Appendix A12

It is estimated that the above protocol will require at least one day to complete, but may take significantly longer. This proposed test protocol may be altered during the examination depending upon the results of the testing. Each party understands that should deviations from this protocol become necessary, the representatives present at the examination may participate in any discussions regarding these deviations. Interested Parties who are not represented at the repair facility have no say about the process.

Interested Parties may be present during this evaluation of evidence. The Interested Parties must notify Daniel Berglund (612-564-4885) if they plan to attend. Parties will follow the Revised Memorandum of Understanding. The data and photographs generated during the execution of this protocol will be made available upon request to all Interested Parties at cost.

Appendix A13

TEST PROTOCOL NO. 4

FOR SHERCO NO. 3 LP ROTOR-B BLADES FROM FAILED L-1 WHEEL
ENGEL METALLURGICAL PROJECT 954-001

Date: April 4, 2012

This protocol will be executed at Engel Metallurgical Ltd. As per previous protocols, all of the components selected for metallurgical evaluation relative to the Sherco No. 3 failure were protected, crated and shipped to Engel Metallurgical Ltd. for storage. These components were unpacked per the protocol dated March 12, 2012. It is expected that these activities will commence on or about April 17, 2012, immediately after the completion of Protocol No. 4.

The following metallurgical examination and testing protocol is proposed for the evaluation of the Sherco No. 3 LP Rotor-B failed L-1 wheel blades that was removed from LP rotor-B. All cutting will be performed without any coolant (that is, "dry cut") unless otherwise agreed by the parties present during the metallurgical testing. Photographs will be taken to document the location of each section removed from the blades. Prior to the commencement of this protocol, the parts will have been photographed at Engel Metallurgical and will be made available to all parties attending.

Data generated during the execution of this protocol will be shared amongst all parties present. To ensure that time is used efficiently, a single person designated by Les Engel shall take all photographs of the blades during the examination and testing. All parties present will have an opportunity to identify regions of interest and ensure that the appropriate photographs have been taken by the designated photographer. Should any party determine that the photography process described herein is inefficient or ineffective, the parties present may agree on a different process for photographing the evidence.

1. Perform visual examination of as-received blades. Images will be taken of areas of interest. Subsequent evaluation tasks will also be documented photographically.

2. Energy dispersive spectroscopy (EDS) will be performed on surface deposits. Samples can be directly analyzed or deposits can be removed using cotton swabs and/or adhesive carbon tabs.

3. Clean select blades with detergent.

4. Perform visual examination of cleaned blades at magnifications of 1X to 30X.

5. With the agreement of parties present, perform fluorescent penetrant inspection on selected blade roots.

6. Obtain weights of selected blades with minimal damage.

7. A section will be removed from one blade for quantitative chemical analysis.

8. A section will be removed from selected blades for hardness testing.

Appendix A14

9. Select and remove metallographic cross section(s) from selected blades.

10. Metallographic cross section(s) will be prepared in accordance with standard metallographic practice.

11. Examine the metallographic cross section(s) using a metallograph and/or SEM/EDS. Images will be taken at areas of interest.

12. If cracks are found in blade roots: a) open selected cracks; b) perform visual examination of fracture surfaces; c) perform SEM/EDS evaluations of fracture surfaces; d) perform metallographic evaluation in cracked areas

It is estimated that the above protocol will require at least three days to complete, but may take significantly longer and will continue until completion. This proposed test protocol may be altered during the examination depending upon the results of the testing. Each party understands that should deviations from this protocol become necessary, the representatives present at the examination may participate in any discussions regarding these deviations. Interested Parties who are not represented at the repair facility have no say about the process.

Interested Parties may be present during this evaluation of evidence. The Interested Parties must notify Daniel Berglund (612-564-4885) if they plan to attend. Parties will follow the Revised Memorandum of Understanding. The data and photographs generated during the execution of this protocol will be made available upon request to all Interested Parties at cost.

Appendix A15

TEST PROTOCOL NO. 5

FOR SHERCO NO. 3 GENERATOR SHAFT FRACTURE ADJACENT TO THE GENERATOR COLLECTOR RING (ENGEL EVIDENCE NUMBERS S14771 AND S14873)

Date: April 17, 2012

This protocol will be executed at Engel Metallurgical Ltd. As per previous protocols, all of the components selected for metallurgical evaluation relative to the Sherco No. 3 failure were protected, crated and shipped to Engel Metallurgical Ltd. for storage. These components were unpacked per the protocol dated March 12, 2012. Laboratory testing is expected to commence at 9:00 a.m. on May 1, 2012.

The following metallurgical examination and testing protocol is proposed for the evaluation of the Sherco No. 3 generator shaft fracture. This protocol includes both mating fracture surfaces (Engel evidence numbers S14771 and S14873). All cutting will be performed without any coolant (that is, "dry cut") unless otherwise agreed by the parties present during the metallurgical testing. Prior to the commencement of this protocol, the parts will have been photographed at Engel Metallurgical and will be made available to all parties attending.

Data generated during the execution of this protocol will be shared amongst all parties present. To ensure that time is used efficiently, a single person designated by Les Engel shall take all photographs during the examination and testing. All parties present will have an opportunity to identify regions of interest and ensure that the appropriate photographs have been taken by the designated photographer. Should any party determine that the photography process described herein is inefficient or ineffective, the parties present may agree on a different process for photographing the evidence.

1. Perform a visual examination of the shaft fracture, as-received. Images will be taken at areas of interest.

2. Remove lead bars if possible.

3. Energy dispersive spectroscopy (EDS) will be performed on surface deposits using cotton swabs and/or adhesive carbon tabs.

4. Select and remove section(s) from the shaft fracture for further evaluation.

5. Perform visual examinations of the removed section(s) of the fracture surface at magnifications of 1X to 30X with the aid of a stereomicroscope. Images may be taken of areas of interest.

6. Using a scanning electron microscope (SEM) with EDS capabilities, examine the removed section(s) of the fracture surface. Perform EDS analyses of surface deposits.

7. Clean the fracture surface sample(s) examined in step 6 ultrasonically in 1% Alconox solution, rinse with hot water and ethyl alcohol followed by drying in hot air. If this

methodology is insufficient to clean the fracture surface(s), other cleaning methods may be necessary. Any further surface cleaning will be performed by agreement of parties present.

8. Perform visual examinations of the cleaned fracture surface sample(s) at magnifications of 1X to 30X with the aid of a stereomicroscope. Images may be taken of areas of interest.

9. Perform SEM/EDS on the cleaned fracture surface sample(s). Images will be taken of areas of interest.

10. Select and remove metallographic cross section(s) from the shaft fracture.

11. Metallographic cross section(s) will be prepared in accordance with standard metallographic practice.

12. Examine the metallographic cross section(s) using a metallograph and/or SEM/EDS. Images will be taken at areas of interest.

13. If needed, perform microhardness testing on selected metallographic cross section(s).

14. A section will be removed from the shaft for quantitative chemical analysis.

15. A section will be removed from shaft for hardness testing.

16. Perform tensile testing on longitudinally oriented specimens.

It is estimated that the above protocol will require at least five days to complete, but may take significantly longer. If it takes longer than the one week scheduled, the examination will continue on a weekly bases until complete. This proposed test protocol may be altered during the examination depending upon the results of the testing. Each party understands that should deviations from this protocol become necessary, the representatives present at the examination may participate in any discussions regarding these deviations. Interested Parties who are not represented at the repair facility have no say about the process.

Interested Parties may be present during this evaluation of evidence. The Interested Parties must notify Daniel Berglund (612-564-4885) if they plan to attend. Parties will follow the Revised Memorandum of Understanding. The data and photographs generated during the execution of this protocol will be made available upon request to all Interested Parties at cost.

Appendix A17

TEST PROTOCOL NO. 6

FOR SHERCO NO. 3 ALTEREX SHAFT FRACTURES: ALTEREX SHAFT FRACTURE ADJACENT TO THE NO. 11 BEARING (ENGEL EVIDENCE NUMBERS S15023/S14765); ALTEREX SHAFT FRACTURE ADJACENT TO THE NO. 12 BEARING (ENGEL EVIDENCE NUMBERS S15024/S14767; AND THE ALTEREX SHAFT FRACTURE AT THE ALTEREX COLLECTOR RING (ENGEL EVIDENCE NUMBERS S14767/S14770).

Date: April 17, 2012

This protocol will be executed at Engel Metallurgical Ltd. As per previous protocols, all of the components selected for metallurgical evaluation relative to the Sherco No. 3 failure were protected, crated and shipped to Engel Metallurgical Ltd. for storage. These components were unpacked per the protocol dated March 12, 2012. Laboratory testing is expected to commence at 9:00 a.m. on May 1, 2012.

The following metallurgical examination and testing protocol is proposed for the evaluation of the three Sherco No. 3 alterex shaft fractures: Alterex shaft fracture adjacent to the No. 11 bearing (Engel evidence numbers s15023/s14765); Alterex shaft fracture adjacent to the No. 12 bearing (Engel evidence numbers s15024/s14767); and the Alterex shaft fracture at the Alterex collector ring (Engel evidence numbers s14767/s14770). All cutting will be performed without any coolant (that is, "dry cut") unless otherwise agreed by the parties present during the metallurgical testing. Prior to the commencement of this protocol, the parts will have been photographed at Engel Metallurgical and will be made available to all parties attending.

Data generated during the execution of this protocol will be shared amongst all parties present. To ensure that time is used efficiently, a single person designated by Les Engel shall take all photographs during the examination and testing. All parties present will have an opportunity to identify regions of interest and ensure that the appropriate photographs have been taken by the designated photographer. Should any party determine that the photography process described herein is inefficient or ineffective, the parties present may agree on a different process for photographing the evidence.

1. Perform a visual examination of the fracture surfaces, as-received. Images will be taken of areas of interest.

2. Remove lead bars if possible

3. Energy dispersive spectroscopy (EDS) will be performed on surface deposits using cotton swabs and/or adhesive carbon tabs.

4. Select and remove section(s) from the fracture surfaces for further evaluation.

5. Perform visual examinations of the removed section(s) of the fracture surfaces at magnifications of 1X to 30X with the aid of a stereomicroscope. Images may be taken in areas of interest.

6. Using a scanning electron microscope (SEM) with EDS capabilities, examine the removed section(s) of the fracture surfaces. Perform EDS analyses of surface deposits

7. Clean the fracture surface samples examined in step 6 ultrasonically in 1% Alconox solution, rinse with hot water and ethyl alcohol followed by drying in hot air. If this methodology is insufficient to clean the fracture surfaces, other cleaning methods may be necessary. Any further surface cleaning will be performed by agreement of parties present.

8. Perform visual examinations of the cleaned fracture surface samples at magnifications of 1X to 30X with the aid of a stereomicroscope. Images may be taken of areas of interest.

9. Perform SEM/EDS on the cleaned fracture surface samples. Images will be taken of areas of interest.

10. Select and remove metallographic cross sections from the shaft fractures.

11. Metallographic cross sections will be prepared in accordance with standard metallographic practice.

12. Examine the metallographic cross sections using a metallograph and/or SEM/EDS. Images will be taken at areas of interest.

13. If needed, perform microhardness testing on selected metallographic cross section(s).

14. Sections will be removed from shaft for quantitative chemical analysis.

15. Sections will be removed from shaft for hardness testing.

16. Perform tensile testing of longitudinally oriented specimens.

It is estimated that the above protocol will require at least five days to complete, but may take significantly longer. If it takes longer than the one week scheduled, the examination will continue on a weekly bases until complete. This proposed test protocol may be altered during the examination depending upon the results of the testing. Each party understands that should deviations from this protocol become necessary, the representatives present at the examination may participate in any discussions regarding these deviations. Interested Parties who are not represented at the repair facility have no say about the process.

Interested Parties may be present during this evaluation of evidence. The Interested Parties must notify Daniel Berglund (612-564-4885) if they plan to attend. Parties will follow the Revised Memorandum of Understanding. The data and photographs generated during the execution of this protocol will be made available upon request to all Interested Parties at cost.

Appendix A19

TEST PROTOCOL NO. 7

FOR SHERCO NO. 3 LP ROTOR-B FAILED L-1 RIM
ENGEL METALLURGICAL PROJECT 954-001

Date: March 29, 2012

This protocol will be executed at Engel Metallurgical Ltd. As per previous protocols, all of the components selected for metallurgical evaluation relative to the Sherco No. 3 failure were protected, crated and shipped to Engel Metallurgical Ltd. for storage. These components were unpacked per the protocol dated March 12, 2012. Laboratory testing is expected to commence at 9:00 AM on April 3, 2012.

The following metallurgical examination and testing protocol is proposed for the evaluation of the Sherco No. 3 LP Rotor-B failed L-1 wheel rim that was removed from LP rotor-B. All cutting will be performed without any coolant (that is, "dry cut") unless otherwise agreed by the parties present during the metallurgical testing. Photographs will be taken to document the location of each section removed from the rim. Prior to the commencement of this protocol, the parts will have been photographed at Engel Metallurgical and will be made available to all parties attending.

All data generated during the execution of this protocol will be shared amongst all parties present. To ensure that time is used efficiently, a single person designated by Les Engel shall take all photographs of the rim during the examination and testing. All parties present will have an opportunity to identify regions of interest and ensure that the appropriate photographs have been taken by the designated photographer. Should any party determine that the photography process described herein is inefficient or ineffective, the parties present may agree on a different process for photographing the evidence.

1. Perform visual examination of rim as-received. Images will be taken of areas of interest.

2. Remove selected surface deposit samples from wheel rim for subsequent energy dispersive spectroscopy (EDS). Samples will be removed using cotton swabs and/or adhesive carbon tabs.

3. Perform EDS on the samples collected in Task 2, as well as samples removed at Xcel prior to shipment and at the GE Chicago repair shop during the removal of the rim.

4. Select and remove area(s) from the wheel rim for further evaluation.

5. Perform visual examinations of existing as-received fracture surfaces at magnifications of 1X to 30X with the aid of a stereomicroscope. Images may be taken of areas of interest.

6. Open selected cracks to expose the fracture surfaces, as needed.

7. Perform visual examinations of exposed crack, fracture surfaces in as-received condition at magnifications of 1X to 30X with the aid of a stereomicroscope. Images may be taken of areas of interest.

8. Using a scanning electron microscope (SEM) with EDS capabilities, examine select fracture surface(s).

9. If necessary, determine if and what further analytic method may be required for the surface analysis of the fracture surfaces. Any further chemical analysis beyond EDS would likely need to be completed at a facility outside of Engel Metallurgical.

10. Clean fracture surface(s) examined during Task 8 ultrasonically in 1% Alconox solution, rinse with hot water and ethyl alcohol followed by drying in hot air. If this methodology is insufficient to clean the fracture surface(s), other cleaning methods may be necessary. Any further surface cleaning will be performed by agreement of parties present.

11. Perform visual examinations of the cleaned fracture surfaces at magnifications of 1X to 30X with the aid of a stereomicroscope. Images will be taken of areas of interest.

12. Perform SEM/EDS on the cleaned fracture surfaces. Images will be taken of areas of interest.

13. Remove a radial section of the rim exhibiting an intact dovetail (finger portion to which the blades are attached) for subsequent dimensional evaluation. The dimensions, measurement techniques and locations of the dimensional evaluation will be agreed upon by all parties present prior to commencement. A single record of all dimensions will be collected.

14. Select and remove metallographic cross section(s) from the rim.

15. Metallographic cross section(s) will be prepared in accordance with standard metallographic practice.

16. Examine the metallographic cross section(s) using a metallograph and/or SEM/EDS. Images will be taken at areas of interest.

17. Perform microhardness testing on selected metallographic cross section(s).

18. Perform hardness testing on selected radial section(s) from the rim.

19. If needed and with the agreement of parties present, perform high sensitivity fluorescent penetrant inspection of the remaining portions of the rim.

20. Perform radial room temperature tensile tests on samples from fingers of the dovetail region of the rim.

21. Perform quantitative chemical analysis of wheel rim material.

The evaluation of these components will continue on a weekly basis until completed. It is estimated that the above protocol will require at least five days to complete, but may take significantly longer. This proposed test protocol may be altered during the examination depending upon the results of the testing. Each party understands that should deviations from this protocol become necessary, the representatives present at the examination may participate in

any discussions regarding these deviations. Interested Parties who are not represented at the repair facility have no say about the process.

Interested Parties may be present during this evaluation of evidence. The Interested Parties must notify Daniel Berglund (612-564-4885) if they plan to attend. Parties will follow the Revised Memorandum of Understanding. The data and photographs generated during the execution of this protocol will be made available upon request to all Interested Parties at cost.

Appendix A22

PROPOSED TEST PROTOCOL NO.10

FOR SHERCO NO. 3
Sherco No. 3 Deposits Analysis (Cotton, Misc Material).

Date: May 7, 2012

This protocol will be executed at Engel Metallurgical Ltd. Laboratory testing is expected to start when the EDS is available and will continue until completed. It is expected that this this protocol will occur contemporaneously with Protocol 7, but may occur shortly thereafter.
The following examination and testing protocol is proposed for the evaluation of the Sherco No. 3 deposits analysis (cotton, miscellaneous material).

Data generated during the execution of this protocol will be shared amongst all parties present.

1. Perform EDS analyses of surface deposits removed from various components of Sherco No. 3. The EDS analyses of the deposits are normally performed at 20,000 counts. The count level can be changed based on the concentration of particular elements to assure statistically sound test results.

2. Determine if any additional work is needed on the samples

It is estimated that the above protocol will require at least several days to complete. The examination will continue on a weekly bases until complete. This proposed protocol may be altered during the examination depending upon the results of the testing. Each party understands that should deviations from this protocol become necessary, the representatives present at the examination may participate in any discussions regarding these deviations. Interested Parties who are not represented at the repair facility have no say about the process.

Interested Parties may be present during this evaluation of evidence. The Interested Parties must notify Daniel Berglund (612-564-4885) if they plan to attend. Parties will follow the Revised Memorandum of Understanding. The data and photographs generated during the execution of this protocol will be made available upon request to all Interested Parties at cost.

APPENDIX B

SHERCO UNIT NO. 3

INSTRUMENTED DATA FROM NOVEMBER 17 TO 19, 2011

Appendix B1

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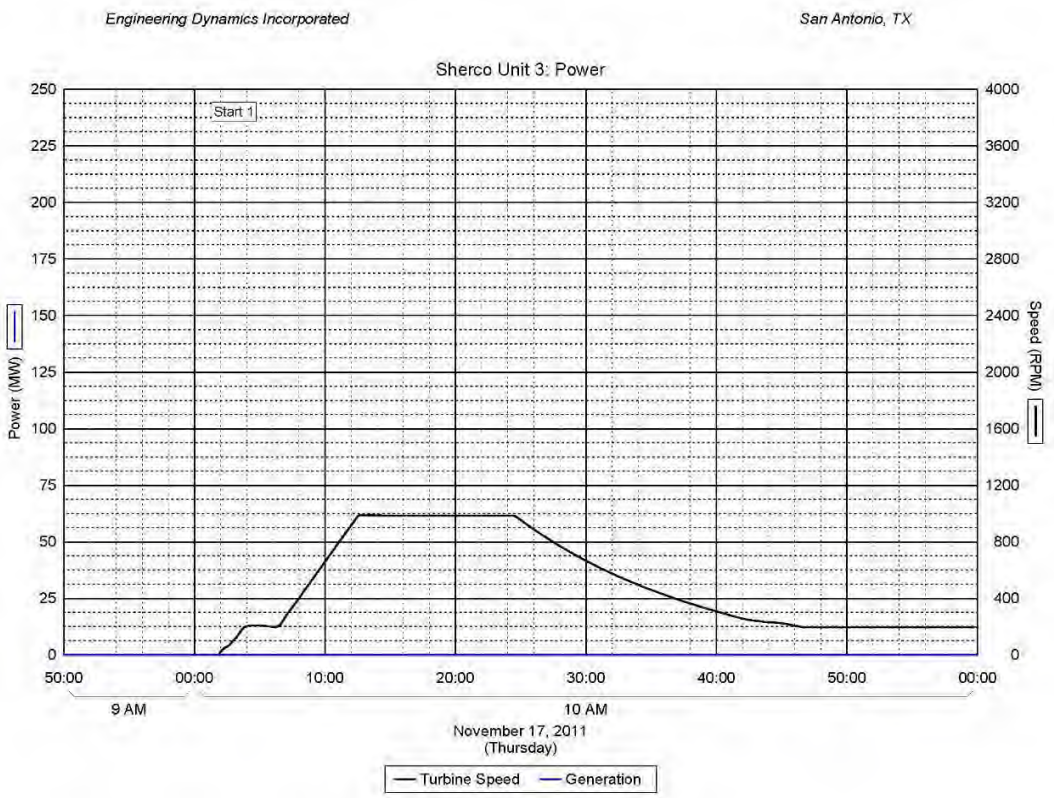

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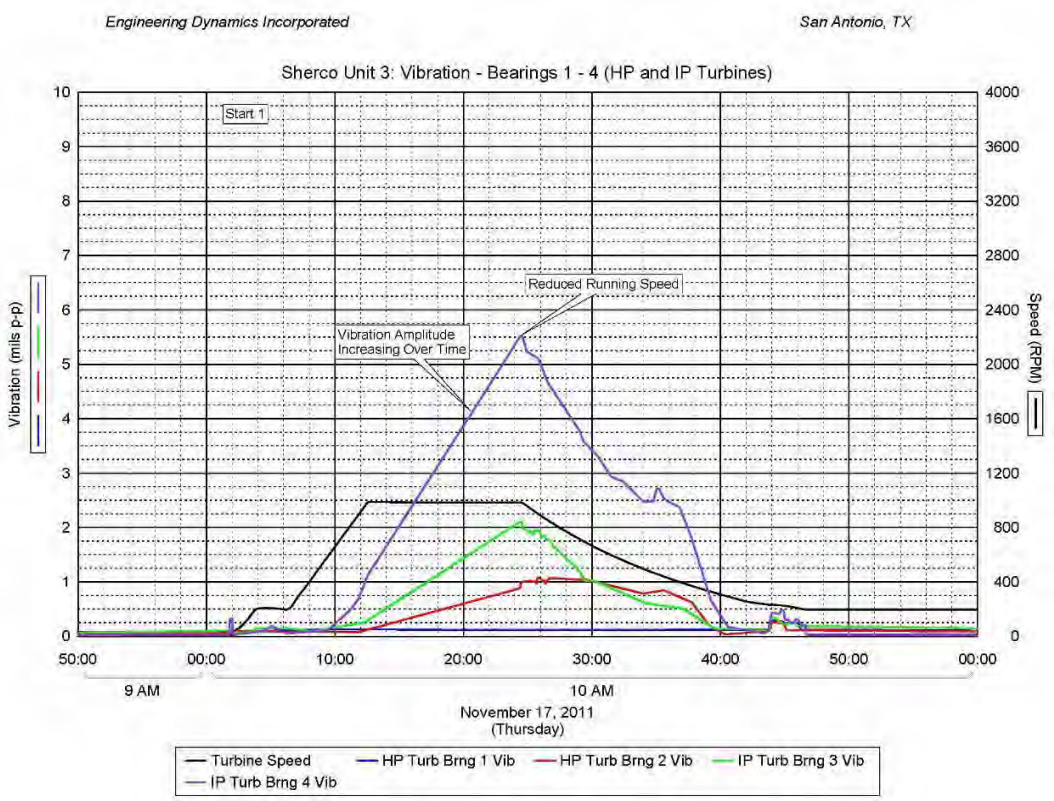

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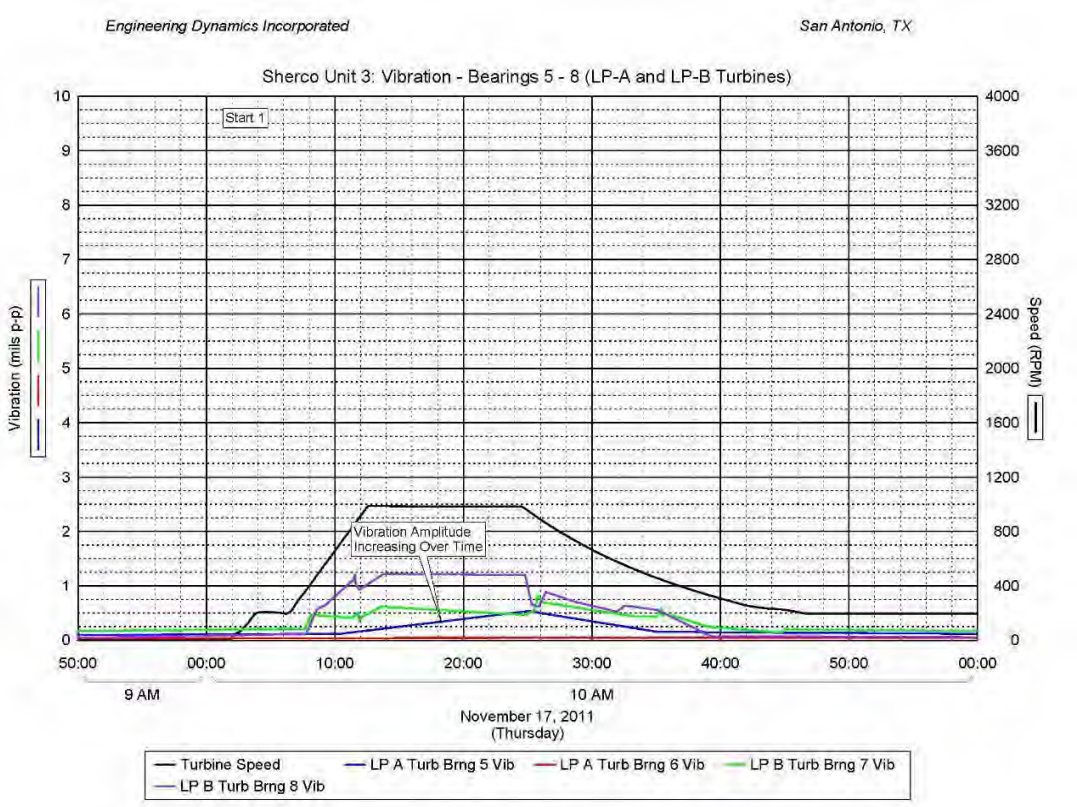

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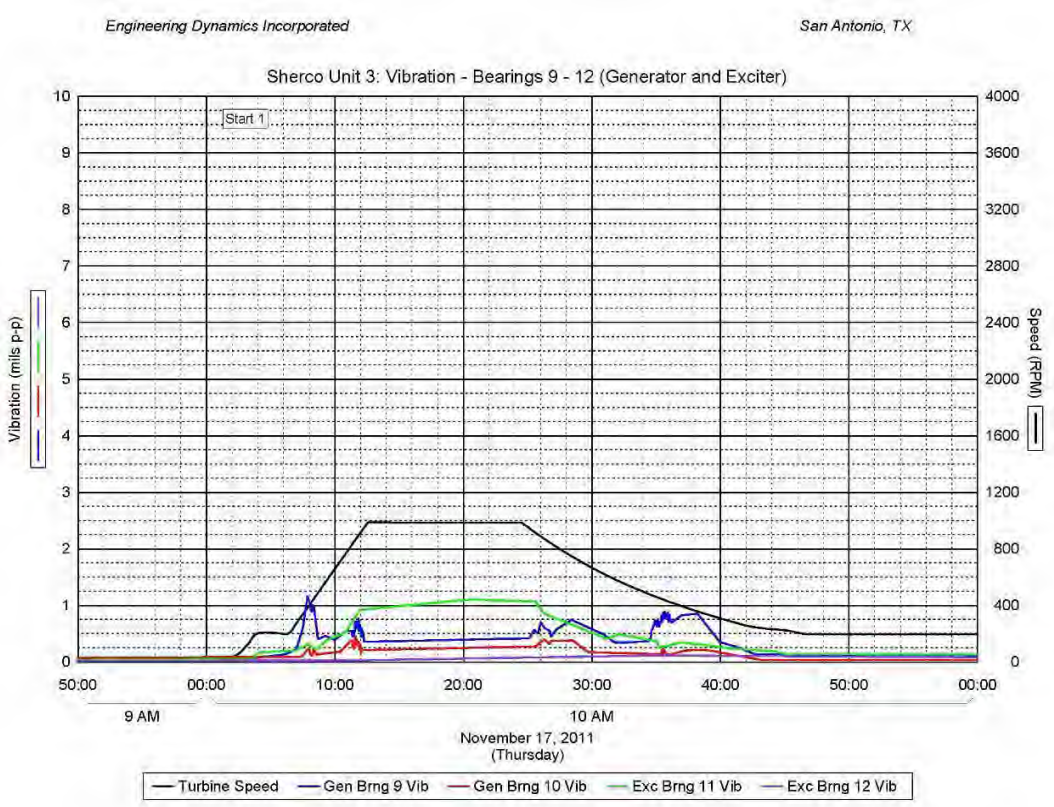

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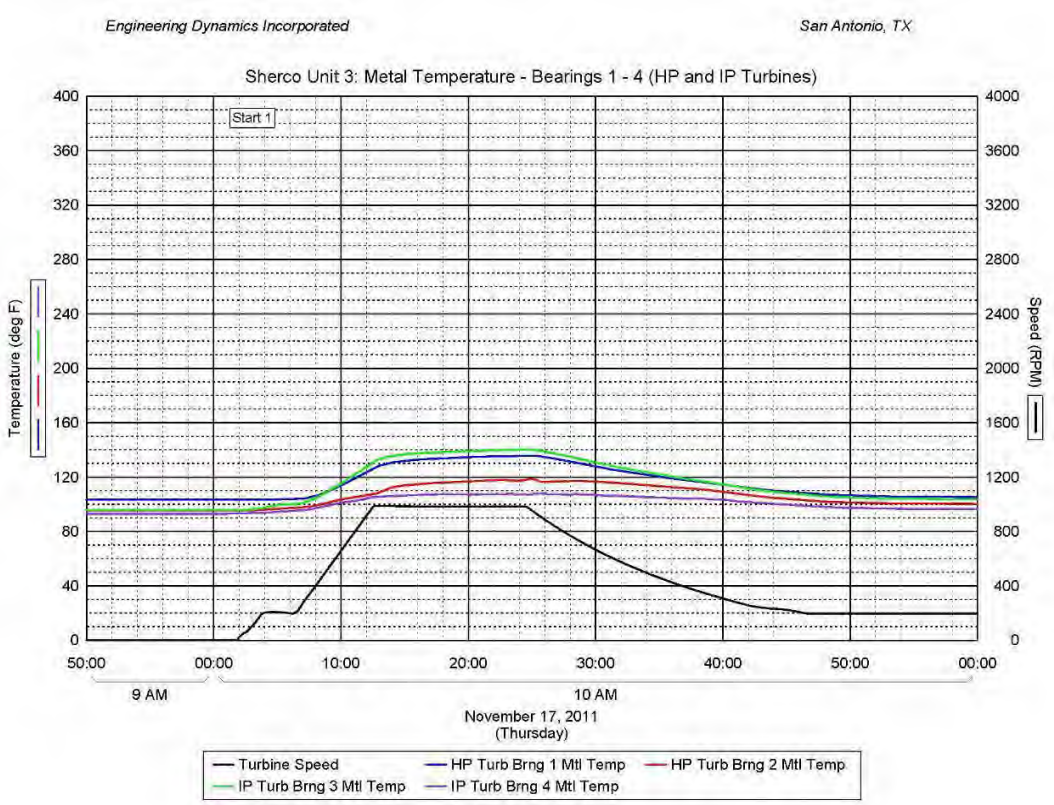

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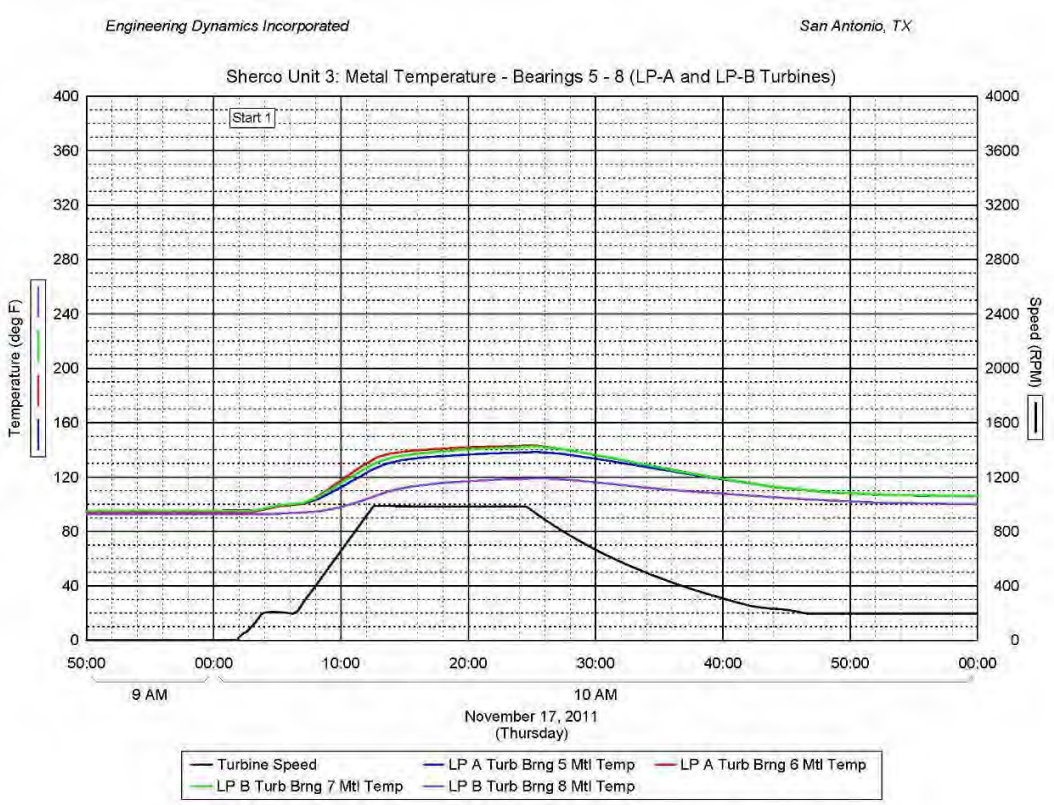

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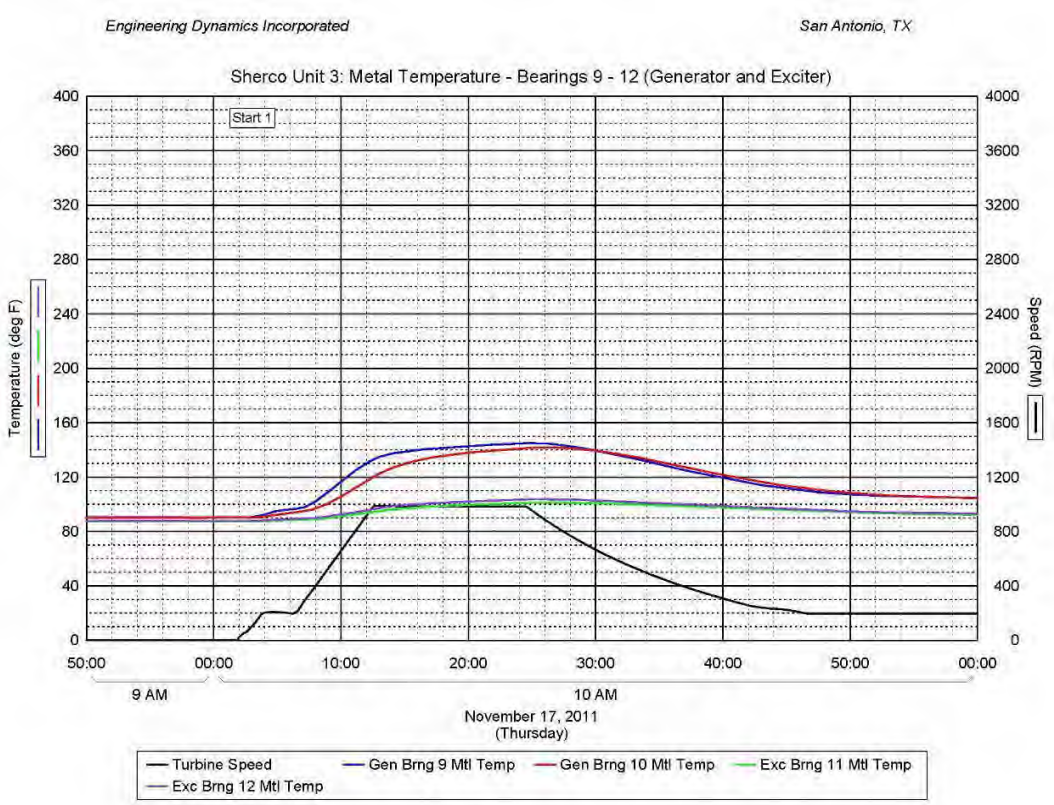

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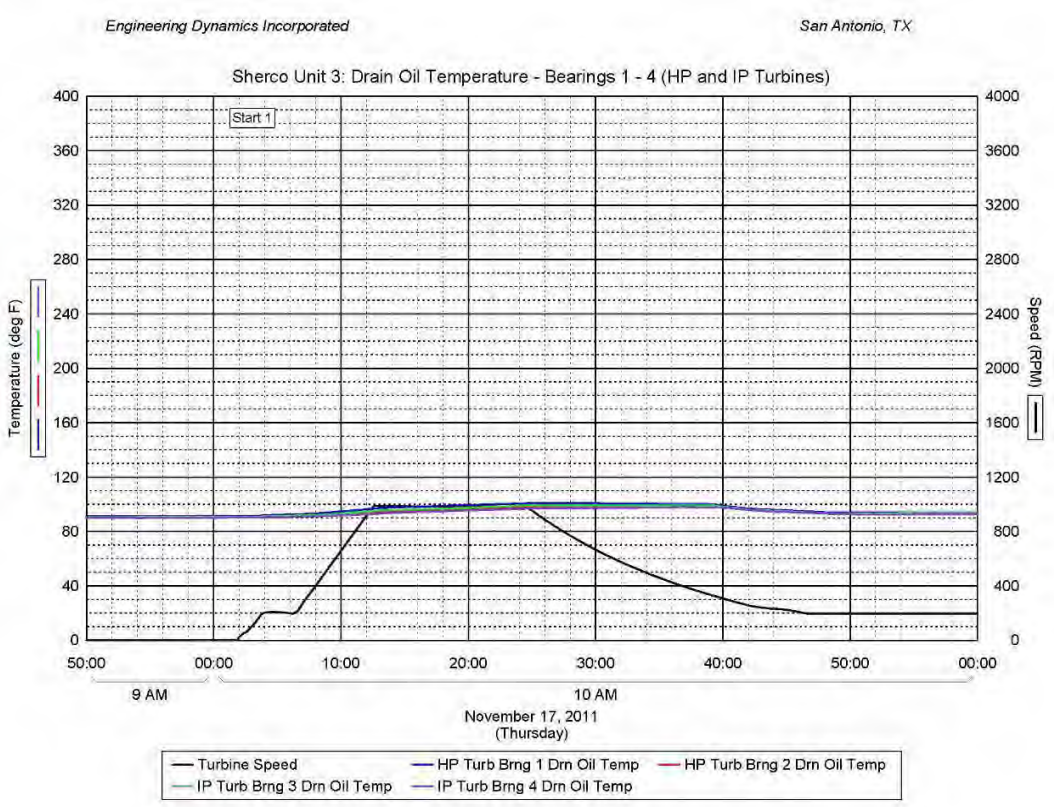

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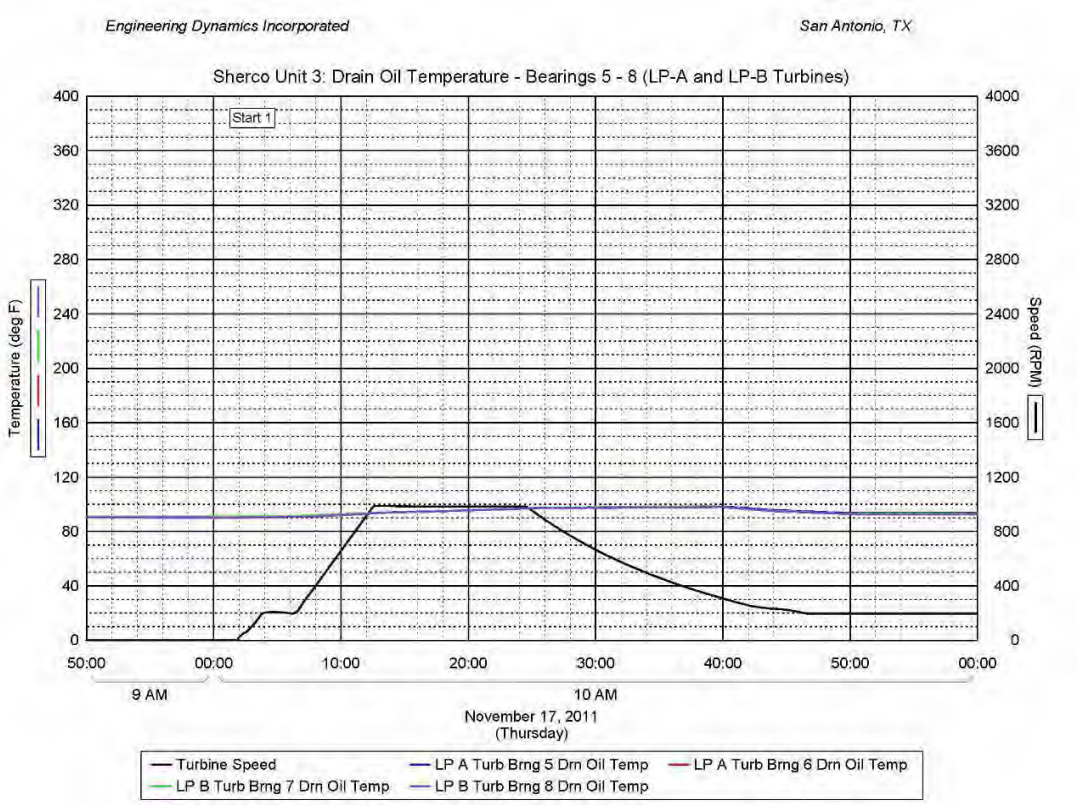

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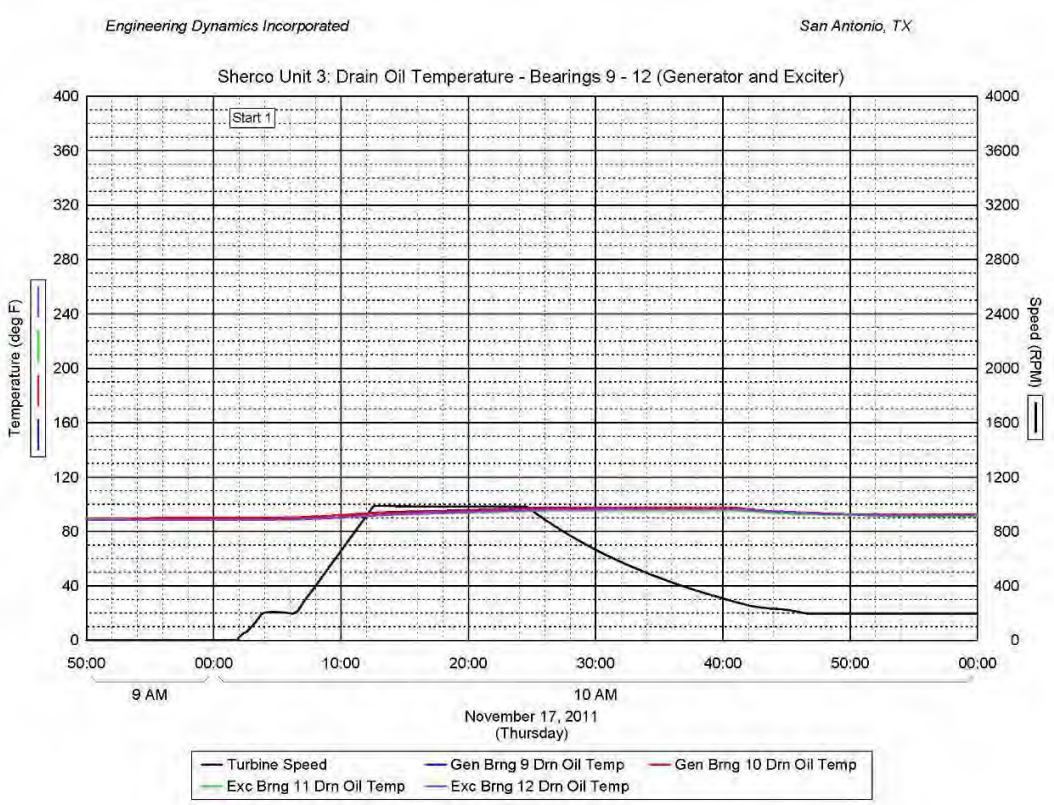

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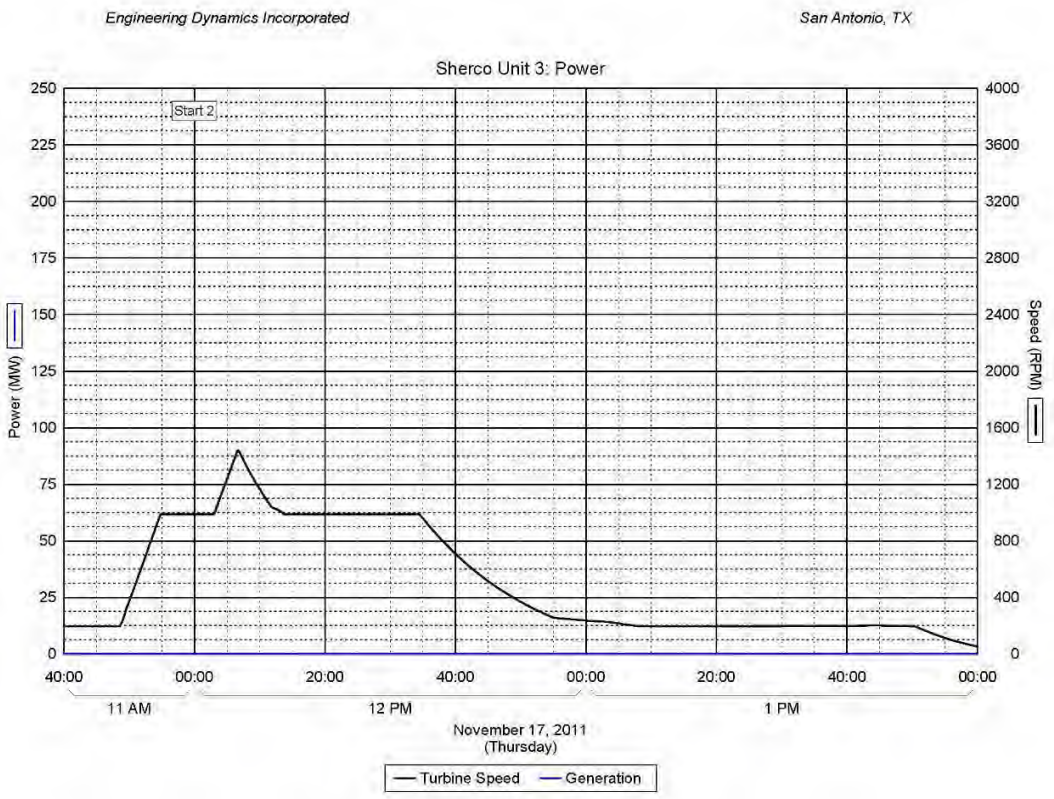

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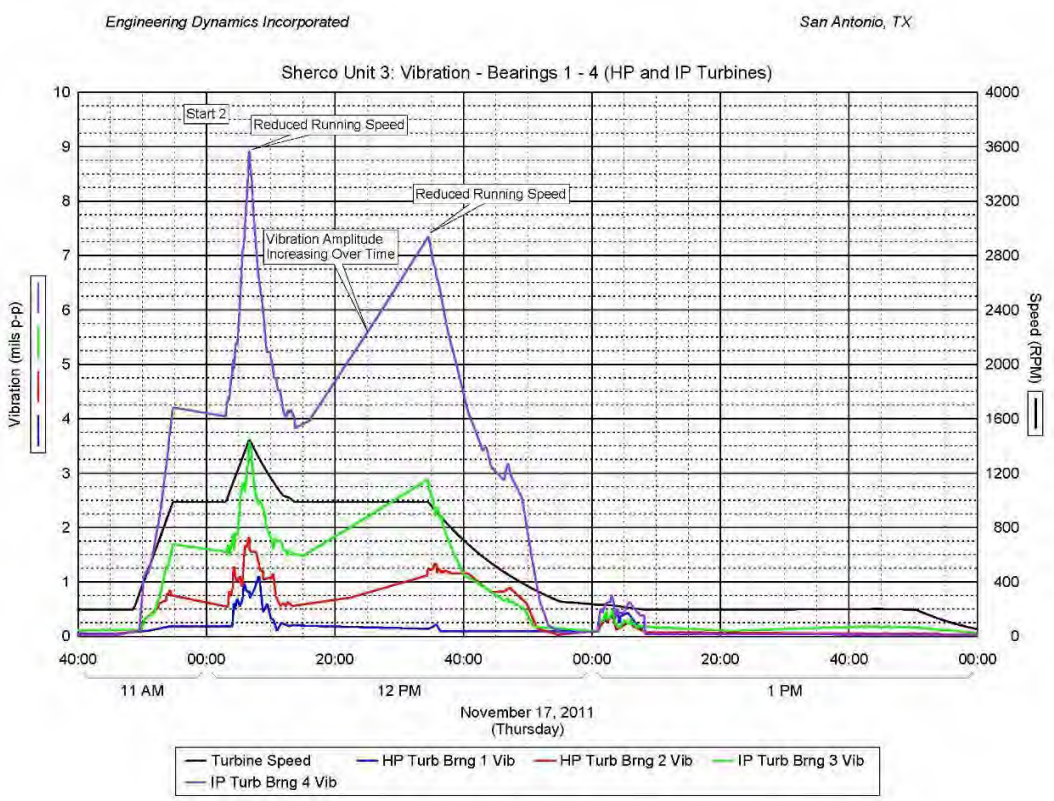

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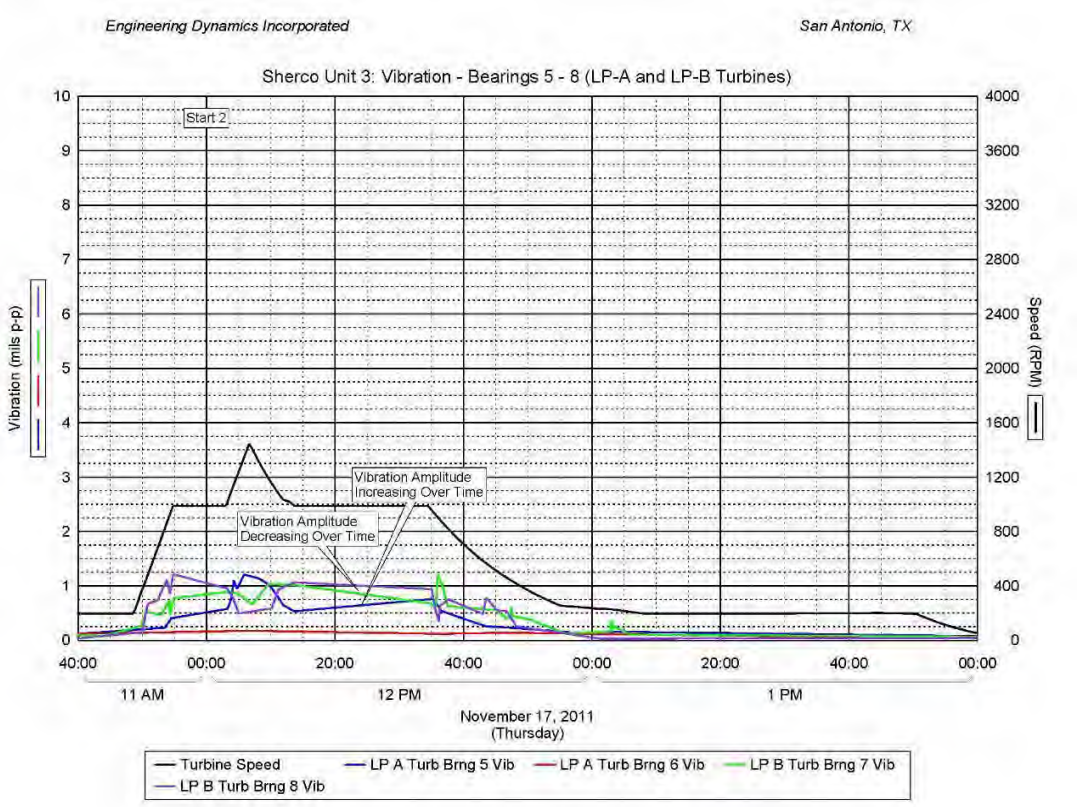

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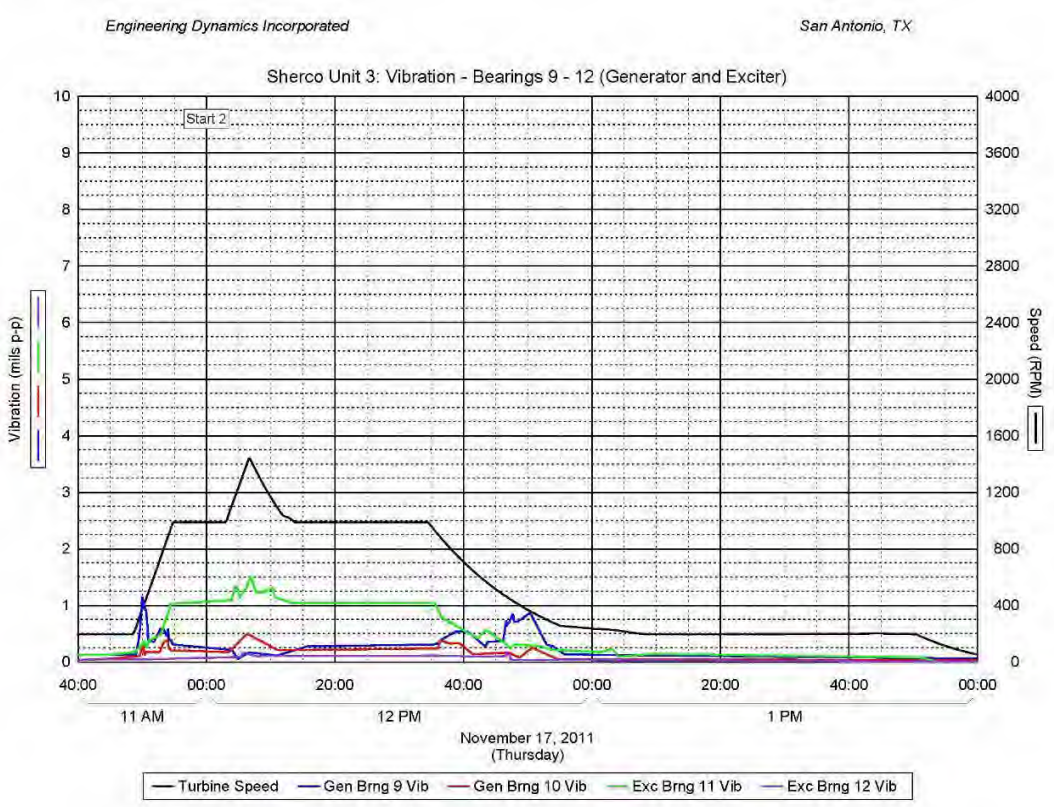

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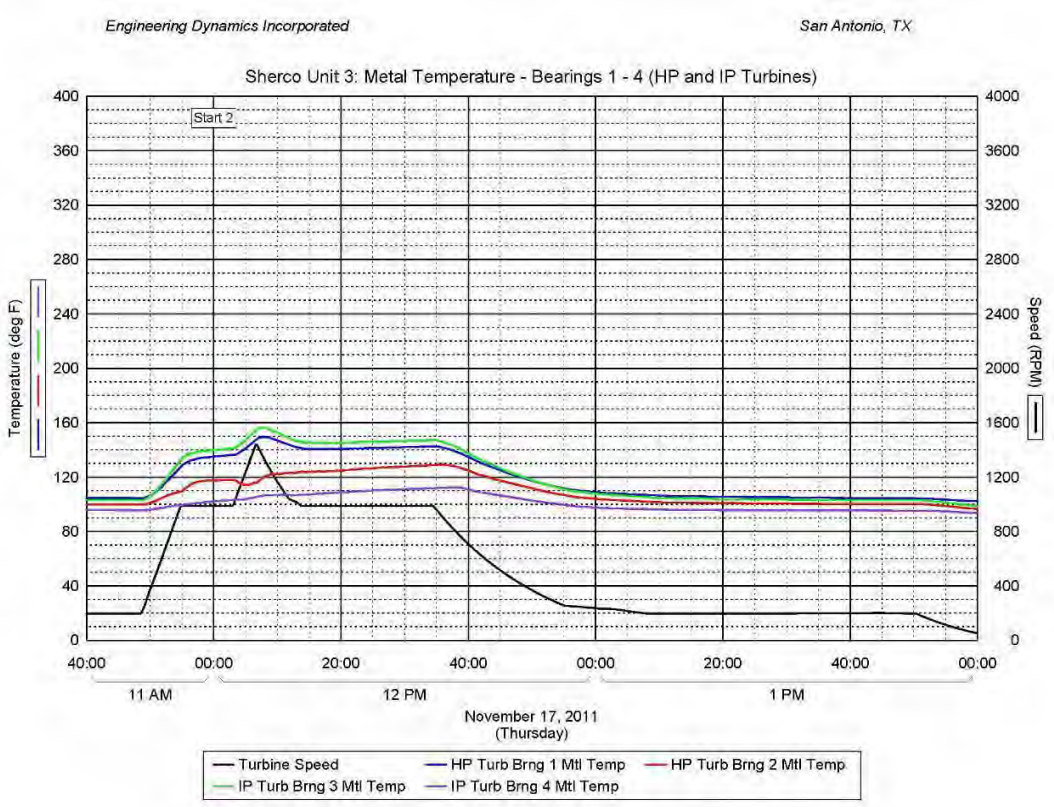

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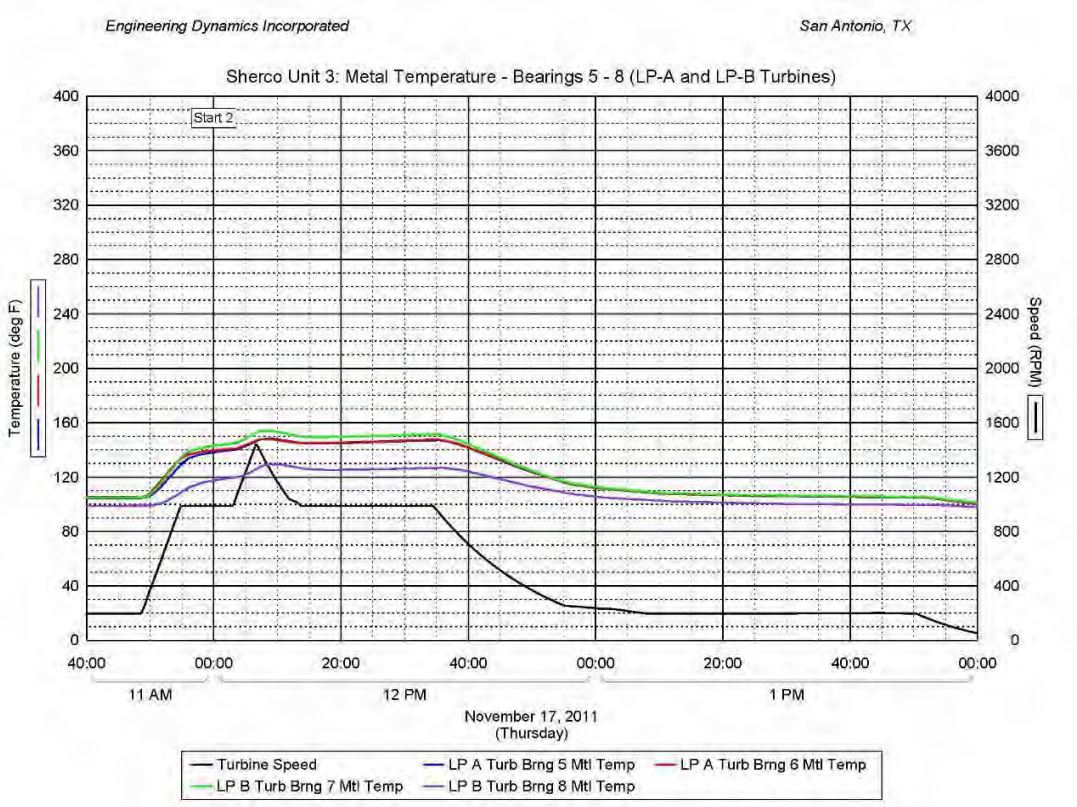

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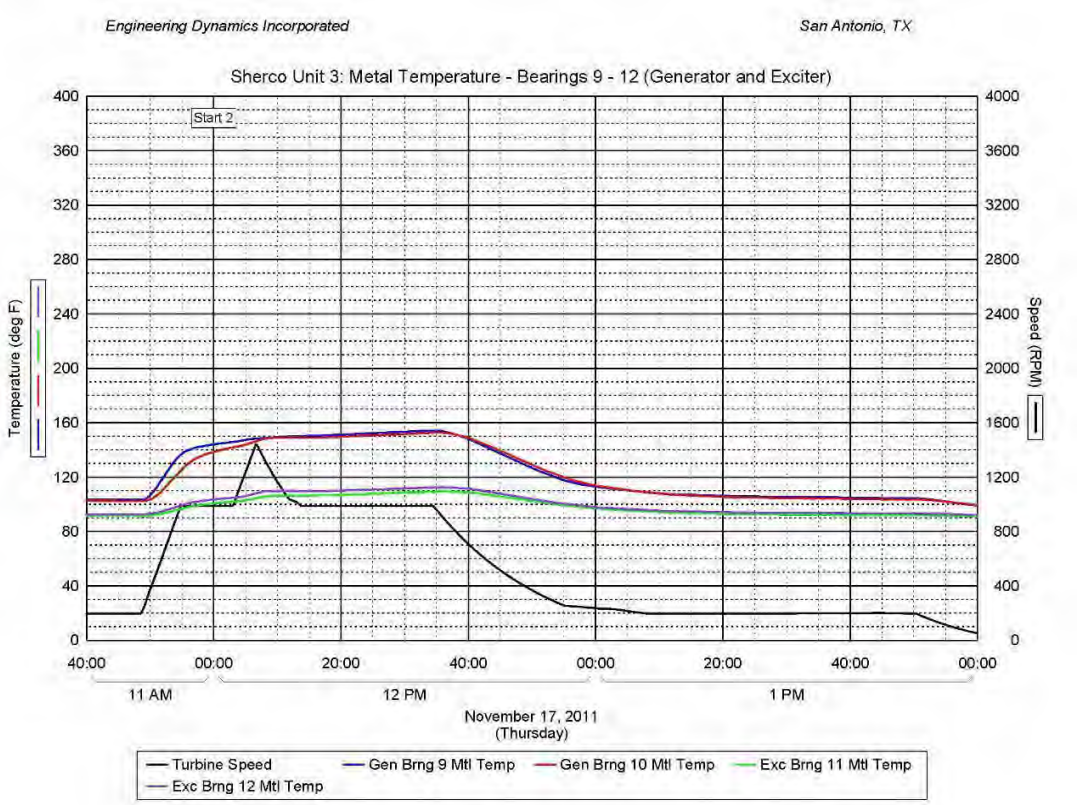

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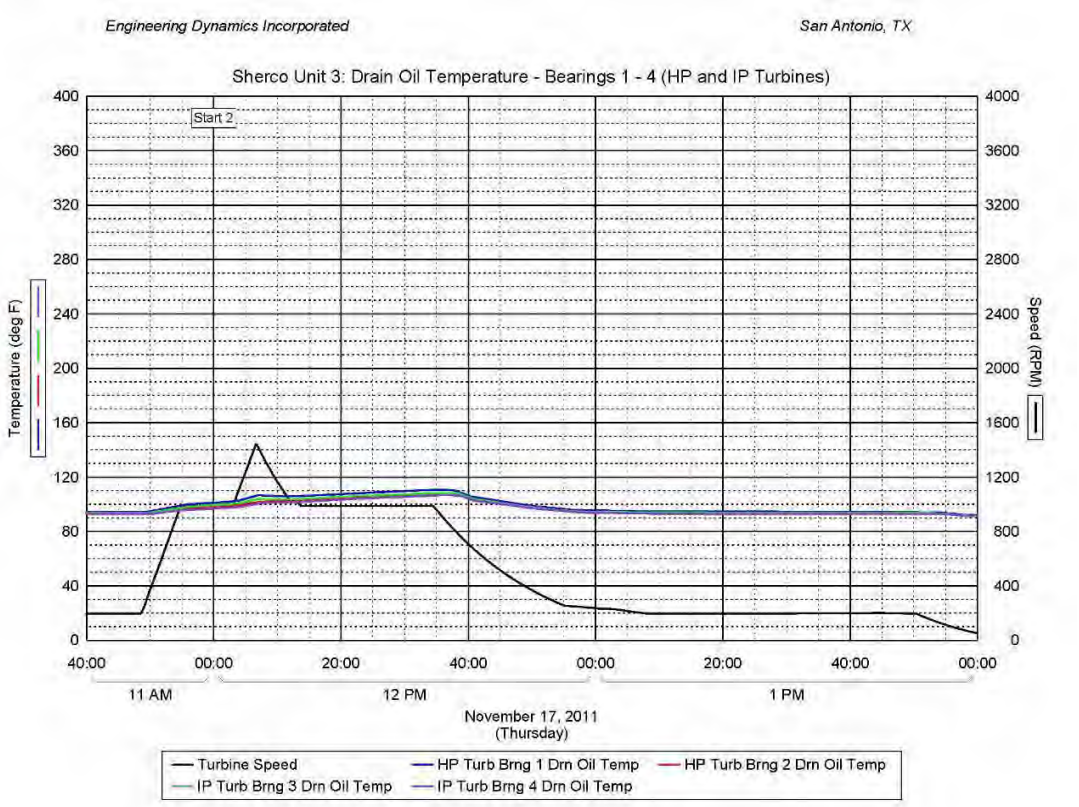

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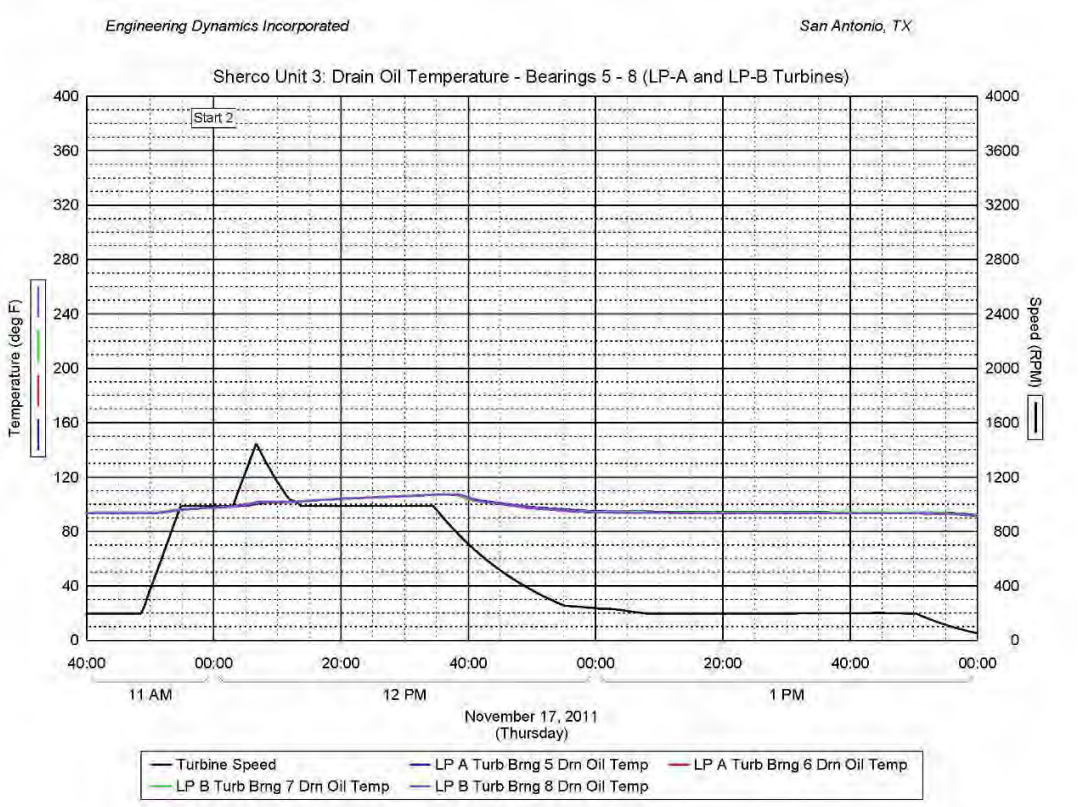

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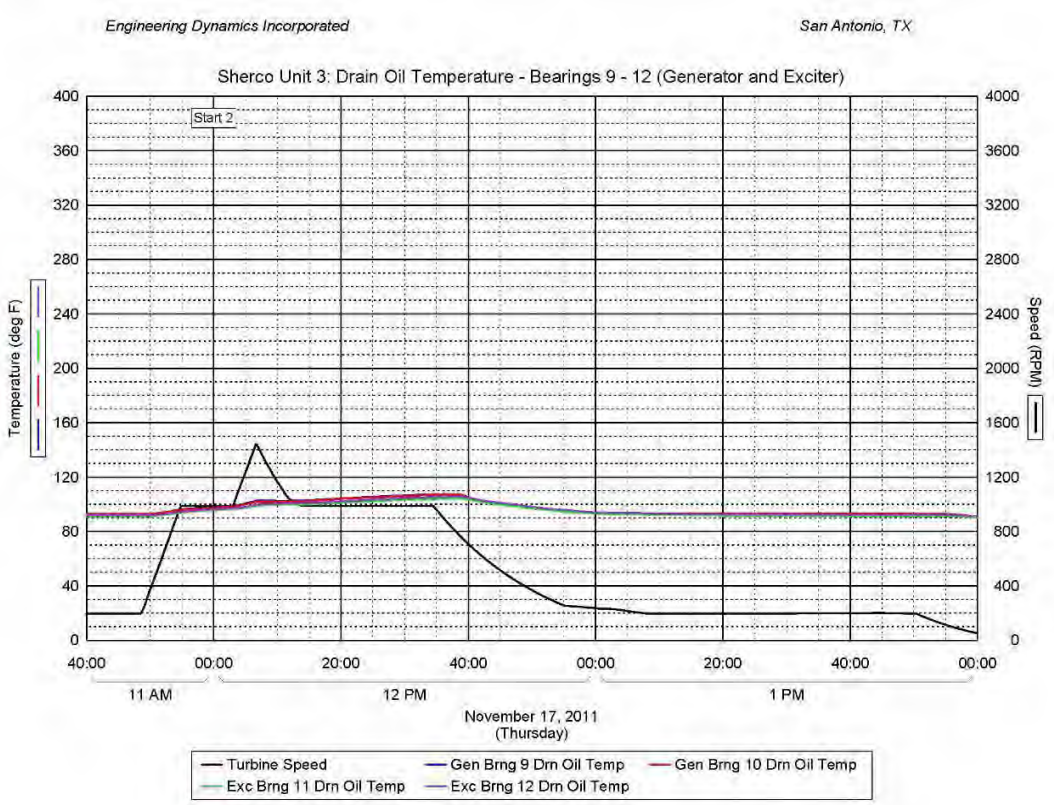

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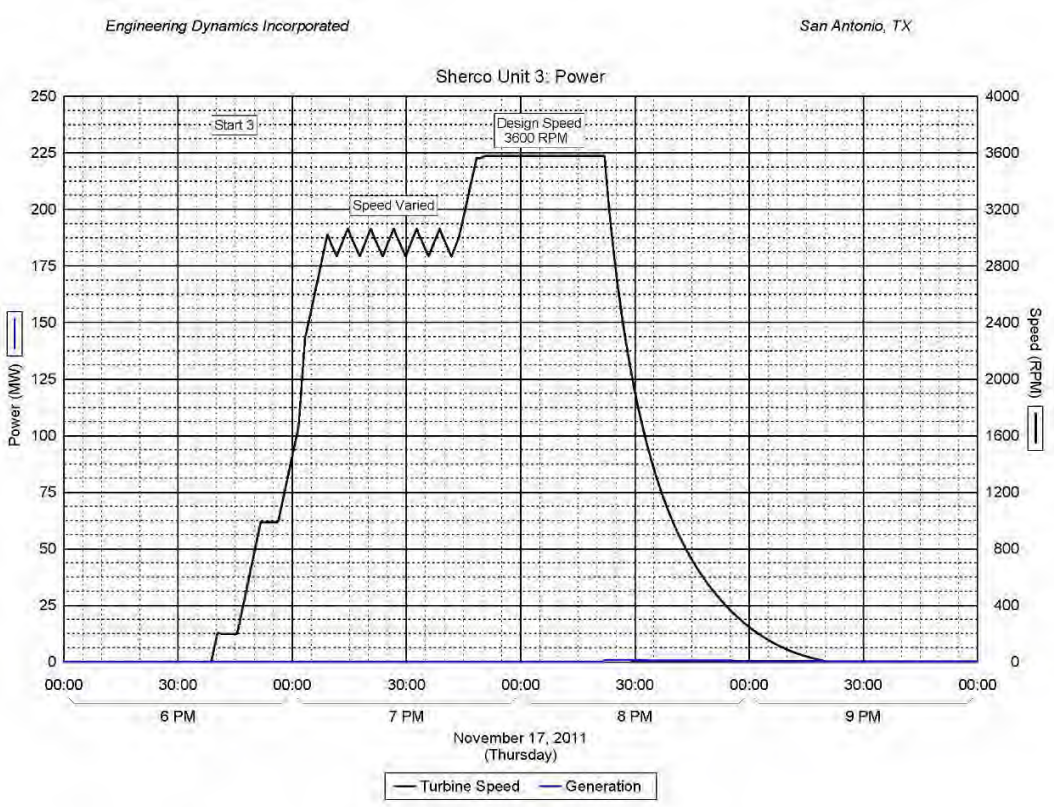

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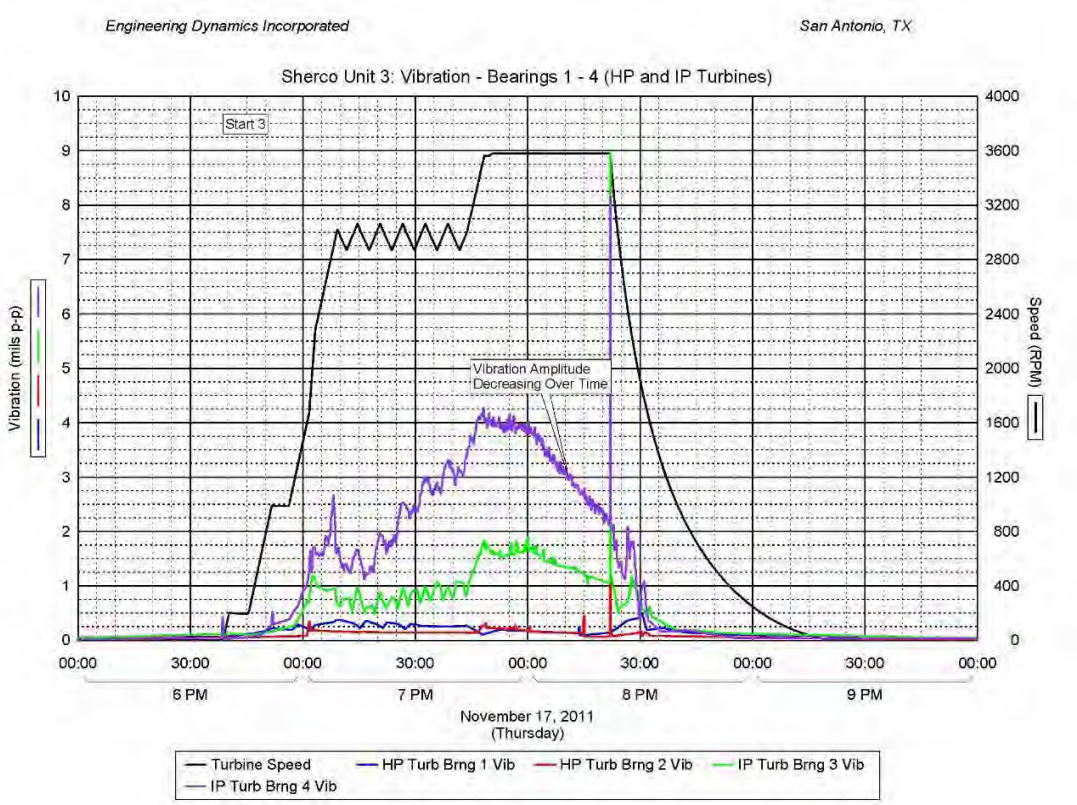

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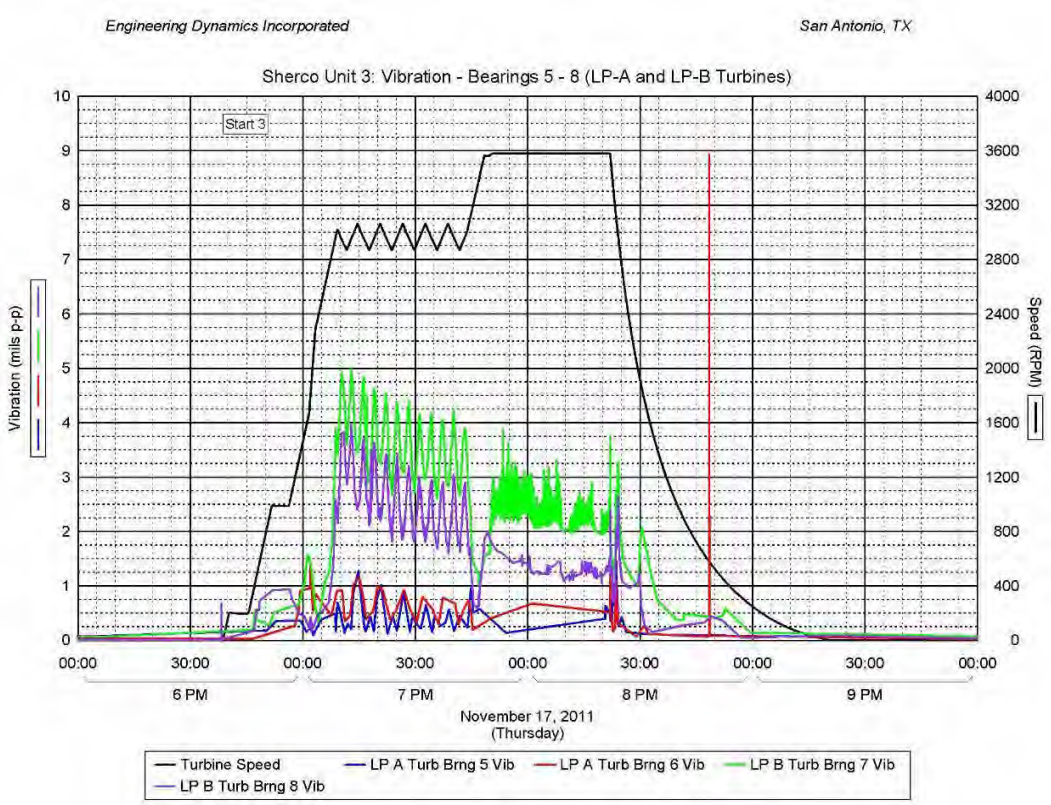

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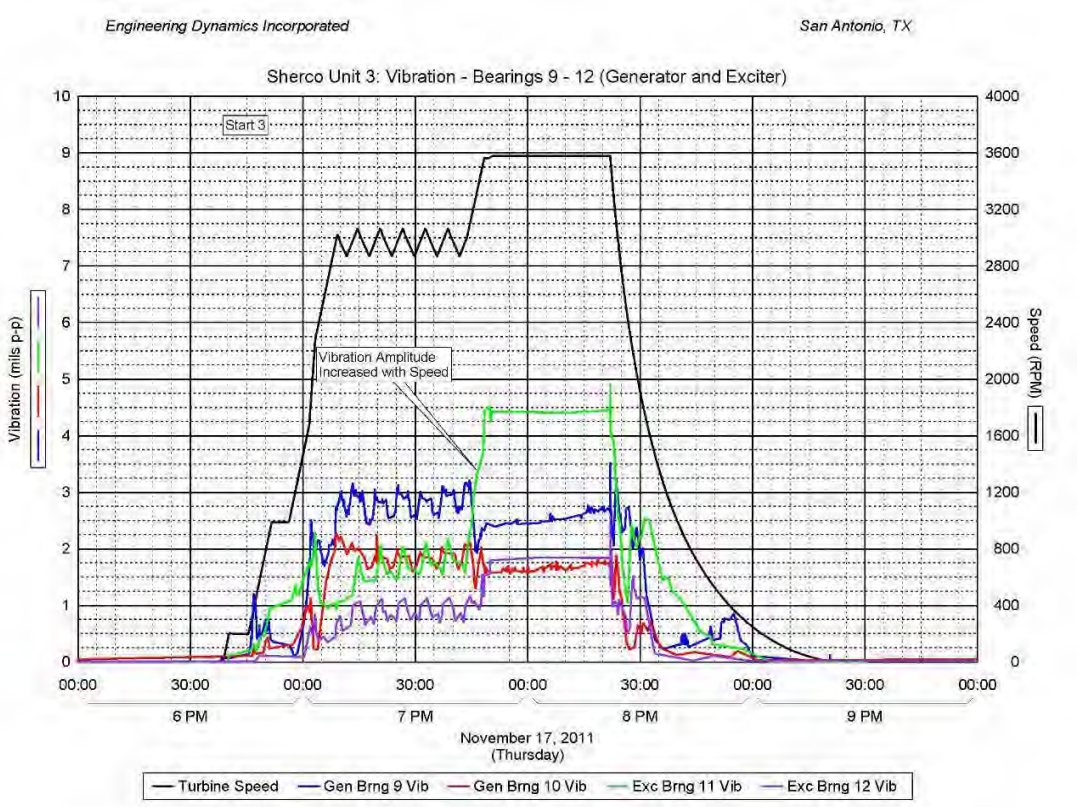
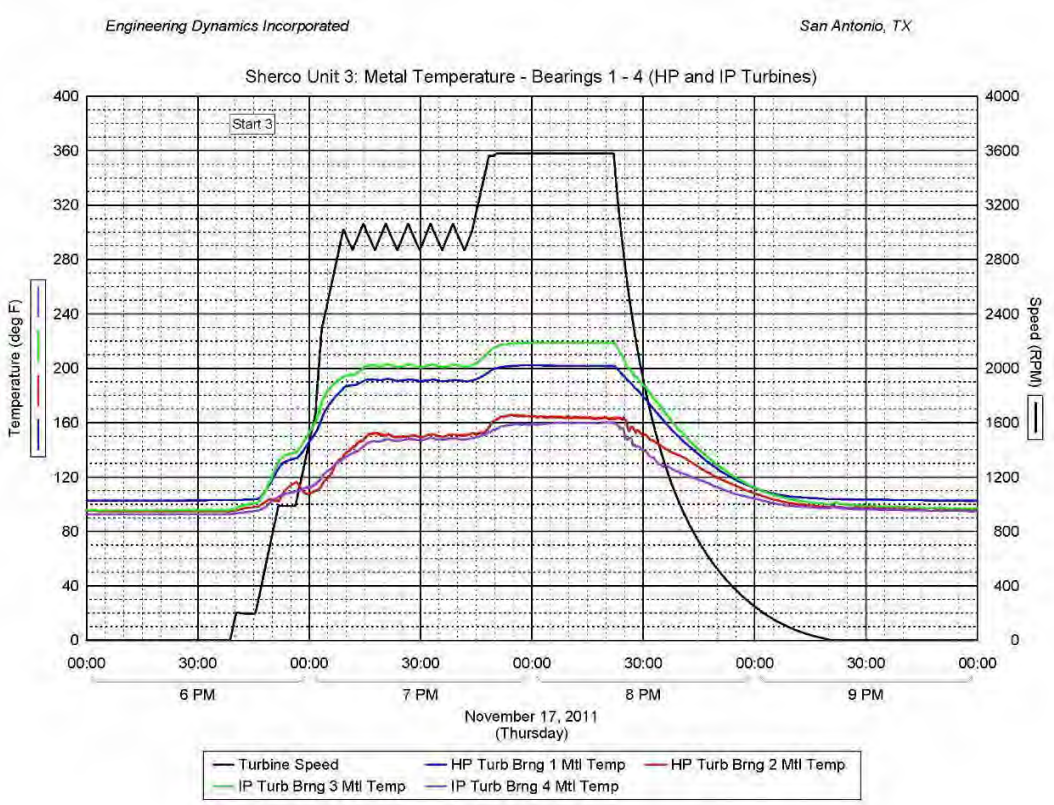


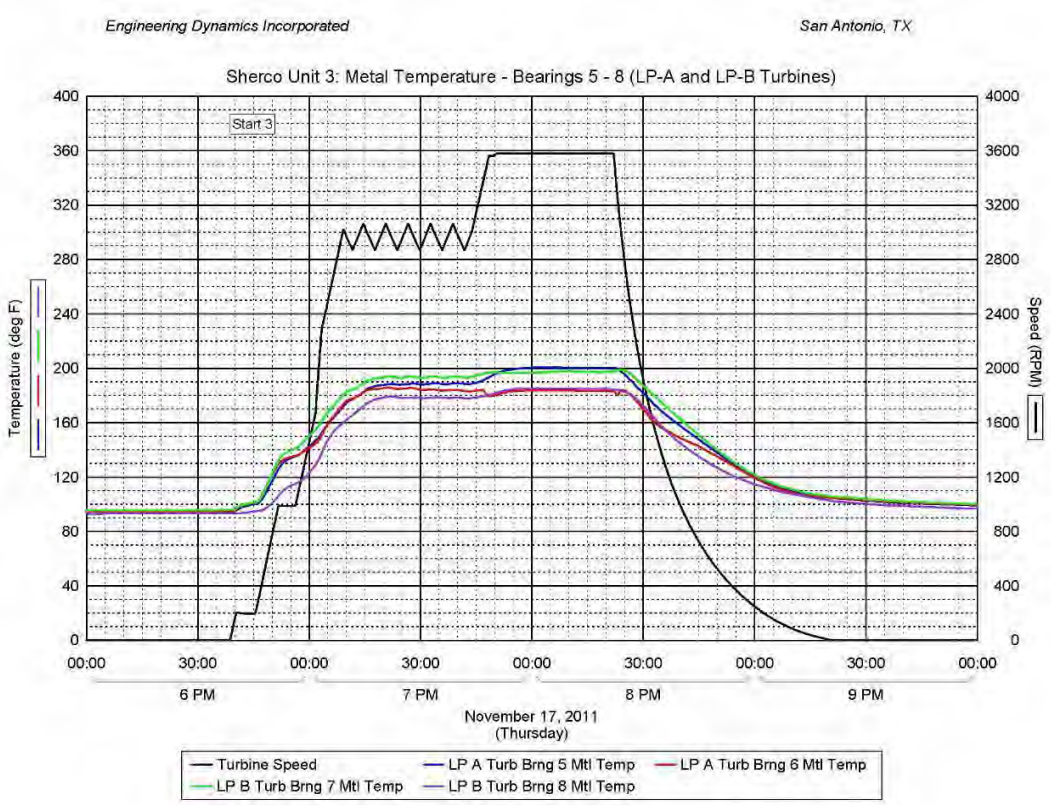
Appendix B25

Run 3



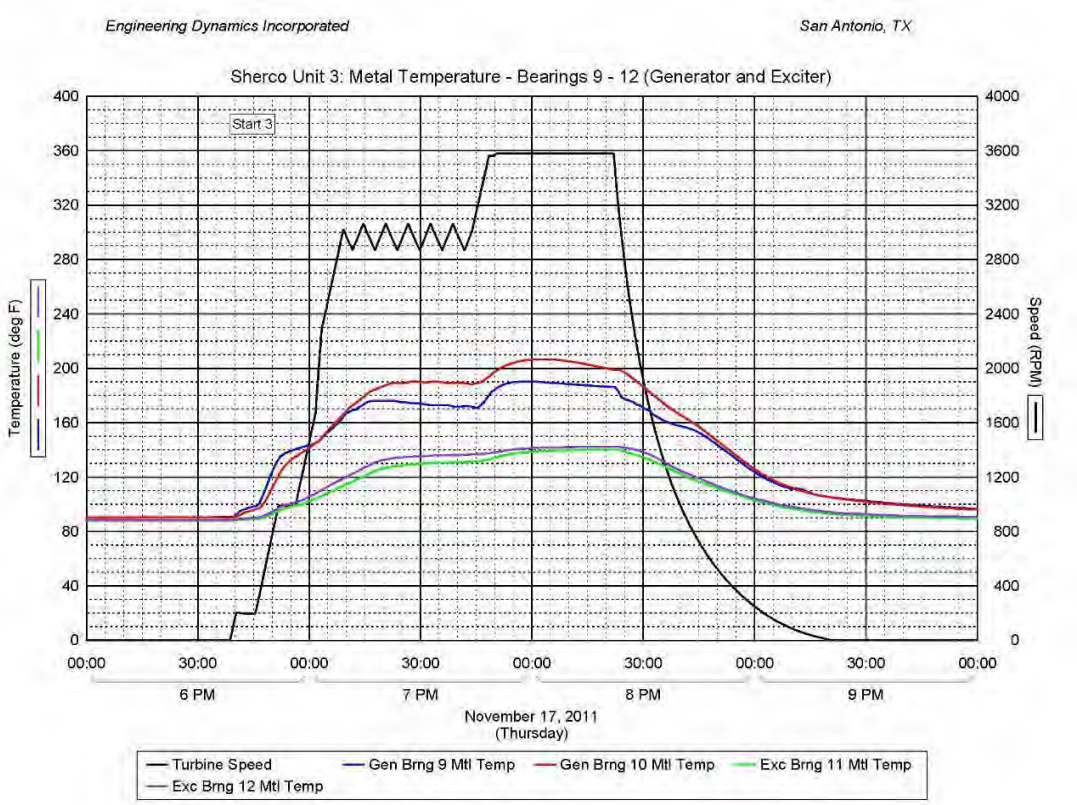
Appendix B26

Run 3



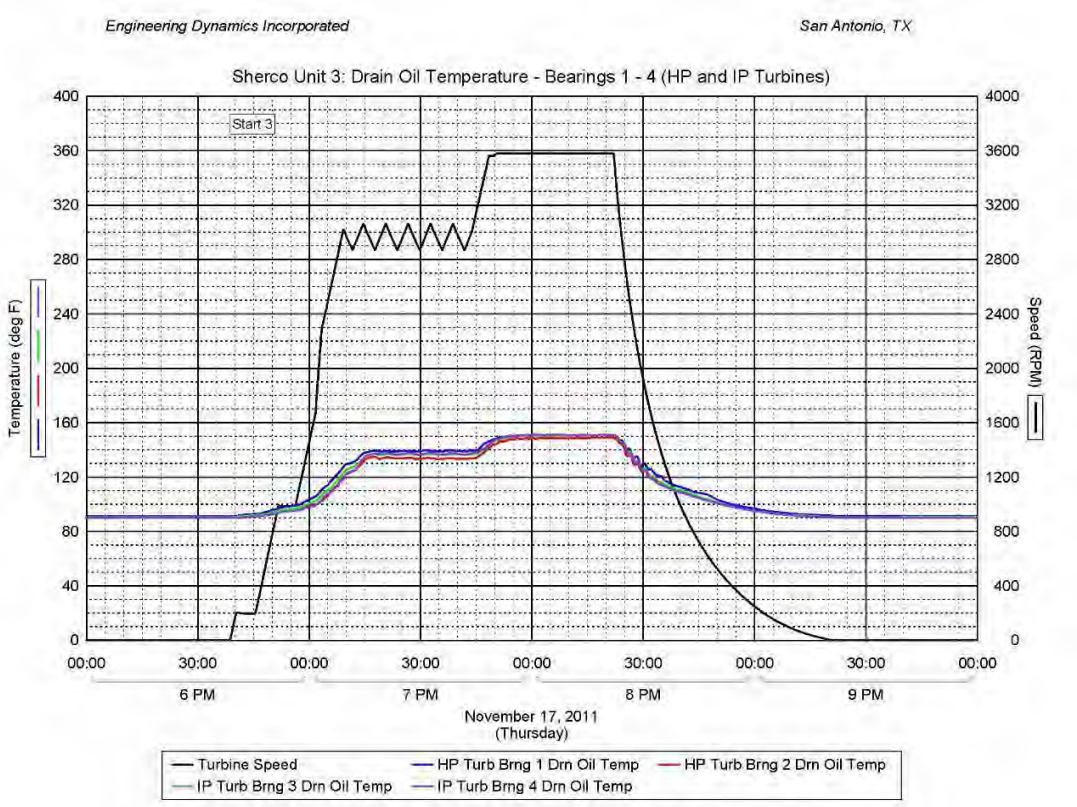
Appendix B27

Run 3



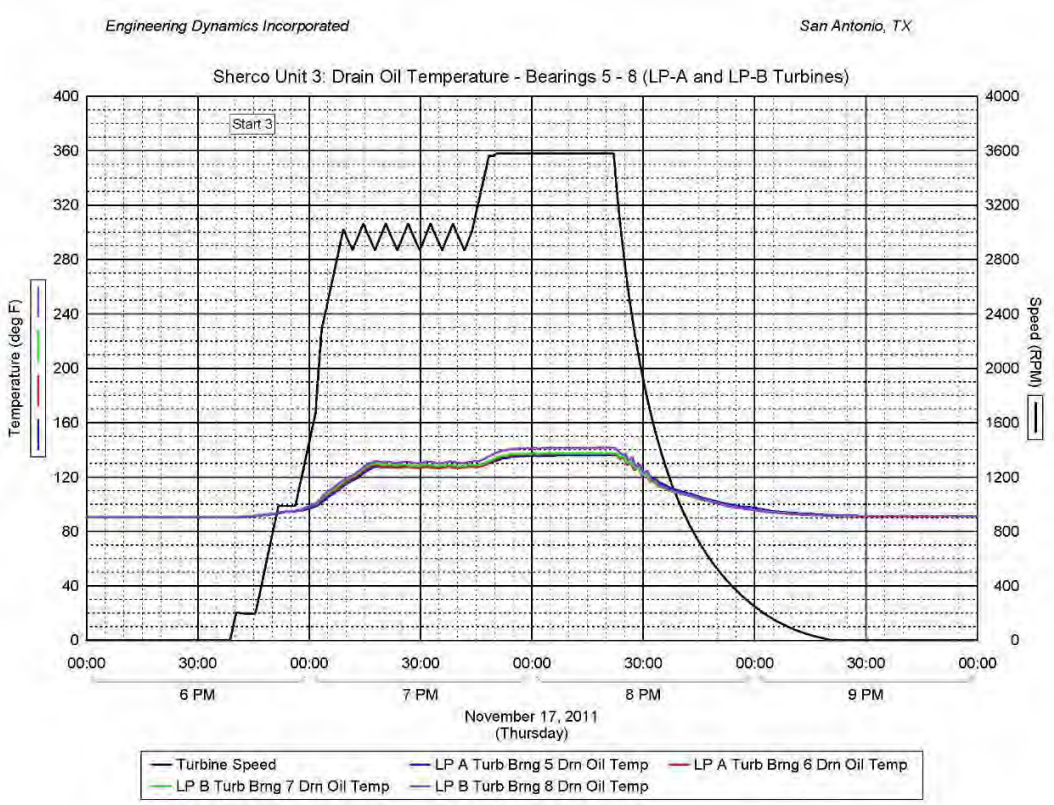
Appendix B28

Run 3



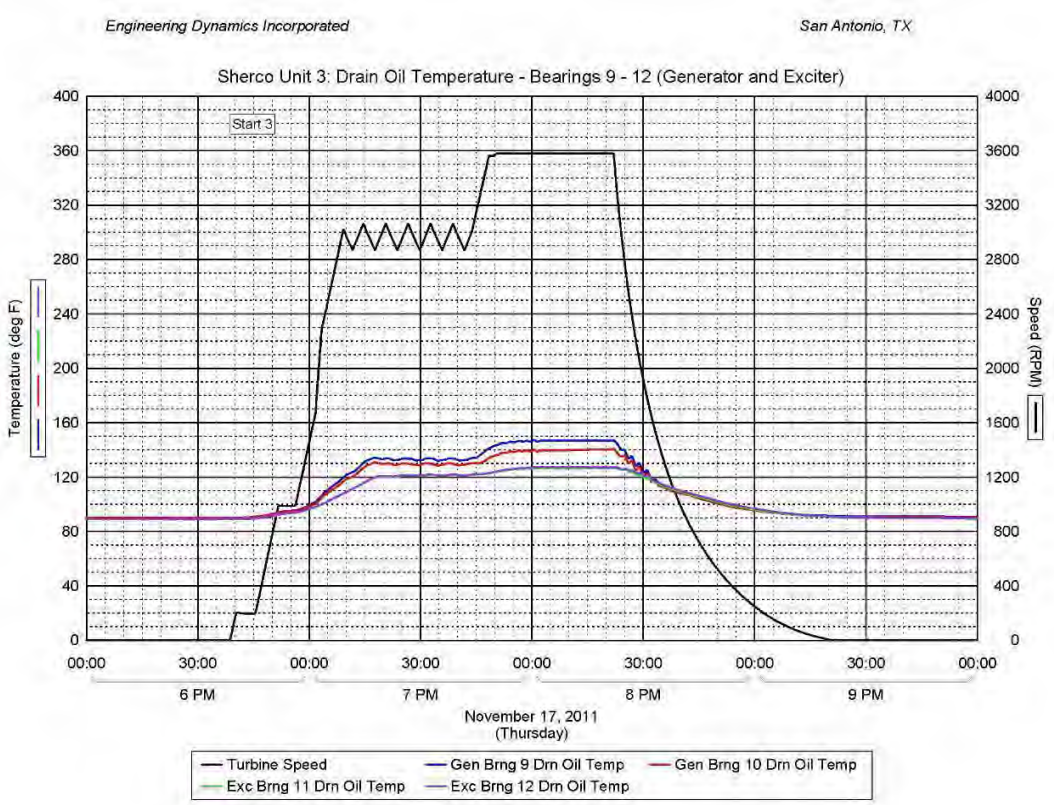
Appendix B29

Run 3



Appendix B30

Run 3

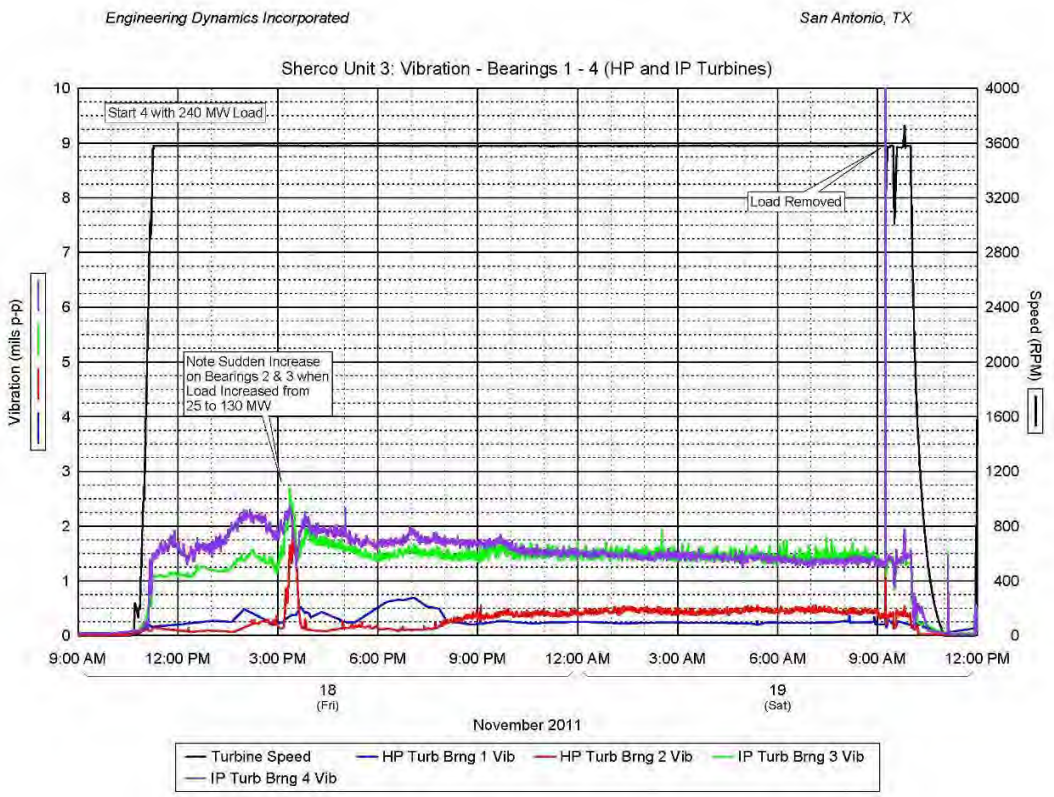


Appendix B31

Run 4

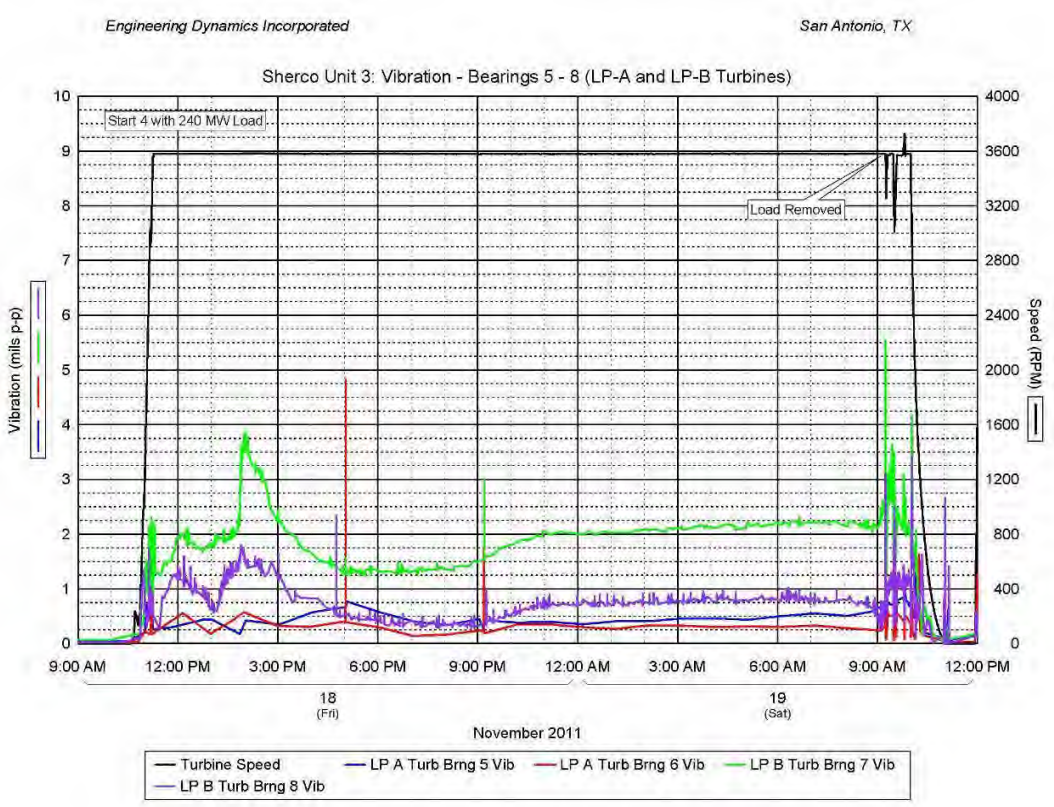
Appendix B32

Run 4



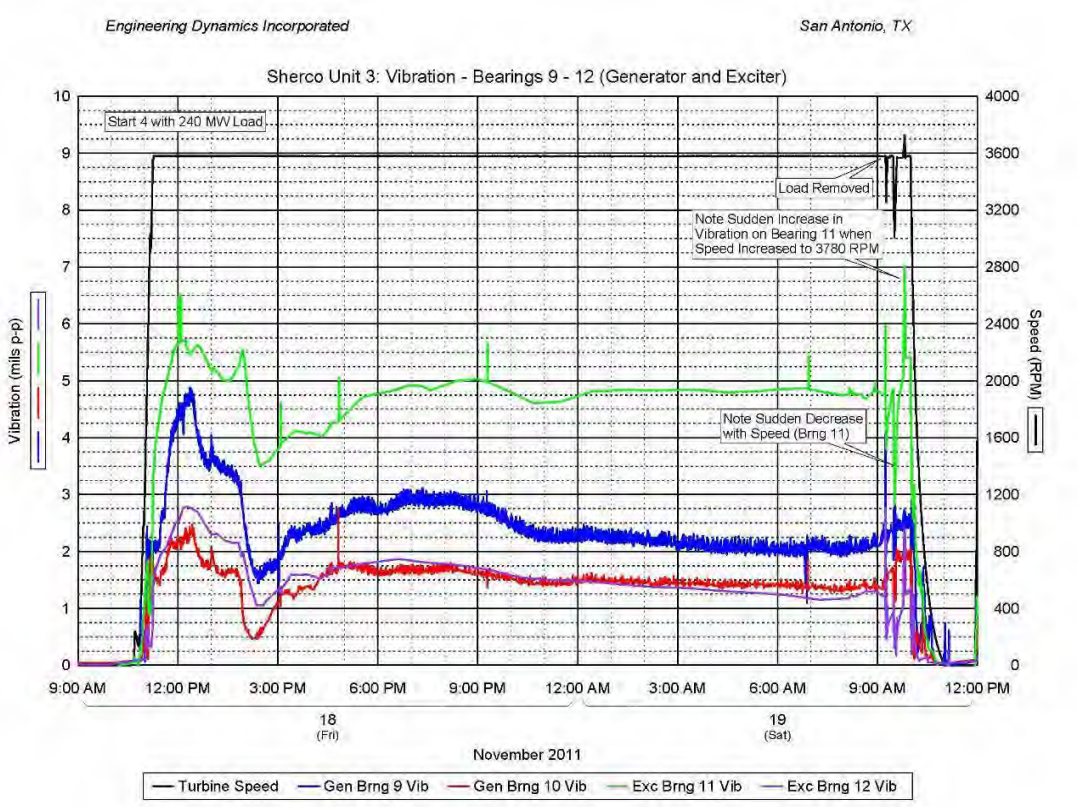
Appendix B33

Run 4



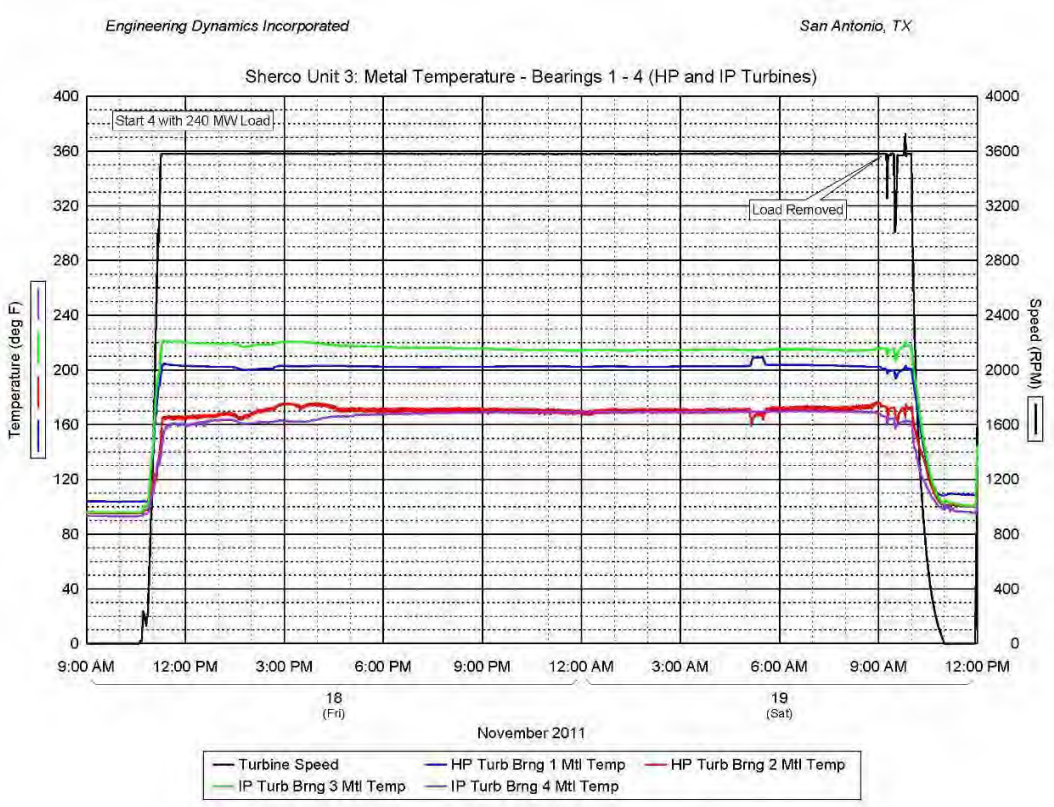
Appendix B34

Run 4



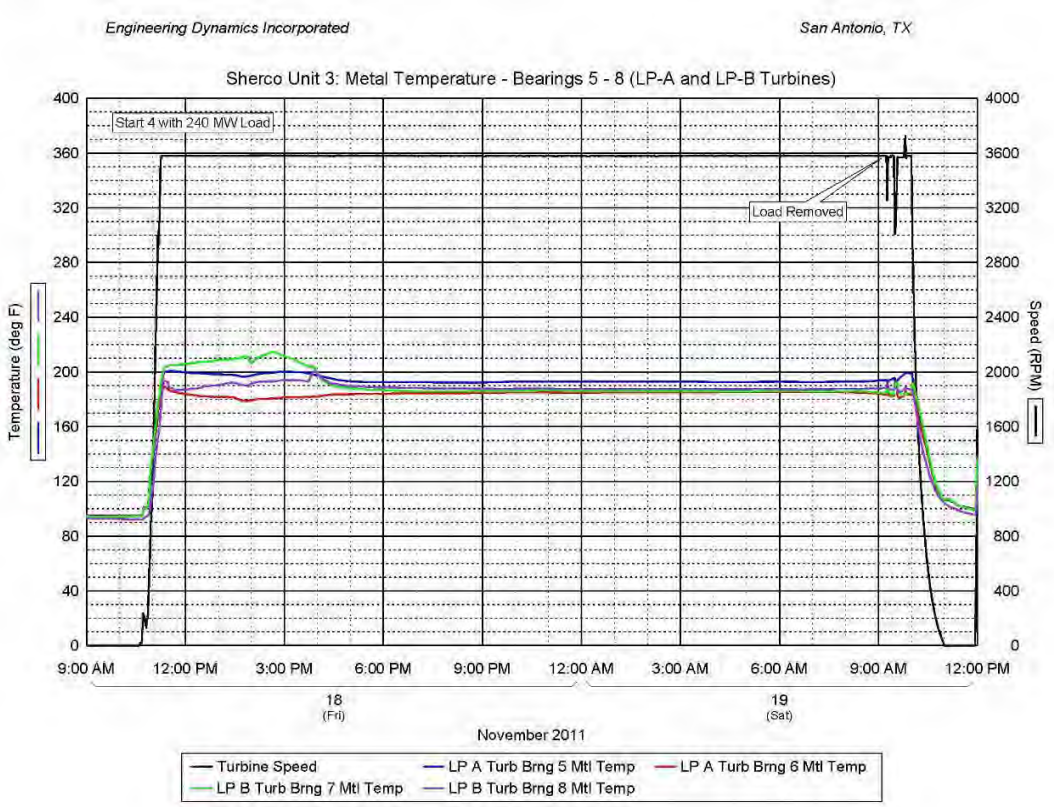
Appendix B35

Run 4



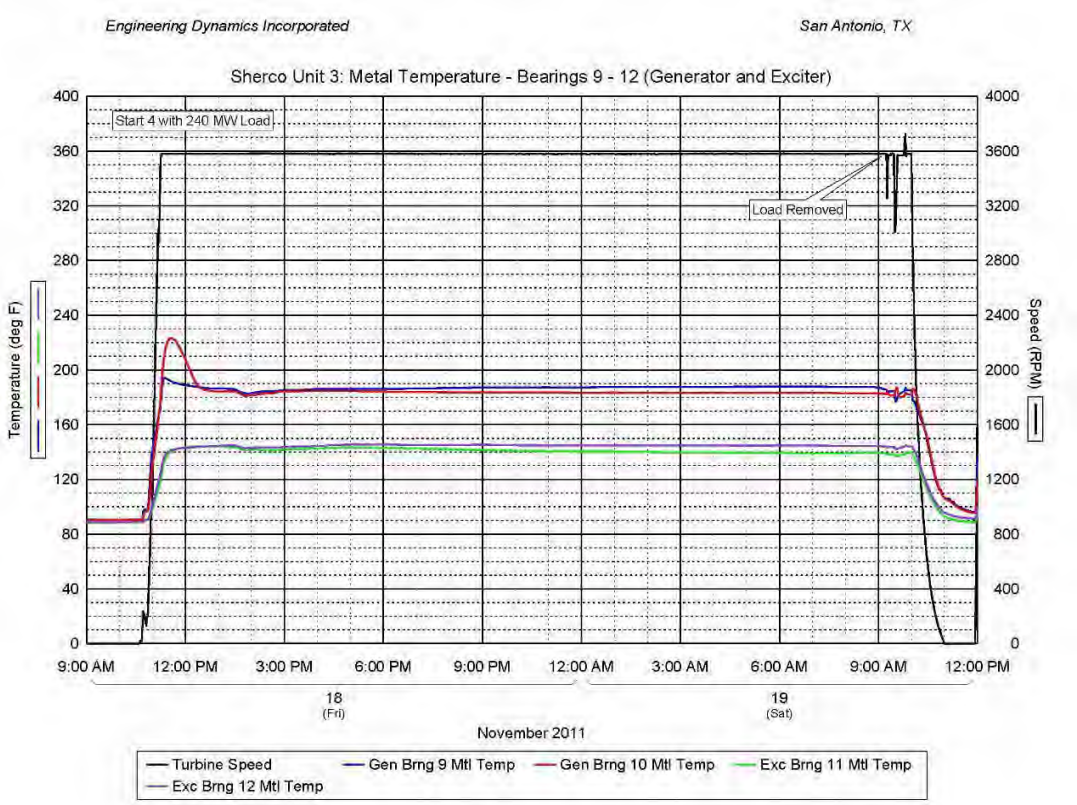
Appendix B36

Run 4



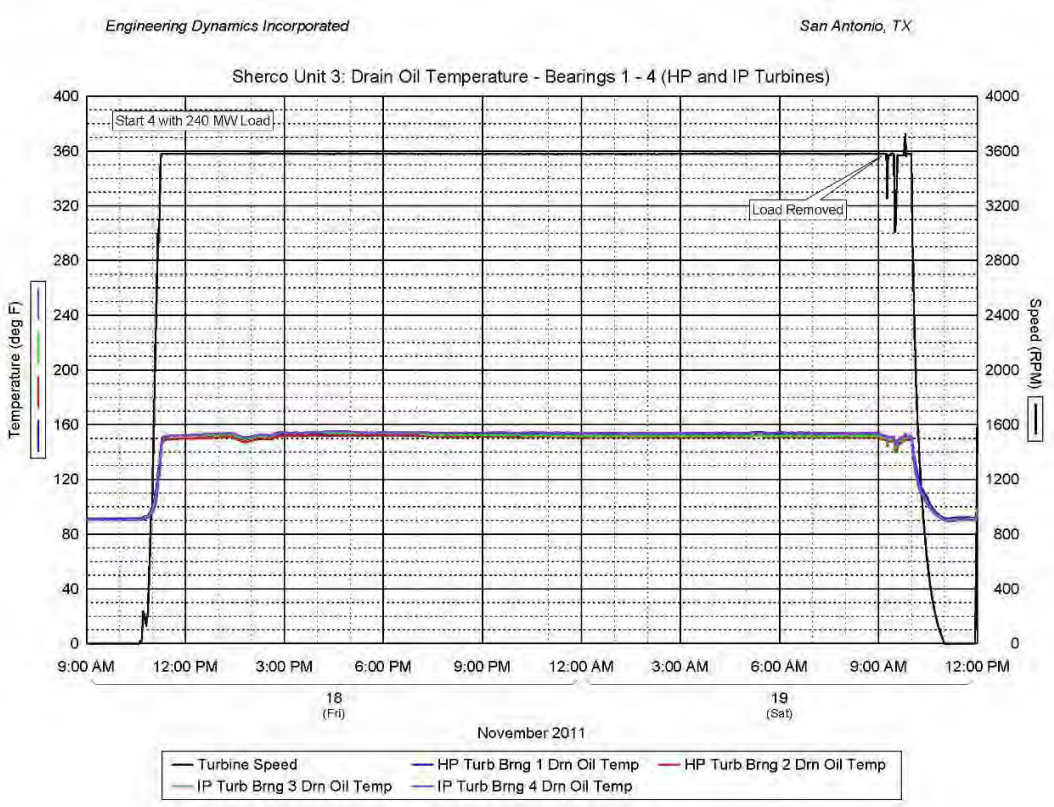
Appendix B37

Run 4



Appendix B38

Run 4

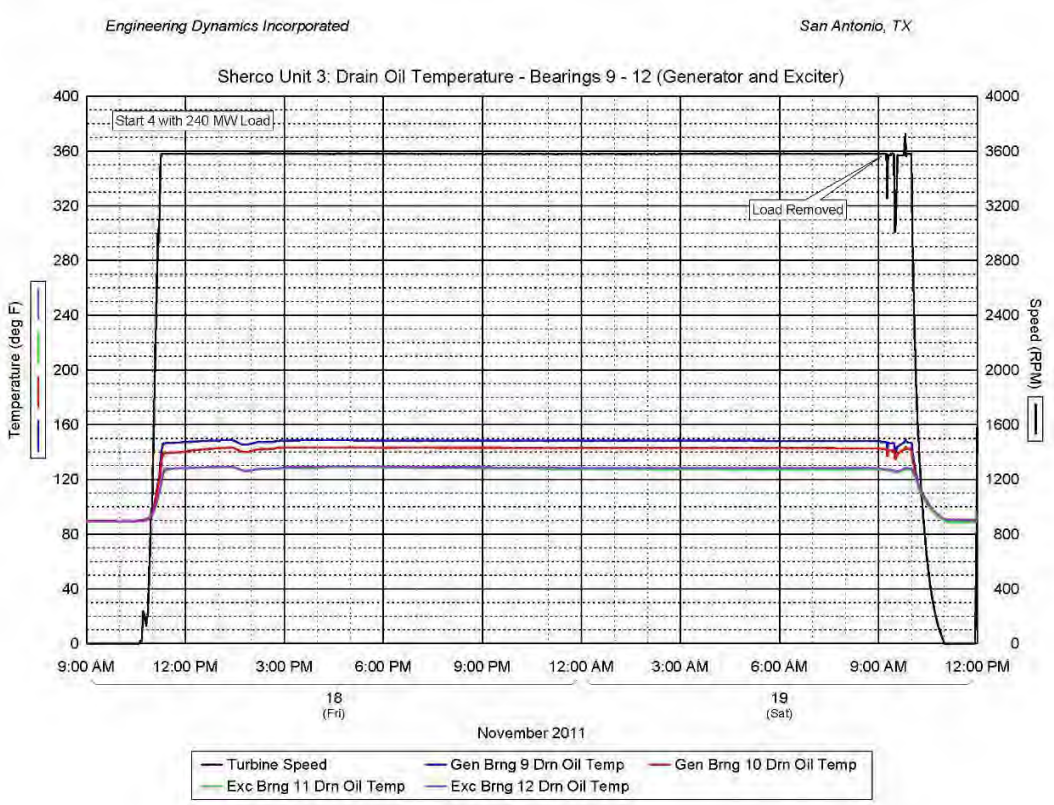


Appendix B39

Run 4

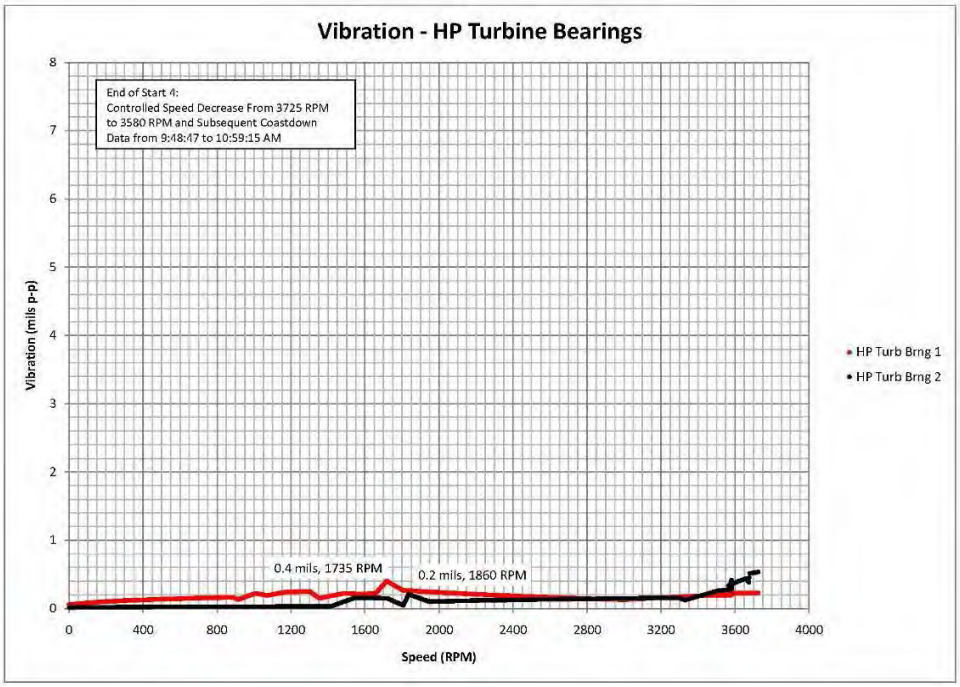
Appendix B40

Run 4



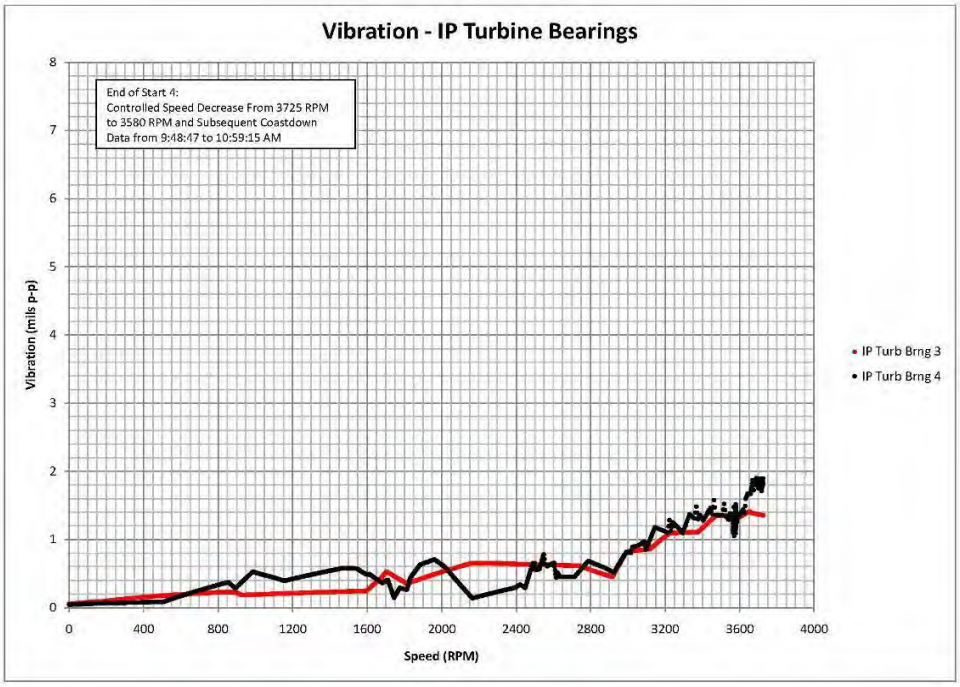
Appendix B41

Coast Down After Run 4



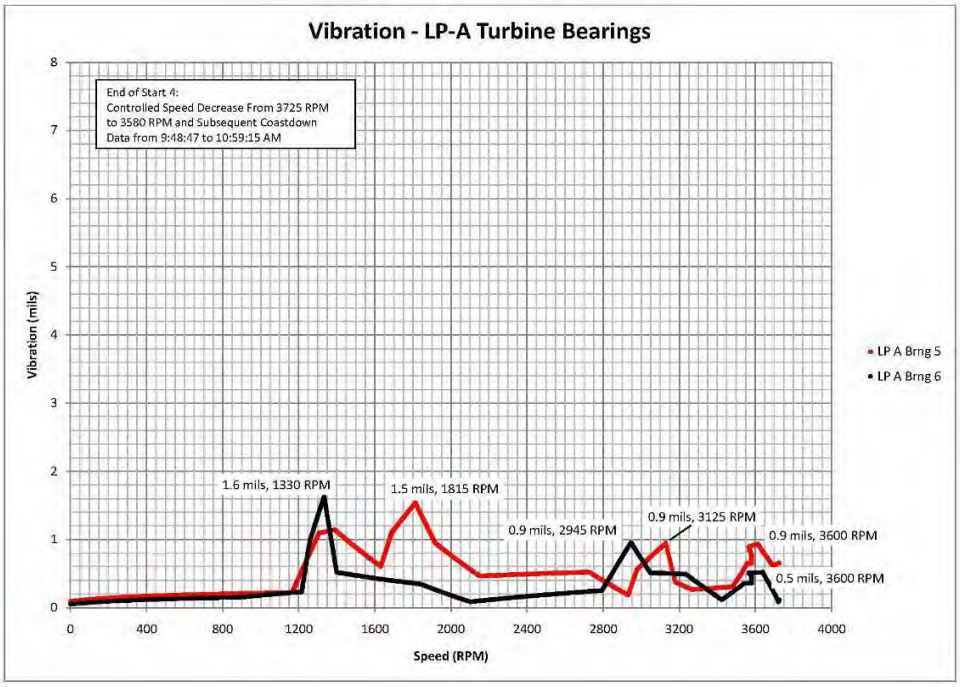
Appendix B42

Coast Down After Run 4



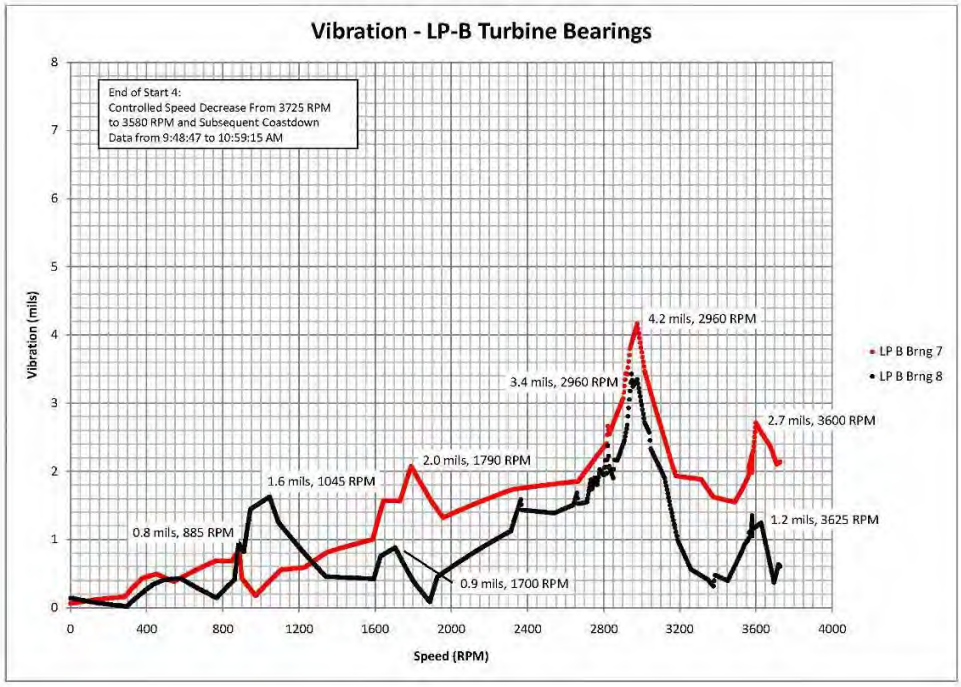
Appendix B43

Coast Down After Run 4



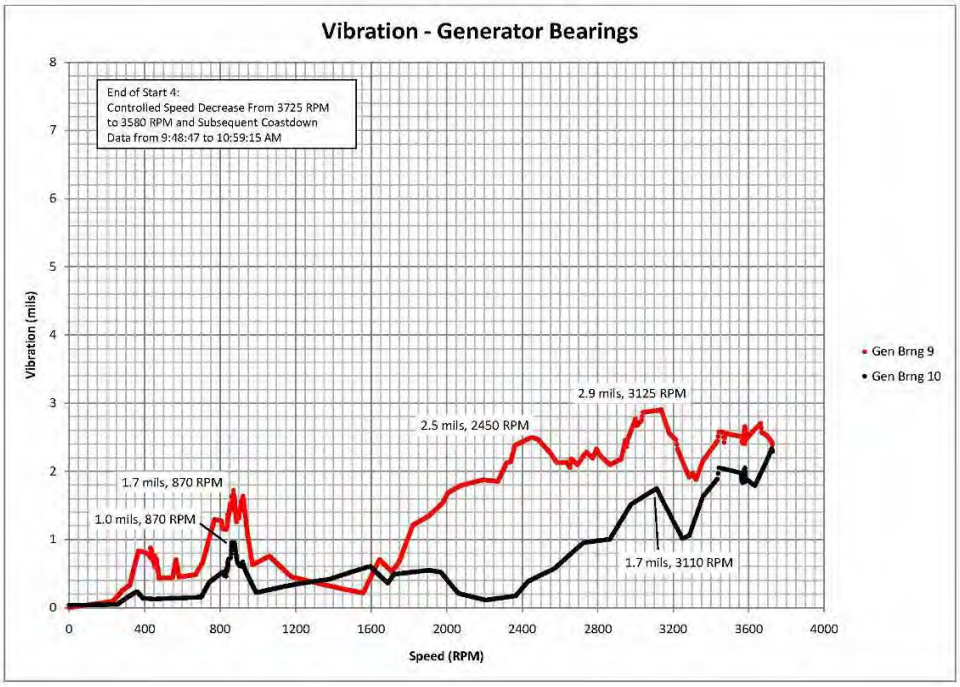
Appendix B44

Coast Down After Run 4



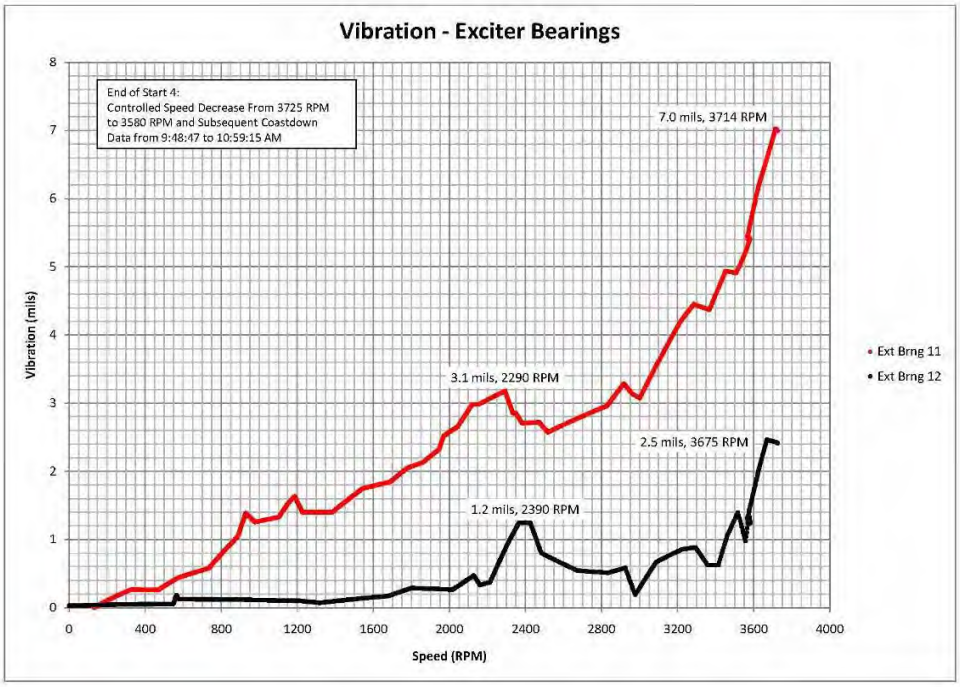
Appendix B45

Coast Down After Run 4



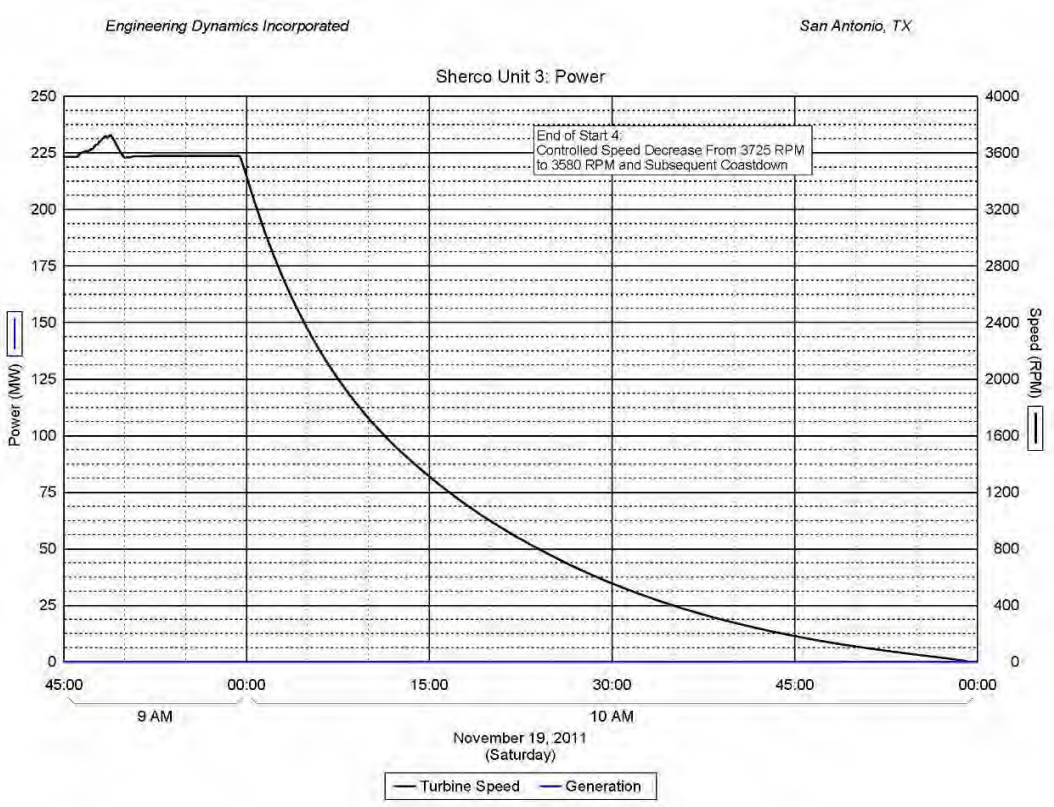
Appendix B46

Coast Down After Run 4



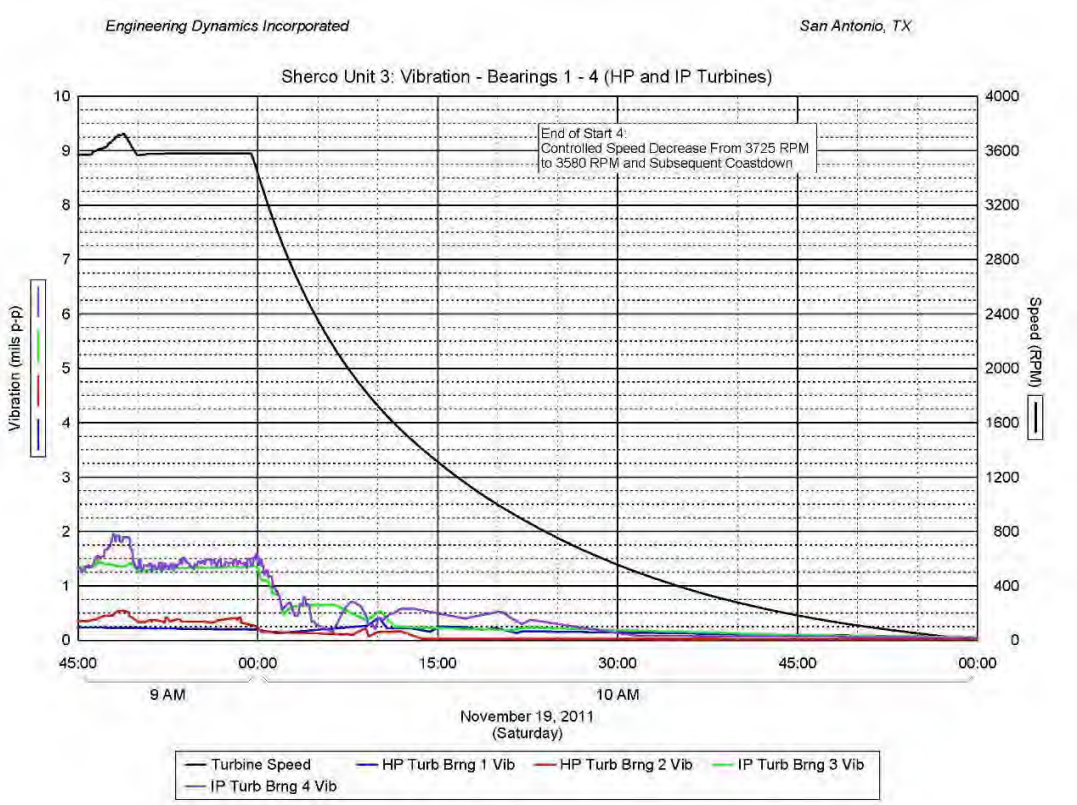
Appendix B47

Coast Down After Run 4



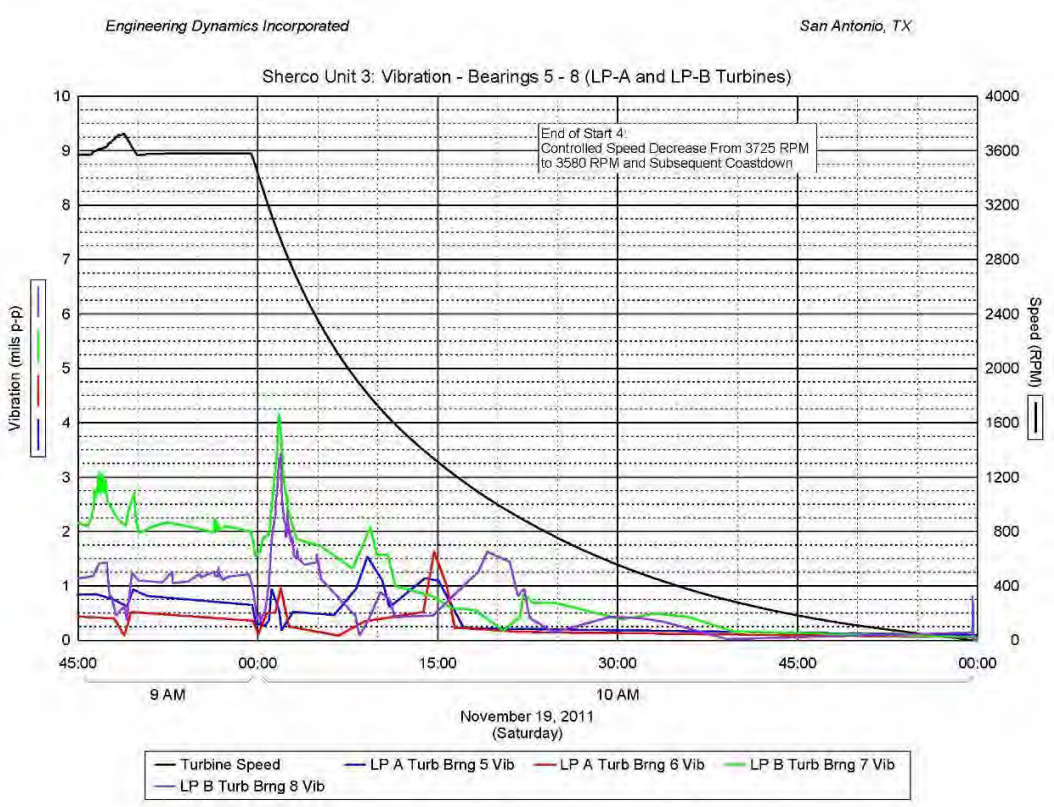
Appendix B48

Coast Down After Run 4



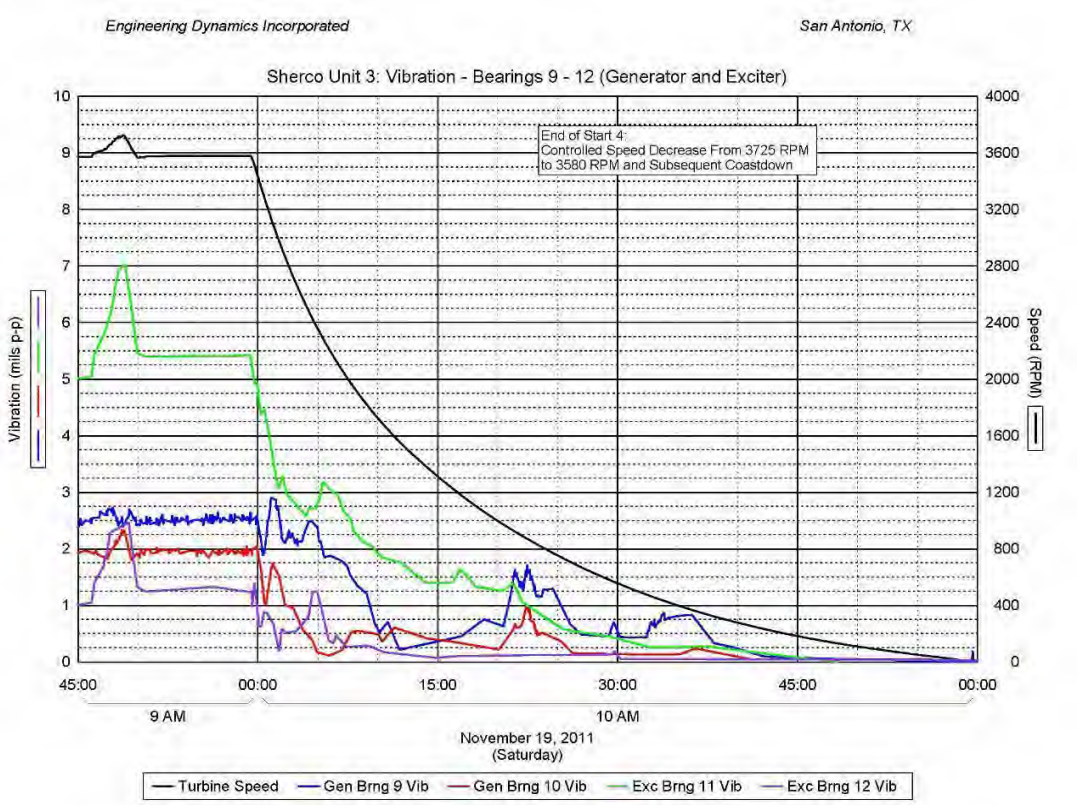
Appendix B49

Coast Down After Run 4



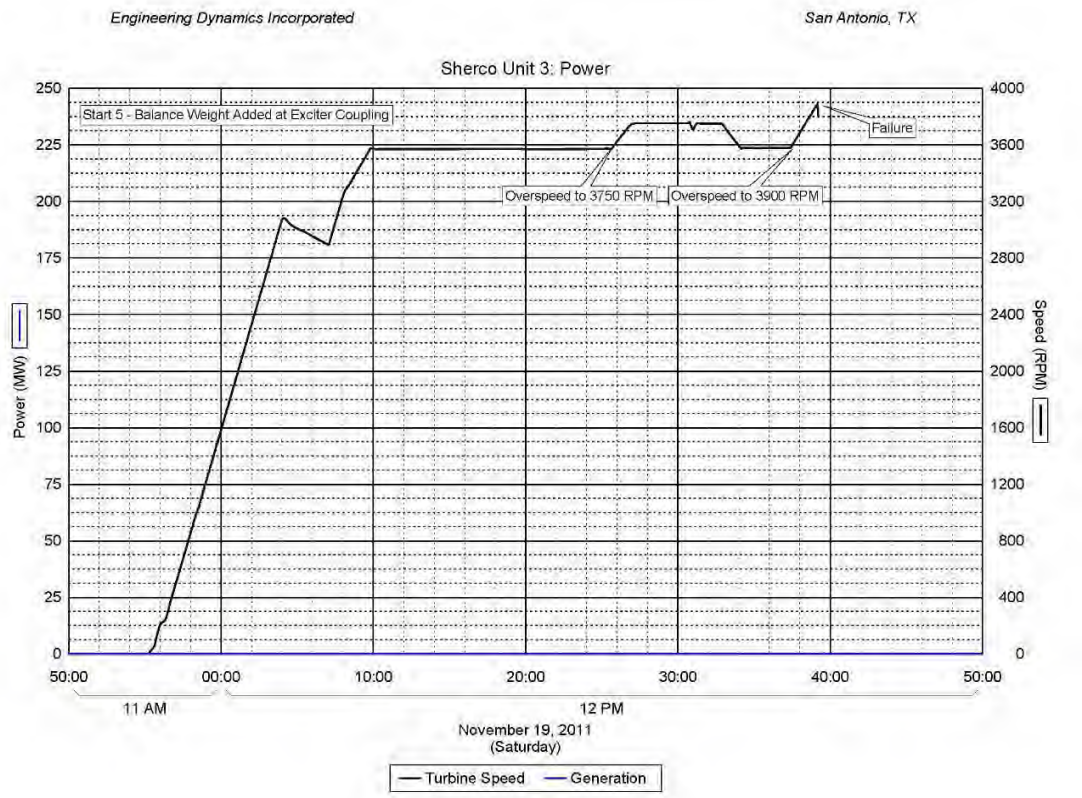
Appendix B50

Coast Down After Run 4



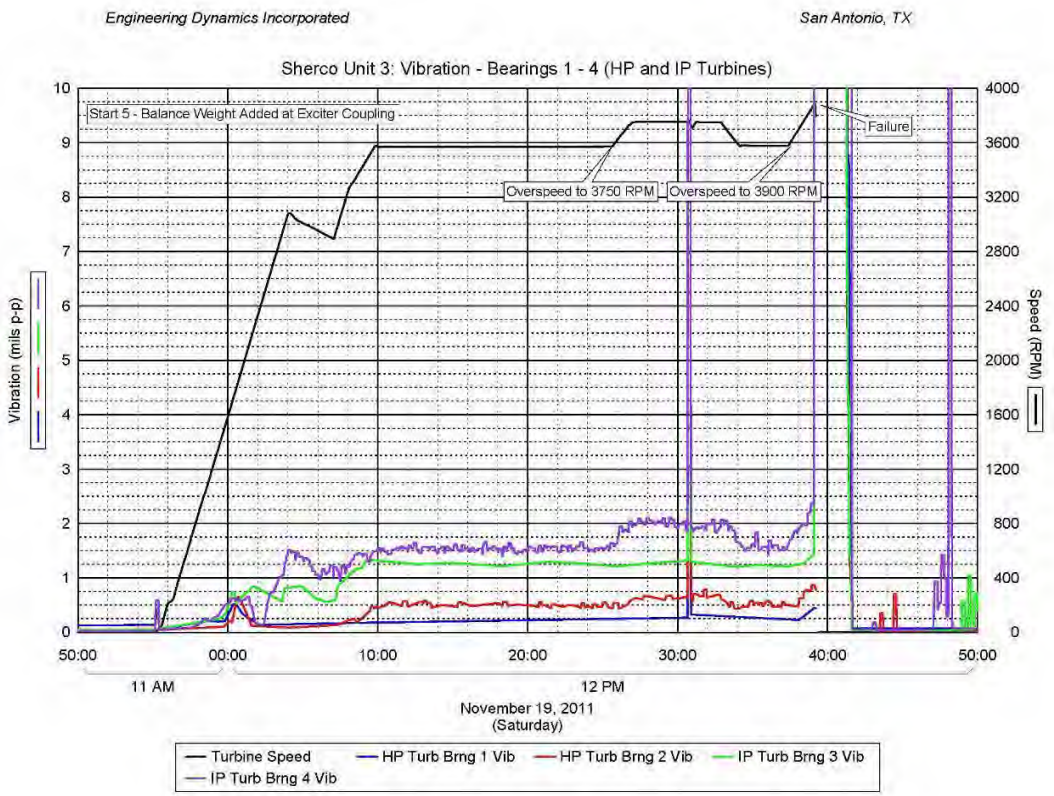
Appendix B51

Run 5



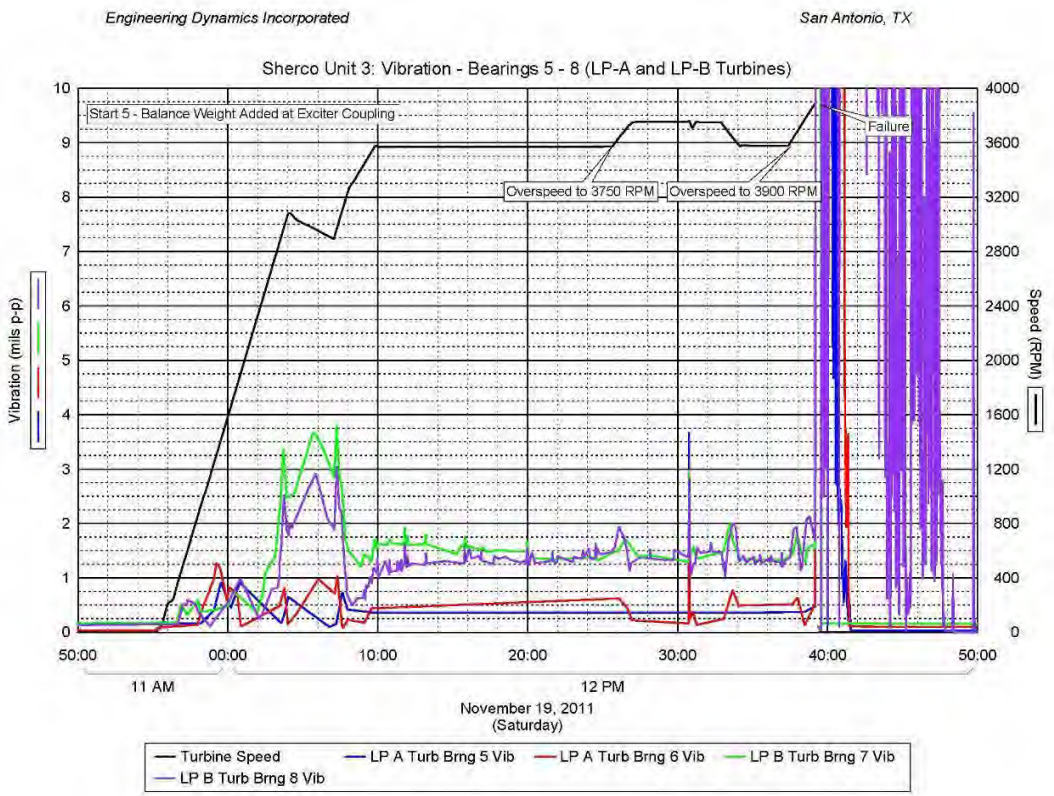
Appendix B52

Run 5



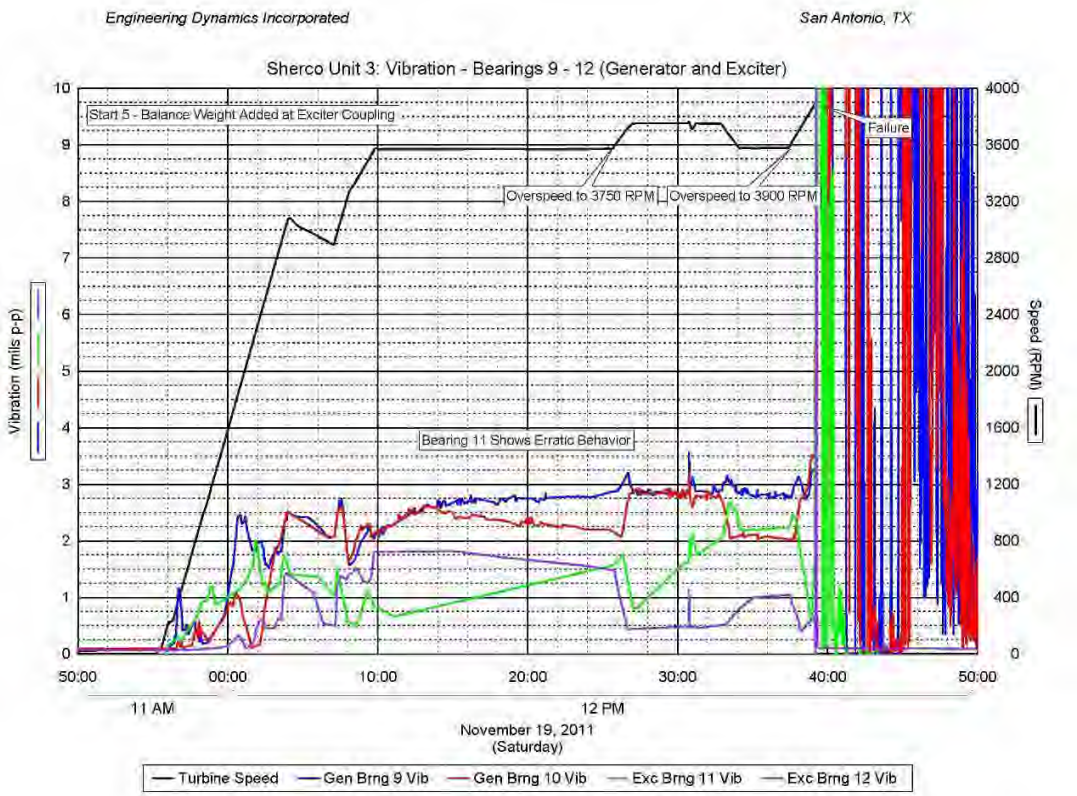
Appendix B53

Run 5



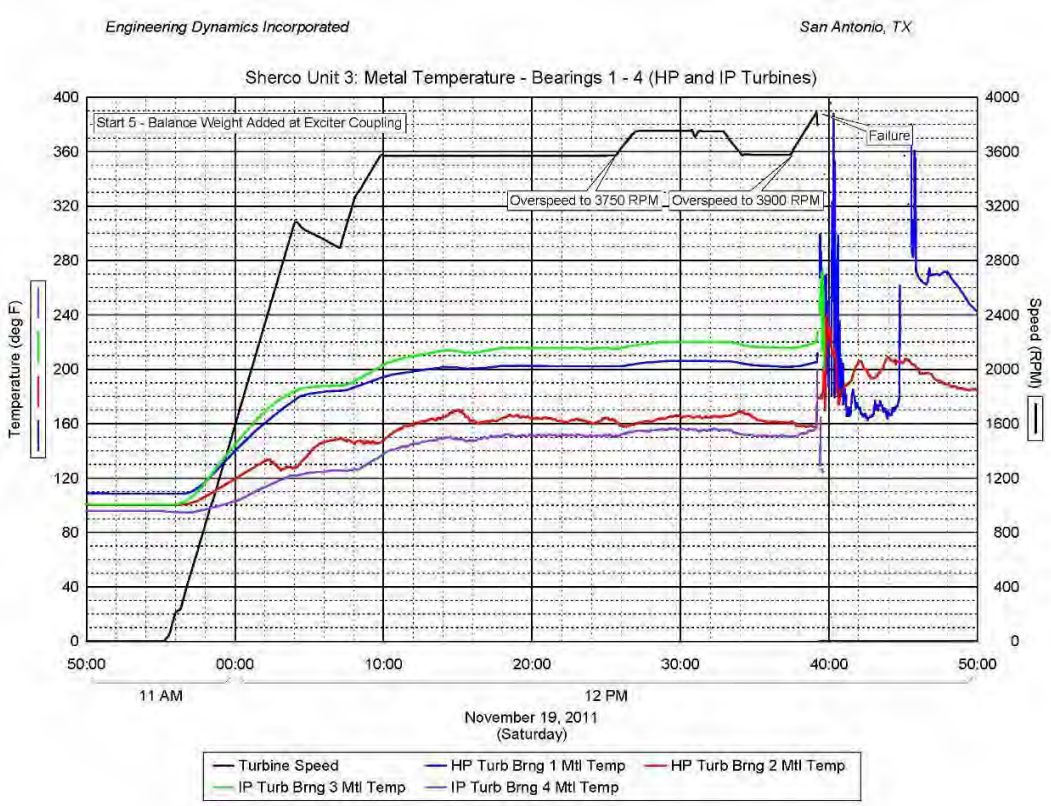
Appendix B54

Run 5



Appendix B55

Run 5

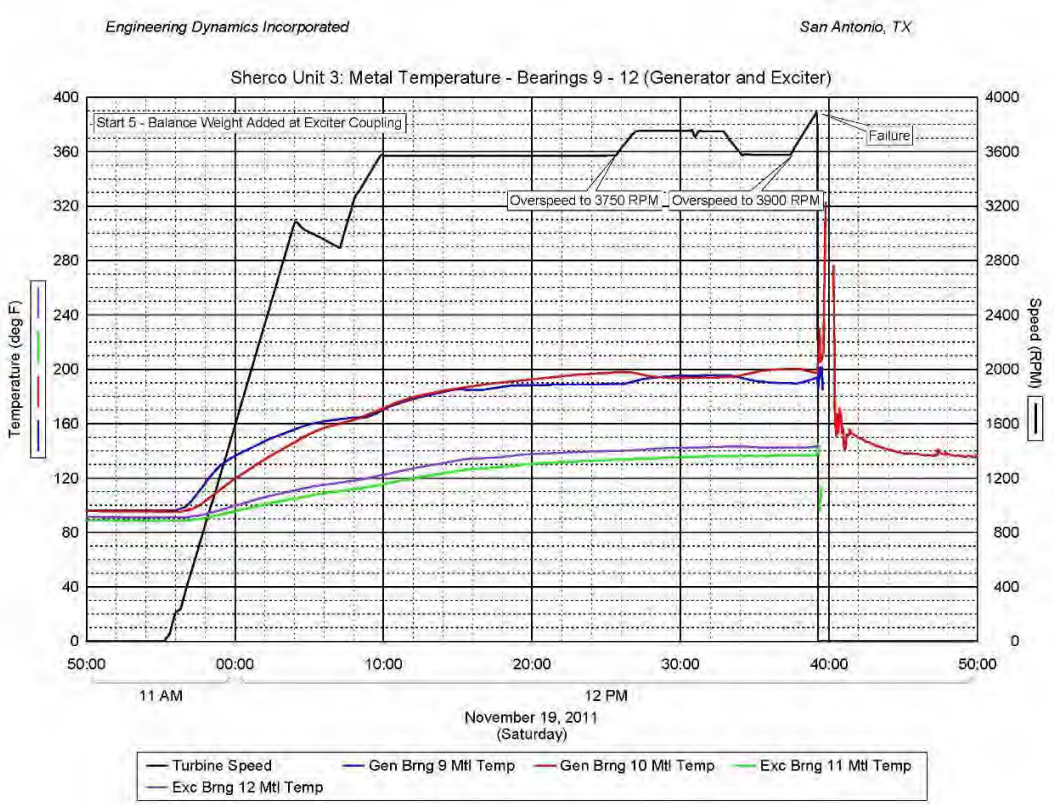


Appendix B56

Run 5

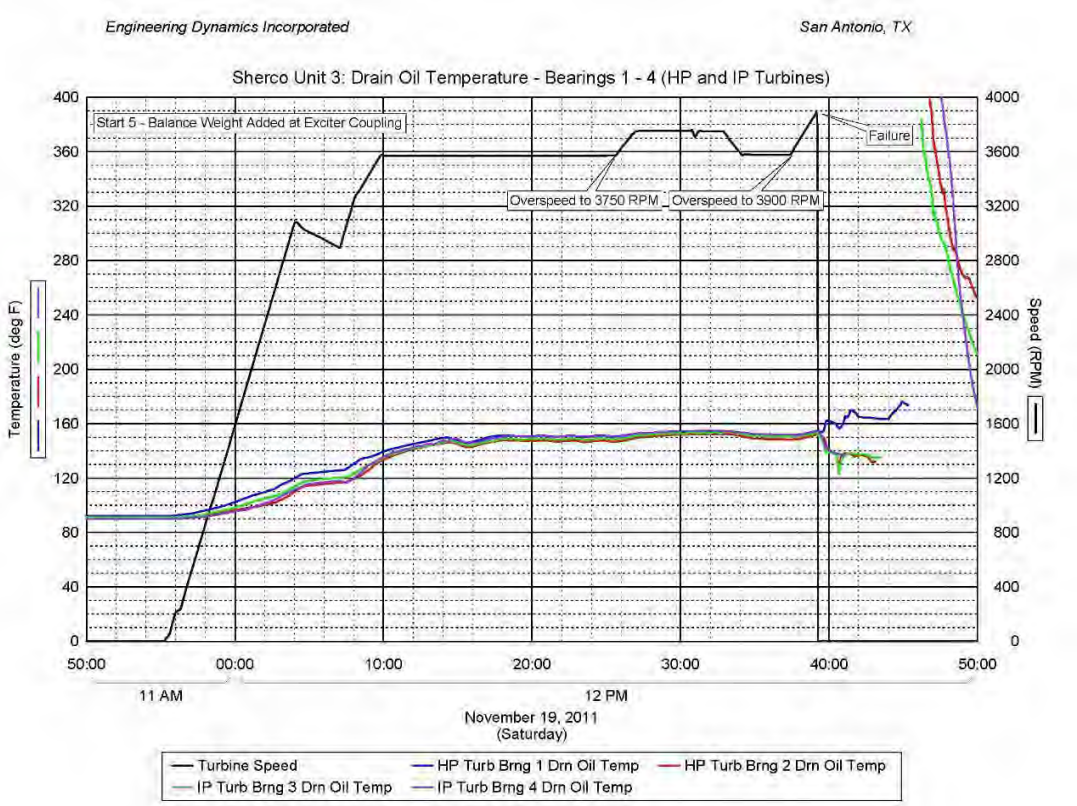
Appendix B57

Run 5



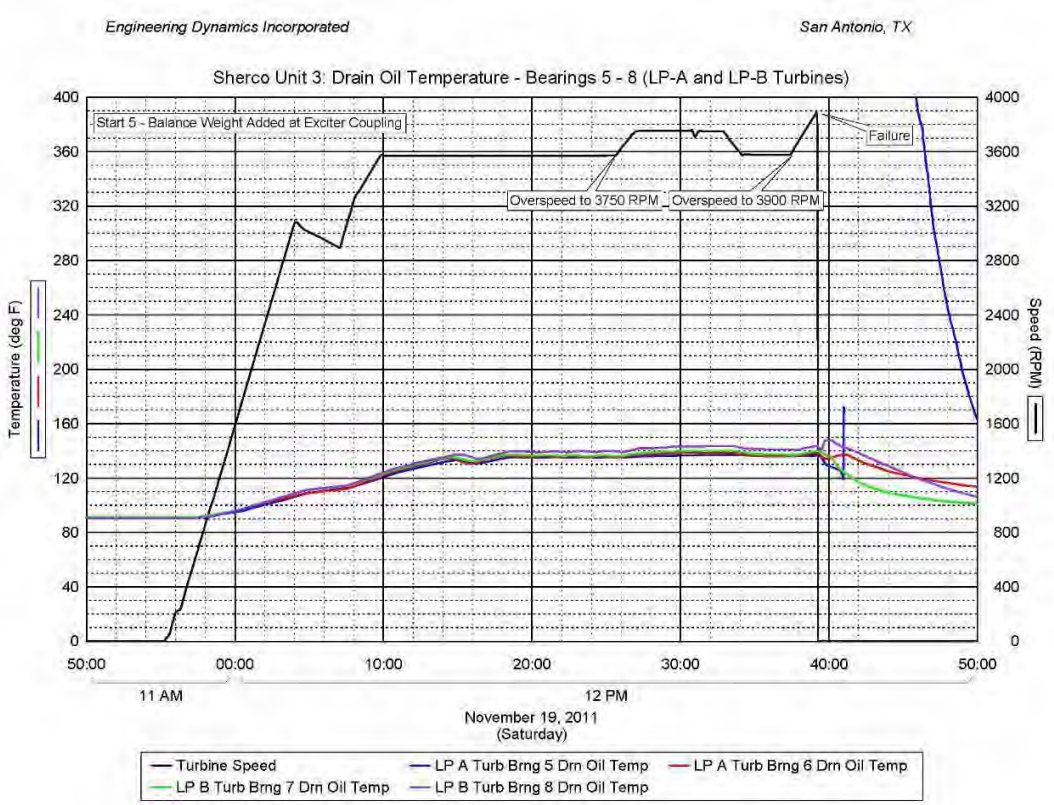
Appendix B58

Run 5



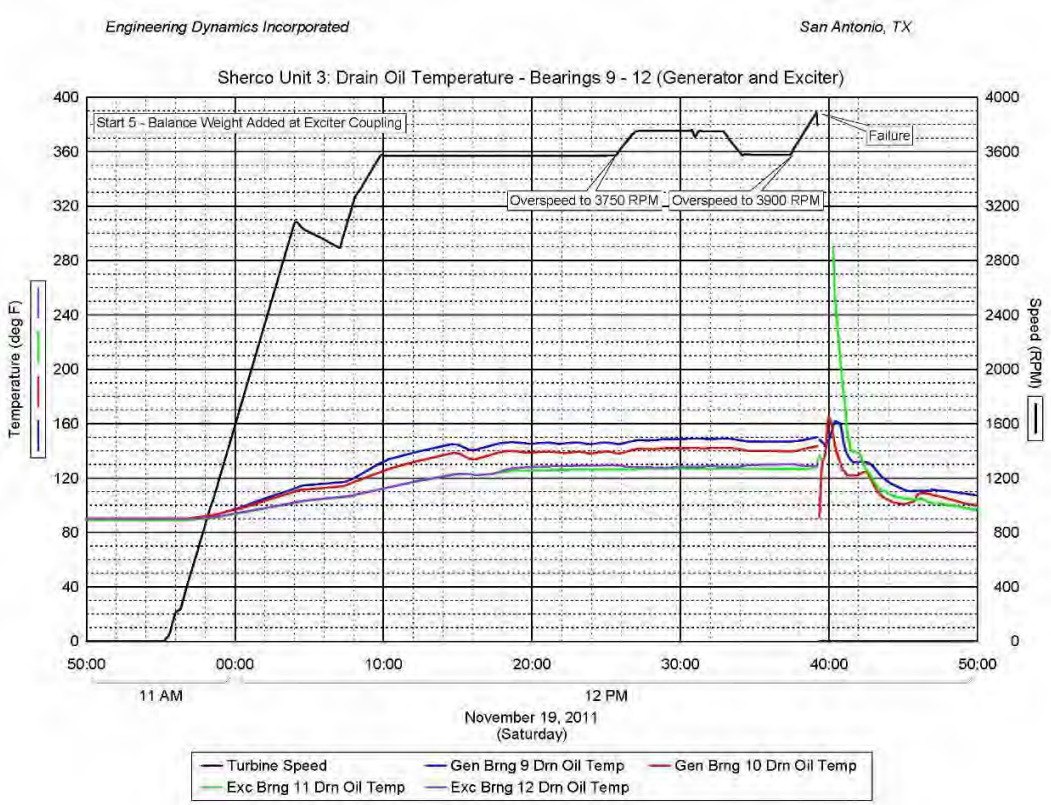
Appendix B59

Run 5



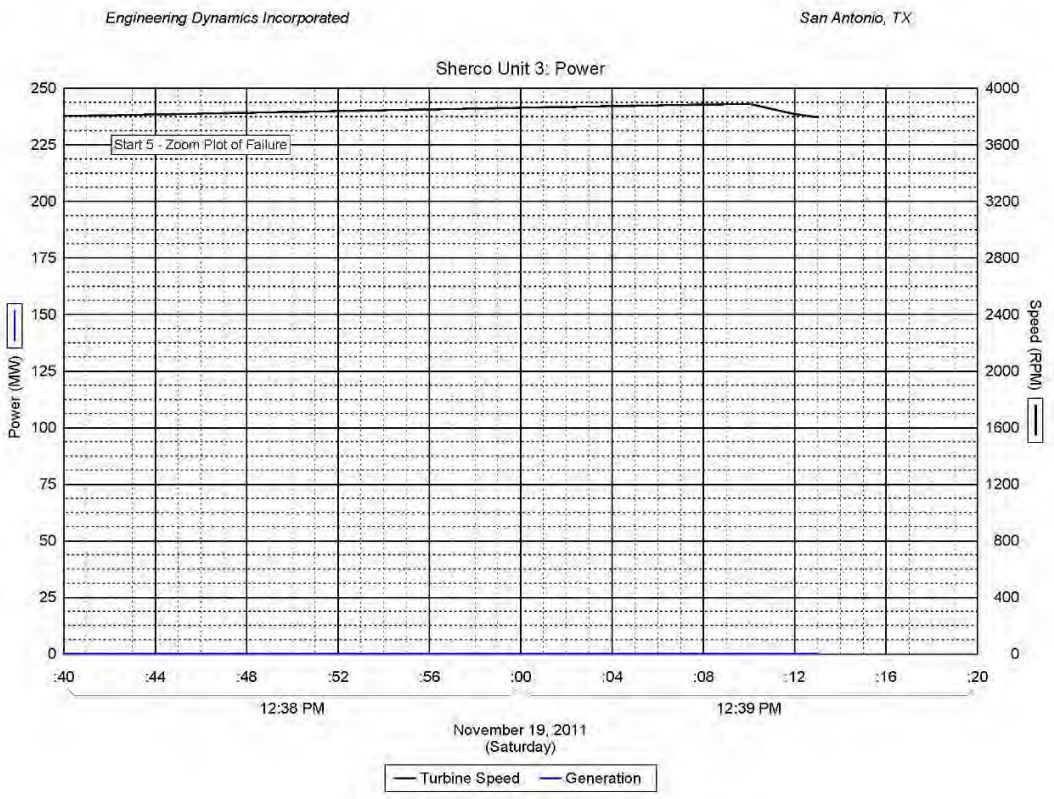
Appendix B60

Run 5



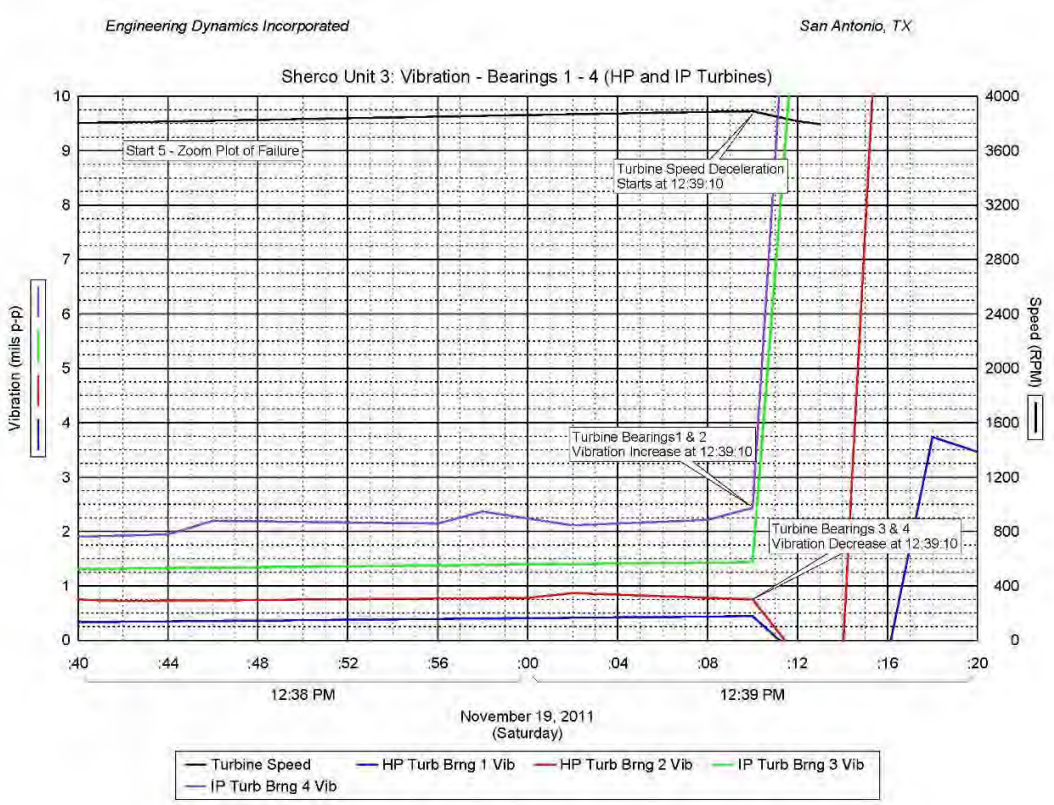
Appendix B61

Zoom to Failure-Run 5



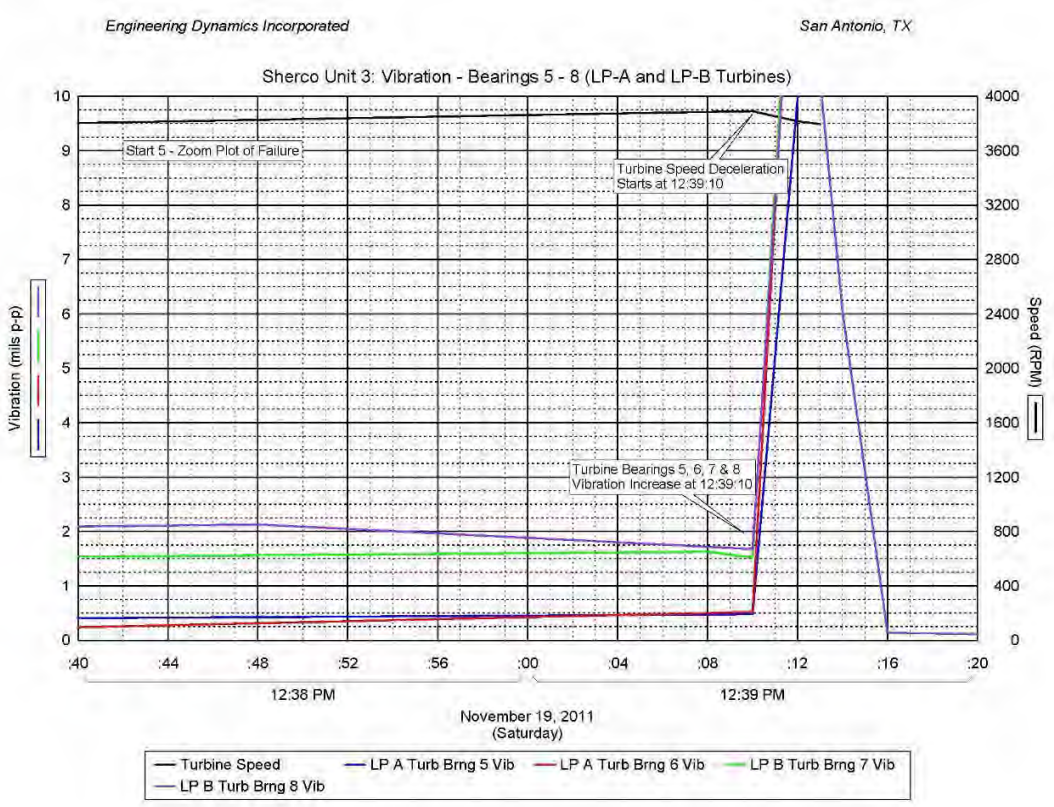
Appendix B62

Zoom to Failure-Run 5



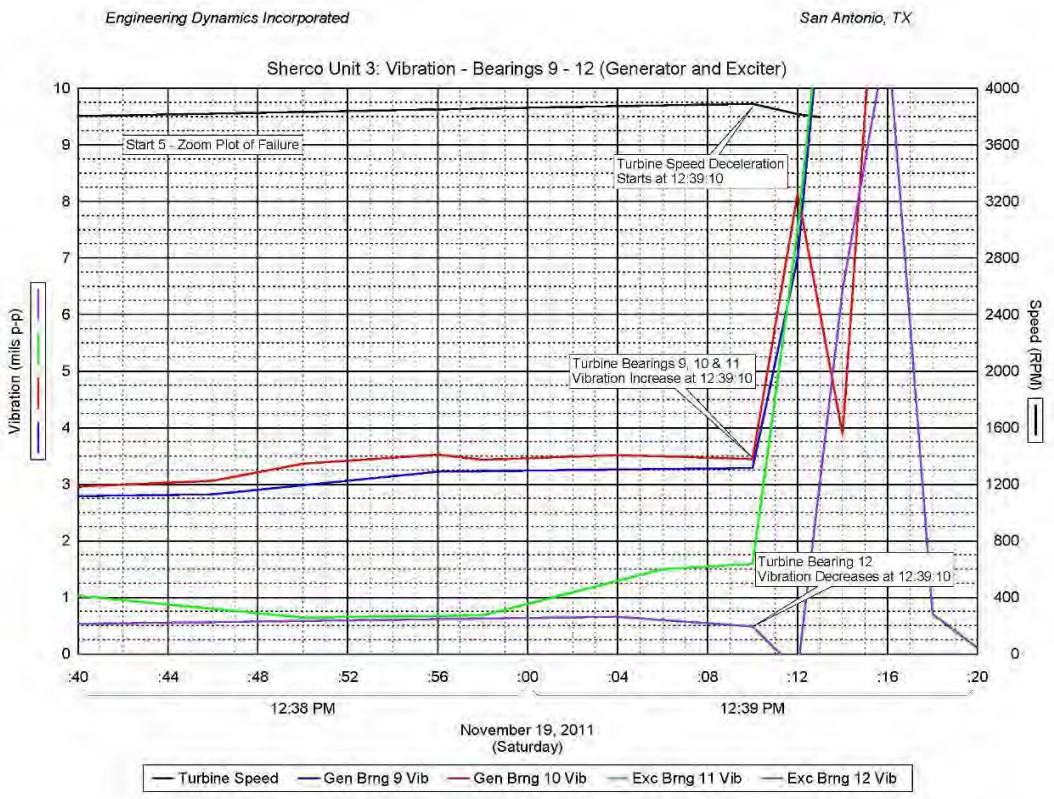
Appendix B63

Zoom to Failure-Run 5



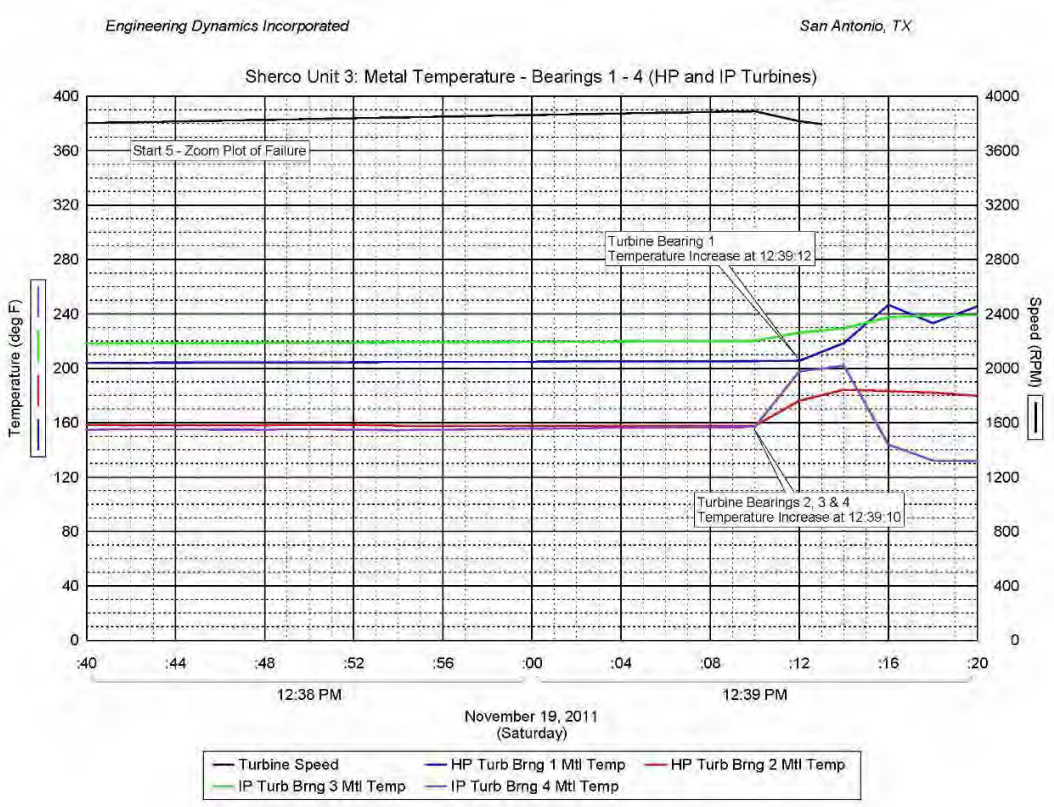
Appendix B64

Zoom to Failure-Run 5



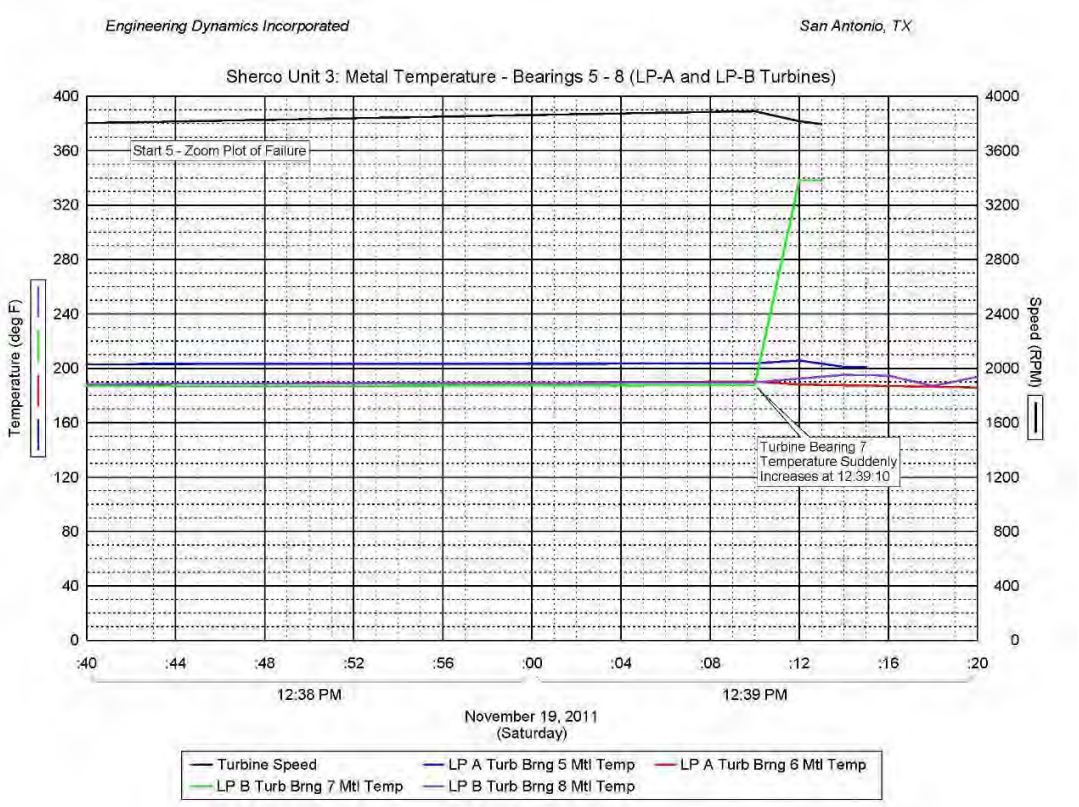
Appendix B65

Zoom to Failure-Run 5



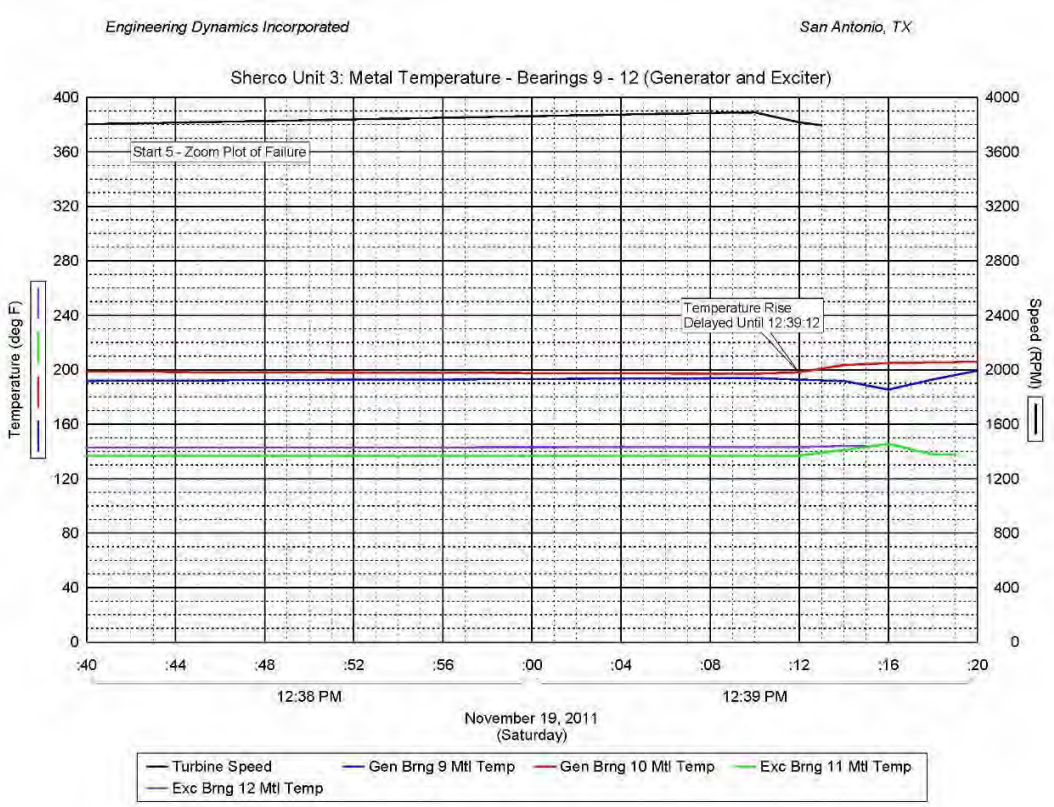
Appendix B66

Zoom to Failure-Run 5



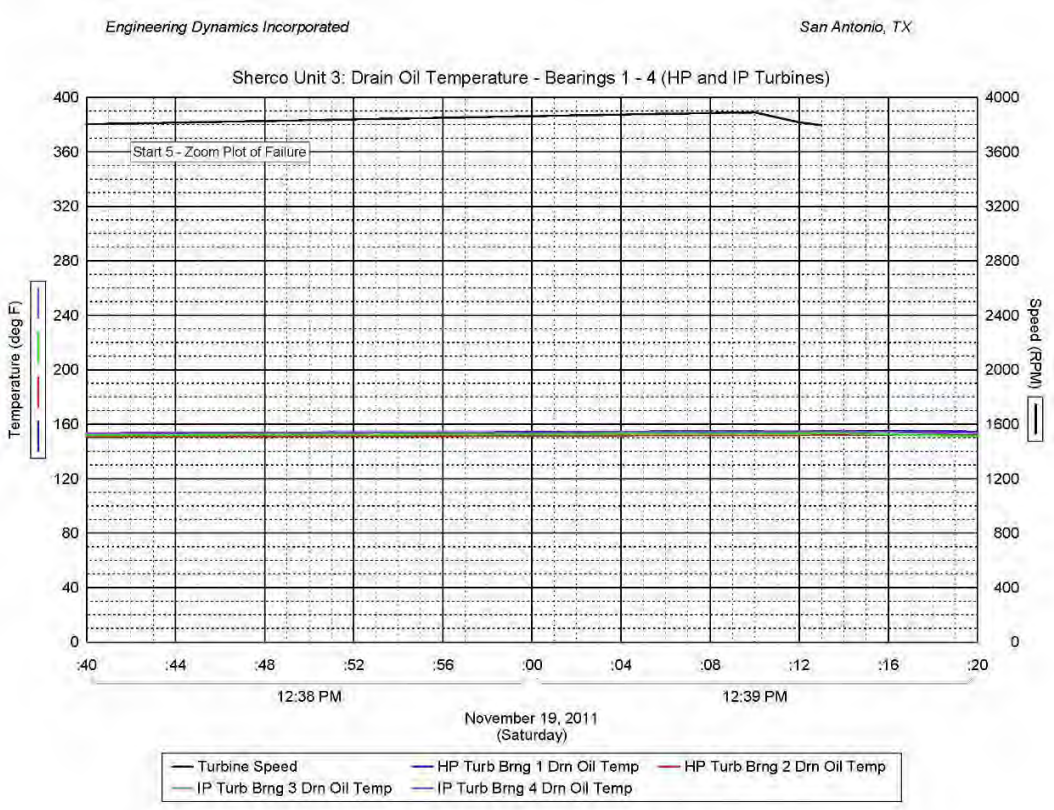
Appendix B67

Zoom to Failure-Run 5



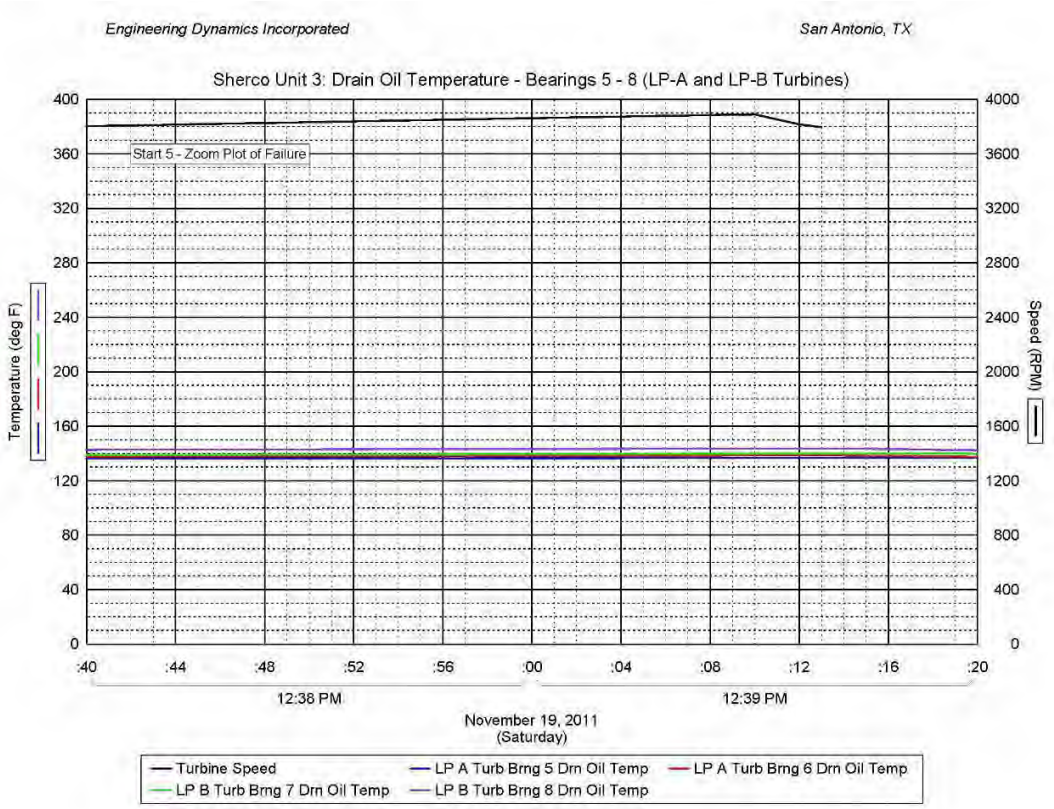
Appendix B68

Zoom to Failure-Run 5



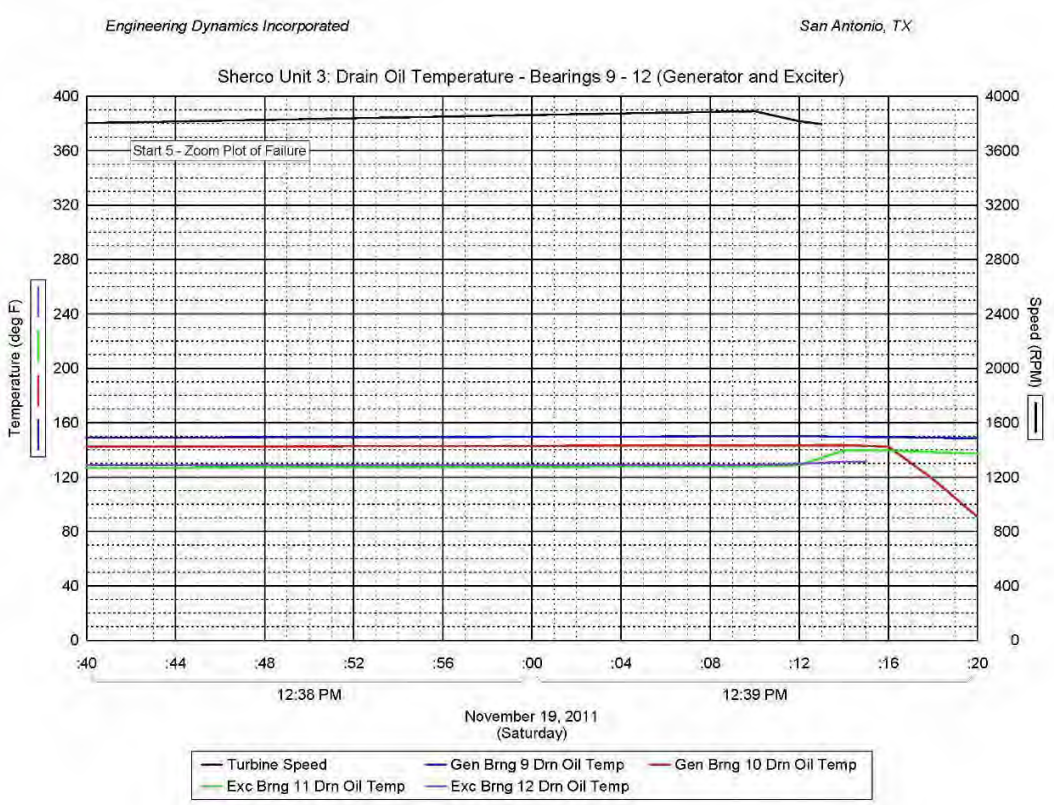
Appendix B69

Zoom to Failure-Run 5

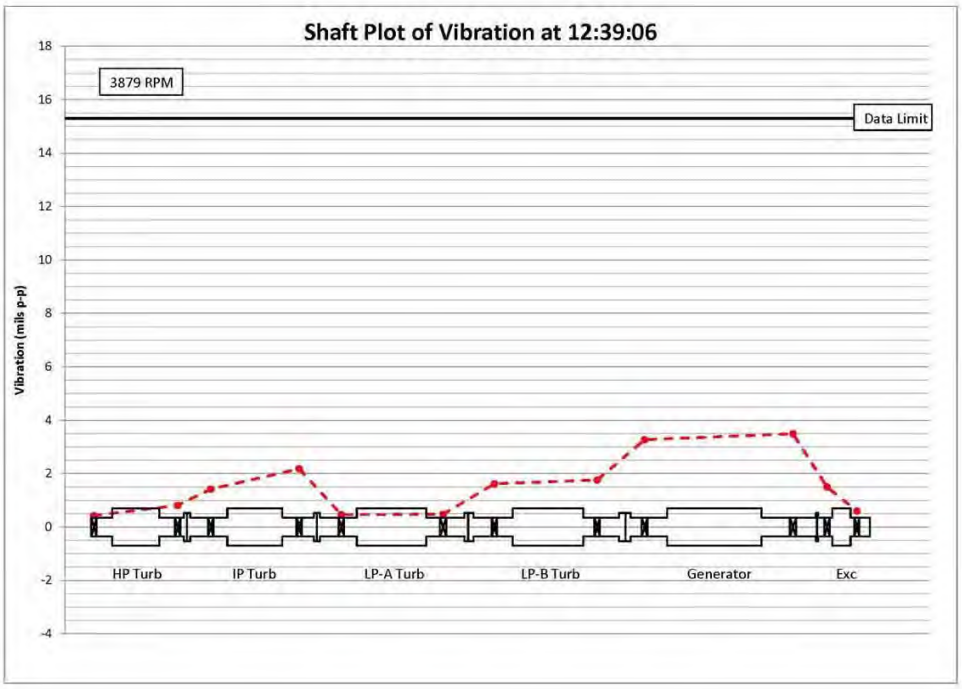


Appendix B70

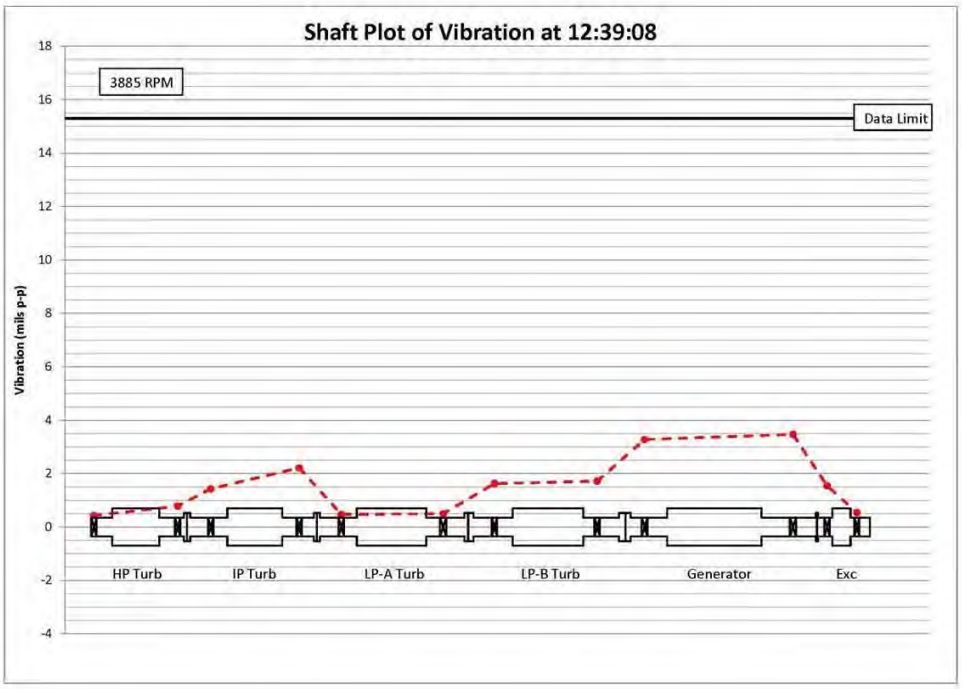
Zoom to Failure-Run 5



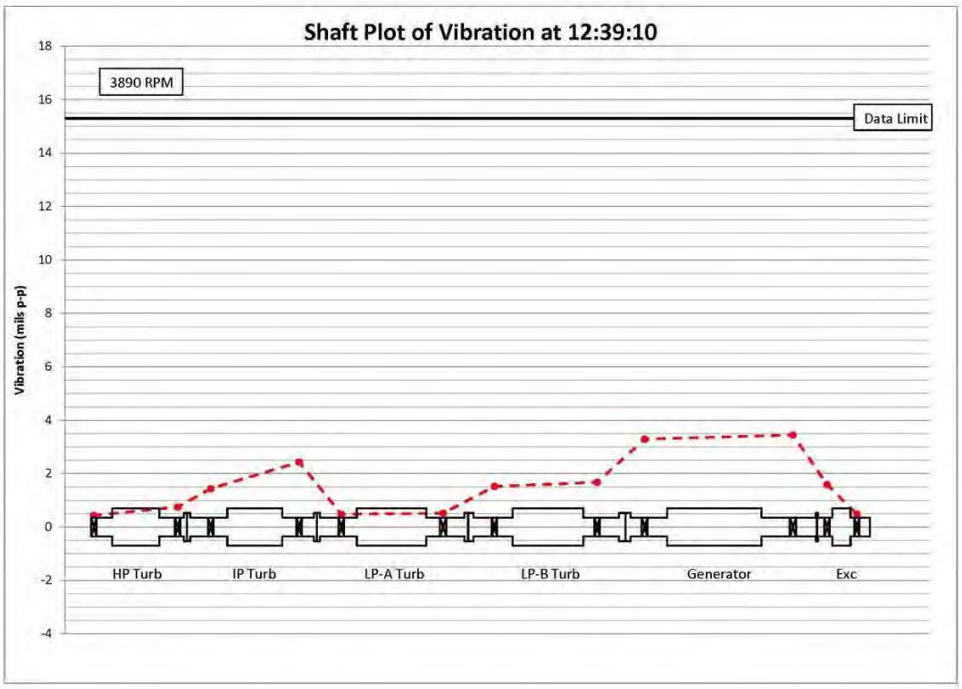
Appendix B71



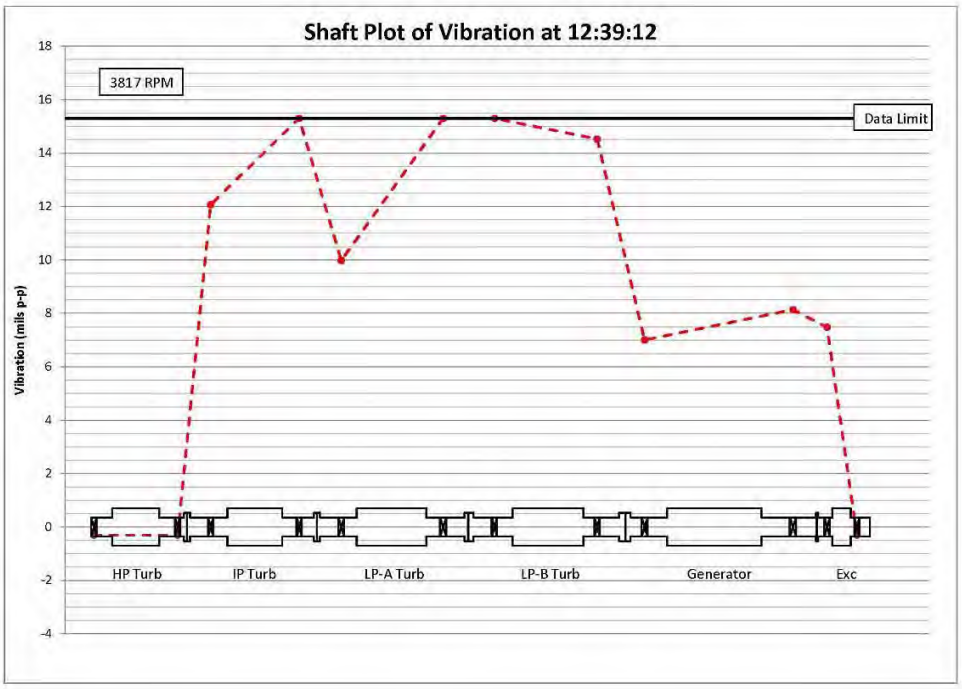
Appendix B72



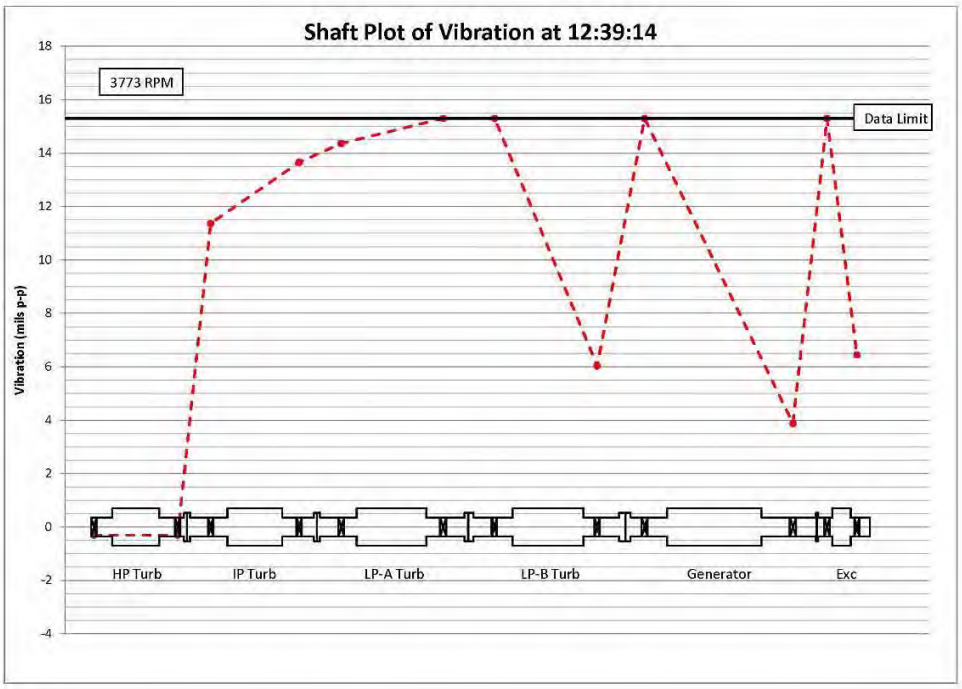
Appendix B73



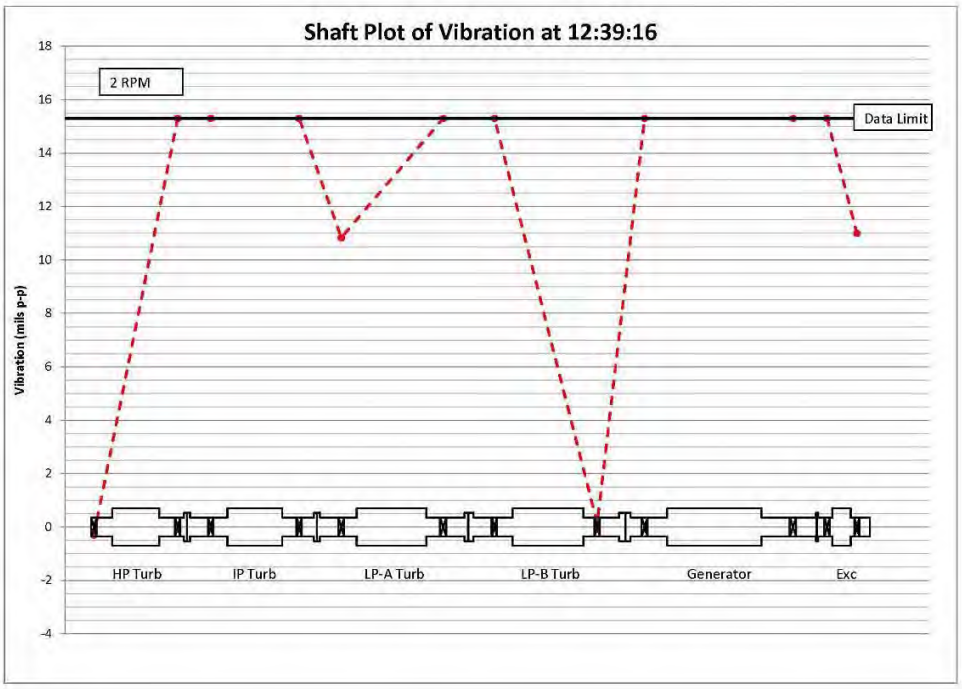
Appendix B74



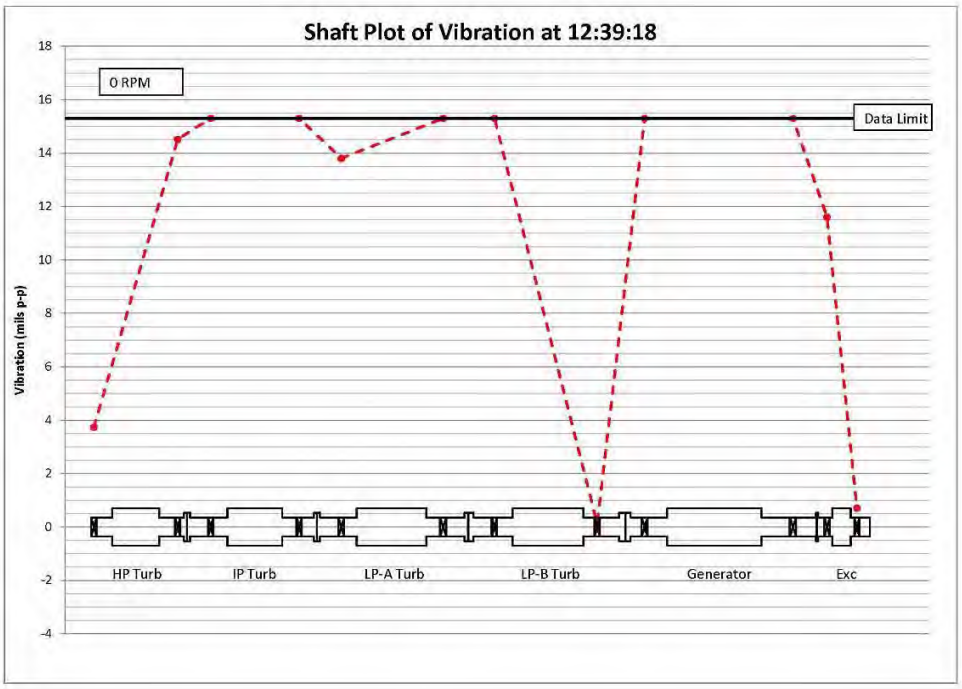
Appendix B75



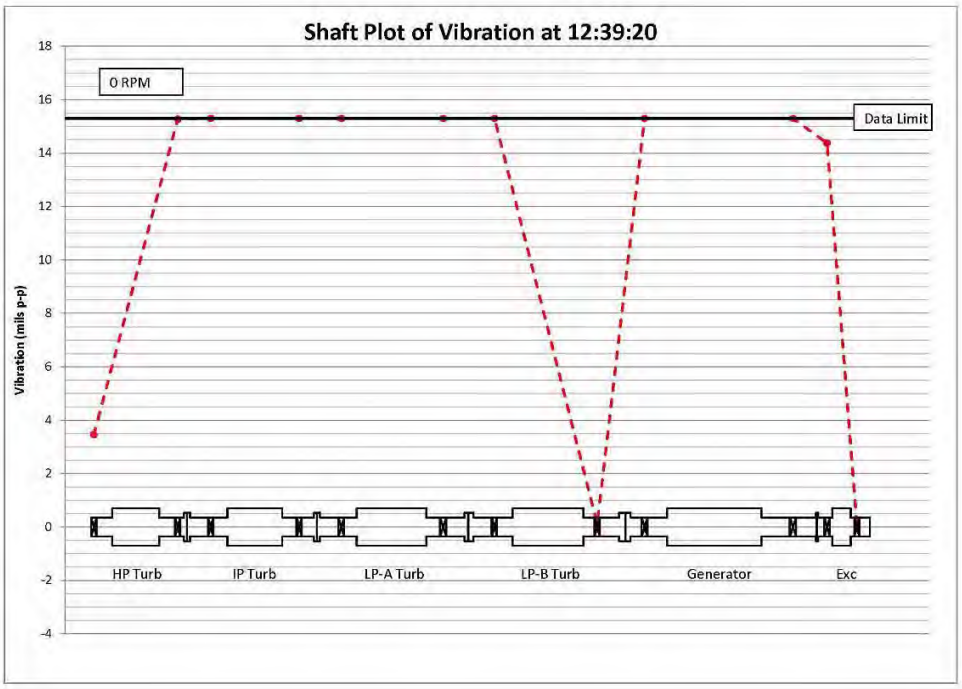
Appendix B76



Appendix B77



Appendix B78



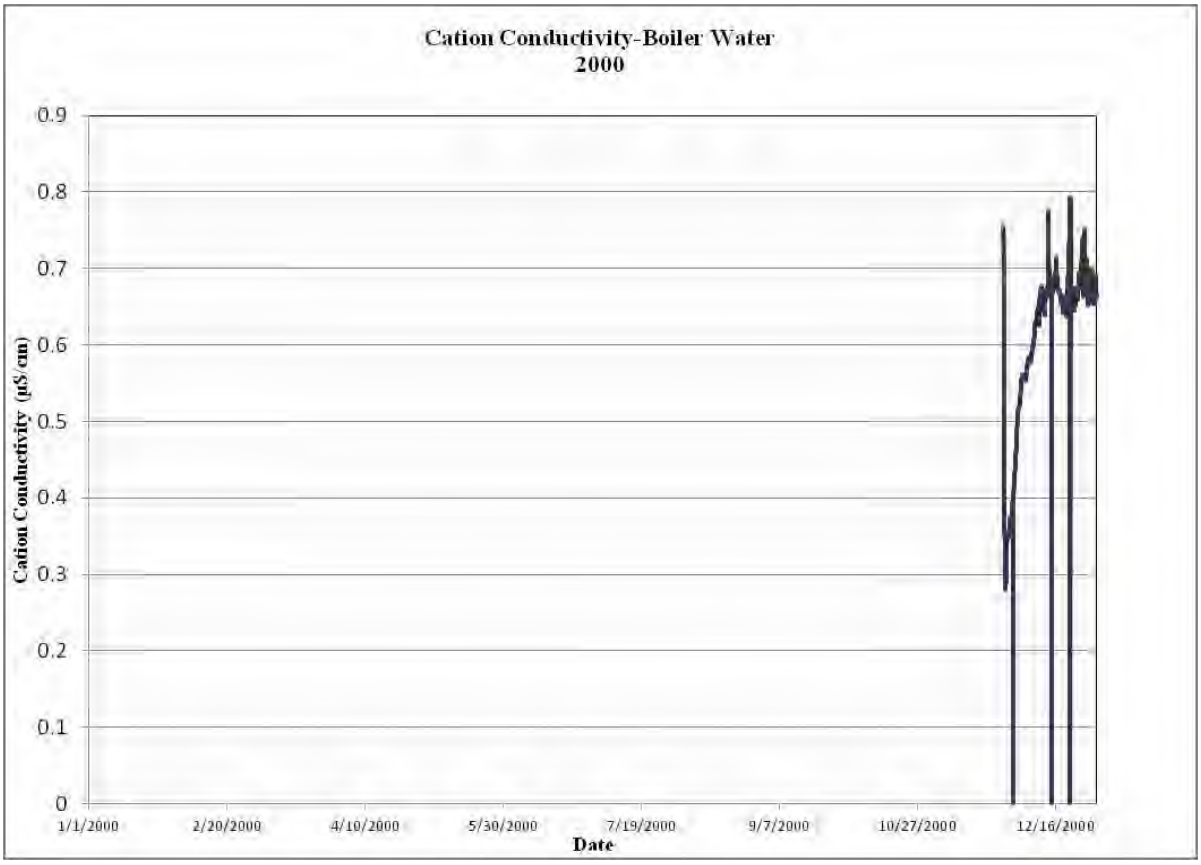
APPENDIX C

SHERCO UNIT NO. 3

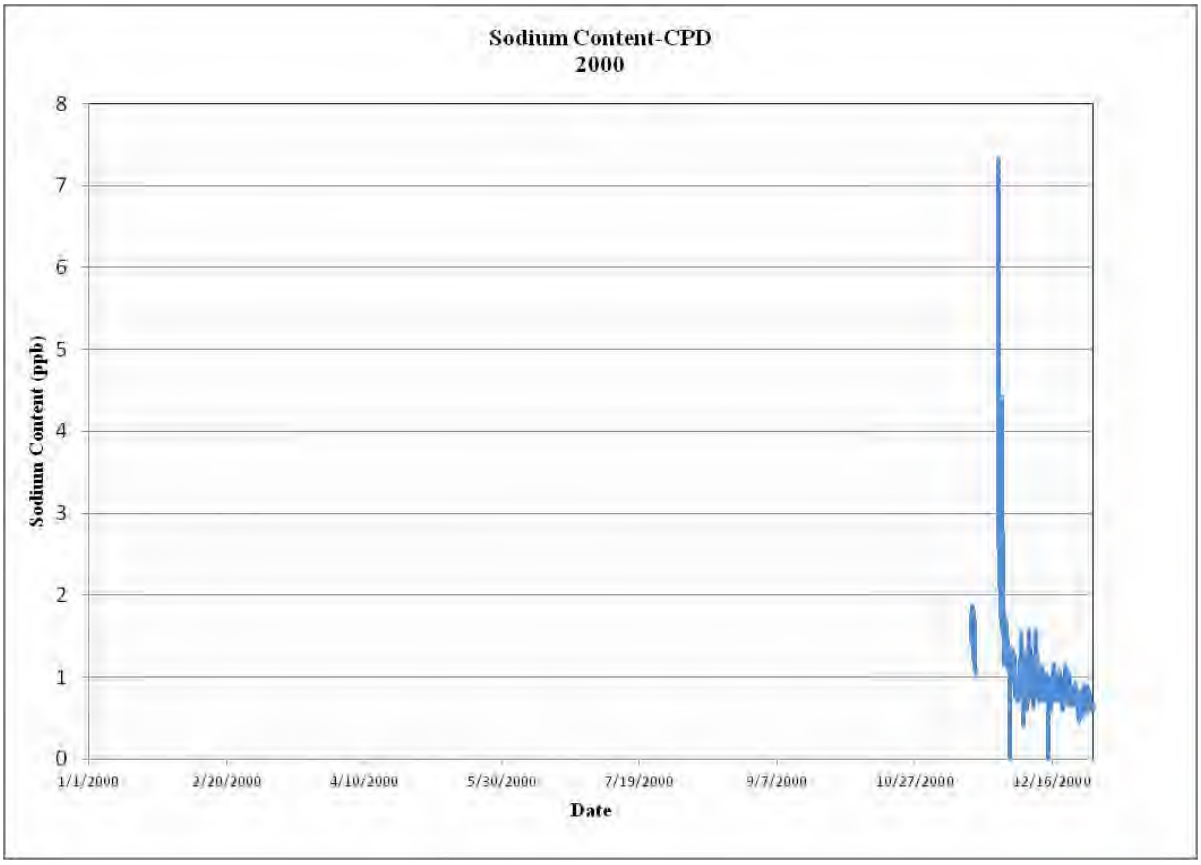
ONLINE WATER/STEAM CHEMISTRY DATA

2000 TO 2011

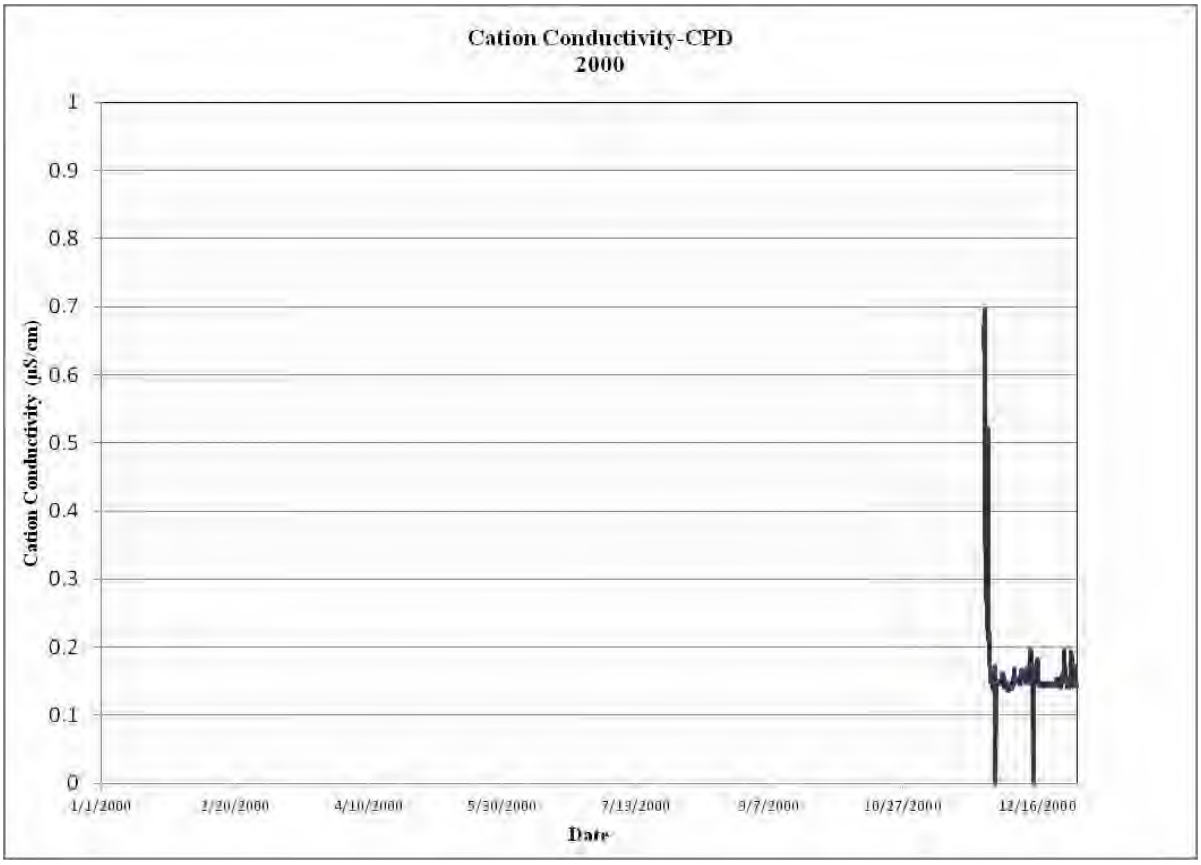
Appendix C1


Cation Conductivity-Boiler Water
2000
Cation Conductivity (µS/cm)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/2000
2/20/2000
4/10/2000
5/30/2000
7/19/2000
9/7/2000
10/27/2000
12/16/2000
Date

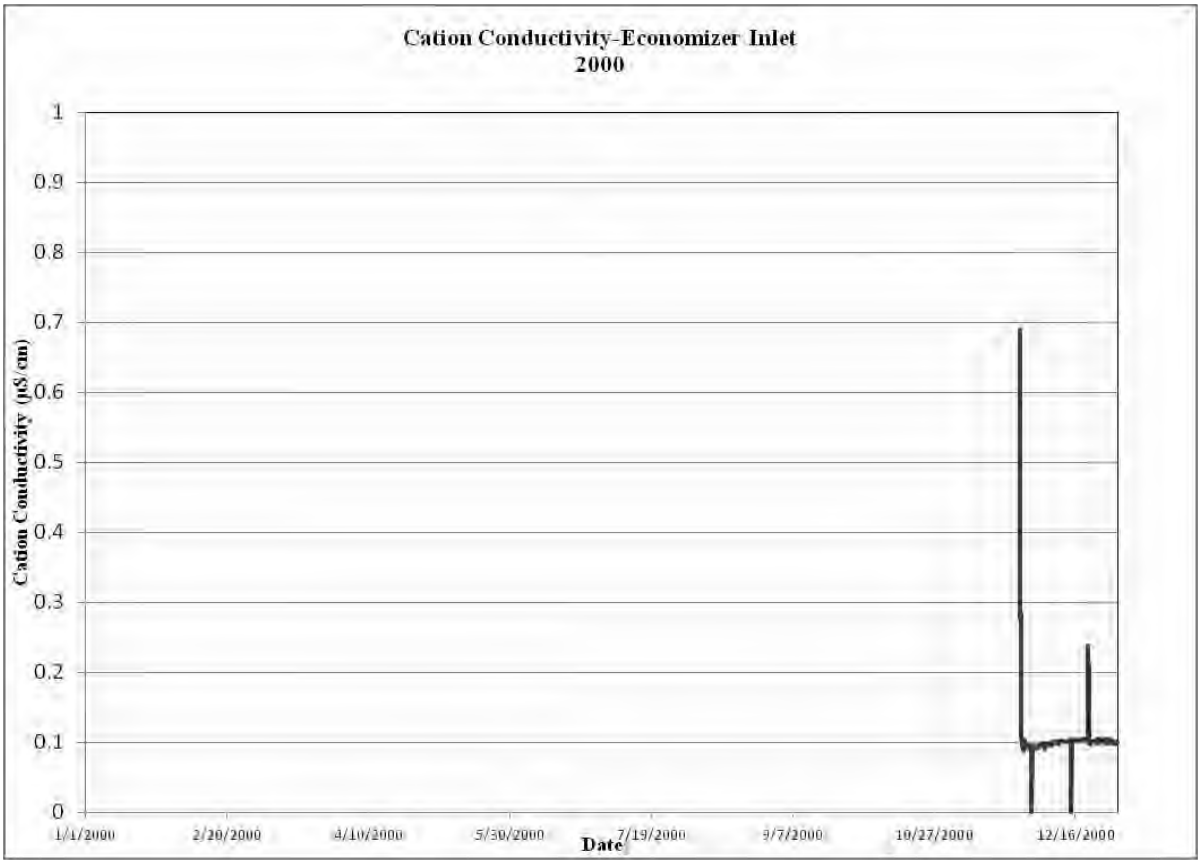
Appendix C2


Sodium Content-CPD
2000
Sodium Content (ppb)
8
7
6
5
4
3
2
1
0
1/1/2000
2/20/2000
4/10/2000
5/30/2000
7/19/2000
9/7/2000
10/27/2000
12/16/2000
Date

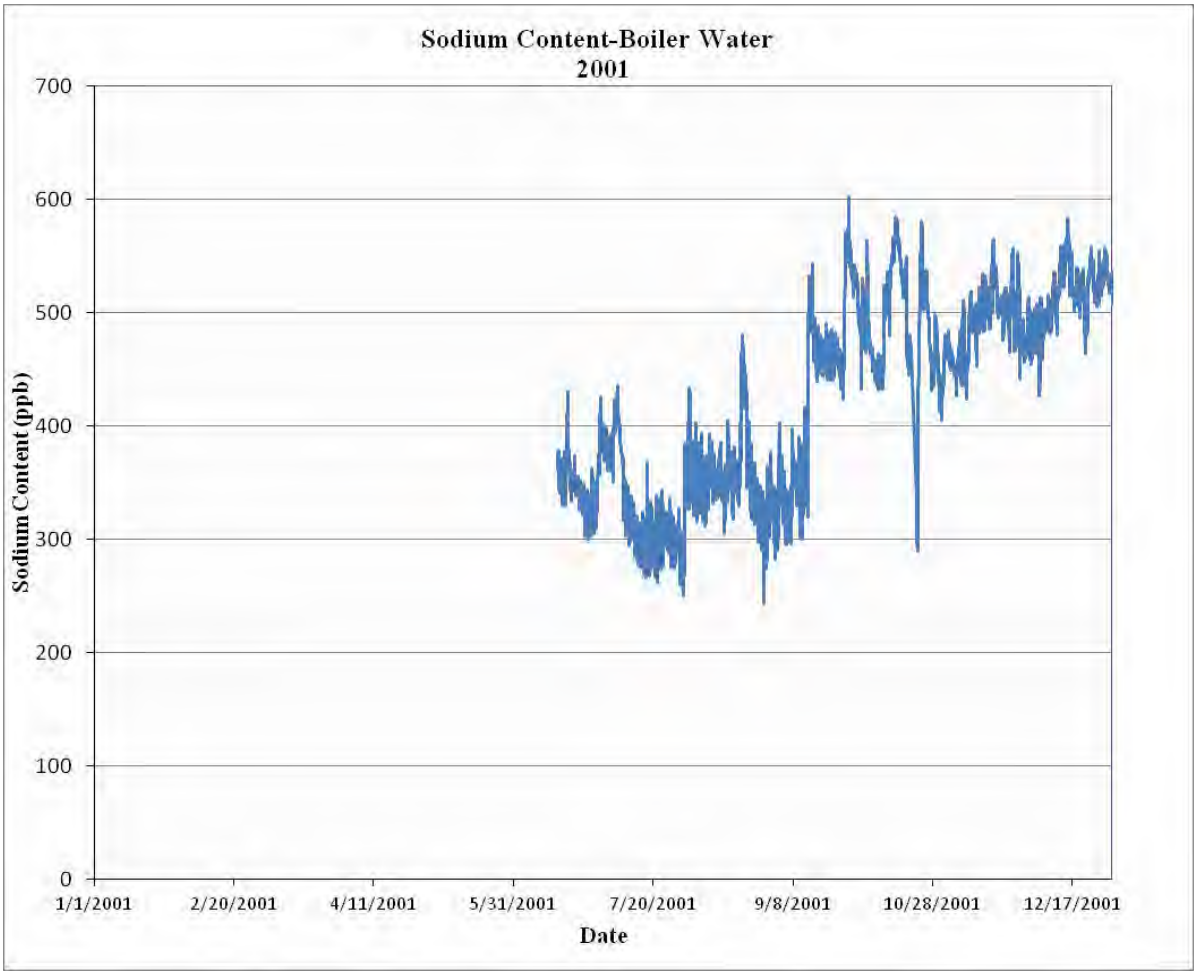
Appendix C3


Cation Conductivity-CPD
2000
Cation Conductivity (µS/cm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/2000
3/20/2000
4/10/2000
5/30/2000
7/13/2000
9/7/2000
10/27/2000
12/16/2000
Date

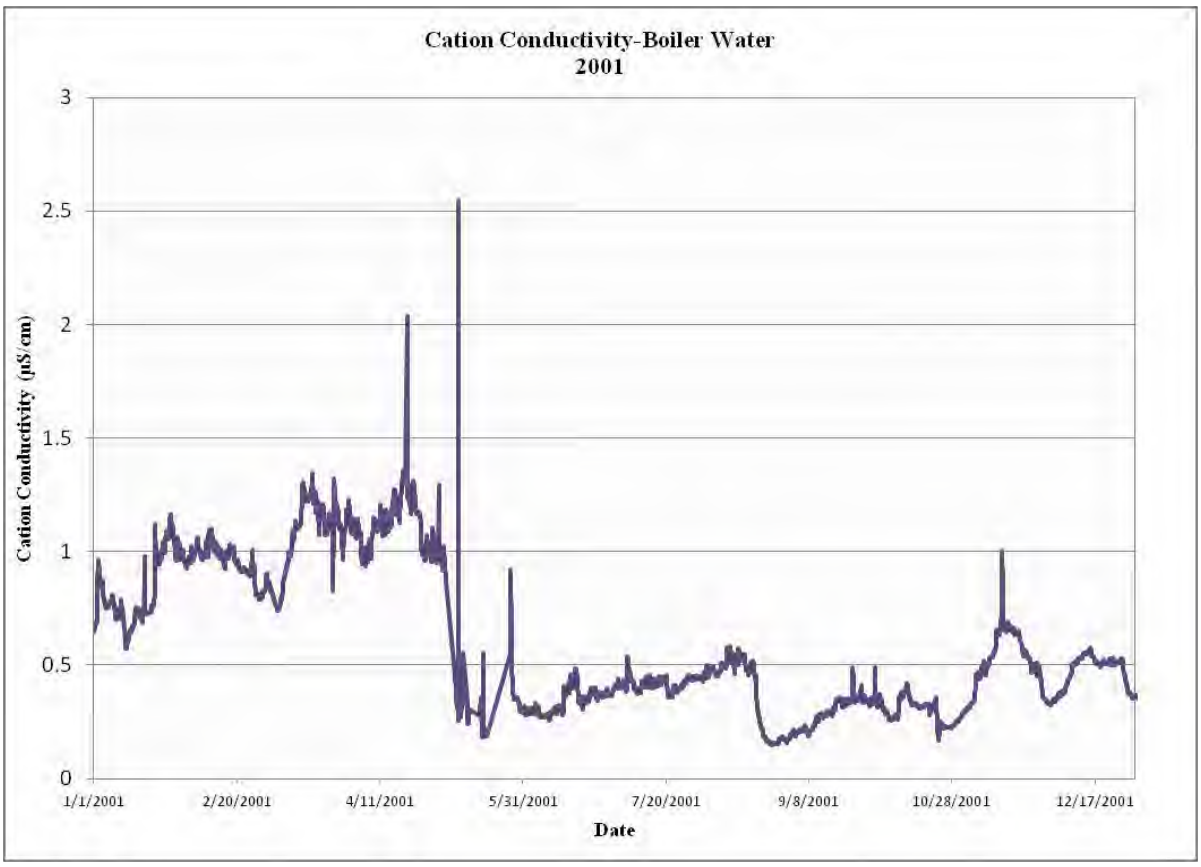
Appendix C4


Cation Conductivity-Economizer Inlet
2000
Cation Conductivity (µS/cm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/2000
2/20/2000
4/10/2000
5/30/2000
7/19/2000
9/7/2000
10/27/2000
12/16/2000
Date

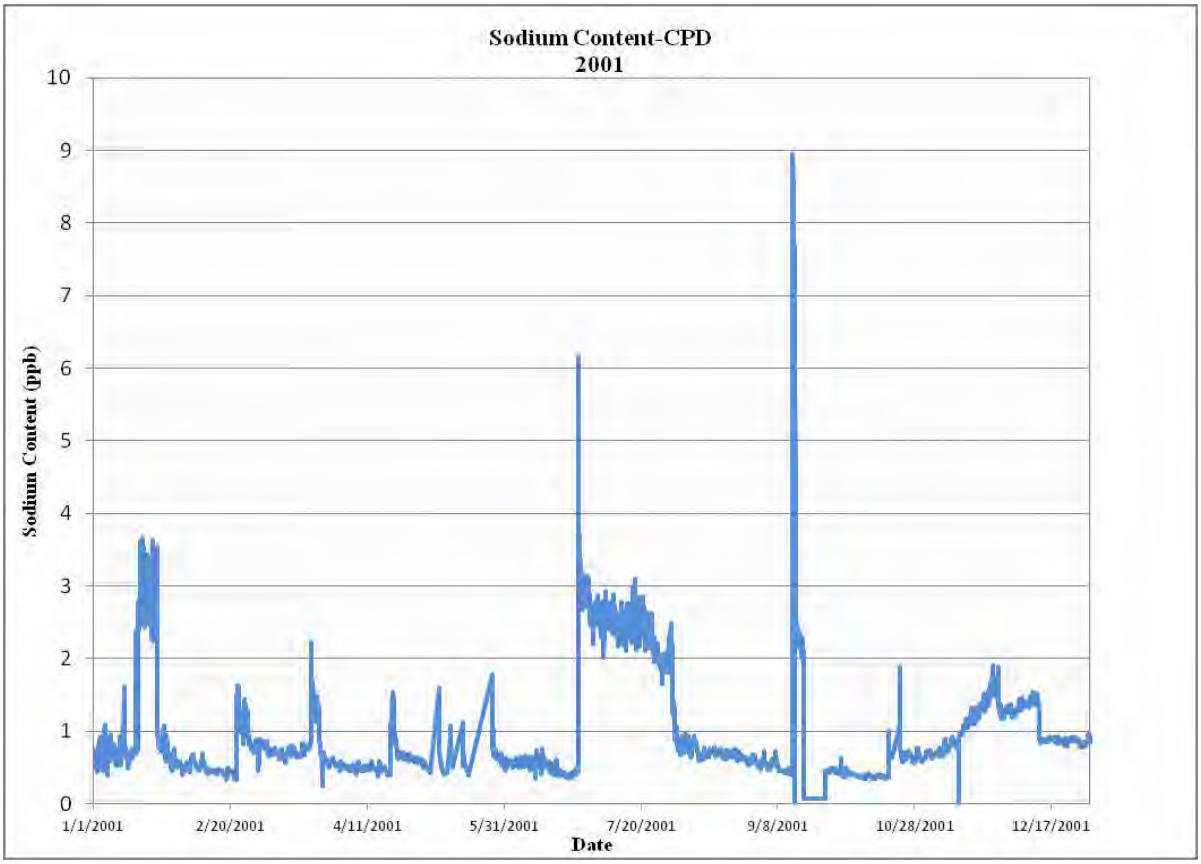
Appendix C5


Sodium Content-Boiler Water
2001
Sodium Content (ppb)
700
600
500
400
300
200
100
0
1/1/2001
2/20/2001
4/11/2001
5/31/2001
7/20/2001
9/8/2001
10/28/2001
12/17/2001
Date

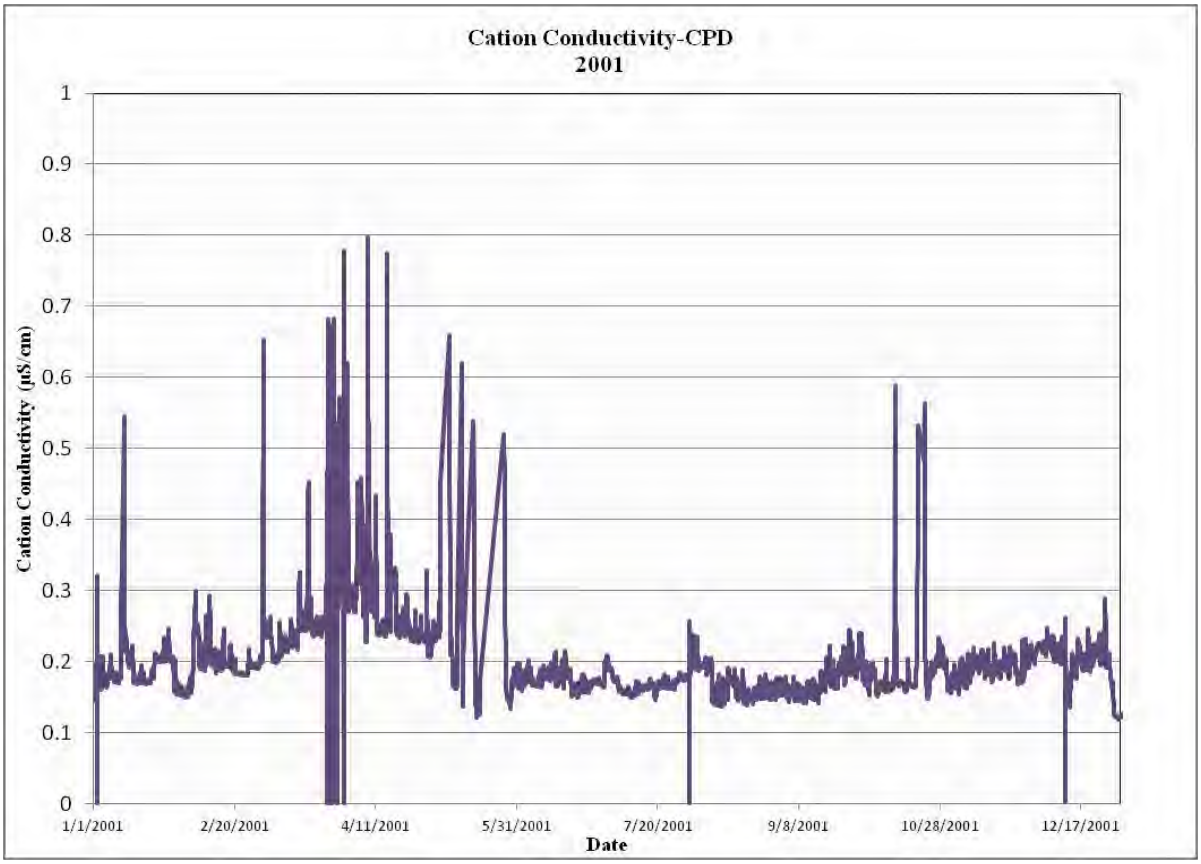
Appendix C6


Cation Conductivity-Boiler Water
2001
Cation Conductivity (µS/cm)
3
2.5
2
1.5
1
0.5
0
1/1/2001
2/20/2001
4/11/2001
5/31/2001
7/20/2001
9/8/2001
10/28/2001
12/17/2001
Date

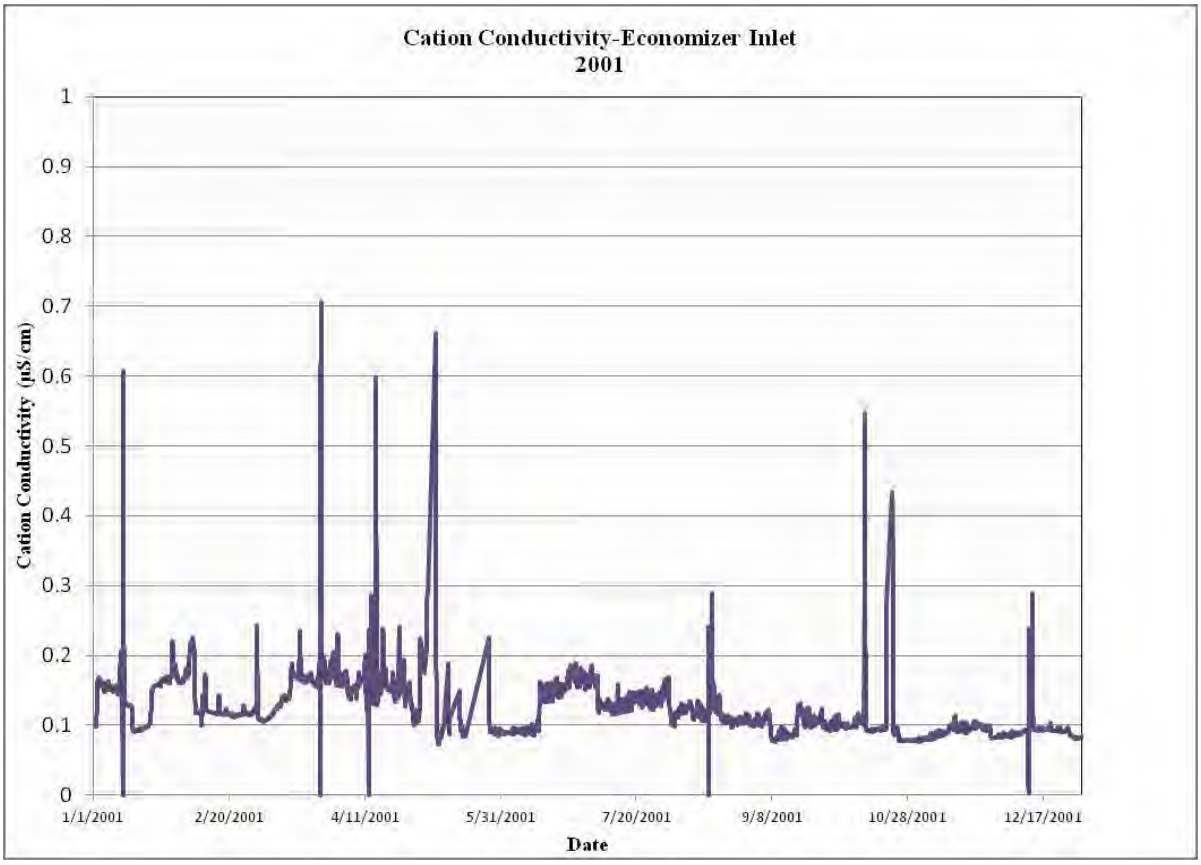
Appendix C7


Sodium Content-CPD
2001
Sodium Content (ppb)
10
9
8
7
6
5
4
3
2
1
0
1/1/2001
2/20/2001
4/11/2001
5/31/2001
7/20/2001
9/8/2001
10/28/2001
12/17/2001
Date

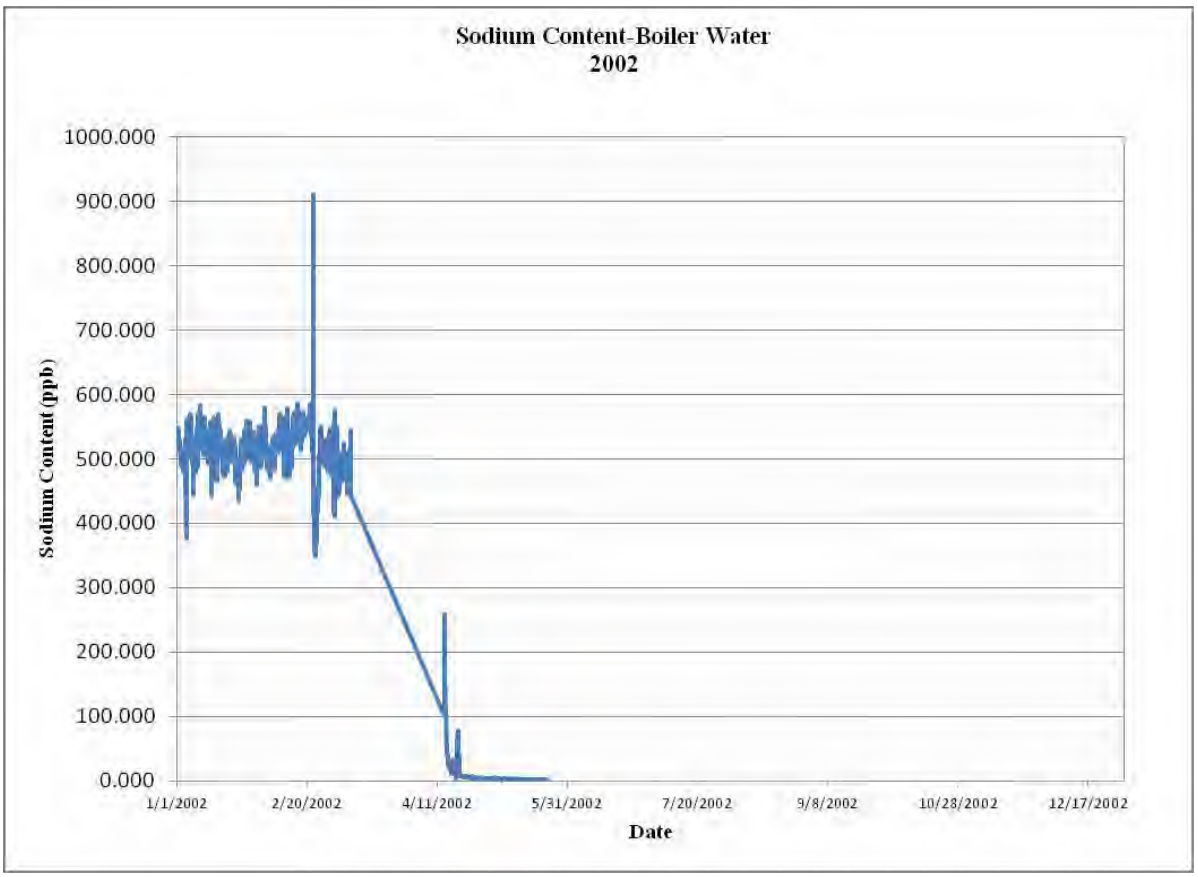
Appendix C8


Cation Conductivity-CPD
2001
Cation Conductivity (µS/cm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/2001
2/20/2001
4/11/2001
5/31/2001
7/20/2001
9/8/2001
10/28/2001
12/17/2001
Date

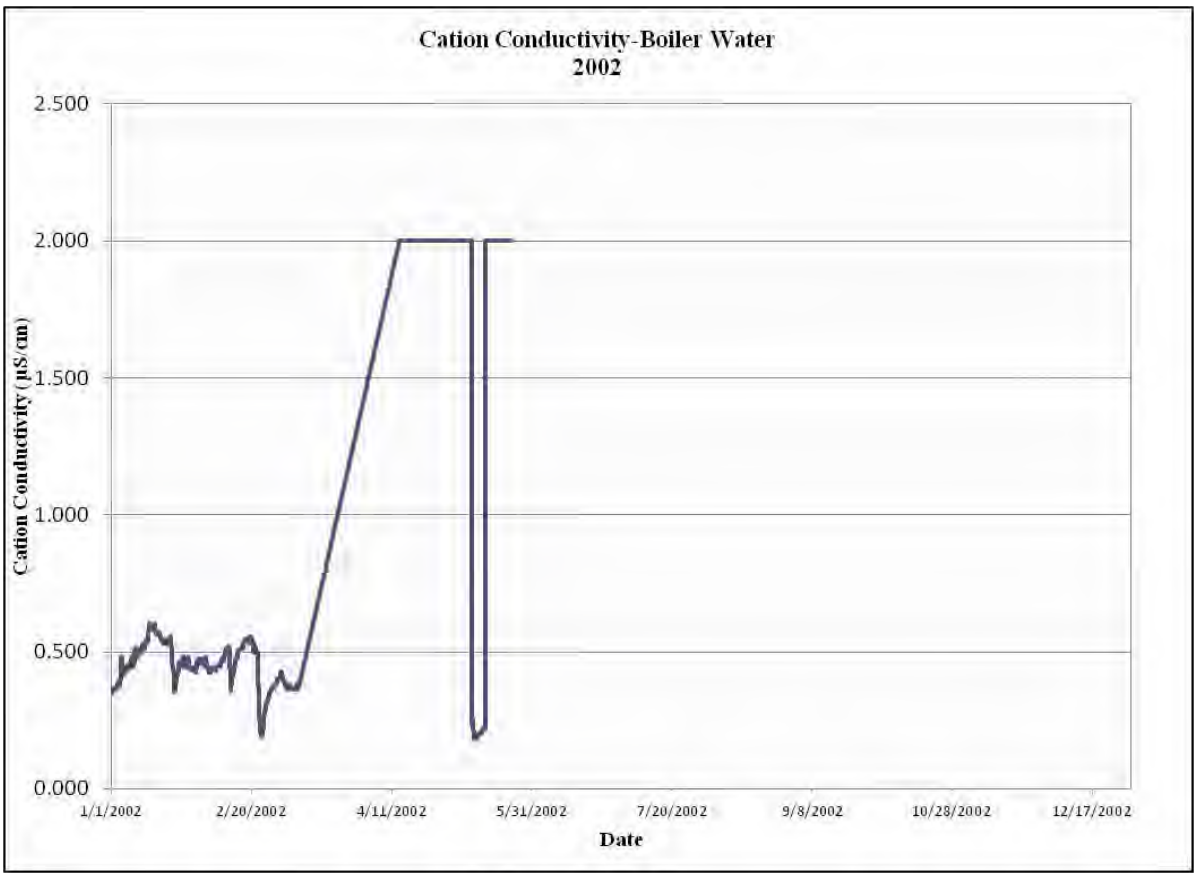
Appendix C9


Cation Conductivity-Economizer Inlet
2001
Cation Conductivity (µS/cm)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/2001
2/20/2001
4/11/2001
5/31/2001
7/20/2001
9/8/2001
10/28/2001
12/17/2001
Date

Appendix C10



Appendix C11



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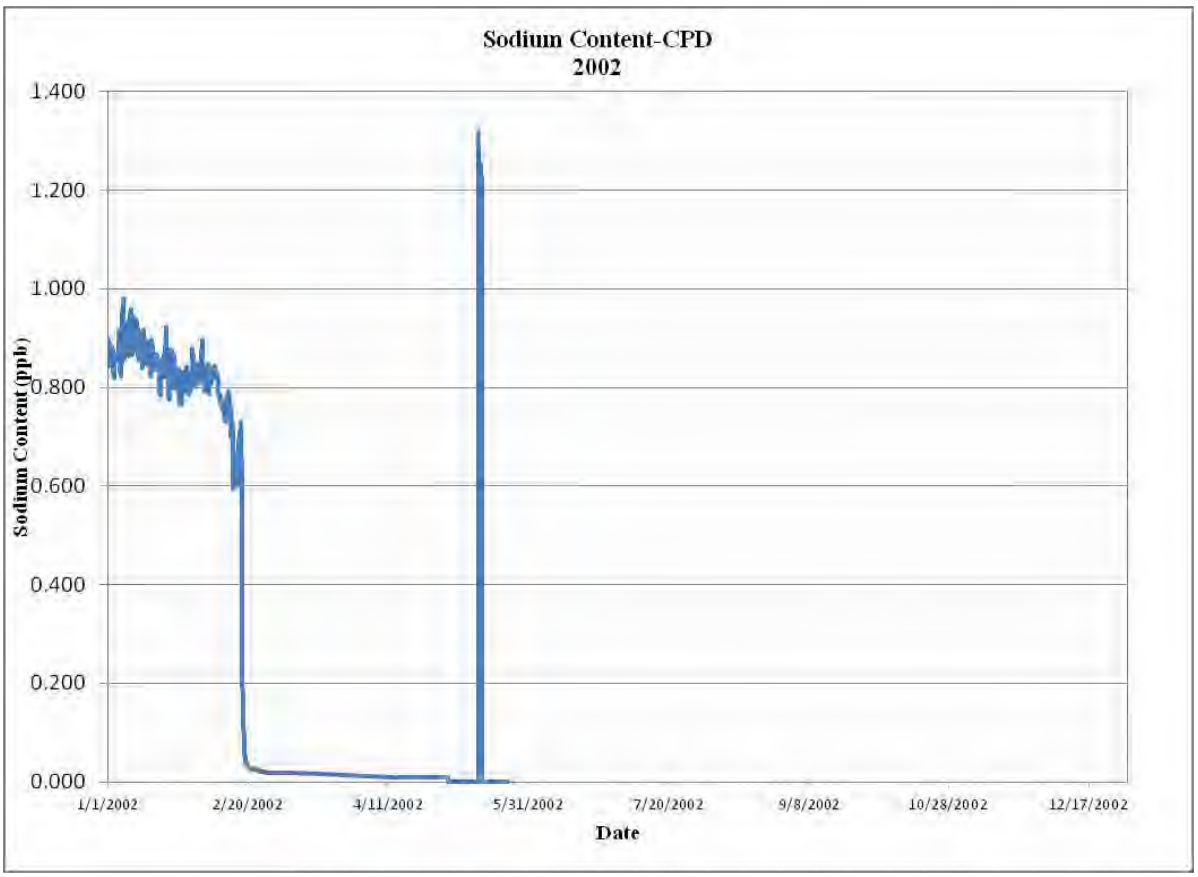
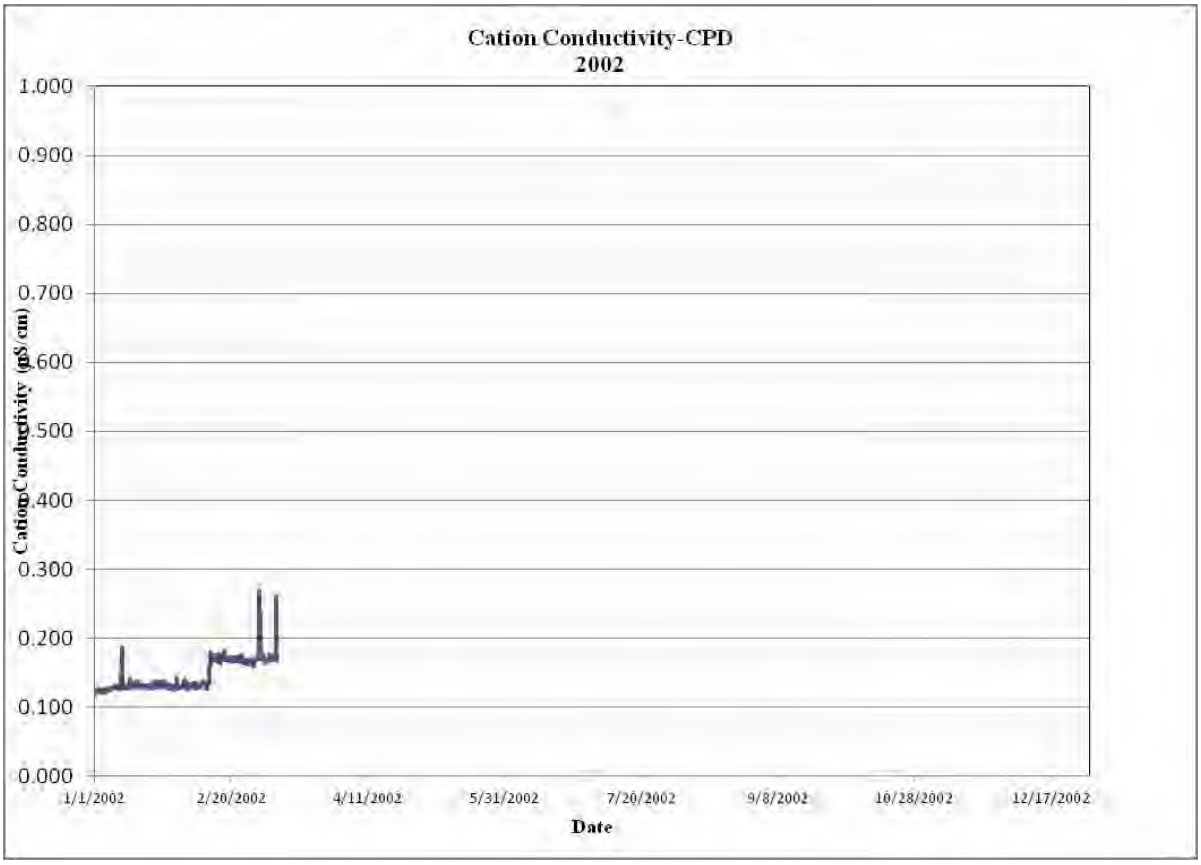
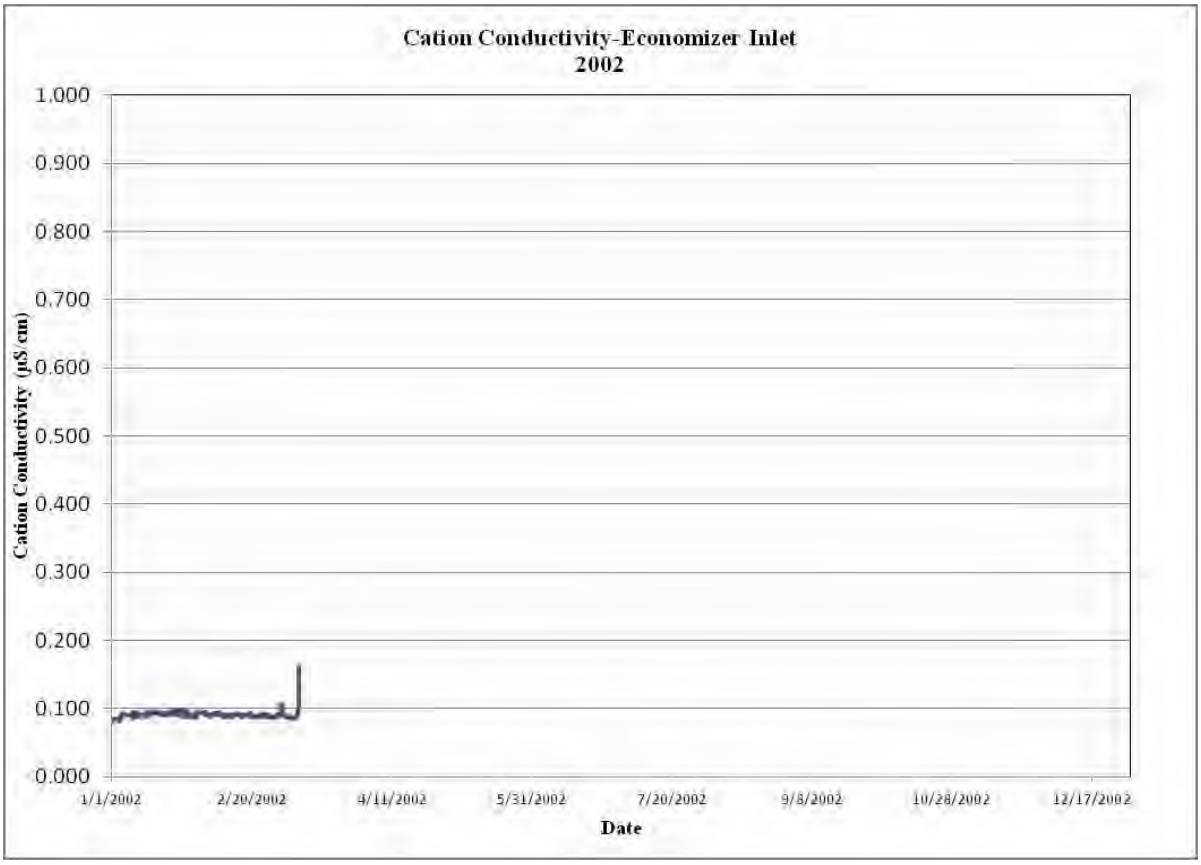


Appendix C13



Appendix C14



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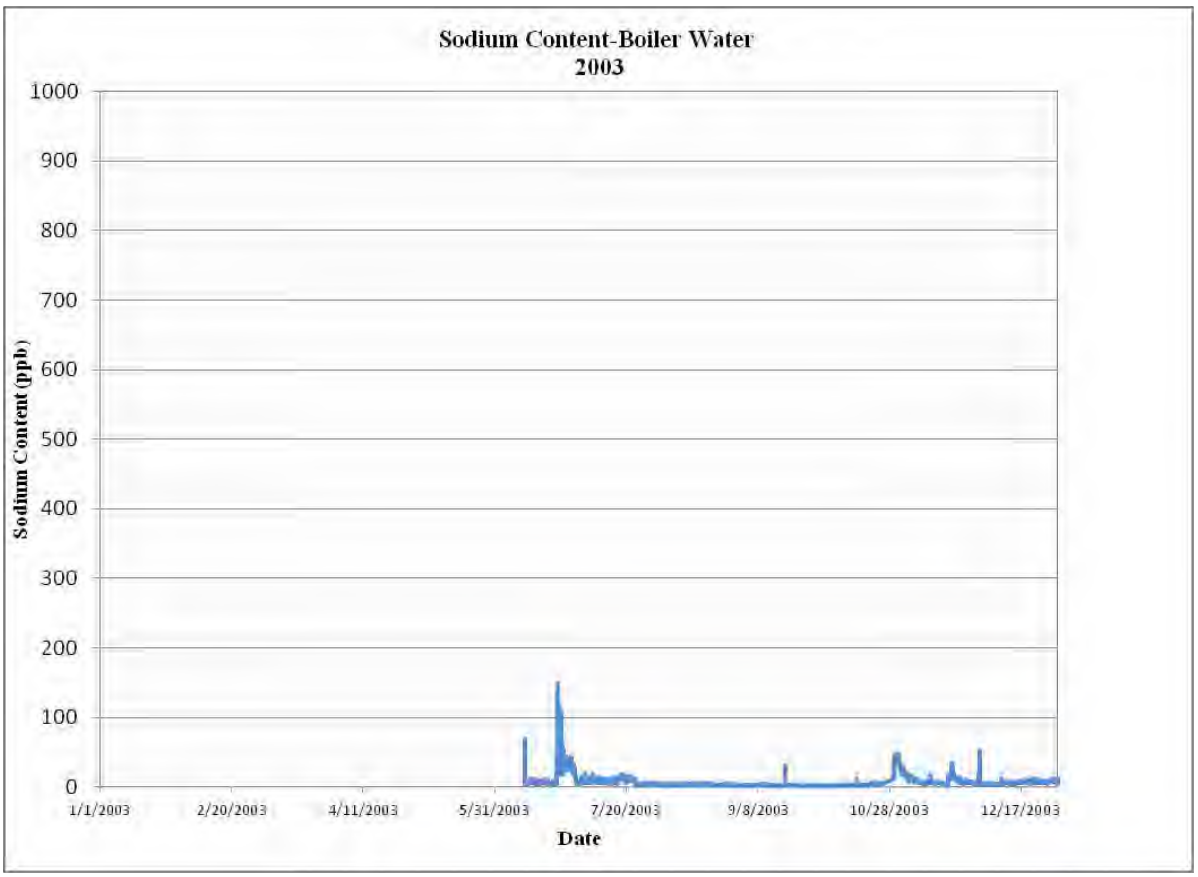

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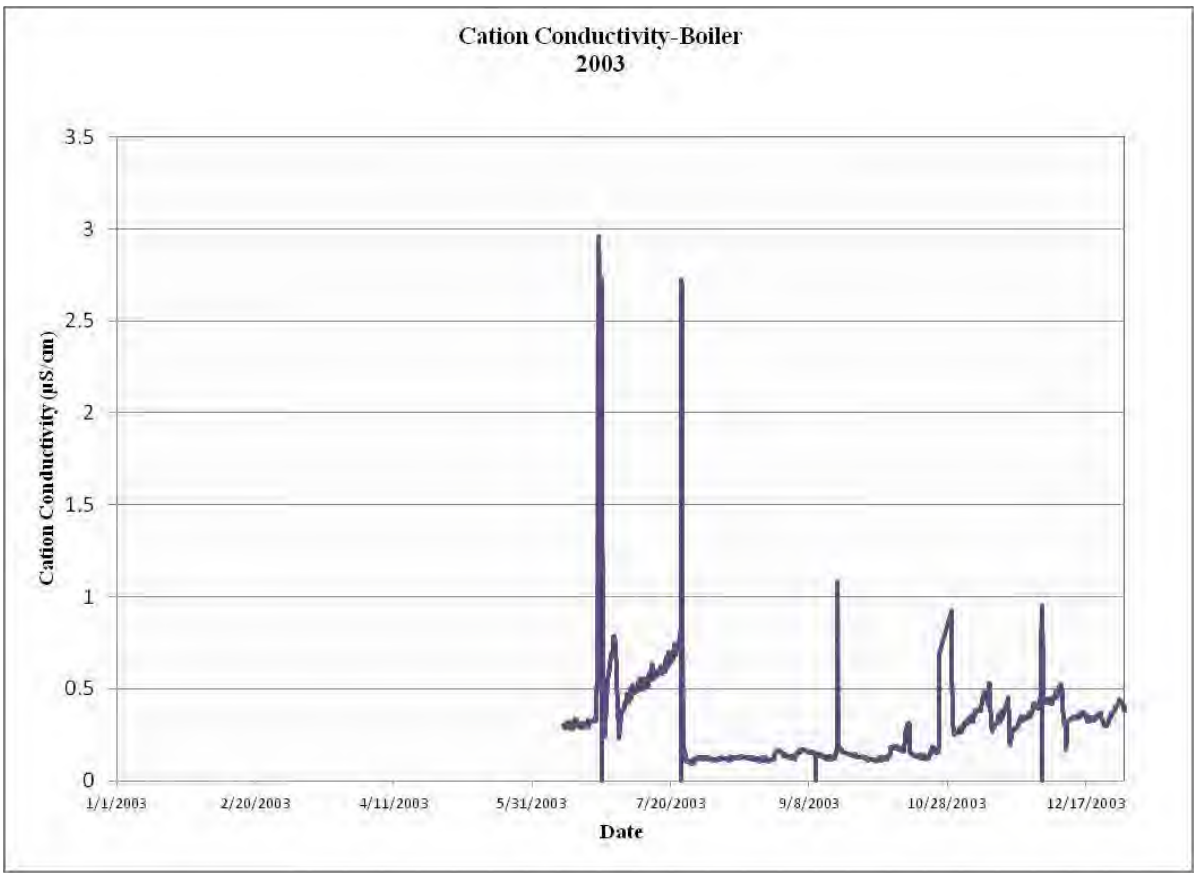
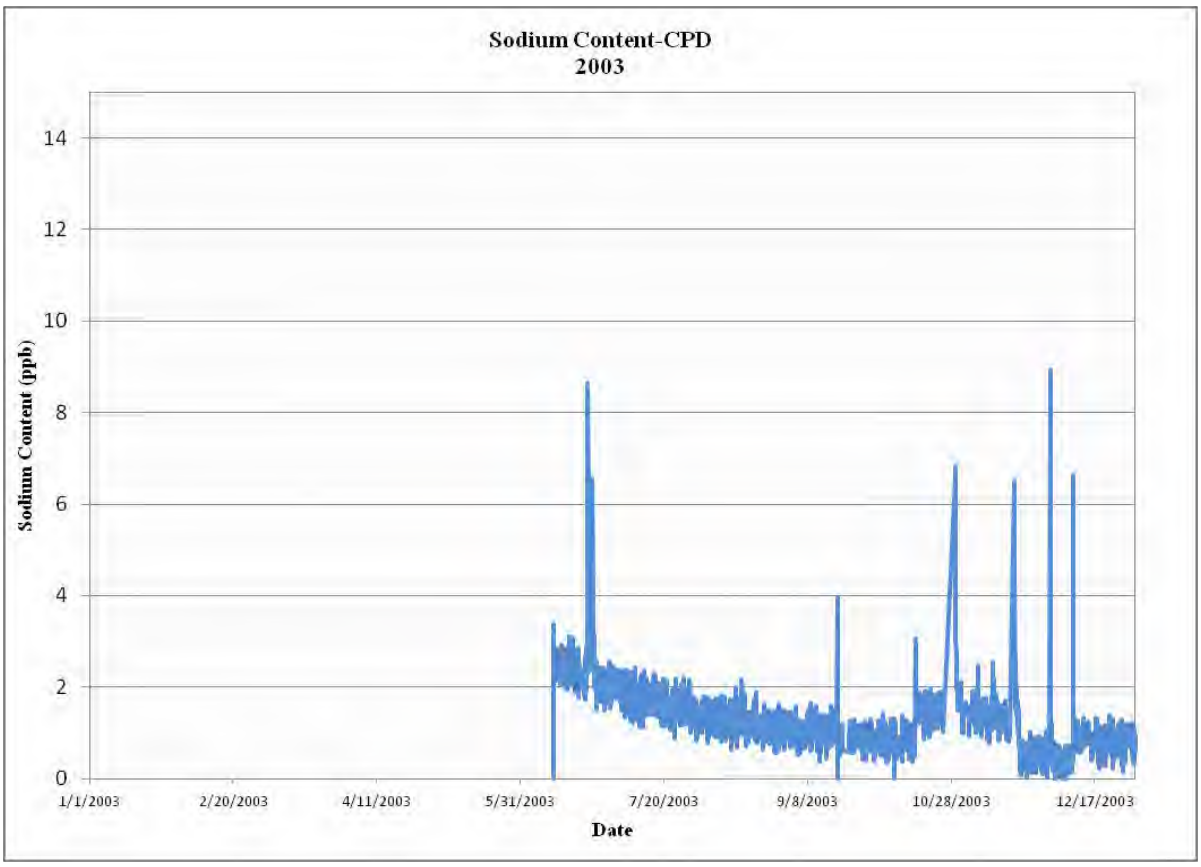
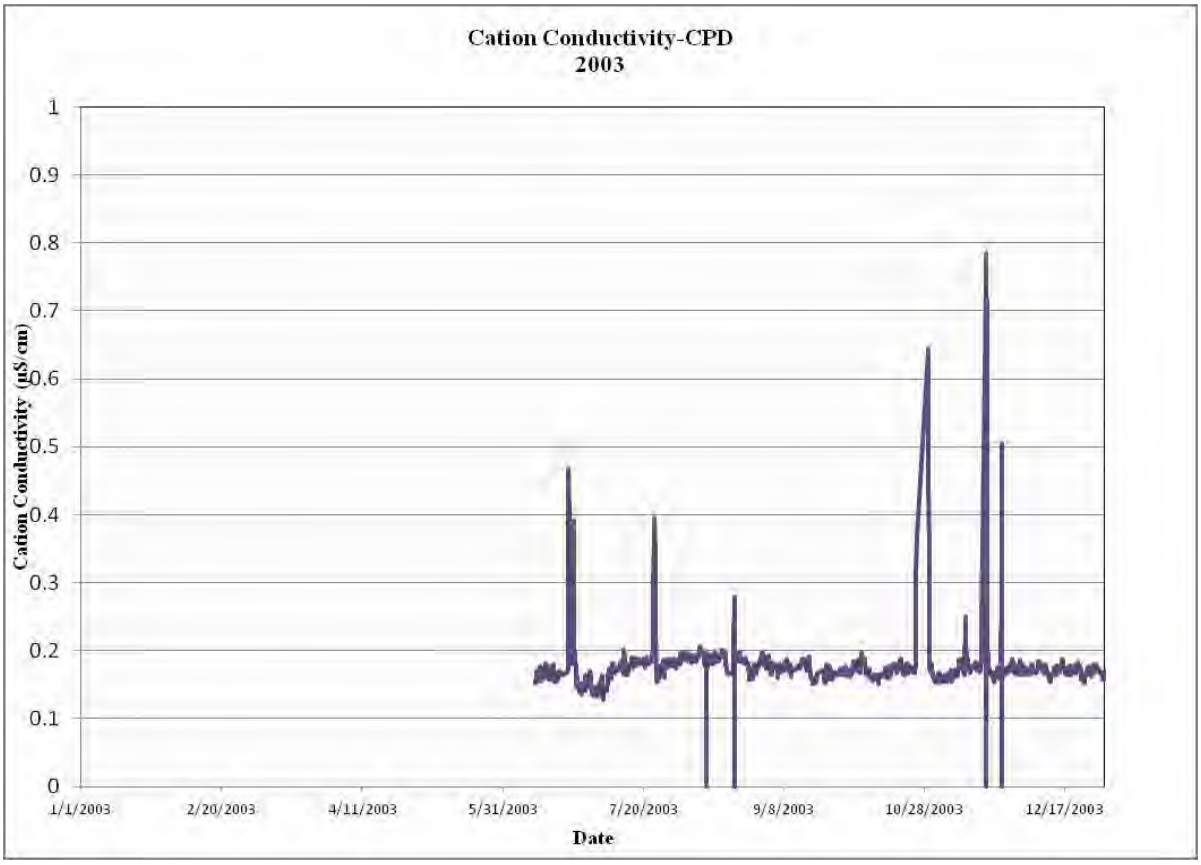


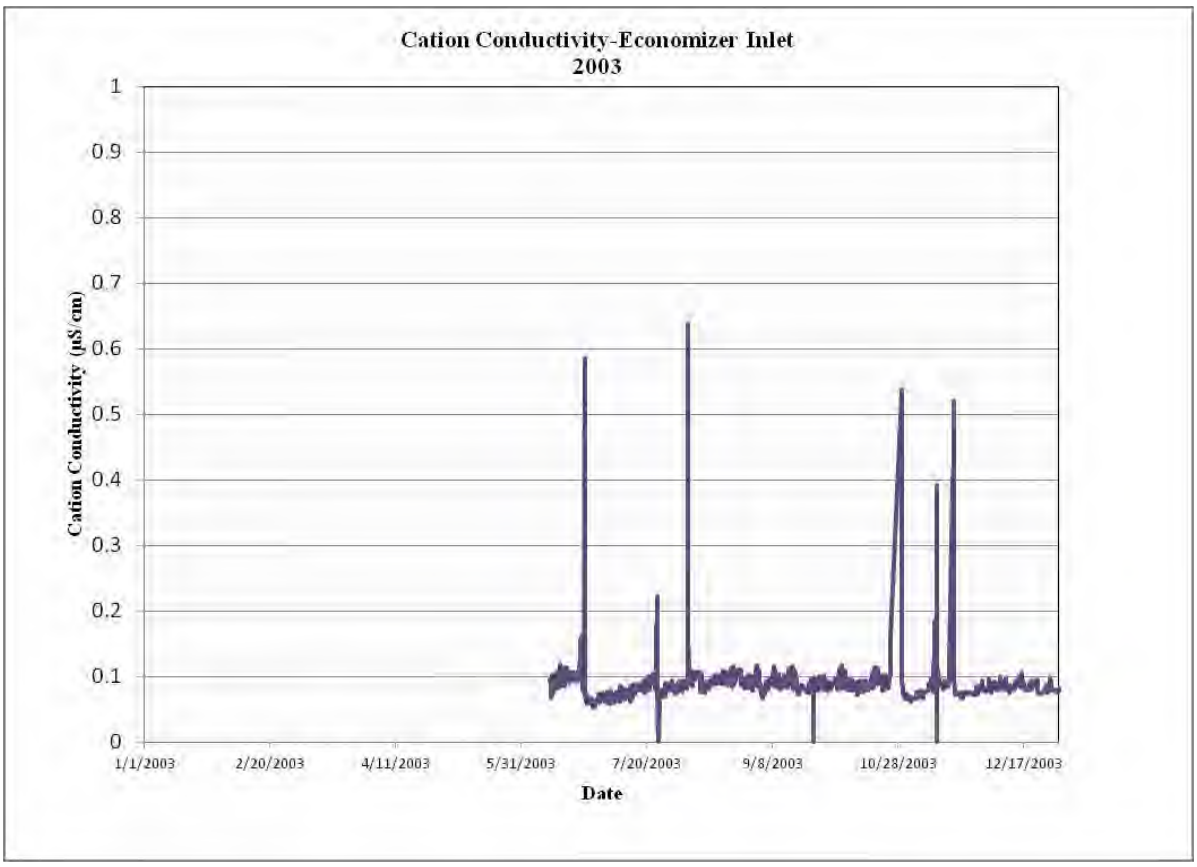
Appendix C17



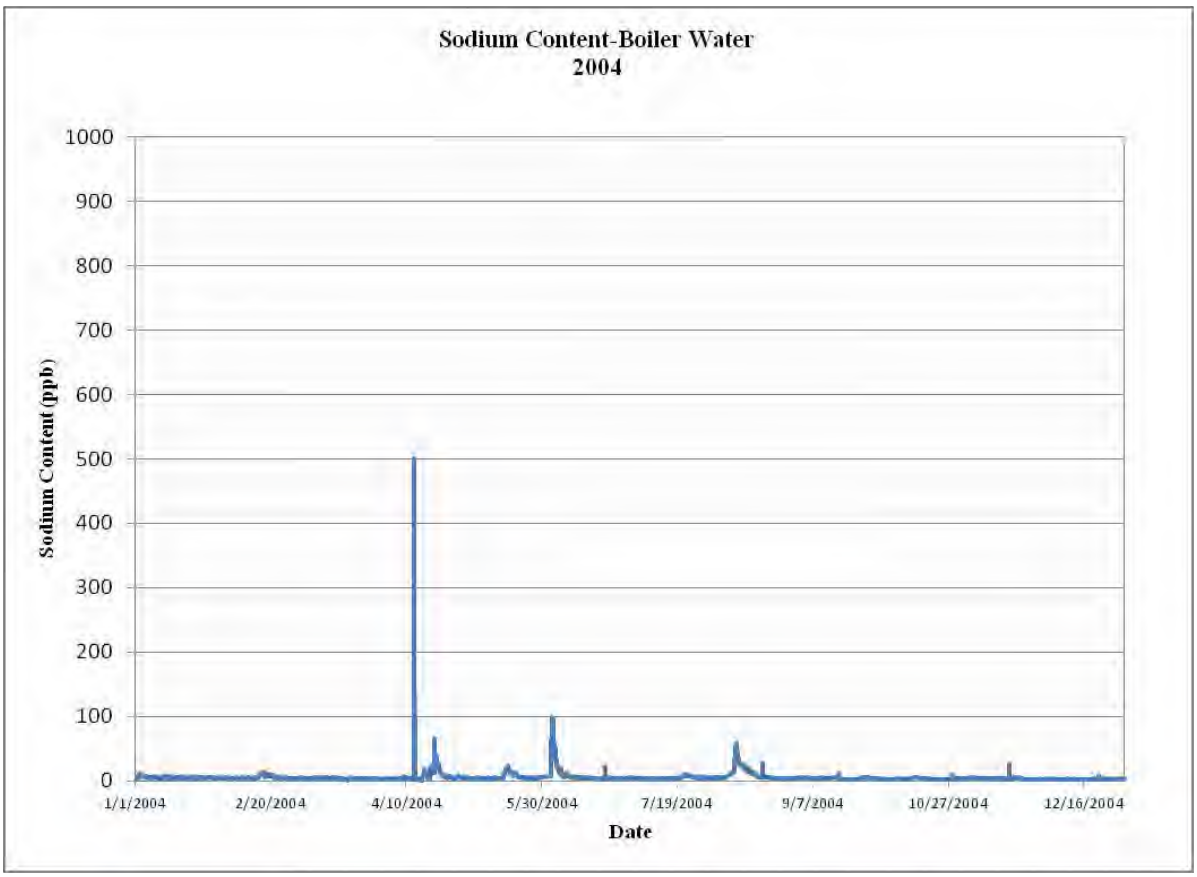
Appendix C18



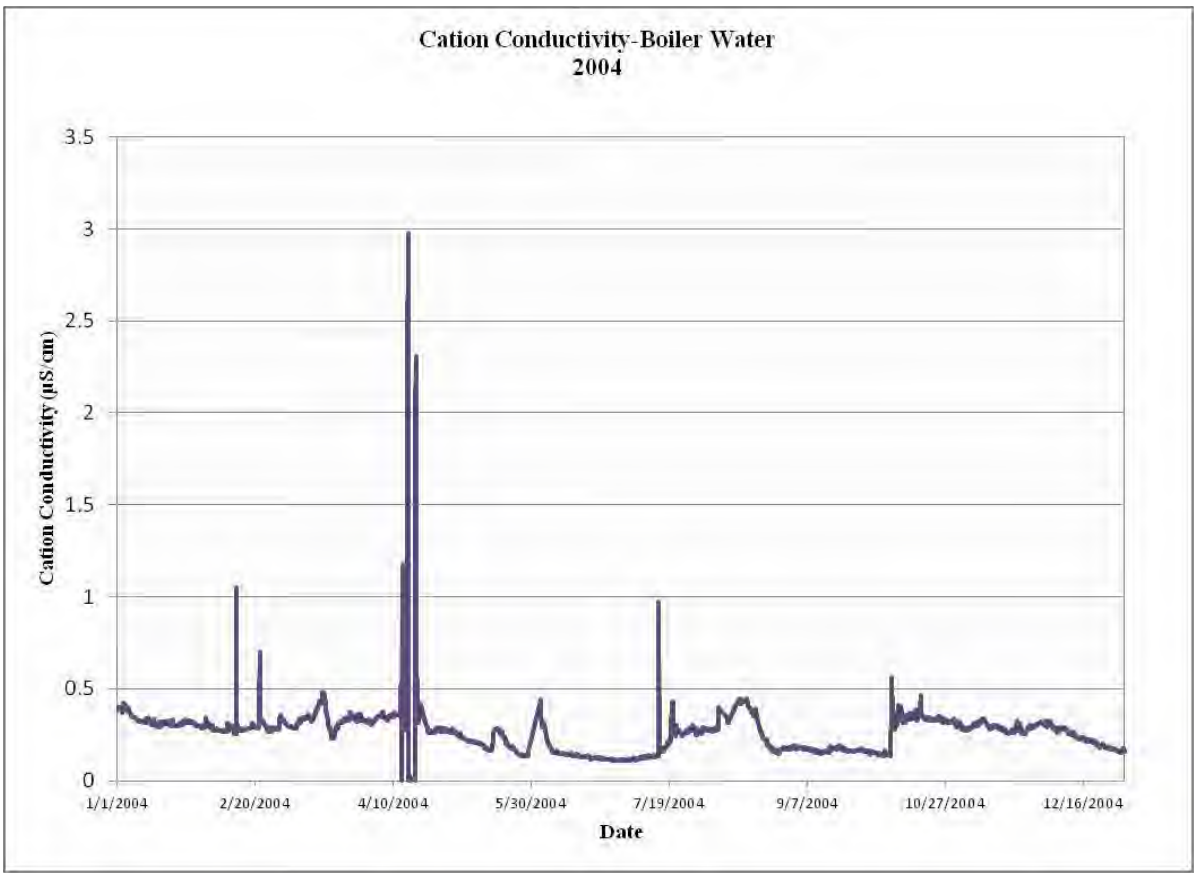
Appendix C19



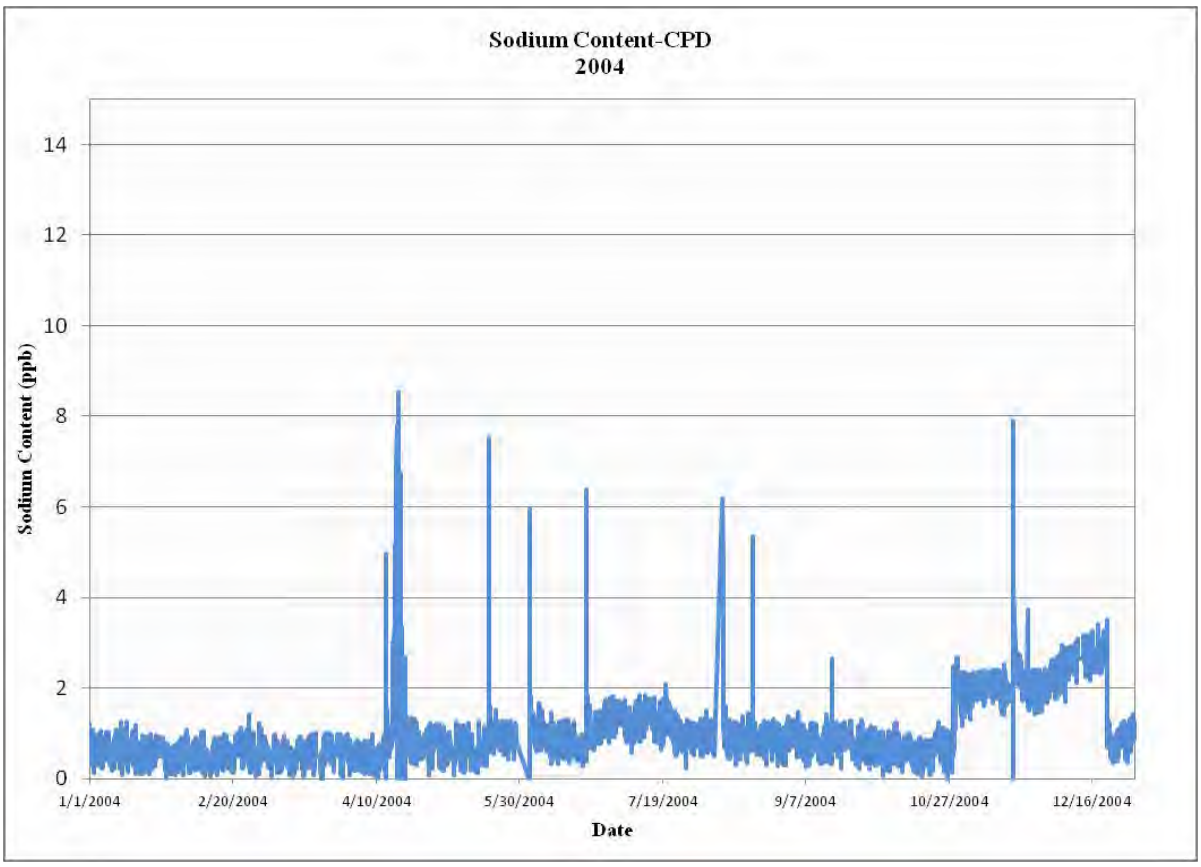
Appendix C20



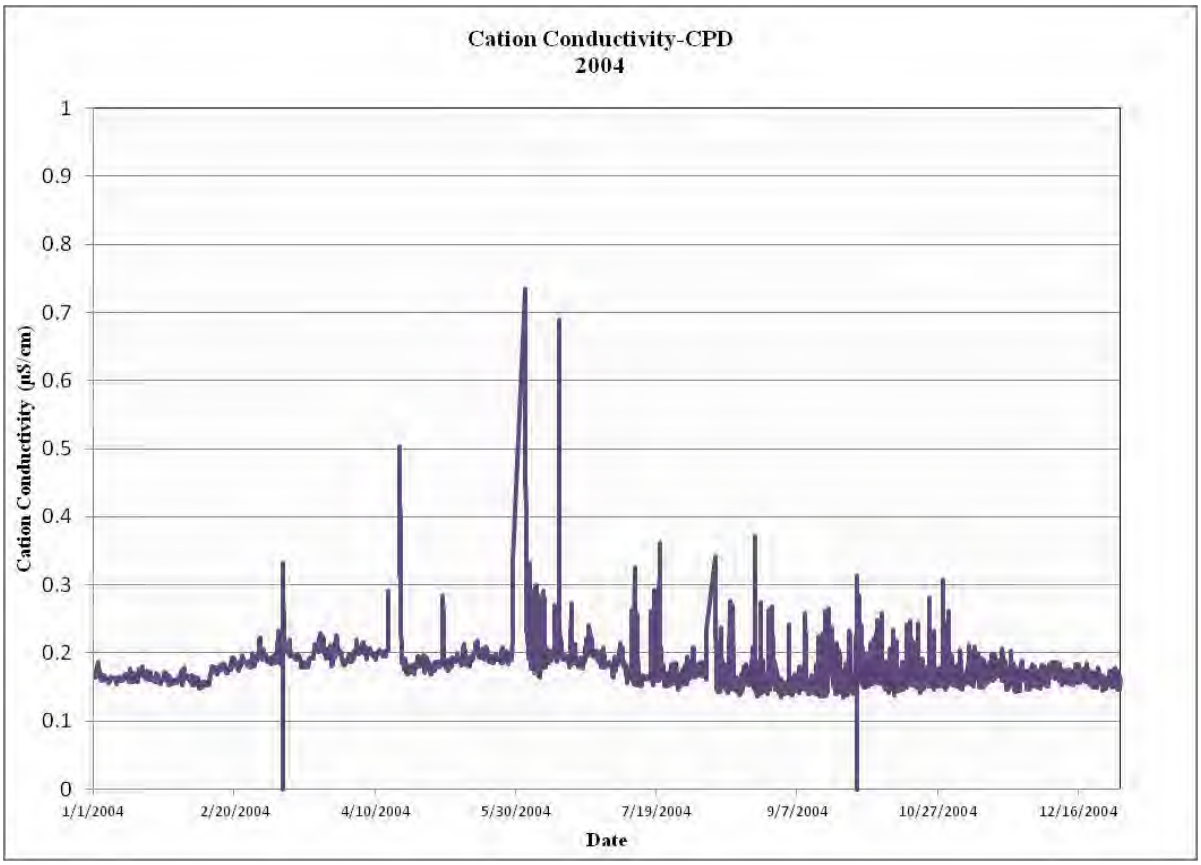
Appendix C21



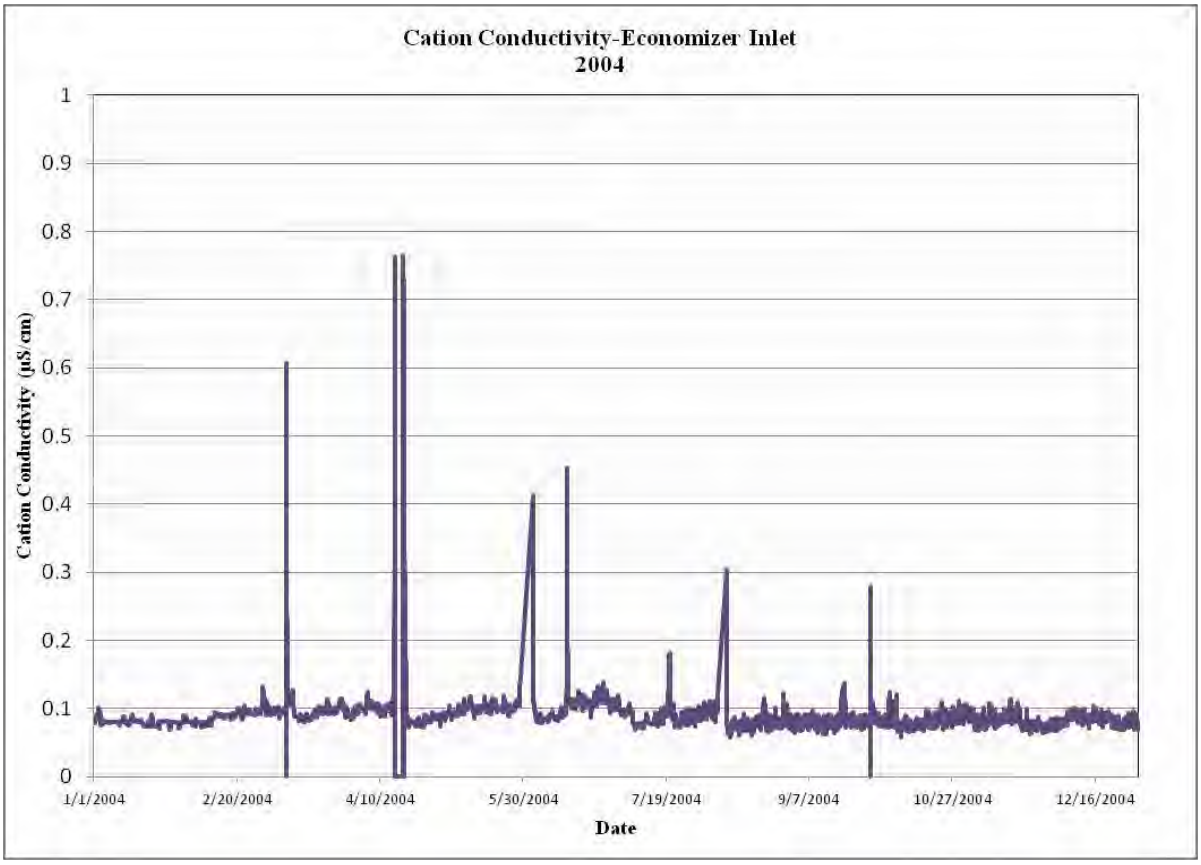
Appendix C22



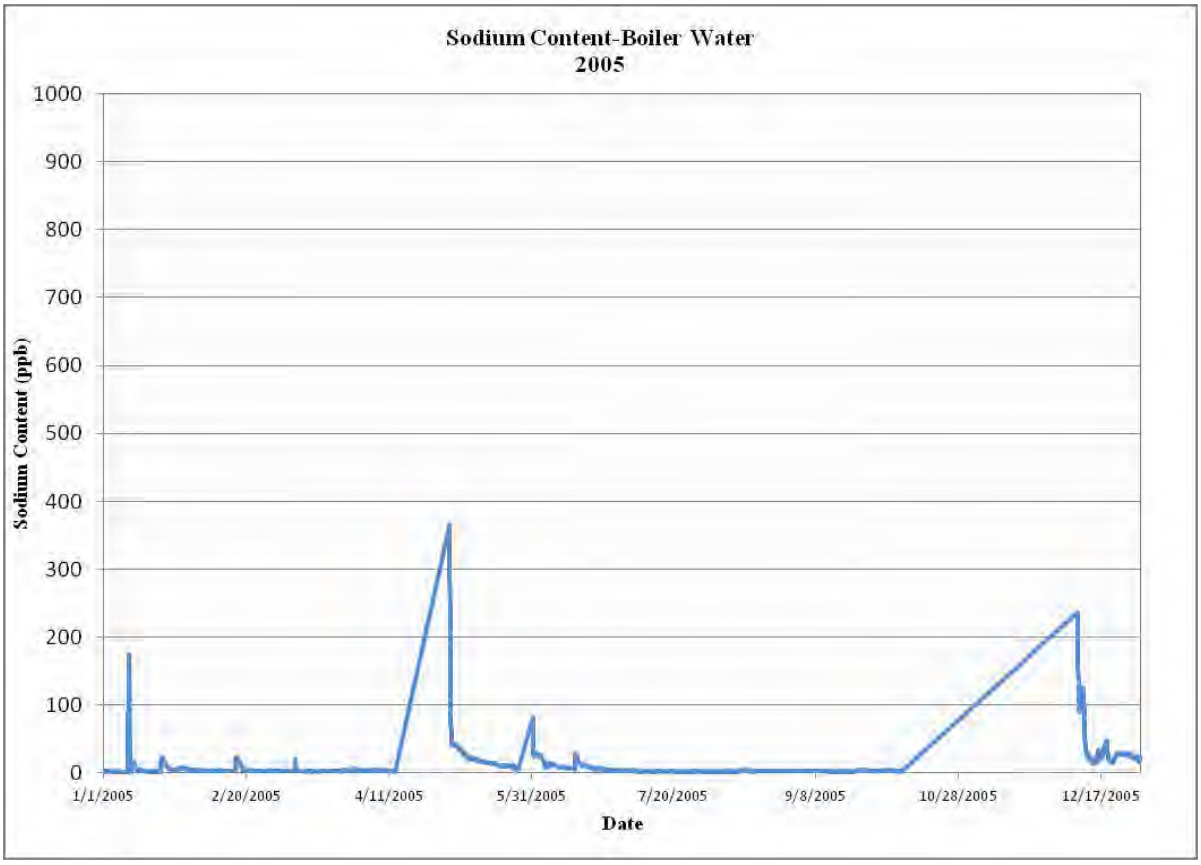
Appendix C23



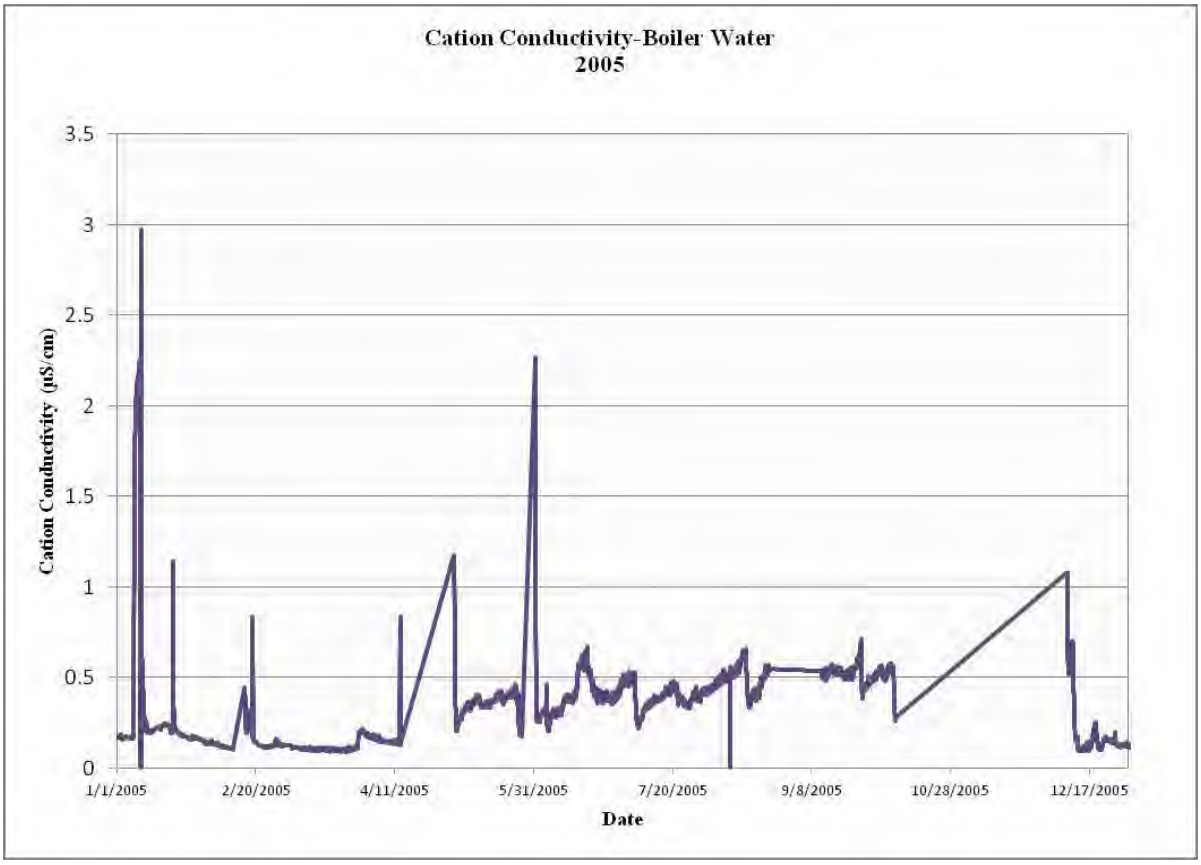
Appendix C24



Appendix C25



Appendix C26



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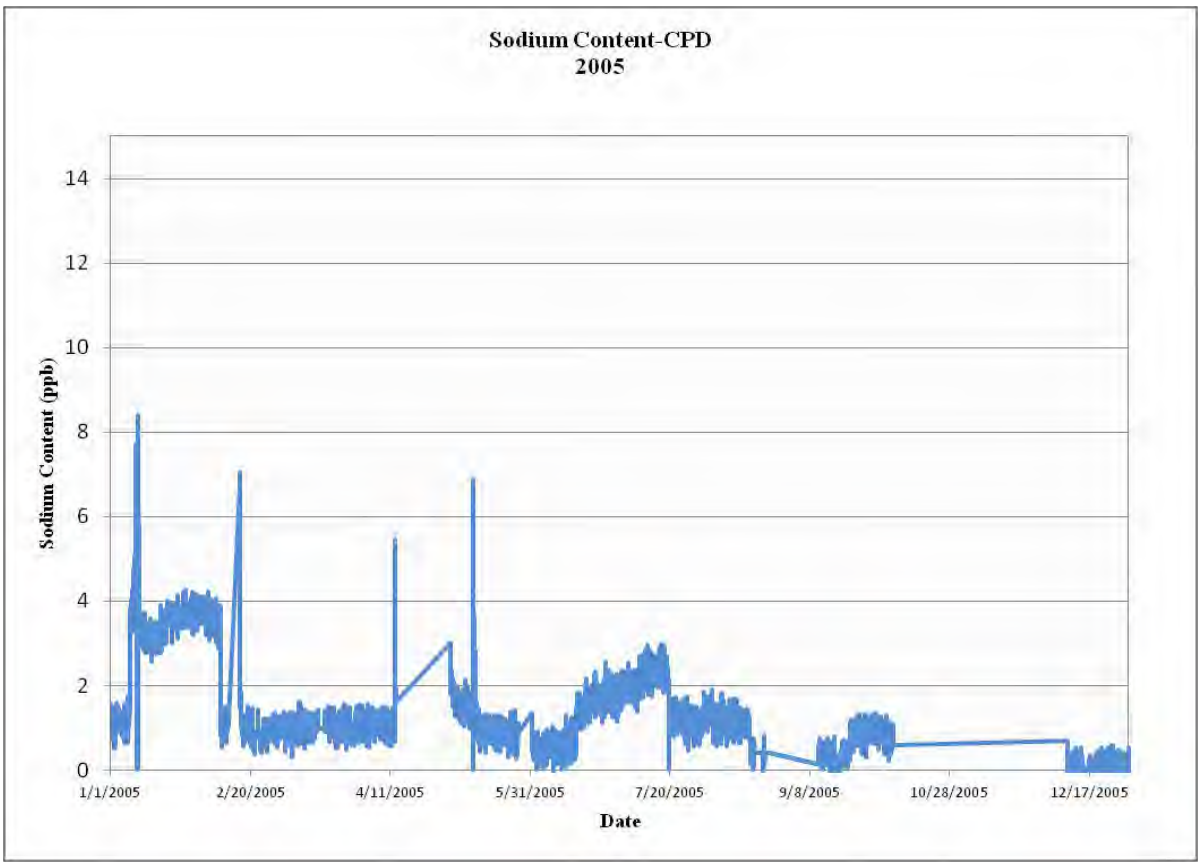

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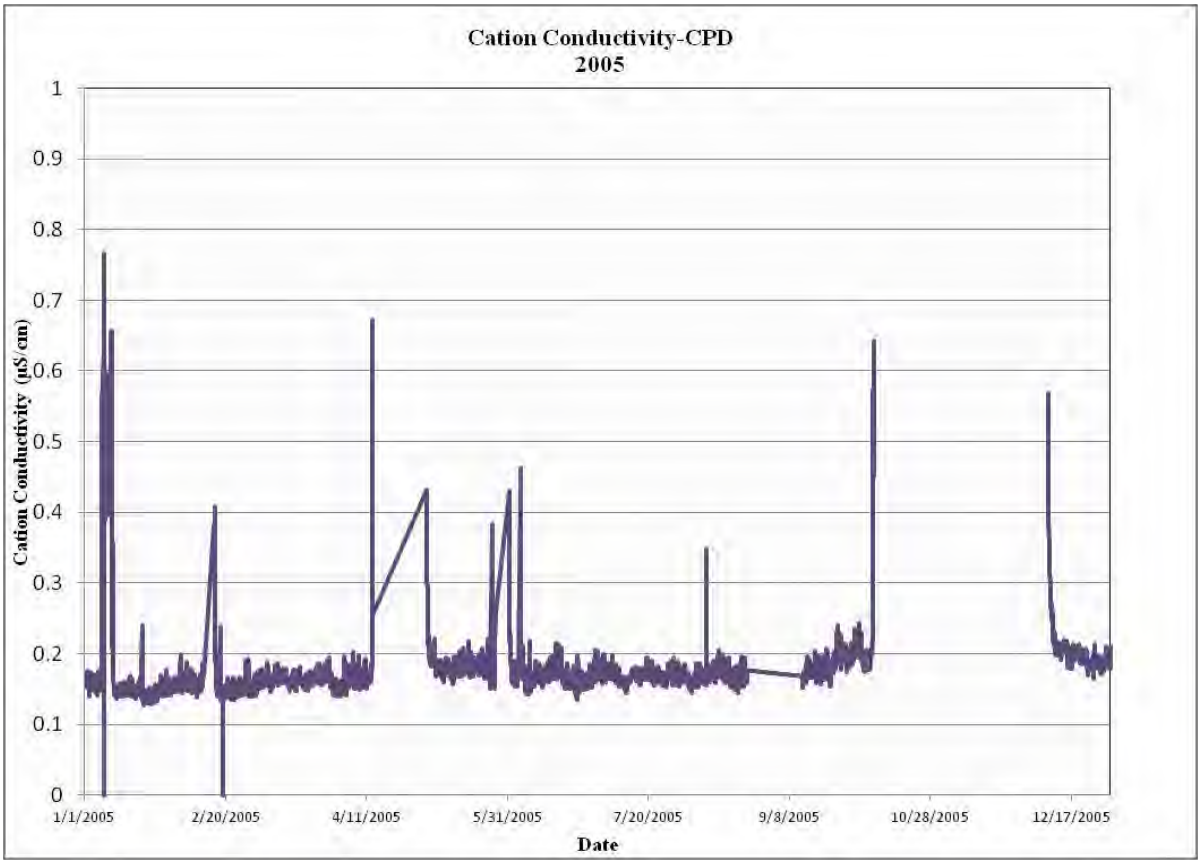
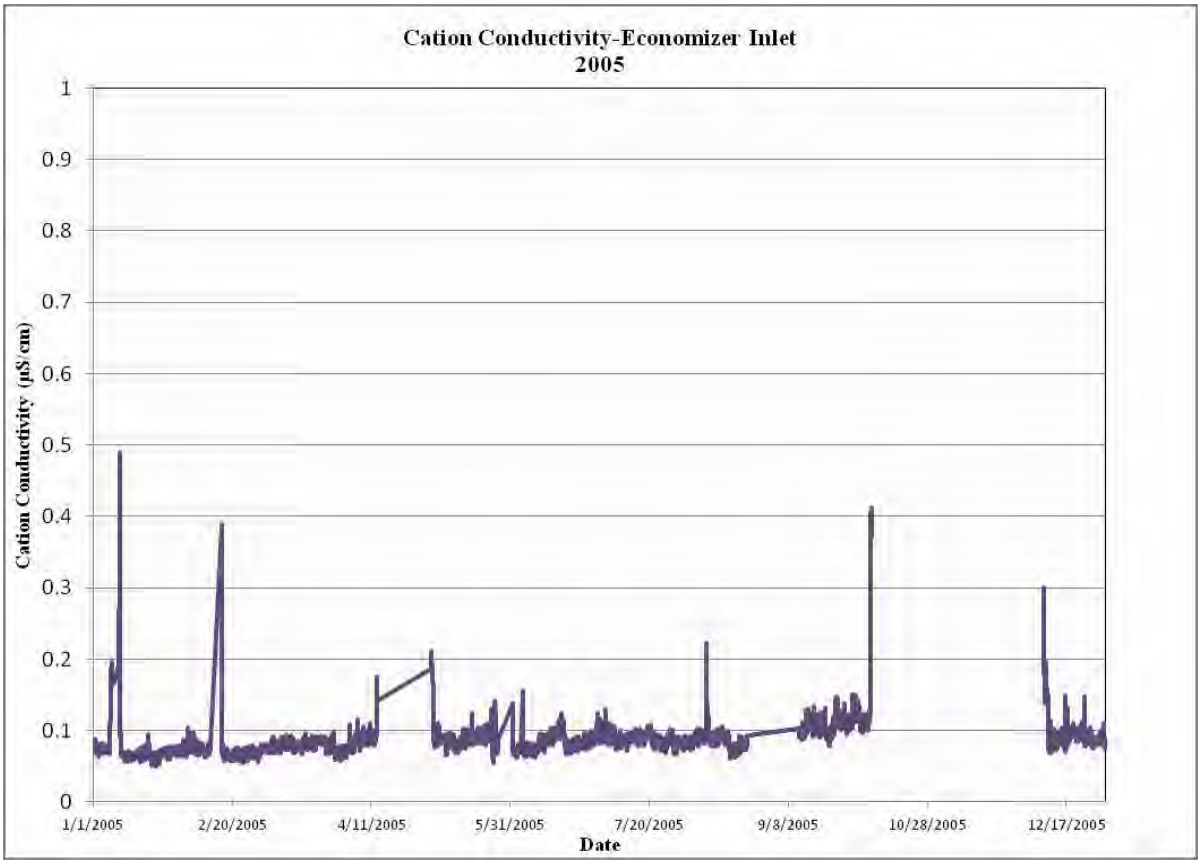
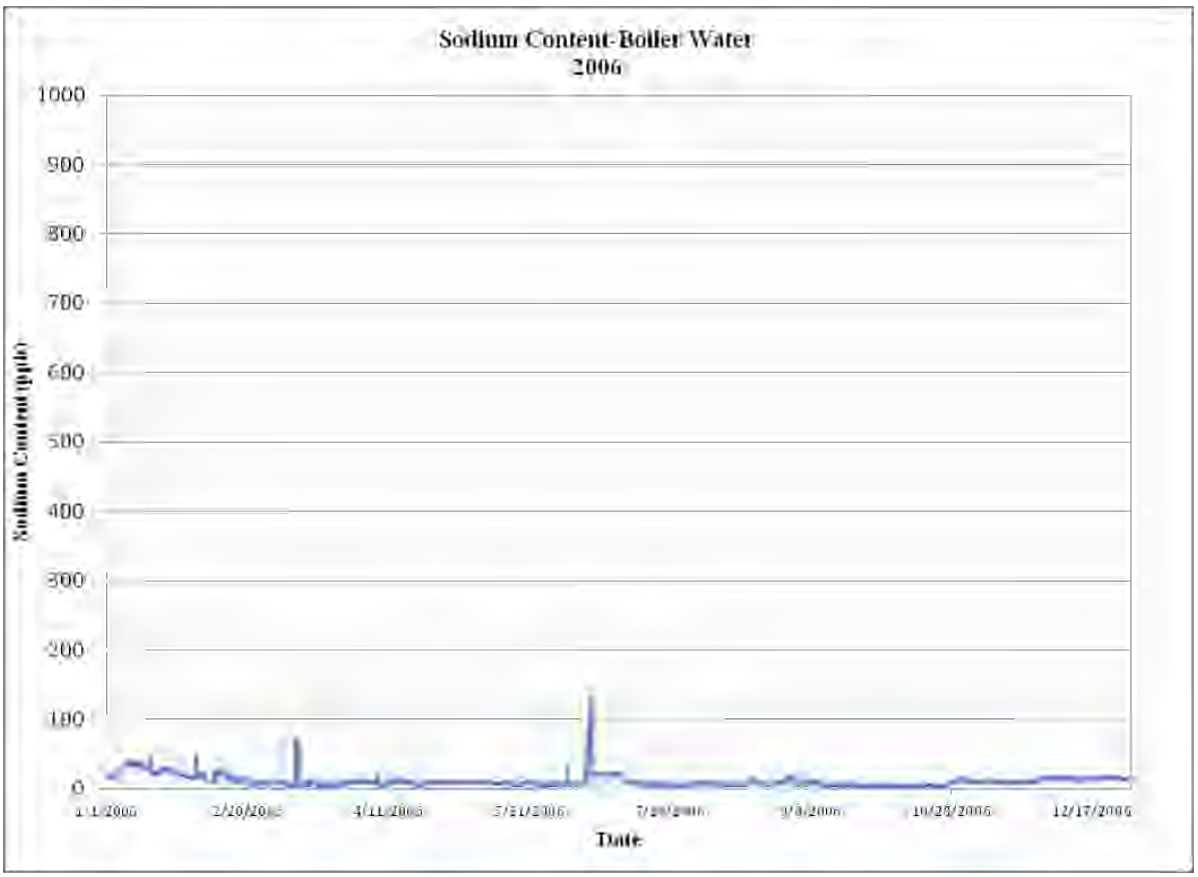


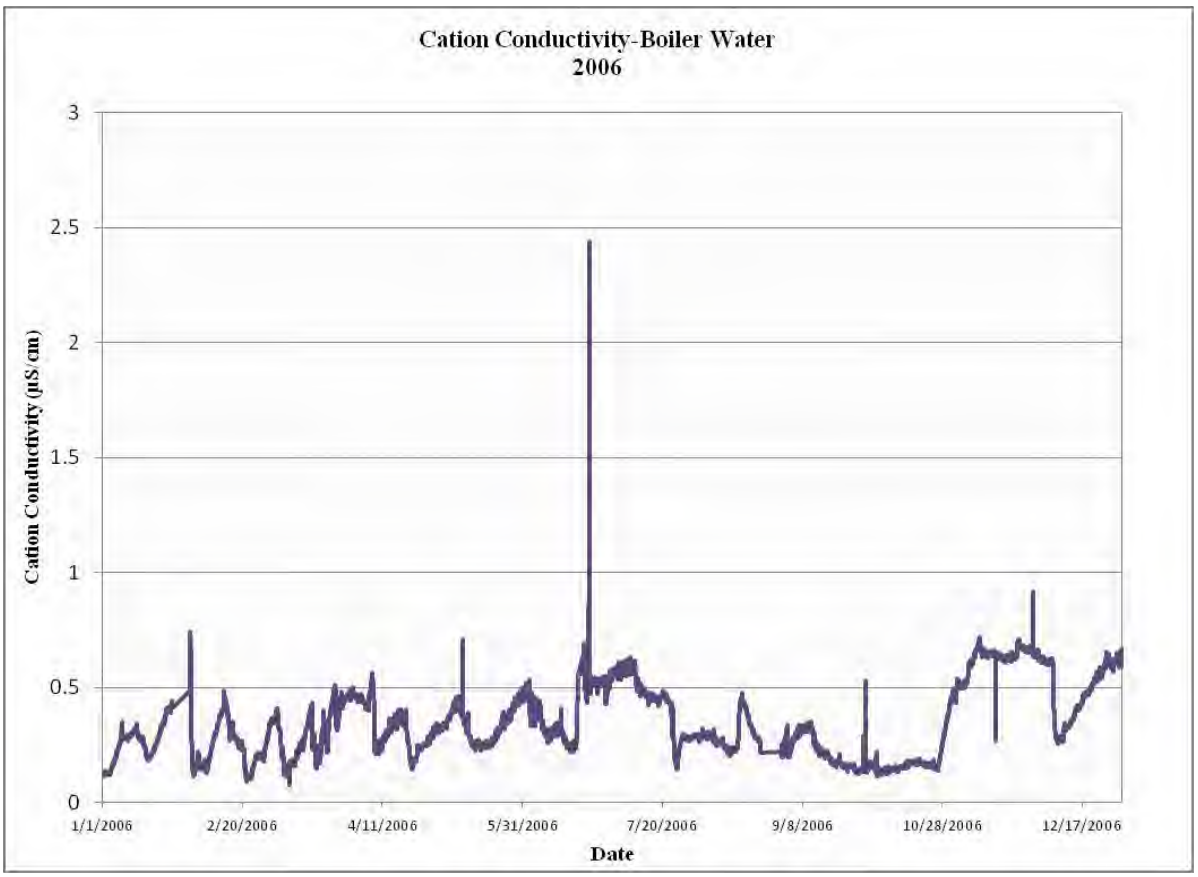
Appendix C29



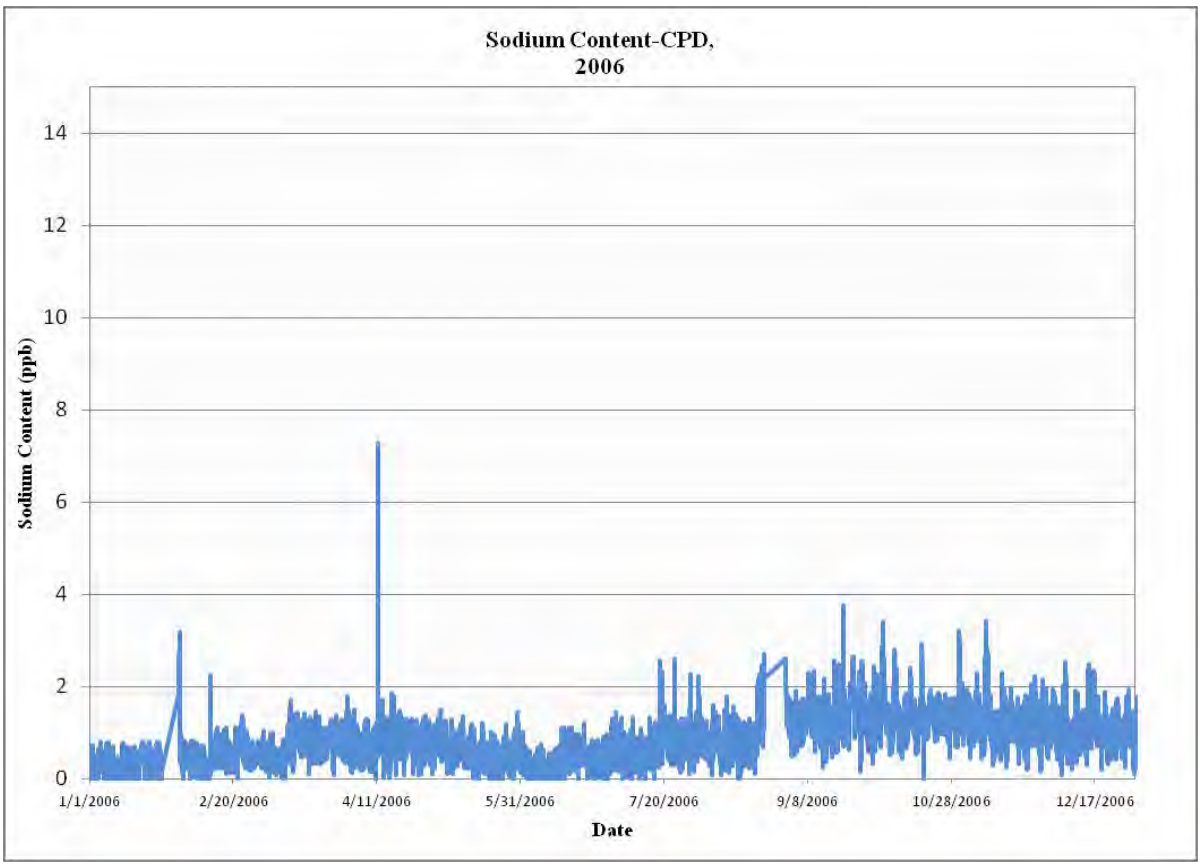
Appendix C30



Appendix C31



Appendix C32



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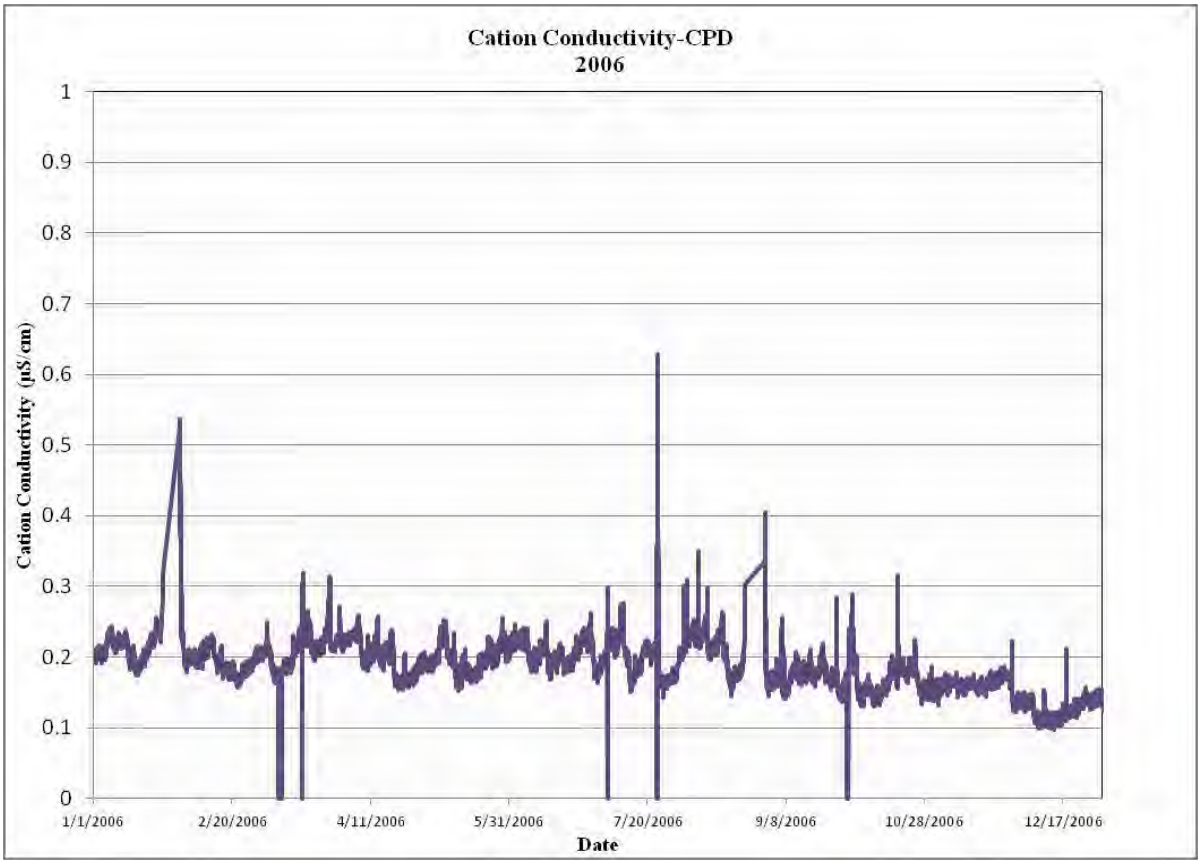
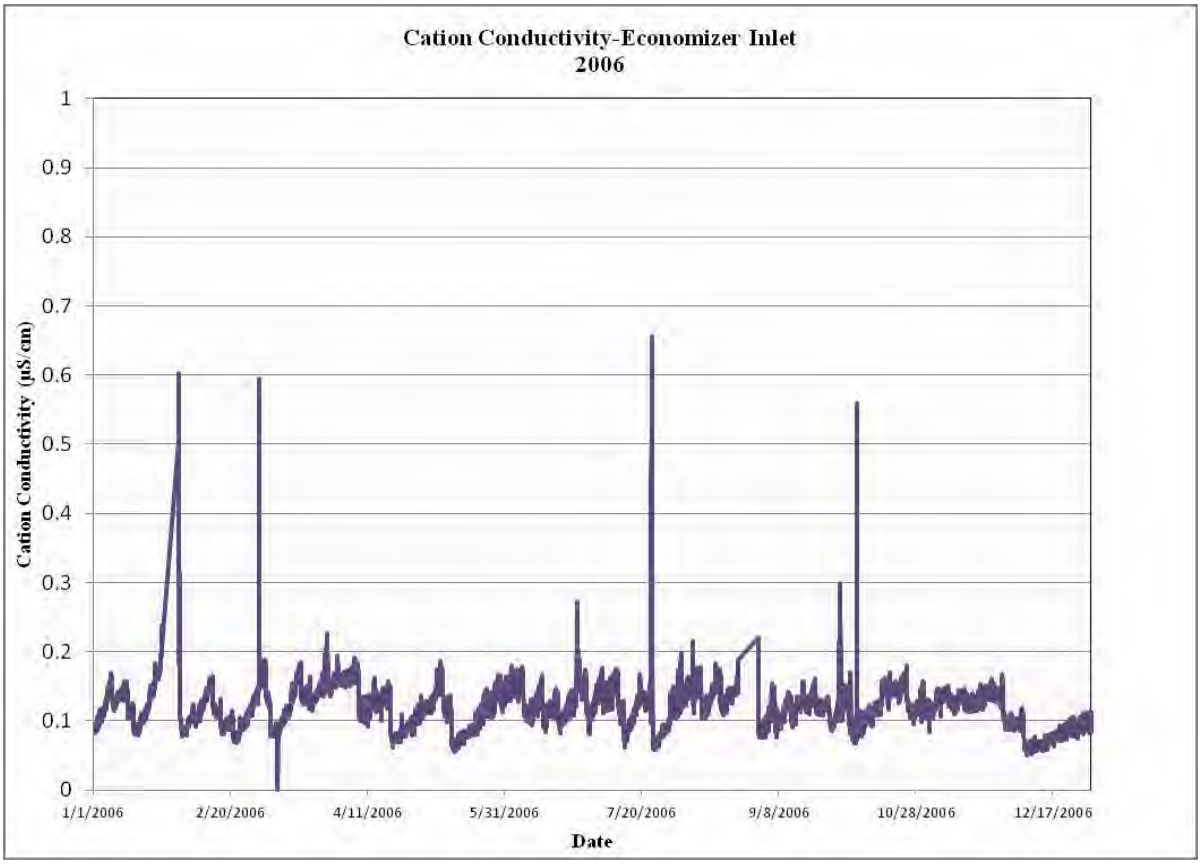


Appendix C34



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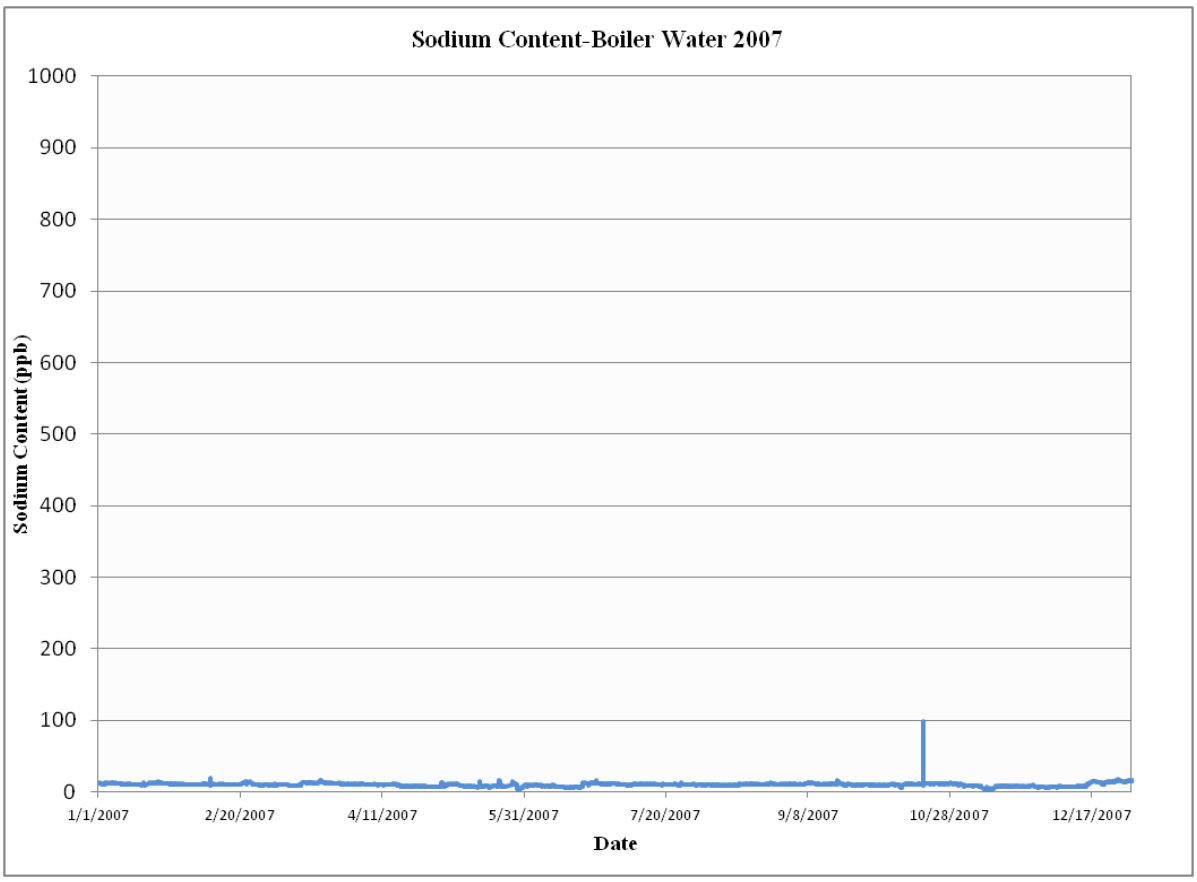

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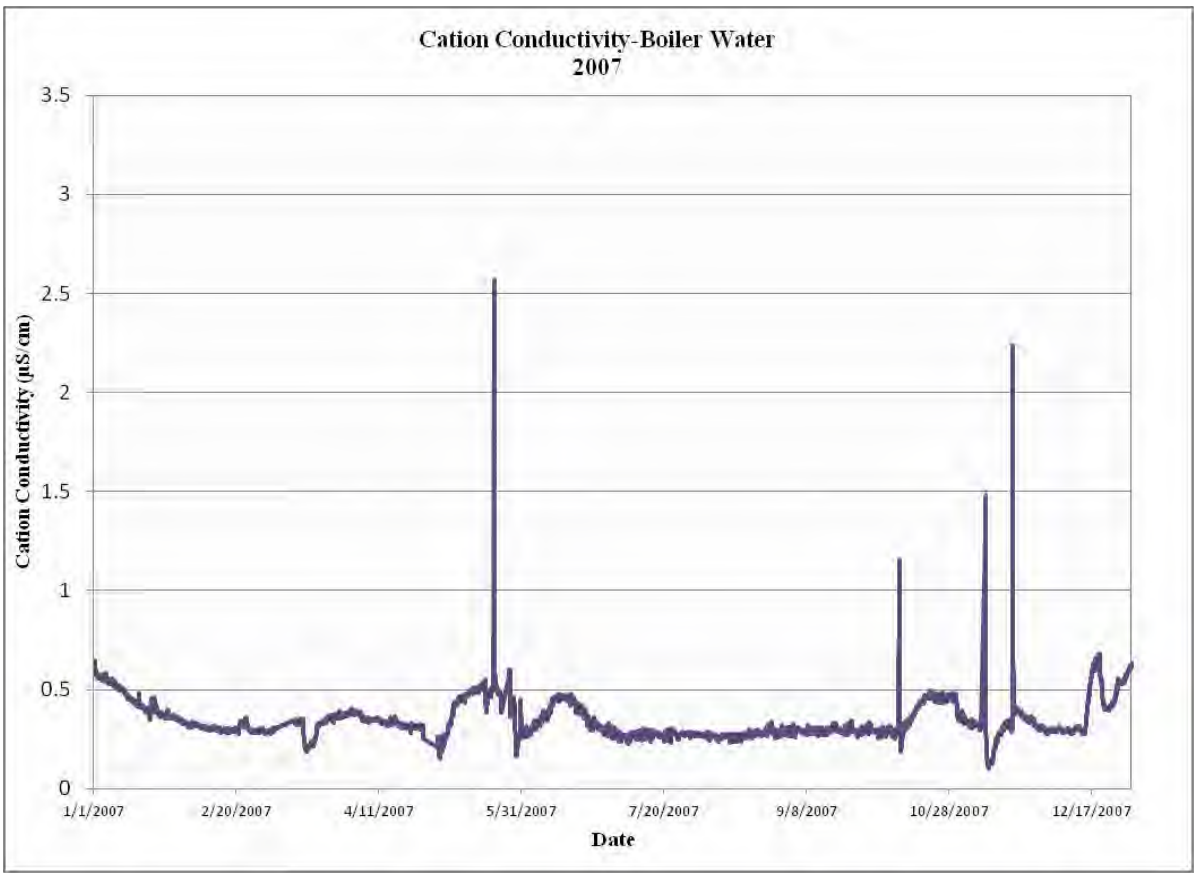
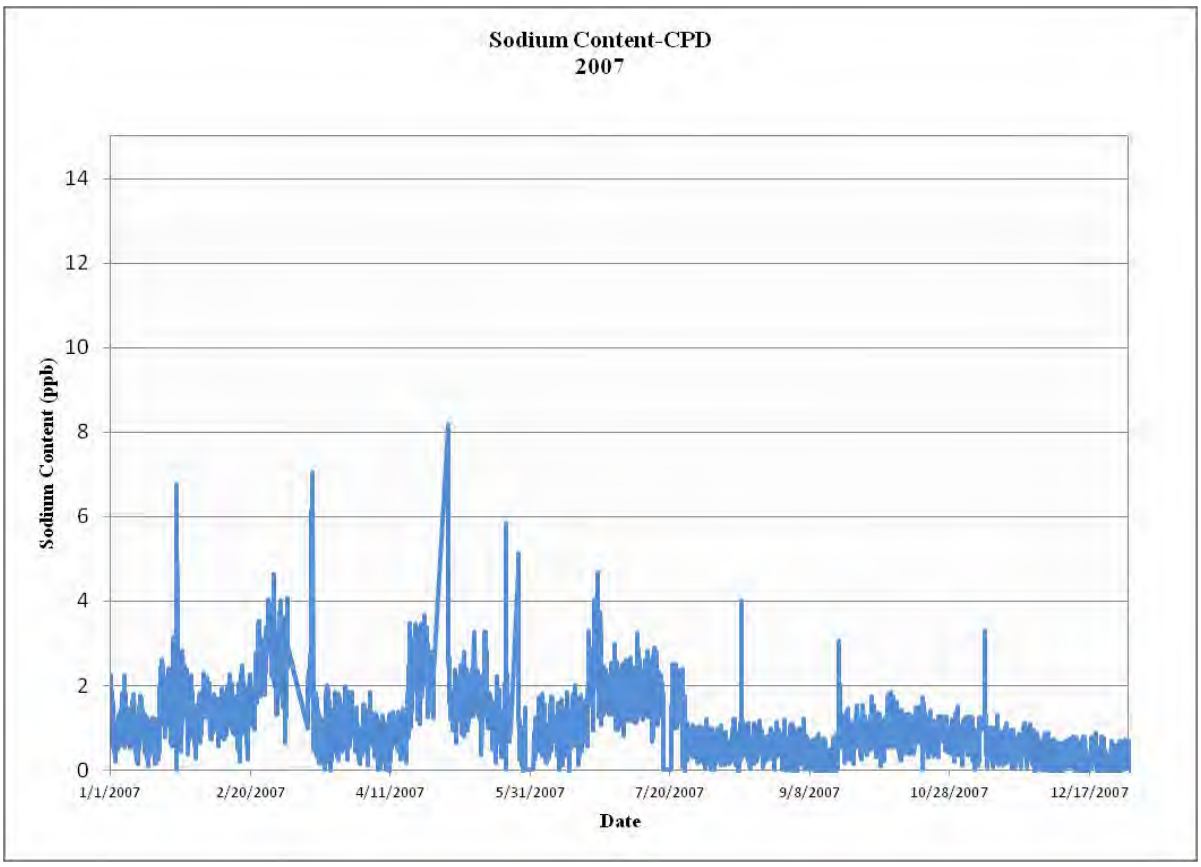
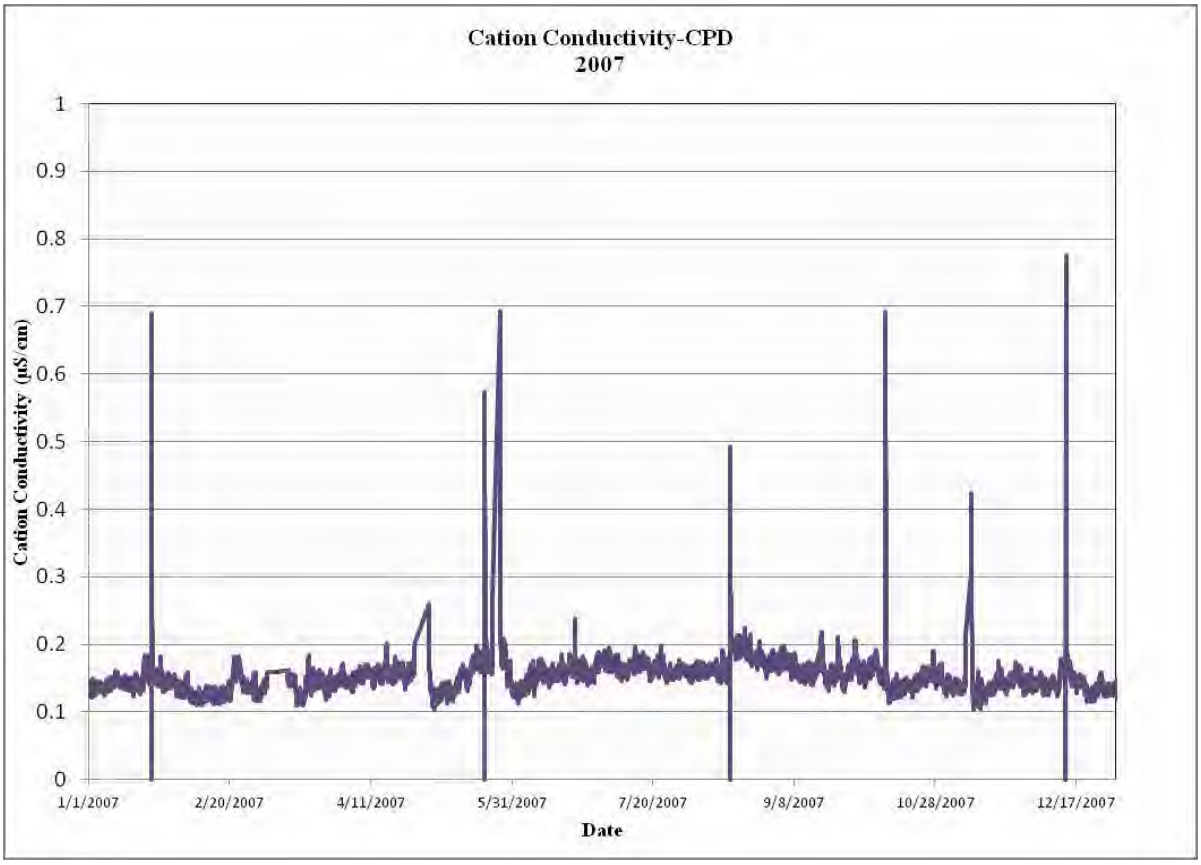


Appendix C37



Appendix C38



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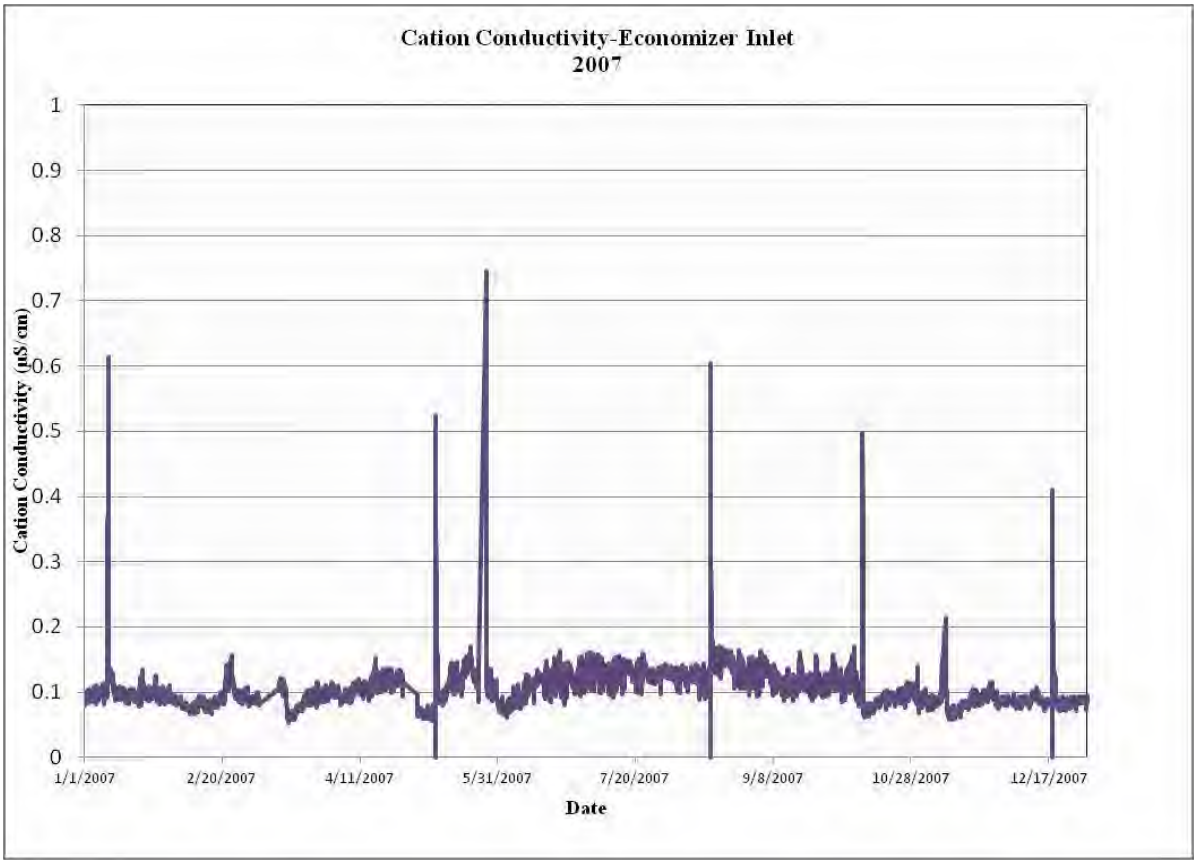
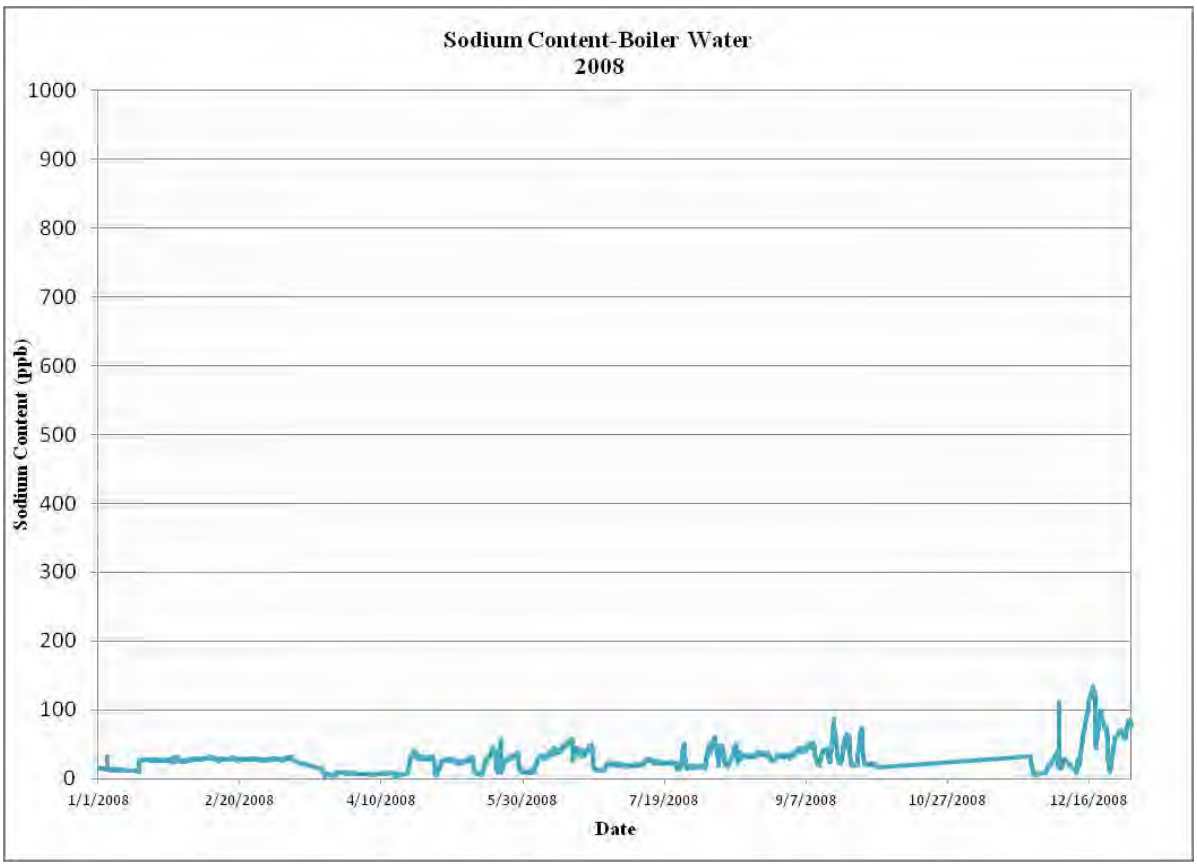
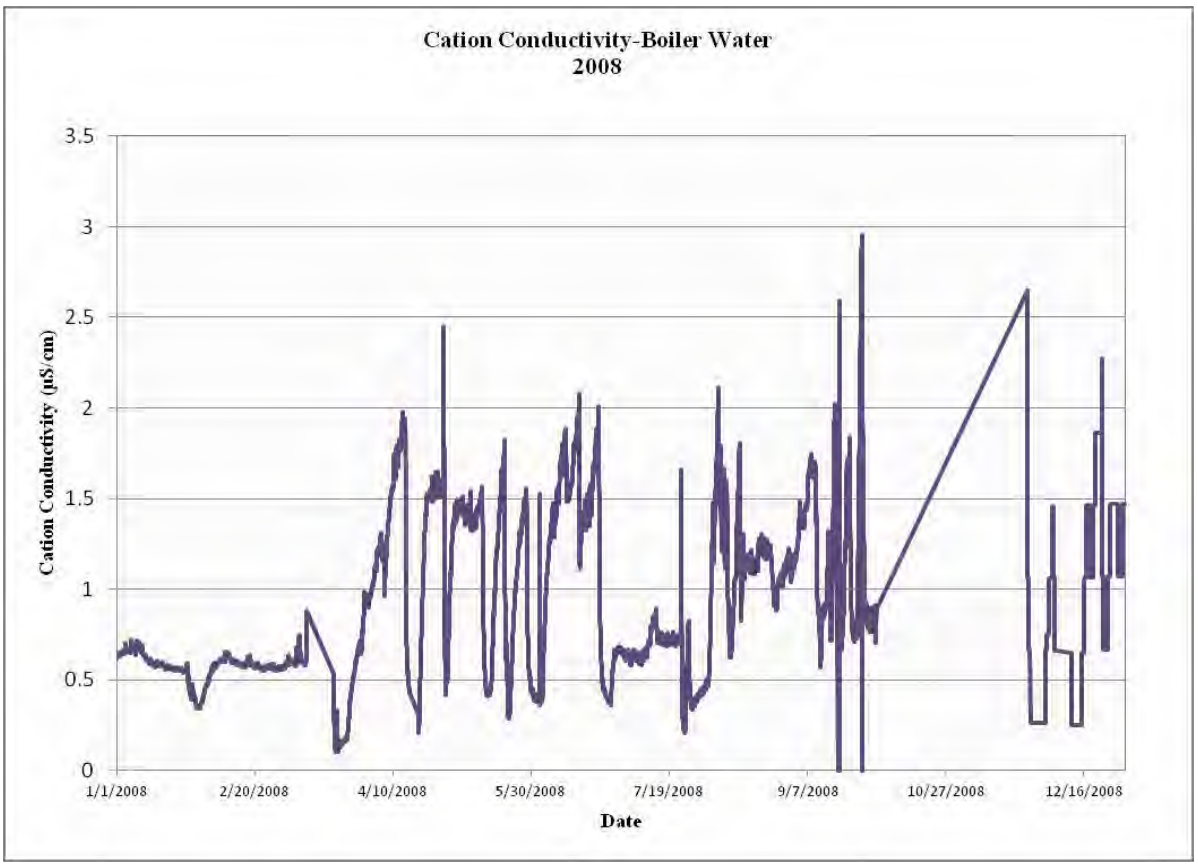


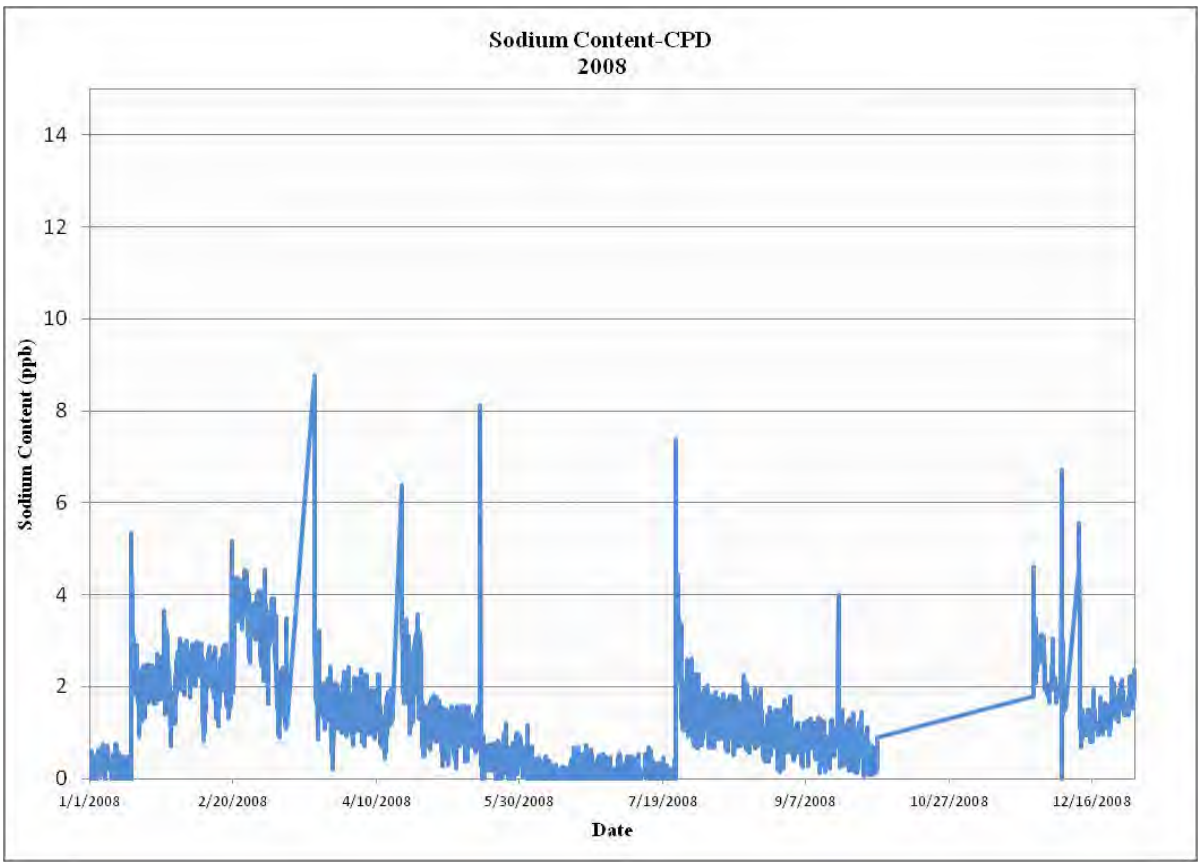
Appendix C40



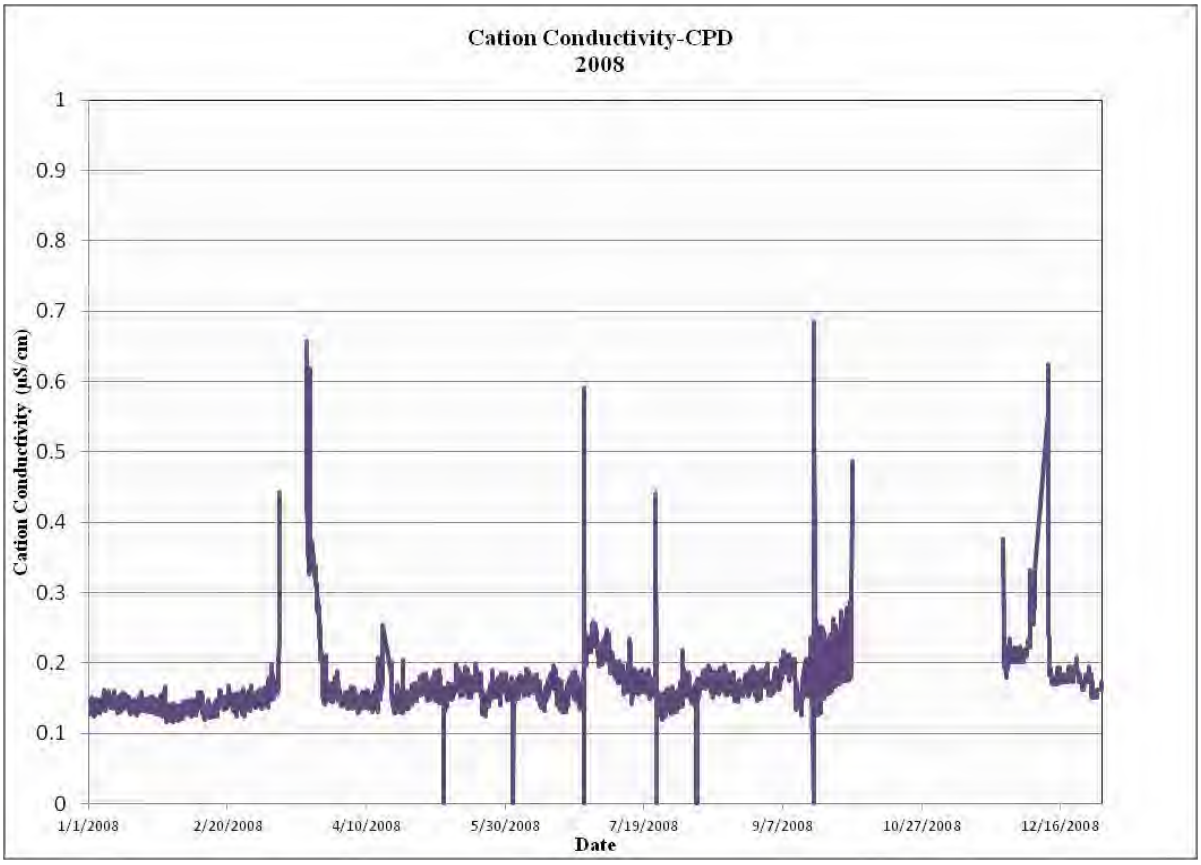
Appendix C41



Appendix C42



Appendix C43



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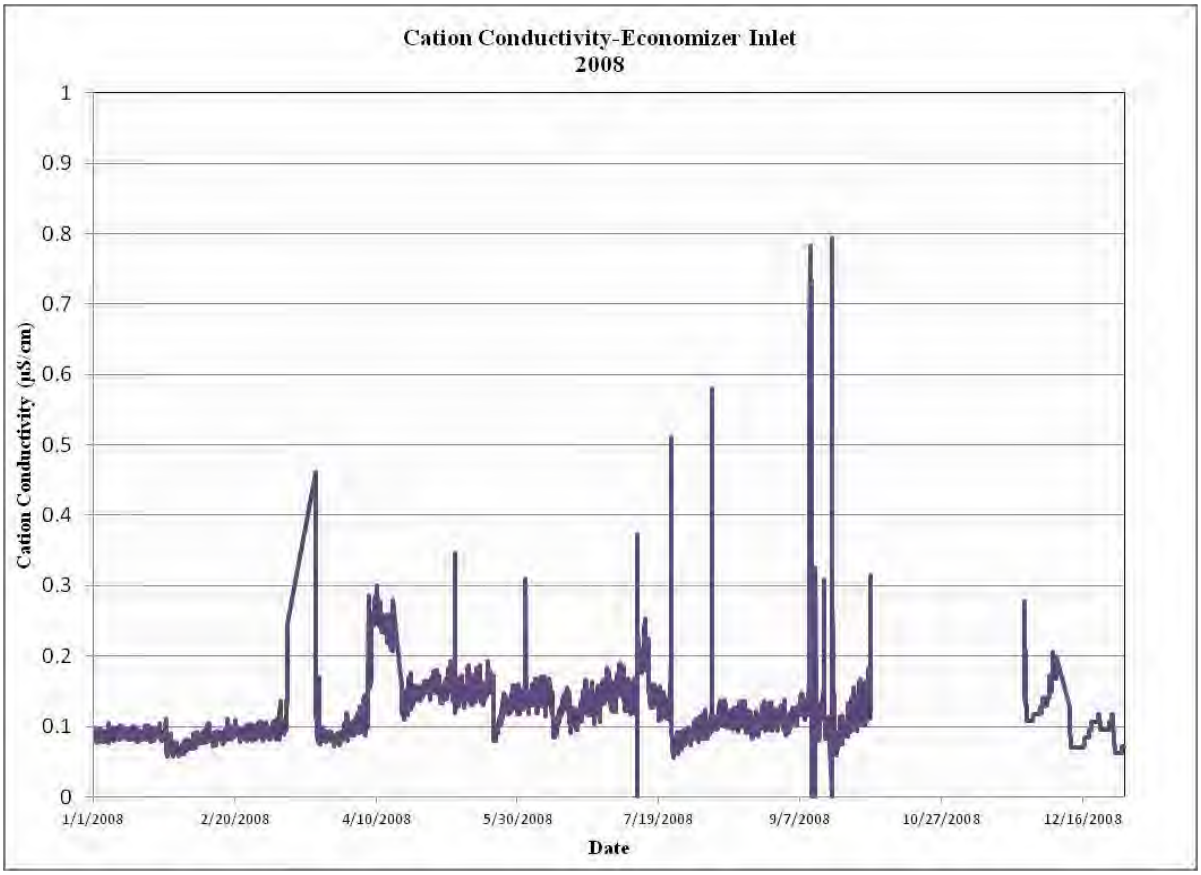

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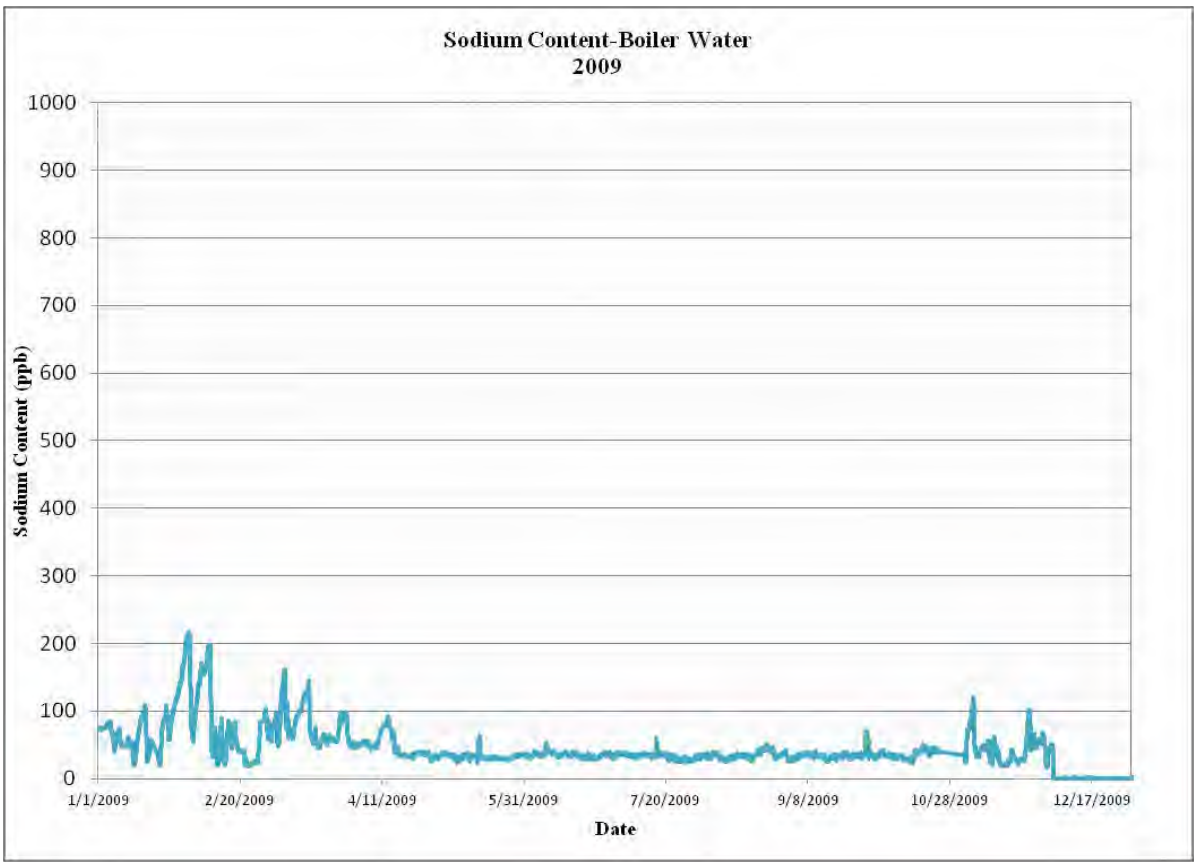

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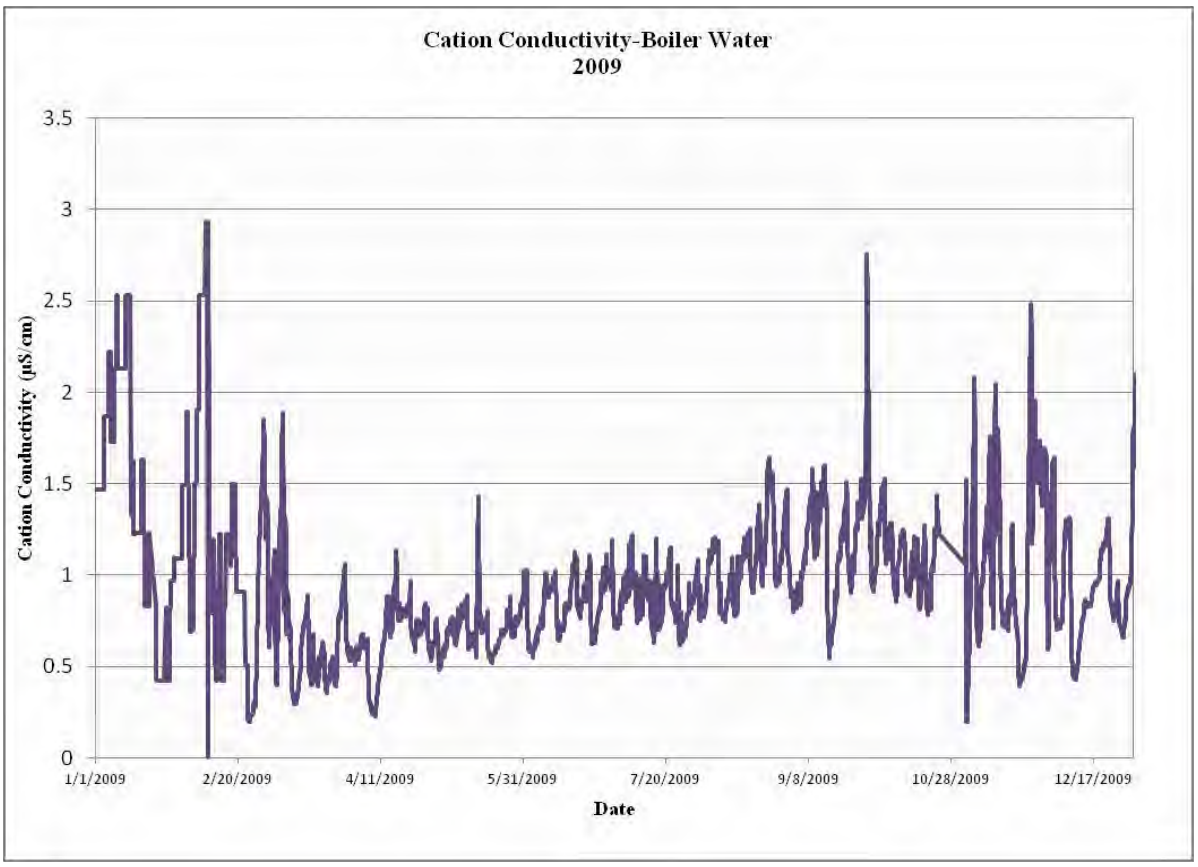
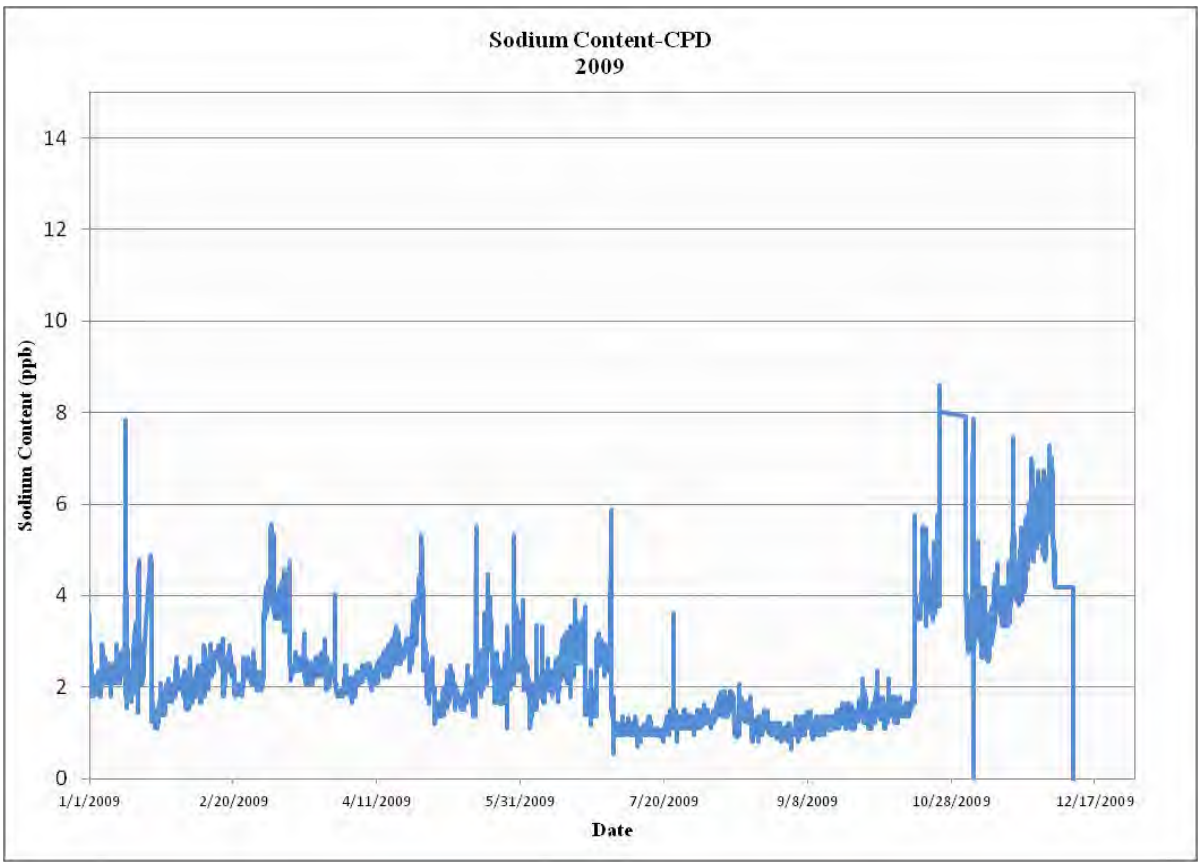
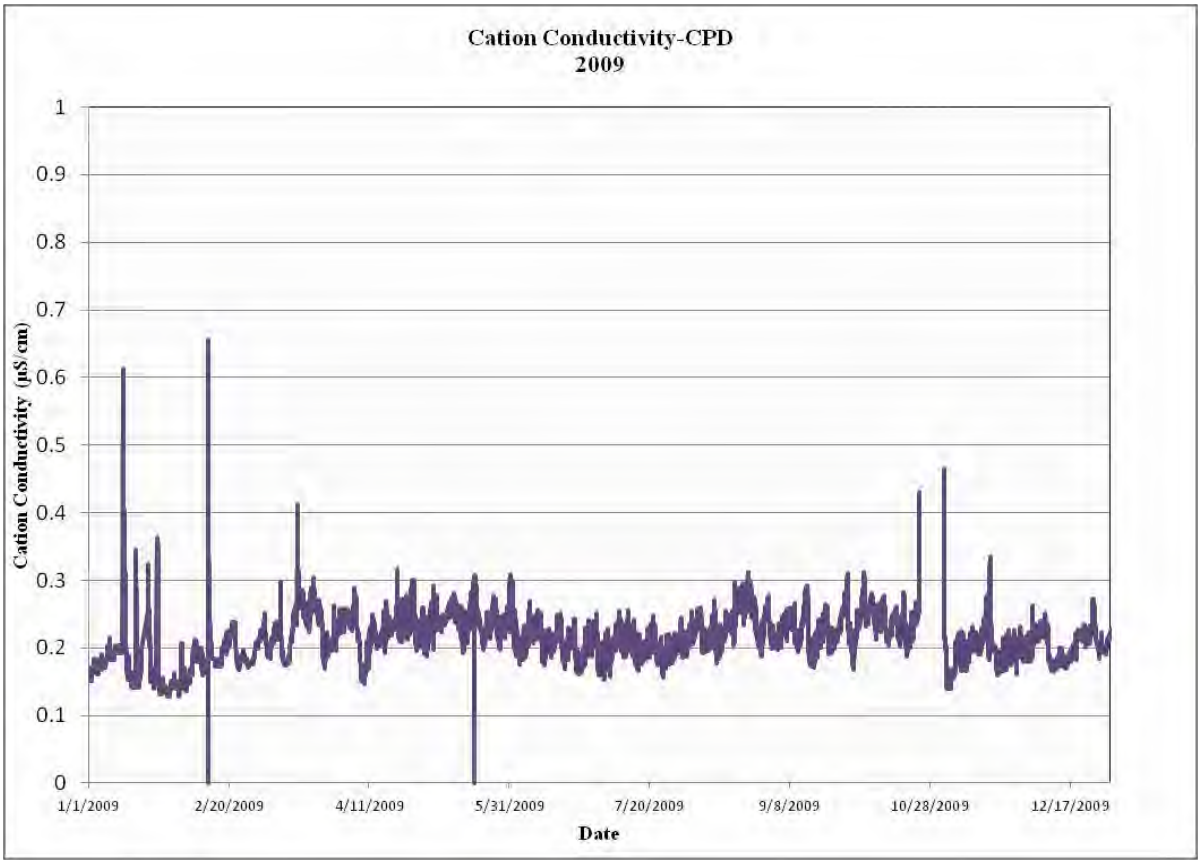


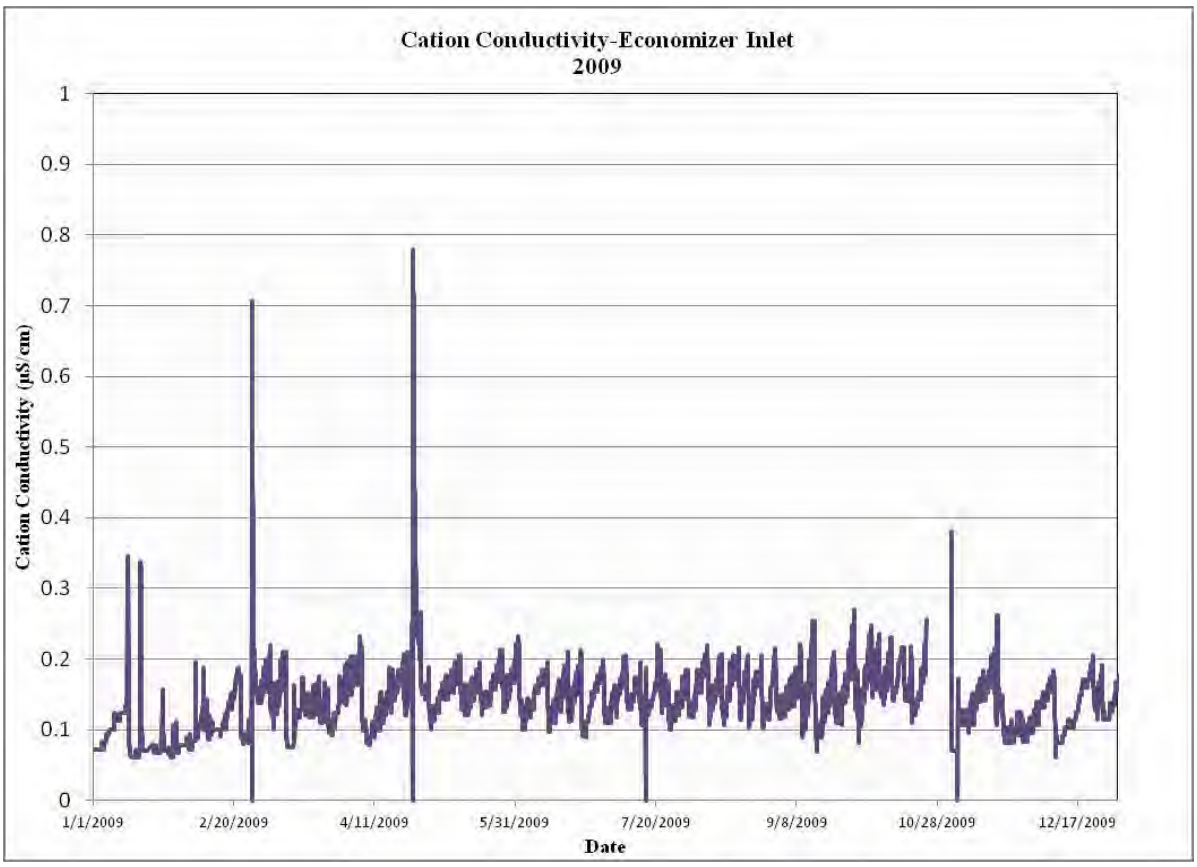
Appendix C47



Appendix C48



Appendix C49



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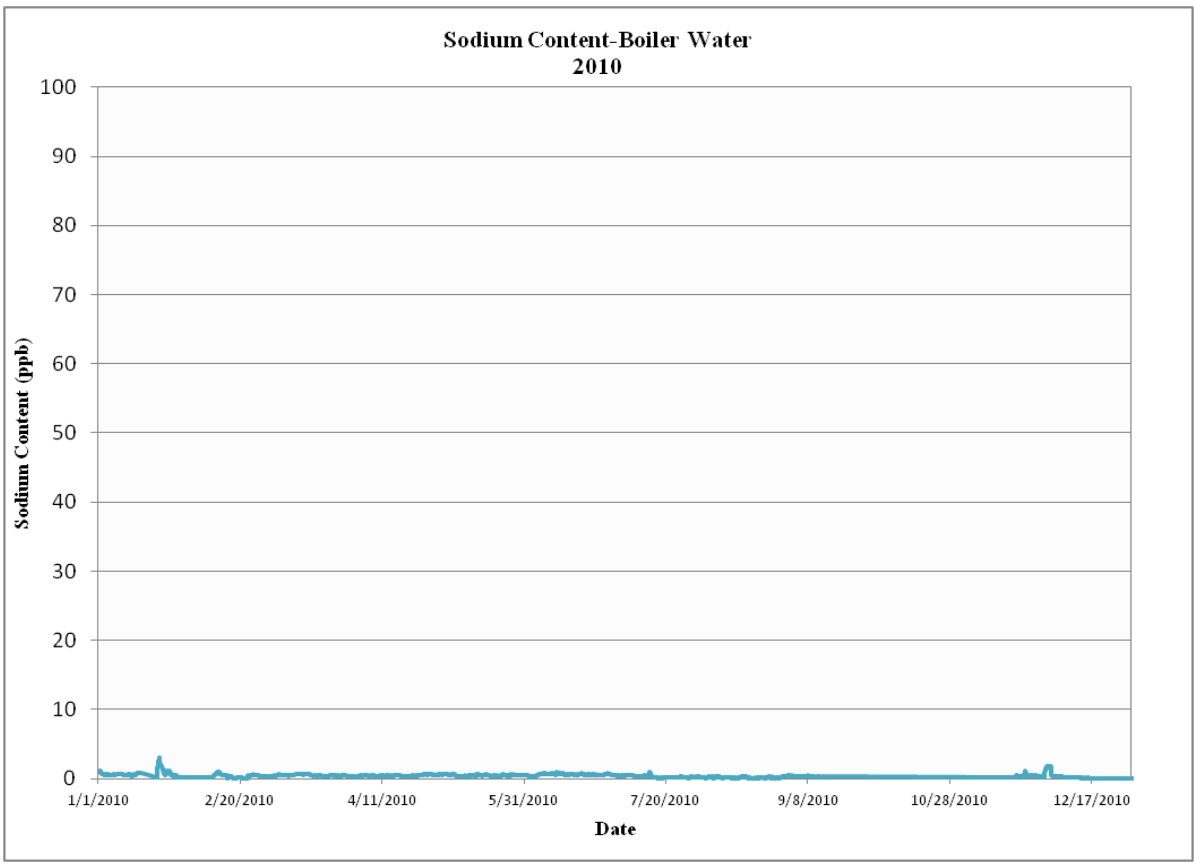

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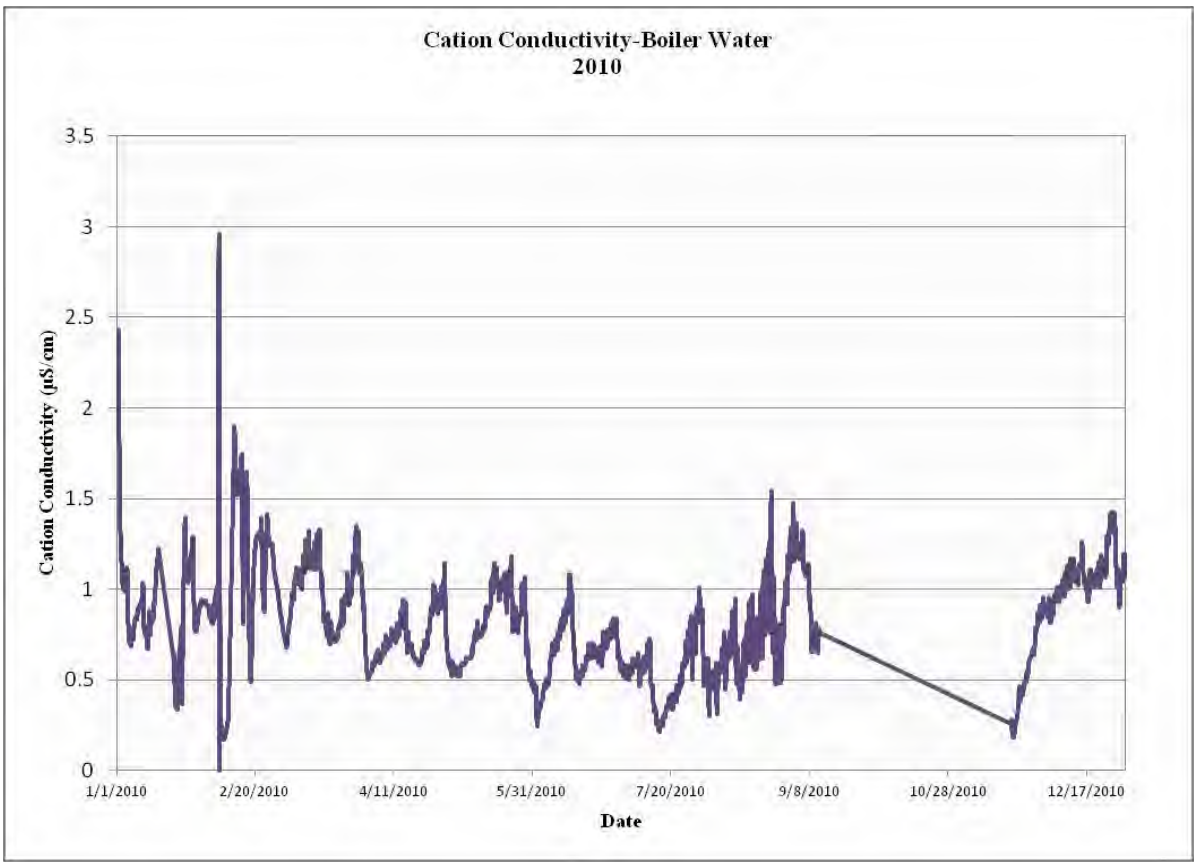
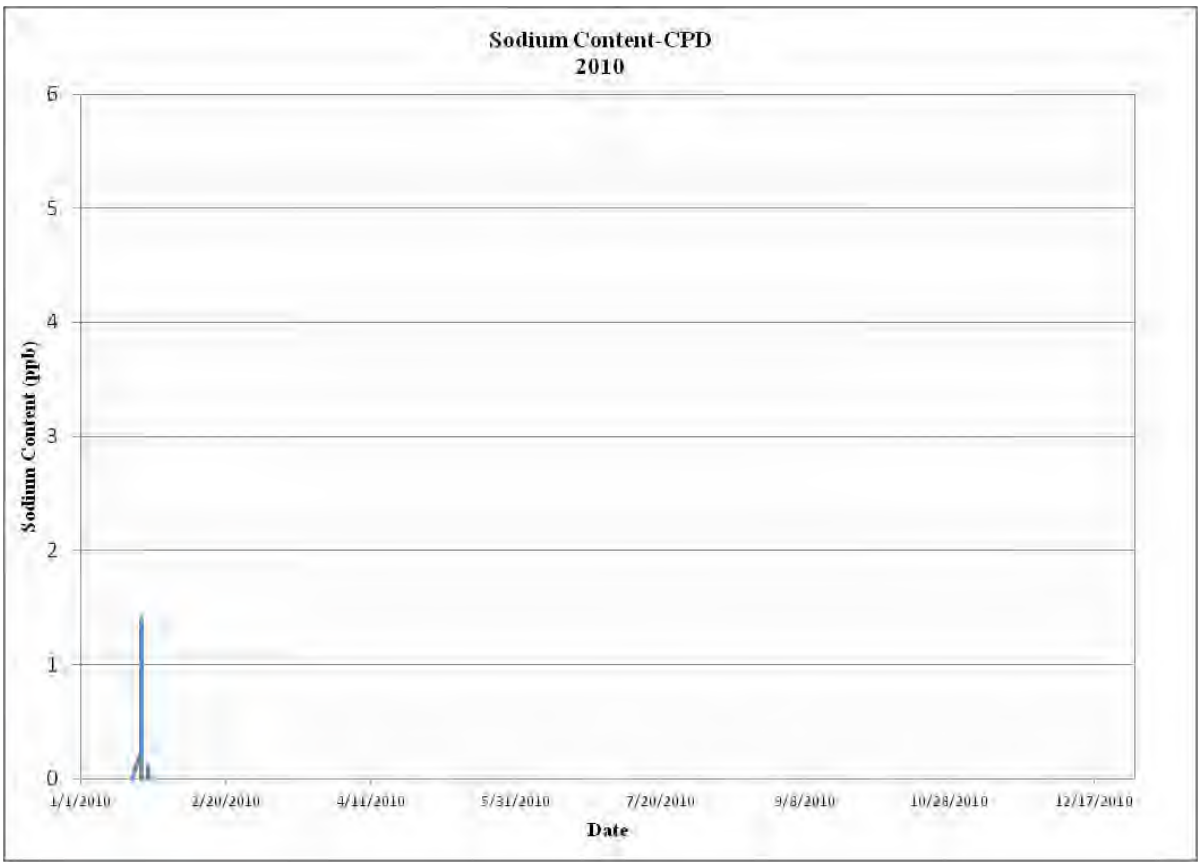


Appendix C52



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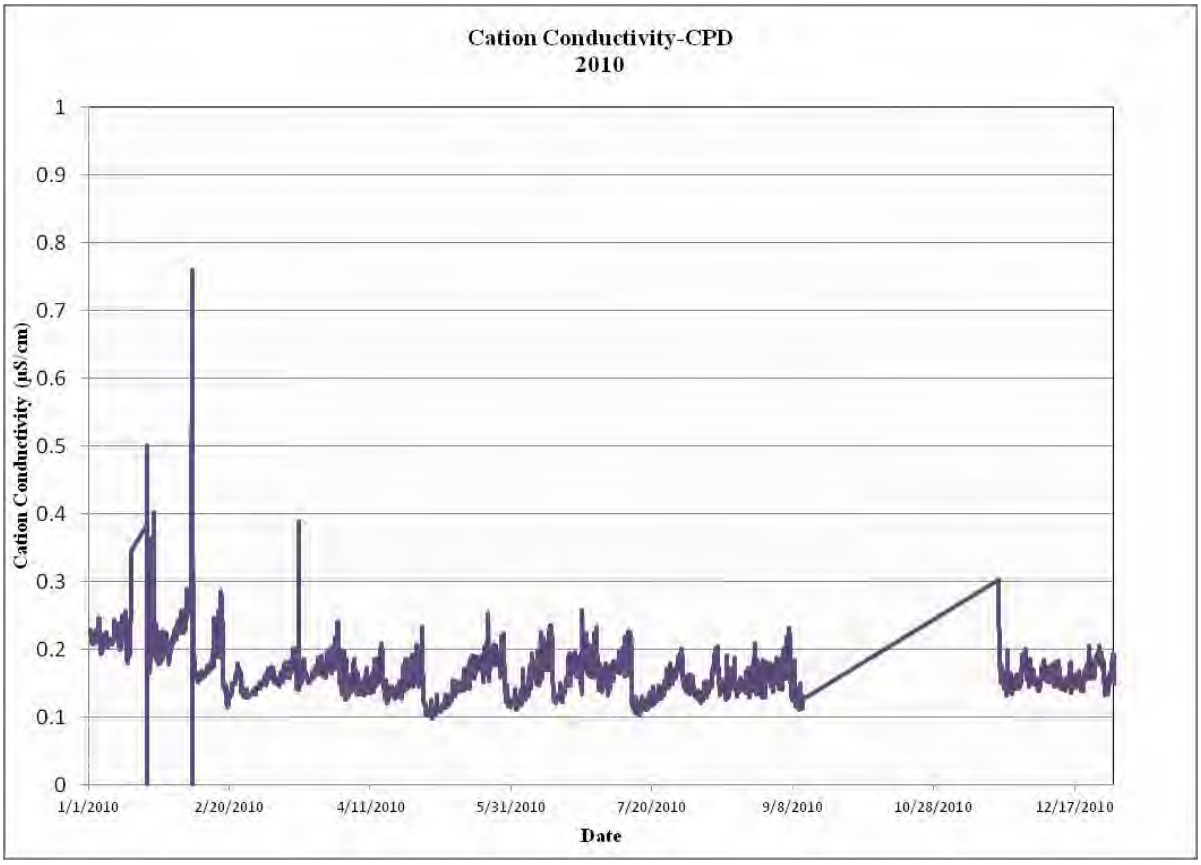
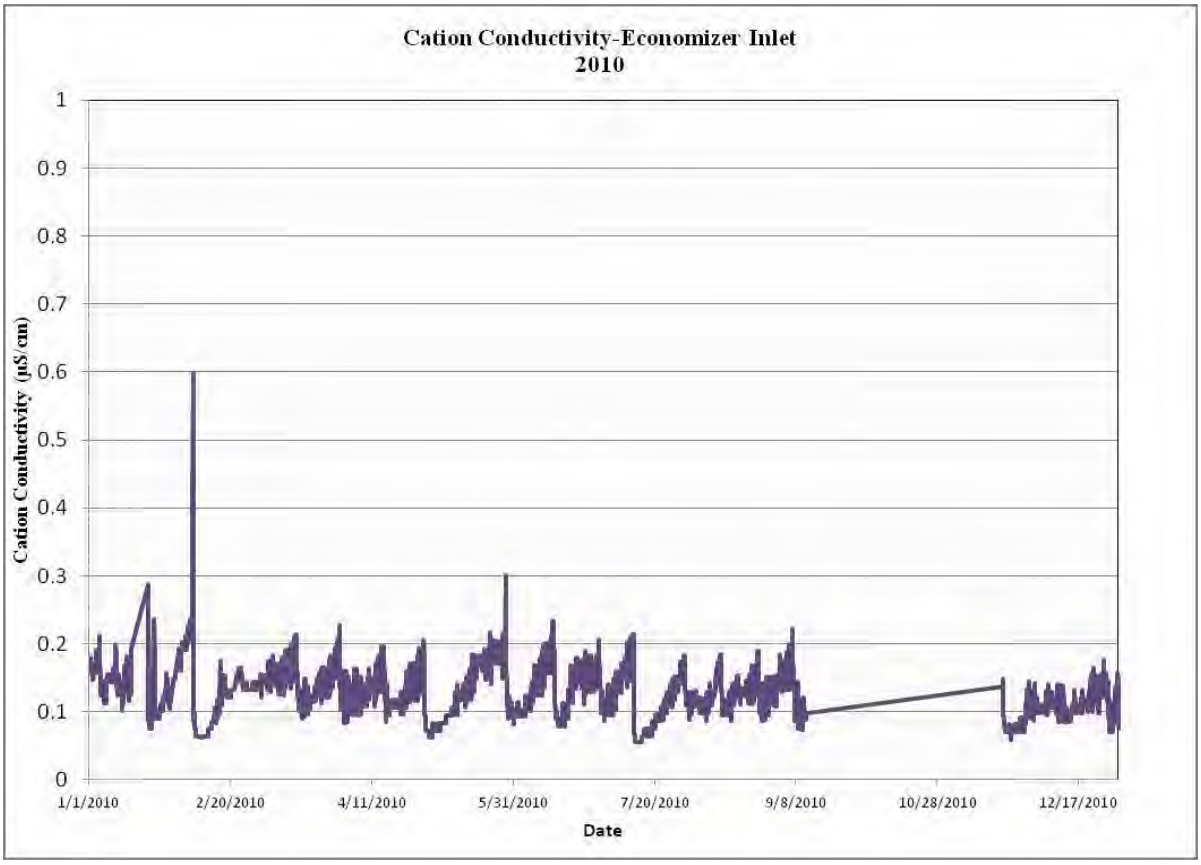
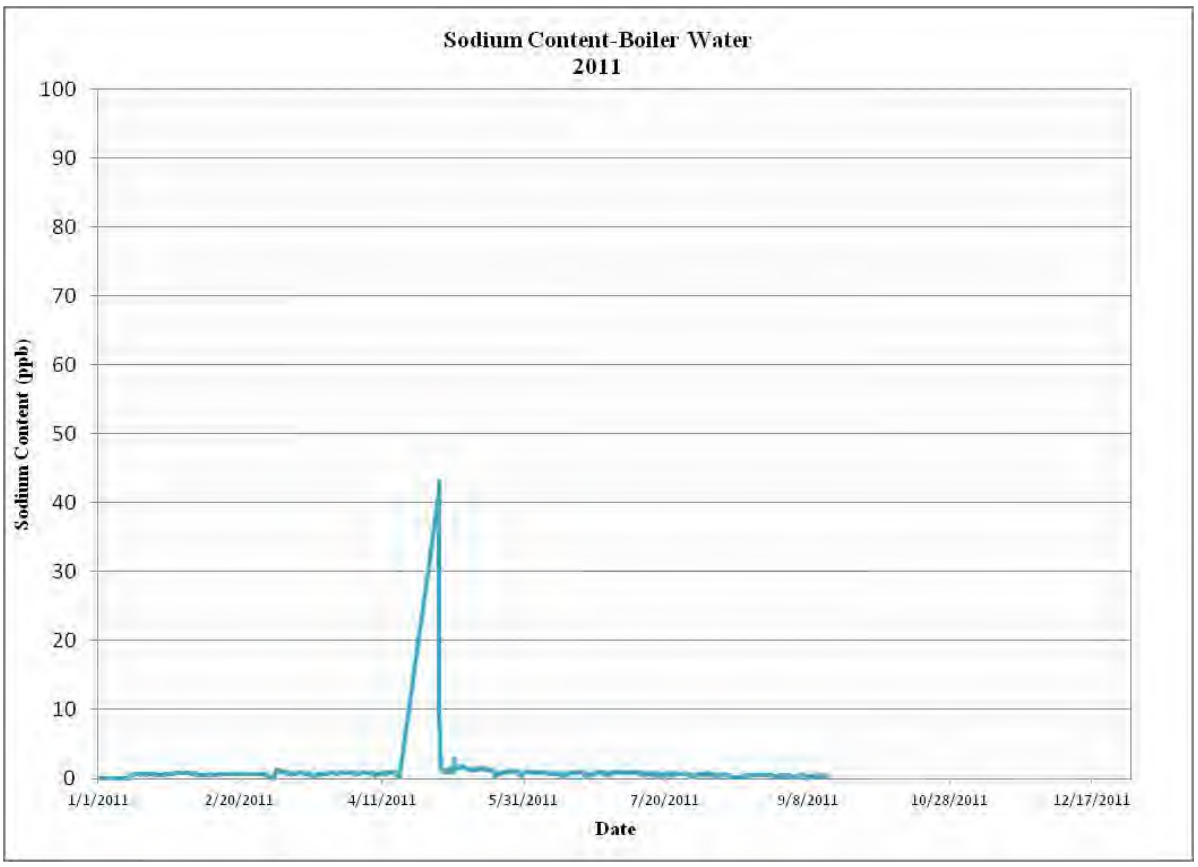


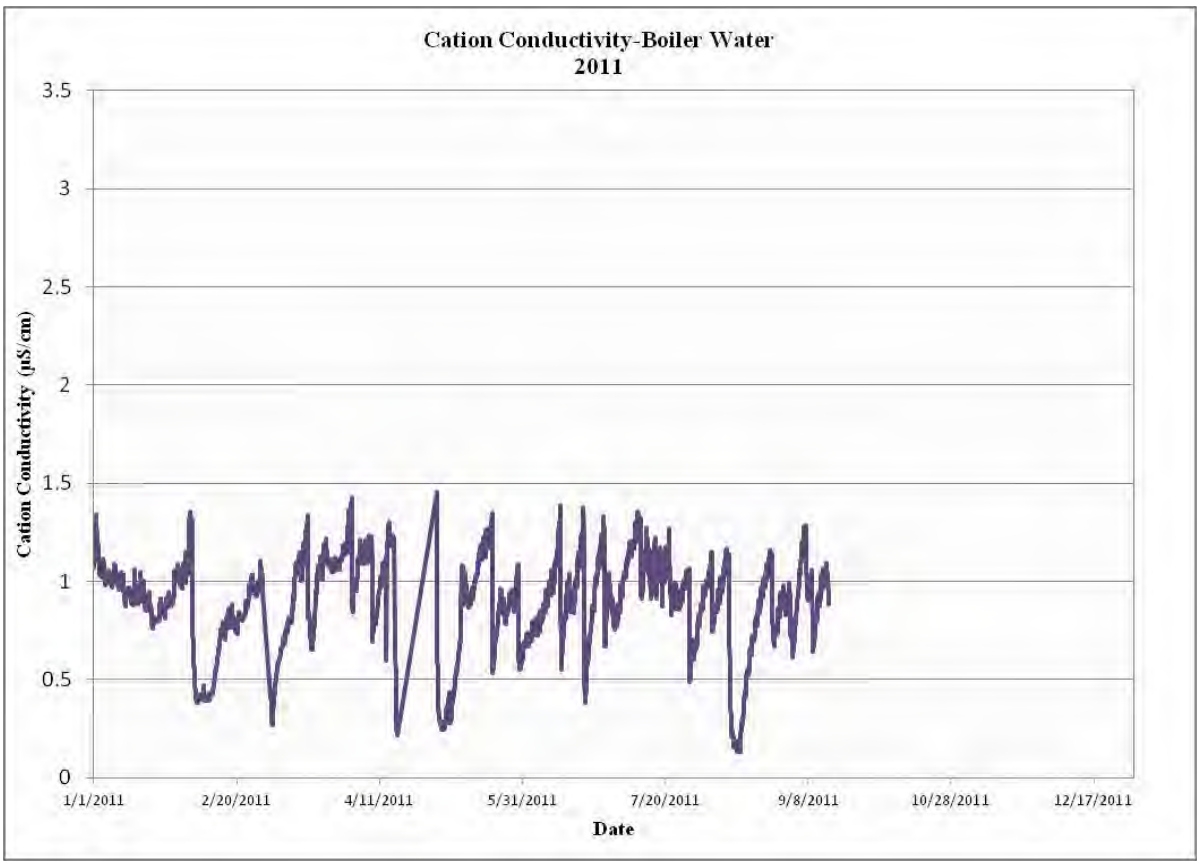
Appendix C54



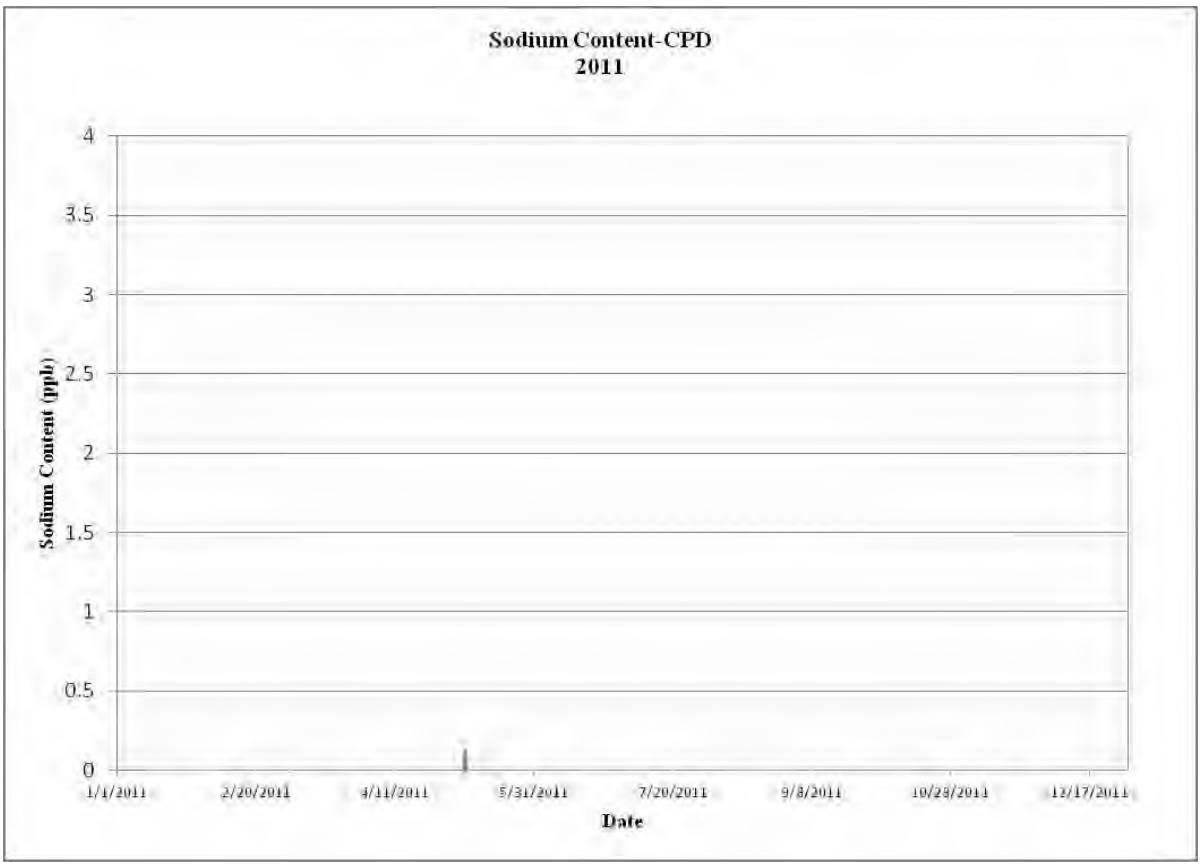
Appendix C55



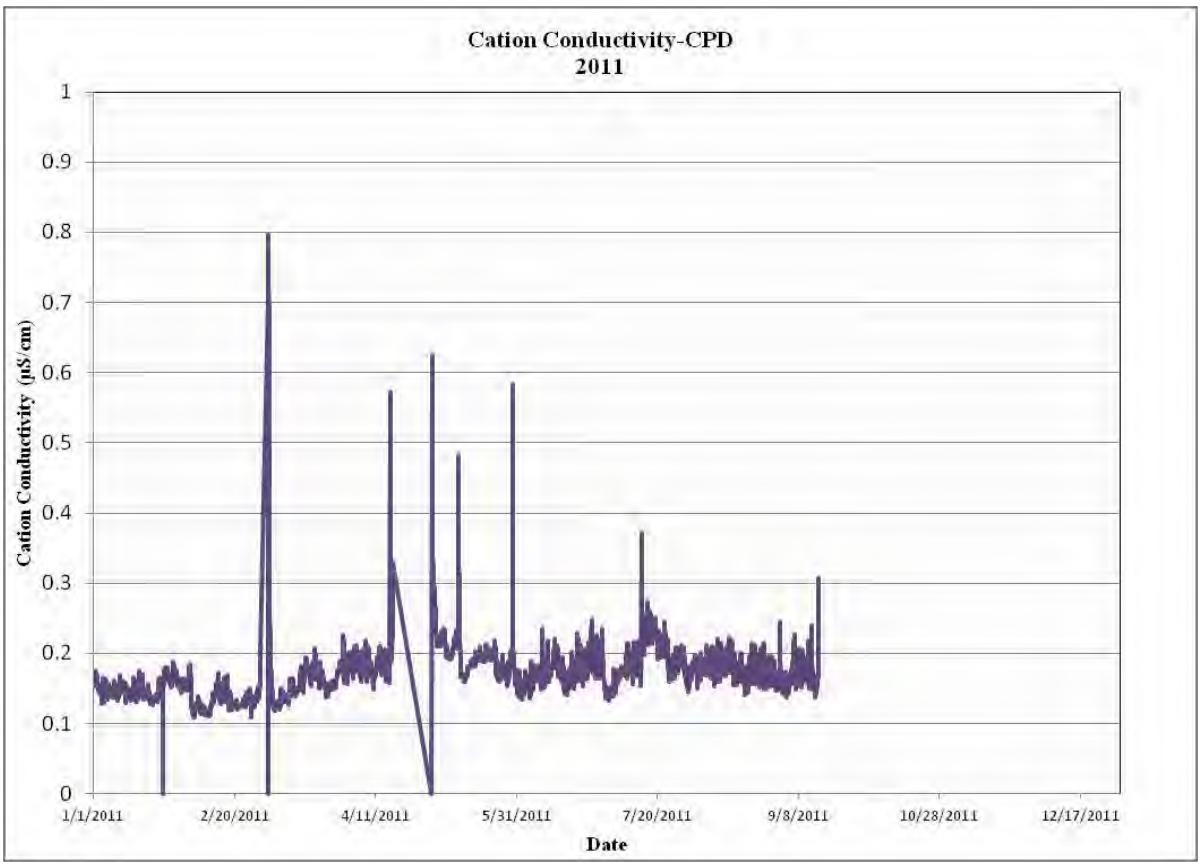
Appendix C56



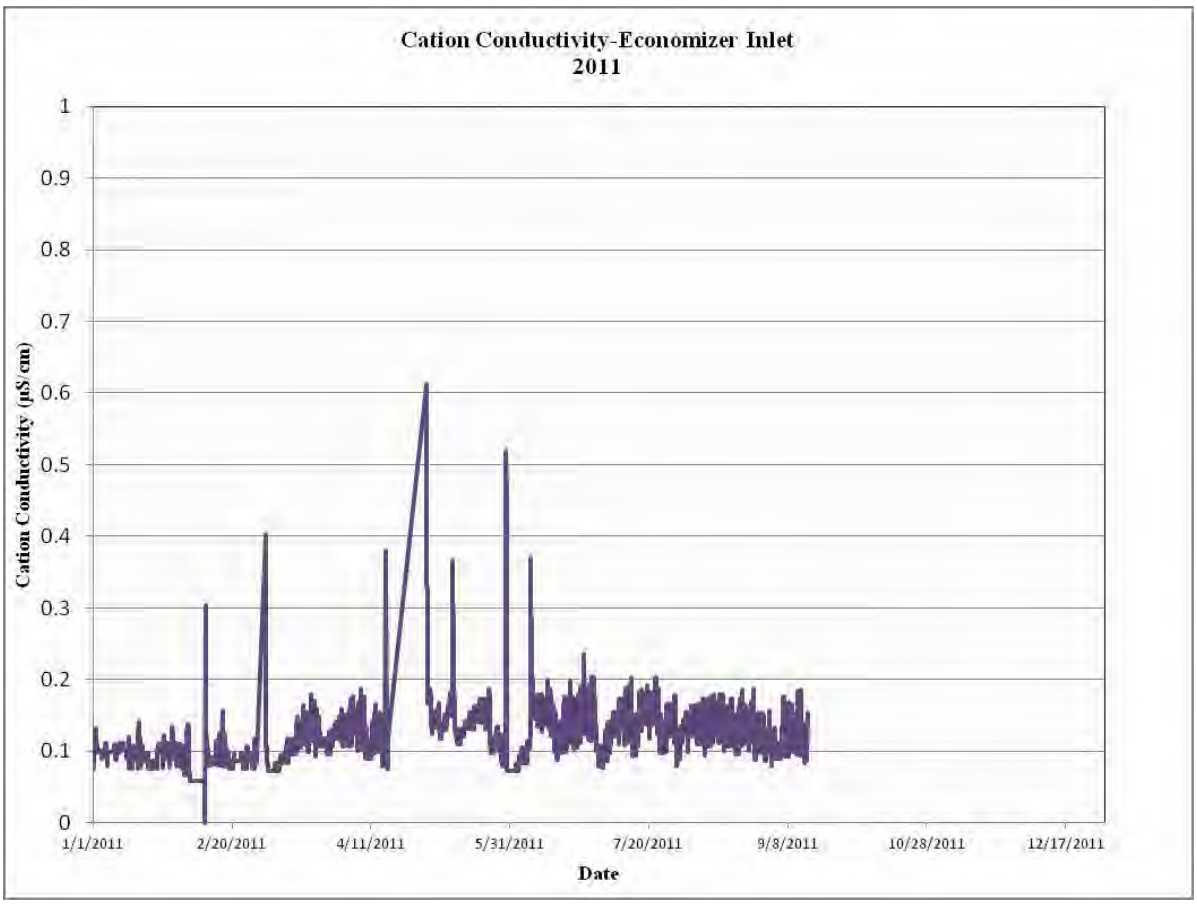
Appendix C57



Appendix C58



Appendix C59



APPENDIX D

GENERAL ELECTRIC US PATENT 7,387, 494 B2
FINGER DOVETAIL ATTACHMENT
BETWEEN TURBINE ROTOR WHEEL AND BUCKET
FOR STRESS REDUCTION

Appendix D1

US007387494B2

(12) **United States Patent**
Yehle et al.

(10) **Patent No.: US 7,387,494 B2**
(45) **Date of Patent: Jun. 17, 2008**

(54) **FINGER DOVETAIL ATTACHMENT BETWEEN A TURBINE ROTOR WHEEL AND BUCKET FOR STRESS REDUCTION**

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(73) Assignee: **General Electric Company**, Schenectady, NY (US)

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(51) **Int. Cl.**
F01D 5/30 (2006.01)

(52) **U.S. Cl.** ..... **416/217**; 416/220 R

(58) **Field of Classification Search** ..... 416/215, 416/217, 219 R, 220 R, 248

See application file for complete search history.

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Assistant Examiner—Devon Hanna
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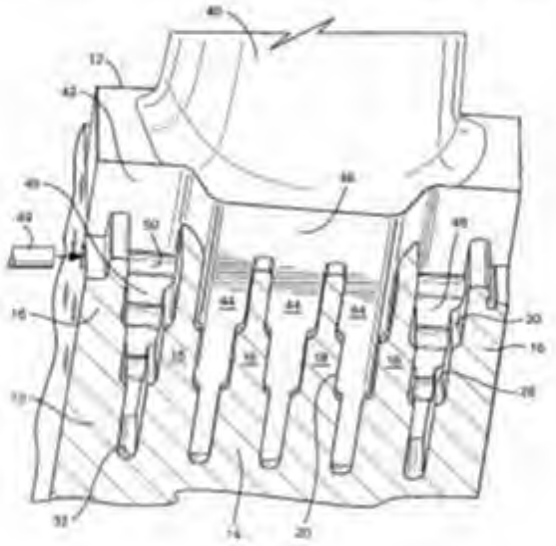
(57) **ABSTRACT**

A bucket to wheel dovetail attachment includes axially spaced radially extending wheel fingers having discrete sections of decreased axial thickness in a radial outward direction with transition fillets between sections of different thicknesses. The wheel fingers define wheel finger slots for receiving correspondingly shaped bucket dovetail fingers. Pins interconnect the buckets and rotor wheel. The slot bottoms likewise have fillets. The fillets on the wheel fingers and slot bottoms have a blend of different radii with the larger radii outward of the smaller radii to reduce stress concentrations and to avoid stress corrosion cracking in steam turbine applications.

7 Claims, 2 Drawing Sheets



Appendix D2

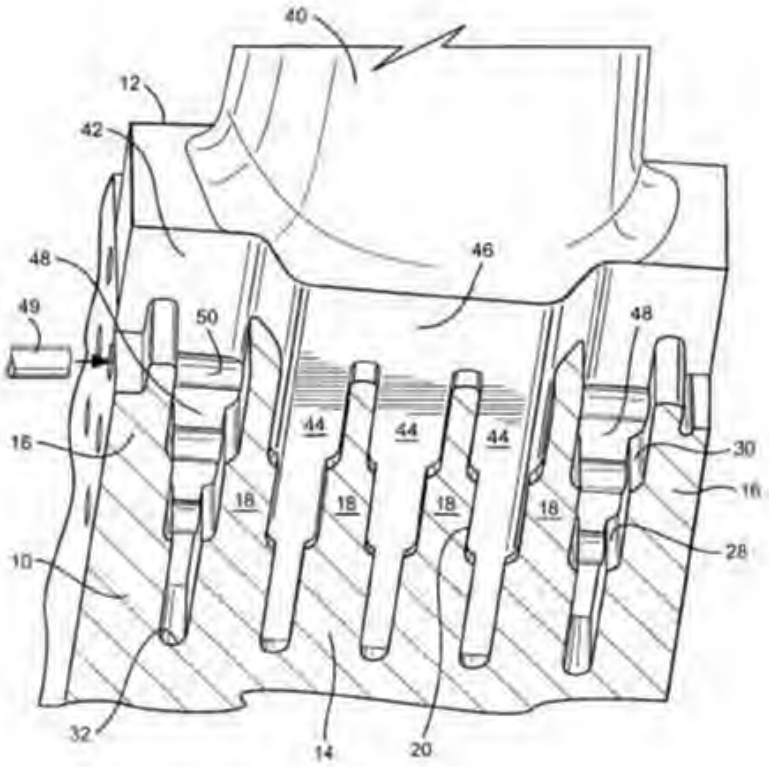


Fig. 1

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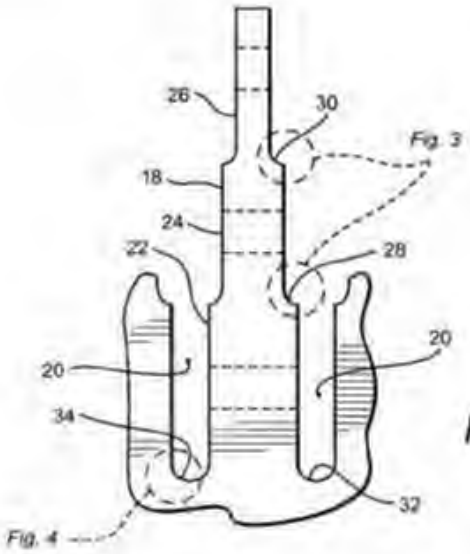

Fig. 2

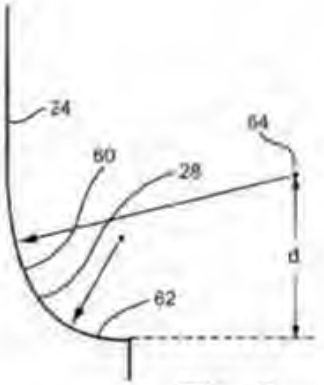

Fig. 3

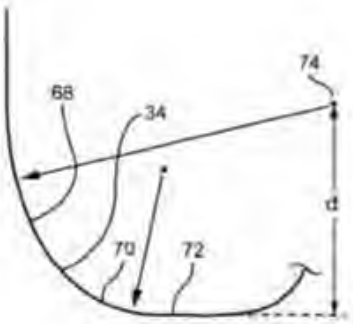

Fig. 4

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FINGER DOVETAIL ATTACHMENT BETWEEN A TURBINE ROTOR WHEEL AND BUCKET FOR STRESS REDUCTION

The present invention relates to an attachment between a rotor wheel dovetail and a dovetail on buckets for minimizing the concentrated stress caused by the centrifugal force of the buckets in the wheel fingers and particularly relates to a compound fillet in the wheel finger transition between sections of different radial thicknesses and at wheel finger slot bottom locations for stress reduction for a given set of radii.

BACKGROUND OF THE INVENTION

In turbines, particularly steam turbines, attachments between the plurality of buckets and the rotor wheel is typically accomplished using radial entry bucket dovetail fingers and radial fingers about the margins of the rotor wheel. For example, the finger dovetails on the buckets include a plurality of axially spaced fingers having sections which decrease in thickness in a radial inward direction for reception in slots defined between axially adjacent radially outwardly projecting fingers having sections which decrease in thicknesses in a radial outward direction about the margin of the rotor wheel. Axially extending pins secure the fingers of the wheel and bucket to one another. Single radius fillers are conventionally provided in the wheel fingers at the transitions between the sections of different thicknesses. Similar fillets have been used at the bottom of the finger slots in the wheel.

In many steam turbine applications, the finger dovetails operate in an environment that is conducive to stress corrosion cracking (SCC). SCC is accelerated by the stress levels that are present in the wheel transition fillets and slot bottoms. These stresses are normally acceptable. However in steam turbines having contaminated steam, cracks can initiate and if left undetected, may grow to a depth that will cause failure of the wheel fingers. Experience has shown that wheel dovetail fingers crack while bucket dovetails typically do not crack. This is because the materials used for the rotors are much less resistant to SCC than are the materials used for the buckets. For example, NiCrMoV and similar low alloy steels are typically used in rotors whereas 12 Cr steels are typically used for buckets as these materials afford an optimum combination of properties available for current low pressure design. Typically a single radius at the wheel transition fillets and slot bottom have been used and these have experienced SCC cracking in the field. Accordingly, there is a need to provide an effective means of avoiding SCC in wheel dovetails which is compatible with existing thrust paths, does not affect bucket dovetail geometry and will reduce the stress concentration.

BRIEF DESCRIPTION OF THE INVENTION

In a preferred embodiment of the present invention there is provided a rotor wheel for a turbine comprising: a plurality of fingers spaced axially from one another and extending circumferentially about a margin of the wheel for receiving fingers of buckets; the wheel fingers including a series of circumferentially extending sections of reduced axial extent in a radial outward direction, axially adjacent wheel fingers at radially innermost locations along the wheel margin defining a bottom of a generally dovetail-shaped slot between the adjacent wheel fingers, the bottom of the slot having a pair of fillets with each bottom slot fillet comprised of first and second radii with the first radius of each bottom slot fillet having a larger radius than the second radius thereof.

In another embodiment of the present invention there is provided a rotor wheel and bucket attachment for a turbine comprising, a plurality of fingers carried by the rotor wheel spaced axially from one another and extending circumferentially about a margin of the wheel, the wheel fingers defining wheel finger slots therebetween having a bottom; a plurality of buckets each having a plurality of bucket fingers extending radially into the wheel finger slots; pins extending generally axially through the wheel and bucket fingers to secure the buckets and wheels to one another; the wheel fingers including a plurality of circumferentially extending sections of reduced axial thickness in a radially outward direction, each of the wheel fingers having fillets at transitions between radially adjacent sections and at the bottom of the finger wheel slots, at least one of the fillets for each wheel finger being comprised of first and second radii with the first radius being larger than the second radius.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a fragmentary perspective view of portions of a bucket and its attachment to the margin of a rotor wheel of a turbine;

FIG. **2** is an enlarged fragmentary lengthwise view of the wheel finger dovetails; and

FIGS. **3** AND **4** are enlarged fragmentary views of the fillets at the transitions of the wheel finger sections of different thicknesses and at the bottom of the slots, respectively.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, particularly to FIG. **1**, there is illustrated a fragmentary portion of the margin of a rotor wheel **10** illustrating the attachment of a plurality of buckets, only one bucket **12** being illustrated, to the rotor wheel. Rotor wheel **10** includes a plurality of radially outwardly extending fingers **14**, two end fingers **16** being located along axial opposite sides of the wheel **10**. The fingers **14** and **16** form a wheel dovetail. Four intermediate wheel fingers **18** extend between the end wheel fingers **16**. The wheel fingers **16** and **18** extend continuously in a circumferential direction about the margin of the wheel and project radially outwardly defining wheel finger slots **20** therebetween. Each wheel finger **18**, as best illustrated in FIG. **2**, includes a series of circumferentially extending sections or steps of reduced axial extent in a radial outward direction. For example, the wheel finger **18** illustrated in FIG. **2** includes reduced thickness sections **22**, **24** and **26** with the reductions in thickness being stepped radially outwardly. A fillet **28** forms a transition between the thickest section **22** and the intermediate section **24** on each of the

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opposite sides of each wheel finger. A fillet **30** also forms a transition between the intermediate thickness section **24** and the final radial outwardly thinnest section **26** on each of the opposite sides of each wheel finger. Referring back to FIG. **1**, it will be appreciated that the end wheel fingers **16** similarly have fillets **28** and **30** along their axially inside surfaces at the transitions between the sections of different axial thickness.

Also as best illustrated in FIG. **2**, the slots **20** between the adjacent wheel fingers **18** and between the end wheel fingers **16** and axially outermost intermediate wheel fingers **18** terminate at their radial inner ends in bottom slots **32**. Bottom slots **32** define fillets **34** with the side wall surfaces of the adjacent wheel fingers.

Each bucket **12** includes an airfoil **40** having a root or base **42** from which project radially inwardly a plurality of dovetail-shaped fingers **44**. The fingers **44** are generally complementary in shape to the finger slots between adjacent intermediate wheel fingers **18**. The base **42** of each bucket **12** has a recess, not shown, on one side and a tongue-slot projection **46** along its opposite side. The intermediate fingers **44** lie flush with the surfaces of the recess and projection **46**.

Bucket **12** also includes end fingers **48** on adjacent axially opposite sides of the bucket. The end fingers **48** are thus tangentially offset from the intermediate bucket fingers **44**. The end fingers **48** have a plurality, three being preferred, of semi-cylindrical openings **50**. Each of the intermediate fingers **44** of the bucket **12** has a full circular opening centered with the semi-circular openings **50**. Additionally, the wheel fingers **16** and **18** have circular openings aligned with the semi-circular end bucket fingers **48** and the circular openings of the intermediate bucket fingers **44**. Thus, when the buckets are mounted radially onto the rotor wheel **10**, the bucket fingers and the wheel fingers intermediate with the openings aligned axially relative to one another. Pins **49** may thus be received within the aligned openings and secured to maintain the attachment between the buckets and the rotor wheel. It will be appreciated that adjacent buckets have end fingers **48** with semi-cylindrical openings and the adjacent buckets therefore share the pins with one another in that regard.

As noted previously, the wheel finger dovetails of conventional turbines have a single radius at each of the transitions between the sections of the fingers of different thicknesses and at the bottoms **32** of the finger slots. In a preferred embodiment of the present invention, there is provided at each wheel finger transition area location a compound fillet to reduce the stress. It will be appreciated that the wheel and bucket dovetail carry a centrifugal loading through the pins which secure the buckets and the wheel to one another. These forces give rise to stress in the wheel dovetail and peak stresses in the fillets and slot bottom region of the wheel fingers. In a preferred aspect of the present invention, a compound fillet **61** is used, i.e. a fillet having a first large radius **60** and a second smaller radius **62**. For example as illustrated in FIG. **3** showing transition fillets **28** between wheel finger sections **22**, **24** and **24**, **26**, the large radius **60** blends into the side surface of the adjacent finger and blends into the smaller radius **62**. As a representative example, the large radius may be 0.225 inches while the small radius may be 0.080 inches. The distance d from the large radius center **64** is 0.130 inches. Thus the larger radius **60** lies radially outwardly of the smaller radius **62**. From a stress concentration standpoint, the larger radius is accordingly more resistant to stress.

Additionally, referring to FIG. **4**, each fillet forming the bottom **32** of each slot similarly has a compound fillet. For example the fillet **34** includes a large radius **68** and a smaller radius **70**. Each large radius section **68** transitions into the side wall of the base of the wheel fingers **18** or **16** while each small radius **70** transitions from the larger radius **68** into a small flat **72** at the base of the slot bottom **32**. The large radius **68** may, for example, be 0.225 inches and the small radius **70** 0.080 inches. The center of the large radius may be 0.140 inches in a radial direction from the bottom of the slot. The flat may extend axially a distance of about 0.11 inch.

By the foregoing geometry, the bucket to wheel finger dovetail configuration has peak stresses in the wheel finger transition locations and bottom slots sufficiently low to avoid stress corrosion cracking of the wheel fingers. Also and significant from manufacturing and operational standpoints, the compound fillets at the transition areas and bottom slot locations are compatible with existing broach pulls and do not affect bucket dovetail geometry thus enabling a reduction in stress in the wheel fingers without changes to the configuration of the buckets.

While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiment, it is to be understood that the invention is not to be limited to the disclosed embodiment, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

1. A rotor wheel for a turbine comprising:

a plurality of fingers spaced axially one from another and extending circumferentially about a margin of the wheel for receiving fingers of buckets;

said wheel fingers including a plurality of circumferentially extending sections of successively reduced axial extent in a radial outward direction;

each of said wheel fingers having fillets at transitions between radially adjacent sections;

each wheel finger fillet being comprised of first and second radii with the first radius having a larger radius than the second radius; and

wherein axially adjacent wheel fingers at radially innermost locations along the wheel margin define a bottom of a generally dovetail-shaped slot between the adjacent wheel fingers, the bottom of said slot having a pair of fillets with each bottom slot fillet comprised of first and second radii with the first radius of each bottom slot fillet having a larger radius than the second radius thereof, wherein the bottom of said slot includes a flat extending axially and circumferentially between the second radius of each of said pair of bottom slot fillets.

2. A wheel according to claim **1** wherein said larger first radius of said wheel finger fillets lies along said wheel finger radially outwardly of said second radius of each of said wheel finger fillets at each fillet location.

3. A rotor wheel according to claim **1** wherein the first radius of each bottom slot fillet lies radially outwardly along the wheel finger radially outwardly of the second radius of said bottom slot fillet.

4. A rotor wheel for a turbine comprising:

a plurality of fingers spaced axially from one another and extending circumferentially about a margin of the wheel for receiving fingers of buckets;

said wheel fingers including a plurality of circumferentially extending sections of successively reduced axial extent in a radial outward direction;

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axially adjacent wheel fingers at radially innermost locations along the wheel margin defining a bottom of a generally dovetail-shaped slot between the adjacent wheel fingers;

the bottom of said slot having a pair of fillets with each bottom slot fillet comprised of first and second radii with the first radius of each bottom slot fillet being a larger radius than the second radius thereof, wherein the first radius of each bottom slot fillet lies outwardly along the wheel finger radially outwardly of the second radius thereof, and wherein the bottom of said slot includes a flat extending axially and circumferentially between the second radius of each of said pair of bottom slot fillets.

8. A rotor wheel and bucket attachment for a turbine comprising:

a plurality of fingers carried by said rotor wheel spaced axially from one another and extending circumferentially about a margin of the wheel, said wheel fingers defining wheel finger slots therebetween having a bottom;

a plurality of buckets each having a plurality of bucket fingers extending radially into said wheel finger slots;

pins extending generally axially through said wheel and bucket fingers to secure the buckets and wheels to one another;

said wheel fingers including a plurality of circumferentially extending sections of reduced axial thickness in a radially outward direction;

each of said wheel fingers having fillets at transitions between radially adjacent sections and at the bottom of the finger wheel slots, wherein the fillets at the bottom of each finger wheel slots are compound-radius fillets separated by a flat.

6. An attachment for a turbine according to claim 5 wherein each of the fillets at the transitions between radially adjacent sections have said first and second radii, with the first radius larger than the second radius.

7. An attachment for a turbine according to claim 6 wherein each of said larger first radii lies along said wheel fingers radially outwardly of said second radii at each fillet location.

* * * * *

APPENDIX E

GENERAL ELECTRIC TECHNICAL INFORMATION

LETTERS 1121-3A, 1121-3AR and 1277-2

Appendix E1

JUN - 9 1992
GE Industry
Sales & Services

June 1, 1992

Mr. Steve Kollmann, Mgr.
Operations & Maintenance Support
Northern States Power Company
414 Nicollet Mall
Minneapolis, MN 55401

SUBJECT: TIL 1121-3A, Inspection of Steam Turbine
Rotor Wheel Finger Dovetails
TB(s) 170X544, 170X609, 170X819, 170X117, 32357, 32388, 170X351, 118318

Dear Steve:

Enclosed is a copy of Technical Information Letter 1121-3A for your review and implementation. This TIL was written to provide you with GE's latest techniques for nondestructive testing of rotor wheel finger dovetails. These techniques were developed to provide a uniform test procedure for all vendors when performing this inspection.

If you have any questions or comments about this information, please call me.

Sincerely,

James P. Force
MGR., ENGINEERING SERVICES
(612) 542-0315

Att.

CC: J.P. Brandt, Sherco
J.L. Hill, Riverside
W. Hill, Monticello
P. Graika, High Bridge

Appendix E2

GE POWER GENERATION
1 RIVER ROAD
SCHENECTADY, NY 12345

GE POWER GENERATION
PRODUCT SERVICE

TIL 1121-3A

TECHNICAL INFORMATION LETTER

May 15, 1992

170X117, 092357, 092358
NORTHERN STATES PWR CO
RIVERSIDE 009

INSPECTION OF STEAM TURBINE ROTOR WHEEL FINGER DOVETAILS

APPLICABLE TO: All steam turbine rotors which have buckets attached with finger dovetails.

PURPOSE

Provide complete instructions for nondestructive testing of rotor wheel finger dovetails.

DISCUSSION

GE is continually improving the techniques for inspection of turbine components to help operators extend the life of their units. This TIL presents a new magnetic particle inspection (MPI) procedure for turbine rotor wheel finger dovetails. It allows an accurate test to be performed in this region whenever the buckets are removed.

The finger dovetail geometry is not conducive to inspection without removing buckets, except for inspection of certain portions of the end fingers (Figure 1 of this TIL). The only reliable test which clearly identifies the presence of any indications is an MPI when the buckets are removed.

The MPI procedure attached to the Customer Section of this TIL was developed by the GE Nondestructive Test Engineering group to provide a uniform procedure for all test vendors.

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RECOMMENDATIONS

1. Whenever buckets are removed, a detailed MPI should be performed on the rotor wheel finger dovetails. The recommended procedure, with a Test Results form, is provided in Attachment 1. This inspection should be performed as early as possible within the outage period, and the Test Results form sent immediately to GE for evaluation and recommendations. Your local Power Generation Services (PGSD) or International Power Systems (IPSD) representative can provide assistance in sending the data to the proper office. Your PGSD or IPSD representative can also provide assistance in obtaining testing services if the local test vendor is unable to perform the inspection.

2. Abnormal operation or unusual operating events that cause concern for long term reliability of the unit may be reason to consider removal of buckets, before normal replacement, for MPI of the dovetail area.

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TIL 1121-3A
Figure 1

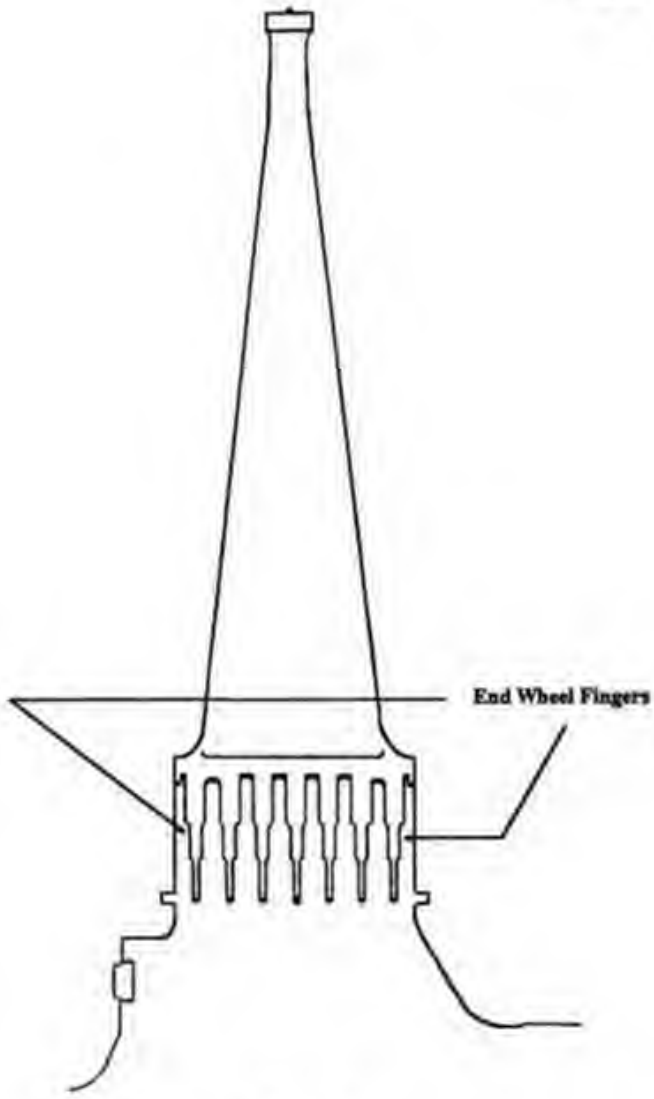

Figure 1
Steam Turbine Rotor Wheel
with Finger Dovetails

Appendix E5

TIL 1121-3A
Attachment 1

WHEEL FINGER DOVETAIL MAGNETIC PARTICLE INSPECTION (MPI)

SCOPE

This procedure describes the use of wet fluorescent magnetic particle inspection (MPI) to detect stress corrosion cracking (SCC) on steam turbine wheels with finger dovetails. Three different techniques are provided for a thorough examination of the entire surface of the finger. This includes the root radii between fingers and the inside surfaces of the pin holes (Figure 1). A data form is attached, to report the test results to GE for evaluation and recommendations.

> **NOTE:** This test should be completed at the beginning of the outage, to allow time for evaluation of test results and recommendations for any further action.

PREPARATION

1. The rotor must be removed from the unit and the finger dovetail buckets removed from the wheel(s).

2. Surfaces to be tested shall be clean and free of scale, dirt, oil, grease and any other extraneous material that would interfere with the inspection. GE recommends a forceful application of Zircon-M™ sand or equivalent, using dry compressed air as a propellant. An alternative method uses forceful application of glass beads, with dry compressed air as a propellant. However, the use of glass beads is not as effective as the use of Zircon-M sand.

3. The test area shall be covered with a hood or cover to exclude as much ambient white light as possible.

4. Personnel performing the MPI shall be qualified in accordance with the recommendations of ASNT document SNT-TC-1A. They shall be certified to at least NDT Level II Magnetic Particle Testing.

At least two magnetic particle operators are required at any one time to adequately perform these inspections. The use of two inspection teams simultaneously performing inspections on opposite sides of the wheels will greatly reduce total inspection time.

MATERIALS AND EQUIPMENT

1. Fluorescent MPI material, such as Magnaflux Corporation Magnaglo™ #14AM Prepared Bath, Magnaglo #208, or equivalent.

2. Power source, with alternating current and either half-wave or full-wave rectified direct current. A 4000 amp minimum magnetizing unit is recommended.

TRADEMARK: Zircon-M is a trademark of the E. I. Dupont De Nemours Company.
Magnaglo is a trademark of the Magnaflux Corporation.

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MATERIALS AND EQUIPMENT, cont.

3. Welding cables, 4/0, to carry the current.

4. High intensity ultraviolet light with a wavelength of 3200-4000 angstrom units. The black light intensity shall be 5000 microwatts/sq cm, minimum, at a distance of 15 in. (38 cm).

5. Magnaflux Quantitative Quality Indicators (QQIs), or equivalent, to demonstrate adequate magnetic field strength.

6. Mirrors, narrow enough to fit between adjacent dovetails in the region of the innermost pin hole. The mirrors should be as thin as possible; polished stainless steel works well. They should be mounted on a wand long enough to be able to view the entire dovetail surface. The mirrors shall be mounted to achieve a 45 degree angle with the dovetail face for ease of viewing. Two mirrors are required, one looking left and one looking right, to view opposing walls.

7. One piece of magnetic material, 0.25 x 4 x 5 inches (0.64 x 10 x 13 cm), used as a shunt to bridge the fingers and contain the magnetic field during the longitudinal magnetization inspection.

8. Marker with a low halogen and sulphur content (e.g., Marks-a-Lot® marker or equivalent) to identify previously inspected positions.

9. Brass or copper rod, smaller in diameter than the pin holes and about twice as long as the total dovetail width.

10. Gauss meter, to read residual magnetism of ±3 Gauss.

INSPECTION TECHNIQUES

GENERAL INSPECTION NOTES AND PRECAUTIONS

1. Areas which are to be inspected with MPI shall be demagnetized before beginning the inspection. Use alternating current (AC). The 4/0 cables should be connected to the ends of the rotor as described in the Direct Circular Magnetization Inspection, paragraph 1.a, below. Adjust the magnetizing unit to the maximum setting, and reduce the current from the maximum value to zero while the magnetizing unit is on. Demagnetization is adequate when the residual magnetism reads within ±3 Gauss on a Gauss meter.

2. The magnetizing unit's maximum current setting shall never be used for any of the inspections described below. The current should be 100-200 amps below the maximum possible so that a higher current can be used for proper demagnetization.

Marks-a-Lot is registered by Dennison Carter.

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GENERAL INSPECTION NOTES AND PRECAUTIONS, cont.

3. All magnetic particle inspections shall be performed using the continuous method. The inspection medium shall be applied to the surface of the dovetail while the magnetizing current is being applied. The magnetizing current remains on after the application of the medium is stopped, about 8-10 seconds, until the draining of medium stops.

4. The Quantitative Quality Indicators (QQIs) are used to demonstrate the adequacy of the magnetizing force for all techniques. Two QQIs shall be placed on the face of the dovetail, grooved side down. The first shall be placed at the extremity of the area of interest, near the outside diameter of the dovetail. The second shall be placed between the middle two fingers, near the bottom of the fingers. This is the area of least accessibility. The QQIs should be carefully taped along their edges to assure tight contact between QQI and dovetail face.

Current shall be turned on and held constant while the inspection medium is applied to the surface of the QQI. The appearance of a line(s) of fluorescent particles approximately perpendicular to the lines of magnetic flux in the part is the indication of adequate field strength. This demonstration is required at the beginning of each different technique.

5. When inspecting the dovetail surfaces for indications, the black light shall be positioned so that its area of maximum intensity will directly illuminate the specific area being inspected. If the black light has multiple intensity capability, the maximum intensity shall be used.

6. Inspections shall be performed from the lower part of a segment to the upper part of a segment, so that the area being inspected will be clean and free from runoff or residue from previous inspections. Refer to Figure 3.

7. Although indications in the area between the first transition in dovetail thickness and the outside diameter (OD) can be viewed without the use of a mirror, a mirror is required for inspections from the first transition down to the root radius. The mirror shall be held at an angle which will provide a clear view of the dovetail face. The direction of mirror movement shall be from the root radius outward toward the OD (a radial scanning motion). Care shall be taken to avoid allowing the mirror to come in contact with the surface being inspected before the actual scan of that surface, to avoid the potential creation of any false indications.

Subsequent scans shall assure an overlap of the scanning surface from the previous scan.

8. Between each technique, the dovetail area shall be wiped clean, using acetone or alcohol to remove any residual inspection medium. The surface should be illuminated by black light to verify adequate removal of residual medium.

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INSPECTIONS

To obtain coverage for indications in any orientation, magnetic fields shall be generated in the dovetails using at least the first two of the following techniques. These are direct circular magnetization and longitudinal magnetization. A third technique, induced circular magnetization, may also be used, at the discretion of the utility. This method is very sensitive to defects inside the pin holes, and defects oriented radially to each pin hole on the dovetail surface, but is extremely time consuming.

1. **Direct Circular Magnetization**

The turbine rotor is used as the conductor of current. The magnetic lines of force will be oriented circumferentially with respect to the wheel. The orientation of indications will be in the radial direction on the wheel faces and in the axial direction inside the pin holes.

a. To generate direct circular magnetization in the wheel dovetails, connect one cable from the power supply to each end of the rotor. For rotors with bore plugs or with tapped holes, connections should be made per Figure 2A. For rotors without tapped end holes, the cable connections may have to be made similar to Figure 2B or 2C.

> **CAUTION:** Extreme caution should be taken to assure that all connections are properly tightened. Loose connections could cause arcing to the rotor.

b. The current setting should be 3500 amps initially. Adjust as required to provide an adequate magnetizing force using QQIs.

c. Record any indications on the attached data form.

2. **Longitudinal Magnetization**

The orientation of any indications will be circumferential with respect to the dovetails.

a. Wind a three turn coil using the 4/0 cable to establish longitudinal magnetization in the dovetails. The turns must be complete. The maximum coil dimension shall be about 48 in. (122 cm). The coil shall be placed in contact with the dovetails so that the upper and lower segments of the coil each intersect all of the dovetails at appproximately a right angle. The sides of the coil shall be laid on the body of the rotor on both sides of the wheel fingers in order to achieve adequate magnetic field strength at the extremities of the dovetails. Refer to Figure 3.

NOTE: The optimum positions of the coil for this inspection are the 1:30-4:30 and 7:30-10:30 clock positions. The rotor should then be rotated by 90 degrees and inspected from the new 1:30-4:30 and 7:30-10:30 positions (e.g. below). This allows proper particle flow and runoff without pooling of suspension.

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INSPECTIONS, cont.

2. **Longitudinal Magnetization**, cont.

b. The initial current setting shall be 1500 amps (4500 ampere-turns with a three turn coil). Adjust as required to provide an adequate magnetizing force using QQIs.

c. To contain the magnetism within the dovetails, place the shunt across the outside diameter of the fingers so that all fingers are covered simultaneously. Refer to Figure 3. The shunt shall be left in place for as long as the current remains on.

d. The magnetic particle suspension shall be sprayed onto the dovetail surfaces underneath the 4 inch (10 cm) height of the shunt. The current is turned on during particle application and shall remain on for about 8-10 seconds following removal of spray suspension.

e. The inspection area for any one "shot" is limited to the dovetail surfaces within this shunt zone. Care shall be taken to properly mark the areas previously inspected. Successive inspections shall assure a minimum overlap of 0.5 in. (1.3 cm) of the shunt height.

f. The inspection sequence (movement of the shunt within a given coil position) shall be from the lower end of the coil to the upper end.

g. Movement of the coil around the outer diameter of the dovetails shall include a minimum overlap of 12 in. (31 cm) from the previous coil position.

h. Record any indications on the attached data form.

3. **Circular Magnetization** (Optional)

This method uses a central conductor placed through aligned pin holes. It is very sensitive to defects oriented radially to the pin holes and axially to the rotor inside the holes, but is very time consuming.

a. Pass the brass or copper rod through a set of aligned pin holes. Connect one power cable from the power supply to each end of the rod. While current is flowing, apply magnetic particles to both sides of each pin hole through which the central conductor is located.

b. The current setting should be 175 amps initially. Adjust the current as required using the QQIs.

c. Carefully remove the conductor from the holes and inspect the inside of the holes for any indications

d. Record any indications on the attached data form.

e. Care should be taken to mark those sets of pins which have already been inspected.

Appendix E10

DEMAGNETIZATION

The unit shall be demagnetized after all inspections have been completed. Use the same procedure described in General Inspection Notes and Precautions, para. 1, above.

RETURN OF DATA FORM

The completed data form should be given to the local GE representative. It will be sent to the main GE office for evaluation and recommendation.

Appendix E11

TIL 1121-3A
Attachment 1
Figure 1

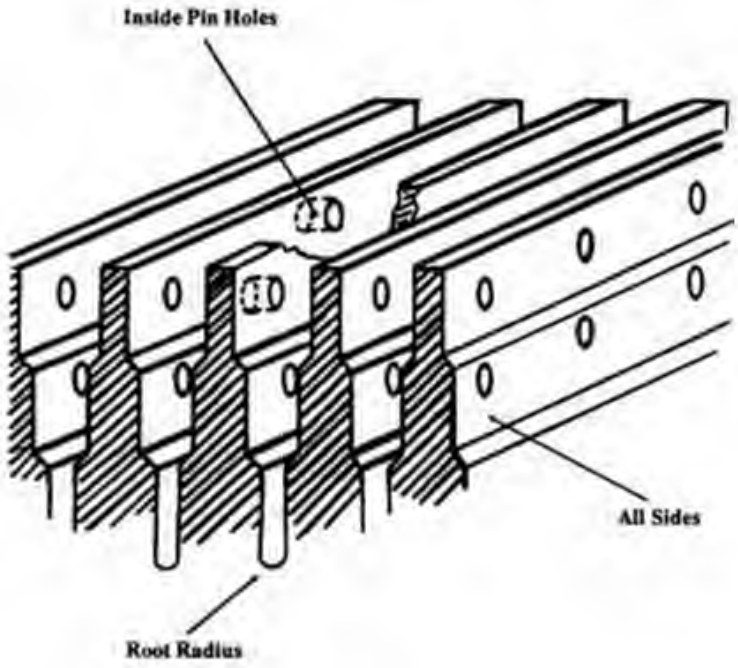


Figure 1
Inspection Locations

Appendix E12

TIL 1121-3A
Attachment 1
Figure 2

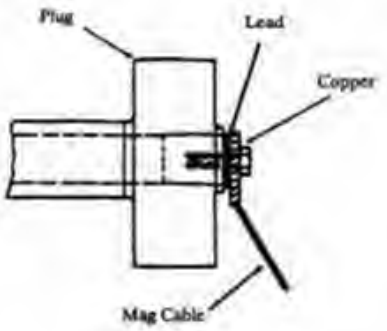


Figure 2A
Bore Plug

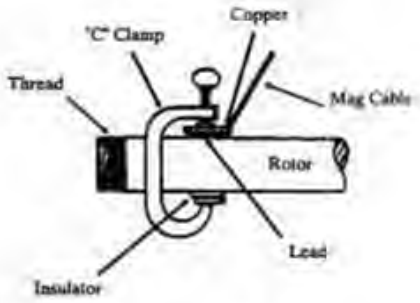


Figure 2B
Governor End of Rotor

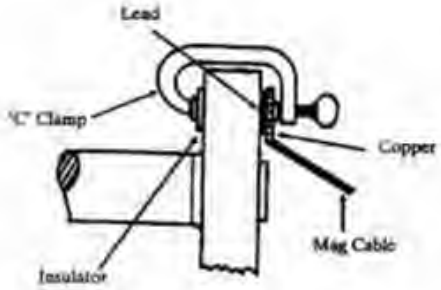


Figure 2C
Coupling Face

Figure 2
Attachment of Cables to Rotor

Appendix E13

TIL 1121-3A
Attachment 1
Figure 3

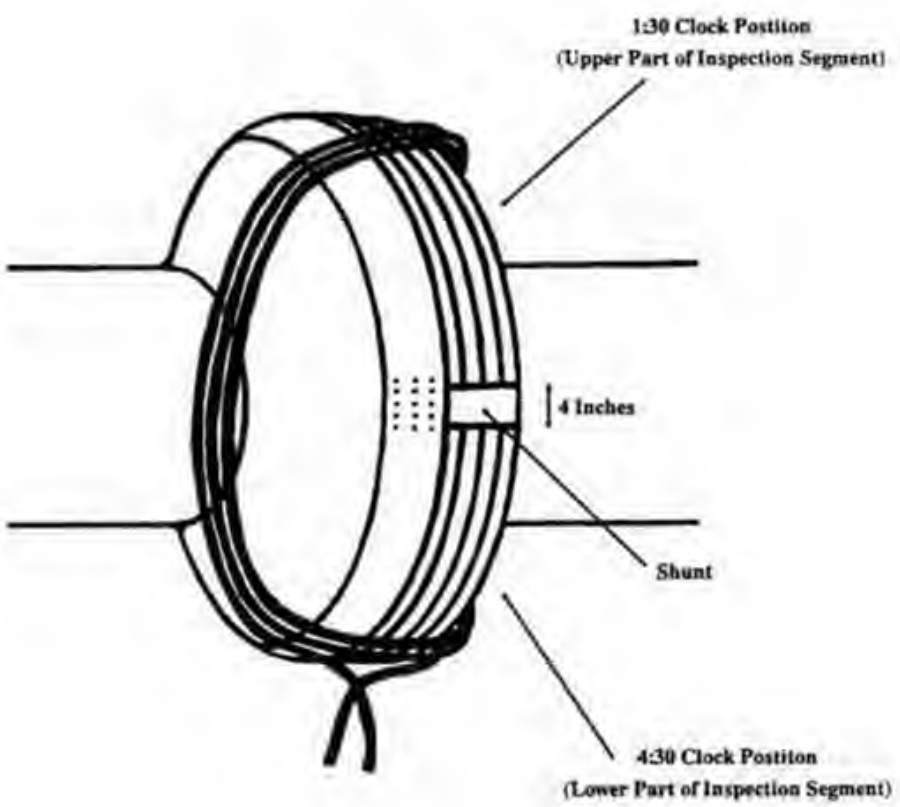


Figure 3
Longitudinal Magnetization
with 3-Turn Coil and Shunt

Appendix E14

TIL 1121-3A
Attachment 1
Data Sheet 1 of 2

TURBINE WHEEL FINGER DOVETAIL MAGNETIC PARTICLE TEST RESULTS

Turbine number _____ Inspection date _____

Customer _____ Station _____

Rotor (LPA, LPB,..) _____ Type of unit _____

Rotor S/N _____ End _____ Stage _____

Finger dovetail type: Flat _____ or Nested _____

Mag. particle inspection company _____
Person to contact _____

Describe all indications below and on the attached sketch. Include an accurate description of the location, length and orientation for all indications. Use a separate sketch for indications on each different dovetail face. Include additional sketches as required for indications in other locations.

Dovetails are numbered consecutively, with the #1 dovetail on the admission end of the wheel (see sketch). Rows of pin holes are numbered consecutively in the direction of rotation, with the #1 row located directly below the #1 flat-type dovetail bucket or directly below the back edge of the #1 nested-type dovetail bucket.

Indications detected? Yes ____ No ____

Location of indication(s) (Check all that apply.)

Dovetail number(s) _____ Pin hole row number(s) _____
Admission side face ___ Discharge side face ___
Pin hole region: Inner ___ Middle ___ Outer ___
Root radius between dovetail number ___ and number ___
Inside surface of pin hole ___
Wheel/wheel fillet ___
Other (describe) ___

Comments:

SEND IMMEDIATELY TO:

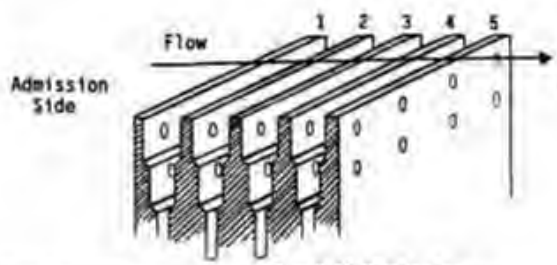
GE POWER GENERATION SERVICES
5353 GAMBLE DRIVE
MINNEAPOLIS, MN 55416

TEL (612) 542-0332 FAX (612) 542-0355

11/91 TVT

Appendix E15

TIL 1121-3A
Attachment 1
Data Sheet 2 of 2



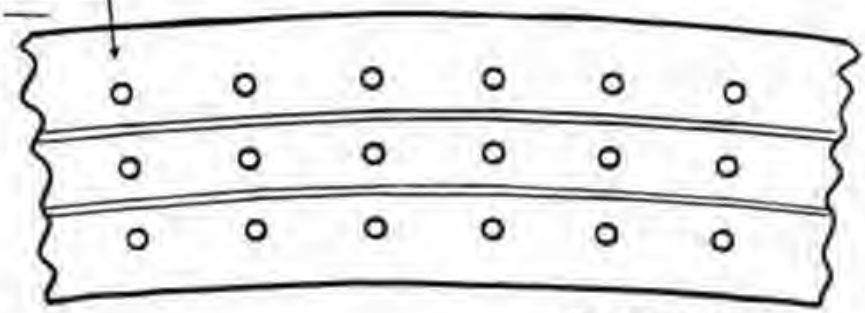
Dovetail Numbering

WHEEL FINGER DOVETAIL MAGNETIC PARTICLE TEST DATA SHEET
(Sketch indications below.)

Rotor _____ Dovetail # ____ Date _____
End _____ Stage ____ Inspector _____

Admission Side

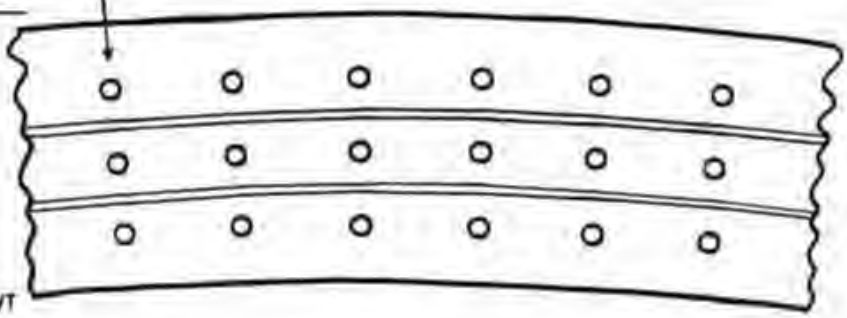
Pin Hole
Row # ____



(Not to scale)

Discharge Side

Pin Hole
Row # ____



11/91 TVT

Appendix E16

MAR 23 1993

GE Power
Generation Services

March 12, 1993

Mr. James P. Brandt
Plant Manager
NSP Sherburne Generating Plant
13999 Industrial Boulevard
Becker, MN 55308-9611

SUBJECT: [redacted]-3AR1
Inspection of Steam Turbine Rotor Wheel Finger Dovetails
TBs 170X544, 609, 819

Enclosed is a copy of Technical Information Letter 1121-3AR1 for your review and consideration.

This TIL was written to provide you with GE's latest recommendations for nondestructive testing of rotor wheel finger dovetails. Please include these recommendations in your maintenance planning.

If you have any questions or comments regarding these procedures please call me.

Sincerely,

Mark A. Peterson
MGR., ENGINEERING SERVICES
(612) 542-0332

CC: S. Kollmann

High Bridge	TBs 118318
Monticello	TBs 170X361
Riverside	TBs 32357, 32388, 170X117
Sherco	TBs 170X544, 609, 819

Appendix E17

GE POWER GENERATION
1 RIVER ROAD
SCHENECTADY, NY 12345

GE POWER GENERATION
PARTS & PRODUCT SERVICE

TIL 1121-3AR1

TECHNICAL INFORMATION LETTER

February 1, 1993

INSPECTION OF STEAM TURBINE ROTOR WHEEL FINGER DOVETAILS

APPLICABLE TO: All steam turbines with rotors which have buckets attached with finger dovetails.

PURPOSE

Provide complete instructions for nondestructive testing of rotor wheel finger dovetails.

BACKGROUND

Many magnetic particle inspections (MPI) of rotor wheel finger dovetails have been performed by prudent steam turbine owners to detect stress corrosion and/or fatigue cracking. In two instances, out of the hundreds of MPIs performed, cracks which were not discovered during the performance of the inspection procedure were observed. Consequently, GE has examined the MPI procedure for rotor wheel finger dovetails and developed an improved version.

DISCUSSION

Attached to this TIL is an improved magnetic particle inspection procedure for turbine rotor wheel finger dovetails. It allows a more accurate test to be performed in this region whenever the buckets are removed.

The finger dovetail geometry is not conducive to inspection without removing buckets, except for inspection of certain portions of the end fingers. See Figure 1. The most reliable test which clearly identifies the presence of any indications is an MPI when the buckets are removed.

The attached improved MPI procedure was developed by GE Nondestructive Test Engineering to provide a uniform procedure for anyone performing the test.

Appendix E18

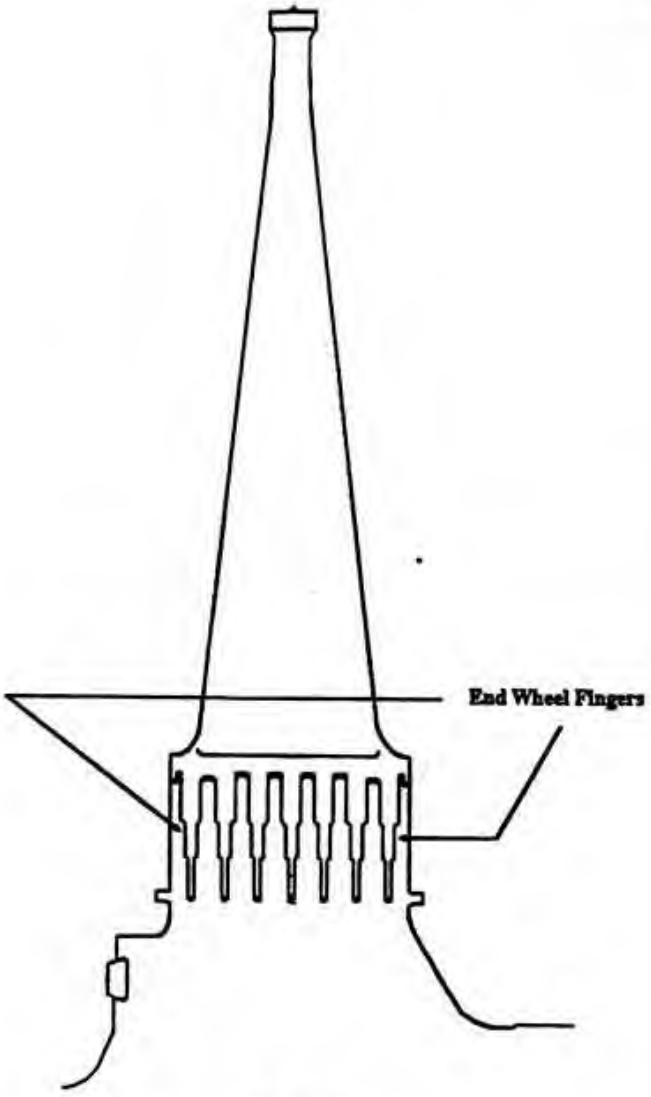


Figure 1
Steam Turbine Rotor Wheel
with Finger Dovetails

Appendix E19

RECOMMENDATIONS

1. Whenever buckets are removed, a detailed MPI should be performed on the rotor wheel finger dovetails in accordance with the attached procedure. This inspection should be performed as early as possible within the outage period, and the test results sent immediately to GE for evaluation and recommendations. Your local GE field service representative can forward the data to the proper GE organization, and can also provide assistance with obtaining testing services.

   NOTE

   Although GE will perform the attached MPI, it is not necessary that GE do so. It is highly recommended that, regardless of who performs the inspection, the attached procedure be followed.

2. Abnormal events or operational anomalies that cause concern for long term reliability of the unit may be reason to consider removal of buckets, before normal replacement, for MPI of the dovetail area. Abnormal events or operational anomalies are any out-of-the-ordinary occurrences, during operation or maintenance, which may increase the risk of stress corrosion and/or fatigue cracking, such as but not limited to the following:

   a. caustic or chemical ingestion or contamination
   b. carryover from boiler
   c. leaking condenser heater tube
   d. overspeeds
   e. water ingestion

   If in doubt, GE will help evaluate the need for additional MPI of the rotor wheel finger dovetail area. Contact your local GE field service representative.

Appendix E20

TIL 1121-3AR1
Attachment 1

WHEEL FINGER DOVETAIL MAGNETIC PARTICLE INSPECTION (MPI)

SCOPE

This procedure describes the use of wet fluorescent magnetic particle inspection (MPI) to detect stress corrosion cracking (SCC) on steam turbine wheels with finger dovetails. Three different techniques are provided for a thorough examination of the entire surface of the finger. This includes the root radii between fingers and the inside surfaces of the pin holes (Figure 1). A data form is attached, to report the test results to GE for evaluation and recommendations.

NOTE

This test should be completed at the beginning of the outage, to allow time for evaluation of test results and recommendations for any further action.

PREPARATION

1. The rotor must be removed from the unit and the finger dovetail buckets removed from the wheel(s).

2. Surfaces to be tested shall be clean and free of scale, dirt, oil, grease and any other extraneous material that would interfere with the inspection. GE recommends a forceful application of Zircon-M™ sand or equivalent, using dry compressed air as a propellant. An alternative method uses forceful application of glass beads, with dry compressed air as a propellant. However, the use of glass beads is not as effective as the use of Zircon-M sand.

3. The test area shall be covered with a hood or cover to exclude as much ambient white light as possible.

4. Personnel performing the MPI shall be qualified in accordance with the recommendations of ASNT document SNT-TC-1A. They shall be certified to at least NDT Level II Magnetic Particle Testing.

   At least two magnetic particle operators are required at any one time to adequately perform these inspections. The use of two inspection teams simultaneously performing inspections on opposite sides of the wheels will greatly reduce total inspection time.

MATERIALS AND EQUIPMENT

1. Fluorescent MPI material, such as Magnaflux Corporation Magnaglo™ #14AM Prepared Bath, Magnaglo #208, or equivalent.

2. Power source, with alternating current and either half-wave or full-wave rectified direct current. A 4000 amp minimum magnetizing unit is recommended.

TRADEMARK: Zircon-M is a trademark of the E. I. Dupont De Nemours Company. Magnaglo is a trademark of the Magnaflux Corporation.

Appendix E21

MATERIALS AND EQUIPMENT, cont.

3. Welding cables, 4/0, to carry the current.

4. High intensity ultraviolet light with a wavelength of 3200-4000 angstrom units. The black light intensity shall be 5000 microwatts/sq cm, minimum, at a distance of 15 in. (38 cm).

5. Magnaflux Quantitative Quality Indicators (QQIs), or equivalent, to demonstrate adequate magnetic field strength.

6. Mirrors, narrow enough to fit between adjacent dovetails in the region of the innermost pin hole. The mirrors should be as thin as possible; polished stainless steel works well. They should be mounted on a wand long enough to be able to view the entire dovetail surface. The mirrors shall be mounted to achieve a 45 degree angle with the dovetail face for ease of viewing. Two mirrors are required, one looking left and one looking right, to view opposing walls.

7. One piece of magnetic material, 0.25 x 4 x 5 inches (0.64 x 10 x 13 cm), used as a shunt to bridge the fingers and contain the magnetic field during the longitudinal magnetization inspection.

8. Marker with a low halogen and sulphur content (e.g., Marks-a-Lot* marker or equivalent) to identify previously inspected positions.

9. Brass or copper rod, smaller in diameter than the pin holes and about twice as long as the total dovetail width.

10. Gauss meter, to read residual magnetism of ±3 Gauss.

INSPECTION TECHNIQUES

GENERAL INSPECTION NOTES AND PRECAUTIONS

1. Areas which are to be inspected with MPI shall be demagnetized before beginning the inspection. Use alternating current (AC). The 4/0 cables should be connected to the ends of the rotor as described in the Direct Circular Magnetization Inspection, paragraph 1.a, below. Adjust the magnetizing unit to the maximum setting, and reduce the current from the maximum value to zero while the magnetizing unit is on. Demagnetization is adequate when the residual magnetism reads within ±3 Gauss on a Gauss meter.

2. The magnetizing unit's maximum current setting shall never be used for any of the inspections described below. The current should be 100-200 amps below the maximum possible so that a higher current can be used for proper demagnetization.

Marks-a-Lot is registered by Dennison Carter.

Appendix E22

GENERAL INSPECTION NOTES AND PRECAUTIONS (Continued)

3. All magnetic particle inspections shall be performed using the continuous method. The inspection medium shall be applied to the surface of the dovetail while the magnetizing current is being applied. The magnetizing current remains on after the application of the medium is stopped, about 8-10 seconds, until the draining of medium stops.

4. The Quantitative Quality Indicators (QQIs) are used to demonstrate the adequacy of the magnetizing force for all techniques. Two QQIs shall be placed on the face of the dovetail, grooved side down. The first shall be placed at the extremity of the area of interest, near the outside diameter of the dovetail. The second shall be placed between the middle two fingers, near the bottom of the fingers. This is the area of least accessibility. The QQIs should be carefully taped along their edges to assure tight contact between QQI and dovetail face.

   Current shall be turned on and held constant while the inspection medium is applied to the surface of the QQI. The appearance of a line(s) of fluorescent particles approximately perpendicular to the lines of magnetic flux in the part is the indication of adequate field strength. This demonstration is required at the beginning of each different technique.

5. When inspecting the dovetail surfaces for indications, the black light shall be positioned so that its area of maximum intensity will directly illuminate the specific area being inspected. If the black light has multiple intensity capability, the maximum intensity shall be used.

6. Inspections shall be performed from the lower part of a segment to the upper part of a segment, so that the area being inspected will be clean and free from runoff or residue from previous inspections. Refer to Figure 3.

7. Although indications in the area between the first transition in dovetail thickness and the outside diameter (OD) can be viewed without the use of a mirror, a mirror is required for inspections from the first transition down to the root radius. The mirror shall be held at an angle which will provide a clear view of the dovetail face. The direction of mirror movement shall be from the root radius outward toward the OD (a radial scanning motion). Care shall be taken to avoid allowing the mirror to come in contact with the surface being inspected before the actual scan of that surface, to avoid the potential creation of any false indications.

   Subsequent scans shall assure an overlap of the scanning surface from the previous scan.

8. Between each technique, the dovetail area shall be wiped clean, using acetone or alcohol to remove any residual inspection medium. The surface should be illuminated by black light to verify adequate removal of residual medium.

Appendix E23

INSPECTIONS

To obtain coverage for indications in any orientation, magnetic fields shall be generated in the dovetails using at least the first two of the following techniques. These are direct circular magnetization and longitudinal magnetization. A third technique, induced circular magnetization, may also be used, at the discretion of the utility. This method is very sensitive to defects inside the pin holes, and defects oriented radially to each pin hole on the dovetail surface, but is extremely time consuming.

1. Direct Circular Magnetization

The turbine rotor is used as the conductor of current. The magnetic lines of force will be oriented circumferentially with respect to the wheel. The orientation of indications will be in the radial direction on the wheel faces and in the axial direction inside the pin holes.

a. To generate direct circular magnetization in the wheel dovetails, connect one cable from the power supply to each end of the rotor. For rotors with bore plugs or with tapped holes, connections should be made per Figure 2A. For rotors without tapped end holes, the cable connections may have to be made similar to Figure 2B or 2C.

CAUTION

Extreme caution should be taken to assure that all connections are properly tightened. Loose connections could cause arcing to the rotor.

b. The current setting should be 3500 amps initially. Adjust as required to provide an adequate magnetizing force using QQIs.

c. Record any indications on the attached data form.

2. Longitudinal Magnetization

The orientation of any indications will be circumferential with respect to the dovetails.

a. Wind a three turn coil using the 4/0 cable to establish longitudinal magnetization in the dovetails. The turns must be complete. The maximum coil dimension shall be about 48 in. (122 cm). The coil shall be placed in contact with the dovetails so that the upper and lower segments of the coil each intersect all of the dovetails at appproximately a right angle. The sides of the coil shall be laid on the body of the rotor on both sides of the wheel fingers in order to achieve adequate magnetic field strength at the extremities of the dovetails. Refer to Figure 3.

NOTE

The optimum positions of the coil for this inspection are the 1:30-4:30 and 7:30-10:30 clock positions. The rotor should then be rotated by 90 degrees and inspected from the new 1:30-4:30 and 7:30-10:30 positions (2.g, below). This allows proper particle flow and runoff without pooling of suspension.

Appendix E24

INSPECTIONS (Continued)

2. **Longitudinal Magnetization** (Continued)

   b. The initial current setting shall be 1500 amps (4500 ampere-turns with a three turn coil). Adjust as required to provide an adequate magnetizing force using QQIs.

   c. To contain the magnetism within the dovetails, place the shunt across the outside diameter of the fingers so that all fingers are covered simultaneously. Refer to Figure 3. The shunt shall be left in place for as long as the current remains on.

   d. The magnetic particle suspension shall be sprayed onto the dovetail surfaces underneath the 4 inch (10 cm) height of the shunt. The current is turned on during particle application and shall remain on for about 8-10 seconds following removal of spray suspension.

   e. The inspection area for any one "shot" is limited to the dovetail surfaces within this shunt zone. Care shall be taken to properly mark the areas previously inspected. Successive inspections shall assure a minimum overlap of 0.5 in. (1.3 cm) of the shunt height.

   f. The inspection sequence (movement of the shunt within a given coil position) shall be from the lower end of the coil to the upper end.

   g. Movement of the coil around the outer diameter of the dovetails shall include a minimum overlap of 12 in. (31 cm) from the previous coil position.

   h. Record any indications on the attached data form.

3. **Circular Magnetization** (Optional)

   This method uses a central conductor placed through aligned pin holes. It is very sensitive to defects oriented radially to the pin holes and axially to the rotor inside the holes, but is very time consuming.

   a. Pass the brass or copper rod through a set of aligned pin holes. Connect one power cable from the power supply to each end of the rod. While current is flowing, apply magnetic particles to both sides of each pin hole through which the central conductor is located.

   b. The current setting should be 175 amps initially. Adjust the current as required using the QQIs.

   c. Carefully remove the conductor from the holes and inspect the inside of the holes for any indications

   d. Record any indications on the attached data form.

   e. Care should be taken to mark those sets of pins which have already been inspected.

Appendix E25

DEMAGNETIZATION

The unit shall be demagnetized after all inspections have been completed. Use the same procedure described in General Inspection Notes and Precautions, para. 1, above.

RETURN OF DATA FORM

The completed data form should be given to the local GE representative. It will be sent to the main GE office for evaluation and recommendation.

Appendix E26

TIL 1121-3ARi
Attachment 1
Figure 1

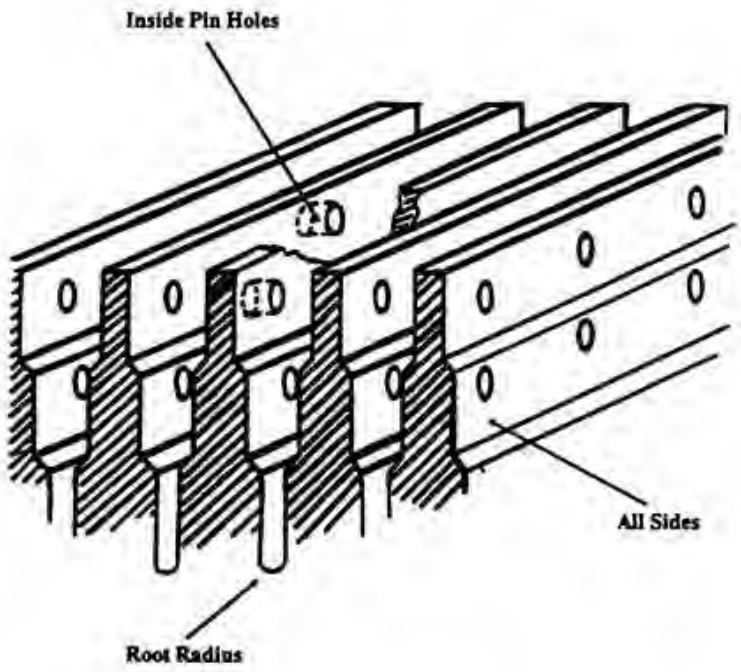


Figure 1
Inspection Locations

Appendix E27

TIL 1121-3AR1
Attachment 1
Figure 2

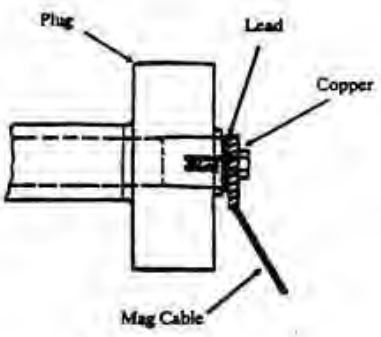


Figure 2A
Bore Plug

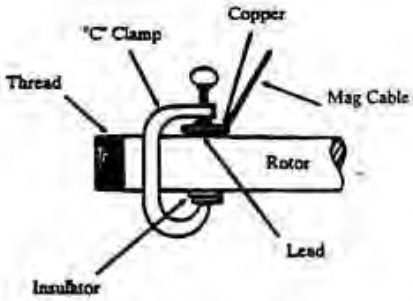


Figure 2B
Governor End of Rotor

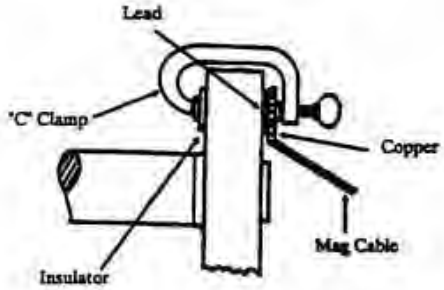


Figure 2C
Coupling Face

Figure 2
Attachment of Cables to Rotor

Appendix E28

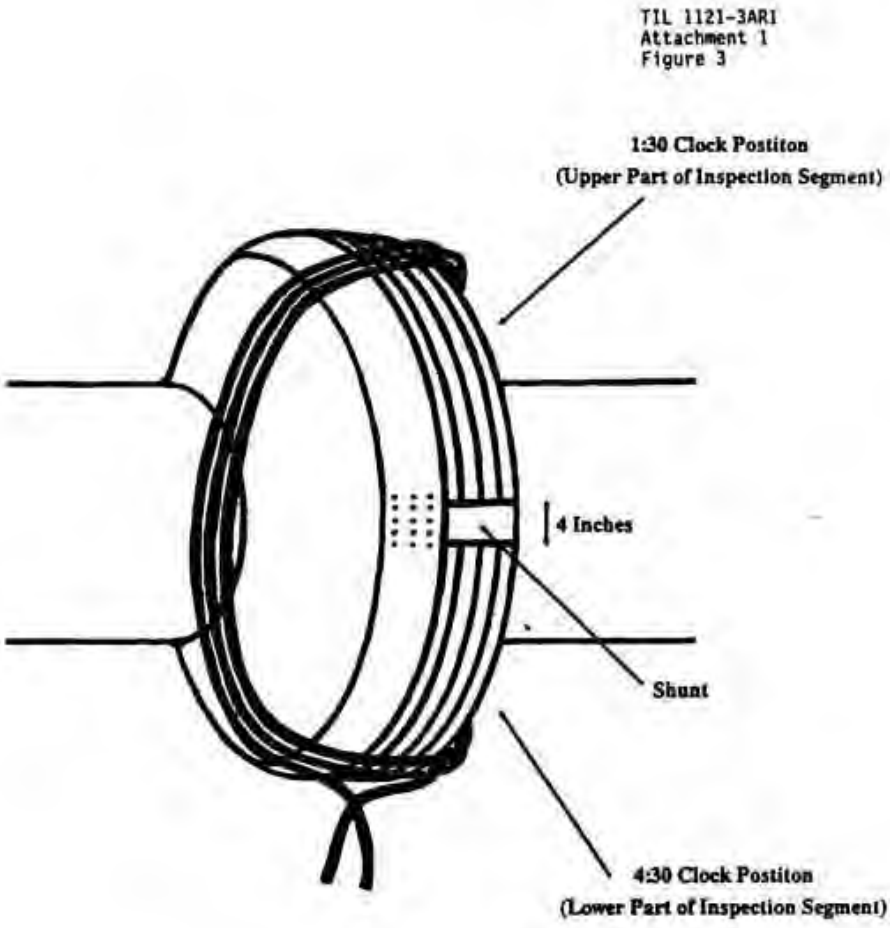


Figure 3
Longitudinal Magnetization
with 3-Turn Coil and Shunt

Appendix E29

TIL 1121-3AR1
Attachment 1
Data Sheet 1 of 2

TURBINE WHEEL FINGER DOVETAIL MAGNETIC PARTICLE TEST RESULTS

Turbine number _____ Inspection date _____

Customer _____ Station _____

Rotor (LPA, LPB,..) _____ Type of unit _____

Rotor S/N _____ End _____ Stage _____

Finger dovetail type: Flat _____ or Nested _____

Mag. particle inspection company _____
Person to contact _____

Describe all indications below and on the attached sketch. Include an accurate description of the location, length and orientation for all indications. Use a separate sketch for indications on each different dovetail face. Include additional sketches as required for indications in other locations.

Dovetails are numbered consecutively, with the #1 dovetail on the admission end of the wheel (see sketch). Rows of pin holes are numbered consecutively in the direction of rotation, with the #1 row located directly below the #1 flat-type dovetail bucket or directly below the back edge of the #1 nested-type dovetail bucket.

Indications detected? Yes ____ No ____

Location of indication(s) (Check all that apply.)

Dovetail number(s) _____ Pin hole row number(s) _____
Admission side face ___ Discharge side face ___
Pin hole region: Inner ___ Middle ___ Outer ___
Root radius between dovetail number ___ and number ___
Inside surface of pin hole ___
Wheel/wheel fillet ___
Other (describe) ___

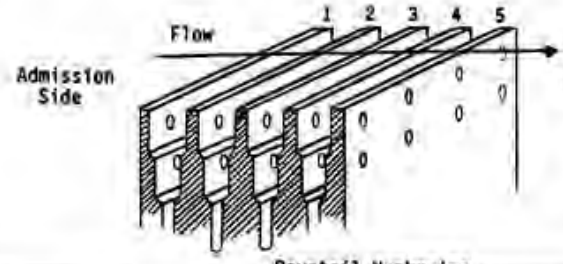
Comments:

SEND IMMEDIATELY TO: Steam Turbine Service Engineering
Bucket and Rotor Service Engineer
GE Company
1 River Road Bldg 37-3C
Schenectady, NY 12345
Phone: (518) 385-9641 Fax: (518) 385-2438

11/91 TVT

Appendix E30

TIL 1121-3AR1
Attachment 1
Data Sheet 2 of 2



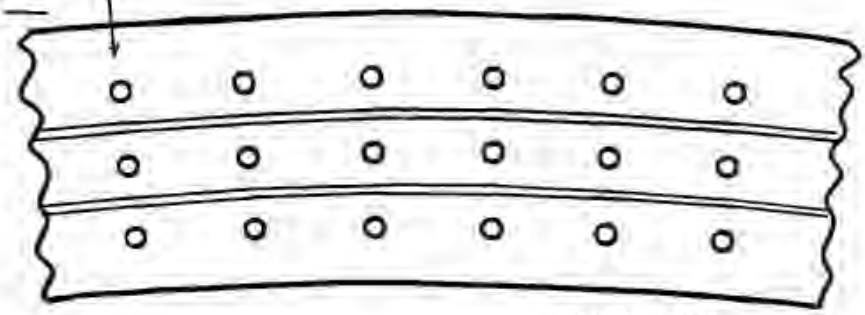
Dovetail Numbering

WHEEL FINGER DOVETAIL MAGNETIC PARTICLE TEST DATA SHEET
(Sketch indications below.)

Rotor End _____ Dovetail # ____ Stage ____ Date _____ Inspector _____

Admission Side

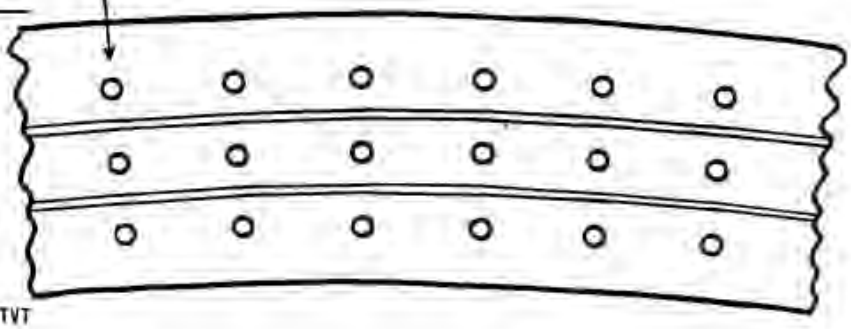
Pin Hole Row # ____



(Not to scale)

Discharge Side

Pin Hole Row # ____



11/91 TVT

Appendix E31

TIL 1277-2
GE ENERGY SERVICES
PRODUCT SERVICE
December 2,1999

g

TECHNICAL INFORMATION LETTER

INSPECTION OF LOW PRESSURE ROTOR WHEEL DOVETAILS ON STEAM TURBINES WITH FOSSIL FUELED ONCE-THROUGH BOILERS.

APPLICABLE TO
All US fossil steam turbines with once-through boilers

PURPOSE
To inform users of need to inspect low pressure rotor wheel dovetails on steam turbines to detect possible Stress Corrosion Cracking.

BACKGROUND / DISCUSSION
Over the past several years cases of intergranular Stress Corrosion Cracking (SCC) have been found in low pressure rotor dovetails of fossil steam turbine units with once through boilers. These rotors had been in service for extended periods. These incidents have involved both Tangential dovetails, figure 1
And Finger dovetails, figure 2

SCC has been known to occur with the presence of a Conducive Environment, Applied Stress Levels and a Material that can crack in this environment. The steel used for low-pressure rotors has been in service since the early 1960's due to its superior toughness required for these applications. Subsequent investigations by GE, other suppliers and institutions have found these alloys to have good SCC resistance for the strength levels used. Low-pressure rotors of this composition continue to be the materials of choice for steam turbine manufacturers.

Units operating with Once-Through boilers have a higher susceptibility for SCC. The most vulnerable location in the steam turbine for SCC is believed to be the Wilson Line or the point at which saturation occurs. This region is typically the L-1 or L-2 stage for a conventional reheat steam turbine. There are many factors that influence SCC including condensate polisher and other feed water treatment histories.

Most cases have involved the L-1 and L-2 stages. On rare occasions SCC cracking has also been found further upstream. GE can ultrasonically inspect tangential entry stages, without the need to remove buckets. Meaningful inspection of finger dovetails is not possible without removal of the buckets. SCC of finger dovetail stages has involved the internal fingers with no external indication of cracking and indications have also been found away from dovetail pinholes.

Appendix E32

RECOMMENDATIONS

1. Steam chemistry must be carefully monitored and controlled, to avoid ingestion of harmful contaminants into the turbine. For GE recommendations on steam chemistry control, refer to GEK 72281.

2. Inspect Dovetails for cracking.
   A. All tangential entry L-1 through L-4 wheel dovetails, on units with once-through boilers, with more than 10 years of service should be ultrasonically inspected. This testing is normally part of a GE in-service rotor evaluation conducted per TIL 956 or it may be conducted as a stand-alone test. GE's Phased Array Dovetail Ultrasonic Test is recommended. If it's decided to remove buckets, the wheel must be tested using florescent magnetic particle testing and a wet continuous method.

Figure 1. Tangential Dovetail

   B. For inspection of finger dovetails all of the buckets must be removed. Stages with finger dovetails cannot be inspected ultrasonically. For units with once-through boilers and more than 10 years of service, given the possible existence of cracking and the affect on unit reliability, the owner should make preparations for the inspection of all rows of finger dovetails during a convenient maintenance outage.

If buckets are removed, the surfaces must be properly cleaned using approved methods and thoroughly inspected for SCC indications in both the tangential and radial directions using florescent magnetic particle testing and a wet continuous method of testing. Stages with finger dovetails are to be tested in accordance with TIL 1121.

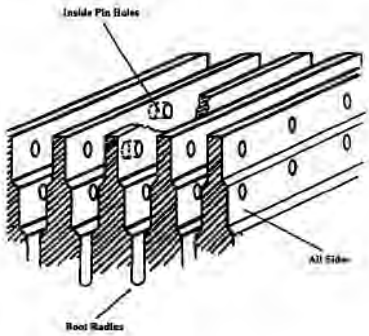


Figure 2. Finger Dovetail

3. Inspection results should be thoroughly documented and forwarded immediately to GE Energy Services for review and recommendation.

In the event that SCC is discovered, initiate repairs at the current outage. Weld repairs, using GE's FineLine weld process, using a forged ring, or GE's weld buildup restoration technology, are the best options. Tangential entry stages may be restored by machining, for either temporary or longer-term service depending on the severity of the cracking found.

For assistance in implementing the above recommendations, contact your local General Electric District Office representative.

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May 29, 2013

Mr. Darin Schottler
Xcel Energy
414 Nicollet Mall, MP7
Minneapolis, MN 55401

SUBJECT: Sherburne County Unit No. 3 - Root Cause Analysis of Steam Turbine Generator Event of November 19, 2011

Dear Mr. Schottler:

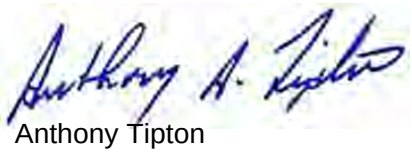
Enclosed is a copy and a CD containing an Adobe Acrobat (.pdf) file of Report No. 14439 covering our root cause analysis of the steam turbine generator event of November 19, 2011 in Unit No. 3 at the Sherburne County plant.

We appreciate this opportunity to be of service.

Very truly yours,

THIELSCH ENGINEERING, INC.

Ara Nalbandian, P.E.
Vice President, Professional Engineering



Anthony Tipton
Senior Metallurgical Engineer

Enclosures

cc: Mr. Tim Thornton, Briggs and Morgan, P.A. w/encl.

kh/43110126