JAN 1 3 1994

MEMORANDUM FOR: J. Costello, Section Leader
SSEB/DE/RES

FROM: H. Graves
SSEB/DE/RES

SUBJECT: MEETING NOTES, AMERICAN CONCRETE INSTITUTE (ACI) ANNUAL CONVENTION, NOVEMBER 7 - 12, 1993, MINNEAPOLIS, MINNESOTA

ACI 349 - Subcommittee 3, Task Force on Test Data

The Task Force (J. Rotz, Bechtel; J. Daly, Sargent & Lundy; and C. Heinz, Drillco) met for 3 hours on Sunday afternoon, November 7, 1993, at the Park Inn Hotel. The audience included members of ACI's 349-3 committee and six visitors. The goal of the Task Force was to review and comment on the similarities, differences, and applicability of a compilation of anchor test data from: Germany; England; Sweden; Prague; and the USA (see enclosure 1).

Task Force observations were: (1) over fifty percent of the test data was single anchor static tests; (2) ACI pullout formula was conservative for shallow embedments ≤100mm; and (3) German CC-method was conservative for deeper embedments ≥200mm. It was also noticed that anchor tests pullout values varied for similar U.S. and German compressive concrete strengths. In the open discussion, the differences in test data due to concrete strength was attributed to: water/cement ratio, and aggregate type. The German's use a natural stone aggregate in concrete; whereas, in the U.S. a crushed stoned aggregate is used.

The Task Force concluded that more test data was needed for: dynamic loads; deep embedments; edge distance; group spacing; and cracked concrete.

ACI 349 - Subcommittee 3, Embedded Steel

The Subcommittee met for a full day Monday, November 8, 1993, at the Hyatt Regency Hotel. Meeting agenda items discussed are highlighted below.

Items discussed included Appendix B, chapters B. 4, Design requirements for concrete and B.5, Anchorage requirements. The committee decided to look at chapters B.4 and B. 5 to determine how and what to change in these chapters if the German CC-method is adopted. The subcommittee will continue to review this issue. Highlights of the Sunday Task Force meeting was discussed with the full subcommittee. The subcommittee decided that in order to adopt the CC-method some clarifications on concrete test data (i.e., water/cement ratio and aggregate type) were needed and that some factors used in the CC-method may require adjustments (e.g. h_e - embedment depth).

Also discussed was an NRC paper, "Staff Position on Steel Embedments," which was written by NRR/ECGB during the review of the Advanced Boiling Water Reactor. I indicated that this position would change and the subcommittee should wait for a final version before they mailed Committee comments on the Staff Position to NRC. Finally, I briefed the subcommittee on the research being performed at the University of Texas at Austin (see enclosure 2). Mr. D. Godfrey, Trentec, expressed an interest in the test program and wanted to know how his newly

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PDR ORG NREA
PDR

[illegible]

DF05

marketed undercut anchor, "The Swedge Bolt," could be included in the program. I suggested to him that he write a letter to E. Beckjord in order to have his product considered.

ACI 349 - Main Committee

The main committee met for a half day on Tuesday, October 27, 1992. The highlights of the meeting were the subcommittee chairmen reports.

Subcommittee 1 - Materials, reported that the subcommittee would be distributing, by the next meeting (April 1993), a report titled "Evaluation Guidelines for Concrete Nuclear Safety Related Structures." This report will address concrete degradation mechanisms. Contact H. Ashar, NRR, for further information. Subcommittee 2 - Design, reported that the effort to review ACI 318 chapter 21 - Seismic Design, for incorporation into ACI 349 was still under way. Subcommittee 3 - Embedded Steel, as reported above. Subcommittee 4 - Repository Structures (new subcommittee), reported that an outline of the subcommittee proposed activities had been developed.

The outline covers design of below grade or underground concrete vaults for waste disposal. Since ACI 349 was not developed originally for concrete waste structures the subcommittee will propose additional criteria for vault design. The proposed criteria will include permeability, life/durability, and minimum cracking requirements for concrete waste structures. R. Shewmaker, NMSS, attended the subcommittee 4 meeting and may have more information on items discussed. NRC members will make an effort to attend future meetings of this subcommittee.

ACI 355 Anchorage to Concrete

This committee met on Thursday, November 11, 1993. I did not attend the meeting.

Original Signed by,
Herman Graves
Herman L. Graves
Structural & Seismic Engineering Branch
Division of Engineering, RES

Enclosures: As stated
cc w/encls:
J. Ma
H. Ashar
G. Bagchi
C. Tan
R. Shewmaker
DISTRIBUTION: RESReading Chron/Circ PDR HGraves JCostello AMurphy JCraig LShao
SSEB/DE/RES
HGraves
1/13/94 HG

January 13, 1994 B:\TRIP-MIN.MN

ENCLOSURE 1

NOTE: FOR CODE USE ONLY

DETERMINATION OF RELATIVE
ACCURACY OF
ACI VS. CC METHOD

corrected
11/8/93

PREPARED FOR USE BY:

ACI 349 SUBCOMMITTEE 3
NOV.,1993

BY: JACK DALY
CHRIS HEINZ
JULIUS ROTZ

ACI 349 SUBCOMMITTE 3
TASK FORCE ON ANCHORAGE TEST DATA
November 7, 1993

REVIEW METHODOLOGY

MEMBERS: C. Heinz, J. Rotz, J. Daly

SCOPE: Review experimental test data available for cast-in-place and retrofit anchors subjected to tension loads only. All test data that involve shear loads or bolt failure was excluded from this study.

SOURCE OF DATA: Professor R. Klingner provided our group with a compilation of test data from Germany, England, Swe~~e~~den, Prague, CSFR, and the USA. It is our understanding that this data formed the basis for the "CC Method" currently under evaluation. We also obtained additional data from tests recently completed at a domestic nuclear plant. All data was compiled into a single database. See Table 1 for listing of files.

PROCEDURES: The ultimate concrete strength was calculated for each test using both the current Appendix B requirements and the CC Method as described in Professor R. E. Klingner's letter to Mr. Richard Orr dated January 25, 1993. These predicted results were compared to the actual failure load to judge the relative accuracy of each of the methods. A questionnaire was also developed to collect information concerning the properties of the concrete used and the various test apparatus/procedures to confirm that the test results from the separate test programs were not biased in any way.

DEFINITIONS:

d: Diameter of anchor
d_o: Diameter of anchor head
he_f: Effective embedment length
ϕ: Understrength factor

ψ_1, ψ_2, ψ_3: Modification factors
C_1: Edge distance
fcc200: Actual concrete strength (cube)
f'c: Actual concrete strength (cylinder)

ASSUMPTIONS

- An anchor was categorized as "no edge effect" if C_1 is $\geq 1.5 * he_f$

- The "ACI" predicted values are in strict accordance with the requirements listed in ACI-349, Appendix B, with ϕ = 1.0

- The "CC Method" values are based on the following:

ϕ = 1.0

Nn = $\left(\frac{A_N}{A_{NO}}\right) (\psi_1)\ (\psi_2)\ (\psi_3) * K * \sqrt{f_c'} * he_f^{1.5}$

ψ_1 = 1.0 (no eccentricity assumed

ψ_2 = $(.7 + .2 * \frac{C_1}{he_f}) \leq 1.0$

ψ_3 = 1.4 (uncracked concrete assumed
K = 28 for cast in place and undercut anchors
= 25 for ductile expansion anchors

f_c' = fcc200/1.18 for all tests except USA9 thru USA12.

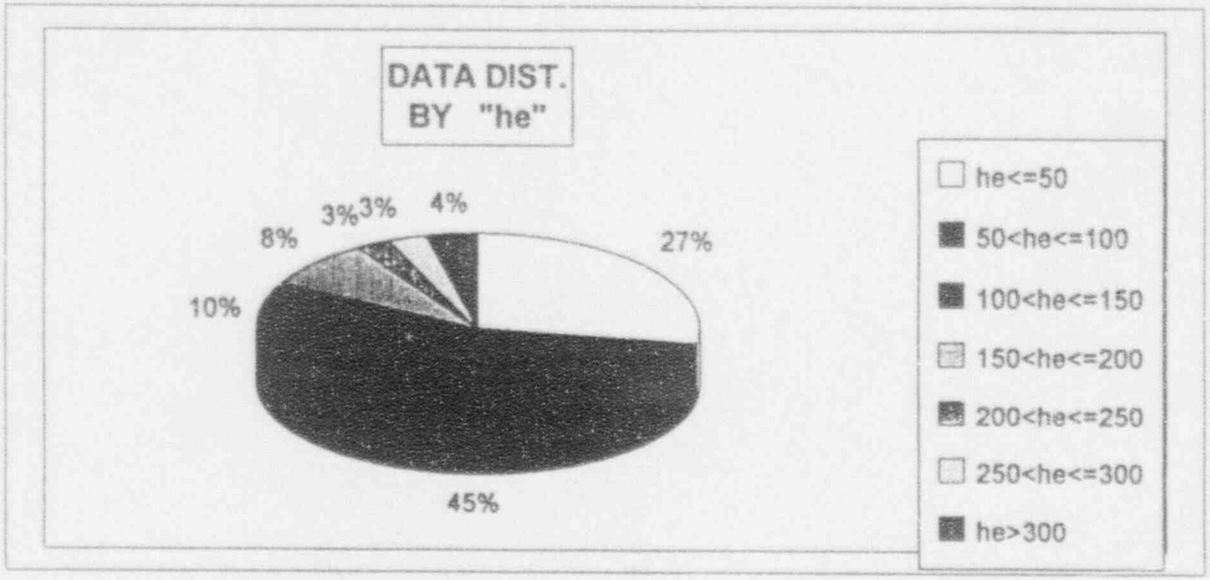
f_c' = fcc200 for those tests

- Where the type of anchor was not specifically identified in the data, a cast in place or undercut anchor was assumed unless; i) d_o was left blank or listed as 0.0 or, ii) d_o was blank and $he_f/d \geq$ 8.

TABLE 1

SPRDSHT. FILE NAME	1-BOLT NO EDGE	1-BOLT EDGE	2-BOLT	4-BOLT
D2ENG		▨		
D2GER	▨	▨		
D3USA		▨		
D4GER			▨	
D5USA				▨
D6USA	▨	▨		▨
D7ENG	▨			
D7GER	▨			
D7SWE	▨			
K3USA.	▨			
K4GER	▨			
K4SWE	▨			
K5ARGER		▨		
K5SWE		▨		
K6USA		▨		
KM2GER				▨
KM4GER				▨
KM4USA				▨
PRAGUE,CSFR	▨			
USA08				▨
USA09	▨			
USA10			▨	
USA11				▨
USA12		▨		

(mm)	1 BOLT C1<1.5he	1 BOLT C1>1.5he	1 BOLT TOTAL	2 BOLT C1<1.5he	2 BOLT C1>1.5he	2 BOLT TOTAL	4 BOLT C1<1.5he	4 BOLT C1>1.5he	4 BOLT TOTAL	TOTAL	% OF TOTAL
he<=50	25	266	291		25	25		3	3	319	28%
50<he<=100	78	377	455		48	48	12	14	26	529	46%
100<he<=150	17	71	88		14	14		10	10	112	10%
150<he<=200	21	39	60		1	1		32	32	93	8%
200<he<=250	6	17	23			0		7	7	30	3%
250<he<=300	11	14	25			0		5	5	30	3%
he>300	12	30	42			0		3	3	45	4%
TOTAL	170	814	984	0	88	88	12	74	86	1158	
% OF TOTAL	15%	70%		0%	8%		1%	6%			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BY "he"
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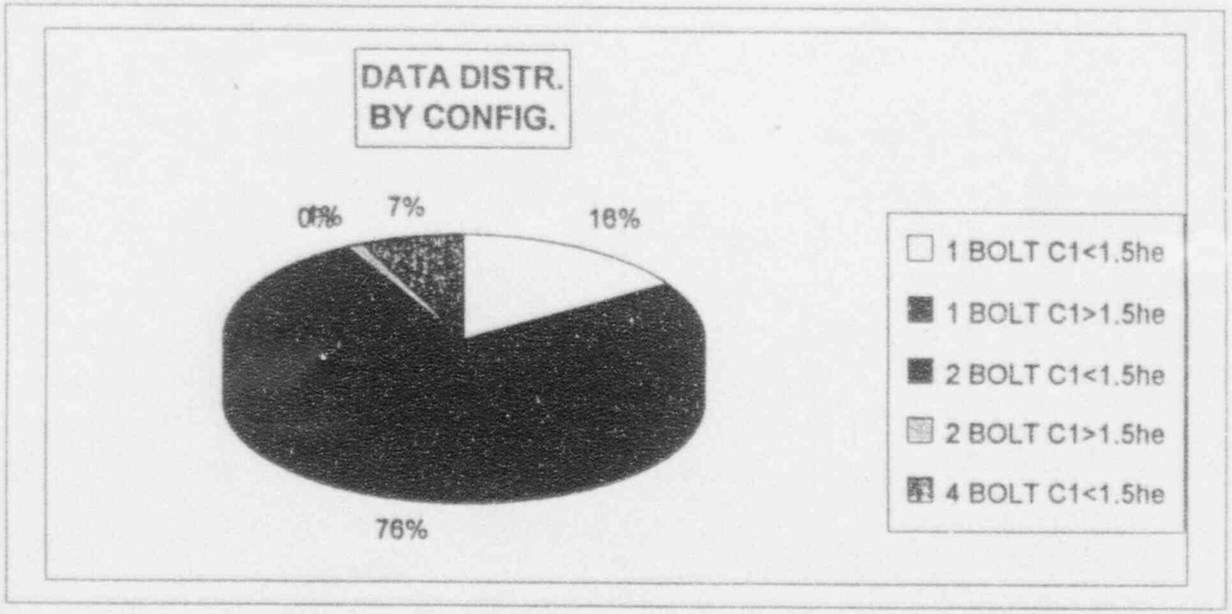
45%
10%
8%
3%
3%
4%
he<=50
50<he<=100
100<he<=150
150<he<=200
200<he<=250
250<he<=300
he>300


DATA DISTR.
BY CONFIG.
16%
76%
0%
1%
7%
1 BOLT C1<1.5he
1 BOLT C1>1.5he
2 BOLT C1<1.5he
2 BOLT C1>1.5he
4 BOLT C1<1.5he

SINGLE BOLT NEAR AN EDGE								
	ACI				CC METHOD (UNCR)			
hef	0 TO 100	101T0200	he>201	TOTAL	0 TO 100	101 TO 200	he>201	TOTAL
T/P<=.65	0	6	18	24	3	2	0	5
.65<T/P<=.85	15	16	7	38	32	9	1	42
.85<T/P<=1.0	17	2	2	21	28	9	6	43
1.0<T/P<=1.2	21	10	2	33	21	11	15	47
1.2<T/P<=1.5	24	6	0	30	13	8	5	26
1.5<T/P<=2.0	19	0	0	19	5	2	2	9
T/P>2.0	3	0	0	3	0	0	0	0
TOTAL	99	40	29	168	102	41	29	172
AVE.	1.22	0.91	0.68	% T/P <=1.0	0.98	1.02	1.13	% T/P <=1.0
STD. DEV.	0.37	0.26	0.17	49%	0.37	0.28	0.18	52%

SINGLE BOLT AWAY FROM AN EDGE								
	ACI				CC METHOD (UNCR)			
hef	0 TO 100	101T0200	he>201	TOTAL	0 TO 100	101 TO 200	he>201	TOTAL
T/P<=.65	0	2	15	17	26	4	0	30
.65<T/P<=.85	3	14	18	35	123	21	1	145
.85<T/P<=1.0	15	18	13	46	215	22	28	265
1.0<T/P<=1.2	68	30	10	108	201	50	15	266
1.2<T/P<=1.5	162	30	5	197	59	24	13	96
1.5<T/P<=2.0	198	27	1	226	6	1	4	11
T/P>2.0	184	1	0	185	0	0	0	0
TOTAL	630	122	62	814	630	122	61	813
AVE.	1.75	1.22	0.86	% T/P <=1.0	0.97	1.04	1.1	% T/P <=1.0
STD. DEV.	0.54	0.33	0.24	12%	0.19	0.2	0.21	54%

2 BOLT NEAR AN EDGE

	ACI				CC METHOD (UNCR)			
hef	0 TO 100	101T0200	he>201	TOTAL	0 TO 100	101 TO 200	he>201	TOTAL
T/P<=.65				0				0
.65<T/P<=.85				0				0
.85<T/P<=1.0				0				0
1.0<T/P<=1.2				0				0
1.2<T/P<=1.5				0				0
1.5<T/P<=2.0				0				0
T/P>2.0				0				0
TOTAL	0	0	0	0	0	0	0	0
AVE.				% T/P <=1.0				% T/P <=1.0
STD. DEV.				#DIV/0!				#DIV/0!

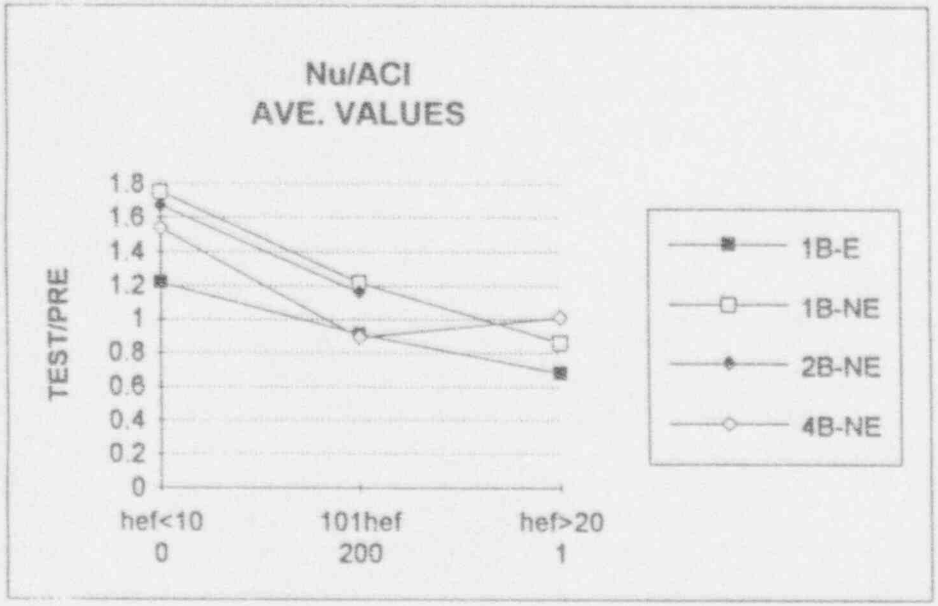
2 BOLT AWAY FROM AN EDGE

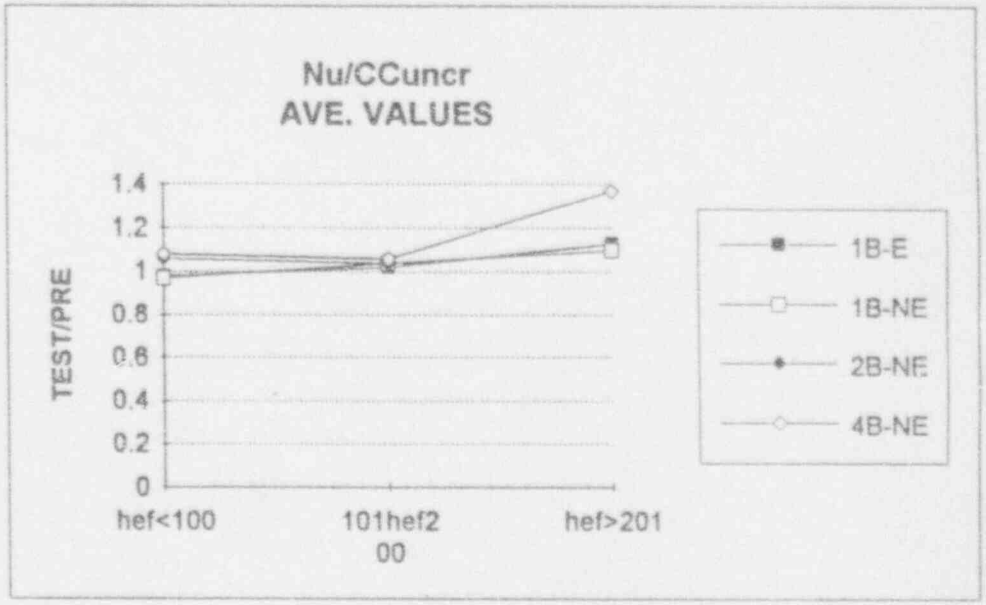
	ACI				CC METHOD (UNCR)			
hef	0 TO 100	101T0200	he>201	TOTAL	0 TO 100	101 TO 200	he>201	TOTAL
T/P<=.65	0	0	0	0	1	2	0	3
.65<T/P<=.85	1	2	0	3	17	1	0	18
.85<T/P<=1.0	1	2	0	3	15	4	0	19
1.0<T/P<=1.2	9	9	0	18	14	13	0	27
1.2<T/P<=1.5	17	9	0	26	16	3	0	19
1.5<T/P<=2.0	23	1	0	24	3	0	0	3
T/P>2.0	15	0	0	15	0	0	0	0
TOTAL	66	23	0	89	66	23	0	89
AVE.	1.67	1.16		% T/P <=1.0	1.06	1.04		% T/P <=1.0
STD. DEV.	0.52	0.22		7%	0.26	0.17		45%

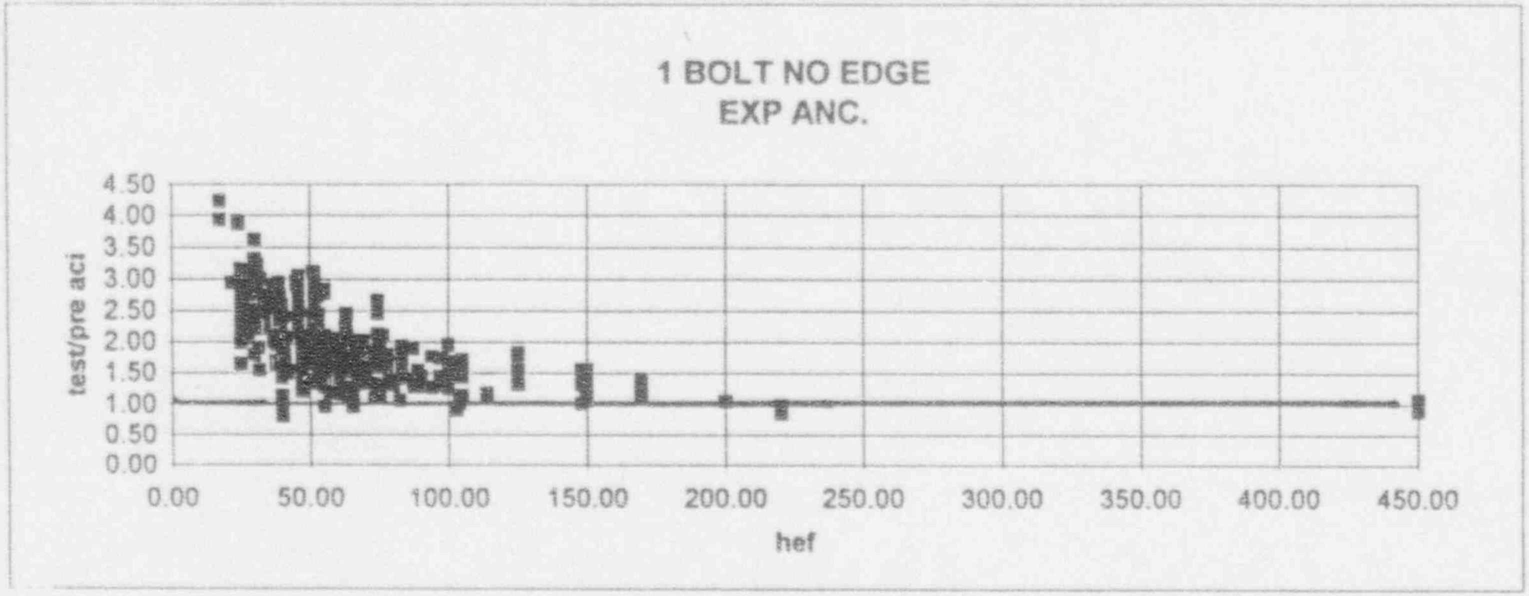
4 BOLT NEAR AN EDGE								
	ACI				CC METHOD (UNCR)			
hef	0 TO 100	101T0200	he>201	TOTAL	0 TO 100	101 TO 200	he>201	TOTAL
T/P<=.65	1	0	0	1	0	0	0	0
.65<T/P<=.85	4	0	0	4	2	0	0	2
.85<T/P<=1.0	1	0	0	1	3	0	0	3
1.0<T/P<=1.2	4	0	0	4	2	0	0	2
1.2<T/P<=1.5	2	0	0	2	2	0	0	2
1.5<T/P<=2.0	0	0	0	0	2	0	0	2
T/P>2.0	0	0	0	0	1	0	0	1
TOTAL	12	0	0	12	12	0	0	12
AVE.	0.98			% T/P <=1.0	1.22			% T/P <=1.0
STD. DEV.	0.25			50%	0.4			42%

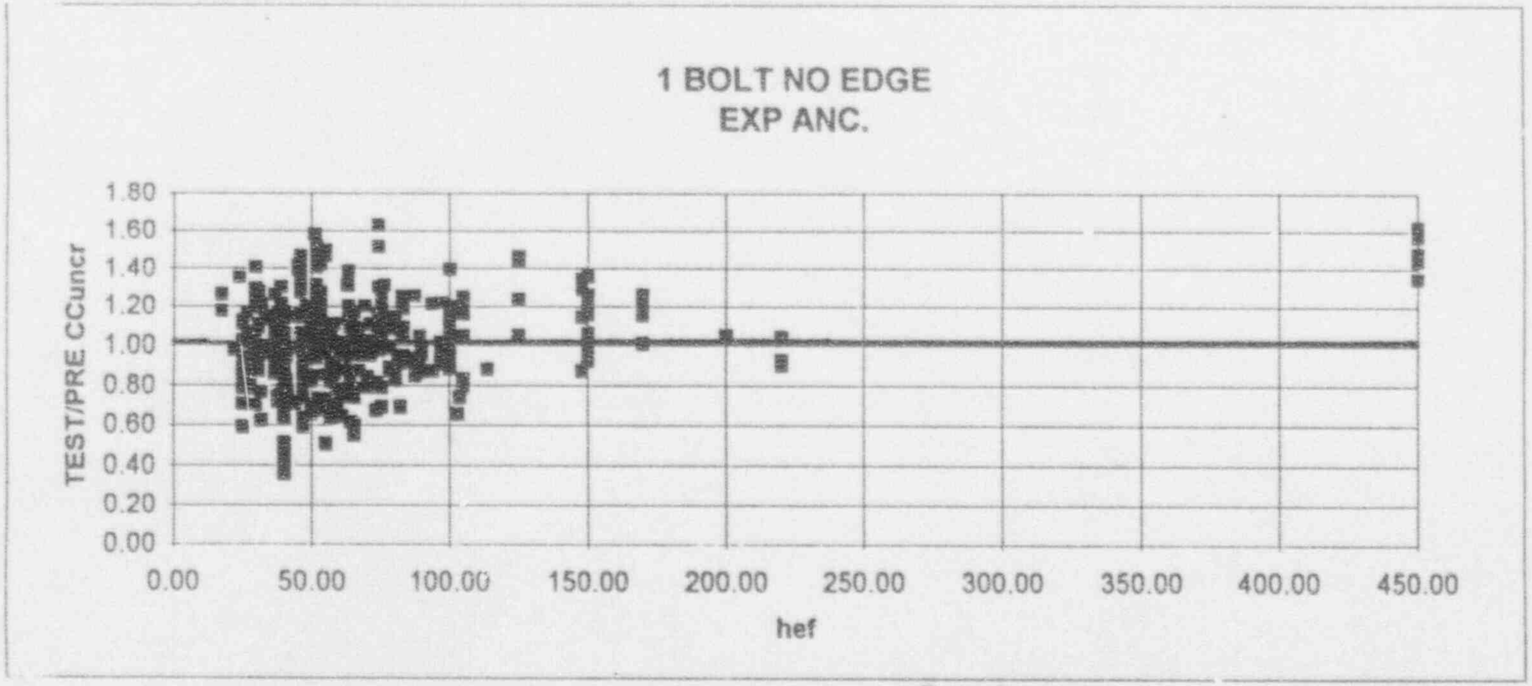
4 BOLT AWAY FROM AN EDGE								
	ACI				CC METHOD (UNCR)			
hef	0 TO 100	101T0200	he>201	TOTAL	0 TO 100	101 TO 200	he>201	TOTAL
T/P<=.65	1	1	3	5	2	0	0	2
.65<T/P<=.85	0	22	0	22	1	0	2	3
.85<T/P<=1.0	1	6	2	9	2	12	2	16
1.0<T/P<=1.2	2	11	7	20	6	20	3	29
1.2<T/P<=1.5	5	1	3	9	4	5	7	16
1.5<T/P<=2.0	6	0	0	6	2	4	0	6
T/P>2.0	3	0	0	3	1	0	0	1
TOTAL	18	41	15	74	18	41	14	73
AVE.	1.54	0.89	1.01	% T/P <=1.0	1.08	1.06	1.37	% T/P <=1.0
STD. DEV.	0.49	0.18	0.27	49%	0.36	0.1	0.37	29%

AVERAGE VALUES OF TEST/PREDICTED	ACI			CC METH		
	hef<100	101hef20	hef>201	hef<100	101hef20	hef>201
1B-E	1.22	0.91	0.68	0.98	1.02	1.13
1B-NE	1.75	1.22	0.86	0.97	1.04	1.1
2B-E						
2B-NE	1.67	1.16		1.06	1.04	
4B-E	0.98			1.22		
4B-NE	1.54	0.89	1.01	1.08	1.06	1.37






1 BOLT NO EDGE
EXP ANC.
test/pre aci
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
450.00
hef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EXP ANC.
TEST/PRE CCuncr
1.80
1.60
1.40
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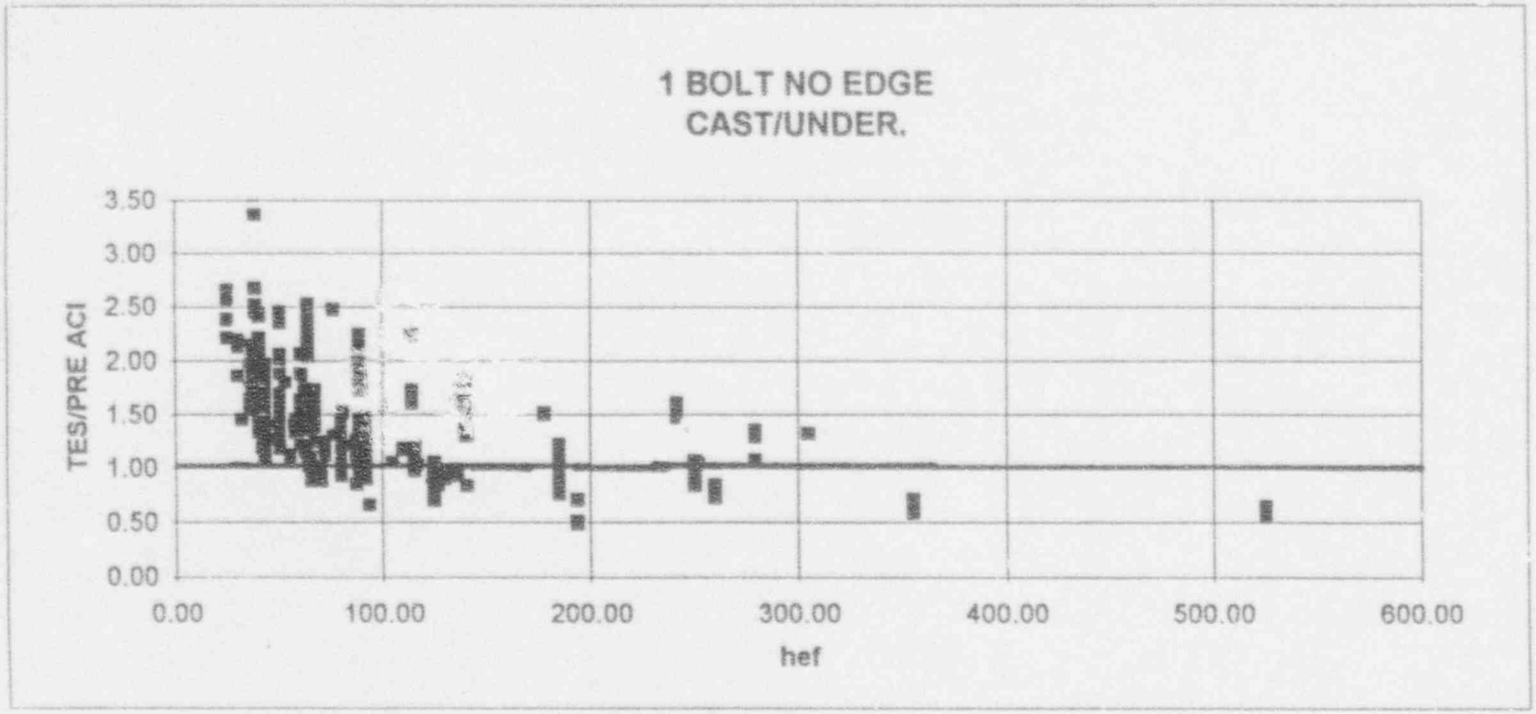
hef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CAST/UNDER.
TES/PRE ACI
3.50
3.00
2.50
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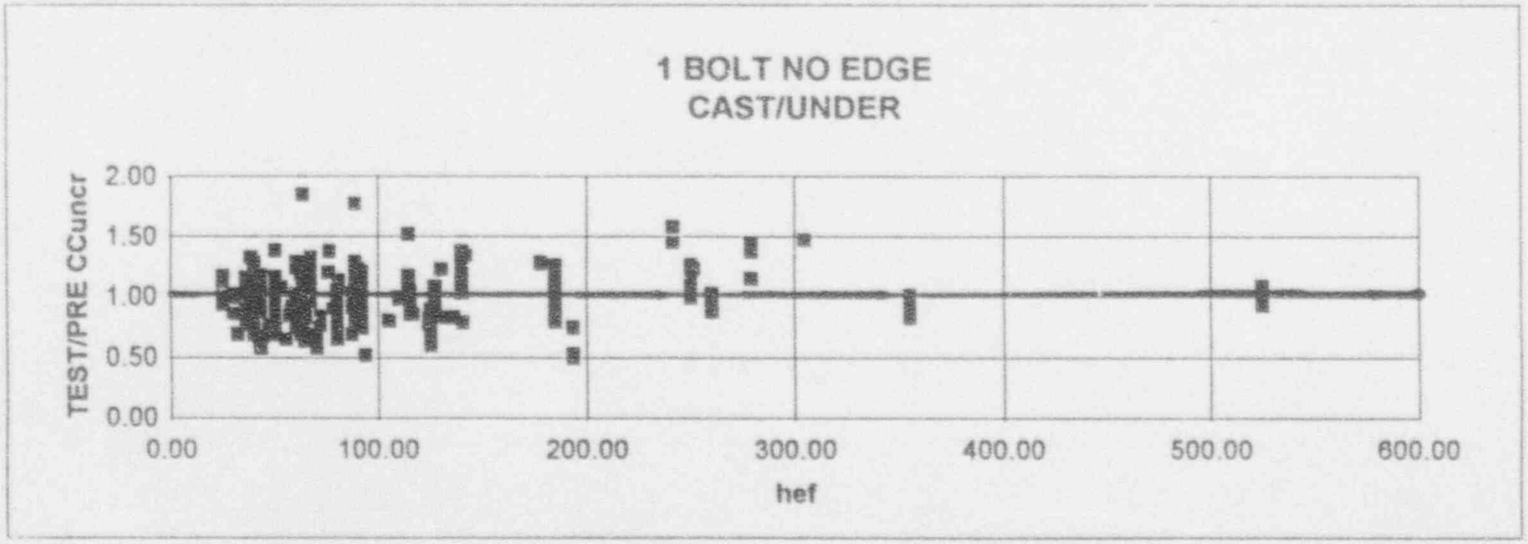
hef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CAST/UNDER
TEST/PRE CCuncr
2.00
1.50
1.00
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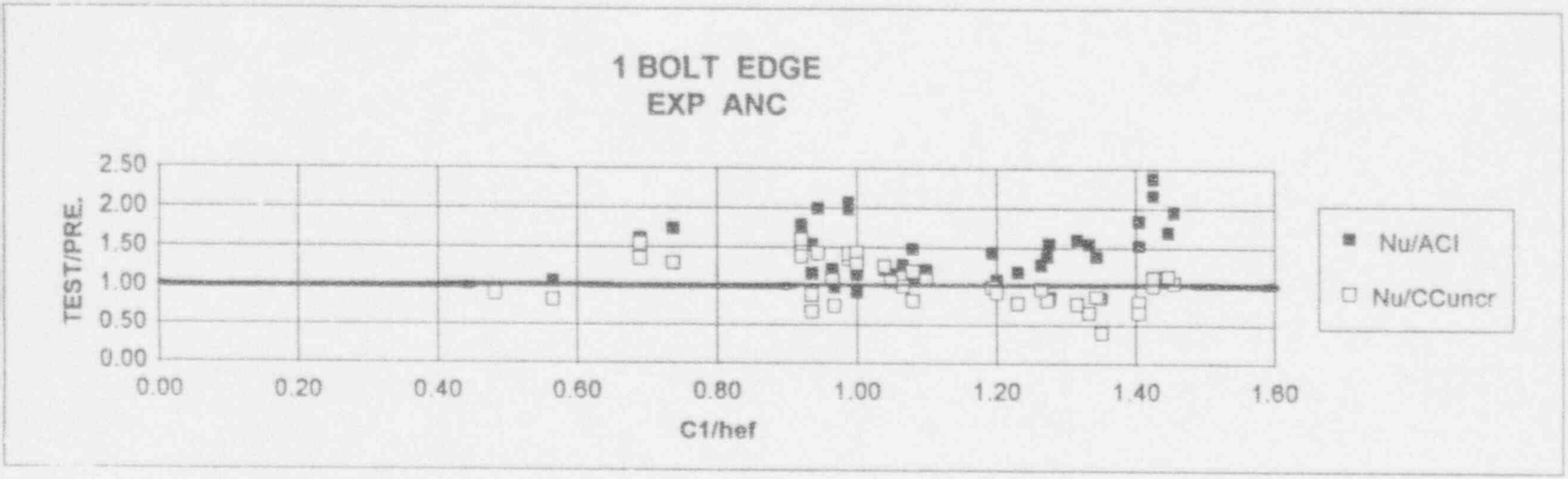
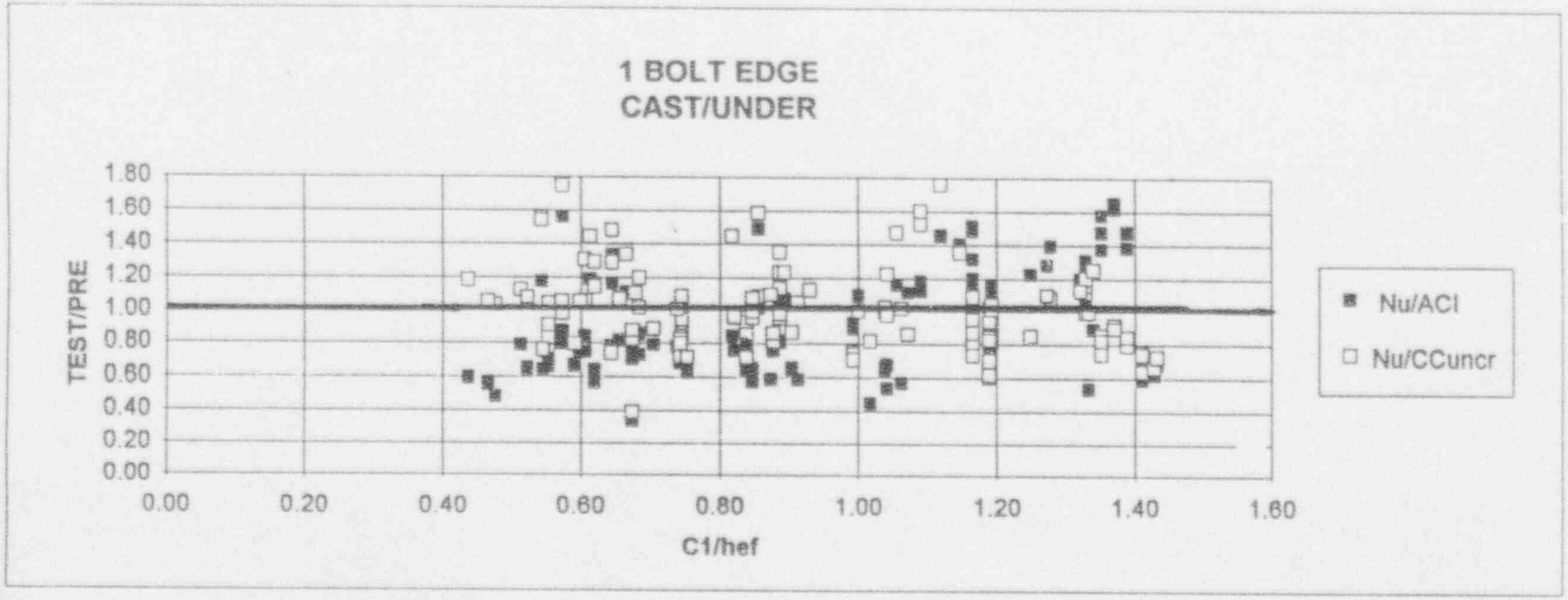
300.00
400.00
500.00
600.00
hef


1 BOLT EDGE
EXP ANC
TEST/PRE.
2.50
2.00
1.50
1.00
0.50
0.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
C1/hef
Nu/ACI
Nu/CCuncr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CAST/UNDER
TEST/PRE
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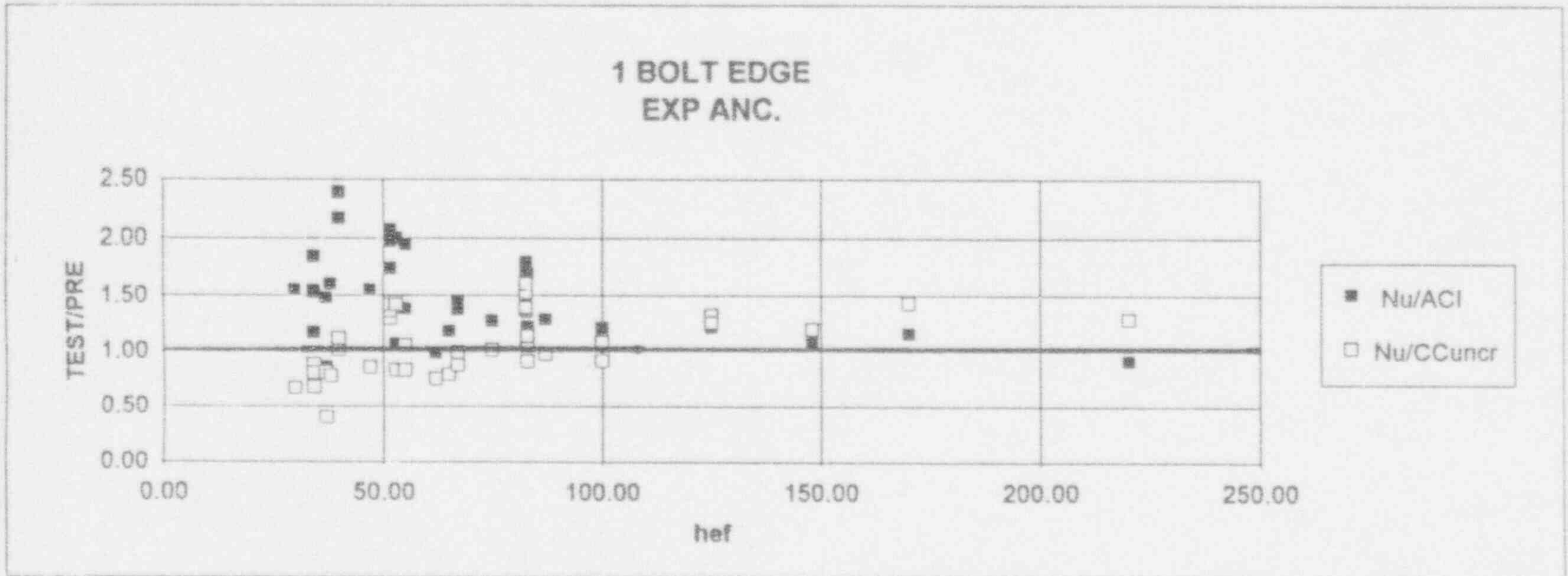
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
C1/hef
Nu/ACI
Nu/CCuncr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EXP ANC.
TEST/PRE
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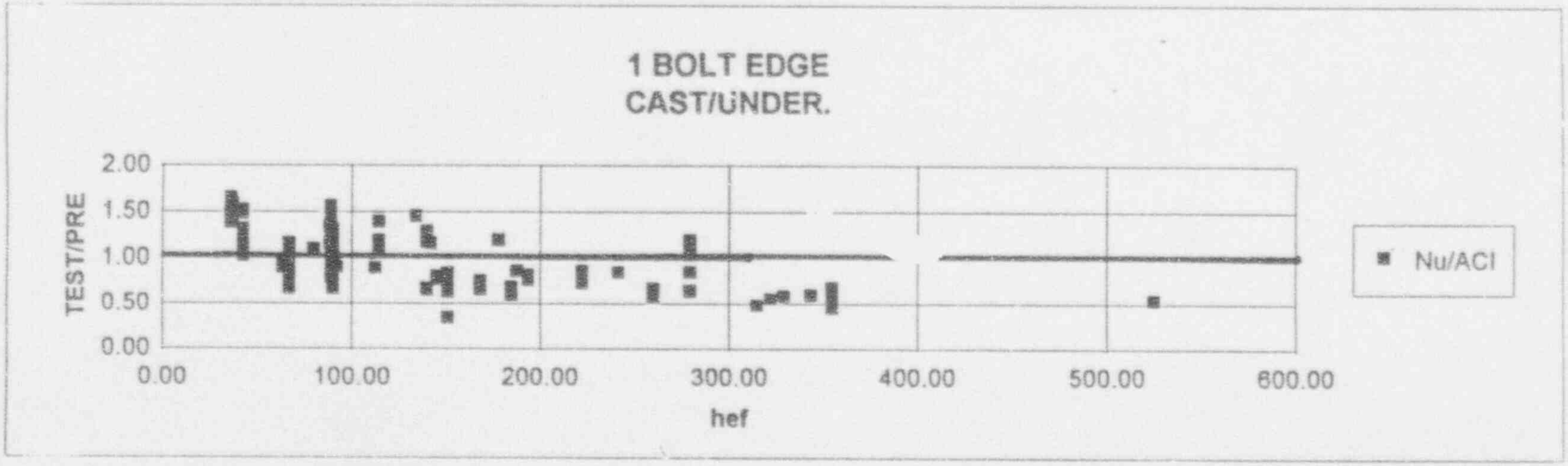
2.00
1.50
1.00
0.50
0.00
0.00
50.00
100.00
150.00
200.00
250.00
hef
Nu/ACI
Nu/CCuncr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CAST/UNDER.
TEST/PRE
2.00
1.50
1.00
0.50
0.00
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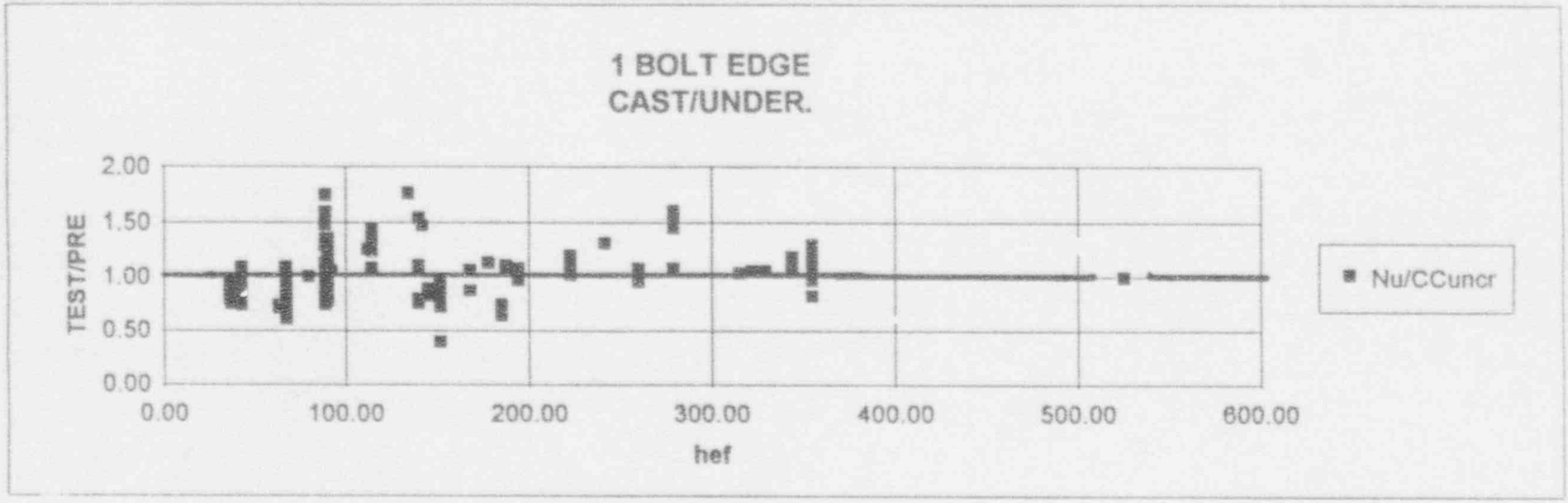
100.00
200.00
300.00
400.00
500.00
600.00
hef
Nu/ACI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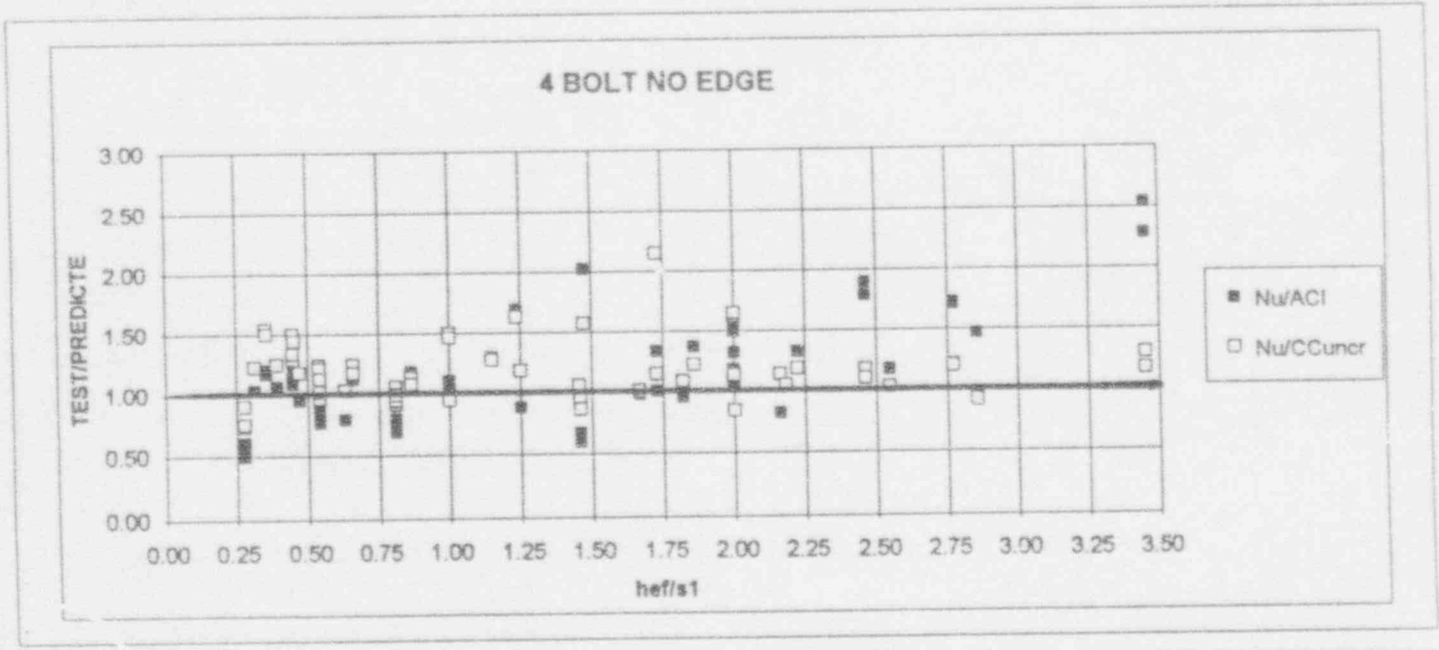
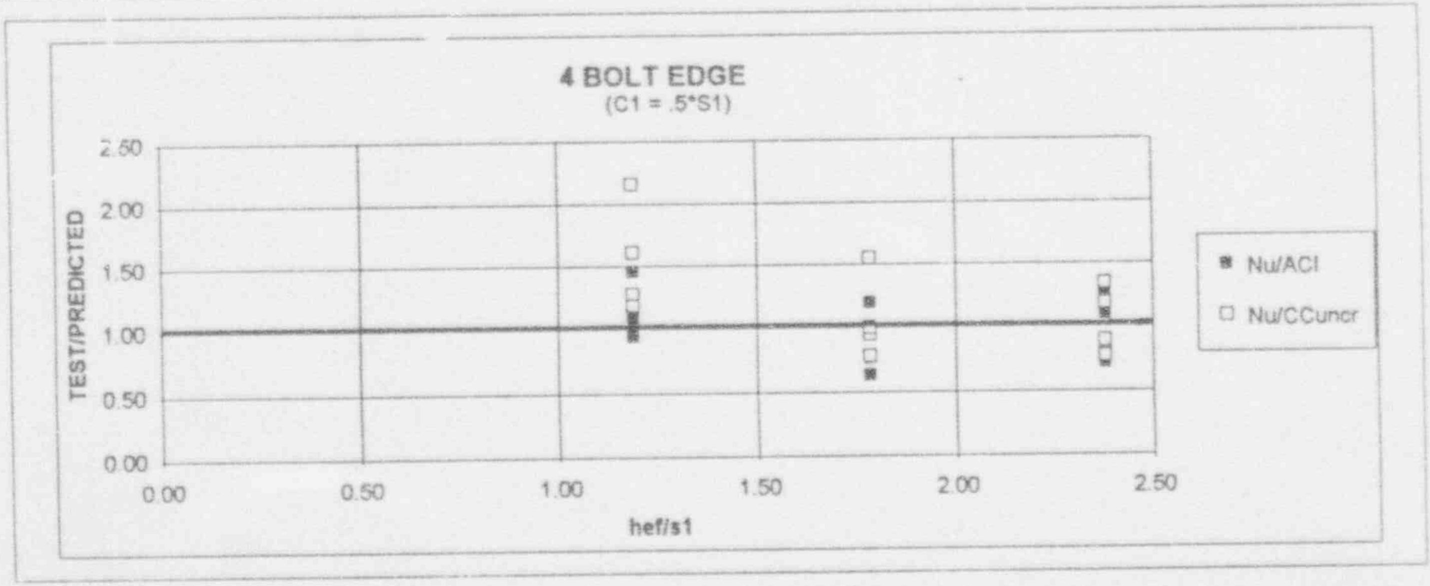
CAST/UNDER.
TEST/PRE
2.00
1.50
1.00
0.50
0.00
0.00
100.00
200.00
300.00
400.00
500.00
600.00
hef
Nu/CCuncr


4 BOLT NO EDGE

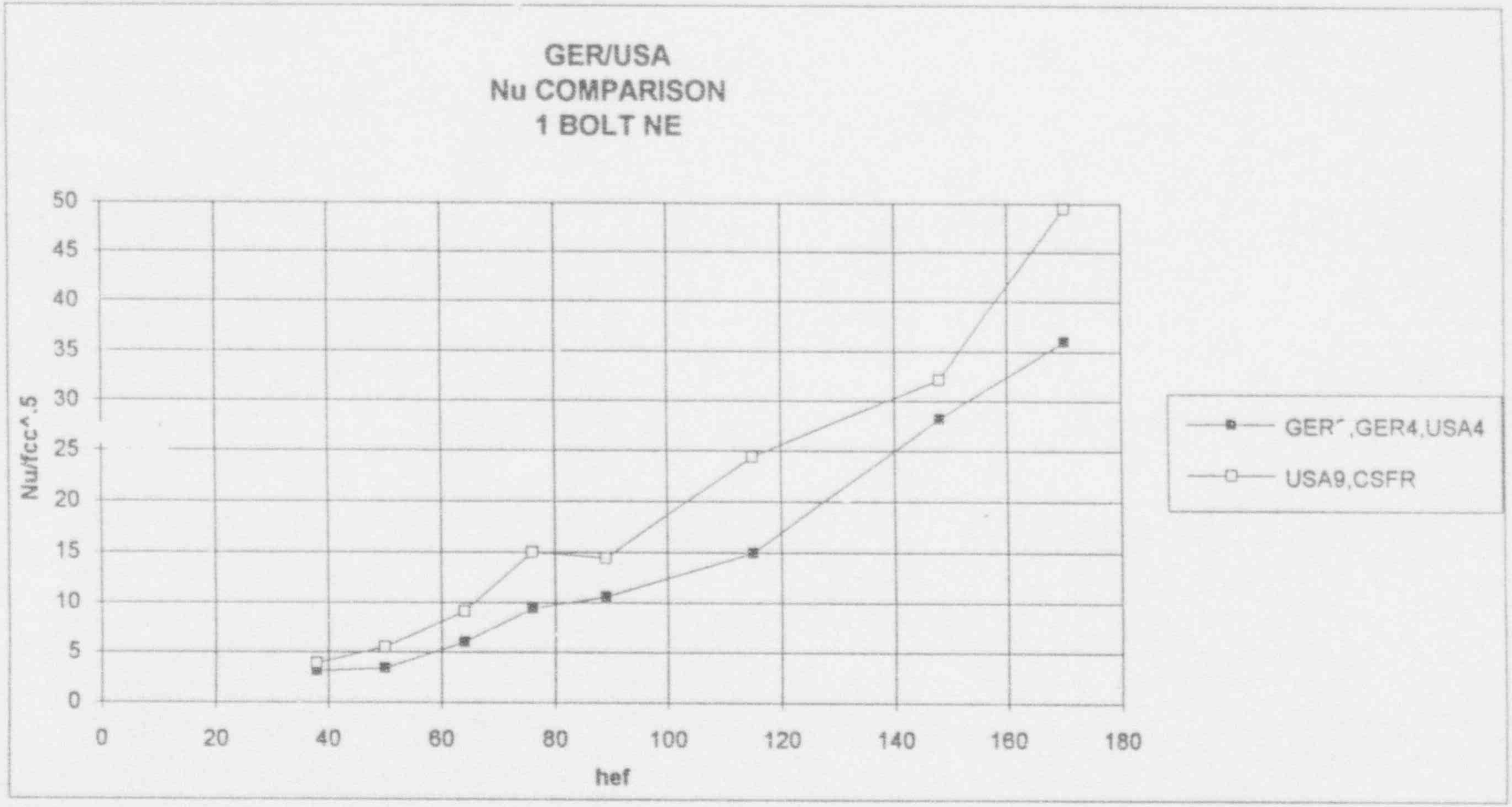

4 BOLT EDGE
(C1 = .5*S1)

GER7 DATA VERY INCONSISTANT WITH USA8

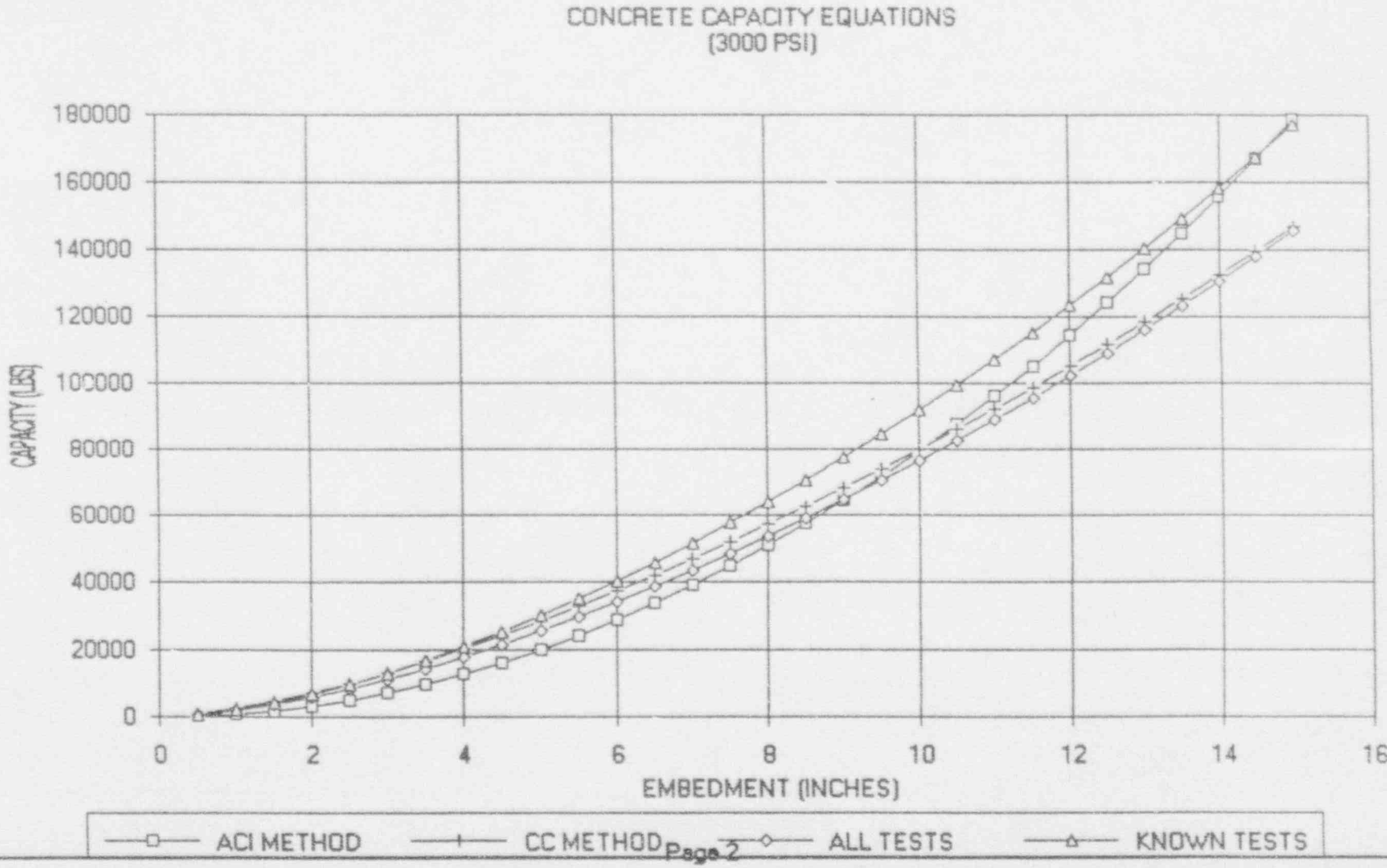
TEST NUMBER	ANCH TYPE	NUMBER OF ANC	d (mm)	do (mm)	hef (mm)	fcc200 (MPa)	c1 (mm)	s1 (mm)	s2 (mm)	Nu,m (kN)	Nu/ACI	Nu/CCcr	Nu/CCuncr
GER7-12		4	22.20	34.90	360.30	29.90	999	100	100	500.00	0.49	1.04	0.74
GER7-13		4	22.20	34.90	360.30	30.80	999	100	100	518.00	0.50	1.06	0.76
GER7-14		4	22.20	34.90	360.30	27.40	999	100	100	585.00	0.60	1.27	0.91
USA8-11	U	4	19.05		225.43	29.44	999	102	102	574.99	1.22	2.02	1.44
USA8-12	U	4	19.05		227.01	29.44	999	102	102	602.82	1.27	2.10	1.50
USA8-3	U	4	15.88		227.01	29.44	999	102	102	519.35	1.09	1.81	1.29
USA8-4	U	4	15.88		227.01	29.44	999	102	102	537.90	1.13	1.87	1.34
USA8-5	U	4	19.05		287.34	29.44	999	102	102	834.67	1.20	2.16	1.54
USA8-6	U	4	19.05		285.75	29.44	999	102	102	806.84	1.17	2.10	1.50

CASES WHERE Nu/ACI <=.65

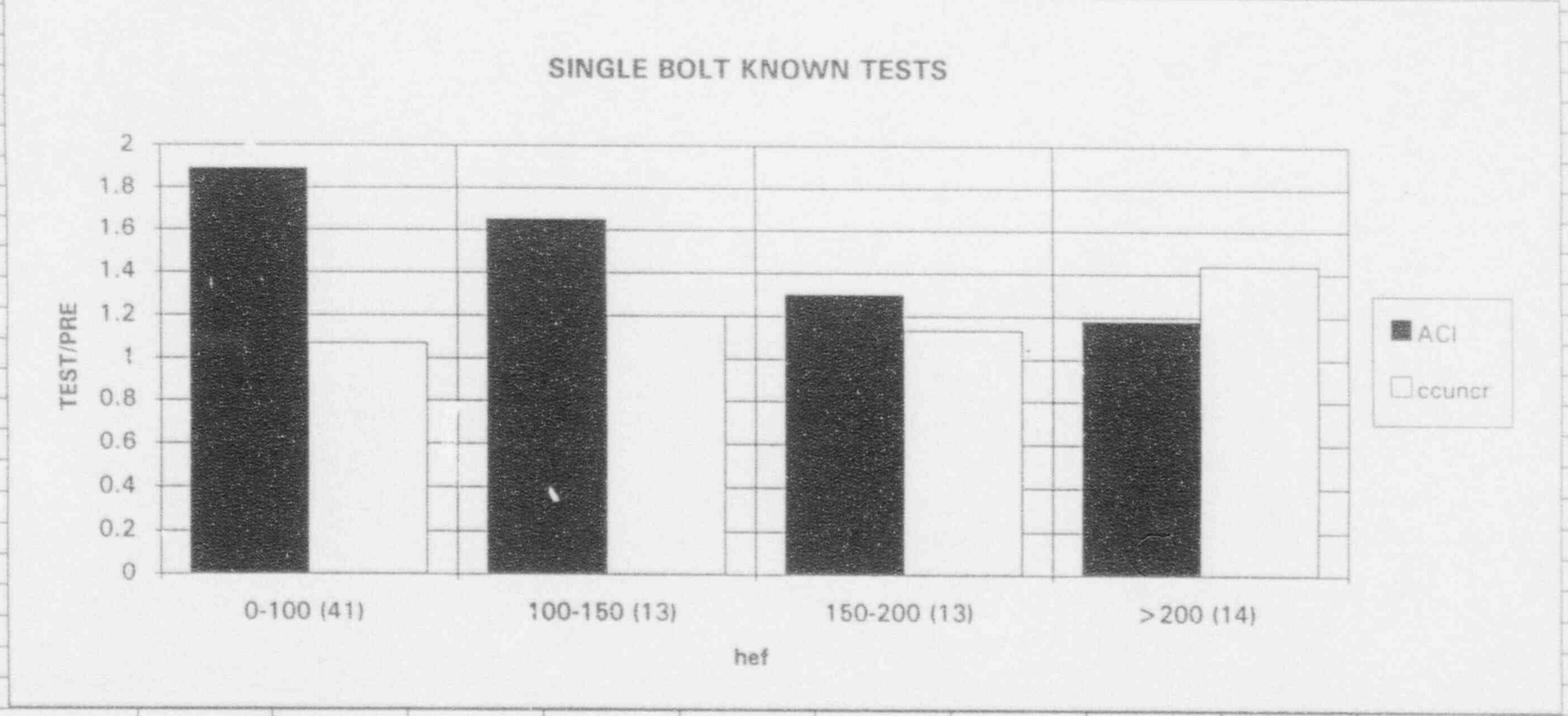
TEST NUMBER	ANCH TYPE	NUMBER OF ANC	d (mm)	do (mm)	hef (mm)	fcc200 (MPa)	c1 (mm)	s1 (mm)	s2 (mm)	Nu,m (kN)	Nu/ACI	Nu/CCcr	Nu/CCuncr	
USA4-7		4	6.00	0.00	28.90	16.50	305	305	305	6.60	0.51	0.27	0.19	VERY SHALLOW
GER7-28		4	22.00	35.00	185.00	28.90	640	270	270	390.00	0.59	1.21	0.86	?????
GER7-12		4	22.20	34.90	360.30	29.90	999	100	100	500.00	0.49	1.04	0.74	TEST DIFFERENT THAN SIMILAR P
GER7-13		4	22.20	34.90	360.30	30.80	999	100	100	518.00	0.50	1.06	0.76	TEST DIFFERENT THAN SIMILAR P
GER7-14		4	22.20	34.90	360.30	27.40	999	100	100	585.00	0.60	1.27	0.91	TEST DIFFERENT THAN SIMILAR P


GER/USA
Nu COMPARISON
1 BOLT NE
Nu/fcc^.5
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120
140
160
180
hef
GER1,GER4,USA4
USA9,CSFR

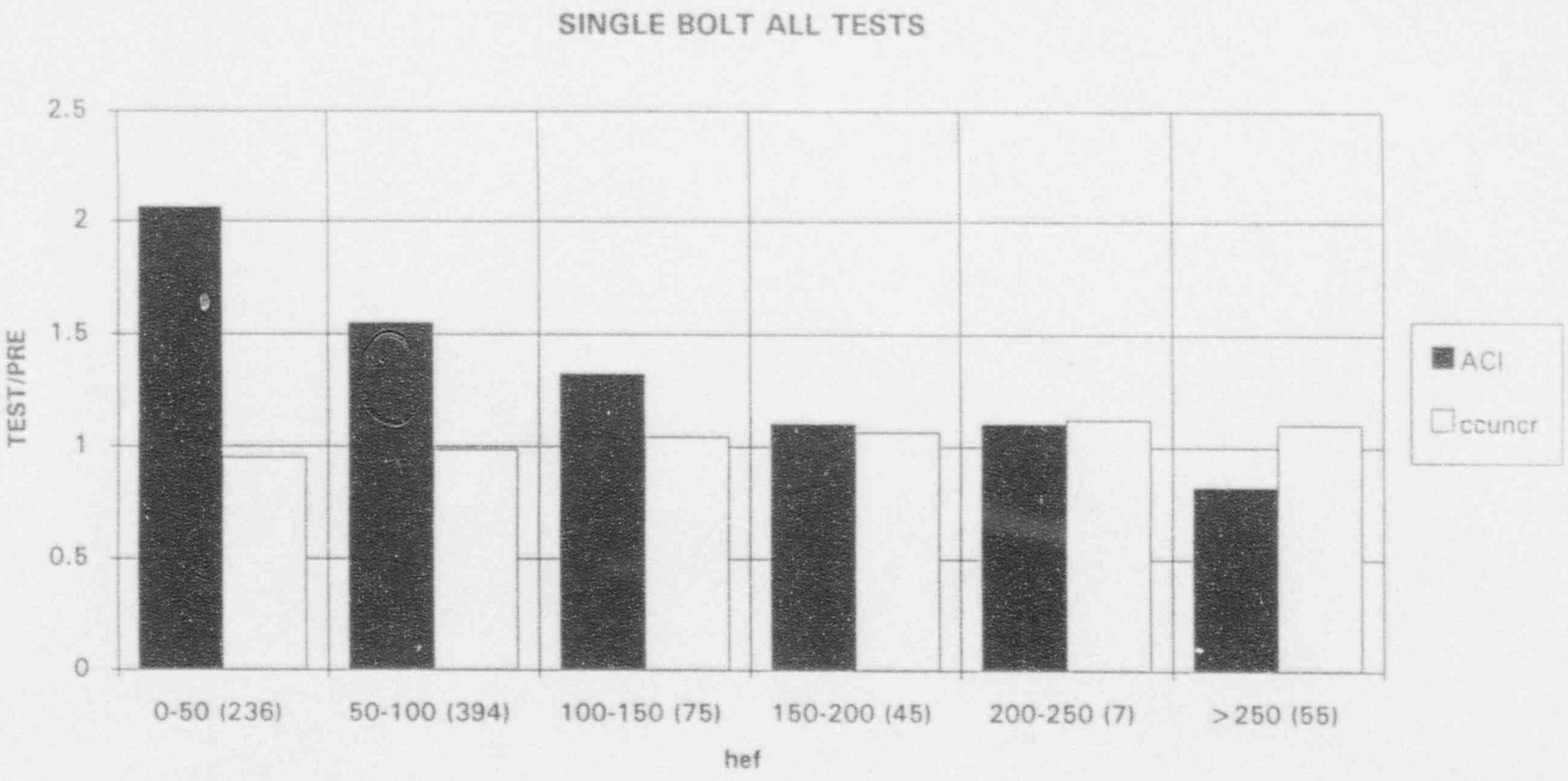
ACI	Pu=12.56*emb^2*f'c^.5
CC	Pu=40*emb^1.5*f'c^.5
ALL TESTS	Pu=17.4*emb^1.59*f'c^.57
KNOWN TESTS	Pu=25*emb^1.62*f'c^.54


CONCRETE CAPACITY EQUATIONS
(3000 PSI)

RANGE	ACI	CC	ccuncr
0-100 (41)	1.89	1.50	1.07
100-150 (13)	1.65	1.68	1.20
150-200 (13)	1.30	1.59	1.14
>200 (14)	1.18	2.01	1.44

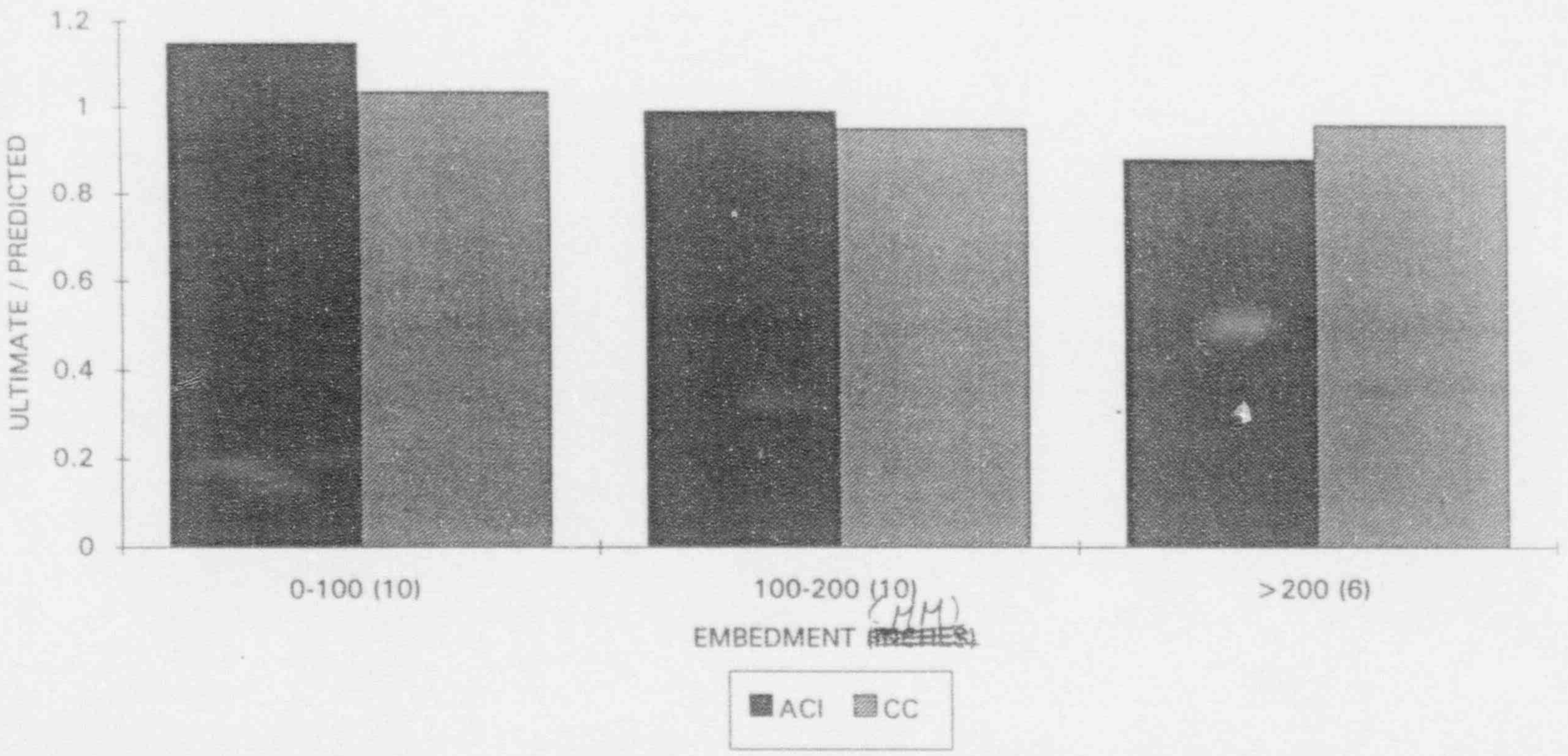


RANGE				
	ACI	CC	ccuncr	ALL
0-50 (236)	2.06	1.33	0.95	TESTS
50-100 (394)	1.55	1.38	0.99	
100-150 (75)	1.32	1.46	1.04	
150-200 (45)	1.10	1.49	1.06	
200-250 (7)	1.10	1.57	1.12	
>250 (55)	0.82	1.54	1.10	



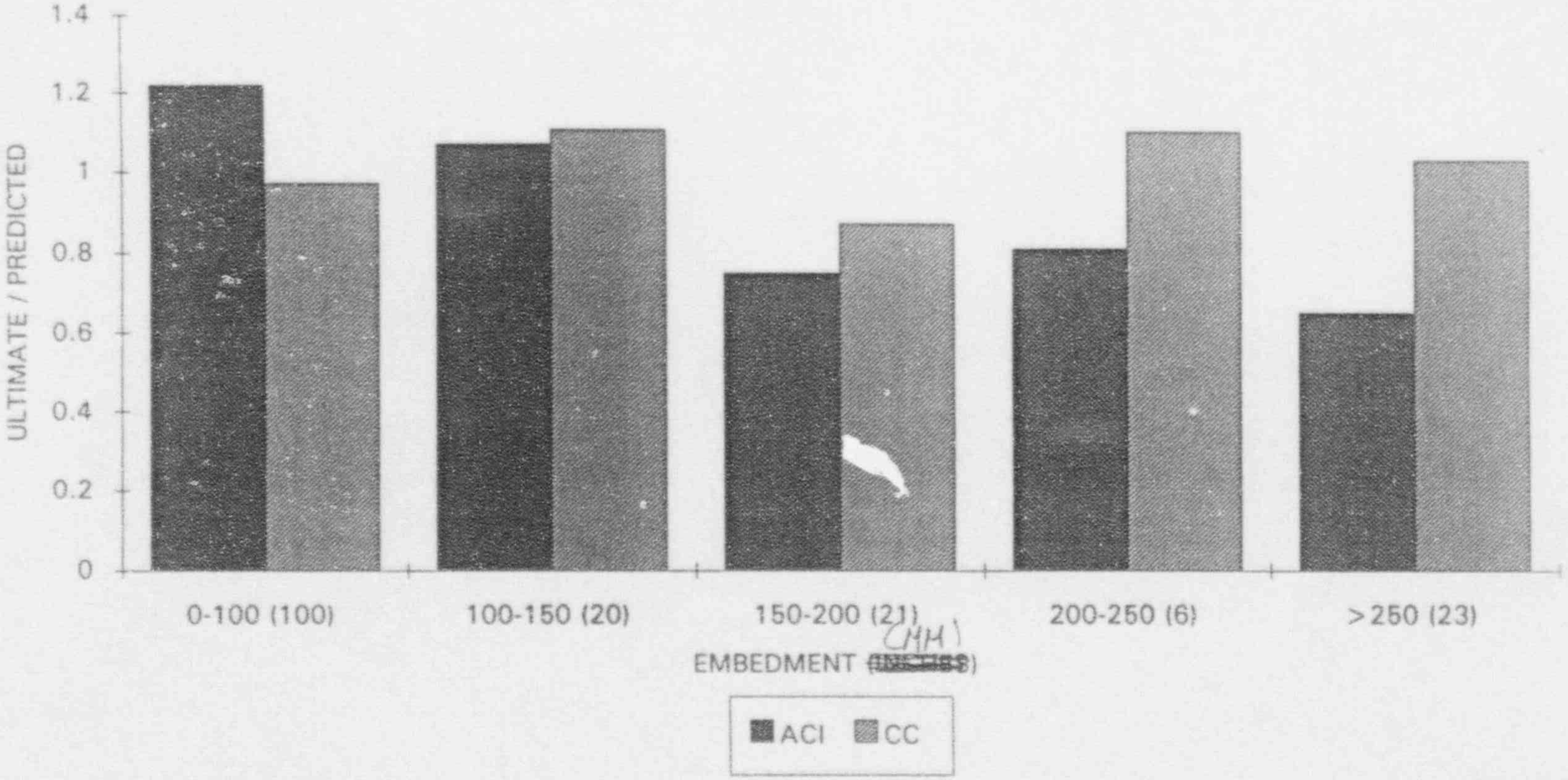
RANGE (MM)	ACI	CC	CCuncr	KNOWN TESTS
0-100 (10)	1.15	1.45	1.04	
100-200 (10)	0.99	1.33	0.95	
>200 (6)	0.88	1.34	0.96	

EDGE DISTANCE COMPARISON
FOR KNOWN TESTS

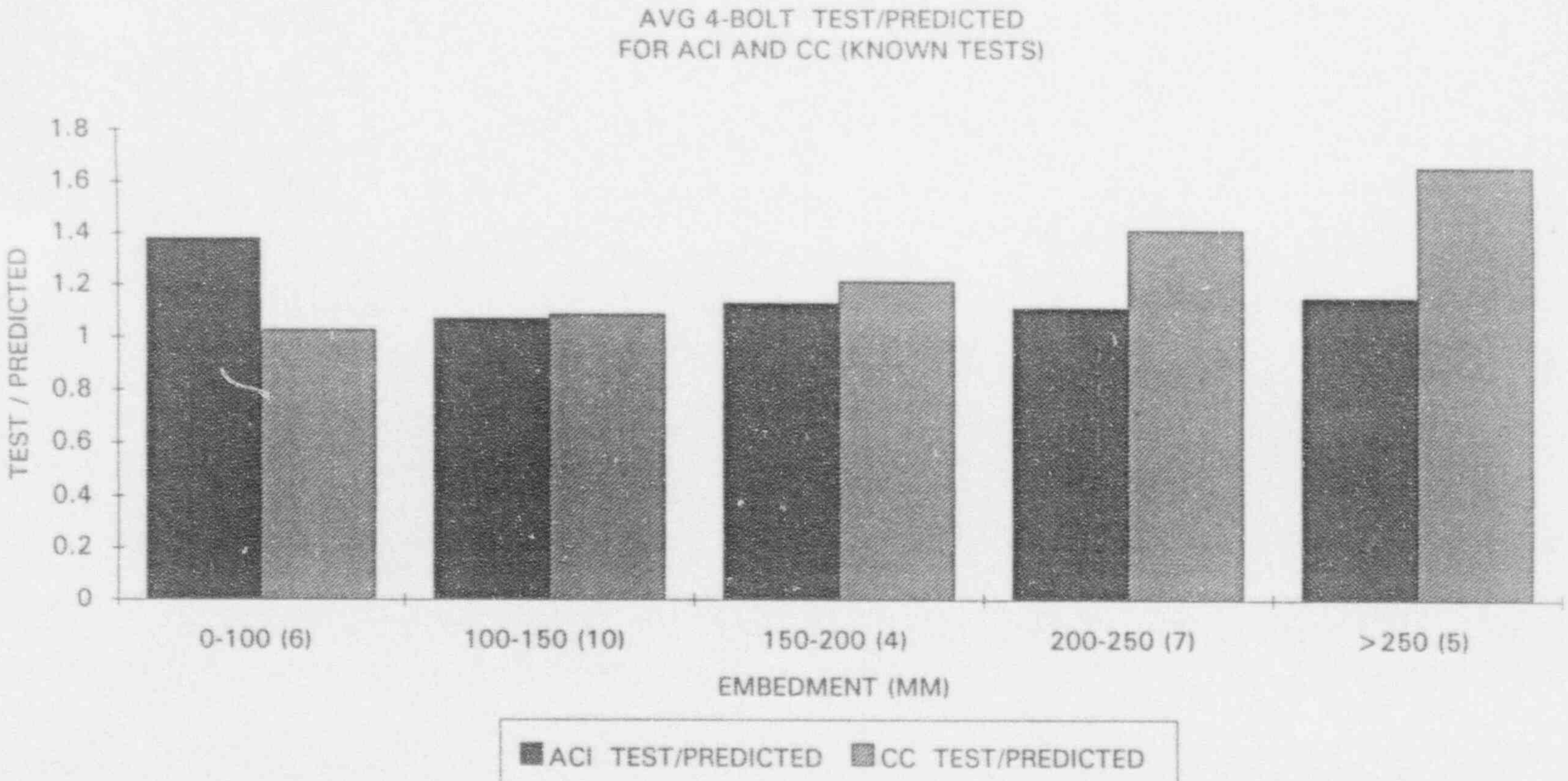


RANGE (MM)	ACI	CC	CCuncr	ALL
0-100 (100)	1.22	1.36	0.97	TESTS
100-150 (20)	1.07	1.55	1.11	
150-200 (21)	0.75	1.22	0.87	
200-250 (6)	0.81	1.54	1.10	
>250 (23)	0.65	1.44	1.03	

EDGE DISTANCE COMPARISON
FOR ALL TESTS

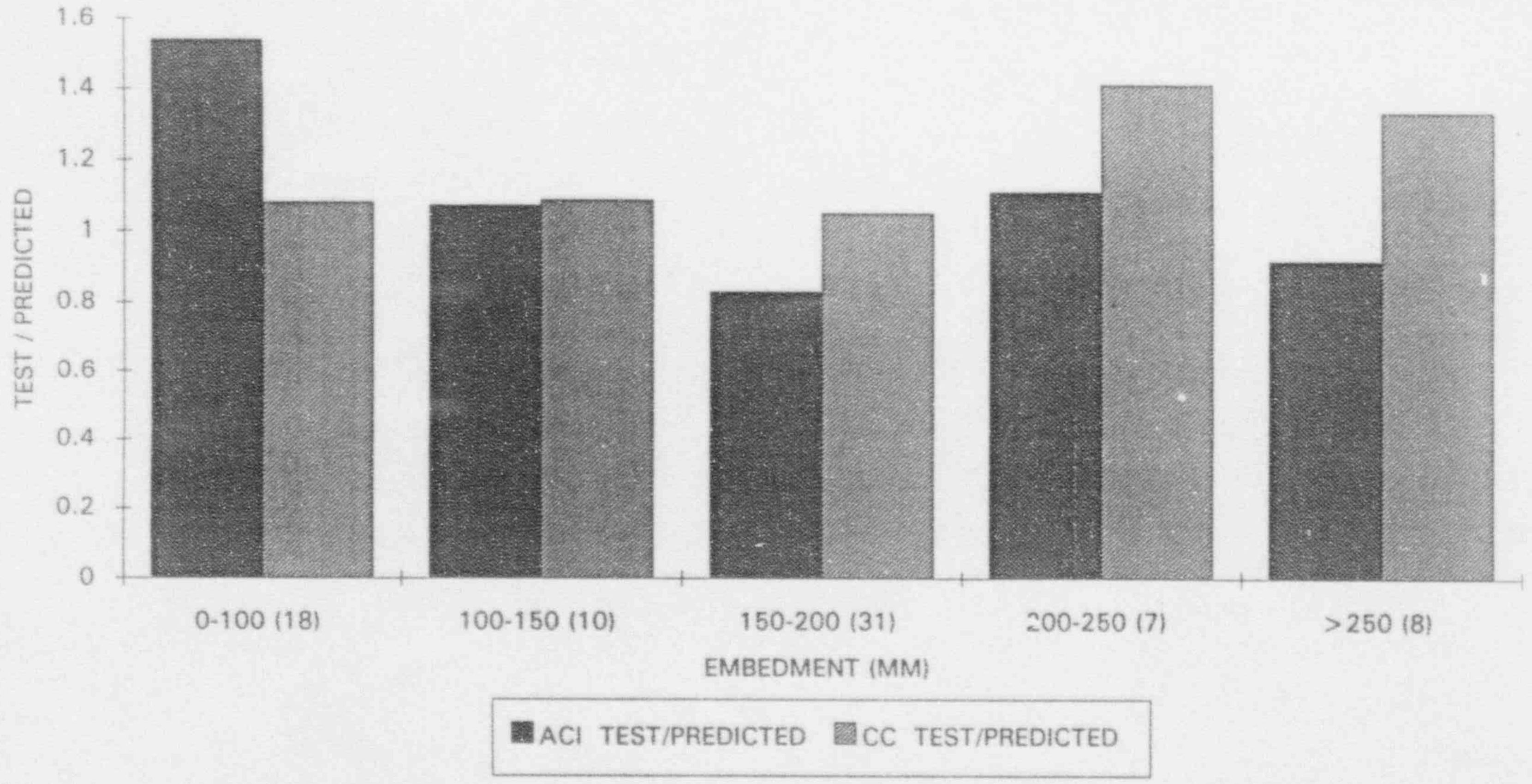


RANGE (MM)	ACI(AVG) TEST/PRED	CC(AVG) TEST/PRED	CCuncr TEST/PRED
0-100 (6)	1.38	1.44	1.03
100-150 (10)	1.07	1.52	1.09
150-200 (4)	1.13	1.70	1.21
200-250 (7)	1.11	1.98	1.41
>250 (5)	1.15	2.32	1.66



RANGE (MM)	ACI(AVG) TEST/PRED	CC(AVG) TEST/PRED	CCuncr TEST/PRED
0-100 (18)	1.54	1.51	1.08
100-150 (10)	1.07	1.52	1.09
150-200 (31)	0.83	1.47	1.05
200-250 (7)	1.11	1.98	1.41
>250 (8)	0.92	1.87	1.34

AVG 4-BOLT TEST/PREDICTED
FOR ACI AND CC (ALL TESTS)



OBSERVATIONS:

- Overall database heavily weighted towards shallow single anchor tests
- General overall difference between results of "Known Tests" vs. All Tests
- ACI is conservative for shallow anchors (<= 100mm)
- ACI becomes less conservative with increasing embedment
- CC Method is less conservative at shallow embedments
- CC Method is overly conservative at deep embedments
- ACI is unconservative for some edge distance configuations
- Based on "averages" CC Method appears to be more accurate than ACI,but the number of times each method overpredicted the ultimate load is similar.

CONCLUSIONS:

- ACI is reliable except in tension close to an edge at embedments > 150mm.
- CC Method requires futher modifications before acceptance
- The European tests results (Nu) are typically 10 to 30% lower than similar "Known Tests"

RECOMMENDATIONS:

- Modify ACI to address the effect of edge distance.
- Modify the CC Method :
    - i) increase the exponent on hef from 1.5 to ??
    - ii) increase the exponent on f'c from .5 to ??
    - iii) develop a spacing (variable?) requirement based on embedment
- Resolve the difference between the sets of test data before using as a basis for final code modifications

ENCLOSURE 2

Anchor Bolt Behavior and Strength during Earthquakes

The U. S. Nuclear Regulatory Commission has begun work at The University of Texas at Austin on anchorage testing. The Principal Investigator is Dr. Richard Klingner and the NRC Technical Monitor is Herman Graves. The contract objective is:

> ...to verify, by testing, the adequacy of the assumption used in U. S. nuclear power plant designs that under seismic loads, the behavior and strength of cast-in-place, expansion, and undercut anchor bolts and their supporting concrete do not differ significantly from those for static conditions...

The tasks to be performed under the contract include the following:

- conduct static and dynamic tests on single and multiple-anchor connections to uncracked and cracked concrete, including the influence of reinforcement and edge effects.

A Test Matrix for Phase I is shown on the following page.

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Table 1: Test Matrix for Phase I

SERIES	DESCRIPTION	CONCRETE STRENGTH	ANCHORS TESTED
1-1	Static tensile tests of single anchors failing in unreinforced concrete	±3, ~~±4.5~~, ±5.5 ksi	3/8, 5/8, 3/4, 1
1-2	Dynamic tensile tests of single anchors failing in unreinforced concrete	---	3/8, 5/8, 3/4, 1
1-3	Static tensile tests of single anchors failing in reinforced concrete	---	5/8
1-4	Dynamic tensile tests of single anchors failing in reinforced concrete	±3, ~~±4.5~~, ±5.5 ksi	5/8
1-5	Static tensile tests of single anchors in unreinforced, cracked concrete	---	3/8, 5/8, 3/4, 1
1-6	Dynamic tensile tests of single anchors in unreinforced, cracked concrete	---	3/8, 5/8, 3/4, 1
1-7	Static tensile tests of single anchors in reinforced, cracked concrete	±3, ~~±4.5~~, ±5.5 ksi	5/8
1-8	Dynamic tensile tests of single anchors in reinforced, cracked concrete	---	5/8

Note: At least five anchors will be tested for each anchor diameter. Test Matrix is subject to change.

The Swedge Bolt

$$P_d = 4\Phi\sqrt{f_c}\,A_c \geq F_u A_t$$

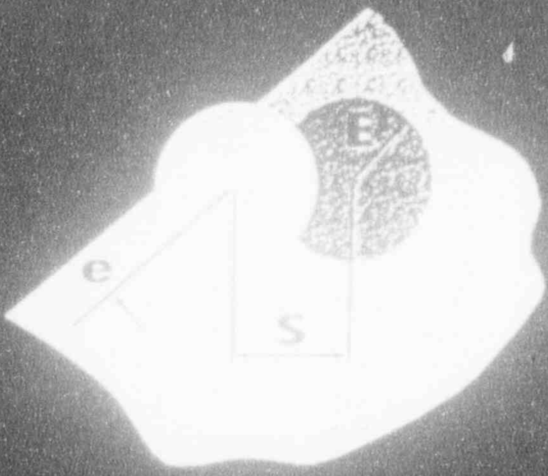
$$P_s = \Phi F_y A_t$$

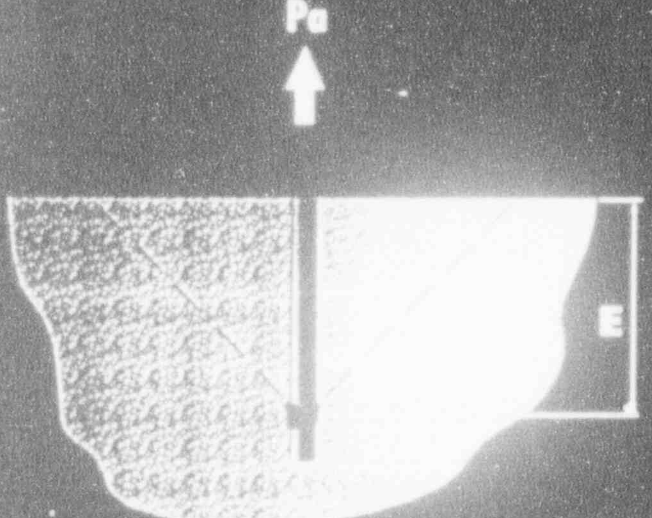
$$A_c = E^2(\pi - \theta + \epsilon\sqrt{1-\epsilon^2})$$

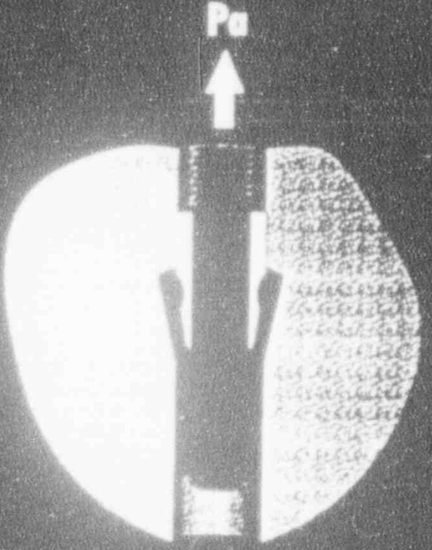
$$\theta = \arccos \epsilon$$

$$\epsilon = \frac{S}{2E}$$

$$S = 2e$$







An Improved Ductile Undercut Concrete Anchor

ENCLOSURE 3

The SWedge Bolt

$$P_d = 4\Phi\sqrt{f'_c}\,A_c \geq F_u A_t$$

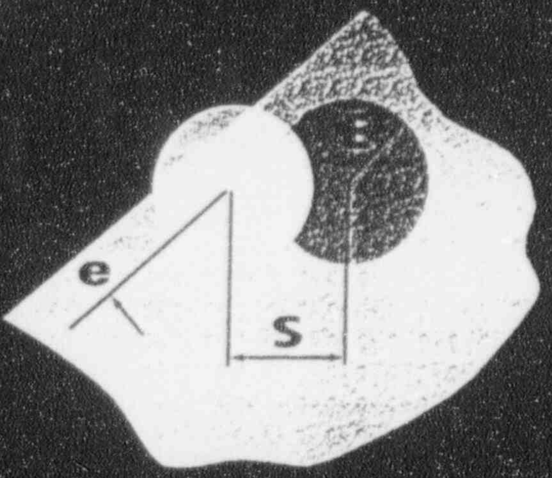
$$P_s = \Phi F_y A_t$$

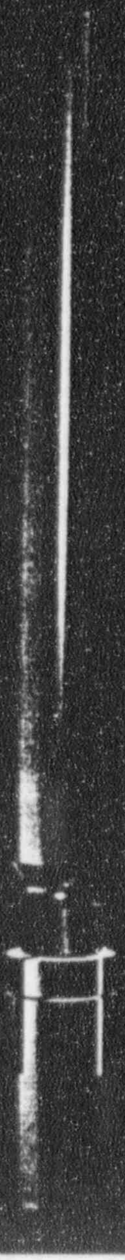
$$A_c = E^2(\pi - \theta + \epsilon\sqrt{1-\epsilon^2})$$

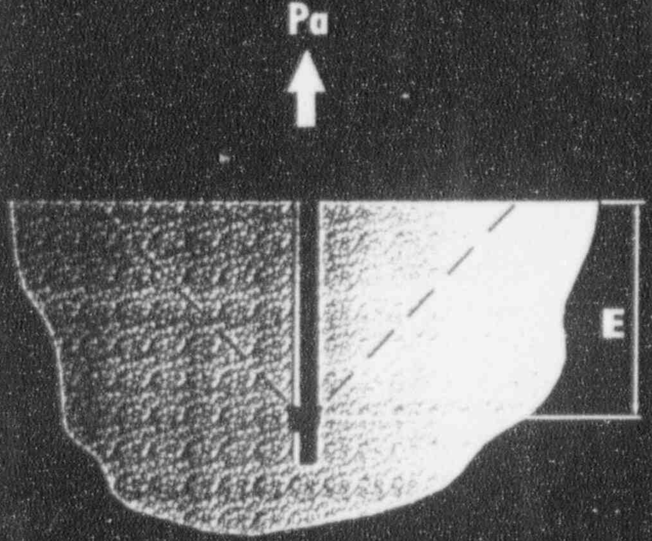
$$\theta = \arccos \epsilon$$

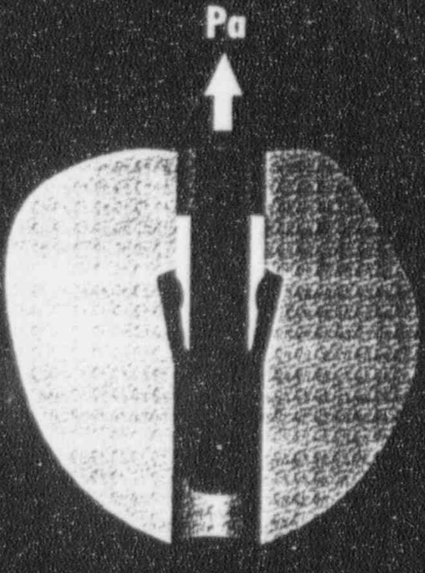
$$\epsilon = \frac{S}{2E}$$

$$S = 2e$$









An Improved Ductile Undercut Concrete Anchor

Rod Size	Maximum Anchor Strength $U \le .81 F_y A_t$ (lbs.)	Required Concrete Pullout Strength $P_d \ge A_t F_u$ (lbs.)
1/2 - 13	12,070	19,900
3/4 - 10	28,400	46,800
1 - 8	51,500	84,900
1 1/4 - 7	82,400	135,700

Above values based on the requirements of ACI 349 Appendix B with F_y = 105 KSI, F_u = 140 KSI max for SA/A193-B7 rod material.

A Guaranteed Ductile Anchorage System

Presently, ACI 349 requires that the concrete strength P_d be equal to, or greater than, the tensile strength of the anchor steel component as determined using the minimum tensile strength specified for the steel material.

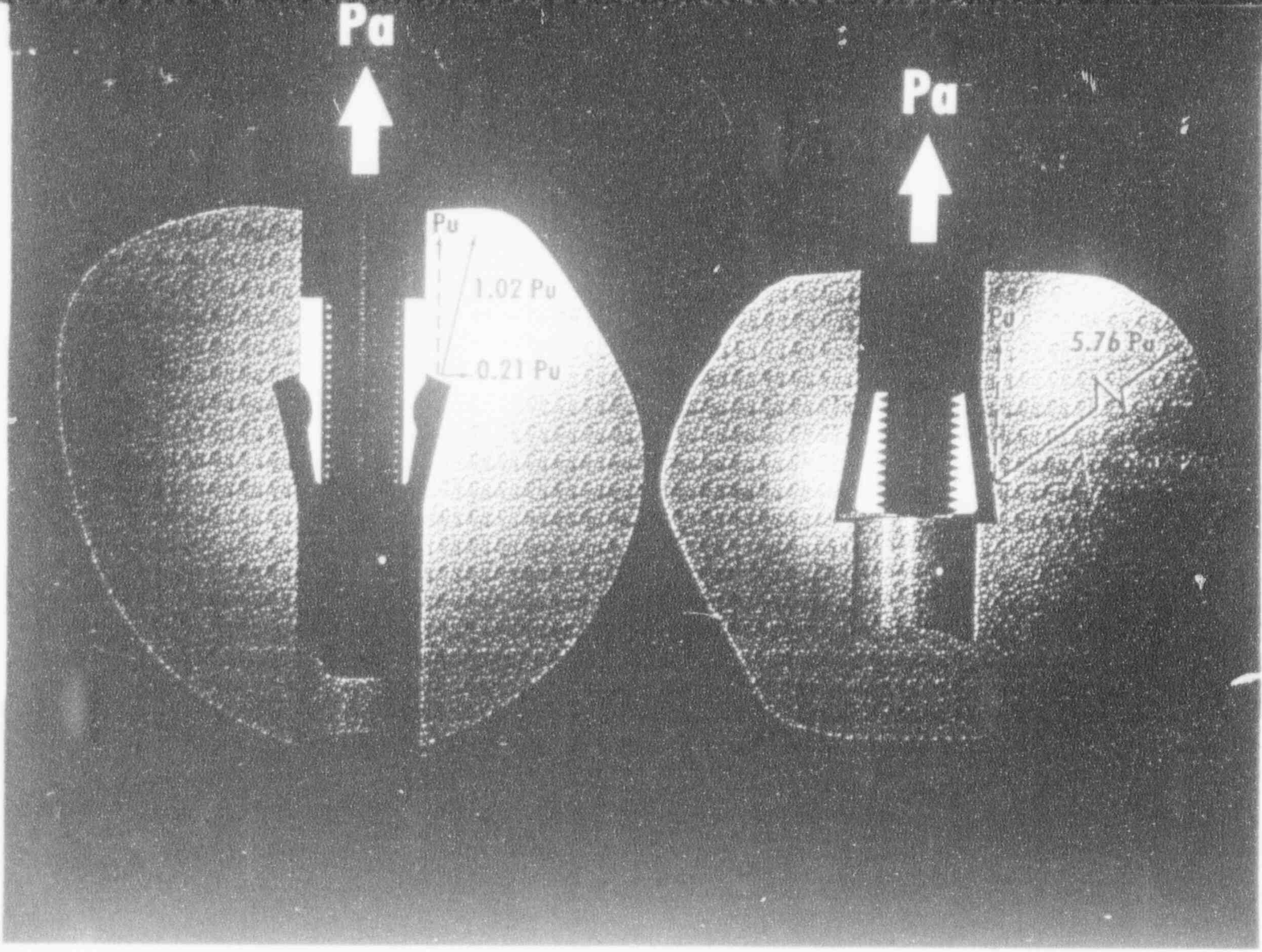
In the case of SA/A193 B7 material, the minimum specified yield stress is 105 KSI and the minimum specified tensile stress is 125 KSI. However, these values can be significantly higher for the actual material.

When the ratio of the tensile stress to yield stress is relatively low and the actual yield stress to minimum specified yield stress approaches this ratio, the ductility of the anchorage system may be decreased accordingly.

The design and manufacture of the Swedge Bolt has eliminated this possible reduction in ductility through established design and material quality control procedures.

P_d Controlled Based On Full Size Tensile Test

Bolt Tensile Capacity will not exceed the values listed above and will be verified by full size tensile test in addition to the requirements of the material specification.



Inverted Conical Undercut Swedge Bolt

Typical Upright Conical Undercut Anchor

Reduced Anchorage Lateral Forces

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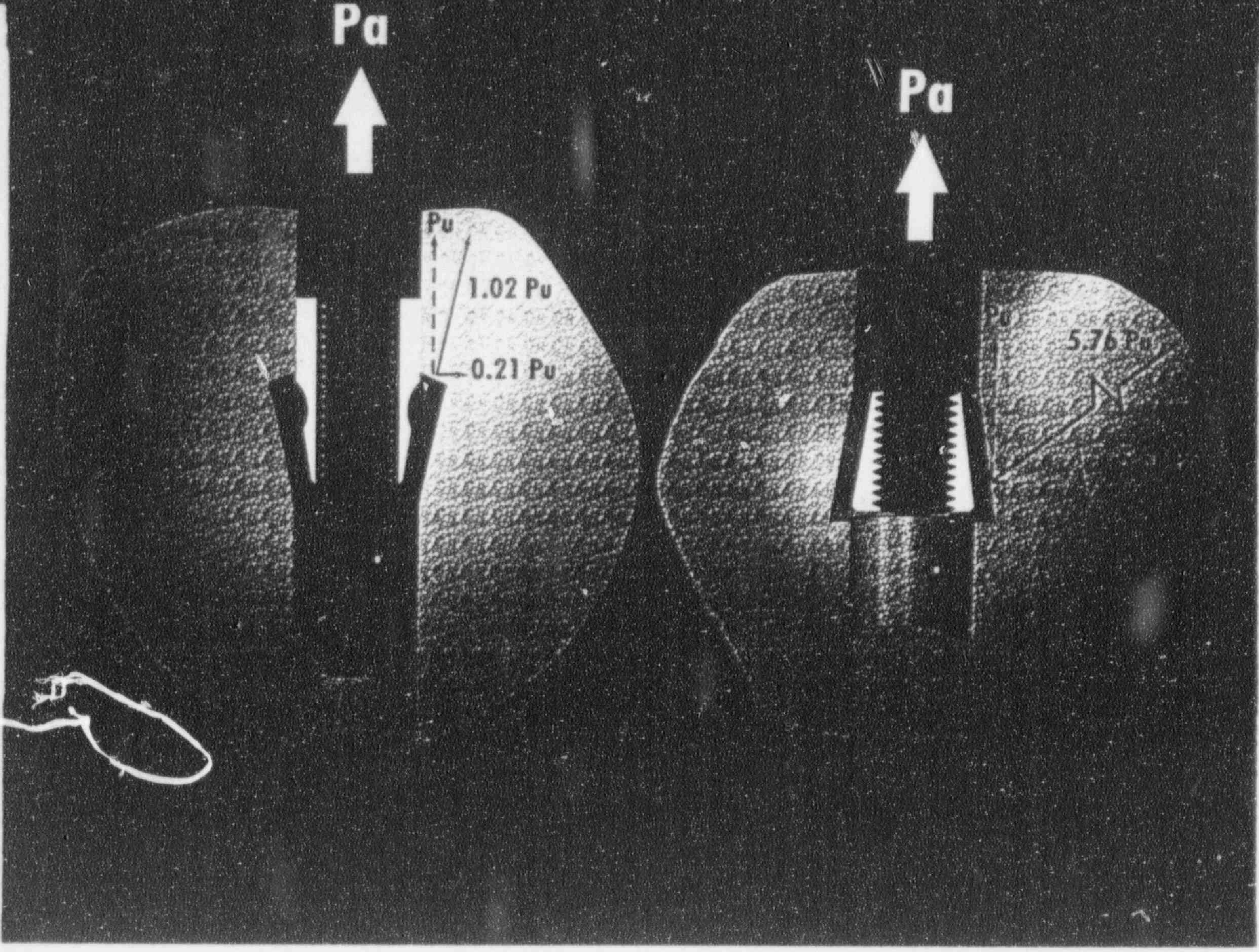

Inverted Conical
Undercut Swedge Bolt

Typical Upright
Conical Undercut Anchor

Reduced Anchorage Lateral Forces

Undercut anchors have been effective in increasing the strength and reliability of drilled in concrete anchors. However, typical upright conical undercut anchors still exhibit the same large lateral forces as generated in wedge anchors.

The Swedge Bolt utilizes an inverted undercut cone to transfer the applied load to the concrete. The Swedge is drawn into the cone, forcing the Swedge fingers over the spreader and to bear against the base of the undercut, causing the fingers to deform and conform to the confined volume defined by the undercut. This swedging action creates a steel mechanical anchor that transfers the applied load to the concrete in a more direct axial direction while generating very minor lateral loads compared to other drilled in anchors.

The Swedge Bolt

High Strength Concrete Anchorage For Engineered Applications

Designers have long seen the need for a drilled in high strength anchorage combining ductility, reliability, strength, and flexibility. Until now, these options were not available in a single anchorage. Couple these variables with low cost, domestic manufacture and the Swedge Bolt truly becomes the anchorage of choice. Conceived and designed by a leader in the concrete and nuclear power fields for over 20 years, the Swedge Bolt design incorporates standard materials to produce a revolutionary anchorage mechanism.

Swedge Bolt* Advantages

Professional Engineering Staff Available

- Trentec can provide professional engineering services to assist in custom designing your unique concrete anchor or complete anchorage system.

Removable Threaded Rod

- Allows for removal or replacement of threaded rod without affecting the anchorage.

- Allows for a flush base for equipment setting, relocation, and re-installation.

Strength Reliability

- The Swedge Bolt Anchorage Mechanism will develop the tensile strength of the threaded rod constantly.

Unique Component Traceability

- The Swedge Bolt is manufactured under strict quality control standards to meet project requirements. For nuclear applications the Swedge Bolt is manufactured in accordance with Trentec's Nuclear Quality Assurance Program.

ACI 349 APP. B Requirements

- Concrete anchorage systems that utilize the Swedge Bolt may be designed in accordance with the requirements of ACI 349 for ductile anchors.

Controlled Maximum Tensile Stength

- Trentec will guarantee the maximum tensile strength for each diameter of threaded rod and the Swedge Bolt certification will state the actual tensile strength of the threaded rod.

Custom Designed Bolts

- The Swedge Bolt anchorage mechanism concept can be used for stainless steel and mild carbon steel and still meet the requirements of ACI 349 APP. B.

Trentec, a world-wide designer and fabricator of Personnel Airlocks, Custom Doors, and Concrete Cutting Systems, is proud to add the Swedge Bolt to its line of products.

We encourage you to contact our sales representative to find out more about the Swedge Bolt, or any of our other products or services.

* Pat. Pending
* Trade Mark applied for

Trentec

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