COM-75-001
Revision 0
December 1983
COM075.0200

FLAW EVALUATION AND REPAIR PLAN
QUAD CITIES UNIT 2 & DRESDEN UNIT 3
FALL 1983 OUTAGES

Prepared for

Commonwealth Edison Company
Chicago, Illinois

Prepared by:

NUTECH Engineers, Inc.
San José, California

nutech
ENGINEERS

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

This report summarizes the flaw evaluation and repair plan, including the weld overlay design and analysis methodology being used for the affected stainless steel piping systems at Commonwealth Edison Company's Quad Cities Nuclear Power Station Unit 2 and Dresden Nuclear Power Station Unit 3 during the Fall 1983 outages. This plan addresses ultrasonic examination results which are believed to be indicative of intergranular stress corrosion cracking (IGSCC) in the vicinity of some of the welds on the concerned systems.

Each flaw indication is evaluated to determine whether a repair is necessary. Note, for small flaws, a repair may not be necessary. Figure 1 shows the disposition sequence for a typical flaw. Since both Dresden Unit 3 and Quad Cities Unit 2 are also implementing IHSI during the current outage, IHSI is performed on welds with flaws that are deemed to be candidates to be left "as-is", whenever practical. Based on the post-IHSI UT examination, a decision is made either to leave the flaw "as-is" or to perform a weld overlay repair.

For flaws that are repaired by weld overlay, the overlay thickness (which is a function of flaw depth, flaw length, and applied stresses) is sufficient to provide full IWB-3640 margin. The purpose of each overlay is to arrest any further propagation of cracking and to restore original safety margins to the weld. Analysis of flaw indications to date demonstrate that weld overlays do in fact arrest crack growth completely.

The flaw evaluation and repair criteria meet the intent of the guidelines set forth by the NRC in recently issued SECY-83-267C dated November 7, 1983 (Reference 1). The detailed evaluation criteria and the design/analysis approach are discussed in Sections 2.0, 3.0, and 4.0.

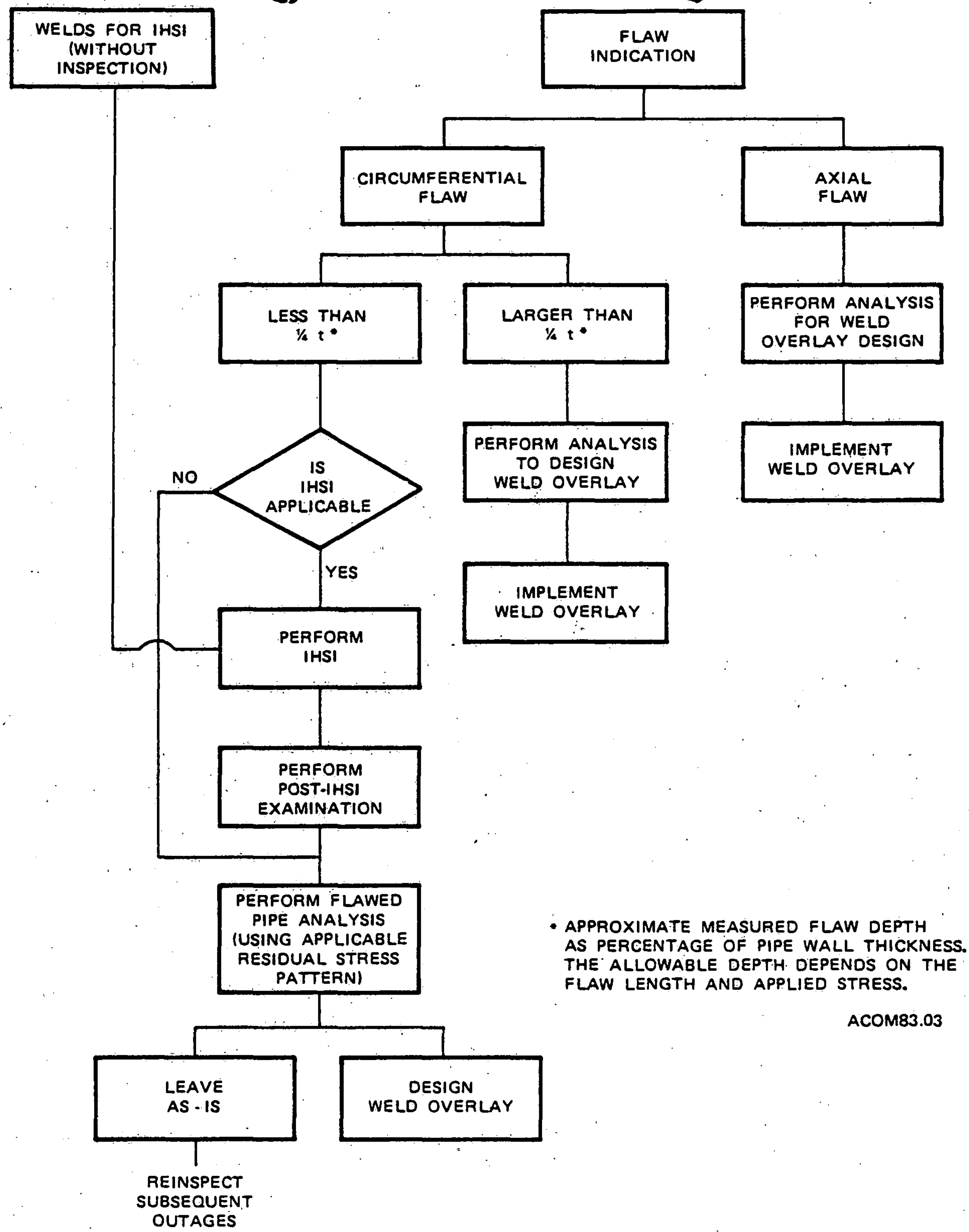

Figure 1

TYPICAL FLAW DISPOSITION SEQUENCE

2.0 EVALUATION METHODOLOGY

This section describes the criteria that are applied to evaluate the acceptability of the weld overlay repairs or flawed pipe analyses. The intent of the design criteria described below is to demonstrate equivalent margins of safety for the strength and fatigue considerations in the ASME Code, Section III design rules. In addition, because of the IGSCC conditions that led to the need for repairs, IGSCC resistant materials have been selected for the weld overlay repairs. Criteria are also provided below for fracture mechanics evaluation of the repairs.

2.1 Strength Evaluation

Adequacy of the strength of the weld overlay repairs with respect to applied mechanical loads is demonstrated with an ASME Boiler and Pressure Vessel Code Section III, Class 1 (Reference 3) analysis for each repair.

2.2 Fatigue Evaluation

The stress values obtained from the above strength evaluation are combined with thermal and other secondary stress conditions to demonstrate adequate fatigue resistance for the design life of each repair in accordance with the requirements of Reference 3.

2.3 Fracture Mechanics Evaluation

A conservative method is used to demonstrate the adequacy of the weld overlay repair. All relevant UT indications are assumed to be twice the confirmed crack depth. The intermittent flaws are assumed to be continuous for these evaluations. The weld overlay is then designed such that the requirements of Reference 2 are satisfied.

IGSCC growth depends on the total steady-state stress. The major contributor to steady-state stress is weld residual stress. The residual stresses due to the original butt weld plus those due to the weld overlay are determined by analysis.

The conservative upper-bound crack growth law (Reference 5) for these analyses is

$$\frac{da}{dt} = 4.116 \times 10^{-12} K^{4.615}$$

where, da = differential crack size

dt = differential time

K = applied stress intensity factor

Crack growth as a function of time is calculated assuming an infinitely long crack using the NUTECH computer program NUTCRAK.

This evaluation approach has been used previously and has been reviewed and accepted by the NRC for Dresden Unit 2, Hatch Unit 2, Vermont Yankee, and Brunswick Units 1 & 2.

3.0 EVALUATION METHODOLOGY

The evaluation of a flaw or a weld overlay repair consists of a code stress analysis per Section III (Reference 3) and a fracture mechanics evaluation per Section XI (References 2 and 4). The effect of the repair on piping system is also evaluated.

3.1 Code Stress Analysis

A finite element model of the repaired region is developed using the ANSYS computer program. The stresses in the overlaid pipe (weld region) due to design pressure and applied moments are calculated using the finite element model.

The weld overlay thermal model is taken to be axisymmetric. The exterior boundary is assumed to be insulated. The maximum thermal stresses for use in the fatigue analysis are calculated in accordance with Reference 3.

3.2 Fracture Mechanics Evaluation

The allowable crack depth is calculated based on Reference 2. Crack growth due to fatigue is determined based on the analyses described in Section 3.1. Crack growth due to IGSCC is evaluated based on Reference 2, the applied stresses, and empirical crack growth data.

It is noted that for most flaws where weld overlay repair is applied, the change in the residual stress pattern is sufficient to prevent further crack growth.

3.3 Effect on Repaired Piping Systems

Weld overlay repair causes a small amount of radial and axial shrinkage underneath the overlay. The effect of the observed weld shrinkage on the affected piping systems will be evaluated using the NUTECH computer program PISTAR.

4.0 WELD OVERLAY DESIGN & ANALYSIS PROCEDURE

This section describes the manner in which the flaw evaluation including weld overlay design and analyses is carried out.

4.1 Input Parameters

The following parameters are used as input to the flaw evaluation:

a. Flaw characterization based on UT inspection,
b. Piping system stresses at welds from existing stress reports, and
c. Geometry and pipe wall thickness.

4.2 Weld Overlay Design

The following steps are involved in design of a weld overlay:

a. Applied stresses and flaw length are used to determine the allowable (IWB-3640) flaw size as a fraction of thickness (a/t),
b. The ratio of twice the measured flaw size to the allowable flaw size is used to determine the

overlay thickness required to meet IWB-3640 criteria,

c. It is demonstrated that the required overlay produces a residual stress pattern which arrests further crack growth, and

d. It will also be demonstrated that the overlay by itself is sufficient to meet IWB-3640 requirements for a through-wall or near through-wall flaw.

4.3 Flaw Evaluation and Repair Analyses

The repair may consist of IHSI and/or weld overlay as applicable. For small flaws, the flawed pipe evaluation may demonstrate that no repairs are needed. The analyses performed to demonstrate the adequacy of these repairs/resolutions are described in Sections 4.3.1, 4.3.2, and 4.3.3.

4.3.1 Weld Overlay

Analysis of weld overlay repair is performed in the following steps:

a. Finite element analysis of the repaired geometry is used as input to an ASME Code, Section III, Class 1 stress analysis of the repaired geometry,

b. Weld residual stress analysis of repairs of part-wall flaws is performed,

c. Crack growth analysis using results from the finite element stress analysis and the residual stress analyses is performed to demonstrate that structural integrity of the repaired weld will not be degraded by further crack growth. These analyses generally show complete arrest of IGSCC crack propagation, and

d. A tearing modulus calculation is performed as a supporting study.

4.3.2 Flawed Pipe Analysis

For certain flaw indications, crack growth analyses as discussed in Section 2.3 are performed to justify continued operation without repair (with or without IHSI). These analyses consider the effect of the residual stress pattern to inhibit growth.

4.3.3 IHSI Evaluations

For flaws that have been treated by IHSI, a crack growth analysis is performed assuming twice the measured flaw depth and a post-IHSI residual stress pattern (Reference

6). The flaw is considered acceptable without repair other than IHSI if:

a. No crack growth results in the post-IHSI configuration,

b. The requirements of IWB-3640 are met with the remaining pipe wall (assuming twice the measured flaw depth).

4.4 Documentation

The results of all of the above analyses will be documented in a certified Design Report (one for each plant).

5.0 SUMMARY

The evaluation of the flaw and repairs to the stainless steel piping systems is performed conservatively to provide assurance that the resulting stress levels are acceptable for all design conditions. The stress levels are assessed from the standpoint of load capacity of the components, fatigue, and the resistance to crack growth.

Meeting the acceptance criteria utilized for the analyses will demonstrate that:

1. There is no loss of design safety margin over that provided by the ASME Code, Section III, for Class 1 piping.

2. During the design lifetime of each repair, the observed cracks will not grow to the point where the above safety margins would be exceeded.

In fact, for the flaws evaluated to date, the selected repair method, (weld overlay or IHSI) has been demonstrated to arrest IGSCC crack growth completely.

6.0 REFERENCES

1. NRC Policy Issue SECY-83-267C dated November 7, 1983 from W. J. Dircks to the Commissioners, "Staff Requirements for Reinspection of BWR Piping and Repair of Cracked Piping."

2. ASME Boiler and Pressure Vessel Code, Section XI, Paragraph IWB-3640, "Acceptance Criteria for Austenitic Steel Piping," (Approved by main committee for incorporation into Section XI in 1983).

3. ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, 1980 Edition.

4. ASME Boiler and Pressure Vessel Code, Section XI, 1980 Edition with Addenda through Winter 1981.

5. EPRI Report NP-2423-LD, "Stress Corrosion Cracking of Type-304 Stainless Steel in High Purity Water: A Compilation of Crack Growth Rates," June 1982.

6. EPRI Report NP-2662-LD, "Computational Residual Stress Analysis for Induction Heating of Welded BWR Pipes," December 1982.