

# EXHIBIT 31

Case No. 2-1998-023

J/48

EXHIBIT 31

CENTRAL LABORATORIES SERVICES (CLS)  
CORRECTIVE ACTION REPORT

Initiated by: Sammy R. Walker Date: 9/24/98 CAR No.: 98003

Affected Department(s): Metallurgical Laboratory

Description of Adverse Condition: See continuation sheets.

Recommended Corrective Action: See continuation sheets.

Estimated Completion Date: 12/15/98 Submitted By: Sammy R. Walker  
Department Manager

Significant:  Yes  No Root Cause Analysis Required:  Yes  No

Action Required to Prevent Recurrence: See continuation sheets.

Concurred: Sammy R. Walker Date: 9/25/98  
QA/QC Manager

Approved: Richard L. Marley Date: 9/25/98  
Manager, CLS

Significant Conditions Involving Operating TVA Nuclear Plants

Plant Location: (Working with TVAN Chief Metallurgist for impact review)

Site Management Review/Approval: Refer to Attachment III  
Signature Date

VERIFICATION OF IMPLEMENTATION OF CORRECTIVE ACTION AS DESCRIBED ABOVE:

Verified By: Sammy R. Walker Date: 4/15/99  
QA/QC Manager

Noted: Richard L. Marley Date: 4-23-99  
Manager, CLS

CENTRAL LABORATORIES SERVICES

NONCONFORMANCE REPORT

QA RECORD

Part I: COMPLETED BY QA/QC STAFF

970710U0411

NCR No. 97099 Page 1 of 1  
Item Identification No.: E13950612303 & E13950619303  
Item Description: Central Laboratories Services Technical Reports

Part II: COMPLETED BY THE INITIATOR OF THE NONCONFORMANCE REPORT

Nonconformance Description: E13950612303 and E13950619303 could not be located in RIMS. (CLC Report No. 95-1021)

Initiated By: Sammy R. Walker Date: 6-3-97

Part III: COMPLETED BY DEPARTMENT MANAGER

Review Reports yes  no  Date 6/3/97 Signature J. Miller

Proposed Disposition: Send E13950612303 & E13950619303 to RIMS

Department Manager J. Miller  
Date 6/3/97

Part IV: COMPLETED BY THE QA/QC STAFF

Approved Disposition: As Recommended  Other (Describe)   
Send E13950612303 to RIMS. Place a coversheet explaining that E13950619303 will be sent to RIMS as an endorsement to E13950612303.

Part V: FINAL APPROVAL AND RELEASE FROM NONCONFORMANCE STATUS

\*Significant Condition Adverse to Quality:  No  Yes - CAR

QA/QC Manager: Sammy R. Walker Date: 6-23-97

\*Note: If it is determined at any point in the process that there has been significant impact to quality, the provisions of CLS-QAP 12.2, "Corrective Action," shall be implemented.

CENTRAL LABORATORIES AND FIELD TESTING SERVICES  
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CAR 98003  
CONTINUATION SHEET

Description of Adverse Condition:

This corrective action is being initiated to document the on-going investigation and actions associated with Central Laboratories Report No. 95-1021, WBN Ice Condenser Basket Screws, specifically, the differences between two reports issued by Central Labs to determine failure mode. The two reports in question are: Report No. 95-1021, dated 6/2/95, RIMS No. E13 950602 302 (refer to E13 950612 303 for associated endorsement); and Report No. 95-1021, dated 6/19/98, RIMS No. E13 950619 303 (refer to E13 950622 302 and E13 950711 001 for associated endorsements).

This corrective action report shall compile pertinent information related to issue but shall specifically address the concern as to the difference in the first report, dated 6/2/95, which directly identifies cracks found in new screw sample examined from set "B", whereas, the second report, dated 6/19/95, does not directly mention cracks found in new screw samples from set "B".

Background:

Refer to Attachment I for statements from the Central Labs metallurgists involved with testing, which serves as a summary of the events surrounding this issue.

Sequence of Events:

June 1995:

Issued first report dated 6/2/95 (E13 950602 302).

Issued endorsement to first report on 6/12/95 (E13 950612 303).

Retrieved four copies of first report distributed to customer and issued second report date 6/19/95 (E13 950619 303).

July 1995:

Issued memo from Central Labs Manager to WBN personnel explaining the issuing of the two reports (E13 950711 001).

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**June 1997:**

Received request from WBN personnel to provide copies of both reports. Upon investigation, second report, dated 6/19/95 (E13 950619 303), could not be located in RIMS. Central Labs initiated Nonconformance Report No. 97099 to document that second report could not be located in RIMS and that a signed and completed copy was retrieved from lab files and submitted to RIMS and customer on June 18, 1997. Second report was entered into RIMS as an endorsement to first report dated 6/2/95.

**July 1997:**

Requested by TVA OGC to provide background information concerning the two reports and statements from metallurgical personnel involved in testing. Central Labs provided copies of all reports and endorsements associated with Report No. 95-1021, statements from metallurgical personnel, and a compilation of seventeen identified differences between two reports, to the TVA OGC (see Attachment I for Central Labs personnel statements and list of seventeen differences). The compilation of the seventeen identified differences between the two reports was also made available to TVAN Chief Metallurgist.

**October 1997:**

Issued Central Labs instruction 901.1-2, "Shop Order/Work Order Review Process", to document the review/approval process and documentation of customer conversations directing work scope changes.

**September 1998:**

Met with NRC and WBN personnel, at Central Labs, to review issue and determine necessity of further corrective actions. Central Labs provided WBN personnel a list of differences between first report and second report as related to screw sample sets (refer to Attachment II). Central Labs issued Corrective Action Report No. 98003.

**Investigation:**

In June of 1997, Central Labs received request from WBN personnel to provide copies of Technical Report 95-1021, one report dated 6/2/95 and the other dated 6/19/95. Upon investigation, the second report, dated 6/19/95, could not be located in RIMS. Central Labs initiated Nonconformance Report No. 97099, initiated 6/3/97, to document that second report could not be located in RIMS and that a signed and completed copy was

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**CONTINUATION SHEET**

retrieved from lab files and submitted to RIMS and customer on June 18, 1997. The second report was entered into RIMS as an endorsement to first report (refer to E13 950619 303). At the time of the request for both reports, June 1997, Central Labs' understanding of the request was for clarification of there being two reports, yet only one could be found in RIMS, and why the two reports had differing information. Central Labs felt that this request for clarification had been satisfied by presenting copies of both reports and references to all associated endorsements.

In July 1997, Central Labs was requested by TVA OGC to provide background information concerning the two reports and statements from metallurgical personnel involved in testing. Central Labs provided copies of all reports and endorsements associated with Report No. 95-1021, statements from metallurgical personnel, and a compilation of seventeen identified differences between two reports, to the TVA OGC (see Attachment I for Central Labs personnel statements and list of seventeen differences). The compilation of the seventeen identified differences between the two reports was also made available to TVAN Chief Metallurgist.

As of July 1997, Central Labs was not aware that there was a discrepancy in the two reports, specifically, that report dated 6/2/95 mentioned cracks found in a new screw from Set "B" and report dated 6/19/95 failed to mention this but had substituted a screw from Set "H" to depict similar information. It was not until September 1998, through discussions with WBN personnel and TVAN Chief Metallurgist, that Central Labs became aware of the failure to identify cracks in new screw sample Set "B".

Investigation by TVAN Chief Metallurgist, during Sept - Oct 1998, concluded that "the data pertaining to cracking in the new screw was inadvertently omitted from the second report during efforts to prevent duplication of similar failure mode while maintaining the flow of the first report" (refer to Attachment III).

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CONTINUATION SHEET

Corrective Actions:

1. Central Labs personnel and TVAN Chief Metallurgist to compile a reconciliation of the two reports and review for any potential impact from not directly reporting the cracks found in new screw from sample set "B" in the second report issued 6/19/95 as compared to the first report issued on 6/2/95.

Scheduled Completion Date: 10/1/98  
Date Action Completed: 10/20/98 (Attachment III)

2. Central Labs to review all endorsements to Technical Reports issued by the Metallurgical Lab, from 1/1/95 to 12/31/95, for evidence of similar incidences where information is changed or deleted without adequate documented explanation.

Scheduled Completion Date: 10/1/98  
Date Action Completed: 10/2/98 (Attachment IV)

3. Central Labs to develop and implement sensitivity training similar to that in TVAN to raise awareness of the importance of a critical review/approval of documentation associated with quality-related processes.

Scheduled Completion Date: 12/1/98  
Training by TVAN personnel: 10/19/98 and 12/7/98 (Attachment V)  
(100% of lab personnel involved in quality-related activities)

Closure:

All action items above are completed. During the time frame of this corrective action report, Central Labs also conducted a critical self-assessment that involved a cross-section of laboratory employees and customers. The self-assessment was an action taken separate from the specific problem identified in this corrective action report and the results from the self-assessment team are being reviewed by management.

CENTRAL LABORATORIES AND FIELD TESTING SERVICES  
CORRECTIVE ACTION REPORT

**CAR 98003**

ATTACHMENT I

Metallurgical personnel statements (Compiled July 1997)

CLS investigation into differences between two reports (Compiled June 1997)

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INTEROFFICE MEMORANDUM

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TO: RICHARD L. MORLEY

FROM: DELSA L. FRAZIER *Delora Frazier*

SUBJECT: REPORT NO. 95-1021

DATE: JULY 31, 1997

CC: SAMMY WALKER

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Several ice condenser basket screws were received at the laboratory on an emergency basis. We were asked to perform a failure analysis on the screws that had been identified by Vonda. Upon issue of the first report, Vonda called and had questions concerning statements made about the operating temperatures, which samples had simulated testing performed, clarification as to what tests were performed on what samples.

The role of the laboratory, plant, and corporate is distinct (when metallurgical engineers are involved from each location) in that the laboratory's role has always been to provide failure mechanisms, not root causes as corporate would do, nor corrective action as the plant is charged to do. This is understandable when the lab is not familiar with systems, plant design, operating factors, etc. Nor are we familiar with programmatic concerns for materials and procedure guidelines. The lab is to provide a possible or the most probable failure mechanism based on testing conducted and some possible theoretical conclusions drawn from the data and textbook knowledge on the material. In this case, since Vonda was our primary customer, there were statements in the first report concerning operation that she stated could not be substantiated nor was there information in our possession to document these statements. It was felt that we had crossed over and out of our realm of responsibility. Since the report did not say from whom the information was obtained, it was felt that the laboratory could not make those statements without corroborating information. Sometimes information received from a customer may be his/her opinions on the failure and may not be based on factual information, therefore those statements were not included in the second report.

Additional information was requested since the laboratory was given additional time to "clean up" the first report. Because the first report was general in description of samples and the type of testing, clarification was needed to provide a corrective action for the cause of failure. This was provided in the second report by better documentation on the figure pages, in the tables, and in the text of the second report.

Vonda was asked by me to return her copies of the first report since there were so many changes that needed to be made, an endorsement would be confusing. The report had not gone to RIMS; therefore we could pull it. She returned the four copies that we sent, and stated that she had asked others who had the report (from copies she had made) to destroy. I destroyed the copies, and we issued the second report.

Because time was short, it was not discovered until later, that there was an endorsement to the first report that existed. This was never cleared up, but information given in the endorsement was given in the second report.

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INTEROFFICE MEMORANDUM

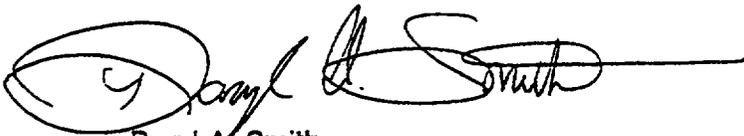
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TO: RICHARD L. MORLEY  
FROM: DARYL A. SMITH  
SUBJECT: REPORT NO. 95-1021  
DATE: JULY 31, 1997  
CC: SAMMY WALKER

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The subject Ice Condenser Basket Screws were received by CLS and given high priority status by the customer. Metallurgy personnel performed the requested analyses then submitted a report to the customer. This "first" report contained statements about the operating conditions of the subject screws. Upon review by the customer, a clarification was made as to the laboratory's role in the investigation: the lab was requested to submit only information which could be proven based on the data obtained at CLS. The laboratory then requested that all copies of the first report be returned to CLS prior to the release of a second revision. The second revision also contained some clarification on some of the data that was obtained. The first report was not submitted to RIMS by CLS personnel because of the second revision. The second report was then submitted to RIMS for archiving purposes. Later, an endorsement which was submitted regarding the first report was found, but since it contained information in the second report, it was not dealt with.



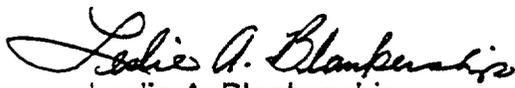
Daryl A. Smith  
Metallurgical Engineer  
Central Laboratories Services

TO: Richard L. Morley  
FROM: Leslie A. Blankenship  
DATE: July 30, 1997  
SUBJECT: Ice Condenser Basket Screw Failures, Watts Bar Nuclear Plant

This is in regard to your request to provide a statement of my best recollection of the events surrounding the reports issued in June 1995 on the ice condenser basket screw failures from the Watts Bar Nuclear Plant (Laboratory Report No. 95-1021).

When the first report was issued, four copies were sent to Vonda Sisson at Watts Bar. When the report was reviewed by plant personnel, there was a request that the laboratory do additional testing and also to change some of the conclusion statements. It was pointed out that some of the conclusions were based on information from the plant which could not be substantiated, such as the operational temperatures of the screws and the possible over torquing of the screws. So we were requested to report only the factual information based on our analyses.

The four reports were returned to the Central Laboratories and since a copy of the report had not been sent to RIMS, a new report was issued which included the additional information requested, along with the removal of the conclusions which were based on information that could not be substantiated by plant personnel.

  
Leslie A. Blankenship  
PSC 1B-C

LAB:CAS

CENTRAL LABORATORIES SERVICES (CLS)  
INVESTIGATION INTO DIFFERENCES IN WATTS BAR ICE CONDENSER BASKET SCREWS  
CLS REPORT 95-1021 DATED 6/2/95 (E13 950602 302) AND  
CLS REPORT 95-1021 DATED 6/19/95 (E13 950619 303)

1. First report states that the screws were zinc plated, while second report states that screws had a coating of zinc plating, cadmium plating, or zinc phosphate. The second report clarifies source of the screw description and also included that the customer requested verification of material type.
2. Wording on description of screws state that one was new (1<sup>st</sup> report) versus one had not been in service (2<sup>nd</sup> report).
3. First report contains statements from the customer (cyclically cooled between 15 deg F and room temperature) and the screws were probably over-torqued when installed. Second report does not state this.
4. Both reports list the chemical results that were found on a representative/typical screw, but second report states from which screw (screw "A") the data was reported. The second report states that the screws were probably zinc phosphate coated, but the data is listed in both reports.
5. The first report does not have microhardness traverse graphs included to indicate carburization, but both reports talk about higher carbon values than those for AISI 1022 steel and Table III, which shows a difference in case to core hardness which would indicate carburization.
6. In the fractography section, both reports discussed the examination of screw "A" (failed) and a screw from "G". A different micrograph is shown in Figure 7 for new screw "A" (1<sup>st</sup> report) versus whole screw "A" (2<sup>nd</sup> report). The second report does not mention set "B" (figure 7), and the first report does not mention set "H" (figure 7). Figure 7 is different in each report.
7. The 1<sup>st</sup> report does not mention the particular screw in which the presence of zinc was found, but both talk about pre-existing cracks, laps at the tip, face and roots of every screw. But there is no mention in second report of fatigue.
8. More explanation was given in the second report concerning the other screws in which no photographic documentation is shown, But the information concerning the screws is given by saying that "similar cracks were found both in the new and used screws".
9. The specific screws that were broken at CLS are not mentioned by name in the 1<sup>st</sup> report. Additional screws were broken at 15 deg F and reported in the second report (possibly additional info from customer). First report used the word "ductile" and "brittle" while the second report refers to it as "void coalescence" and cleavage", respectively - both words indicating the same type of failure. The 2<sup>nd</sup> report discussed "quasi-cleavage", here again, the 1<sup>st</sup> report states "more ductile" and "more brittle", both satting a mixed mode of failure.
10. Because the additional time to do testing on set "H", "G", and "B", metallography was performed and reported in the 2<sup>nd</sup> report. A different microstructure was discovered showing slack quenching.
11. Possible conclusions were not bulleted in the 2<sup>nd</sup> report as in the 1<sup>st</sup>, but the lower ductility of the screws were mentioned in the 2<sup>nd</sup> report when cleavage or brittle fractures were discussed. No mention of high stress appears in the 2<sup>nd</sup> report, nor design limits.

12. The presence of stress concentrators is mentioned in both reports in the discussion of laps found at tips, face, and roots.
13. Corrosion is not mentioned in the 2<sup>nd</sup> report as a possible failure mechanism, but is mentioned at the beginning of the second report as being present in the threaded region.
14. Carbon content, higher values for some samples is mentioned in both reports, but no tie back to lower ductility expected in the 2<sup>nd</sup> report.
15. Pre-existing cracks (quench cracks) were mentioned in the 2<sup>nd</sup> report when the intergranular cracks were discovered in the traverse section of the whole screw from set "A".
16. The second report does not mention thermal changes on the material, but tests were performed in the 2<sup>nd</sup> report to indicate that this was a concern (testing at 15 deg F).
17. The endorsement to the 1<sup>st</sup> report (E13 950612 303) lists which samples had a slack quench microstructure.

CENTRAL LABORATORIES AND FIELD TESTING SERVICES  
CORRECTIVE ACTION REPORT

**CAR 98003**

ATTACHMENT II

CLS list of differences between two reports as related to screw samples sets

(Compiled September 1998)

## INFORMATION ON SAMPLES FROM 95-1021

### SAMPLE A – FRACTURED

#### 1<sup>st</sup> Report

- Received ten fractured screw heads
- Corrosion product observed on screws mostly in the threaded region
- Possibly case hardened — higher carbon content and microhardness readings
- Screws failed in a brittle manner as indicated by the intergranular failure mode seen on all screws. Final fracture area was ductile
- Metallography showed a secondary intergranular crack above the fracture surface
- Lappings from the forming process was observed in the face and root and along pitch of the screws.
- General microstructure was tempered martensite.
- Factors leading to failure: lower ductility, over-torquing, stress concentrators, corrosive environment, quench cracks, thermal cycling.
- Failure mode was intergranular separation with the mechanism was stress overload

#### Endorsement of June 12, 1995

- Not mentioned.

#### 2<sup>nd</sup> Report

- Received ten screw heads that were in service
- Varying amounts of corrosion product was observed mostly in the threaded portion
- Chemistry was similar to 1022 carbon steel.
- Possible case hardened – higher carbon content and microhardness readings
- Fractography showed a intergranular failure, brittle surface. Final fracture area near the center of the shank was ductile.
- Metallography showed secondary intergranular cracks above the fracture surface
- Figure 7 mentions fractured screw A's crack was listed as a secondary crack.
- Microstructure is given as tempered martensite.
- Failure mode was intergranular separation.

### SAMPLE A – NEW OR NOT IN SERVICE

#### 1<sup>st</sup> Report

- One screw received
- Chemistry was similar to AISI 1022 carbon steel.
- Possibly case hardened – from chemistry
- Intergranular cracks (metallography) were found in tooth roots
- Laps and cracks were found in the new screws (not identified as to which new screw) – 2<sup>nd</sup> Paragraph, 2<sup>nd</sup> page
- New screw (not identified) was fractured in the laboratory to determine failure mode. Intergranular fracture in the case and mixed mode in the core was observed.
- General microstructure was tempered martensite

#### Endorsement of June 12, 1995:

- Cracks found in screw.
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.
- Could not be evaluated for metallography as destroyed in previous tests.

**INFORMATION ON SAMPLES FROM 95-1021**  
**SAMPLE A – NEW OR NOT IN SERVICE (Continued)**

2<sup>nd</sup> Report:

- Whole screw that was not in service received for testing
- Chemistries similar to 1022 carbon steel, zinc phosphate coating found on surface
- Possibly case hardened – high carbon content and microhardness readings
- Intergranular cracks were discovered in a transverse section of the screw
- Lapped regions were discovered at the tip, face, and roots of every screw that was examined and is typical of the thread rolling process
- Whole screw fractured in the lab and failed by quasi-cleavage in the case and void coalescence in the core.
- Microstructure was tempered martensite

**SAMPLE B – NEW SCREWS**

1<sup>ST</sup> Report:

- Twelve screws received
- Possible case hardened at the thread tip – listed in text, but improperly identified in Table III.
- Carbon steel – met carbon and sulfur requirements for AISI 1022
- Intergranular cracks found in transverse section
- All screws had laps from forming process
- Cracks in the thread roots
- General microstructure consisted on tempered martensite
- New screw (not identified) was fractured in the laboratory to determine failure mode. Intergranular fracture in the case and mixed mode in the core was observed.

Endorsement of June 12, 1995:

- New set of twelve screws submitted for metallography
- No cracks found
- Slack-quenched microstructure
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Twelve new screws received
- Chemistry similar to 1022 carbon steel
- Case hardened at the tip not the root of the threads based on microhardness in Figure 3, improperly identified in Table III
- Laps found in the tip, face, and roots of the threads
- Simulated testing by fracturing samples at 15°F showed the failure mode to be void coalescence
- Microstructure consisted on tempered martensite
- Slack quenched region found in the thread roots

**SAMPLE C**

1<sup>ST</sup> Report:

- Two samples received
- Case hardened – higher carbon content
- May be 1022 carbon steel – carbon higher

INFORMATION ON SAMPLES FROM 95-1021

SAMPLE C - 1<sup>st</sup> Report (Continued)

- All screws had laps from forming process
- Used screw not identified in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- One of two samples contained cracks
- No slack quenched observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Two screws received
- Chemistry similar to 1022 carbon steel
- Case hardened based on carbon content
- Intergranular cracks found in thread roots
- Simulated testing by fracturing samples at 15°F showed the failure mode to be void coalescence
- Tempered martensitic structure

**SAMPLE D**

1<sup>st</sup> Report:

- Two screws received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No cracks found
- No slack quenching observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Two samples received
- Case hardened – microhardness results and chemistry has high carbon content
- Similar to 1022 carbon steel
- No cracks found in examined sections
- Laps found
- Tempered martensitic structure

INFORMATION ON SAMPLES FROM 95-1021

SAMPLE E

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No cracks found
- No slack quenching observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Two samples received
- Case hardened –chemistry has high carbon content
- Similar to 1022 carbon steel
- Laps found
- Tempered martensitic structure

SAMPLE F

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No cracks found
- No slack quenching observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Two samples received
- Case hardened –chemistry has high carbon content
- Similar to 1022 carbon steel
- Laps found
- Tempered martensitic structure

INFORMATION ON SAMPLES FROM 95-1021

SAMPLE G

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts and microhardness results
- Intergranular cracks found in roots of threads
- Presence of zinc in cracks
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No mention in this report

2<sup>nd</sup> Report:

- Two samples received
- Case hardened – microhardness results and chemistry has high carbon content
- Similar to 1022 carbon steel
- Intergranular cracks found in thread roots
- Presence of zinc in crack
- Laps found
- Screw fractured in the lab and failed by intergranular fracture in the case and mixed mode failure in the core.
- Tempered martensitic structure
- Could not be checked for slack quench as destroyed by other testing

SAMPLE H

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Softer than new screws

Endorsement of June 12, 1995:

- One sample had cracks
- One sample was slack quenched
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

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INFORMATION ON SAMPLES FROM 95-1021

SAMPLE H Continued

2<sup>nd</sup> Report

- Two samples received
- Case hardened – microhardness results and chemistry has high carbon content
- Similar to 1022 carbon steel
- Intergranular cracks found in thread roots
- Laps found
- Slack quench structure observed
- Tempered martensitic structure

Both reports mention the fact that the samples that had been in service contained corrosion products.

CENTRAL LABORATORIES AND FIELD TESTING SERVICES  
CORRECTIVE ACTION REPORT

**CAR 98003**

ATTACHMENT III

ACTION ITEM 1

TVAN Chief Metallurgist Reconciliation Report

EXHIBIT 31  
PAGE 20 OF 35 PAGE(S)

~~RCM~~  
RRG  
SRW

J. E. Maddox, EQB 1A-WBN

WATTS BAR NUCLEAR PLANT ICE CONDENSER SCREWS

Attached for your information is a copy of the report which reconciles primarily technical differences in TVA Central Laboratory documents, issued during the June 1995 timeframe, regarding Watts Bar ice condenser screws. The reconciliation effort identified two important findings which were associated with omission of technical data from reports issued. However, it is concluded that these omissions were inadvertent, and that laboratory test results indicate overall metallurgical core properties of the screws were adequate for the intended application.

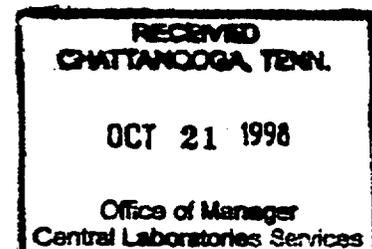
*Terry R. Woods*

Terry R. Woods  
Chief Metallurgical and Codes Engineer  
LP 4H-C

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EXHIBIT 31  
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## RECONCILIATION OF WATTS BAR NUCLEAR PLANT (WBN) ICE CONDENSER BASKET SCREWS REPORT

### Introduction

The purpose of this document is to provide reconciliation of differences in information contained in the June 2, 1995 report (first report), an intermediate endorsement on June 12, 1995, and the June 19, 1995 report (second report) from TVA Central Laboratory on Watts Bar ice condenser basket screws. This reconciliation will address differences in data and terminology presented in each document, and also assess the impact of inclusion or exclusion of information from either report. An itemized listing of these differences has been prepared by TVA Central Laboratories Metallurgical Section, and the results are shown in Attachment A. Also, Central Laboratories has prepared a detailed comparison of the similarities and difference in information for each screw sample set in each report. These results are given in Attachment B. The attachments were reviewed by the TVA Nuclear (TVAN) Chief Metallurgical Engineer and will be used in conjunction with each report as the basis for this reconciliation effort.

### Discussion

The primary difference between the two reports center around information that was either included in, or excluded from, the second report which was dated June 19, 1995. More specifically, this reconciliation will address the following four items.

1. The second report deletes customer provided background statements.
2. The second report deletes the "bulletized" conclusion section which was contained in the first report, thereby, omitting some of the information that was contained therein.
3. Pertinent information regarding cracks found in a new screw from sample sets A and B, which was given in the first report, was omitted from the second report. Also, the second report differed in terminology when referring to the new screw from set "A".
4. Additional test data and results, which were not presented in the first report due to time restraints, along with data from additional testing (which was requested after issuance of first report), was presented in the second report.

A detailed discussion of each of these issues is provided as follows.

### Items 1 and 2

The deletion of information from the second report pertaining to Items 1 and 2 was based on the fact that much of the information was not, nor could be, substantiated through metallurgical laboratory testing. In referring to Item 1, Report 1 states that "the customer indicated that the screws were cyclically cooled and warmed between 15°F and room temperature. The customer also indicated that the screws were probably over-torqued when installed." In Item 2, the bulletized conclusion (2) also addresses possible over-torquing, and contributes it to stresses higher than design limits. The conclusion (7) also states that thermal cycling may have initiated micro cracking. Based on a review of the first report during June 1995, no objective evidence from metallurgical testing or document review was provided regarding stresses exceeding design limits or that the ice condenser was thermally cycled. Upon discussion with Central Laboratory personnel, it was concluded that this information was included in the report based on verbal input

from the customer and was not necessarily the results of any findings from laboratory analyses. It was also concluded and agreed to that Central Laboratory personnel did not have access to

information regarding design limits nor did they have first hand knowledge pertaining to operational mode of the Watts Bar ice condenser. Therefore, it was jointly agreed between Central Laboratory personnel participating in this evaluation and the TVAN corporate and site engineering representatives to remove the above information from the June 19, 1995 (second report) since testing did not provide any objective evidence which could support those conclusions.

The remaining information captured in these bullets was essentially integrated into the text of the second report with few modifications.

### Item 3

The next major issue pertains to omission of metallurgical data and results regarding pre-existing cracking in new screws. The first report states that "similar cracks were discovered in the new screw received in set "A" and in the transverse section of a new screw sample examined from set B." It also refers to Figure 7 which shows a 400X as polished transverse view of a crack present in a new screw from set B. However, in the second report, the terminology differed when addressing the new screw from set "A", and also there was a total omission of any information pertaining to cracking in the new screw from set B.

The second report refers to the new screw from set "A" as being "one whole screw that was not in service." This statement leads one to assume that the new screw and whole screw is "one in the same," indicating that it was a new screw directly from Power Stores. However, the assumption may be misleading, because there is no evidence that any new screws from set "A" were ever checked out of Power Stores and submitted to TVA Central lab for this evaluation. Upon conferring with site personnel, the screws origin could not be verified, but it is postulated that the screw was probably one of the screws that was retrieved from the ice condenser floor and submitted along with the fractured screws of set "A" for metallurgical evaluation. Examination of this screw showed evidence of what is considered to be fabrication induced cracking which was restricted to the case or surface hardened region. This finding was documented in the first report and subsequent endorsement. The second report makes a comparison between features (fracture surface deposits) which indicate fabrication induced case cracking in set "C" screws and the whole screw from set "A". Therefore, based on the metallurgical evidence contained in the first report and the relative comparison which was discussed in the second report, it is concluded that the whole screw from set "A" most probably experienced cracking during the fabrication process.

The information regarding pre-existing cracking in a new screw from set "B" is contained in the first report only. Neither the endorsement or the second report mentions any evidence of cracking in this screw set. However, the evidence from the first report suggests that cracking did occur during the fabrication process. This should have been considered an important finding by the Central Laboratory Metallurgical Staff and should have been included in the second report which was issued to the site. Failure to include such pertinent information could impact or alter corrective actions employed to address this issue.

The primary reason provided by Central Laboratory personnel for omission of statements from the second report pertaining to cracking in the new set "B" screw is given as follows.

The first report was done on an emergency basis and all samples received were not completely analyzed. After issuing the first report a request was made to perform additional testing/analysis on

those screws that were not addressed in the initial report. The results of the additional request was initially documented in the intermediate endorsement. However, after it was determined that a

second report would need to be issued in order to address certain unsubstantiated information contained in the first report, it was decided to also incorporate the additional test results in the second report. In order to maintain the flow of the original report, the initial figure 7 was reconfigured to include these results. Figure 7 was selected because the cracking observed in the original figure 7 (depicting samples A and B) was similar to that observed in sample H and in the "whole screw A" depicted in the revised figure 7. Therefore this substitution of H instead of B documented a similar cracking mode but failed to capture the fact that the cracking observed in B was from a new screw.

An explanation pertaining to the omission of this information was documented by informal memorandum from "Delsa Frazier, Metallurgical Engineer Central Laboratory and Field Testing Services" to "Terry R. Woods" dated September 3, 1998. Based on the information provided in this memorandum, and subsequent interview of Central Laboratory personnel involved in this effort, the data pertaining to cracking in the new screw was inadvertently omitted from the second report during efforts to prevent duplication of similar failure mode while maintaining the flow of the first report.

#### Item 4

Additional testing was performed on screws from all sample sets after issue of the first report. This testing consisted of additional hardness measurements and metallographic examinations to further document the condition of the screw material. Also, Central Laboratory personnel performed impact type testing at room temperature and 15°F on screws from sets A, B, C, and G, and the results were issued in the second report.

The most important finding from additional metallography was that a slack quench microstructure was identified in certain portions of screws from sets B and H. This finding showed that the microstructure was not homogeneous throughout. A quenched and tempered (Q&T) microstructure is considered to be the preferred microstructure for this application because it yields optimum mechanical properties. Slack quenching results in a mixed microstructure (i.e., ferrite plus pearlite plus bainite) and tends to lower mechanical properties of the material. However, since some screws that contained cracks were not specifically examined for slack quenching, and some screws which were cracked showed cracking in the Q&T portion instead of slack quench region, it is inconclusive as to the role or effect this mixed microstructure may have played, if any, in the cracking of these screws.

Additional hardness testing showed values which were consistent with those presented in the first report. However, it is noted that the average core hardness in all screws tested from both the first and second report exceeded the Westinghouse Specification of 40 HRC. A comparison of these hardness values to the observed microstructure determined that the slightly higher average core hardness values did not have an adverse effect on the mechanical properties of the material.

Results of the screws that were broken in the lab, both at room temperature and 15°F, showed fracture surfaces that were consistent with surface hardening type heat treatments in medium carbon steels. A cleavage type fracture was noted (in general) in the hardened outer surface and void coalescence (ductile type failure) was noted (in general) in the core. Although surface cracking may have been previously observed in some of the screws, this testing, along with the

micro-hardness traverse suggest that the overall heat treatment produced desirable core properties in the material.

### Conclusion

The most important finding from the reconciliation effort was that information regarding possible fabrication induced cracking in a new screw (1 of 12) from set "B" was omitted from the second report. This information, if evaluated independently, may have suggested that a fabrication or process deficiency exist which could result in screws not meeting minimum required properties for the intended application. Also, key information regarding mixed microstructure and "impact type" testing was addressed in the second report and was not part of the first report. Its significance is that , although the mixed microstructure is not considered optimum, the laboratory impact test results along with hardness measurements indicates that the overall core metallurgical properties were adequate for the intended application. Each of these findings are important in that they should be considered when determining appropriate corrective action for adequately addressing this issue.

## ATTACHMENT A

CENTRAL LABORATORIES SERVICES (CLS)  
INVESTIGATION INTO DIFFERENCES IN WATTS BAR  
ICE CONDENSER BASKET SCREWS  
CLS REPORT 95-1021 DATED 6/2/95 (E13 950602 302)  
CLS REPORT 95-1021 DATED 6/19/95 (E13 950619 303)

1. First report states that the screws were zinc plated, while second report states that screws had a coating of zinc plating, cadmium plating, or zinc phosphate. The second report clarifies source of the screw description and also included that the customer requested verification of material type.
2. Wording on description of screws state that one was new (1<sup>st</sup> report) versus one had not been in service (2<sup>nd</sup> report).
3. First report contains statements from the customer (cyclically cooled between 15 deg F and room temperature) and the screws were probably over-torqued when installed. Second report does not state this.
4. Both reports list the chemical results that were found on a representative/typical screw, but second report states from which screw (screw "A") the data was reported. The second report states that the screws were probably zinc phosphate coated, but the data is listed in both reports.
5. The first report does not have microhardness traverse graphs included to indicate carburization, but both reports talk about higher carbon values than those for AISI 1022 steel and Table III, which shows a difference in case to core hardness which would indicate carburization.
6. In the fractography section, both reports discussed the examination of screw "A" (failed) and a screw from "G". A different micrograph is shown in Figure 7 for new screw "A" (1<sup>st</sup> report) versus whole screw "A" (2<sup>nd</sup> report). The second report does not mention set "B" (figure 7), and the first report does not mention set "H" (figure 7). Figure 7 is different in each report.

7. The 1<sup>st</sup> report does not mention the particular screw in which the presence of zinc was found, but both talk about pre-existing cracks, laps at the tip, face and roots of every screw. But there is no mention in second report of fatigue.
8. More explanation was given in the second report concerning the other screws in which no photographic documentation is shown, but the information concerning the screws is given by saying that "similar cracks were found both in the new and used screws."
9. The specific screws that were broken at CLS are not mentioned by name in the 1<sup>st</sup> report. Additional screws were broken at 15 deg F and reported in the second report (possibly additional info from customer). First report used the word "ductile" and "brittle" while the second report refers to it as "void coalescence" and "cleavage", respectively - both words indicating the same type of failure. The 2<sup>nd</sup> report discussed "quasi-cleavage", here again, the 1<sup>st</sup> report states "more ductile" and "more brittle," both stating a mixed mode of failure.
10. Because the additional time to do testing on set "H", "G", and "B", metallography was performed and reported in the 2<sup>nd</sup> report. A different microstructure was discovered showing slack quenching.
11. Possible conclusions were not bulleted in the 2<sup>nd</sup> report as in the 1<sup>st</sup>, but the lower ductility of the screws were mentioned in the 2<sup>nd</sup> report when cleavage or brittle fractures were discussed. No mention of high stress appears in the 2<sup>nd</sup> report, nor design limits.
12. The presence of stress concentrators is mentioned in both reports in the discussion of laps found at tips, face, and roots.
13. Corrosion is not mentioned in the 2<sup>nd</sup> report as a possible failure mechanism, but is mentioned at the beginning of the second report as being present in the threaded region.

14. Carbon content, higher values for some samples is mentioned in both reports, but no tie back to lower ductility expected in the 2<sup>nd</sup> report.
15. Pre-existing cracks (quench cracks) were mentioned in the 2<sup>nd</sup> report when the intergranular were discovered in the traverse section of the whole screw from set "A".
16. The second report does not mention thermal changes on the material, but tests were performed in the 2<sup>nd</sup> report to indicate that this was a concern (testing at 15 deg F).
17. The endorsement to the 1<sup>st</sup> report (E13 950612 303) lists which samples had a slack quenched microstructure.

## ATTACHMENT B

### INFORMATION ON SAMPLES FROM 95-1021

#### SAMPLE A - FRACTURED

##### 1<sup>st</sup> Report:

- Received ten fractured screw heads
- Corrosion product observed on screws mostly in the threaded region
- Possibly case hardened --- higher carbon content and microhardness readings
- Screws failed in a brittle manner as indicated by the intergranular failure mode seen on all screws. Final fracture area was ductile
- Metallography showed a secondary intergranular crack above the fracture surface
- Lappings from the forming process was observed in the face and root and along pitch of the screws.
- General microstructure was tempered martensite.
- Factors leading to failure: lower ductility, over-torquing, stress concentrators, corrosive environment, quench cracks, thermal cycling.
- Failure mode was intergranular separation and the mechanism was stress overload

##### Endorsement of June 12, 1995

- Not mentioned.

##### 2<sup>nd</sup> Report:

- Received ten screw heads that were in service
- Varying amounts of corrosion product was observed mostly in the threaded portion
- Chemistry was similar to 1022 carbon steel.
- Possible case hardened - higher carbon content and microhardness readings
- Fractography showed a intergranular failure, brittle surface. Final fracture area near the center of the shank was ductile.
- Metallography showed secondary intergranular cracks above the fracture surface
- Set "A" that was not in service - just says a crack not secondary crack.
- Microstructure is given as tempered martensite.
- Failure mode was intergranular separation.

#### SAMPLE A - NEW OR NOT IN SERVICE

##### 1<sup>st</sup> Report:

- One screw received
- Chemistry was similar to AISI 1022 carbon steel.
- Possibly case hardened - from chemistry
- Intergranular cracks (metallography) were found in tooth roots
- Laps and cracks were found in the new screws (not identified as to which new screw) - 2<sup>nd</sup> Paragraph, 2<sup>nd</sup> page
- New screw (not identified) was fractured in the laboratory to determine failure mode. Intergranular fracture in the case and mixed mode in the core was observed.
- General microstructure was tempered martensite

Endorsement of June 12, 1995:

- Cracks found in screw.
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.
- Could not be evaluated for metallography as destroyed in previous tests.

**INFORMATION ON SAMPLES FROM 95-1021**  
**SAMPLE A – NEW OR NOT IN SERVICE (Continued)**

2<sup>nd</sup> Report:

- Whole screw that was not in service received for testing
- Chemistries similar to 1022 carbon steel, zinc phosphate coating found on surface
- Possibly case hardened – high carbon content and microhardness readings
- Intergranular cracks were discovered in a transverse section of the screw
- Lapped regions were discovered at the tip, face, and roots of every screw that was examined and is typical of the thread rolling process
- Whole screw fractured in the lab and failed by quasi-cleavage in the case and void coalescence in the core
- Microstructure was tempered martensite

**SAMPLE B – NEW SCREWS**

1<sup>ST</sup> Report:

- Twelve screws received
- Possible case hardened at the thread tip – listed in text, but improperly identified in Table III
- Carbon steel – met carbon and sulfur requirements for AISI 1022
- Intergranular cracks found in transverse section
- All screws had laps from forming process
- Cracks in the thread roots
- General microstructure consisted of tempered martensite
- New screw (not identified) was fractured in the laboratory to determine failure mode. Intergranular fracture in the case and mixed mode in the core was observed

Endorsement of June 12, 1995:

- New set of twelve screws submitted for metallography
- No cracks found
- Slack-quenched microstructure
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Twelve new screws received
- Chemistry similar to 1022 carbon steel
- Case hardened at the tip not the root of the threads based on microhardness in Figure 3. improperly identified in Table III
- Laps found in the tip, face, and roots of the threads
- Simulated testing by fracturing samples at 15°F showed the failure mode to be void coalescence

- Microstructure consisted on tempered martensite
- Slack quenched region found in the thread roots

### SAMPLE C

#### 1<sup>ST</sup> Report:

- Two samples received
- Case hardened - higher carbon content
  
- May be 1022 carbon steel - carbon higher

#### INFORMATION ON SAMPLES FROM 95-1021 SAMPLE C - 1<sup>ST</sup> Report (Continued)

- All screws had laps from forming process
- Used screw not identified in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

#### Endorsement of June 12, 1995:

- One of two samples contained cracks
- No slack quenched observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

#### 2<sup>nd</sup> Report:

- Two screws received
- Chemistry similar to 1022 carbon steel
- Case hardened based on carbon content
- Intergranular cracks found in thread roots
- Simulated testing by fracturing samples at 15"<sup>T</sup> showed the failure mode to be void coalescence
- Tempered martensitic structure

### SAMPLE D

#### 1<sup>ST</sup> Report:

- Two screws received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No cracks found
- No slack quenching observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Two samples received
- Case hardened - microhardness results and chemistry has high carbon content
- Similar to 1022 carbon steel
- No cracks found in examined sections
- Laps found
- Tempered martensitic structure

INFORMATION ON SAMPLES FROM 95-1021

SAMPLE E

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No cracks found
- No slack quenching observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Two samples received
- Case hardened -chemistry has high carbon content
- Similar to 1022 carbon steel
- Laps found
- Tempered martensitic structure

SAMPLE F

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core

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- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No cracks found
- No slack quenching observed
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

2<sup>nd</sup> Report:

- Two samples received
- Case hardened -chemistry has high carbon content
- Similar to 1022 carbon steel
- Laps found
- Tempered martensitic structure

#### INFORMATION ON SAMPLES FROM 95-1021

##### SAMPLE G

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts and microhardness results
- Intergranular cracks found in roots of threads
- Presence of zinc in cracks
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core
- Tempered martensitic structure
- Used screws possibly harder due to higher carbon content

Endorsement of June 12, 1995:

- No mention in this report

2<sup>nd</sup> Report:

- Two samples received
- Case hardened - microhardness results and chemistry has high carbon content
- Similar to 1022 carbon steel
- Intergranular cracks found in thread roots
- Presence of zinc in crack
- Laps found
- Screw fractured in the lab and failed by intergranular fracture in the case and mixed mode failure in the core.
- Tempered martensitic structure
- Could not be checked for slack quench as destroyed by other testing

SAMPLE H

1<sup>ST</sup> Report:

- Two samples received
- Screws appeared to be case-hardened because of carbon amounts
- All screws examined have laps from forming process
- Used screw (not identified) in simulated laboratory fracture testing that produced intergranular fracture at the case and mixed mode fracture at the core.
- Tempered martensitic structure
- Softer than new screws

Endorsement of June 12, 1995:

- One sample had cracks
- One sample was slack quenched
- Note that orientation was not the same on all samples, therefore cutting may have been done in an area that was not slack-quenched or did not have cracks.

INFORMATION ON SAMPLES FROM 95-1021

SAMPLE H Continued

2<sup>nd</sup> Report:

- Two samples received
- Case hardened - microhardness results and chemistry has high carbon content
- Similar to 1022 carbon steel
- Intergranular cracks found in thread roots
- Laps found
- Slack quench structure observed
- Tempered martensitic structure

Both reports mention the fact that the samples that had been in service contained corrosion products.

September 3, 1998

Terry R. Woods

EXPLANATION OF FIGURE SEVEN IN REPORT NO. 95-1021

In comparing Figure 7 in the first report issued (RIMS No. E13 950602 302) to Figure 7 in the second report issued (RIMS No. E13 950619 303), there were some differences observed. The first one addressed fractured Sample A and Sample B. The second one addressed the "whole screw" Sample A and Sample H.

The first report was done on an emergency basis and all of the samples received were not completely analyzed. After issuing the first report, a request was made to perform additional testing/analysis (metallography) on those screws that were not addressed in the initial report. That work was then performed and an endorsement was issued that stated the findings of the additional testing/analysis.

After it was determined that a second report would need to be issued, it was decided to incorporate the results of the additional testing. In order to keep the flow of the original report, the initial Figure 7 was revised to include these results. Figure 7 was chosen because the cracking observed in the original figure 7 (depicting samples A and B) was similar to the cracking observed in Sample H and in the "whole screw A" depicted in the revised Figure 7.

Therefore, this figure substitution which incorporates Sample H instead of B, was performed in order to include additional test/analysis results while eliminating duplication of a similar failure mode information.

Delsa L. Frazier, Metallurgical Engineer   
Analysis and Evaluation Services  
Central Laboratories and Field Testing Services  
PSC-1B-C