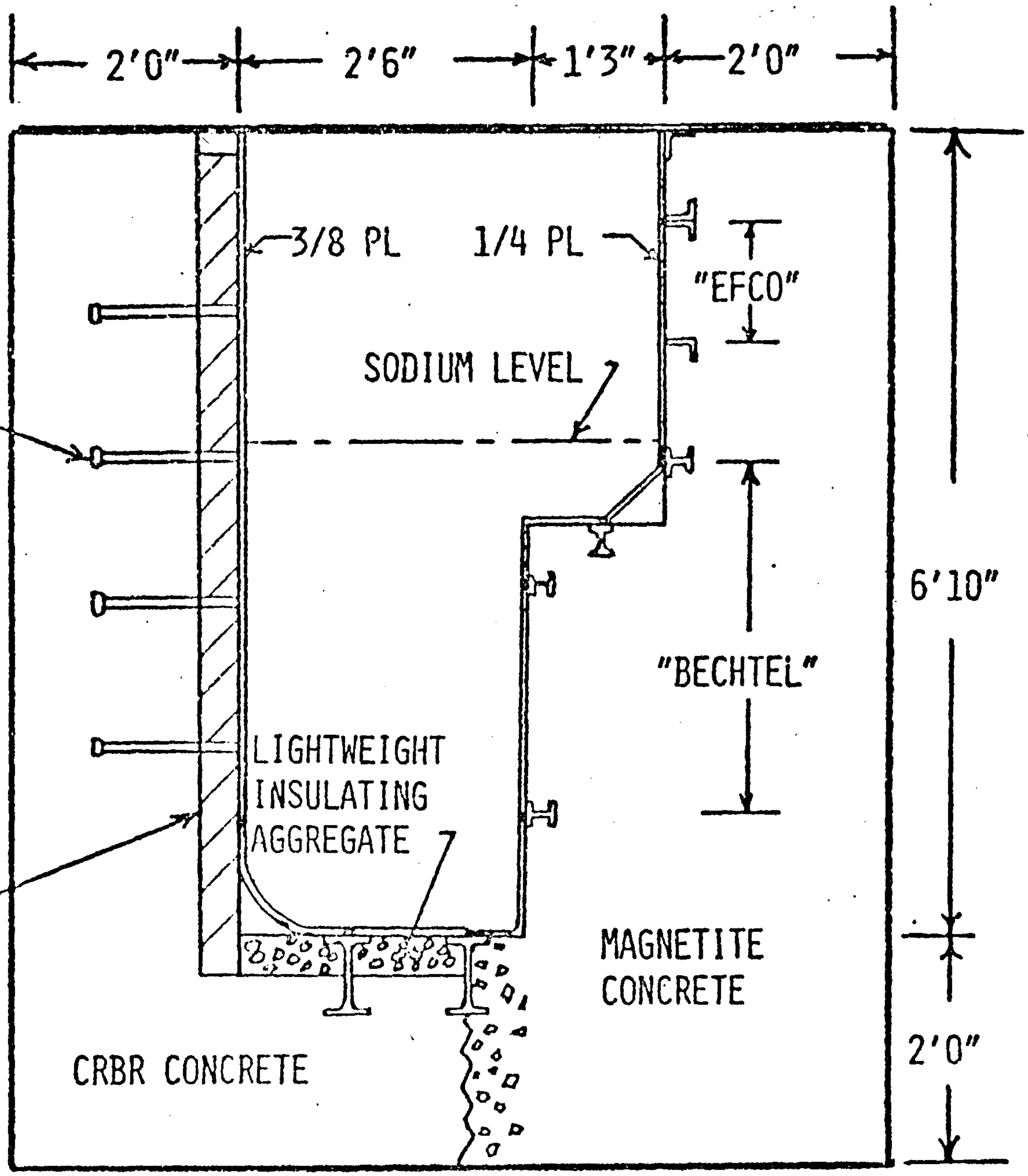

FIGURE 3. Liner Test LT-1, Elevation View.

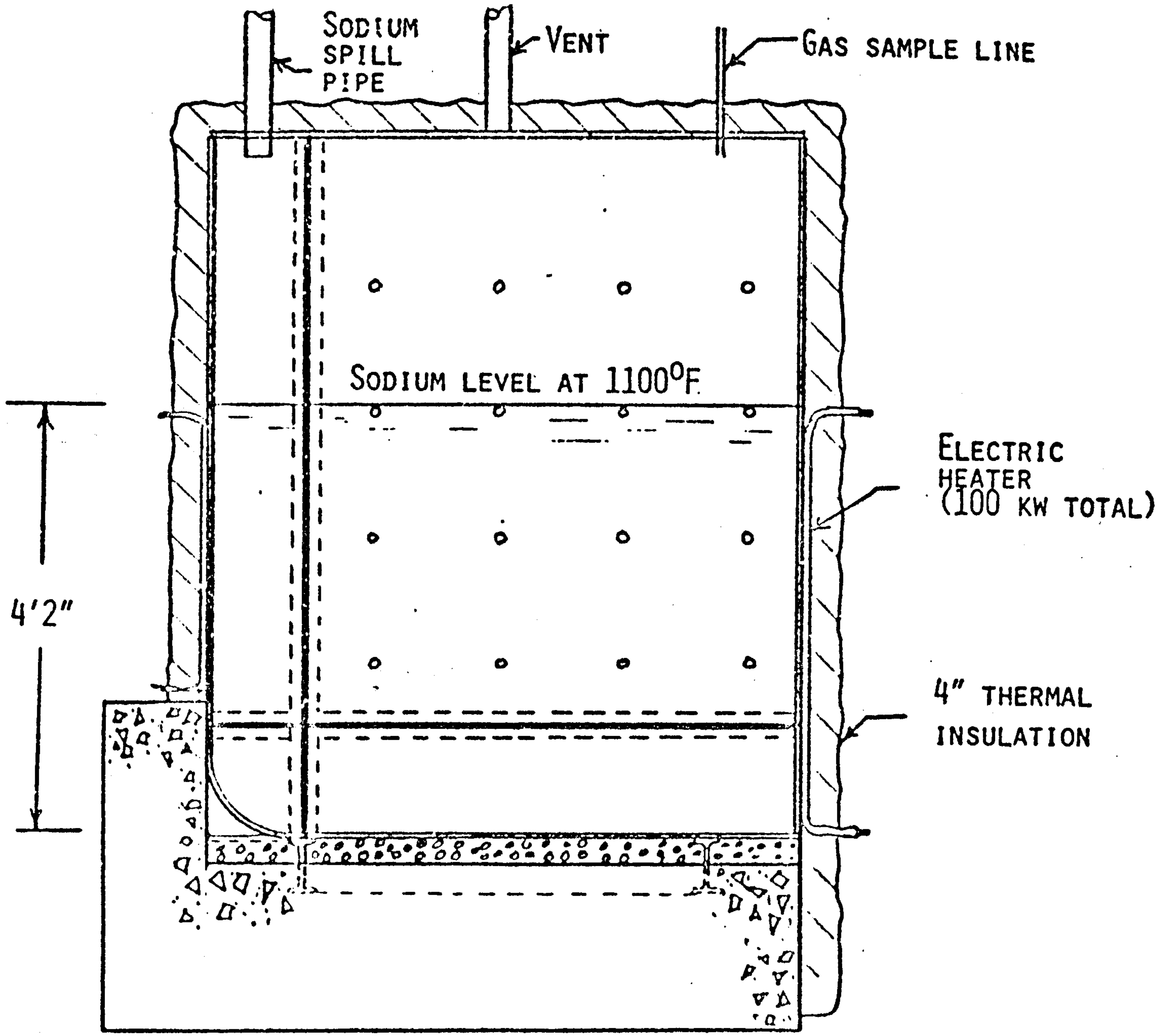

FIGURE 4. Test LT-1 Section Looking at CRBR Wall.

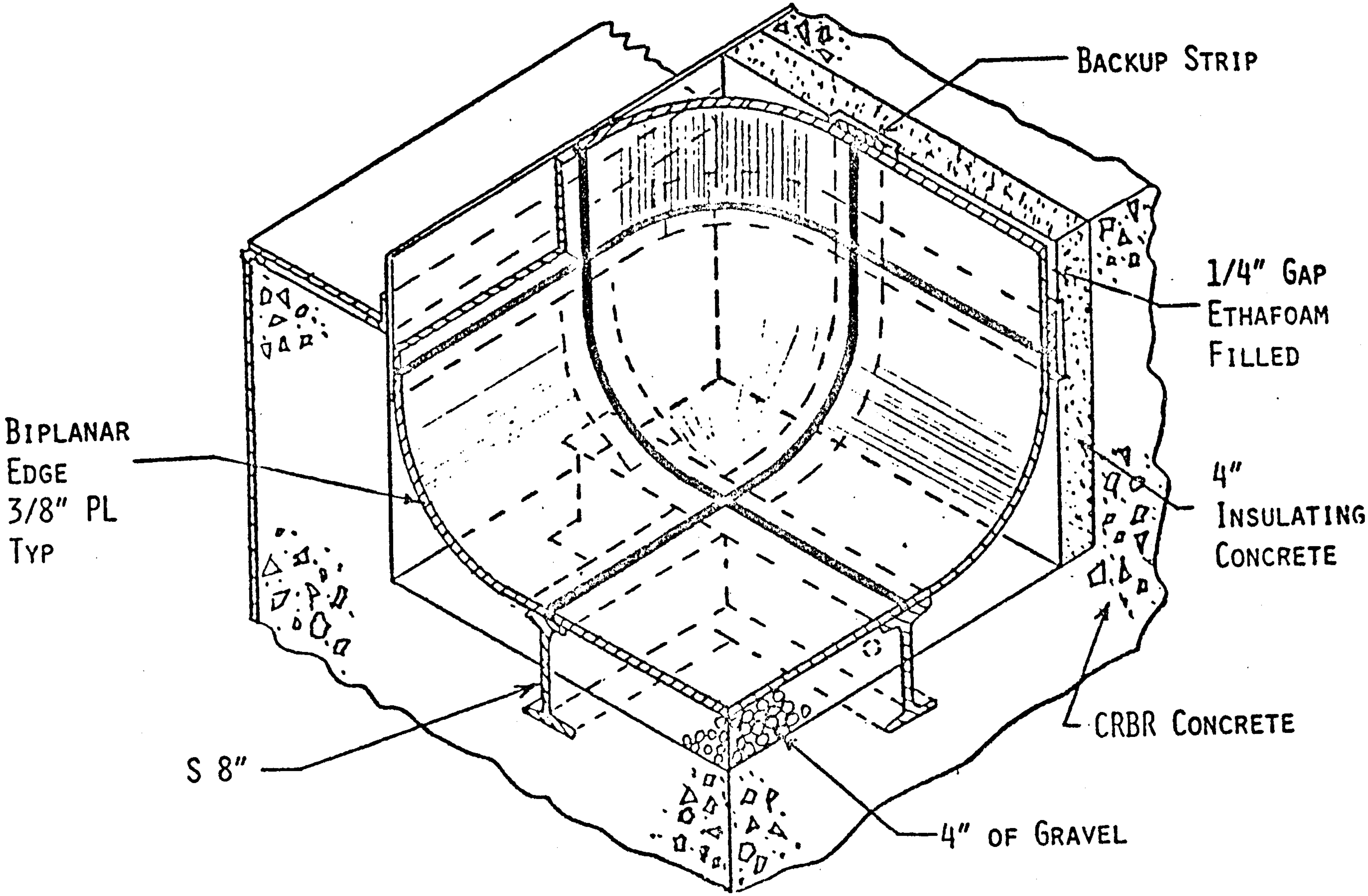

FIGURE 5. LT-1 Tri-planar Corner Detail.

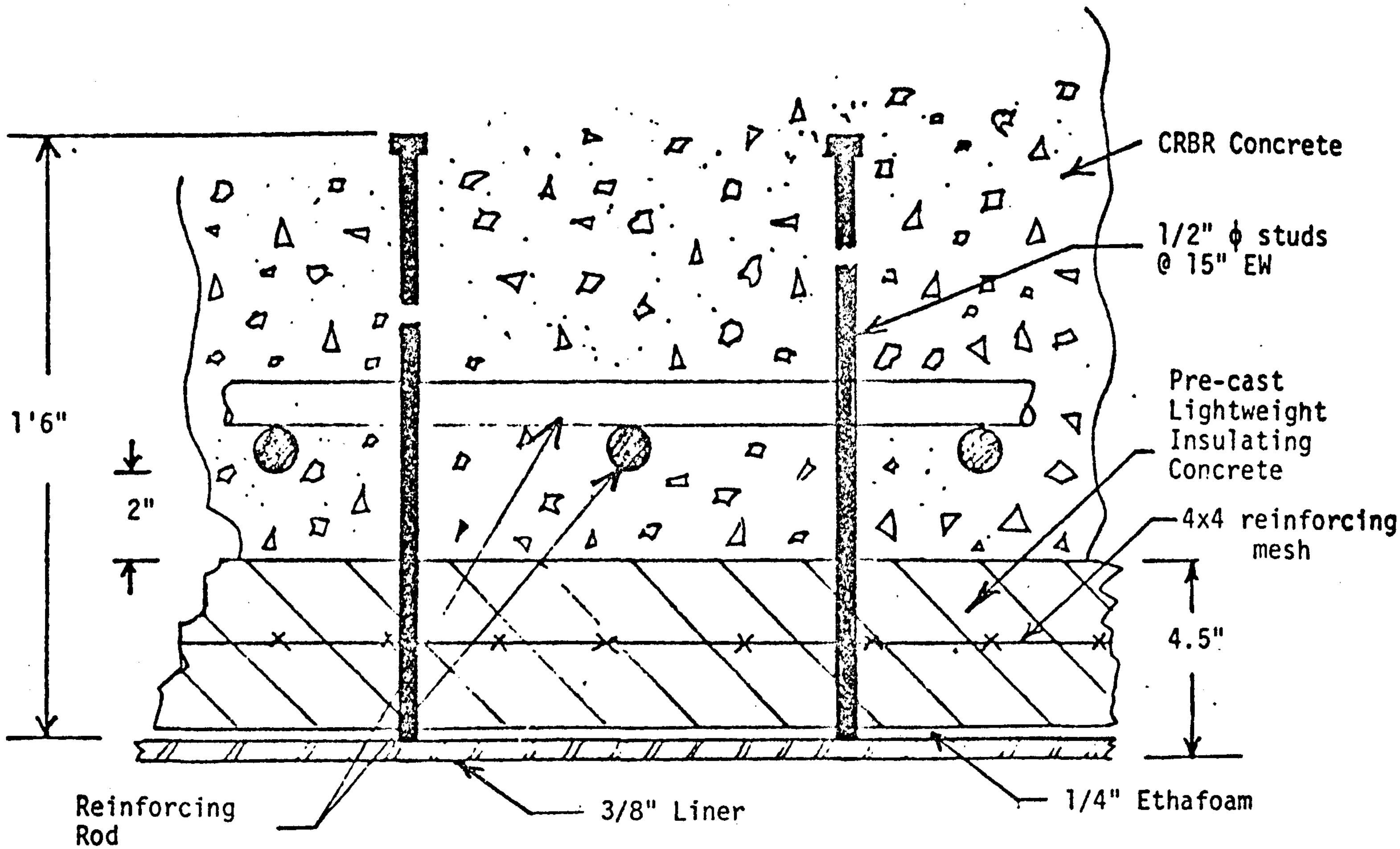

FIGURE 6. Detail of CRBR Pre-Cast Insulating Concrete Form Wall.

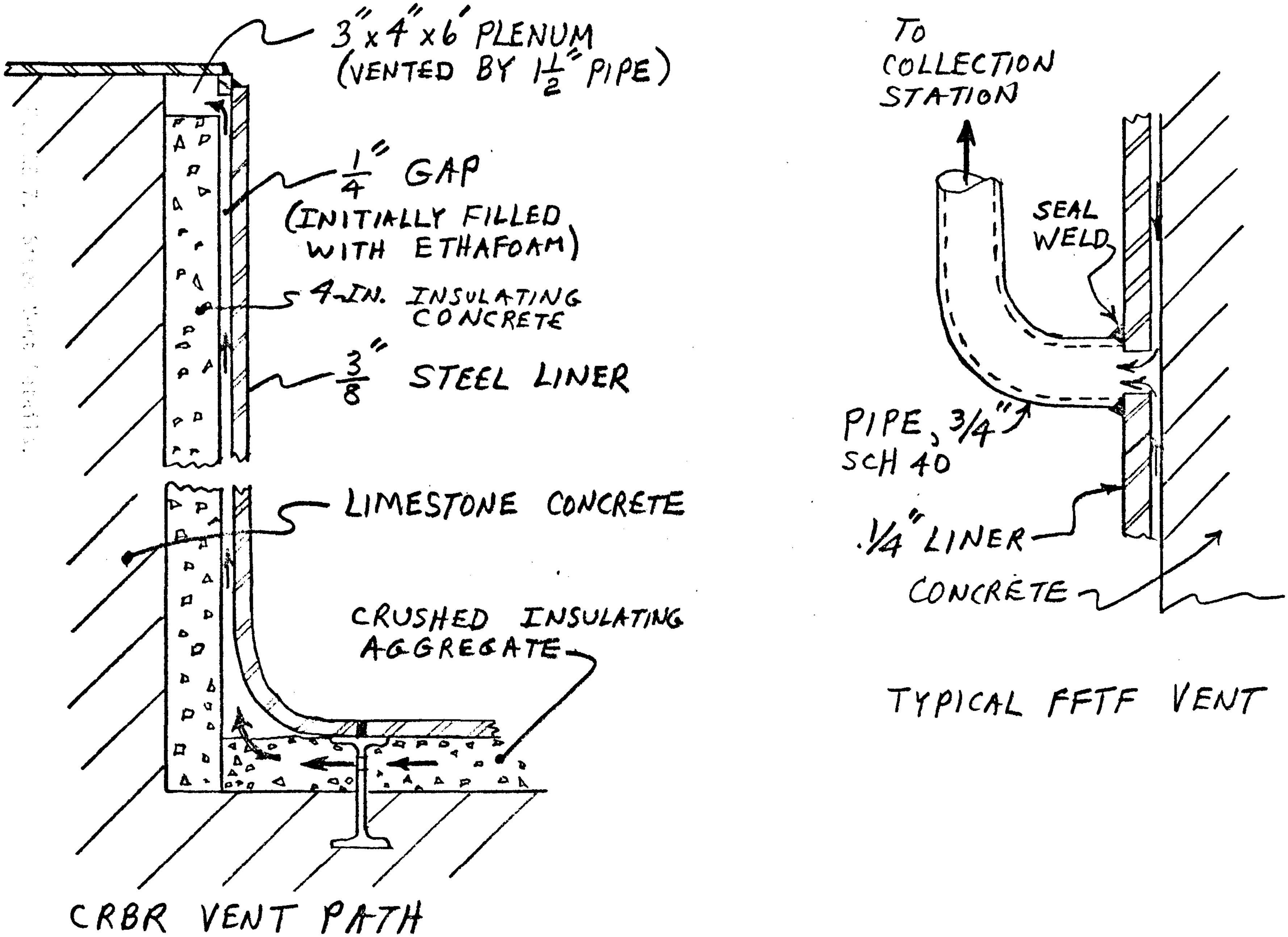

FIGURE 7. Steam Vent Details.

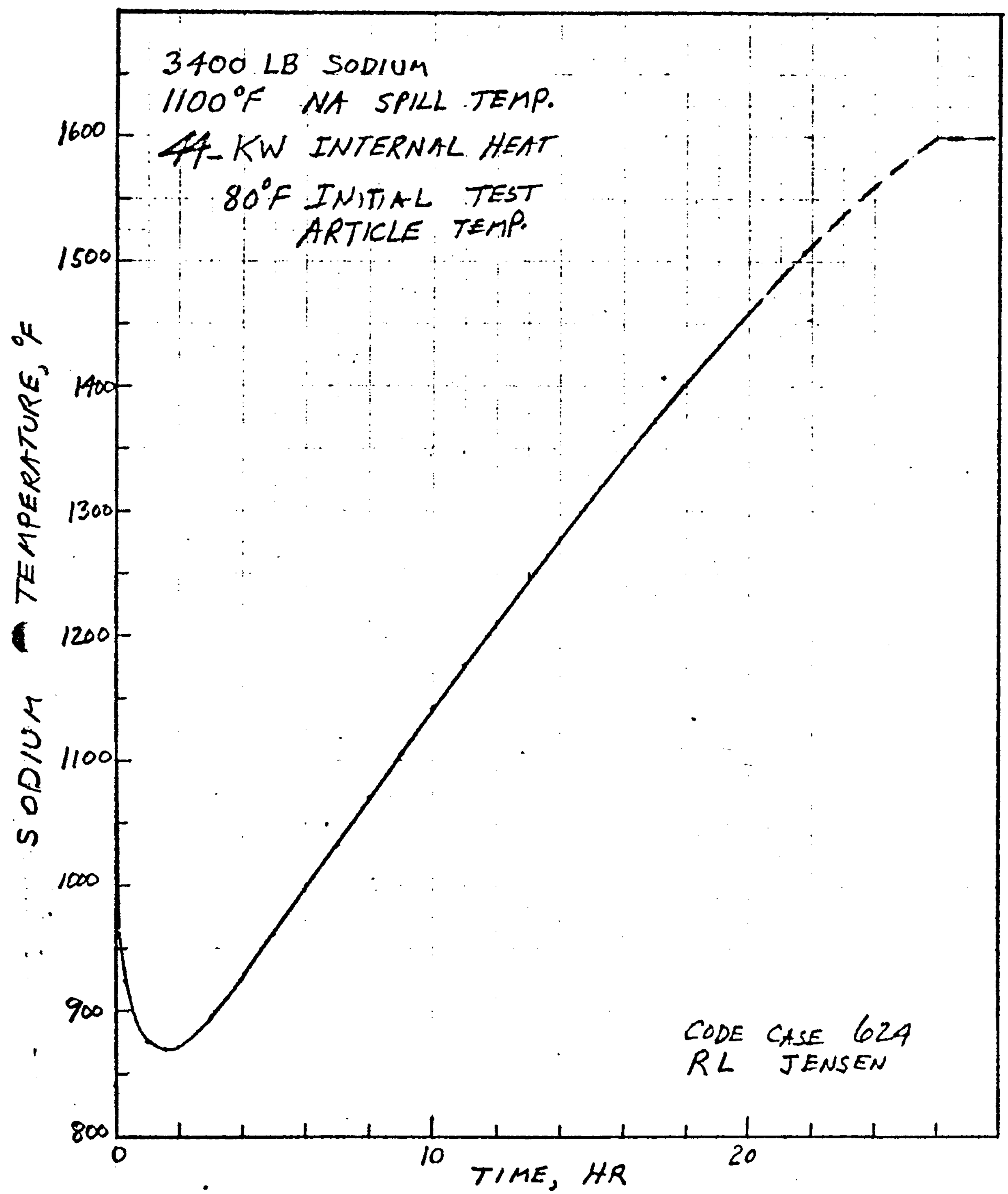

FIGURE 8. CACECO Prediction of Test LT-1 Sodium Pool Temperature.