Westinghouse Energy Systems

Westinghouse Class 3

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Revision 2

# HANDBOOK ON FLAW EVALUATION FOR JOSEPH FARLEY UNITS 1 AND 2 STEAM GENERATORS AND PRESSURIZERS

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## EXECUTIVE SUMMARY

This handbook has been prepared to allow quick, yet accurate, assessment of indications which may be discovered during inservice inspections of the Joseph Farley Units 1 and 2 steam generators and pressurizers. This assessment capability is provided in the form of charts for selected regions of the steam generators and pressurizers. These are contained in Appendix A of this document. Appendix A begins with a simple example demonstrating use of the evaluation charts, followed by a section for each region of the steam generator and pressurizer. Details of the derivation of the charts are provided in the technical basis document [1]. The main body of this handbook provides brief summaries of the various calculations carried out in developing the charts. To evaluate the acceptability of an indication, the user may proceed directly to Appendix A.

Revision 1 of this report was prepared to correct several minor inconsistencies discovered in the original version, and to better describe the overall philosophy used in developing the flaw evaluation charts. This discussion appears on page 1-2.

Revision 2 of this report was prepared to include more detailed guidelines for performing the pressure tests for the secondary side of the steam generator. The earlier versions of the report had provided charts for these tests for the hydrotest only; this revision provides charts for three different pressures.

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## SECTION 1
## INTRODUCTION

This flaw* evaluation handbook has been designed for the evaluation of indications which may be discovered during inservice inspection of the Joseph Farley Units 1 and 2 steam generators and pressurizers. The tables and charts provided in the Appendix of this report allow the evaluation of any indication discovered in the regions listed below without further fracture mechanics calculations. The fracture analysis work has instead been done in advance, in accordance with the criteria of ASME Code Section XI [2], and is documented in a companion background and technical basis report [1]. Use of the handbook will allow the acceptability of much larger indications than would be allowable by only using the standard tables of ASME Section XI [2]. A schematic representation of the flaw evaluation process of ASME Section XI Appendix A is provided in figure 1-1.

This flaw evaluation handbook has been developed as a direct implementation of the analytical requirements of Section XI. In all cases the latest material properties and analytical criteria have been used and the appropriate code editions appear in [2]. These handbooks have been designed for use throughout the operating lifetime of the plants, during which time the applicable edition of section XI will change a number of times.

The handbook is applicable to low alloy steel base metal and welds in the Joseph Farley Units 1 and 2 steam generators and pressurizers. The geometry of each of these regions is shown in figures 1-2 and 1-3, and repeated at the appropriate section of the Appendix. Flaw charts are provided for flaws oriented along each of the welds in both the pressurizers and steam generators. Charts are provided for inside and outside surface and embedded flaws in each region, and for nozzle corner surface flaws for each of the nozzles.

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* The use of the term "flaw" in this document should be taken to be synonymous with the term "indication" as used in Section XI of the ASME Code.

Handbook charts have been constructed for each of the following regions in Joseph Farley Units 1 and 2.

The steam generator:

- o Tubesheet to channel head weld region
- o Tubesheet to stub barrel weld region
- o Stub barrel intermediate seam
- o Lower shell to cone weld region
- o Upper shell to cone weld region
- o Upper shell welds
- o Upper shell to dome weld region
- o Feedwater nozzle to shell weld region
- o Steam outlet nozzle to shell weld region
- o Primary nozzle safe end welds

The pressurizer:

- o Upper shell to head weld
- o Upper shell circumferential welds
- o Upper shell longitudinal welds
- o Lower shell circumferential welds
- o Lower shell longitudinal welds
- o Surge nozzle to head weld
- o Spray nozzle to head weld
- o Safety and relief nozzle to head welds

The highlight of the handbook is the design of a series of flaw evaluation charts for both surface flaws and embedded flaws. Since the characteristics of the two types of flaws are different, the evaluation charts are distinctively different in style. Examples have been provided in the introductory section of the Appendix.

The flaw evaluation charts were designed based on the ASME Code Section XI Code criteria of acceptance for continued service without repair, as contained in paragraph IWB-3600. Through use of the charts, a flaw can be evaluated by Code analytical criteria instantaneously, and no follow-up hand calculation is required. Most important of all, no fracture mechanics knowledge is needed by the user.

The flaw evaluation charts are provided in Appendix A of this document. The notation used for both surface and embedded flaws in this work is illustrated in figure 1-4, and is repeated in each section of the Appendix. For flaw evaluation of an indication discovered in an inspection, turn directly to the Appendix.

## 1.1 <u>Code Acceptance Criteria</u>

There are two alternative sets of flaw acceptance criteria for continued service without repair in paragraph IWB-3600 of ASME Code Section XI. Namely,

1. Acceptance Criteria Based on Flaw Size (IWB-3611)
2. Acceptance Criteria Based on Stress Intensity Factor (IWB-3612)

Both criteria are comparable in accuracy for thick sections, and the acceptance criteria (2) have been assessed by past experience to be less restrictive for thin sections, and for outside surface flaws in many cases. In all cases in this handbook, the most beneficial criterion has been used. All the embedded flaw evaluation charts in this handbook were constructed using acceptance criteria (2), for ease of use, as well as to obtain the maximum benefit, since these criteria will generally be less restrictive for embedded flaws.

### 1.1.1 Criteria Based on Flaw Size

The Code acceptance criteria are stated in IWB-3611 of Section XI. Namely,

$a_f < .1\ a_c$ For Normal Conditions (Upset & Test Conditions Inclusive)

and $a_f < .5\ a_i$ For Faulted Conditions (Emergency Condition Inclusive)

where

$a_f$ = The maximum size to which the detected flaw is calculated to grow at the end of the design life, or till the next inspection time, as applicable.

$a_c$ = The minimum critical flaw size under normal operating conditions (upset and test conditions inclusive)

$a_i$ = The minimum critical flaw size for initiation of nonarresting growth under postulated faulted conditions. (emergency conditions inclusive)

To determine whether a surface flaw is acceptable for continued service without repair, both criteria must be met simultaneously. However, both criteria have been considered in advance in construction of the charts herein. Only the most restrictive results were used in these charts.

### 1.1.2 CRITERIA BASED ON STRESS INTENSITY FACTOR

The term stress intensity factor ($K_I$) is defined as the driving force on a crack. It is a function of the size of the crack and the applied stresses, as well as the overall geometry of the structure. In contrast, the fracture toughness ($K_{Ia}$, $K_{Ic}$) is a measure of the resistance of the material to propagation of a crack. It is a material property and a function of temperature.

The criteria from IWB-3612 of Section XI are:

$$K_I < \frac{K_{Ia}}{\sqrt{10}} \text{ for normal, upset, and test conditions.}$$

$$K_I < \frac{K_{Ic}}{\sqrt{2}} \text{ for emergency and faulted conditions.}$$

where

$K_I$ = The maximum applied stress intensity factor for the flaw size $a_f$ to which a detected flaw will grow, during the conditions under consideration, to the next inspection.

$K_{Ia}$ = Fracture toughness based on crack arrest for the corresponding crack tip temperature.

$K_{Ic}$ = Fracture toughness based on fracture initiation for the corresponding crack tip temperature.

To determine whether a surface flaw is acceptable for continued service without repair, both criteria must be met simultaneously. However, both criteria have been considered in advance when the charts herein were constructed. Only the most restrictive results were used in these charts.

### 1.1.3 PRIMARY STRESS LIMITS

In addition to satisfying the fracture criteria, it is required that the primary stress limits of Section III, paragraph NB 3000 be satisfied. A local area reduction of the pressure retaining membrane must be used, equal to the original area less the area of the indication, and the stresses increased to reflect the smaller cross section. All the flaw acceptance tables provided in this handbook have included this consideration as demonstrated in the technical basis document [1].

## 1.2 SCOPE OF THIS WORK

Finite element stress analyses of the Joseph Farley Units 1 and 2 steam generators and pressurizers under various transients have been performed by Westinghouse, Nuclear Components Division, Pensacola, Florida for this project. Fracture mechanics analyses were performed for various aspect ratios of both surface and embedded flaws using the results of stress analyses associated with emergency, faulted, normal, upset and test conditions. Based on the results of the fracture mechanics analyses surface flaw and embedded flaw charts have been developed.

The fracture and fatigue crack growth evaluations carried out to develop the handbook charts have employed the recommended procedures and material properties for low alloy steels, as contained in Section XI, Appendix A.

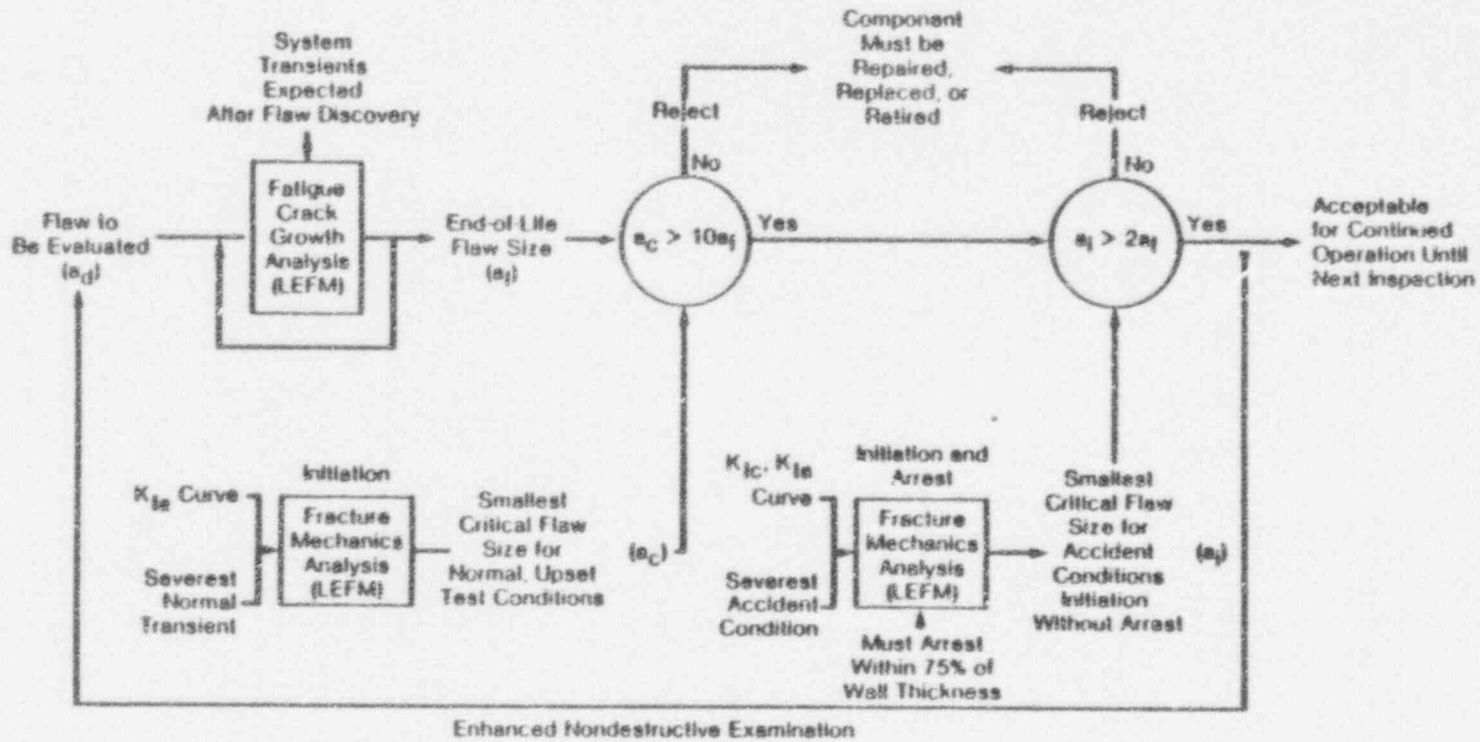



Figure 1-1. Schematic Representation of Appendix A Flaw Evaluation Process

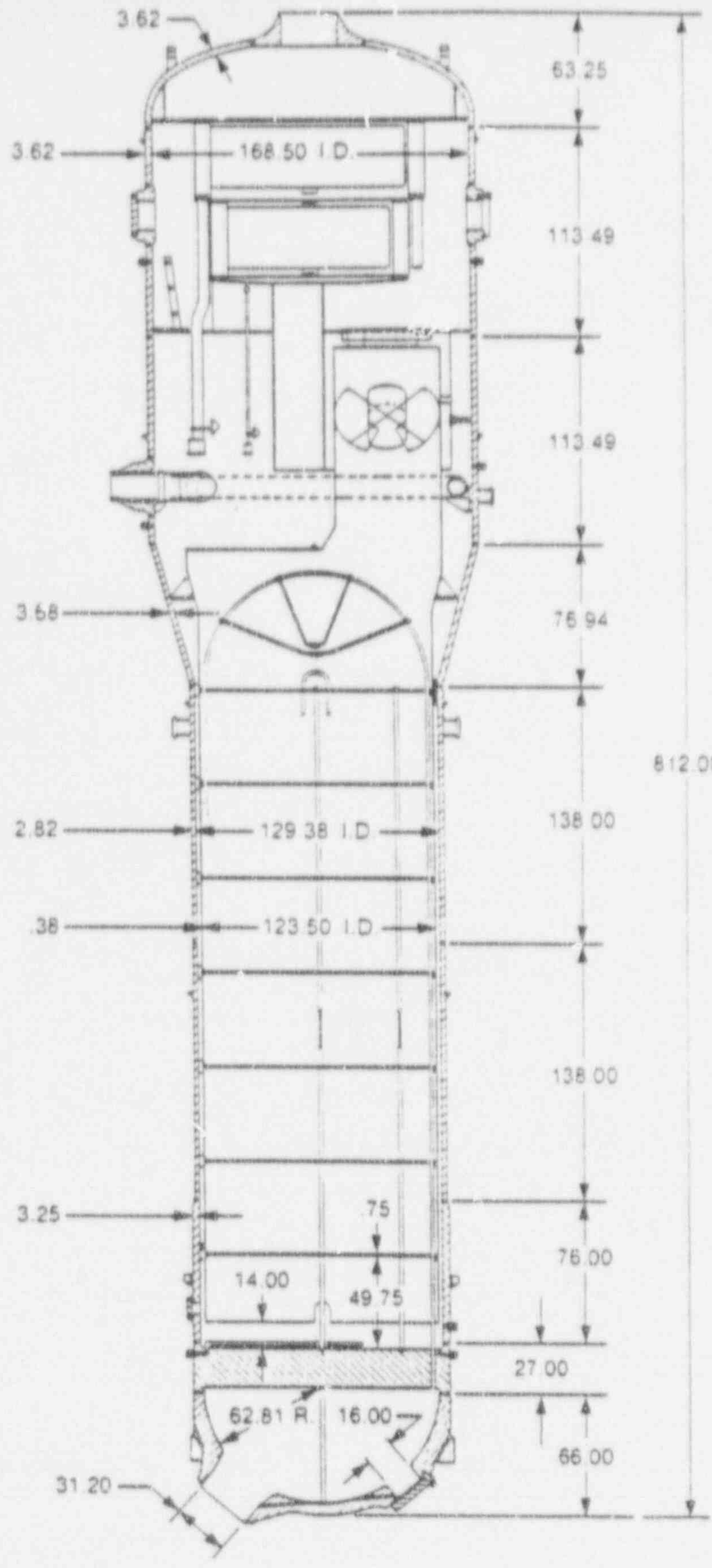



Figure 1-2. Schematic of Josaph Farley Units 1 and 2 Model 51 Steam Generator

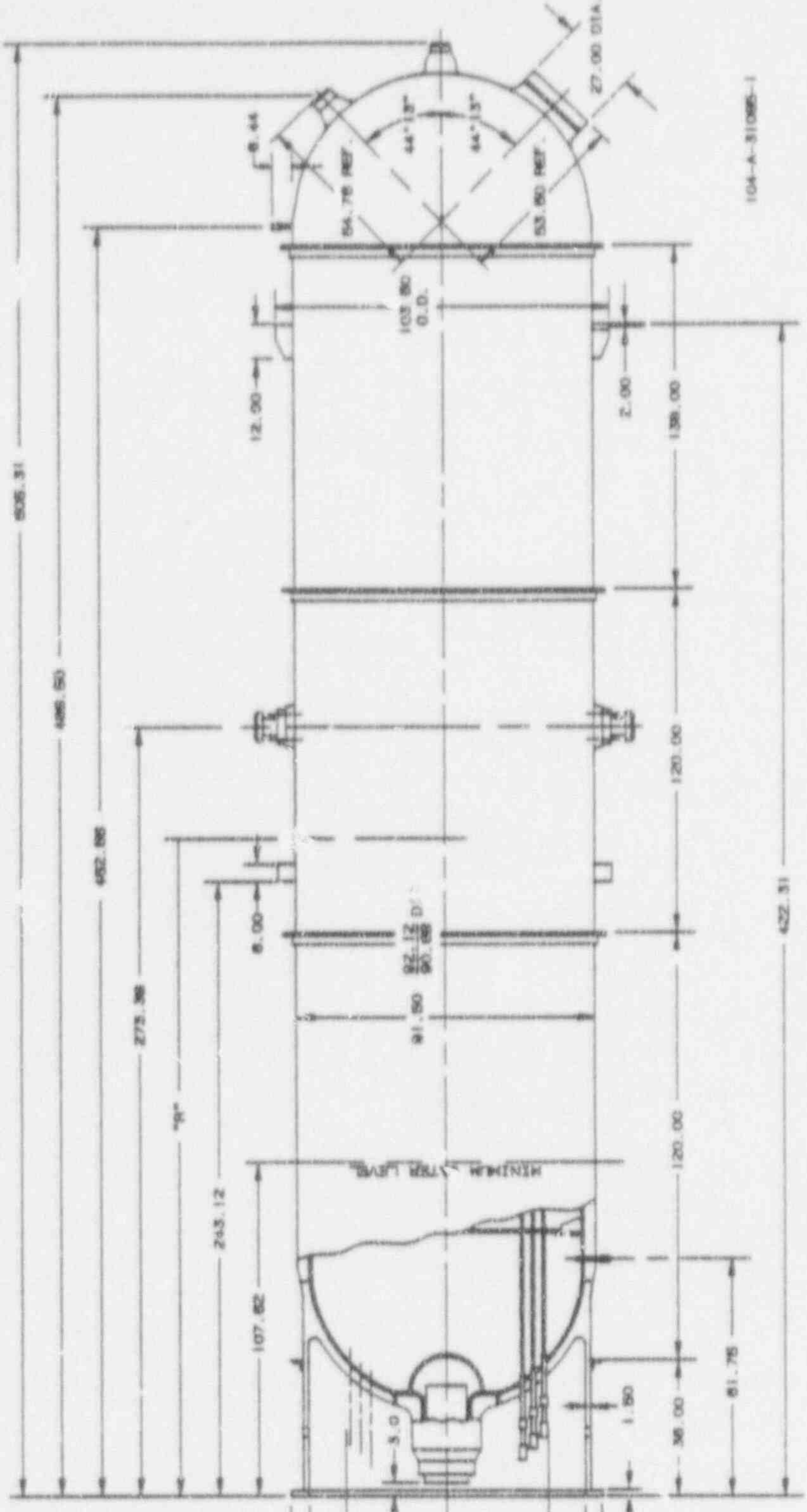
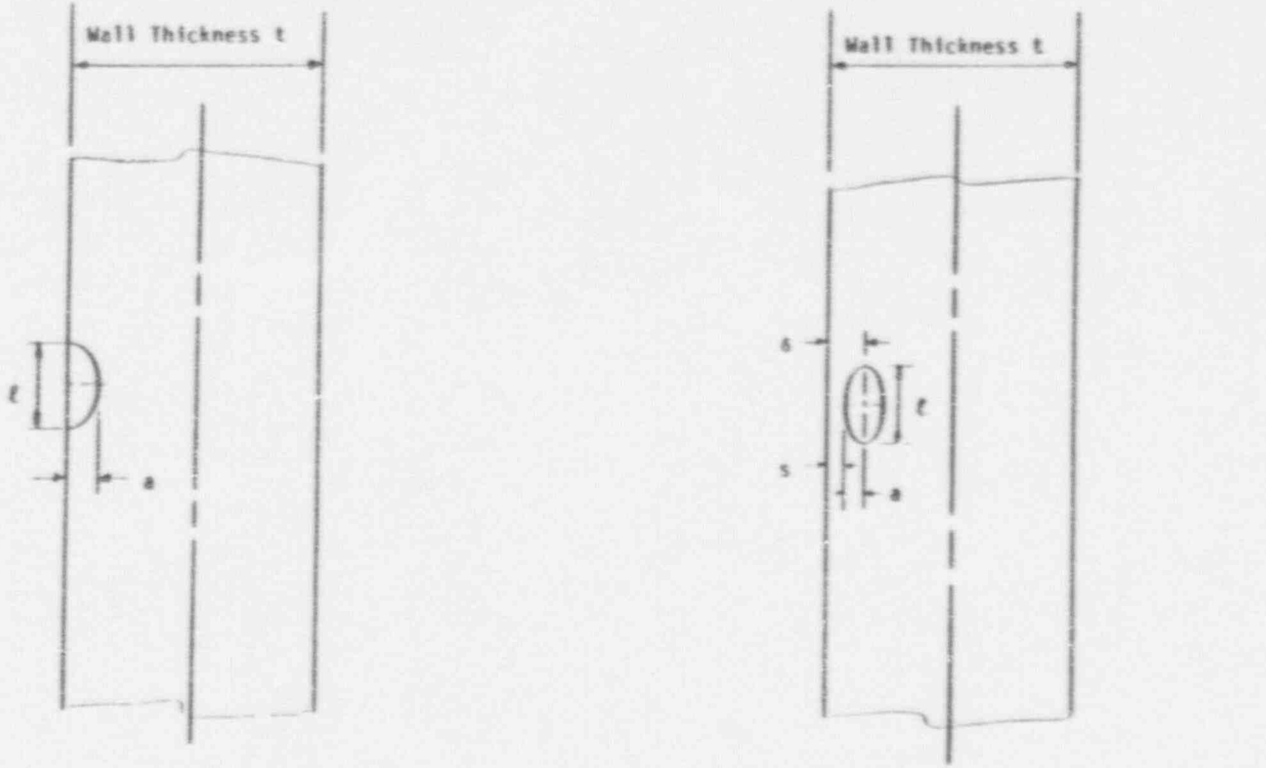


Figure 1-3. Schematic of Joseph Farley Units 1 and 2 Model 84 Pressurizers




TYPICAL SURFACE FLAW INDICATION

TYPICAL EMBEDDED FLAW INDICATION

Figure 1-4. Typical Notation for Surface and Embedded Flaw Indications

# SECTION 2
# LOAD CONDITIONS

The loading conditions used in the analyses described herein were taken directly from the equipment specification for each of the components covered. The fracture analysis methods are the most advanced which are now available, and the material properties are the latest available properties contained in the ASME Code.

The transients for the steam generators are tabulated in Table 2-1 and those for the pressurizers are given in Table 2-2. Both the minimum critical flaw sizes, for criteria (1) of IWB-3611, and the stress intensity factors, for criteria (2) of IWB-3612, are a function of the stresses at the cross-section where the flaw of interest is located. Therefore, the first step in the construction of the charts for the evaluation of a flaw indication is to determine the appropriate limiting load conditions for the location of interest.

The basis for the selection of the most limiting normal/upset/test conditions is straightforward. The transient with the highest surface stresses (thermal and pressure stresses combined) in the region of the indication was chosen as the worst case. For flaws near the outside surface of the vessel separate considerations are required, since most of the thermal transients affect the inside surface, not the outside surface, which is insulated. Therefore, allowable flaw indications at the inside surface are generally smaller than those on the outside surface, as may be seen in the individual charts to follow in the Appendix. The selection of the worst emergency/faulted transient was also based on the highest stresses, but combined with the lowest temperature. This has been discussed in detail in the Technical Basis document [1].

## TABLE 2-1
## SUMMARY OF JOSEPH FARLEY UNITS 1 AND 2 STEAM GENERATOR TRANSIENTS
### PRIMARY SIDE TRANSIENTS

| GROUP # | DESCRIPTION | OCCURRENCES |
|---|---|---|
| 1 | Heatup/Cooldown | 200 |
| 2 | Unit Loading/Unloading | 18300 |
| 3 | Reactor Trip<br>Turbine Roll<br>Loss of Flow | 490 |
| 4 | Loss of Load<br>Loss of Power | 120 |
| 5 | Large Step Decrease<br>Small Step Inc./Dec. | 4200 |
| 6 | Hot Standby | 18300 |
| 7 | SS Fluctuation<br>Boron Conc. Equalization | $3.187 \times 10^6$ |
| 8 | OBE | 400 |
| 9 | Primary Hydro | 5 |
| 10 | Primary Leak Test | 50 |

### SECONDARY SIDE TRANSIENTS

| GROUP # | TRANSIENT | CYCLES FOR THIS TRANSIENT | TOTAL CYCLES IN GROUP |
|---|---|---|---|
| 1 | Heatup and Cooldown | 200 | 200 |
| | Turbine Roll Test | 10 | |
| 2 | Plant Loading and Unloading | 18300 | 18300 |
| 3 | Small Step Load Increase | 2000 | 4000 |
| | Small Step Load Decrease | 2000 | |
| 4 | Loss of Power | 40 | 800 |
| | Large Step Load Decrease | 200 | |
| | Loss of Load | 80 | |
| | Loss of Flow | 80 | |
| | Reactor Trip | 400 | |
| 5 | Hot Standby Operation | 18300 | 18300 |
| 6 | Loss of Power - 32°F Cold Water into Hot<br>Dry Empty Steam Generator | 1 | 1 |
| 7 | OBE | 50 | 50 |
| 8 | Steady State Fluctuations | $3.15 \times 10^6$ | $3.15 \times 10^6$ |
| 9 | Secondary Hydrotest | 5 | 5 |

TABLE 2-2

SUMMARY OF PRESSURIZER TRANSIENTS

JOSEPH FARLEY UNITS 1 AND 2

| GROUP # | TRANSIENT | NO. CYCLES |
|---|---|---|
| 1 | Heatup/Cooldown | 200 |
| 2 | Heatup 1/Cooldown 6 | 400 |
| 3 | Heatup 2/Cooldown 5 | 400 |
| 4 | Heatup 3/Cooldown 4 | 400 |
| 5 | Heatup 4/Cooldown 3 | 400 |
| 6 | Heatup 5/Cooldown 2 | 400 |
| 7 | Heatup 6/Cooldown 1 | 400 |
| 8 | Cooldown 7 | 1200 |
| 9 | Unit Load/Unload | 36600 |
| 10 | Group A<br>Loss of Flow<br>Large Step Load Decr.<br>Small Step Load Incr.<br>Small Step Load Decr. | 4280 |
| 11 | Loss of Load<br>Loss of Power | 120 |
| 12 | Reactor Trip | 400 |
| 13 | Boron Concentration | 36600 |
| 14 | Inadvertent Auxiliary Spray | 10 |
| 15 | Primary Hydro | 5 |
| 16 | Primary Leak<br>Turbine Roll | 60 |
| 17 | OBE | 50 |

# SECTION 3
# FATIGUE CRACK GROWTH

In applying code acceptance criteria as introduced in Section 1, the final flaw size $a_f$ used in criteria (1) is defined as the minimum flaw size to which the detected flaw is calculated to grow at the end of the design life, or until the next inspection time. In this handbook, inspection every 10 years is assumed.

These crack growth calculations have been carried out for all the key regions in the Joseph Farley Units 1 and 2 steam generators and pressurizers. This section will examine the calculations, and provide a brief description of the methodology used as well as the assumptions. A more detailed discussion is contained in the Technical Basis document [1].

The crack growth calculations reported here are extensive because a range of flaw shapes have been considered to encompass the range of flaw shapes which could be encountered in service.

The analysis procedure involves postulating an initial flaw at specific regions and predicting the growth of that flaw due to an imposed series of loading transients. The input required for a fatigue crack growth analysis is basically the information necessary to calculate the parameter $K_I$, which depends on the crack and structure geometry and the range of applied stresses in the area where the crack exists. Once $K_I$ is calculated, the growth due to that particular stress cycle can be calculated by equations given in figure 3-1. This increment of growth is then added to the original crack size, and the analysis proceeds to the next transient. The procedure is continued in this manner until all the transients expected to occur in the period of evaluation have been analyzed.

The transients considered in the analysis are all the design transients contained in the appropriate steam generator or pressurizer equipment specification, as shown in Section 2. These transients are spread equally over the design lifetime of the vessel, with the exception that the preoperational tests are considered first. Faulted conditions are not considered because their frequency of occurrences is too low to affect fatigue crack growth. Crack growth calculations for the steam generator and pressurizer were carried out for a range of flaw depths and three basic types. The first type was a surface flaw

with length equal to six times its depth. The second was a continuous surface flaw, which represents a worst case for surface flaws. The third was an embedded flaw. For the steam generator, the length was assumed equal to three times its width (through wall dimension), while for the pressurizer the length was assumed equal to five times its width. This difference had little effect on the magnitude of crack growth calculated. For all cases the flaw was assumed to maintain a constant shape as it grew. The expressions used for calculating stress intensity factors for the various flaw types are documented in the technical basis document. [1]

The crack growth rate curves used in the analyses were taken directly from Appendix A of Section XI of the ASME Code. Water environment curves were used for all inside surface flaws, and the air environment curve was used for embedded flaws and outside surface flaws.

The reference crack growth curves for water environments are shown in figure 3-1 and growth rate is a function of both the applied stress intensity factor range, and the R ratio ($K_{min}/K_{max}$) for the transient. The crack growth rate reference curve for air environments is a single curve, with growth rate being only a function of applied K. This reference curve is also shown in figure 3-1. This figure appeared in the 1980 edition of the ASME code, and review of current research results indicates it is unlikely to change for many years.

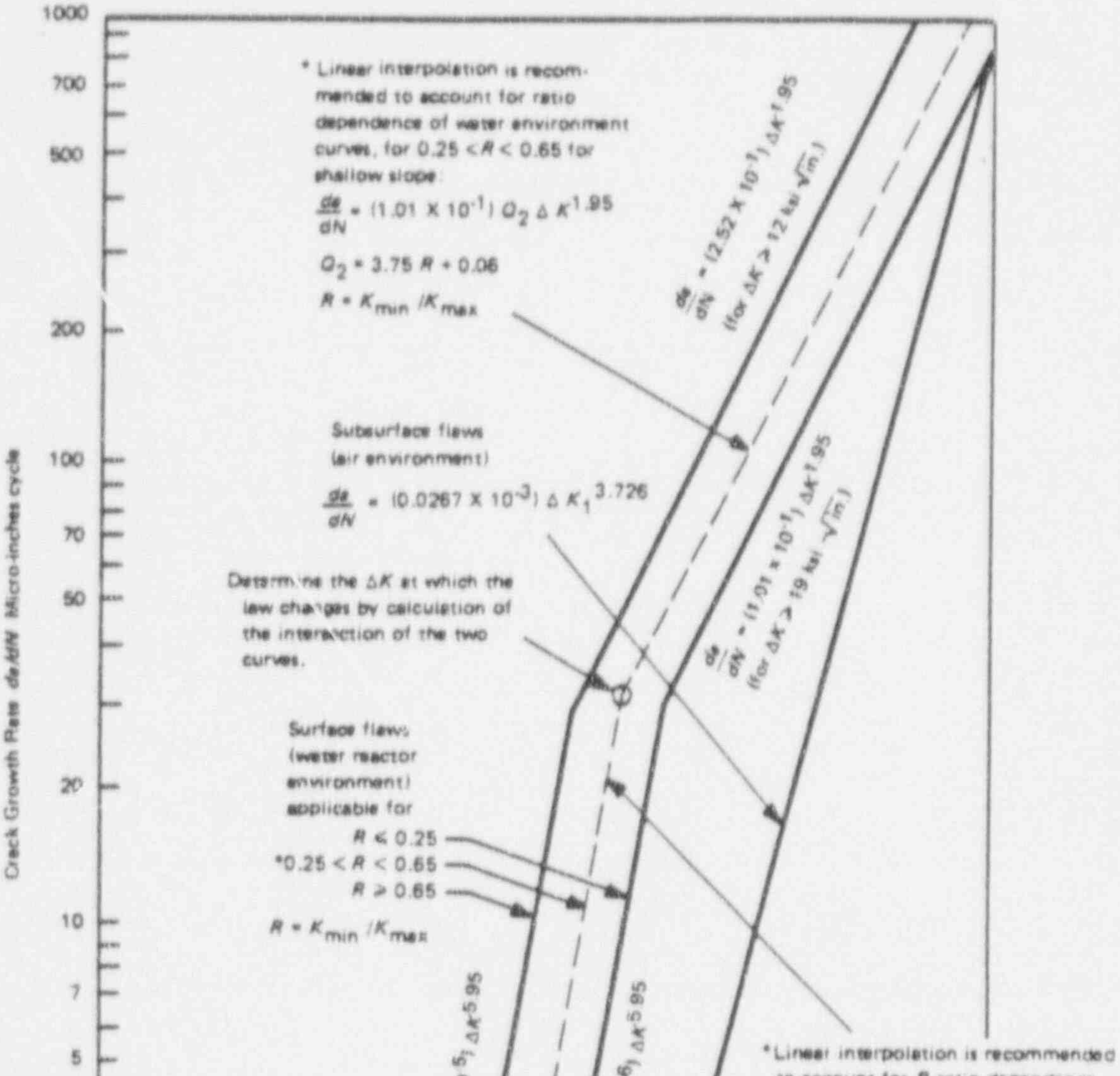



Figure 3-1. Reference Fatigue Crack Growth Curves for Carbon and Low Alloy Ferritic Steels

## SECTION 4
## CRITICAL FLAW SIZE CALCULATIONS

### 4.1 INTRODUCTION

The key parameters used in the evaluation of any indications discovered during inservice inspection are two critical flaw parameters required for the evaluation of an indication in any given location. The first of these is calculated using stresses from governing normal, upset, and test conditions. The second is calculated based on stresses for the governing emergency and faulted conditions. The parameters based on these conditions correspond to the two ASME code criteria defined in Section 1.1.1.

Critical flaw sizes were calculated for postulated inside surface semi-elliptical flaws having a length equal to six times their depth. To allow the evaluation of indications of various shapes, critical flaw sizes are calculated for embedded flaws as well as surface flaws of other shapes. Critical flaw sizes were calculated for emergency and faulted as well as normal and upset conditions. Hydro and leak test conditions were considered separately for the steam generators, since their severity can be controlled by temperature.

The selection of the governing transient for emergency faulted, normal, upset, and test conditions can be done easily based on the results of the available stress analyses. The details of this work are provided in the technical basis document [1].

### 4.2 STRESS INTENSITY FACTOR CALCULATIONS

One of the key elements of the critical flaw size calculations is the determination of the driving force or stress intensity factor. This was done for each of the regions using expressions available in the literature. In all cases the stress Intensity factor for the critical flaw size calculations utilized a representation of the actual stress profile rather than a linearization. This was necessary to provide the most accurate determination possible of the critical flaw size and is particularly important for

consideration of emergency and faulted conditions where the stress profile is generally nonlinear and often very steep.

## 4.3 FRACTURE TOUGHNESS

The other key element in the determination of critical flaw sizes is the fracture toughness of the material. The fracture toughness has been taken directly from the reference curves of Appendix A, ASME Section XI. In the transition temperature region these curves can be represented by the following equations:

$$K_{Ic} = 33.2 + 2.806 \exp. [0.02 (T-RT_{NDT} + 100°F)]$$

$$K_{Ia} = 26.8 + 1.233 \exp. [0.0145 (T-RT_{NDT} + 160°F)]$$

where $K_{Ic}$ and $K_{Ia}$ are in ksi $\sqrt{\text{in}}$.

The upper shelf temperature regime requires utilization of a shelf toughness which is not specified in the ASME Code. A value of 200 ksi $\sqrt{\text{in}}$ has been used here. This value is consistent with general practice in such evaluations, as shown for example in reference [3] which provides the background and technical basis of Appendix A of ASME Section XI. The value of $RT_{NDT}$ used in these toughness equations was taken from the limiting properties of materials in both the steam generator and pressurizer and these values are obtained directly from Nuclear Components Division, Pensacola, Florida. The limiting $RT_{NDT}$ for the steam generators was found to be 30°F for the base metal and 10°F for the welds. For the pressurizer, the limiting $RT_{NDT}$ was also found to be 30°F for the base metal and 10°F for the welds.

## SECTION 5
## REFERENCES

1. Lee, Y.S. and Bamford, W. H., "Background and Technical Basis: Handbook on Flaw Evaluation for the Joseph Farley Units 1 and 2 Main Coolant System," Westinghouse Electric Corporation, WCAP-12447, September 1989.

2. ASME Code Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," 1983 edition (used for updated code allowable limits); 1983 edition, Winter 1985 Addendum (used for flaw evaluation of austenitic stainless steel piping); 1989 edition (used for reference crack growth curve, stainless steel.)

3. Marston, T. U. editor, "Flaw Evaluation Procedures, ASME Boiler and Pressure Vessel Code, Section XI," Electric Power Research Institute report EPRI-NP719SR, August 1978.

# APPENDIX A
# FLAW EVALUATION CHARTS

## APPENDIX A
## FLAW EVALUATION

### A-1 INTRODUCTION TO EVALUATION PROCEDURE

The evaluation procedures contained in ASME Section XI are clearly specified in paragraph IWB-3600. Use of the evaluation charts herein follows these procedures directly, but the steps are greatly simplified.

Once the indication is discovered, it must be characterized as to its location, length ($\ell$) and depth dimension (a for surface flaws, 2a for embedded flaws), including its distance from the clad-base metal interface (S) for embedded indications. This characterization is discussed in further detail in paragraph IWA 3000 of Section XI.

The following parameters must be calculated from the above dimensions to use the charts (see figure 1-4 in section 1):

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter (for embedded flaws only), $\delta/t$

where

$t$ = wall thickness of region where indication is located

$\ell$ = length of indication

$a$ = depth of surface flaw; or half depth of embedded flaw in the width direction

$\delta$ = distance from flaw centerline to surface (for embedded flaw only)
($\delta = S + a$)

$S$ = smallest distance from edge of embedded flaw to surface

Once the above parameters have been determined and the determination made as to whether the indication is embedded or surface, then the two parameters may be plotted directly on the appropriate evaluation chart. Its location on the chart determines its acceptability immediately.

Important Observations on the Handbook Charts

Although the use of the handbook charts is conceptually straight forward, experience in their development and use has led to a number of observations which will be helpful.

Surface Flaws

An example handbook chart for surface flaws is shown in figure A-1.1. The flaw indication parameters (whose calculation is described above) can be plotted directly on the chart to determine acceptability. The lower curve shown (labelled Code allowable limit) is simply the acceptance standards from IWB 3500, which are tabulated in Section XI. If the plotted points fall below these lines, the indication is acceptable without analytical justification having been required. If the plotted point falls <u>between</u> the Code allowable limit lines and the lines labeled "upper limits of acceptance" it is acceptable by virtue of its meeting the requirements of IWB 3600, which allow acceptance by fracture analysis. (Flaws between these lines would, however, require future monitoring per IWB 2420 of Section XI). The analysis used to develop these lines is documented in the companion technical basis document [1]. There are three of these lines shown in the charts, labeled 10, 20 and 30 years. The years indicate for how long the acceptance limit applies from the date that a flaw indication is discovered, based on fatigue crack growth calculations.

As may be seen in figure A-1.1, the chart gives results for surface flaw shapes up to a semi-circular flaw ($a/\ell = 0.5$). For the unlikely occurrence of flaws for which the value of $a/\ell$ exceeds 0.5, the limits on acceptance for $a/\ell = 0.5$ should be used. The upper limits of acceptance have been set at (a maximum of) twenty percent of the wall thickness in all cases, as discussed in Section 5. of [1].

Embedded Flaws

An example chart for embedded flaws is shown in figure A-1.2. The heavy diagonal line in the figure can be used directly to determine whether the indication should be characterized as an embedded flaw or whether it is sufficiently close to the surface that it must be considered as a surface flaw (by the rules of Section XI). If the flaw parameters produce a plotted point below the heavy diagonal line, it is acceptable by analysis per [1] if the point is below the appropriate $a/\ell$ limit line. If it is above the line, it cannot be justified by analysis, and is, therefore, not acceptable.

The flaw evaluation charts for embedded flaws are presented in a form which does not allow a direct presentation of the standards from Section XI, IWB 3500. For comparison purposes, these standards have been presented graphically in Figure A-1.3. If an indication is below the appropriate standards limit of Figure A-1.3, it is acceptable without analytical evaluation.

For cases where there are no branching limit lines below the heavy diagonal line (see figure A-3.5 for example) then all flaws classified as embedded are acceptable. The only limitation is, as discussed in Section 6 of reference [1]:

$$\frac{2a}{t} < 0.25$$

Note that the embedded flaw evaluation charts are applicable for flaws near either the inner or outer surface, and the parameters "S" and "$\delta$" are defined from the nearest surface.

Another important observation is the procedure to be used for an embedded flaw whose plotted point falls above the heavy diagonal line, and must therefore be considered a surface flaw. An example of this is provided in "Embedded flaw Example 1", but it is important to note that when this must be done, the depth of the flaw is redefined. The new depth is equal to 2a + S, as shown in the example, which becomes the effective crack depth a* to be used in the surface flaw chart in such cases.

General Observations

Detailed examples of the use of the charts for both surface and embedded flaws are presented below, for the specific cross section. Some points are worthy of

note for locations between the cross sections which have been analyzed. A flaw indication between these two cross sections should use acceptance criteria interpolated linearly between the two appropriate charts. Similar procedures should be followed for interpolation between other regions.

Modification of Hydrostatic and Leakage Test Temperatures

If an indication is discovered in the steam generators which is justified for further service without repair by the flaw evaluation charts of this report, an increase in the minimum temperature at which the hydrotest and leak tests must be conducted may be necessary to ensure the required margins of Section XI are maintained. Charts are provided for determination of this temperature in each of sections A-2 to A-10. The required temperature is a function of the size and location of the indications discovered. Separate treatments have been developed for embedded and surface indications.

The charts in these sections provide a simple method for determining the required minimum temperature for any subsequent hydrostatic or leakage tests. Once an indication has been characterized, its size and location within the wall of the vessel ($\delta/t$) determine the allowable hydrostatic or leakage test temperature. This may be done by simply plotting the indication on the appropriate chart. Separate charts have been provided for surface and embedded indications.

Surface Flaw Example 1

Suppose an indication has been discovered which is a surface flaw and has the following characterized dimensions:

$a = 0.30$ in.
$\ell = 1.5$ in.
$t = 6.69$ in.

The flaw parameters for the use of the charts are:

$a/t = 0.045$ (4.5%)

$a/\ell = 0.20$

Plotting these parameters on figure A-1.1 it is quickly seen that the indication is acceptable by analysis per [1]. To justify operation without repair it is necessary to submit this plot along with the Technical Basis document [1] to the regulatory authorities.

Embedded Flaw Example 1

A longitudinal embedded flaw of 1.75" x 5.00", located within 0.575" from the surface, was detected. Determine whether this flaw should be considered as an embedded flaw.

$2a = 1.75"$
$S = 0.575"$
$\delta = S + a = 0.575 + 1/2\ (1.75) = 1.45"$
$t = 6.69"$
$\ell = 5.0"$

and,

$a = 1/2 \times 1.75"$
$= .875"$

Using figure A-1.2:

$$\frac{a}{t} = \frac{0.875}{6.69} = 0.13$$

$$\frac{\delta}{t} = \frac{1.45}{6.69} = 0.22$$

Since the plotted point (X) is above the diagonal line, the flaw must be considered a surface flaw. Now, since the flaw must be considered as a surface flaw, the depth must be redefined as the distance from the surface to the deepest point of the flaw. This is equivalent to circumscribing the embedded flaw with a semi-elliptic surface flaw. Operationally, the parameters are recalculated as follows. Defining a* as the corrected crack depth for the surface flaw,

$a^*$ = 2a + S = 2.325"

$\ell$ = 5.0"

$a^*/t$ = 0.347

$a^*/\ell$ = 0.465

Refering to figure A-1.1 for the surface flaw, it is quickly seen that this flaw is much too large to be acceptable and must be repaired.

Embedded Flaw Example 2 (Point A)

Suppose an indication has been discovered which is embedded, and has the following characterized dimensions:

2a = 1.0 in.
$\ell$ = 1.5 in.
t = 9.16 in.
S = 0.75 in.

Calculating the flaw parameters, we have:

a/t = 0.0546

$a/\ell$ = 0.333

$\delta$ = S + a = 1.25 in.  $\delta$/t = 0.136

Plotting these parameters on the embedded flaw evaluation chart, figure A-1.2 it may be quickly seen that the indication is embedded, and is acceptable by analysis (point A), since it lies below the $a/\ell$ = 0.333 limit case.

Embedded Flaw Example 3 (Point B)

Suppose an indication has been discovered which is embedded, and has the following characterized dimensions:

$2a = 1.47"$      $a = 0.73"$

$\ell = 2.20"$      $S = 1.325$

$t = 9.16"$

Calculating the flaw parameters, we have:

$a/t = 0.08$

$a/\ell = 0.33$

$\delta = S + a = 2.06$

$\delta/t = 0.225$

Plotting these parameters on figure A-1.2 (point B) we see that the indication is acceptable, since it falls below the line which is applicable to $a/\ell = 0.333$. (Note that if $a/\ell = 0.167$, for example, the indication would not be acceptable, since point B would lie above that line, as may be seen in the figure.)

<u>Embedded Flaw Example 4 (Point C)</u>

A longitudinal embedded flaw of 1.15" x 5.38" was detected at a distance S = 1.075 in. underneath the surface. Evaluate the flaw for code acceptance for continued service without repair.

The flaw geometry parameters are determined as follows:

$t = 6.69"$

$S = 1.075"$

$\delta = S + a = 1.65"$

$\ell = 5.38"$

and

$a = 1/2 \times 1.15$:

$= .575"$

$$\frac{\delta}{t} = \left(\frac{1.65}{6.69}\right) = 0.247$$

$$\frac{a}{\ell} = \left(\frac{0.575}{5.38}\right) = 0.107$$

$$\frac{a}{t} = \left(\frac{0.575}{6.69}\right) = 0.086$$

Evaluate the flaw by referring to figure A-1.2 and plotting the point (as point C). This is above the code acceptance limit line for $a/\ell = 0.167$, which should also be used for $a/\ell < 0.167$; therefore, the flaw is not acceptable, and must be repaired.

Note: The code acceptance lines become identical with the surface/embedded flaw demarcation line with which they link up at points near the surface. Therefore, in figure A-1.2 the code acceptance line for flaws near the surface, $\delta/t$ less than 0.125, is identical with the "surface/embedded flaw demarcation line up till 1980 Code".

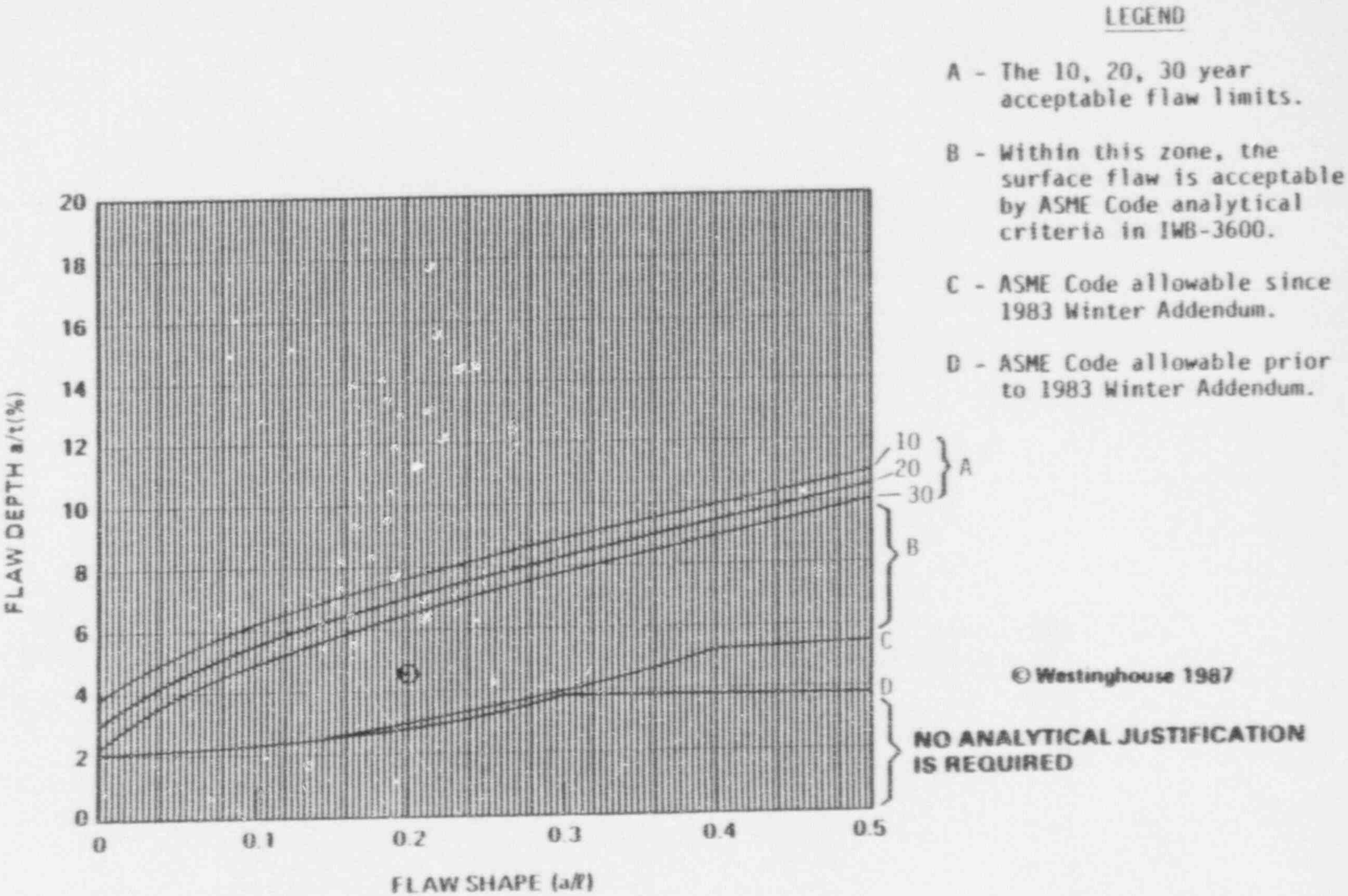





Figure A-1.1. Example of Surface Flaw Treatment

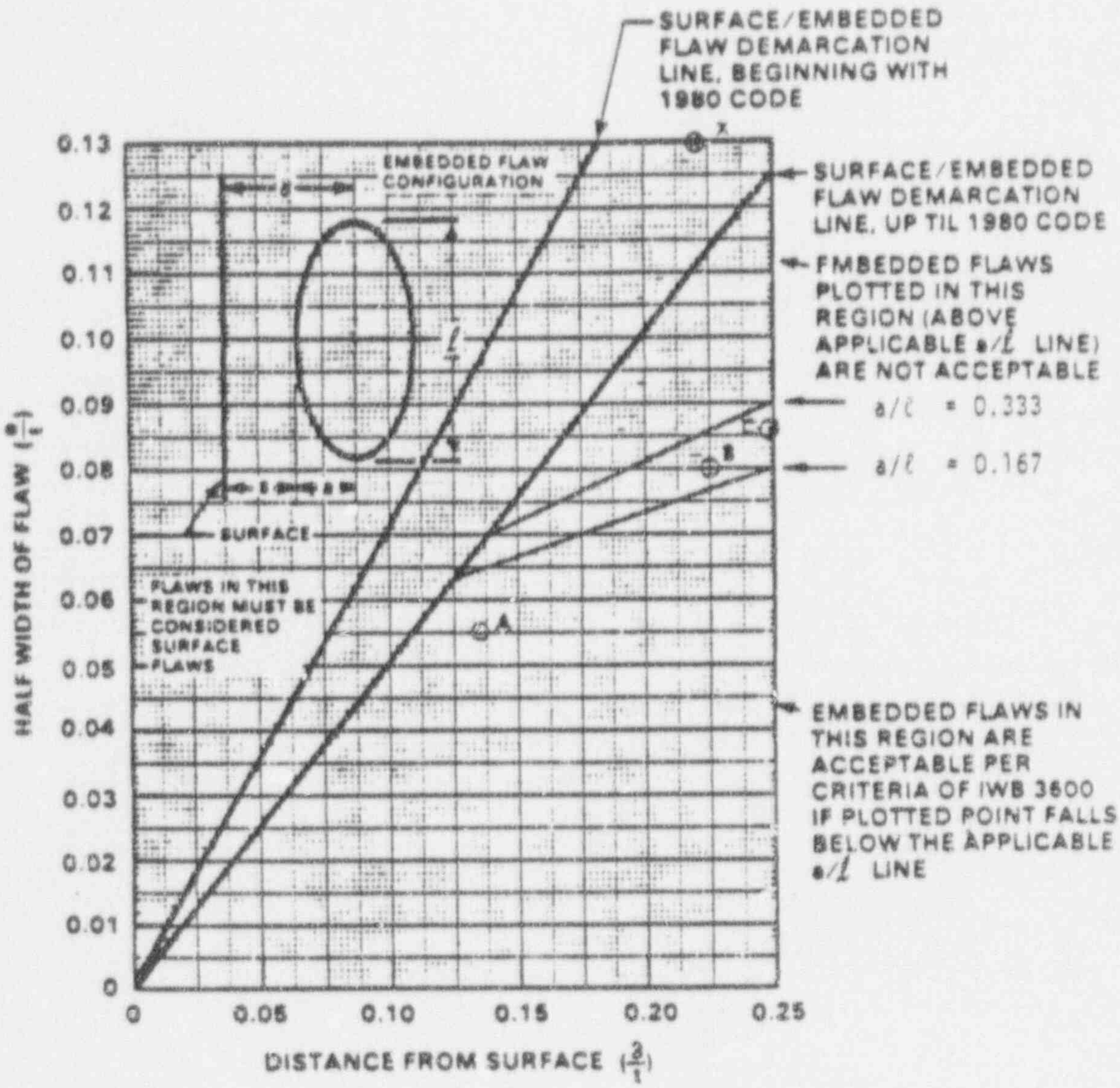



Figure A-1.2. Example of Embedded Flaw Treatment

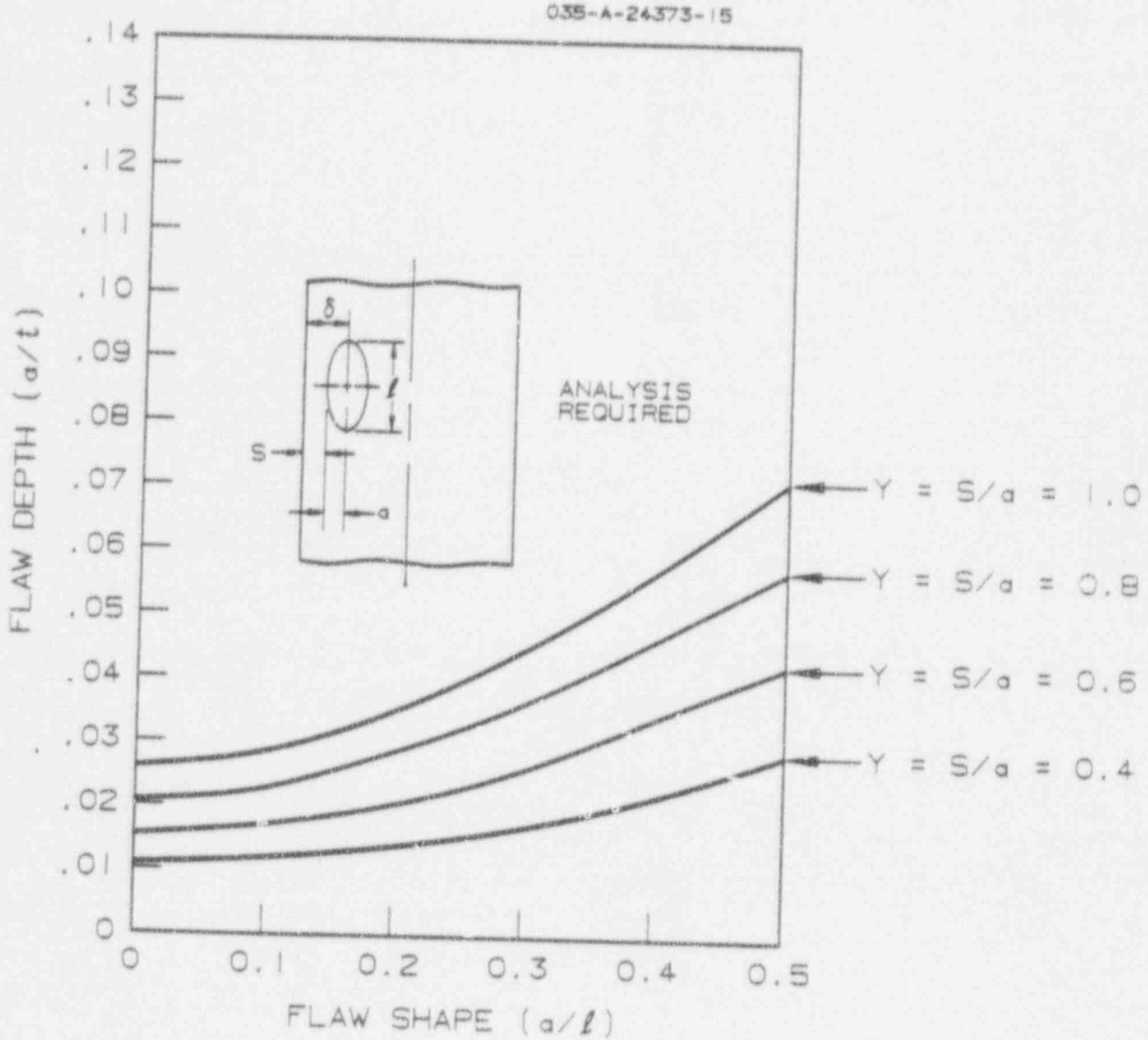



Figure A-1.3. Acceptance Standards for Embedded Flaws, from Tables IWB 3511-1

## A-2 TUBESHEET-CHANNEL HEAD WELD REGION - STEAM GENERATOR

### A-2.1 SURFACE FLAW (LONGITUDINAL AND CIRCUMFERENTIAL FLAW)

The geometry and terminology used for flaws in this region is depicted in figure A-2.1.

The following parameters must be determined for surface flaw evaluation with the charts.

- o Flaw shape parameter $a/\ell$

- o Flaw depth parameter $a/t$

where

$a$ = the surface flaw depth detected, (in.)
$\ell$ = the surface flaw length detected, (in.)
$t$ = wall thickness at the weld ($t$ = 5.02")

The surface evaluation charts for this region are listed below:

Figure A-2.2 Surface Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Tubesheet Channel Head Junction

Figure A-2.3 Surface Flaw Evaluation Chart for Circumferential Flaws at the Outside Surface of the Tubesheet Channel Head Junction

## A-2.2 EMBEDDED FLAWS

The geometry and terminology used for embedded flaws at the tubesheet channel head junction is depicted in figure A-2.1.

Basic Data:

$t$ = 5.02 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the monitor diameter) (in.)

$\ell$ = Flaw length (Major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization criteria

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

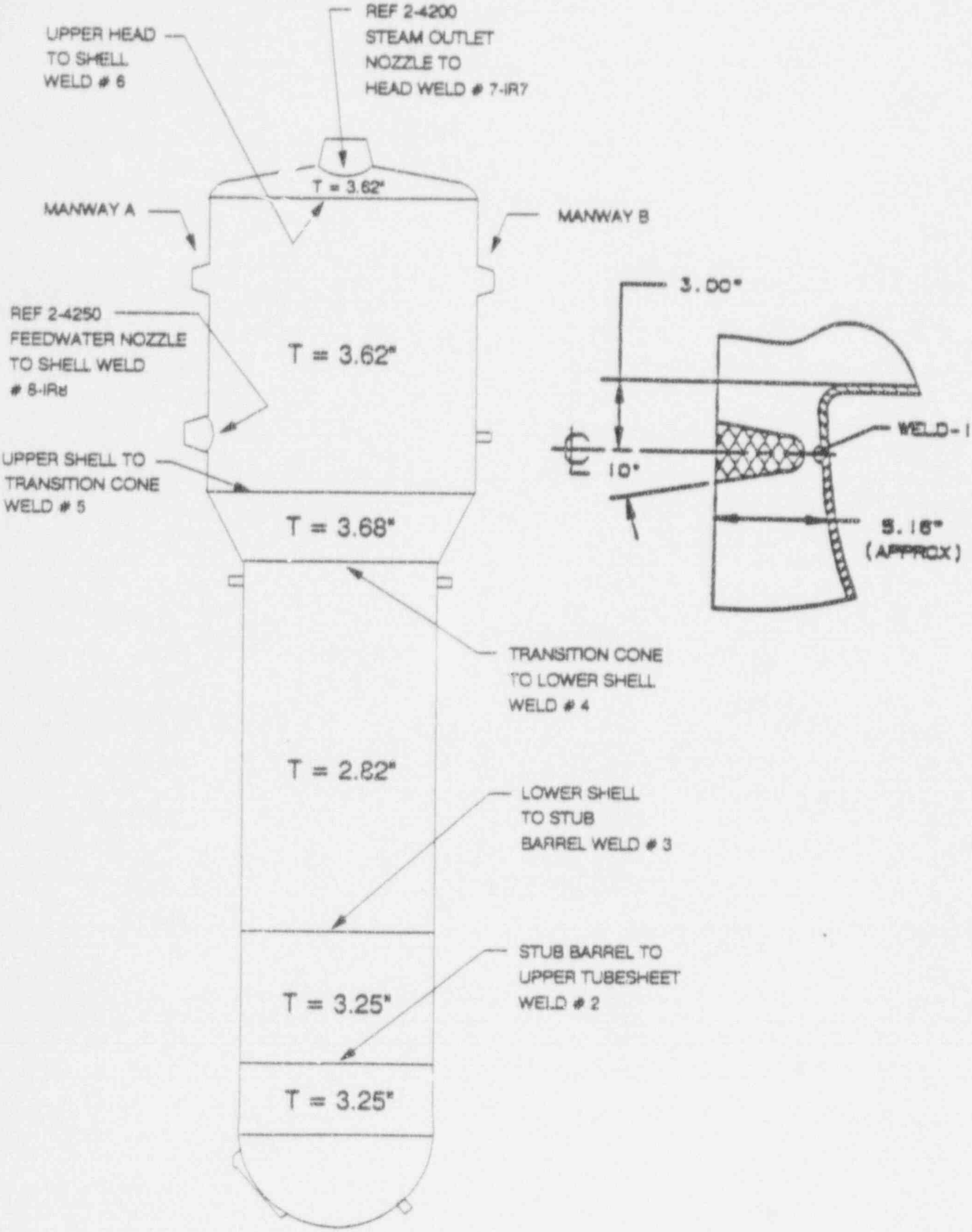
The embedded evaluation chart for the Tubesheet-Channel Head Weld:

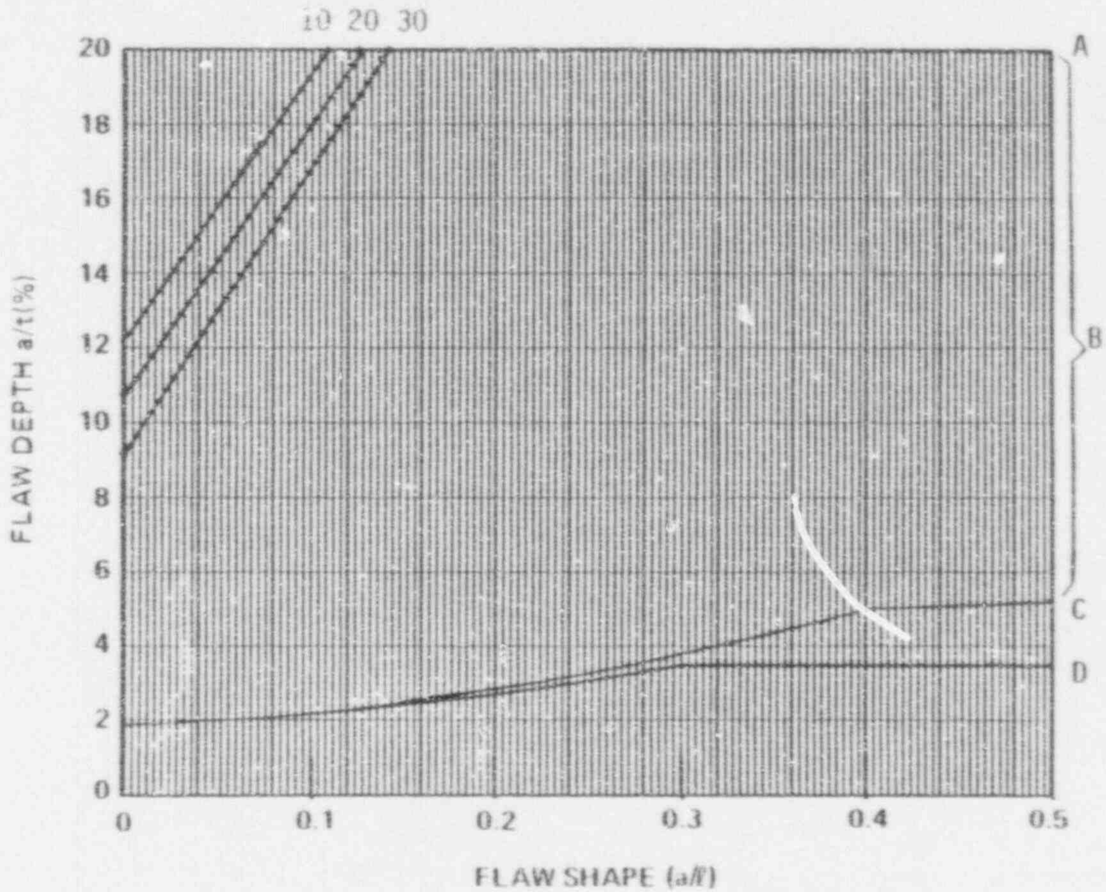
Figure A-2.4 Embedded Flaw Evaluation Chart for Longitudinal Flaws in the Tubesheet Channel Head Junction

Figure A-2.5 Test Temperature Determination Chart for Circumferential Flaws in the Tubesheet Channel Head Junction for Primary Hydro Test

Figure A-2.1

Geometry and Terminology for Flaws at the Tubesheet-Channel Head Junction






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

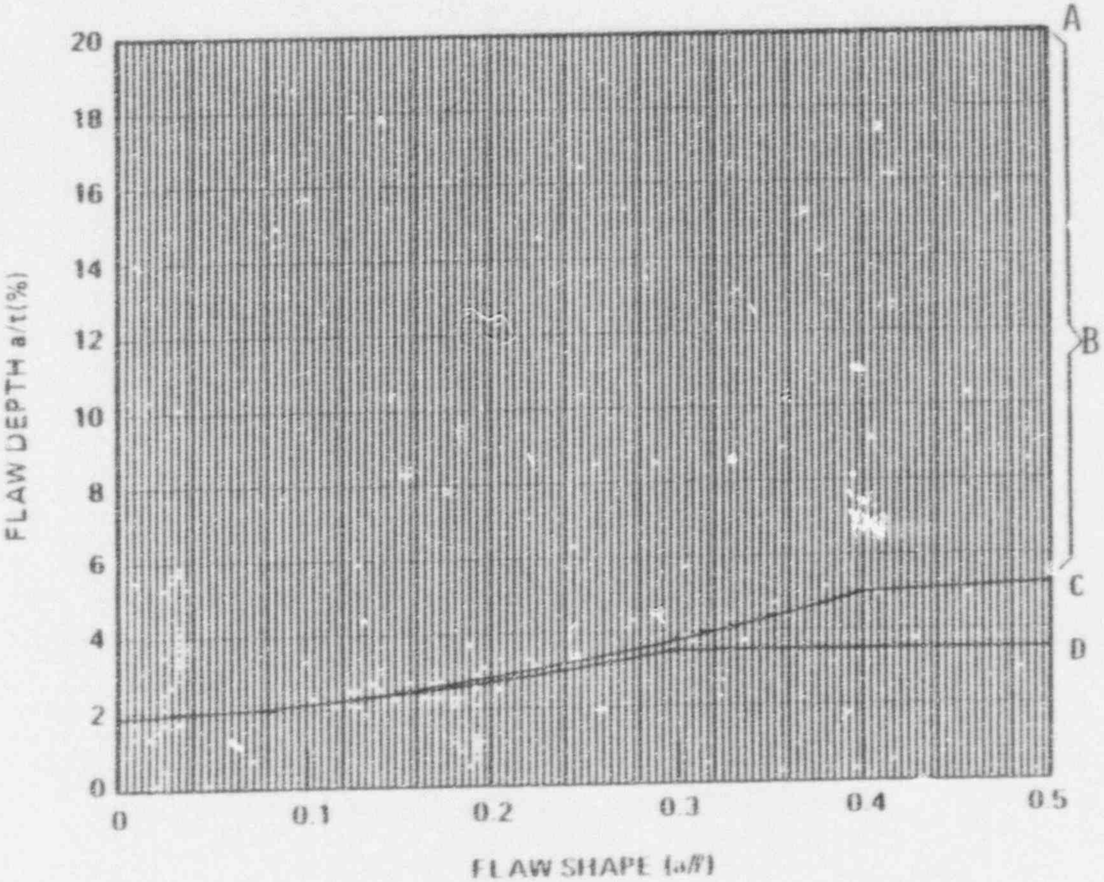
D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-2.2 Flaw Evaluation Chart for the Tubesheet Channel Head Junction

X Inside Surface   X Surface Flaw   ___ Longitudinal Flaw

___ Outside Surface   ___ Embedded Flaw   X Circumferential Flaw




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-2.3 Flaw Evaluation Chart for the Tubesheet Channel Head Junction

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

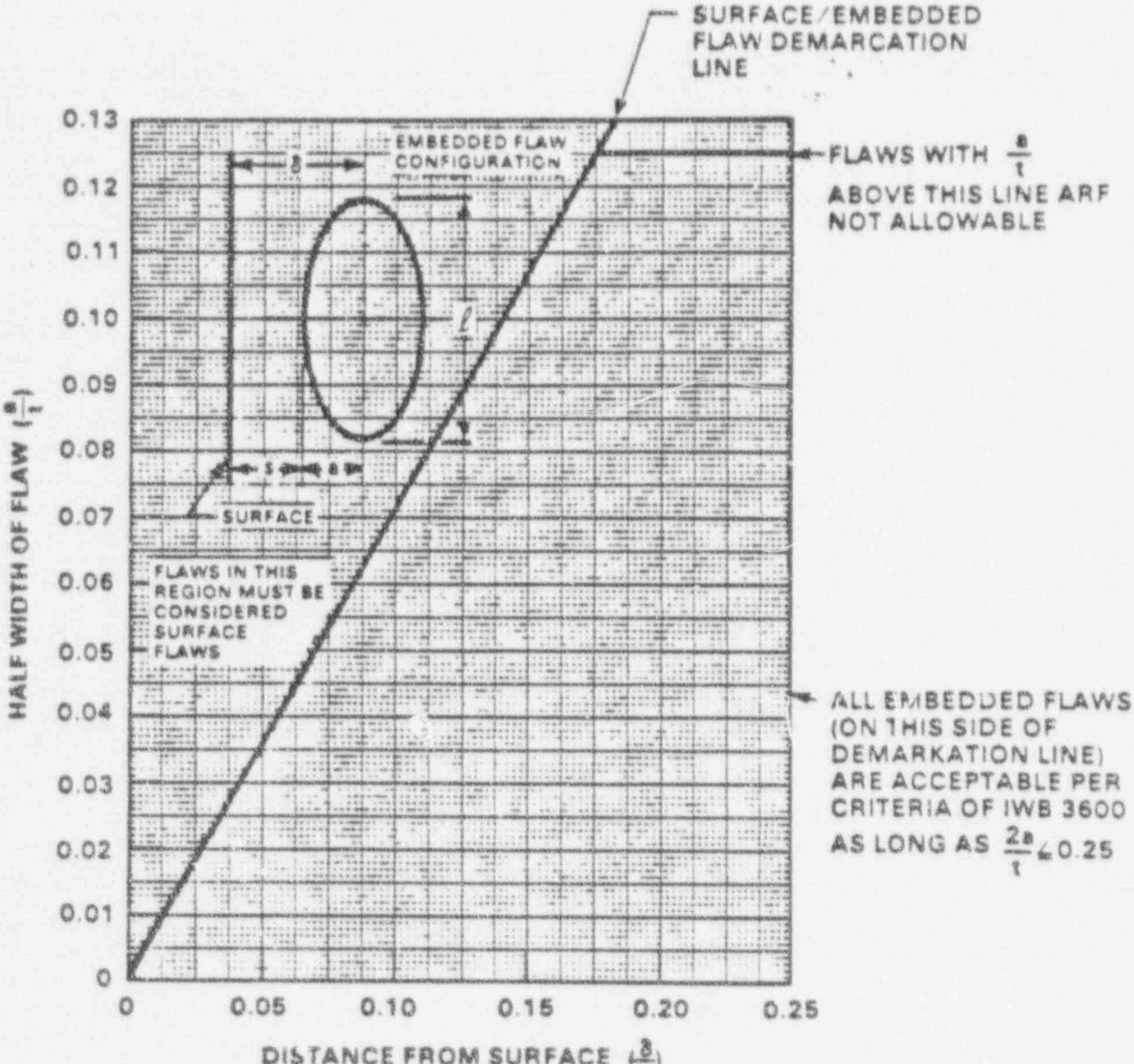



Figure A-2.4 Flaw Evaluation Chart for the Tubesheet-Channel Head Junction

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-3 TUBESHEET-STUB BARREL WELD - STEAM GENERATOR

### A-3.1 SURFACE FLAWS

The geometry and terminology for surface flaws at the tubesheet-stub barrel weld region of the steam generator is depicted in figure A-3.1.

The following parameters must be determined for surface flaw evaluation with the charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = The surface flaw depth detected (in.)
$\ell$ = The surface flaw length detected (in.)
$t$ = Wall thickness at the weld ($t$ = 3.19")

The surface flaw evaluation charts for this region are listed below

| | |
|---|---|
| Figure A-3.2 | Surface Flaw Evaluation Chart for Circumferential Flaws at the Tubesheet - Stub Barrel Weld |

### A.3-2 EMBEDDED FLAWS

The geometrical description of an embedded flaw in this region is depicted in figure A-3.1.

Basic Data:

$t$ = 3.19 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

a = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per ASME Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw:

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, a/t
- o Surface proximity parameter, $\delta/t$

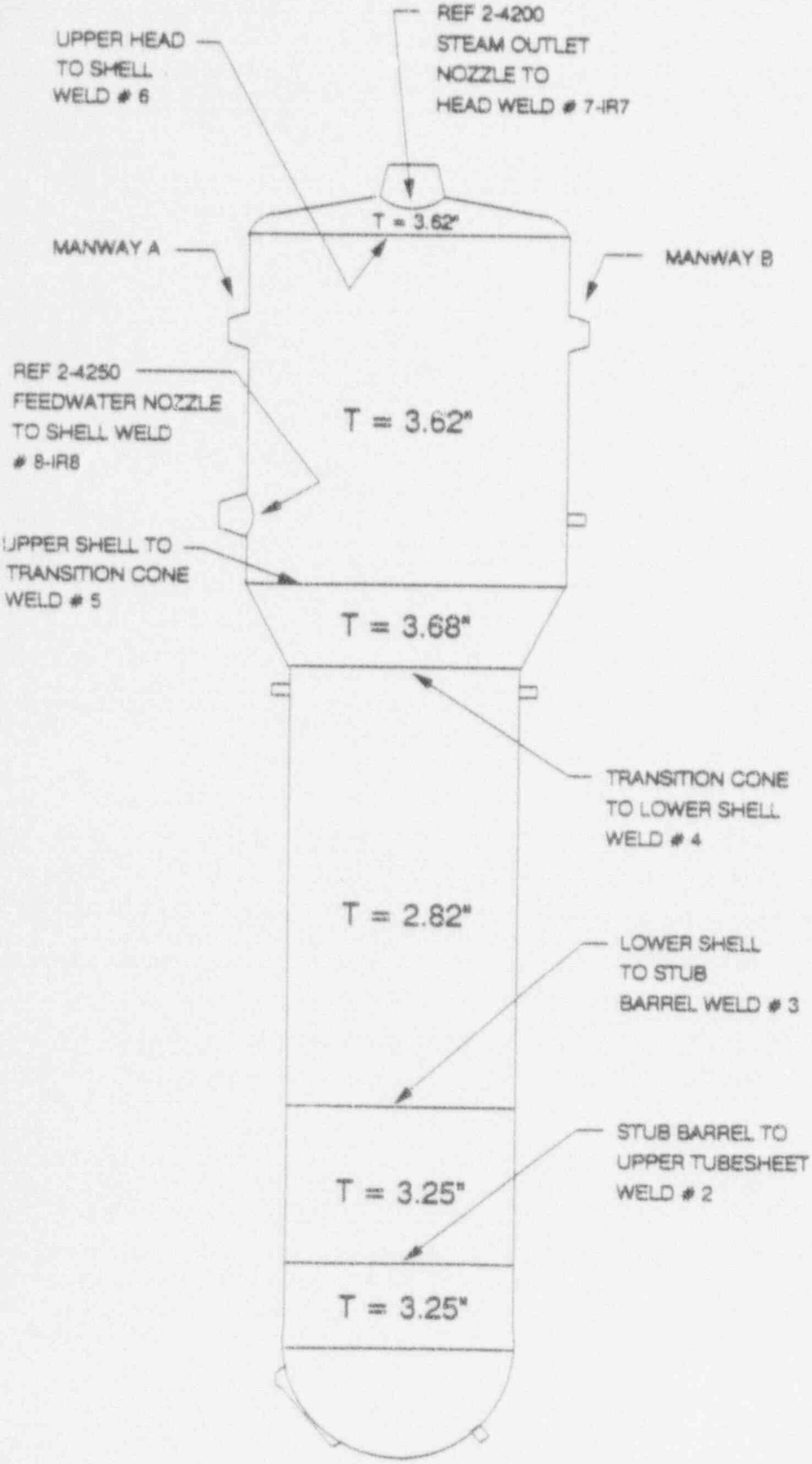
The evaluation chart for embedded flaws;

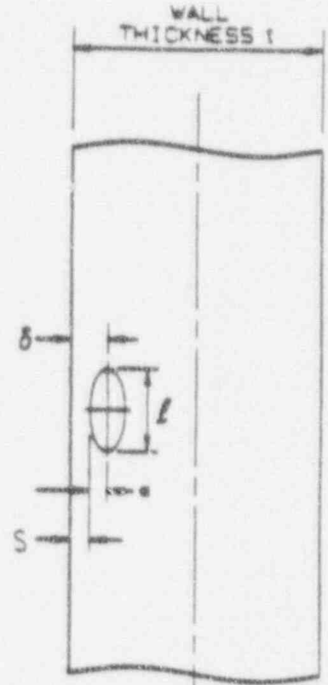
The evaluation charts for embedded flaws in this region are listed below:

- o Figure A-3.3 Embedded Flaw Evaluation Chart for Circumferential and Longitudinal Flaws in the Tubesheet to Stub Barrel Weld Region.
- o Figure A-3.4 through Figure A.3-6 Test Temperatures Determination Charts for Embedded Circumferential and Longitudinal Flaws in the Tubesheet Stub Barrel Weld for Secondary Hydro Test and Secondary Leakage Tests for Farley Unit 1.
- o Figure A-3.7 through Figure A-3.9 Test Temperatures Determination Charts for Embedded Circumferential and Longitudinal Flaws in the Tube-sheet Stub Barrel Weld for Secondary Hydro Test and Secondary Leakage Tests for Farley Unit 2

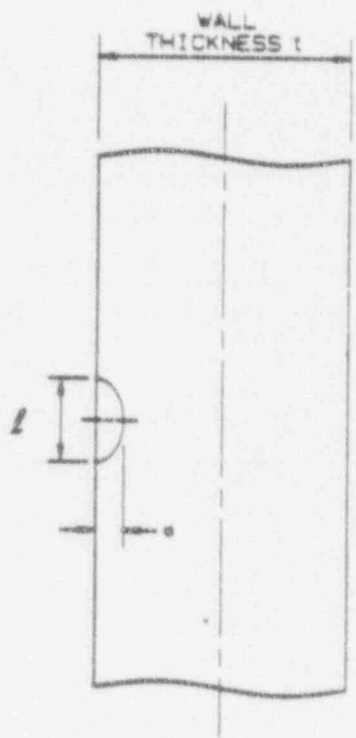
Figure A-3.1

Geometry and Terminology for Flaws at the Tubesheet - Stub Barrel

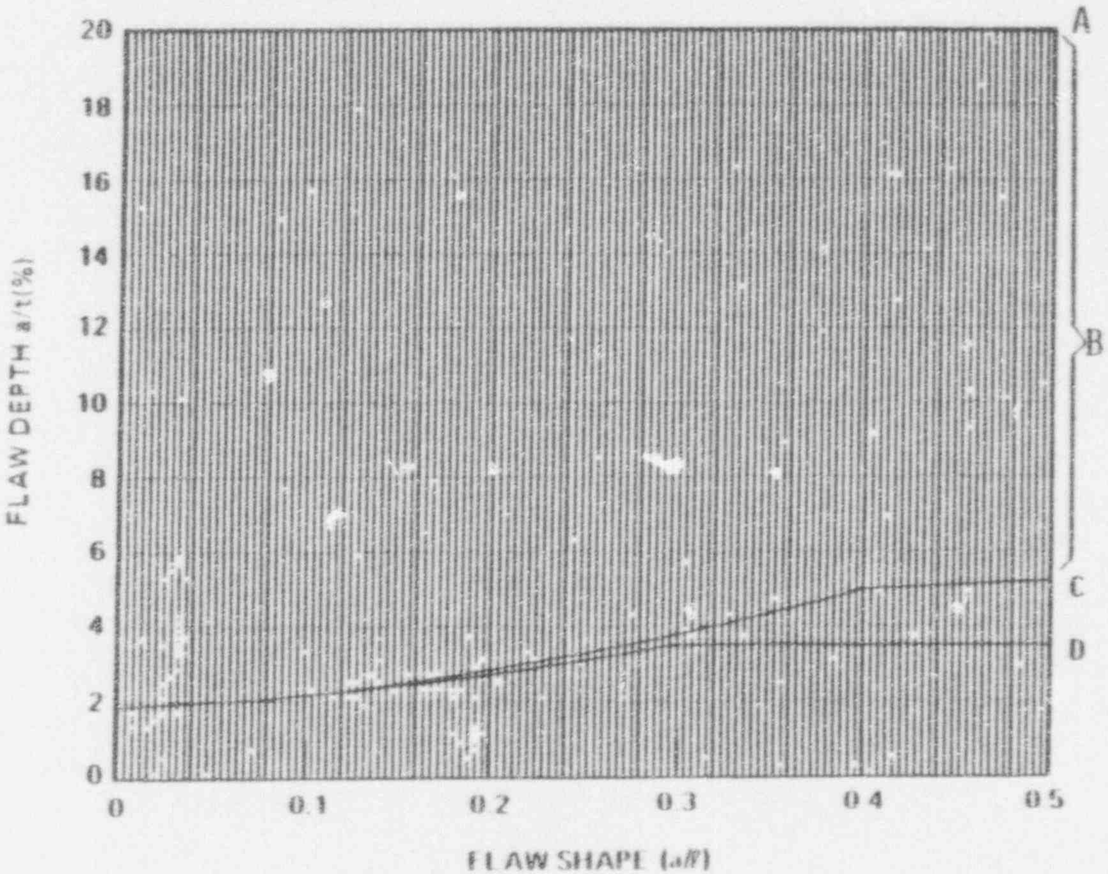



TYPICAL EMBEDDED FLAW INDICATION




TYPICAL SURFACE FLAW INDICATION




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-3.2 Flaw Evaluation Chart for the Tubesheet - Stub Barrel Weld

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

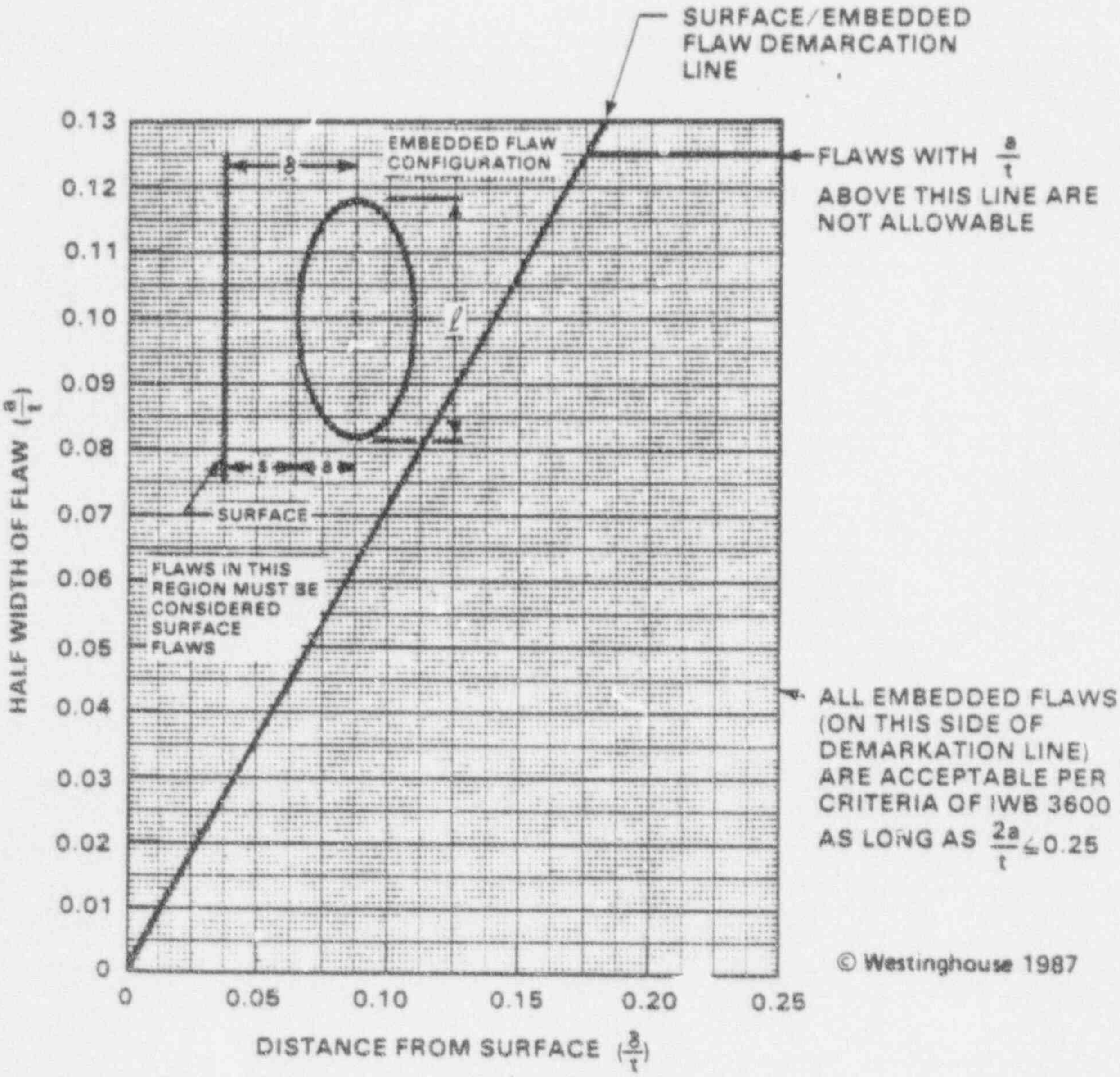



Figure A-3.3 Flaw Evaluation Chart for the Tubesheet to Stub Barrel Weld Region.

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

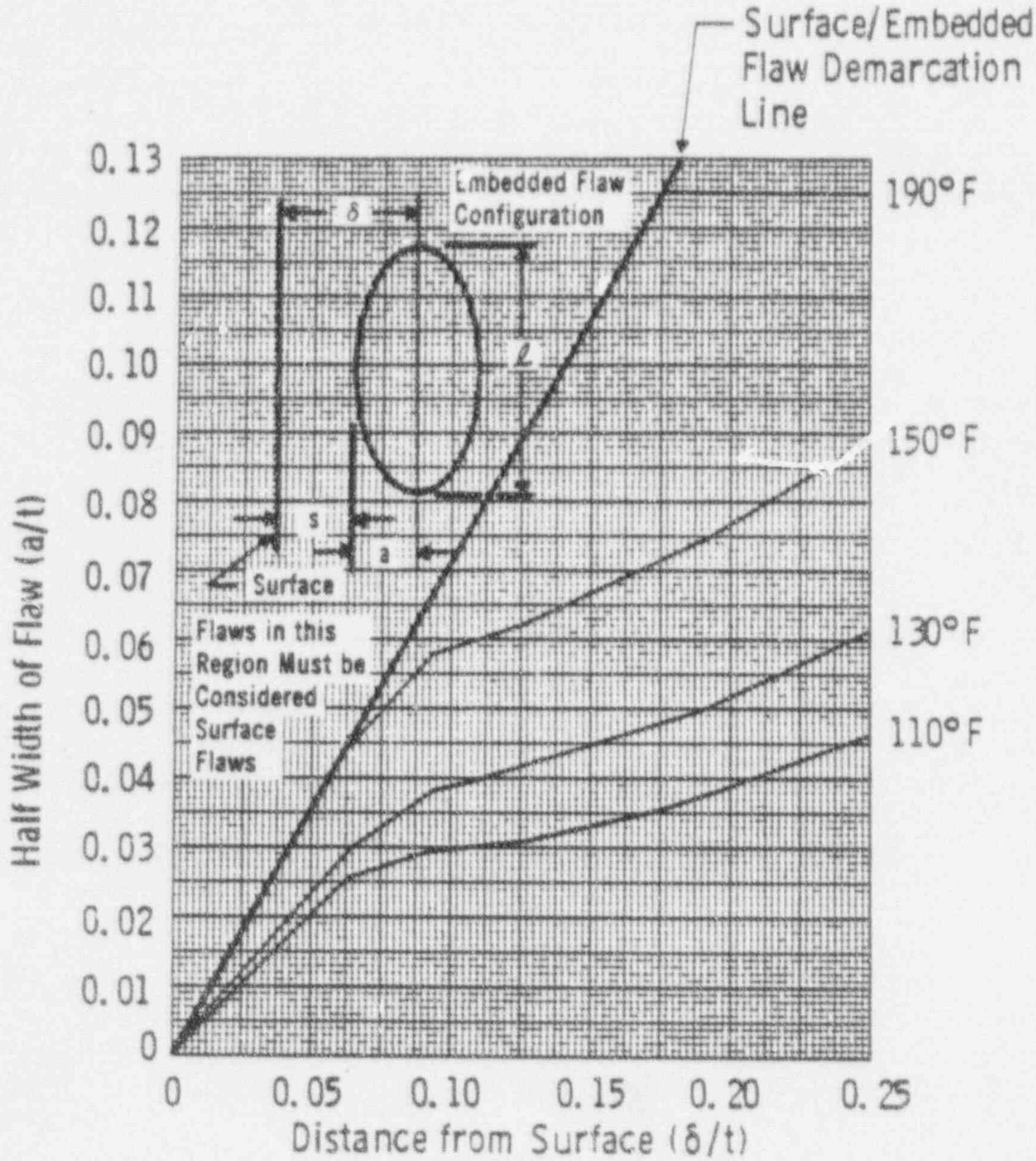



Figure A-3.4 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Unit 1

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

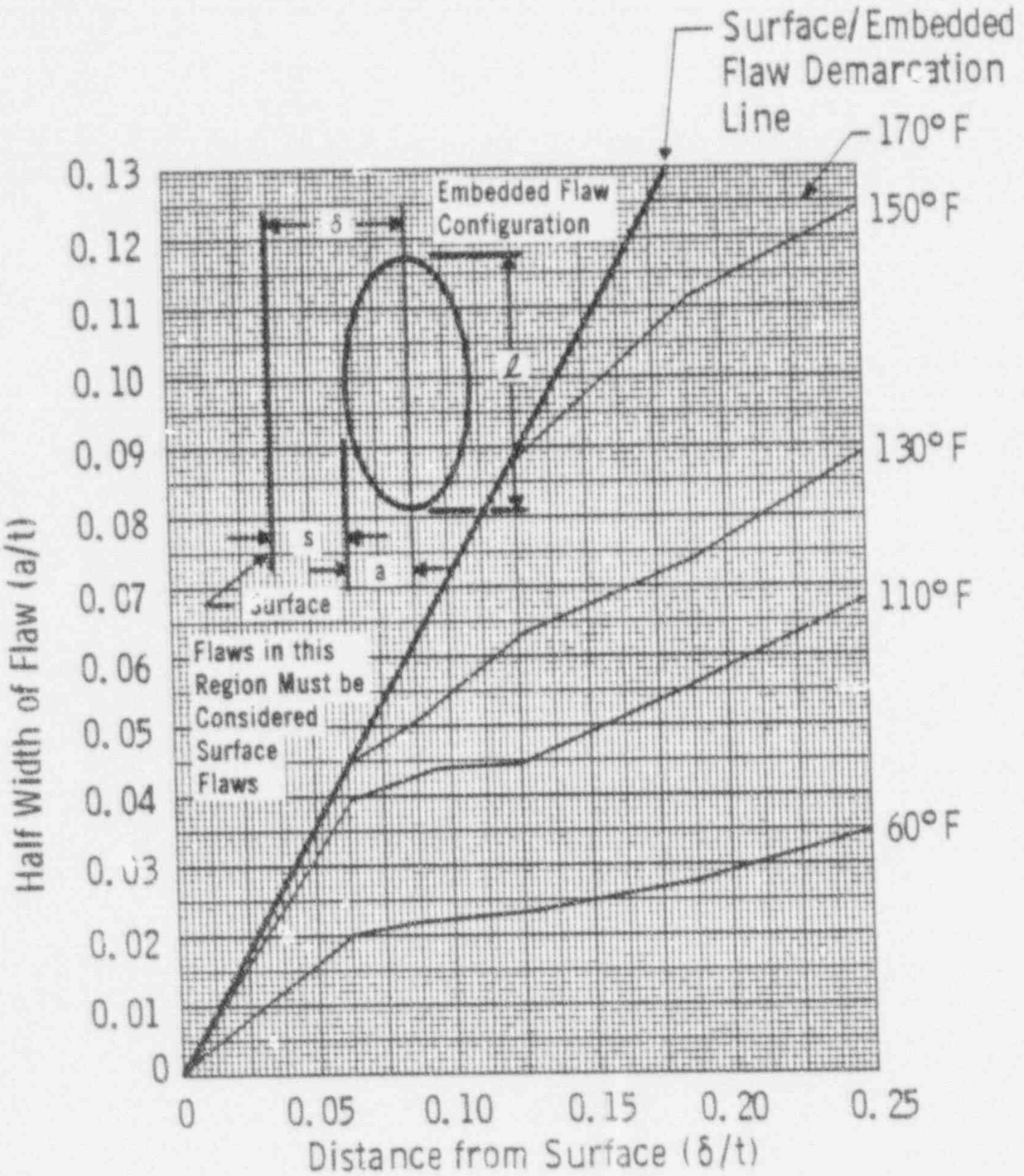



Figure A-3.5 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Unit 1

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

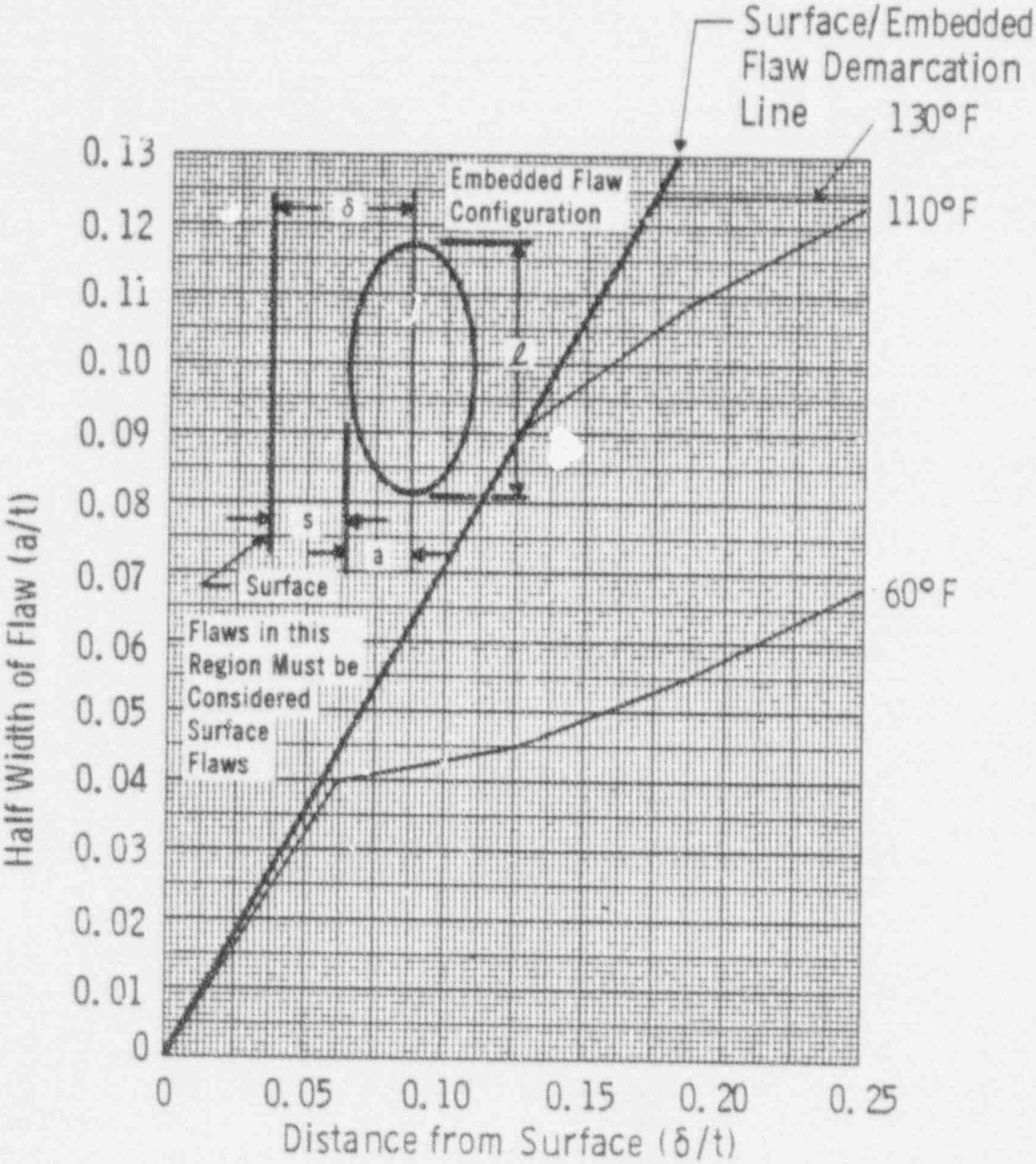



Figure A-3.6 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Unit 1

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

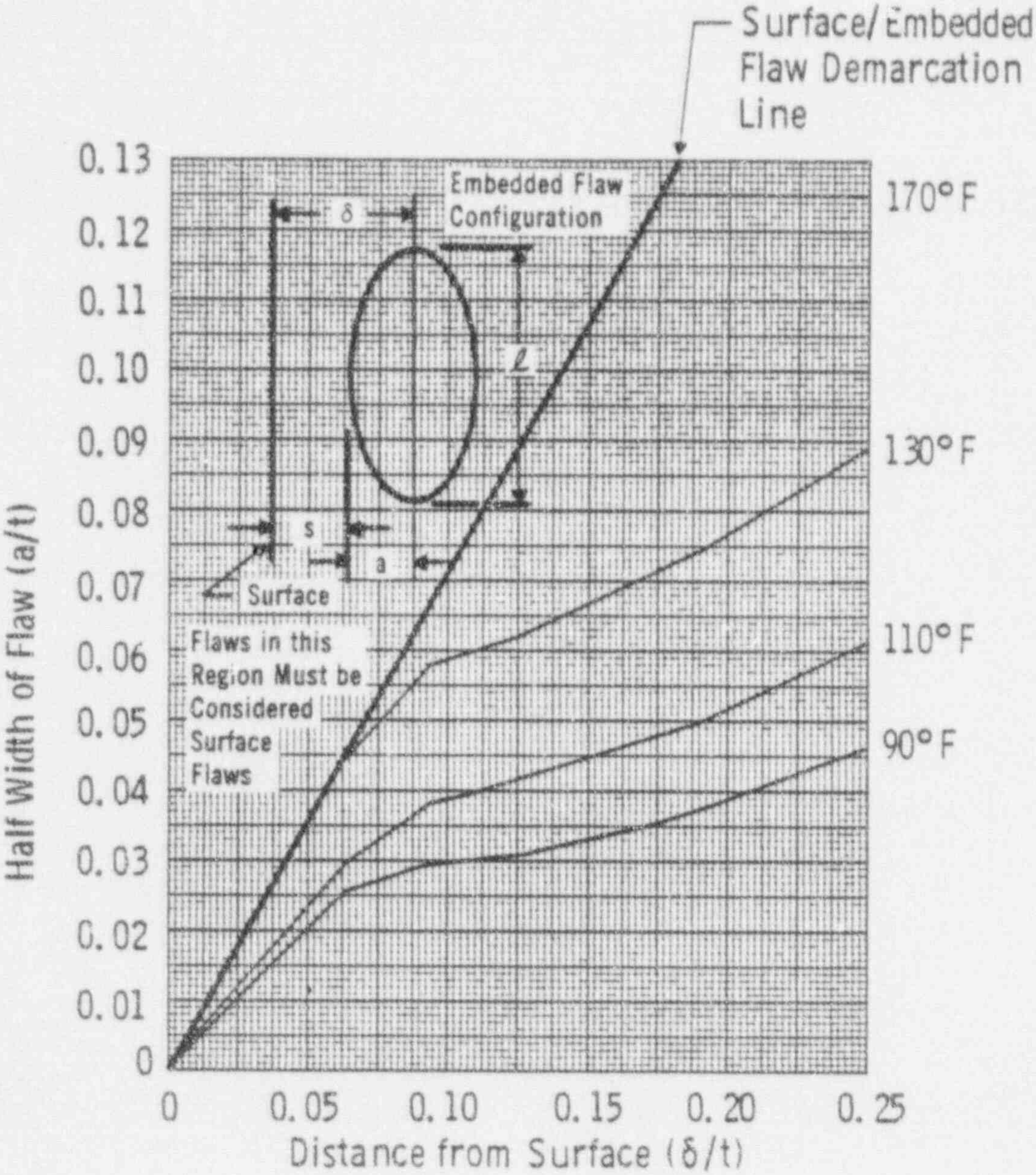



Figure A-3.7 Determination of Leakage Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Unit 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

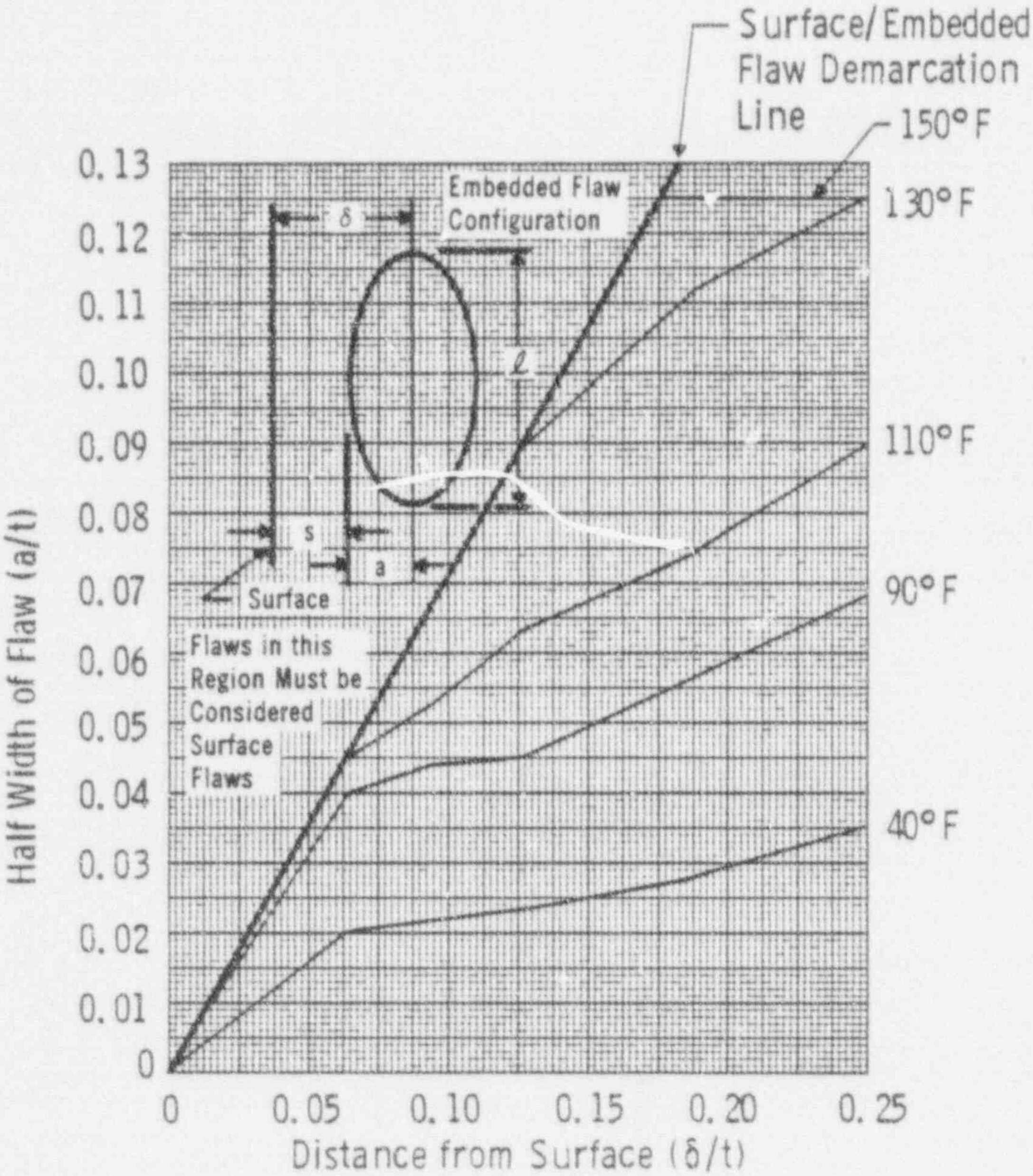



Figure A-3.8 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Unit 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

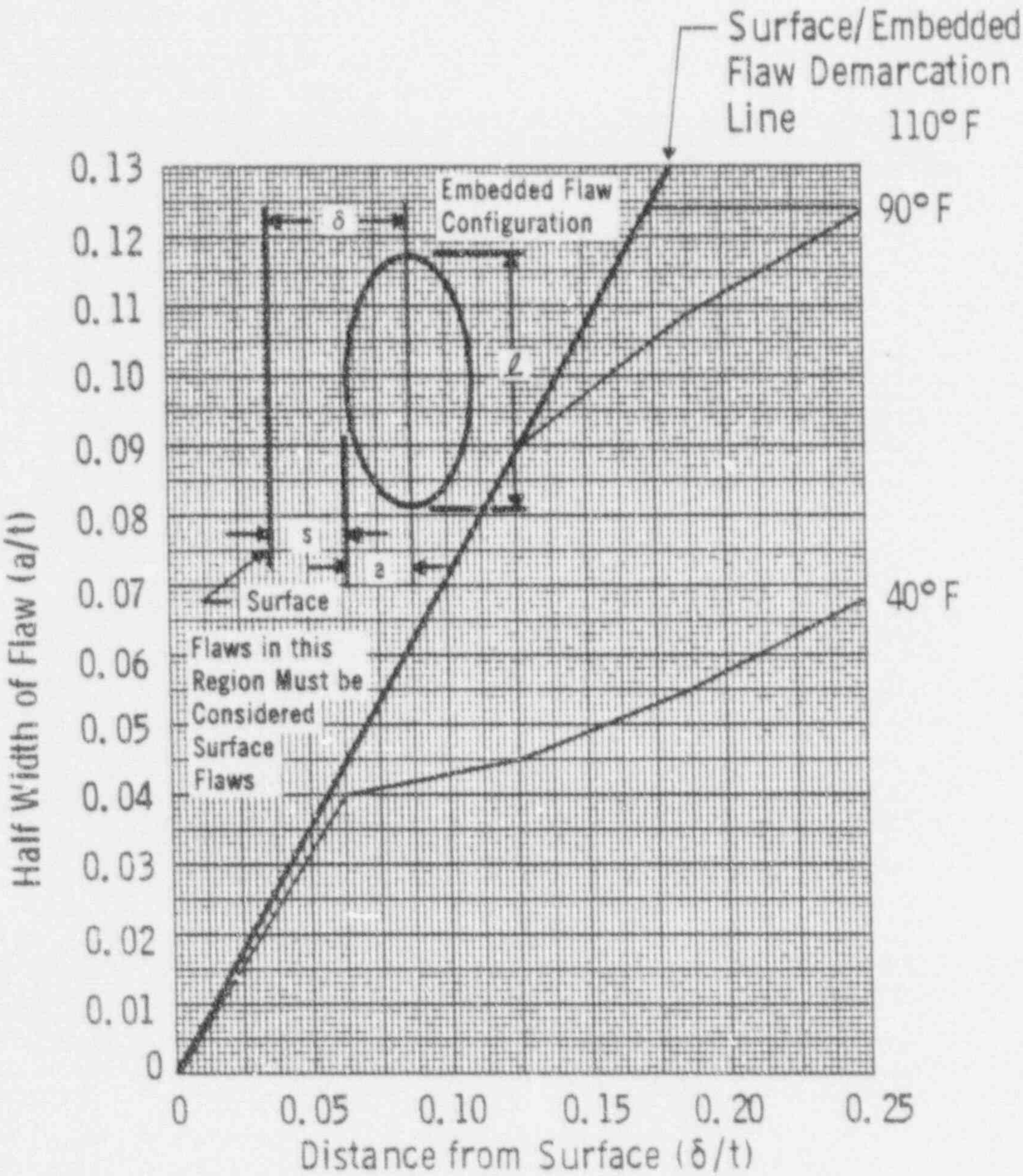



Figure A-3.9 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Unit 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-4 STUB BARREL WELDS - STEAM GENERATOR

### A-4.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-4.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.19")

The surface flaw evaluation charts for this region are listed below

Figure A-4.2 Surface Flaw Evaluation Chart for the Stub Barrel Intermediate Seam Weld

Figure A-4.3 Inside Surface Flaw Evaluation Chart for the Stub Barrel Longitudinal Seams

Figure A-4.4 Outside Surface Flaw Evaluation Chart for the Stub Barrel Longitudinal Seams

### A-4.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is depicted in figure A-4.1.

Basic Data:
$t$ 3.19 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

a = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth directions beyond which it must be considered a surface flaw, per Section XI characterization rules

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, a/t
- o Surface proximity parameter, $\delta$/t

The evaluation chart for embedded flaws is found in figure A-4.3.

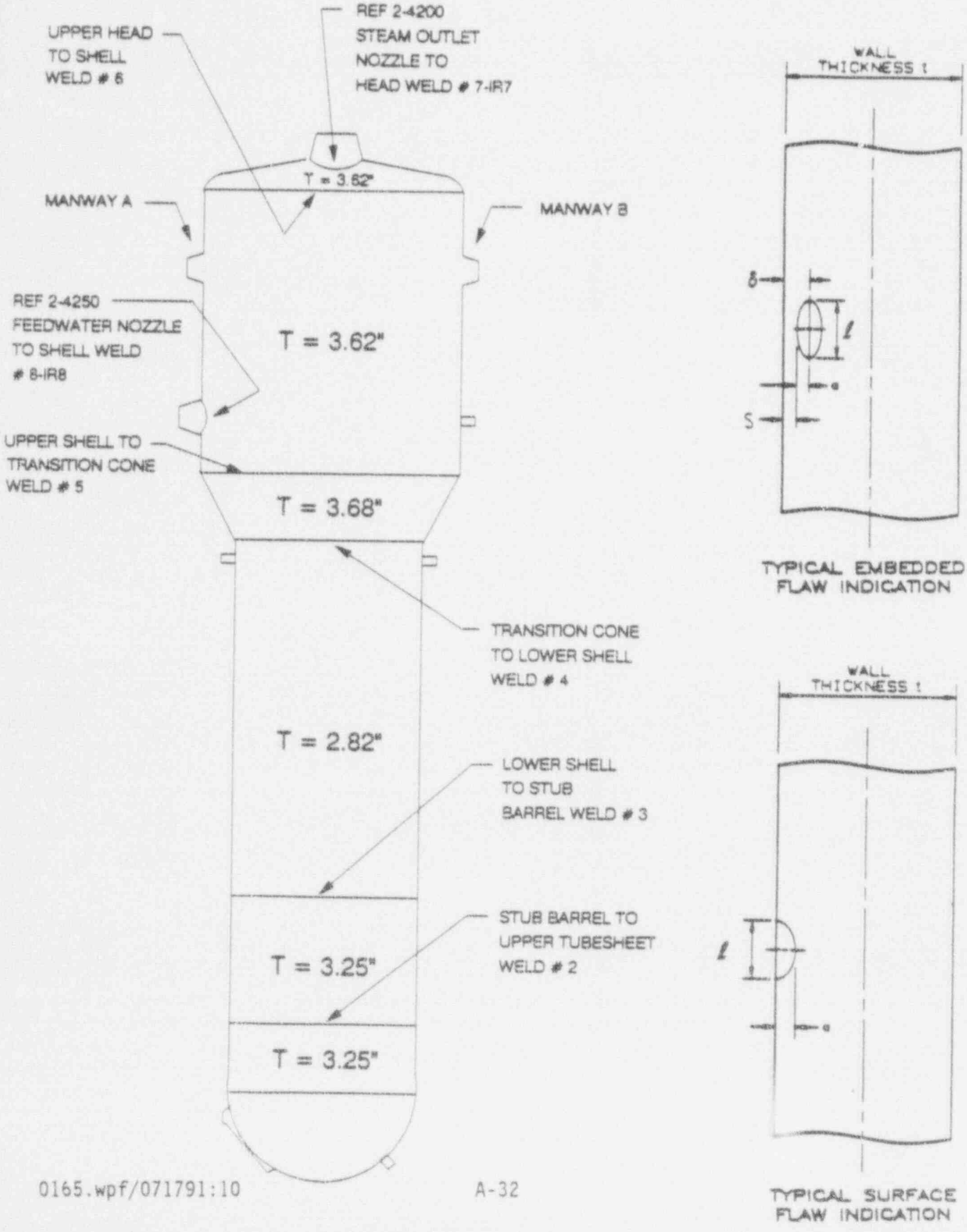
In view of figure A-4.5, an embedded flaw in this figure will be acceptable regardless of its size, shape, and location, as long as a/t < 0.125 in figure A-4.1. This determination can be made by plotting the indication parameters in the figure. If the plotted point falls below the diagonal line the indication is embedded, and is therefore acceptable. In addition to this chart, test temperature determination charts for both secondary hydro and leak tests have been provided.

The evaluation charts for embedded flaws are listed below:

Figure A-4.5 Embedded Flaw Evaluation Chart for Flaws in the Stub Barrel Welds

Figure A-4.1

Geometry and Terminology for Flaws at the Stub Barrel Welds



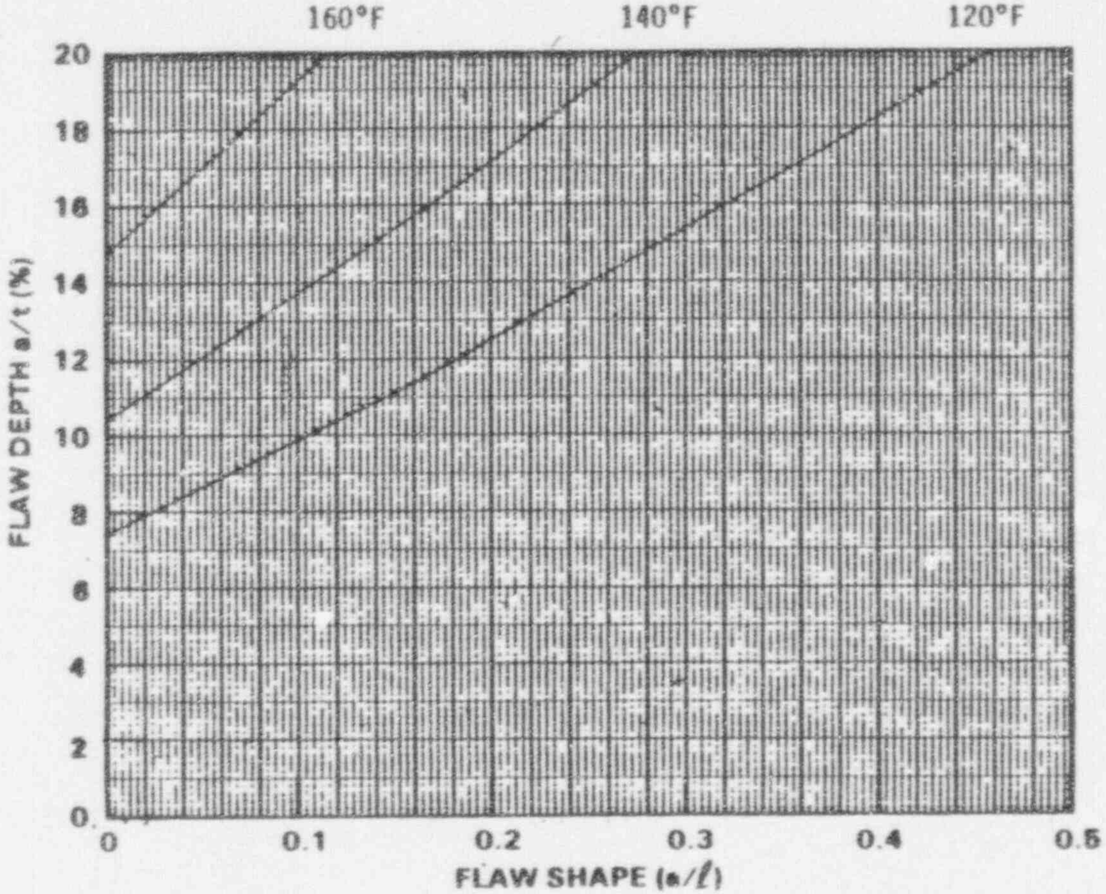
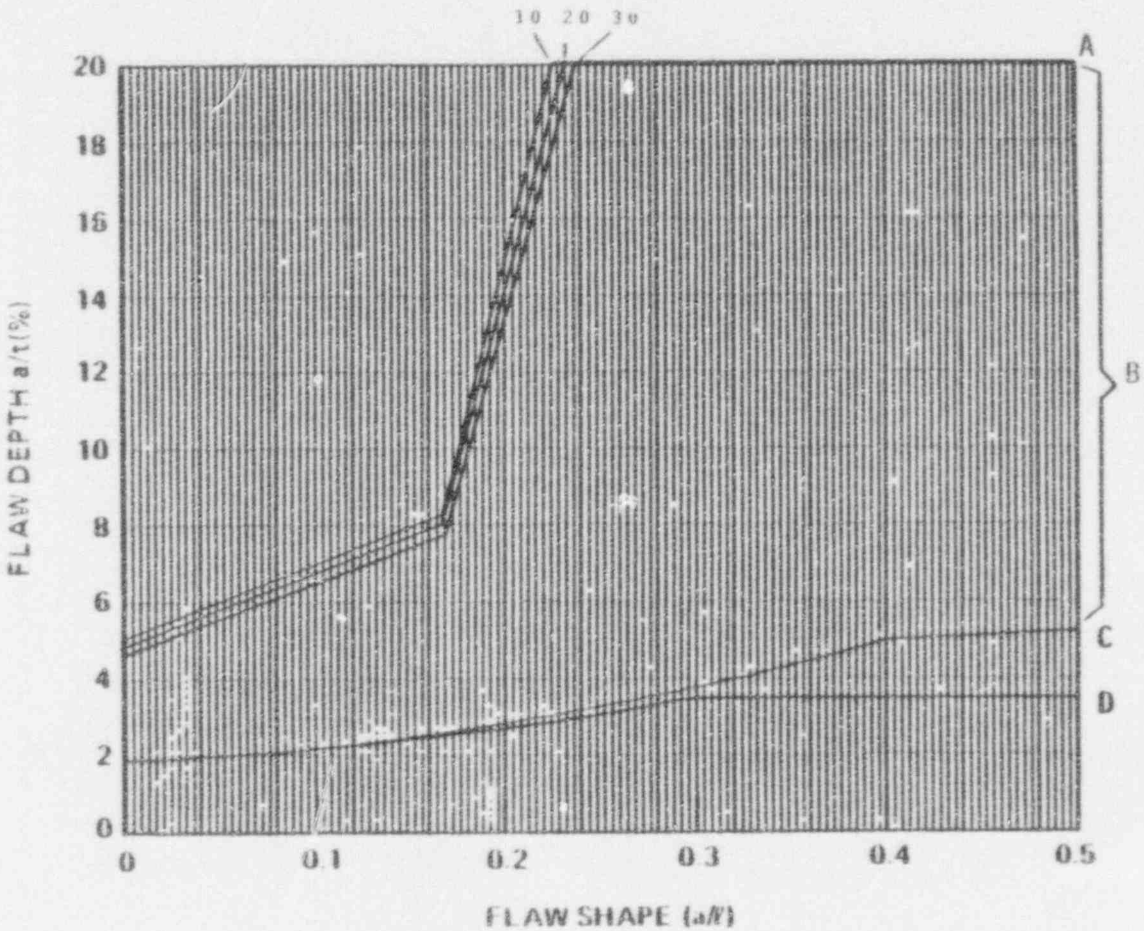



Figure A-4.2 Flaw Evaluation Chart for the Stub Barrel Region

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

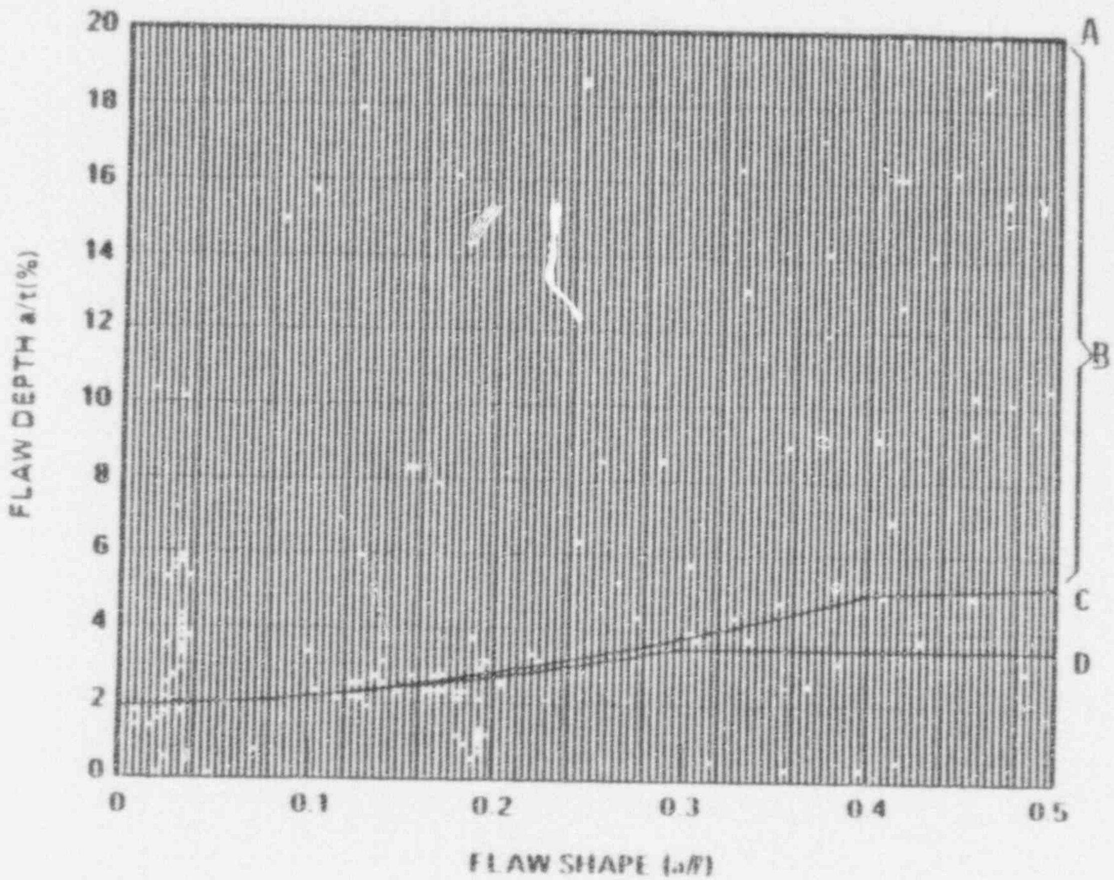
C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-4.3 Flaw Evaluation Chart for the Stub Barrel Region

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-4.4 Flaw Evaluation Chart for the Stub Barrel Region

___ Inside Surface _X_ Surface Flaw _X_ Longitudinal Flaw

_X_ Outside Surface ___ Embedded Flaw _X_ Circumferential Flaw

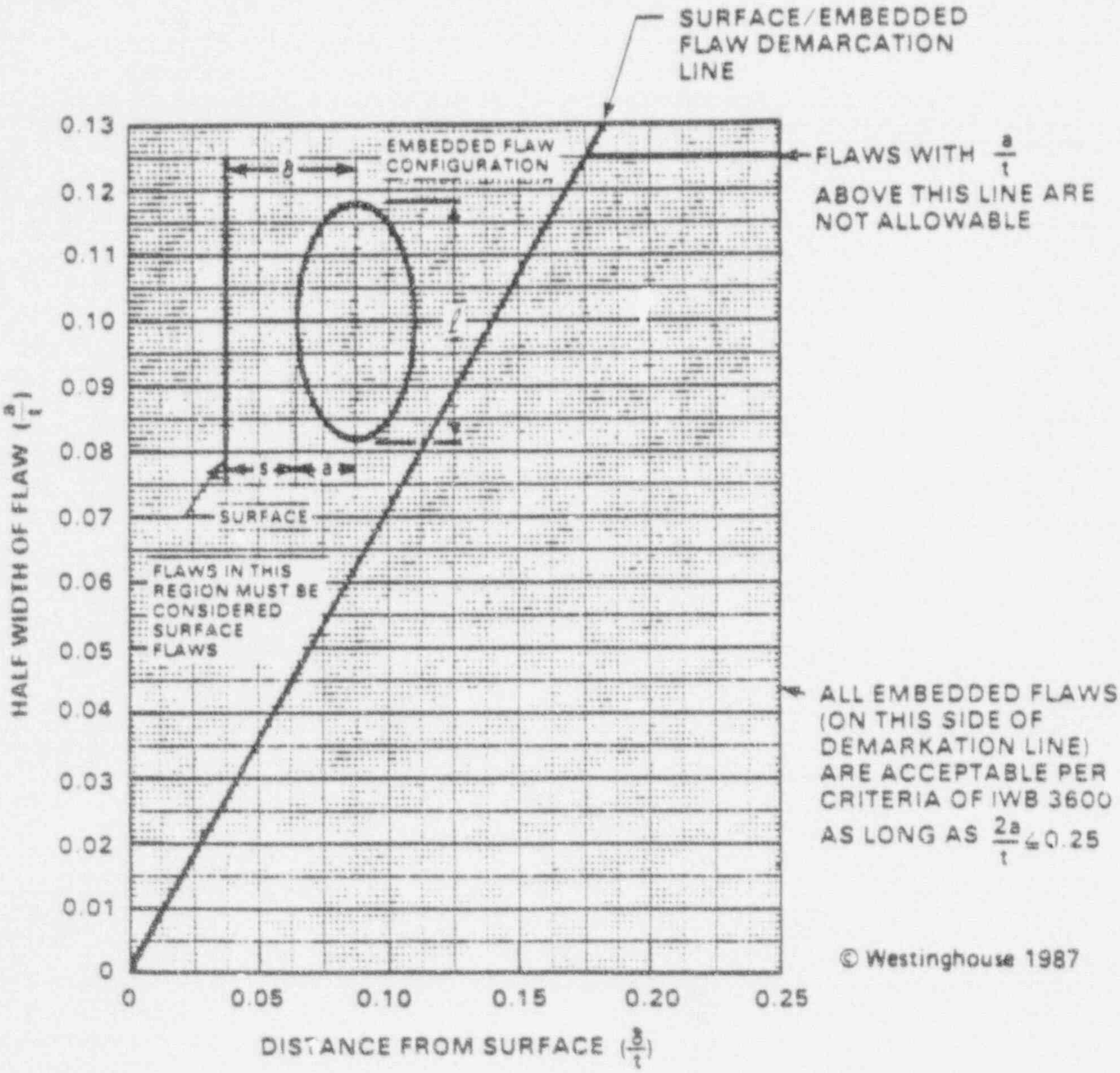



Figure A-4.5 Flaw Evaluation Chart for the Stub Barrel Region

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

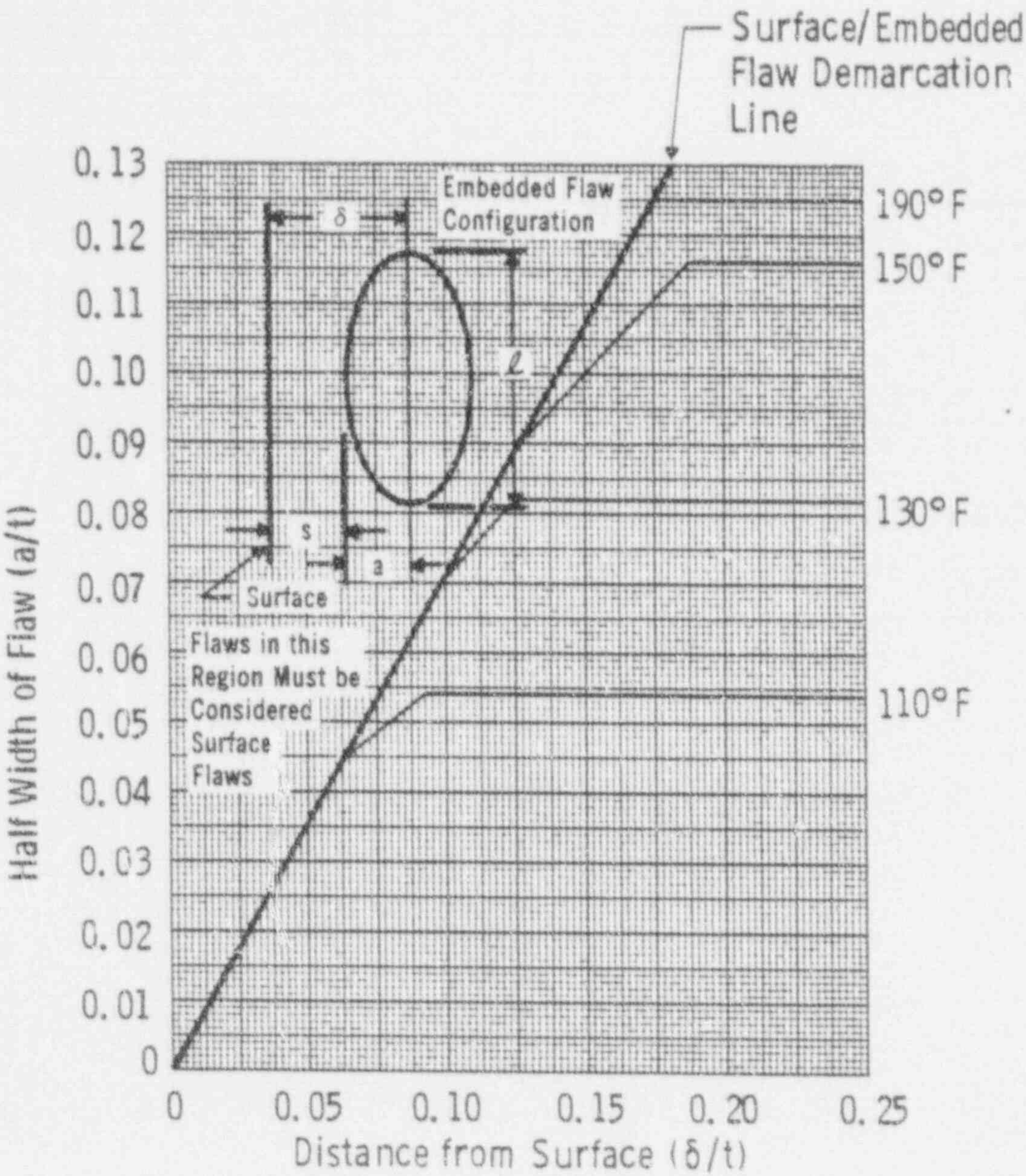



Figure A-4.6 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

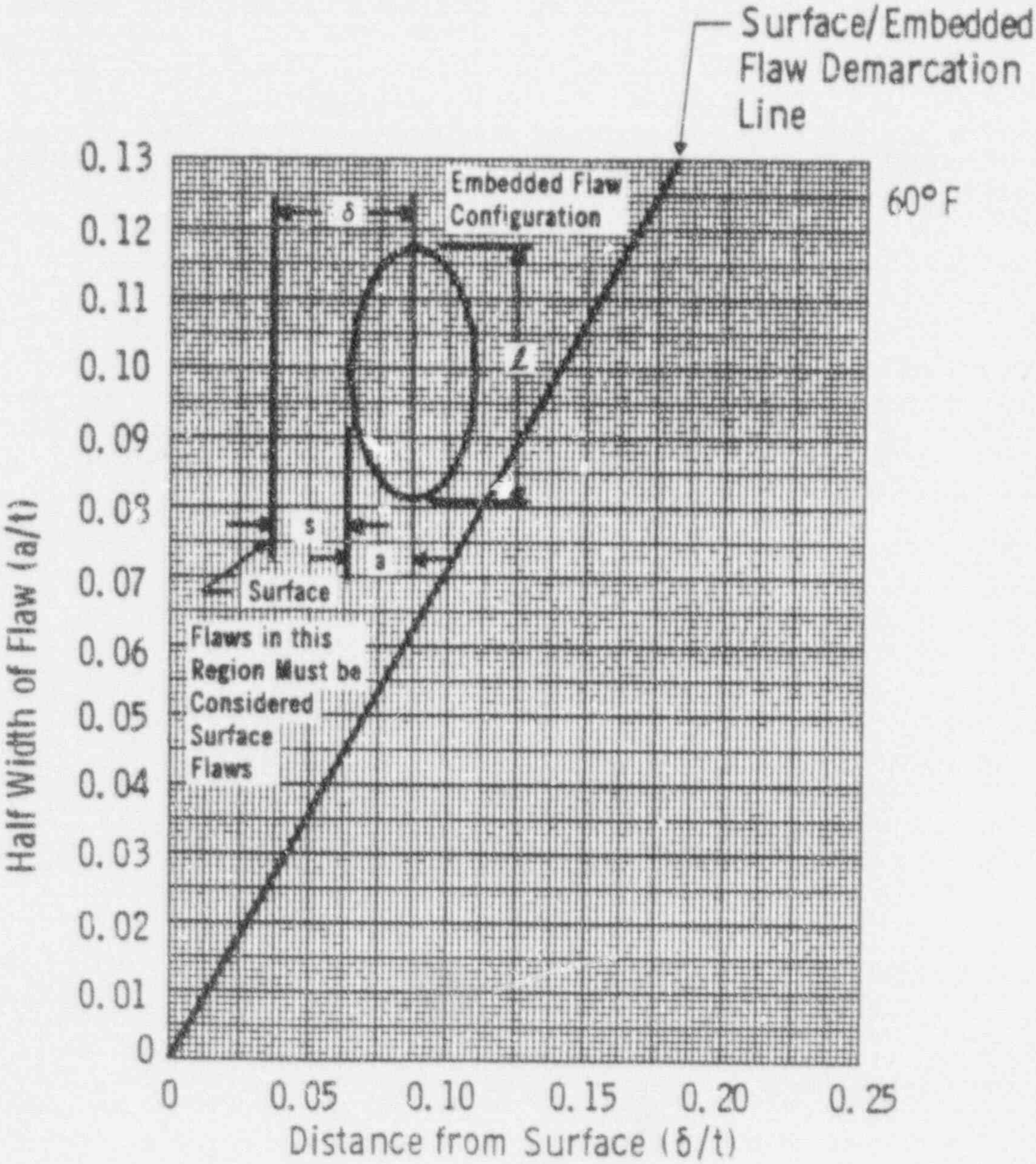



Figure A-4.7 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356, 1085, 750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

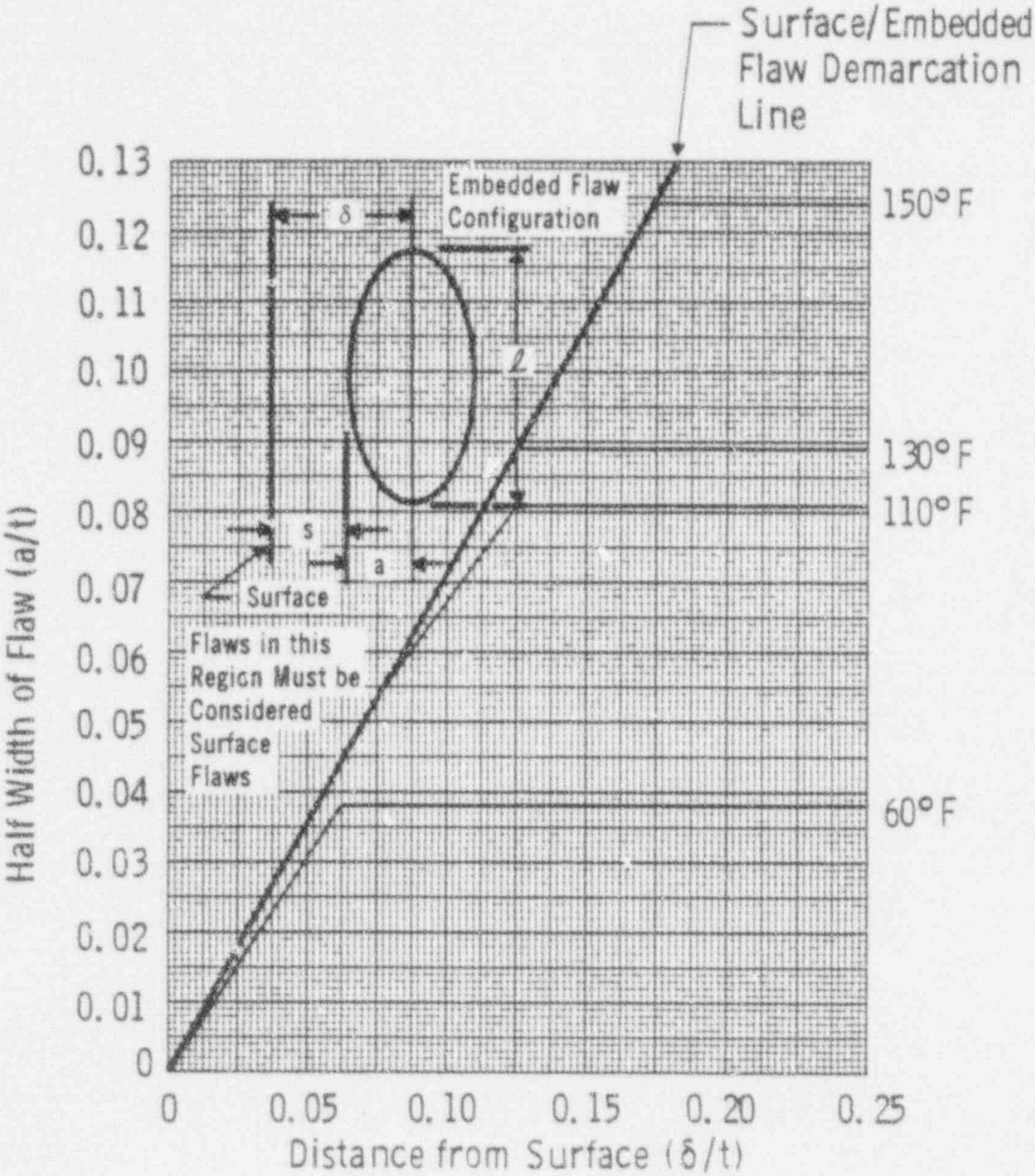



Figure A-4.8 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

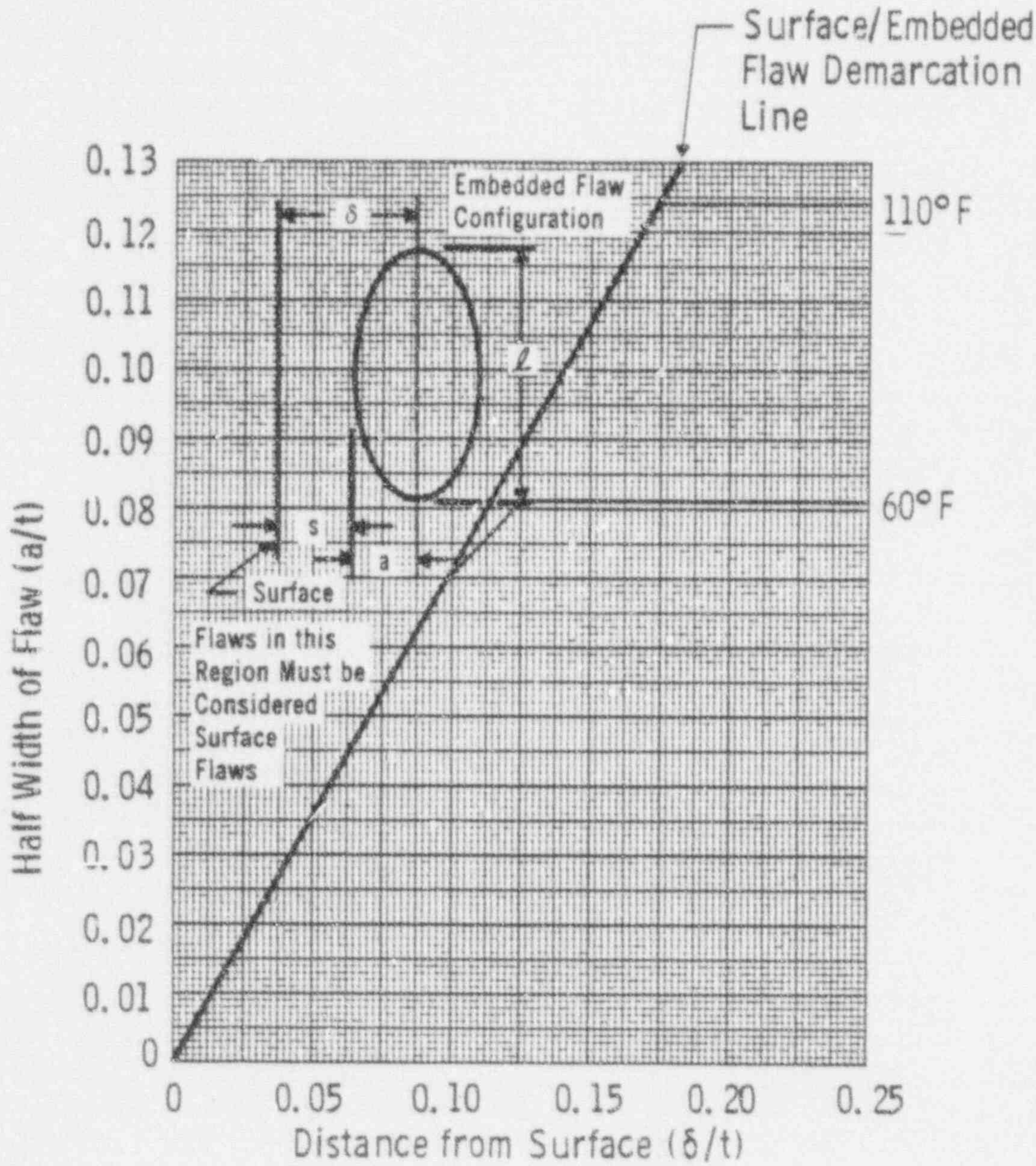



Figure A-4.9 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

## A-5 LOWER SHELL-CONE WELD - STEAM GENERATOR

### A-5.1 SURFACE FLAWS

The geometry and terminology for surface flaws in the lower shell - cone weld region is depicted in figure A-5.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 2.84")

The surface flaw evaluation charts for this region are listed below:

Figure A-5.2 Surface Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Lower Shell-Cone Weld

Figure A-5.3 Surface Flaw Evaluation Chart for Circumferential Flaws at the Outside Surface of Lower Shell-Cone Weld

A-5.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is depicted in figure A-5.1.

Basic Data:

$t$ = 3.19 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth directions beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

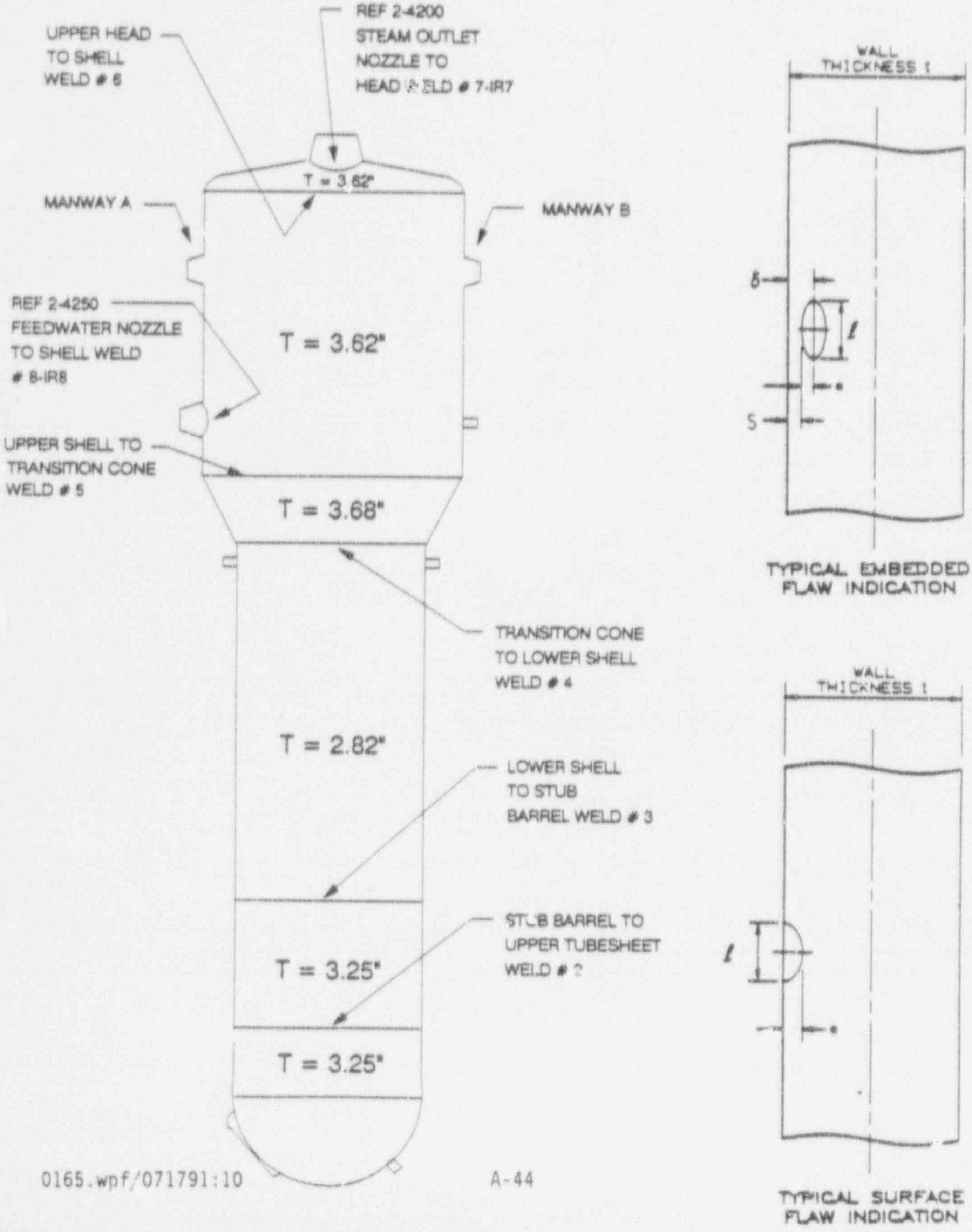
- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

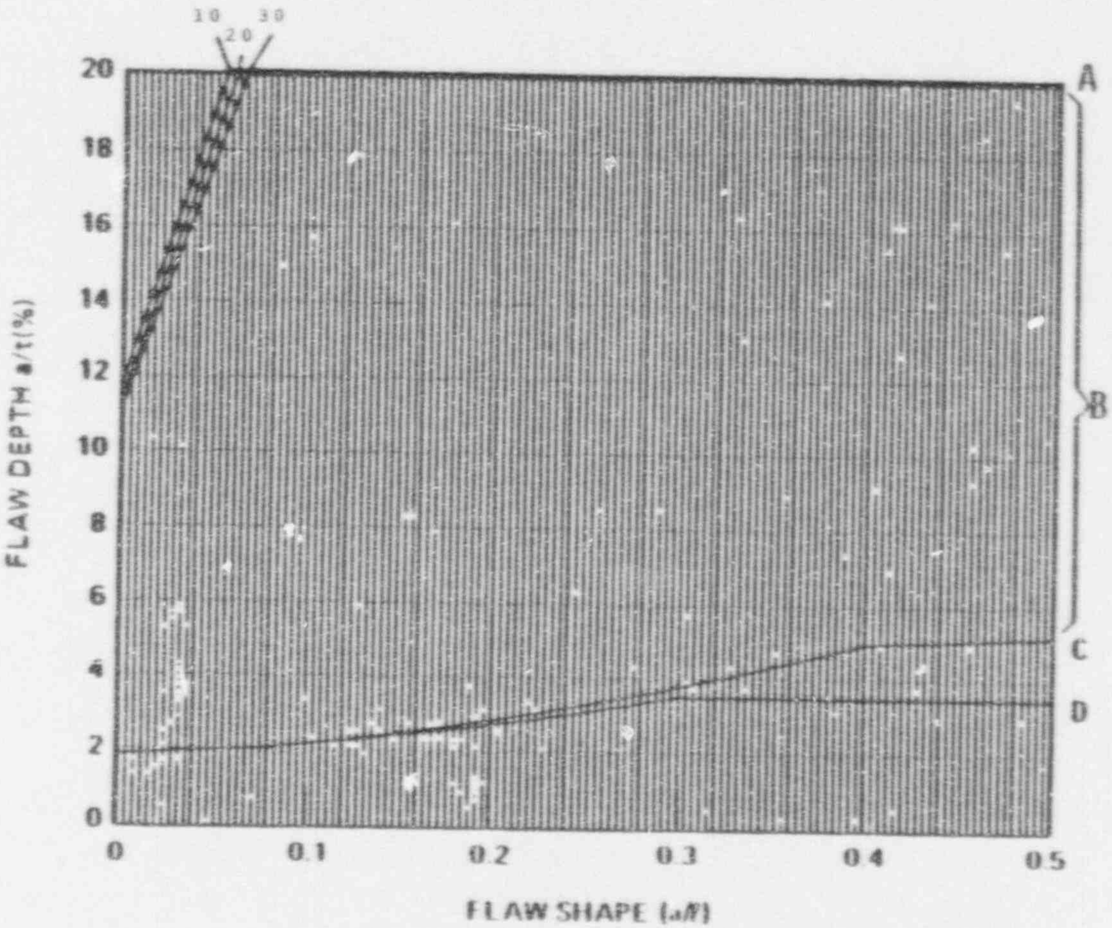
The evaluation chart for embedded flaws is found in figure A-5.4.

In view of figure A-5.4, all embedded flaws which meet the criterion $a/t < 0.125$ will be acceptable regardless of their size, shape, and location.

The embedded flaw evaluation charts for the lower shell-core weld are as follows:

Figure A-5.1
Geometry and Terminology for Flaws at Lower Shell-Cone Weld






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

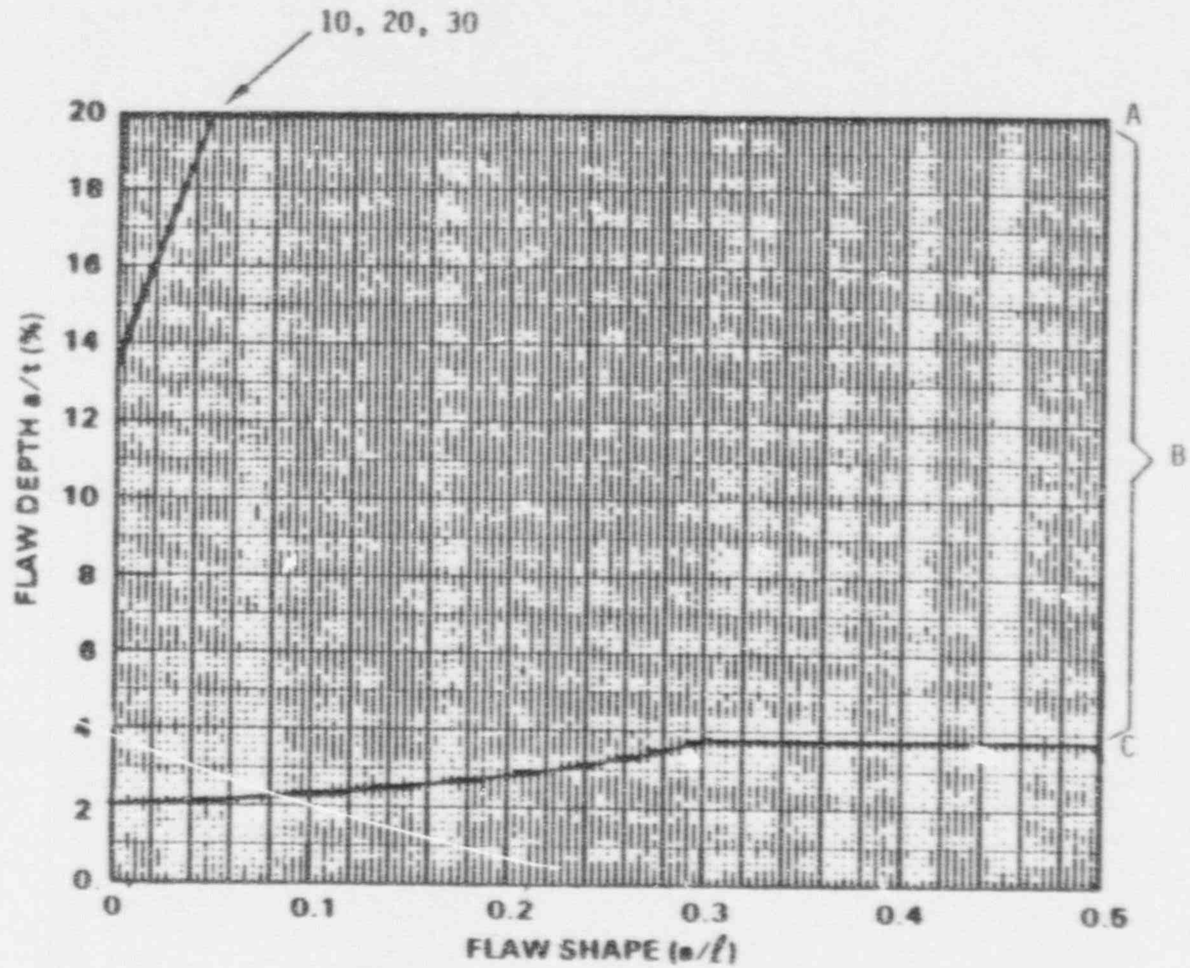
C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-5.2 Flaw Evaluation Chart for the Lower Shell-Cone Weld of the Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable.

Figure A-5.3 Flaw Evaluation Chart for the Lower Shell-Cone Weld of the Steam Generator

___ Inside Surface  X Surface Flaw  ___ Longitudinal Flaw

X Outside Surface  ___ Embedded Flaw  X Circumferential Flaw

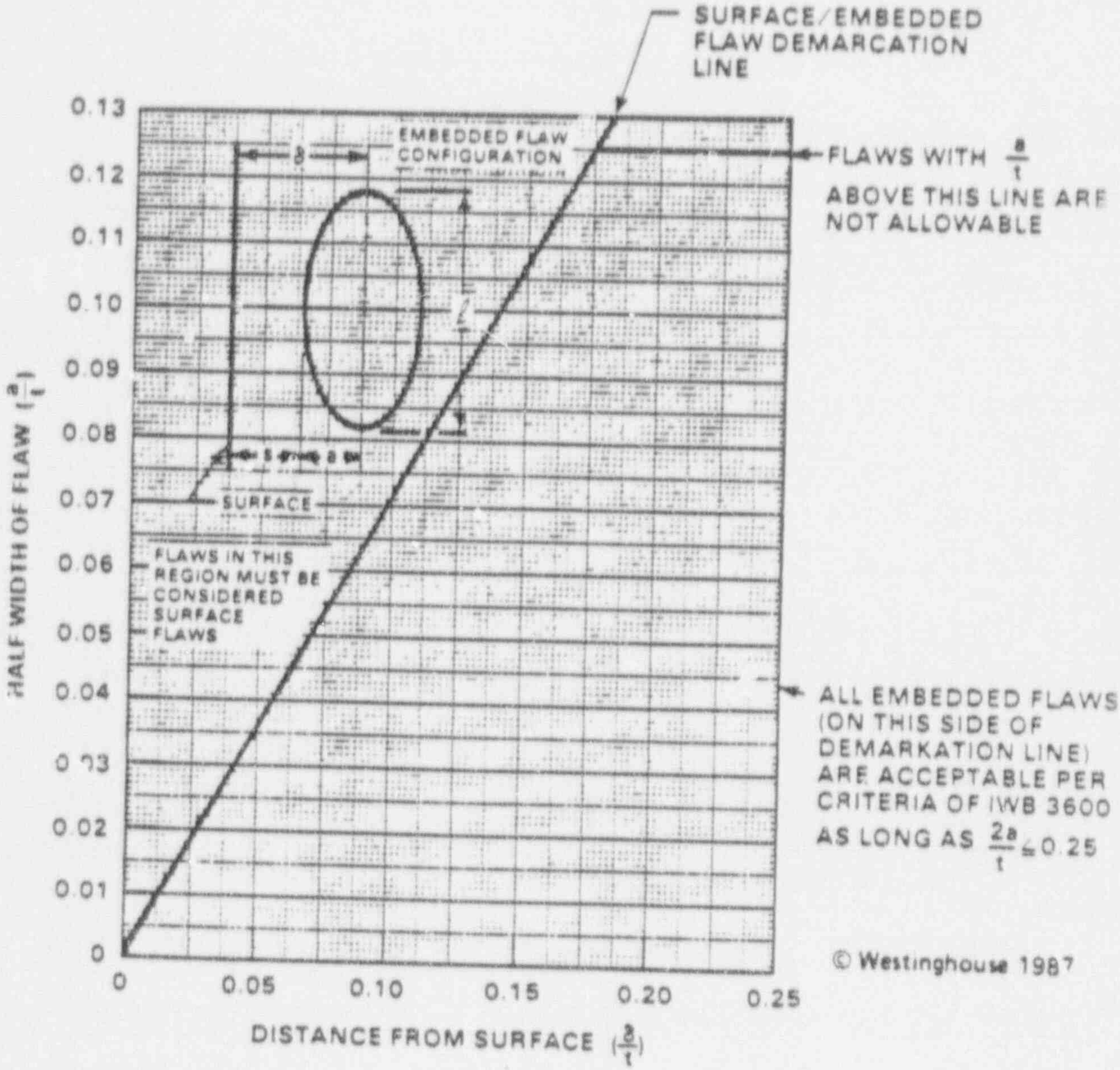



Figure A-5.4 Embedded Flaw Evaluation Chart for the Lower Shell-Cone Weld of the Steam Generator

| | | |
|---|---|---|
| X Inside Surface | __ Surface Flaw | __ Longitudinal Flaw |
| X Outside Surface | X Embedded Flaw | X Circumferential Flaw |

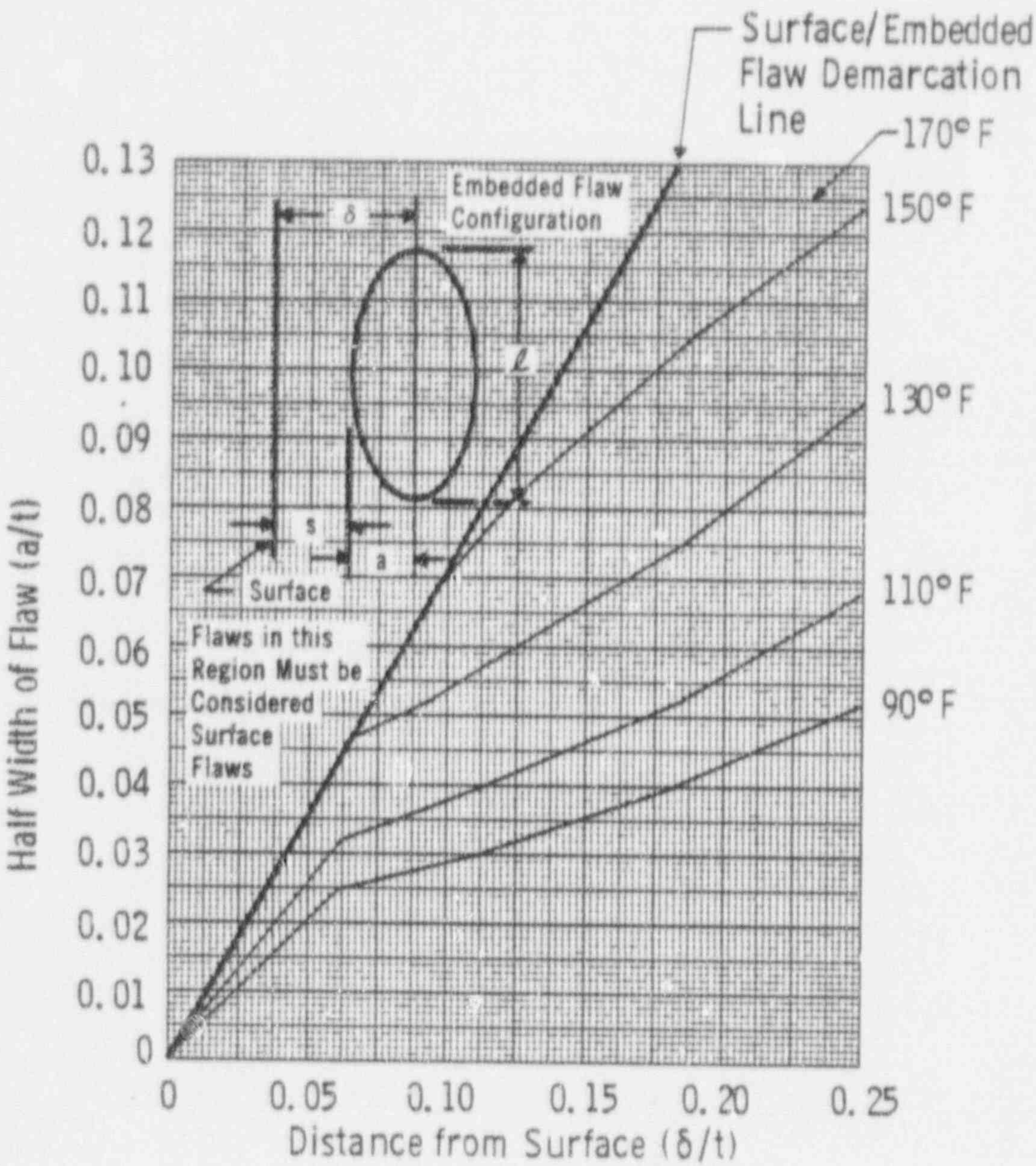



Figure A-5.5 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| ___ | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

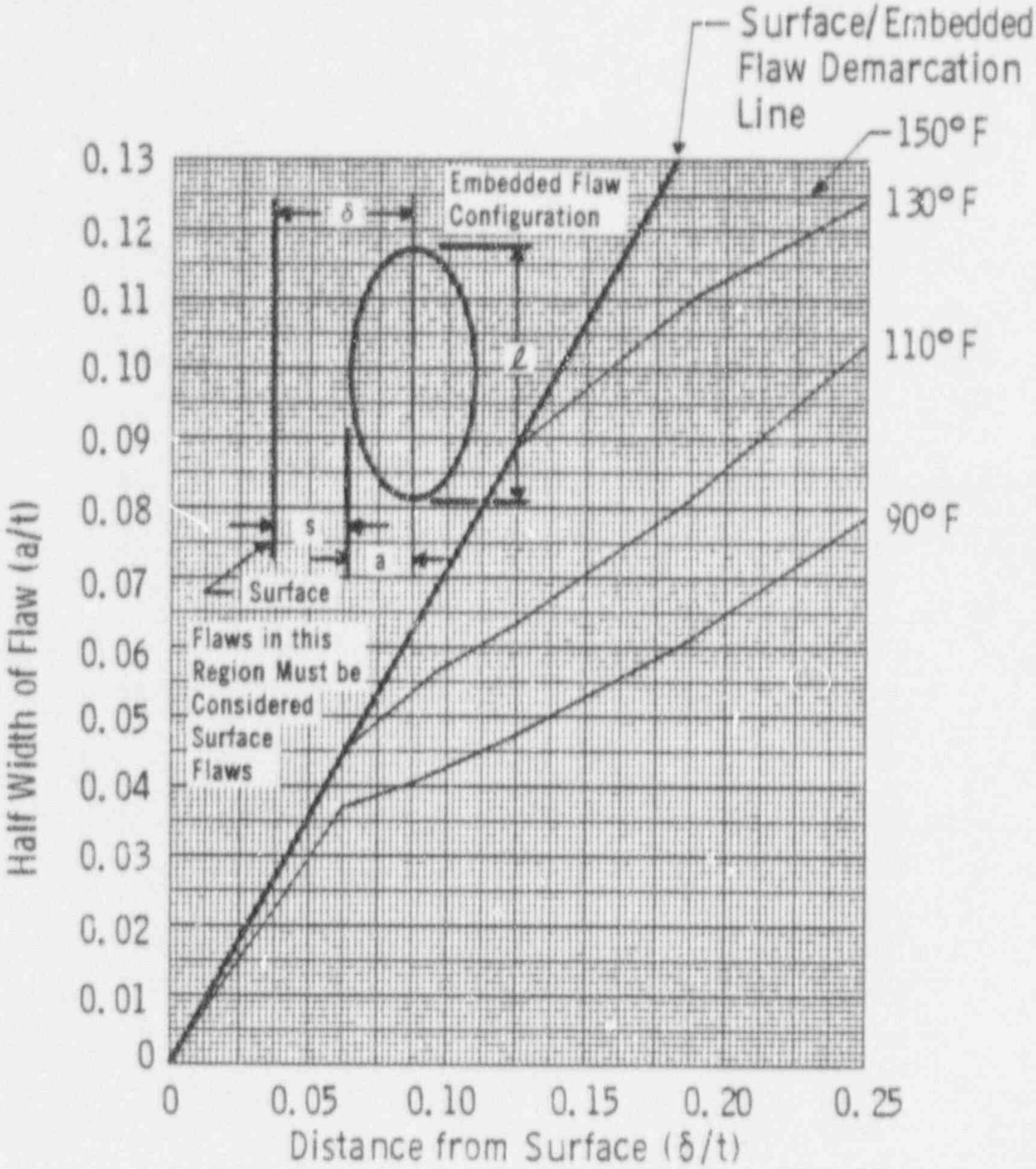



Figure A-5.6 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| ___ | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

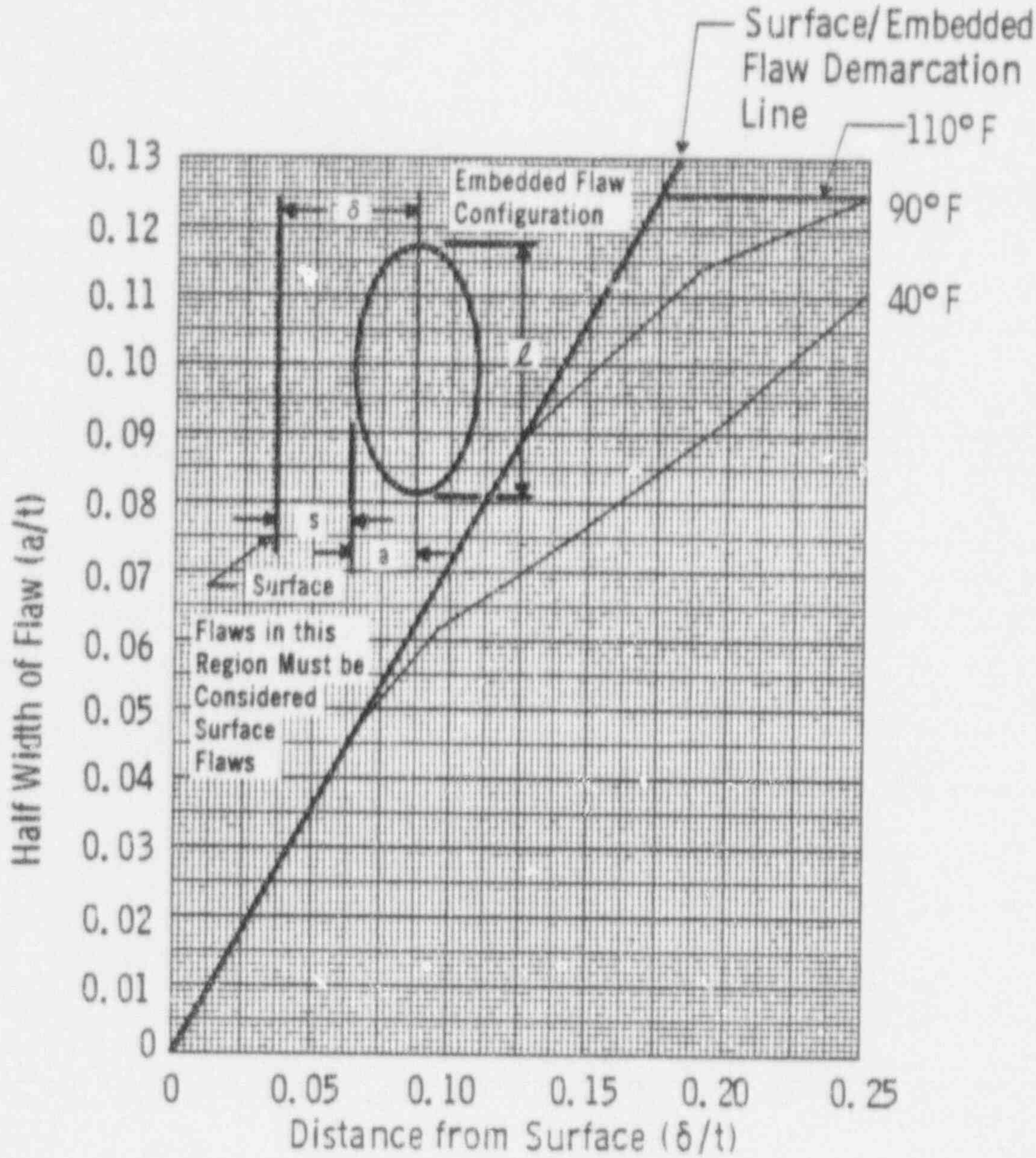



Figure A-5.7 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| ___ | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-6 UPPER SHELL-CONE WELD - STEAM GENERATOR

### A-6.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-6.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.62")

The surface flaw evaluation charts for this region are listed below:

Figure A-6.2 Surface Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Upper Shell-Cone Weld of the Steam Generator

Figure A-6.3 Surface Flaw Evaluation Chart for Circumferential Flaws at the Outside Surface of the Upper Shell-Cone Weld of the Steam Generator

A-6.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is depicted in figure A-6.1.

Basic Data:

$t$ = 3.62 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

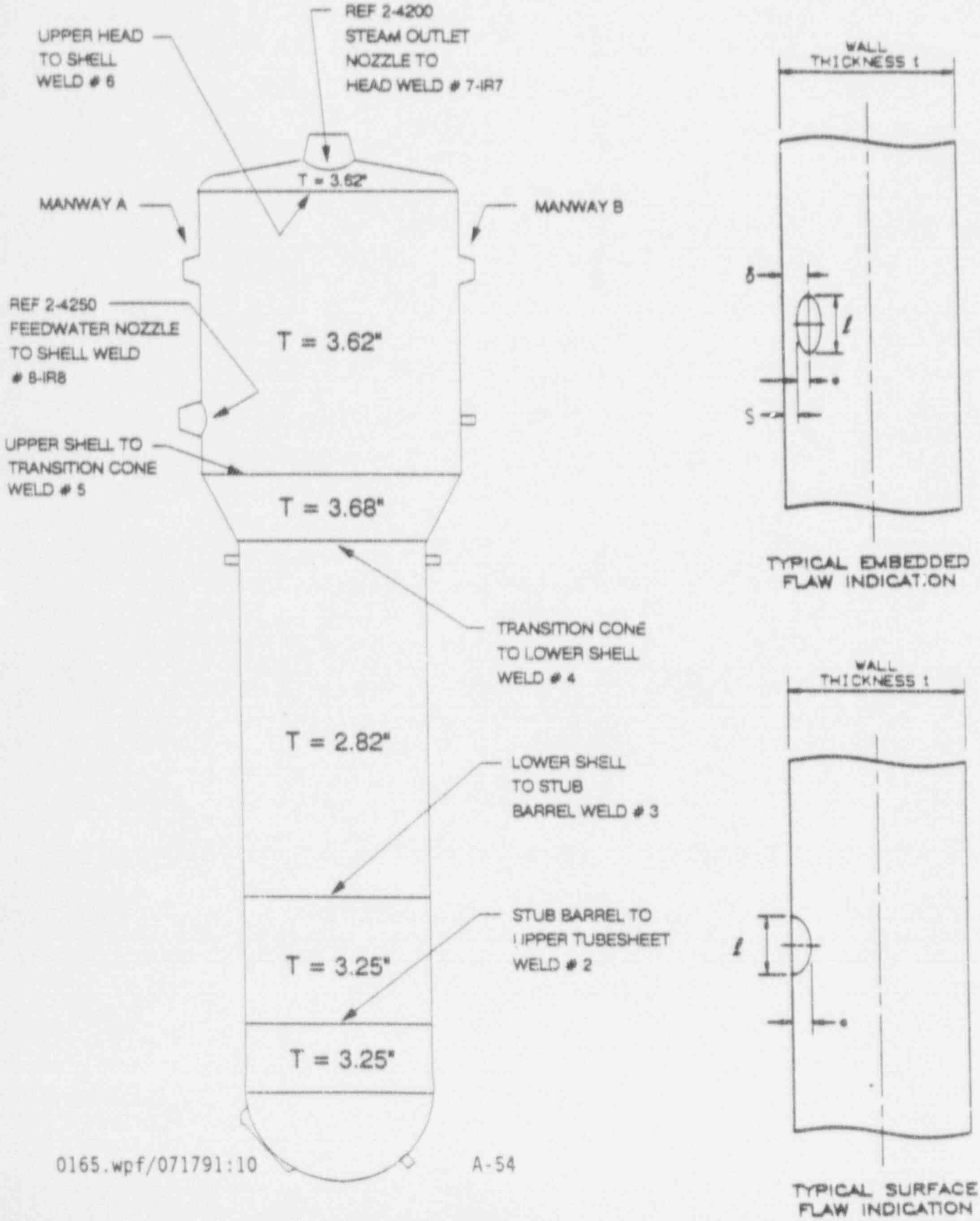
The evaluation charts for embedded flaws for this region are listed below:

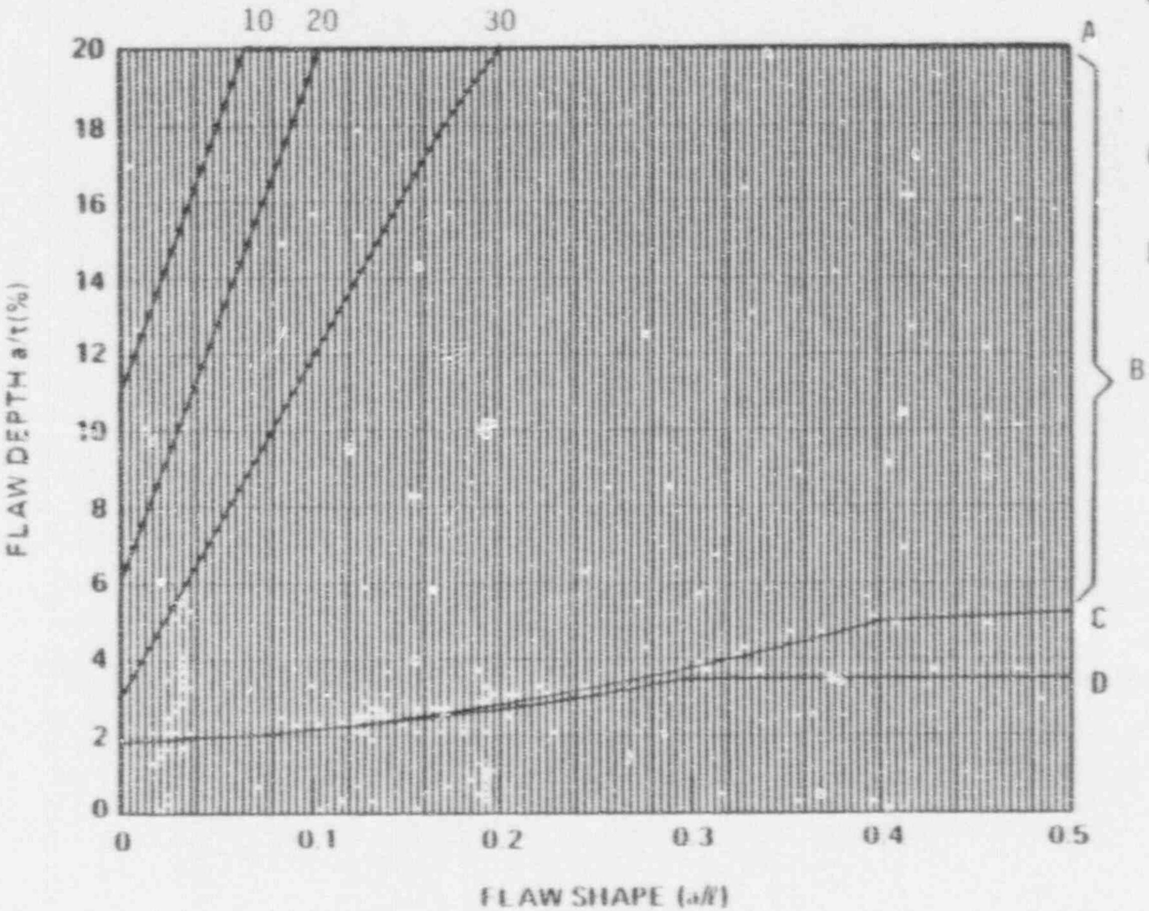
Figure A-6.4 Embedded Flaw Evaluation Chart for Circumferential Flaws in the Upper Shell-Cone Weld of the Steam Generator

Figure A-6.5 Test Temperature Determination Chart for Embedded Flaws in the Upper Shell-Cone Weld of the Steam Generator for Secondary Hydro Test for Farley Units 1 and 2

| | |
|---|---|
| Figure A-6.6 through Figure A-6.7 | Test Temperature Determination Chart for Embedded Flaws in the Upper Shell-Cone Weld of the Steam Generator for Secondary Leakage Tests |

Figure A-6.1
Geometry and Terminology or Flaws at Upper Shell Cone
Weld - Steam Generator






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

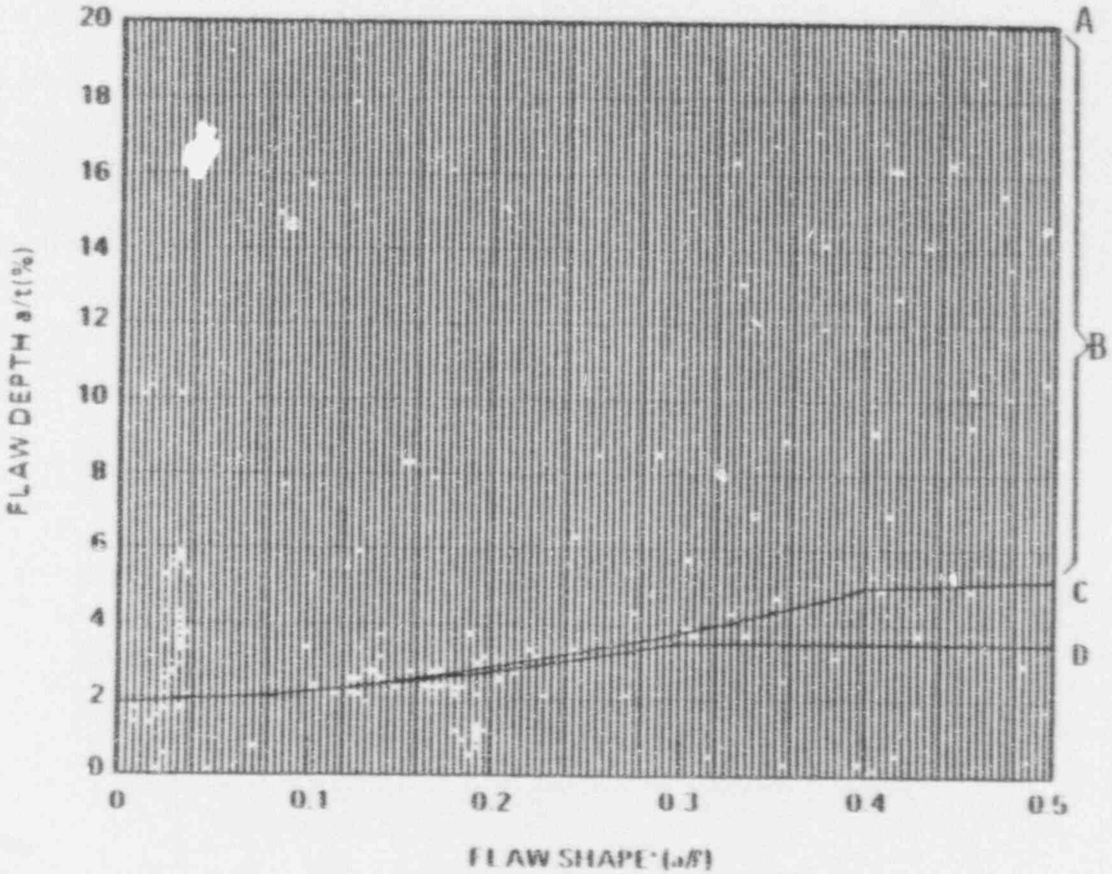
D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-6.2 Flaw Evaluation Chart for the Upper Shell-Cone Weld - Steam Generator

X Inside Surface X Surface Flaw ___ Longitudinal Flaw

___ Outside Surface ___ Embedded Flaw X Circumferential Flaw




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allow[illegible] since 1983 Winter Adde[illegible]m.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-6.3 Flaw Evaluation Chart for the Upper Shell-Cone Weld - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

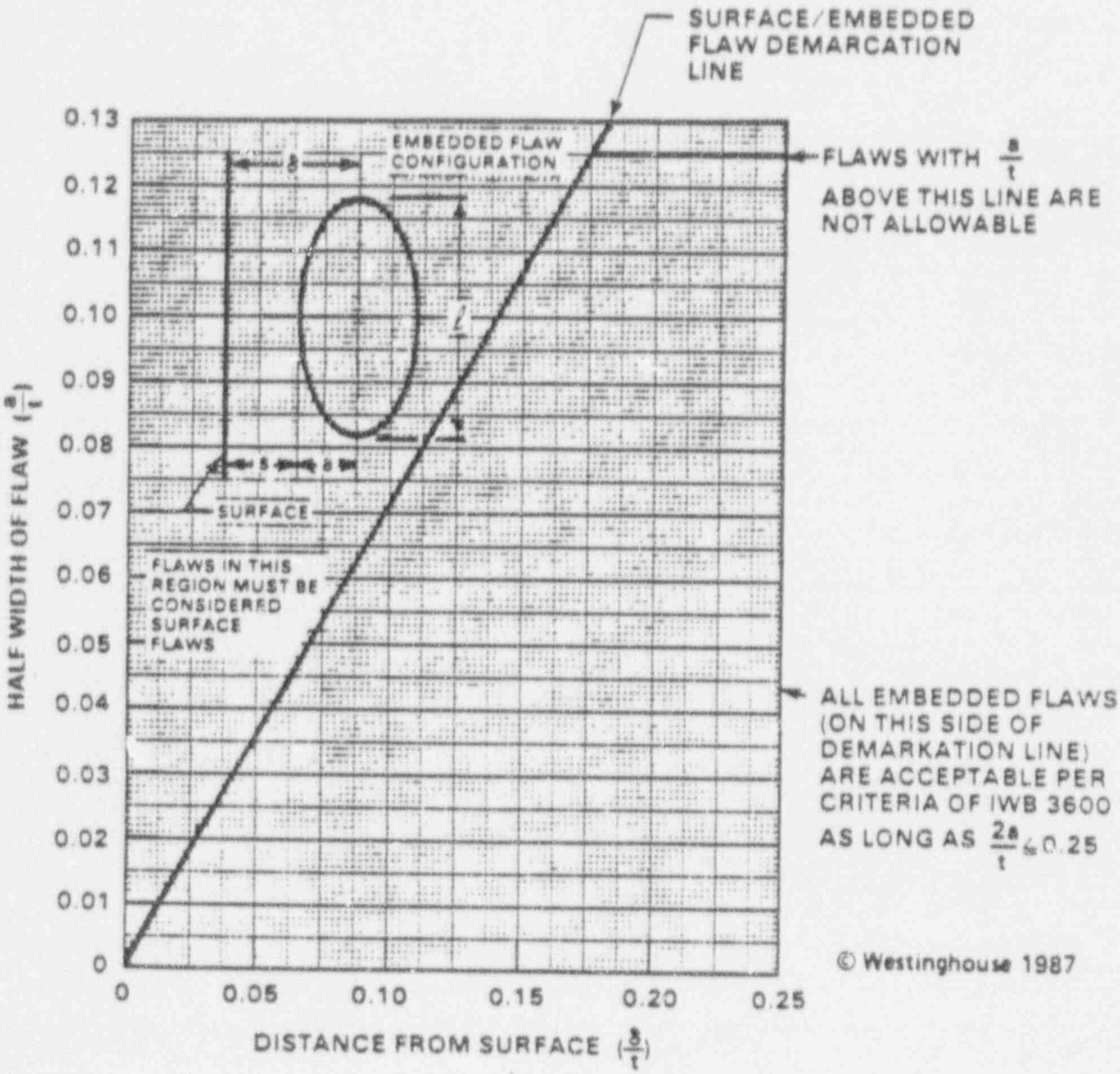



Figure A-6.4 Flaw Evaluation Chart for the Upper Shell-Cone Weld - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

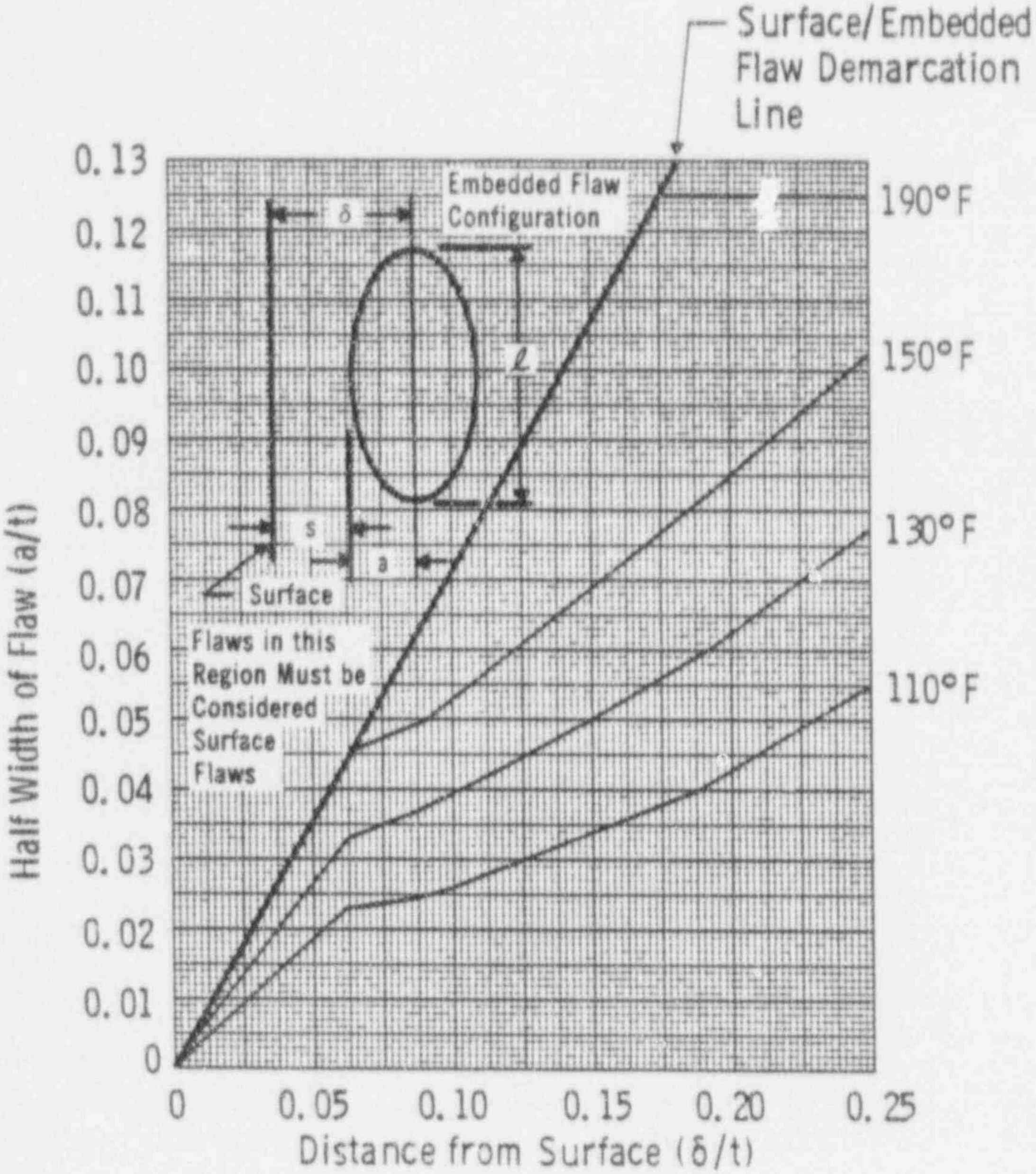



Figure A-6.5 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

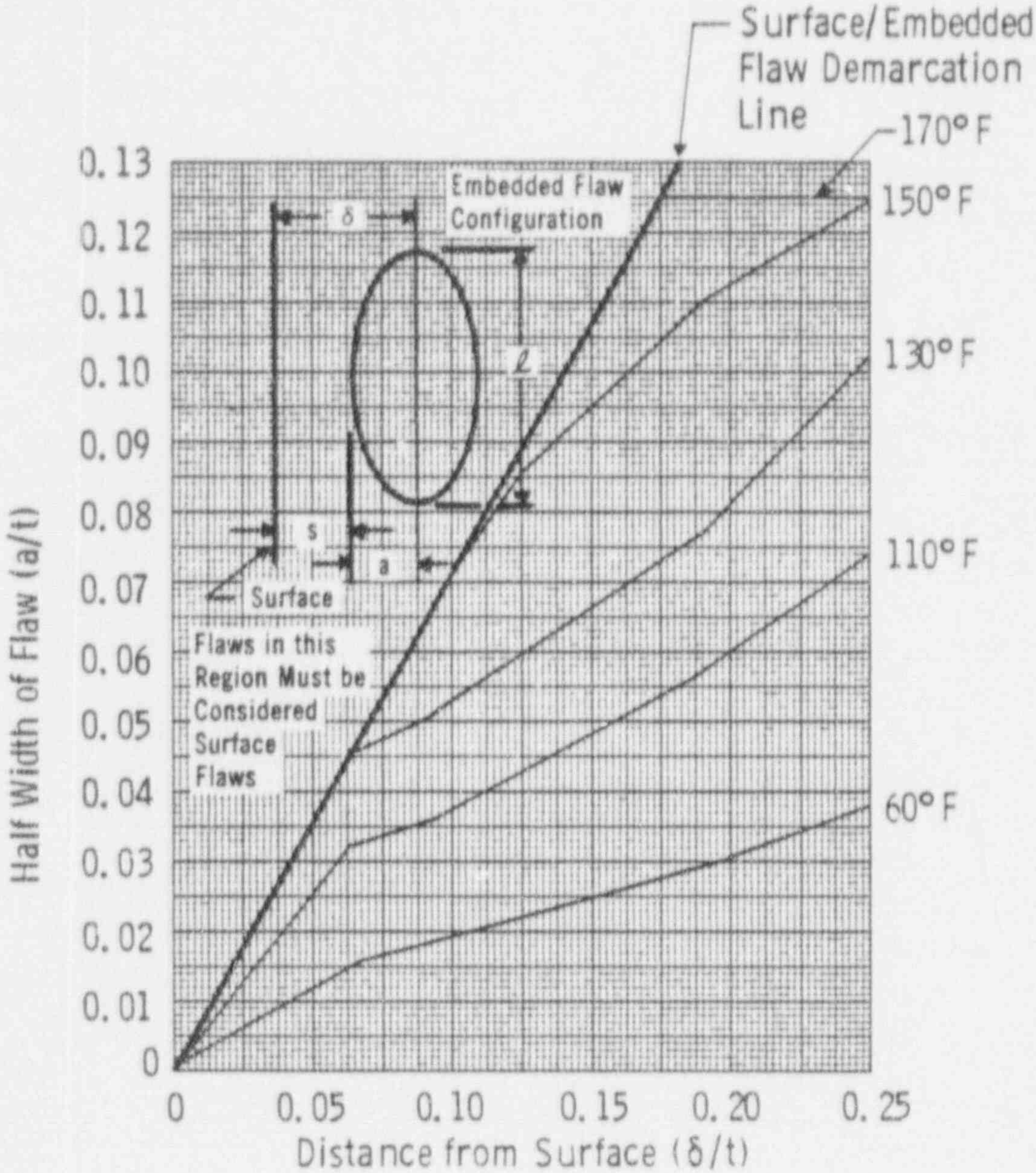



Figure A-6.6 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

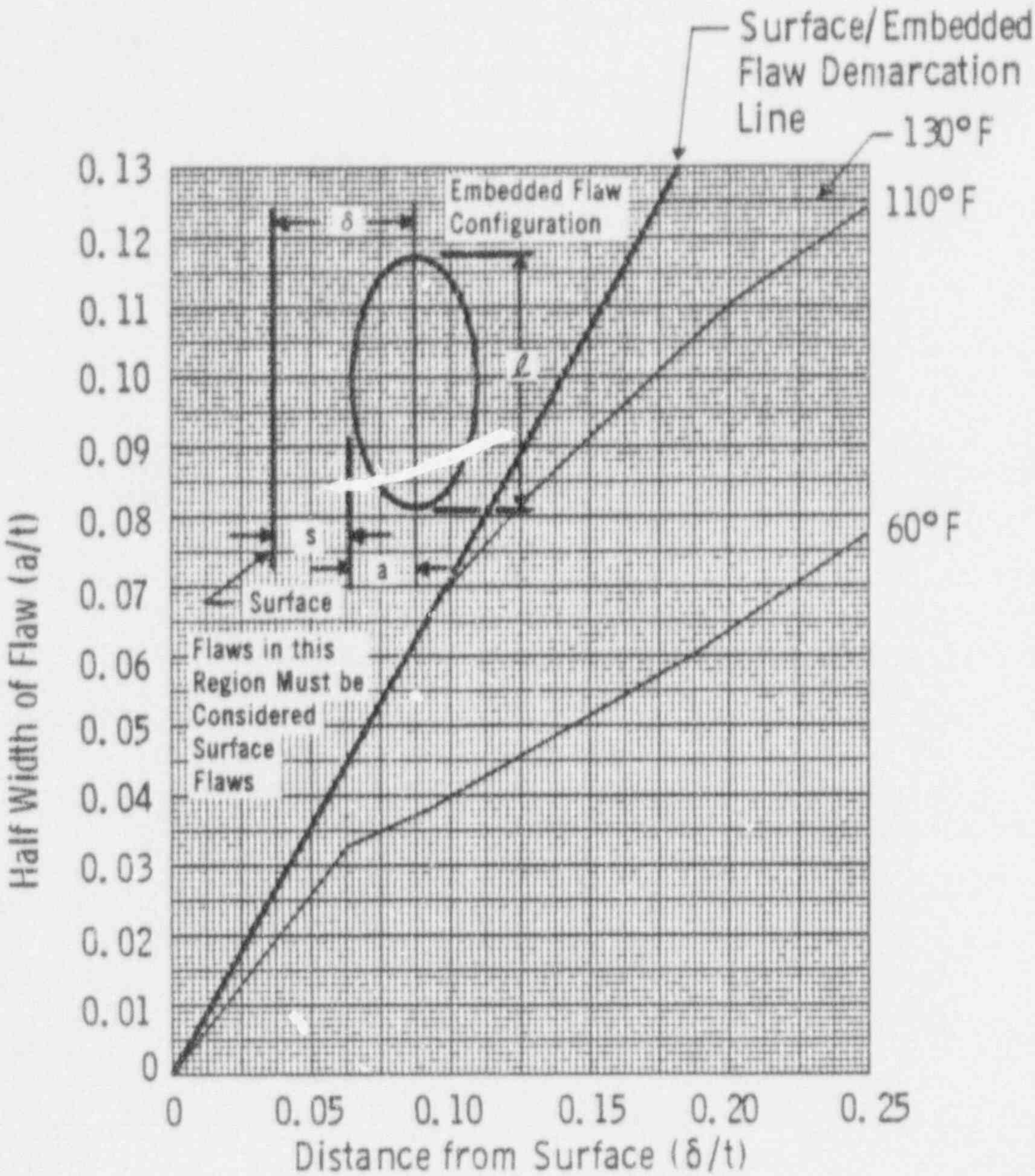



Figure A-6.7 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-7 UPPER SHELL WELDS - STEAM GENERATOR

### A-7.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-7.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.62")

The surface flaw evaluation charts for this region are listed below:

Figure A-7.2 Surface Flaw Evaluation Chart for Longitudinal Flaws at the Inside Surface of the Upper Shell

Figure A-7.3 Surface Flaw Evaluation Chart for Longitudinal Flaws at the Outside Surface of the Upper Shell

Figure A-7.4 Surface Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Upper Shell

Figure A-7.5 Surface Flaw Evaluation Chart for Circumferential Flaws at the Outside Surface of the Upper Shell

### A-7.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is depicted in figure A-7.1.

Basic Data:

$t = 3.62$ in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

a = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per ASME Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

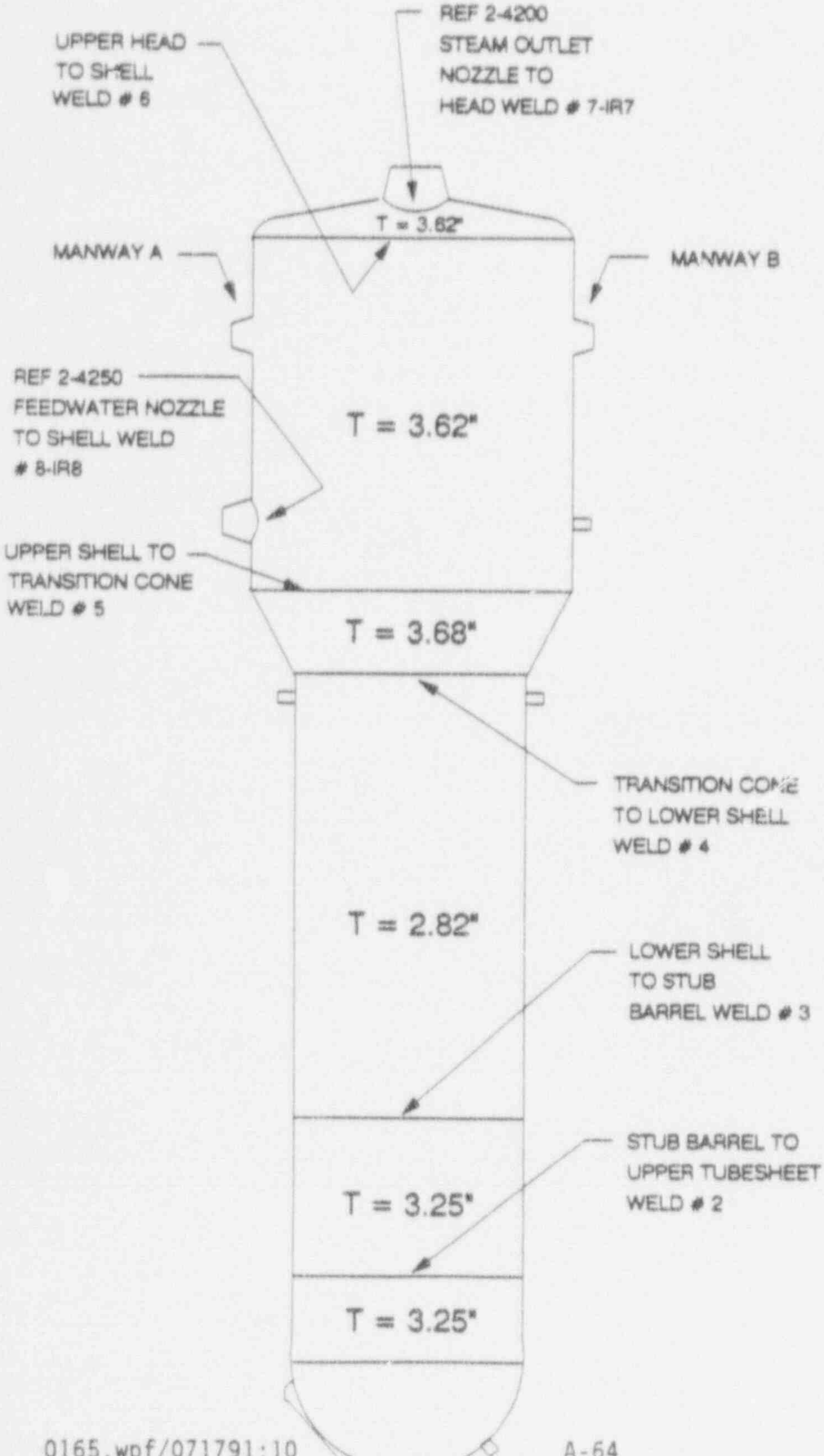
The evaluation charts for embedded flaws for the this region are listed below:

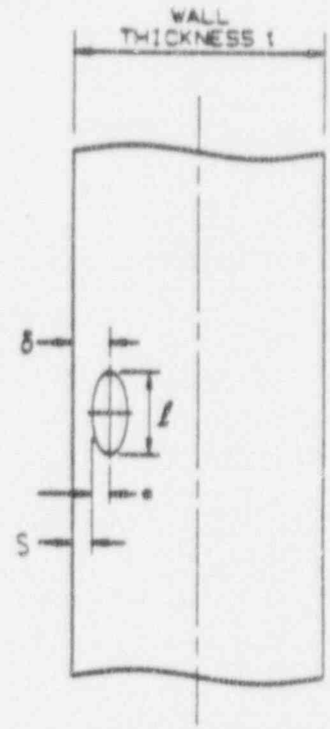
Figure A-7.6 Embedded Flaw Evaluation Chart for Flaws in the Upper Shell of the Steam Generator

Figure A-7.7 Test Temperature Determination Chart for Longitudinal Embedded Flaws in the Upper Shell of the Steam Generator for Secondary Hydro Test for Farley Units 1 and 2

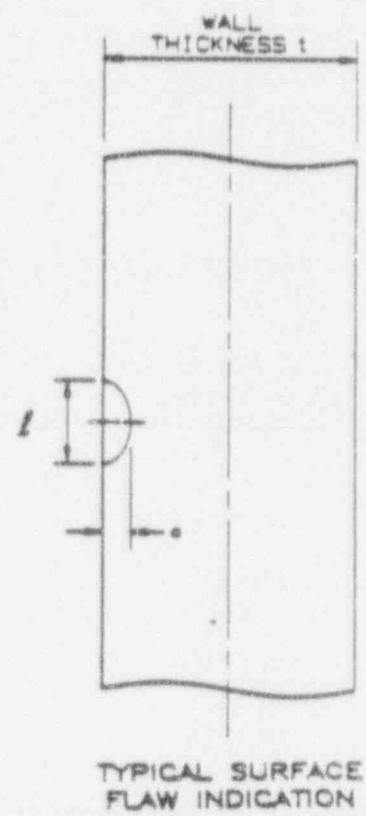
Figure A-7.8 through Figure A.7-9 Test Temperature Determination Chart for Longitudinal Embedded Flaws in the Upper Shell of the Steam Generator for Secondary Leakage Tests for Farley Units 1 and 2

Figure A-7.1
Geometry and Terminology for Flaws at Upper Shell
Welds - Steam Generator

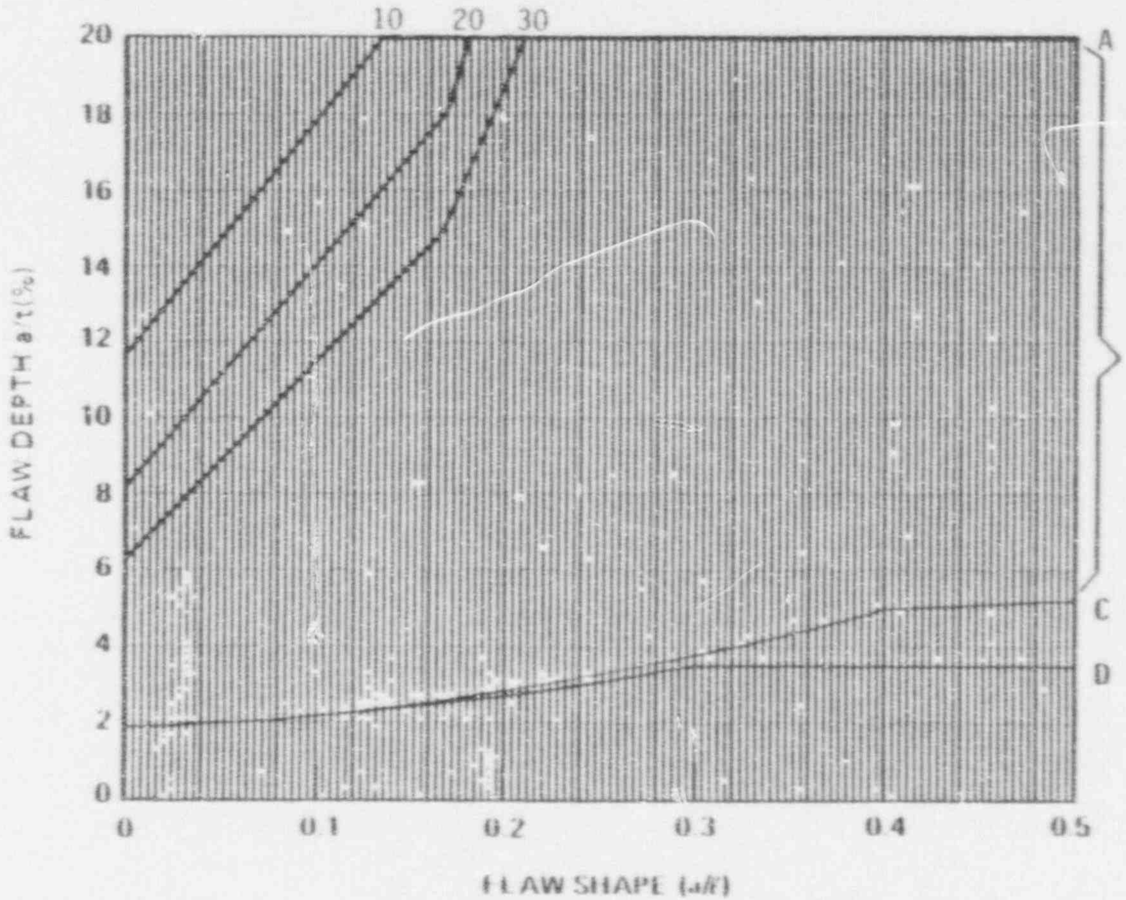



TYPICAL EMBEDDED
FLAW INDICATION




TYPICAL SURFACE
FLAW INDICATION




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

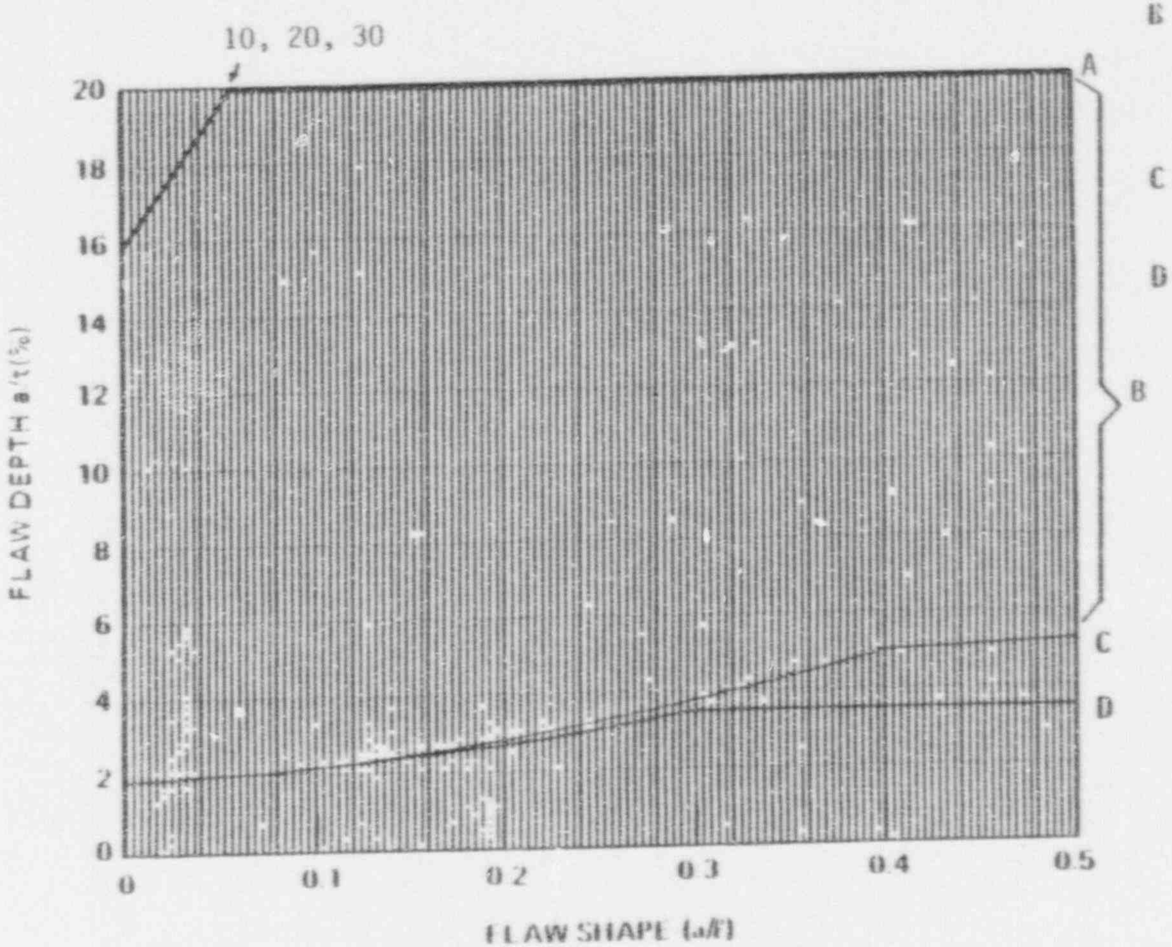
C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-7.2 Surface Flaw Evaluation Chart for the Upper Shell - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| | Outside Surface | | Embedded Flaw | | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

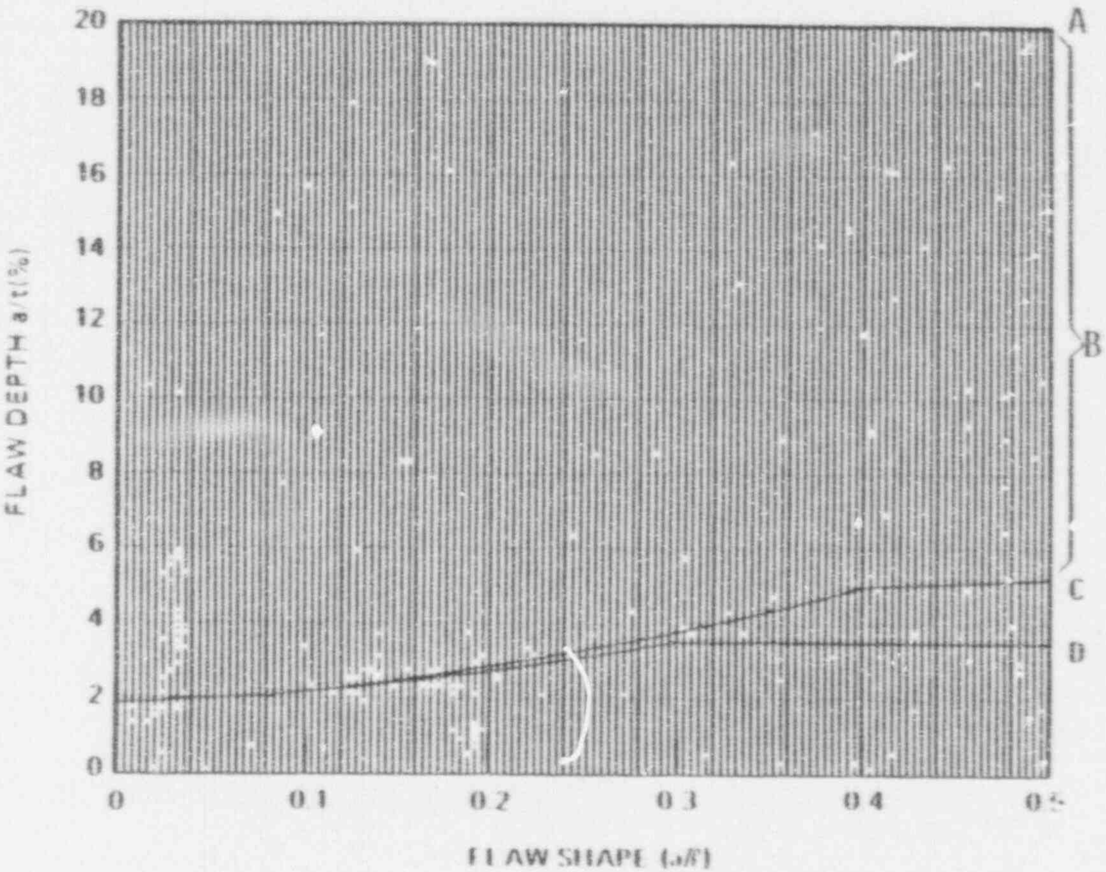
C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-7.3 Surface Flaw Evaluation Chart for the Upper Shell - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | ___ | Circumfereatial Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-7.4 Surface Flaw Evaluation Chart for the Upper Shell - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

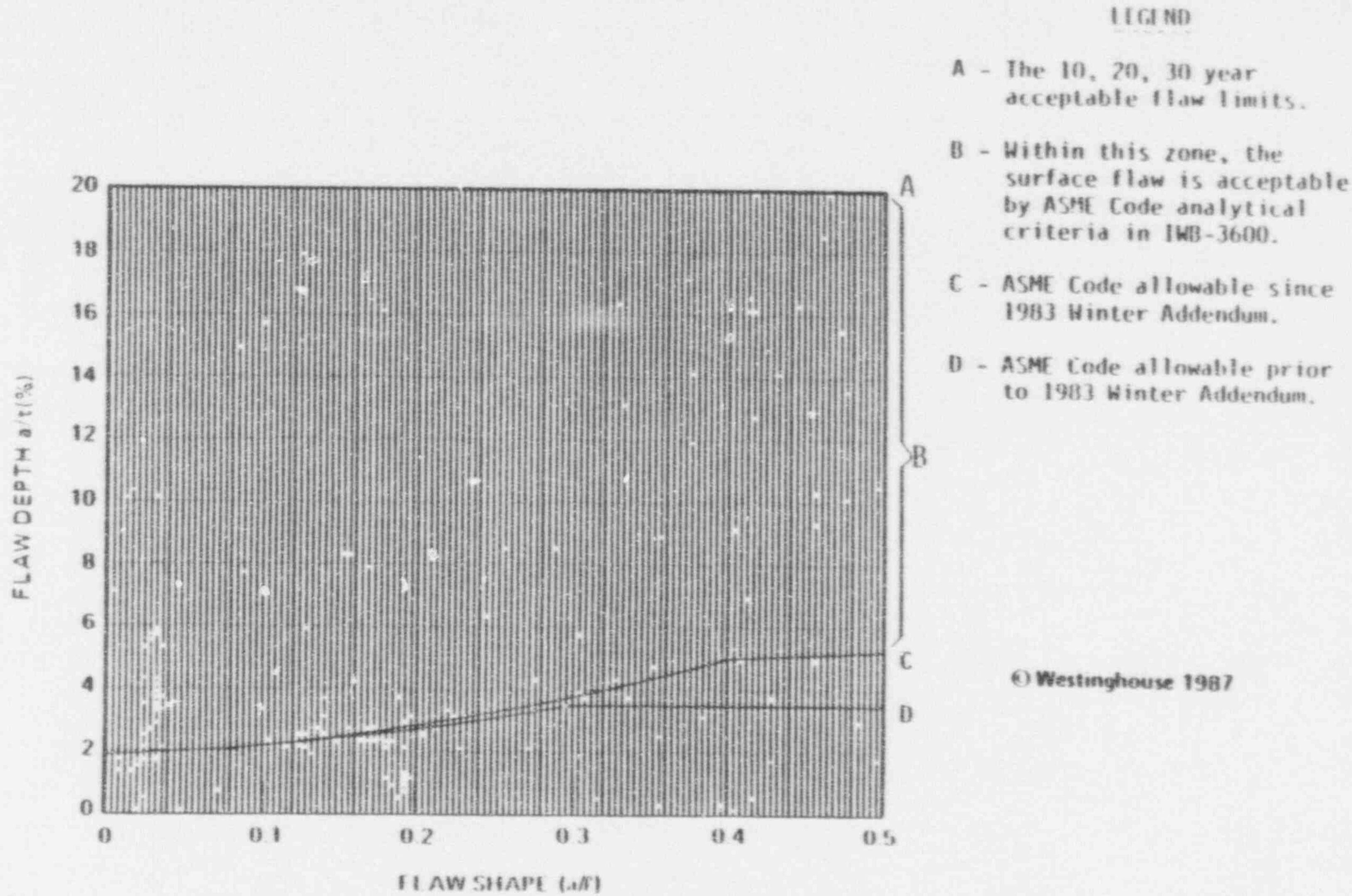



Figure A-7.5 Surface Flaw Evaluation Chart for the Upper Shell - Steam Generator

___ Inside Surface X Surface Flaw ___ Longitudinal Flaw

X Outside Surface ___ Embedded Flaw X Circumferential Flaw

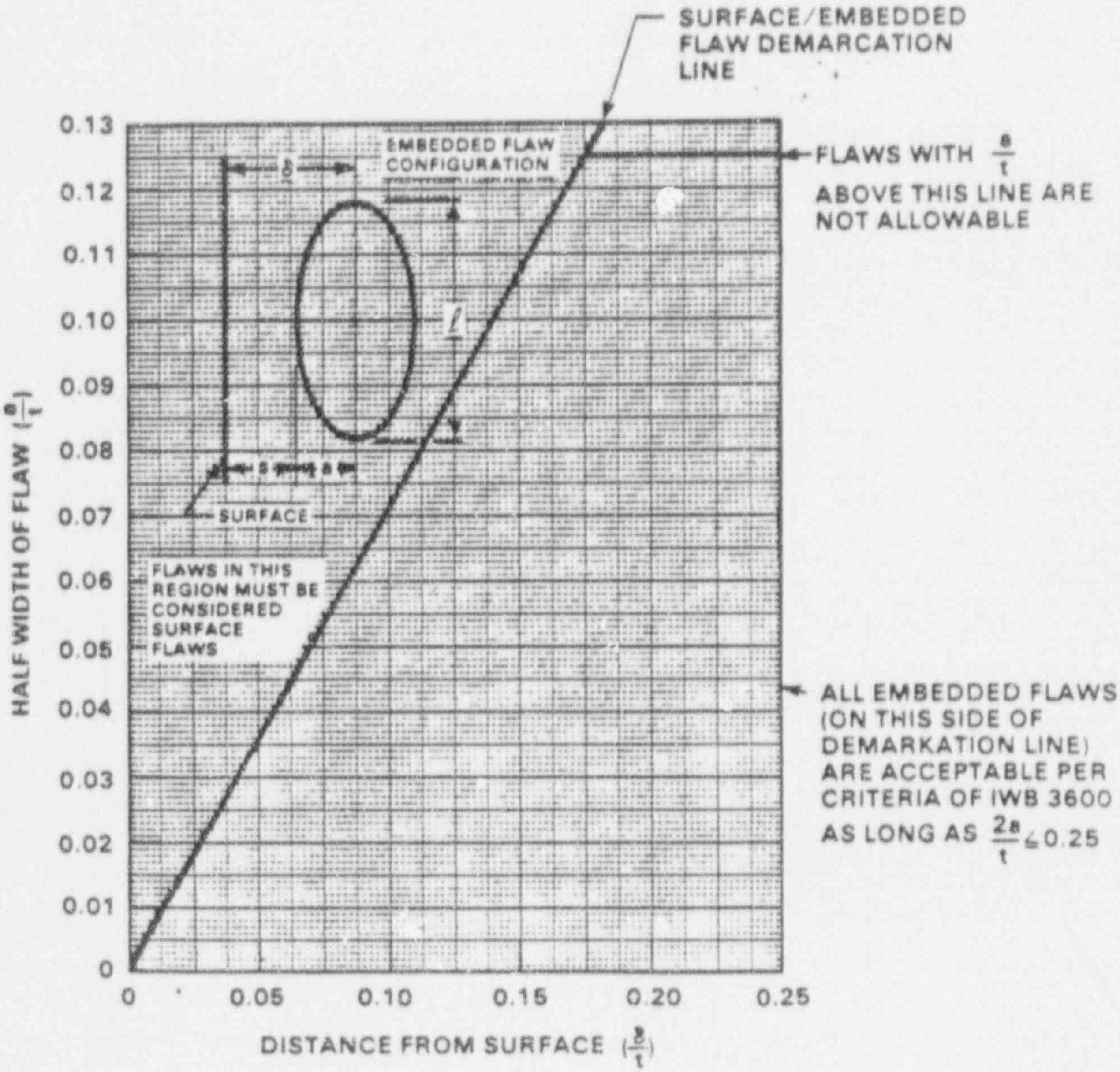



Figure A-7.6 Embedded Flaw Evaluation Chart for the Upper Shell - Steam Generator

X Inside Surface ___ Surface Flaw X Longitudinal Flaw

X Outside Surface X Embedded Flaw X Circumferential Flaw

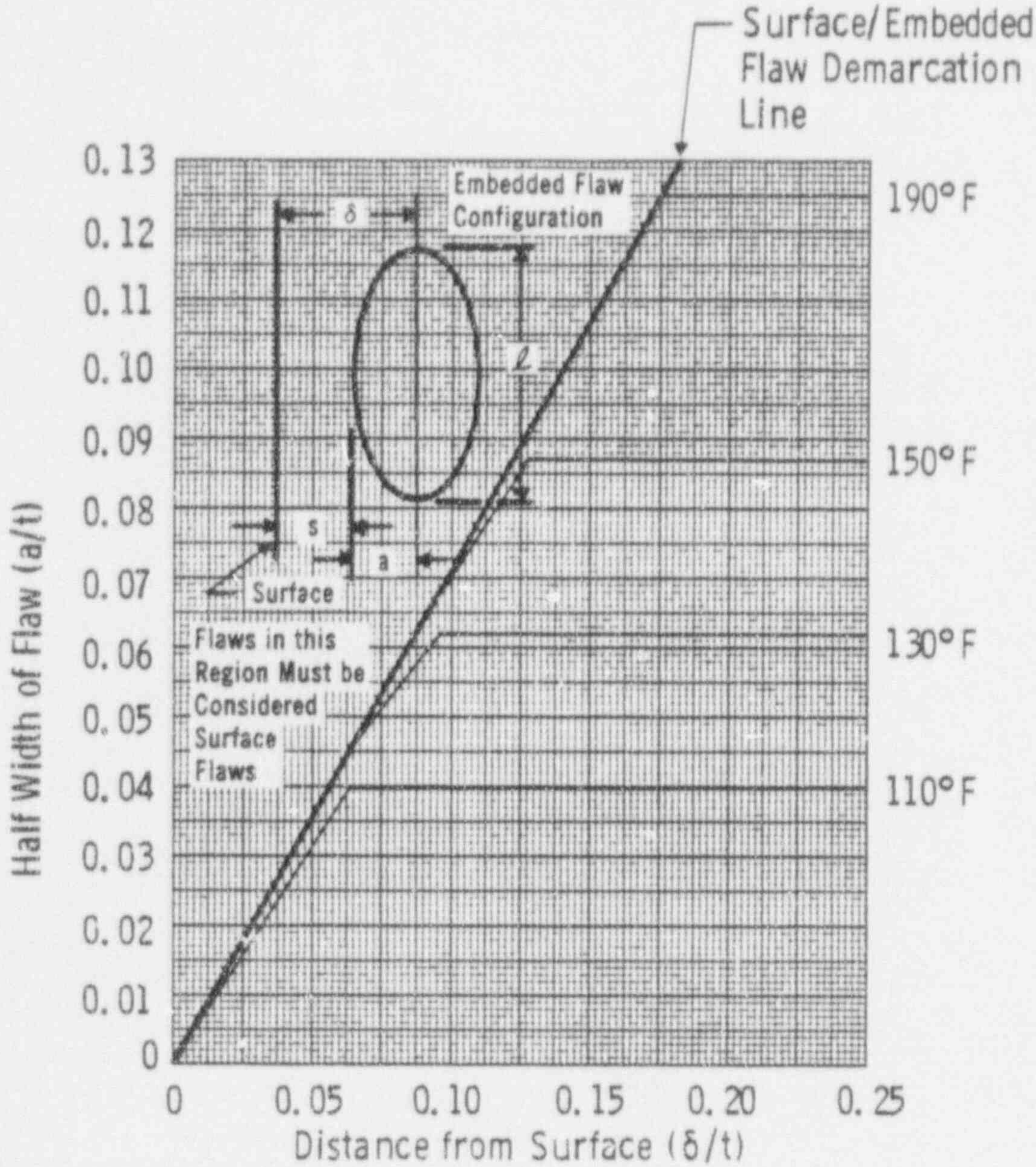



Figure A-7.7 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | __ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

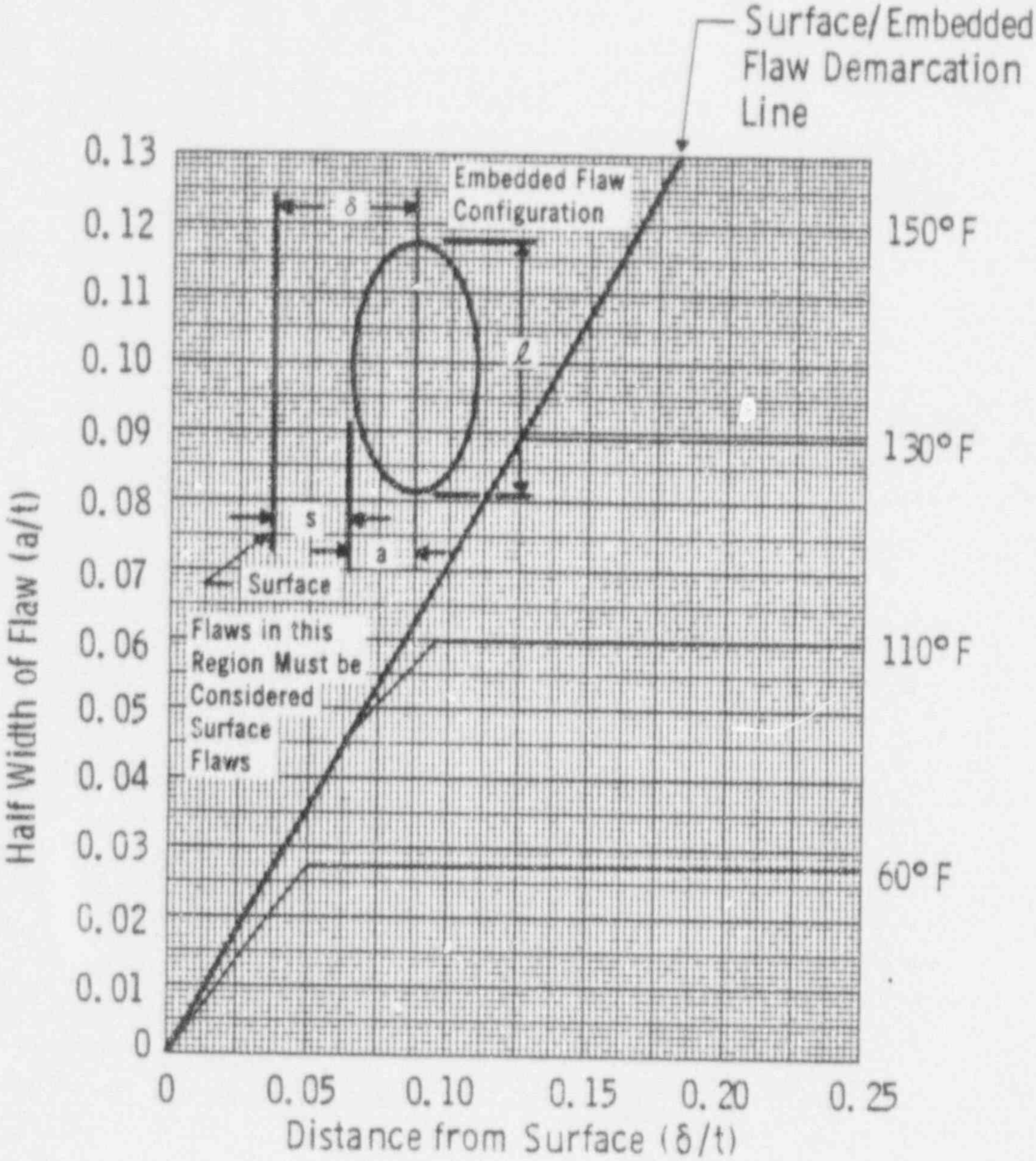



Figure A-7.8 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

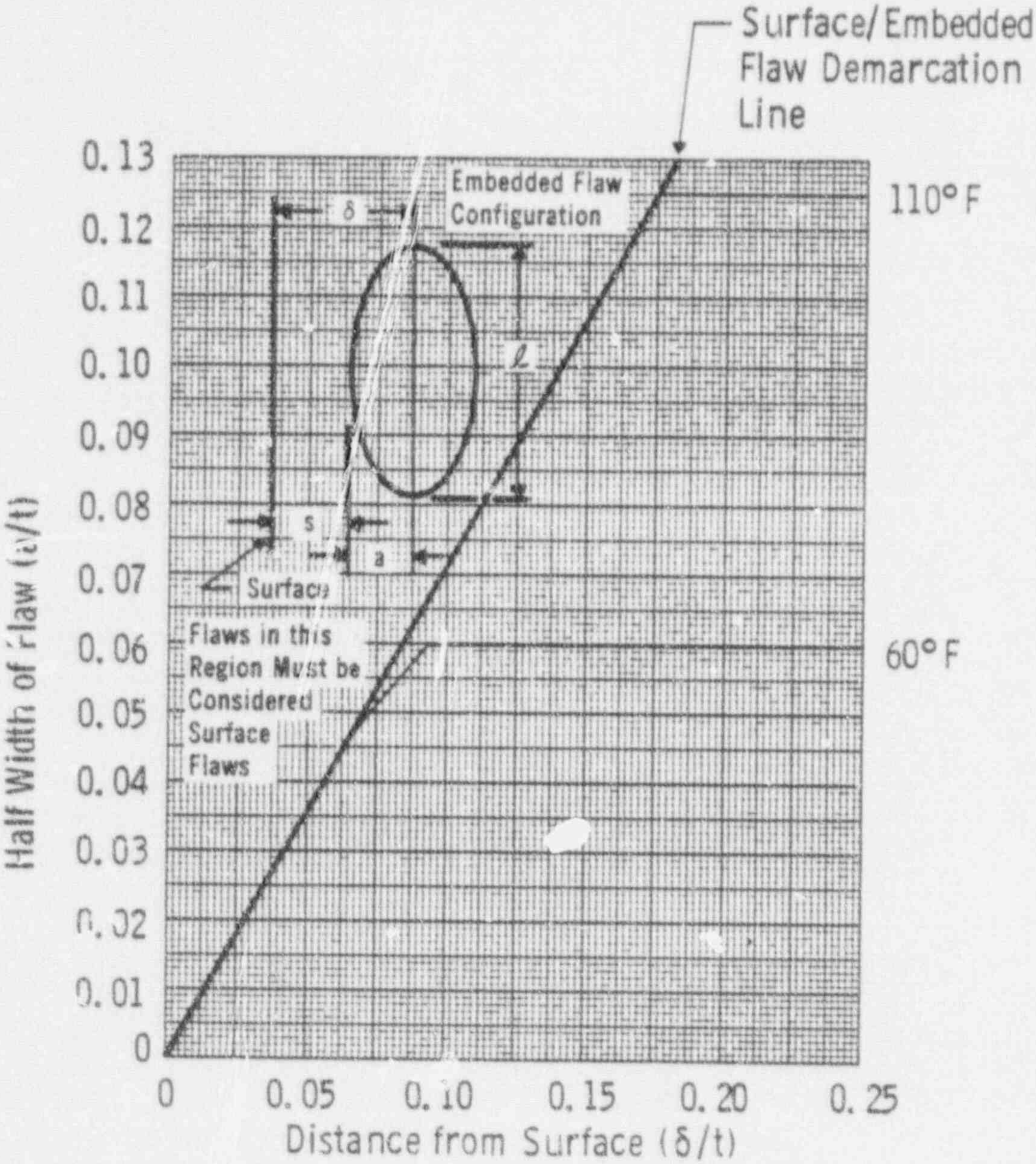



Figure A-7.9 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

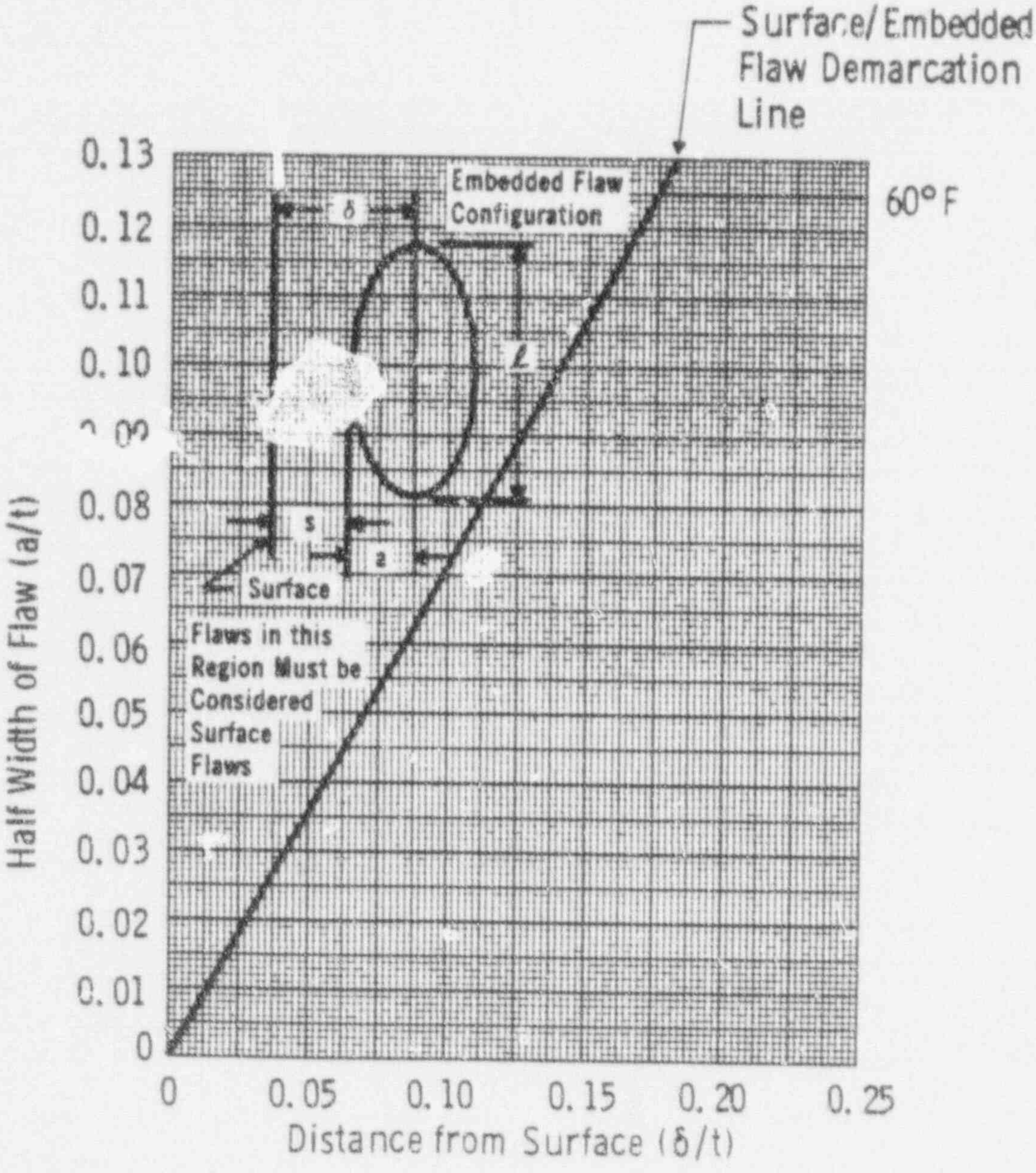



Figure A-7.10 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

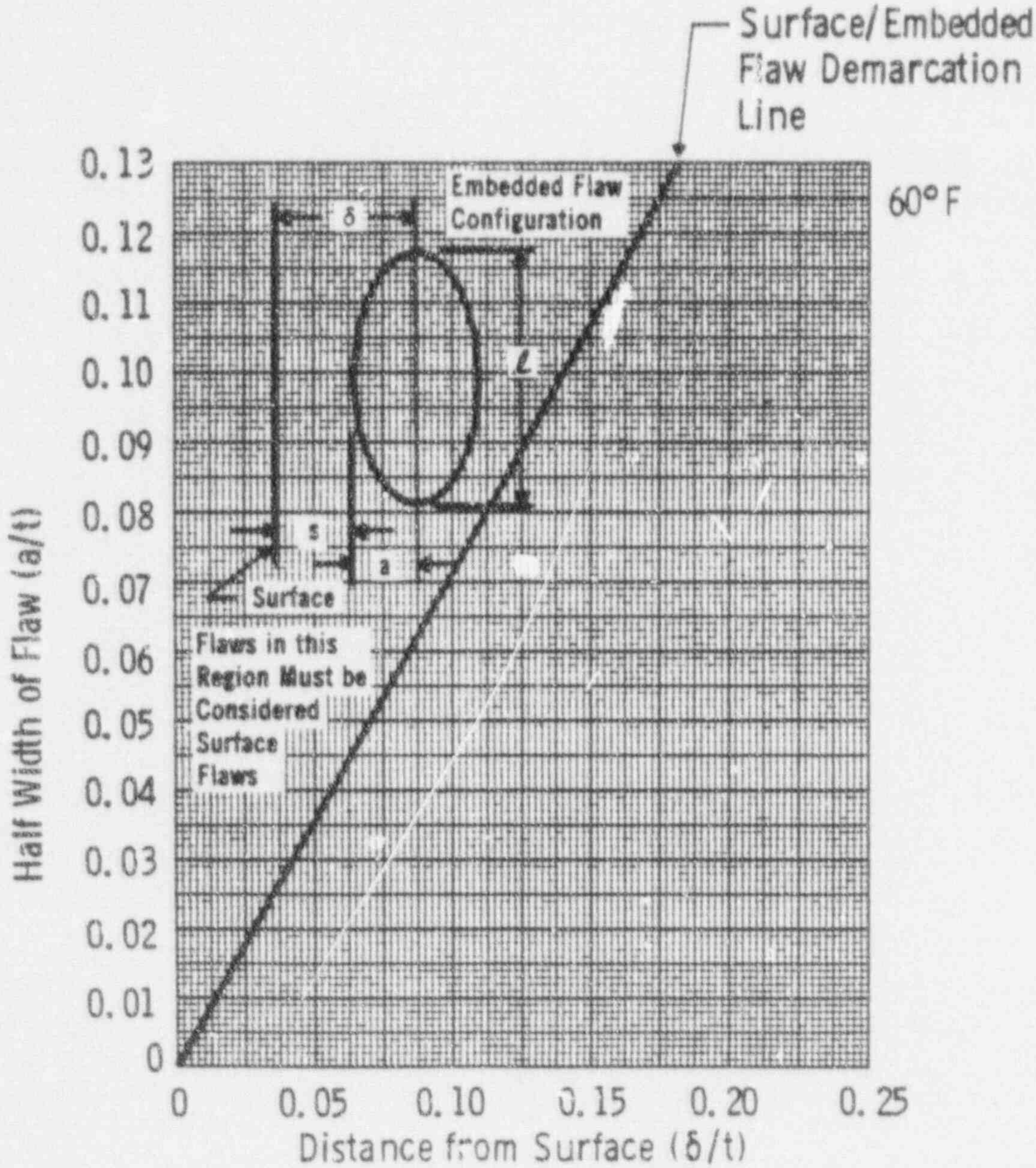



Figure A-7.11 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

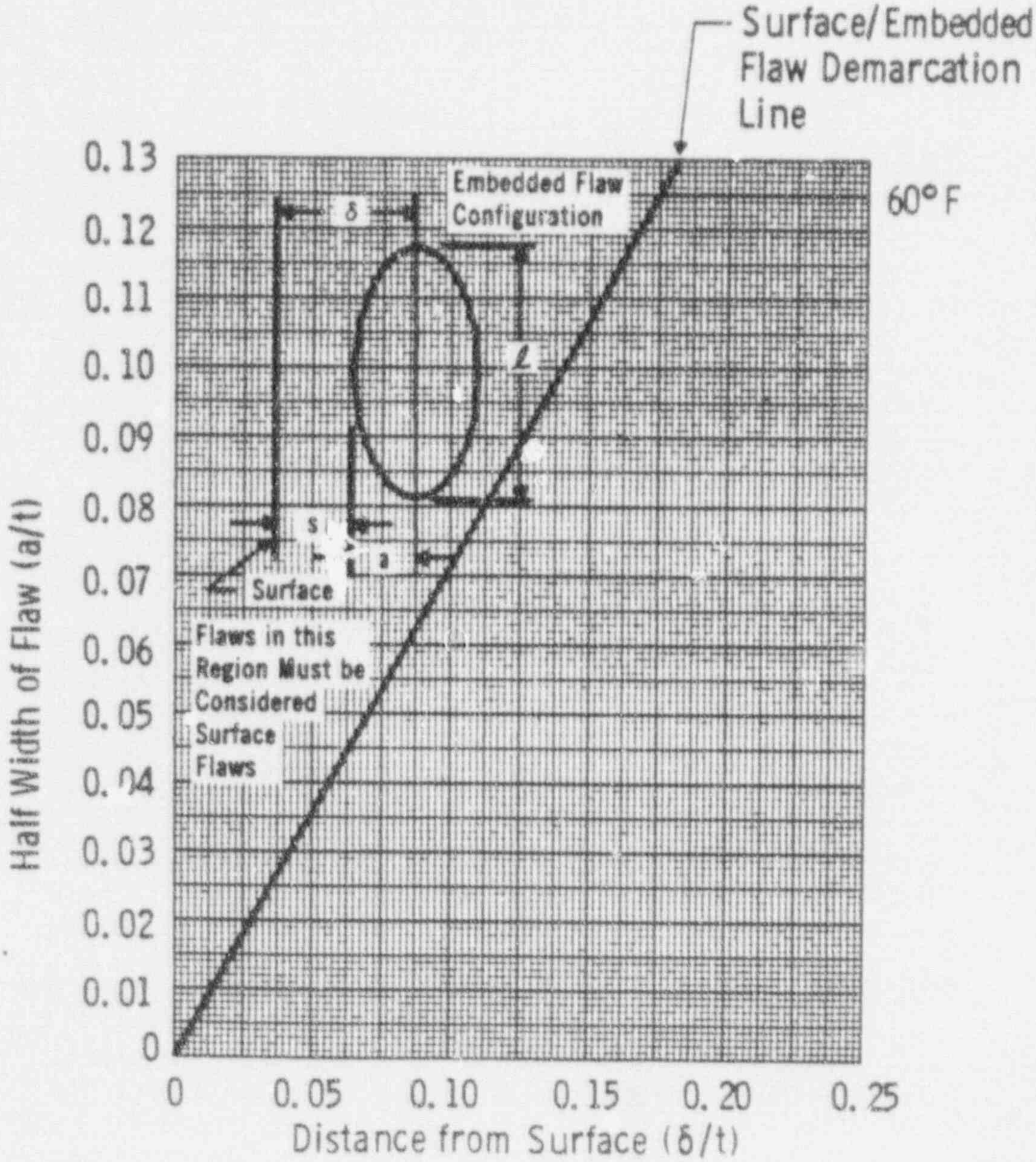



Figure A-7.12 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-8 UPPER SHELL-DOME WELD - STEAM GENERATOR

### A-8.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-8.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$

- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.76")

The surface flaw evaluation charts for this region are listed below:

Figure A-8.2 Surface Flaw Evaluation Chart for Circumferential Flaws in the Upper Shell-Dome Weld of the Steam Generator

### A-8.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region are depicted in figure A-8.1.

Basic Data:

$t$ = 3.76 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)
$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

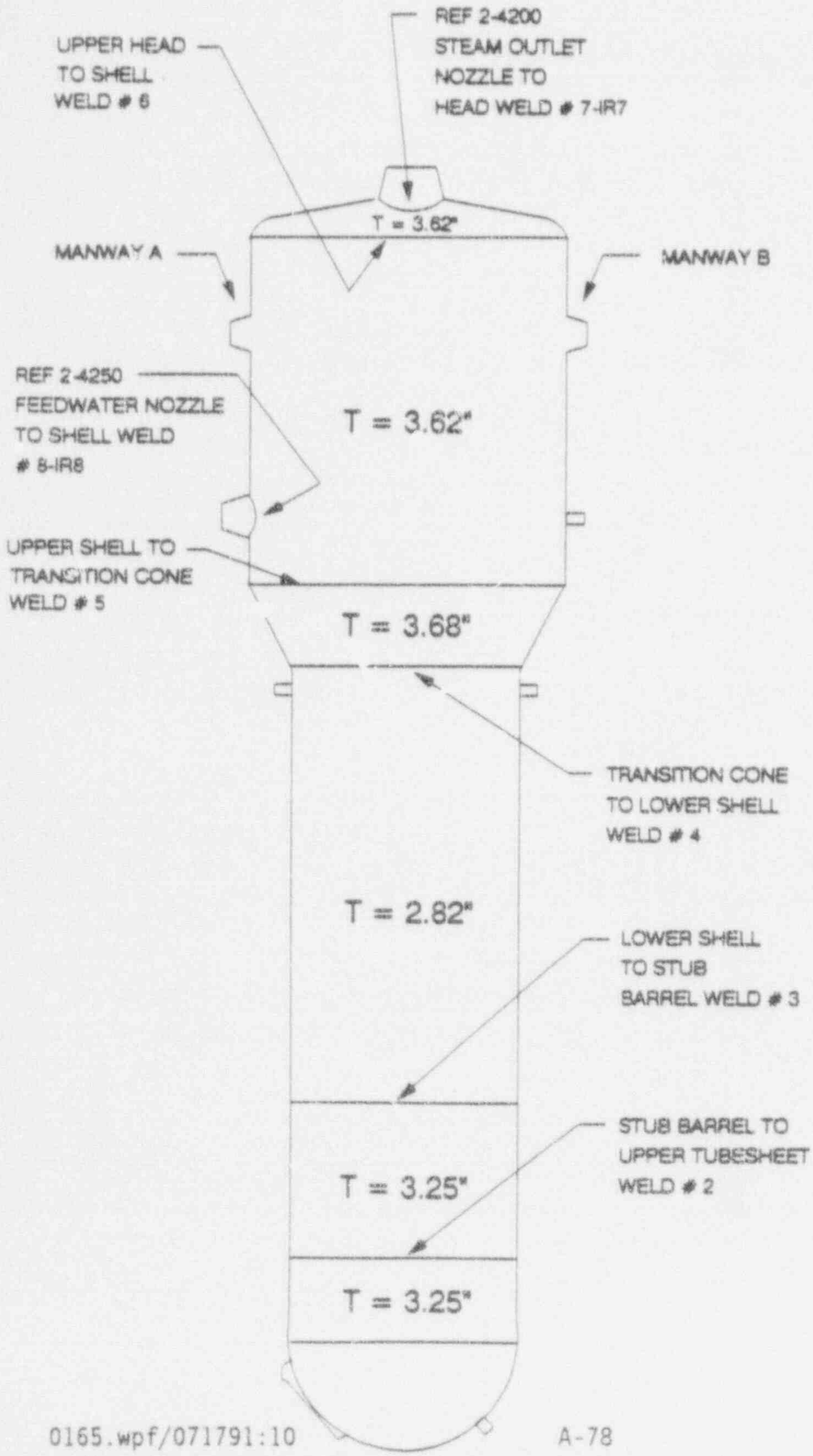
- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

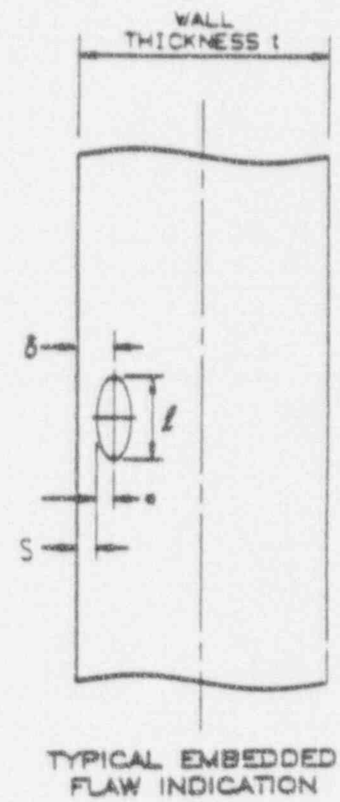
Evaluation charts for embedded flaws are listed below:

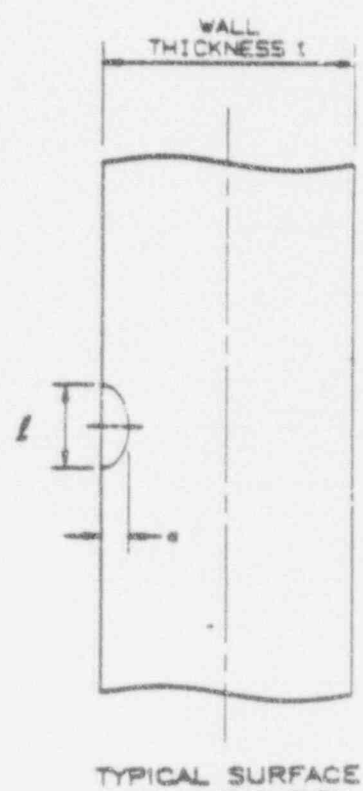
| | |
|---|---|
| Figure A-8.3 | Embedded Flaw Evaluation Chart for Circumferential Flaws in the Upper Shell-Dome Weld of the Steam Generator |
| Figure A-8.4 | Test Temperature Determination Chart for Circumferential Flaws in the Upper Shell-Dome Weld of the Steam Generator for the Secondary Hydro Test for Farley Units 1 and 2 |
| Figure A-8.5 through Figure A-8.6 | Test Temperature Determination Chart for Circumferential Flaws in the Upper Shell-Dome Weld of the Steam Generator for the Secondary Leakage Tests for Farley Units 1 and 2 |

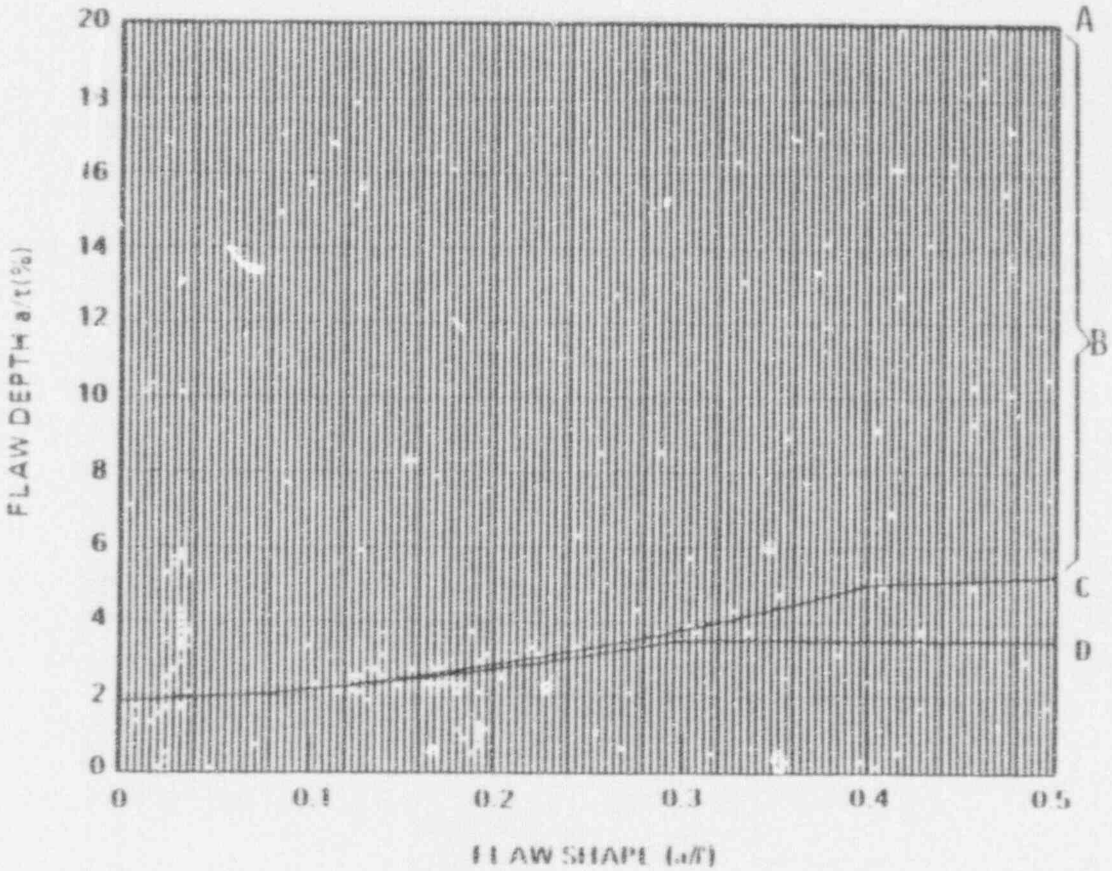
Figure A-8.1

Geometry and Terminology for Flaws at Upper Shell Dome Weld of the Steam Generator






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-8.2 Surface Flaw Evaluation Chart for the Upper Shell-Dome Weld of the Steam Generator

X Inside Surface X Surface Flaw ___ Longitudinal Flaw

X Outside Surface ___ Embedded Flaw X Circumferential Flaw

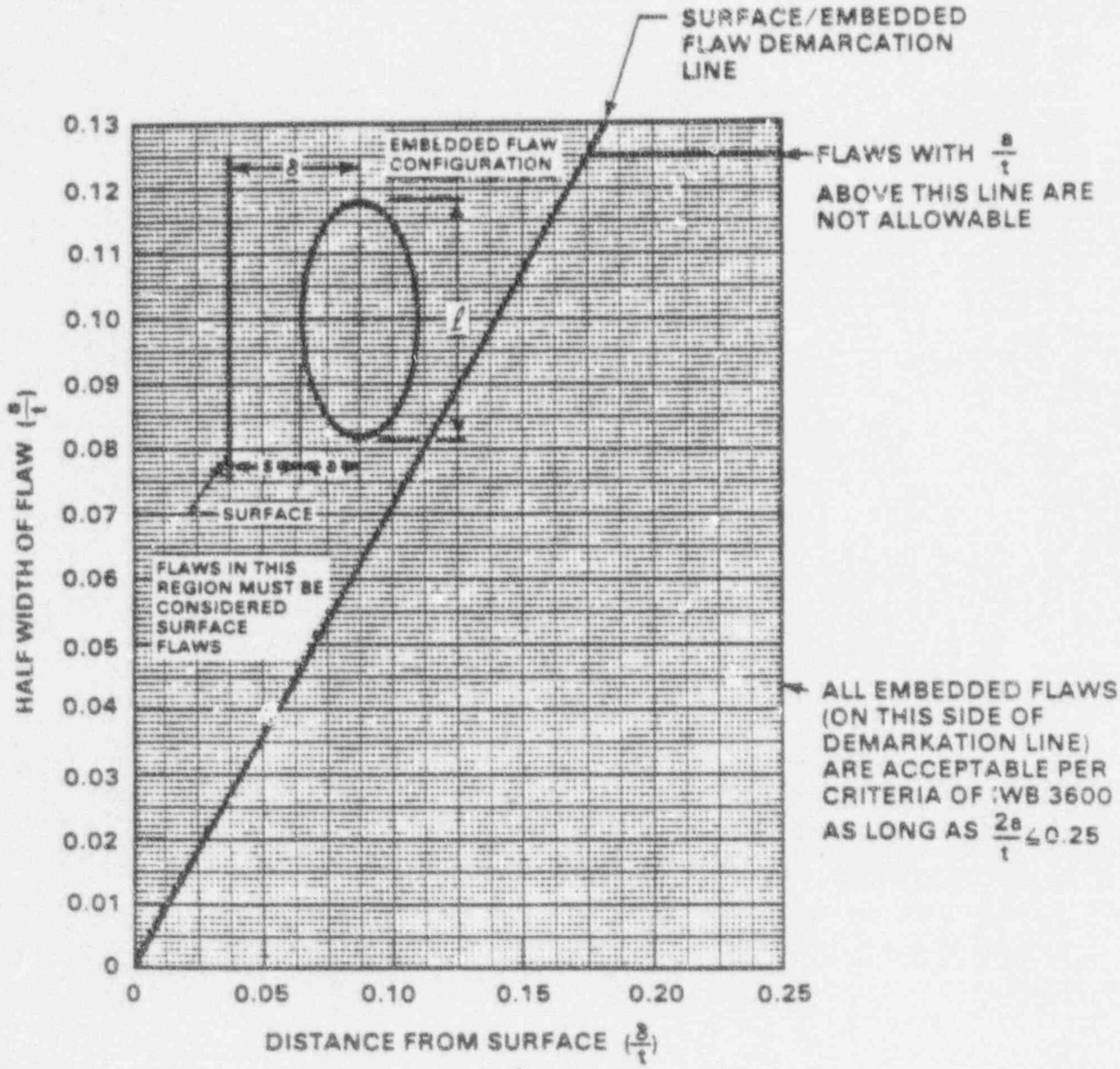



Figure A-8.3 Flaw Evaluation Chart for the Upper Shell-Dome Weld of the Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | | Surface Flaw | | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

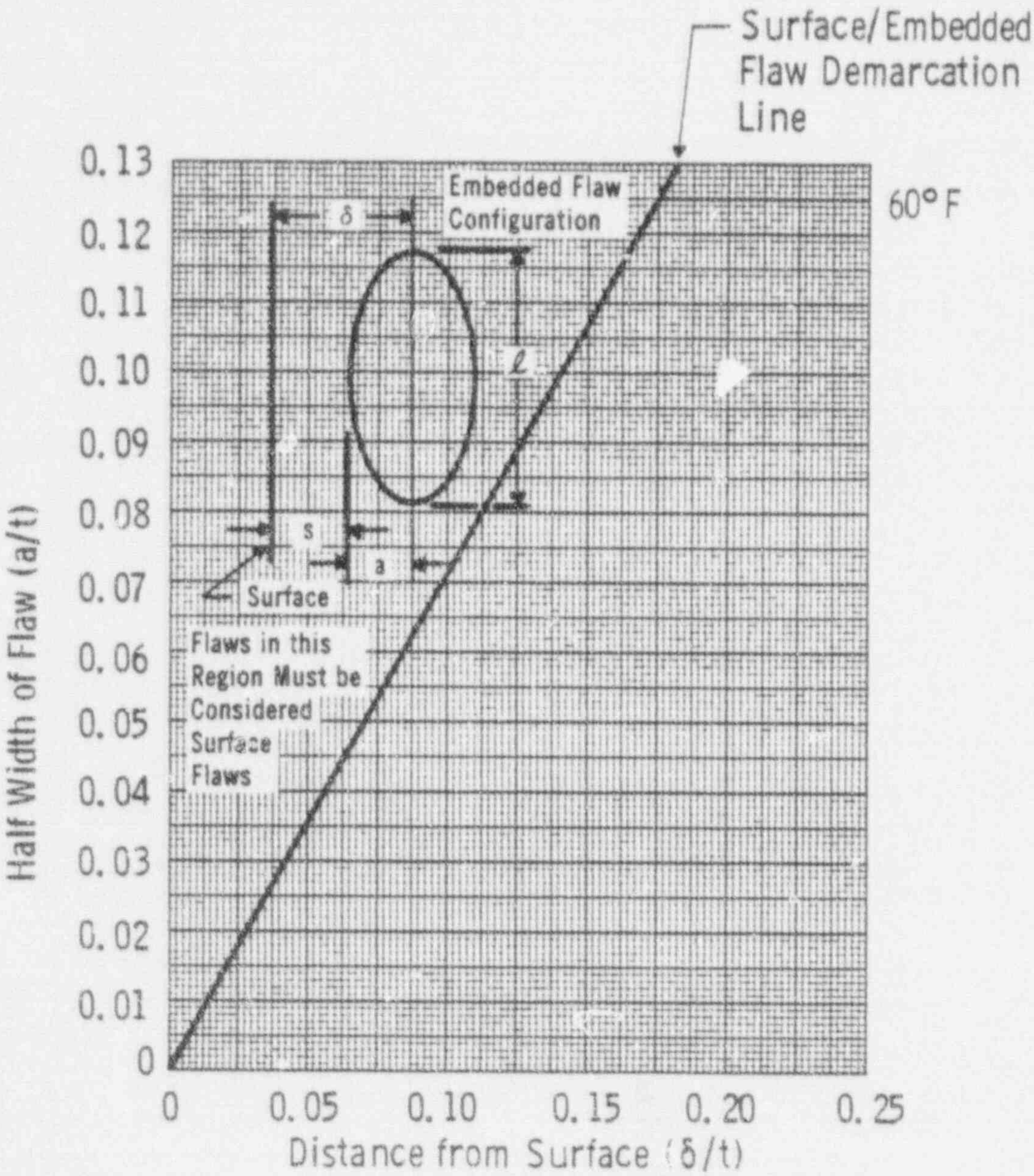



Figure A-8.4 Determination of Hydrostatic Test Temperatures for Circumferential Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

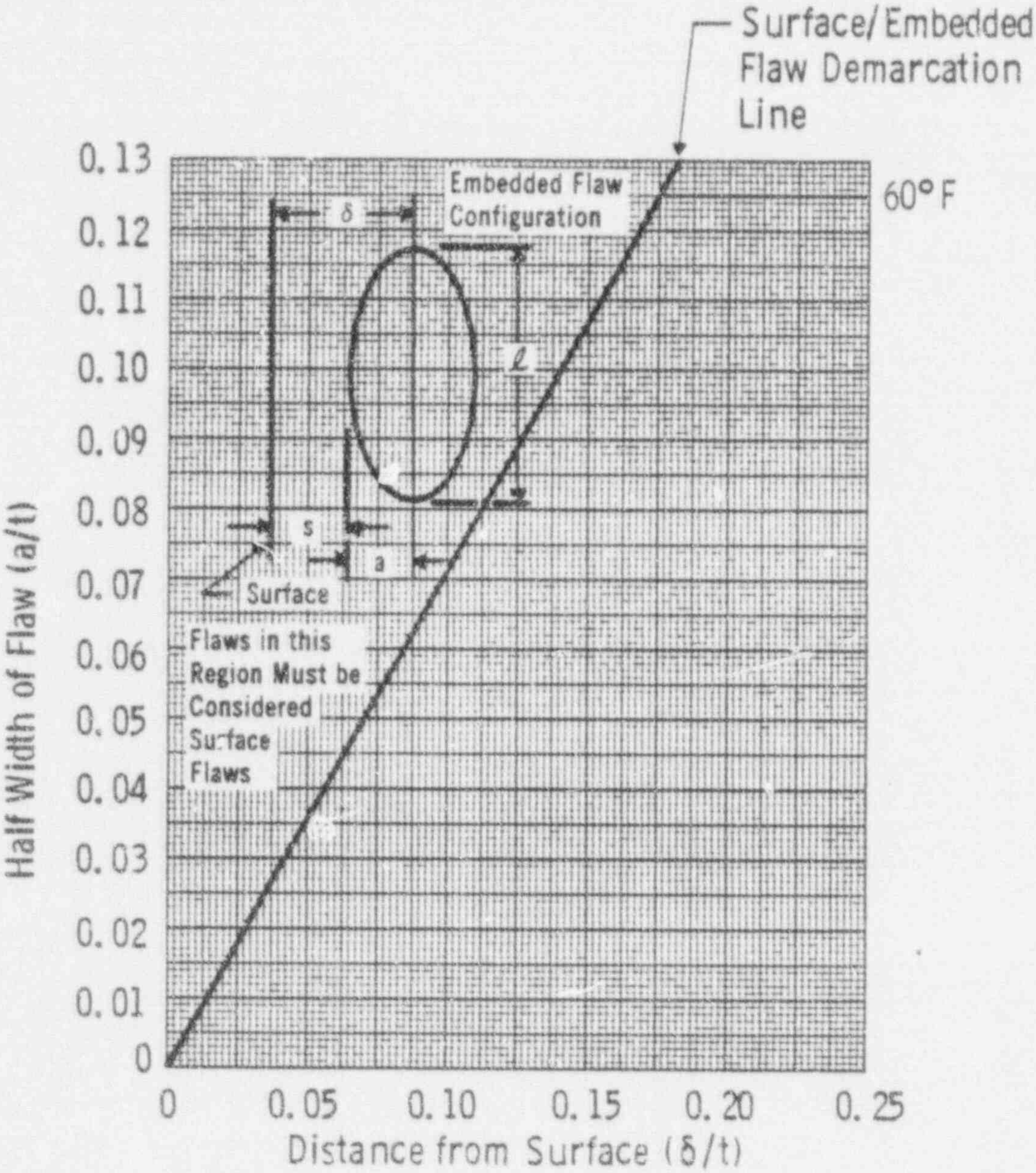



Figure A-8.5 Determination of Leakage Test Temperatures for Circumferential Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

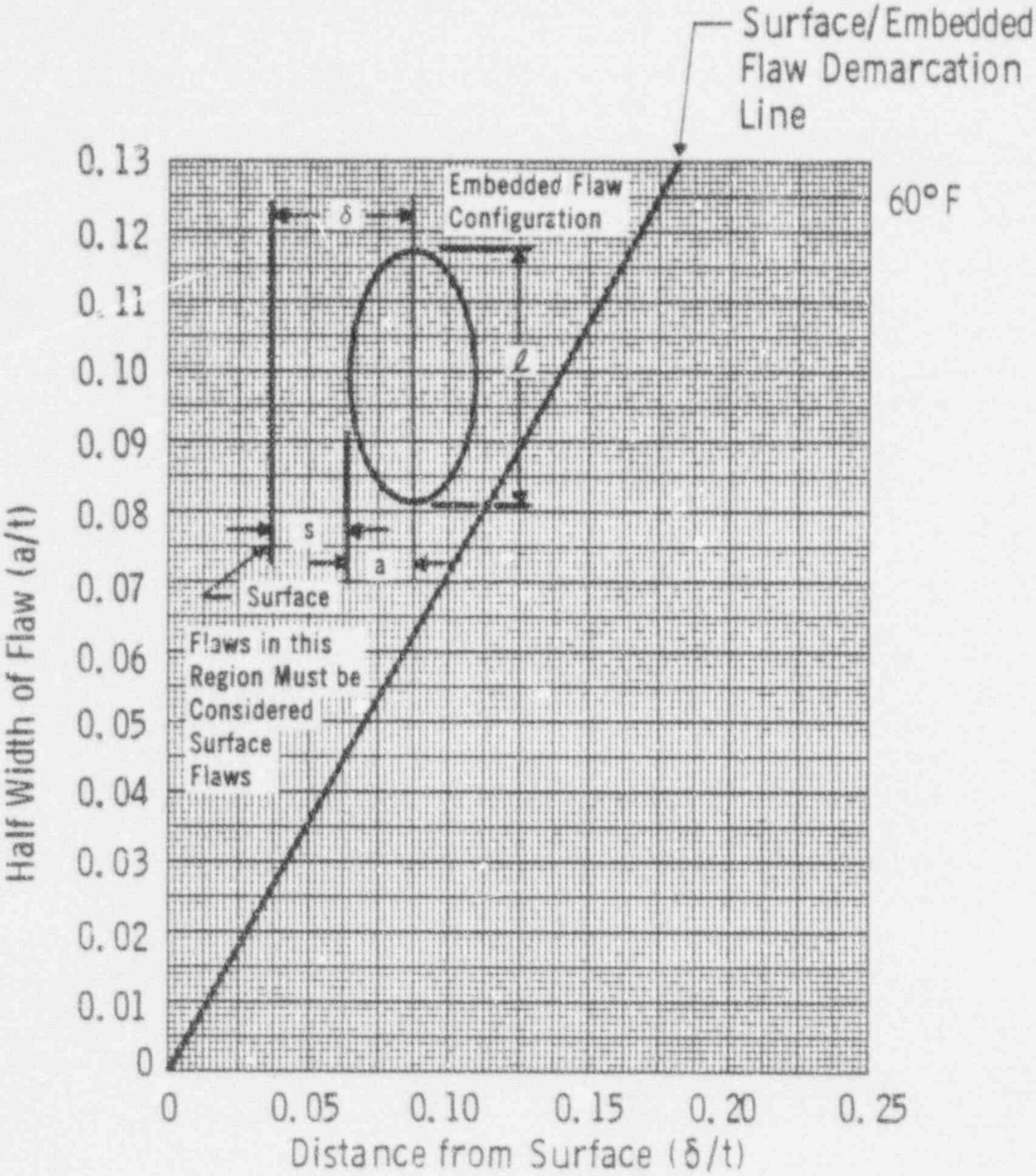



Figure A-8.6 Determination of Leakage Test Temperatures for Circumferential Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-9 FEEDWATER NOZZLE REGION - STEAM GENERATOR

### A-9.1 SURFACE FLAWS - NOZZLE TO SHELL WELD

The geometry and terminology for surface flaws in the feedwater nozzle to shell weld region is depicted in figure A-9.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)

$\ell$ = the surface flaw length detected (in.)

$t$ = wall thickness at the feedwater nozzle ($t$ = 3.62")

The surface flaw evaluation charts for the feedwater nozzle are listed below

Figure A-9.2 Flaw Evaluation Chart for Longitudinal Flaws at the Inside Surface of the Feedwater Nozzle - Shell Weld

Figure A-9.3 Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Feedwater Nozzle - Shell Weld

Figure A-9.4 Flaw Evaluation Chart for Flaws at the Outside Surface of the Feedwater Nozzle - Shell Weld

### A.9-2 EMBEDDED FLAWS - NOZZLE TO SHELL WELD

The geometrical description of an embedded flaw in the feedwater nozzle to shell weld region is depicted in figure A-9.1.

Basic Data:

$t = 3.62$ in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

a = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

The evaluation charts for embedded flaws are listed below:

Figure A-9.5 Embedded Flaw Evaluation Chart for Flaws near the Inside Surface of the Feedwater Nozzle

Figure A-9.6 Test Temperature Determination Chart for Circumferential Embedded Flaws in the Feedwater Nozzle for the Secondary Hydro Test and Secondary Leak Test

A-9.3 SURFACE FLAWS - FEEDWATER NOZZLE CORNER

The geometry and terminology for surface flaws in the feedwater nozzle corner region is depicted in figure A-9.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, a/ℓ
- o Flaw depth parameter, a/t

where

a = the surface flaw depth detected (in.)

ℓ = the surface flaw length detected (in.)

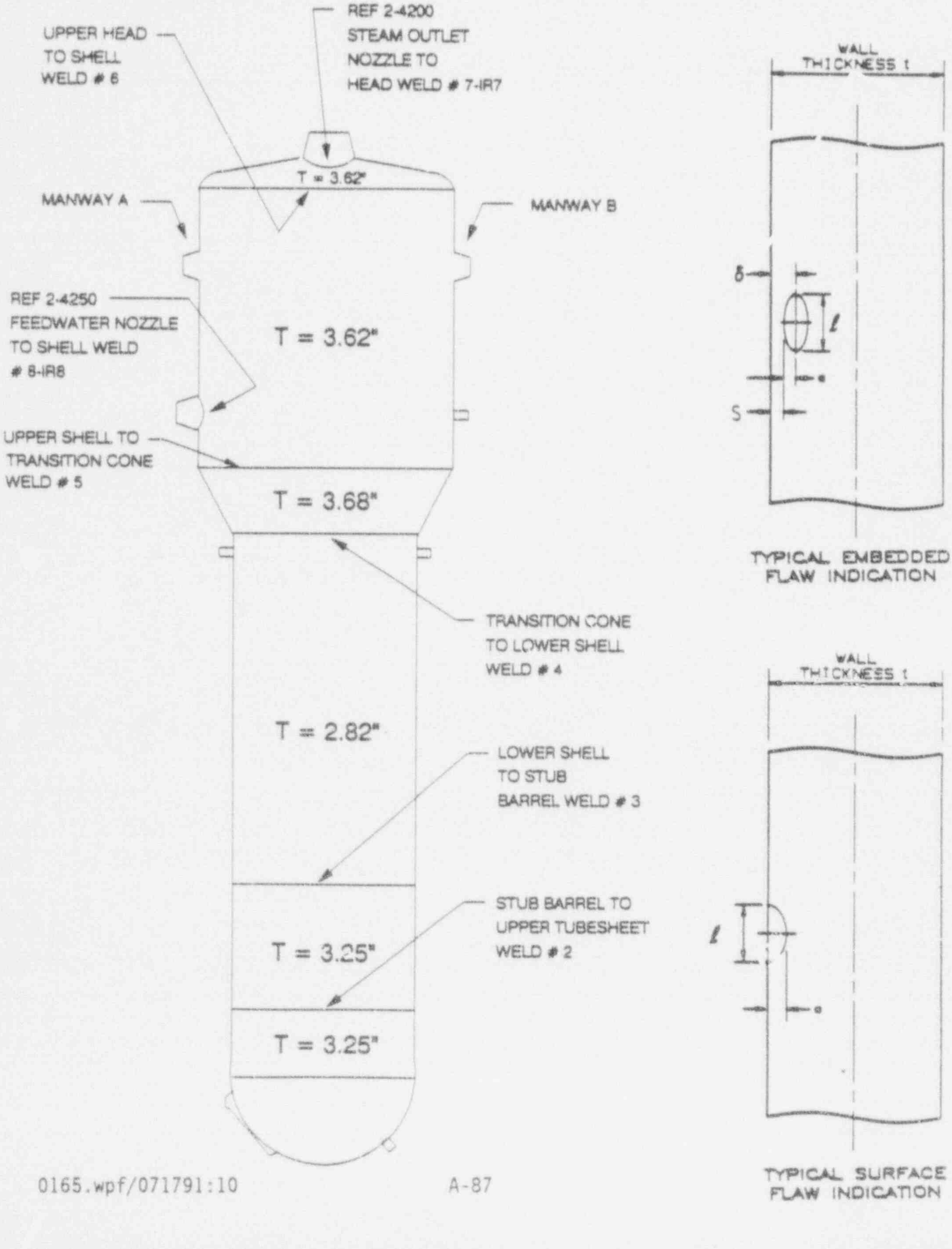
t = wall thickness at the feedwater nozzle (t = 6.33")

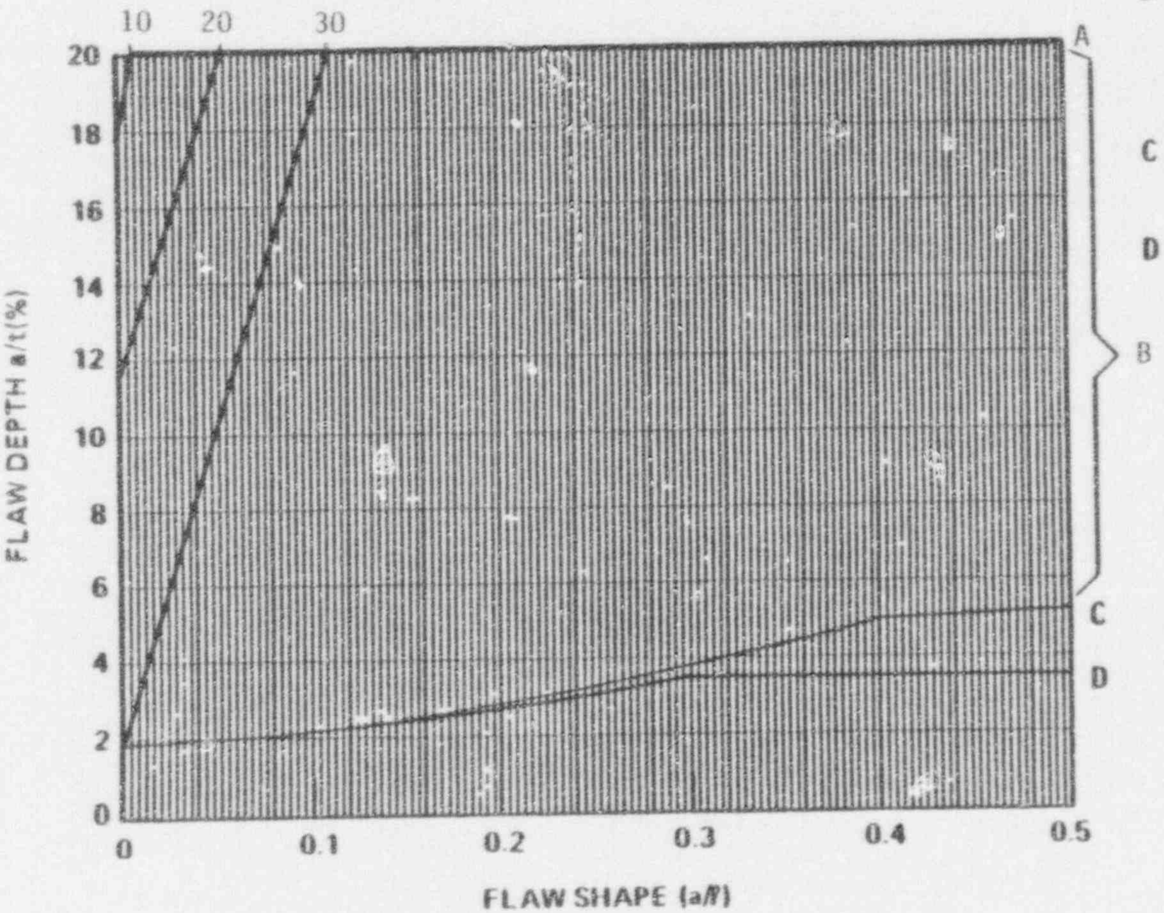
The surface flaw evaluation chart for the feedwater nozzle corner is listed below

Figure A-9.7 Flaw Evaluation Chart for Longitudinal Flaws at the Inside Surface of the Feedwater Nozzle - Corner Region

Figure A-9.1

Geometry and Terminology for Flaws at the Feedwater Nozzle Region






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

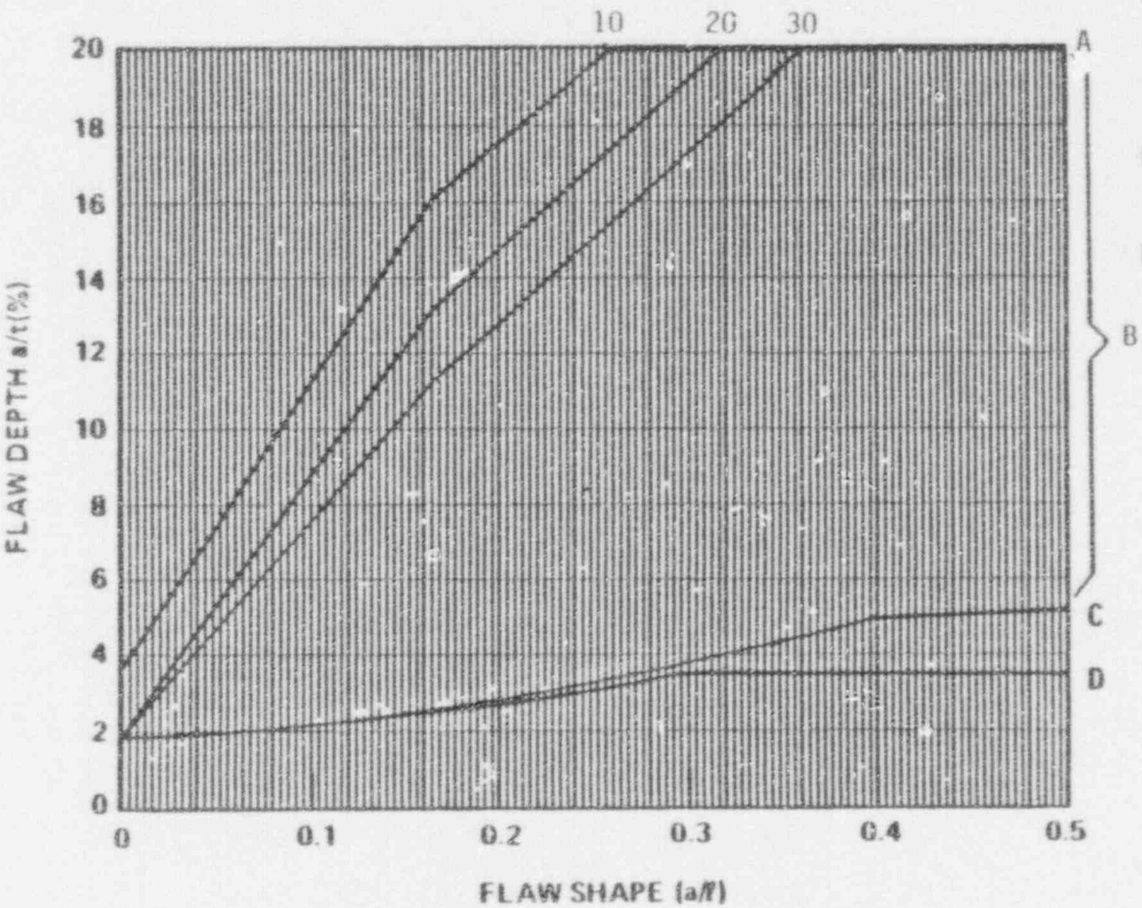
B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-9.2 Surface Flaw Evaluation Chart for the Feedwater Nozzle - Shell Weld

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

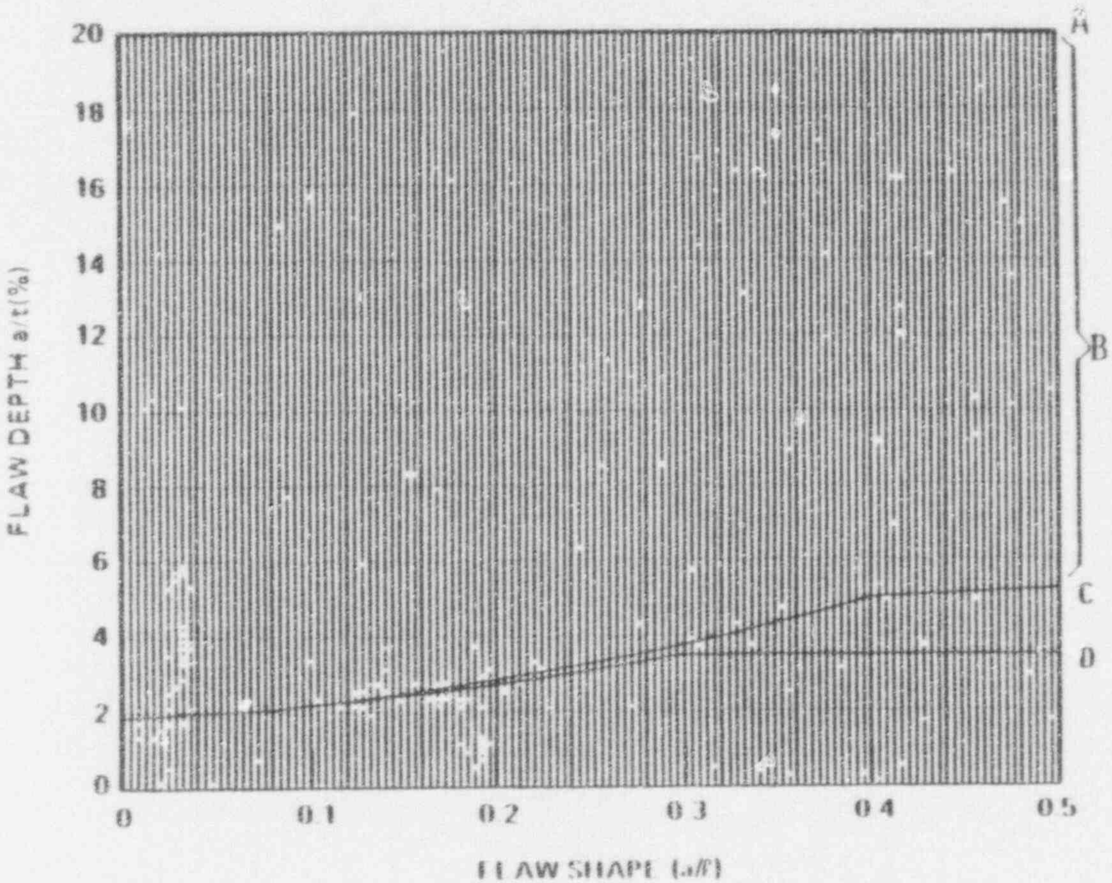
C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-9.3 Surface Flaw Evaluation Chart for the Feedwater Nozzle - S[illegible] [illegible]

X Inside Surface　X Surface Flaw　___ Longitudinal Flaw

___ Outside Surface　___ Embedded Flaw　X Circumferential Flaw




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-9.4 Surface Flaw Evaluation Chart for the Feedwater Nozzle - Shell Weld

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

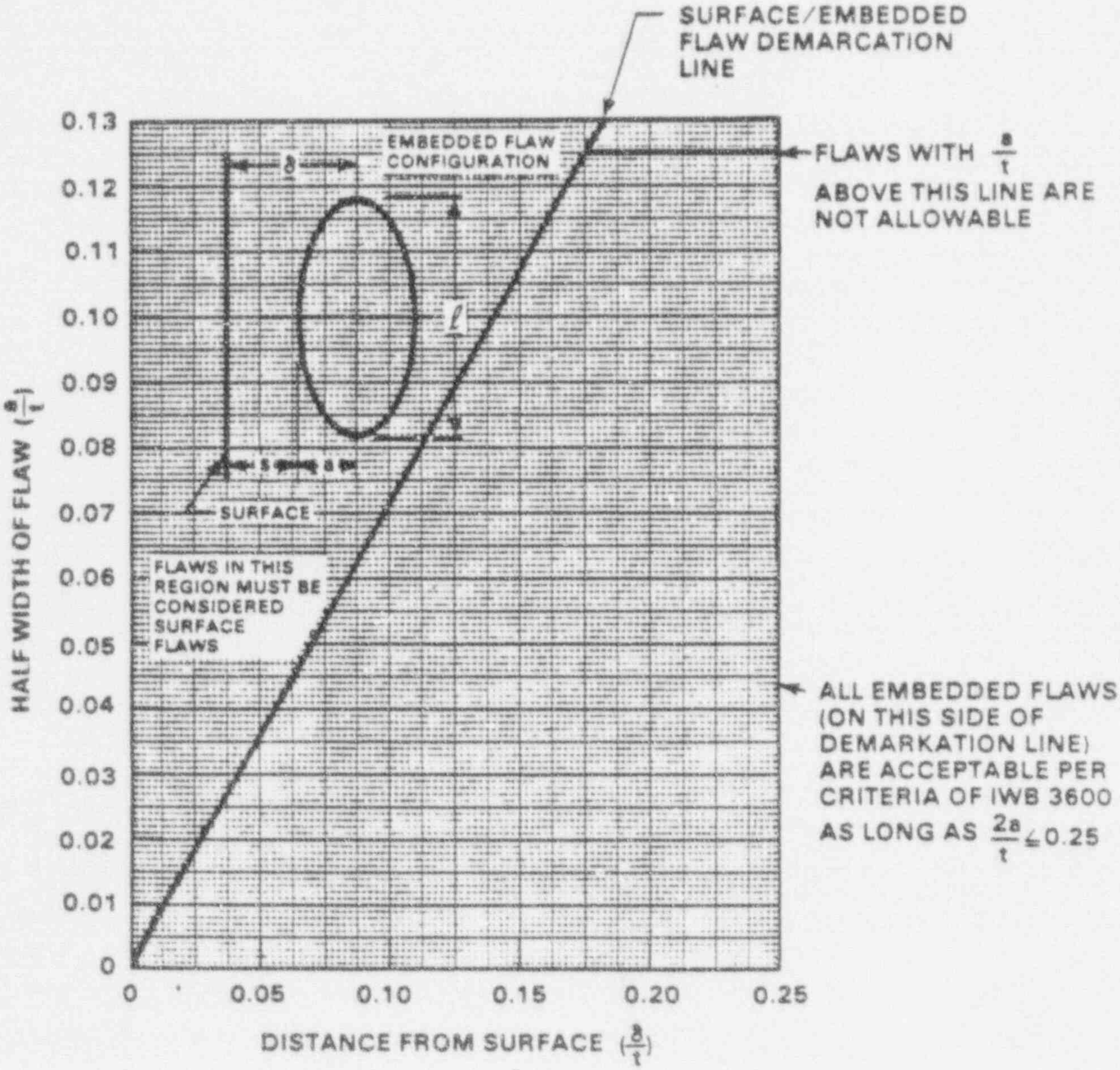



Figure A-9.5 Flaw Evaluation Chart for the Feedwater Nozzle - Shell Weld

X Inside Surface ___ Surface Flaw X Longitudinal Flaw

X Outside Surface X Embedded Flaw X Circumferential Flaw

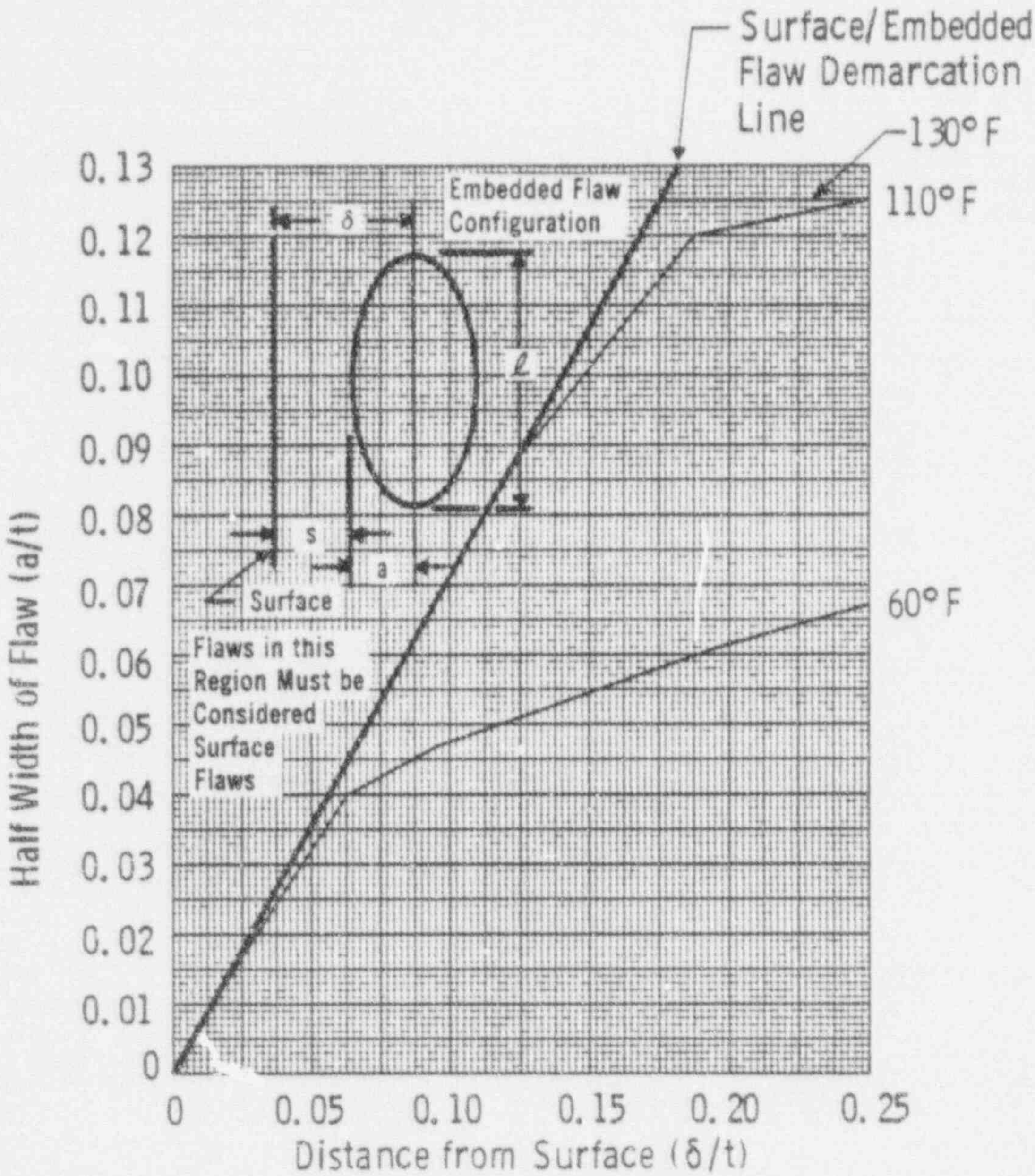



Figure A-9.6 Determination of Hydrostatic Test Temperatures for Longitudinal Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

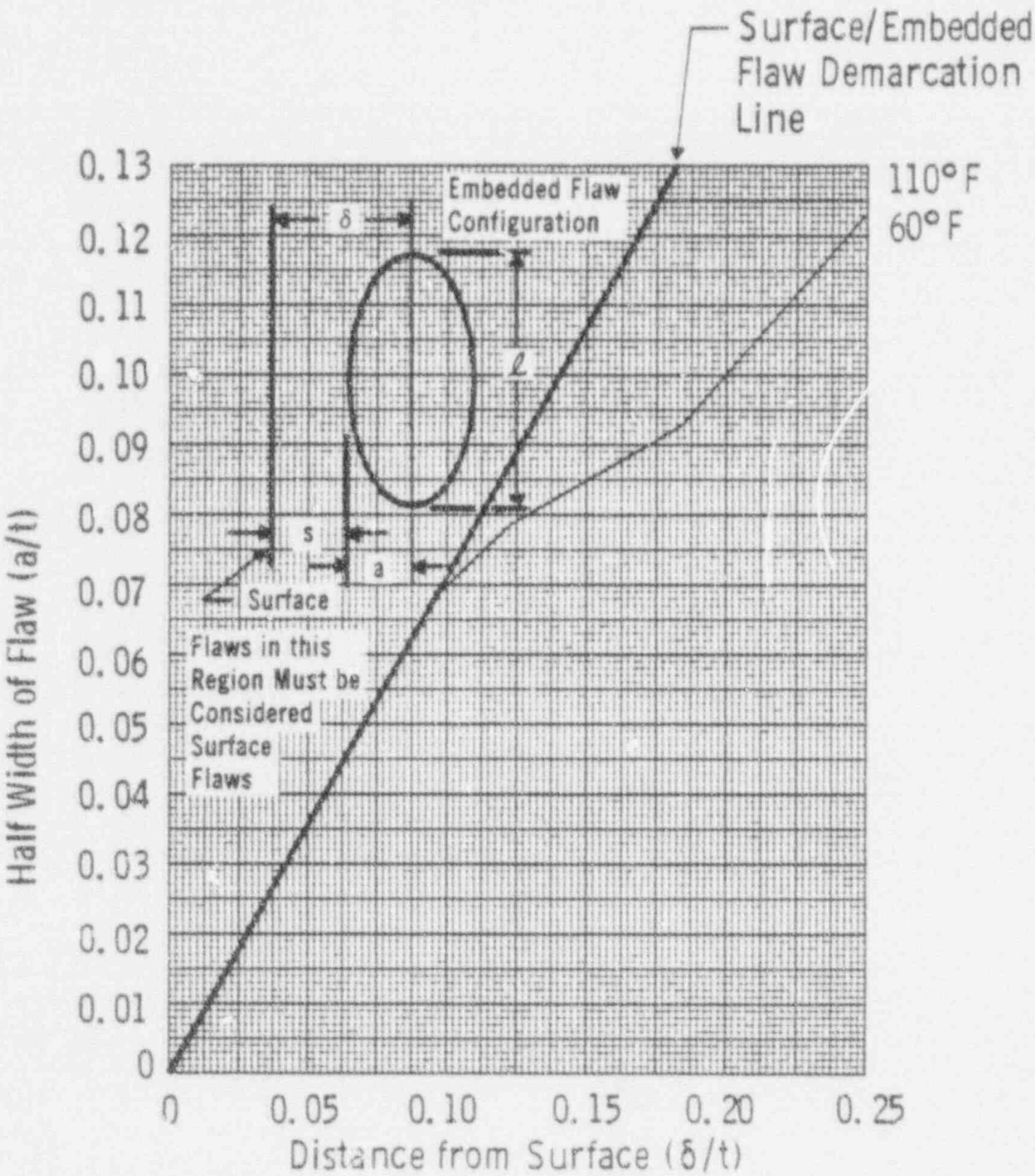



Figure A-9.7 Determination of Leakage Test Temperatures for Longitudinal Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

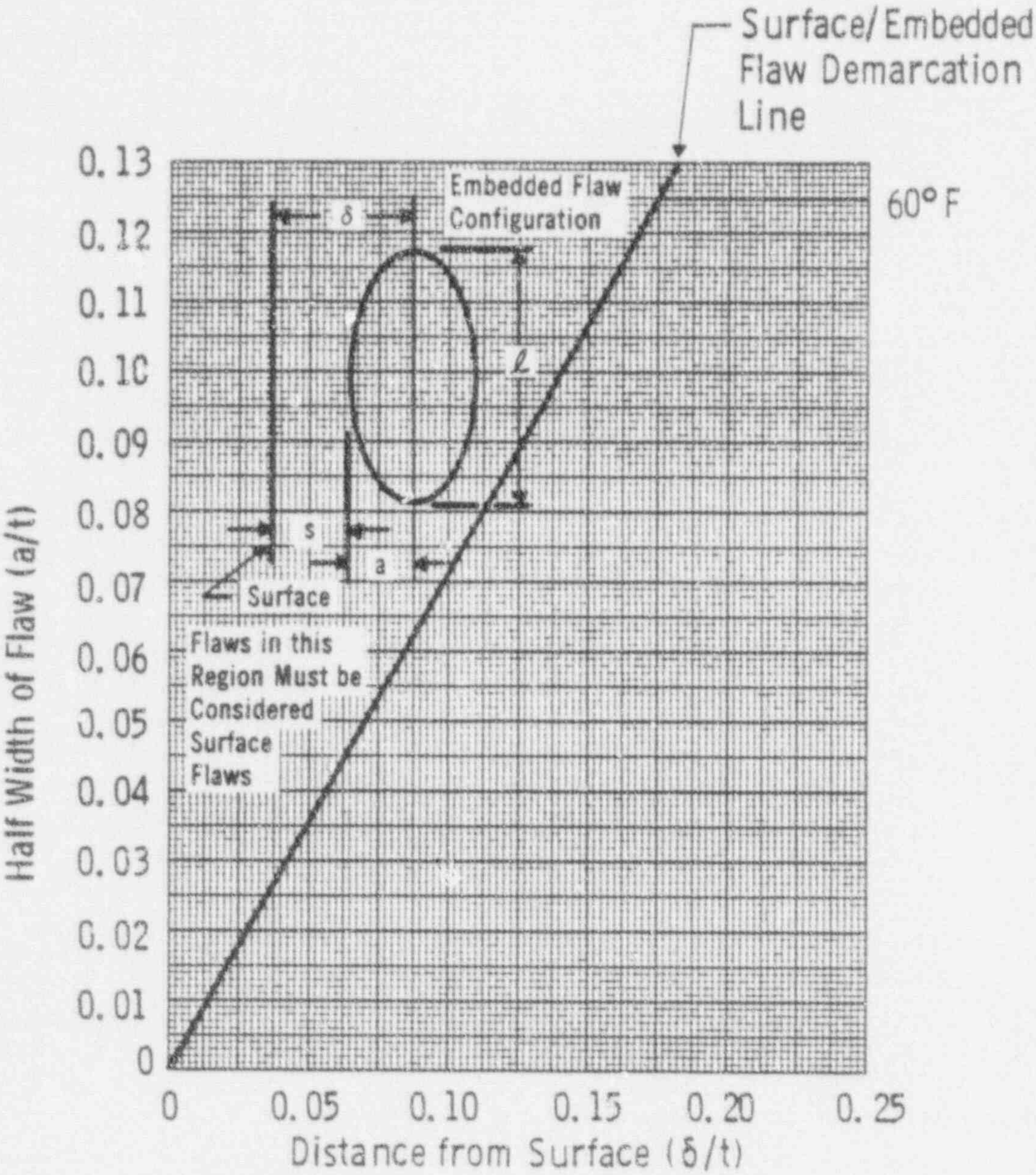



Figure A-9.8 Determination of Leakage Test Temperatures for Longitudinal Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

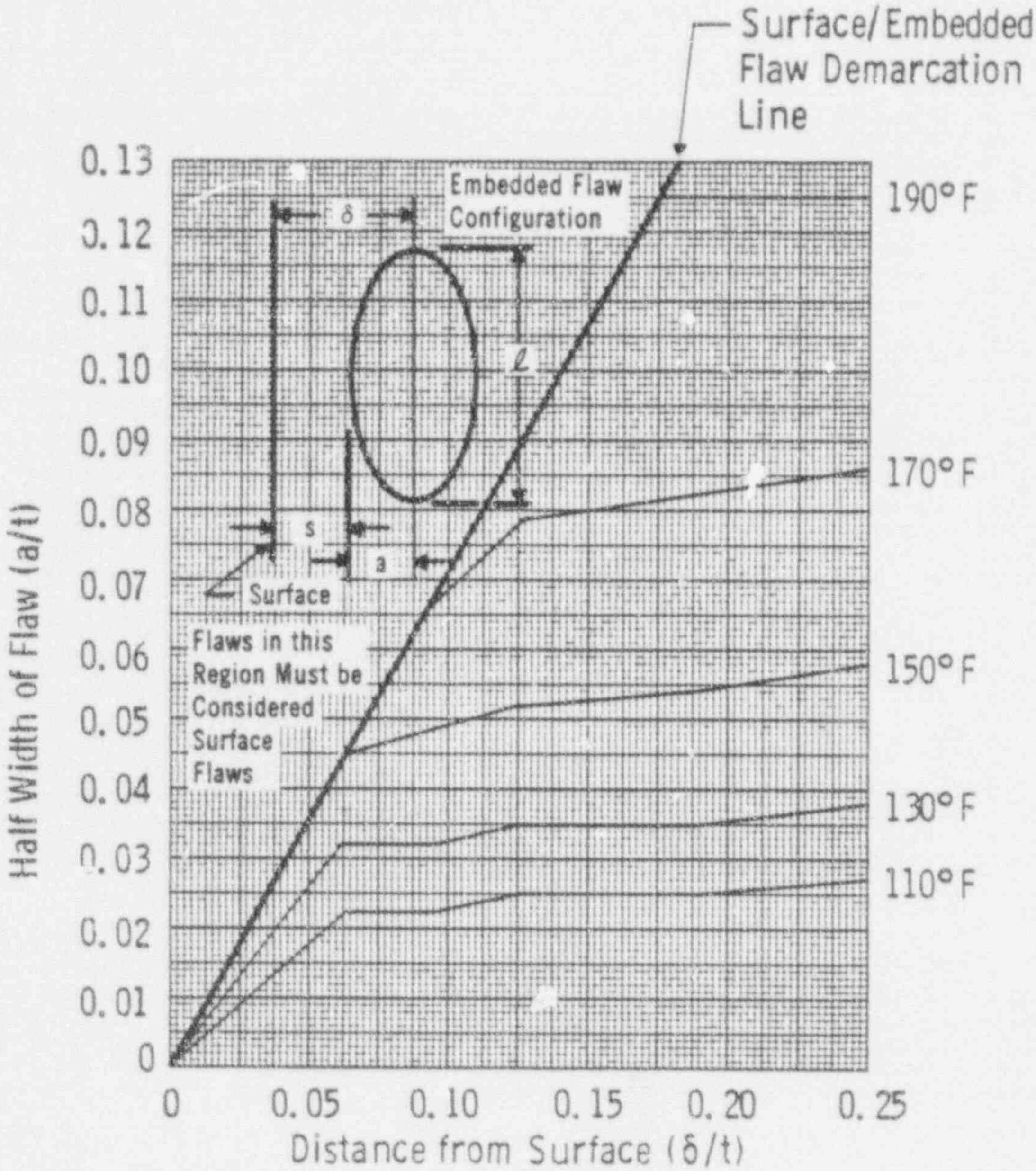



Figure A-9.9 Determination of Hydrostatic Test Temperatures for Circumferential Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

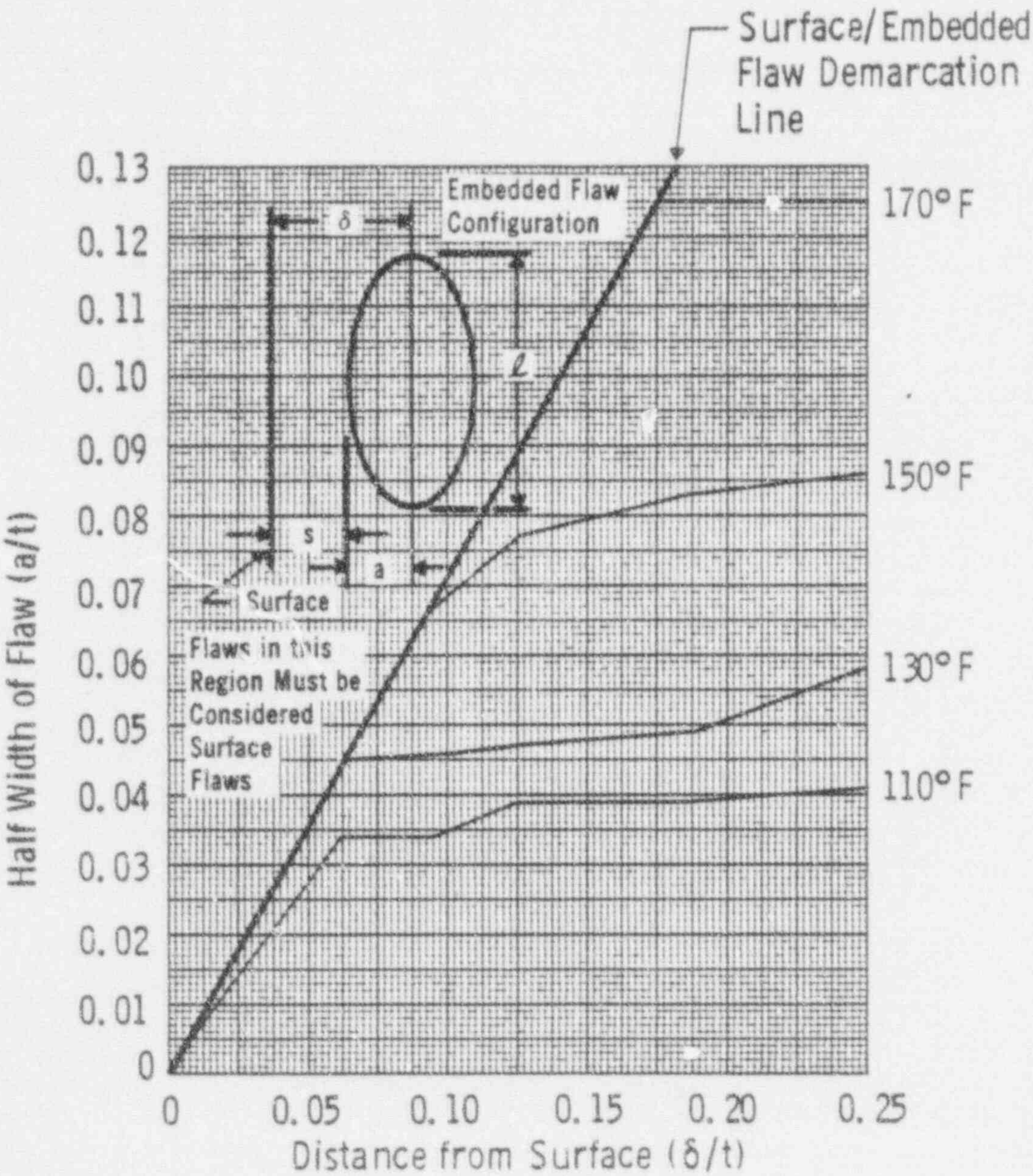



Figure A-9.10 Determination of Leakage Test Temperatures for Circumferential Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

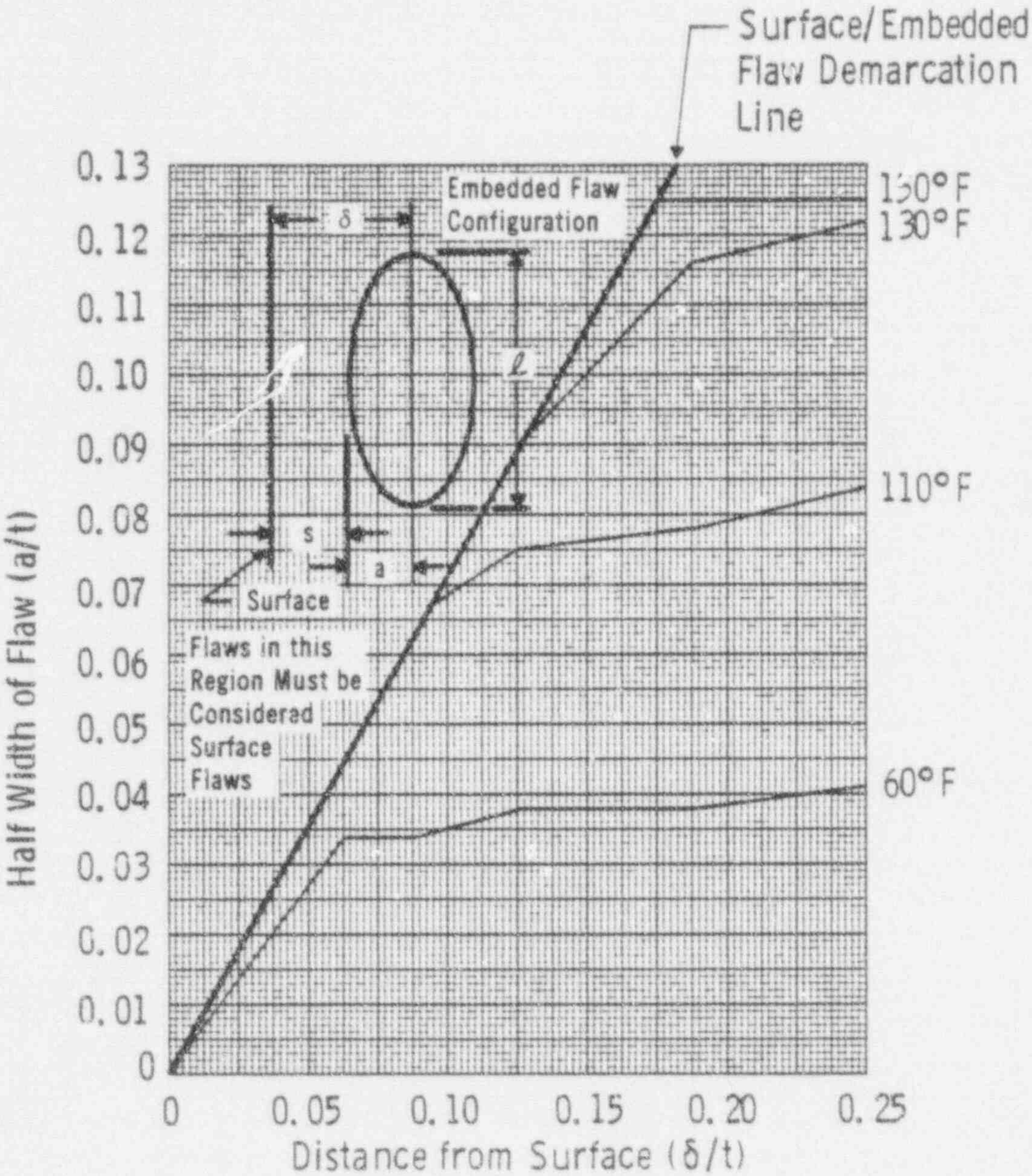



Figure A-9.11 Determination of Leakage Test Temperatures for Circumferential Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

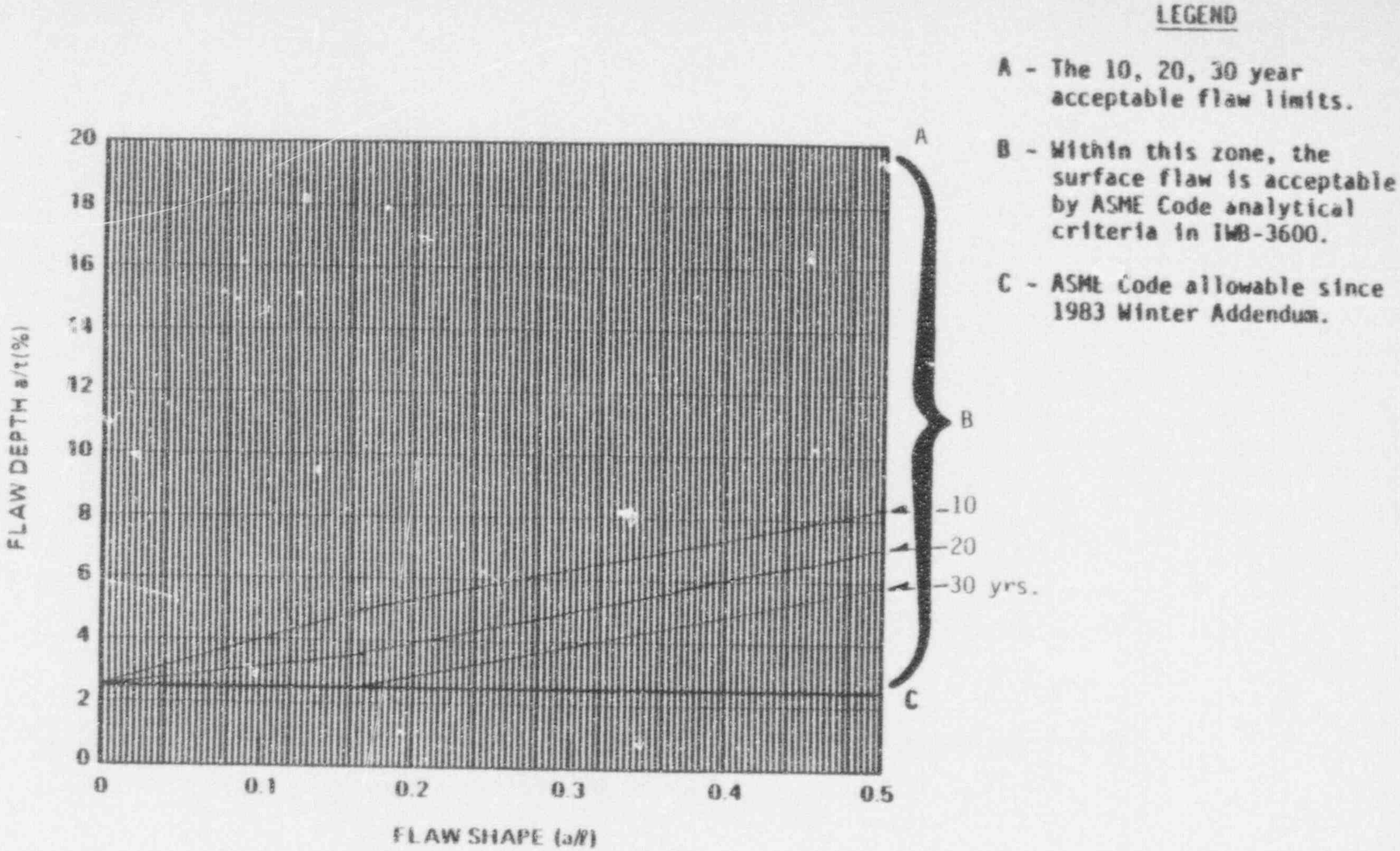



Figure A-9.12 Surface Flaw Evaluation Chart for the Feedater Nozzle Corner Region

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |

## A-10 STEAM OUTLET NOZZLE TO HEAD WELD - STEAM GENERATOR

### A-10.1 SURFACE FLAWS

The geometry and terminology for surface flaws in the steam outlet nozzle-head weld region is depicted in figure A-10.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.77")

The surface flaw evaluation charts for this region are listed below:

Figure A-10.2 Surface Flaw Evaluation Chart for Circumferential Flaws at the Steam Outlet Nozzle to Head Weld of the Steam Generator

## A-10.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is depicted in figure A-10.1.

Basic Data:

$t$ = 3.77 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth directions beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

The evaluation chart for embedded flaws is found in figure A-10.3.

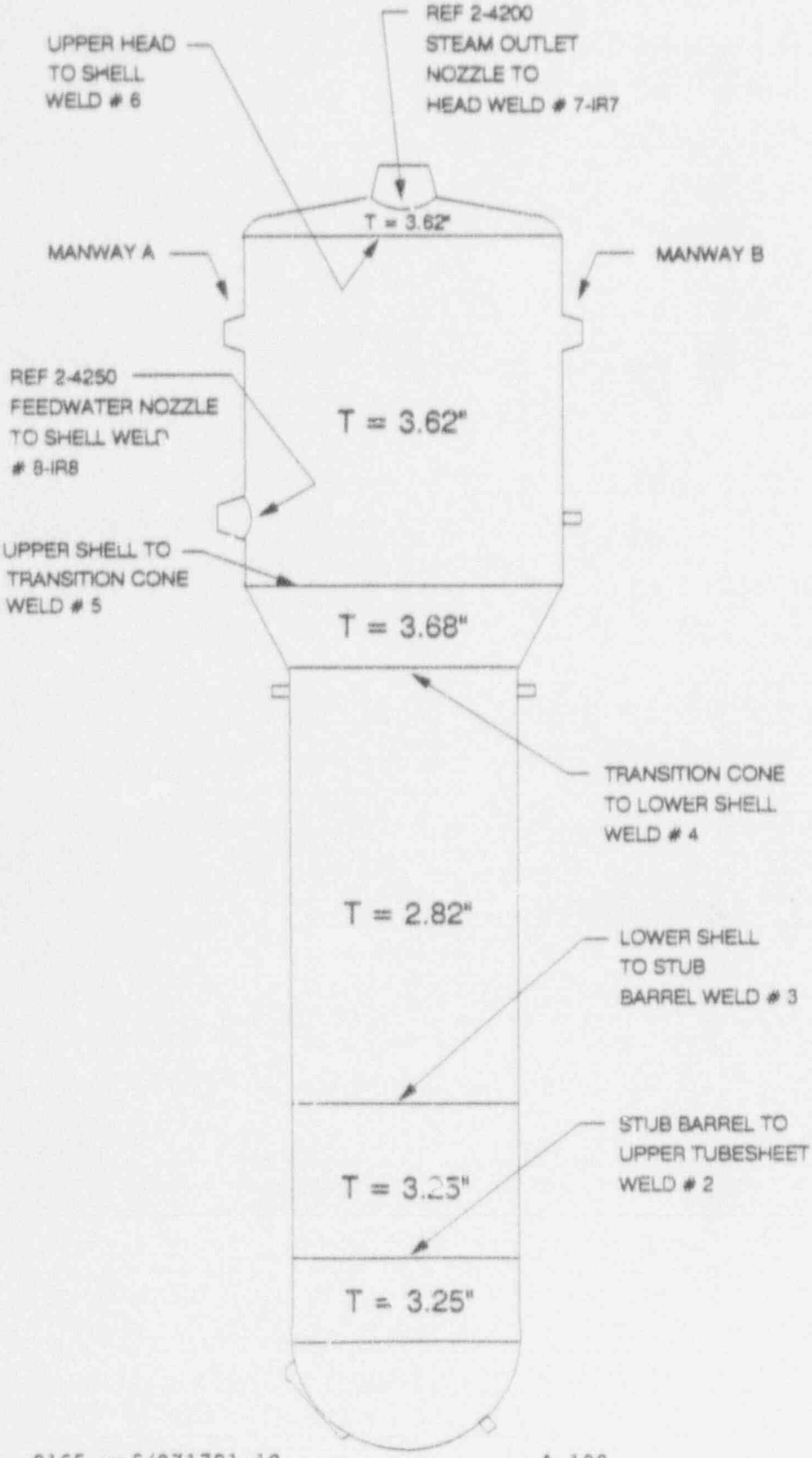
In view of figure A-10.4, all embedded flaws which meet the criterion $a/t \leq$ 0.125 will be acceptable regardless of their size, shape, and location.

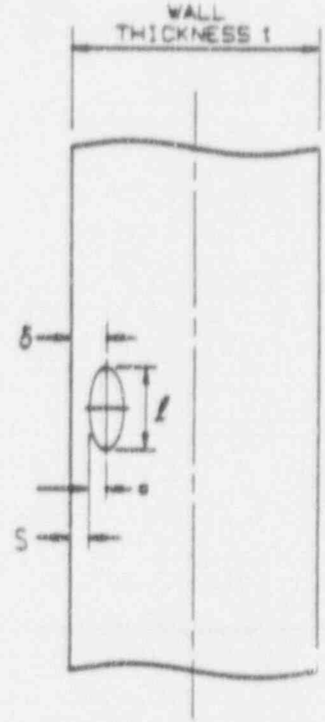
The embedded flaw evaluation charts for the steam outlet nozzle to head weld:

Figure A-10.3 Embedded Flaw Evaluation Chart for Circumferential Flaws in the Steam Outlet Nozzle to Head Weld - Steam Generator

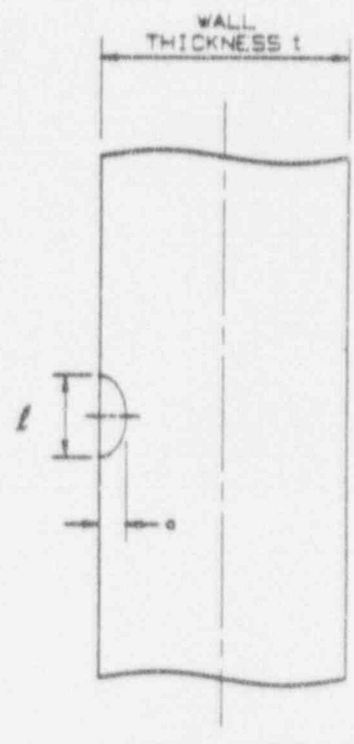
Figure A-10.4 through Figure A-10.6 Test Temperature Determination Chart for Circumferential Flaws near the Inside Surface of the Steam Outlet Nozzle to Head Weld - Steam Generator for Secondary Hydro Test and Secondary Leak Tests

Figure A-10.1
Geometry and Terminology for Flaws at Steam Outlet Nozzle to Head Weld

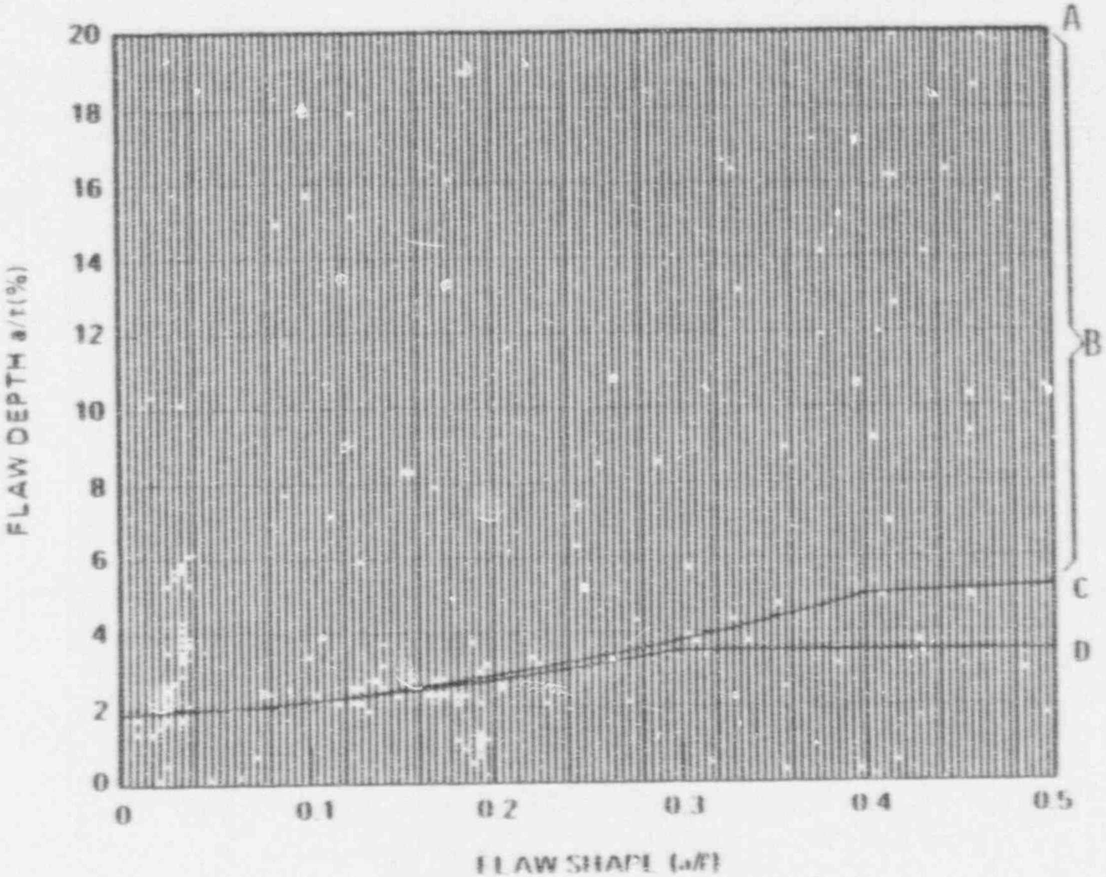



TYPICAL EMBEDDED
FLAW INDICATION




TYPICAL SURFACE
FLAW INDICATION




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-10.2 Flaw Evaluation Chart for Steam Outlet Nozzle to Head Weld - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | | Longitudinal Flaw |
| X | Outside Surface | | Embedded Flaw | X | Circumferential Flaw |

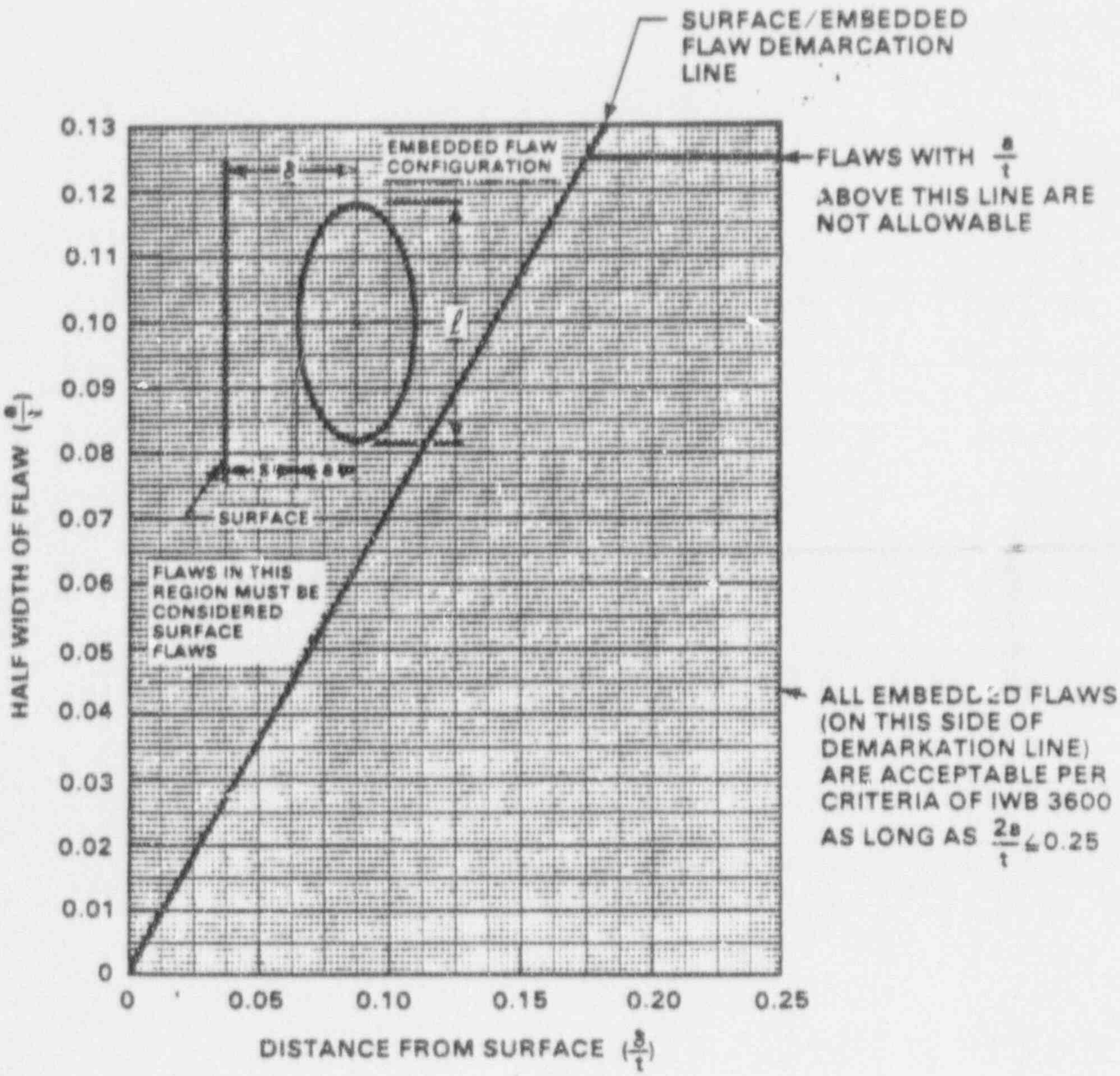



Figure A-10.3 Flaw Evaluation Chart for the Steam Outlet Nozzle to Head Weld - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | | Surface Flaw | | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

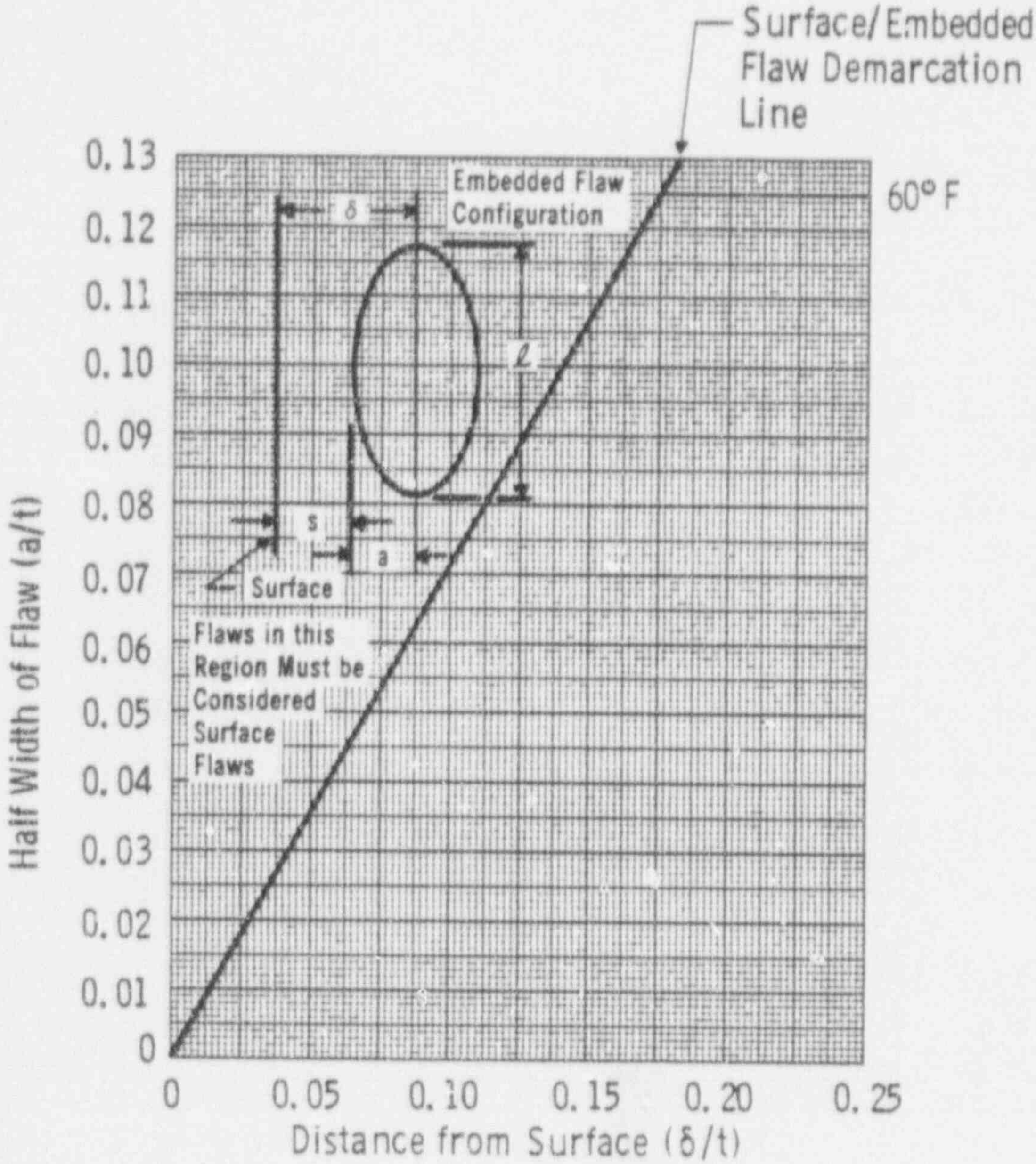



Figure A-10.4 Determination of Hydrostatic Test Temperatures for Embedded Flaws (p=1356 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

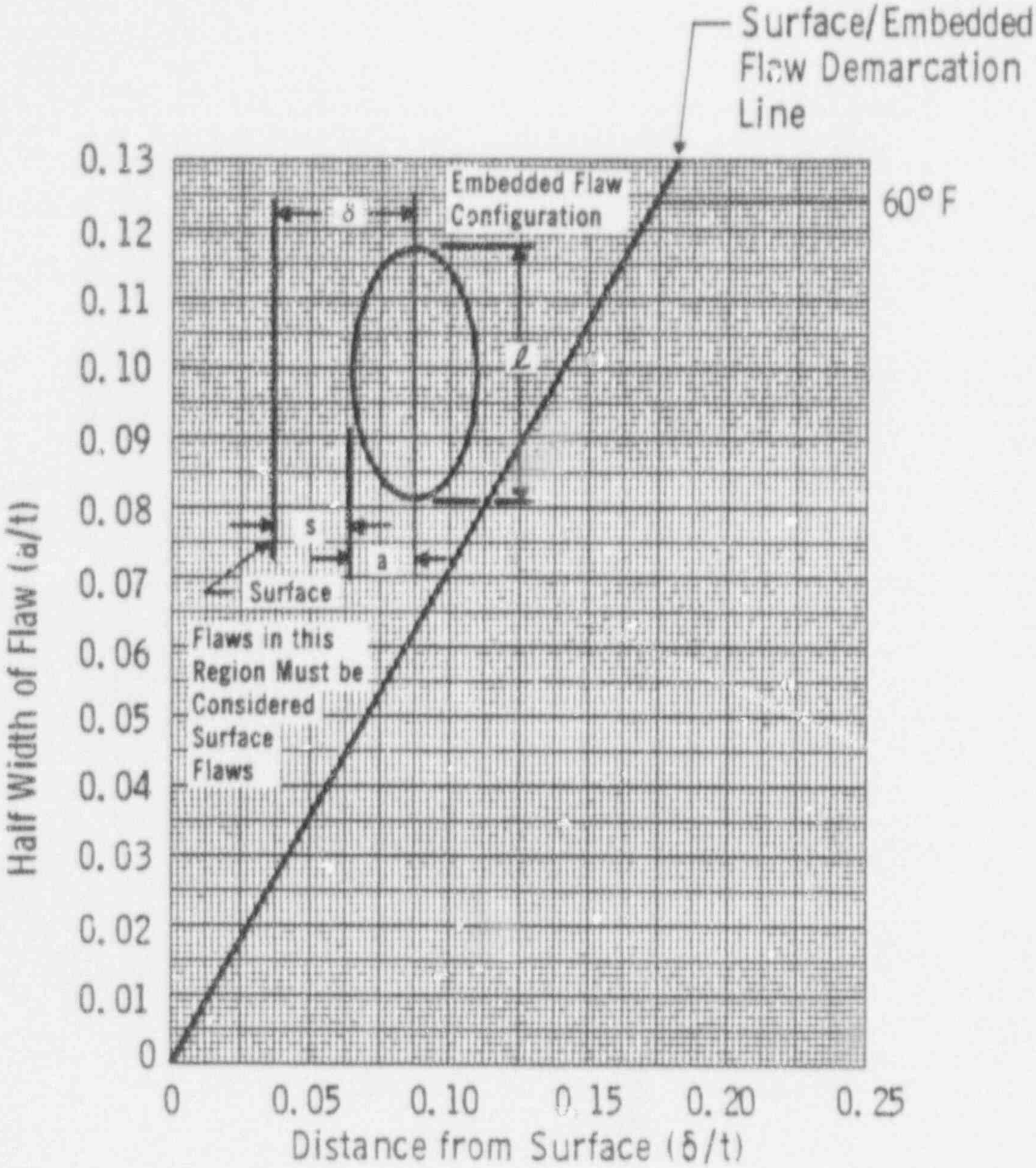



Figure A-10.5 Determination of Leakage Test Temperatures for Embedded Flaws (p=1085 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

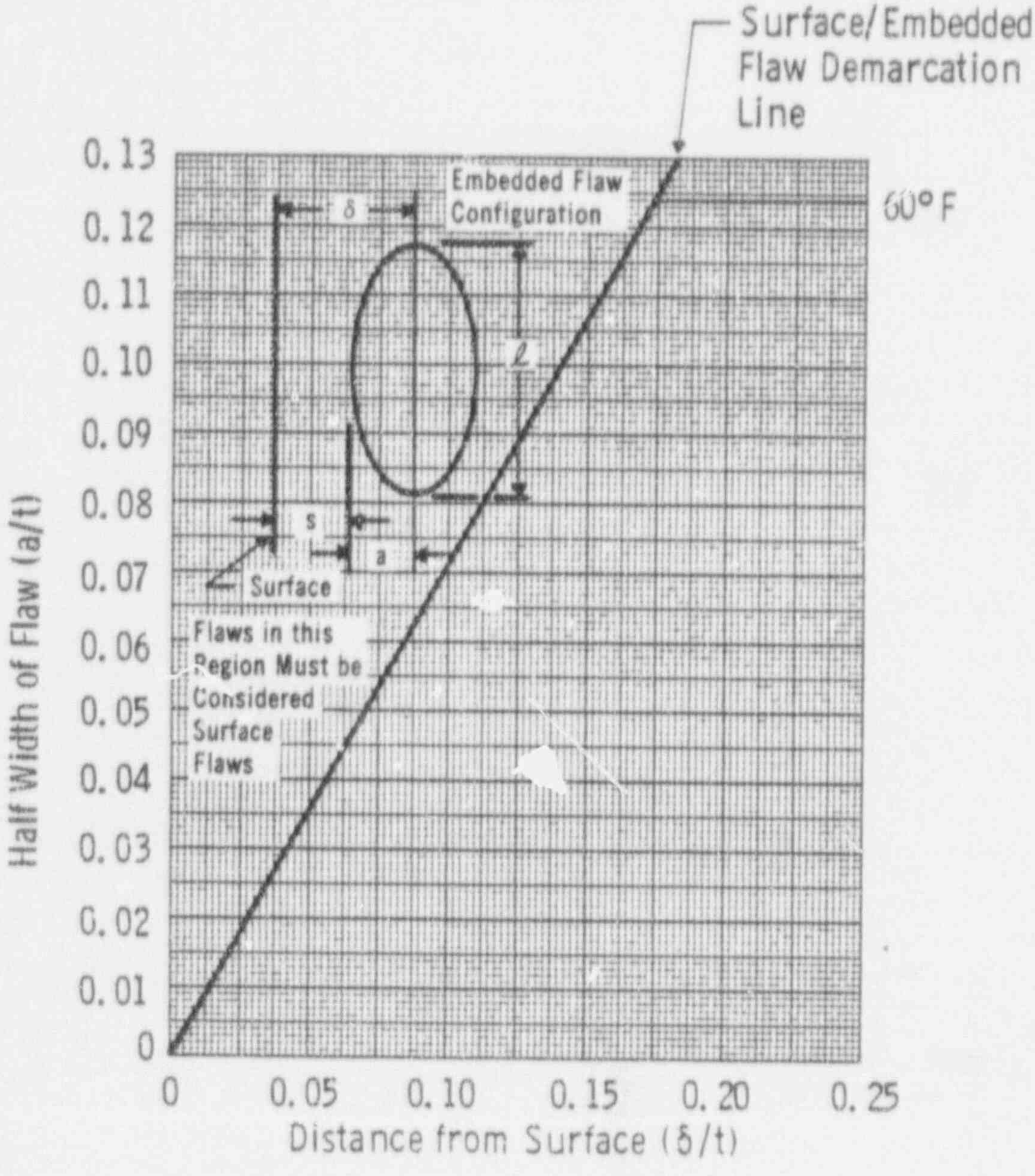



Figure A-10.6 Determination of Leakage Test Temperatures for Embedded Flaws (p=750 psi) for Farley Units 1 and 2

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-11 PRIMARY NOZZLE SAFE END WELD - STEAM GENERATOR

### A-11.1 SURFACE FLAWS

The geometry and terminology for surface flaws in the primary nozzle safe-end weld region is depicted in figure A-11.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.45")

The surface flaw evaluation charts for this region are listed below:

Figure A-11.2 Surface Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Primary Nozzle Safe End Weld - Steam Generator

Figure A-11.3 Surface Flaw Evaluation Chart for Circumferential Flaws at Outside Surface of Primary Nozzle Safe End Weld - Steam Generator

## A-11.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is depicted in figure A-11.1.

Basic Data:

$t$ = 3.77 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth directions beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

The evaluation chart for embedded flaws is found in figure A-11.4.

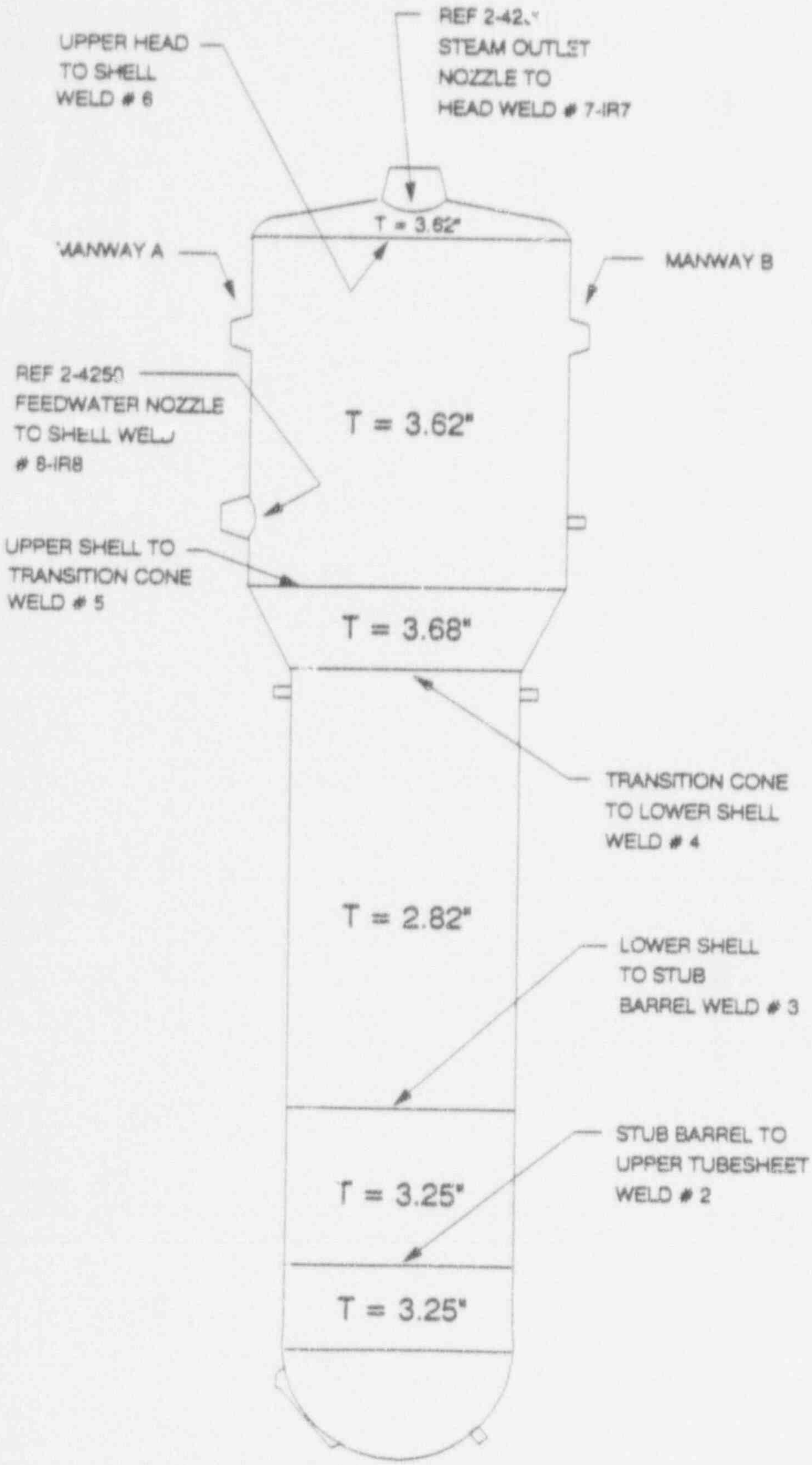
In view of figure A-11.4, all embedded flaws which meet the criterion a/t <0.125 will be acceptable regardless of their size, shape, and location.

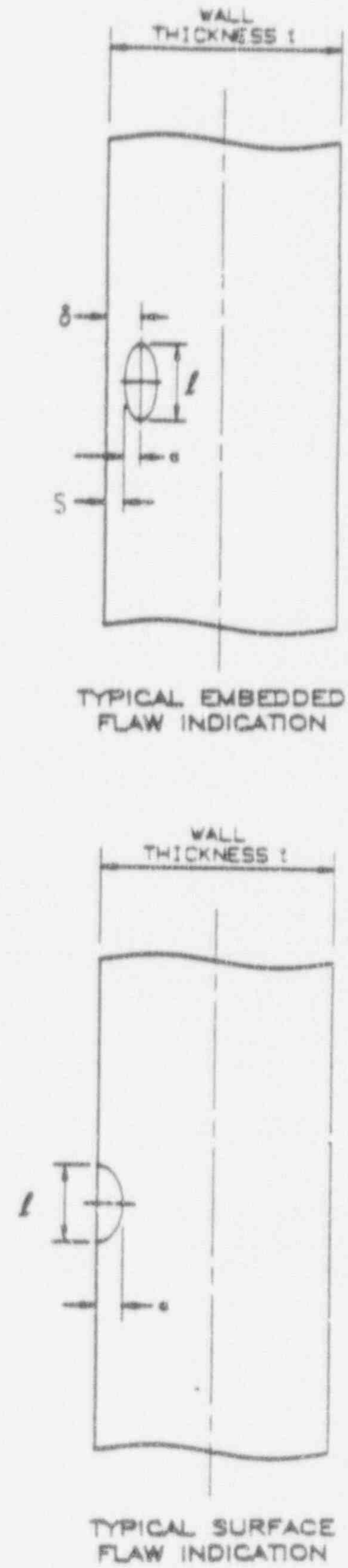
The embedded flaw evaluation chart for the Primary Nozzle Safe End Weld:

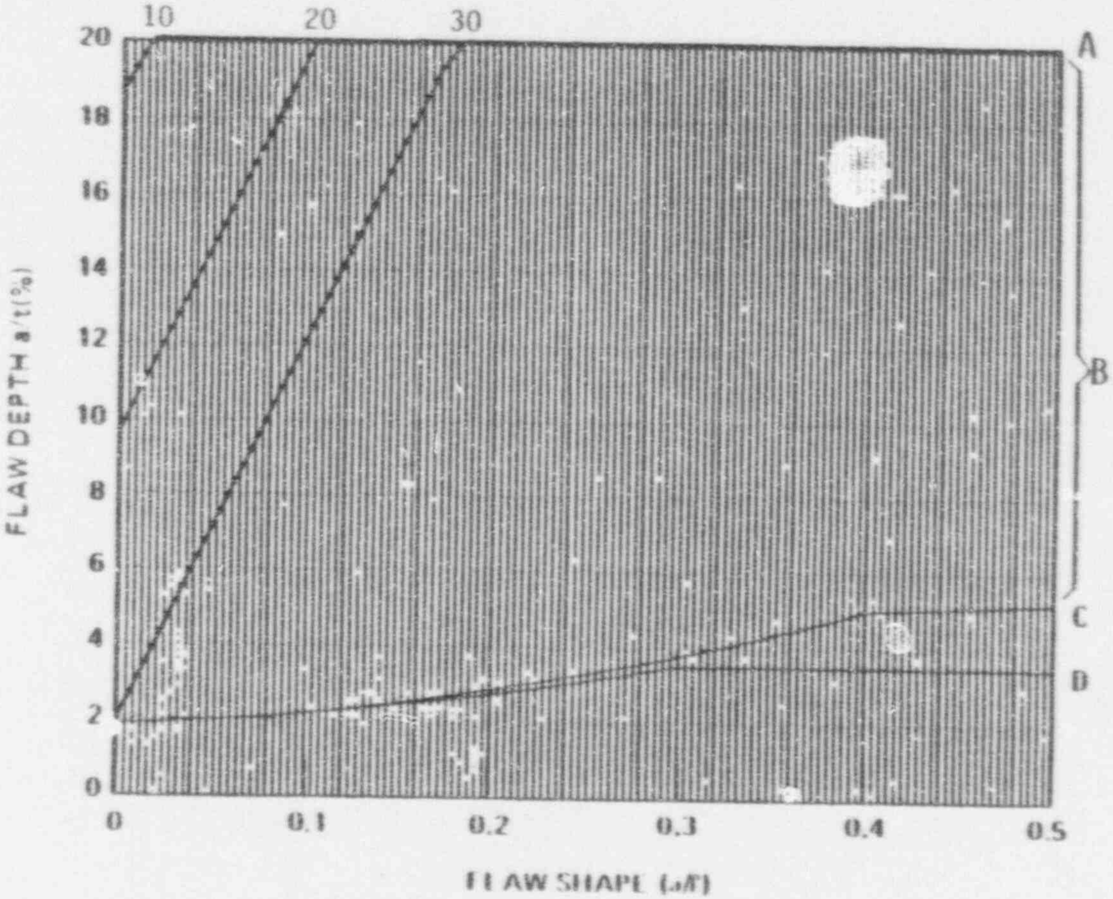
Figure A-11.4 Embedded Flaw Evaluation Chart for Circumferential Flaws in the Primary Nozzle Safe End Weld - Steam Generator

Figure A-11.1

Geometry and Terminology for Flaws at Primary Nozzle Safe End Welds






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

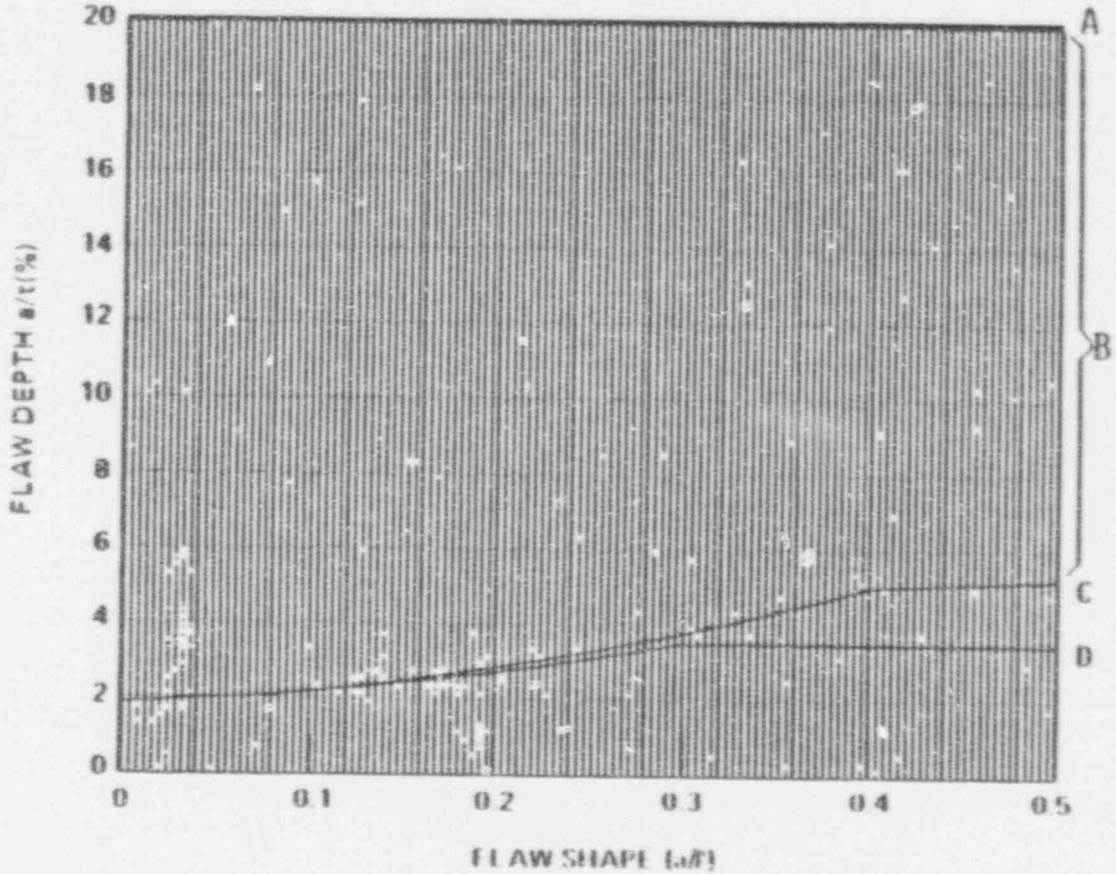
D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-11.2 Flaw Evaluation Chart for the Primary Nozzle Safe End Weld - Steam Generator

X Inside Surface   X Surface Flaw   __ Longitudinal Flaw

__ Outside Surface   __ Embedded Flaw   X Circumferential Flaw




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-11.3 Flaw Evaluation Chart for the Primary Nozzle Safe End Weld - Steam Generator

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

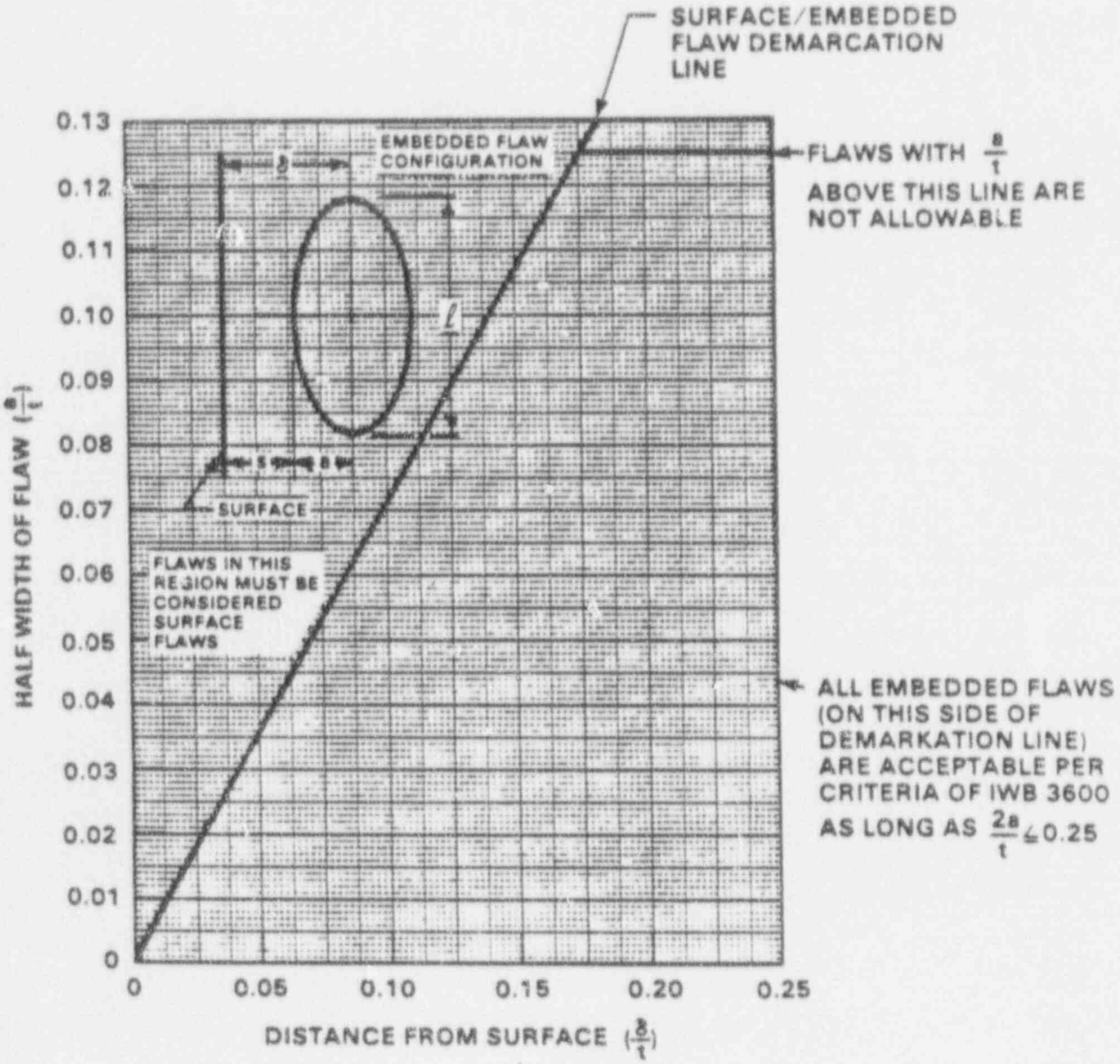



Figure A-11.4 Flaw Evaluation Chart for the Primary Nozzle Safe End Weld - Steam Generator

X Inside Surface ___ Surface Flaw ___ Longitudinal Flaw

X Outside Surface X Embedded Flaw X Circumferential Flaw

## A-12 UPPER SHELL TO HEAD WELD - PRESSURIZER

### A-12.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-12.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 1.9")

The surface flaw evaluation charts for these regions of the pressurizer are listed below:

Figure A-12.2 Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Upper Shell to Head Weld - Pressurizer

Figure A-12.3 Flaw Evaluation Chart for Circumferential Flaws at the Outside Surface of the Upper Shell to Head Weld - Pressurizer

A-12.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region appear in figure A-11.1.

Basic Data:

$t$ = 1.9 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

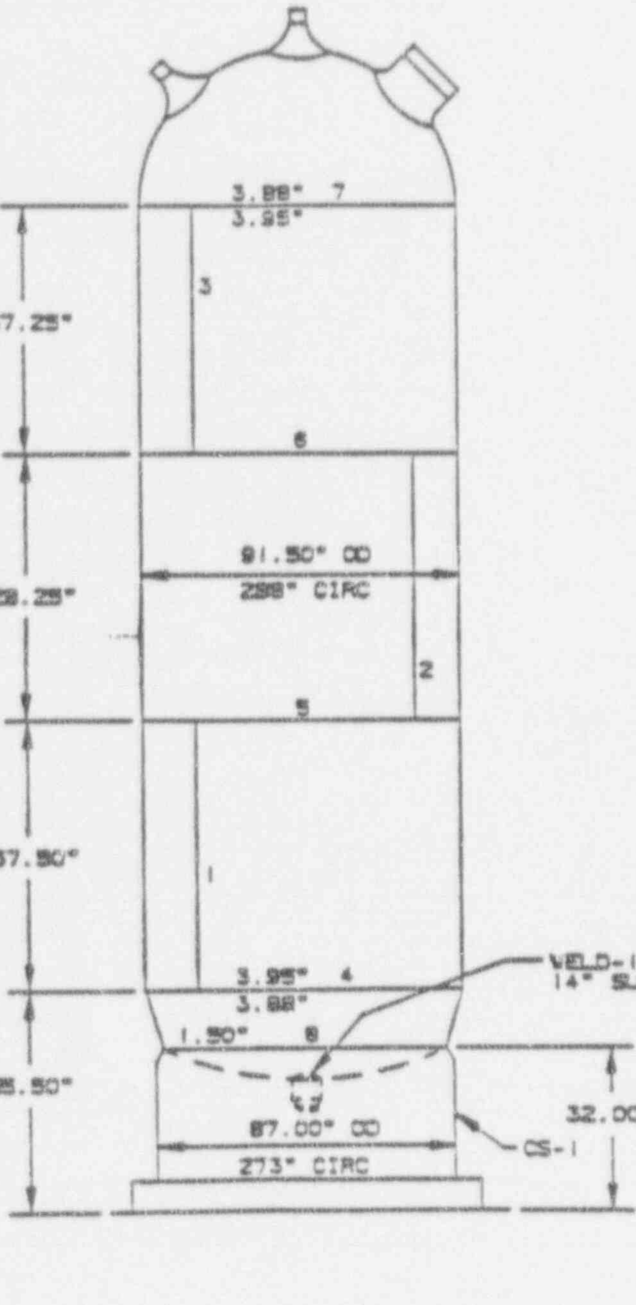
The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

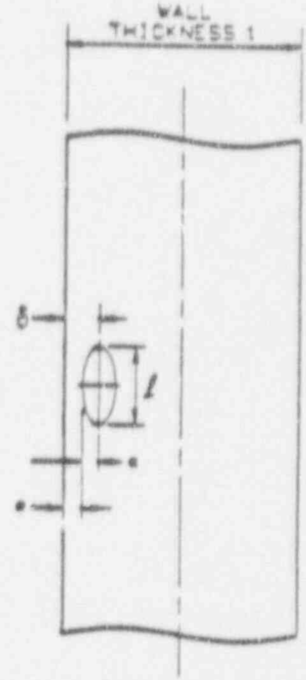
- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

Evaluation charts for embedded flaws in these regions of the pressurizer are listed below:

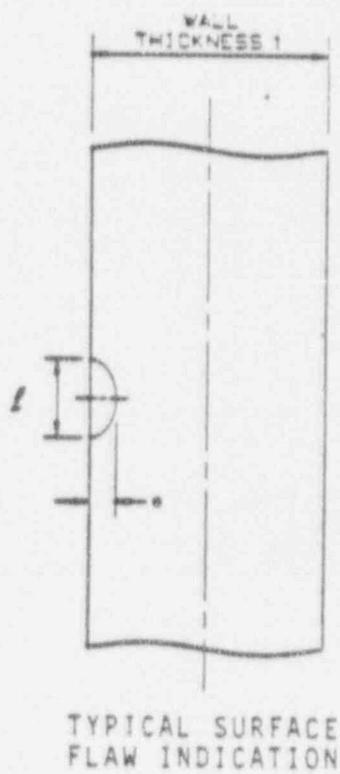
Figure A-12.4 Embedded Flaw Evaluation Chart for Circumferential Flaws at the Upper Shell to Head Weld - Pressurizers

Figure A-12.1
Geometry and Terminology for Flaws in the Upper Shell
to Head Weld - Pressurizer

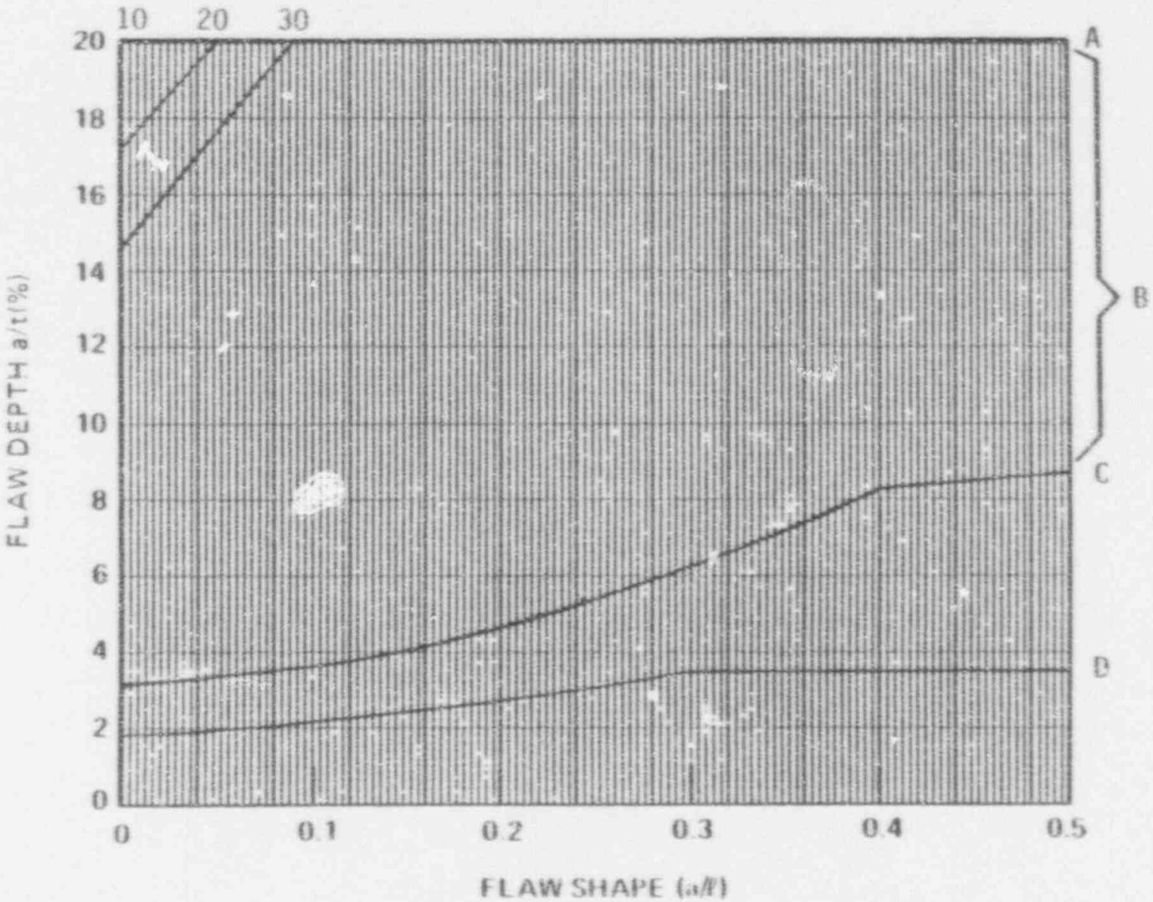



TYPICAL EMBEDDED
FLAW INDICATION




TYPICAL SURFACE
FLAW INDICATION




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

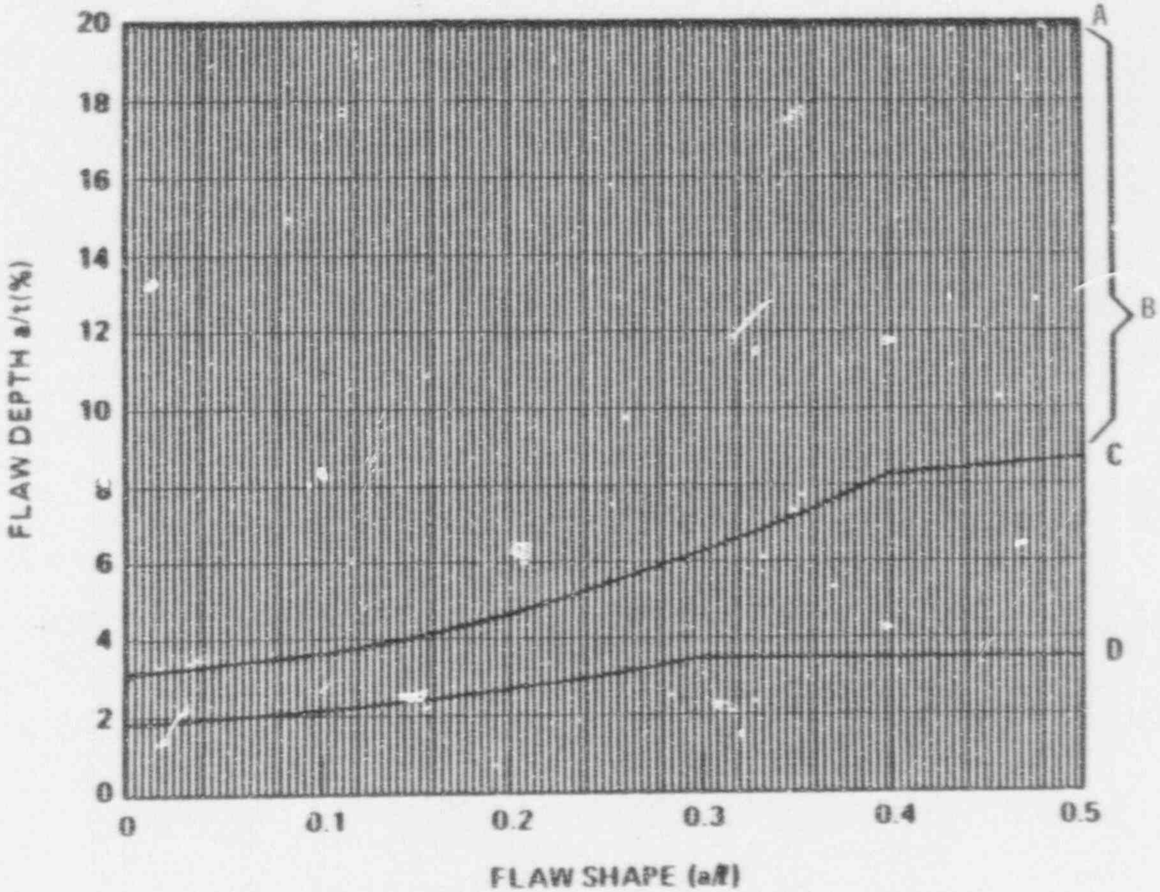
D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-12.2 Flaw Evaluation Chart for the Upper Shell to Head Weld - Pressurizer

X Inside Surface  X Surface Flaw  ___ Longitudinal Flaw

___ Outside Surface  ___ Embedded Flaw  X Circumferential Flaw




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-12.3 Flaw Evaluation Chart for the Upper Shell to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | | Longitudinal Flaw |
| X | Outside Surface | | Embedded Flaw | X | Circumferential Flaw |



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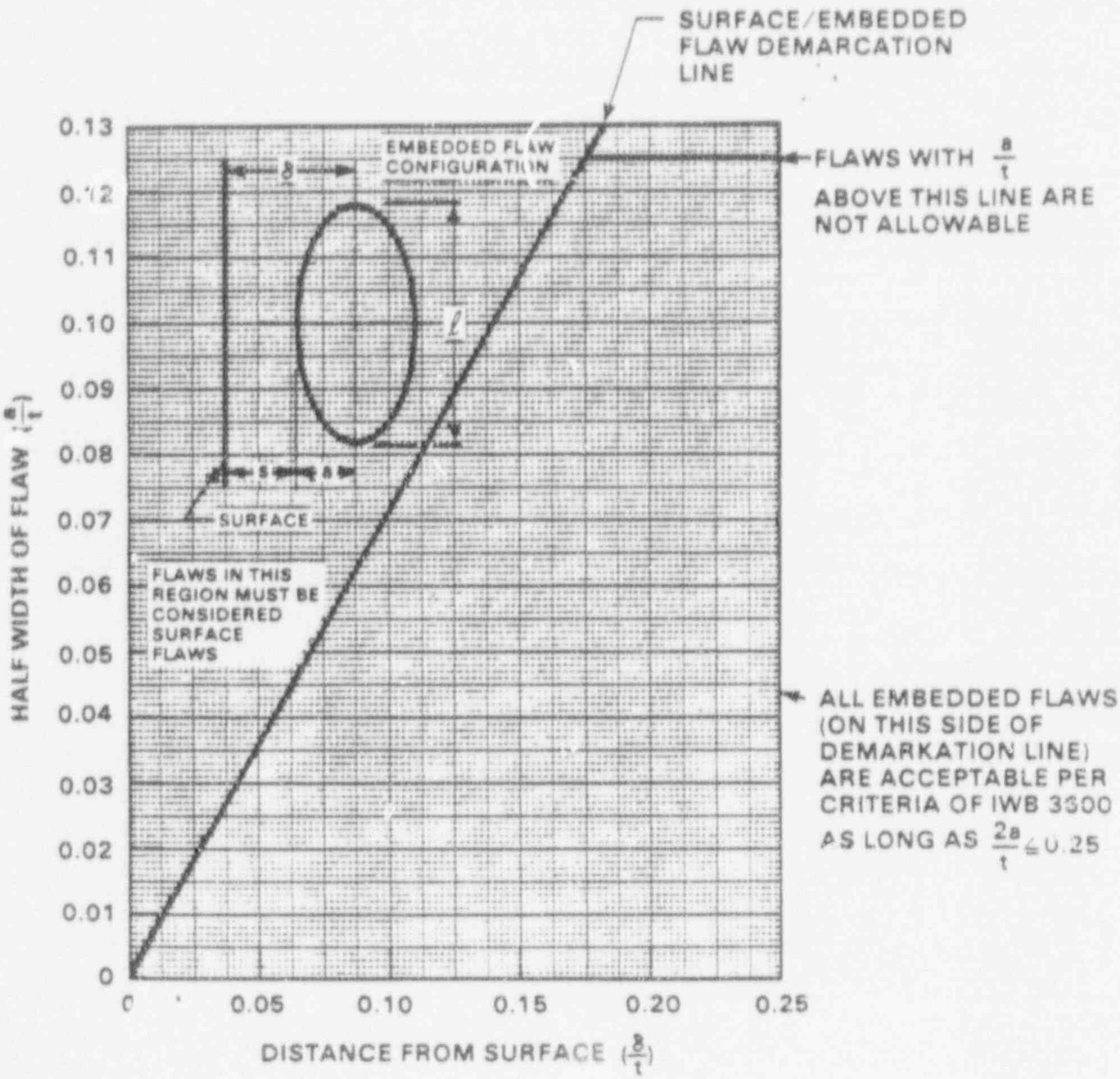



Figure A-12.4 Flaw Evaluation Chart for the Pressurizer Upper Shell to Head Weld - Pressurizer

X Inside Surface ___ Surface Flaw X Longitudinal Flaw

X Outside Surface X Embedded Flaw X Circumferential Flaw

## A-13 UPPER SHELL CIRCUMFERENTIAL WELDS - PRESSURIZER

### A-13.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-13.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.75")

The surface flaw evaluation charts for these regions of the pressurizer are listed below:

Figure A-13.2 Surface Flaw Evaluation Chart for Circumferential Flaws at Inside Surface of the Upper Shell Circumferential Welds - Pressurizer

Figure A-13.3 Surface Flaw Evaluation Chart for Circumferential Flaws at the Outside Surface of the Upper Shell - Pressurizer

A-13.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is shown in figure A-13.1.

Basic Data:

t = 3.75"

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

a = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

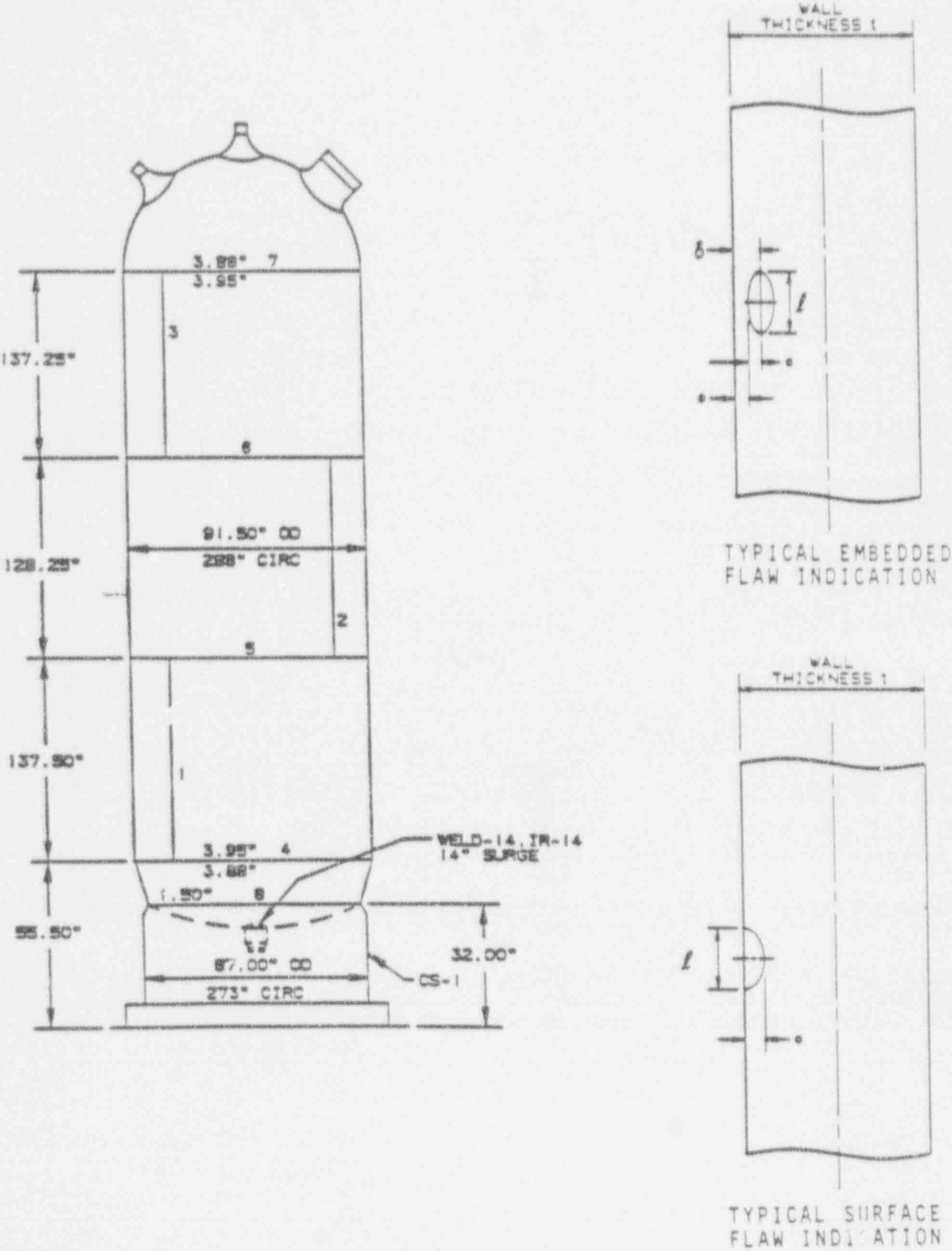
The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

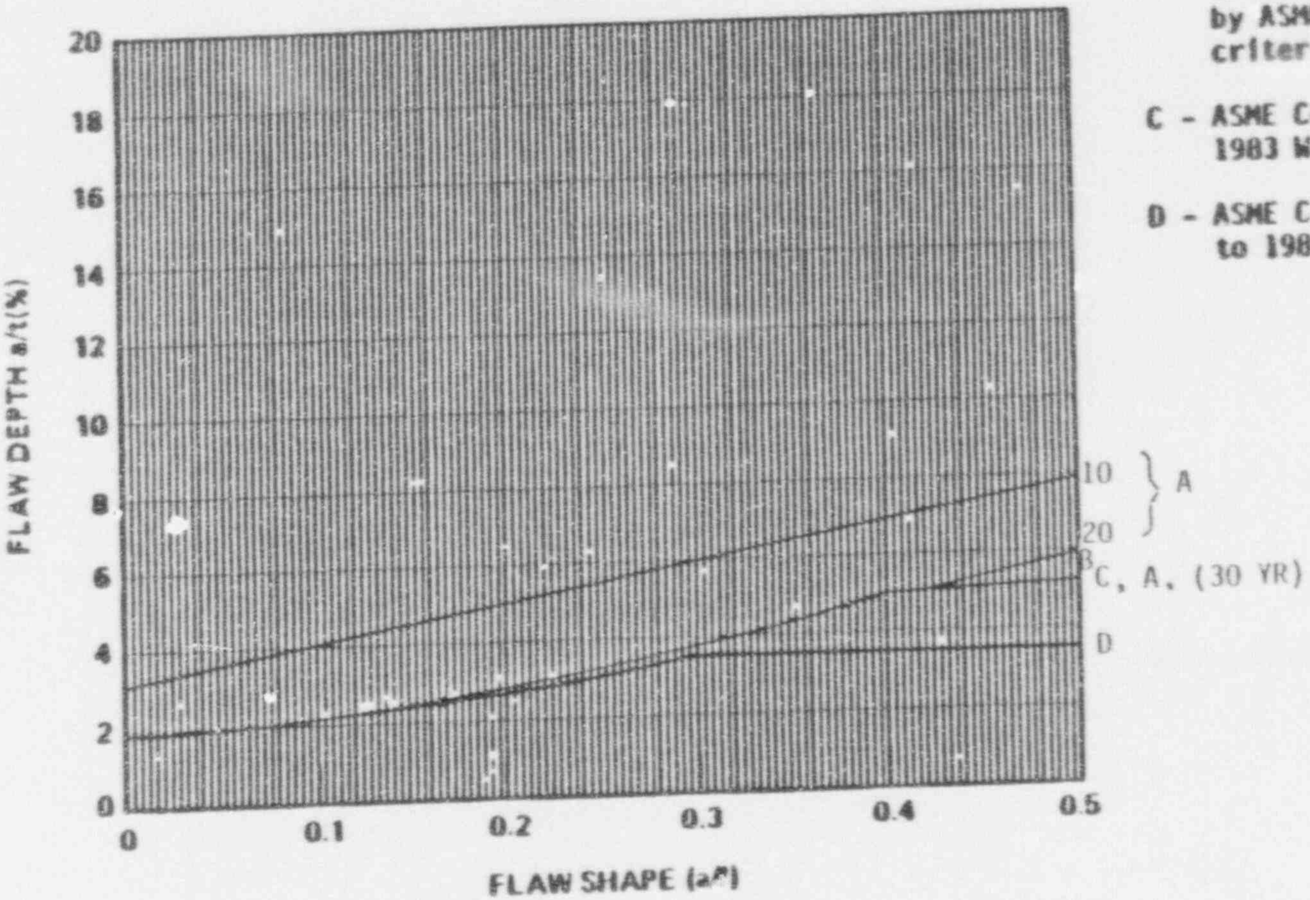
- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, a/t
- o Surface proximity parameter, $\delta/t$

Evaluation charts for embedded flaws in these regions of the pressurizer are listed below:

Figure A-13.4 Embedded Flaw Evaluation Chart for Circumferential Flaws at the Upper Shell Circumferential Welds - Pressurizer

Figure A-13.1
Geometry and Terminology for Flaws in the Upper Shell
Circumferential Welds - Pressurizer






A-124

LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-13.2 Flaw Evaluation Chart for the Upper Shell Circumferential Welds - Pressurizer

X Inside Surface  X Surface Flaw  ___ Longitudinal Flaw
___ Outside Surface  ___ Embedded Flaw  X Circumferential Flaw

3652s/031089:10

LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

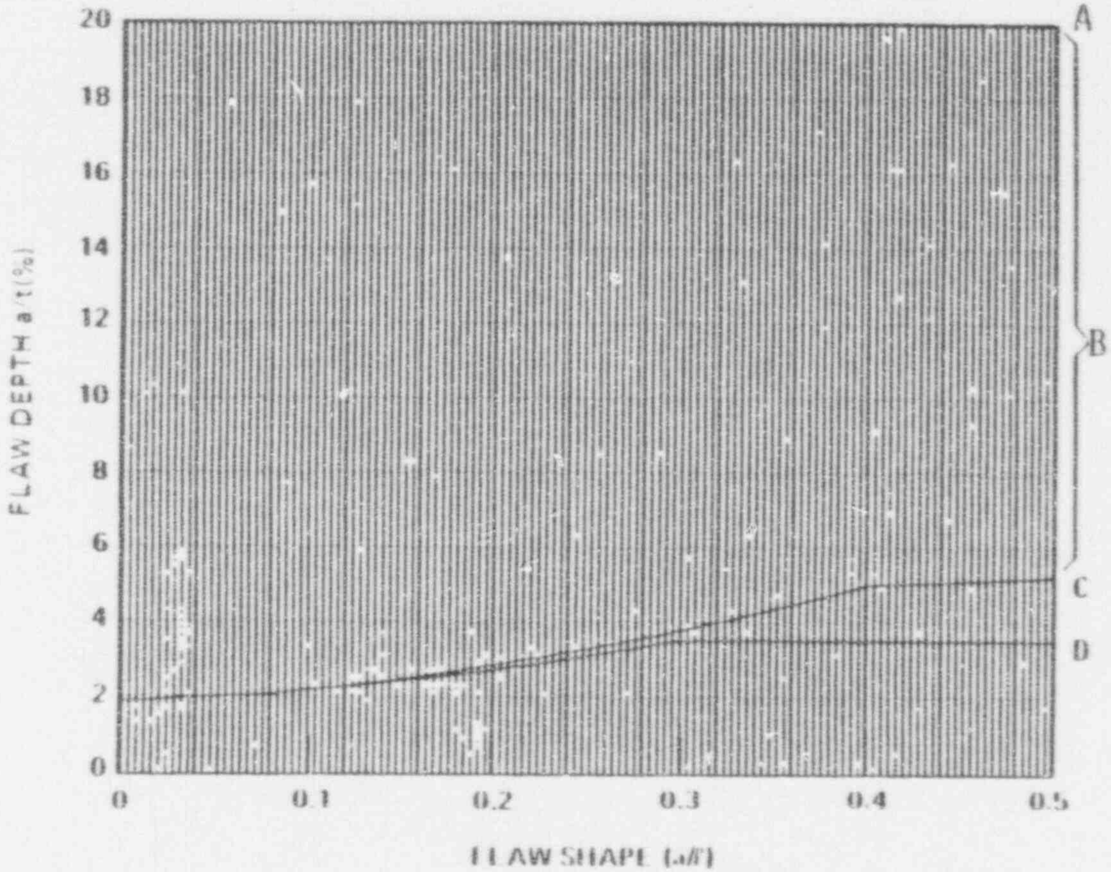





Figure A-13.3 Flaw Evaluation Chart for the Upper Shell Circumferential Welds - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

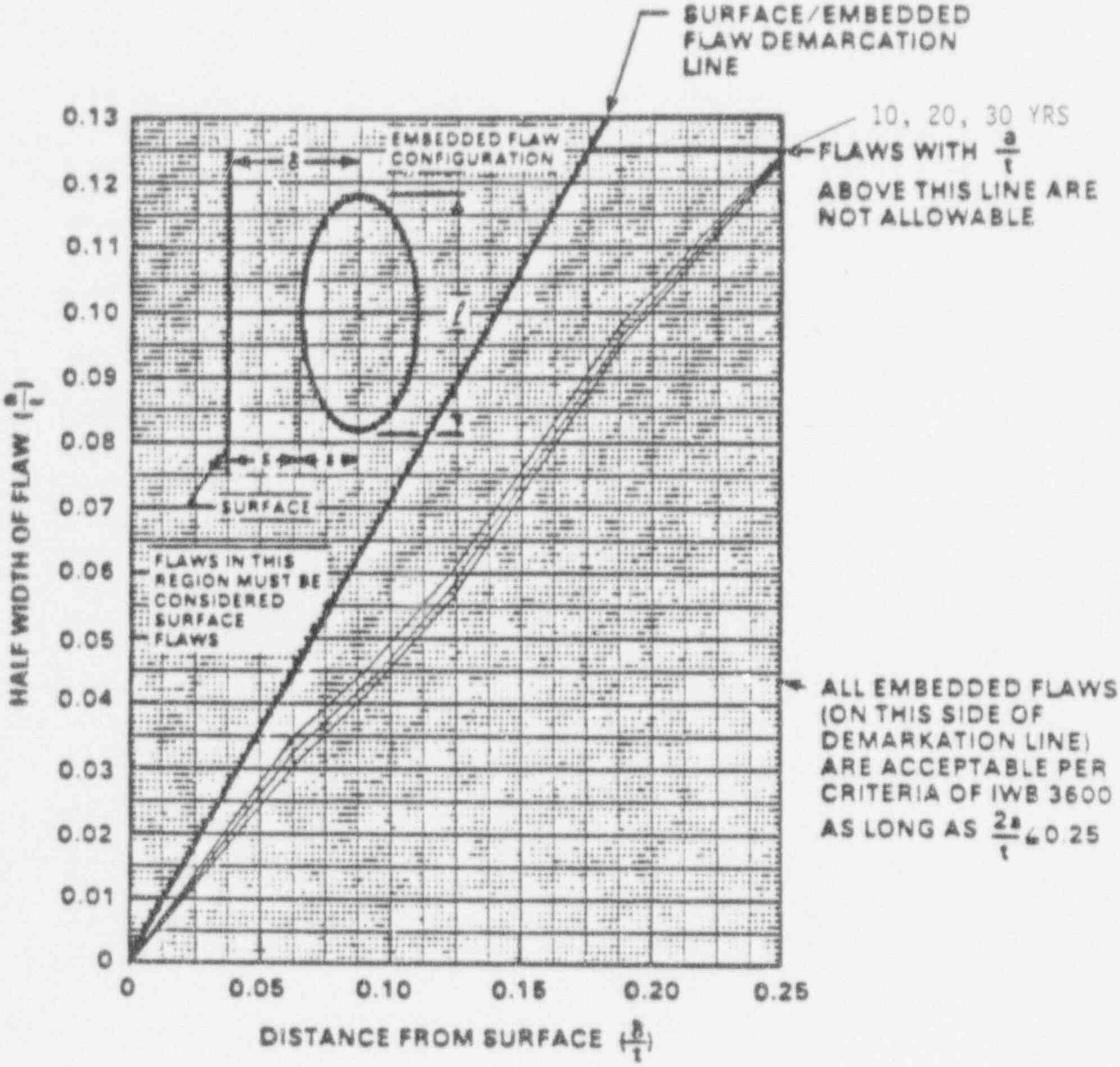



Figure A-13.4 Flaw Evaluation Chart for the Upper Shell Circumferential Welds - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

## A-14 UPPER SHELL LONGITUDINAL WELDS - PRESSURIZER

### A-14.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-14.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.75")

The surface flaw evaluation charts for these regions of the pressurizer are listed below:

Figure A-14.2 Flaw Evaluation Chart for the Inside Surface of the Upper Shell Longitudinal Welds - Pressurizer

Figure A-14.3 Flaw Evaluation Chart for the Outside Surface of the Upper Shell Longitudinal Welds - Pressurizer

A-14.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is shown in figure A-14.1.

Basic Data:

t = 3.75"

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

a = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

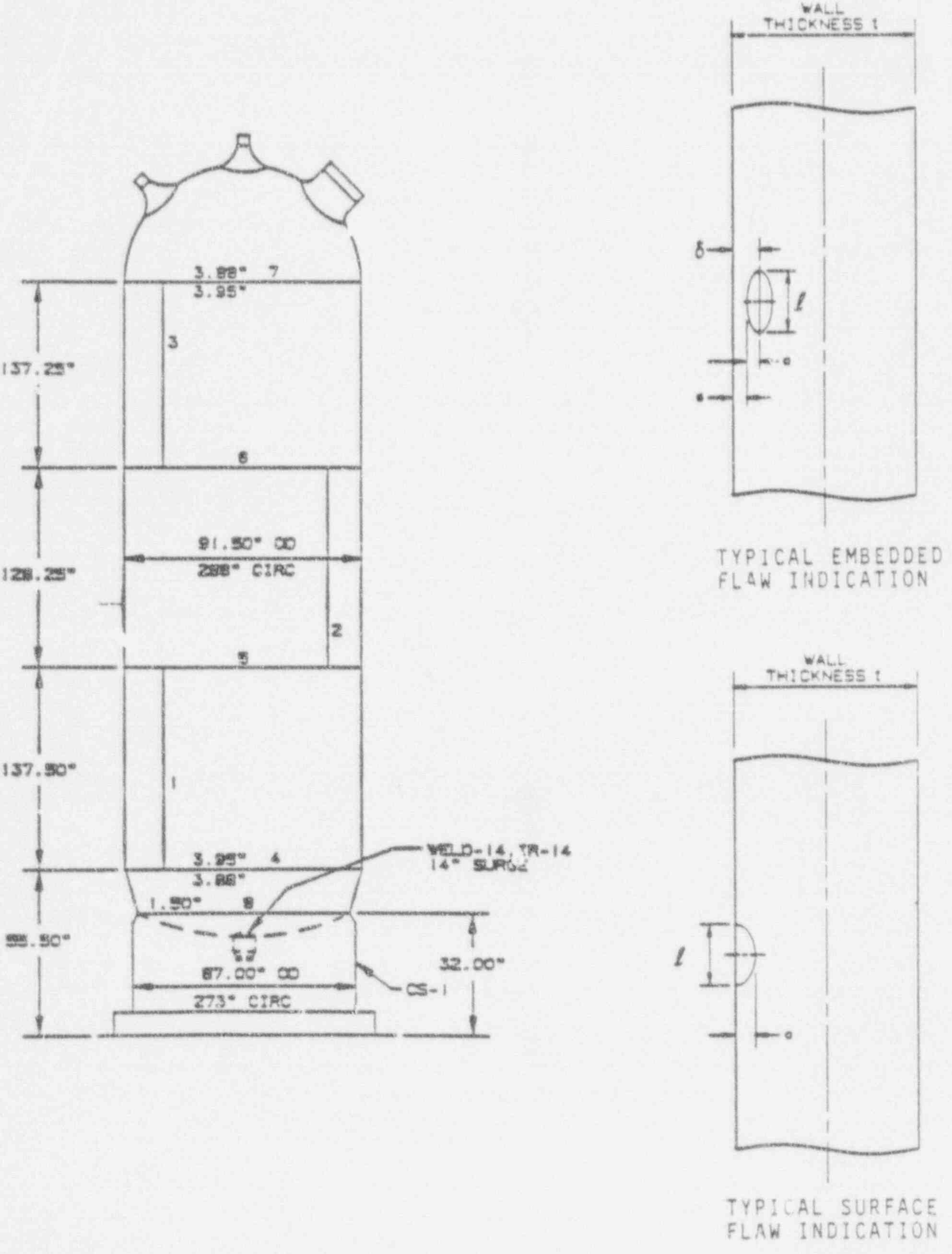
- Flaw shape diameter, $a/\ell$
- Flaw depth parameter, $a/t$
- Surface proximity parameter, $\delta/t$

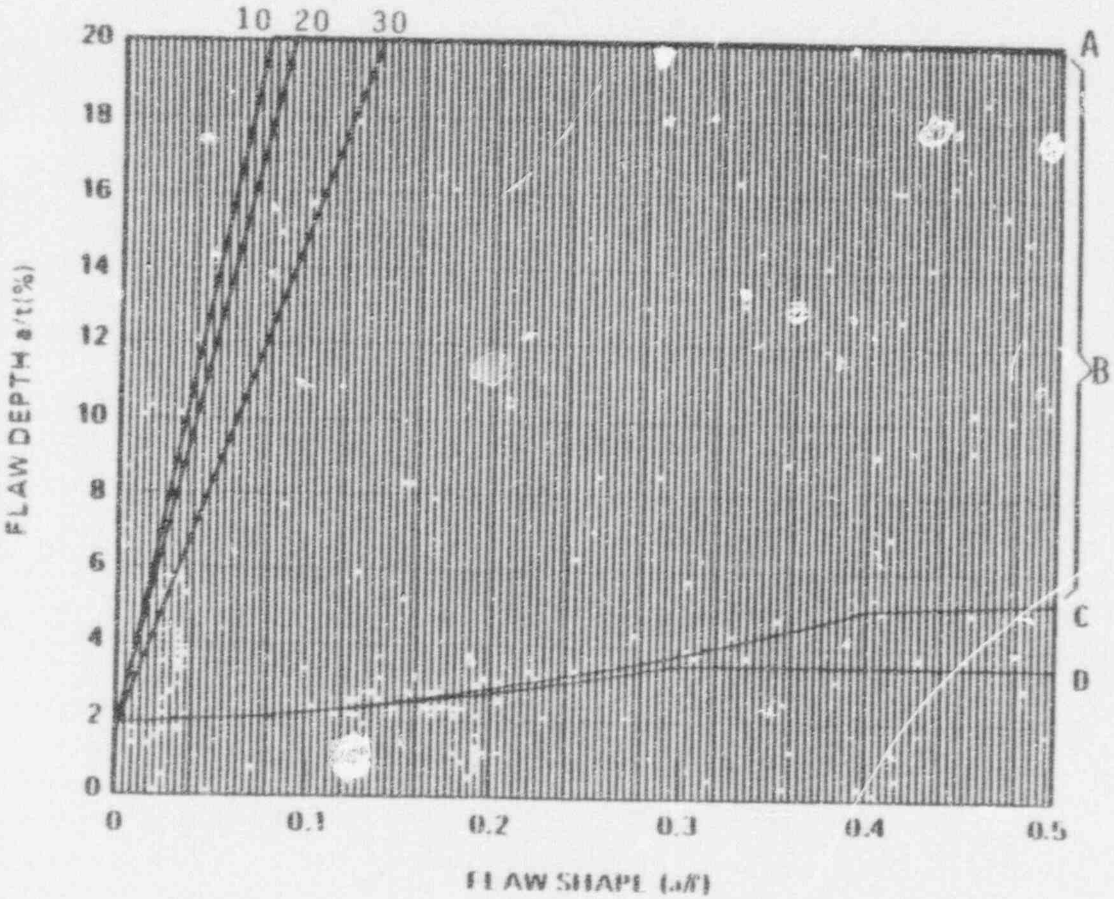
Evaluation charts for embedded flaws in these regions of the pressurizer are listed below:

Figure A-14.4 Embedded Flaw Evaluation Chart for the Upper Shell Longitudinal Welds - Pressurizer

Figure A-14.1

Geometry and Terminology for Flaws in the Upper Shell Longitudinal Welds - Pressurizer






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

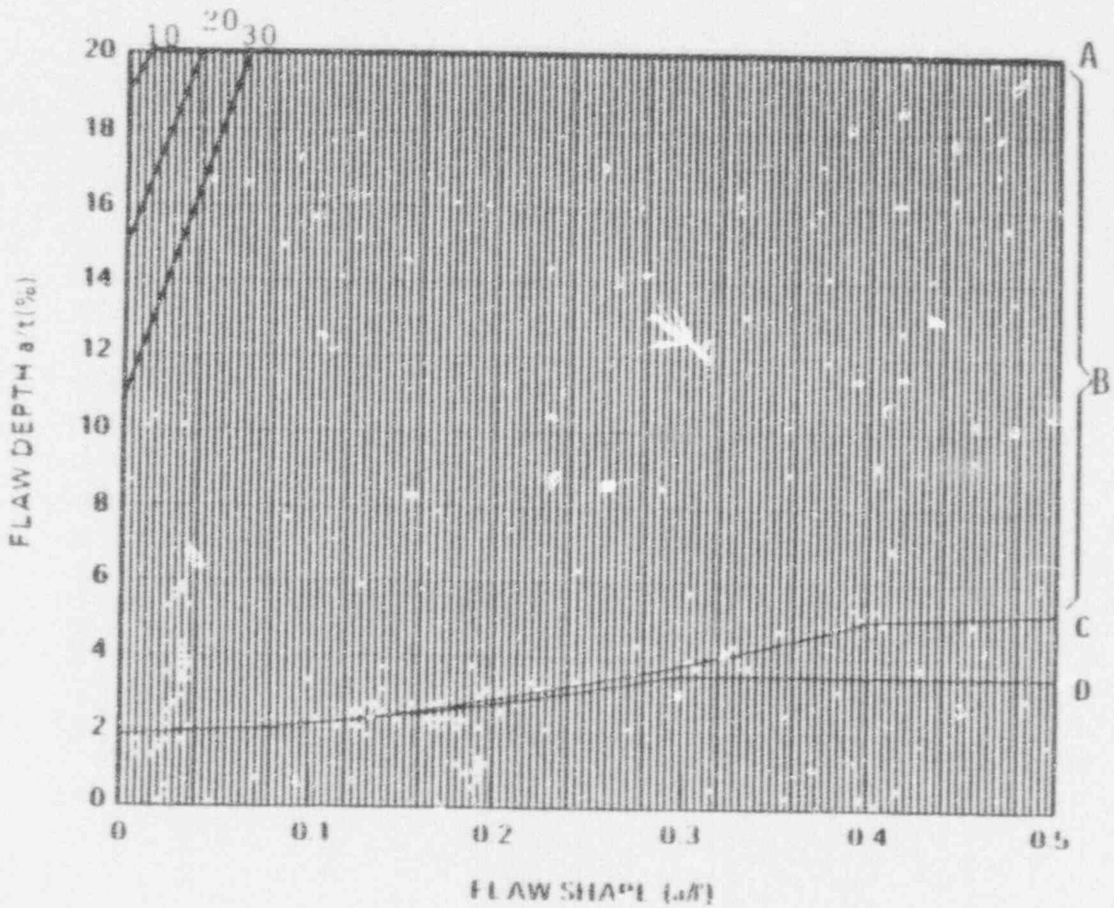
D - ASME Code allowable prior to 1983 Winter Addendum.





Figure A-14.2 Flaw Evaluation Chart for the Upper Shell Longitudinal Welds - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-14.3 Flaw Evaluation Chart for the Upper Shell Longitudinal Welds - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |

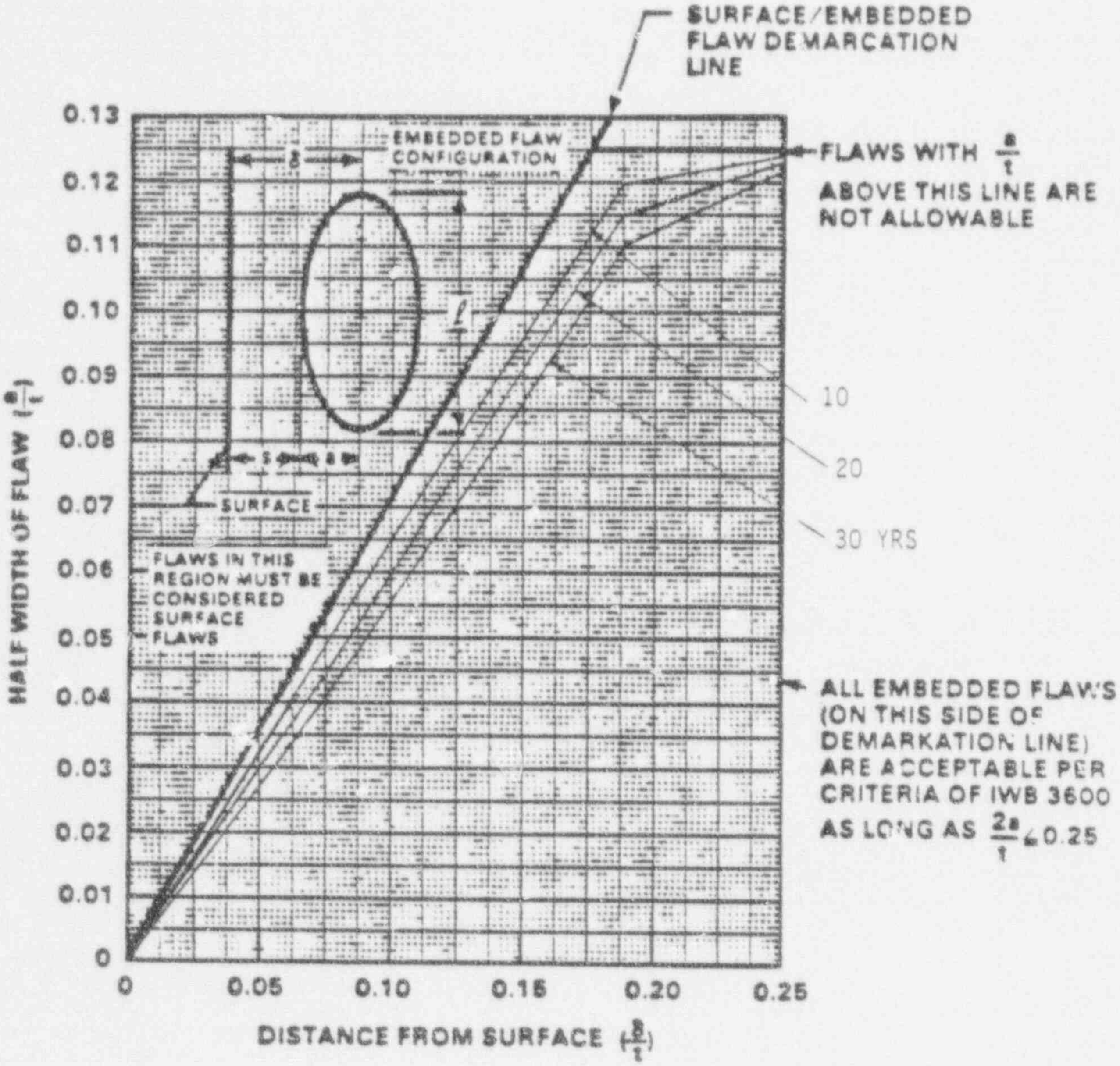



Figure A-14.4 Flaw Evaluation Chart for the Upper Shell Longitudinal Welds - Pressurizer

X Inside Surface X Surface Flaw X Longitudinal Flaw

X Outside Surface ___ Embedded Flaw ___ Circumferential Flaw

## A-15 LOWER SHELL CIRCUMFERENTIAL WELDS - PRESSURIZER

### A-15.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-15.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

a = the surface flaw depth detected (in.)

0 = the surface flaw length detected (in.)

t = wall thickness (t = 3.0")

The surface flaw evaluation charts for the region of the pressurizer are listed below:

| | |
|---|---|
| Figure A-15.2 | Flaw Evaluation Chart for the Inside Surface of Lower Shell Circumferential Welds - Pressurizer |
| Figure A-15.3 | Flaw Evaluation Chart for the Outside Surface of Lower Shell Circumferential Welds - Pressurizer |

## A-15.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is shown in figure A-15.1.

Basic Data:.

$t$ = 3.0"

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined aa one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = Maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

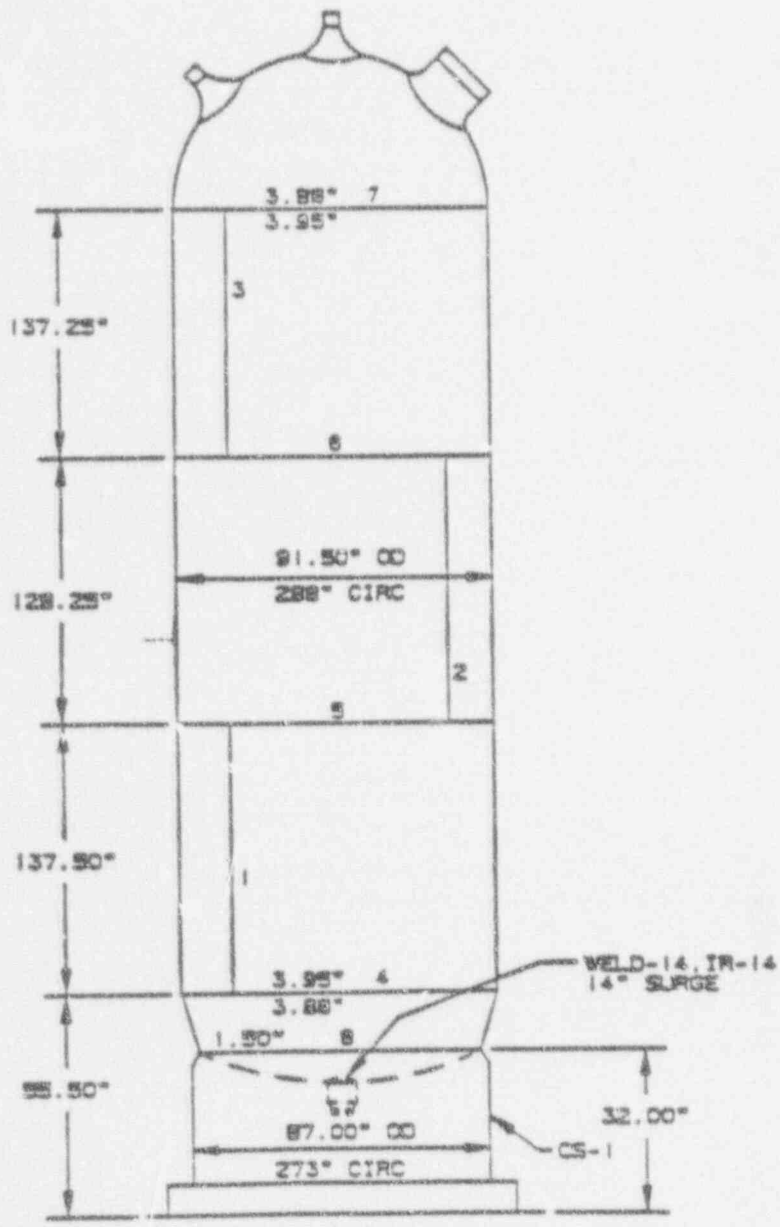
- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta$

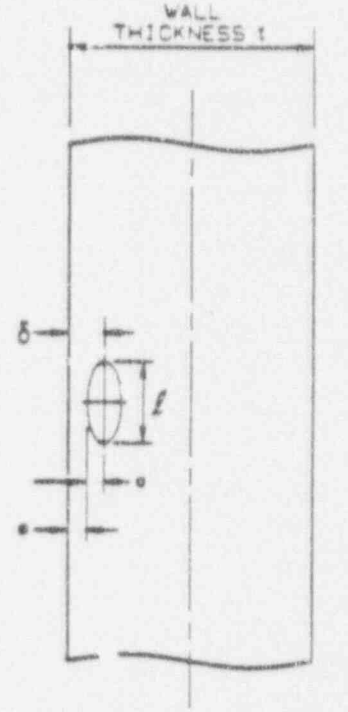
Evaluation charts for embedded flaws in the region of the pressurizer are listed below:

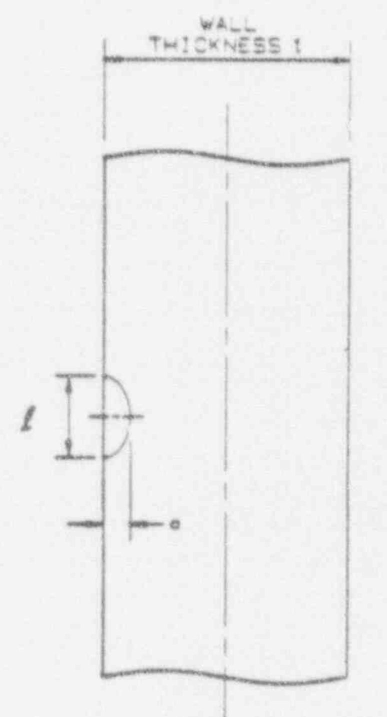
Figure A-15.4 Embedded Flaw Evaluation Chart for Circumferential Flaws in the Lower Shell Circumferential Welds of the Pressurizer

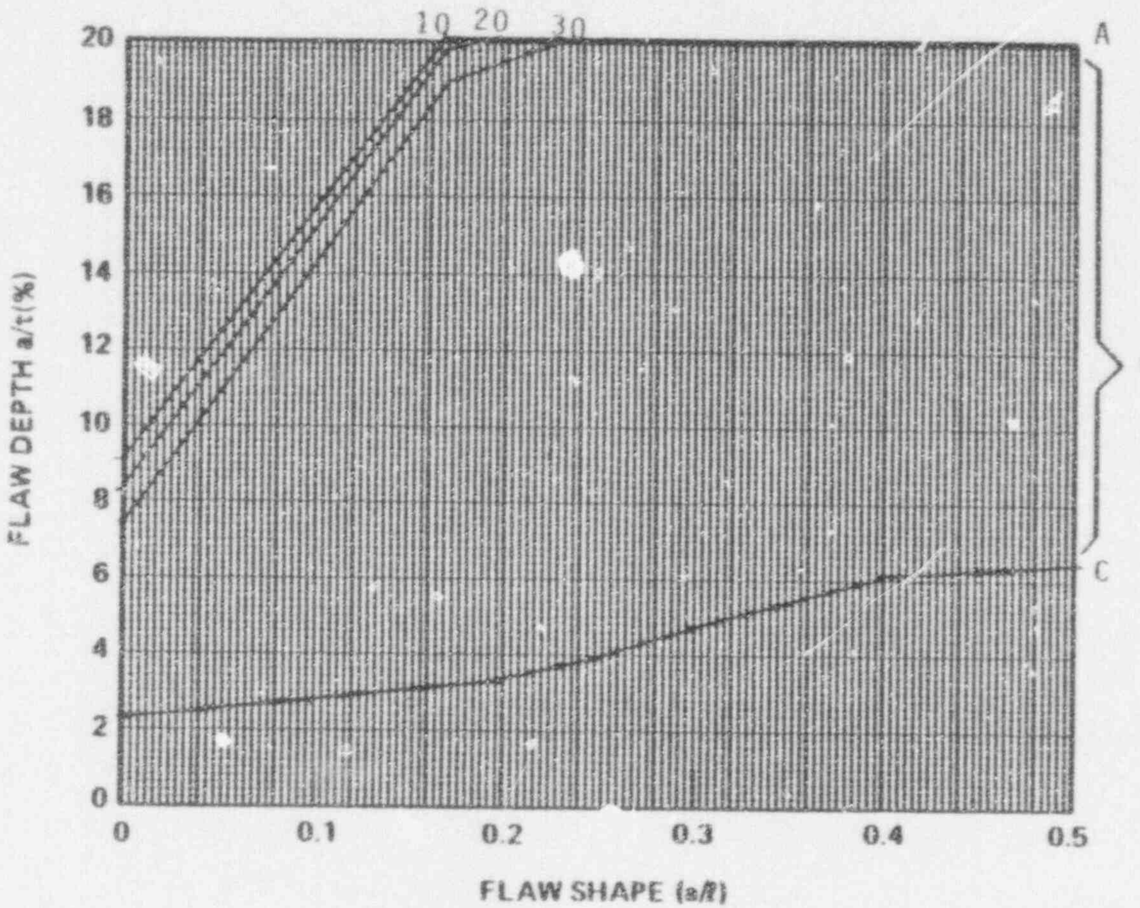
Figure A-15.1

Geometry and Terminology for Flaws at the Lower Shell Circumferential Welds






LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

Figure A-15.2 Flaw Evaluation Chart - Lower Shell Circumferential Welds - Pressurizer

X Inside Surface    X Surface Flaw    ___ Longitudinal Flaw

___ Outside Surface    ___ Embedded Flaw    X Circumferential Flaw



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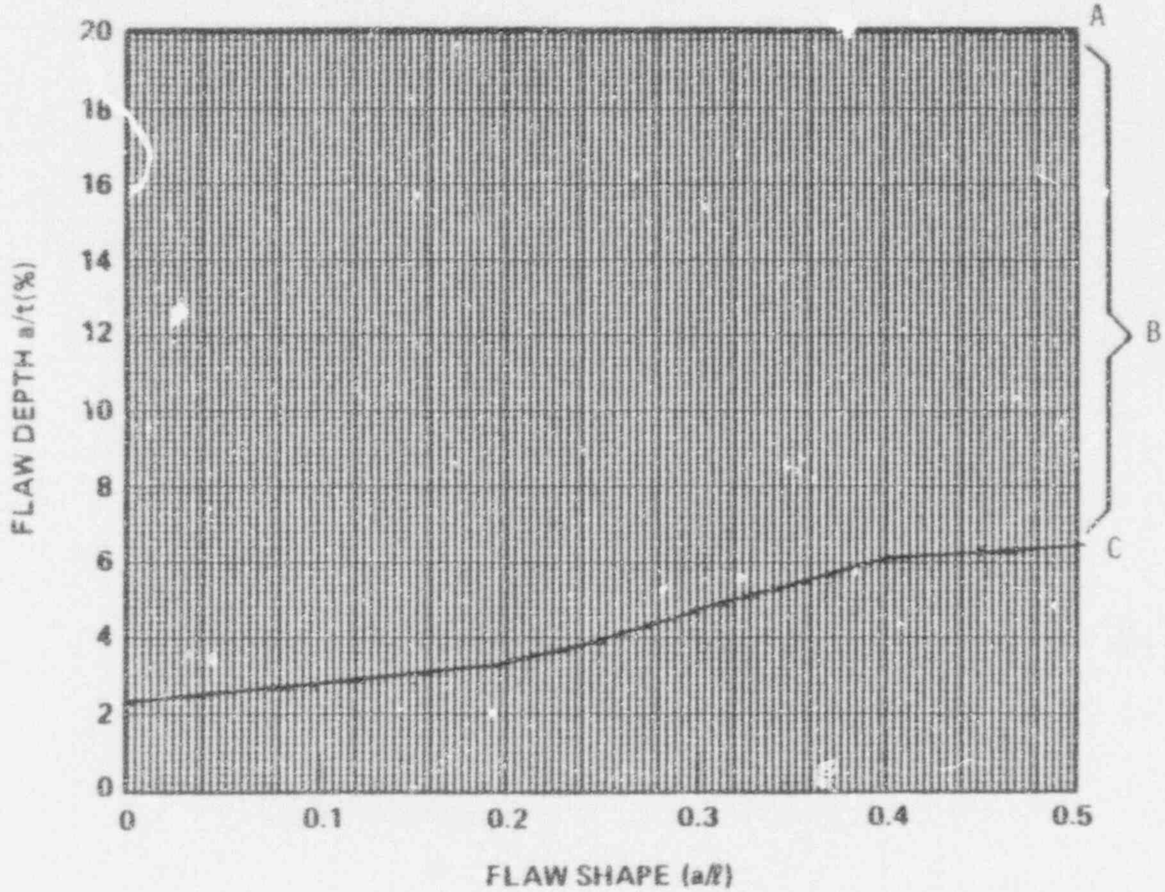


LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

Figure A-15.3 Flaw Evaluation Chart for the Lower Shell Circumferential Welds of the Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

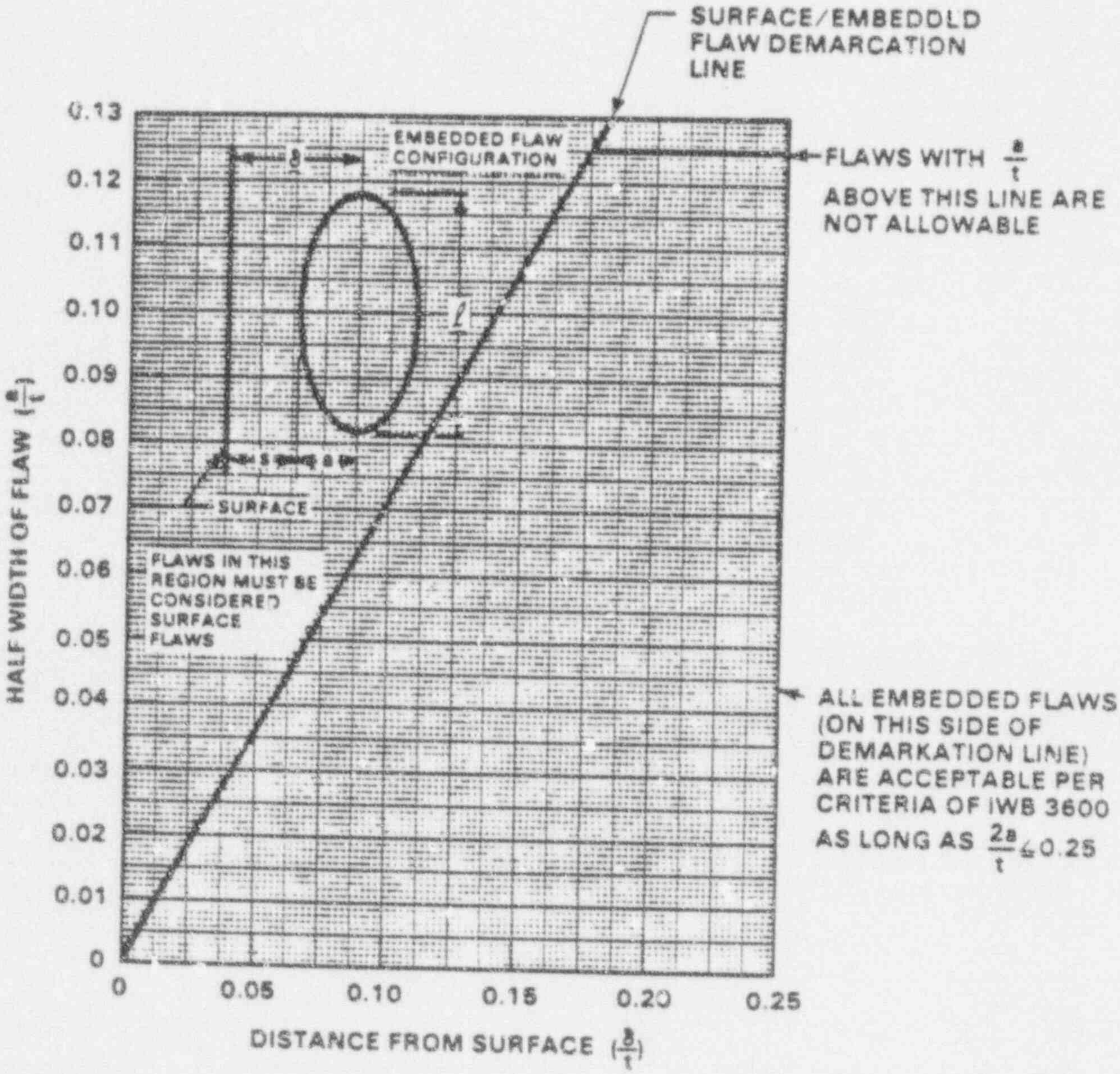


Figure A-15.4 Flaw Evaluation Chart for the Lower Shell Circumferential Welds of the Pressurizer

X Inside Surface ___ Surface Flaw ___ Longitudinal Flaw
X Outside Surface X Embedded Flaw X Circumferential Flaw

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## A-16 LOWER SHELL LONGITUDINAL WELDS - PRESSURIZER

### A-16.1 SURFACE FLAWS

The geometry and terminology for surface flaws in this region is depicted in figure A-16.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.75")

The surface flaw evaluation charts for these regions of the pressurizer are listed below:

Figure A-16.2 Flaw Evaluation Chart for the Inside Surface of the Lower Shell Longitudinal Welds - Pressurizer

Figure A-16.3 Flaw Evaluation Chart for the Outside Surface of the Lower Shell Longitudinal Welds - Pressurizer

A-16.2 EMBEDDED FLAWS

The geometry and terminology for embedded flaws in this region is shown in figure A-16.1.

Basic Data:

$t$ = 3.75 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

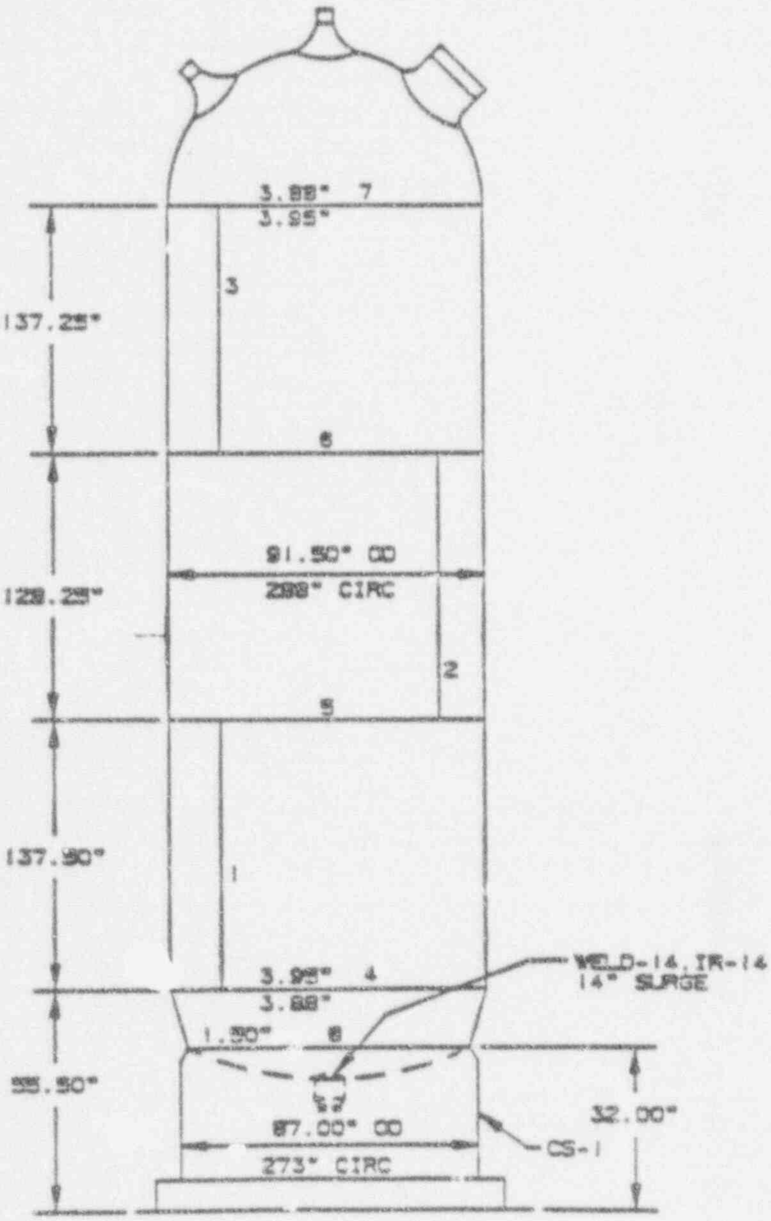
The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

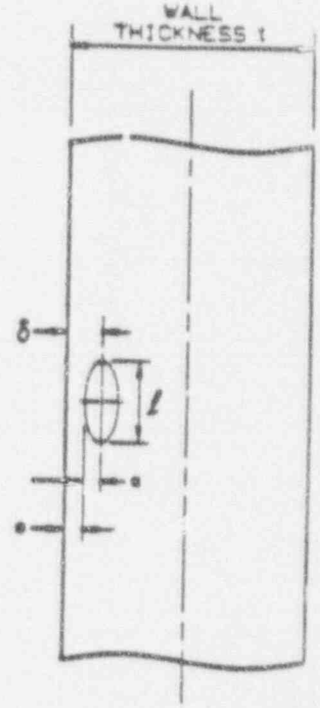
- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

Evaluation charts for embedded flaws in these regions of the pressurizer are listed below:

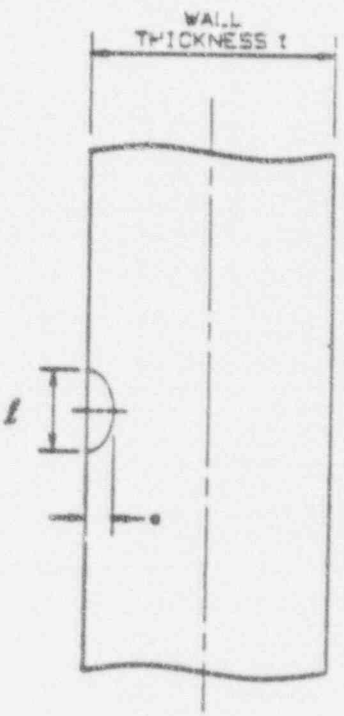
Figure A-16.4 Embedded Flaw Evaluation Chart for the Lower Shell Longitudinal Welds - Pressurizer

Figure A-16.1
Geometry and Terminology for Flaws in the Lower Shell
Longitudinal Welds - Pressurizer

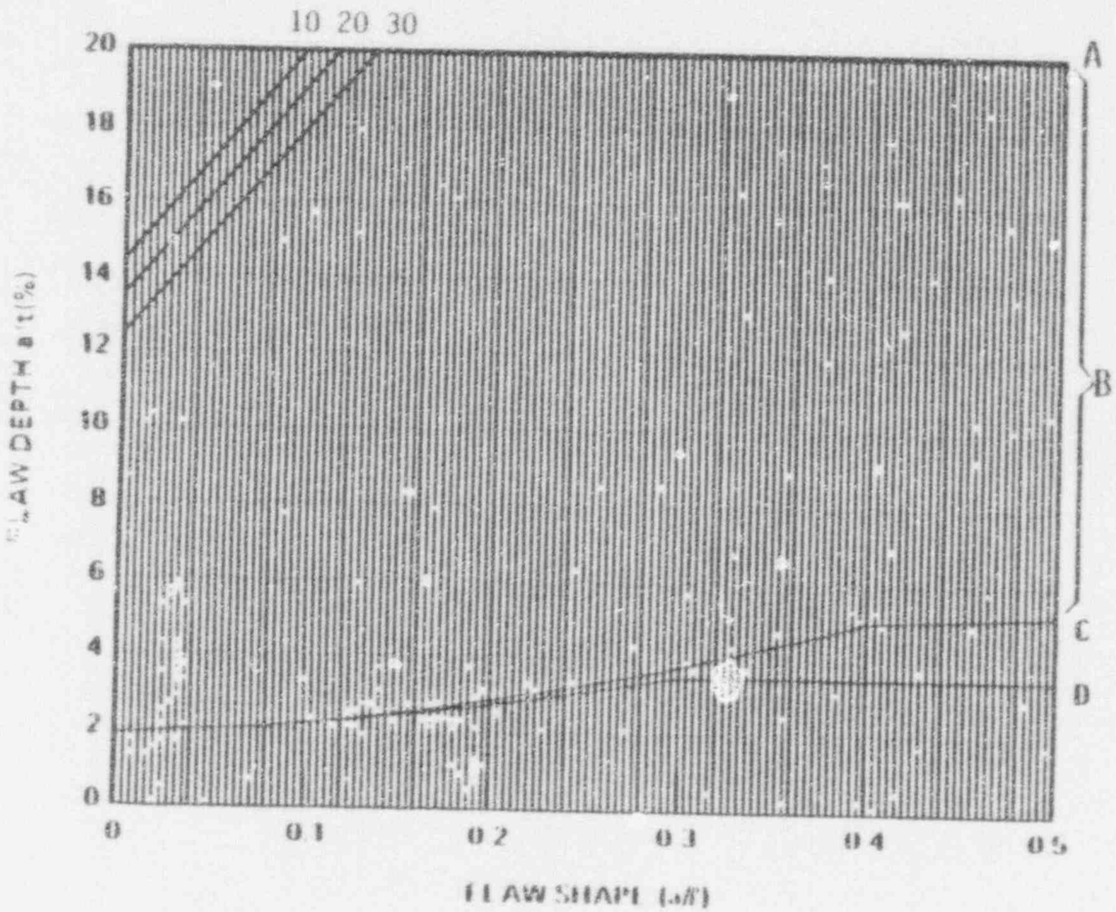



TYPICAL EMBEDDED
FLAW INDICATION




TYPICAL SURFACE
FLAW INDICATION




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

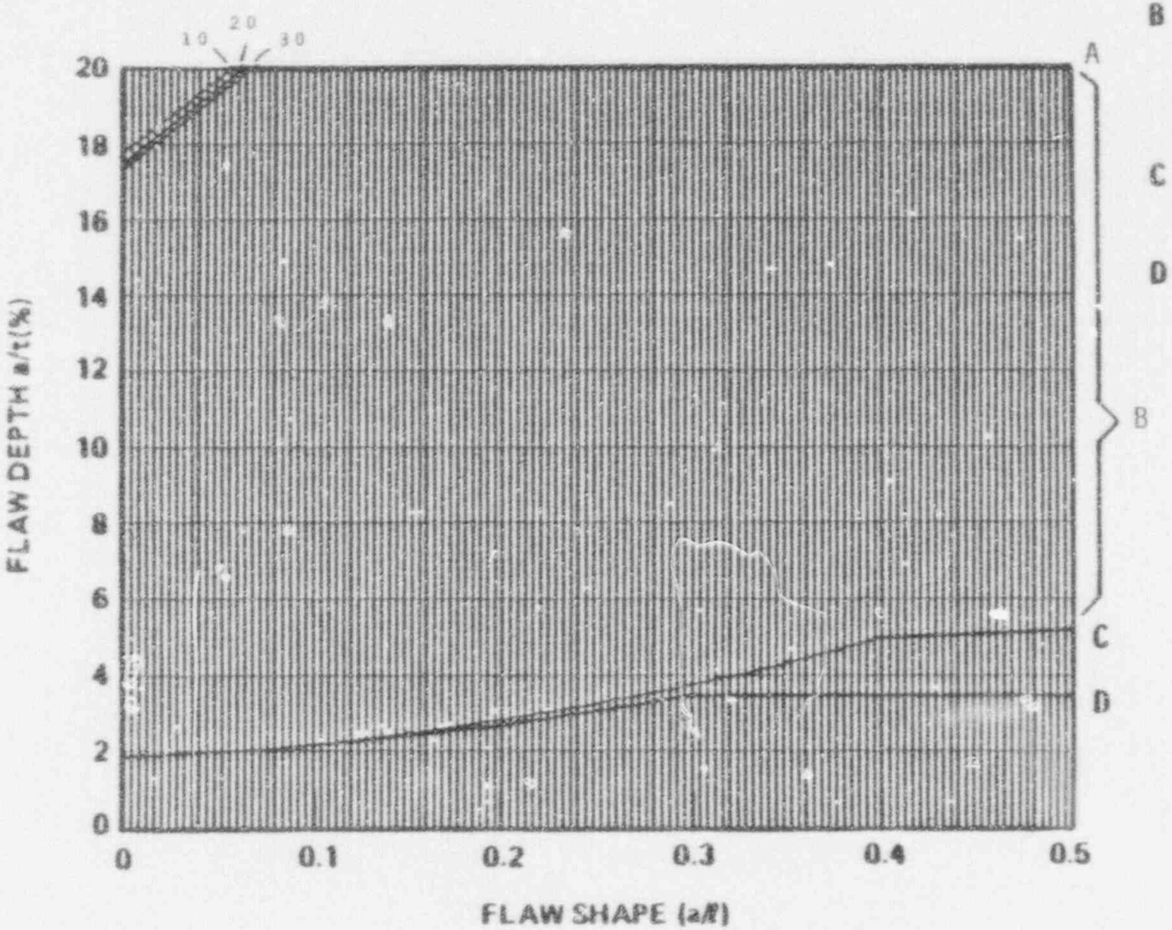
C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-16.2 Flaw Evaluation Chart for the Lower Shell Longitudinal Welds - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-16.3 Flaw Evaluation Chart for the Lower Shell Longitudinal Welds - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |

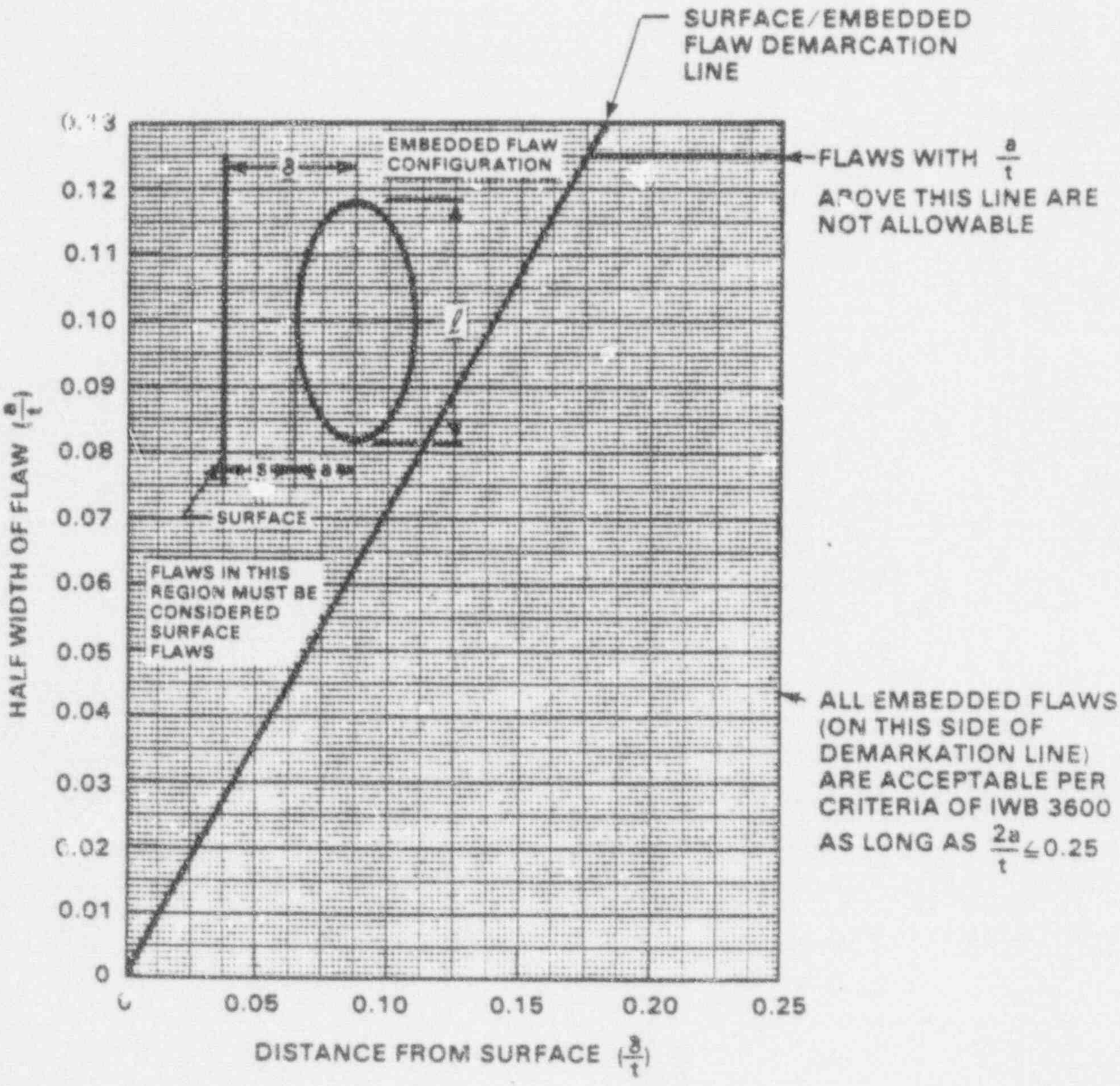



Figure A-16.4 Flaw Evaluation Chart for the Lower Shell Longitudinal Welds - Pressurizer

X Inside Surface ___ Surface Flaw X Longitudinal Flaw

X Outside Surface X Embedded Flaw ___ Circumferential Flaw

A-17.2 EMBEDDED FLAWS - NOZZLE TO HEAD WELD

The geometry and terminology for embedded flaws in this region is shown in figure A-17.1.

Basic Data:

$t$ = 3.0 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw:

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

## A-17 SURGE NOZZLE - PRESSURIZER

### A-17.1 SURFACE FLAWS - NOZZLE TO HEAD WELD

The geometry and terminology for surface flaws in this region is depicted in figure A-17.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 3.0")

The surface flaw evaluation charts for this region of the pressurizer are listed below:

Figure A-17.2 Flaw Evaluation Chart for Circumferential Flaws at the Inside Surface of the Surge Nozzle to Head Weld - Pressurizer

Figure A-17.3 Flaw Evaluation Chart for Circumferential Flaws at the Outside Surface of the Surge Nozzle to Head Weld - Pressurizer

Figure A-17.4 Flaw Evaluation Chart for Longitudinal Flaws at the Inside Surface of the Surge Nozzle to Head Weld - Pressurizer

Figure A-17.5 Flaw Evaluation Chart for Longitudinal Flaws at the Outside Surface of the Surge Nozzle to Head Weld - Pressurizer

Evaluation charts for embedded flaws in this region of the pressurizer are listed below:

Figure A-17.4 Embedded Flaw Evaluation Chart for Longitudinal Flaws in the Surge Nozzle to Head Weld - Pressurizer

Figure A-17.5 Embedded Flaw Evaluation Chart for Circumferential Flaws in the Surge Nozzle to Head Weld - Pressurizer

A-17.3 SURFACE FLAWS - SURGE NOZZLE CORNER

The geometry and terminology for surface flaws in the surge nozzle corner region is depicted in figure A-17.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)

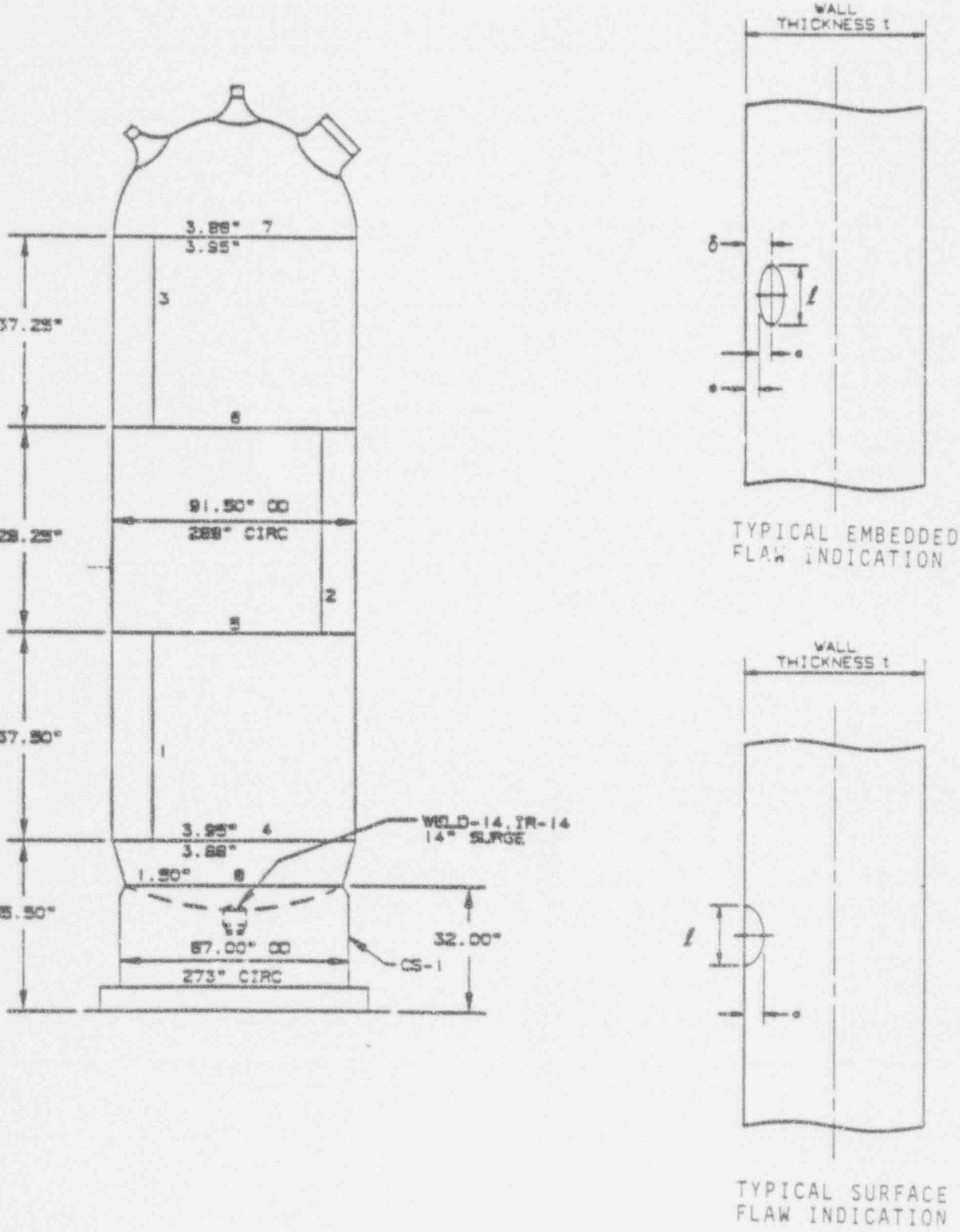
$\ell$ = the surface flaw length detected (in.)

$t$ = wall thickness at the nozzle corner ($t$ = 3.58")

The surface flaw evaluation charts for the surge nozzle corner are listed below

Figure A-17.6 Flaw Evaluation Chart for Longitudinal Flaws at the Inside Surface of the Surge Nozzle - Corner Region

Figure A-17.1
Geometry and Terminology for Flaws in the Surge Nozzle to Head Weld - Pressurizer



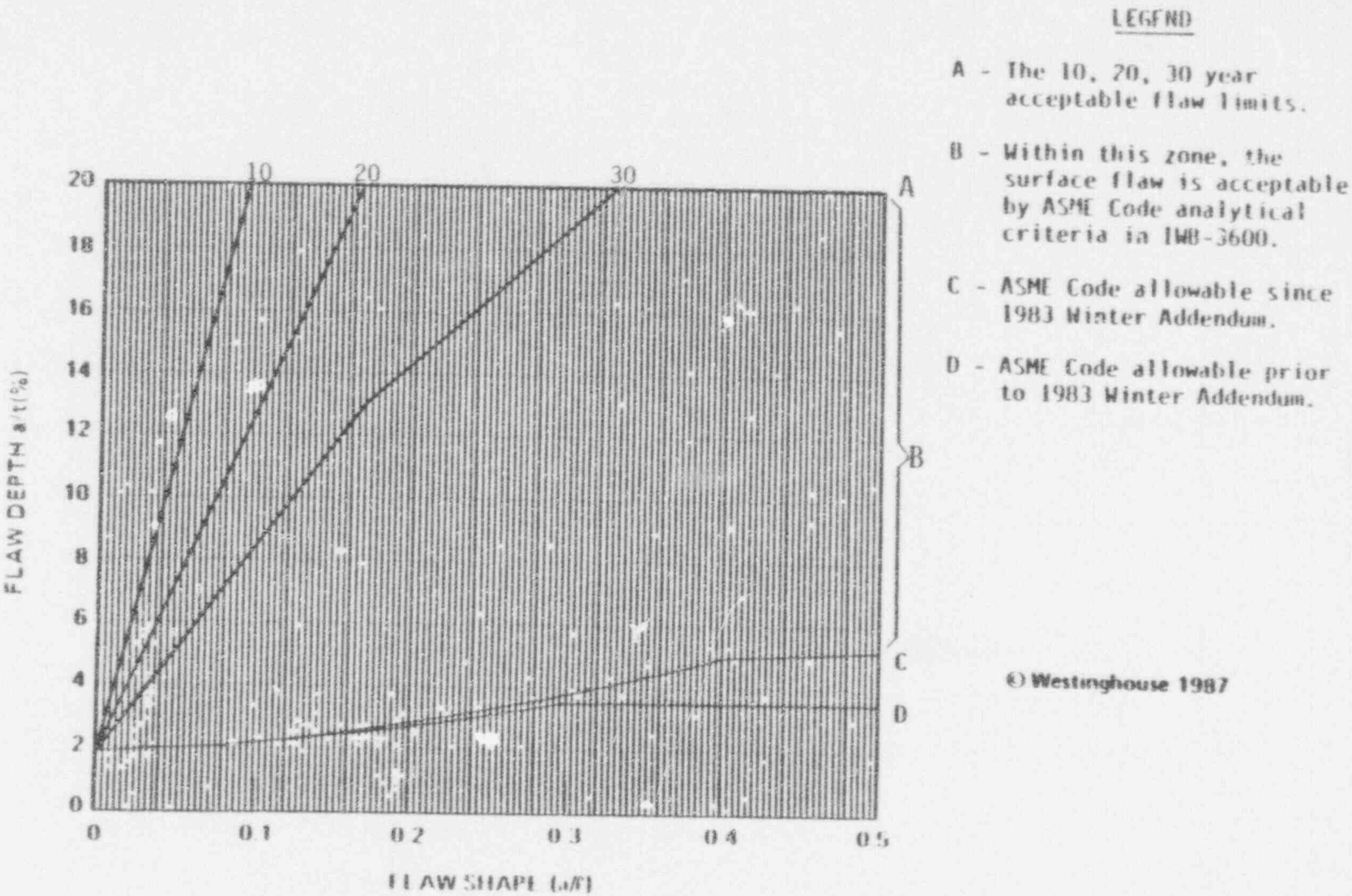
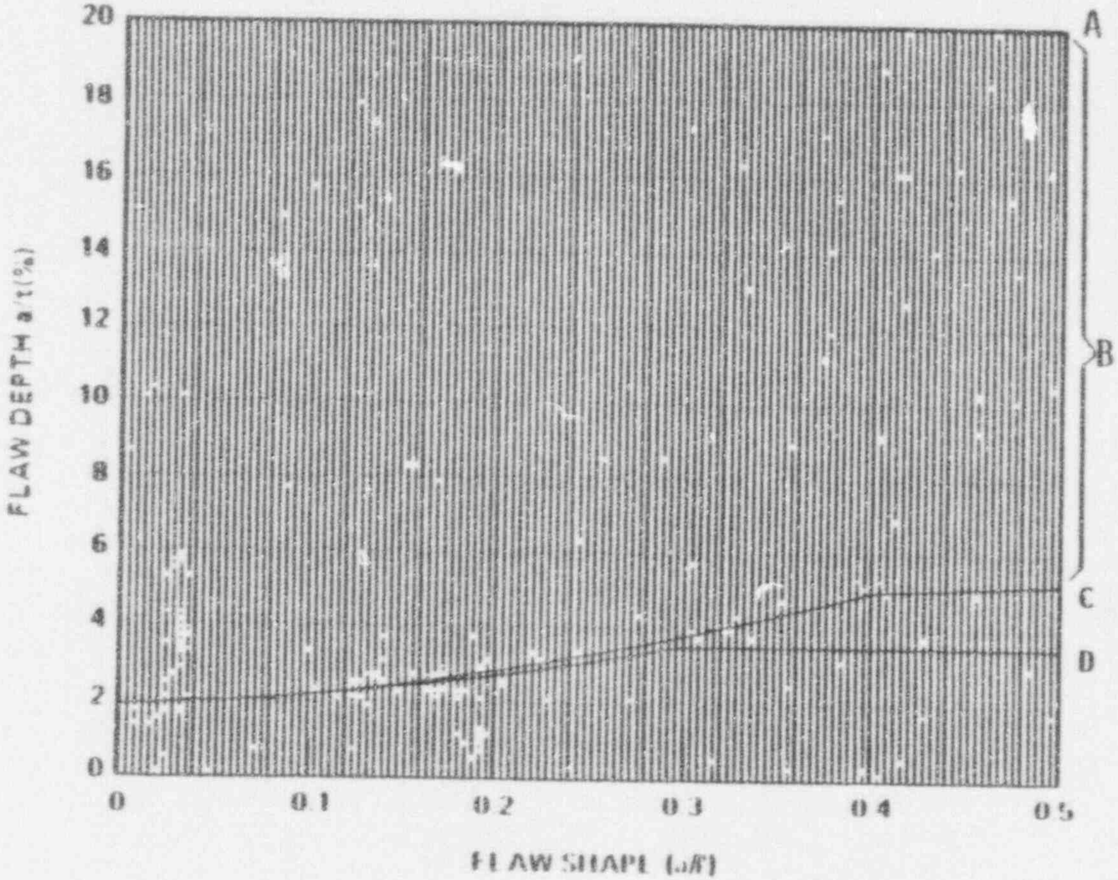



Figure A-17.2 Flaw Evaluation Chart for the Surge No..zle to Head Weld - Pressurizer

X Inside Surface X Surface Flaw ___ Longitudinal Flaw

___ Outside Surface ___ Embedded Flaw X Circumferential Flaw




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-17.3 Flaw Evaluation Chart for the Surge Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |

**LEGEND**

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

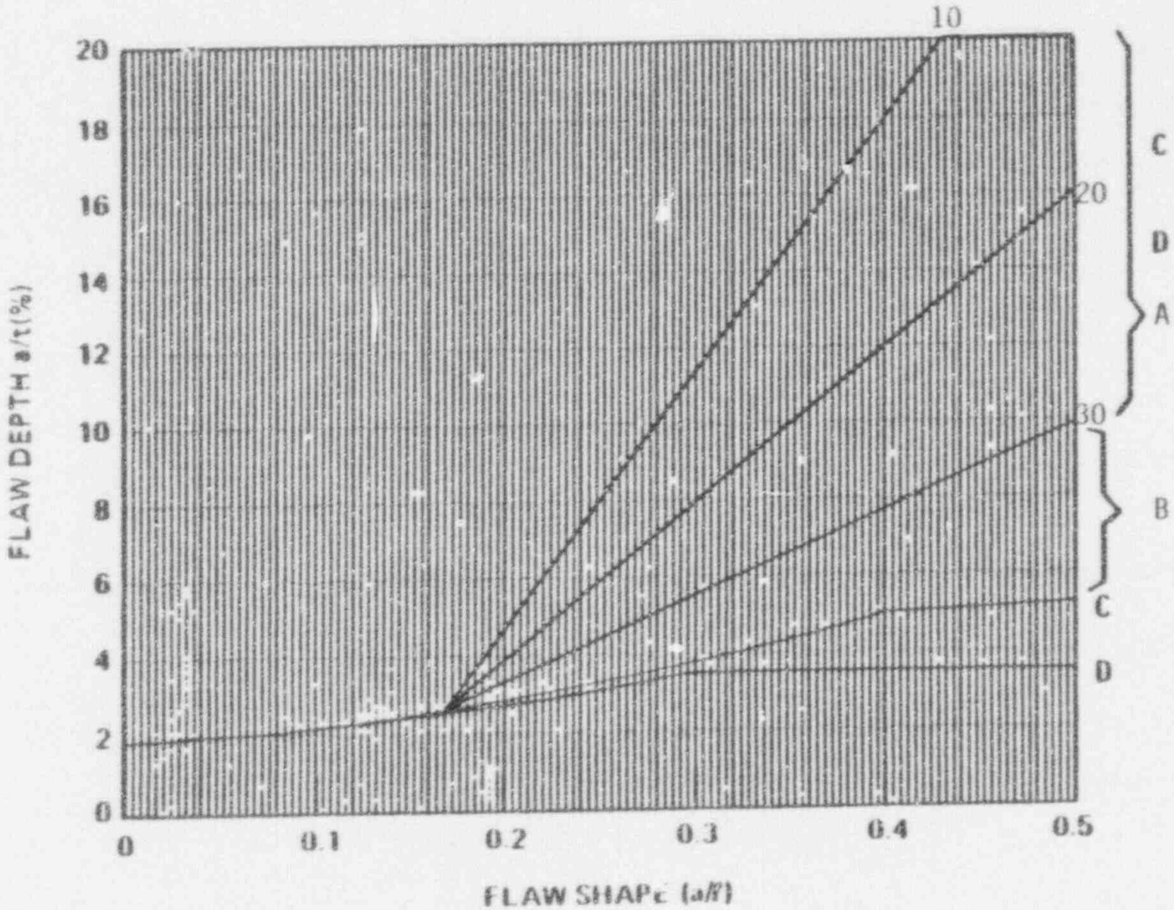
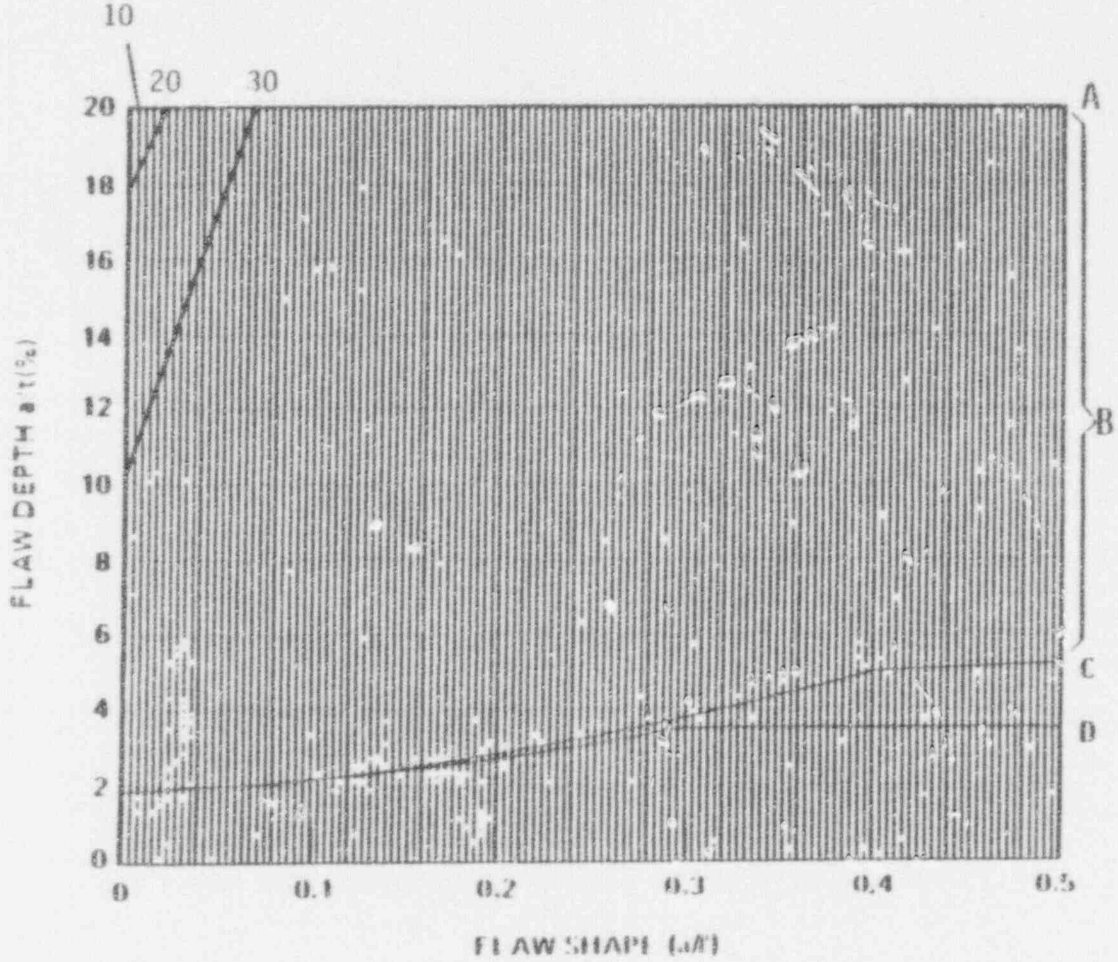





Figure A-17.4 Flaw Evaluation Chart for the Surge Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| ___ | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-17.5 Flaw Evaluation Chart for the Surge Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |

# 1

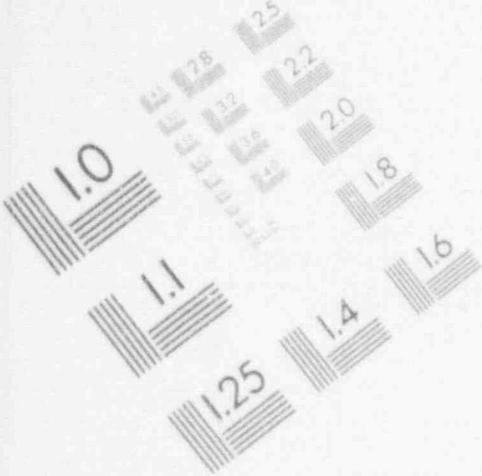
## IMAGE EVALUATION TEST TARGET (MT-3)

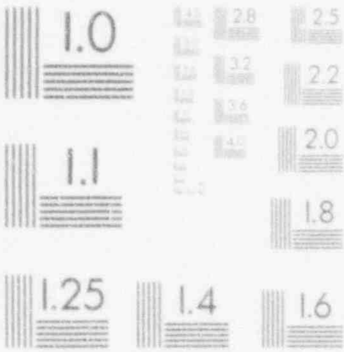
150mm

6"

# 1

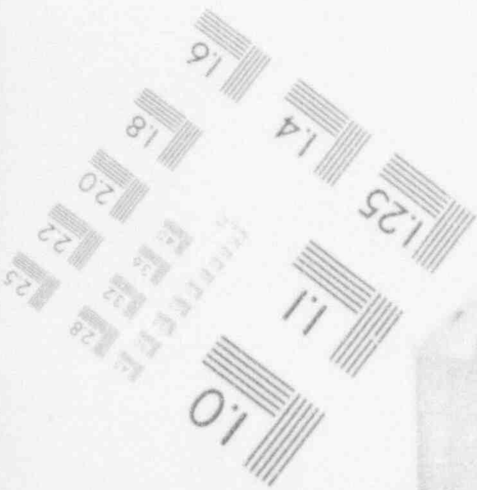
## IMAGE EVALUATION TEST TARGET (MT-3)

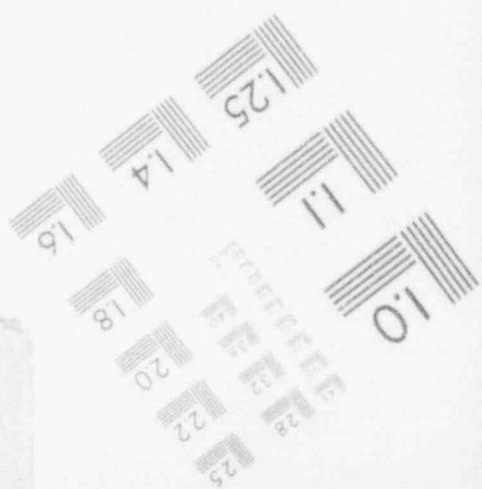





150mm

6"





# 1

## IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

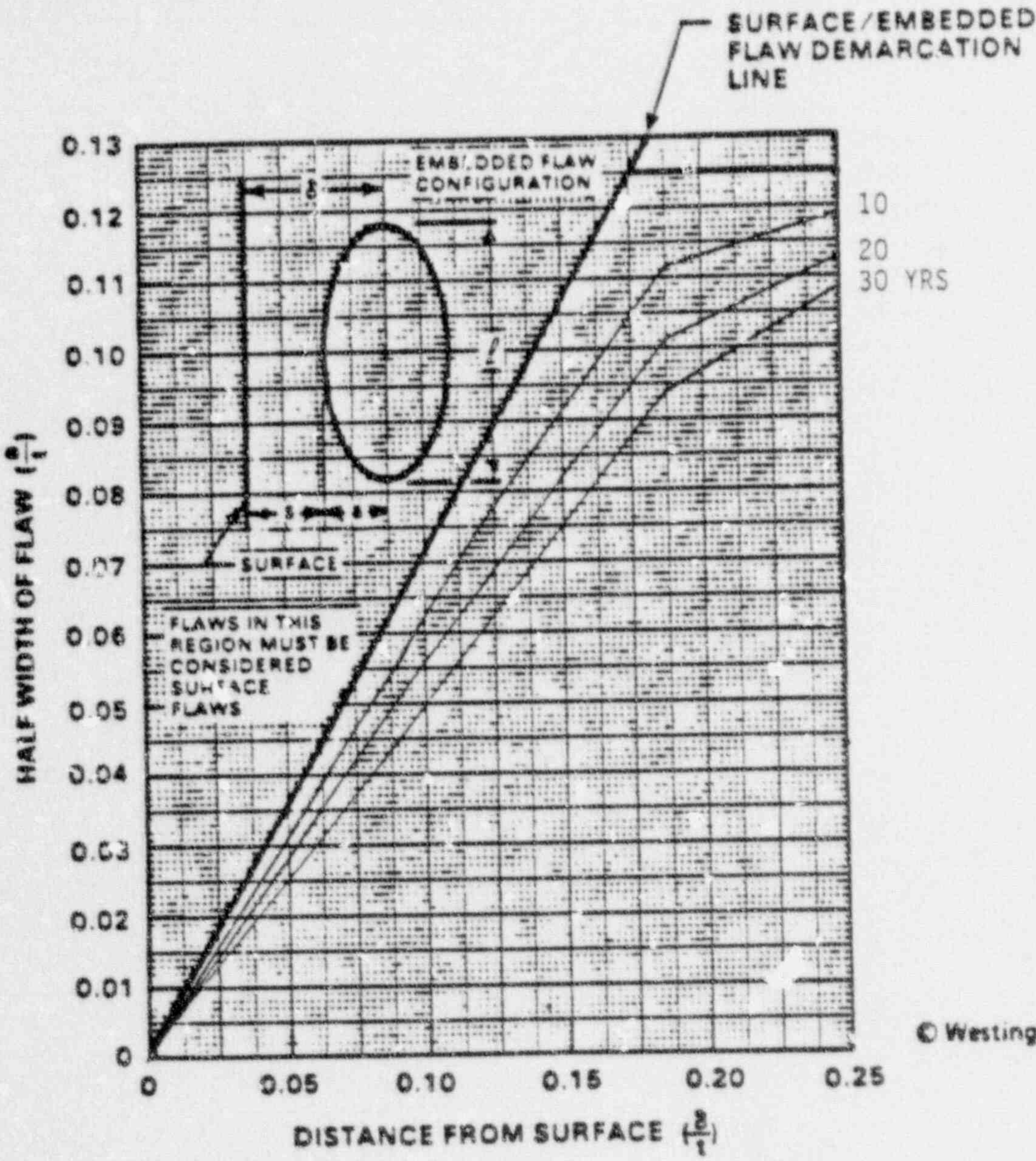





Figure A-17.6 Evaluation Chart for the Surge Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | ___ | Circumferential Flaw |

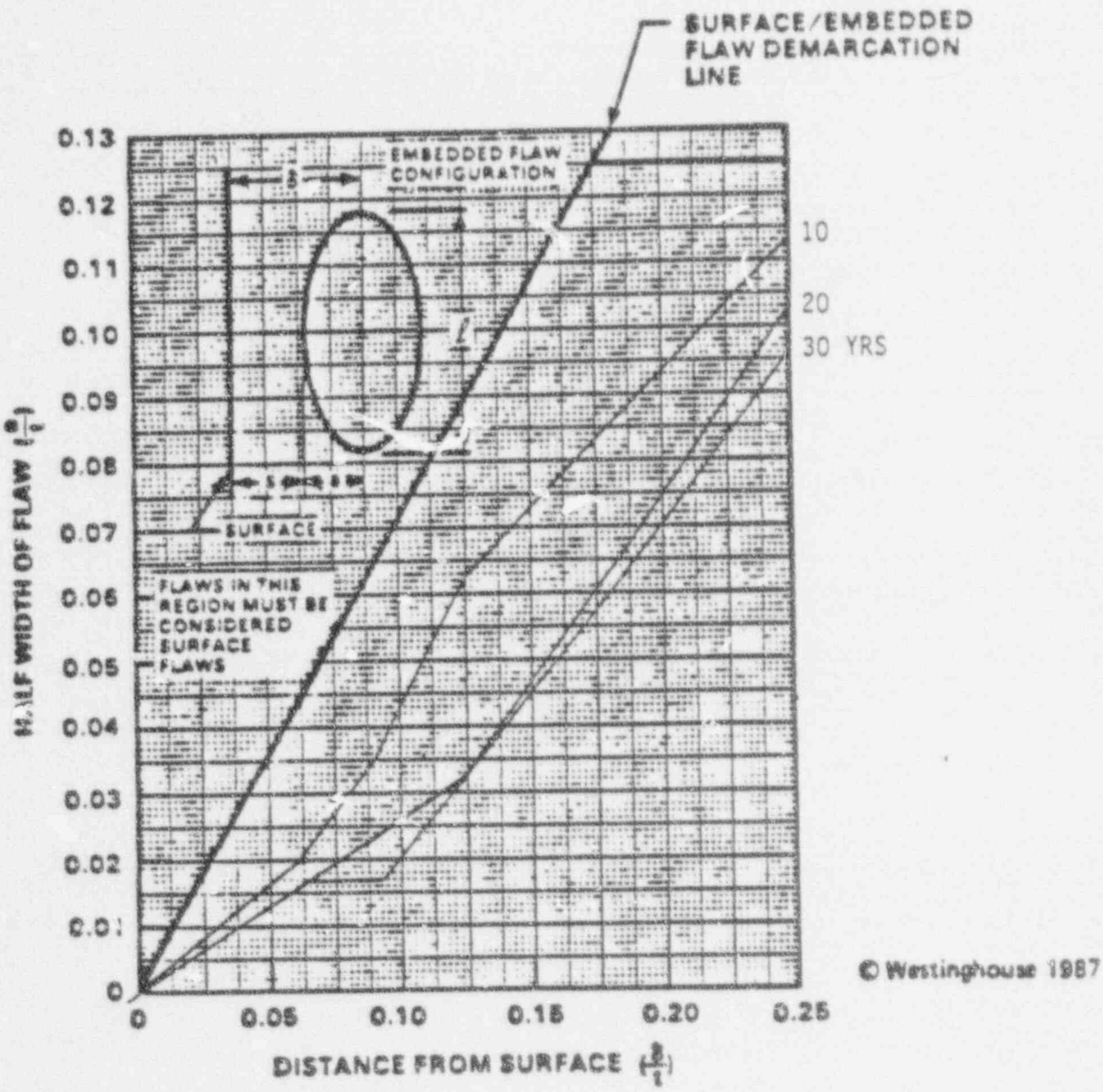



Figure A-17.7 Evaluation Chart for the Surge Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | ___ | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | X | Embedded Flaw | X | Circumferential Flaw |

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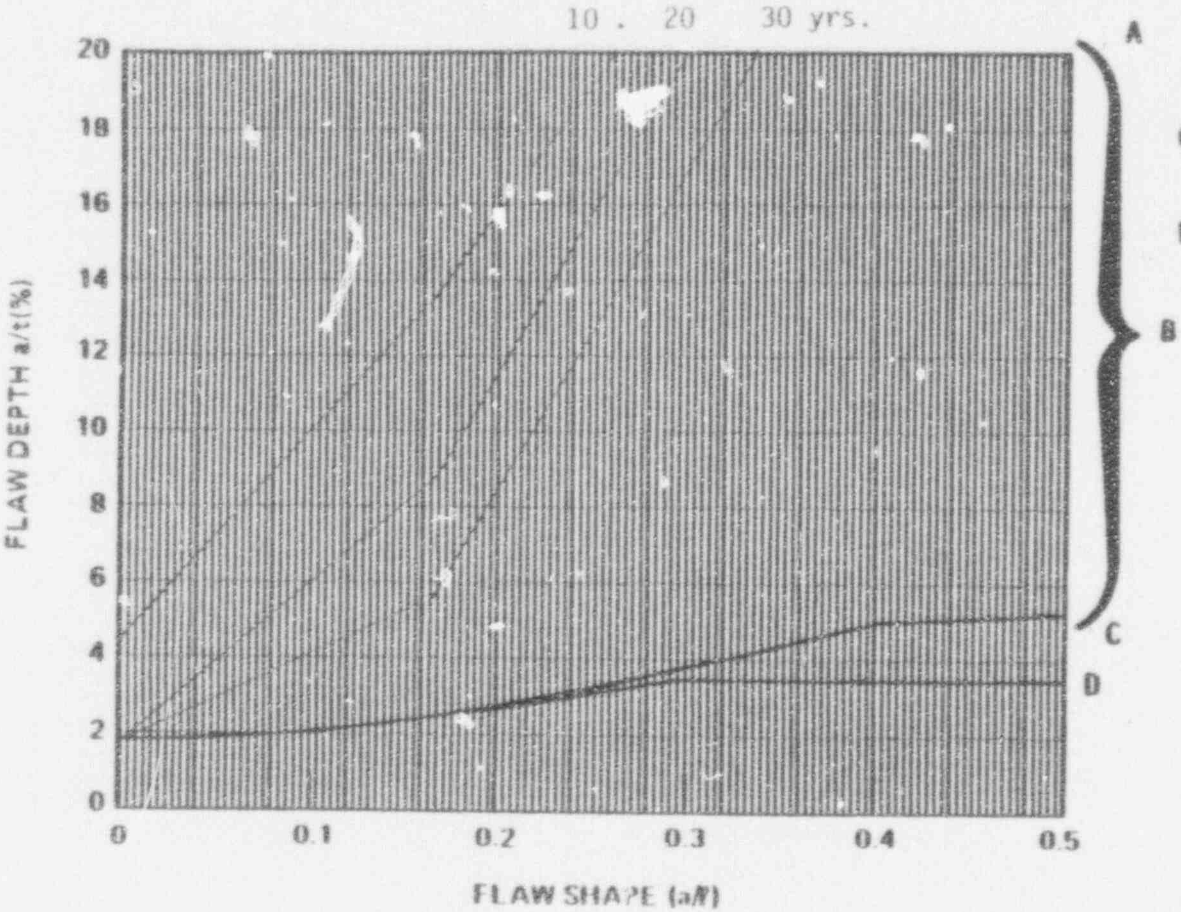



LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-17.8 Flaw Evaluation Chart for the Surge Nozzle Corner Region

X Inside Surface    X Surface Flaw    X Longitudinal Flaw

__ Outside Surface    __ Embedded Flaw    __ Circumferential Flaw



3652s/013090:10

## A-18 SPRAY NOZZLE - PRESSURIZER

### A-18.1 SURFACE FLAWS - NOZZLE TO HEAD WELD

The geometry and terminology for surface flaws in this region is depicted in figure A-18.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 2.5")

The surface flaw evaluation charts for this region of the pressurizer are listed below:

Figure A-18.2 Flaw Evaluation Chart for the Inside Surface of the Spray Nozzle to Head Weld - Pressurizer

Figure A-18.3 Flaw Evaluation Chart for the Outside Surface of the Spray Nozzle to Vessel Weld - Pressurizer

Figure A-18.4 Flaw Evaluation Chart for the Inside Surface of the Spray Nozzle to Head Weld - Pressurizer

Figure A-18.5 Flaw Evaluation Chart for the Outside Surface of the Spray Nozzle to Head Weld - Pressurizer

A-18.2 EMBEDDED FLAWS - NOZZLE TO HEAD WELD

The geometry and terminology for embedded flaws in this region is shown in figure A-18.1.

Basic Data:

- $t$ = 2.5 in.
- $\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)
- $a$ = Flaw depth (defined as one half of the minor diameter) (in.)
- $\ell$ = Flaw length (major diameter) (in.)
- $a_o$ = maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

Evaluation charts for embedded flaws in these regions of the pressurizer are listed below:

Figure A-18.6 Embedded Flaw Evaluation Chart for the Spray Nozzle to Head Weld - Pressurizer

## A-18.3 SURFACE FLAWS - SPRAY NOZZLE CORNER

The geometry and terminology for surface flaws in the spray nozzle corner region is depicted in figure A-19.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)

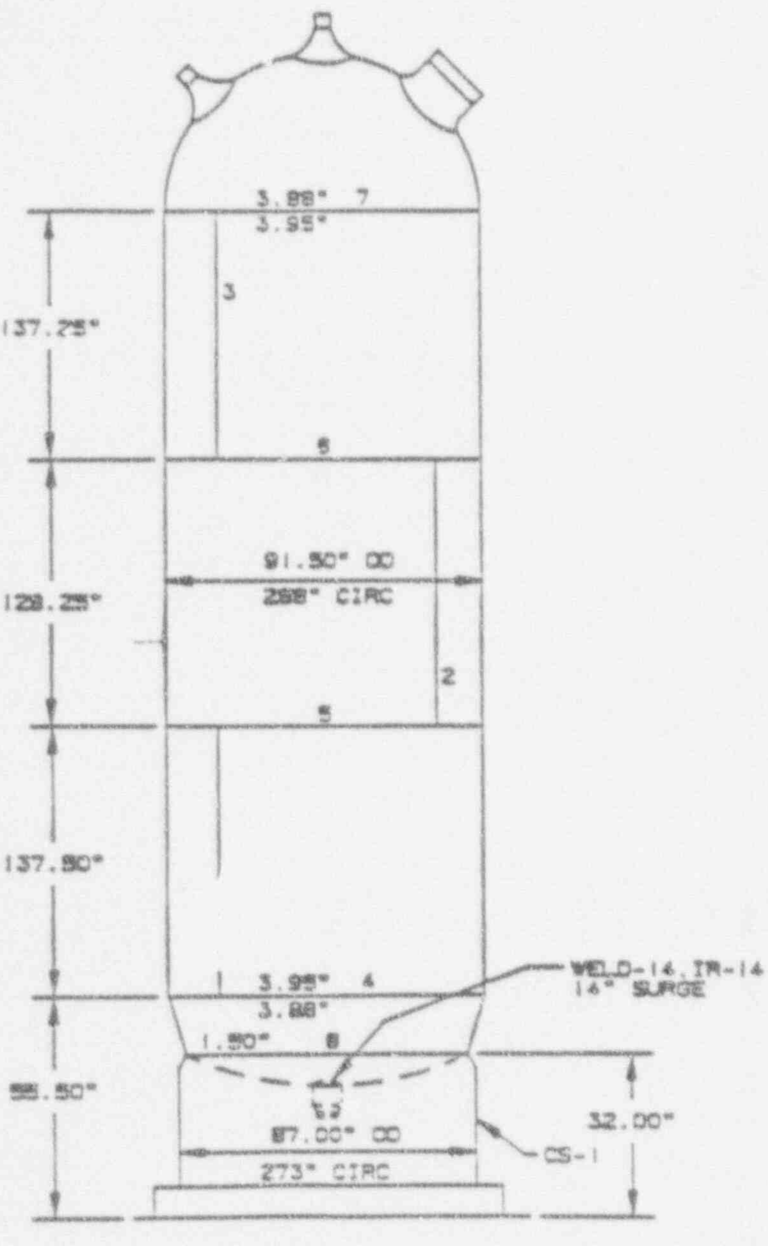
$\ell$ = the surface flaw length detected (in.)

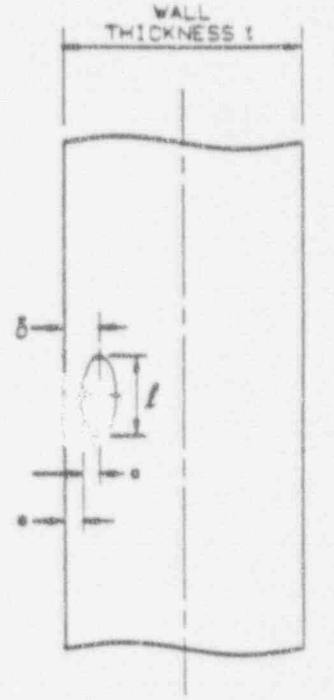
$t$ = wall thickness at the nozzle corner ($t$ = 3.29")

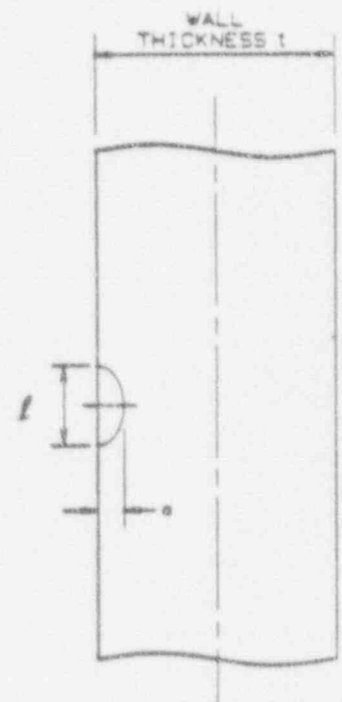
The surface flaw evaluation charts for the spray nozzle corner are listed below

Figure A-18.7 Flaw Evaluation Chart for Longitudinal Flaws at the Inside Surface of the Spray Nozzle - Corner Region

Figure A-16.1
Geometry and Terminology for Flaws in the Spray Nozzle to Head Weld - Pressurizer



## LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

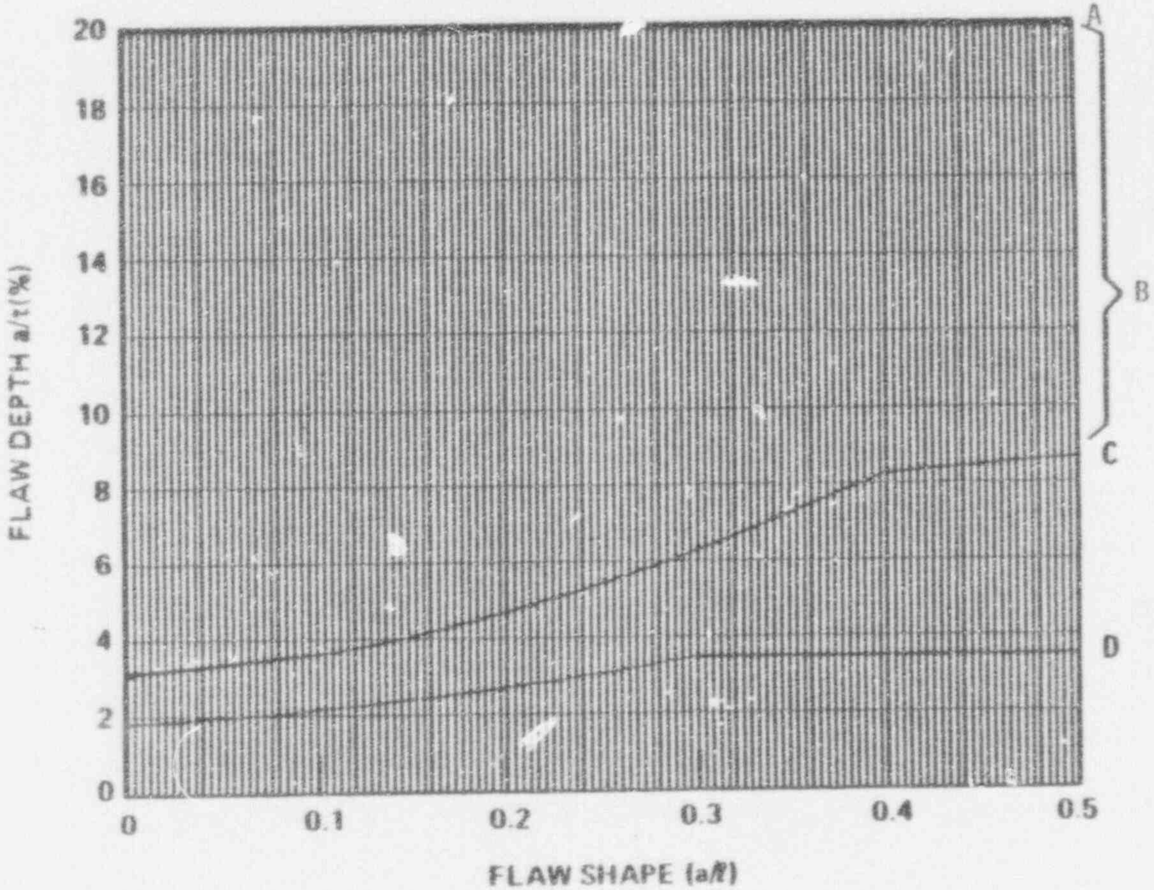
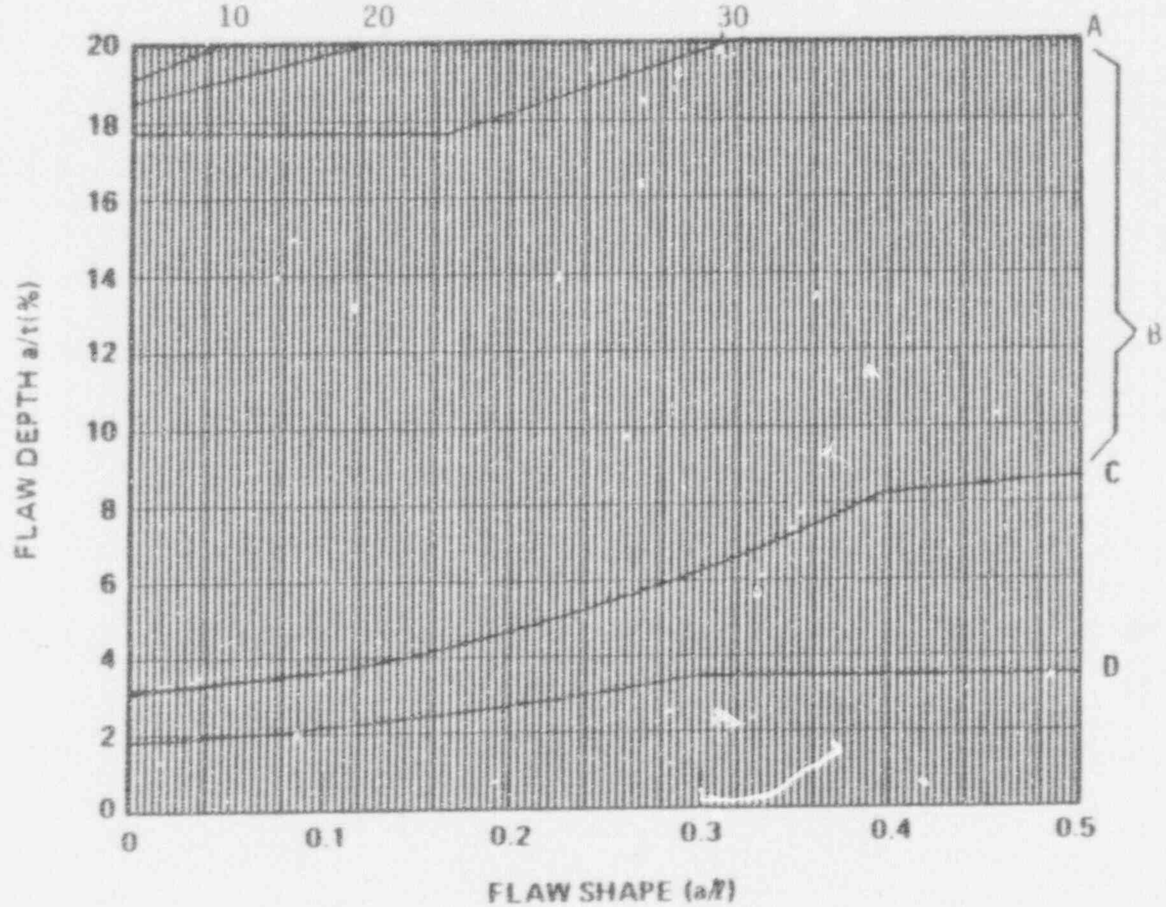



Figure A-18.2 Flaw Evaluation Chart for the Spray Nozzle to Head Weld - Pressurizer

X Inside Surface X Surface Flaw ___ Longitudinal Flaw

___ Outside Surface ___ Embedded Flaw X Circumferential Flaw




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

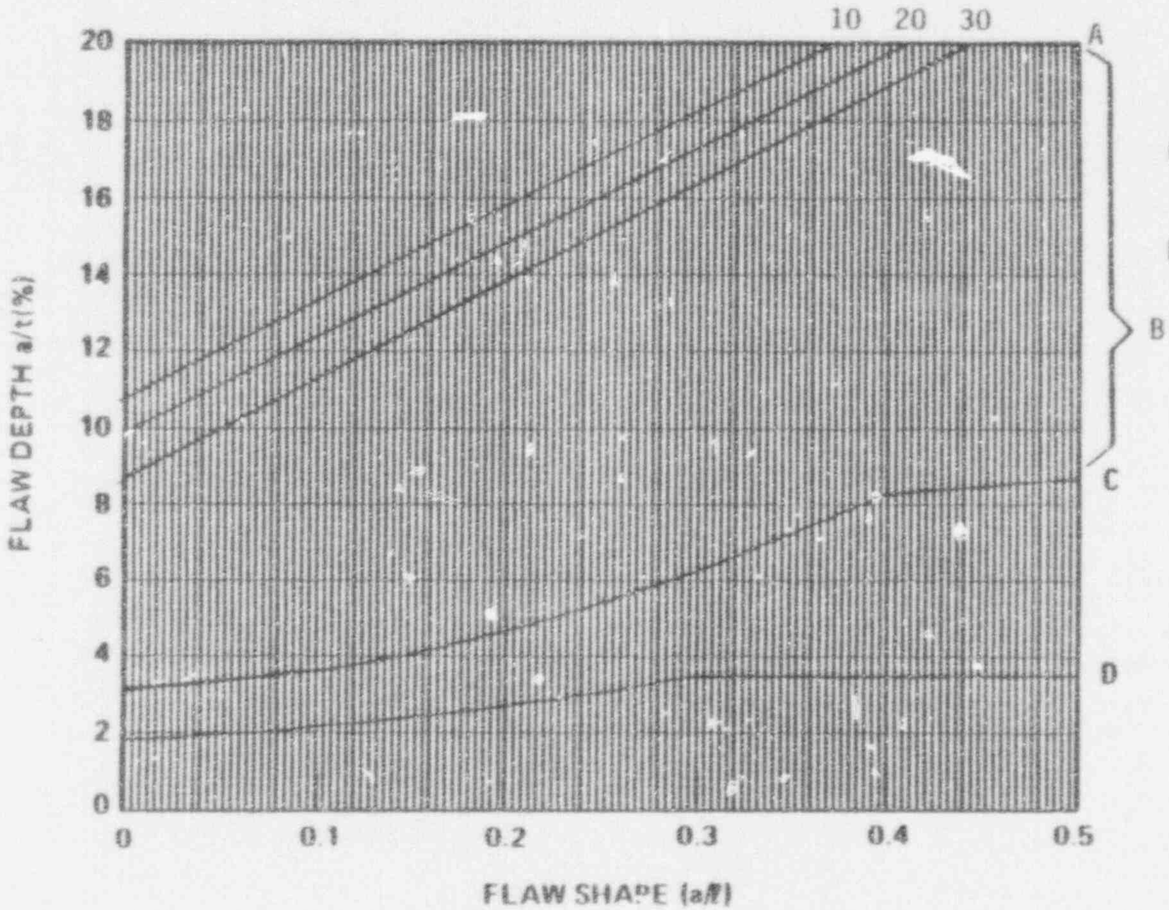
C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.



Figure A-18.3 Flaw Evaluation Chart for the Spray Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | ___ | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | X | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

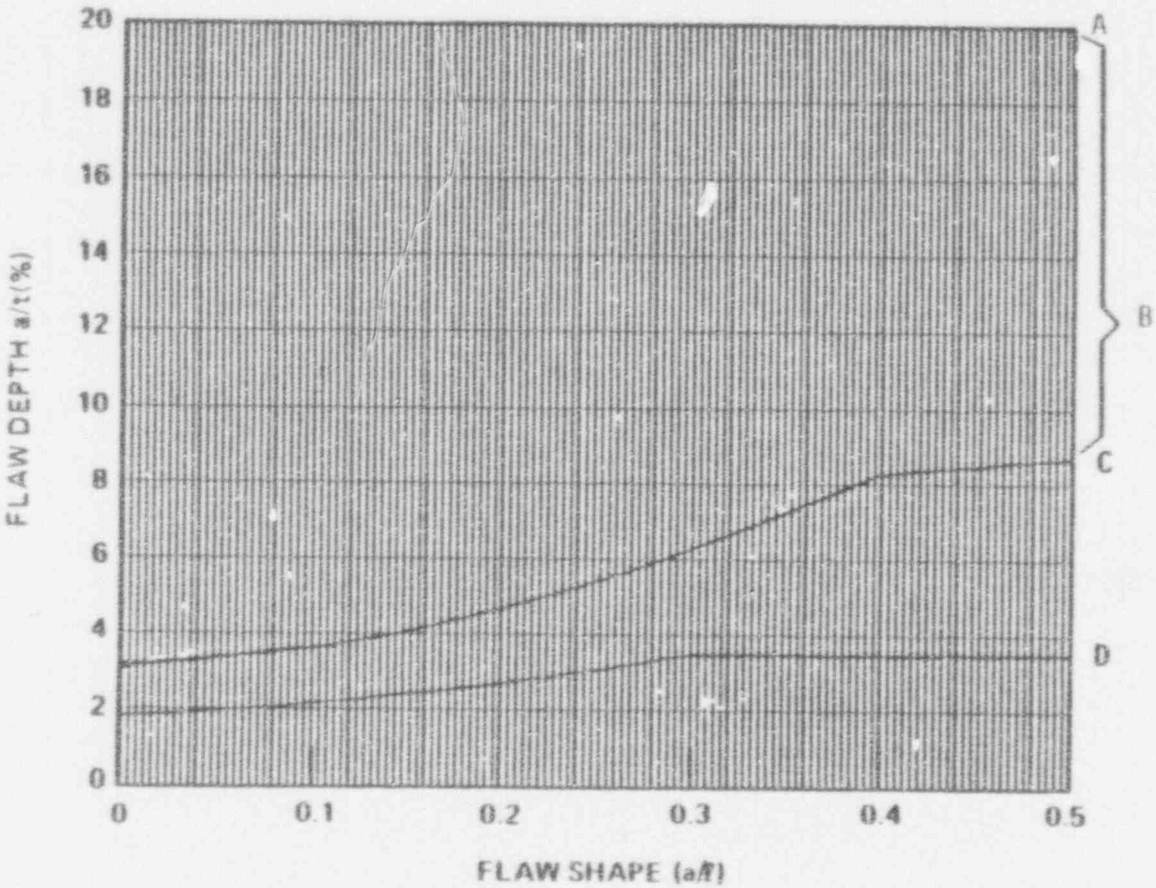
B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-18.4 Flaw Evaluation Chart for the Spray Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| X | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| | Outside Surface | | Embedded Flaw | | Circumferential Flaw |




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-18.5 Flaw Evaluation Chart for the Spray Nozzle to Head Weld - Pressurizer

| | | | | | |
|---|---|---|---|---|---|
| ___ | Inside Surface | X | Surface Flaw | X | Longitudinal Flaw |
| X | Outside Surface | ___ | Embedded Flaw | ___ | Circumferential Flaw |

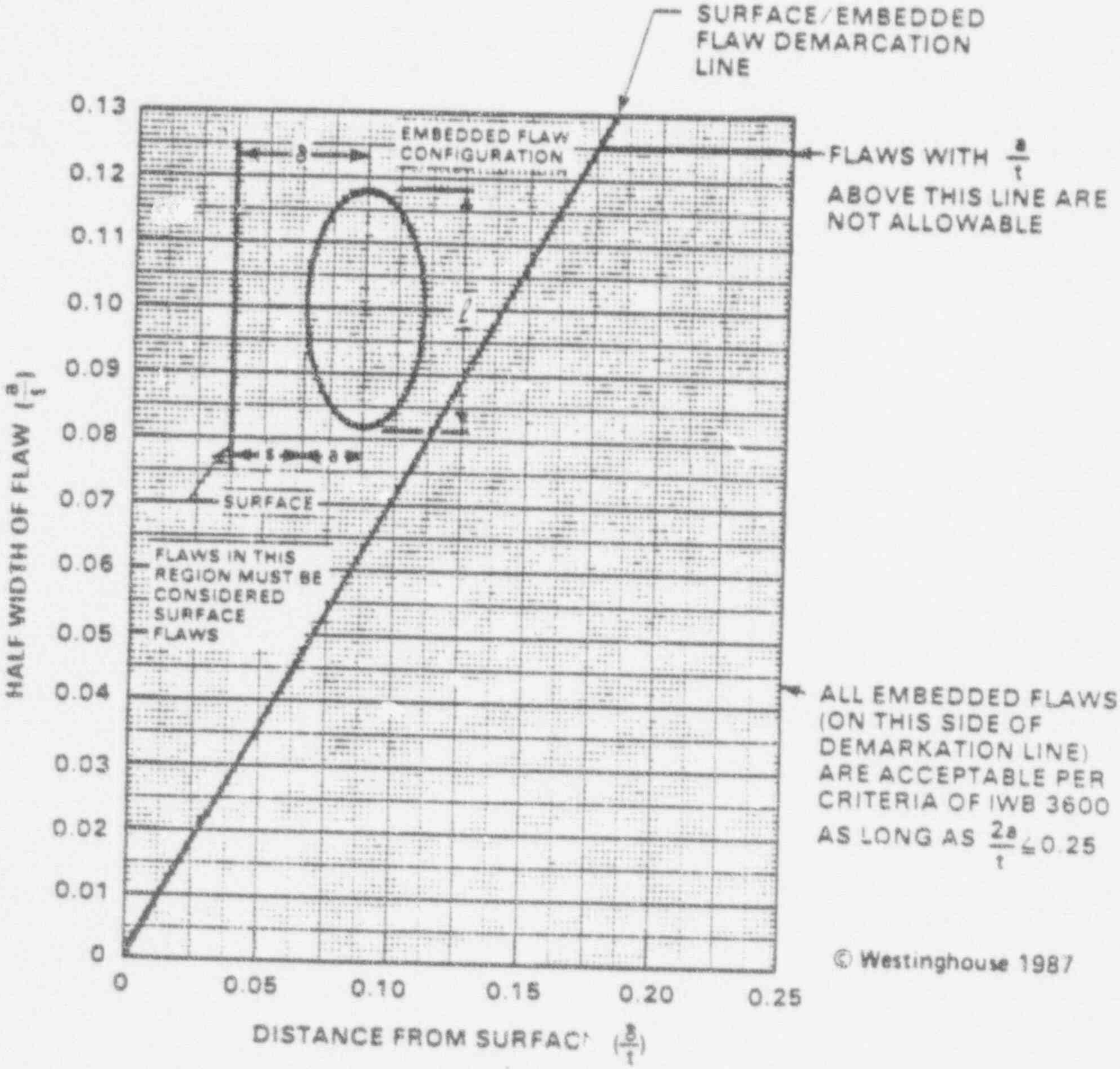



Figure A-18.6 Flaw Evaluation Chart for the Spray Nozzle to Head Weld - Pressurizer

X Inside Surface ___ Surface Flaw X Longitudinal Flaw

X Outside Surface X Embedded Flaw X Circumferential Flaw

LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

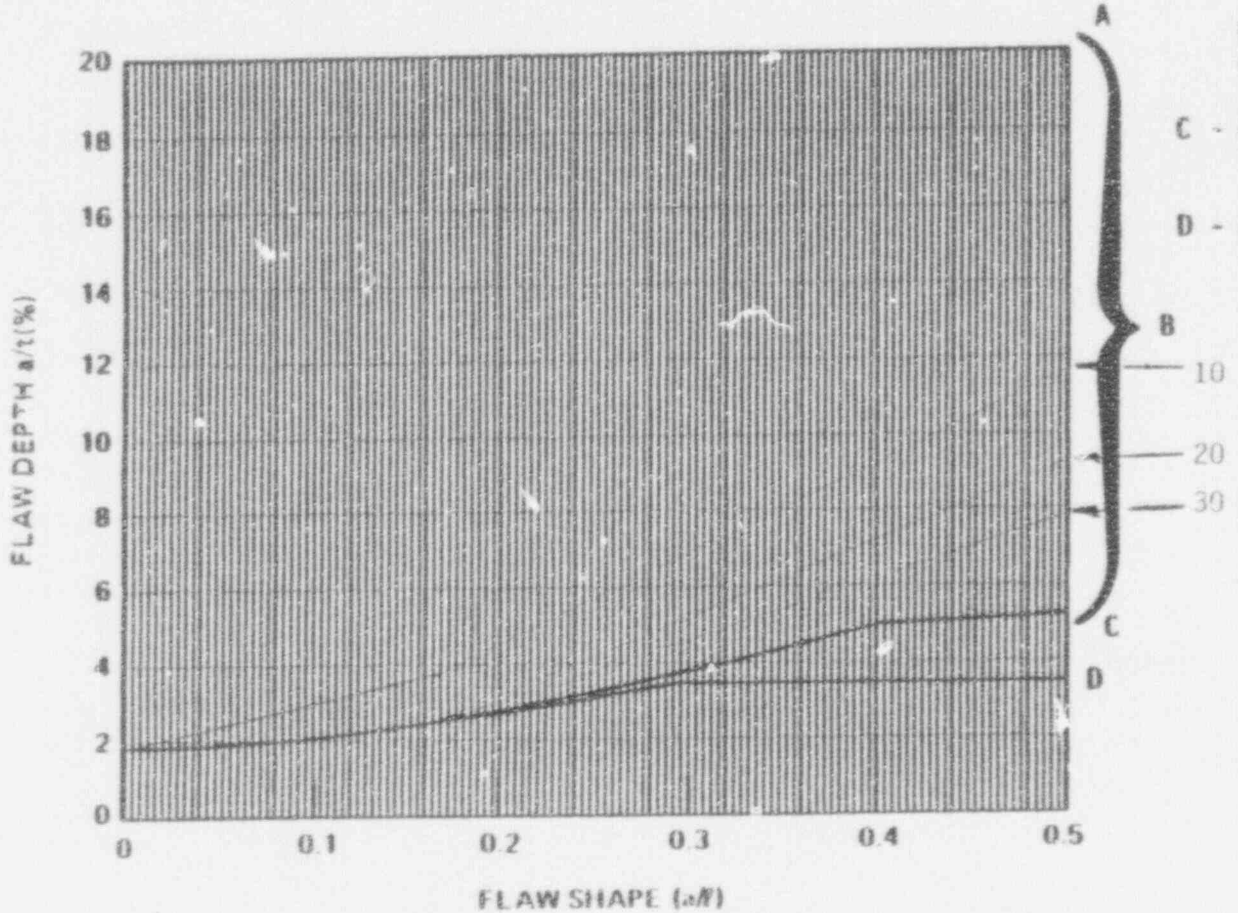



Figure A-18.7 Flaw Evaluation Chart for the Spray Nozzle Corner Region

X Inside Surface X Surface Flaw X Longitudinal Flaw

__ Outside Surface __ Embedded Flaw __ Circumferential Flaw

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## A-19 SAFETY AND RELIEF NOZZLES - PRESSURIZER

The safety and relief nozzles are separate nozzles, but are of identical geometry. The governing loads for both nozzles have been used to develop the charts in this section.

### A-19.1 SURFACE FLAWS - NOZZLE TO SHELL WELD

The geometry and terminology for surface flaws in the nozzle to shell weld region is depicted in figure A-19.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)
$\ell$ = the surface flaw length detected (in.)
$t$ = wall thickness ($t$ = 2.5")

The surface flaw evaluation charts for this region of the pressurizer are listed below:

Figure A-19.2 Flaw Evaluation Chart for the Inside Surface of the Safety and Relief Nozzle to Head Welds - Pressurizer

Figure A-19.3 Flaw Evaluation Chart for the Outside Surface of the Safety and Relief Nozzle to Vessel Welds - Pressurizer

## A-19.2 EMBEDDED FLAWS - NOZZLE TO SHELL WELD

The geometry and terminology for embedded flaws in the nozzle to shell weld region is shown in figure A-19.1.

Basic Data:

$t$ = 2.5 in.

$\delta$ = Distance of the centerline of the embedded flaw to the surface (in.)

$a$ = Flaw depth (defined as one half of the minor diameter) (in.)

$\ell$ = Flaw length (major diameter) (in.)

$a_o$ = maximum embedded flaw size in depth direction, beyond which it must be considered a surface flaw, per Section XI characterization rules.

The following parameters must be calculated from the above dimensions to use the charts for evaluating the acceptability of an embedded flaw

- o Flaw shape diameter, $a/\ell$
- o Flaw depth parameter, $a/t$
- o Surface proximity parameter, $\delta/t$

Evaluation charts for embedded flaws in these regions of the pressurizer are listed below:

Figure A-19.4 Embedded Flaw Evaluation Chart for the Safety and Relief Nozzle to Head Welds - Pressurizer

A-19.3 SURFACE FLAWS - SAFETY AND RELIEF NOZZLE CORNER

The geometry and terminology for surface flaws in the safety and relief nozzle corner regions is depicted in figure A-19.1.

The following parameters must be prepared for surface flaw evaluation charts

- o Flaw shape parameter, $a/\ell$
- o Flaw depth parameter, $a/t$

where

$a$ = the surface flaw depth detected (in.)

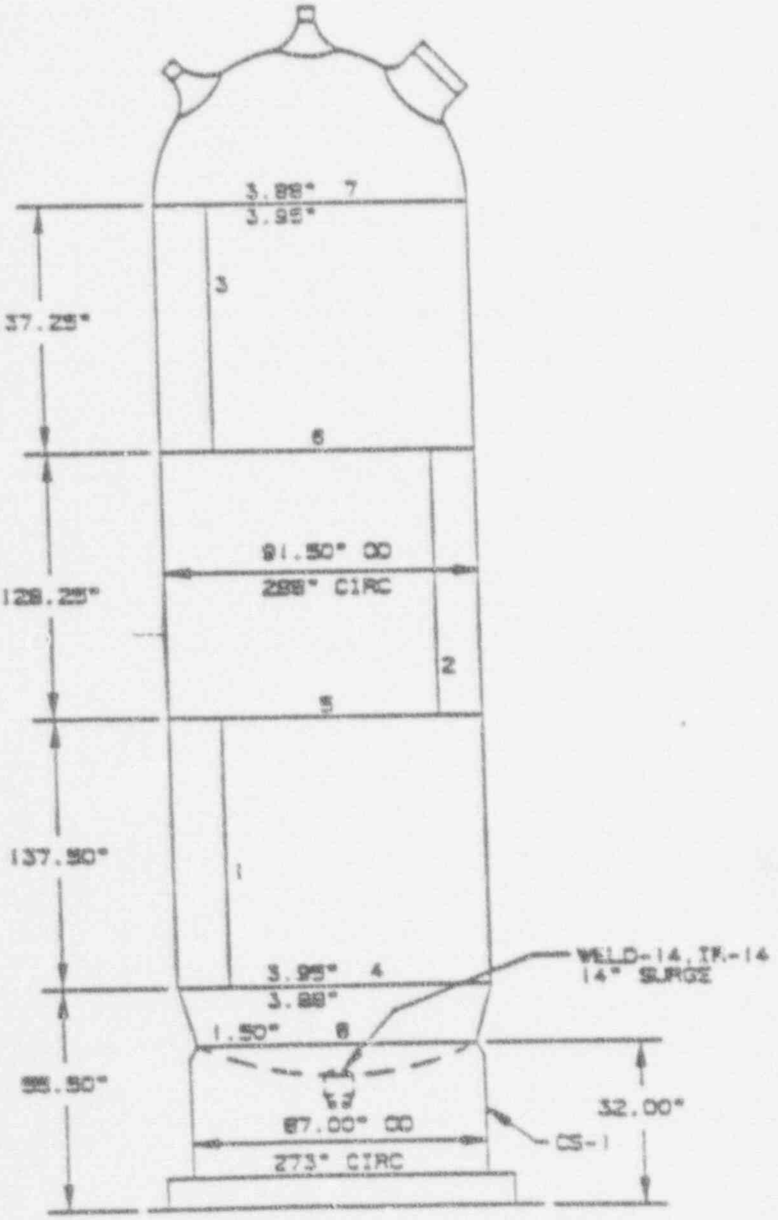
$\ell$ = the surface flaw length detected (in.)

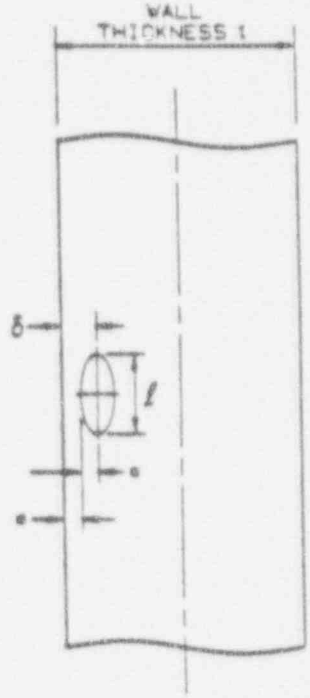
$t$ = wall thickness at the nozzle corner (t = 4.35")

The surface flaw evaluation charts for the safety and relief nozzle corner are listed below

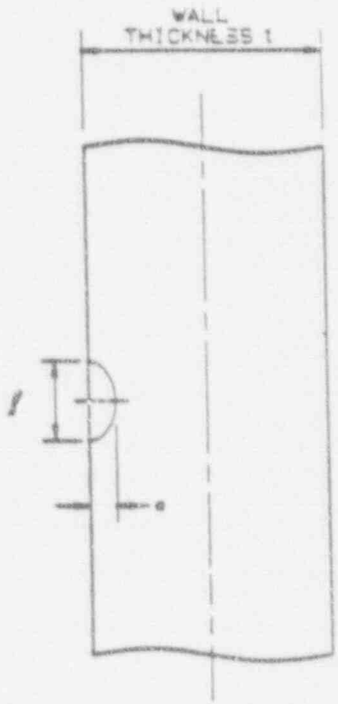
Figure A-9.7 Flaw Evaluation Chart for Longitudinal Flaws at the Inside Surface of the Safety and Relief Nozzle - Corner Region

Figure A-19.1
Geometry and Terminology for Flaws in the Safety and Relief Nozzle to Head Welds - Pressurizer

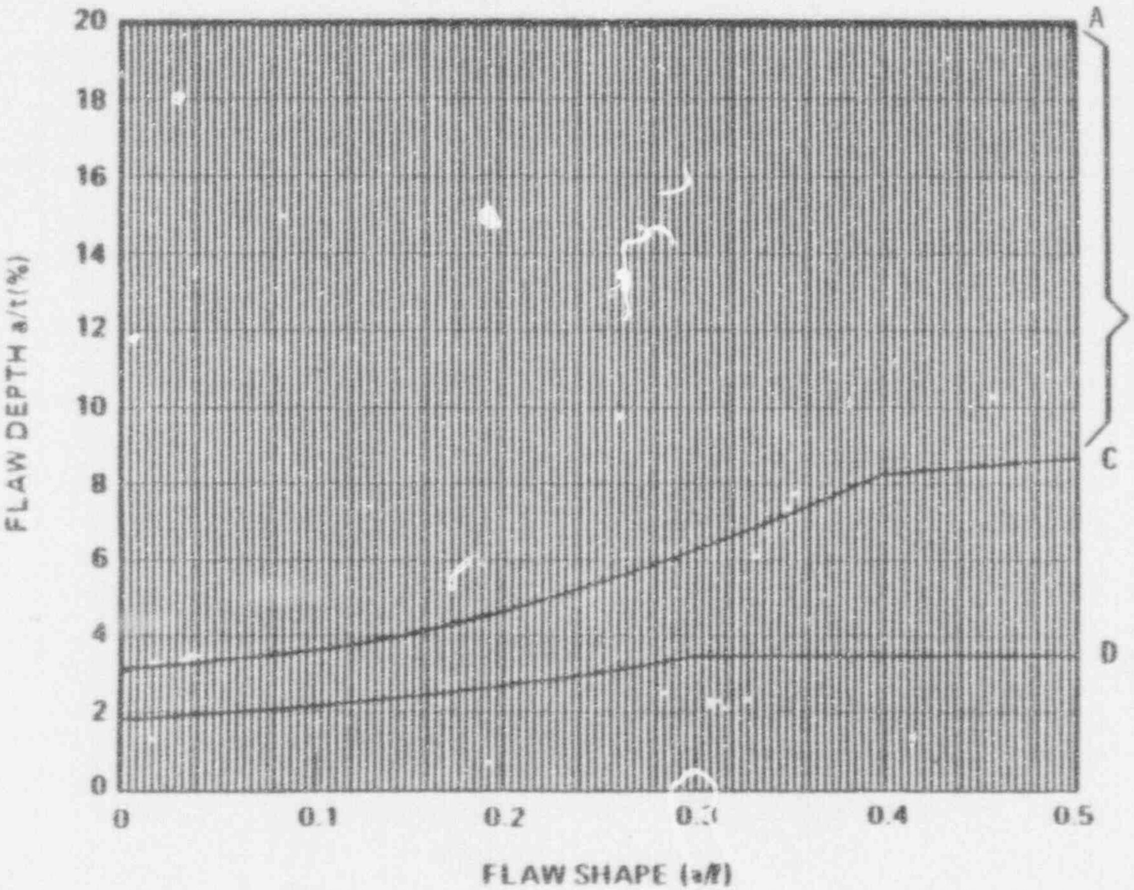



TYPICAL EMBEDDED
FLAW INDICATION




TYPICAL SURFACE
FLAW INDICATION




LEGEND

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable since 1983 Winter Addendum.

D - ASME Code allowable prior to 1983 Winter Addendum.

Figure A-19.2 Flaw Evaluation Chart for the Safety and Relief Nozzle to Head Welds - Pressurizer

X Inside Surface X Surface Flaw X Longitudinal Flaw

___ Outside Surface ___ Embedded Flaw X Circumferential Flaw

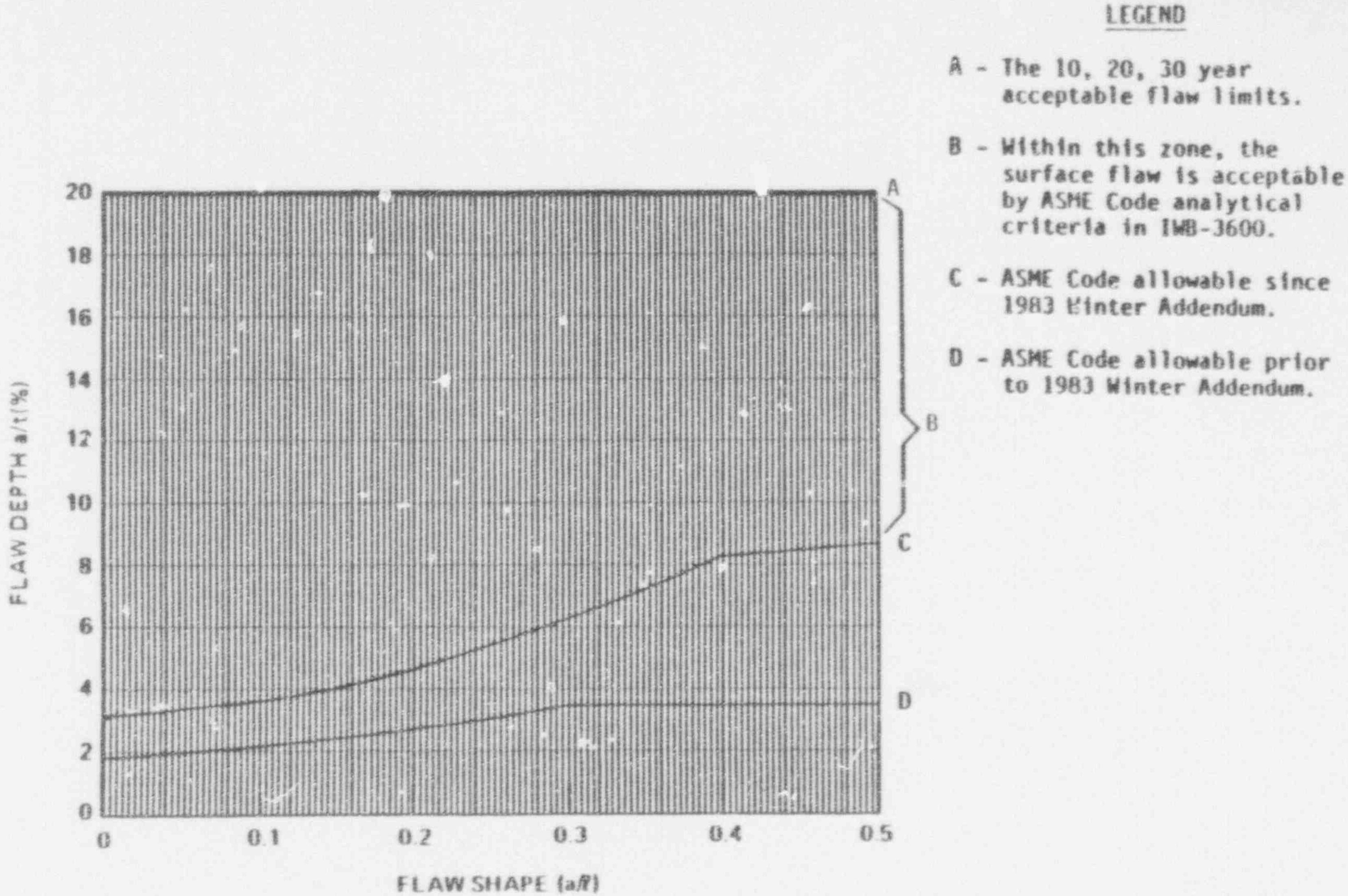



Figure A-19.3 Flaw Evaluation Chart for the Safety and Relief Nozzle to Head Welds - Pressurizer

___ Inside Surface   X Surface Flaw   X Longitudinal Flaw

X Outside Surface   ___ Embedded Flaw   X Circumferential Flaw

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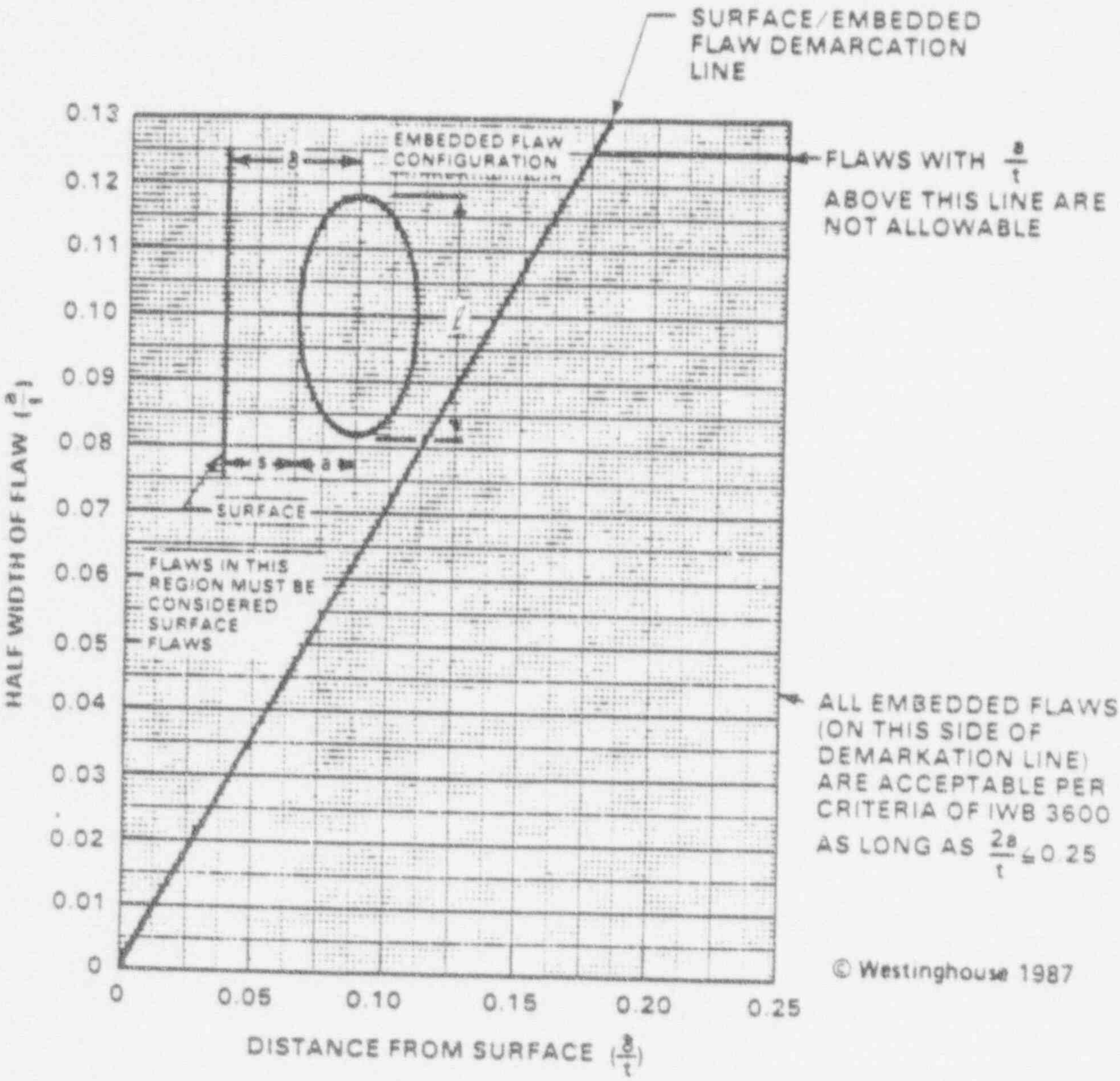




Figure A-19.4 Flaw Evaluation Chart for the Safety and Relief Nozzle to Head Welds - Pressurizer

X Inside Surface ___ Surface Flaw X Longitudinal Flaw

X Outside Surface X Embedded Flaw X Circumferential Flaw

**LEGEND**

A - The 10, 20, 30 year acceptable flaw limits.

B - Within this zone, the surface flaw is acceptable by ASME Code analytical criteria in IWB-3600.

C - ASME Code allowable

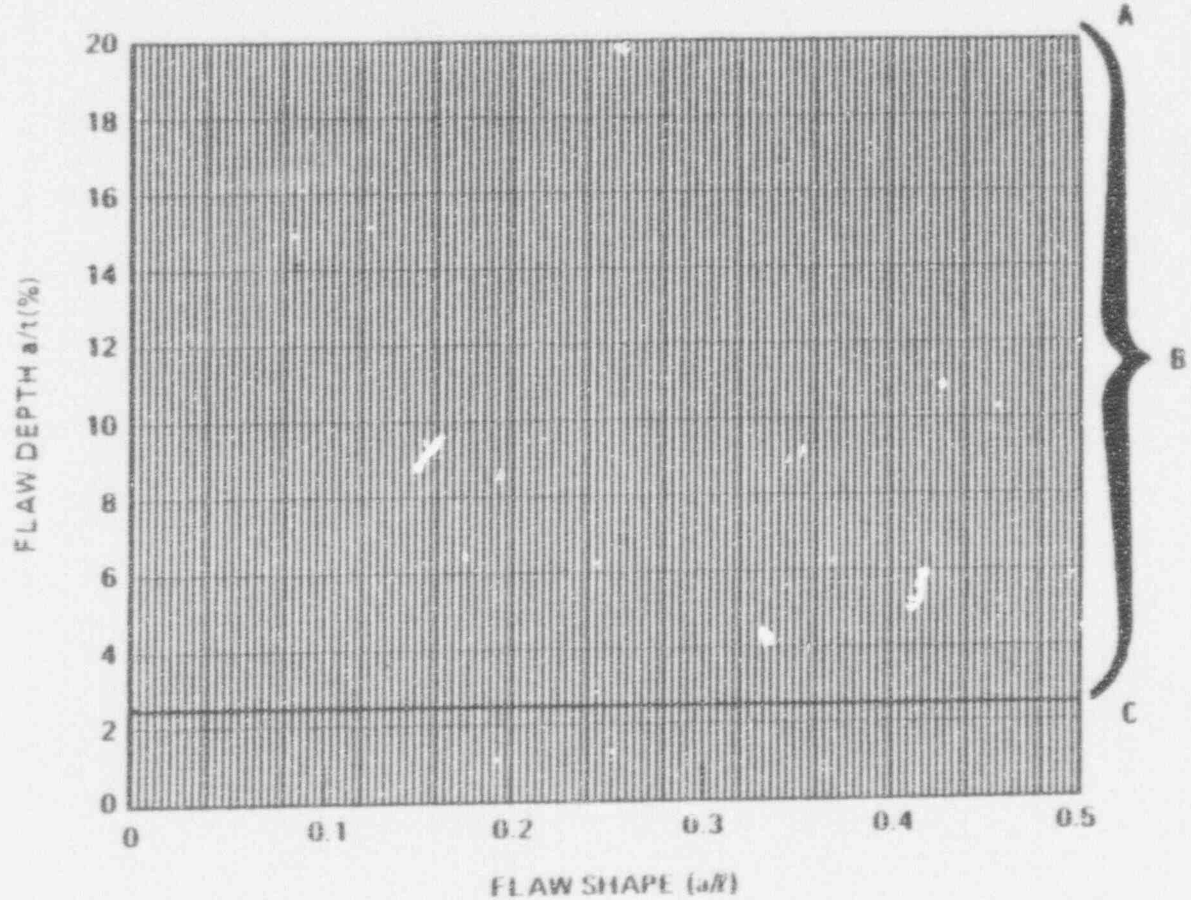


Figure A-19.5 Flaw Evaluation Chart for the Safety and Relief Nozzle Corner Region

X Inside Surface X Surface Flaw X Longitudinal Flaw

__ Outside Surface __ Embedded Flaw __ Circumferential Flaw