Con Edison
Consolidated Edison Company of New York, Inc.
Indian Point Station
Broadway & Bleakley Avenue
Buchanan, New York 10511-1099

December 11, 1987

Re: Indian Point Unit 2
Docket No. 50-247

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Steam Generator Inservice Inspection

During November, 1987 routine inservice inspection (ISI) examination of the Indian Point Unit 2 Steam Generator #22 girth weld (upper transition, weld No. 6), ultrasonic reflectors were detected on the inside weld circumference. Visual examination of the inside circumference revealed essentially horizontal intermittent linear indications around the weld length. Ultrasonic and magnetic particle examinations were extended to 100% of the girth weld on all four steam generators and a program to effect repairs by grinding was initiated.

Attached is a report of the stress and fatigue analysis which has been performed to support the final weld configuration after repair. The evaluation addresses local minimum shell thickness and stress and fatigue considerations. The evaluations were performed using detailed finite element analyses and simple mechanics formulations for the loading condition defined in the steam generator Design Specification. The evaluations were used to determine the guidelines for the configuration of the material grindout and as justification for the as repaired conditions. The analyses considered grindout configurations one inch and 3/4 inch deep with additional local grindouts. A fracture mechanics evaluation supporting leak-before-break for the grindout configurations is also attached.

A post repair ultrasonic and magnetic particle test was performed to confirm that no surface indications remain following completion of repairs. It is our intention to perform further ultrasonic testing of the repaired welds during subsequent refueling outages, in accordance with the ASME Code Section XI examination requirements. In addition, we will be conducting supplemental visual and magnetic particle exams on 1/3 of the inside circumference of the weld on Steam Generator No. 22 during each of the next two refueling outages.

A047

Should you or your staff have any questions, please contact us.

Very truly yours,

Stephen Bram
Vice President
Nuclear Power

cc: Mr. William Russell
Regional Administrator - Region I
U.S. Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, PA 19406

Senior Resident Inspector
U.S. Nuclear Regulatory Commission
P.O. Box 38
Buchanan, NY 10511

Ms. Marylee Slosson
Project Directorate I-1
Division of Reactor Projects I/II
U.S. Nuclear Regulatory Commission
Washington, DC 20555

STRESS AND FATIGUE ANALYSIS
AND GRINDOUT GUIDELINES

STRESS AND FATIGUE ANALYSIS AND GRINDOUT GUIDELINES

A stress analysis and fatigue usage evaluation has been performed to justify the acceptability of the weld grind out configurations on the basis of the ASME Code Section III, Subsection NB, for the remaining service life of the steam generators. The evaluations are performed using detailed finite element analysis and simple mechanics formulations for the loading conditions defined in the Westinghouse Design Specification. Both uniform grind configurations and local overgrinds are justified.

Uniform Grind Configurations

Two uniform grind configurations were evaluated with the purpose of conservatively enveloping the actual grinding pattern achieved. These are a 0.75 inch deep uniform grind configuration, Figure 1, and a 1.0 inch deep uniform grind configuration, Figure 2. The areas of deepest penetration have a land section of four inches and two inches, respectively. The blend-out to the shell inner surface is with a 2:1 taper at each end of the land. A 0.5 inch radius is assumed at the blend of the taper to the land.

Loading Conditions

The design and normal operating, steady state and transient conditions evaluated are provided in the Westinghouse Design Specification. Table 1 summarizes the transient conditions analyzed and the corresponding number of occurrences (cycles) for each. Design pressure is 1085 psi and design temperature is 600^{o}F. Secondary side operating conditions of temperature and pressure utilize the current operating parameters for the steam generators, 501^{o}F and 685 psi.

Two of the transients, reactor trip and feedwater cycling, require detailed heat transfer evaluation in the girth weld region because their effects are not mitigated by the water pool. With the reactor trip, the steam generator water level will drop and may drop to well below (100 inches) the girth weld region. When auxiliary feedwater injection occurs, the cold water drops from the feedring to the downcomer flow resistance (DCFR) plate, spreads out circumferentially and flows outward to the shell wall. At that time, the water is at a temperature of 160^{o}F. The cold water impinging on the shell would occur at an elevation adjacent to the elevation of the DCFR plates. Three DCFR plate positions have been evaluated (Figure 3) to assess the effect on fatigue usage and primary plus secondary stress range.

During hot standby when feedwater cycling occurs, the water level in the generator is approximately seven inches above the feedring. Cold water from the feedring mixes with the pool on its way to the downcomer region and contacts the shell with a temperature of 427^{o}F about 13 inches above the girth weld.

Tentative Pressure Thickness

Using the ASME Code, Section III, Subsection NB, paragraph NB-3324, a tentative wall thickness that would satisfy design pressure load requirements may be computed using the formula

$$t = \frac{pR}{S - 0.5p}$$

where p is design pressure, 1085 psi, R is the inside radius, 79.5 inches, and S is the allowable stress 1.5 S_m, 40,050 psi, for the local membrane condition being evaluated. The resulting tentative thickness is 2.2 inches. Finite element analysis results in the following section confirm the conservatism of this thickness for pressure loadings. Fatigue usage and primary plus secondary stress range are shown below to be the limiting modes of failure for determining the required minimum thickness.

The secondary hydrotest pressure is specified as 1085 psi, the same as design pressure, and an accident condition pressure limit of 1195 psi is provided by the main steam safety relief valves. The secondary hydrotest condition is covered by the design pressure calculation and the accident condition limit has more margin to its allowable than the design pressure calculation. The accident pressure limit of 1195 psi is 10% higher than design pressure whereas the allowable is 40% higher for the accident condition.

Results of Analysis of Uniform Grind Configurations

The steady state and transient pressure and temperature stress solutions were obtained using the finite element models of Figures 4 and 5 for the 0.75 inch and 1.0 inch uniform grind configurations, respectively. Local primary and primary plus secondary stress limits are satisfied as shown in Tables 2 and 3 for the three cases of DCFR plate elevations described previously.

The fatigue usage per year for each of the three is presented in Table 4. Case 3, or the upper plate position, results in the minimum time to reach a usage of 1.0, 19.2 years and 20.6 years. This case represents a plate position where the top surface is about 0.5 inch above the weld centerline for the 1.0 inch model and 1.5 inches above the weld centerline for the 0.75 inch model. Case 2 represents a plate position where the top of the plate is about 1.5 inches below the weld centerline for the 1.0 inch grind configuration and 2.5 inches below for the 0.75 inch configuration. Case 1 represents the best of the three positions at about 4.0 inches below the weld centerline. This case would require 26.1 years and 27.3 years to reach a usage of 1.0 for the two configurations.

The effect of moving the DCFR plate from an up position (Case 3) to a low position (Case 1) in three years time can be assessed with the usage per year values. Taking the 1.0 inch grind configuration, for example, lowering the plates in this manner would result in a fatigue usage of 1.0 in 25 years.

Local Grind Acceptability

The assessment of the acceptability of local grind regions has addressed two possibilities. The first is that a local grind with the required 0.5 inch radius at the bottom and a 2:1 taper is left within the uniform grind configuration envelope and the second is that a similar local grind is needed beyond the 0.75 inch or 1.0 inch depth in the flat of the uniform grind configuration.

The method used for the first case is to determine that the solution for the uniform grind is conservative relative to a local grind within that envelope. For the second case, the depth of local grind is determined that does not result in a higher stress situation than that represented by the uniform grind configurations. Figures 6 and 7 illustrate the 0.25 inch acceptable local grind depth (with 0.5 inch radius and 2:1 taper) that satisfies the criteria for the second case. For the first case, it is acceptable to have a local grind that is of equal depth to the depth represented in each uniform grind configuration (again with the 0.5 inch radius and 2:1 taper).

Any of the local grinds may be of any length circumferentially up to and including the total circumference and multiple grinds are acceptable. In addition, with the 0.5 inch radius and 2:1 taper, the runout in the circumferential direction has no restriction on spacing in between adjacent runouts.

TABLE 1

INDIAN POINT 2 (IPP)
UMBRELLA TRANSIENT CONDITIONS

TRANSIENT		CYCLES
1	Cold Shutdown	200
2	No Load	200
3	100% Power (Plant Load/Unload)	14500
4	Small Step Load Decrease	2000
5	Steady-State Fluctuations (+)	1.0E+06
6	Steady-State Fluctuations (-)	1.0E+06
7	Large Step Load Decrease (200) Small Step Load Increase (2000)	2200
8	Loss of Power (40) Loss of Load (80) Loss of Flow (80) Secondary Side Leak Tests (5)	205
9	Reactor Trip	400
10	Feedwater Cycling	25000
11	Secondary Hydrotest (Init.)	1
12	Secondary Hydrotest (Subs.)	50

NOTE: Reactor Trip and Feedwater Cycling Involve both pressure and thermal effects. All other conditions involve only a change in steam temperature and pressure.

TABLE 2

SUMMARY OF PRIMARY STRESS INTENSITIES
- DESIGN PRESSURE LOADING

GRIND DEPTH	STRESS INTENSITY	ALLOWABLE 1.5 Sm
1.0"	19.12	40.05
3/4"	19.55	40.05

NOTE: Bending stresses in the shell and cone due to the change in shell diameter at the shell cone are classified as Secondary stresses, as the induced moments are self-equilibrating, and the stresses are therefore displacement limited.

TABLE 3

SUMMARY OF MAXIMUM PRIMARY PLUS SECONDARY STRESS RANGE

GRIND DEPTH	CASE	STRESS RANGE	ALLOWABLE 3 Sm
1.0"	1	74.18	80.10
	2	78.22	80.10
	3	79.78	80.10
3/4"	1	70.07	80.10
	2	78.56	80.10
	3	79.76	80.10

TABLE 4

SUMMARY OF FATIGUE RESULTS
LOWER DISCONTINUITY

GRIND DEPTH	CASE	USAGE/ YEAR	YEARS TO GIVE USAGE = 1.0
1.0"	1	0.0383	26.14
	2	0.0442	22.62
	3	0.0520	19.22
3/4"	1	0.0366	27.34
	2	0.0408	24.49
	3	0.0485	20.61

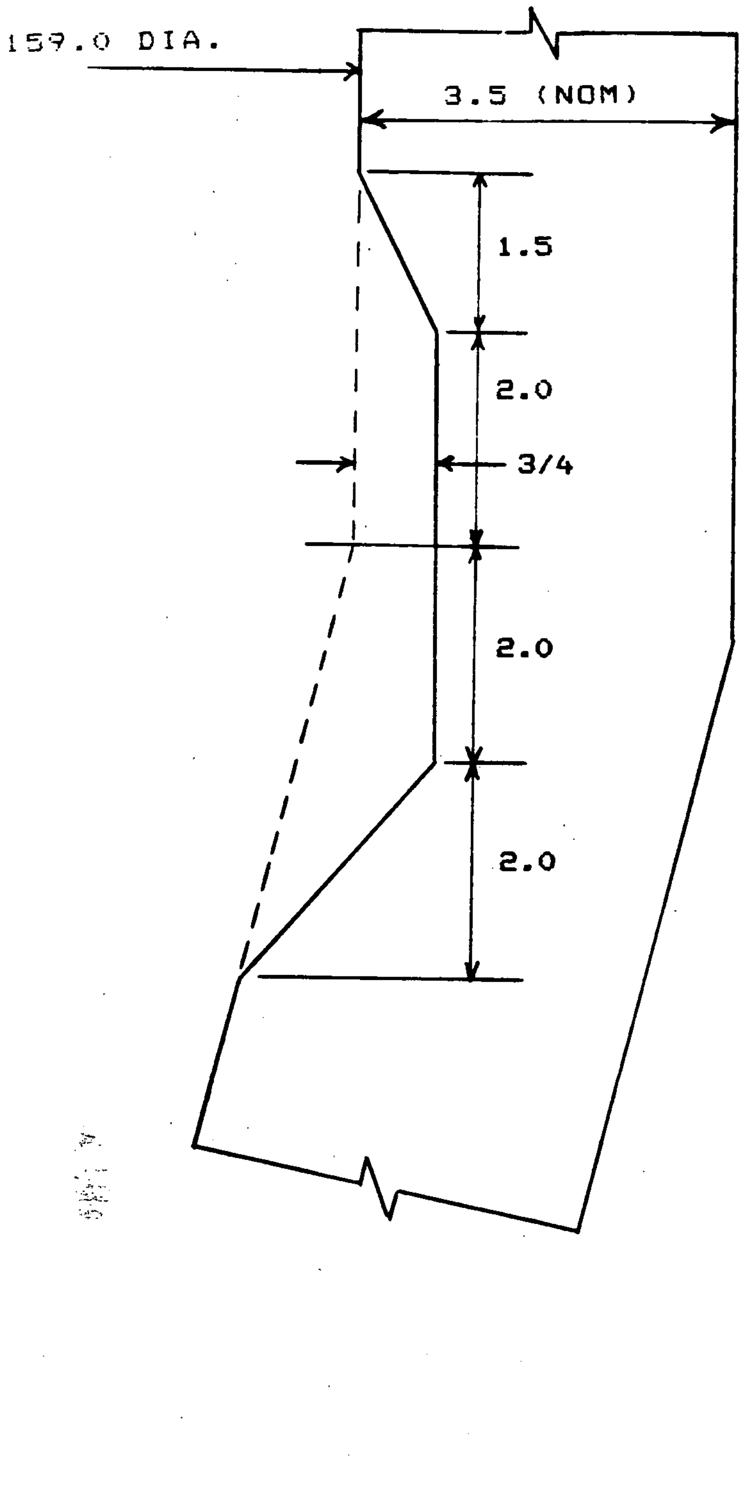

FIGURE 1. GEOMETRY FOR 3/4" GRIND

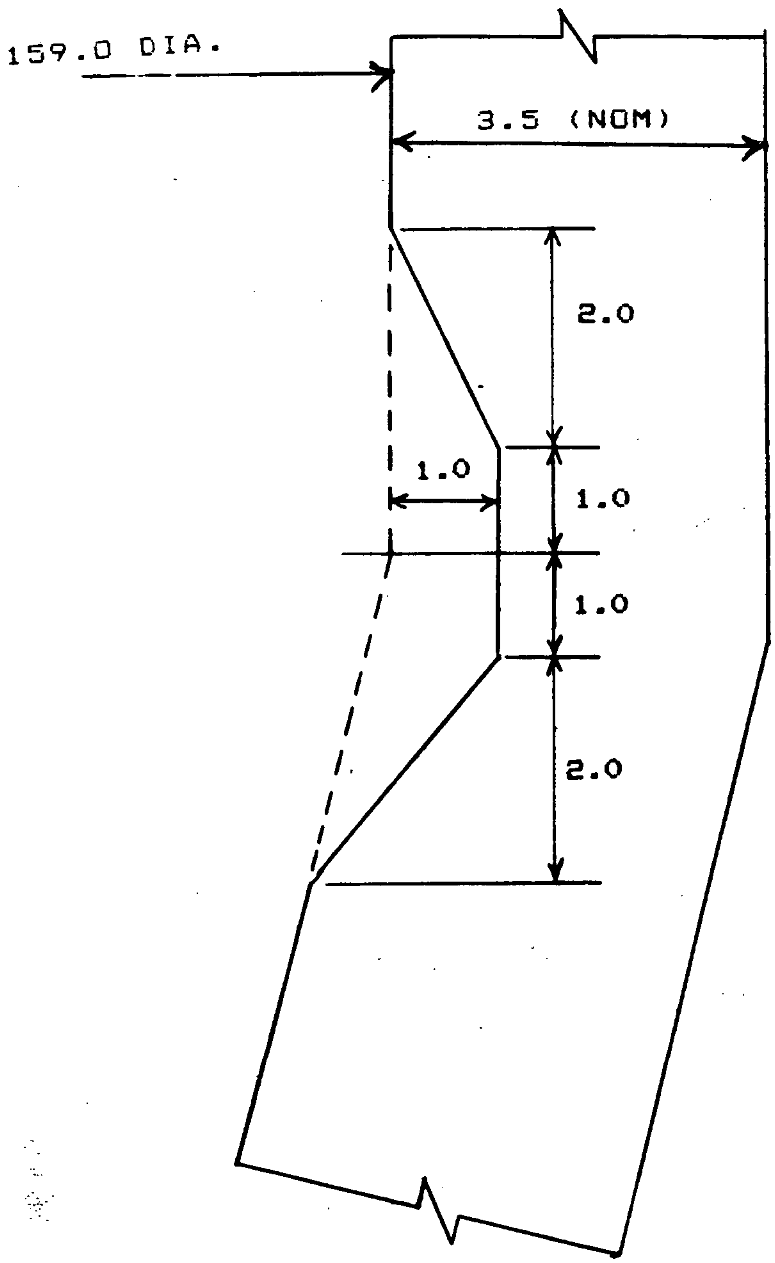

FIGURE 2. GEOMETRY FOR 1.0" GRIND

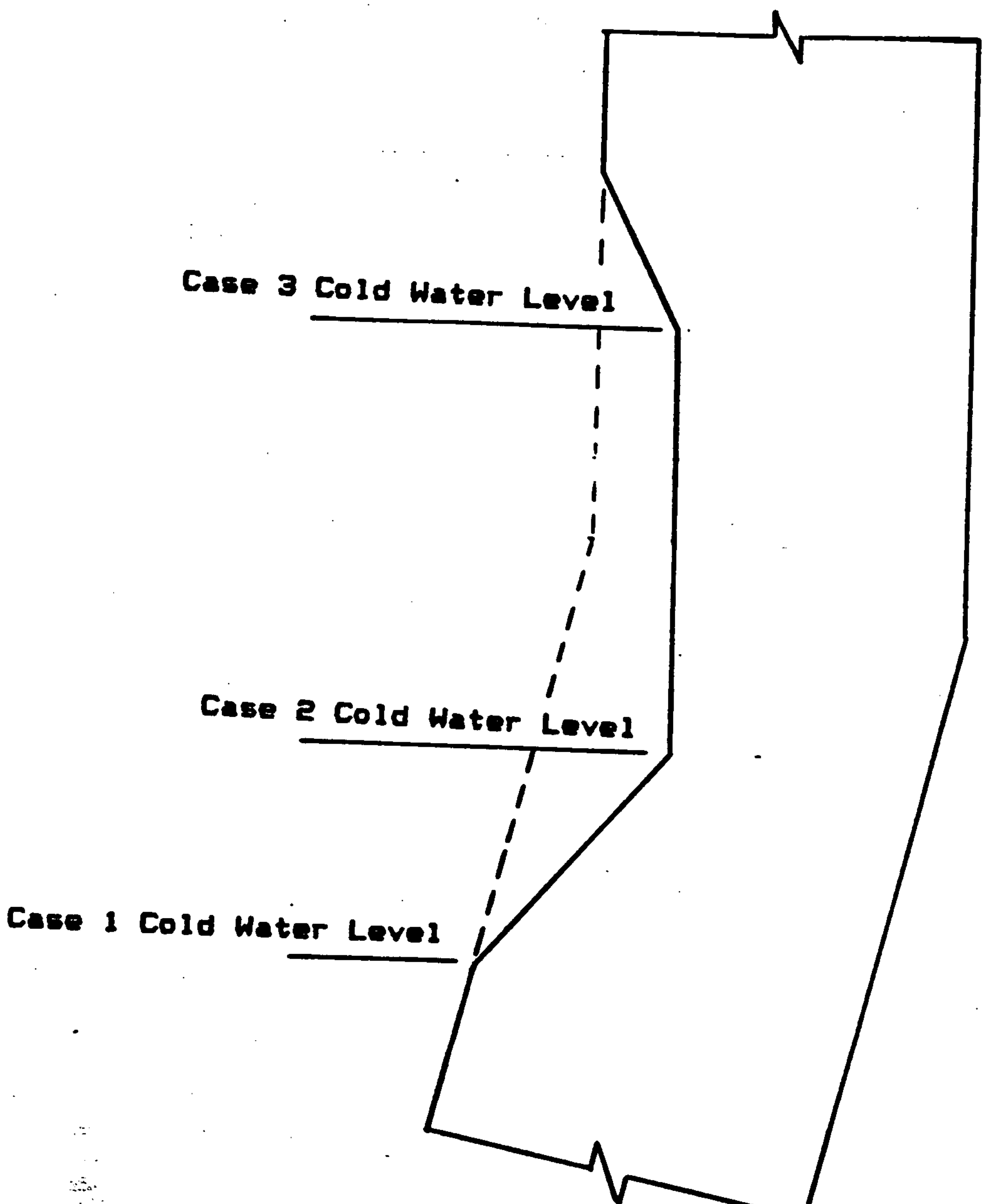

FIGURE 3

REACTOR TRIP BOUNDARY CONDITIONS CONSIDERED
TYPICAL FOR BOTH 1.0" AND 3/4" GRIND MODELS

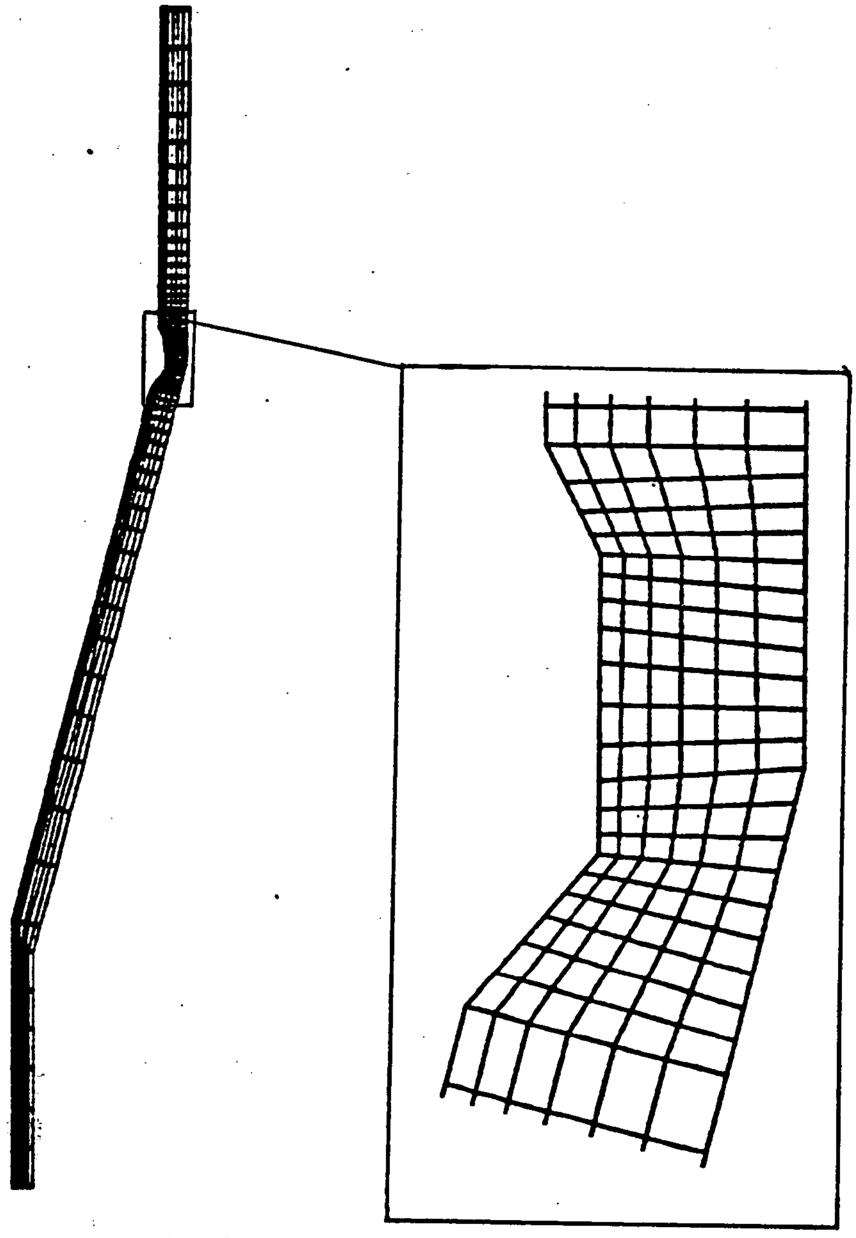

FIGURE 4

FINITE ELEMENT MODEL FOR 3/4" GRIND

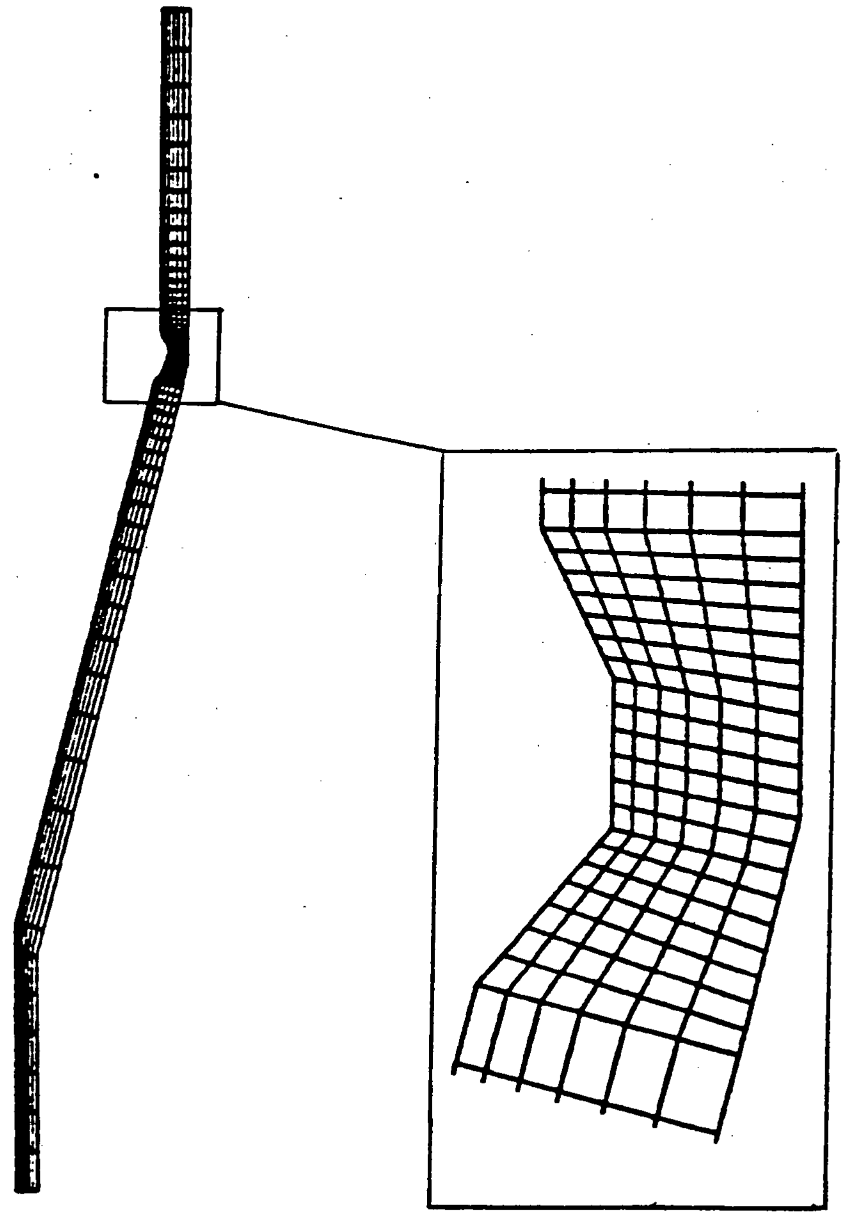

FIGURE 5

FINITE ELEMENT MODEL FOR 1.0" GRIND

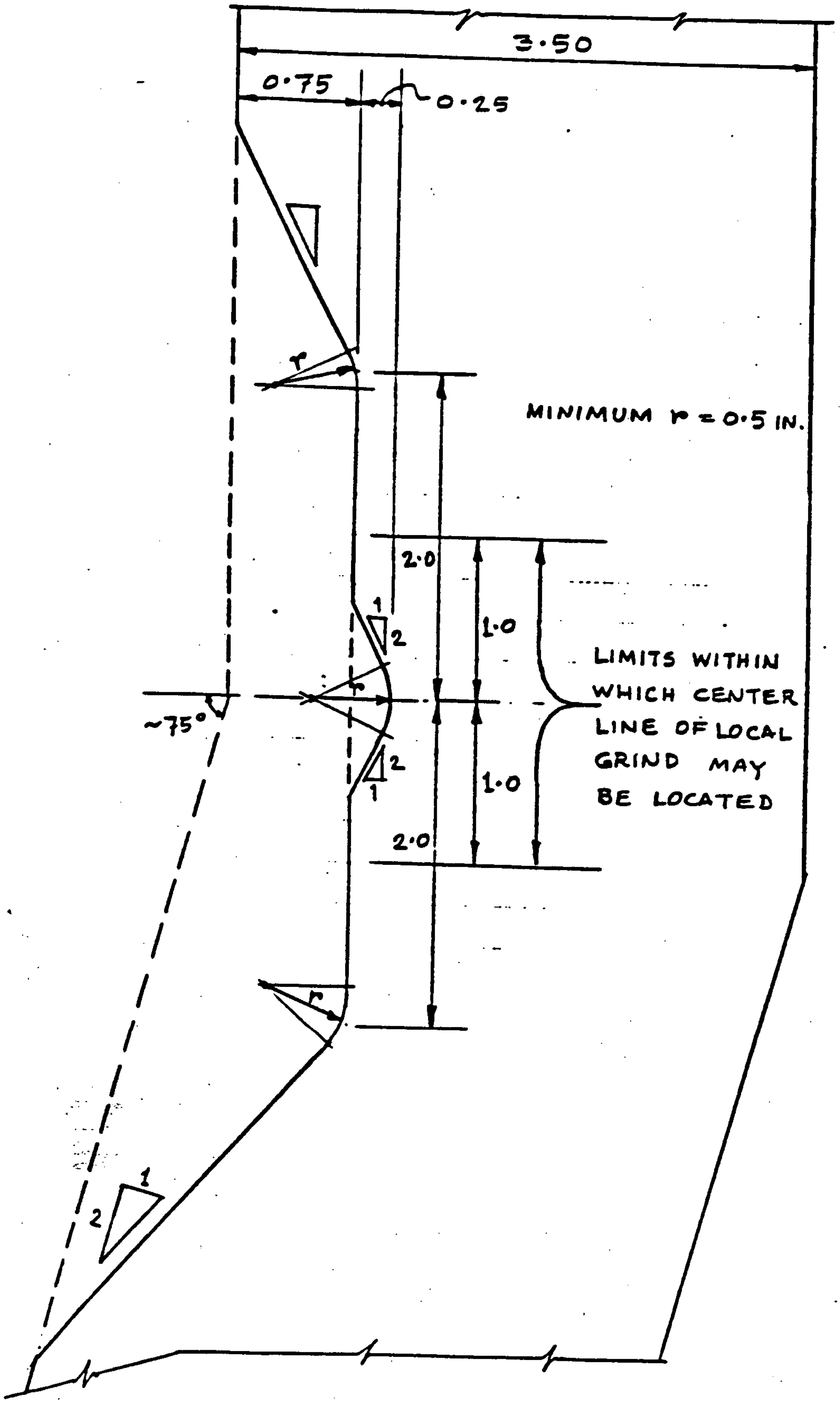

FIGURE 6. 0.75 in. Deep Grindout Profile with 0.25 in. Deep Local Grindout

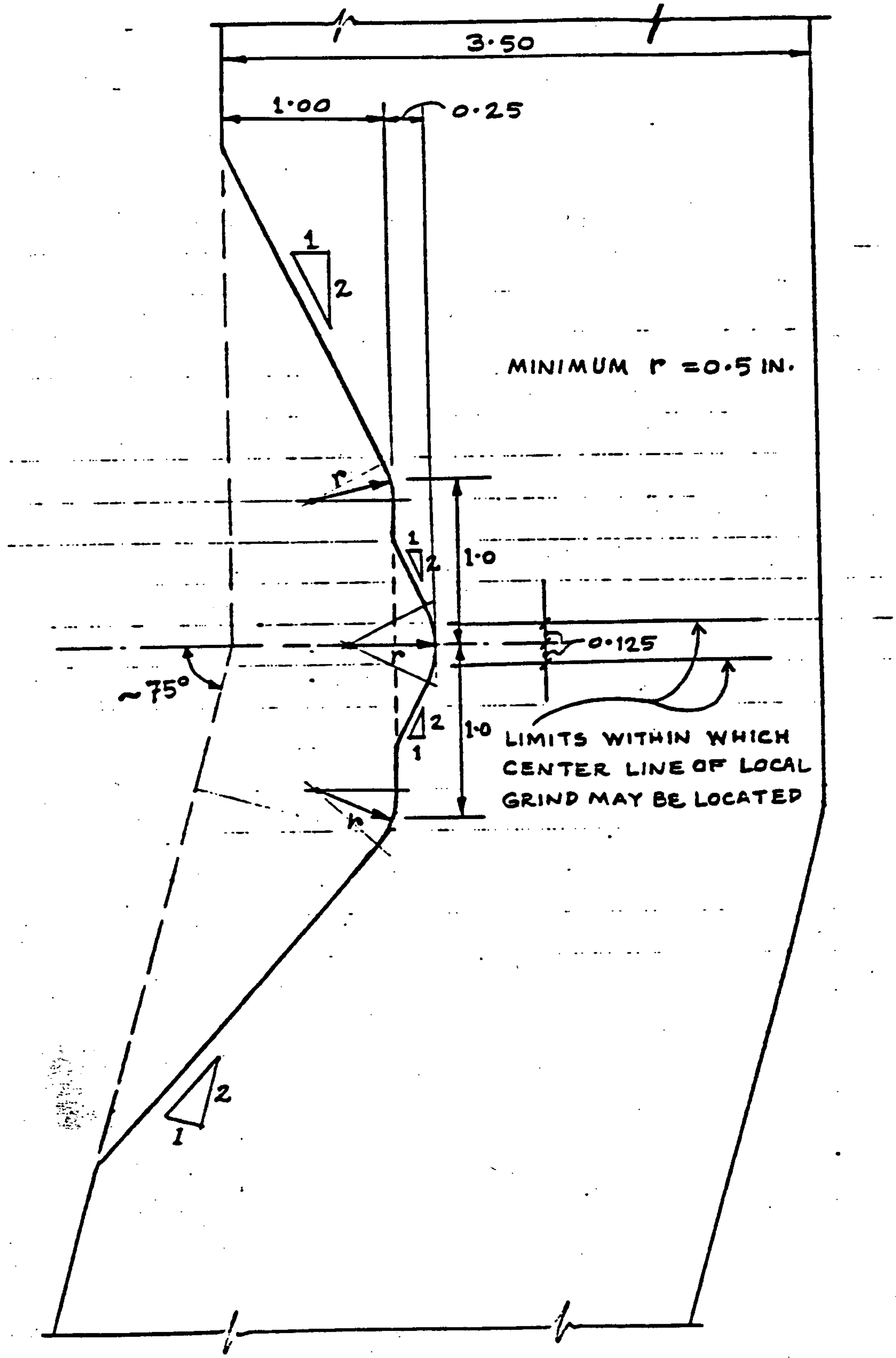

FIGURE 7. 1.00 in. Deep Grindout Profile with 0.25 in. Deep Local Grindout

CONSIDERATION OF LEAK BEFORE BREAK

The initial length of a through-wall flaw was calculated to assess the likelihood of leak before break for the upper shell-cone intersection, considering the ground sections.

The critical flaw length was found by considering the most limiting transient, reactor trip, and postulating a range of through-thickness circumferential flaws of increasing length. The critical flaw length is then found as the length at which the applied stress intensity factor first exceeds the fracture toughness. Since we are concerned with a realistic safety assessment, the static fracture toughness K_{Ic} from Section XI of the ASME Code will be used. At the minimum temperature of the loss of flow transient, the fracture toughness is on the upper shelf, and therefore $K_{Ic} = 200 \text{ ksi} \sqrt{\text{in}}$.

The applied stress intensity factor was calculated using the well-known expression for a through-wall flaw in a plate or large diameter cylinder:

$$K_I = \sigma \sqrt{\pi a}$$

The results of the calculations give a critical length of 7.6 inches for the grinding depth of 0.75 inches, and a critical length of 7.0 inches for the deeper grind of 1.0 inch. The actual behavior is expected to be ductile, which leads to the conclusion that the actual critical length is greater than the numbers reported above. In any event, a crack length much shorter than these lengths would lead to detectable leakage.