RA

INVESTIGATION OF SIX WIRE
CLADDING DEFECTS IN B&W
REACTOR VESSEL
620-0014-51

REPORT NO. 14
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1.0 INTRODUCTION

The internal surfaces of the NSS14 reactor vessel were overlay clad with a single layer of stainless steel using the B&W six wire process. The consumables were prior tested to a minimum chemistry requirement of 19% chromium and 9% nickel. The contractual analysis requirements for the production overlay were 0.08% carbon max., 17% chromium min., and 7% nickel min., with a minimum ferrite content in the deposit of 5%. Initial cladding of the I.D. surfaces of the vessel was performed in December 1970 with the overlay of the A181 Lower Head Dome to Dutchman Transition Forging Assembly. The A170 Shell Assembly was clad in February 1971 and the A169 Vessel Flange to Nozzle Belt Assembly was completed in April 1971. Each assembly was liquid penetrant inspected after performance of an intermediate post weld heat treatment with no significant defect condition detected.

As a result of the Oconee incident, it was decided to remove the flow vanes installed in the lower head of the vessel. After removal of the vanes a liquid penetrant inspection was performed of the locally ground areas to verify the integrity of the newly exposed cladding surfaces. Rejectable indications were obtained in these areas which initiated a comprehensive repeat inspection of the entire six wire cladding in the vessel. This inspection revealed a general cladding problem with rejectable penetrant indications being discovered in each clad component.

An investigation of the defect condition and the conclusions reached are described below.

2.0 CLADDING HISTORY AND INSPECTION RESULTS

2.1 Consumables

Three consumable combinations were used for six wire cladding of the NSS14 reactor vessel. The qualification records for these consumables are shown in Attachment A. The area of application of each consumable combination is as shown below.

QUALIFICATION	WIRE	FLUX	LOCATION OF USE
WF 173-1	Sandvik 308L Heat #7-08381	Arcos 642CDG Lot #9N8F	A181
WF 190	Sandvik 308L Heat #4-95192	Arcos 642CDG Lot #9E3F	A170
WF 192	Sandvik 308L Heat #4-95171	Arcos 642CDG Lot #9E1F	A169

Each of the combinations produced a six wire deposit that complied with the internal qualification requirement of 19% chromium and 9% nickel minimum. The combinations were thus tolerant of a maximum dilution condition in production overlay operations, consistent with meeting a required 0.08% max. carbon content.

2.2 Penetrant Inspection History After Discovery Of Problem

The initial rejectable penetrant indications in the areas where flow vanes had been removed were rounded in appearance. Further grinding and re-inspection of these areas revealed numerous small randomly oriented linear defects. As a result of this discovery, a complete inspection was performed of the cladding on the dutchman transition forging. Linear indications were detected over 90% of the cladding surface, the condition becoming more apparent after grinding of the as-deposited surface. Two areas located 90° apart were then probed to determine the cladding thickness on the dutchman forging. The values obtained established the thickness to be in the vicinity of 0.230", which is slightly below the normal expected thickness for this process. A complete inspection was then performed of the lower head dome, after buffing of the surface to achieve a clean condition. Linear indications were detected in areas occupying approximately 30% of the dome surface.

Four bands located 90° apart were subsequently inspected along the length of the vessel i.e. from the vessel flange to the dutchman transition forging. Numerous rejectable linear indications were discovered at this time in the core region shell cladding. This discovery initiated a 100% inspection of the six wire cladding in the core region and nozzle belt resulting in the detection of linear indications in both components. It should be noted that inspection of the nozzle belt cladding showed mainly acceptable rounded indications. Grinding of the surface then revealed a linear condition on repeat penetrant inspection.

2.3 Production Cladding Chemistry

The laboratory records for the vessel cladding are shown in Attachment B. Review of this data shows acceptable chemistry values for each of the clad assemblies. The data also indicates values which are generally in excess of 18% chromium and 8% nickel. It would thus appear from this data that dilution was not excessive during cladding of the vessel.

2.4 Ferrite Survey Of Dutchman Transition Forging

On discovery of linear penetrant indications over 90% of the cladding surface in the dutchman transition forging it was decided to establish whether hot cracking was the operative mechanism for the condition detected. A ferrite survey was therefore made at 6" increments of the six wire cladding deposited on the dutchman transition forging and immediate adjacent beads on the lower head dome. Ten beads in all were inspected, the results of the survey being shown in Attachment C. Included in the sketches are the areas which showed the worst penetrant indications. It is apparent from these records that the defect condition was equally prevalent in areas containing 10% ferrite as in other areas with lower measured values.

2.5 Check Analysis Of Cladding In Defective Areas

Four samples were removed for analysis from defective regions in the dutchman cladding. The results obtained and the locations of the samples are shown below.

BEAD #	LOCATION	%C	%Cr	%Ni	%Mn	%S
4	Z Axis	0.061	18.97	8.63	1.70	0.011
8	Y Axis	0.064	19.09	8.67	1.53	0.008
8	Z Axis	0.077	17.78	8.10	1.50	0.017
10	W Axis	0.073	17.59	8.14	1.85	0.008

Respective ferrite predictions of 8%, 9%, 6% and 6% were obtained for the four samples. The latter two values do indicate a reasonably high dilution condition. It is therefore possible that some of the linear penetrant indications in the dutchman cladding were fissures associated with boundary regions locally denuded in ferrite phase. Values of 8% and 9% ferrite are too high to suggest a hot cracking mechanism and may be indicative of similar defects to those observed in the nozzle belt cladding. Since no samples were removed for metallographic examination, however, it is impossible to define the exact nature and type of defects present in this assembly.

2.6 Defect Removal

Local probe grinding indicated that the defects were confined to the surface region of the cladding and could be removed with a remnant cladding thickness in excess of the minimum requirement of 1/8". Grinding was performed until an acceptable penetrant condition was established throughout the vessel. The maximum defect condition occurred in the lower head assembly where 0.060 inches had to be removed to achieve an acceptable penetrant inspection. Defect depths in the core region and nozzle belt cladding were found to be somewhat shallower, an acceptable penetrant condition being achieved after removal of 0.030 - 0.040".

3.0 TEST PROGRAM

3.1 Examination Of NSS14 And Other Production Six Wire Cladding

3.1.1 Two nozzle cutouts from the NSS14 reactor vessel were removed from bonded storage and penetrant inspected after performance of a buffing operation. Linear indications were discovered in the cladding deposited on these cutouts, which was similar in appearance to indications observed in the reactor vessel. A metallographic examination was performed of areas showing penetrant indications in order to establish the nature and type of defects present in the cladding.

3.1.2 Four nozzle cutouts from other contracts were examined to establish whether similar defects were present in the six wire cladding. Penetrant inspection revealed very few indications and thus metallography was performed at random with specimens being selected from locations showing different ferrite values.

3.2 Evaluation Of Effects Of Variations In Cladding Parameters

[redacted]

Ex. 4

4.0 TEST RESULTS

4.1.1 NSS14 Cladding Results

Figure 1 shows a view of a cross-section of NSS14 cladding containing surface defects. Figures 2 and 3 show higher magnification views of the defects and indicate that the defects are interdendritic with entrapped slag also present. The defects are not associated with regions locally denuded in ferrite phase. Work done at the Alliance Research Center[1] on samples from the same cutouts also confirms the presence of slag in the defects and a completely normal distribution of ferrite phase in the vicinity of the defects.

The failure to detect the presence of these surface defects during the inspection cycle performed after an intermediate post weld heat treatment is disturbing. It has been the experience of Mt. Vernon Works that defects in six wire cladding (including fissuring created by high dilution) are rarely detected at this stage of fabrication. Problems are normally detected only after multiple heat treatment cycles. The extent of a defect condition is also rarely established until a surface grinding operation has been performed to remove the as-deposited surface. It was therefore decided to thermally cycle samples of NSS14 cladding in a similar manner to that which occurs during production heat treatment, in order to establish whether the heat treatment cycles alter the defect size or appearance. Figures 5 and 6 show defects that were detected by dye penetrant inspection after performance of the heat treatment. Significant scale buildup has occurred but it would appear that no growth or major alteration has occurred as a result of heat treatment.

4.1.2 Production Cladding Samples

Metallographic examination of the four production nozzle belt cutouts failed to reveal any evidence of defects similar to those detected in the NSS14 reactor vessel cladding. Extensive sampling was performed of each cutout with special emphasis being placed on specimen removal from locations with varying ferrite contents. Isolated instances of surface fissures were observed with the majority of the defects falling in a depth range of 0.001 to 0.004". Figure 10 shows the worst case defect condition observed, which was removed from NSS 9 cutout material that had been subjected to a 40 hour post weld heat treatment at 1100-1150°F.

4.2 Cladding Trial Results

[redacted]

Travel Speed inch/minute	Cladding Thickness	Deposit Ferrite Content

[redacted]

EX. 4

5.0 DISCUSSION

Examination of production cladding from the NSS14 nozzle belt has revealed surface defects, which from location and appearance can be categorized as interdendritic shrinkage. The present of entrapped slag further indicates that the defects formed during the weld metal solidification process. Measurement of the ferrite content in the samples and metallographic examination of the structure shows an adequate quality of ferrite phase adjacent to the surface of the defects. It would thus appear that this type of defect is not related to hot cracking or fissuring commonly observed in austenitic stainless weld metals containing low quantities of low ferrite phase.

It is postulated that this type of defect would be expected to occur most readily in a situation where heat input was at a maximum and very high weld pool temperatures were created. Such conditions would be conducive to growth of a coarse dendritic structure and hence maximum chance of development of interdendritic shrinkage. The cladding thickness of the nozzle belt component was established to be in the range of 0.375 to 0.400", which would indicate that a deviation occurred from the prescribed process parameters during production cladding. The most rational explanation for the observed thickness would be that the welding head was not correctly positioned and that a speed some what slower than the required [redacted] also have been used. Positioning of the head behind center position with respect to direction of rotation can result in a significant increase in cladding thickness, even with travel speeds close to the required [redacted] Location of the head past center will also result in a situation where molten cladding would tend to be concentrated under the arc, thereby reducing dilution from the base material and increasing weld pool temperatures. It is thus believed that the most rational explanation for the defects in the nozzle belt cladding is incorrect set up of the welding head during production welding. An attempt was made with 28" I.D. pipe to experimentally evaluate this concept. [redacted]

Examination of the ferrite records for the lower head assembly shows defects have occurred equally in cladding containing either moderate or high ferrite contents. The chip samples removed from defective regions in the six wire beads show Schaeffler predictions of 6 to 9% ferrite. The 6% ferrite values would not rule out the presence of a limited fissuring condition in certain areas of the lower head assembly, but the equal prevalence of penetrant indications in regions of high ferrite content suggests similar defects to those located in the nozzle belt cladding may also have been present. Two cladding thickness measurements were made in the lower head assembly, which only indicated a thickness in the vicinity of 0.230". [redacted]

Ex. 4

Small interdendritic shrinkage defects with entrapped slag were detected in experimental deposits made with low travel speeds and increased voltages above the range prescribed for the process. The use of marginal increases in voltage above the [redacted] range cannot be ruled out as never occurring in production, especially if supervision is faced with a high dilution condition in a difficult component to clad such as a dome assembly. [redacted]

These defects are not readily explained on the basis of the low ferrite content of the deposit, since they are not characteristic of the fissuring condition that would be normally expected. These factors coupled with the detection of small shrinkage defects containing entrapped slag in cladding made with correct parameters raise the question of whether the six wire process is inherently susceptible to shrinkage type defects.

Review of the work done in the present study does indicate that shrinkage defects of a size detectable by penetrant inspection can occur in six wire cladding deposited with considerable variations of parameters. It is considered that the high heat input of this process makes it particularly susceptible to solidification defects, which may prove impossible to totally eliminate during production cladding operations. Further work is required, however, if it is desired to conclusively establish whether defect occurrence and magnitude show a positive correlation with welding parameters and practices used.

6.0 CONCLUSIONS

(1) Metallographic examination of NSS14 nozzle cutouts revealed the presence of solidification defects at the surface of the cladding. It is believed that these defects are characteristic of interdendritic shrinkage and occurred in the latter stages of the weld metal solidification process.

(2) The failure of penetrant inspection to detect these cladding defects after an initial intermediate post weld heat treatment is not fully understood. The ability of penetrant inspection to reveal the condition after grinding of the as-deposited surface in the nozzle cutouts, suggests that the problem is related to some surface characteristic of the cladding. Penetrant inspection has also failed to reveal fissuring type defects in the past when the inspection was performed on the as-deposited surface after an initial heat treatment. Grinding of the surface also facilitates detection of this type of defect. It would therefore appear probable that a surface film condition must exist, which prevents entry of dye into a surface defect.

(3) It is believed that the type of defect observed during metallographic examination is most readily explained on the basis of the use of a practice leading to extremely high weld pool temperatures. Experimentation to date is not complete, but does indicate that the six wire process may be inherently susceptible to some extent to this type of problem.

7.0 RECOMMENDATIONS

Ex 4

(1) [redacted] Experience with Mt. Vernon cladding problems continues to indicate that linear type defects in six wire cladding cannot be properly detected until after removal of the as-deposited surface.

(2) Further studies should be made of the incidence [redacted]

Ex. 4

(3) A review should be made by Welding Development personnel of what data exists on the amperage values obtained with different lots of 642CDG and 642CDK fluxes. Consideration should be given to evaluation of the effect of this variation on incidence of defect.

(4) The six wire process deposits cladding with thickness considerably in excess of minimum Equipment Specification requirements. An increase in travel speed to reduce this thickness is not possible because of a resultant deterioration in deposit quality. It is believed that an evaluation should now be made to establish whether a reduction in thickness can be achieved by using reduced wire feed rates. [redacted]

(5) If further refinement of the six wire process is determined to be not feasible, serious consideration should be given to use of this type of process with a reduced number of wires.

(1). Reference - I.R. Sprung: LR:73:6509-01:1
Metallurgical investigation of NSS14 wix wire cladding.

ATTACHMENT A

RECORD OF FILLER WIRE QUALIFICATION TEST

TEST NO. WF-173-1

DIAMETER	ELECTRODE SPECIFICATION AND WELDING PROCESS	FILLER WIRE IDENTIFICATION AND/OR FLUX	CORE WIRE HEAT NO.
1/16"	2E4-156-20 6 Arc Clad (SST)	Sandvik 308L Stn. Stl. 642 CDG Lot 9N8F	7-08381

P. ORDER NUMBER	TYPE OF CURRENT	AMPERES

WET BATCH EQUIVALENCY CHEMICAL ANALYSIS TESTS

BATCH	LAB. NO.	PAD	C.	MN.	P.	S.	SI.	CR.	NI.	MO.	OTHER
	9071	5 Wire	.067					19.16	9.23		
	9070	6 Wire	.068					20.01	9.49		
	9069	Base Metal	.035								
	TEST REPORT	ANALYSIS									

TENSILE PROPERTIES

TEST NO.	HEAT TREATMENT	ULT. TEN. STR. PSI	YIELD POINT PSI	E-LONG IN 2" %	RED OF AREA %
		N.R.			

SPY ______ IMPACT TEST @ ______ OF ______ FT/LB. ENERGY LOAD

HEAT TREATMENT	TEST NO.	FT/LB.	TEST NO.	FT. LB.
	N.R.			

GUIDED BEND TESTS

FACE	ROOT	SIDE
		Acceptable
N.R.	N.R.	Acceptable

MICRO OR MACRO FISSURE ANALYSIS.	Acceptable

MATERIAL APPROVAL	APPROVED	REJECTED
NAVSHIPS - 250/1500-1	N/A	
ASME - COMM'L NUCLEAR	X	
STEAM GENERATORS	N/A	

GROOVE WELD TEST

RADIOGRAPHIC EXAMINATION

WE HEREBY CERTIFY THAT THE ABOVE MATERIAL HAS BEEN TESTED IN ACCORDANCE WITH THE ABOVE LISTED SPECIFICATION AND IS IN CONFORMANCE WITH ALL REQUIREMENTS.

WIRE FOLIO NO. 508-579

IX FOLIO NO. 499-004

WORKS Mt. Vernon

CONTRACT NO. ______

DATE 10/13/70

SIGNED Babcock & Wilcox Company

INSPECTION AGENCY ______

INSPECTOR J.B. Toon (signature) J.B. Toon

BARBERTON, OHIO

[illegible]CORD OF FILLER WIRE QUALIFICATION TEST

TEST NO. WF 190

[illegible]	[illegible]	FILLER WIRE IDENTIFICATION	[illegible]
1/16	2E4-156-20 6 Arc Clad (SST)	Sandvik 308L STN STL 642 CDG Lot 9E3F	4-95192

P. ORDER NUMBER	TYPE OF CURRENT	AMPERES

WET BATCH EQUIVALENCY CHEMICAL ANALYSIS TESTS

[illegible]	[illegible]	PAD	C.	MN.	P.	S.	SI.	CR.	NI.	MO.	[illegible]
	9541	5 wire	.073					20.04	10.04		
	9542	6 wire	.059					20.45	10.34		
	9540	Build-up	.040					23.43	11.45		
	TEST REPORT	ANALYSIS									

TENSILE PROPERTIES

TEST NO.	HEAT TREATMENT	ULT. TEN. STR. PSI	YIELD POINT PSI	E-LONG IN 2" %	RED OF AREA %
		N.R.			

CHARPY ______ IMPACT TEST @ ______ OF ______ FT/LB. ENERGY LOAD

HEAT TREATMENT	TEST NO.	FT/LB.	TEST NO.	FT. LB.
	N.R.			

GUIDED BEND TESTS

FACE	ROOT	SIDE
		Acceptable
N.R.	N.R.	Acceptable

MICRO OR MACRO FISSURE ANALYSIS.	ACCEPTABLE

MATERIAL APPROVAL	APPROVED	REJECTED
NAVSHIPS - 250/1500-1	N/A	
ASME - COMM'L NUCLEAR	X	
STEAM GENERATORS	N/A	

GROOVE WELD TEST

RADIOGRAPHIC EXAMINATION

WE HEREBY CERTIFY THAT THE ABOVE MATERIAL HAS BEEN TESTED IN ACCORDANCE WITH THE ABOVE LISTED SPECIFICATION AND IS IN CONFORMANCE WITH ALL REQUIREMENTS.

[illegible] FOLIO NO. 508-577

[illegible] FOLIO NO. 499-004

[illegible] Mt. Vernon

CONTRACT NO. ______

DATE 12/9/70

SIGNED Babcock & Wilcox

INSPECTION AGENCY ______

INSPECTOR [signature] J.B. TOON

ATTACHMENT A
THE BABCOCK & WILCOX COMPANY
POWER GENERATION DIVISION
BARBERTON, OHIO

RECORD OF FILLER WIRE QUALIFICATION TEST — TEST NO. WF 192

DIAMETER	ELECTRODE SPECIFICATION AND WELDING PROCESS	FILLER WIRE IDENTIFICATION AND/OR FLUX	CORE WIRE HEAT NO.
1/16	2E4-156-20 6 Arc. Clad. (SST)	SANDVIK 308L STN STL 642 CDG Lot # 9E1F	4-95171

P. ORDER NUMBER	TYPE OF CURRENT	AMPERES

WET BATCH EQUIVALENCY CHEMICAL ANALYSIS TESTS

BATCH	LAB. NO.	PAD	C.	MN.	P.	S.	SI.	CR.	NI.	MO.	CO
	9731	5 wire	.075					19.03	9.43		.060
	9732	6 wire	.061					19.88	9.98		.060
	9736	1" Build up	.033					23.42	11.30		.060
	9733	Base Material	.210								
				Ferrite 5 wire 10-15%							
					6 wire 10-15%						
	TEST REPORT	ANALYSIS									

TENSILE PROPERTIES

TEST NO.	HEAT TREATMENT	ULT. TEN. STR. PSI	YIELD POINT PSI	E-LONG IN 2" %	RED OF AREA %
		N/R			

CHARPY ____ IMPACT TEST @ ____ OF ____ FT/LB. ENERGY LOAD

HEAT TREATMENT	TEST NO.	FT/LB.	TEST NO.	FT. LB.
	N/R			

GUIDED BEND TESTS

FACE	ROOT	SIDE
N/R	N/R	Acceptable
		Acceptable

MICRO OR MACRO FISSURE ANALYSIS.	ACCEPTABLE

MATERIAL APPROVAL	APPROVED	REJECTED
NAVSHIPS - 250/1500-1	N/A	
ASME - COMM'L NUCLEAR	X	
STEAM GENERATORS	N/A	

GROOVE WELD TEST
RADIOGRAPHIC EXAMINATION

WE HEREBY CERTIFY THAT THE ABOVE MATERIAL HAS BEEN TESTED IN ACCORDANCE WITH THE ABOVE LISTED SPECIFICATION AND IS IN CONFORMANCE WITH ALL REQUIREMENTS.

WIRE FOLIO NO. 508-577
FLUX FOLIO NO. 499-004
WORKS Mt. Vernon
CONTRACT NO. ____

DATE January 19, 1971
SIGNED Babcock & Wilcox Co.
INSPECTION AGENCY ____
INSPECTOR [signature]

ATTACHMENT B

CONTRACT 620-0014-51-1 S/N A169-2014-51-1 SHEET

DATE	FERRITE	BEAD No.	LAB No.	C	Cr	Ni	Co		
3/10/71	10-15%	START 1ST	10084	.067	18.92	9.34	.046		
"	"	1+90°	10085	.067	18.44				
"	"	1+180°	10086	.066	18.47				
"	"	1+270°	10087	.064	18.73				
"	"	2	10088	.055	19.89				
3/11/71	"	3	10101	.072	19.72				
"	"	4	10102	.066	20.73				
"	"	5	10103	.070	20.33				
"	"	6	10104	.071	19.97	FLANGE & NOZZLE BELT			
"	"	7	10105	.068	19.91				
"	"	8	10110	.072	19.79				
3/12/71	"	9	10111	.069	20.31	WIRE HEAT 495171 & D9570T			
"	"	10	10112	.073	19.81				
"	"	11	10113	.073	19.86				
"	"	12	10114	.072	19.83				
"	"	13	10115	.070	20.16	FLUX LOT #9E1F			
3/15/73	"	14	10117	.067	19.91		0A8F		
"	"	15	10118	.063	20.17	WF 192			
"	"	16	10119	.070	19.47	WF 133			
"	"	17	10120	.066	20.05				
"	"	18	10124	.066	19.97				
"	"	19	10125	.061	20.08				
"	"	20	10127	.060	20.24				
3/16/71	"	21	10128	.062	18.18				
"	"	22	10129	.061	19.48				

ATTACHMENT B

CONTRACT 620-0014-51-1 S/N A169-2014-51-1 SHEET

DATE	FERRITE	BEAD No.	LAB No.	C	Cr	Ni	Fe		
3/16/71	10-15%	23	10134	.057	20.37				
3/17/71	"	24	10135	.062	20.12				
"	"	25	10138	.065	19.68				
ACCEPT #201573									

ATTACHMENT B

CONTRACT 620-0014-51-1 S/N A170-2014-51-1 SHEET

DATE	FERRITE	BEAD No.	LAB No.	C	Cr	Ni	Co		
1/27/71	7.5-10%	START 1ST	9865	.063	18.83				
"	"	1+90°	9866	.063	18.94				
1/28/71	"	1+180°	9868	.060	18.96	10.02	.064		
"	"	1+270°	9871	.059	18.87				
"	10-15%	2	9872	.057	19.53				
"	"	3	9875	.056	20.07				
1/29/71	"	4	9879	.060	19.62				
"	"	5	9881	.054	20.07				
"	"	6	9882	.057	19.49				
"	"	7	9883	.057	20.13				
"	"	8	9887	.057	20.38				
"	"	9	9889	.062	20.12				
"	"	10	9894	.062	19.82				
"	"	11	9898	.062	20.21				
"	"	12	9899	.063	20.05				
2/1/71	"	13	9902	.064	20.18				
"	"	14	9905	.066	20.06				
"	"	15	9908	.063	20.14				
"	"	16	9912	.066	19.87	WIRE HEAT #495192			
2/2/71	"	17	9921	.063	20.14				
"	"	18	9922	.064	20.19	FLUX #9E3F			
"	"	19	9925	.062	19.97				
"	"	20	9927	.060	20.24				
"	"	21	9928	.060	20.43				
"	"	22	9930	.053	19.85				

ATTACHMENT B

CONTRACT 620-0014-51-1 S/N A170-2014-51-1 SHEET

DATE	FERRITE	BEAD No.	LAB No.	C	Cr	Ni	Fe		
2/2/71	10-15%	23	9938	.058	20.00				
"	"	24	9939	.057	20.11				
2/3/71	"	25	9945	.053	20.55				
"	"	26	9947	.056	20.36				
2/4/71	"	27	9956	.055	20.56				
"	"	28	9957	.058	20.51				
"	"	29	9958	.062	19.82				
"	"	30.	9963	.063	20.41				
2/5/71	"	31	9966	.067	19.66				
"	"	32	9967	.065	19.83				
"	"	33	9968	.065	20.04				
"	"	34	9969	.062	20.17				
"	"	35	9970	.064	20.17				
"	"	36	9971	.065	20.28				
"	"	37	9973	.065	19.84				
"	"	38	9982	.072	20.06				
2/6/71	7.5-10%	39	9983	.074	19.45				
2/8/71	10-15%	40	9985	.067	19.90				
"	"	41	9956	.069	19.78				
2/9/71	"	42	9987	.069	19.65				
"	"	LAST BEAD 43	9988	.063	20.33				
ACCEPT #208634									
WIRE HEAT #495192									
FLUX #9E3F									
WF 190									

ATTACHMENT B

CONTRACT 620-0014-51 S/N A181-2014-1 SHEET 1 of 1

DATE	FERRITE	BEAD No.	LAB No.	C	Cr	Ni	Co		
12/9/70	7.5-10%	START	9573	.063	17.76	8.31	.040		
"	"	1+90°	9574	.063	18.22				
"	"	1+180°	9576	.067	18.01				
"	"	1+270°	9578	.066	18.12				
"	10-15%	2	9579	.058	18.86				
"	"	3	9581	.055	19.32				
"	"	4	9583	.063	18.68				
"	"	5	9588	.056	19.79	DOME AND DUTCHMAN			
"	"	6	9590	.060	19.11				
12/10/70	"	7	9594	.053	19.61				
"	"	8	9595	.061	18.58	WIRE HT.NO. 708381			
"	"	9	9596	.052	19.39	FLUX - 9N8F			
"	"	10	9598	.063	18.38	WF - 173-1			
"	"	11	9602	.055	19.58				
"	"	12	9603	.057	19.42				
"	"	13	9606	.057	18.88				
"	"	14	9607	.064	18.54				
12/11/70	"	15	9608	.053	19.46				
"	"	16	9609	.050	19.96				
"	"	17	9610	.057	19.15				
"	"	18	9611	.059	18.99				
"	"	19	9612	.057	18.68				
"	"	21	9613	.059	18.93				
"	"	23	9614	.056	19.44				
"	"	25	9616	.059	19.07				

ATTACHMENT B

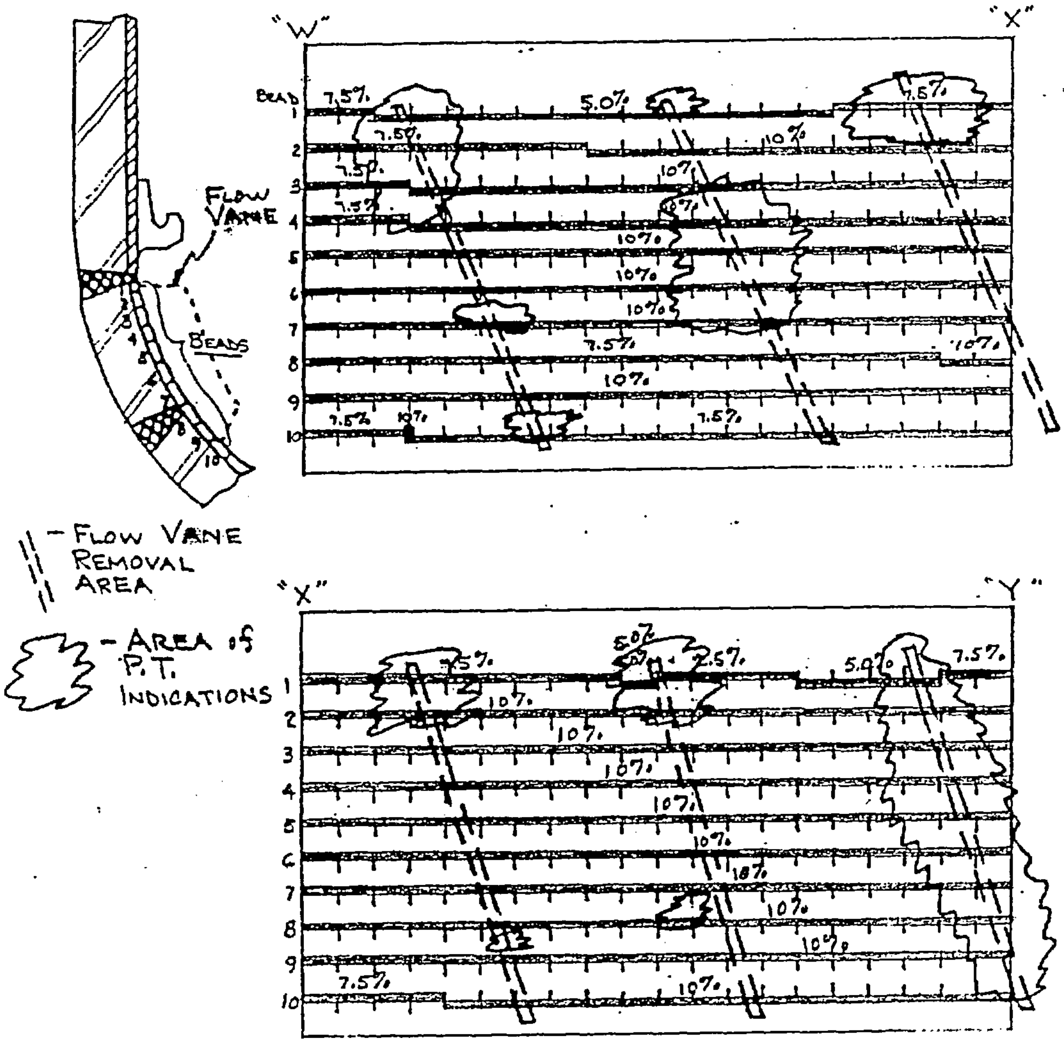
CONTRACT 620-0014-51 S/N A181-2014-1 SHEET 1 of 1

DATE	FERRITE	BEAD No.	LAB No.	C	Cr	Ni	Fe		
12/11/70	10-15%	LAST 28	9620	.052	20.07				
ACCEPT #201591									

BDS 1743-4

QUALITY CONTROL
INSPECTION

BABCOCK & WILCOX POWER GENERATION GROUP BARBERTON, OHIO



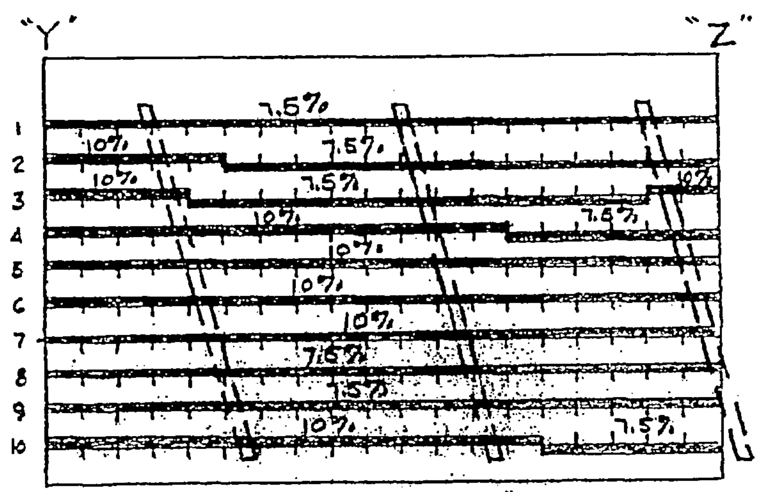
ATTACHMENT No. C (SKETCH No. 1)

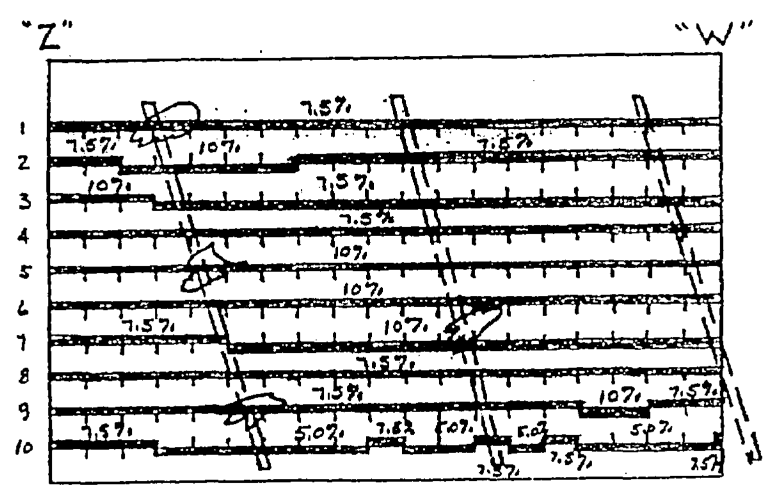
CUSTOMER
SUBJECT
JOB. NO.
DWG. NO. MK#
BY
DATE

BDS 1243-4

QUALITY CONTROL
INSPECTION

BABCOCK & WILCOX POWER GENERATION GROUP BARBERTON, OHIO





ATTACHMENT No. 6 (SKETCH No. 2)

CUSTOMER
SUBJECT

JOB. NO.
DWG. NO. MK#
BY
DATE

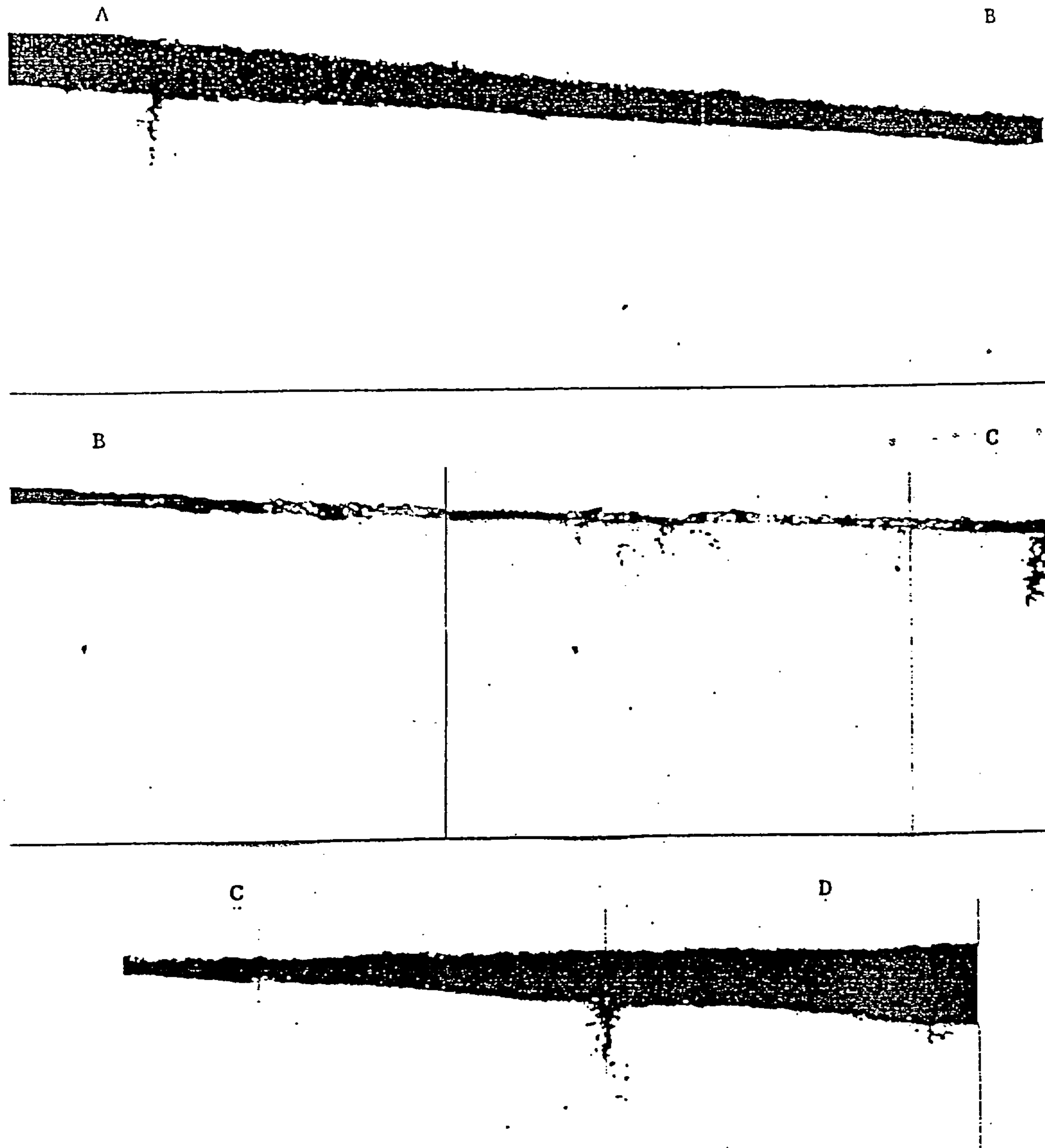
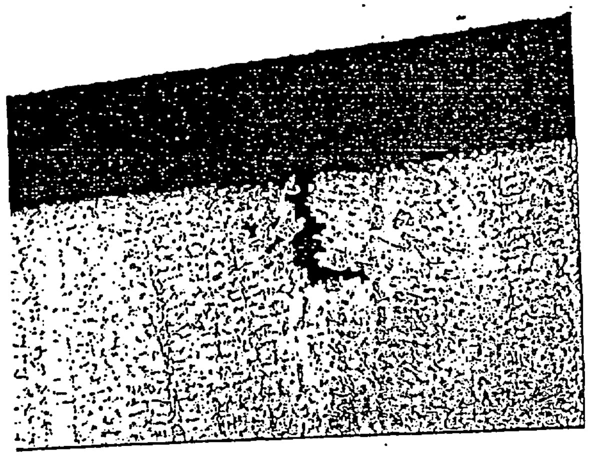
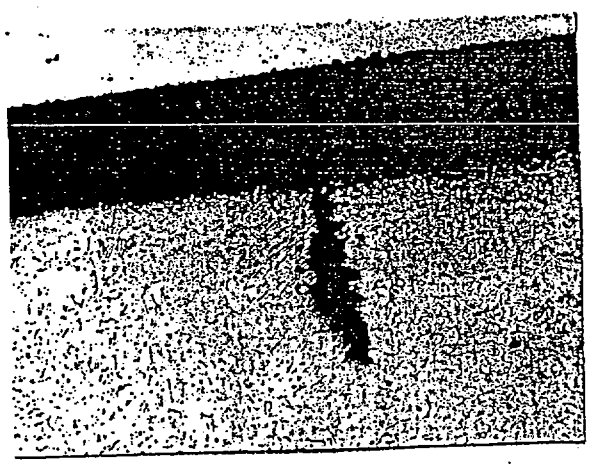


Fig 1 (x50) Unetched. Showing solidification defects present at surface of NSS 14 6-wire cladding.



a (x100) Etchant - Kallings Reagent



b (x100) Etchant - Kallings Reagent

Fig 2 Showing interdendritic solidification defects at surface of NSS 14 6-wire cladding.

Fig 3 (x500) Higher magnification view of solidification defect shown in Fig 2a.

Fig 4 (x500) Higher magnification view of solidification defect shown in Fig 2b.

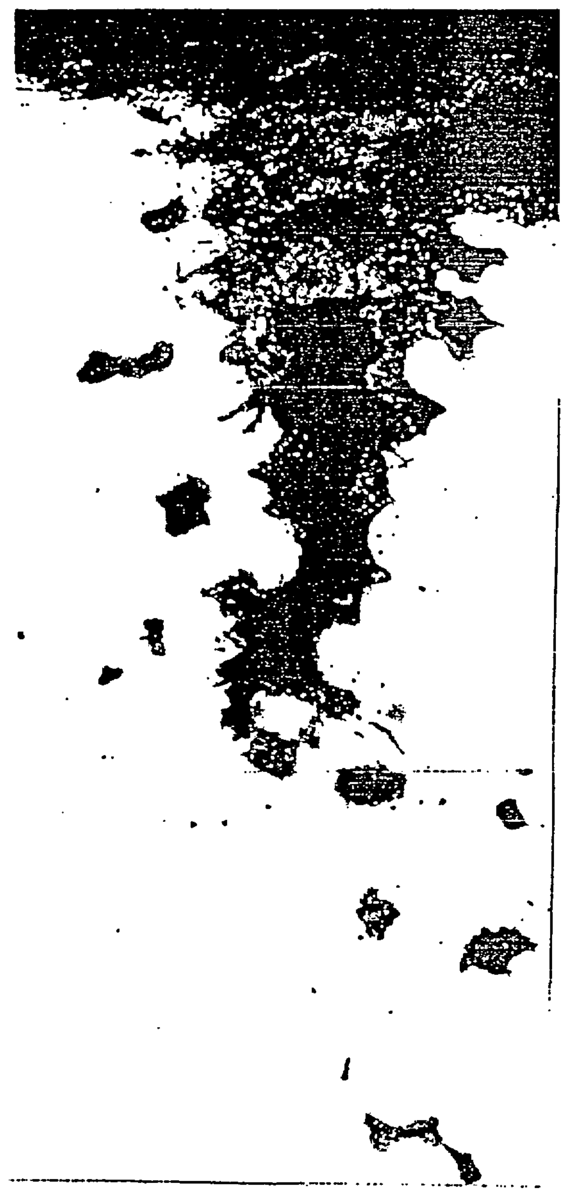


Fig 5 (x500) Showing structure of solidification defect in NSS 14 cladding after exposure to simulated production heat treatment cycles.

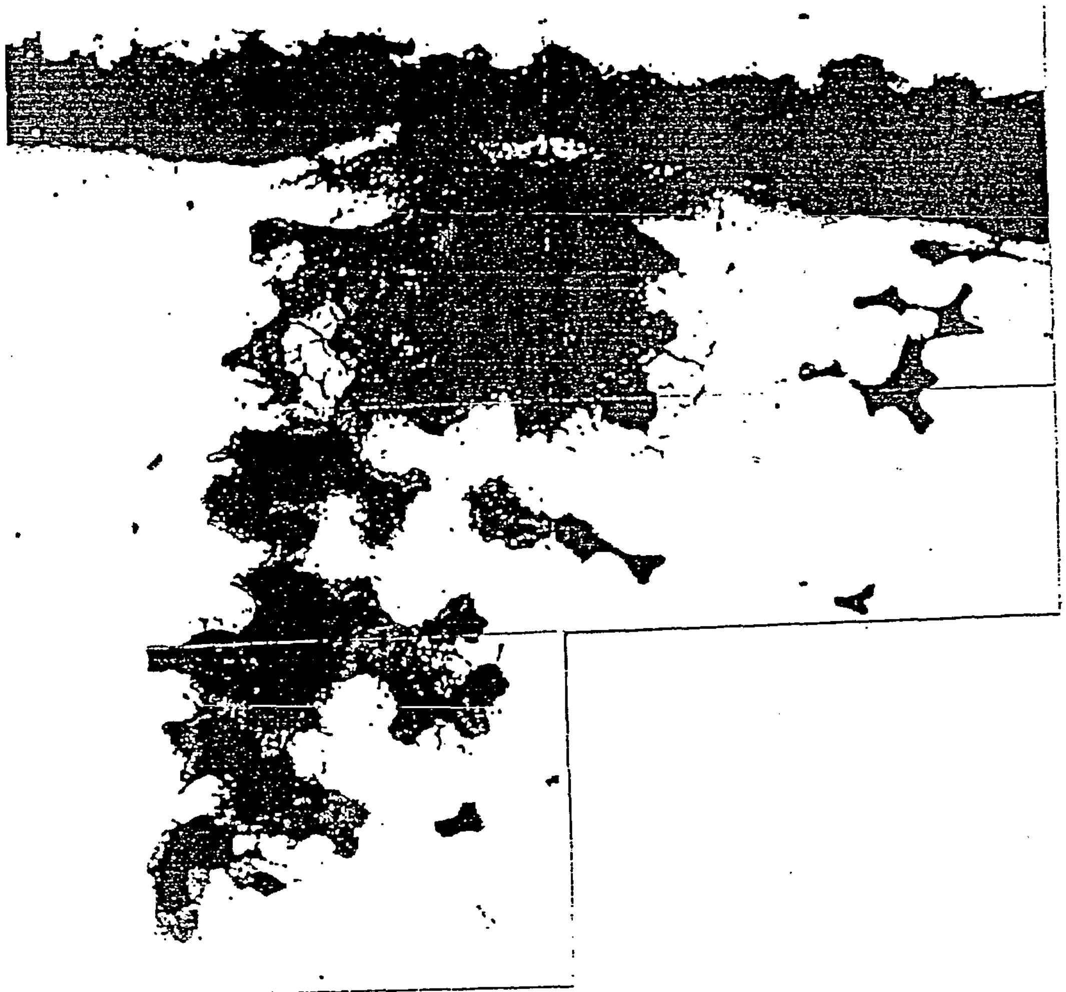
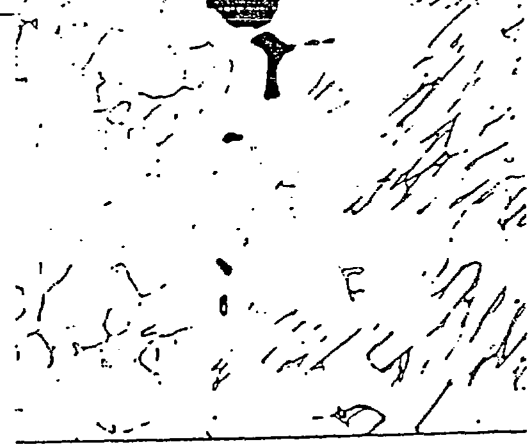


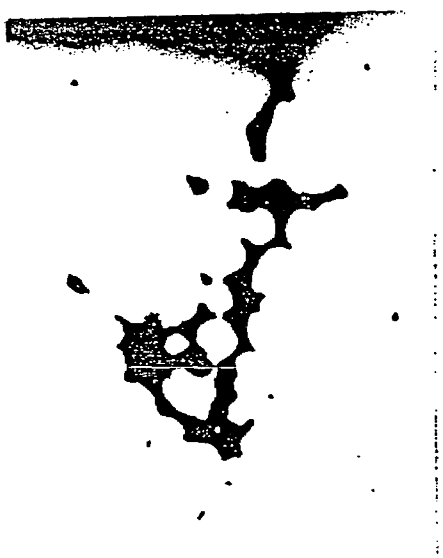
Fig 6 (x500) Showing structure of solidification defect in NSS 14 cladding after exposure to simulated production heat treatment cycles.

Fig. 7 (x500) Defect observed in experimental six wire cladding deposited using correct parameters. Etchant - Kallings Reagent

Fig. 8 (x500) Defect observed in experimental six wire cladding deposited using 3½"/minute Travel Speed and 35 Volts. Electrolytic Etch - 10%oxalic.

a (x500) Etchant - Kallings Reagent



b (x500) Unetched

Fig. 9 Defects observed in experimental six wire cladding deposited using 3½"/minute Travel Speed and 33 Volts.

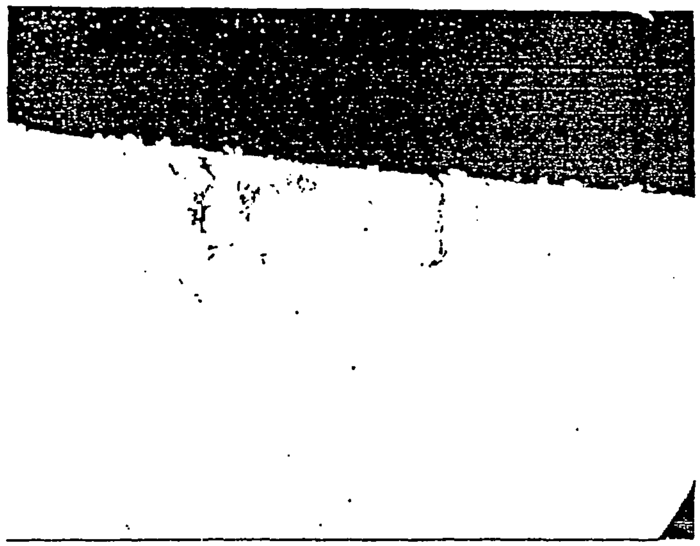
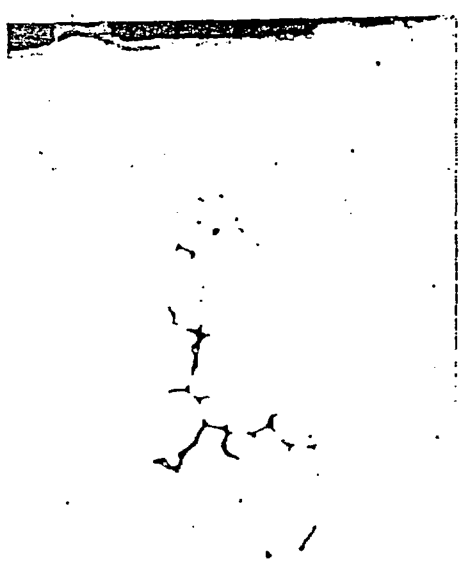


Fig. 10 (x100) Unetched. Defects observed at surface of NSS 9 production cladding.



a (x250) Unetched

b (x250) Unetched

Fig. 11 Defects observed in experimental cladding deposited in 28" I.D. pipe with welding head positioned 1" ahead of center.