

8108180349

PRESENTATION

- | | |
|---------------------|------------|
| 1. INTRODUCTION | W. PETRO |
| 2. SPP-6 PROGRAM | D. INGMIRE |
| 3. EFFECT OF STRAIN | A. MORCOS |
| 4. SUMMARY | W. PETRO |

CHRONOLOGICAL SEQUENCE OF EVENTS
RELATING TO CADWELD PRESENTATION

- Aug. '79 PSI HALTS ALL CATEGORY I WORK, AUG. 7.
NRC CONFIRMS CESSITATION OF CATEGORY I
WORK, AUGUST 15. NRC ISSUES NINE-POINT
CONFIRMING ORDER.
- FEB. '80 PSI SUBMITS STEPWISE PROCESS TO RESUME
CATEGORY I WORK, FEBRUARY 28.
- MAY '80 NRC APPROVES PSI "BROWN BOOK," STEPWISE
PROCESS TO RESUME CATEGORY I WORK, INCLUD-
ING CONSTRUCTION VERIFICATION PROGRAM,
MAY 15.
- JUNE '80 NRC CONCURS WITH PSI CONSTRUCTION VERIFI-
CATION PROCEDURE SPP-6, REVISION 3, JUNE 4.
- JULY '80 NRC CONCURRENCE WITH TESTING PROGRAM.
- AUG. '80 PSI SUBMITS CONSTRUCTION VERIFICATION FINAL
REPORT ("INCLUDING TESTING PROGRAM") TO
REGION III, AUGUST 27.
- OCT. '80 NRC MEETS WITH PSI AT MARBLE HILL SITE ON
OCT. 31 TO PRESENT NRC DRAFT PROPOSAL FOR
ADDITIONAL TESTING OF ACCESSIBLE CADWELDS.
- Nov. '80 PSI-NRC HOLDS MEETING IN CHICAGO, TO MAKE
PRESENTATION ON CADWELD INSPECTION AND
TESTING PROGRAM, AFTER 2 MONTHS OF INFORMAL
MEETINGS AND CONFERENCE CALLS WITH REGION
III, NOVEMBER 10.

SUMMARY

PROGRAM MET ACCEPTANCE CRITERIA

SAMPLE SIZE EXCEEDED THAT REQUIRED FOR A 95/95 CONFIDENCE/RELIABILITY

STRAIN EFFECT IS INSIGNIFICANT

CONCLUSION

NO FURTHER TESTING IS REQUIRED

AGENDA FOR MEETING ON
"CADWELDS - MARBLE HILL"
1/08/81

AGENDA

- A. BACKGROUND OF CADWELD DATA
 - SPP-6 VISUAL INS. RESULTS - PURPOSE & SCOPE
 - 1. (CONSTRUCTION VERIFICATION PROGRAM AT MARBLE HILL)
 - 2. RADIOGRAPHY RESULTS
 - 3. TENSILE TEST RESULTS

- B. PSI EVALUATION OF ADEQUACY OF EMBEDDED AND ACCESSIBLE CADWELDS
 - 1. PROGRAM - OVERALL COMMITMENTS AND RESULTS
 - 2. ADEQUACY OF EMBEDDED CADWELDS
 - 3. GAGE MARKS NOT TRUE VISUAL REJECTIONS
 - 4. STRAIN EFFECT
 - 5. CONCLUDING STATEMENT

- C. NRC CONCERNS/QUESTIONS

HANDOUT INFORMATION

PRODUCTION AND SISTER SPLICE TEST RESULTS
SIMILARITIES AND DIFFERENCES BETWEEN ACCESSIBLE AND
INACCESSIBLE CADWELDS
SUMMARY OF LOCATIONS FOR CADWELD SPLICES - UNITS 1 & 2

DEFINITIONS

STANDARD SPLICE:

A SPLICE WHICH MEETS ALL ACCEPT/REJECT CRITERIA (BOTH THE GAGE MARK AND CENTERING CRITERIA AND THE PHYSICAL CRITERIA FOR VOIDS, RECESS, SLAG, POROSITY, ETC.) SEE FLIMSY ON ACCEPT/REJECT CRITERIA.

VISUALLY REJECTED SPLICE:

A SPLICE THAT FAILS ONE OR MORE OF THE ACCEPT/REJECT CRITERIA.

SUBSTANDARD SPLICE:

A SPLICE THAT FAILS TENSILE TESTING (TEST LESS THAN 75,000 PSI).

PHYSICAL VISUAL REJECT:

EXCESSIVE VOIDS, EXCESSIVE FILLER RECESS POROSITY, SLAG, LACK OF FILLER METAL, TWO TAP HOLES, TAP HOLE BURNOUT.

GAGEMARK VISUAL REJECT:

NO GAGEMARKS, GAGEMARKS NOT CENTERED WITH TAP HOLE, GAGEMARKS EXCEED TOLERANCE OR LESS THAN TOLERANCE.

TYPE "T" SPLICE (T-VERTICAL, TV OR T-HORIZONTAL TH):

DEVELOP FULL POSITIVE ULTIMATE STRENGTH MECHANICAL CONNECTIONS BETWEEN TWO REINFORCING BARS WITH A COMMON SLEEVE IN TENSION AND COMPRESSION. TRANSITION SPLICES ARE USED WHEN BARS OF DIFFERENT SIZE ARE TO BE SPLICED.

DEFINITIONS, CONT.

TYPE "B" SPLICE (B-VERTICAL OR BV):

PROVIDE A MECHANICAL MEANS OF CONNECTING REINFORCING BARS TO
STRUCTURAL STEEL PLATES AND SHAPES.

ACCEPT/REJECT CRITERIA FOR SPP-6 AND SPECIFICATION Y-2722

1. FILLER METAL MUST BE VISIBLE AT THE ENDS OF THE SPLICE SLEEVE.
2. FILLER METAL MUST BE VISIBLE AT THE TAP HOLE.
3. FILLER METAL SHALL NOT BE RECESSED MORE THAN 1/2 INCH AT SLEEVE ENDS.
4. SPLICES SHALL NOT CONTAIN SLAG AT TAP HOLE OR SLEEVE ENDS.
5. SPLICES SHALL NOT CONTAIN POROSITY AT TAP HOLE OR SLEEVE ENDS.
6. VOID AREA SHALL NOT EXCEED

2.65	SQUARE	INCHES	FOR	#18
2.00	"	"	"	#14
1.50	"	"	FOR	#11
1.58	"	"	FOR	#10
1.03	"	"	FOR	#10,9,8, 7,6
0.53	"	"		5
0.47	"	"		4
7. DISTANCE BETWEEN GAGE MARK AND STRUCTURAL STEEL PLATE OR SHAPE FOR TYPE B SPLICE

12 ± 1/2	INCHES
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8. A. DISTANCE BETWEEN GAGE MARKS FOR A TYPE T SPLICE SHALL BE

24 1/4 ± 1/2	INCHES
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B. THE CENTERLINE OF THE DISTANCE BETWEEN GAGE MARKS SHALL FALL WITH THE DIAMETER OF THE TAP HOLE.
9. NO GAGE MARKS VISIBLE - WAS A REJECT CRITERIA EVEN THOUGH A PERMANENT MARKING SYSTEM IS NOT REQUIRED.

SUMMARY OF INSPECTION PROGRAM

TOTAL NUMBER OF CADWELDS INSPECTED	2431
TOTAL NUMBER OF INSPECTED ITEMS	19448
TOTAL NUMBER OF VISUAL REJECTED ITEMS (CASES OF REJECTION)	576
TOTAL NUMBER OF CADWELDS WITH VISUAL REJECTIONS	504

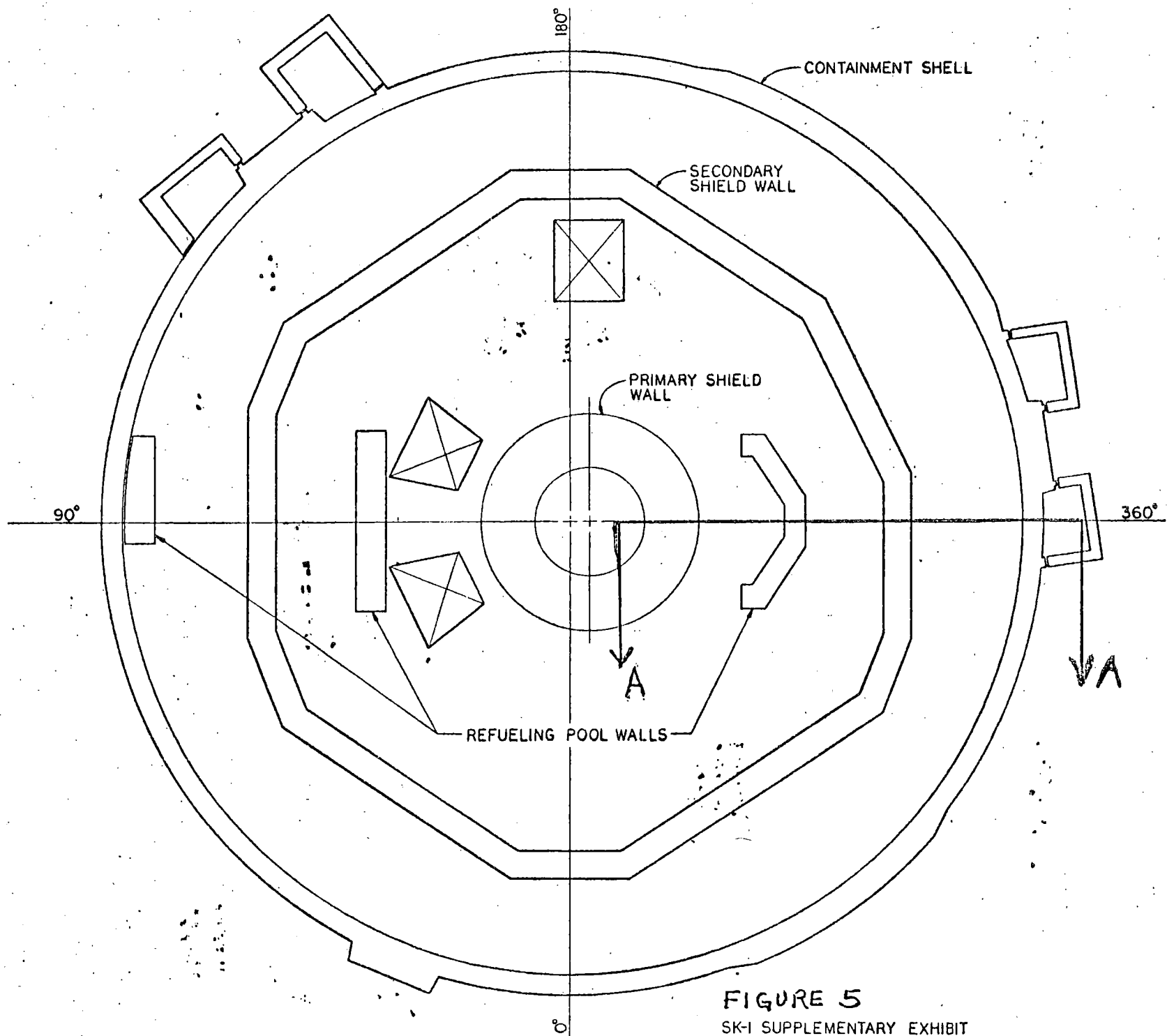


FIGURE 5

SK-1 SUPPLEMENTARY EXHIBIT
 CADWELDS WITH PHYSICAL REJECTIONS
 (VOIDS, RECESS, POROSITY, SLAG)

PURPOSE OF TESTING:

1. TO PROVE THAT THE TYPE OF VISUAL REJECT PRESENT IN THE ACCESSIBLE POPULATION OF CADWELDS AT MARBLE HILL ARE NOT SUBSTANDARD SPLICES.
2. TO ASSURE THAT VISUALLY REJECTED SPLICES MEET THE STRESS AND AVERAGE STRESS REQUIREMENTS (75 KSI MINIMUM, 90 KSI AVERAGE FOR 15) AT A 95% RELIABILITY WITH A 95% CONFIDENCE FACTOR.

NOTE: THE ONLY REASON THE ACCESSIBLE SPLICES WERE TESTED WAS DUE TO THE NECESSITY OF EVALUATING THE TYPES OF REJECTS IN THE ACCESSIBLE POPULATION TO DRAW CONCLUSIONS ON THE ACCEPTABILITY OF BURIED CADWELDS.

SCOPE OF TESTING

RANDOM SAMPLE TOTAL POPULATION

- SCOPE OF TESTING: 1. SELECT 59 RANDOM NUMBERS FROM ENTIRE POPULATION OF ACCESSIBLE CADWELDS AND DETERMINE BY VISUAL INSPECTION, RADIOGRAPHY OR TENSILE TESTING THAT THE SPLICES MEET THE SPECIFIED VISUAL INSPECTION CRITERIA: THE RADIOGRAPH CRITERIA FOR GAGE MARK REJECTION OR THE SPLICE MUST BE CUT OUT AND TESTED ACCORDING TO STRESS REQUIREMENTS.

SCOPE OF TESTING

RANDOM SAMPLE TOTAL POPULATION

2. FOR CONSERVATISM, GROUP ALL VISUAL GAGE MARK REJECTS AND RADIOGRAPH SPLICES TO OBTAIN A 95% CONFIDENCE FACTOR THAT THE REBARS ARE INSTALLED/EMBEDDED CORRECTLY WITHIN THE SLEEVE OR IF RADIOGRAPHED OUTSIDE OF TOLERANCE THEN TENSILE TEST RT REJECTS.

ADDITIONAL WORST CASES

PHYSICAL REJECTS

3. FOR CONSERVATISM DETERMINE WORST CASES OF ALL VISUAL PHYSICAL REJECTS AND TENSILE TEST TO SHOW ACCEPTANCE OF MINIMUM AND AVERAGE STRESS.

SUMMARY OF PHYSICAL TESTS

INSPECTED ITEM	VISUAL REJECTS TOTAL NUMBER	NUMBER TESTED	NUMBER PASSED	METHOD OF TEST	TENSILE TEST RESULTS (PSI)*		
					Highest	Lowest	Average
Excessive Void Area	103	13	13	T	105,000 **	84,445	98,206
Excessive Recess Of The Filler Metal	7	2	2	T	102,205	100,787	101,496
Slag Penetration Beyond The Sleeve At The Tap Hole	26	8	8	T	100,641	89,333	96,203
Tap Hole Burnout	3	3	3	T	97,500	92,564	95,188
Porosity In The Sleeve Ends	14	4	4	T	105,000 **	89,333 **	96,277
No Filler Metal Visible At The Sleeve Ends	1	1	1	T	109,764		
2 Tap Holes	2	1	1 (MU)	T	97,000		
TOTALS	156***	32	30(T) 1(MU)		109,764	84,445	97,710

T = Tensile Test

(MU) = Mockup

* = Acceptance Criteria; $\leq 75,000$ psi for individual splice and average of any 15 test results had to meet or exceed 90,00 psi.

** = Same splice TV-434; 38,333 TV-541; 105,000

*** = 2 splices which had "indeterminant" conditions:
TV-1087 & TV-1101 2 tap holes are not included.

SUMMARY OF GAUGE MARK TESTS

INSPECTED ITEM	VISUAL REJECTS TOTAL NUMBER	NUMBER TESTED	NUMBER PASSED	METHOD OF TEST	TENSILE TEST RESULTS (PSI) *		
					Highest	Lowest	Average
No Gauge Marks	203	25	25	RT			
Out of Tolerance Gauge Marks	106	29	27 2	RT T	97,750	89,750	93,750
**Centerline Of Gauge Marks Not Within Diameter Of Tap Hole	111	19	15 4	RT T	99,250	76,500	93,500
TOTAL	420***	73	66 6	RT T	99,250	76,500	93,583

RT = Radiograph
T = Tensile Test

* = Acceptance Criteria: $\leq 75,000$ psi for individual splice and average of any 15 test results had to meet or exceed 90,000 psi.

** = Bar ends must be within the outline of the tap hole.

*** = Splice had "indeterminate" condition (BV-63, 2 gage marks) not included.

RELIABILITY OF TEST PROGRAM

ACCESSIBLE CADWELDS TOTAL	2431		
		<u>CONFIDENCE</u>	<u>RELIABILITY</u>
RANDOM SAMPLE TOTAL POPULATION (2431)	59	95%	95%
SAMPLE OF GAGE WORK VISUAL REJECT POPULATION (381)	58	95%+	95%+
ADDITIONAL WORST CASES PHYSICAL REJECTS (115)	21	-	-
TOTAL ACCEPTABLE SPLICES INSPECTED & TESTED (1884)		95%	99%

STRAIN IN CADWELD SPLICES

•NRC CONCERN: SPLICES FAILING VISUAL EXAMINATION
COMPROMISE STRUCTURAL INTEGRITY

- RESPONSE:
- CODE REQUIREMENTS
 - ERICO TESTS
 - STRESSES AND CRACK CONSIDERATIONS AT MARBLE HILL

FIGURE 1

CODE REQUIREMENTS

STRENGTH, NOT STRAIN, IS CRITERION IN GOVERNING CODES, REGULATORY GUIDES OR MANUFACTURER'S RECOMMENDATIONS.

ACI-349-76 NOT GOVERNING - HOWEVER, MET FOR T-SPLICES IN CONTAINMENT SHELL AND BASEMAT.

FIGURE 2

ERICO TESTS

REINFORCED CONCRETE BEAM 8" WIDE X 12" DEEP

- 1 BEAM, UNSPLICED BARS
- 2 BEAMS, VERY SOFT UNSTAGGERED SPLICES (1 1/2" PLUG)
- 1 BEAM STANDARD CADWELD SPLICES

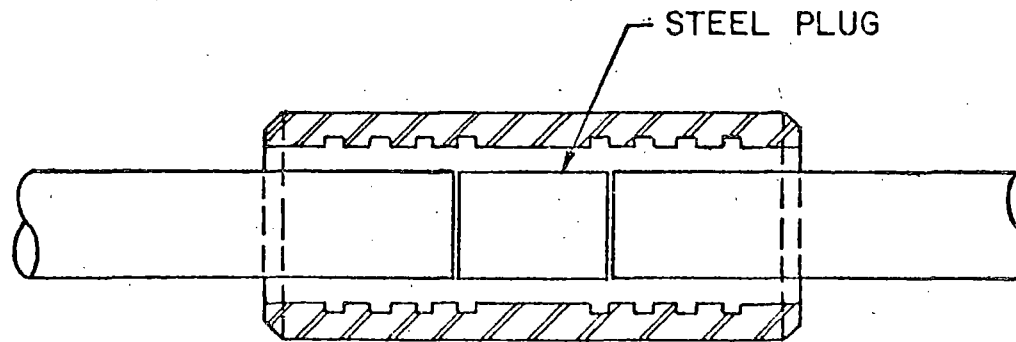
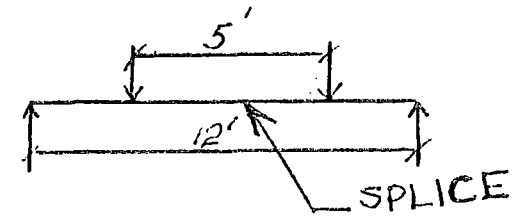
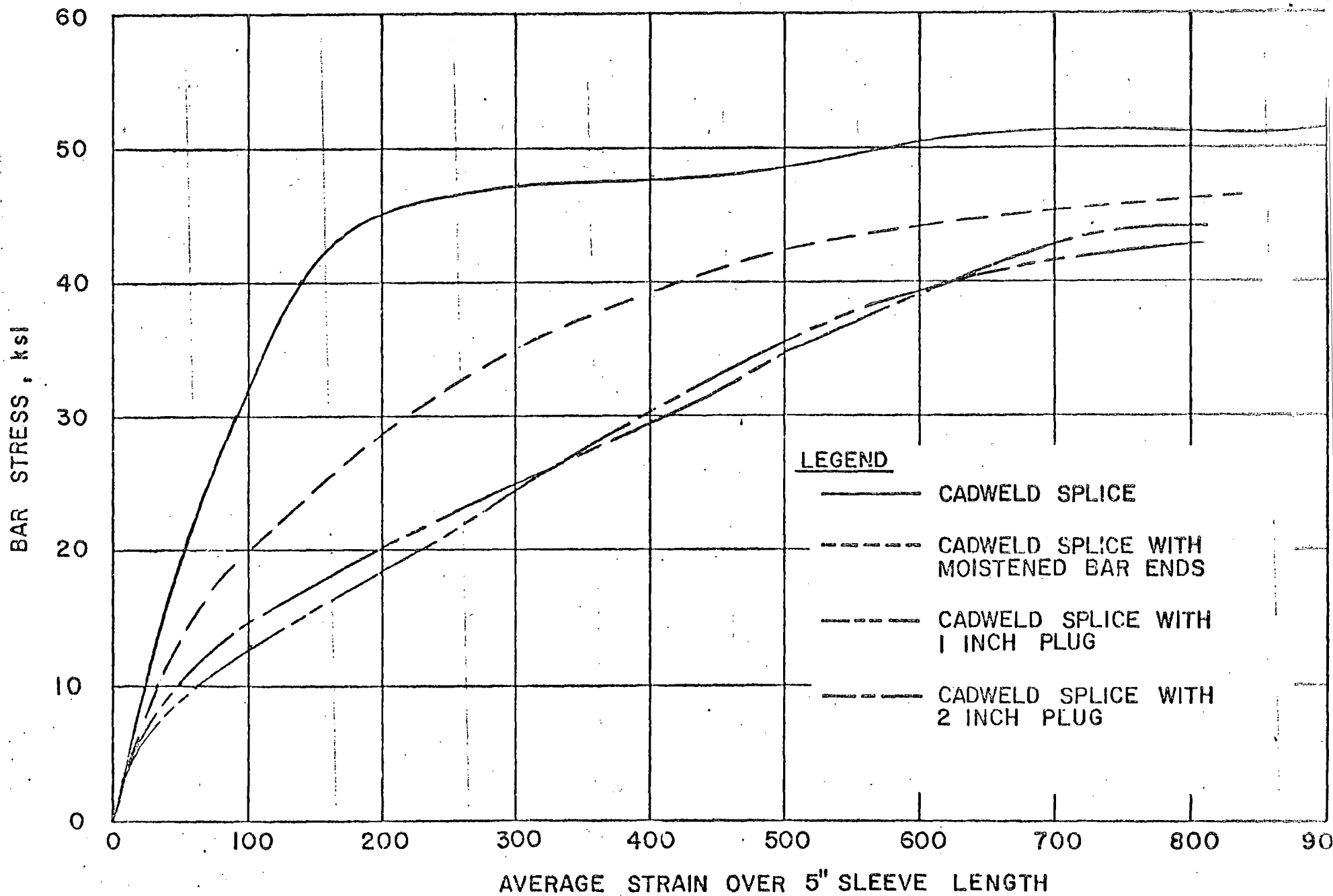


FIGURE 3



STRESS-STRAIN CURVES FOR SPLICE BARS
 FIGURE 4

RESULTS OF ERICO TESTS
BEAMS LOADED TO FAILURE

- DUCTILE FAILURE
- SIMILAR CRACK PATTERN
- SAME ULTIMATE MOMENT CAPACITY
- SAME DEFLECTIONS AT LOAD 50% OF ULTIMATE
- DEFLECTIONS AT YIELD 15% TO 20% HIGHER FOR SOFT SPLICES
- SAME DEFLECTIONS AT POINT OF FAILURE

FIGURE 5

APPLIED LOAD, KIPS

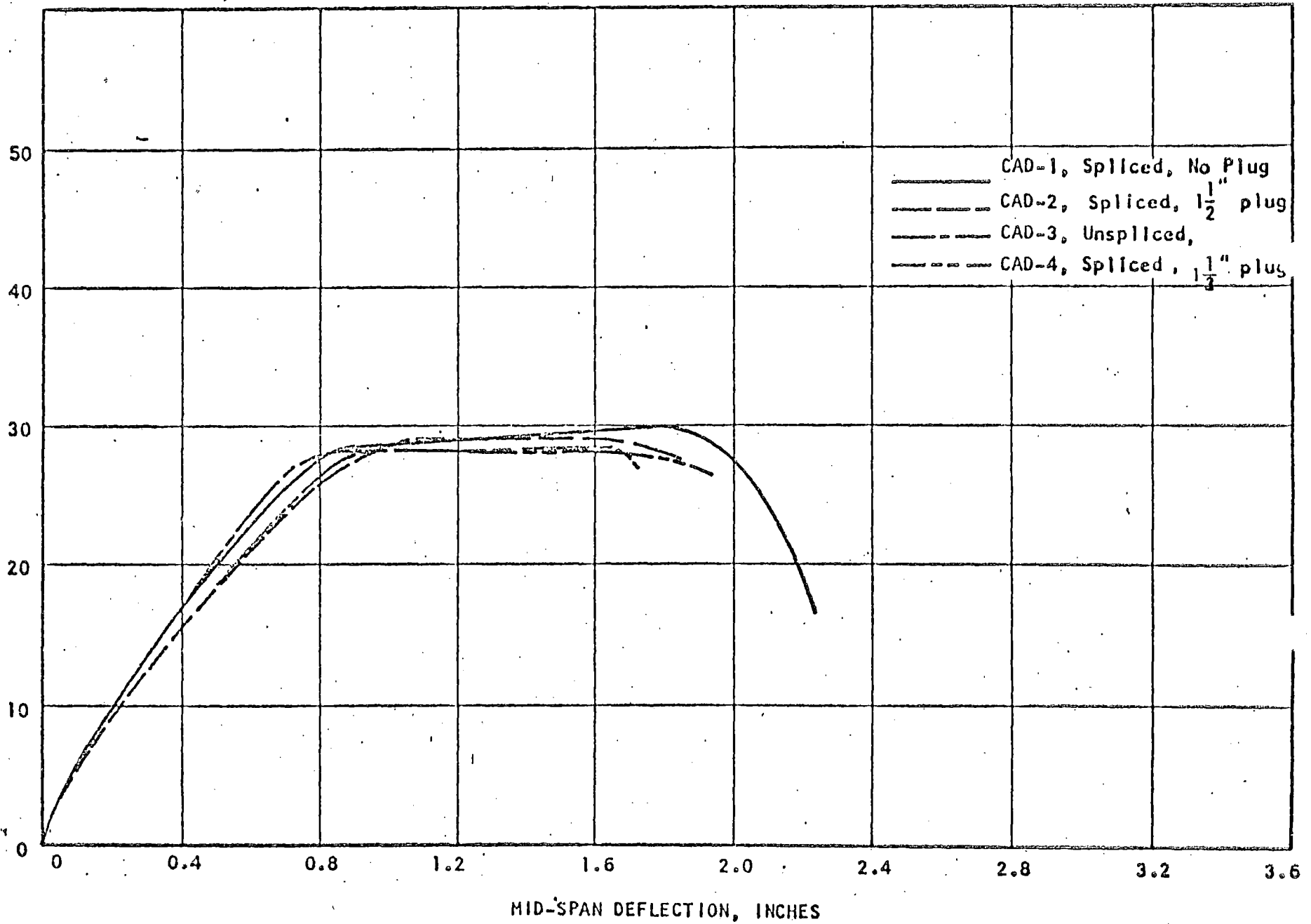


FIGURE 6

LOAD-DEFLECTION CURVES FOR ALL THE BEAMS (Reference 1)

MARBLE HILL LESS SEVERE THAN ERICO TESTS

- . BLOW OUT (MOISTENED) CONDITION MORE CRITICAL THAN MARBLE HILL.
- . ERICO TESTS HAVE A RIGID PLUG PREVENTING THE SLEEVE FROM GRIPPING THE BAR.
- . ERICO'S PLUG WORSE THAN MARBLE HILL'S WORST CASE.
- . IN ERICO'S TESTS, 100% REINFORCING IN THE BEAM WAS SPLICED WITH SOFTENED CADWELDS AT SECTION OF MAXIMUM MOMENT; WHILE AT MARBLE HILL A MAXIMUM OF 8% OF BARS IN ONE WALL HAD PHYSICAL VISUAL REJECTIONS (THE WORST PASSED TENSILE TESTS).

FIGURE 7

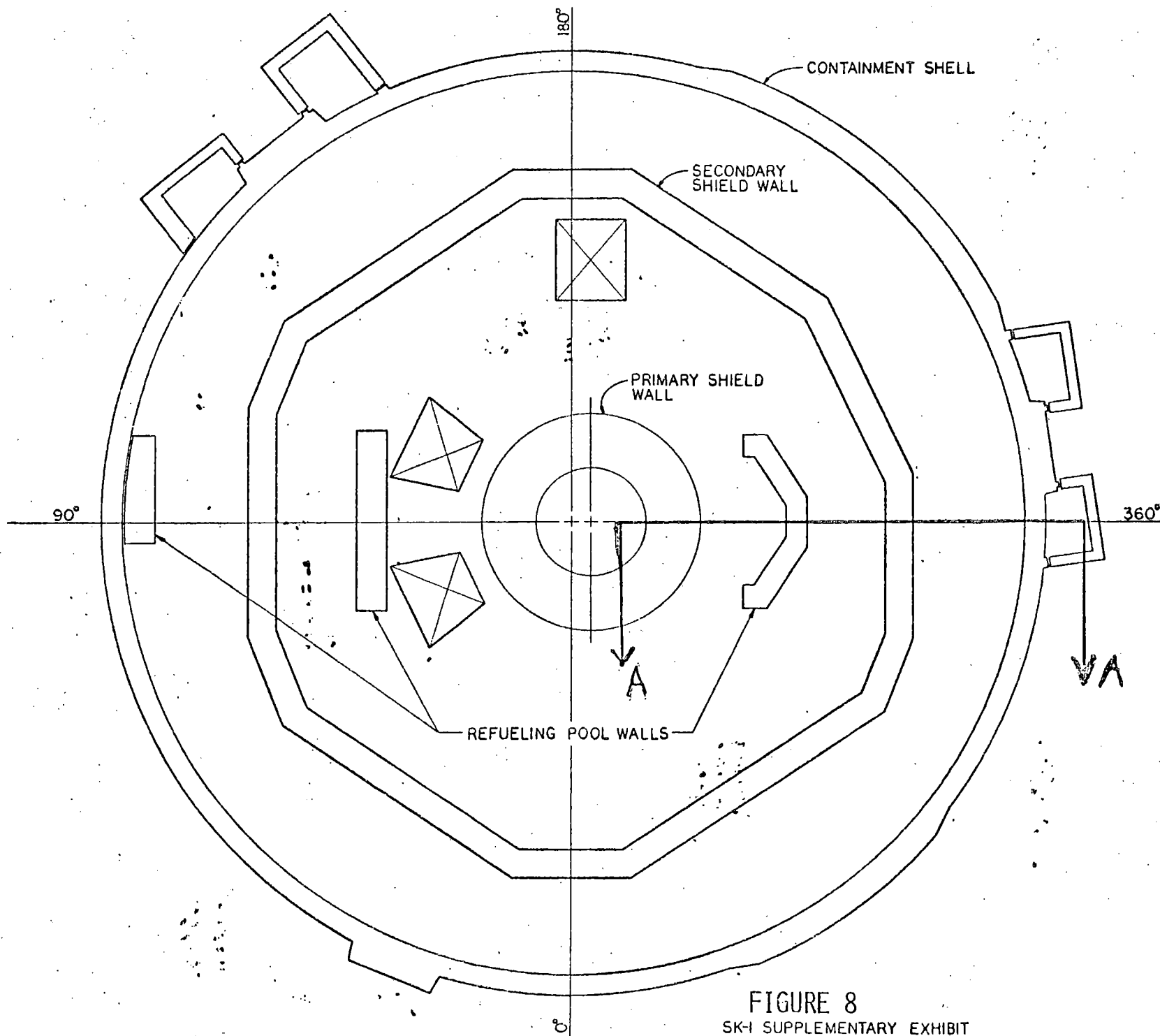
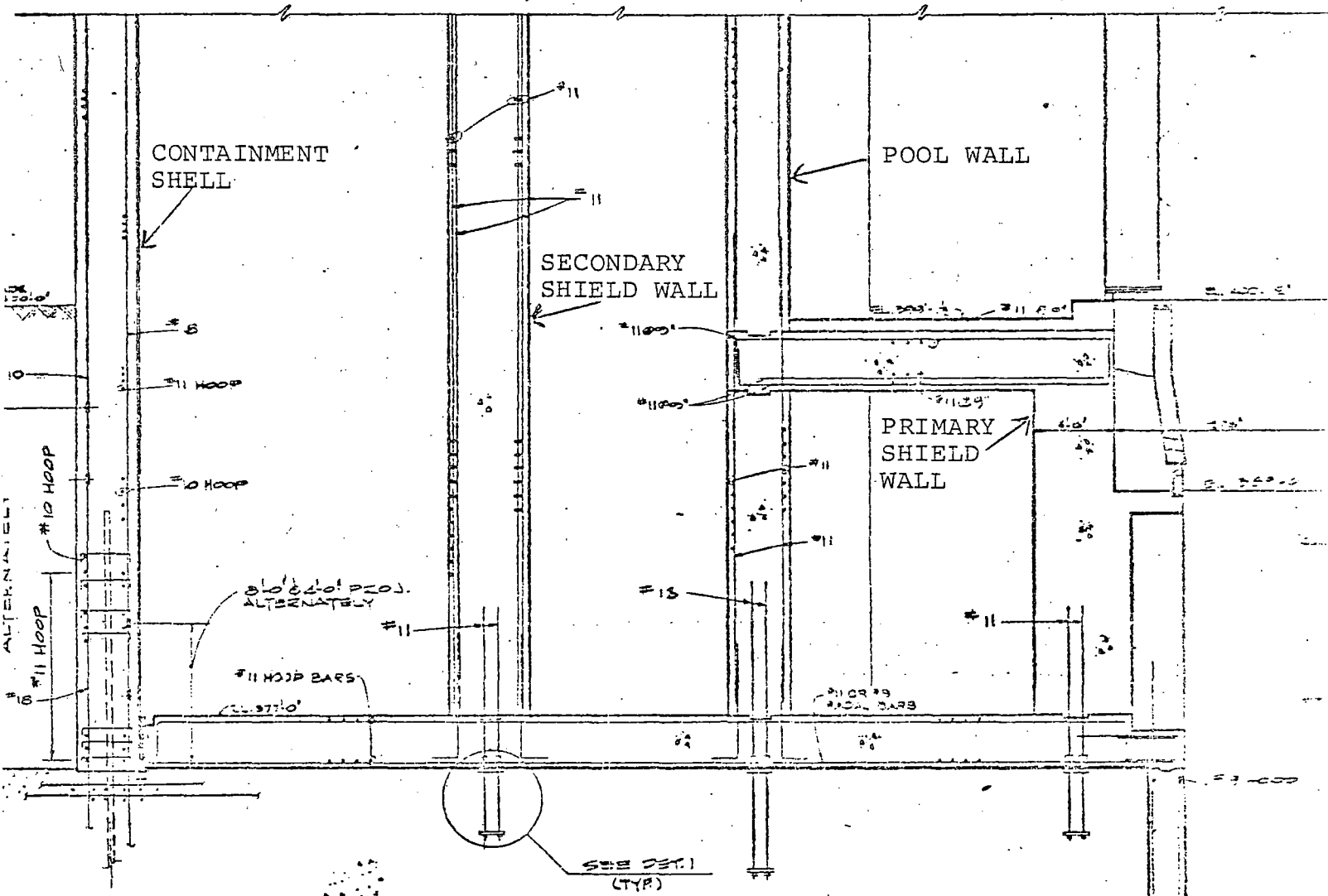


FIGURE 8
 SK-1 SUPPLEMENTARY EXHIBIT
 CADWELDS WITH PHYSICAL REJECTIONS
 (VOIDS, RECESS, POROSITY, SLAG)

PLAN @ EL.374'-0"



- SECTION A -

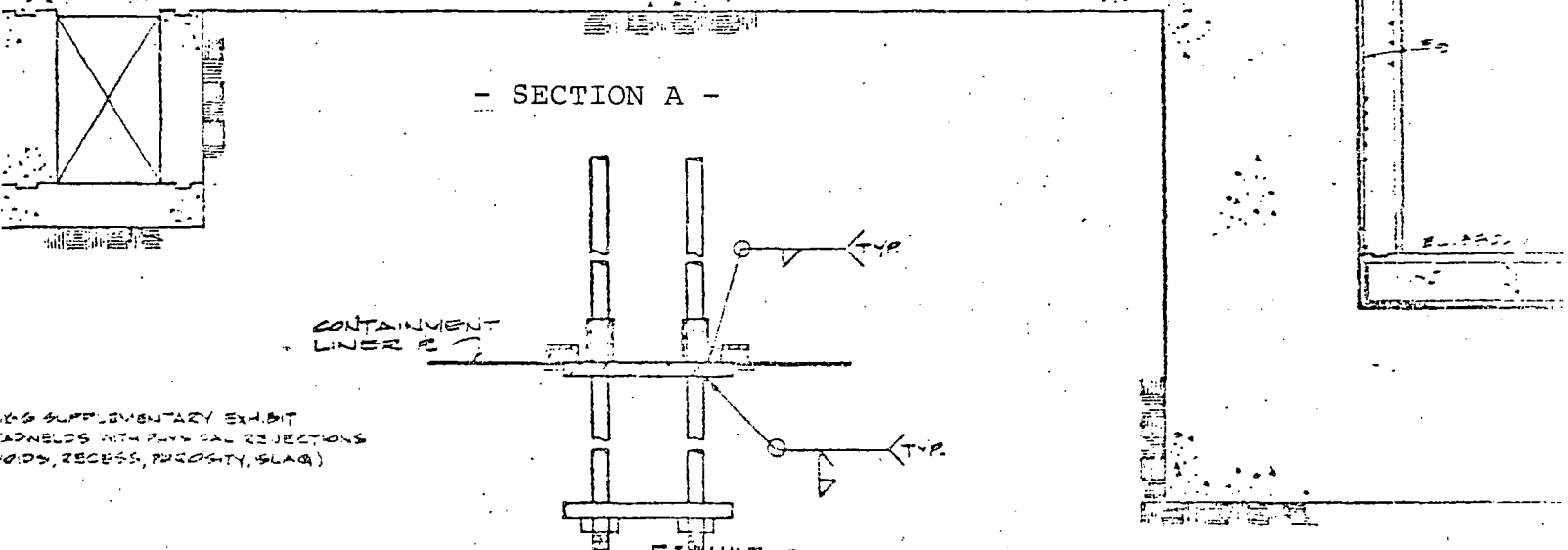


FIGURE 9

DETAIL 1

SUMMARY OF VISUAL INSPECTION RESULTS OF SPLICES
WITH PHYSICAL REJECTIONS (RECESS, VOIDS, SLAG, POROSITY)

<u>LOCATION</u>	<u>PERCENT OF TOTAL</u>
PRIMARY SHIELD WALL	8.2
SECONDARY SHIELD WALL	6.6
REFUELING POOL WALLS	3.4
CONT. SHELL @ EL. 378'-0"	1.3
CONT. SHELL @ EL. 382'-0"	0.7
CONT. SHELL @ EL. 390'-0"	2.1
CONT. SHELL @ EL. 394'-0"	2.1
CONT. SHELL @ EL. 397'-0"	0.1
CONT. SHELL @ EL. 414'-0"	0.3

FIGURE 10

STRESS AND CRACK ANALYSIS - CONTAINMENT INTERNALS

ASSUMING ALL SPLICES VISUALLY ACCEPTABLE

- A. WALL IS IN COMPRESSION FOR NORMAL, NON-SEISMIC LOADING
- B. 48.6 KSI STEEL STRESS FOR THE MOST SEVERE LOADING

ASSUMING VISUALLY REJECTED SPLICES NON-EXISTENT

- A. WALL IS IN COMPRESSION FOR NORMAL NON-SEISMIC LOAD
- B. 52 KSI STEEL STRESS FOR THE MOST SEVERE LOADING

ALLOWABLE STRESS PER ACI 318-71 IS 54 KSI

CRACK INSIGNIFICANT

COVERED BY 3' CONCRETE SLAB

OCCURS ONLY UNDER SEISMIC CONDITION, FOR A SHORT TIME

FIGURE 11

STRESS AND CRACK ANALYSIS - CONTAINMENT SHELL

· ASSUMING VISUALLY REJECTED SPLICES ARE NONEXISTENT, STRESSES ARE WITHIN
· DESIGN ALLOWABLES FOR ALL LOADING CONDITIONS.

· NO SIGNIFICANT CRACKS EXIST UNDER NONSEISMIC SERVICE LOADS (DUE TO POST
· TENSIONING).

· ANY CRACKS UNDER SEISMIC LOADS ARE CLOSED BY COMPRESSION LOADS FROM THE
· POST TENSIONING SYSTEM.

FIGURE 12

CONCLUSION

STRAIN CONSIDERATION RELATING TO PHYSICAL VISUAL REJECTIONS SHOWS NO
IMPAIRMENT OF THE STRUCTURAL INTEGRITY AND SERVICEABILITY AT MARBLE HILL.

FIGURE 13

HANDOUT INFORMATION
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DISTRIBUTION OF VISUAL REJECTS	1 PAGE

TOTAL CADWELD POPULATION - GENERAL RESULTS

2434 TOTAL SPLICES AVAILAEBLE
FOR INSPECTION

3 VOID (NOT INSTALLED)	- V
1794 VISUALLY ACCEPTABLE	- A
499 VISUALLY REJECTABLE	- R
133 INACCESSIBLE	- I
<u>5</u> REJECT/INACCESSIBLE	-R/I
2434 TOTAL	

OF THE 2431 IN-PLACE SPLICES INSPECTED THERE WERE 502 SPLICES WHICH DID NOT MEET THE VISUAL INSPECTION CRITERIA. IN ADDITION TWO SPLICES BV-1087 AND BV-1101 WERE IDENTIFIED DURING THE INSPECTION AS HAVING TWO TAP HOLES. BV-1087 AND BV-1101 HAVE BEEN INCLUDED IN THE 504 SPLICE TOTAL.

504 INDIVIDUAL SPLICES WITH ONE OR MORE CASE OF REJECTION	-504
INCLUDING (2 INDETERMANENT CASES BV-1083 AND BV-1101 (2 TAP HOLES)	(0)
60 INDIVIDUAL SPLICES WITH TWO CASES OF REJECTION	- 60
7 INDIVIDUAL SPLICES WITH THREE CASES OF REJECTION	- <u>12</u>
TOTAL CASES OF REJECTION	576

59 RANDOM NUMBERS OF A TOTAL 2,434 SPLICE POPULATION

1) 2047 BV-908 (A)	21) 1317 BV-186 (A)	41) 2161 BV-1022 (A)
2) 2145 BV-1006 (A)	22) 0543 TV-912 (R)	42) 0628 TV-870 (A)
3) 0178 TV-179 (A)	23) 1979 BV-840 (A)	43) 0552 TV-921 (A)
4) 0579 TV-948 (A)	24) 1406 BV-275 (A)	44) 0819 TV-845 (R)
5) 1039 TV-560 (R)	25) 1180 BV-49 (A)	45) 0783 TV-732 (A)
6) 1646 BV-515 (A)	*) 2295 BV-1164 (I)	46) 0433 TV-1121 (R)
7) 0484 TV-1070 (A)	26) 1138 BV-7 (A)	47) 0089 TV-90 (A)
8) 1428 BV-297 (A)	27) 1894 BV-763 (A)	48) 1765 BV-634 (A)
9) 1279 BV-148 (A)	28) 0280 TV-357 (A)	49) 0939 TV-712 (R)
10) 0573 TV-942 (A)	29) 1854 BV-723 (A)	50) 1472 BV-341 (A)
11) 1443 BV-312 (A)	30) 0489 TV-1065 (A)	*) 1567 BV-436 (I)
12) 2157 BV-1018 (A)	31) 1178 BV-47 (A)	51) 2064 BV-925 (A)
13) 2413 TH-38 (A)	32) 1989 BV-850 (A)	52) 2135 BV-996 (A)
14) 0990 TV-511 (A)	33) 0322 TV-279 (A)	53) 0287 TV-244 (A)
15) 0972 TV-594 (A)	34) 0932 TV-705 (A)	54) 0254 TV-331 (A)
16) 0985 TV-506 (R)	35) 2269 BV-1130 (A)	55) 0070 TV-70 (R)
17) 0222 TV-223 (A)	36) 1999 BV-860 (A)	*) 2389 TH-14 (I)
18) 0127 TV-128 (A)	*) 2356 BV-1225 (I)	56) 0643 TV-885 (A)
19) 0212 TV-213 (R)	37) 1929 BV-798 (A)	57) 1224 BV-93 (A)
20) 1193 BV-62 (R)	38) 1140 BV-9 (A)	58) 0881 TV-654 (R)
	39) 0634 TV-876 (A)	59) 0154 TV-155 (R)
	40) 0045 TV-45 (A)	

* Splice was exposed but inaccessible to any inspections or tests.

Note 1: 48 splices inspected as acceptable

3 splices rejected due to physical visual defects
(TV-70; TV-155; TV-560)

8 splices rejected due to gage mark visual defects
(BV-62; TV-506; TV-654; TV-712; TV-845; TV-912;
TV-213; TV-1121)

59 Total random numbers

Note 2: Three gage mark visual rejects did not pass the radiography procedure and were tensile tested. These were TV-506, TV-654 and TV-845.

Note 3: Tensile Test Results:

<u>Splice I.D.</u>	<u>Tensile Strength</u>	<u>Type of Failure</u>
TV-70	95,276	Bar Failure
TV-155	103,937	Bar Failure
TV-560	97,500	Bar Failure
TV-506	99,250	Sleeve Failure
TV-654	99,250	Pullout
TV-845	99,000	Bar Failure

TEST GROUP 2 - GAGE MARK VISUAL REJECTS

LIST OF SPLICES RADIOGRAPHED FROM G.M. VISUAL REJECT POPULATION

1. BV-63	21. BV-828	39. TV-171
2. BV-133	22. BV-837	40. TV-235
3. BV-236	23. BV-911	41. TV-339
4. BV-350	24. BV-920	42. TV-341
5. BV-356	25. BV-1122	43. TV-343
6. BV-377		44. TV-358
7. BV-485	26. TH-23	45. TV-360
8. BV-488	27. TH-26	46. TV-366
9. BV-539	28. TH-28	47. TV-370
10. BV-605	29. TH-43	48. TV-440
11. BV-665		49. TV-454
12. BV-670	30. TV-41	50. TV-729
13. BV-755	31. TV-51	51. TV-777
14. BV-757	32. TV-55	52. TV-959
15. BV-759	33. TV-73	53. TV-1017
16. BV-768	34. TV-75	54. TV-1029
17. BV-816	35. TV-77	55. TV-1052
18. BV-820	36. TV-79	56. TV-1131
19. BV-823	37. TV-82	57. TV-1133
20. BV-827	38. TV-85	58. TV-1134

Note: 1. 58 splices radiographed for 95% reliability with 95% confidence factor. Only 54 required for population of 390.

Note: 2. Three gage mark visual rejects did not pass the radiography procedure and were tensile tested with results as follows:

<u>Splice I.D.</u>	<u>Tensile Strength</u>	<u>Type of Failure</u>
TV-777	76,500	Pullout
TV-1131	89,750	Pullout
TV-1133	97,750	Bar Failure

TEST GROUP 3 - WORST CASES OF PHYSICAL REJECTS

The following splices were tensile tested based on the worse cases in Appendices B, C, D, E, F & G in Car PC 0602.

<u>Splice I.D.</u>	<u>Tensile Strength</u>	<u>Type of Failure</u>
1. BV-68	99,750	Bar Failure
2. BV-242	100,641	Bar Failure
3. BV-541	105,000	Bar Failure
4. BV-626	101,000	Bar Failure
5. BV-635	100,000	Sleeve Failure
6. BV-742	92,564	Pullout
7. BV-757	94,872	Weld Broke
8. BV-796	102,308	Pullout
9. BV-1139	97,500	Pullout
10. TV-68	99,591	Bar Failure
11. TV-80	102,205	Bar Failure
12. TV-87	109,764	Bar Failure
13. TV-91	102,835	Bar Failure
14. TV-153	100,787	Bar Failure
15. TV-174	87,402	Pullout
16. TV-285	84,445	Pullout
17. TV-408	92,444	Pullout
18. TV-433	99,556	Pullout
19. TV-434	89,333	Pullout
20. TV-729	95,500	Bar Failure
21. TV-890	97,500	Bar Failure
22. MU-2	97,000	Bar Failure

SUMMARY TENSILE TESTING

<u>Splice Identification</u>	<u>Tensile Strength</u>	<u>Type of Failure</u>	<u>Remarks</u>
1. BV-68	99,750	Bar Failure	
2. BV-242	100,641	Bar Failure	
3. BV-541	105,000	Bar Failure	
4. BV-626	101,000	Bar Failure	
5. BV-635	100,000	Sleeve Failure	
6. BV-742	92,564	Pullout	
7. BV-757	94,872	Weld Broke	Weld of "Butted sleeves
8. BV-796	102,308	Pullout	
9. BV-1139	97,500	Pullout	
10. TV-68	99,591	Bar Failure	
11. TV-70	95,276	Bar Failure	
12. TV-80	102,205	Bar Failure	
13. TV-87	109,764	Bar Failure	
14. TV-91	102,835	Bar Failure	
15. TV-153	100,787	Bar Failure	
16. TV-155**	103,937	Bar Failure	
17. TV-174	87,402	Pullout	Weld metal did not fail sheared deformations off bar corner of bar fractured
18. TV-285	84,445	Pullout	" " " "
19. TV-408	92,444	Pullout	
20. TV-433	99,556	Pullout	
21. TV-434	89,333	Pullout	
22. TV-506*	99,250	Sleeve Failure	Sheared deformations off bar
23. TV-560	97,500	Bar Failure	
24. TV-654*	99,250	Pullout	
25. TV-729	95,500	Bar Failure	
26. TV-777*	76,500	Pullout	Sheared deformations off bar
27. TV-845*	99,000	Bar Failure	
28. TV-890	97,500	Bar Failure	
29. TV-1131*	89,750	Pullout	Sheared deformations off bar
30. TV-1133*	97,750	Bar Failure	
31. MW-2	97,000	Bar Failure	

* Worst cases gage mark failure

** TV-155 from random 59 numbers

Of the 30 production splices pulled out and tested:

The types of failures broke down as follows:

- 2 Sleeve Failures
- 16 Bar Failures
- 11 Pullouts (Bar pulled out of sleeve)
- 1 Butt Weld Failure

—
30 Total

Of the 11 pullouts:

- 6 Pulled out at above 90,000 psi
- 5 Pulled out due to deformations shearing off bar
- 0 Pulled out due to lack of or failure of filler metal

—
11 Total

PRODUCTION AND SISTER SPLICE TEST RESULTS

CONTAINMENT #1	<u>6</u> PRODUCTION	<u>185</u> SISTER
CONTAINMENT #2	<u>4</u> PRODUCTION	<u>166</u> SISTER
TOTALS	10 PRODUCTION*	351* SISTER

* NOTE 1. ALL PRODUCTION AND SISTER SPLICES PASSED THE MINIMUM AND AVERAGE STRESS CRITERIA.

NOTE 2. SEE ATTACHMENT PAGE 6(B) FOR PRODUCTION, SISTER AND QUALIFICATION TEST RESULT DISTRIBUTION.

CADWELD IN-PROCESS TENSILE TESTS RESULTS

Cadweld Splices		TV-18	TH-11	BV-11	TV-10	BV-18	TV10-18	TV14-18	TV11-18	TH-8	TH-9
Number of Tests	407	201	26	84	8	24	40	11	9	2	2
Average Strength (ksi)	102.93	100.98	103.52	107.36	100.47	98.50	106.13	100.93	104.14	106.58	99.60
Standard Deviation (ksi)	5.99	4.45	5.23	7.12	2.59	4.34	5.14	4.48	6.64	-	-
Coefficient of Variation (%)	5.82	4.40	5.05	6.63	2.57	4.40	4.84	4.44	6.38	-	-
Range (ksi)	29.94	18.25	24.35	27.05	7.71	12.25	15.59	16.44	19.10	4.55	0
Min. Strength (ksi) and Mode of Failure	87.11 P	91.25 BF	92.43 BF	90.00 BF	96.53 BF	92.74 BF	93.38 P	87.11 P	95.64 BF	104.30 BF	99.60 P
Max. Strength (ksi) and Mode of Failure	117.05 BF	109.50 BF	116.79 BF	117.05 BF	104.25 SF	105.00 BF	108.97 BF	103.55 BF	114.74 BF	108.86 BF	99.60 P
Mode of Failure	P	18	4	7	0	1	0	1	3	0	2
	SF	8	4	2	0	2	0	0	0	0	0
	BF	381	193	17	84	5	24	39	8	9	2
	Visually Rejected ^c	1	0	0	1	0	0	0	0	0	0
	TOTAL	408	201	26	85	8	24	40	11	9	2
Probability of strength exceeding 90 ksi	.9842	.9931	.9951	.9925	ab .9975	.9748	.9991	ab .9825	ab .9750	-	-
Prob. of average of 15 consecutive tests exceeding 90 ksi	b .9999997	b .9999997	b .9999997	b .9999997	ab .9999997	b .9999997	b .9999997	ab .9999997	a .999975	-	-

Notes:

a - t-student distribution
b - larger than the number shown
c - rejected by the lab because of slag at tap hole

Notation :

BF = Bar Failure
P = Pull out of the bar
SF = Sleeve Failure

SIMILARITIES BETWEEN
EMBEDDED & ACCESSIBLE CADWELDS

SPLICE TYPE & SIZE	TOTAL SHOTS		TOTAL										TOTALS
	REJECT/OPERATORS*		ALL OPERATORS	REJECTS/OPERATORS*									
	UNIT 1	UNIT 2	UNIT 2	F	G	L	S	X	JJ	KK	CC		
18-18V	570	532	1104	67	35	16	0	1	32	0	0	151	
18-14V	127	173	300	15	11	13	0	0	0	0	0	39	
18-10V	481	433	914	32	0	0	40	4	73	0	0	149	
BV-11	912	862	1774	28	0	50	0	0	18	38	1	134	
				<u>142</u>	<u>46</u>	<u>79</u>	<u>40</u>	<u>5</u>	<u>123</u>	<u>38</u>	<u>1</u>	<u>473**</u>	
			TOTAL REJECTS	154	46	79	40	5	130	39	1		

* 28 QUALIFIED CADWELD OPERATORS, ONLY EIGHT SHOT REJECTS IDENTIFIED UNDER SPP-6 PROGRAM.
(NOTE: REJECTS HERE ARE INDIVIDUAL SPLICES)

** 473 OF 502 INDIVIDUAL SPLICE REJECTS (94%) SHOT BY 8 OPERATORS ON ONLY 4 TYPES OF SPLICE.

8

SIMILARITIES AMONG OPERATORS
REJECT DISTRIBUTION BY CATEGORY

OPERATOR	BAR SIZE & TYPE	GAGE MARK REJECT CASES*	EXC.REC. VCIDS CASES*	POROSITY & SLAG CASES*	OTHERS	CASES
F	#18-TV	111	10	18	1	
	#11-BV	18	10	3	0	
	OTHERS	7	0	2	2	
G	#18-TV	50	1	0	0	
	#11-BV	0	0	0	0	
	OTHERS	0	0	0	0	
L	#18-TV	32	0	2	0	
	#11-BV	21	24	4	1	
	OTHERS	0	0	0	0	
S	#18-TV	33	16	0	0	
	#11-BV	0	0	0	0	
	OTHERS	0	0	0	0	
X	#18-TV	5	1	0	0	
	#11-BV	0	0	0	0	
	OTHERS	0	0	0	0	
JJ	#18-TV	96	20	9	1	
	#11-BV	2	15	1	0	
	OTHERS	4	2	0	1	
KK	#18-TV	0	0	0	0	
	#11-BV	29	11	1	0	
	OTHERS	1	0	0	0	
CC	#18-TV	0	0	0	0	
	#11-BV	1	0	0	0	
	OTHERS	0	0	0	0	
SUB-TOTALS	#18-TV	327	48	29	2	
	#11-BV	71	60	9	1	
	OTHERS	12	2	2	3	
TOTALS		410	110	40	6	= 566**

*NOTE: CASES ARE INDIVIDUAL TYPES OF REJECTION.

SOME INDIVIDUAL SPLICES HAVE MULTIPLE CASES OF REJECTION.

**THIS NUMBER EXCLUDES HORIZONTAL SPLICES WHICH DO NOT HAVE GAGE MARKS.

C

OPERATOR DISTRIBUTION

<u>Operator</u>	<u>Unit 1 Actual</u>	<u>Unit 2 Actual</u>	<u>Unit 2 Rejects</u>	<u>Statistical Probability For Rejects In Unit 1</u>	
				<u>All Categories</u>	<u>Physical Categories Only</u>
JJ	258	579	130	58	17
F	648	650	154	154	44
S	37	132	40	11	3
G	287	203	46	65	19
X	98	39	5	12	3
L	240	396	79	48	14
KK	178	457	39	15	4
LL	398	16	1	25	7
Totals	<u>2,144</u>	<u>2,472</u>	<u>494**</u>	<u>388*</u>	<u>111</u>

* Statistical probability of cadweld splice rejects in Unit 1 based on percentage of operator rejects from accessible splices (SPP-6) from Unit 2.

** Horizontal splices not included in this total.

INSPECTOR DISTRIBUTION

UNITS 1 AND 2

<u>Inspector</u>	<u>Unit 1 Cadwelds (Actual)</u>	<u>Unit 2 Cadwelds (Actual)</u>	<u>Unit 2 Rejects (Actual)</u>	<u>Statistical Probability For Rejects In Unit 1</u>	
				<u>All Categories</u>	<u>Physical Categories Only</u>
#1	98	1,242	289	23	7
#2	1,880	1,405	117	157	45
#3	48	299	60	10	3
#4	109	92	14	17	5
#5	510	200	12	31	9
#6	346	35	6	59	17
#7	880	366	4	10	3
<hr/>					
Subtotals	3,871	3,639	502	307	89
<hr/>					
#8-11	590	633	0	0	0
<hr/>					
Totals	4,461	4,272	502	307	89

CADWELD SPLICE DISTRIBUTION

<u>Operator</u>	<u>Splice Type</u>	<u>Number of Rejects</u>		<u>Number of Shots</u>		<u>Total Shots</u>
		<u>Cont. #2</u>		<u>Cont. #1</u>	<u>Cont. #2</u>	
JJ	18/18V	32		7	130	137
JJ	18/10V	73		2	186	188
JJ	11 BV	18		249	174	423
JJ	18 BV	7		0	89	89
F	18/18V	67		197	184	381
F	18/14V	15		18	85	103
F	18/11V	3		0	32	32
F	18/10V	32		187	99	286
F	18 BV	9		120	72	192
F	11 BV	28		126	178	304
S	18/10V	40		37	132	169
G	18/18V	35		222	137	359
G	18/14V	11		65	66	131
X	18/18V	1		18	23	41
X	18/10V	4		80	16	96
L	18/18V	16		126	58	184
L	18/14V	13		36	22	58
L	11 BV	50		78	316	394
KK	18 BV	1		24	101	125
KK	11 BV	38		154	356	510
CC	<u>11 BV</u>	<u>1</u>		<u>398</u>	<u>16</u>	<u>414</u>
	Total	494		2,144	2,472	4,616

Splices With Multiple Defects - 66

X Splices With 1 Physical & 1 G.M. Defect -23

* Splices With 3 Defects

1. BV-378	X	23. TV-87	X	45. TV-473	
2. BV-541		24. TV-93	*	46. TV-533	
3. BV-720	X	25. TV-97	*	47. TV-607	
4. BV-724	X	26. TV-110	X	48. TV-632	
5. BV-742		27. TV-153		49. TV-684	X
6. BV-757	X	28. TV-155	X	50. TV-729	*
7. TV-18		29. TV-184		51. TV-773	
8. TV-40		30. TV-192		52. TV-777	
9. TV-46		31. TV-230	X	53. TV-840	
10. TV-50	X	32. TV-339		54. TV-863	X
11. TV-55		33. TV-351		55. TV-869	
12. TV-59	*	34. TV-354		56. TV-890	X
13. TV-65	X	35. TV-356	X	57. TV-914	
14. TV-66	X	36. TV-370		58. TV-926	X
15. TV-68	X	37. TV-401	X	59. TV-940	
16. TV-70		38. TV-403	X	60. TV-959	
17. TV-73	X	39. TV-433		61. TV-967	
18. TV-77	*	40. TV-434		62. TV-971	
19. TV-78	X	41. TV-437		63. TV-983	X
20. TV-79	*	42. TV-440		64. TV-1025	
21. TV-80	X	43. TV-446		65. TV-1064	
22. TV-82		44. TV-459		66. TV-1134	

Individual Splices	504
2 Cases	66
3 Cases	6
	<hr/> 576

DISTRIBUTION OF REJECTS BY TYPE/SIZE AND VISUAL REJECT CATEGORY

Cadweld Type/Size	CAR PC 0602 Appendix											Totals
	A	B	C	D	E	F	G	H	J	K	L	
18-18TV	67	1	0	3	6	1	0	61	7	23	0	169
18-14TV	15	2	0	2	9	0	0	10	0	9	0	47
18-11TV	0	0	0	0	0	0	0	3	0	0	0	3
18-10TV	39	38	7	5	4	0	1	37	3	53	0	187
18-BV	10	2	0	0	2	1	0	0	1	0	3	19
11-BV	61	60	0	4	5	1	0	0	7	3	0	141
11-TH	8	0	0	0	0	0	0	0	0	0	0	8
9-TH	2	0	0	0	0	0	0	0	0	0	0	2
Totals	202	103	7	14	26	3	1	111	18	88	3	576

Key:

Appendix A	No Gage Marks	H	Sleeve Not Centered
B	Excessive Voids	J	Gage Marks Exceed Tolerance
C	Excessive Recess	K	Gage Marks Less Than Tolerance
D	Porosity at Sleeve Ends or Tap Hole	L	Indeterminant - 2TH and 2GM
E	Slag at Sleeve Ends or Tap Hole		
F	Tap Hole Burnout		
G	No Filler Metal Visible		

CADWELD SAMPLING & TESTING FREQUENCIES

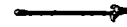
HORIZONTAL

VERTICAL

DIAGONAL

(For Each Grade & Size)

1 P From 1st 10



1 P From Splices
3 S 11-100



1 P From Each
or Subsequent
1.5 Group of 33

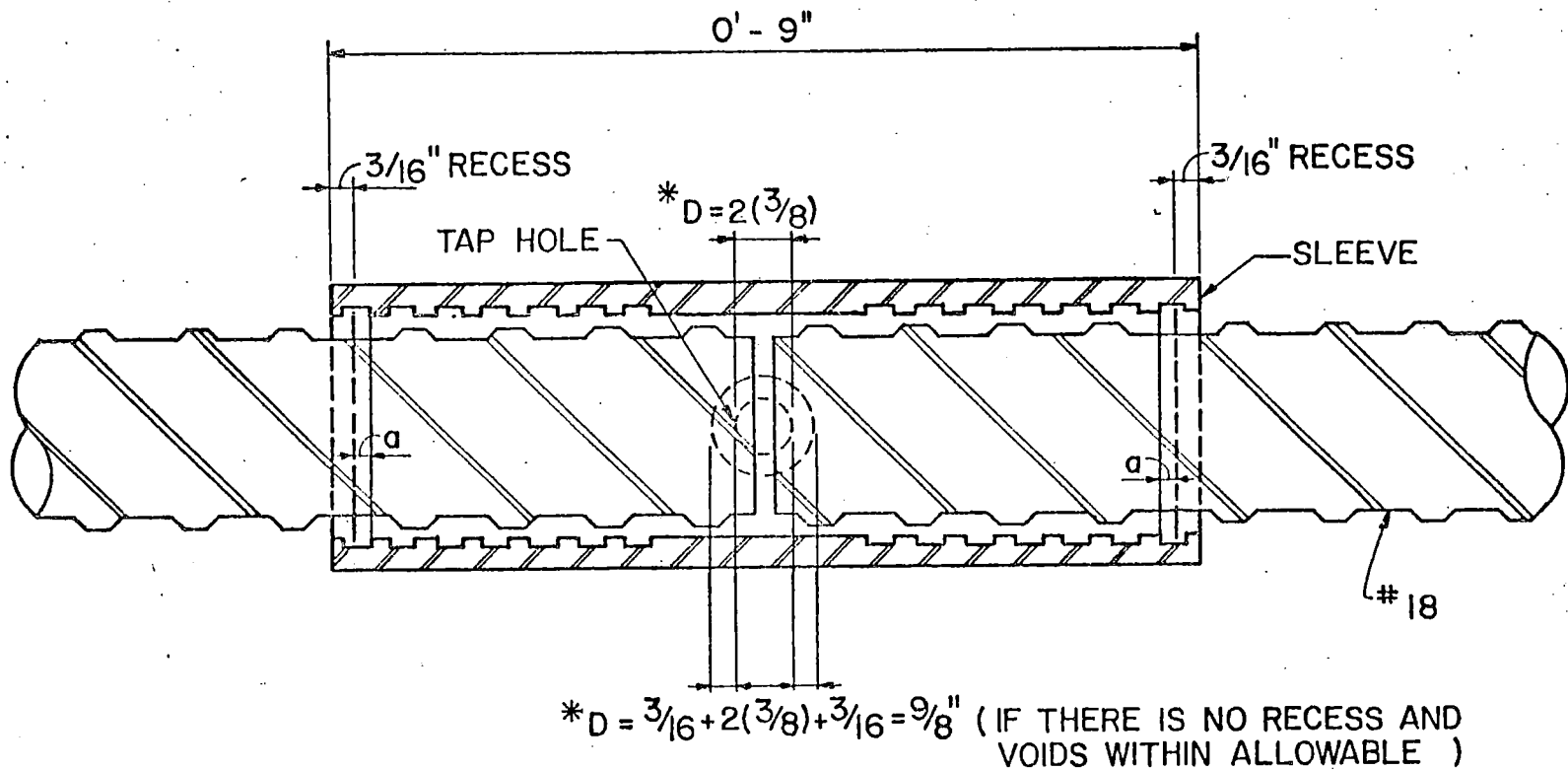


- Notes:
1. Samples from curved bar production shall be straight sister splices
 2. Samples from B-type production shall be sister splices
 3. Selection of samples shall be from recognized methods of random sampling
 4. For back to back sister samples:

1 S From 1st 20

2 S From Splices 11-100

1 S From Each Subsequent Group of 33



* ENDS OF THE BARS SHALL BE WITHIN THE DIAMETER D .

RADIOGRAPHIC EXAMINATION ACCEPTANCE CRITERIA FOR OFF CENTERED BAR ENDS

DISTRIBUTION OF VISUAL REJECT

SPLICES

CASES

328	Individual Splices, only 1 G.M. Defect	328
23	Individual Splices, only 1 G.M. Defect & 1 Phy. Defect	23
29	Individual Splices, only 2 G.M. Defects	58
4	Individual Splices, only 2 G.M. Defects & 1 Phy. Defect	8
2	Individual Splices, only 1 G.M. Defect & 2 Phy. Defects	2
1	Individual Splice, with 2 G.M. Defects	1

387	Subtotal-Individual Splices with at least 1 G.M. Defect	420
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109	Individual Splices, only 1 Phy. Defect	109
23	Individual Splices, only 1 Phy. Defect & 1 G.M. Defect	23
8	Individual Splices, only 2 Phy. Defects	16
4	Individual Splices, 1 Phy. Defect & 2 G.M. Defects	4
2	Individual Splices, 2 Phy. Defects & 1 G.M. Defect	4

146	Subtotal-Individual Splices with at least 1 Phy. Defect	156
-----	---	-----

CASES

SPLICES

437	Splices with one Defect	437
46	Splices with 1 G.M. & 1 Phy. Defect	23
58	Splices with 2 G.M. Rejects	29
16	Splices with 2 Phy. Defects	8
12	Splices with 1 Phy. & 2 G.M. Defects	4
6	Splices with 2 Phy. & 1 G.M. Defects	2
1	Splice with 2 G. Marks	1

576

504