Commonwealth Edison
1400 Opus Place
Downers Grove, Illinois 60515

April 30, 1993

Dr. Thomas E. Murley, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Attn: Document Control Desk

Subject: Quad Cities Nuclear Power Station Unit 2
Additional Information Supporting a
Request for NRC Approval of a Non-Code Repair
for a Recirculation System Pipe Flaw
NRC Docket No. 50-265

References: (a) J.L. Schrage to T.E. Murley letter dated April 19, 1993

(b) Teleconferences between CECo (J. Schrage, et. al.) and NRC (D. Lynch, et. al.) on April 22 and 23, 1993

Dear Dr. Murley:

During the current refueling outage for Quad Cities Station Unit 2 (Q2R12), Commonwealth Edison Company (CECo) identified a flaw in a two-inch line on the Recirculation System. In Reference (a), CECo transmitted a description of the flaw, a description of the proposed repair, a safety assessment of the proposed repair, and a request for NRC approval of the proposed repair. As stated in Reference (a), the proposed repair is not an ASME Code Section XI approved repair. In the Reference (b) teleconferences, representatives from CECo and the NRC discussed the proposed repair for the flaw. During the teleconference, CECo presented the results of additional calculations pertaining to the affects of weld overlay shrinkage on a potential failure path along the weld-to-socket interface. The calculations indicated that for an assumed flaw in the weld overlay-to-socket interface, and an 18-month operating cycle, crack growth projections (for both IGSCC growth and fatigue crack growth) will remain within the requirements of ASME Section XI and NUREG 0313 (for IGSCC growth). The results of the additional calculations are provided in the Attachment and Enclosures.

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Based upon the results of these calculations, CECo respectfully requests review and approval of the proposed non-code repair by May 15, 1993. This schedule request is based upon the current schedule of outage activities (unit start-up is currently scheduled for May 26, 1993).

If there are any questions concerning this matter, please contact John L. Schrage at (708) 663-7283.

Sincerely,

John L. Schrage
Nuclear Licensing Administrator

Attachment
Enclosure (1-4)

cc: A. Bert Davis, Regional Administrator-RIII
C.P. Patel, Project Manager-NRR
T.E. Taylor, Senior Resident Inspector-Quad Cities
R.A. Hermann-NRR
Office of Nuclear Facility Safety-IDNS

a:typg:sl:8

ATTACHMENT

Analysis of Potential Weld Overlay-to-Socket Interface Failure Mechanisms

1.0 INTRODUCTION

During the Reference (b) teleconference, the NRC raised a concern with respect to the proposed non-code repair for weld 02-F2B at Quad Cities Station (Reference (a)). The NRC concern with the proposed non-code repair was the existence of a potential failure path along the original fillet weld-to-socket shoulder interface (Figure 1) for the following degradation mechanisms:

- IGSCC, and
- Fatigue cracking

Weld overlay shrinkage will affect the weld overlay-to-socket interface in the following ways:

1. The axial component of weld overlay shrinkage will create axial force and bending moments on weld 02-F2B and generally increase the sustained stress state in bypass line 2-0209B-2", and
2. The combination of heat input during waterbacked welding and the radial component of weld overlay shrinkage will create residual welding stresses along the weld overlay-to-socket interface.

2.0 Weld Overlay Axial Shrinkage Affect

Weld overlay axial shrinkage affects have been addressed utilizing Pacific Nuclear's PISTAR piping analysis program. As shown in Figure 2, the bypass line was modeled and then subjected to an axial shrinkage at nodes T1 through T3. Based upon bounding axial shrinkage values of 5/16" to 3/8" associated with 4" long weld overlays on 8", 10", and 12" NPS weldments, a total upperbound axial shrinkage value of 1/4" was estimated for the proposed 2.25" long weld overlay to be applied to weld 02-F2B. This axial shrinkage at weld 02-F2B resulted in the axial force and bending moments presented in Table 1.

Table 1
Piping Model
Weld Overlay Axial Shrinkage Loads

NODE ID	AXIAL FORCE (lbs.)	Y-AXIS MOMENT (in.-lbs.)	Z-AXIS MOMENT (in.-lbs.)
1	238	-2235	-1270

The design internal pressure for the Reactor Recirculation system at Quad Cities Station is 1,250 psi. Bypass line 2-020B-2" is not contained in the Quad Cities Station Unit 2 Final Safety Analysis Report (FSAR) piping analysis computer output packages, therefore, a representative deadweight stress value of 500 psi was assumed to act upon weld 02-F2B. Because of the unconstrained geometry of the bypass line, restraint-of-free end displacement thermal stress acting on weld 02-F2B was assumed to be negligible.

During the April 23, 1993 CECo/NRC teleconference, the resulting sustained stress load combination (weld overlay axial shrinkage + internal pressure + deadweight + thermal) magnitude acting on weld 02-F2B was reported as 5.6 ksi. This stress magnitude was conservatively based upon the geometry of the bypass line. For the fracture mechanics evaluations presented below, a 2.7 ksi sustained stress load combination value was used, based upon a 0.5" assumed weld overlay thickness joining the bypass line to the socket shoulder.

As illustrated in Figure 3, it is not believed that weld overlay axial shrinkage will affect the residual welding stress along the weld overlay-to-socket shoulder interface because it does not affect the existing internal gap condition between the bypass line and the socket-like coupling.

3.0 Weld Overlay Radial Shrinkage Affects

As qualitatively illustrated in Figure 4, weld overlay radial shrinkage will create an "hourglass" profile along the length of the weld overlay. This profile must routinely be addressed during the surface conditioning of a weld overlay for volumetric UT examination. This geometric deformation is similar to that created by the Mechanical Stress Improvement Process (MSIP) which takes advantage of this profile to create a residual bending stress at the edge of the MSIP tool. This residual bending stress is compressive along the inside surface of the weldment and tensile along the outside surface of the weldment as shown in Figure 4. Therefore, our experience with weld overlays and MSIP would have us conclude that a residual welding stress is created at the weld overlay-to-socket shoulder interface that actually works to arrest crack growth along this potential failure path.

4.0 Potential IGSCC Failure Mechanism

NUREG-0313 Paragraph 2.1.1(4) states that cast austenitic stainless steel with a maximum of 0.035% carbon and a minimum of 7.5% (or FN) ferrite is considered resistant to sensitization and IGSCC. Because we are not aware of any cases of IGSCC in cast stainless steel components in an operating nuclear power plant and are only aware of IGSCC welding cases in experimental mock-ups fabricated using extreme welding heat input conditions designed to cause IGSCC, we do not believe that IGSCC is a realistic failure mechanism along the fillet weld-to-socket shoulder interface even though valve MO 2-0202-6B is considered IGSCC-susceptible per NUREG-0313.

Even though this valve's carbon content is probably over 0.035%, CECo has measured the valve's ferrite content which resulted in a general ferrite measurement of greater than 20 FN. As shown in Figure 5 (ASTM Special Test Publication 756, 1982), a welded CF8M cast material with a maximum allowable ASTM A-351 carbon content of 0.08% and a ferrite content of 20 FN would appear to be IGSCC-resistant.

Despite the position that the fillet weld-to-socket shoulder interface is actually under a beneficial weld residual stress state and that this interface is probably not IGSCC-susceptible, CECo has performed a parametric study of IGSCC growth along this interface for various assumed weld residual stress conditions. This study used the following IGSCC growth formula from Appendix A of NUREG-0313:

$$\frac{da}{dt} = 3.59 \times 10^{-8} K^{2.161}$$

where: da = change in flaw depth, in.

dt = change in time, hrs.

K = crack tip stress intensity, ksi in.

This formula was applied to a 360° long, 10% through-wall flaw in a cylinder with a 2.375" inside diameter and a 0.5" wall thickness. This flaw configuration was subjected to the 2.7 ksi sustained stress magnitude presented in Section 2.0 and +0/-0, +10/-10, and +20/-20 ksi through-wall residual stress profiles, as shown in Enclosure 1. This enclosure illustrates that after 18 months (13,140 hours) of operation, a 10% through-wall flaw is predicated to grow to approximately 30% through-wall under a +20/-20 residual stress profile. As discussed in Section 3.0 a +20/-20 ksi residual welding stress profile is very conservative as the heel of the fillet weld-to-socket shoulder interface is most likely under compression due to the radial aspect of weld overlay shrinkage.

Per ASME Section XI Table IWB-3641-5, a 360° long, 30% through-wall flaw would be permitted to have a stress ratio of 0.80. For an allowable design stress intensity of 16.95 ksi for 304 stainless steel at a 550°F operating temperature, this results in an allowable applied primary stress of 13.6 ksi, or approximately 9 times the applied design internal pressure stress. Therefore, because of the low sustained stress level acting on the weld overlay thickness, IGSCC growth is predicted to be well within ASME Section XI/NUREG-0313 requirements after one cycle of operation.

5.0 Potential Fatigue Cracking Failure Mechanism

CECo has also performed a parametric study of fatigue crack growth along the fillet weld-to-socket shoulder interface for various assumed residual stress conditions and assumed cyclic stress magnitudes. This study used the following environmentally-assisted fatigue crack growth formula from a flawed piping evaluation task force paper (Evaluation of Flaws in Austentic Steel Piping", transactions of the ASME - Journal of Pressure Vessel Technology, Volume 108, August 1986):

$$\frac{da}{dN} = C \times E \times S \times K^n$$

where: da = change in flaw depth, in.

dN = change in applied load cycles

K_{min} = min. applied stress intensity factor

K_{max} = max. applied stress intensity factor

$K = K_{max} - K_{min}$, psi in.

$C = 2 \times 10^{-19}$

E = 10 (for BWR environments)

$R = K_{min} / K_{max}$

$S = (1.0 - 0.5\,R^2)^{-4}$

n = 3.3

This formula was applied to the same initial IGSCC flaw and cylinder geometry, sustained stress magnitude, and through-wall residual stress profiles presented in Section 4.0 with the addition of +5/-5, +10/-10, +15/-15, and +20/-20 ksi cyclic stresses.

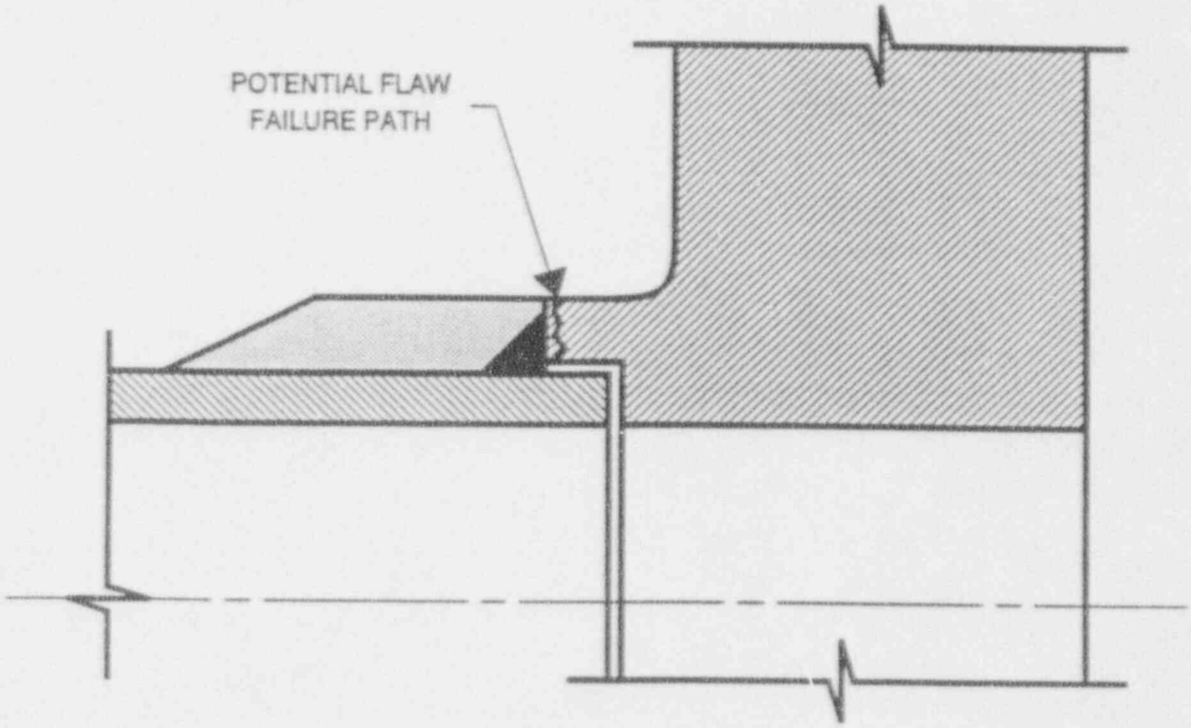
Enclosures 2 through 4 present the results of this fatigue crack growth study. The curves presented in these enclosures demonstrate that for reasonable cyclic and welding residual stress magnitudes, a 10% through-wall flaw can withstand thousands of application cycles before reaching ASME Section XI maximum allowable flaw depths of 60% (0.30"). These curves also demonstrate that for high cyclic and welding residual stress magnitudes, a 10% through-wall flaw would be driven very quickly through-wall. Consequently, because we do not have any leaking flaws along the fillet weld-to-socket shoulder interface at weld 02-F2B and this weld has been in service for greater than 20 years, these high cyclic and residual stress magnitude assumptions are not realistic.

6.0 Conclusion

Based upon the analysis described above, it is CECo's position that even if the cast body is IGSCC-susceptible; and if there exists a flaw in the weld overlay-to-socket shoulder interface; and if an adverse residual welding stress exists along this interface, an assumed flaw will not undergo enough IGSCC growth to exceed ASME Section XI/NUREG-0313 requirements within an 18 month operating cycle. CECo has also demonstrated that if a flaw exists in the weld overlay-to-socket shoulder interface; and if a reasonable magnitude of adverse residual welding stress exists along this associated interface; and if a reasonable applied stress magnitude and associated number of application cycles exists, an assumed flaw will not undergo enough fatigue crack growth to exceed ASME Section XI requirements within a reasonable number of load application cycles. If higher levels of residual welding and applied stress are assumed, significant and noticeable fatigue crack growth should have previously been observed at the fillet weld-to-socket shoulder interface at weld 02-F2B.

FIGURE 1

POTENTIAL FATIGUE CRACKING/IGSCC FAILURE PATH



(FLAW.WPG)

FIGURE 2

QUAD CITIES UNIT 2 BYPASS LINE 2-0209B-2"

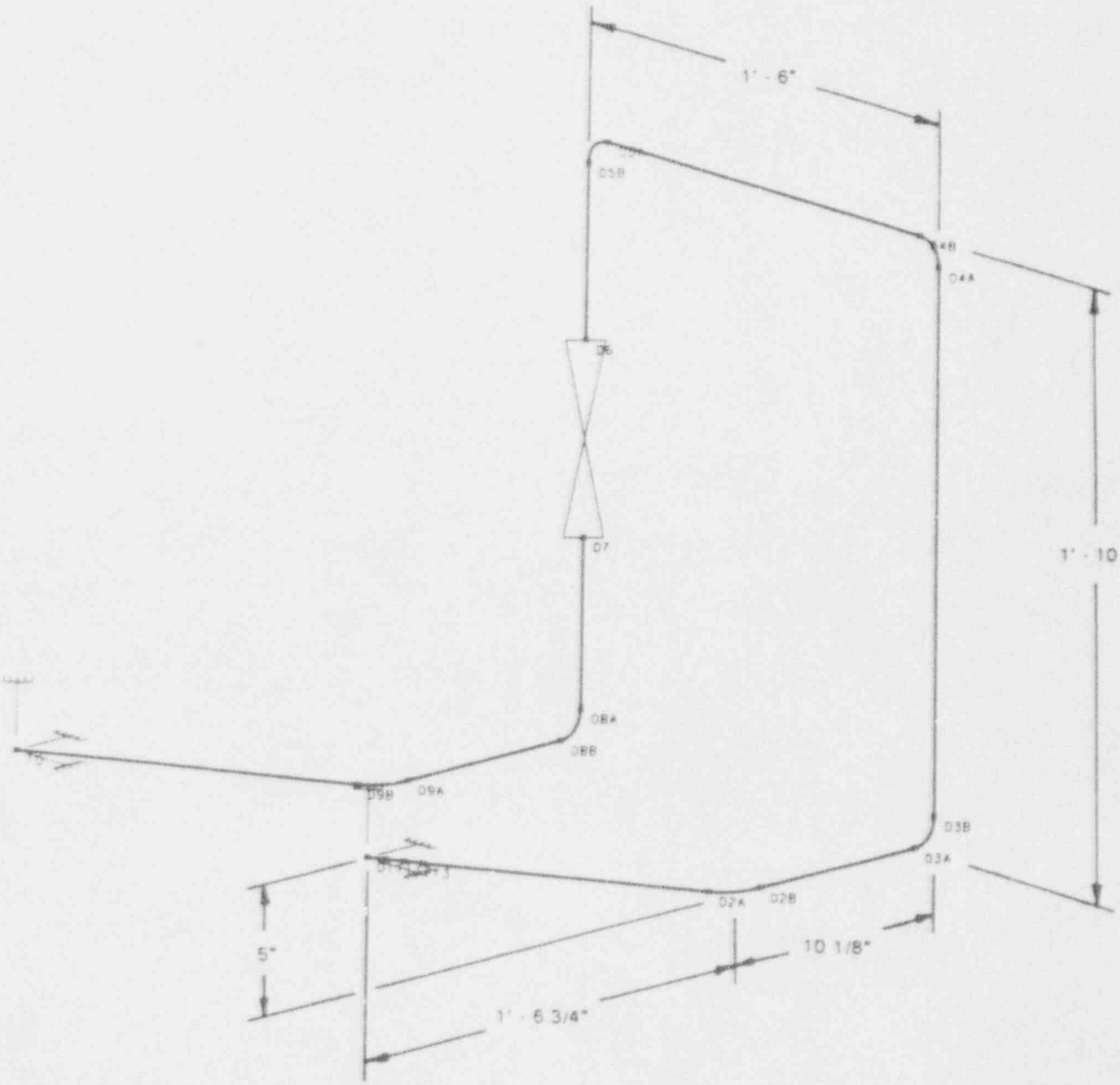
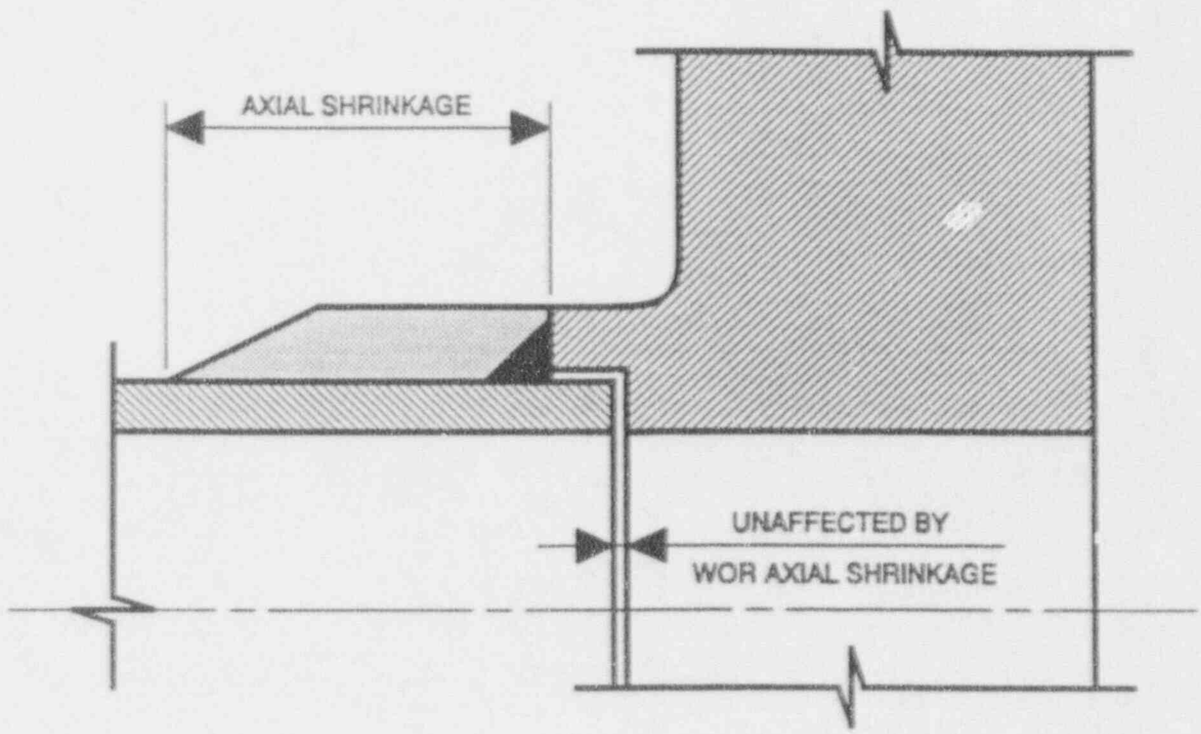


FIGURE 3

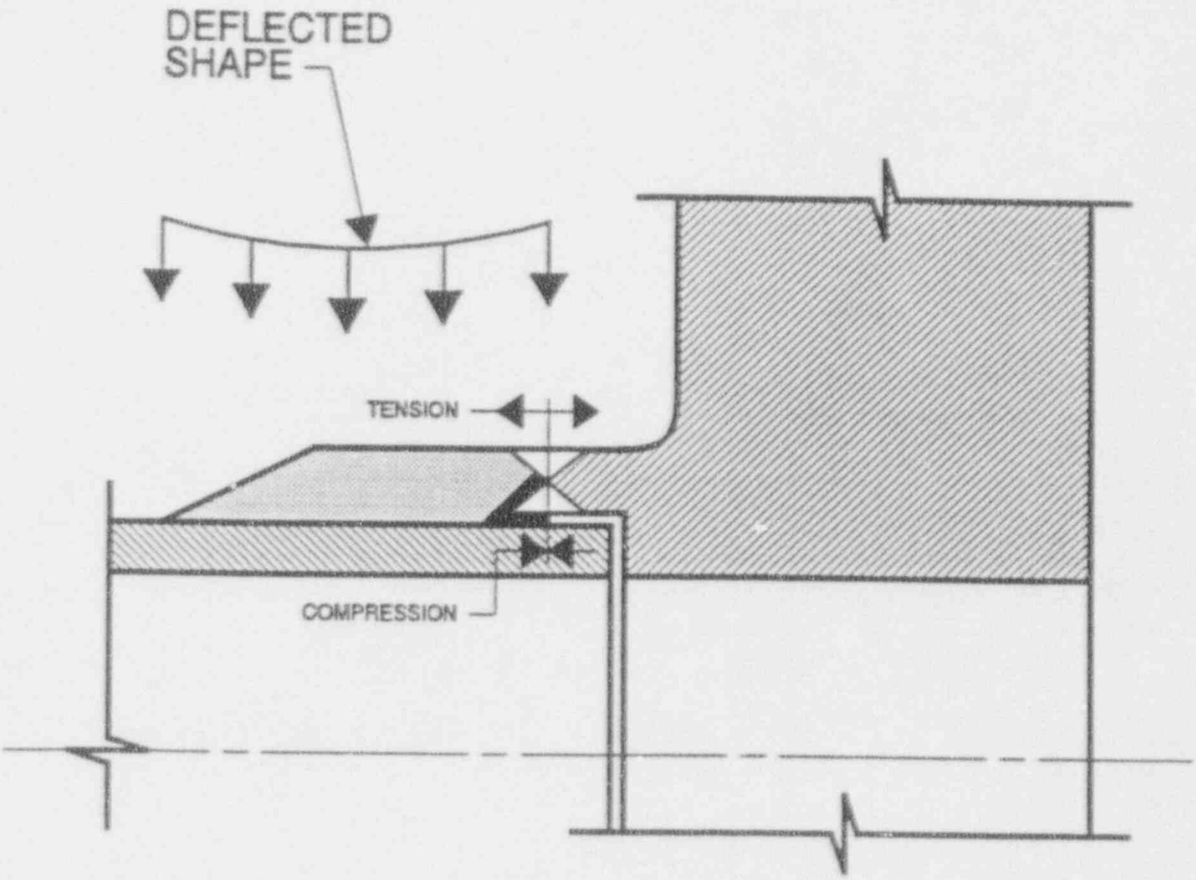
WELD OVERLAY AXIAL SHRINKAGE AFFECTS



(SHRINK.WPG)

FIGURE 4

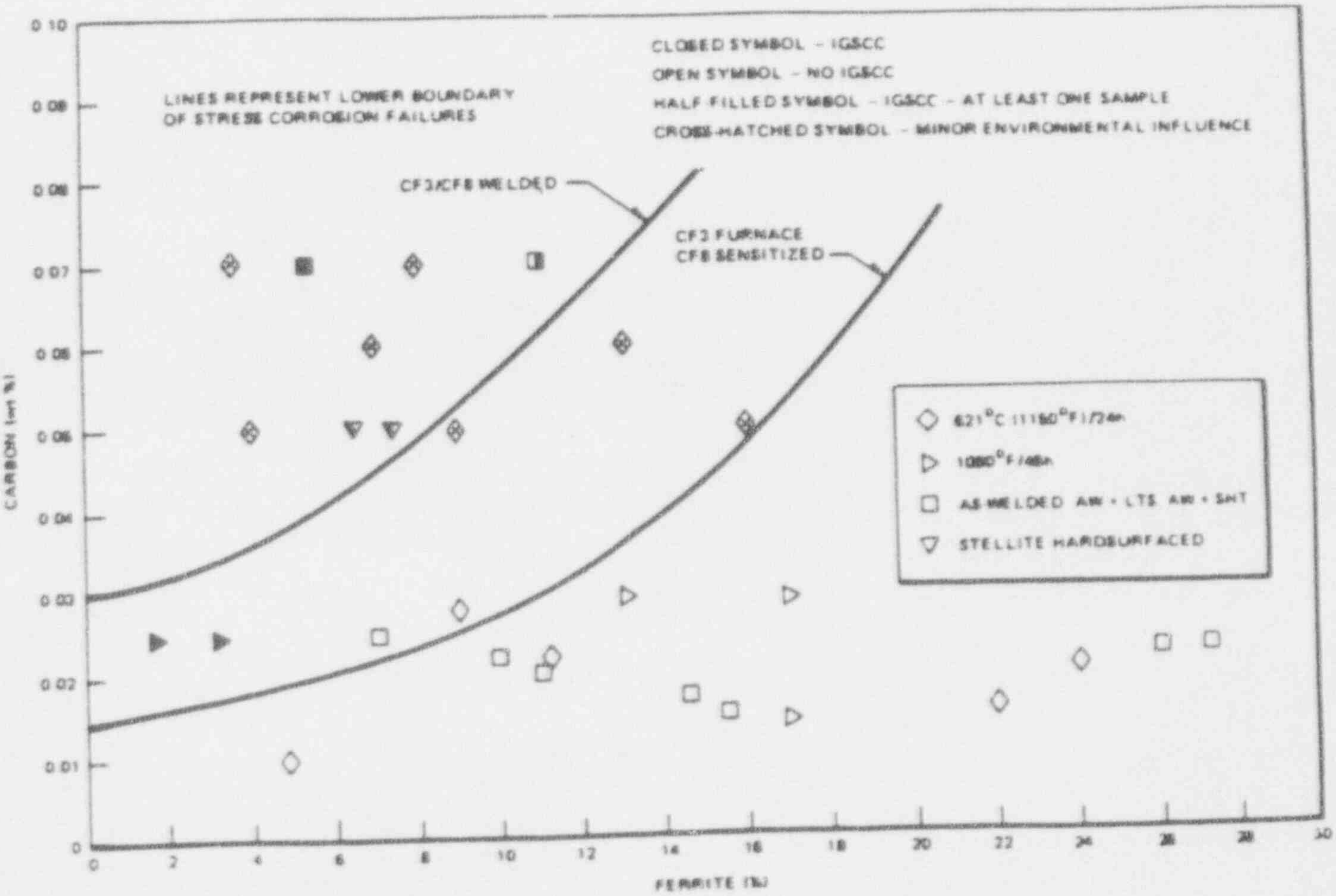
WELD OVERLAY RADIAL SHRINKAGE AFFECTS



(RADIAL.WPG)

FIGURE 5
IGSCC RESISTANCE AS A FUNCTION OF CARBON VS. FERRITE CONTENT

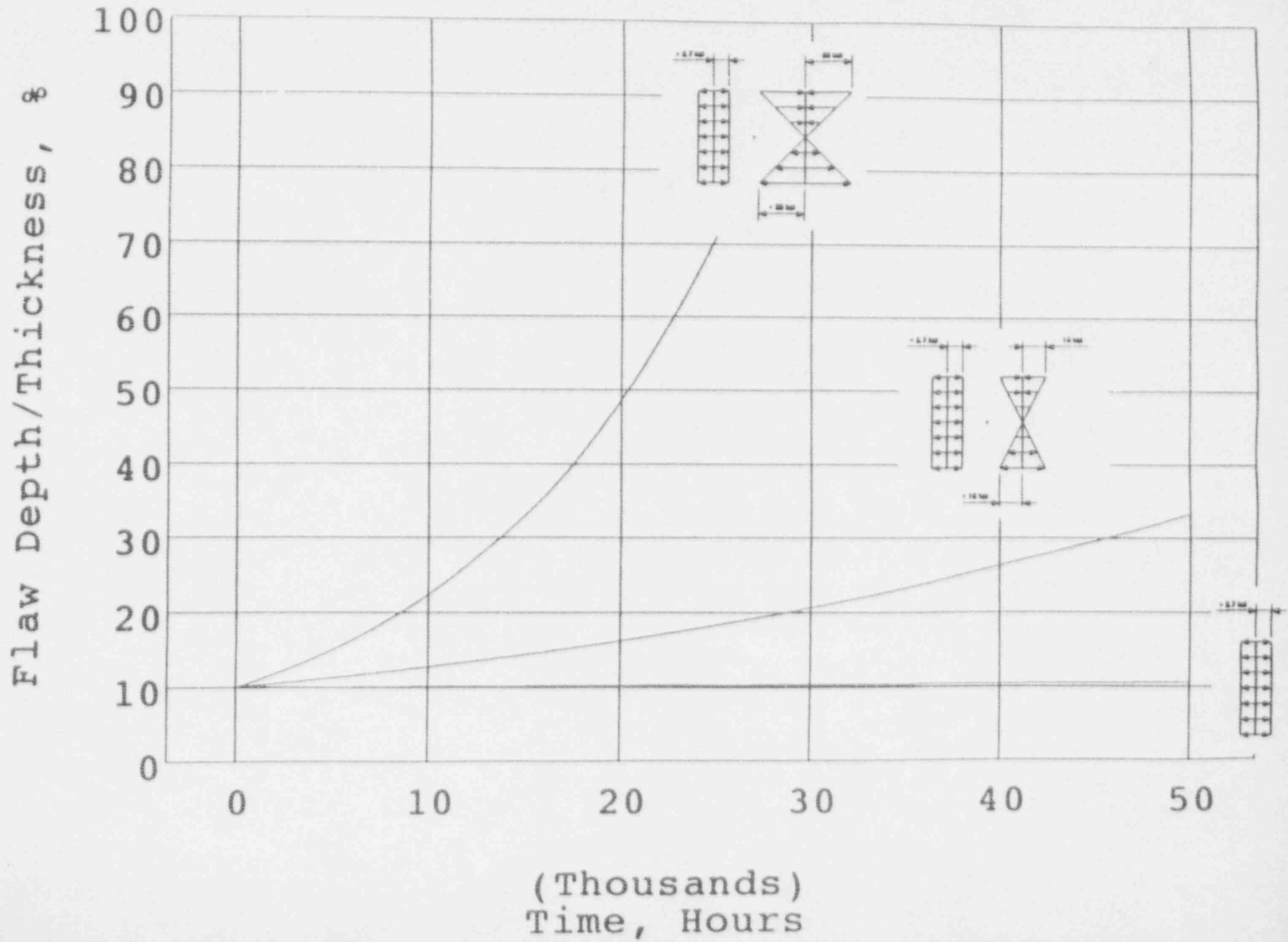
Reference: "Intergranular Stress Corrosion Cracking Resistance of Austenitic Stainless Steel Castings", American Society of Testing and Materials (ASTM)Materials (ASTM) Special Technical Publication 756, 1982, pp. 26-47)



ENCLOSURE 1

IGSCC PARAMETRIC STUDY

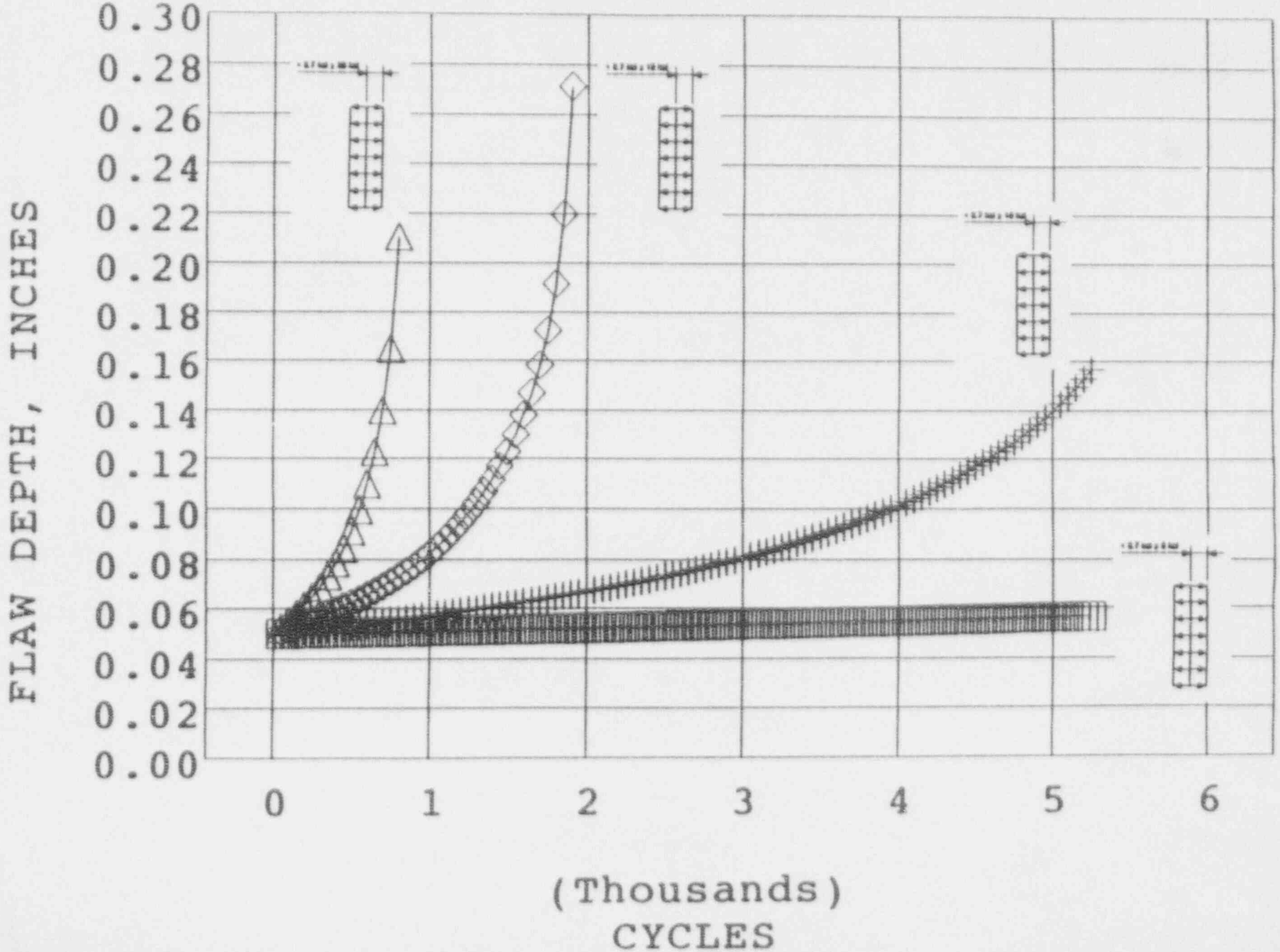
+0/-0, +10/-10, and +20/-20 ksi Residual Stress Profiles


Flaw Depth/Thickness, %
0
10
20
30
40
50
60
70
80
90
100
0
10
20
30
40
50
(Thousands)
Time, Hours

ENCLOSURE 2

FATIGUE CRACK GROWTH PARAMETRIC STUDY

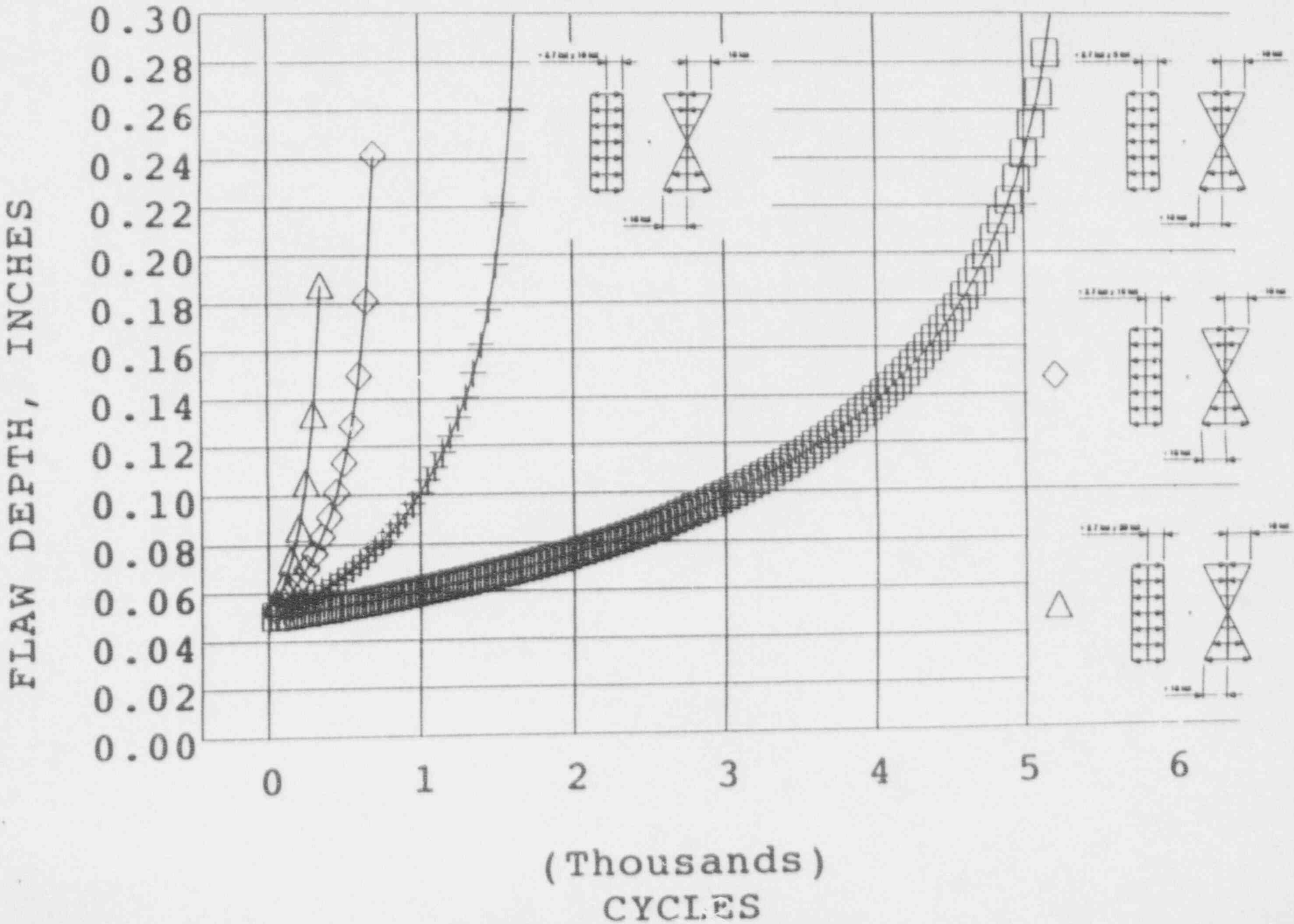
+0/-0 ksi Residual Stress Profiles


FLAW DEPTH, INCHES
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
1
2
3
4
5
6
(Thousands)
CYCLES

ENCLOSURE 3

FATIGUE CRACK GROWTH PARAMETRIC STUDY

+10/-10 ksi Residual Stress Profiles

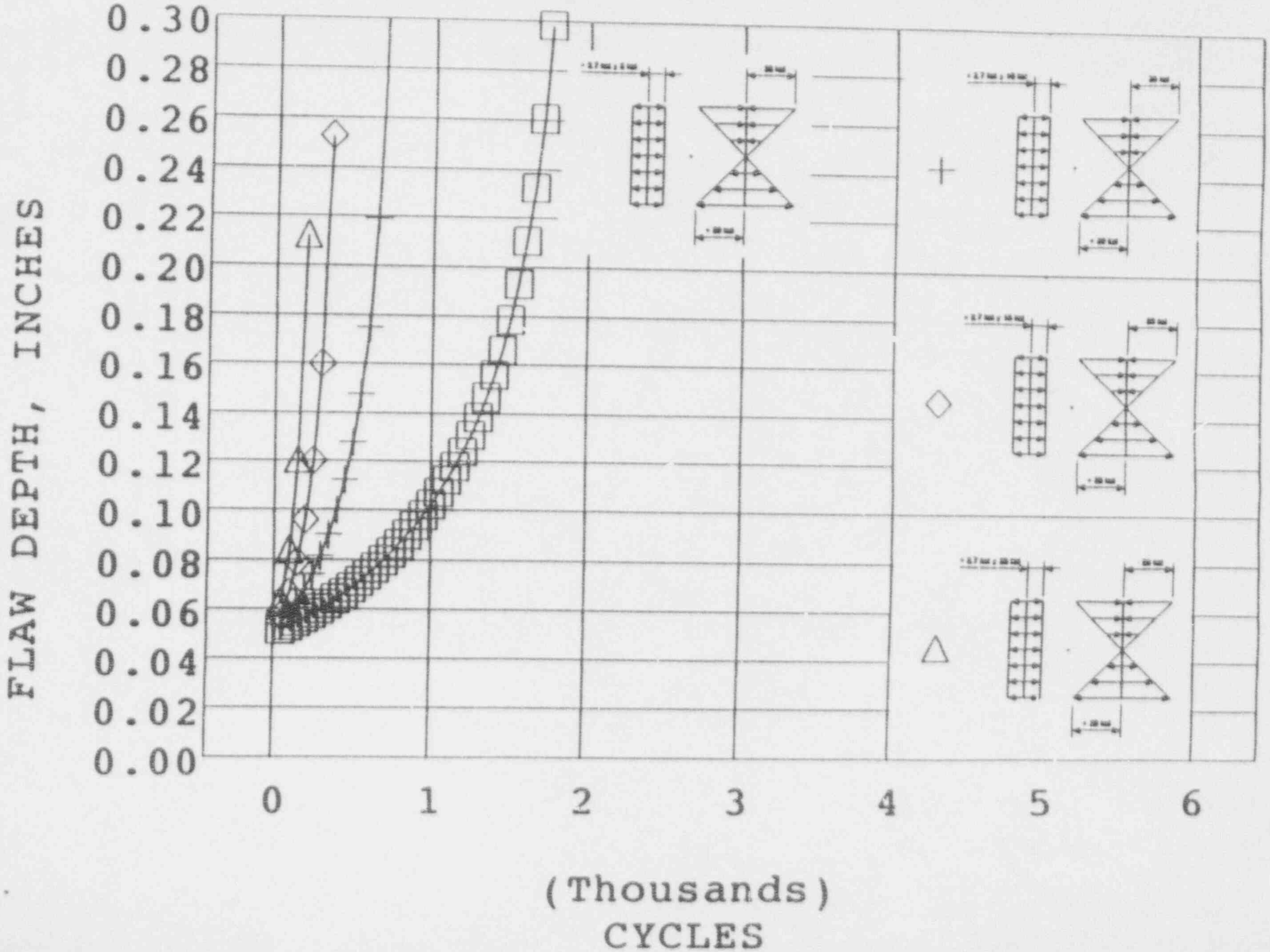


FLAW DEPTH, INCHES
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
0.18
0.20
0.22
0.24
0.26
0.28
0.30
0
1
2
3
4
5
6
(Thousands)
CYCLES

ENCLOSURE 4

FATIGUE CRACK GROWTH PARAMETRIC STUDY

+20/-20 ksi Residual Stress Profiles


FLAW DEPTH, INCHES
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
1
2
3
4
5
6
(Thousands)
CYCLES