Pressurized Water Reactor Steam Generator Examination Guidelines: Revision 7

Requirements

(Non-Proprietary Version of 1013706)

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PRODUCT DESCRIPTION

This report provides requirements for examination plans and processes that are necessary to meet the performance criteria set forth in the Nuclear Energy Institute (NEI) 97-06 *Steam Generator Program.*

Results and Findings

This document continues to provide recommendations and requirements to the industry for sampling and inspection of steam generator tubing. The qualification for techniques and personnel is described in detail. Additionally, this document recognizes the improved performance of new steam generator tubing materials in the absence of foreign objects and in the presence of good chemistry controls. Data quality parameters continue to be an important attribute of an effective steam generator inspection. Inspection frequencies as described in the Technical Specification Task Force (TSTF) document TSTF 449 *Steam Generator Tube Integrity* are contained within this document. With these recommendations and requirements in place and implemented by the utility, this document makes a significant contribution to meeting the requirements of NEI 97-06.

Challenges and Objectives

Steam Generator tubing, when degraded, can provide a challenge to the required safety functions in terms of structural stability and leakage. It is imperative that the condition of the steam generator be known such that appropriate repairs and operating parameters can be applied. Nondestructive examination (NDE) is the first step in determining the condition of the steam generator. This document is intended to be used by utility engineers, program managers, NDE personnel and plant management in support of:

- Implementation of NEI 97-06
- Meeting the sampling and inspection requirements of TSF 449
- Technique and personnel qualification for input to condition monitoring and operational assessments

Applications, Values, and Use

The fundamental elements of NEI 97-06 represent a balance of prevention, inspection, evaluation, repair, and leakage monitoring measures. Implementation of these elements requires maintenance of this document to ensure applicability to the utility for management of steam generator issues.

EPRI Perspective

NEI 97-06 requires the performance of condition monitoring and operational assessment of the steam generator tubing during and after an outage. These guidelines provide the recommendations and requirements for inspection, technique validation, data quality, and qualification of techniques and personnel.

This document reflects the current industry practices, with enhancements where the industry felt it necessary. Data management requirements were addressed for the first time in this document. The Appendix G damage mechanisms were updated as a result of steam generator replacement projects. A new appendix on qualification of UT personnel was included to separate UT personnel qualification from Appendix G in the same manner that Appendix J was separated from Appendix H for UT technique qualifications. The Inspection frequencies as described in TSTF 449 *Steam Generator Tube Integrity* were included to ensure compliance with the utility technical specifications. The use of mandatory/shall/should/recommend was addressed in accordance with the *Steam Generator Management Program Administrative Procedures, Revision 1.* Additionally, the performance based requirements previously contained in Section 4 have been deleted.

This revision considered all previous interim guidance issued since the last revision and upon issuance of this document, all previous interim guidance should be considered superseded.

Approach

A utility ad hoc committee under the direction of the NDE IRG was convened to complete this revision. The main committee was organized with utility members chairing individual sub-committees for each book section and appendix. Each sub-committee contained participants from both utility and vendor organizations. The objective of this approach was to ensure that input was received from across the industry and that the most qualified personnel were available to work on the applicable sections. The sub-committees developed draft material for review by the main committee. Numerous telecons, web conferences, and meetings were conducted over an eighteen-month period to develop the final draft.

Keywords

Nuclear steam generators
In-service inspection
Eddy current
PWR SG tubing
SGMP

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INTRODUCTION AND BACKGROUND

1.1 Purpose

This document is the seventh revision of the *PWR Steam Generator Examination Guidelines* [1], originally published in 1981 and revised in 1984, 1988, 1992, 1996, 1997, and 2002. The purpose of this document is to provide requirements and guidance for meeting the following objectives:

- Identification of degradation which is present in the steam generator tubes,
- Qualification of NDE systems used to detect and/or size degradation.

The requirements provided within this document promote accountability for the examination process, and provide for subsequent verification of compliance by internal or external audit. The protocol for deviating from specific requirements of this document is in the *EPRI Steam Generator Management Program Administrative Procedures* [2]. Where regulatory requirements differ from requirements contained in this guideline, a technical justification for deviation is not required.

The requirements provided by this document assist in meeting the objectives of NEI 97-06, *Steam Generator Program Guidelines* [3]. NEI 97-06 brings consistency to the development and implementation of a program that monitors the condition of steam generator tubes against acceptable performance criteria in a manner sufficient to provide reasonable assurance that the steam generators remain capable of fulfilling their intended safety function.

1.2 Scope

This revision adheres to the guidance of NEI 97-06 and the Steam Generator Management Program (SGMP) Administrative Procedure.

This document provides the requirements and associated bases for performing SG tube inspections, including selection of periodic inspection samples, validation of NDE systems to detect and size tubing flaws, and specification of requirements for qualification of examination techniques and data analysis personnel.

The development and revision protocol of this guideline and subsequent revisions are governed by the latest revision of the Steam Generator Management Program Administrative Procedures.

1.3 Background

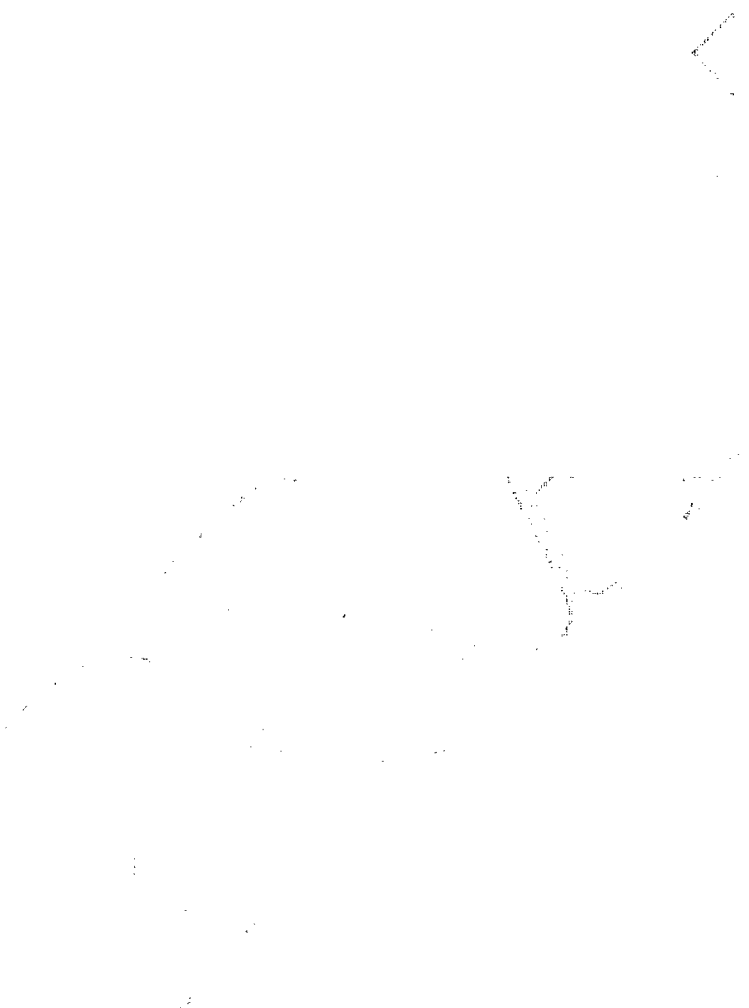
2
COMPLIANCE RESPONSIBILITIES

2.1 Introduction

The objective of this section is to identify organizational responsibilities necessary to ensure examination activities are effectively implemented for safe and reliable steam generator operation.

2.2 Management Responsibilities

2.3 Examination and Engineering Responsibilities



3
MATERIAL BASED EXAMINATION REQUIREMENTS

3.1 Introduction

This section outlines pre-service inspection (PSI), in-service inspection (ISI) requirements, and sample plan expansions for steam generators fabricated from Alloy 600 Mill Annealed, Alloy 600 thermally treated (TT), Alloy 690 TT, and Alloy 800 materials. Additional inspections may be required based on the degradation and/or tube integrity assessments. It is recommended that the requirements contained within this Section for Alloy 600 TT be applied to Alloy 800.

Extended inspection periods for Alloy 600 thermally treated (TT), and Alloy 690 TT are predicated on the premise that these materials will not experience in-service corrosion degradation within the first inspection period.

3.2 Steam Generator Pre-Service Inspection Requirements

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3.5.2 Subsequent Inspection Examination Sleeves

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3.5.4 Subsequent Inspection of Other Repairs

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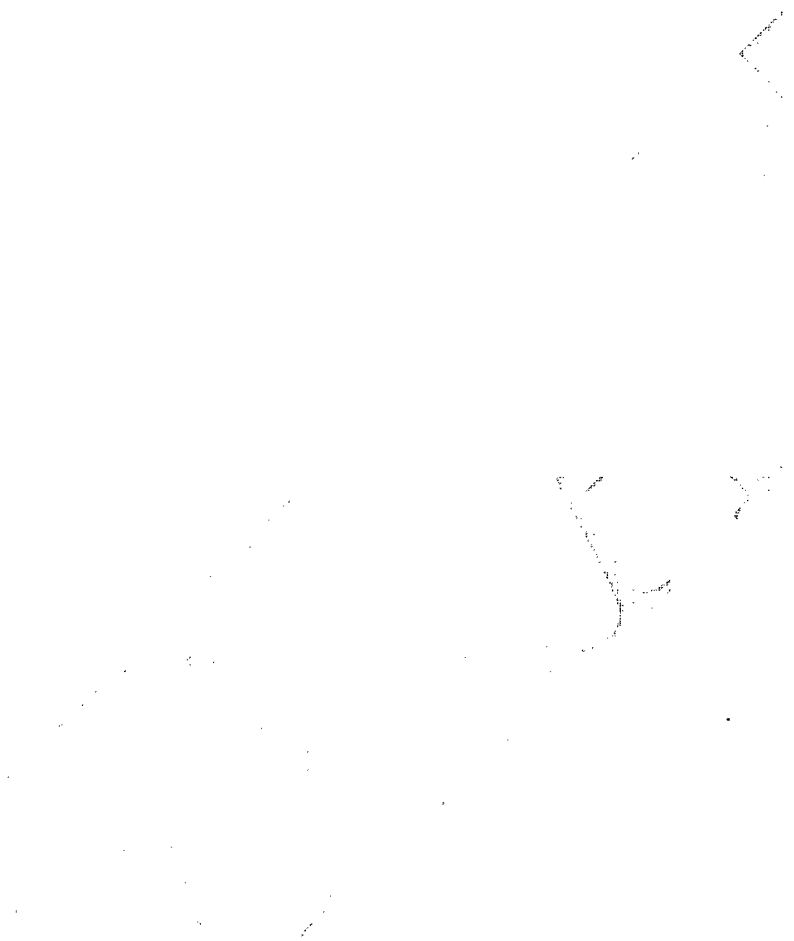

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4
SAMPLING REQUIREMENTS FOR PERFORMANCE-BASED EXAMINATIONS

This section has been deleted.

5
STEAM GENERATOR ASSESSMENTS

5.1 Introduction

The following assessments are considered important elements of a written comprehensive SG program:

- Degradation assessment
- Condition monitoring assessment
- Operational assessment
- Primary-to-secondary leakage assessment
- Self-assessment

An overview of these assessments is provided here for completeness and integration of the program. Detailed requirements are provided in the EPRI *Steam Generator Integrity Assessment Guidelines* and the NEI 97-06 *Steam Generator Program Guidelines.*

5.2 Degradation Assessment

5.3 Condition Monitoring Assessment

5.4 Operational Assessment

5.5 Primary-to-Secondary Leakage Assessment

5.6 Self-Assessment

6
SYSTEM PERFORMANCE

6.1 Introduction

This section provides requirements for technique performance, analysis performance, data management performance, data quality, human performance, analysis feedback, verification, contractor oversight and visual inspection. In combination, they are referred to as system performance and each part adds value to ensure the tube examination results are useful in condition monitoring and operational assessments. System performance needs to be capable of detecting, characterizing, and monitoring degradation that challenges the integrity of the component being examined. Under field conditions, system performance is influenced by the capabilities of the process, procedures, examination equipment, techniques, and personnel. Ultimately, the licensee is responsible for the quality and accuracy of the inspection, providing oversight, review, and approval of all processes and procedures being used, work activities, and the integrity of the final results.

Ultrasonic testing is not generally used as a production examination technique and therefore the specific requirements in this section do not apply. However, when ultrasonic testing is used as an input to tube integrity assessments, it is recommended that personnel and techniques be qualified in accordance with Appendices J and K and the intent of this section's requirements apply to the extent practical.

6.2 Technique Performance Requirements

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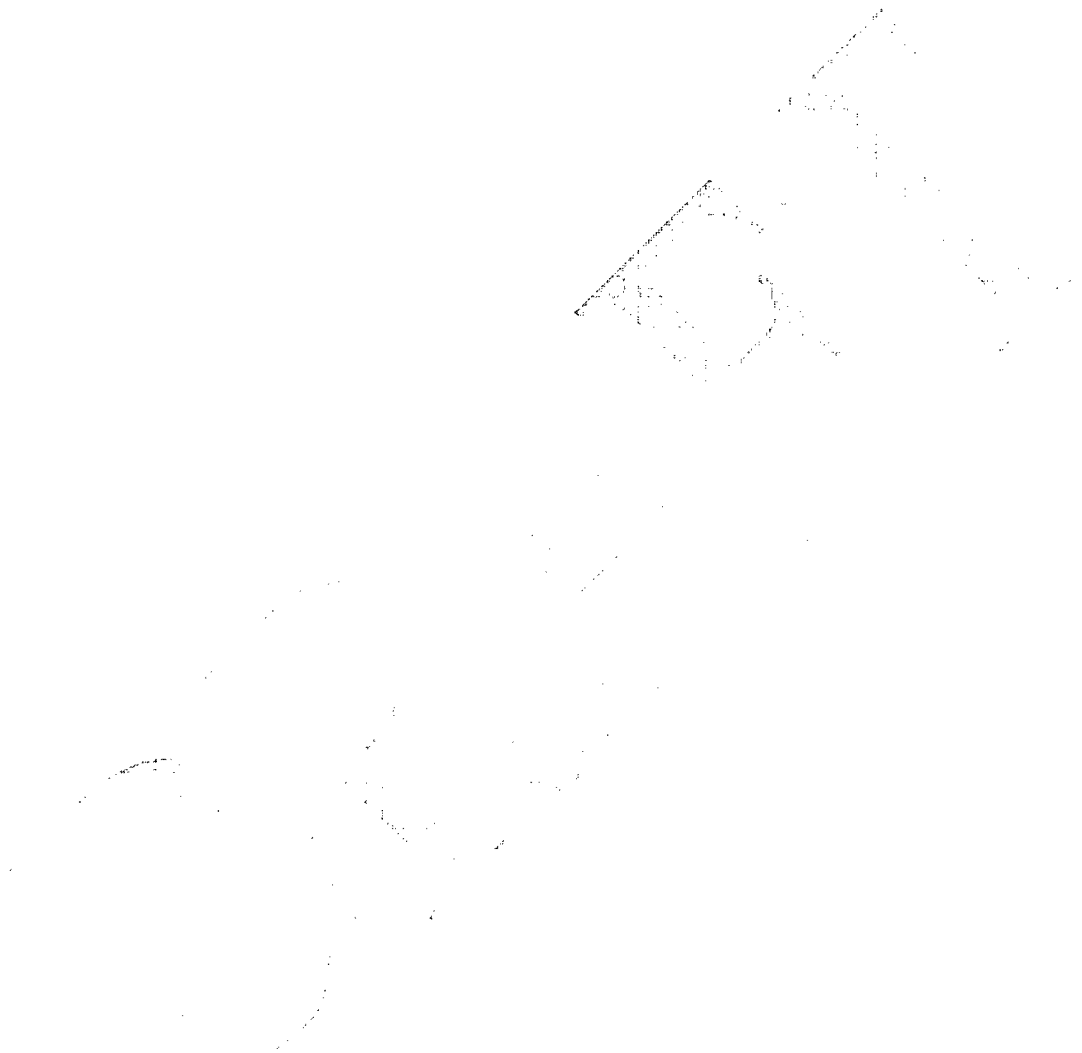

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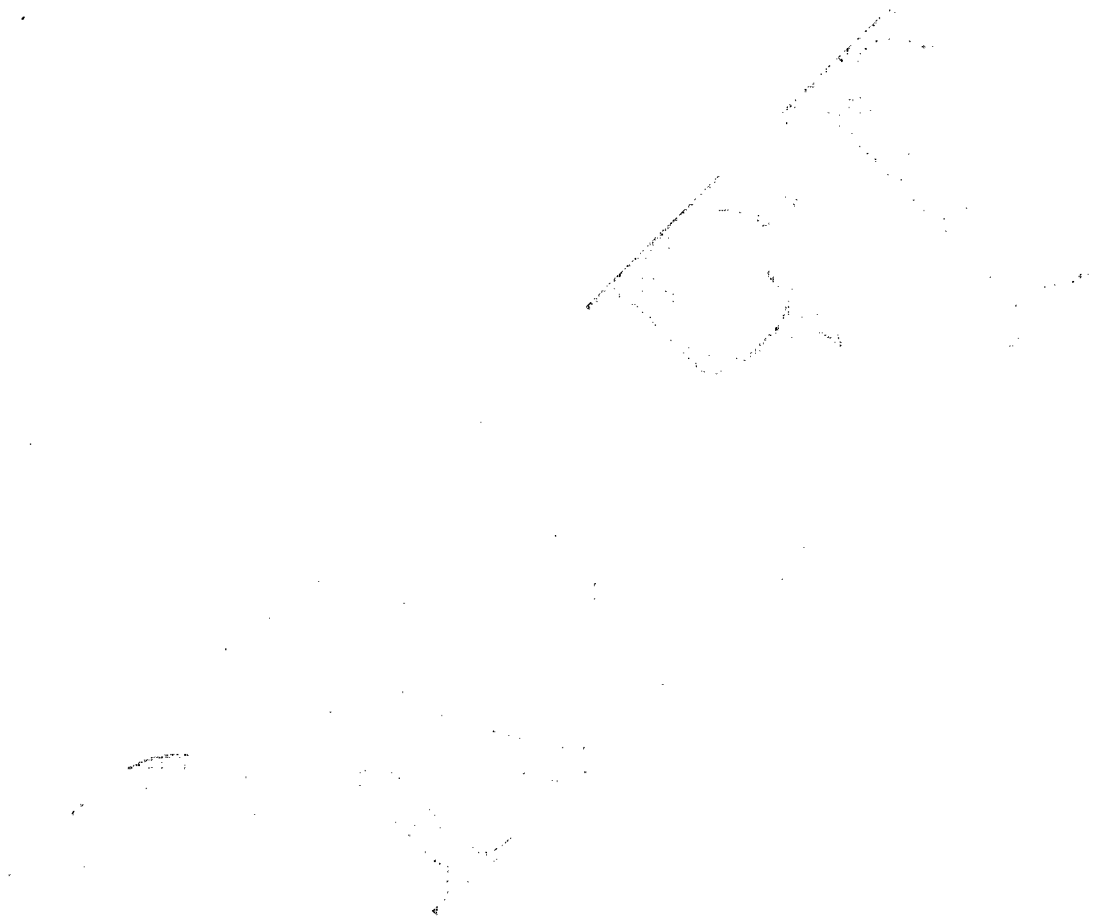

6.4.2.7 Final Archiving

6.5 Data Quality Requirements

Table 6-2

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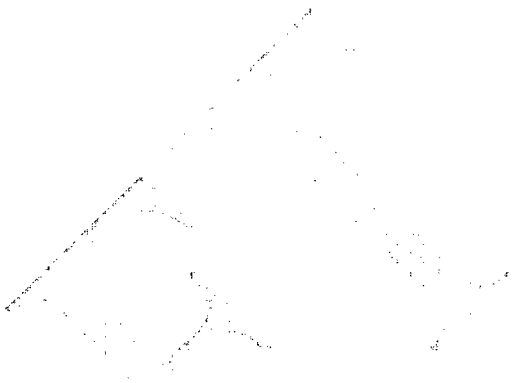

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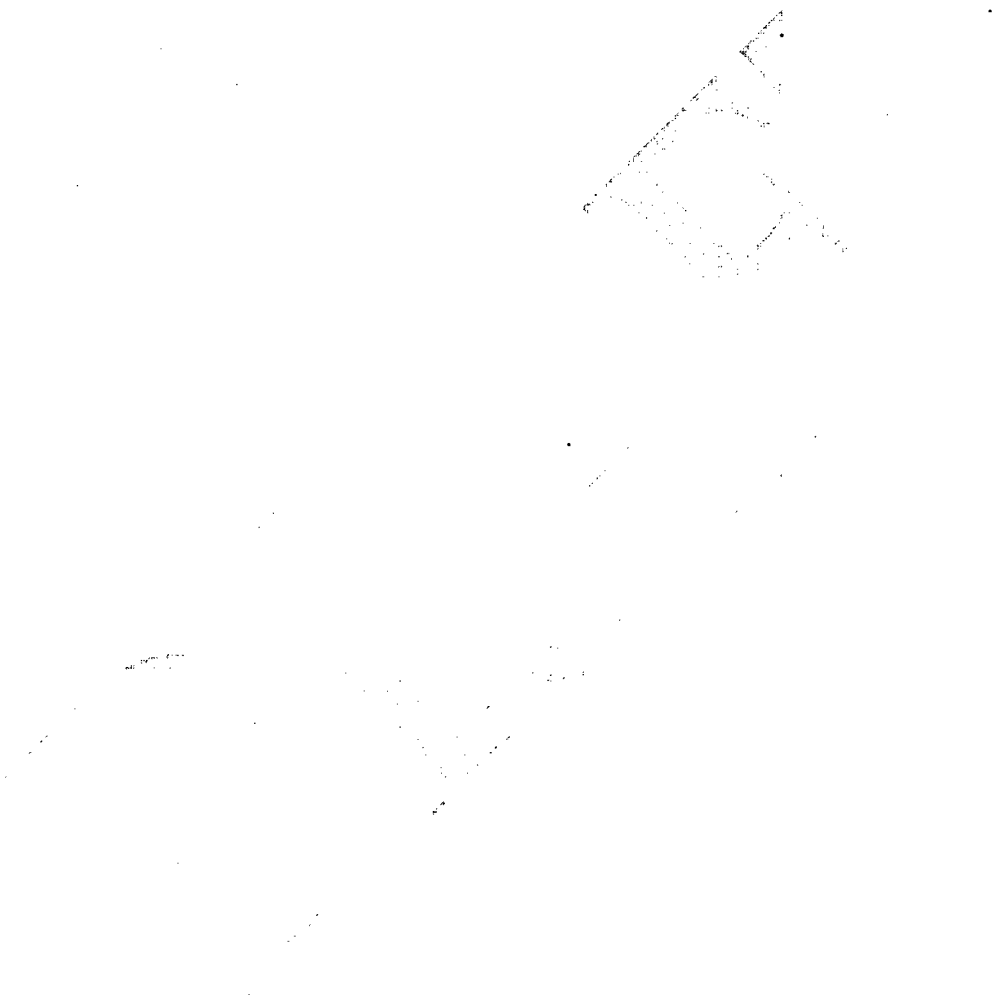
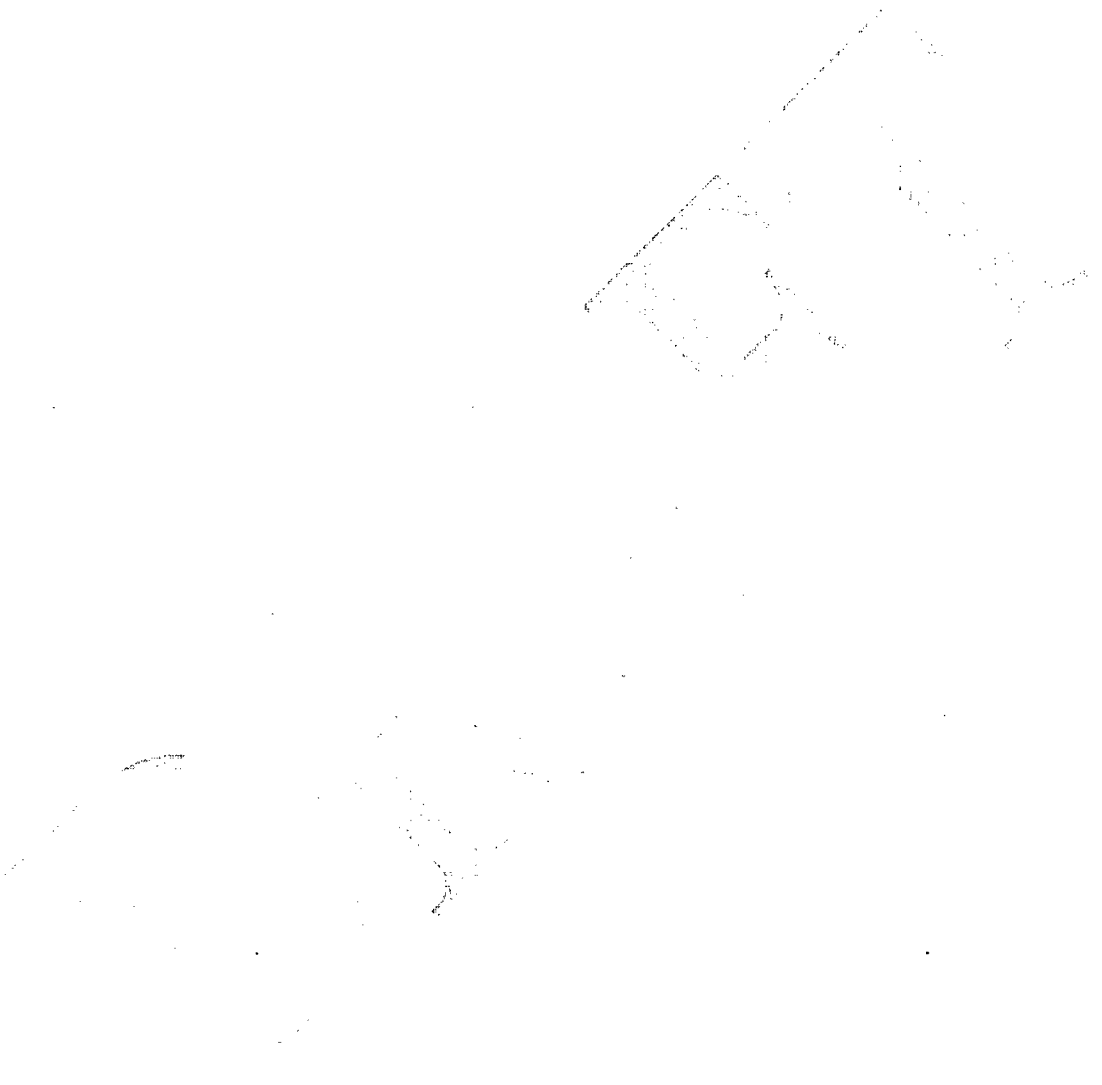
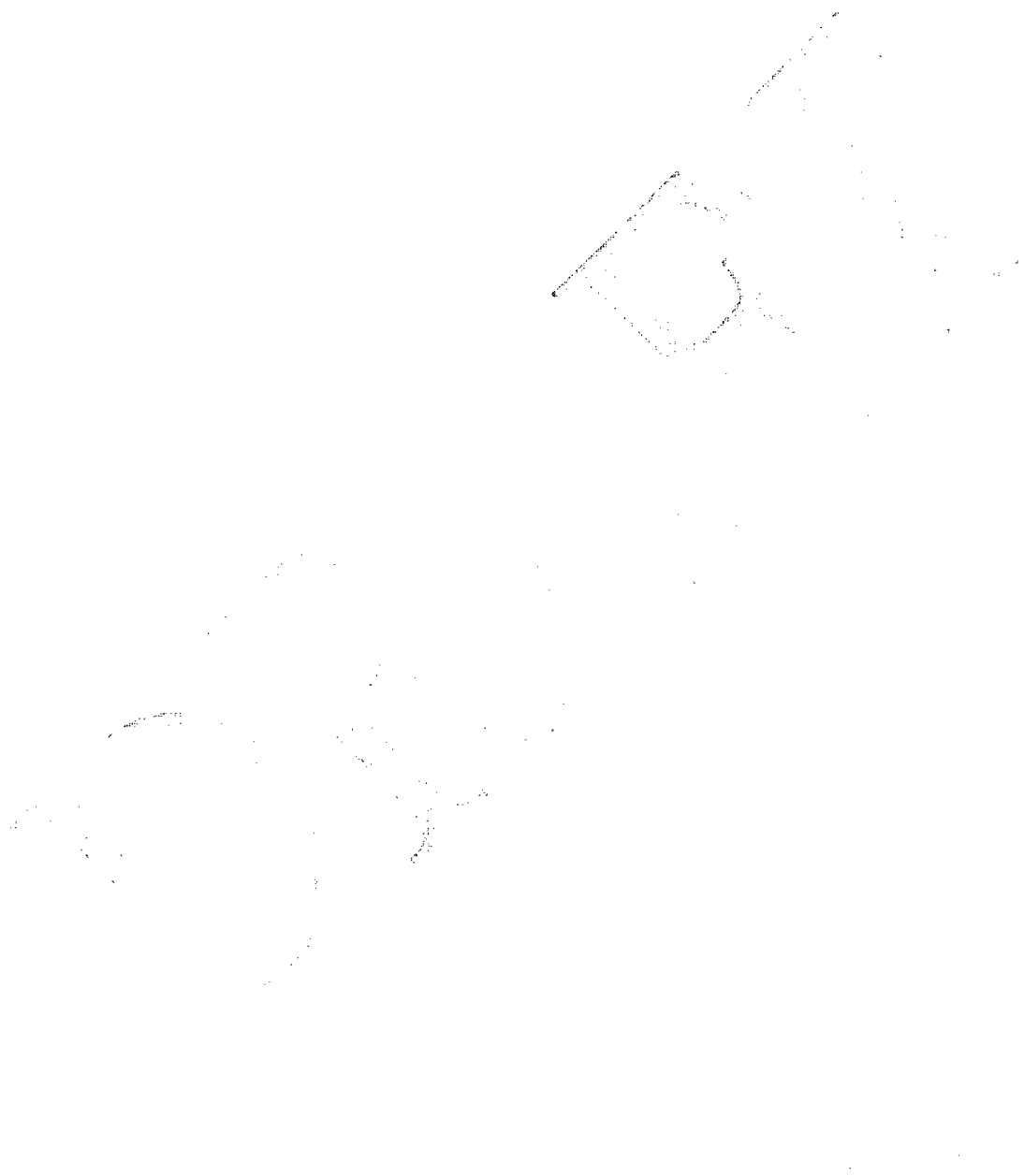
SUMMARY OF REQUIREMENTS

Summary of Requirements

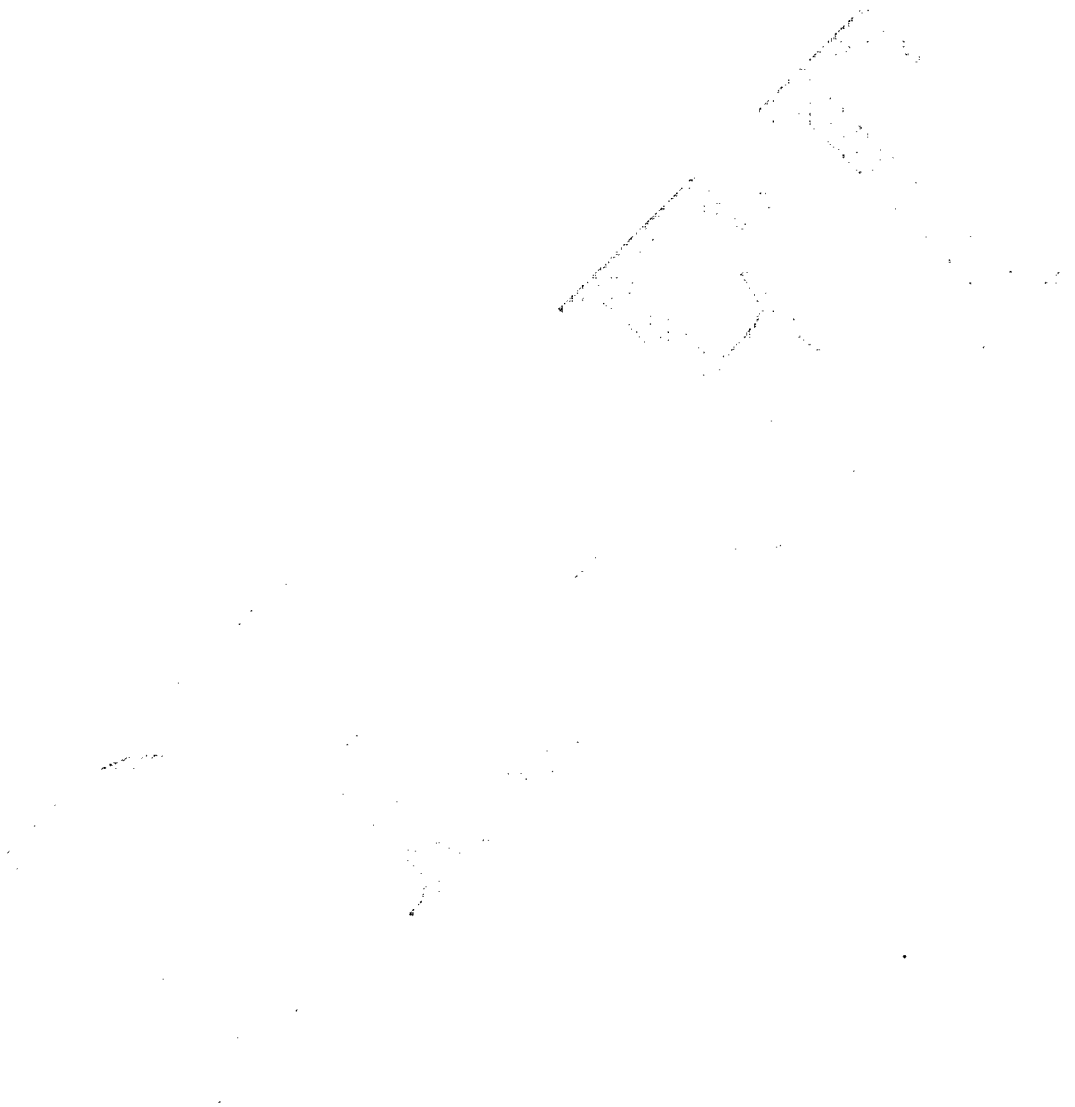




Summary of Requirements



Summary of Requirements



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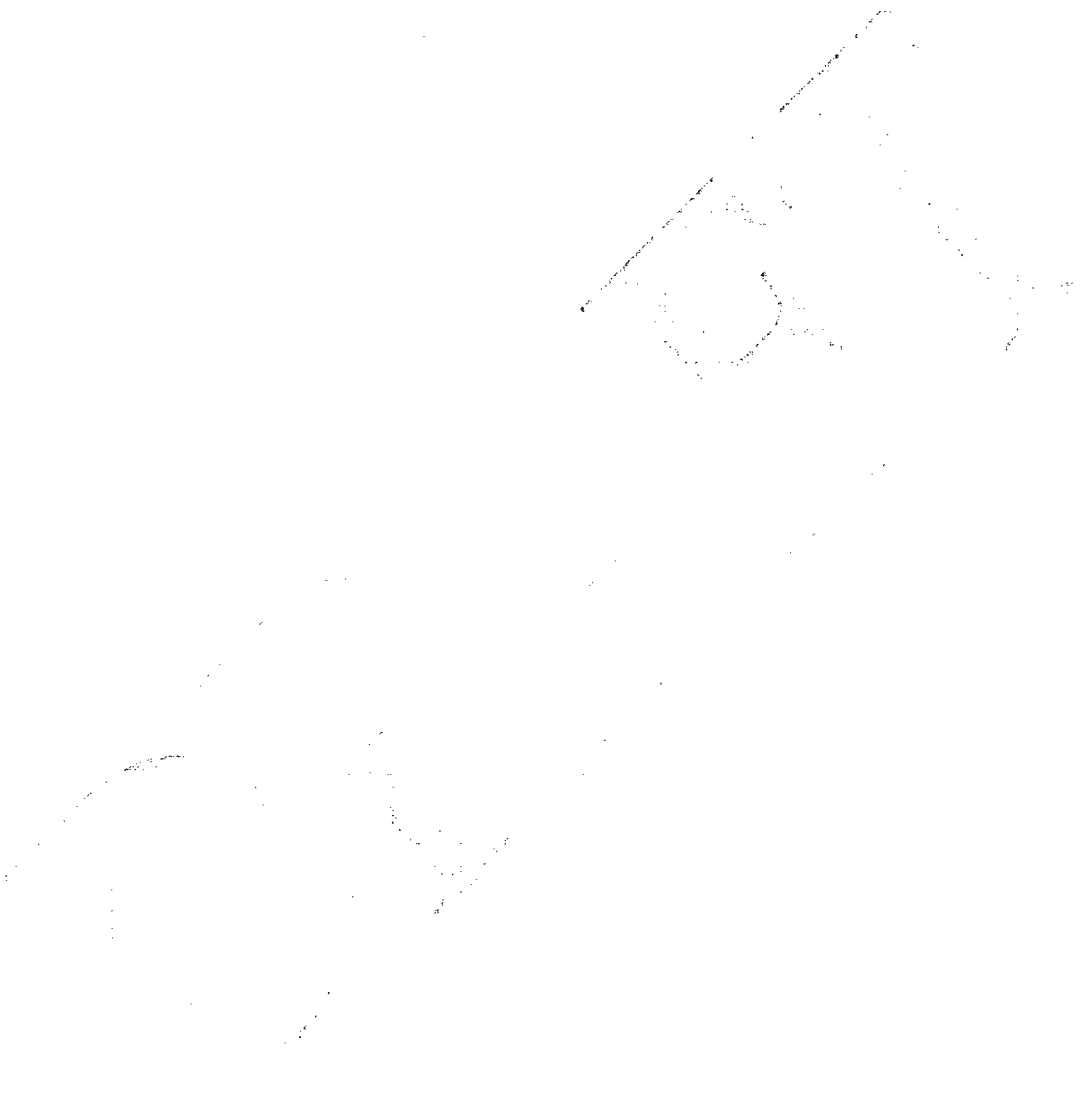

Summary of Requirements

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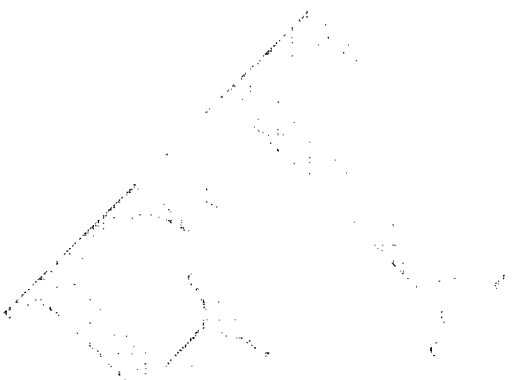
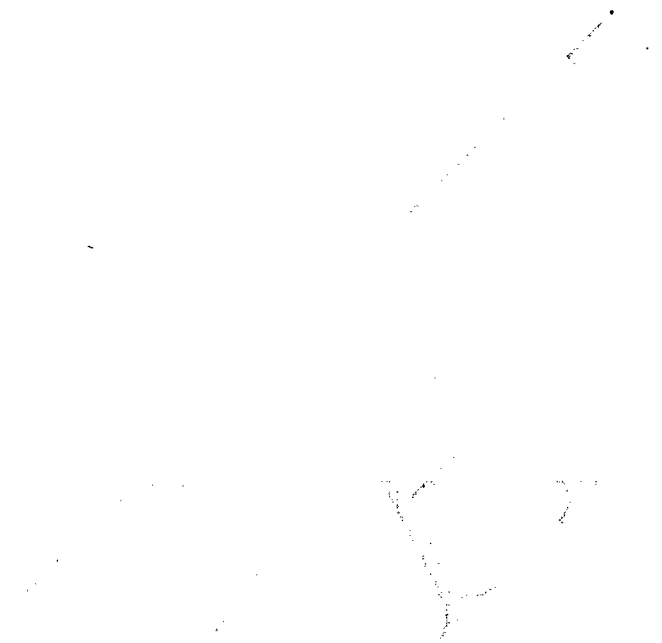
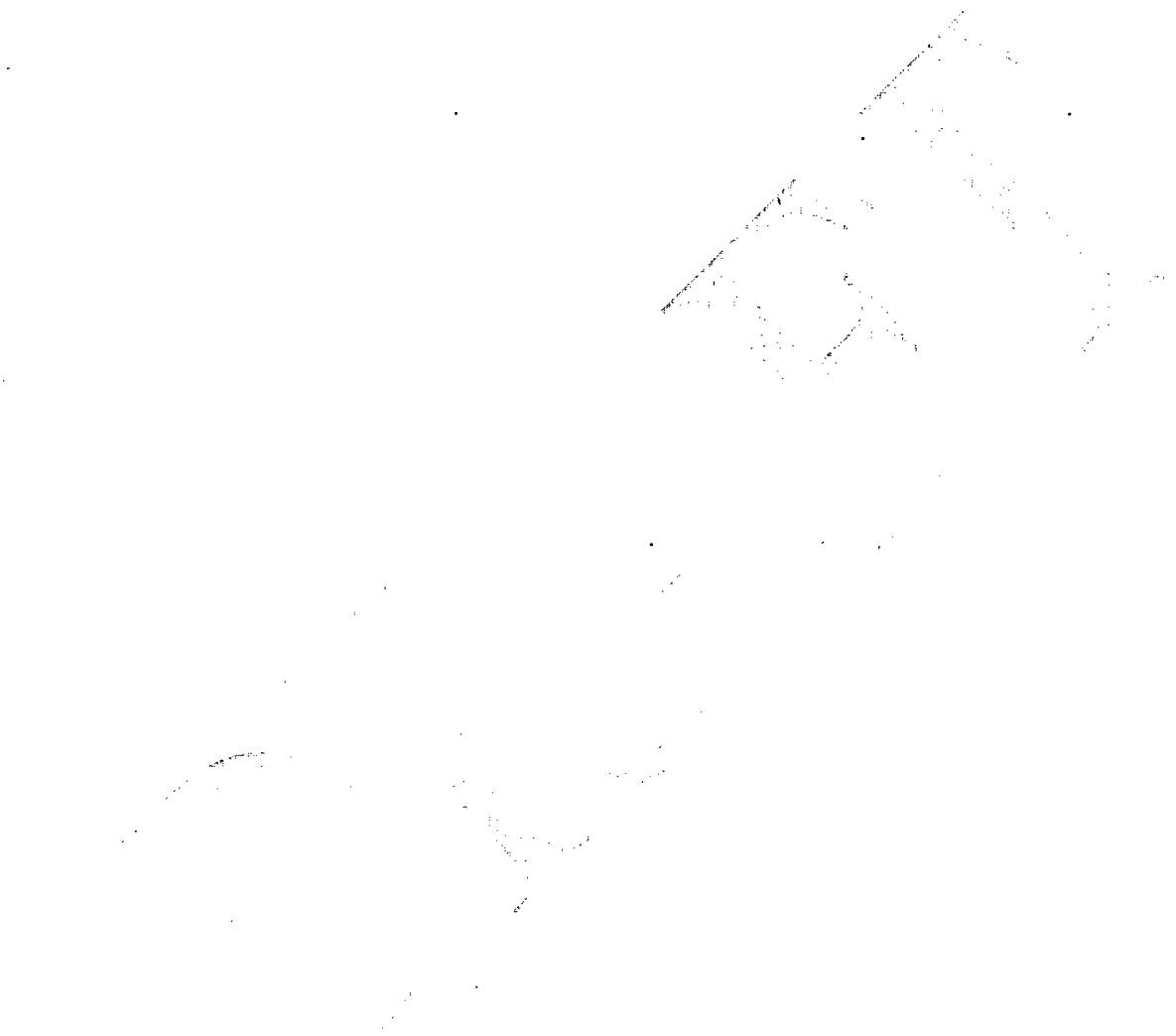




Summary of Requirements



8
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2. *Steam Generator Management Program Administrative Procedures, Revision 1.* EPRI, Palo Alto, CA: 2004. 1011274.
3. *Steam Generator Program Guidelines.* Nuclear Energy Institute (NEI) 97-06. 2005.
4. *The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code*, Sections V and XI.
5. *American Society of Nondestructive Testing (ASNT)* SNT-TC-1A.
6. *American National Standard Institute (ANSI)* CP-189.
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8. *Steam Generator Integrity Assessment Guidelines, Revision 2.* EPRI, Palo Alto, CA: 2006. 1012987.
9. *PWR Steam Generator Tube Plug Assessment Document.* EPRI, Palo Alto, CA: 1997. TR-109495.
10. *PWR Primary-to-Secondary Leakage Guidelines, Revision 3.* EPRI, Palo Alto, CA: 2004. 1008219.

A
SAMPLING BASIS

A.1 Periodic Sample Size

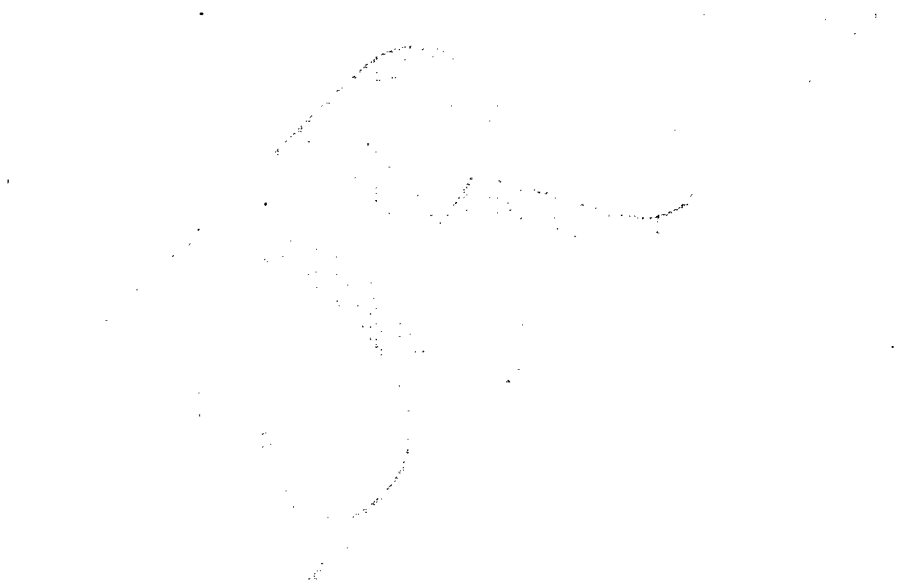
The objective of conducting inspections of steam generator (SG) tubes is to monitor the condition of SG tubes against acceptable performance criteria in a manner sufficient to provide reasonable assurance that SGs remain capable of fulfilling their intended safety function. The purpose of examining samples of tubes rather than examining all tubes in SGs is to reduce the impact of meeting this objective. Consequently, the principal consideration in determining the appropriate sample size for tube examinations is the level of confidence that can be placed in the information obtained about the condition of SG tubes from examining a tube sample of given size.

A.1.1 Level of Confidence Relative to Sample Size and the Number of Tubes Affected by Degradation

Table A-1

A.1.2 Statistical Basis for Level of Confidence

B
STANDARDIZED ANALYSIS REPORT FORMAT



C
STANDARDIZED RAW DATA FORMAT

C.1 Overview

This document proposes a standard format archive for EC data files. The intent of this proposal is standardize format and content and to leverage existing file format standards to enable all vendors and researchers to easily access the data using existing industry standard tools.

C.2 Key Features of a Standardized Eddy Current Data File Format

C.3 General Structure

Table C-1

Table C-2

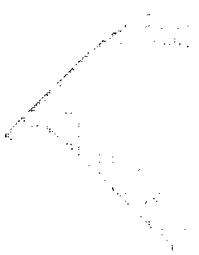
Figure C-1

C.4 General File Format Rules

C.5 Header File Format

C.6 Tester Configuration File Format

C.7 Block Map File Format



C.8 Block Data File Format

C.9 Filelist Format

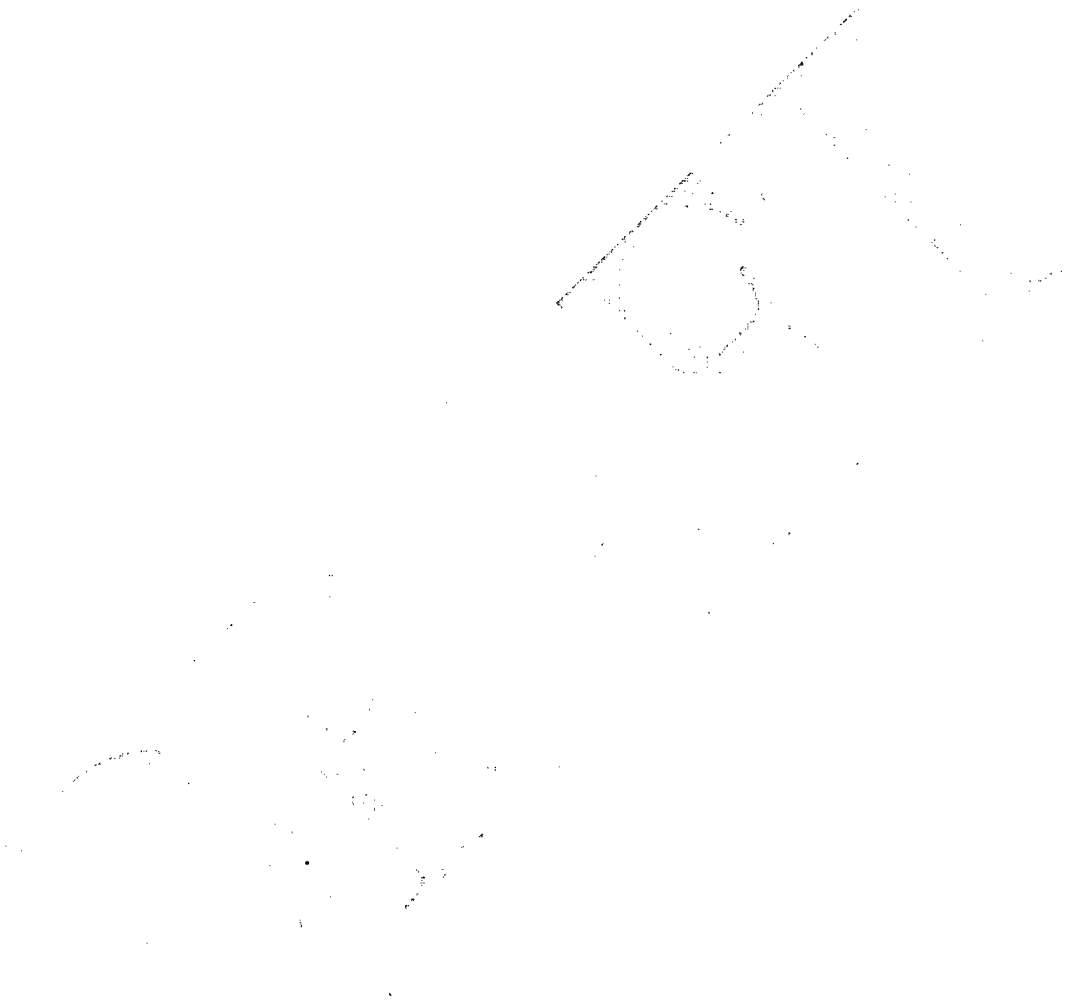
C.10 Message File Format

C.11 Summary File Format

Figure C-2

C.12 Glossary

D



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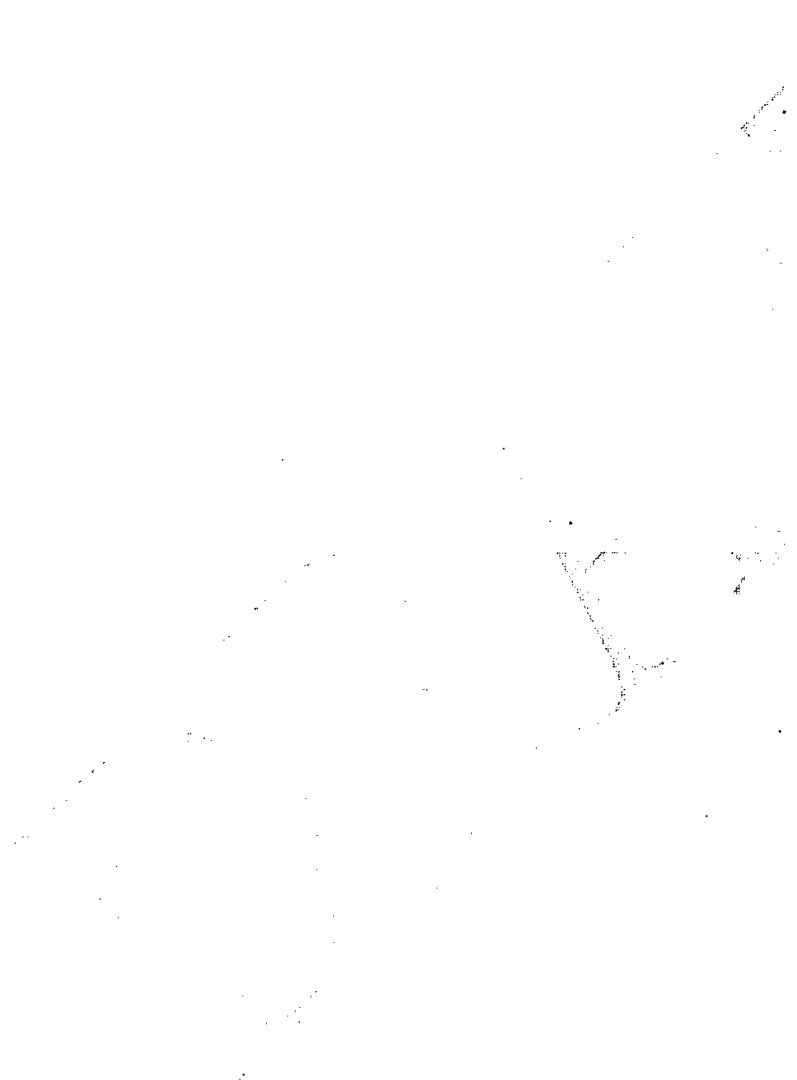
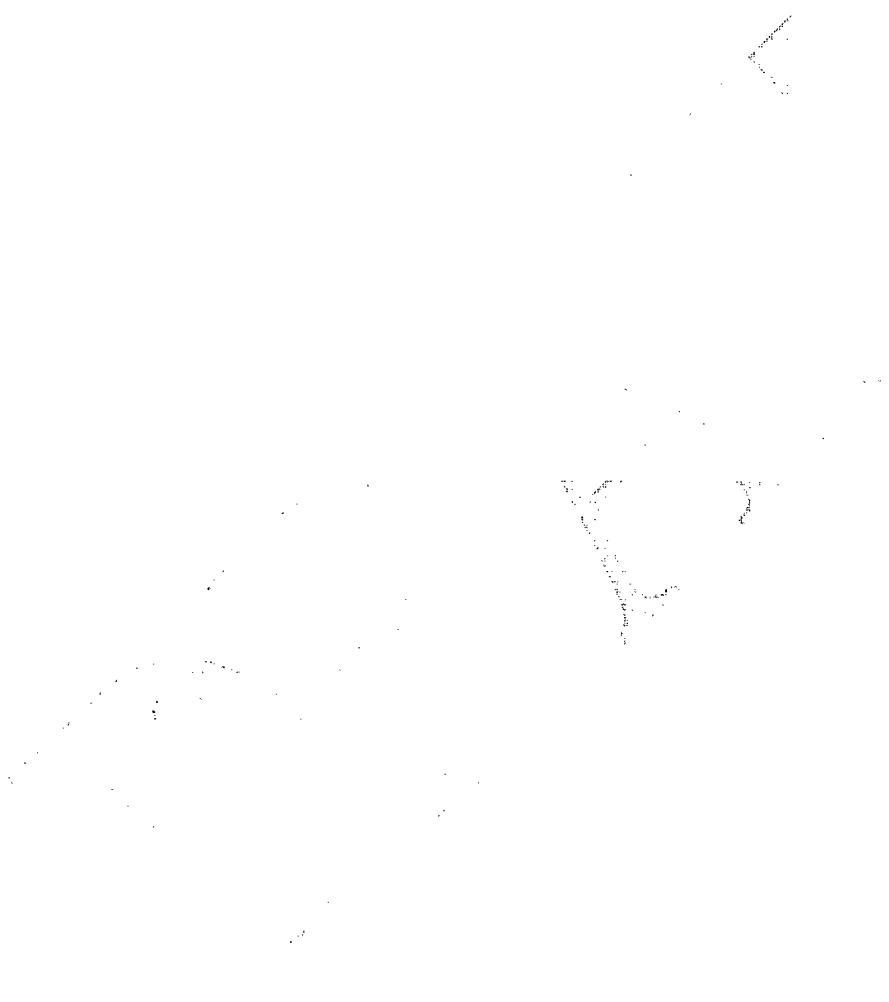
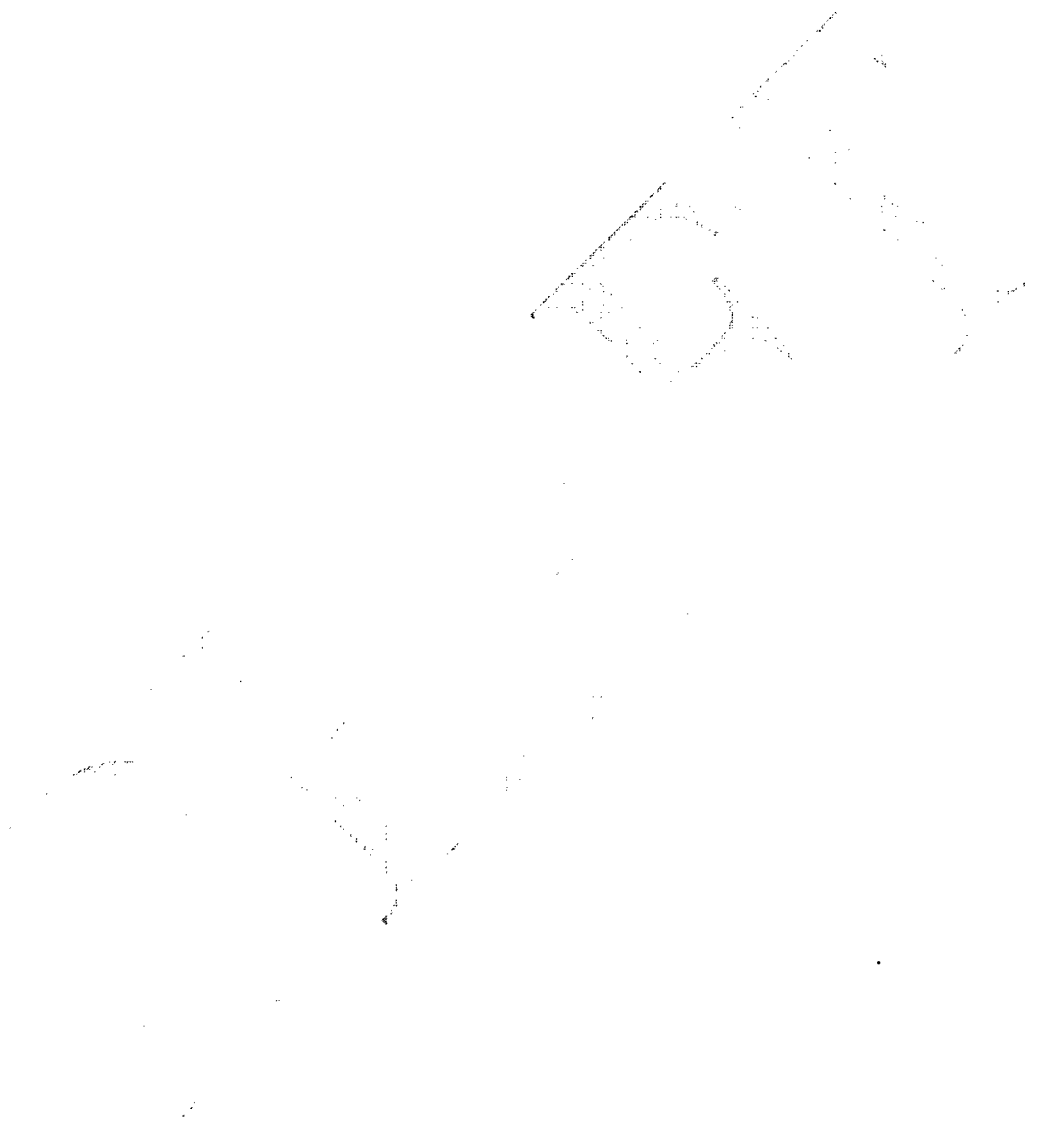


F
TERMINOLOGY

F.1 Definitions

The following definitions are provided to ensure a uniform understanding of terms used in this guideline.





F.3 Three-Letter Codes

The purpose of defining three-letter codes is to standardize their use in the industry. The use of Table F-1 codes on an industry-wide basis is recommended. A three-letter designation is used to describe eddy current inspection results. The codes are grouped into seven categories that describe actions required to assist in the correct disposition of the results. If new three letter codes are developed, then it is recommended that the user assign the applicable category.

Table F-1

Table F-1 (cont.)

G
QUALIFICATION OF EDDY CURRENT EXAMINATION PERSONNEL FOR ANALYSIS OF EDDY CURRENT EXAMINATION DATA

G.1 Scope

This appendix specifies personnel training and qualification requirements for eddy current examination personnel who analyze eddy current examination data for pressurized water reactor steam generator (SG) tubing. Its purpose is to ensure a continuing uniform knowledge base and skill level for data analysts. The appropriate knowledge base is imparted using a comprehensive classroom and laboratory training program.

This appendix uses depth as a basis to establish flawed grading units based on the premise that repair criteria is expressed in terms of percent through-wall (TW). Other NDE parameters, for example, amplitude can be substituted as grading units to demonstrate performance in accordance with this appendix when the applicable repair limit is expressed in terms of other NDE parameters. It is recommended that grading units be established over the full range of the parameter.

Analysts are qualified by successful completion of written and practical examinations defined in this appendix.

G.2 Qualification Level

G.2.1 General Requirements

G.3 Written Practice

G.3.1 General Requirements

G.3.1.1 Training

G.3.1.2 Examinations

G.3.2 Responsibilities

G.3.3 Use of an Outside Agency

G.3.4 Transfer of QDA Qualifications

G.3.5 Confidentiality

G.3.6 Availability of Training Course Materials

G.4 Qualification Requirements

G.4.1 Training

G.4.1.1 Program, Facilities, and Materials

G.4.1.2 QDA Training Course Content and Duration

G.4.1.3 Site Specific Performance Demonstration (SSPD) Training

G.4.2 QDA Examinations

G.4.2.1 Qualification Examinations and Data Sets

G.4.2.1.1 Written Examinations

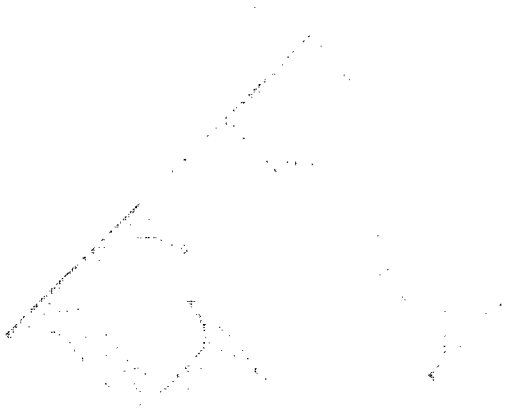
G.4.2.1.2 Practical Examination

Table G-1

Table G-2

Table G-3

G.4.2.2 Analyst Qualification Criteria



G.4.2.3 Re-examination

G.4.2.3.1 Written Examination

G.4.2.3.2 Practical Examination

G.4.2.5 QDA Requalification

G.4.2.6 New Technique/Damage Mechanism for QDA Qualification

G.4.2.7 QDA Qualification Records

G.4.3 SSPD Examinations

G.4.3.1 Examinations and Data Sets

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G.4.3.1.2 Practical Examinations

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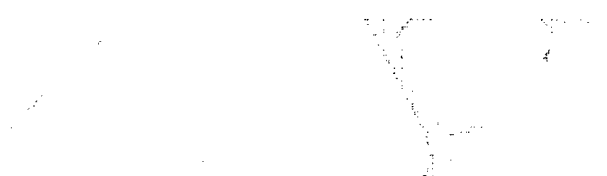
G.4.3.2.1 Written Examination

G.4.3.2.2 Practical Examination

G.4.3.3 Re-Examination

G.4.3.4 SSPD Performance Feedback

Attachment G-1
QDA Training And Laboratory Program Contents



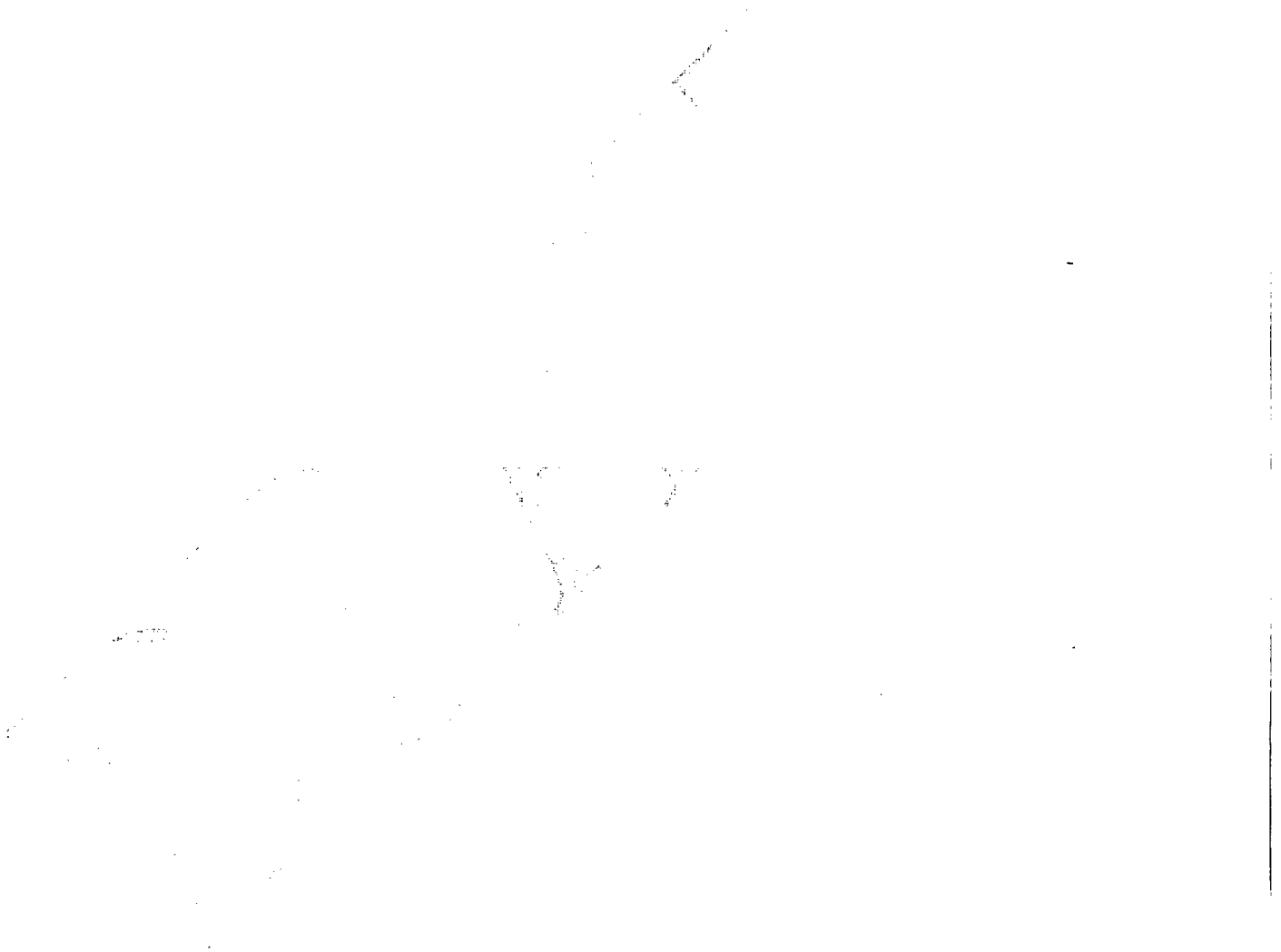


Figure G-1: Qualification Flow Chart

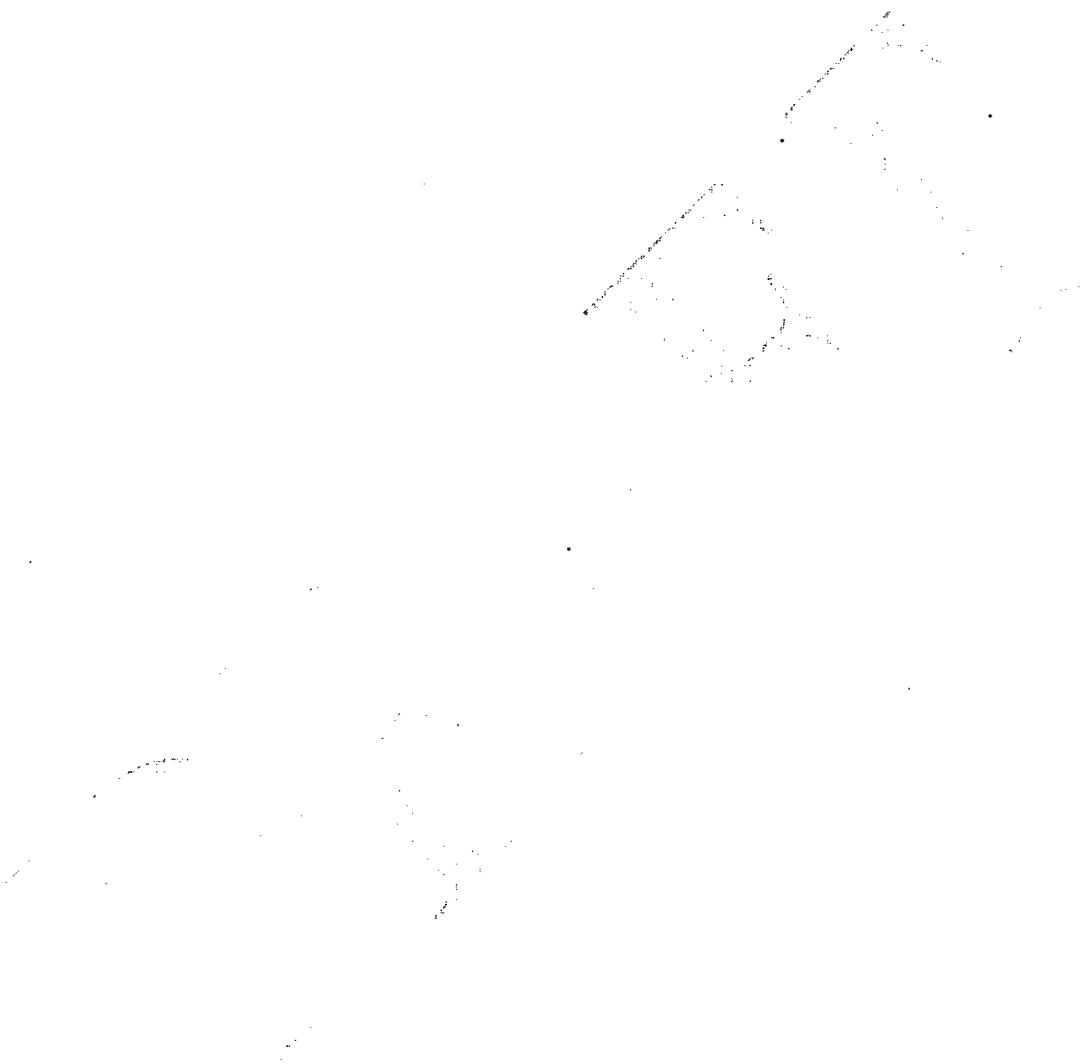


Figure G-2: Requalification Flow Chart

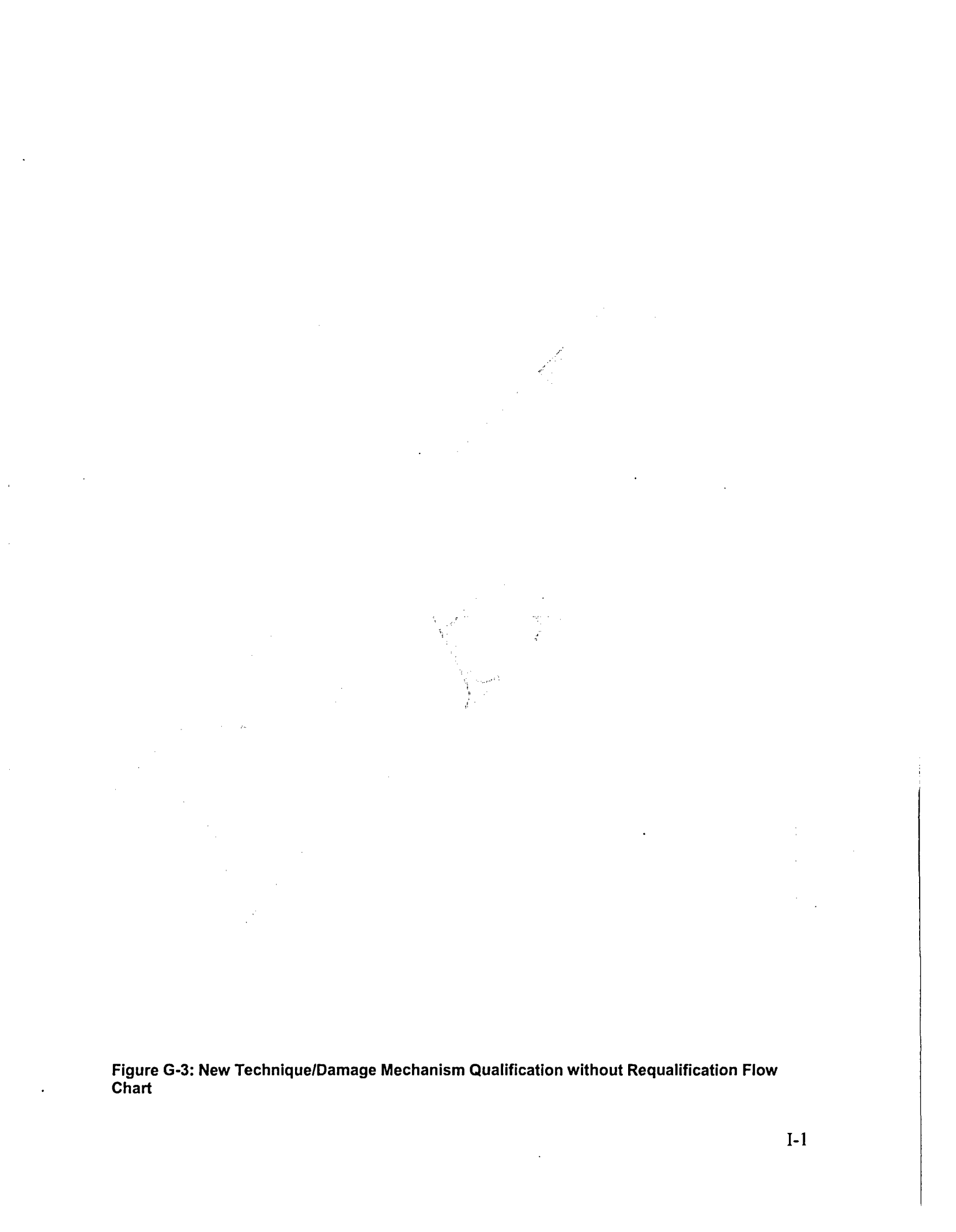


Figure G-3: New Technique/Damage Mechanism Qualification without Requalification Flow Chart

H
PERFORMANCE DEMONSTRATION FOR EDDY CURRENT EXAMINATION

H.1 Scope

a. This appendix provides performance demonstration requirements for eddy current examination techniques and equipment.

H.2 General Examination System Requirements

H.2.1 Technique Requirements

H.2.1.1 Examination Technique Specification Sheet

H.3 Performance Demonstration

H.3.1 General

H.3.2 Essential Variable Ranges

H.3.3 Requalification

H.3.4 Disqualification of Techniques

H.4 Essential Variable Tolerances

H.4.1 Instruments and Probes

H.4.1.1 Cable

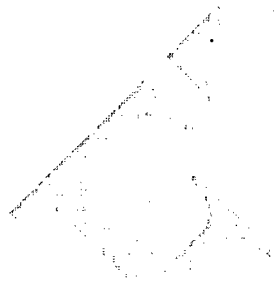
H.4.1.2 Frequency/Material/Wall Thickness

H.4.1.3 Array Probe Sensing Area Coverage

H.4.2 Computerized System Algorithms

H.4.3 Calibration Methods

H.5 Record of Qualification



Supplement H1
Equipment Characterization

H1.1 Scope

This supplement specifies essential variables associated with eddy current data acquisition instrumentation and establishes a protocol for essential variable measurement.

H1.2 Eddy Current Instrument

H1.2.1 Signal Generation

H1.2.1.1 Total Harmonic Distortion

H1.2.1.2 Output Impedance

H1.2.2Amplification, Demodulation and Filtering

H1.2.2.1 Input Impedance

H1.2.2.2 Amplifier Linearity and Stability

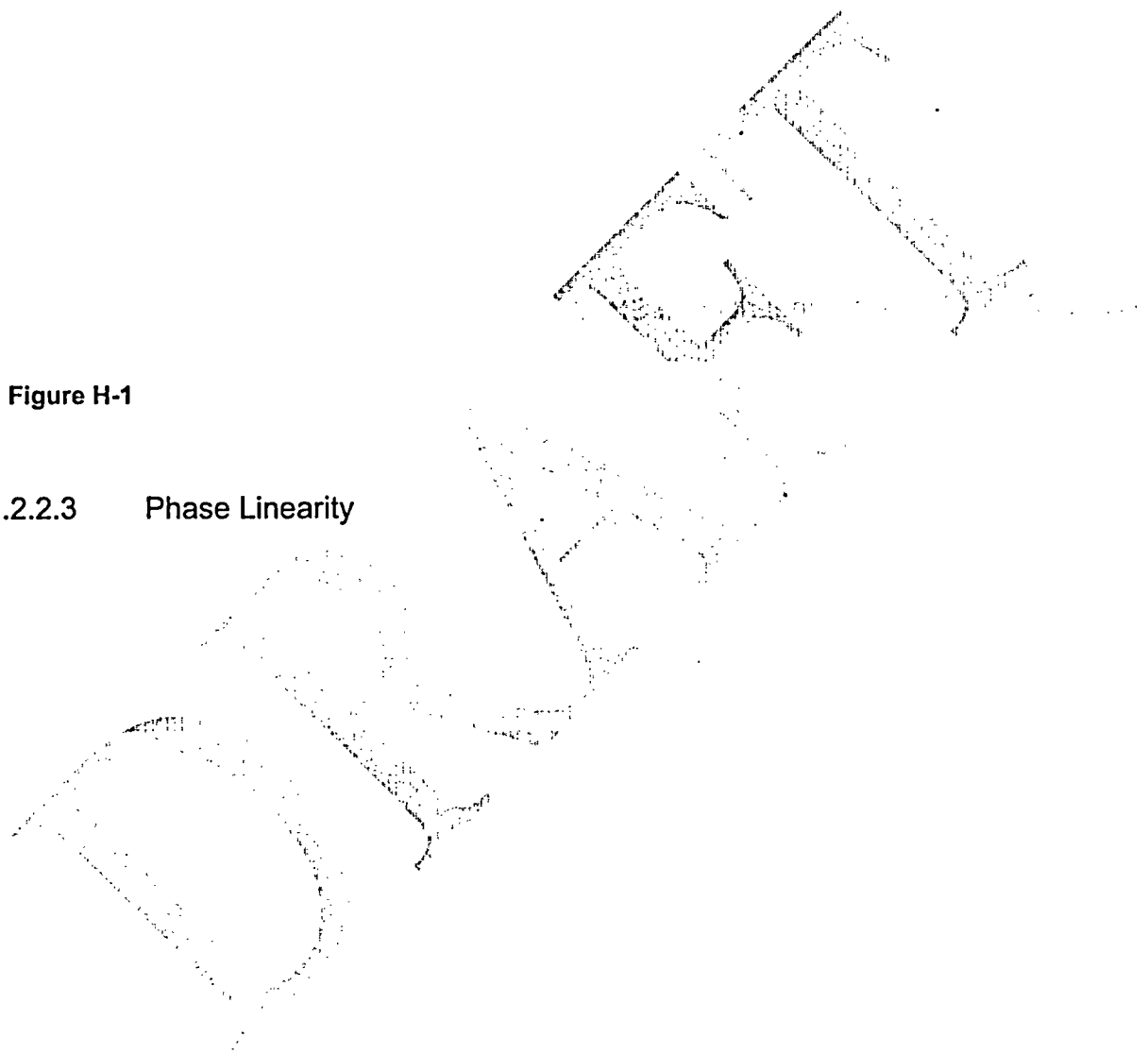


Figure H-1

H1.2.2.3 Phase Linearity

H1.2.2.4 Bandwidth and Demodulation Filter Response

H1.2.3Analog-to-Digital Converter

H1.2.3.1 Analog-to-Digital Resolution

H1.2.3.2 Dynamic Range

H1.2.3.3 Digitizing Rate

H1.2.4Channel Crosstalk

H1.3 Probe Characterization

H1.3.1 Impedance

H1.3.2 Center Frequency

H1.3.3 Coil Configuration Sensing Area

H1.3.3.1 Bobbin Probes

H1.3.3.1.1 Effective Scan Field Width

H1.3.3.1.2 Fill Factor Coefficient

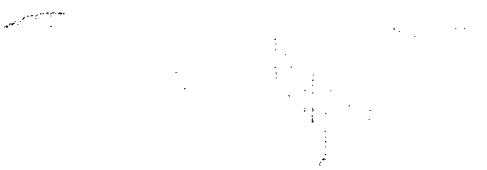
H1.3.3.1.3 Depth Coefficient

H1.3.3.1.4 Axial Length Coefficient

H1.3.3.1.5 Transverse Width Coefficient

H1.3.3.1.6 Phase-to-Depth Curve

H1.3.3.1.7 Direct Current Saturation Strength



H1.3.3.2 Rotating Probes

H1.3.3.2.1 Effective Scan Field Width

H1.3.3.2.2 Effective Track Field Width

H1.3.3.2.3 Lift-Off Value

H1.3.3.2.4 Depth Coefficient

H1.3.3.2.5 Axial Length Coefficient

H1.3.3.2.6 Transverse Width Coefficient

H1.3.3.2.7 Phase-to-Depth Curve

H1.3.3.3 Array Probes

H1.3.3.3.1 Effective Scan Field Width

H1.3.3.3.2 Diametral Off-Set Value

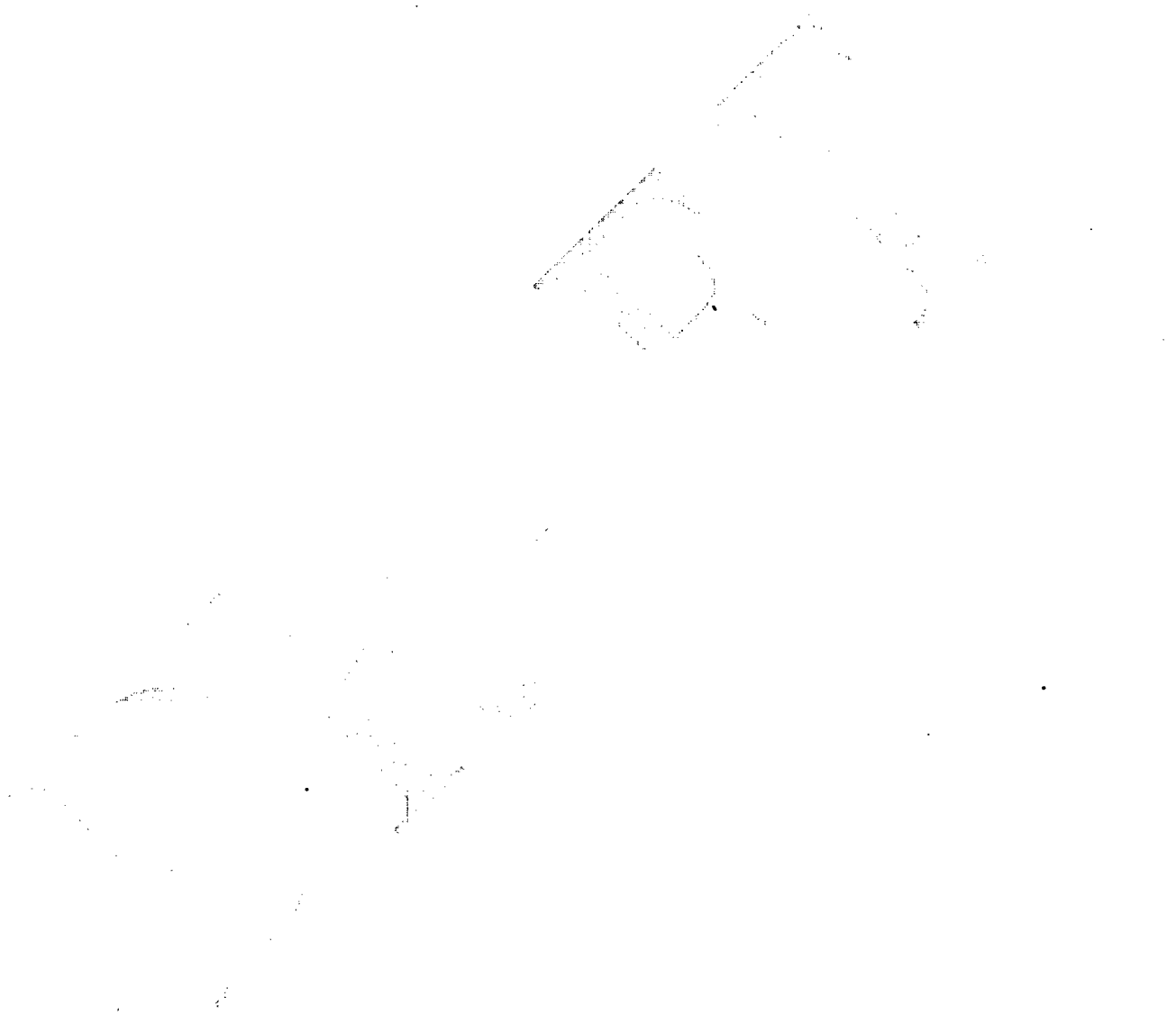
H1.3.3.3.3 Depth Coefficient

H1.3.3.3.4 Axial Length Coefficient

H1.3.3.3.5 Transverse Width Coefficient

H1.3.3.3.6 Phase-to-Depth Curve

H1.3.3.3.7 Tube Circumference Coverage



Supplement H2
Qualification Requirements for Examination of Steam Generator Tubing

H2.1 General

SG tubing examination techniques and equipment used to detect and size flaws are qualified by performance demonstration.

H2.2 Qualification Data Set Requirements

H2.2.1 General

Table H-1

H2.2.2Detection Data Set

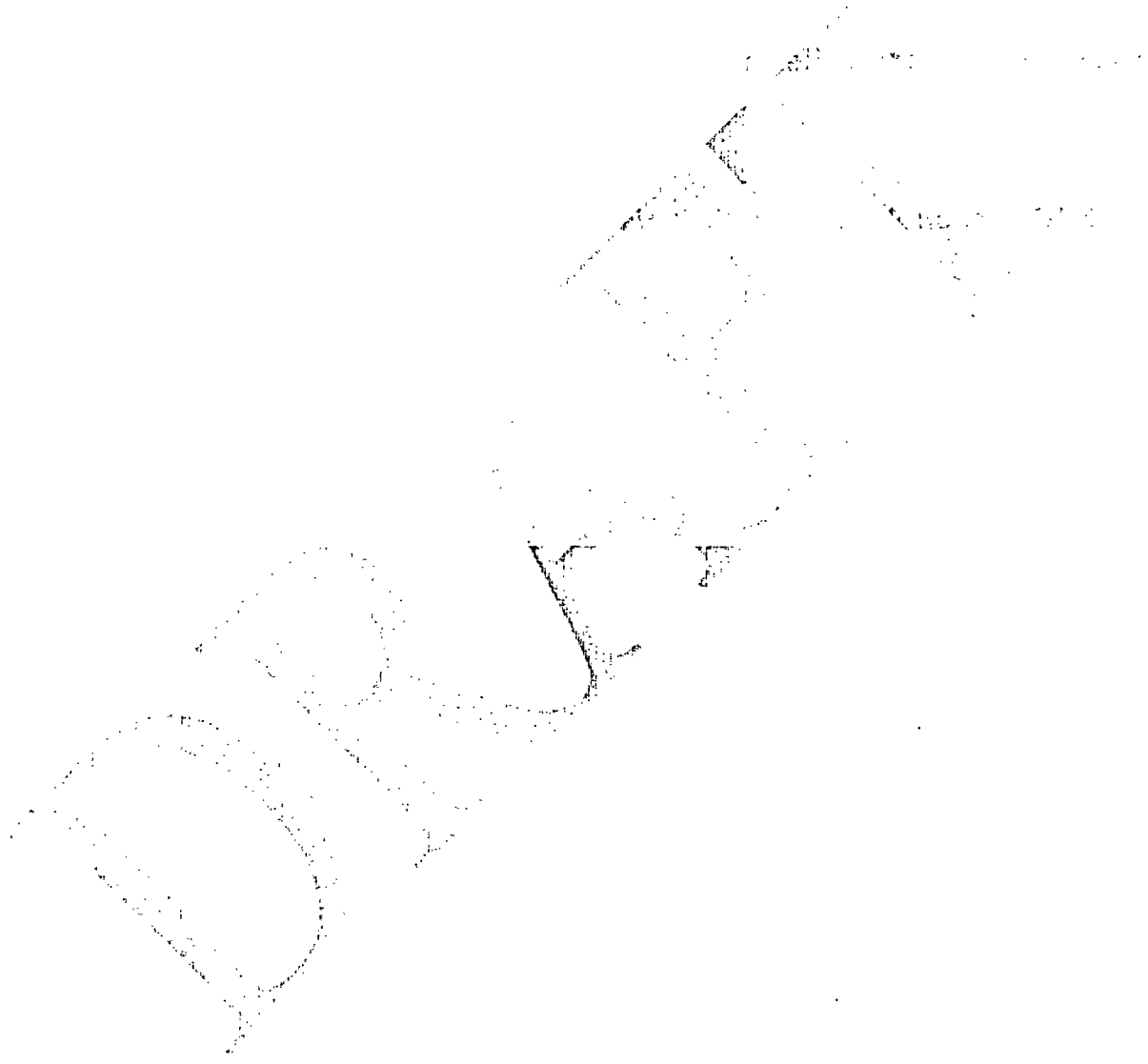
Table H-2

H2.2.3Sizing Data Set

H2.3 Acceptance Criteria

H2.3.1Detection Acceptance Criteria

H2.3.2Technique Sizing Performance



Supplement H3
Protocol for Performance Demonstration Database Revision

H3.1 Scope

This supplement establishes the method to revise the Appendix G performance demonstration database (PDD). Revisions include additions/deletions of existing data, inclusion of new techniques or deletion of existing techniques.

H3.2 Administrative Responsibilities

H3.2.1 New Techniques

H3.2.2 Existing Techniques

H3.3 Technique Originator Responsibilities

H3.4 Performance Demonstration Database Curator Responsibilities

H3.5 Performance Demonstration Database Peer Review Procedure

H3.5.1 Team Structure

H3.5.2 Conduct of the Review

Supplement H4
Protocol for Technique Peer Review

H4.1 Scope

This supplement establishes the method and protocol for conducting industry peer reviews of Appendix H or J techniques.

H4.2 Administrative Responsibilities

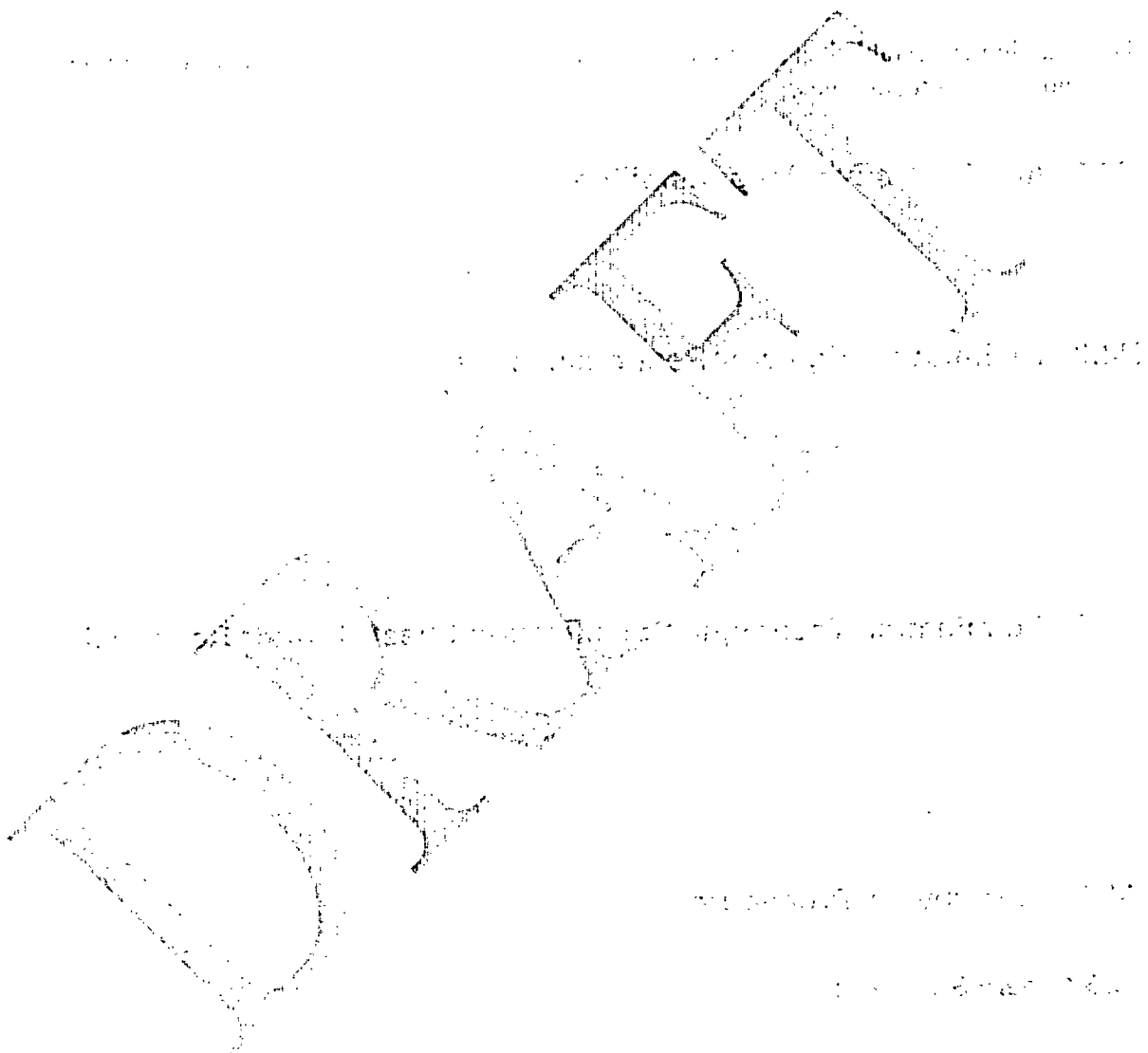
H4.3 Technique Originator Responsibilities

H4.4 Examination Technique Specification Sheet Curator Responsibilities

H4.5 Peer Review Procedure

H4.5.1 Team Structure

H4.5.2Conduct of the Review



I

J
PERFORMANCE DEMONSTRATION FOR ULTRASONIC EXAMINATION

J.1 SCOPE

a. This appendix provides performance demonstration requirements for ultrasonic examination techniques and equipment for examination of steam generator (SG) tubing.

J.2 PERFORMANCE DEMONSTRATION

J.2.1 General

J.2.2 Essential Variable Ranges

J.2.3 Requalification

J.2.4 Disqualification of Techniques

J.3 ESSENTIAL VARIABLE TOLERANCES

J.3.1 Instruments and Search Units

J.3.2 Computerized System Algorithms

J.3.3 Calibration Methods

J.4 RECORD OF QUALIFICATION

J.4.1 Examination Technique Specification Sheet (ETSS)

Supplement J1
Equipment Characterization

J1.1 SCOPE

This supplement specifies essential variables associated with ultrasonic data acquisition instrumentation and establishes a protocol for essential variable measurement.

J1.2 PULSERS, RECEIVERS, SEARCH UNIT, AND CABLE

J1.2.1 Search Unit

J1.2.1.1 Transducer Wave Propagation Mode

J1.2.1.2 Transducer Measured Angle

J1.2.1.3 Search Unit Transducer Evaluation

J1.2.1.4 Focused Search Units

J1.2.1.5 Signal-to-Noise Ratio

J1.2.1.6 Confirmation

J1.2.1.7 Requirements for Pulse Echo Tip Diffraction Sizing Techniques

J1.2.2 Substituting a Pulser/Receiver or Ultrasonic Instrument

J1.2.3 Cable

J1.3 DOCUMENTATION AND REVIEW OF CHANGES

Supplement J2
Qualification Requirements for Examination of Steam Generator Tubing

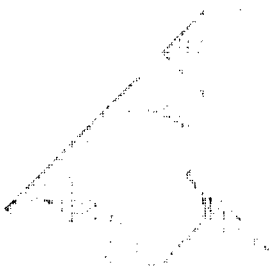
J2.1 GENERAL

SG tubing examination techniques and equipment used to detect and size flaws are qualified by performance demonstration. New industry qualified techniques shall meet the requirements of Supplement H4 for conduct of the peer review process. It is recommended that new site specific qualified techniques meet the intent of Supplement H4 for conduct of the peer review process by the developing organization.

J2.2 QUALIFICATION DATA SET REQUIREMENTS

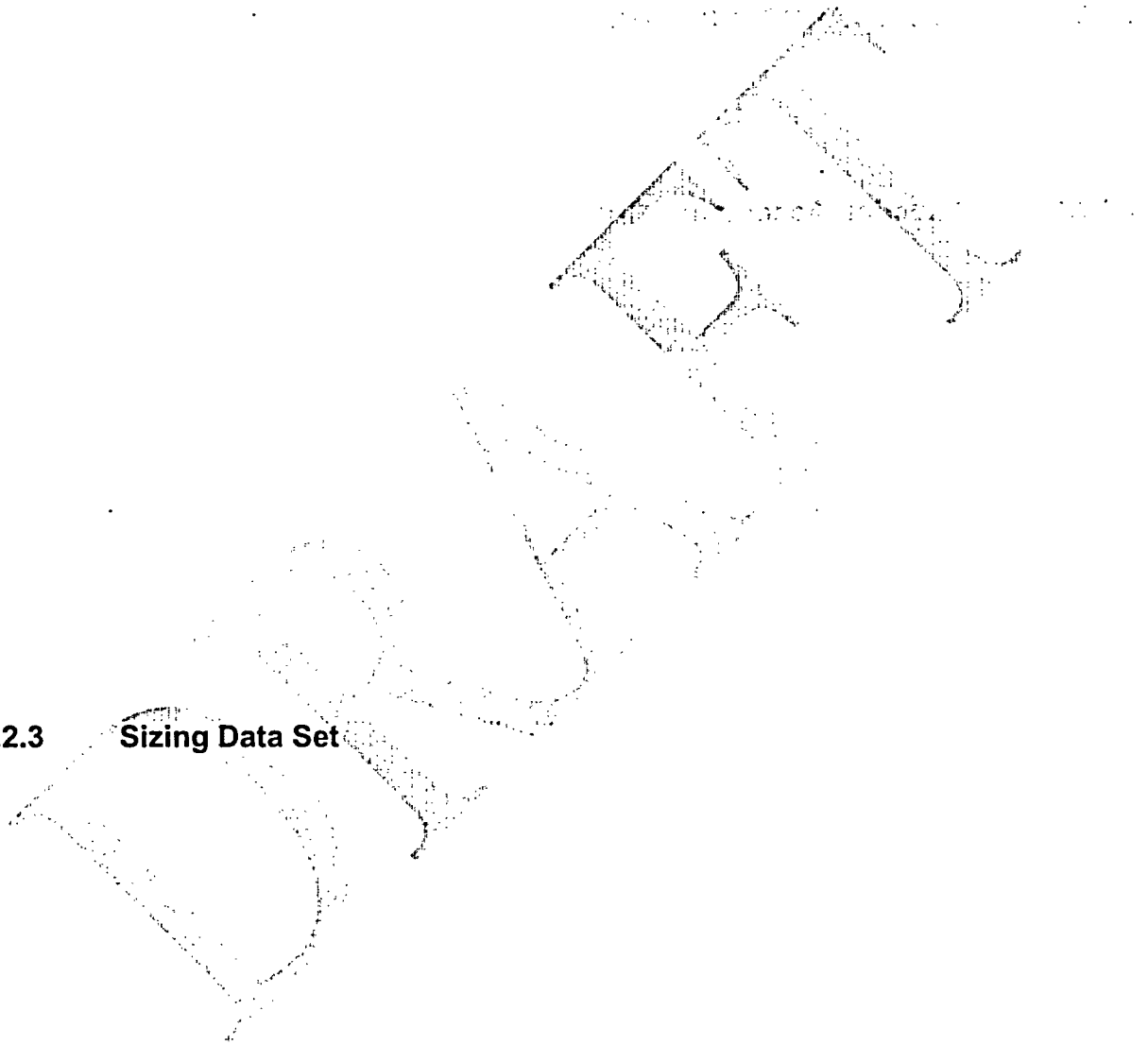
J2.2.1 General

Table J2-1



J2.2.2 Detection Data Set

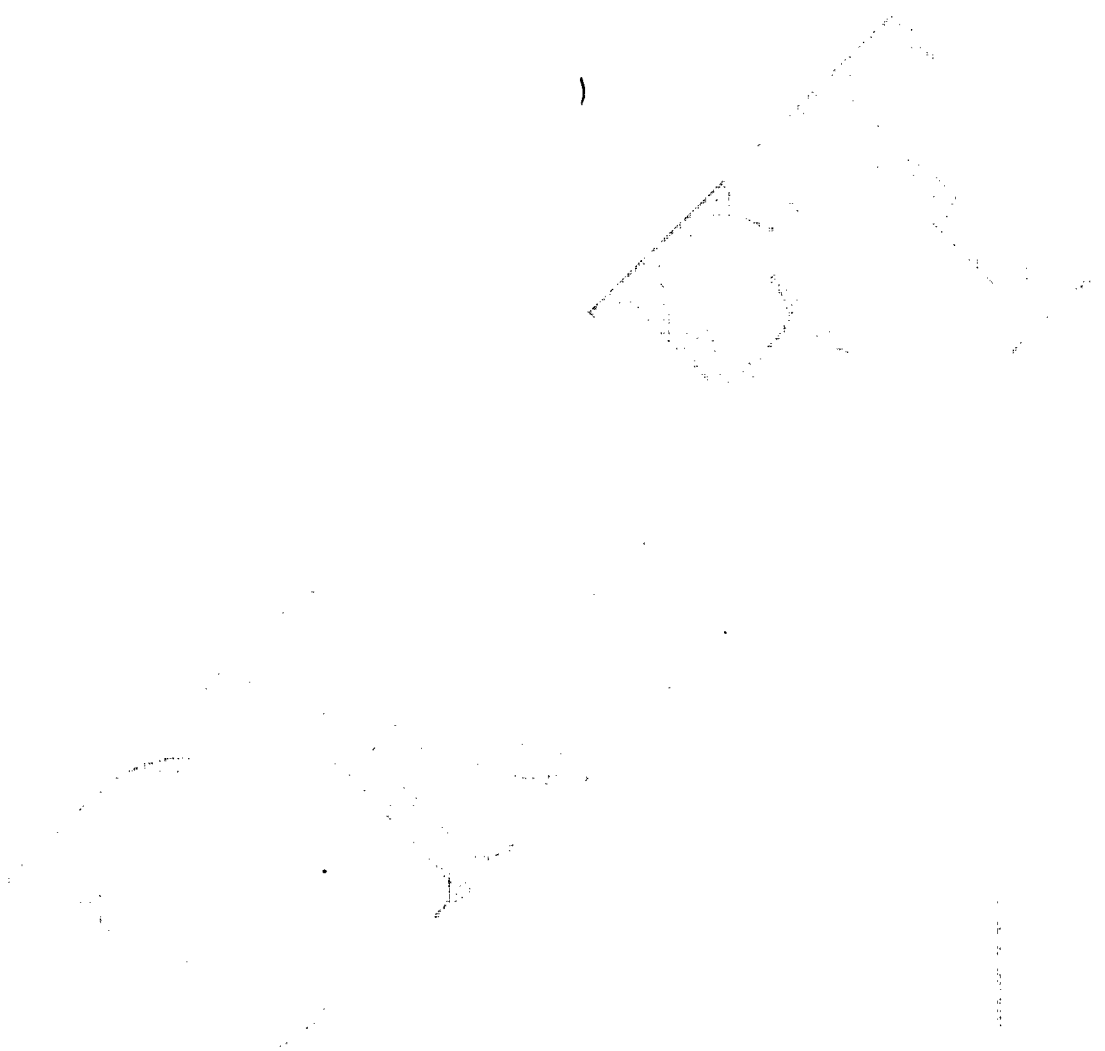
Table J2-2



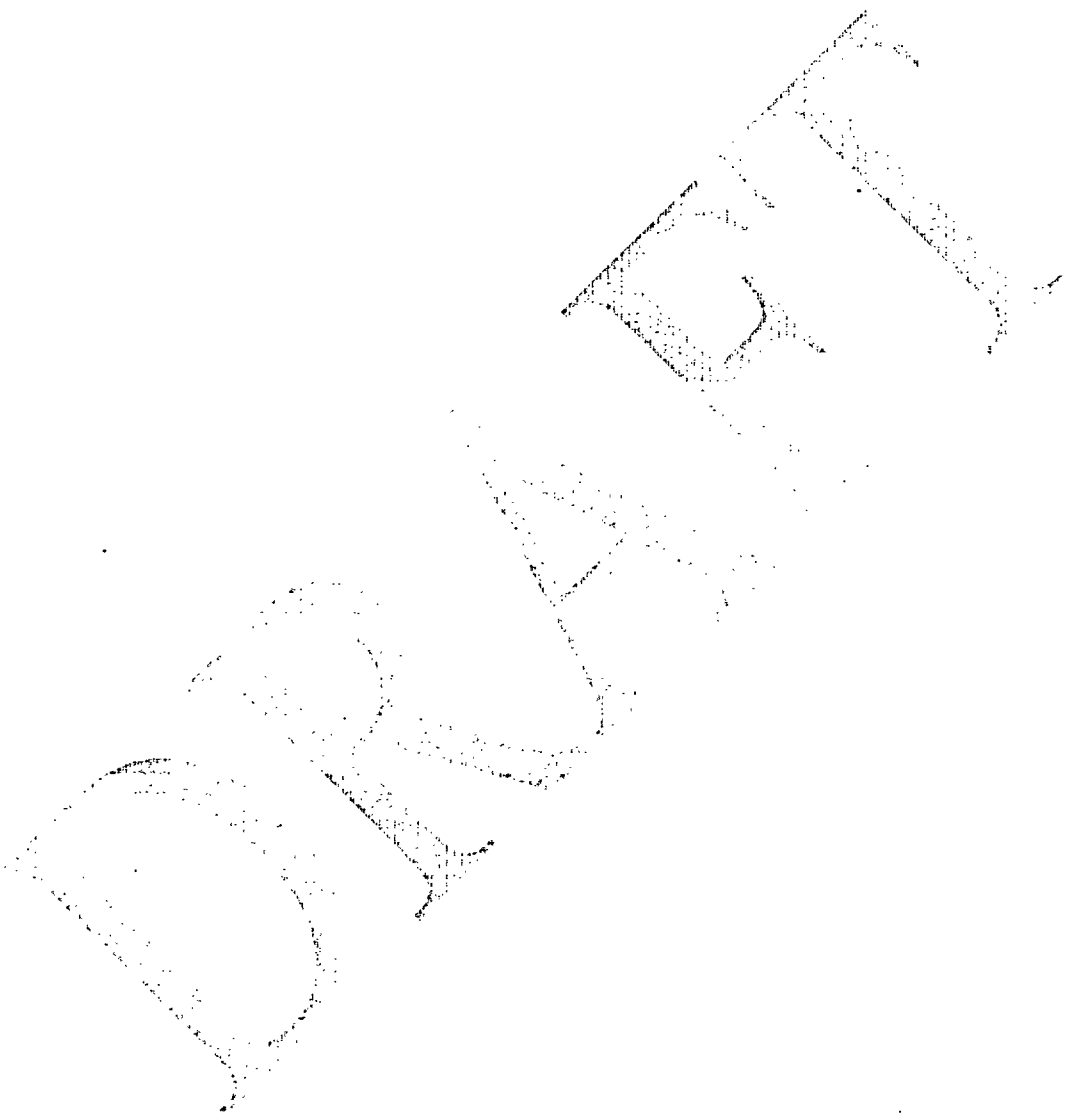
J2.2.3 Sizing Data Set

J2.3 ACCEPTANCE CRITERIA

J2.3.1 Detection Acceptance Criteria



J2.3.2 Technique Sizing Performance



K

QUALIFICATION OF PERSONNEL FOR ANALYSIS OF ULTRASONIC EXAMINATION DATA

Scope

This appendix specifies training and qualification requirements for personnel who analyze steam generator (SG) tubing ultrasonic examination data. Its purpose is to ensure a uniform knowledge base and skill level for ultrasonic data analysts. Analysts are qualified by successful completion of written and practical examinations as defined in this appendix.

1.1 WRITTEN PRACTICE REQUIREMENTS

1.1.1 Training and Examination

1.1.2 Responsibilities

1.1.3 Use of an Outside Agency

1.1.4 Transfer Qualifications

1.1.5 Confidentiality

1.1.6 Availability of Training Course Materials

1.2 QUALIFICATION REQUIREMENTS

Table K-1

1.2.1 Training

1.2.2 Written Examination

1.2.3 Practical Examination

1.2.3.1 General

1.2.3.2 Practical Data Set

1.2.3.3 Analysis Qualification Criteria

Table K-2

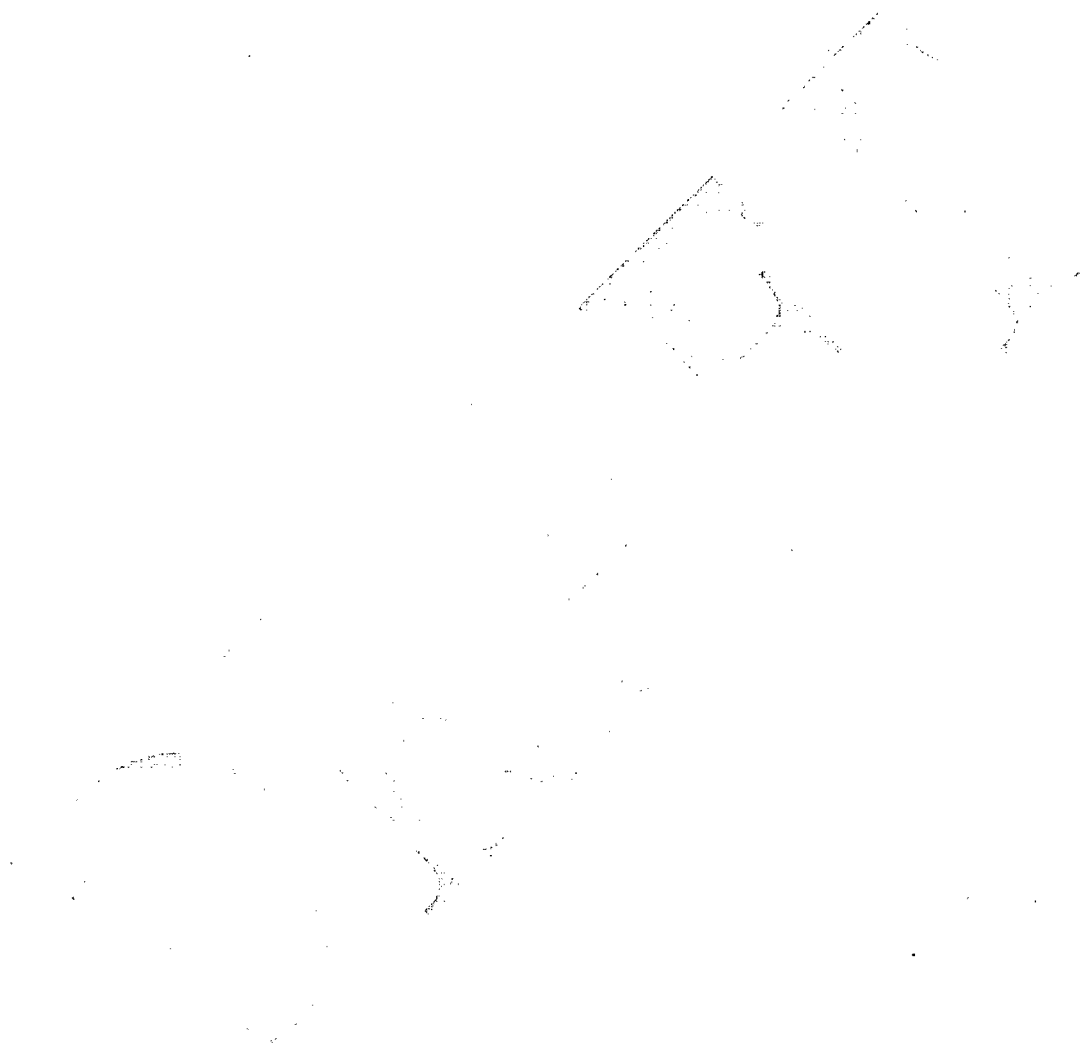


Table K-3

1.3 RE-EXAMINATION

1.3.1 Written Examination

1.3.2 Practical Examination

1.4 INTERRUPTED SERVICE

1.5 REQUALIFICATION

1.6 SITE SPECIFIC PERFORMANCE DEMONSTRATION (SSPD)

1.6.1 SSPD Training

1.6.2 Written Examinations

1.6.3 Practical Examination

1.6.3.1 Detection and Orientation

1.6.3.2 Sizing

1.6.4 Retesting

Attachment K-1