ATTACHMENT 1
ST-HL-AE-2652
MAY 12, 1988
HOUSTON LIGHTING & POWER COMPANY

EVALUATION OF THE ESSENTIAL COOLING WATER SYSTEM AT THE SOUTH TEXAS PROJECT ELECTRIC GENERATING STATION

Revision 0
May 12, 1988

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Evaluation of the Emergency Cooling Water System at the South Texas Project

I. INTRODUCTION

On April 1, 1988, several small bore socket connections in the ECW were observed to be leaking in a seepage fashion. Corrosion products and wetness were found on the surface. This discovery resulted in an intensive effort to determine the scope of the problem, its root cause and the necessary corrective actions.

A letter including an Action Plan was submitted to the NRC on April 21, 1988 (ST-HL-AE-2632). This plan included investigations into cause of corrosion, sampling of components by metallurgical sectioning, a review of the feasibility of non-destructive examination, stress and structural integrity analysis, on-going monitoring and the development of a replacement program for susceptible components in the small bore piping system.

The following is a summary of actions that have been taken to date and those planned.

II. NATURE AND CAUSE OF CORROSION

On April 11, 1988 three (3) components were removed from the system and examined for material condition and nature of the corrosion. The results of this diagnostic investigation are included in the Bechtel report (Attachment 2). The following conclusions were reached.

- The nature of corrosion is "dealloying", a phenomenon in which the aluminum in one of the microstructural phases selectively corroded, leaving the balance of the matrix intact.
- The material of the cast valves (ASME SB148 Grade CA954) and fittings (typically ASME SB148 Grade CA952) contained the Gamma-2 phase. This condition lends itself to selective corrosion of the Gamma-2 phase, causing dealloying, in severe corrosive environments.
- The attack was significant at crevices, tapering off in parts away from the crevice.
- The chemistry of the water in the socket crevices was significantly more acidic than the bulk water chemistry, thus causing the severe condition which, in combination with the metallurgical condition of the materials, resulted in the selective corrosion.
- Piping and weld metal had suffered no corrosion, demonstrated that alloy CA614 was not subject to the observed phenomenon.

III. IMMEDIATE ACTIONS

A program of walkdowns was immediately instituted, which resulted in the detection of more indications of seepage. The seepages in many cases are difficult to identify because of the extremely low seepage rates. As a result it took several cycles of inspection to identify all leaking components. The baseline has now been established and the rate of occurrence of new leaks is low (See Figure 1). The maximum leak rate was estimated to be 10 ml/day.

Leaking components were removed from the system and sectioned to characterize the degree of corrosion and the structural integrity of the system. Additional' fittings which had less than 70% margin in design wall thickness to meet Cod. stress allowables (under all loading conditions) were replaced to improve the structural integrity margins of the system. Fittings that were removed were replaced with spare aluminum bronze fittings or pipe. Replaced fittings (except the first four removed) were re-heat-treated by annealing and water quenching. Valves were replaced by available spare aluminum bronze valves. When the spare valves were depleted, carbon steel valves (N-stamped in accordance with ASME Code, Section III, Class 3) were installed.

These replacements restored the small bore system to a leak tight condition with improved structural integrity margins. The remaining partially dealloyed components in the system were analyzed as described below for structural integrity. The intent is to implement permanent corrective action prior to startup following the first refueling outage for Unit 1 and prior to fuel load on Unit 2.

IV. EVALUATION OF AREA OF DEALLOYING OF SAMPLES

Removed components were sent to Bechtel Materials & Quality Services for evaluation of area of dealloying. While most of the components removed had at least one socket end leaking, the sample included some components which had neither side leaking, as a result of the location of the cuts in the piping system. The sample was thus randomly selected.

The socket ends were examined for area of dealloying by cutting, polishing and etching. The worst case total area of dealloying was estimated by an iterative process of progressive slicing and etching. Figure 2 shows, in summary, the distribution of socket ends that were cut and evaluated in this fashion.

It has been observed that fittings were, in general, less dealloyed than valves, which is attributed to the lower aluminum content of the CA952 alloy used in small bore fittings. The total sample of susceptible cast materials, contained mostly leaking valves of the CA954 alloy and is thus biased in the conservative direction.

V. STATISTICAL ANALYSIS

The results of the measurement of dealloyed area in the sample of 24 leaking and 41 non-leaking socket ends were statistically analyzed to project the worst case dealloyed area in a previously leaking (replaced) socket end, and in a non-leaking socket end. It was determined with 95% probability and 95% confidence level that a socket end in the present non-leaking population has no more than 55% area dealloyed. The mean area dealloyed is 20% as shown in Figure 3.

VI. EVALUATION OF STRUCTURAL INTEGRITY

The worst case dealloyed cross section in the current population (with "leakers" and high stress points eliminated) was evaluated for structural integrity as follows.

Stress Evaluation

Stress analyses were performed on the components conservatively assuming them to be 100% dealloyed (although the 95% probable worst case is 55% dealloyed). The strength of dealloyed materials was established by tensile tests as 30 ksi. Calculations were performed with this strength for the sustained and secondary loads in accordance with the ASME Code, Section III, and were found to be within Code allowables with significant margin.

Fracture Evaluation and Limit Load Analysis

Additionally, a linear elastic fracture mechanics screening analysis was performed. The fracture analysis treated the dealloying as a planar flaw which is highly conservative since there is actually no discontinuity. Brittle fracture was demonstrated not to be the controlling mechanism.

A limit load analysis for plastic collapse was then performed using two bounding cases: dealloying uniformly distributed in a circumferential plane, and dealloying concentrated in a worst case bending plane. In addition, the increase in the extent of dealloying three years into the future was also evaluated. The composite sections, allowing for the specification properties for aluminum bronze and 30 ksi for the dealloyed section, showed good margins to failure.

Rate of Corrosion

Attachment 2 establishes the rate of corrosion based on standard corrosion models, with the parameters based on observations at the South Texas Project. It is assumed conservatively, that the observed corrosion occurred over a 3 year period, though parts of the system may have been wetted earlier. It is also assumed, for the purposes of this projection, that in the worst case, 100% dealloying occurs over 3 years, although the mean area of dealloying for the leaking connections was 48%. This established a rate constant for the corrosion curve for observed phenomenon specific to the project. The projections of structural integrity discussed above are based on increased dealloying based on this projection.

Proof Tests

To establish the load capacity of partially dealloyed components, proof tests of partially dealloyed components were conducted. The proof tests subjected whole fittings with partial dealloying to hydrostatic pressure up to failure. The tests included components that had previously leaked. These components did not fail under proof test but eventually the leak rate exceeded the hydrostatic pump capacity. A test on a component without leakage resulted in the failure of a test cap before the fitting. Figure 4 shows the results in summary. It can be seen that the pressure load capacity of partially dealloyed components (even with prior through wall seepage) is from 49 to 74 times the design pressure. This demonstrated substantial safety margin. By comparison, the ASME code only requires a hydrostatic test at 1.25 times the design pressure.

Tensile Tests

Tensile tests measured the strength of the composite partially dealloyed cross section and of the dealloyed material itself. Figure 5 is a summary of these tests. Based on this, it can be seen that the dealloyed section has substantial strength, and contributes to the overall load carrying capacity.

VII. SHORT TERM PROGRAM

Prior to startup following the first refueling outage on Unit 1, HL&P will continue the present augmented surveillance program. Work is continuing to identify a more permanent solution.

VIII. CORRECTIVE ACTION FOR SMALL BORE COMPONENTS

A more permanent solution for susceptible small bore valves and fittings will be implemented prior to startup following the first refueling outage for Unit 1. The more permanent solution for susceptible small bore valves and fittings will be implemented for Unit 2 prior to fuel load. In preparation for this, alternate materials are being reviewed and tested. The options being examined include the following:

- For small bore fittings - reheat treat available spares to a non-susceptible condition; or fabricate from non-susceptible CA 614 piping.

- For valves - nickel aluminum bronze Grade CA958, 70/30 Cupro nickel Grade C71500, aluminum bronze castings equivalent to Grade CA614 (if available), certain stainless steels and carbon steel are being considered. Corrosion and metallurgical checks are in progress to select the material. Weld overlay of socket ends is also being investigated.

IX. LARGE BORE SYSTEM (ABOVE 2" DIAMETER)

No large bore components have leaked; however, some contain materials that have the potential for dealloying. In general, most large bore components have more wall thickness. The following is a review of the potentially susceptible components.

Fittings

Most fittings are wrought products of the CA614 type. This alloy is demonstrated to have no dealloying. Most fittings are also free from crevices. The exceptions are an estimated 42 weld neck flanges and reducing tees installed with backing rings. One backing ring was removed and the area under it examined. A superficial depth of dealloying of 0.015" was found. It appears that backing rings do not promote the same kind of tight crevice corrosion environment as do small bore sockets. The CA952 alloy is used in fittings is less susceptible to dealloying than the CA954 alloy used in valves.

Valves

A high percentage of valves are of the wafer butterfly type which have substantial wall thickness. A sample valve was examined for dealloying. Dealloying up to a depth of 0.16" was found, however these components have a substantial margin to the design minimum wall thickness. The crevice geometry is primarily at the gasket.

Pumps

The ECW pump discharge elbow and some internals are aluminum bronze castings. The ECW screen wash booster pump body is an aluminum bronze casting. Some dealloying indication was observed on the flange face of the booster pump.

Heat Exchangers

The tube sheets and channels of CCW Heat Exchangers and of the essential chiller condenser are plate materials of type CA614, a non-susceptible alloy.

Structural Integrity of Large Bore Components

Stresses at large bore welds with cast components and backing rings were reviewed for design margins and found to be acceptable per ASME Code requirements assuming 100% dealloyed sections.

Using methods similar to those used to evaluate small bore fittings, structural integrity of large bore components was established. Adequate margins were demonstrated.

It is therefore concluded that large bore components have no structural integrity issue.

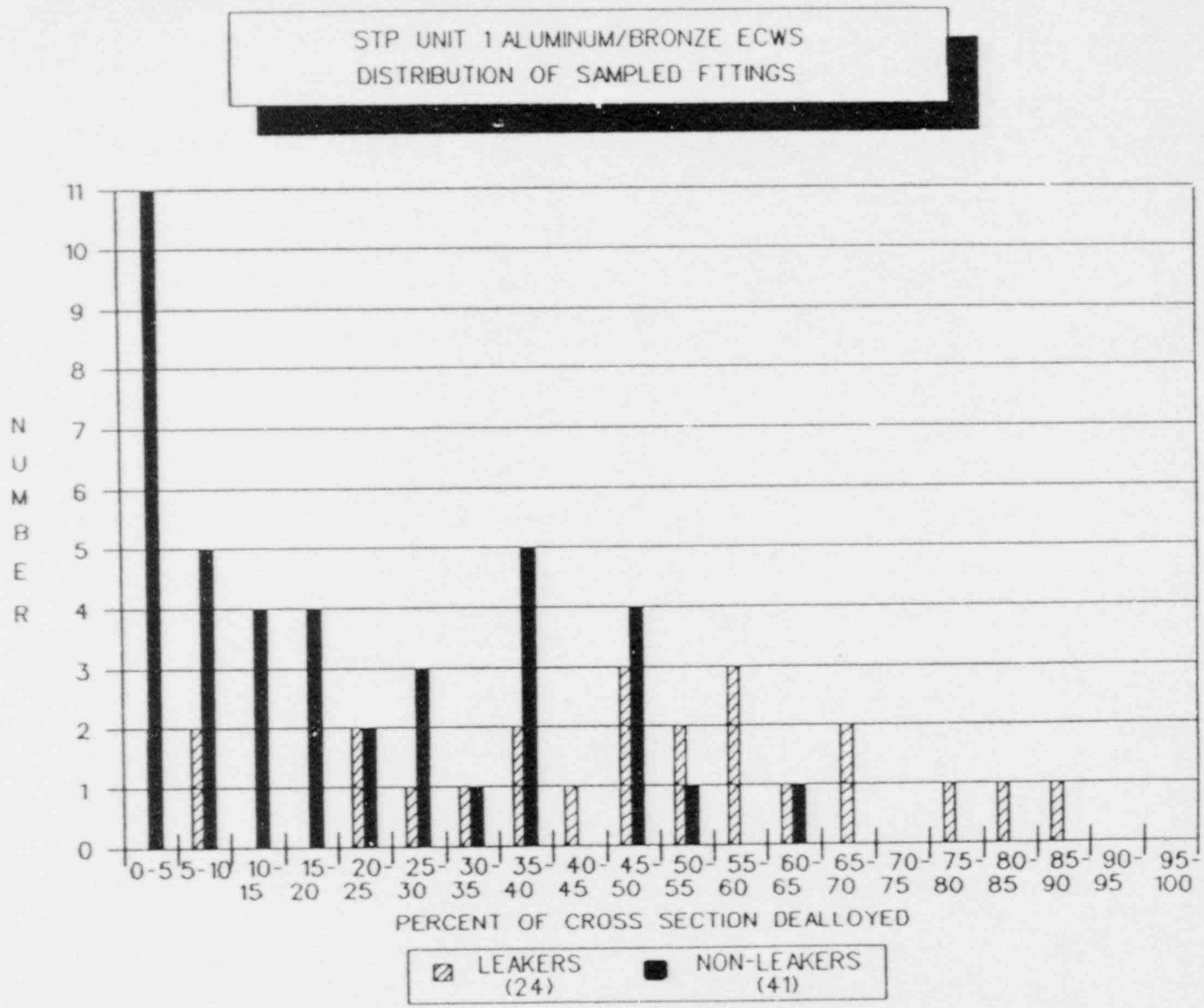
ECW LEAKS SUMMARY CHRONOLOGY

DATE	NUMBER OF LEAKING COMPONENTS TOTAL CUMULATIVE	REPLACED	REMAINING
4/08/88	50		
4/11/88		2	
4/15/88	64		64
4/16/88		9 (TRAIN C OUTAGE)	55
4/19/88	77		66
4/20/88	85		74
4/22/88		26 (TRAIN A OUTAGE	48
4/26/88	89*		52
5/02/88	90		53
5/09/88	90	26 (TRAIN B OUTAGE)	27

* 5 NEW LEAKS IDENTIFIED BUT A PREVIOUS LEAK DETERMINED TO BE A CASTING INDICATION

FIGURE 1

D08/C7



NRCS37

FIGURE 2

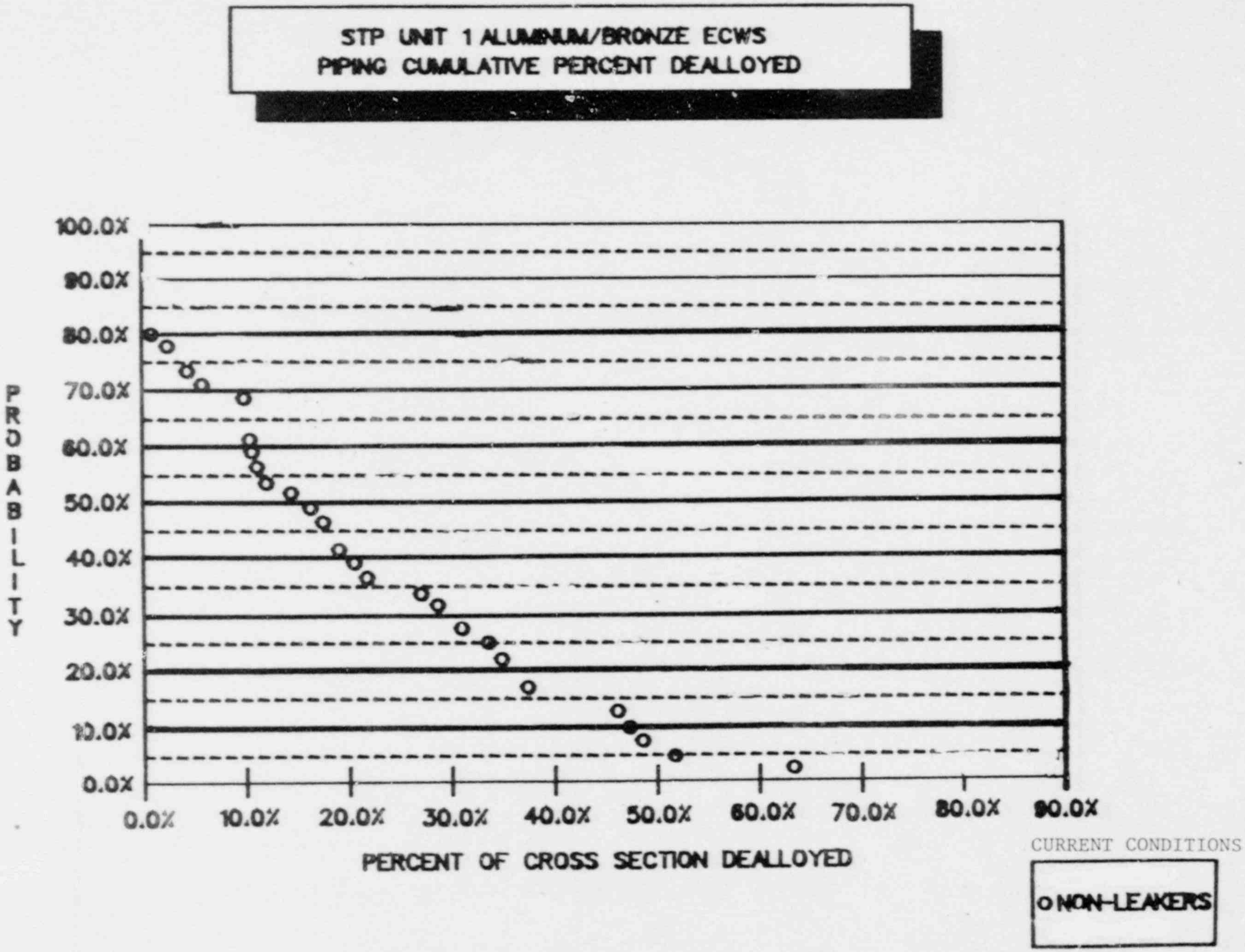

STP UNIT 1 ALUMINUM/BRONZE ECWS
PIPING CUMULATIVE PERCENT DEALLOYED
PROBABILITY
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0.0%
10.0%
20.0%
30.0%
40.0%
50.0%
60.0%
70.0%
80.0%
90.0%
PERCENT OF CROSS SECTION DEALLOYED
CURRENT CONDITIONS
o NON-LEAKERS

FIGURE 3

PROOF TESTS

ITEM	LEAKER/ NONLEAKER	SIZE	MAXIMUM CROSS SECTION AREA DEALLOYED	FAILURE* PRESSURE PSI	PRESSURE RATIO FAILURE TO DESIGN
COUPLING	L	2"	38%	8950	74.6
TEE	L	2"	52%	5900	49.2
ELBOW	NL	2"	0%	6500**	54.2

*FAILURE WAS BY LEAKING FASTER THAN THE 200CC/MIN. PUMP COULD KEEP UP WITH.

CALCULATED THEORETICAL BURST PRESSURE IS 6800.

(ASSUMING NO DEALLOYING & NOMINAL TENSILE PROPERTIES)

** FAILED AT WELD TO CARBON STEEL END PLATE

FIGURE 4

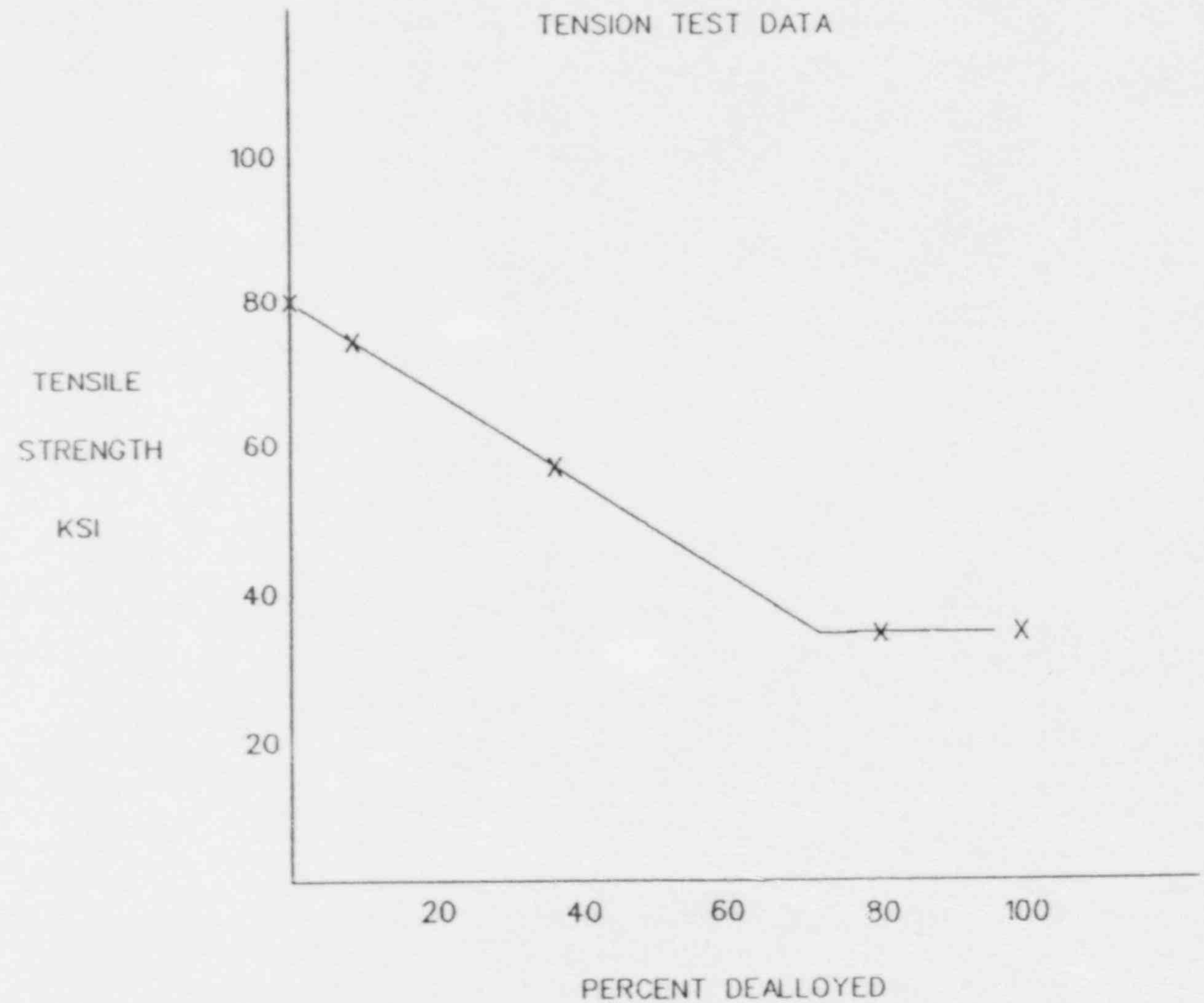


FIGURE 5

NRCS30

ATTACHMENT 2
ST HL-AE-2652
MAY 12, 1988

BECHTEL REPORT
ON
FAILURE ANALYSIS AND STRUCTURAL
INTEGRITY EVALUATION OF LEAKING
ALUMINUM - BRONZE CAST VALVE BODIES
AND FITTINGS IN THE ECW SYSTEM