UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
PENNSYLVANIA POWER & LIGHT COMPANY	)	Docket Nos. 50-387
and	)	50-388
ALLEGHENY ELECTRIC COOPERATIVE INC.	)	
(Susquehanna Steam Electric Station, Units 1 and 2)	)	

AFFIDAVIT OF JOSEPH C. LEMAIRE
IN SUPPORT OF SUMMARY DISPOSITION
OF CONTENTION 7B

County of King)
: ss.
State of Washington)

Joseph C. Lemaire, being duly sworn according to law, deposes and says:

1. I am Manager, Plant Component Behavior Analysis, General Electric Company ("GE") and give this affidavit in support of Applicants' Motion For Summary Disposition of Contention 7B. I have personal knowledge of the matters set forth herein and believe them to be true and correct. A summary of my professional qualifications and experience is attached as Exhibit "A" hereto.

2. Contention 7B states that "The nuclear steam supply system of Susquehanna 1 and 2 contains numerous generic design deficiencies, some of which may never be resolvable, and which, when reviewed together, render a picture of an unsafe nuclear installation which may never be safe enough to operate. Specifically:...[t]he cracking of stainless steel piping in BWR coolant water environments due to stress corrosion has yet to be prevented or avoided."

3. The intergranular stress corrosion cracking (IGSCC) problem exhibited in stainless steel BWR piping of the type used in

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Susquehanna has been thoroughly examined and analyzed as to the cause of cracking. The identified causes of cracking (over yield stresses concurrent with weld heat affected zone sensitization and an agressive environment) are broadly recognized and understood.

4. A program of positive process steps and water chemistry modifications is being implemented to provide additional margin to IGSCC for all stainless steel welds to assure the attainment of the design life with minimal stress corrosion.

Boiling Water Reactor Corrosion Overview

5. Corrosion concerns in water reactors represent one of the major factors affecting reliable materials performance during the operating reactor lifetime. These concerns are not limited to any specific reactor type; although the specific corrosion problems associated with boiling water reactors (BWR) are generally of a different nature than those associated with other type reactors. This discussion will focus on stress corrosion cracking of stainless steel piping of boiling water reactors. The actions taken in solving the pipe cracking problem in BWR piping of the type used at Susquehanna will be examined in detail.

6. In the direct cycle BWR, the major area for technical attention has been associated with the austenitic stainless steel piping systems which recirculate the primary coolant and provide the redundant emergency cooling capacity.

Cracking has been associated with highly stressed, sensitized material due both to furnace sensitization and weld sensitization. The use of furnace sensitized material was eliminated in 1969, but the occurrence of occasional cracking in weld-sensitized heat affected zones is a more recent problem.

7. A key factor in determining the future materials reliability in light water reactor systems is dependent on whether the basic cause of the characteristic cracking problems can be identified, understood, and controlled. This affidavit will present the current status of these efforts in these areas with respect to the Boiling Water Reactor.

Boiling Water Reactor Cracking Experience

8. Austenitic stainless steels are used extensively in the General Electric Boiling Water Reactor (BWR) piping. For this piping, the observed incidence of stress corrosion cracking has been extremely

low. However, following the occurrence of several small hairline intergranular cracks in piping weld heat affected zones (HAZ) of several BWR's in late 1974 and early 1975, a Task Force was established to evaluate the cause of cracking and to recommend mitigating actions that could be taken to minimize the problem in operating plants and to eliminate the cracking in new plants. The Task Force Summary Report[1] listed all corrosion related cracking occurrences that had occurred in BWR piping prior to July 1975 and attributed the cause of cracking to IGSCC in the sensitized region of the weld heat affected zone.

Leak Before Break

9. Safety implications associated with IGSCC of stainless steel piping in BWR's have been carefully considered. This consists of an assessment of the margin to rupture for crack sizes associated with detectable leaks (leak before break). Also an evaluation was made of the pipe leak rates associated with the typical throughwall intergranular cracks and their detectability. All BWR plants utilize austenitic stainless steel piping which, because of high ductility behavior, is extremely unlikely to suffer sudden, brittle-type fracture. This has been demonstrated by the fact that leaks due to IGSCC have been detected in stainless steel piping. No piping severence has ever resulted from IGSCC. All previous experience has resulted in small leakage or nondestructive detection prior to leakage.

10. Like all other BWR plants, Susquehanna has available continuous on-line leak detection systems capable of sensing small leaks and small leak changes. (See affidavit of Walter J. Rhoades). The leak before break principle has been verified for both axial cracks and circumferentially oriented cracks in stainless steel piping through detailed analyses. In addition, metallographic examinations on representative samples of both full penetration and partial penetration cracks caused by IGSCC verify that the crack front tends to propagate in such a manner that wall penetration and subsequent leaking occurs well before the critical crack length (necessary for rupture) is achieved.

Pattern of Cracking

11. Review of the operating histories of all BWR plants has disclosed that occurrences of cracking are rare. Austenitic stainless

steel Type 304 has an acceptable performance history in operating plants. Only 267 out of approximately 34,000 austenitic stainless steel piping weld heat affected zones have experienced IGSCC-weld HAZ cracks in 400 BWR reactor-years of service experience. However, there was a strong pattern of repeated cracking in certain lines.

12. Table 1 provides a list of cracking incidents and a pattern of cracking for Type 304 stainless steel piping as of August 1981. Cracking frequency decreased sharply with increasing pipe size. Generally, cracking has been confined to relatively low flow or intermittent flow systems. This represents a low frequency, strongly system-specific cracking pattern.

13. Field experience indicates that the cracks have generally been located in areas immediately adjacent to welds attaching the piping to elbows or to the fittings. Crack initiation has occurred primarily at 0.18" ± 0.08" from the weld fusion line. This pattern indicates that the susceptible condition of the material is generated by the welding process.

Three Essential Conditions for Cracking

14. It is well known that stress corrosion cracking in pure, high temperature water such as used in Susquehanna requires the following concurrent conditions:[2] Tensile stress in excess of the local yield stress, suitable environmental conditions (i.e., dissolved oxygen), and a susceptible material. Stress corrosion will not occur if any one of these three conditions is absent or reduced below a critical value. This relationship is shown schematically in Figure 1. Examination of these critical operating parameters--stress, environment, and material condition--is necessary to explain the observed pattern of cracking.

Stress State

15. Field experience, laboratory tests, and metallurgical theory indicate that a critical plastic strain is necessary for IGSCC and that the probability of cracking increases with increasing stress (plastic strain) above the yield stress. In addition to the design stresses (pressure, weight, thermal) which are known to be important to IGSCC, two other sources of stress are now known to be important:

- Bending stresses arising from unanticipated thermal effects (natural convection effects) in low flow and intermittent flow lines.
- Residual inside surface stresses (which are pipe-size-dependent) due to weld shrinkage.

16. Weld shrinkage residual stress at the pipe inside surface has been shown both by analysis and by laboratory experiment to decrease sharply with increasing pipe size. These residual tensile stress levels have been shown to vary from approximately 55 to 60 ksi for 4-inch diameter pipe to approximately 30 to 35 ksi for 26-inch-diameter pipe. These results are summarized in Figure 2, and may partially account for the pipe size dependency of the observed cracking.

17. Field experience also indicated that the most vulnerable lines are those with high differential thermal expansion stress. In addition to expansion strains, low flow lines may experience large top-to-bottom temperature gradients which produce additional bending strains. Since these loads cycle with plant startup and shutdown, the incidence of cracking in these lines can be correlated with the number of cold-hot-cold plant cycles.

18. The occasional pile-up of unanticipated stresses described above can combine with unique mechanical characteristics of a welded joint to produce the low frequency of cracking observed in the field.

19. In a welded pipe, analytical studies have shown that weld mass, joint geometry, and weld zone mechanical properties increase the restraint to plastic deformation. Therefore, the stress required to produce the critical strain for IGSCC at weld HAZ's is greater than for uniaxial IGSCC tensile specimens, (i.e., pipe HAZ's are more difficult to crack). This fact explains why cracking is only observed in the occasional very highly stressed lines and also why weld cracking is so difficult to reproduce in the laboratory.

20. It also explains why large diameter pipes have not been the location of frequent cracking; the weld heat affected zones are under the mechanical restraint supplied by the weld bead and higher strength heat affected zone and thus do not experience yield strains (see Figures 3A, 3B and 3C).

Material Condition

21. In addition to the stress state, the material condition obviously plays a major role in determining susceptibility to attack. Both laboratory experiments and theory suggest that grain boundary chromium depletion by chromium carbide precipitation plays an important role in IGSCC. This is supported by the field experience where IGSCC occurred in the theoretically most susceptible material, i.e., Type 304 stainless steel cold worked from weld preparation plus sensitized (from welding) - congruent with welding residual stresses. This appears to be true for all single-phase wrought Type-304 stainless steel product forms. Forgings, seamless pipe, and rolled and welded pipe have all experienced cracking.

22. Experience with other stainless steel conditions has provided valuable information about IGSCC susceptibility. Duplex ($\geq$ 5% ferrite) stainless steel material - weld metal, weld overlay, cast valve bodies, all of which are used at Susquehanna, have successfully experienced all BWR service-related chemical transients without crack initiation and have been found to be extremely resistant to IGSCC in theory and laboratory tests conducted to represent field conditions.

23. Other 300 series austenitic stainless alloys with low carbon content, which are less susceptible to sensitization have seen limited BWR pipe service without weld HAZ cracking (number of weld joints in BWR service are approximately hundreds of each versus thousands of Type 304 weld joints). This behavior is consistent with metallurgical predictions but not conclusive. Crack nucleation for Type-304 stainless steel pipe field welds has been shown to be extremely difficult (requiring thousands of hours). The metallurgical condition of the piping, however, is clearly an important factor in IGSCC, and the presence of a sensitized austenitic structure is the key determining factor.

Environment

24. Examination of the BWR environment has shown that chemistry excursions have not been a major factor in the observed attack, but that attack of highly stressed (strained) weld HAZ's is possible in high purity reactor water after long periods of time.

25. The low-flow lines which have exhibited the highest cracking frequency do not exhibit detrimental water chemistry segregation. Laboratory tests have shown that closed bypass lines do not contain stagnant water during operation; turbulent flow and thermal convection effects produce surprisingly rapid mixing. Core spray lines for distances of feet away from the vessel also exhibit thermal convection effects and rapid mixing.

26. However, the Pipe Task Force findings did show that the frequency of IGSCC incidents correlated well with the number of plant start-up and shut-down cycles. An additional environmental factor is that the oxygen and peroxide contents of the water are high during part of these cycles (3-5 ppm for O_2 and 2-6 ppm H_2O_2). Thus, during the conditions of changing stress and strain states the environment is more oxidizing than at steady state operating conditions. Laboratory tests (constant load, constant extension rate and electrochemical tests) show that the margin against IGSCC damage could be increased by reducing the oxygen content of the water during simulated startup and shutdown conditions. This can be achieved using continuous vacuum deaeration. This recommendation has been implemented at Susquehanna.

Cause

27. The following factors are necessary for IGSCC in stainless steel piping:

1. Magnitude of stress. All types of stresses (fabrication, primary, and secondary) must be considered.

2. Condition of the material. Material susceptibility can be achieved through two circumstances.

a. Sensitization: A change in grain boundary composition due to very high temprature exposure such as may occur during welding or through improper heat treatment, or

b. Cold Work: A high degree of plastic deformation of the material.

These effects are mitigated through solution heat treatment and material hardness controls prior to installatior

3. Environment. Aqueous environment containing dissolved oxygen (higher levels during startup) promotes IGSCC. This environment becomes even more aggressive in a crevice.

28. For cracking to occur it is necessary that all 3 factors be present; however, even when all three are present the incidence of cracking has been extremely low.

The following factors will decrease the potential for IGSCC:

1. Control of stress If the total magnitude of stress can be controlled to an amount below yield, IGSCC is not likely to occur.

2. Solution heat treated material (no sensitization, cold work, or weld residual stress) is essentially immune to IGSCC.

3. Controls in cold work, heat input for welding, control of sensitization, and crevice formations, will minimize potential for IGSCC.

4. Controlled environment with extremely low levels of dissolved oxygen and chloride contaminants is less aggressive.

Laboratory Qualification of Pipe Crack Remedies

29. After identification of the cause of cracking in austenitic stainless steel piping systems a feasible method of reproducing the field cracking in the laboratory was needed for development and qualification of potential remedies for the cracking. Several laboratory high temperature water IGSCC screening tests such as constant extension rate tests and constant load tests have been applied to evaluate qualitative effects of various cracking remedies, but the development of the full-size welded pipe test has been the most significant advance for General Electric's program to eliminate IGSCC of stainless steel piping.

30. This test, which consists of a full-size length of 4-inch diameter pipe containing up to 12 circumferential welds, has been used to exactly reproduce field failures at an accelerated rate. The test utilizes the welded pipe as its own autoclave to contain recirculating water at 550°F and 8 ppm oxygen. The pipe is loaded to stresses above the 550°F yield stress and cycled from zero to maximum load at a rate of one cycle every 90 minutes. The presence of accelerants (high stress, cyclic load, and 8 ppm O_2) accounts for the observed increase in initiation and propagation rate, and the utilization of actual welded pipe allows accurate representation of welding practices, residual stresses, and weld constraint effects. The full-size test has demonstrated a capability to readily crack Type 304 weld HAZ's produced by standard weld techniques

under these highly severe test conditions. Comparing the pipe tests with the field conditions, the mean time to failure for all pipe cracking incidents has been estimated to be 4.7 years. A statistical evaluation of the Type 304 stainless steel laboratory data base indicates a mean time to failure of 22[illegible] hours (159 cycles). Thus, Pipe Test Laboratory conditions represent an acceleration factor of 183 over the 4.7 year mean life estimate for piping stress corrosion incidents.

31. A number of these full-size test stations have been established by General Electric at its Pipe Test Laboratory as part of a comprehensive program to eliminate pipe cracking. The full-size test apparatus and full-size specimen are presented in Figure 4. These test facilities have been used to test a statistically significant number of weld heat affected zones to demonstrate either immunity or a significant improvement over reference Type 304 welds for potential pipe cracking remedies, such as Type 304 stainless steel with carbon less than .030%.

Qualification of Potential IGSCC Mitigating Processing Procedures

32. The cause of pipe cracks as summarized above is stress corrosion cracking which involves three simultaneous factors; stress, environment and material condition. Mitigation of pipe cracking thus relies on the control of any one or several of these factors. The reduction of stress, or improvements made in environment or material condition each have been shown by General Electric to increase the margin against stress corrosion cracking. Of the three factors, design stress rules accounting for all the sources of stress are the most important, and material condition improvement is perhaps the most readily implemented margin improvement. Methods of improving material condition for margin against stress corrosion cracking are summarized as follows:[3]

(All of these have been used by Susquehanna in various locations as stated in the affidavit of Walter J. Rhoades on this subject.)

Solution Heat Treatment

33. Fully solution heat treated material has been shown to be immune to IGSCC in laboratory and in-reactor surveillance tests.[4] Therefore, a very straight forward approach to prevention of pipe cracks is to solution heat treat piping after fabrication is complete. This

eliminates sensitization and residual stress from welding and also minimizes the effect of cold work. Solution heat treatment is not practical, however, on field welds. Qualification of solution heat treatment as a method of preventing IGSCC in weld heat affected zones has been accomplished in the General Electric Pipe Test Laboratory.

Corrosion Resistant Cladding

34. Corrosion Resistant Cladding consists of an austenitic stainless steel weld metal containing more than 8% ferrite in the final fabricated condition. Corrosion Resistant Cladding is applied prior to making the groove weld and is designed to cover the area of the wrought stainless steel which becomes the final weld heat affected zone (Figures 5 and 6). Corrosion Resistant Cladding is effective in preventing IGSCC because weld metal with 8% ferrite when sensitized by the welding process is not susceptible to stress corrosion. Stainless steel weld metal has rarely been found to be susceptible to IGSCC in the field. In the cases where cracking of weld metal has been observed, the ferrite content of the weld metal has been very low (considerably less than 8%) and the material furnace sensitized. Field cracking of weld metal has never been found in 8% or greater ferrite weld metal. Laboratory stress corrosion tests in oxygenated water at 550°F have also produced cracks in furnace sensitized Type 308 weld metal, but only with less than 5% ferrite.

35. The configurations for Corrosion Resistant Cladding are designed to eliminate the condition of wrought stainless steel heat affected zones exposed to the BWR environment. Figure 5 is the preferred configuration for Corrosion Resistant Cladding. Here, the cladding is applied in two steps. The cross hatched area of cladding is applied in two layers and the pipe then solution heat treated. Solution heat treatment at this stage eliminates the slight sensitization caused by the application of cladding. The remaining cladding is now applied, the weld prep machined and the groove weld made. It can be seen by studying Figure 5 that no sensitized wrought stainless steel is exposed to the BWR environment on the inside surface of the pipe. The joint will, therefore, not be susceptible to IGSCC.

36. The Figure 6 configuration differs from Figure 5 in that the cladding is applied all in one step and not solution heat treated prior to making the groove weld. In this case at the end of the cladding, there is a very small zone of sensitized wrought stainless steel exposed on the inside surface of the pipe. This sensitization, which results from application of the cladding, is slight compared to that produced by the groove weld. In addition, the residual stress at the end of the cladding is not as high as it is in the groove weld heat affected zone of an unclad weld. The Figure 6 configuration for Corrosion Resistant Cladding is ideal for field work where solution heat treatment facilities are not readily available, while the Figure 5 approach is well suited to shop fabrication.

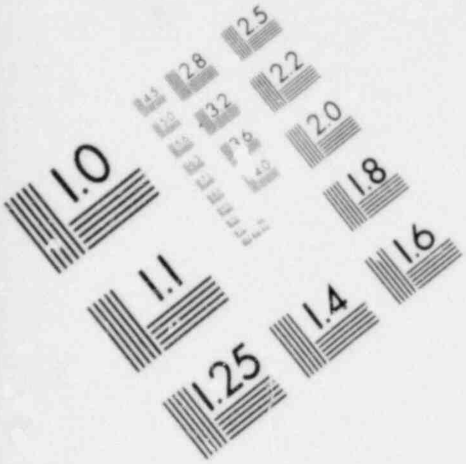
37. Qualification of Corrosion Resistant Cladding and Solution Heat Treatment as methods for preventing IGSCC in weld heat affected zones has been accomplished in the General Electric Pipe Test Laboratory.

Residual Stress Improvement

38. During the welding process, tensile residual stress is induced in the region adjacent to the weld which can combine with applied stresses to cause IGSCC. This stress can be greatly reduced by a technique known as Induction Heating Stress Improvement (IHSI). The IHSI process is applied to piping after it is fully erected. In principle, induction heating is used on the outer pipe surface of completed girth welds, while simultaneously water cooling the inside with flowing water. This produces compressive residual stress on the pipe inside surface in the vicinity of the weld heat affected zone. The creation of these compressive stresses has been confirmed by surface and through-wall strain gage and X-ray diffraction residual stress measurements on welded plus IHSI treated pipes. Confirmation of increased resistance to IGSCC due to the IHSI process has been accomplished by full size pipe tests in the General Electric Pipe Test Laboratory.

Ferrite Control

39. Weld metal with sufficient ferrite level is not susceptible to IGSCC. Because low ferrite (<5%) weld metal can in rare cases crack by IGSCC, it is necessary to maintain ferrite above some minimum level. Currently, ferrite is specified to be $\geq$ 5% for most applications.



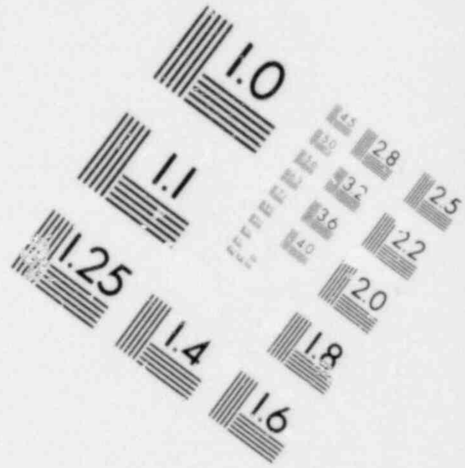
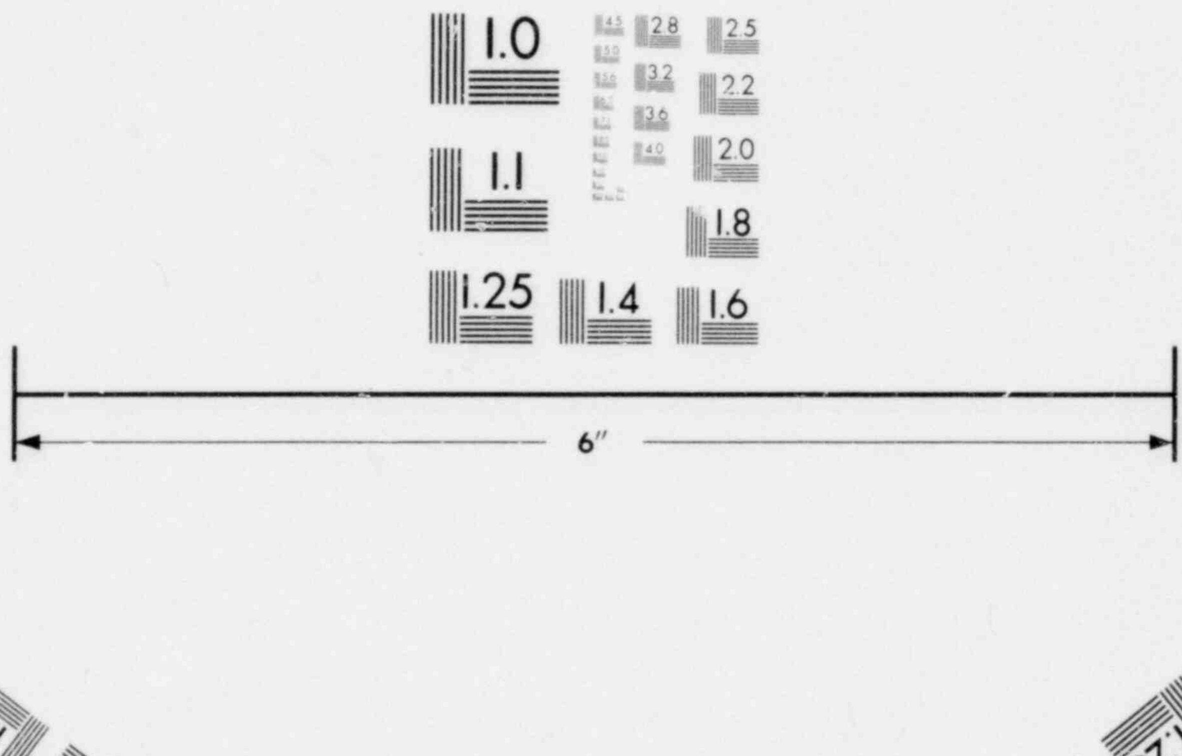
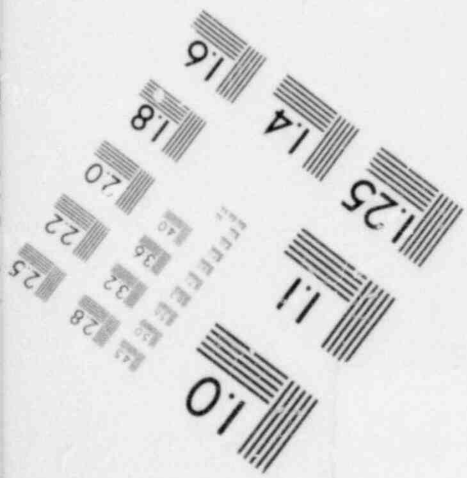
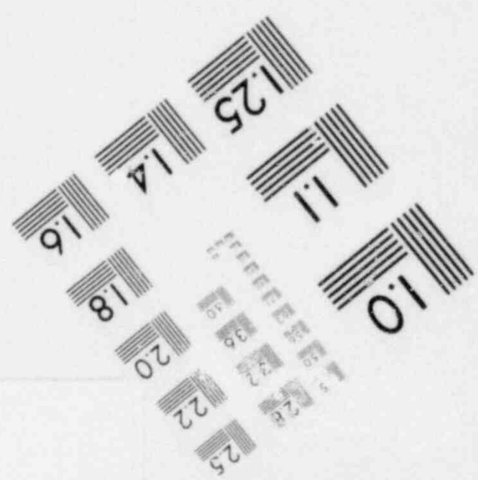
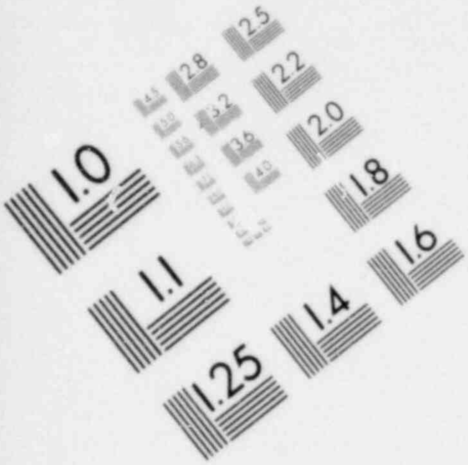


IMAGE EVALUATION
TEST TARGET (MT-3)









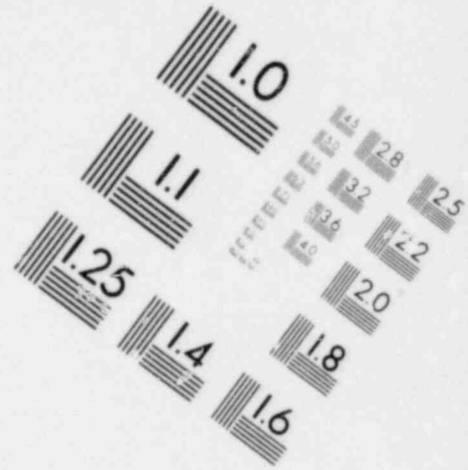
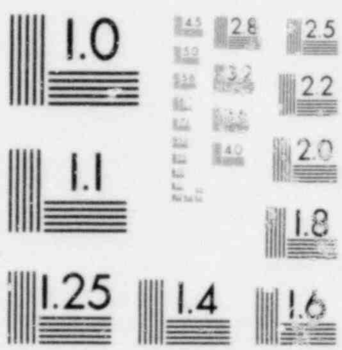


IMAGE EVALUATION TEST TARGET (MT-3)



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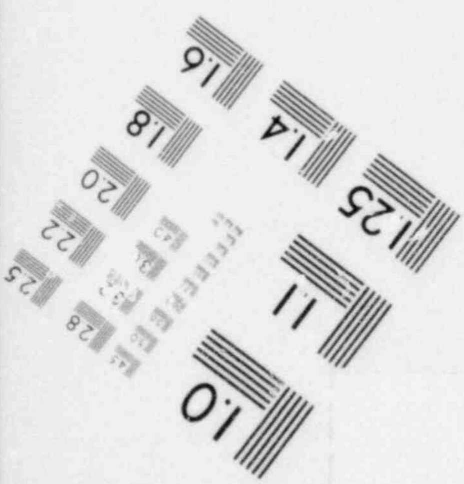

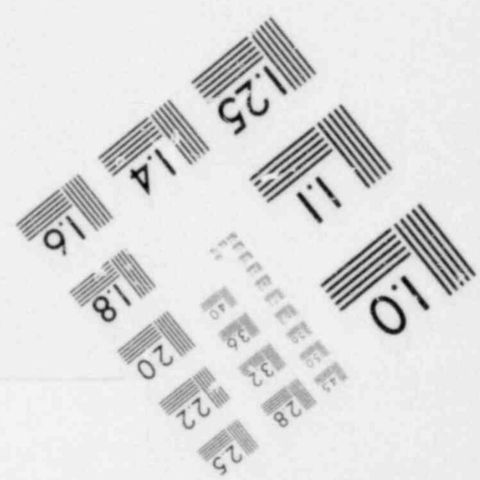

Limited Carbon Type 304 Stainless Steel

40. In addition to the many process controls available for improved margin against IGSCC, a change in the basic alloy chemistry can provide a significant increase in stress corrosion resistance. In particular, the kinetics of carbide precipitation during welding can be reduced by the presence of lower carbon, such as found in Type 304 L stainless steel (.035% maximum carbon). Clearly, the same benefits would be anticipated in limited carbon Type 304 stainless steel with ≤.030% maximum carbon.

41. The improved IGSCC margin of Type 304L stainless steel has been demonstrated by full-size pipe testing. Full size specimens of Type 304L tested by cyclic tension have survived tests that routinely produce IGSCC in higher carbon Type 304. No Type 304L heat affected zones have cracked. A summary of the pipe test results is shown in Table 3. These results are consistent with field observations where cracking has been observed only in piping systems where the carbon content is greater than 0.045% to the extent carbon contents are known (as indicated in Table 4).

42. The use of Type 304L stainless steel provides a positive step applicable to BWR piping situations where the reduced yield strength of low carbon material does not limit its use. It must be noted that Type 304L line replacements have served satisfactorily for over ten years in the same environment which produced failures in Type 304.

ASME Code Compliance

43. The original pipe components have been designed in accordance with the ASME Code which requires the design stresses to be below specified values. This limits the extent of potential cracking since high stress is required to produce IGSCC.

Conclusions

44. The total program to eliminate stainless steel pipe cracking at the Susquehanna station has evolved from an understanding of the cause of cracking and is directed towards addressing each of the major factors contributing to the cause: above yield stresses, sensitized material, and environment. An extensive program of processing controls

and positive process steps has been implemented to achieve successful performance of Type 304 stainless steel in the BWR environment. Moreover, susceptible piping materials as identified in the affidavit of Walter J. Rhoades have been replaced with IGSCC resistant materials. This program should substantially reduce the incidence of stainless steel piping IGSCC at Susquehanna, and provide a high likelihood of detecting any cracking which does occur prior to leakage.

45. Finally, the empirical observation of leak before break and the Leak Detection System at Susquhanna assure that any IGSCC which might occur will be detected and corrected before pipe rupture can take place.

Joseph C Lemaire

JOSEPH C. LEMAIRE

Sworn to and subscribed before me this 28th day of August 1981.

L Dale Montgomery

NOTARY PUBLIC

Residing at Bothell, Washington 98011

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REFERENCES

1) Klepfer, H. H., et. al., "Investigation of Cause of Cracking in Austenitic Stainless Steel Piping", General Electric Report NEDO-21000, July 1975.

2) Giannuzzi, A. J. "Studies on AISI Type-304 Stainless Steel Piping Weldments for Use in BWR application," Electric Power Research Institute, EPRI NP-944, December 1978.

3) Hughes, N. R., and Giannuzzi, A. J., "Evaluation of Near Term BWR Piping Remedies," Electric Power Research Institute, EPRI NP-1222, November 1979.

4) Gordon, G. M., and Blood, R. E., "Reactor Structural Materials Environmental Exposure Program", USAEC Symposium on Materials Performance in Operating Nuclear Systems - CONF-730801, August 1973.

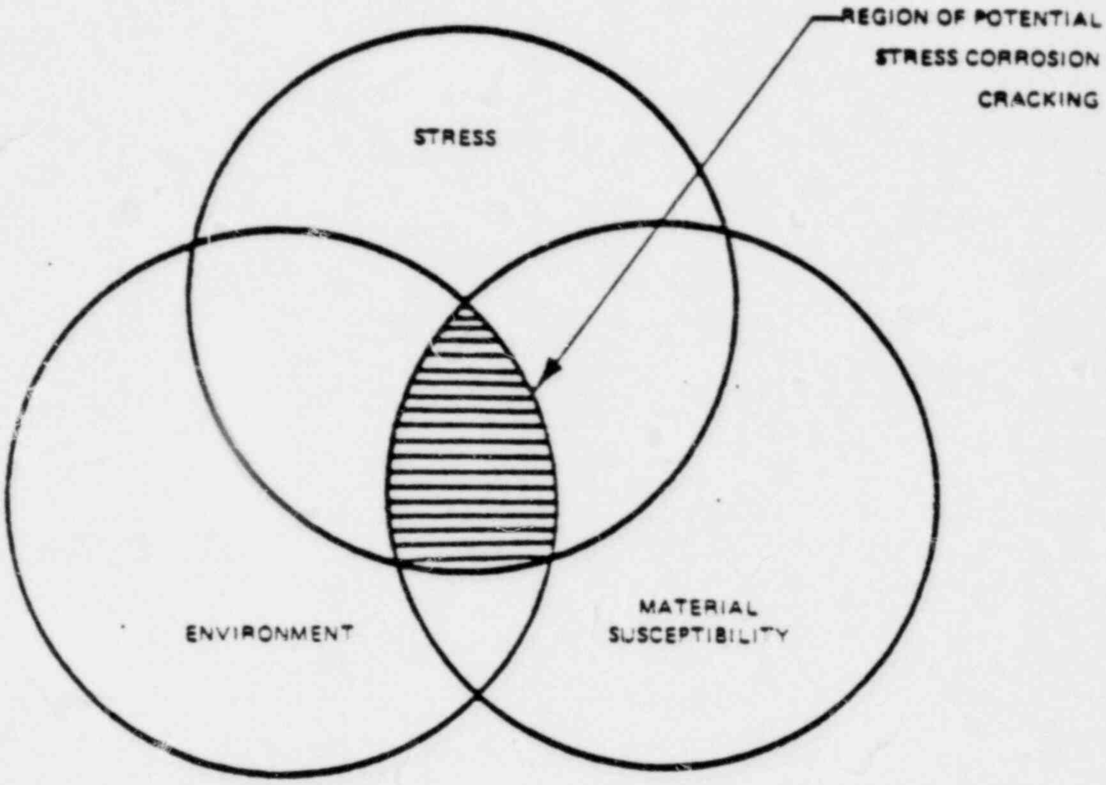


Figure 1. Coincidence of Three Conditions Necessary for Stress Corrosion Cracking.

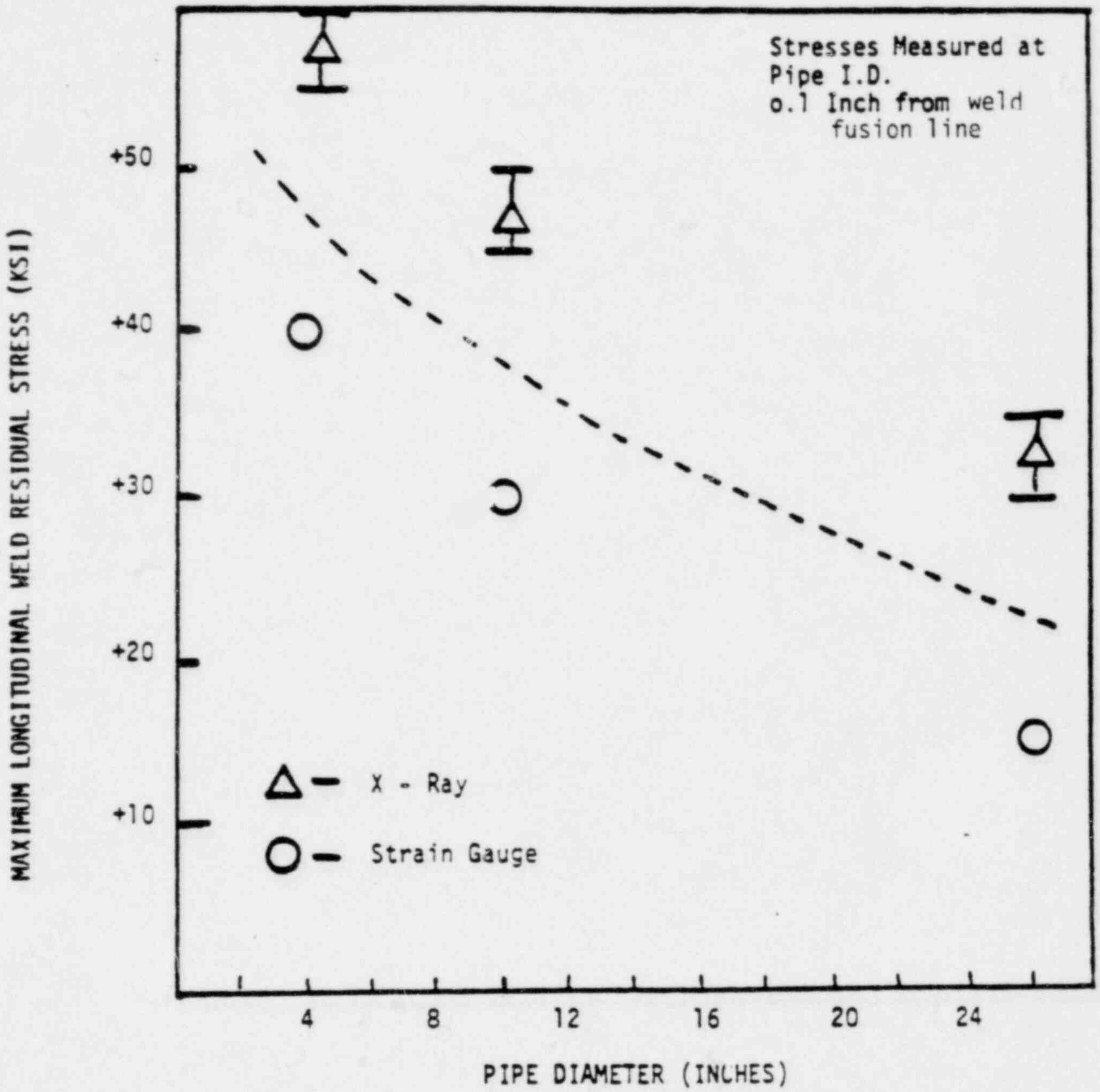


FIGURE 2

EXPERIMENTAL WELD RESIDUAL STRESS MEASUREMENTS VS PIPE SIZE

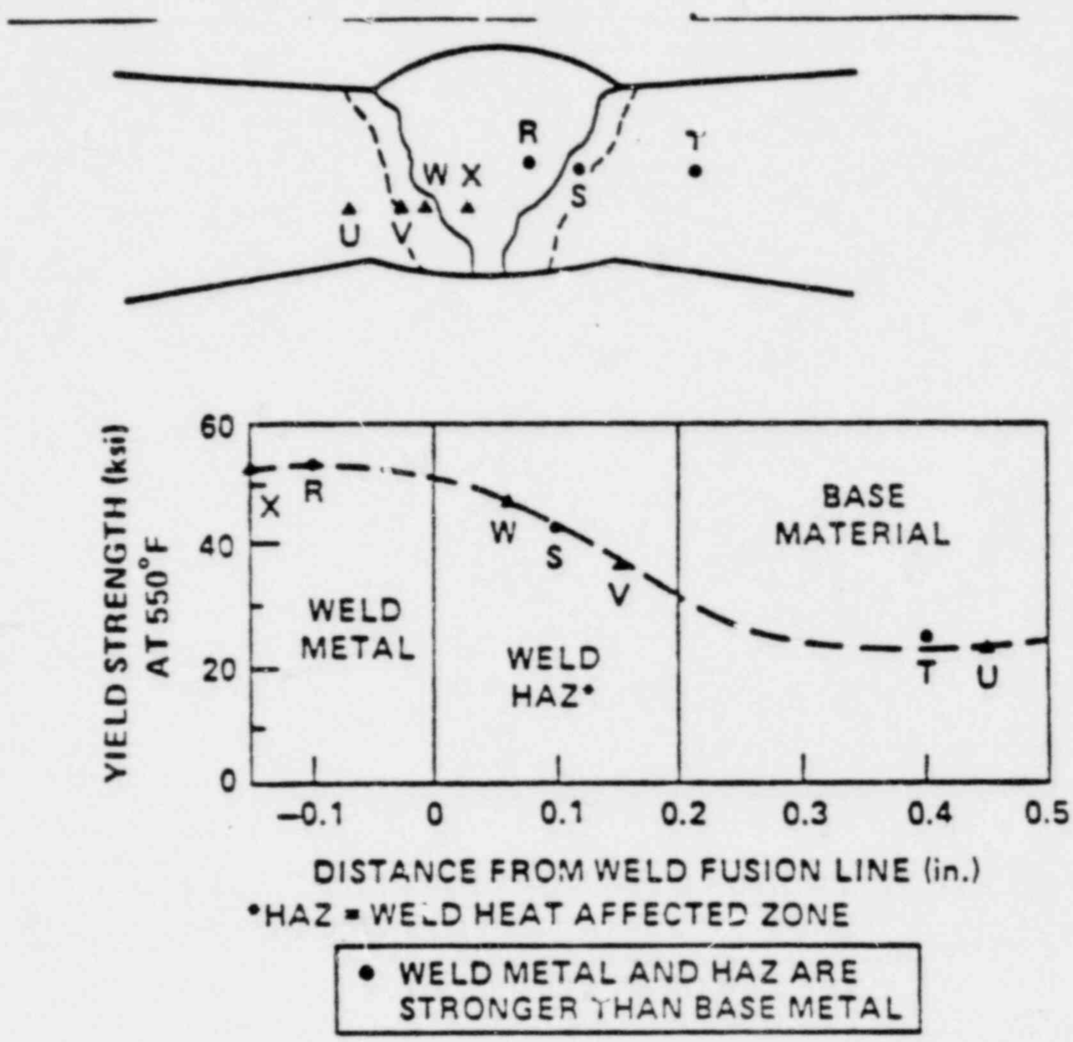
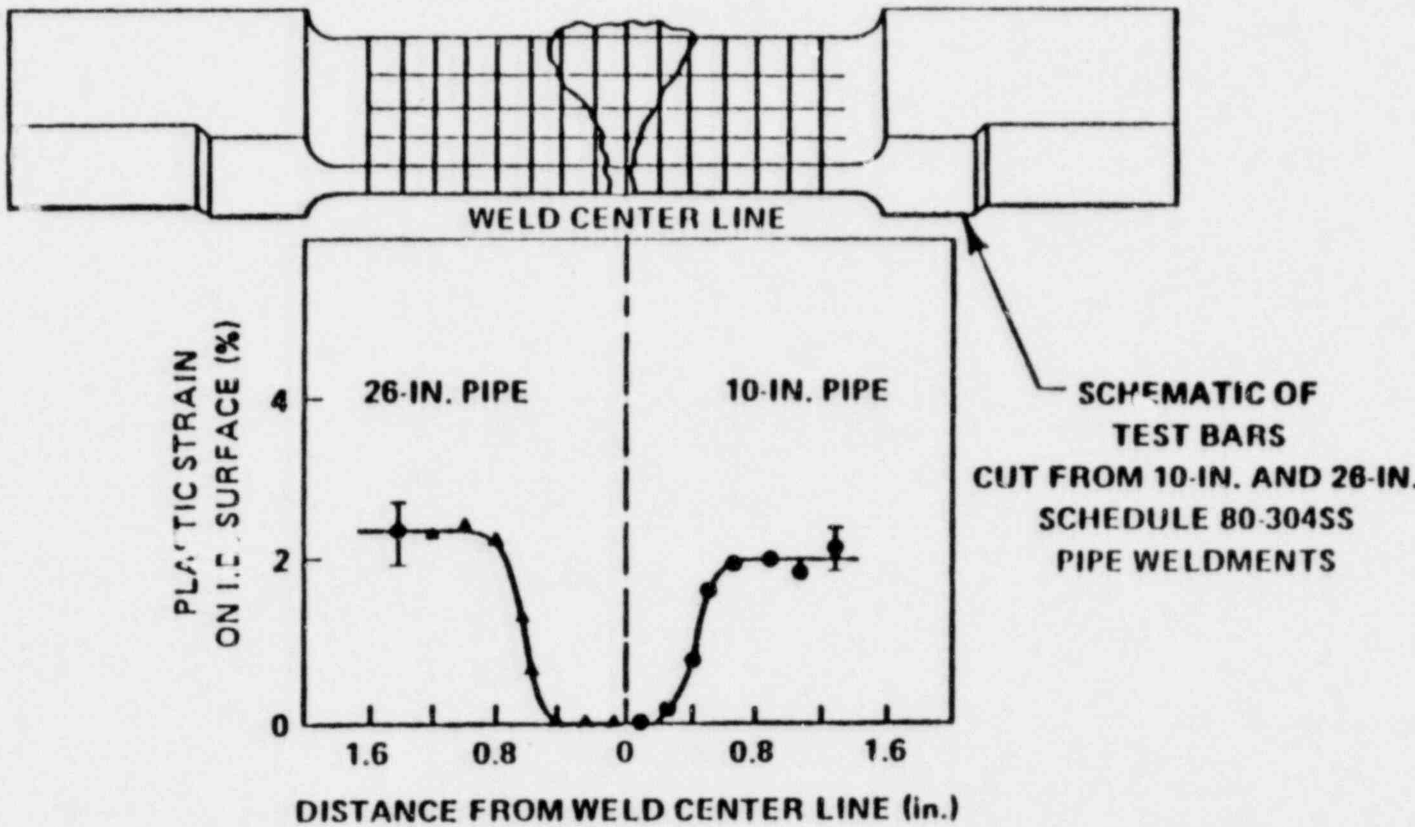


FIGURE 3A - WELD ZONE STRENGTH GRADIENT

FIGURE 3B

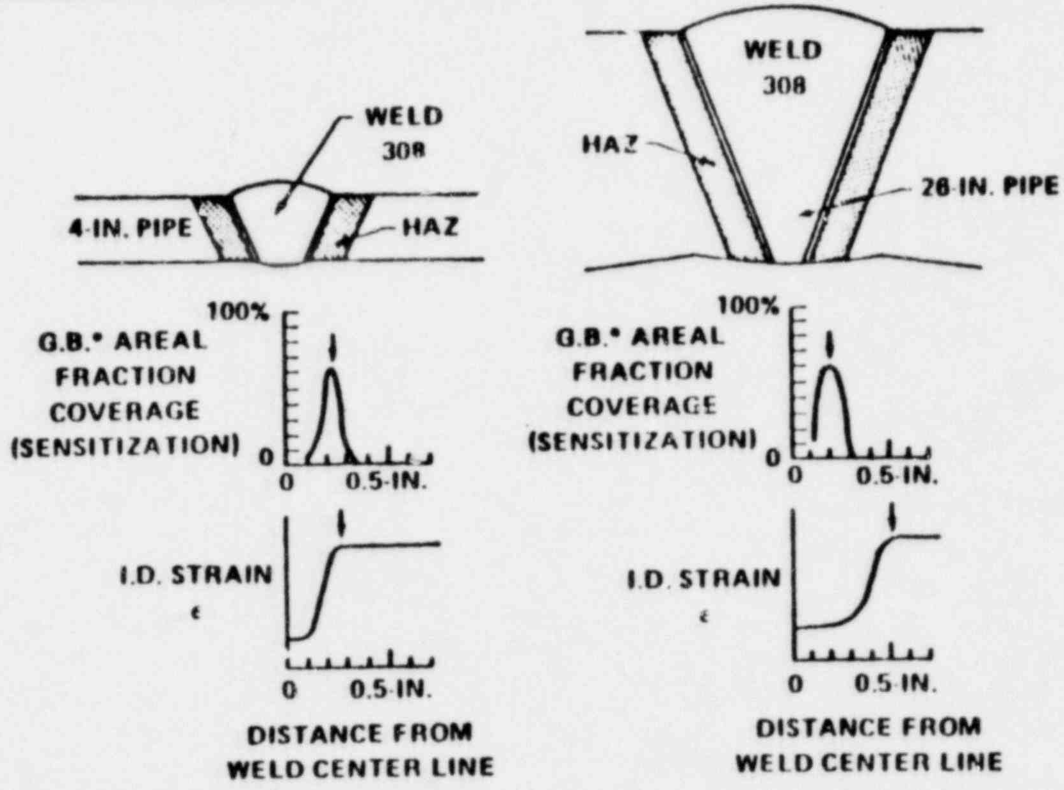
WELD UMBRELLA EFFECT ON I.D. PLASTIC STRAIN DISTRIBUTION UNDER TENSILE TEST AT 550°F



- LARGER PIPE RESTRAINS PLASTIC FLOW FURTHER FROM WELD CENTER LINE

FIGURE 3C

PIPE SIZE EFFECT



*G.B. = GRAIN BOUNDARY

- SIMILAR ENVIRONMENT
- SIMILAR SENSITIZED ZONE
- HIGH I.D. STRAIN NOT COINCIDENT WITH PEAK SENSITIZATION IN 28-IN. PIPE

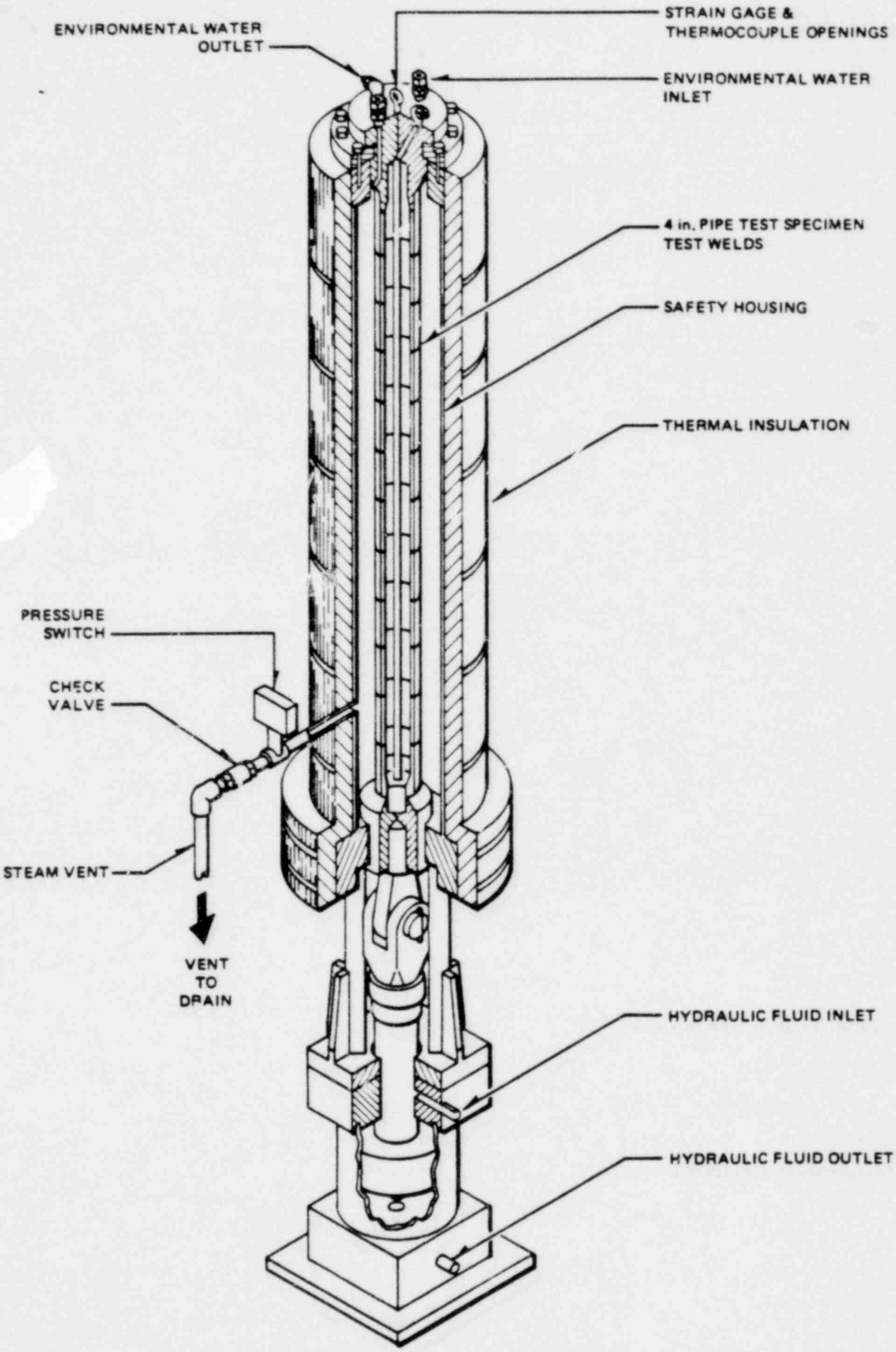


Figure 4. Full Size Pipe Test Apparatus and Welded Pipe Test Specimen

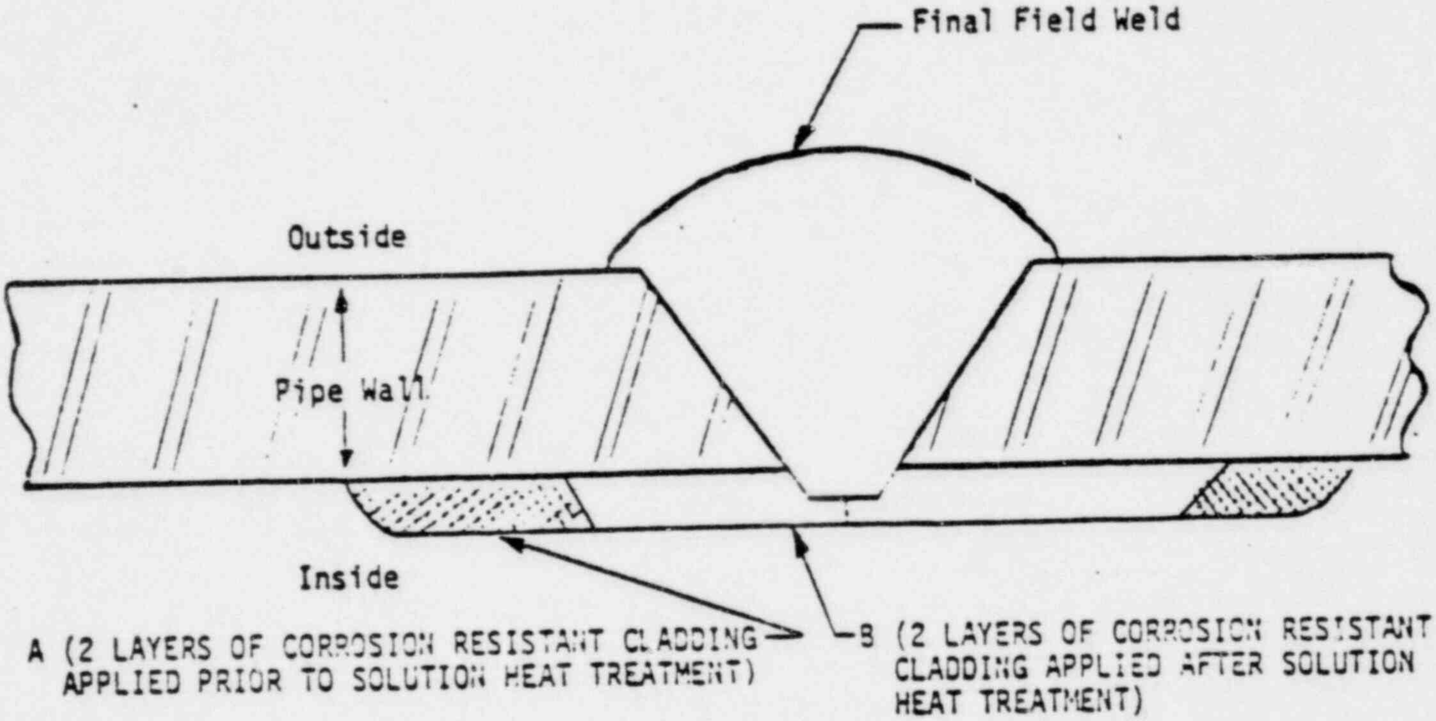


FIGURE 5

CORROSION RESISTANT CLADDING PROCESS FOR TYPE 304 STAINLESS STEEL WELDED PIPING (SOLUTION HEAT TREATED)

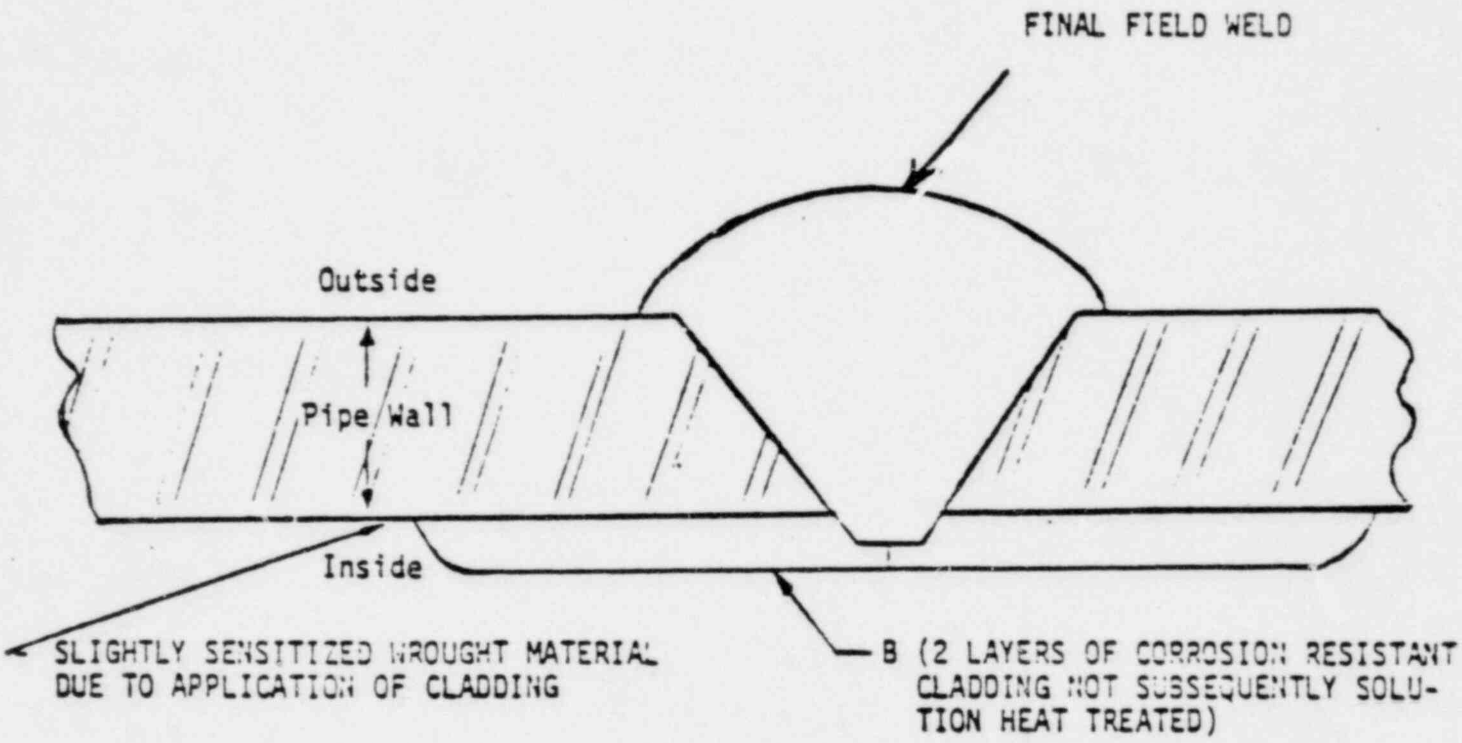


FIGURE 6

CORROSION RESISTANT CLADDING PROCESS FOR TYPE 304 STAINLESS STEEL WELDED PIPING - (NON-SOLUTION HEAT TREATED)

TABLE 1. PATTERN OF CRACKING IN BWR STAINLESS STEEL PIPING
(as of 8/1/81)

System	No. of Cracking Incidents
Recirc Bypass	47
Core Spray	82
CRD Return	3
Reactor Water Cleanup (RWCU)	64
Large Recirc ≥ 10"	16
Small, not CRD/RWCU ≤ 3"	18
Other	37*
TOTAL	267*

* 18 incidents in systems not used in Susquehanna 1 and 2 designs.

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TABLE 2 - PIPE TEST RESULTS OF WELD HEAT INPUT CONTROLLED SPECIMENS - 1.36 x Yield Stress

QUADRANTS CRACKED/ # TESTED

Heat	76K Joules + Grinding*	76K Joules + No Grinding*	40K Joules + Grinding*	40K Joules + No Grinding*
X	9/9	-	9/11	3/8
Y	0/3	0/1	0/7	0/5
HSW on Heat X	4/4	1/4	3/4	0/4
Total	13/16	1/5	12/22	3/17

* Post Weld Grinding
HSW = Heat Sink Welding

SUMMARY OF TYPE 304 AND TYPE 304L STAINLESS STEEL PIPE TEST RESULTS

TABLE 3

GRADE	CARBON CONTENT (%)	TEST CYCLES TO THROUGH-WALL CRACKING	
304	0.07	27	
304	0.07	34	
304	0.07	42	
304	0.07	59	
304	0.07	54	
304	0.06	75	
304	0.06	127	
304	0.06	37	
304	0.06	73	
304	0.06	33	
304	0.05	79	
304	0.045	2300	
304	0.042	97	
304	0.042	380	
304	0.042	>3797	No through-wall IGSCC
304	0.042	>2964	" " " "
304	0.042	>3256	" " " "
304	0.041	839	
304L	0.035	>1935	" " " "
304L	0.032	>5622	" " " "
304L	0.030	>4818	" " " "
304L	0.027	>5251	" " " "
304L	0.026	>2000	" " " "
304L	0.026	>5831	" " " "
304L	0.024	>5198	" " " "
304L	0.020	>5040	" " " "
304L	0.020	>4389	" " " "
304L	0.016	>2284	" " " "
304L	0.015	>5409	" " " "
304L	0.013	>5706	" " " "
304L	0.009	>2000	" " " "
304L	0.009	>2000	" " " "

* 1 cycle = 90 min.

TABLE 4

FIELD PIPE CRACKING INCIDENTS AND CARBON CONTENT

FOR TYPE 304 STAINLESS STEEL

(From NEDO 21000)

Plant	Line*	Carbon Content
Dresden-2 (D-2)	Core Spray (C.S.)	.065
D-2	C.S.	.065
D-2	C.S.	.065
D-2	C.S.	.065
D-2	C.S.	.065
D-2	C.S.	.065
D-2	C.S.	.056
Tsuruga	C.S.	.060
D-2	Recirculation Bypass (R.B).	.070
Millstone	R.B.	.070
Quad Cities 2 (QC-2)	R.B.	.070
QC-2	R.B.	.070
Millstone	R.B.	.068
Monticello	R.B.	.055
Peach Bottom 3 (PB-3)	R.B.	.045
Fukushima 1	R.B.	.050
Hamaoka	R.B.	.060
Dresden-1 (D-1)	R.B.	.076
D-1	R.B.	.066
D-1	R.B.	.048
D-1	R.B.	.076
D-1	Cleanup Supply	.076
JPDR	Shutdown Cooling	.057
Tarapur 1	Control Rod Drive RET	.052

*C.S. = Core Spray
R.B. = Recirculation Bypass
C.U. = Cleanup
CRD = Control Rod Drive System
F.W. = Feedwater

LS:ggt/4C2
8/6/81

BIOGRAPHICAL SKETCH - JOSEPH C. LEMAIRE

Joseph C. Lemaire is currently manager of Plant Component Behavior Analysis, a materials research component within the Nuclear Engineering Division of General Electric Company. He has been responsible for metallurgical failure analysis and environmental qualification of plant structural materials, including nuclear grade materials, at GE. Prior to joining General Electric in 1975, Mr. Lemaire was a nuclear propulsion metallurgist with the U.S. Energy Research and Development Agency, where he supervised nuclear fuel development activities. He holds a Bachelor of Science in Mechanical Engineering from the University of Denver (1970), a Master of Science in Metallurgical Engineering from Massachusetts Institute of Technology (1971), and a Master of Business Administration from Santa Clara University (1979). He is a member of the American Society of Metals (ASM) and the American Nuclear Society (ANS), and has published recent papers on the subject of corrosion technology at the ASM Metals and Welding Conferences and in Corrosion.

EXHIBIT A

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