UNITED STATES
ATOMIC ENERGY COMMISSION
DIVISION OF COMPLIANCE, REGION IV
10395 WEST COLFAX, ROOM 200
DENVER, COLORADO 80215

November 10, 1969

J. P. O'Reilly, Chief
Reactor Inspection and Enforcement Branch
Division of Compliance, Headquarters

THE CADWELD PROBLEM — ADDITIONAL INFORMATION

Mr. A. A. Varela, CO:I, has provided some interesting and valuable information regarding the Cadweld-sleeve problem that involves removal of metal from the sleeve during casting. Mr. Varela made a special effort to obtain this additional information on the circumstances experienced at the Salem Nuclear Station construction site, which were first mentioned in his Report 272/69-3. He has obtained a report from the testing laboratories of the Public Service Electric and Gas Company (PS&GC) on the failure of several #8 Cadweld sleeves. Of particular interest are the three conclusions drawn by PS&GC from the evidence obtained from the tests conducted by this laboratory. They are:

"1. Premature failure of the size 8 cadweld sleeves from Lot No. 11B 68 resulted from excessive thinning of the sleeve wall due to washout of the sleeve material by impingement of the hot liquid metal during the cadweld process.

"2. The spacing between joined rebars in the sleeve was excessive in only two of six failed cadwelds and in three of sixteen not tested production cadwelds. This suggests that spacing of rebars in the sleeves was not a controlling factor as to the cause of washouts.

"3. The amount of metal removed from the ends of the rebars and the washouts in the sleeve material indicate that the temperature of the molten cadweld metal may have been excessive when entering the sleeve."

The above conclusions lead me to believe that the basic cause of burn-through, washout, wastage, or whatever term we apply to the phenomenon, is the condition of the powder, rather than the amount of void volume which receives the liquid metal. You will recall that information Mr. Crews obtained from an Erico representative recently in California was to the effect that relatively large voids within the sleeve (due to improperly spaced rebar or large annuli surrounding rebar) was the principal cause of burn-through. This information now seems clearly contradictory to the findings at the Salem Station, which have been reported by Mr. Varela. It is particularly significant, I believe, that Erico intended to change the thickness of its #8 sleeve, as late as last June, to forestall burn-through.

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Since a new method of packaging the Cadweld powder has been instituted, reportedly because of moisture pickup by the powder, it is conceivable that unusually high liquid metal temperatures could result if the powder has been contaminated with water. Also, of course, lack of homogenization of the powder prior to its use could conceivably cause unusually hot metal at the time of casting. Mr. Seidle has stated that powder having improper proportions of ingredients has found its way to at least one construction site. This obviously could also be a source of unusually high casting temperatures.

I have discussed with Mr. Seidle the content of the documents provided by Mr. Varela. He stated that during the forthcoming Erico inspection, Mr. Kelley will attempt to obtain answers to the questions I have posed previously with regard to the burn-through phenomenon. I am making available, directly to Mr. Seidle, copies of the documents supplied by Mr. Varela, in order that he might utilize this additional information in the preparation for the forthcoming Erico inspection.

John W. Flora

John W. Flora
Senior Reactor Inspector

Attachments:
Exhibit A and Exhibit B

CC: W. C. Seidle, CO:II, w/att
A. A. Varela, CO:I, wo/att

EXHIBIT A

QAV 7/30/69

FORM 108

MEMORANDUM

UNITED ENGINEERS & CONSTRUCTORS INC.

JOB No. 9443.01 OFFICE: Salem Nuclear Gen. Sta.

DEPT. Quality Control DATE: June 13, 1969

TO: Mr. E. Navin JUN 14 '69 J.M.M. COPIES: L. Roscoe
R. Evans
V. Blenx
R. Vurpillat
V. Corbie
File

FROM: Mr. M.R. Halliburton

SUBJECT Report - Failure of #8 Size Cadweld Sleeves

In the normal progression of cadweld crew testing, production samples of two crews work on #8 cadwelds were removed and tested. Crew 23 weld 15H failed in the sleeve below the design strength of the bar. Two previous welds were removed, 13H and 14H. One of these failed in the sleeve at a low value.

The sample selected from Crew 3 work, #560H also failed in the sleeve below design strength. Two previous cadwelds were removed and tested both passed, one just barely. At this point it was recognized that a cadweld sleeve problem existed instead of a cadwelder deficiency.

Mr. George Lind of Erico was notified and caused tests on these sleeves (lot 11B68) to be made by Erico. He reported that the results were "marginal" and Erico would change to a sleeve with 1/16" greater wall thickness for future shipments of #8 sleeves.

Five additional cadwelds were removed and tested by Quality Control. Three of these failed in the sleeve below the design strength of the bar. The score now being 6 failures and 5 passed; Quality Control ordered the cadwelds made with these sleeves removed. This amounts to approximately 85 joints located in the lower and upper rings of the lower containment mat of #1 Unit. Three companion splices will be made and tested on the new thicker sleeves supplied by Erico before production splicing is done.

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Milton R. Halliburton

Milton R. Halliburton
Quality Control Supervisor

EXHIBIT "B"

Public Service Electric and Gas Company

80 Park Place, Newark, New Jersey 07101
Telephone (201) 622-7000

October 17, 1969

Mr. A. A. Varela
Atomic Energy Commission
Division of Compliance
970 Broad Street
Newark, New Jersey 07102

Dear Mr. Varela:

DOCUMENTATION
NO. 1 AND 2 UNITS
SALEM NUCLEAR GENERATING STATION

Enclosed is one copy of the following document as requested by you per your telephone call on October 17, 1969:

Public Service Laboratory Report No. 61396,
Failure of Size 8 Cadweld Sleeves

Very truly yours,

P. W. Schneider
Mechanical Engineer
Electric Engineering Department

AN/DP:ND

PUBLIC SERVICE ELECTRIC AND GAS COMPANY

ELECTRIC DEPARTMENT

TESTING LABORATORY REPORT

Noted
☐ WLC
AUG 5 1969
☐ RAA ☐ PT ☐ RAA
☐ RAL ☐ RM ☐ VS
☐ SFF ☐ RD ☐ [illegible]
☐ WC ☐ RT ☐ CD
☐ LBB

To the Chief Engineer
Electric Engineering Department

July 28, 1969

No. 61396

Attention Structural Engineer

SUBJECT: FAILURE OF SIZE 8 CADWELD SLEEVES - SALEM NUCLEAR GENERATING STATION

INTRODUCTION:

Premature failure occurred in several production and companion cadweld splices of size 8 steel reinforcing bar during tensile testing at the Salem Laboratory. The cadweld splices which are tested in tension on a Forney Testing Machine must meet the 90,000 psi minimum ultimate tensile strength for the A.S.T.M. A 432 reinforcing bar material. One production splice and one companion splice tested on June 7, 1969 failed at an ultimate tensile strength of 89,110 psi (splice 3-960M) and 81,770 psi (splice 23-15MT) respectively. Prior to this date no No. 8 splices had been tested. Because of the low results on the first two tests, nine additional No. 8 cadweld splices were tested on June 10 and June 12. The results of the tests tabulated in Table I show that four of the nine splices failed below the 90,000 psi minimum. Of the total of eleven splices tested, ten broke in the cadweld sleeve through the top hole. The Laboratory was asked to make a detailed study to determine the cause of their failure.

TEST PROCEDURES AND RESULTS:

I. Examination of New Sleeves

All of the failed cadweld sleeves were from Lot No. 11368. Four new sleeves from the lot which had failed were submitted for a dimensional analysis. The identifying numbers on the sleeve were Sleeve No. T-891, T-7-8101, Cart. No. 755, 770. The 1-3/4" outside diameter by 1-1/4" inside diameter sleeve was 5" long and has a cross-sectional area at the top hole of 1.049 square inches. The sleeve contains circumferential internal grooves. The cadweld filler metal locks or keys the sleeve through the internal grooves to the reinforcing bars through the deformations or ribs on the bars.

TEST PROCEDURES AND RESULTS: (CONT'D)

I. Examination of New Sleeves (cont'd)

A dimensional analysis was made on two of the four new sleeves. To determine if there was a difference in dimensions between the new sleeves and those used on cadwelds in the field, a dimensional analysis was also made on cadweld splice 3-551M. The sleeve from the splice was cut longitudinally and the rebar and cadweld material was removed from the internal surface of the sleeve prior to taking dimensions. The results of the dimensional analysis are tabulated as follows.

	Dimensions - inches					
	Inside Diameter at Top Hole		Outside Diameter		Wall Thickness at Top Hole	
Sleeve	Min.	Max.	Min.	Max.	Min.	Max.
New (1)	1.250	1.255	1.751	1.752	0.249	0.254
New (2)	1.253	1.255	1.750	1.752	0.248	0.255
Splice 3-551M	1.260	-	1.750	-	0.241	0.256

The cross-sectional area calculated from the above dimensions was 1.043 square inches for the two new sleeves in the area of the tap hole. The result is in fair agreement with the 1.049 square inch area specified for this type sleeve in specifications published by the Rebar Division of Erico Products Inc. The cross-sectional area of the sleeve at the tap hole is approximately 33% greater than the 0.790 square inch nominal cross-sectional area of the size No. 8 reinforcing bars being joined. Dimensional measurements were also made of the wall thickness in the bottom of the internal grooves of the two new sleeves and the sleeve from production cadweld splice 3-551M. The wall thickness in this area is tabulated as follows.

	Wall Thickness In Grooves - inches	
Sleeve	Min.	Max.
New (1)	0.218	0.233
New (2)	0.198	0.221
Splice 3-551M	0.188	0.195

Of the six cadwelds which failed to meet minimum ultimate tensile strength requirements on tensile testing, two (cadweld No. 3-560M and 23-15MT) had a fracture which extended through an internal groove on the back side of the sleeve (Figure 1).

Chief Engr., Elec. Engr. Dept. July 28, 1969
Report No. 61396

TEST PROCEDURES AND RESULTS: (CONT'D)

I. Examination of New Sleeves (Cont'd)

To determine the strength of the sleeve material a tensile test bar was machined from one of the new sleeves and tested. The yield strength of the sleeve material was 78,800 psi and the ultimate tensile strength was 92,500 psi. The material had an elongation of 14.5% in a 2" gage length. The mill certifies that the sleeve meets a minimum tensile strength of 90,000 psi. The material had a hardness of Brinell 180 to 200 and a metallic structure which was normal for the Type C1026 low carbon steel sleeve material.

II. Examination Of Failed And Unfailed Production Cadweld Sleeves

Visual examination of the six sleeves which failed below the required 90,000 psi minimum ultimate strength (Table I) showed evidence of a thin wall in three of the sleeves (Cadweld No. 23-13M, 23-17M and 23-20M) as shown in Figure 1. All six failed sleeves were cut longitudinally through the tap hole and visually examined after macro etching the cross-section. Each inspection verified the presence of thin wall areas in three of the cadweld sleeves (Figures 2 and 3) at circumferential distances of approximately 120 degrees to 180 degrees (directly opposite) the tap hole. The wall thinning appears to have resulted from a washing out of sleeve material caused by the hot liquid metal entering the tap hole during cadwelding. Microscopic examination of samples taken through the thin wall area showed evidence of undercutting of the sleeve wall and rebar material by the cadweld metal (Figure 4).

A hardness survey made on three of the six sleeves which had failed below minimum required ultimate strength (Cadweld No. 3-560M, 23-13M, and 23-20M) showed hardnesses ranging from Brinell 162 to 200 which is normal for the low carbon steel material.

To determine if sleeve material washouts were a major factor in the failure of No. 8 sleeves, sixteen additional (not tension tested) production cadwelds made with the same lot of sleeves were examined. The results of the examination are tabulated in Table II. Six sleeves chosen at random were cut transversely through the tap hole. Five of these sleeves were found to have some degree of wall thinning due to washouts (Sleeve No. 1, 2, 3, 5 and 6).

TEST PROCEDURES AND RESULTS: (CONT'D)

II. Examination of Failed And Unfailed Production Cadweld Sleeves (Cont'd)

It was also desired to establish if the spacing between rebars in the sleeve was a factor in the premature failure of the cadweld splices. When making the cadweld a 3/16" square by 1" long spacer key is placed in the sleeve between the bars being joined. The six failed cadweld splices and three of the not tension tested production cadwelds having known thin wall areas (splice 1, 5 and 6) were split longitudinally to measure the distance between the ends of the rebars in the sleeve. In addition the ten remaining production cadweld sleeves were split longitudinally, at locations where sleeve washouts were suspected, to measure the distance between rebar ends. No washouts were found in the ten sleeves in the areas chosen for sectioning. The results tabulated in Tables I and II show that of the six failed cadwelds examined, the gap between the rebars being joined was excessive (greater than 0.188") in two cadwelds. Of the sixteen production cadwelds not tension tested, the spacing was excessive in three. The distance between the ends of the rebars in the failed cadwelds ranged from 0.140" to 0.250" (Figure 5). The distance in the production cadwelds having known washout areas (splice 1, 5 and 6) ranged from 0.050" to 0.290" and in the ten production splices where no washouts were found ranged from 0.020" to 0.250". It is probable that where the gap was very small (below 0.100") that no spacer key had been placed between the bars prior to welding. The spacer key was found in only five of the examined joints. Misalignment of one or both of the rebars being joined was found in three of the production cadwelds (No. 1, 5 and 13).

Visual examination showed that considerable metal had been removed from the ends of the rebars adjacent to the tap hole due to impingement of the hot liquid metal in all of the examined cadwelds (Figure 6). The condition which is unavoidable due to the nature of the cadweld process will further tend to increase the spacing of the rebars being joined.

CONCLUSIONS:

1. Premature failure of the size 8 cadweld sleeves from Lot No. 11B 68 resulted from excessive thinning of the sleeve wall due to washout of sleeve material by impingement of the hot liquid metal during the cadweld process.

Chief Engr., Elec. Engg. Dept. July 28, 1969
Report No. 61396

CONCLUSIONS: (CONT'D)

2. The spacing between joined rebars in the sleeve was excessive in only two of six failed cadwelds and in three of sixteen not tested production cadwelds. This suggests that spacing of rebars in the sleeves was not a controlling factor as to the cause of washouts.

3. The amount of metal removed from the ends of the rebars and the washouts in the sleeve material indicate that the temperature of the molten cadweld metal may have been excessive when entering the sleeve.

Materials Division Chief

Laboratory Engineer

HJO/HER:MC

CC Mr. V. Bionx
Mr. M. Halliburton

TABLE I

RESULTS OF TENSILE TESTS AND VISUAL EXAMINATION ON CADWELD SPLICES OF SIZE 8 REINFORCING BARS

Splice No.	Date Tensile Tested	Ultimate Tensile Strength PSI	Remarks **	Visual Exam. Distance Between Rebars Inches
23-15NT	6/7/69	81,770	Failed	0.170
3-560N	6/7/69	89,110	Failed	0.140
23-14N	6/10/69	109,110 *	Passed	-
23-13N	6/10/69	82,780	Failed	0.250
3-562N	6/10/69	90,130	Passed	-
3-559N	6/10/69	93,920	Passed	-
23-17N	6/12/69	87,340	Failed	0.190
23-18N	6/12/69	79,750	Failed	0.190
23-19N	6/12/69	92,150	Passed	-
23-20N	6/12/69	77,220	Failed	0.240
23-21N	6/12/69	95,190	Passed	-

Note: (1) * All splices broke in sleeve with the exception of splice 23-14N which broke in rebars.

(2) **Failed splices broke below 90,000 psi minimum requirements of A 432 specification.

(3) Visual exam showed washouts in sleeve No. 23-13N, 23-17N and 23-20N.

TABLE II

EXAMINATION OF SIZE NO. 8 PRODUCTION CADWELDS

Sleeve No.	Cadweld No.	Distance Between Rebar Ends	Remarks
1	3-548H	0.050"	Wall thinned to 0.180" at 80 degree circumferential distance from hole. One rebar cocked to one side in sleeve
2	3-563H	-	Wall thinned to 0.220" at 90 degrees from hole.
3	3-571H	-	Wall thinned to 0.210" at 80 degrees from hole.
4	3-578H	-	No visible sleeve washout.
5	8-381H	0.290"	Wall thinned to 0.130" at 120 degrees from hole. Both rebars cocked to one side in sleeve.
6	23-26H	0.240"	Wall thinned to 0.180" at 110 degrees from hole.
7	"	0.020"	No visible sleeve washout.
8	3-502H	0.040"	No visible sleeve washout.
9	3-566H	0.060"	No visible sleeve washout.
10	3-567H	0.040"	No visible sleeve washout.
11	3-568H	0.040"	No visible sleeve washout.
12	3-573H	0.160"	No visible sleeve washout.
13	"	0.250	No visible sleeve washout. One rebar cocked to one side in sleeve.
14	3-551H	0.040	No visible sleeve washout.
15	"	0.090	No visible sleeve washout.
16	3-569H	0.040	No visible sleeve washout.

TABLE II (CONT'D)

Notes: (1) * Cadwold sleeve identification not legible.

(2) Sleeve No. 1, 5, 15 and 16 split transversely through tap hole and then split longitudinally.

(3) Sleeve No. 2, 3 and 4 split transversely through tap hole to determine thin wall washout areas only.

(4) Sleeve No. 7 through 14 split longitudinally at circumferential locations found to have washouts in sleeves No. 1 through No. 6. Primary interest in these sleeves was distance between ends of joined rebars.

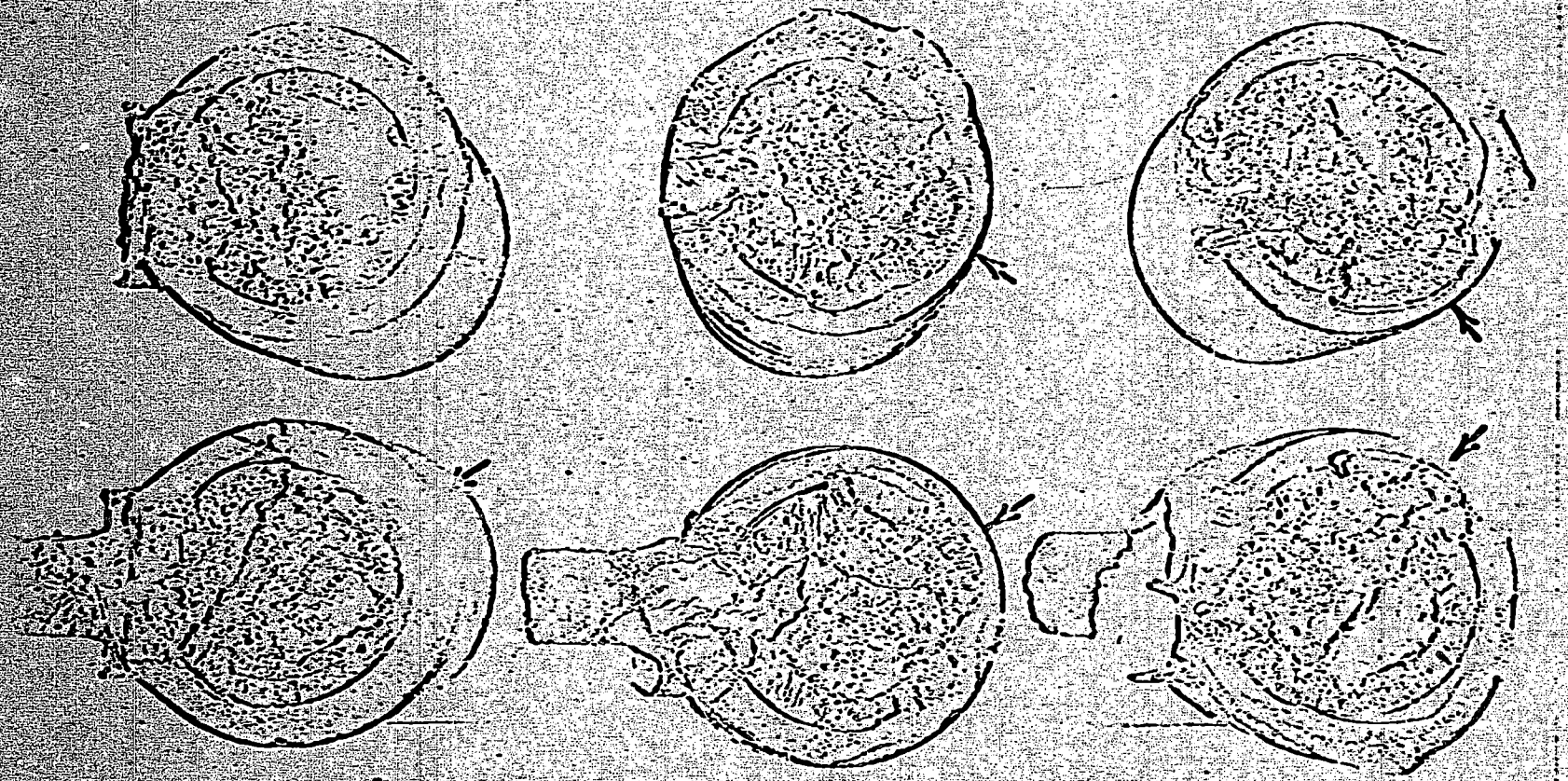


FIGURE 1

Photo No. 2313 Mag. 1X

Three of the cadweld splices which failed below the required minimum ultimate strength showing the thin sleeve wall (arrows) at the fracture through the sleeve in Cadweld 23-13H and 23-20H. Cadweld 3-560H fractured through an internal groove on the back side of the sleeve (arrows).

FIGURE 2

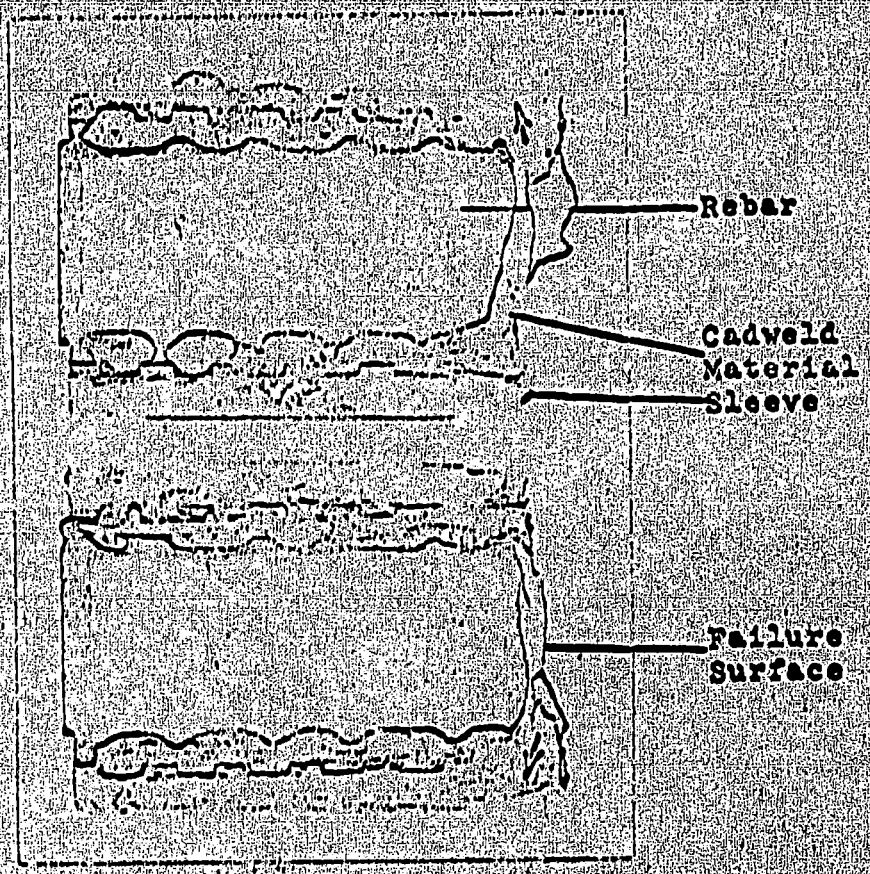


Photo No. 2315 Mag. 1X

The two halves of longitudinally split cadweld splice No. 23-20K. Note the thin wall of the sleeve (arrows) in the area of the failure.

FIGURE 3

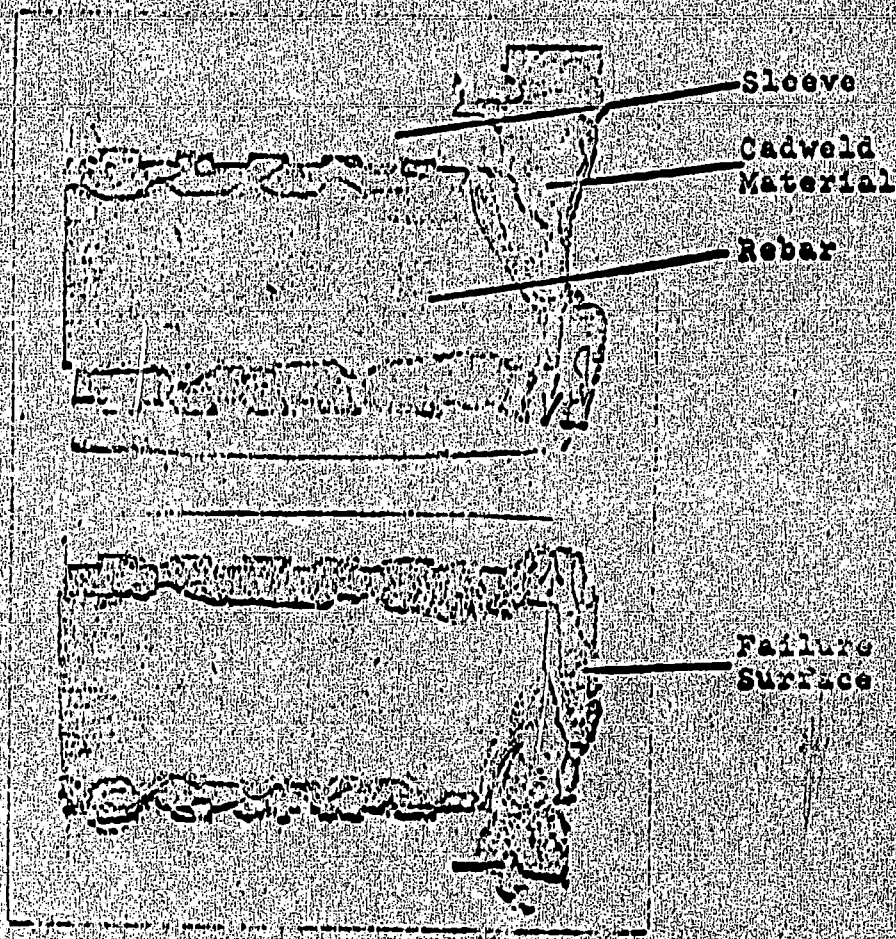
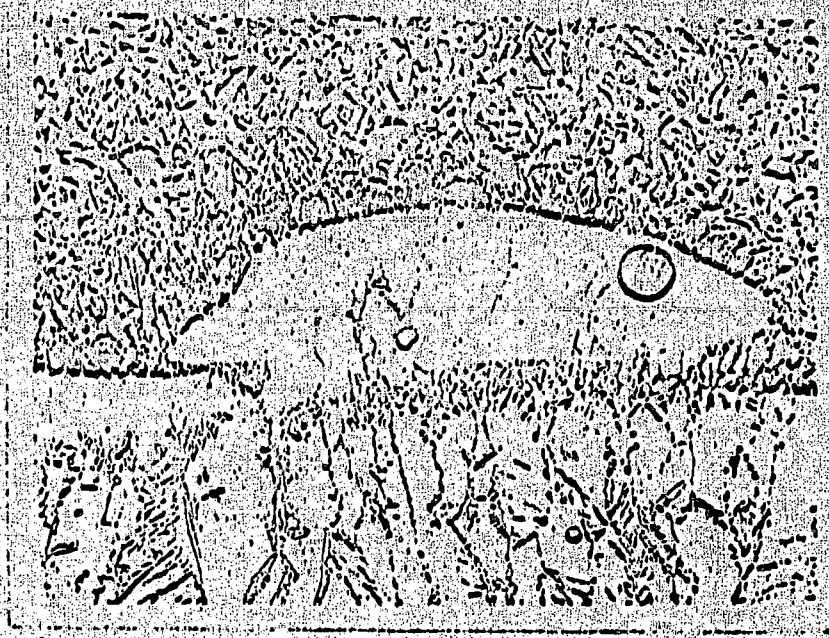


Photo No. 2324 Mag. 1X

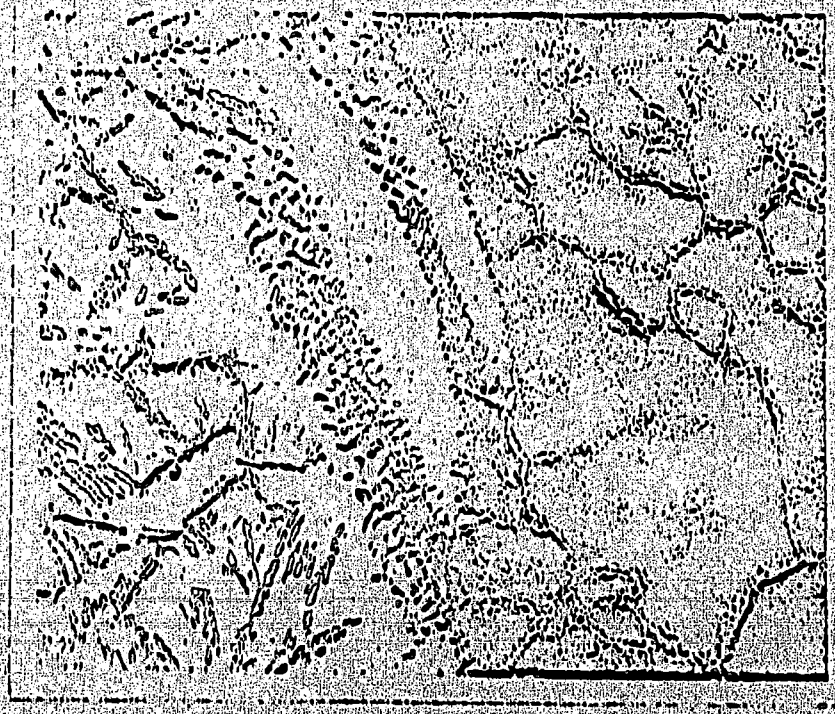
The two halves of longitudinally split cadweld splice No. 23-13H. Note the thin wall of the sleeve (arrows) in the area of the failure.



Sleeve Material

Cadweld Material

Photo No. 2320 Mag. 100X



Cadweld Material

Rebar Material

Photo No. 2321 Mag. 100X

Photomicrographs showing the undercutting and welding of the cadweld material to the sleeve material (top photo) and rebar material (bottom photo) in the area of the thin sleeve wall.

FIGURE 5

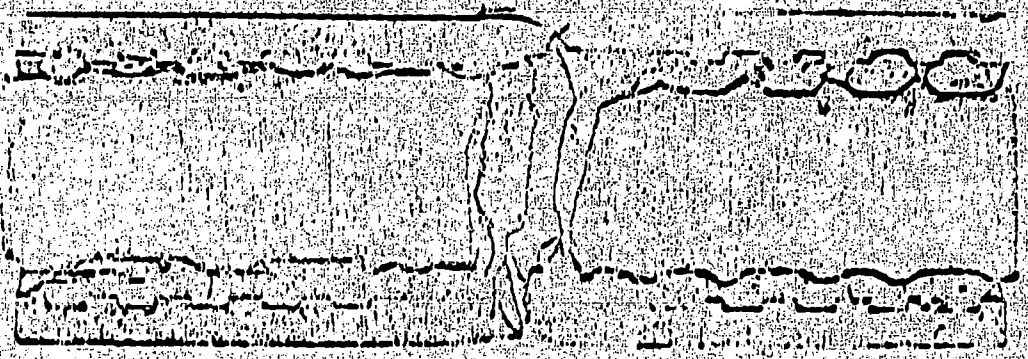


Photo No. 2328 Mag. 1X

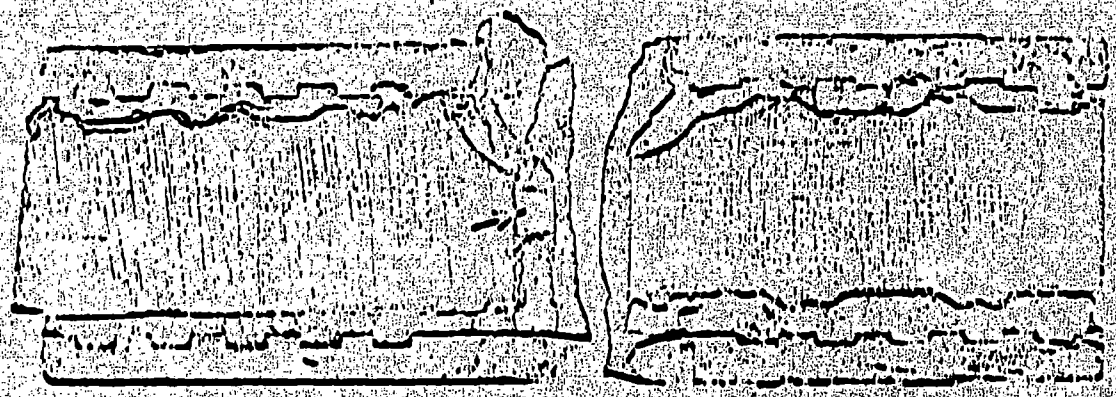


Photo No. 2329 Mag. 1X

Top - A longitudinal cross-section through failed cadweld sleeve No. 23-20H. The spacing between rebars was 0.240" which is excessive.

Bottom - A longitudinal cross-section through failed cadweld sleeve No. 23-18H. The spacing between rebars was 0.190" which is normal. Note the spacer key (arrow).

FIGURE 6

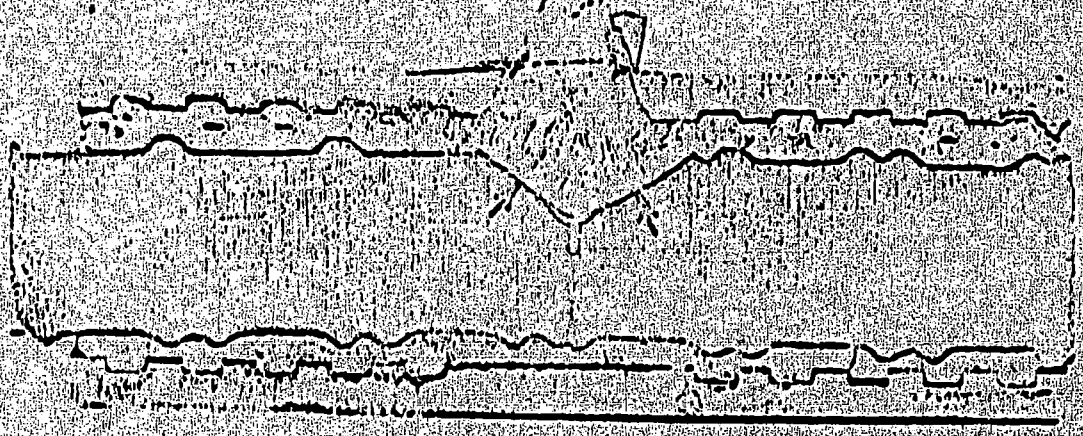


Photo No. 2330 Mag. 1X

A longitudinal cross-section of production cadweld No. 3-551H. Note that considerable metal has been removed from the ends of the rebars (arrows). Note also the very small gap between the rebars indicating that the spacer key may have been absent.