TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

January 11, 1980

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

Dear Mr. Rubenstein:

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

Enclosed are TVA's revised responses to the questions on water level measurement systems inside containment transmitted by your letter to H. G. Parris dated October 5, 1979. These revisions have been made as a result of our telephone conversation with members of the Instrument and Control Systems Branch staff on December 17, 1979. Also enclosed is the additional information requested in the December 7, 1979, telephone conversation on steam flow instrumentation and the Auxiliary Feedwater System. The Sequoyah Nuclear Plant Final Safety Analysis Report will be revised to be consistent with the enclosed responses.

The enclosed responses are based on modifications to the steam generator reference leg design (i.e., insulation) to be completed before initial criticality.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills, Manager
Nuclear Regulation and Safety

Enclosures

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ENCLOSURE

RESPONSE TO L. S. RUBENSTEIN'S LETTER TO H. G. PARRIS
DATED OCTOBER 5, 1979
REVISED PER DECEMBER 17, 1979, TELEPHONE CONVERSATION
WATER LEVEL MEASUREMENT SYSTEMS INSIDE CONTAINMENT

1. Describe the liquid level measuring systems within containment that are used to initiate safety actions or are used to provide post-accident monitoring information. Provide a description of the type of reference leg used, i.e., open column or seal reference leg.

Response

Two types of level measurement systems used inside containment are described below along with the particular application:

A. An open column reference leg is used for steam generator (SG) level measurement. The instrument is connected to the SG liquid by a condensate chamber at the upper tap. The liquid in the reference leg will be at essentially ambient temperature.

Steam Generator Narrow Range Water Level Safety Functions

- Turbine trip and feedwater isolation on high-high steam generator water level
- Reactor trip on low steam generator water level in coincidence with steam flow - feed flow mismatch
- Reactor trip on low-low steam generator water level
- Auxiliary feedwater pump initiation on low-low steam generator water level
- Post-accident monitoring function

Steam Generator Wide Range Water Level Safety Function

- Post-accident monitoring function

B. A sealed reference leg is used for pressurizer level measurement. The instrument uses a seal liquid which is not part of the pressurizer liquid and has a physical barrier (a diaphragm) that transmits the hydraulic pressure from the liquid (steam) to the seal liquid. The diaphragm is located a sufficient distance from the condensate chamber to be at ambient temperature.

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The pressurizer uses a sealed reference leg. The vertical portion of the sealed sense line is outside the cavity that shields the pressurizer and therefore is not subject to short-term heatup.

Since Sequoyah is an ice condenser plant, it does not experience peak temperatures in the upper compartment as high as non-ice condenser plants. The long-term heatup is the only concern.

The bellows sensor is 12 inches below the condensate pot and even with the upper tap. This means if the sense line "boils" dry, there is a 4.3 percent error introduced because of reference leg height. Refer to figures 1 and 2.

Pressurizer Water Level Safety Function

- Reactor trip on high water level

- Post-accident monitoring function

2. **Provide an evaluation of the effect of post-accident ambient temperatures on the indicated water level to determine the change in indicated level relative to actual water level. This evaluation must include other sources of error including the effects of varying fluid pressure and flashing of reference leg to steam on the water level measurements.**

Response

A. Reference Leg Heatup

High energy line breaks inside containment can result in heatup of level measurement reference legs. Increased reference leg water column temperature will result in a decrease of the water column density with a consequent apparent increase in the indicated steam generator water level (i.e., apparent level exceeding actual level).

The following formula can be used to calculate the magnitude of this bias:

$$E = \frac{H_L}{H} \left(\frac{\rho_L,cal - \rho_L}{\rho_f,cal - \rho_g,cal} \right)$$

where:

E = level error due to reference leg heatup, as a fraction of level span,

H = level span = vertical distance between narrow range taps on steam generator,

H_L = height of reference leg,

= maximum vertical distance from lower tap to water level in condensing pot on upper tap. This must be determined for the limiting instrument connections,

ρ_L,cal = water density at containment temperature and steam generator or pressurizer pressure for which the level indication system was calibrated. If this information is not available, an upper-bound density (lower-bound temperature) must be assumed.

ρ_L = water density in reference leg at the time of interest

$(\rho_f,cal - \rho_g,cal)$ = difference between saturated water density and dry saturated steam density at the steam generator or pressurizer pressure for which the level indication system was calibrated. An upper-bound pressure must be assumed.

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This procedure is based on the assumption that the tubing from the upper and lower taps, below the elevation of the lower tap, have the same temperature at all times.

B. Reference Leg Boiling

In addition to the above reference leg density change under subcooled conditions, boiling could conceivably occur in the reference leg following depressurization of any steam generator with high containment temperature. This combination of conditions could only occur following a steamline or feedline rupture inside containment. If such boiling were to occur, it could cause a major bias in the indicated level for a short time period, in the extreme case indicating 100 percent level when the vessel is actually empty.

C. Coolant Density Changes

A bias in indicated water level may also be introduced by changes in pressurizer or steam generator pressure, due to changes in the density of the saturated water and steam within those vessels. While prediction of the effects of rapid depressurization requires complex calculations for each specific case, the bias which would exist at low power under quiescent conditions can be calculated directly, using the following formula:

$$E = \frac{H_L}{H}\left(\frac{\rho_L,cal - \rho_L - \rho_g,cal + \rho_g}{\rho_f,cal - \rho_g,cal}\right) + \frac{L}{H}\left(\frac{\rho_f - \rho_g}{\rho_f,cal - \rho_g,cal} - 1\right)$$

where:

E = level error due to density changes in both the vessel and the reference leg, as a fraction of level span,

L = true water level in the vessel, above the lower level tap,

ρ_r = saturated water density at the pressure of interest,

ρ_g = dry saturated steam density at the pressure of interest, and other symbols have the same meanings as in Section A above.

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D. Seal Bellows Pressure

For the pressurizer water level measurement system, the spring force of the sealing bellows, located between the condensing pot and the top of the reference leg, offers a further effect of reference leg fluid expansion on indicated water level. As the fluid in the reference leg, seal bellows, and sensor bellows expands due to a rise in containment temperature, the seal bellows must expand to accomodate the increased fluid volume. This expansion is resisted by the force of the bellows acting as a spring under tension. The resultant increase in pressure in the bellows above that outside the bellows, i.e. in the top of the pressurizer, is felt in the sensor bellows and results in a reduction in the indicated water level relative the true water level in the pressurizer. This effect is in the opposite direction from the simultaneous increase in indicated level (relative to true level) caused by the effect of reduced density and thus gravitational head in the vertical reference leg tubing on heatup - the effect which has been discussed at such length already. Bounding calculations assuming a wide range of different temperatures in the upper and lower containment compartments indicate that the combination of these two effects due to heatup above the normal operating temperature is always in the direction of indicated level being greater than actual level; that is to say the gravity effect always is greater than the bellows spring effect. In the extreme extension condition, with all components in both compartments assumed to be at 340°F, the extension of the bellows had not yet reached the restraints within the housing, the burst strength of the bellows had not been approached, and the level error due to the spring force of the bellows compensated for less than one-fourth of that due the gravity effect of the heatup. The compensating effect of the bellows spring force has been conservatively neglected in calculating the total level errors.

E. REFERENCE LEG HEATUP ERROR CALCULATION.

POST ACCIDENT AMBIENT TEMPERATURE 280°

$$E = \frac{H_L}{H}\left(\frac{\rho_{LCAL} - \rho_L}{\rho_{fCAL} - \rho_{gCAL}}\right)$$

$H = 144"$

$H_L = 144.4"$

$\rho_{LCAL} = 61.7132$ lb./ft³ — REF LEG CAL TEMP = 120°F

$\rho_L = 57.924$ lb./ft³

$$(\rho_{fCAL} - \rho_{gCAL}) = (46.795 \text{ lb/ft}^3 - 2.094 \text{ lb/ft}^3)$$

$$= 44.701 \text{ lb/ft}^3$$

DRUM CAL AT 925 psig 537°F

$$E = \frac{144.4}{144}\left(\frac{61.7132 - 57.924}{44.701}\right)$$

$E = 0.085$

$E \times 100 = \%$ ERROR $= 8.5\%$

F. COOLANT DENSITY CHANGES CALCULATION ☆

$$E = \frac{H_L}{H}\left(\frac{\rho_{LCAL} - \rho_L - \rho_{gCAL} + \rho_g}{\rho_{fCAL} - \rho_{gCAL}}\right) + \frac{L}{H}\left(\frac{\rho_f - \rho_g}{\rho_{fCAL} - \rho_{gCAL}} - 1\right)$$

$H_L = 144.4$

$H = 144$

$\rho_{LCAL} = 61.7132$ lb/ft³

$(\rho_{fCAL} - \rho_{gCAL}) = 44.701$ lb/ft³ $= (46.795 - 2.094)$

$L =$ (ASSUME 28.8")

$\rho_g = 0.095$ lb/ft³

$\rho_f = 58.306$ lb/ft³

$$E = \frac{144.4}{144}\left(\frac{61.7132 - 57.924 - 2.094 + 0.095}{44.701}\right) +$$

$$\frac{28.8}{144}\left(\frac{58.306 - 0.095}{44.701} - 1\right)$$

$E = 0.040 + 0.060$

$E = 0.100$

$E \times 100 = \%$ ERROR $= 10\%$

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☆ ASSUME 25 psig IN S. G.

3. Provide an analysis of the impact that the level measurement errors in control and protection systems (question 2) have on the assumptions used in the plant transient and accident analysis. This should include a review of all safety and control setpoints derived from level signals to verify that the setpoints will initiate the action required by the plant safety analyses throughout the range of ambient temperatures encountered by the instrumentation, including accident temperatures. If this analysis demonstrates that level measurement errors are greater than assumed in the safety analysis, address the corrective action to be taken. The corrective actions considered should include design changes that could be made to ensure that containment temperature effects are automatically accounted for. These measures may include setpoint changes as an acceptable corrective action for the short term. However, some form of temperature compensation or modification to eliminate or reduce temperature errors should be investigated as a long term solution.

Response

A. Steam Generator Narrow Range Water Level Trip Setpoints

The only high-energy line rupture within the containment for which the steam generator water level provides the primary trip function is a feedline rupture. For such a case the low or low-low water level trip must be actuated when the pressure difference between the narrow range level taps corresponds to a zero-level value. Thus the trip setpoints must be at or above the value that would be indicated at zero true level. Because large steam generator pressure changes are not expected before trip, only the reference leg heatup effects need be considered, and not the effects of system pressure changes.

The determination of the steam generator low-low level trip for Sequoyah is as follows:

Bottom of span (percent)	0
Normal channel accuracy (percent)	+5
Post accident transmitter error (percent)	$\pm$10
Insulated reference leg effects (post accident heatup) (percent)	+3, -0
TOTAL ERROR, percent of span	+18, -15

Trip setpoint	18 percent of span
Allowable setpoint	17 percent of span

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The value of +3 percent, -0 percent used for reference leg effects was obtained from the formula in the response to question 2 part A, assuming that the reference leg temperature does not exceed 340°F before reaching the High containment pressure setpoint.

As the steam generator narrow range reference legs will be insulated and bounding temperatures are available, the formula in the response to question 2 part A has been used for each section of vertical length to which a discreet temperature can be assigned.

The total error allowance of 18% of span can be regarded as including 1% for rack module drift (i.e. "setpoint drift") and 17% allowance for other errors in and uncertainties. Thus the setpoint is to be set at 18% and periodically checked. If the setpoint drifts to 17%, then the drift is as assumed for the worst case, and 17% still remains to accomodate all other errors and uncertainties. At this point the Technical Specifications require resetting back to 18%. Thus the technical specifications assure that the drift error assumed is not exceeded, and that the margin reserved for other errors and uncertainties is preserved.

The setpoint revisions recommended to correct for the reference leg heatup errors comply with Regulatory Guide 1.105, Revision 1, November 1976 as follows:

1. The new setpoint is established with sufficient margin between that value assumed in the safety analyses and the nominal trip setpoints to allow for (a) the inaccuracy of the instrument; (b) uncertainties in the calibration; and (c) the instrument drift that could occur during the interval between calibrations. These components are all included in the error allowances enumerated.

2. The new setpoint is established in that portion of the instrument span (i.e. 0 to 100%) which ensures that the accuracy required is maintained. Instruments are calibrated so as to ensure the required accuracy at the setpoint.

3. The range selected for the instrumentation encompasses the expected operating range of the process variable being monitored (i.e. 0 to 100%) to the extent that saturation does not negate the required action of the instrument.

4. The accuracy of the setpoint is equal to or better than the accuracy assumed in the safety analysis considering the ambient temperature changes, vibration, and other environmental conditions. The instruments have been designed so as not to anneal, stress relieves, or work harden under design conditions to the extent that they will not maintain the required accuracy. Design verification of these instruments has been demonstrated as part of the instrument qualification program discussed in IEEE 323-1971.

These setpoint revisions are conservative in view of the extremely low probability of the simultaneous occurance of all error components enumerated at their extreme valves in an adverse direction.

The above setpoint revisions will be made on those trip setpoints that provide primary protection for accidents that results in an adverse environment inside containment.

The recommended setpoints derived above result in operating restrictions. Westinghouse is therefore evaluating two alternate long term solutions which will permit the lowering of the steam generator water trip setpoints. The two systems under consideration are as follows:

- Mechanical compensation of sealed reference legs

- Temperature compensation of transmitter output

B. Pressurizer Water Level Trip Setpoint

No credit is taken for this reactor trip function following a high energy line rupture inside containment. Thus the trip setpoint need not be revised to include environmental errors.

C. SECONDARY TRIP FUNCTIONS

A review of the FSAR shows that water level protection channels have not been used as "backup" or "secondary" protection for any analyzed event which would cause an adverse containment environment.

4. Review and indicate the required revisions, as necessary, of emergency procedures to include specific information obtained from the review and evaluation of items 1, 2, and 3 to ensure that the operators are instructed on the potential for and magnitude of erroreous level signals. Provide a copy of tables, curves, or correction factors that would be applied to non-accident monitoring systems that will be used by plant operators.

Response

As listed in the response to question 1, the steam generator narrow range water level and pressurizer water level instruments are used for post-accident monitoring. Because of reference leg heatup and process variable changes, the indicated parameters may provide erroneous information to the operator following a high energy line rupture. The limits of allowable indicated water level are provided based on conservative upper bound error calcuations from the response to question 2.

Indicated steam generator water level can be maintained within a range that will assure that adequate heat removal capacity exists. For Sequoyah this range of indicated water level is determined as follows:

	Maximum water level	Minimum water level
Transmitter error, total, adverse environment	+25 percent	-25 percent
Level reference leg, 90°F to 340°F	+15 percent	0
Process pressure error, 800-1100 psia		
@bottom of span	+1 percent	
@top of span		-4 percent
Total bottom of span	+40 percent	
Total top of span		-29 percent

Therefore, to assure the steam generator tubes are covered, the indicated water level must be greater than 40 percent. To assure the steam generator is not filled, the indicated water level must be less than 71 percent.

Indicated pressurizer water level can be maintained within a range that will ensure that a water level exists in the pressurizer. For Sequoyah this range is determined as follows (the reference leg error given below is a boundary analysis and may be reduced by further analysis):

	Minimum water level	Maximum water level
Transmitter error total	+25 percent	-25 percent
Level reference leg, 90°F to 340°F	22 percent	0
Process pressure error 200 - 2350 psia		
@bottom of span	+3 percent	
@top of span		-5 percent
Total bottom of span	+50 percent	
Total top of span		-30 percent

Therefore to assure a water level exists (i.e. not full or empty) the indicated water level must be greater than 50 percent and less than 70 percent.

Furthermore, a remote possibility exists that the fluid in the open reference legs may flash to steam in the depressurized steam generators following a secondlary high energy line rupture. Therefore to alert the operator to the possibility of erroneous indications, the following caution will be inserted in all plant emergency instructions for indicated steam generator water level.

CAUTION: The operator should use several plant indicated variables to verify the existence of water level in one or more steam generators due to the possibility of erroneous level indication due to measurement system errors. The backup variables that should be used include auxiliary feedwater flow, steamline pressure and primary wide range T_{hot} and T_{cold}.

In particular, the operator should not rely upon steam generator water level indications in any depressurized steam generators following a high energy line rupture inside containment. This is due to the possibility of reference leg boiling.

STEAM FLOW CONDENSING POTS

NRC CONCERN

What are the temperature effects on the steam flow instrumentation?

RESPONSE

The condensing chambers on the steam flow instrumentation are located 43 inches apart vertically as shown on figure 3. The effect of sense line heatup on steam flow measurement should be in the high flow direction since the low pressure side of the transmitter has a sense point 43 inches above the high pressure side. The sense lines would be expected to heat up at an approximately equal rate because of their close proximity. An equal heatup rate will cause an apparent high flow shift in the measured signal since the density of the 43-inch water column drops and puts a lower bias pressure on the low pressure side of the transmitter.

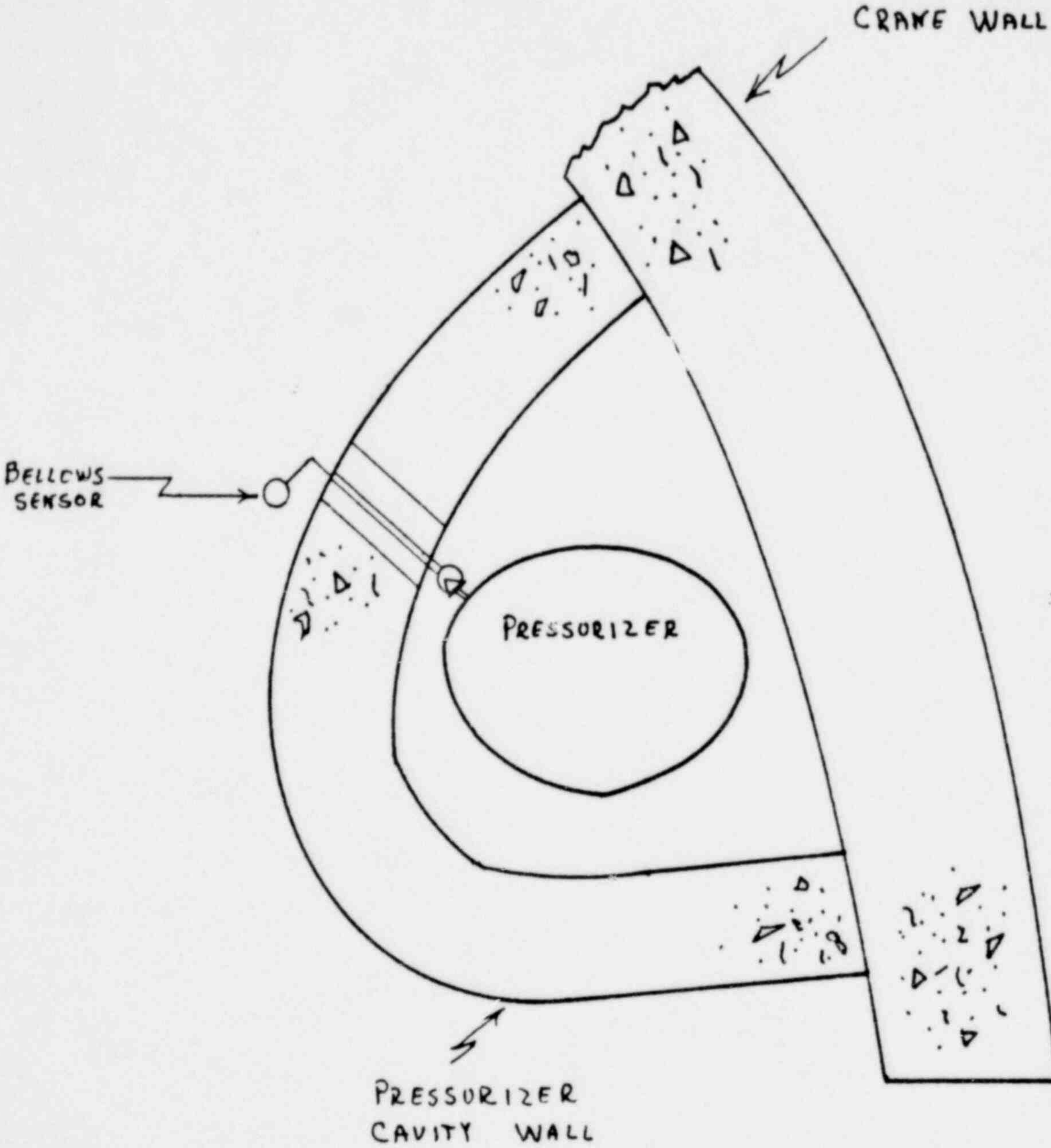
AUXILIARY FEEDWATER (AFW) DESCRIPTION

NRC CONCERN

Is the AFW system controlled by the Steam Generator level measurement (Reference Leg) instrumentation? If so, how does heatup of the reference leg following a pipe break affect the AFW system?

RESPONSE

The Sequoyah AFW systems use transmitters separate from the NSSS system. These transmitters share sense lines, so the heatup problem will affect both. TVA believes the AFW system is satisfactory in that the insulation on the sense line delays the heatup so operator action will not be required for 10 minutes. After this time, the operator will utilize a correction chart to correct the temperature effects on the reference leg. To further ensure that water is reaching the steam generator, AFW flow to each steam generator is indicated in the control room. The AFW flow transmitters are located outside containment and therefore do not experience a harsh environment.



TYPICAL PLAN VIEW OF PRESSURIZER UPPER TAP LEVEL MEASUREMENT

Figure 1

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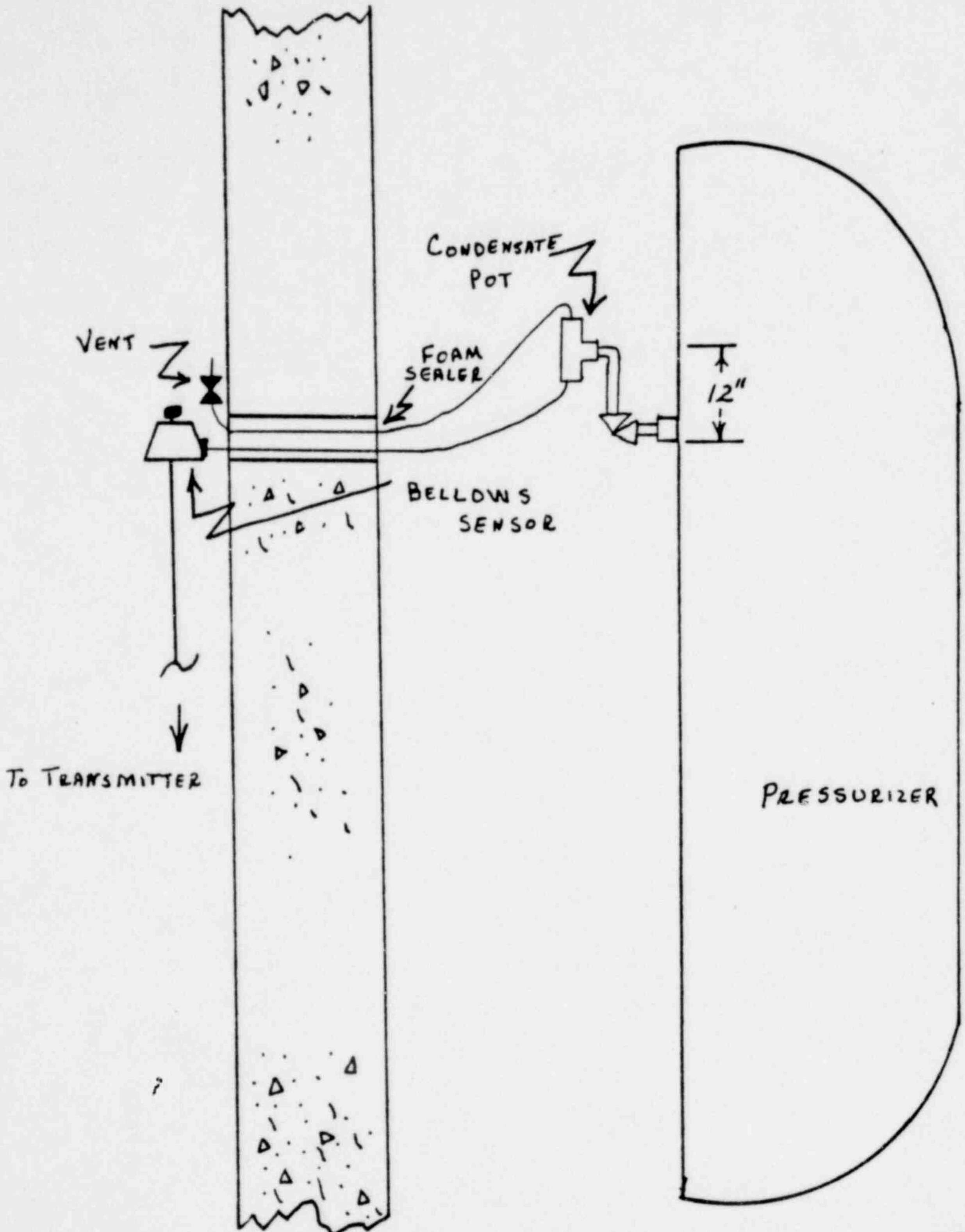

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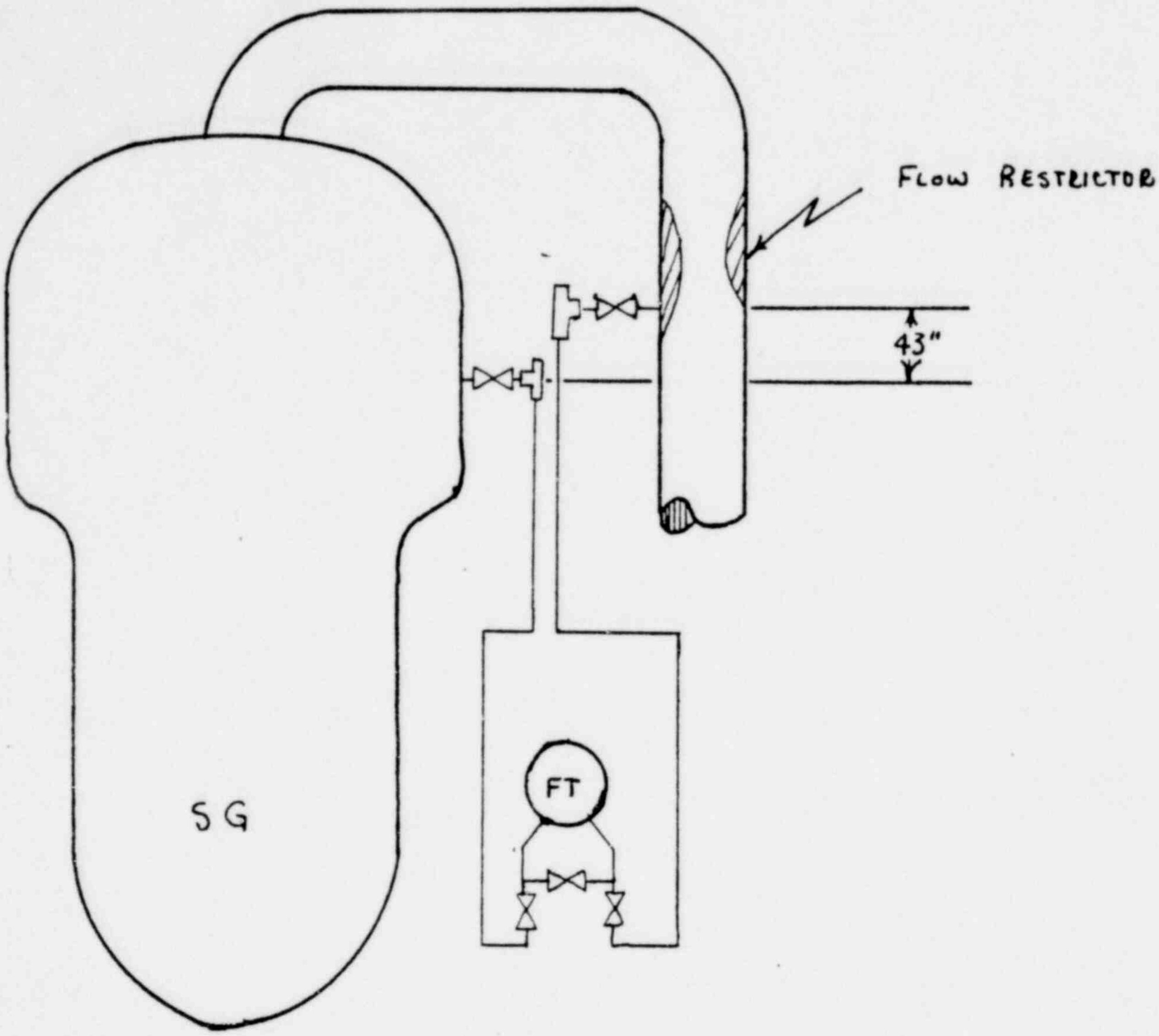
TYPICAL SECTION VIEW OF PRESSURIZER
UPPER TAP LEVEL MEASUREMENT
Figure 2



STEAM FLOW INSTRUMENTATION - FIGURE 3

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