DELIVERED BY HAND

April 20, 2017

Board of Commissioners
of Public Utilities
P.O. Box 21040
120 Torbay Road
St. John's, NL A1A 5B2

Attention: G. Cheryl Blundon
Director of Corporate Services
and Board Secretary

Ladies & Gentlemen:

Re: Approval of Capital Expenditures Supplemental to Newfoundland Power Inc.'s (the "Company") 2017 Capital Budget Application – Rose Blanche Hydroelectric Plant

Introductory

Please find enclosed the original and nine copies of an application (the "Application") for approval of capital expenditures supplemental to the Company's approved 2017 capital budget.

The Company's Rose Blanche hydroelectric generating plant (the "Plant") is located in southwestern Newfoundland, near the community of Rose Blanche, approximately 45 kilometres east of the Town of Port aux Basques. The Plant went into service in 1998 and has operated reliably for 19 years. The normal annual plant production is approximately 23.5 GWh of energy, or about 5.4% of Newfoundland Power's total hydroelectric production.

Turbine No. 1 Damage

On December 14, 2016, maintenance personnel were at the Plant to reset the unit following a trip due to a high bearing temperature. During run-up, unusual noises were heard emanating from Turbine No. 1 and the turbine speed was not increasing as expected. The unit was stopped pending further investigation. On December 18th, the draft tube was removed and numerous cracks were discovered in the runner blades. In addition, the stationary sealing ring in the bottom cover of the scroll case was found to be loose.

Engineering assessments of the turbine generator have determined that operation of both turbines to produce maximum production will not be possible until the damage has been rectified. Returning the Plant to its normal operating condition will require manufacture of a new runner and stationary seal components, procurement of a replacement generator shaft, and disassembly and reassembly of the existing, new and refurbished equipment. The total required capital

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expenditures are estimated at approximately $1,787,000. Most of the cost incurred as a result of the damage to the turbine will be covered by insurance. A report detailing the recommended work is included as Schedule C to the Application.

Rockfall on Access Road

On the morning of November 23, 2016, while performing routine surveillance of the Plant site, power plant maintenance staff observed the results of a significant rockfall near the main dam. The rockfall was observed to have damaged the penstock and blocked vehicle passage to the main dam. The penstock had been struck by falling rock in 4 locations, resulting in denting and paint removal.

The lack of access to the main dam resulting from the rockfall presents significant risk to the ongoing safe, reliable operation of the Plant. There is also potential for further damage to the penstock from future rockfalls. The total capital expenditures required to rectify the damage caused by the rockfall and prevent future damage to the penstock are estimated at approximately $1,494,000. A report detailing the work requirements is included as Schedule D to the Application.

The Application Filing

Schedule A to the Application summarizes the capital expenditures proposed in the Application by asset class.

Schedule B provides formal project descriptions and details on project expenditures.

Schedule C is a report titled *Rose Blanche Hydro Plant Turbine No. 1 Refurbishment* providing additional details on the requirement to refurbish the turbine generator at the Plant.

Schedule D is a report titled *Rose Blanche Hydro Plant Rockfall Remediation* providing additional details on the requirement to remediate the Plant site.

The Application is filed in accordance with the revised Capital Budget Application Guidelines issued in October 2007 (the "Guidelines"), in particular, part *B.1. Application for Approval of Supplemental Capital Expenditures*. The Guidelines provide for approval of a supplemental capital expenditure where a utility determines that a capital expenditure that was not anticipated and included in the annual capital budget is necessary in the year and should not be delayed until the following year. The capital expenditures proposed in the Application were not anticipated at the time of preparation of the Company's 2017 Capital Budget Application. It is necessary to proceed with both projects in 2017. Delaying either project until 2018 is not feasible.

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Concluding

A draft of the Order requested is enclosed for the Board's convenience. If there are any questions in relation to this matter, please contact the undersigned at the direct number noted below.

Yours very truly,

Gerard M. Hayes
Senior Counsel

Enclosure

c.	Tracey Pennell Newfoundland and Labrador Hydro	Dennis Browne, QC Browne Fitzgerald Morgan & Avis

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IN THE MATTER OF the *Public Utilities Act*, (the "Act"); and

IN THE MATTER OF an Application by Newfoundland Power Inc. (the "Applicant") for: approval to proceed with the construction and purchase of certain improvements and additions to its property pursuant to Section 41(3) of the Act.

TO: The Board of Commissioners of Public Utilities (the "Board")

THE APPLICATION OF Newfoundland Power Inc. (the "Applicant") **SAYS THAT:**

A. Introductory

1. The Applicant is a corporation duly organized and existing under the laws of the Province of Newfoundland and Labrador, is a public utility within the meaning of the Act, and is subject to the provisions of the *Electrical Power Control Act, 1994.*

2. The Applicant operates transmission lines, distribution lines and substations to deliver electricity to customers throughout its service territory on the island portion of the Province of Newfoundland and Labrador.

3. The Application proposes total 2017 capital expenditures of $3,281,000 as summarized in Schedule A.

4. The Applicant's Rose Blanche hydroelectric generating plant (the "Plant") is located in southwestern Newfoundland, near the community of Rose Blanche, approximately 45 kilometres east of Port aux Basques. The Plant was commissioned in 1998 with one 7,625 kVA General Electric generator and 2 Sulzer Francis turbines on a common shaft operating under a rated net head of 114.2 m. The turbine-generator is known as a dual Francis compact turbine with a single generator and a turbine located on each end of the generator shaft. The generator with both turbines operating has a combined nameplate capacity of 6.0 MW.

B. Turbine No. 1 Refurbishment - Rose Blanche Hydro Plant

5. On December 14, 2016, maintenance personnel were sent to the Plant to reset the unit following a trip due to high bearing temperature. During run-up of the Plant, unusual noises were heard emanating from the unit and the turbine speed did not increase as expected. The unit was stopped pending further investigation. On December 18th, the draft tube was removed and numerous cracks were discovered in the runner blades of Turbine No. 1. The stationary sealing ring in the bottom cover of the scroll case was also found to be loose. As a result, Turbine No. 1 has been removed from service and the

Plant is currently operating at reduced capacity with only Turbine No. 2 in service. Further assessment revealed damage to the generator shaft. The most cost-effective option for returning the Plant to full capacity is to replace the turbine runner, shaft and associated equipment at a cost of $1,787,000. Schedule B contains a formal description of the project.

6. Schedule C to this Application is a report titled *Rose Blanche Hydro Plant Turbine No.1 Refurbishment,* which details the results of the assessment of the damage to Turbine No. 1 and provides estimates of the expenditures necessary to return the turbine to service.

C. Rockfall Remediation - Rose Blanche Hydro Plant

7. On November 23, 2016, while performing routine surveillance of the Plant site, power plant maintenance staff discovered a rockfall near the main dam. The rockfall had damaged the penstock and blocked vehicular access to the main dam. It is estimated that approximately 500 to 1,000 tonnes of rock material were displaced in the rockfall, including stones as large as 5 tonnes. The significant amount of rock debris on the road entirely blocks vehicular access to the main dam. The rockfall damaged the penstock in 4 locations. Due to ongoing instability of the rock slope, it is not safe to work in the area of the rockfall until the summer. The most cost-effective option to ensure the safe, reliable operation of the Plant is to repair and bury the penstock, construct a ditch to contain future rockfalls and relocate the main dam access road at a cost of $1,494,000. Schedule B contains a formal description of the project.

8. Schedule D to this Application is a report titled *Rose Blanche Hydro Plant Rockfall Remediation,* which provides a detailed assessment of the results of the rockfall and provides estimates of the expenditures necessary to return the Plant site to a safe condition.

D. Justification and Relief Requested

9. The Applicant submits that the proposed expenditures for 2017, as described in paragraphs 5 and 7 hereof, are necessary to provide service and facilities that are reasonably safe and adequate and just and reasonable, all as required pursuant to Section 41 of the Act.

10. Communications with respect to this Application should be sent to Gerard Hayes, Counsel for the Applicant.

11. **THE APPLICANT REQUESTS** that the Board approve:

    (i) pursuant to Section 41 (3) of the Act, the capital expenditures associated with the purchase and construction of the improvements and additions to the Applicant's property as set out in this Application.

DATED at St. John's, Newfoundland and Labrador, this 20th day of April, 2017.

NEWFOUNDLAND POWER INC.

Gerard M. Hayes
Counsel for the Applicant
Newfoundland Power Inc.
P.O. Box 8910
55 Kenmount Road
St. John's, Newfoundland A1B 3P6

Telephone: (709) 737-5609
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IN THE MATTER OF the *Public Utilities Act,* (the "Act"); and

IN THE MATTER OF an Application by Newfoundland Power Inc. (the "Applicant") for: (i) approval to proceed with the construction and purchase of certain improvements and additions to its property pursuant to Section 41(3) of the Act.

AFFIDAVIT

I, Gary Murray, of St. John's in the Province of Newfoundland and Labrador, make oath and say as follows:

1. That I am Vice-President, Engineering and Operations of Newfoundland Power Inc.
2. To the best of my knowledge, information and belief, all matters, facts and things set out in this Application are true.

SWORN to before me at St. John's in the Province of Newfoundland and Labrador this 20th day of April, 2017:

Barrister

Gary Murray

2017 CAPITAL BUDGET SUPPLEMENTAL

Asset Class	Budget (000s)
1. Generation - Hydro	$3,281
Total	**$ 3,281**

2017 CAPITAL PROJECTS (BY ASSET CLASS)

Capital Projects	Budget (000s)	Description[1]
1. Generation Hydro		
RBH Turbine No. 1 Refurbishment	$ 1,787	2
RBH Rockfall Remediation	1,494	4
Total Generation Hydro	**$ 3,281**	
Total Supplemental Capital Expenses	**$ 3,281**	

1 Project descriptions can be found in Schedule B at the page indicated.

GENERATION - HYDRO

Project Title: **Rose Blanche Turbine No. 1 Refurbishment**

Project Cost: **$1,787,000**

Project Description

Newfoundland Power's (the "Company") Rose Blanche hydroelectric generating plant (the "Plant") is located in southwestern Newfoundland, near the community of Rose Blanche, approximately 45 kilometres east of Port aux Basques.

The Plant was commissioned in 1998 with one 7,625 kVA General Electric generator and 2 Sulzer Francis turbines on a common shaft operating under a rated net head of 114.2 m. The turbine-generator is known as a dual Francis compact turbine with a single generator and a turbine located on each end of the generator shaft. The generator with both turbines operating has a combined nameplate capacity of 6.0 MW.

On December 14, 2016 maintenance personnel were at the plant to reset the unit following a trip due to high bearing temperature. During run-up, the onsite maintenance personnel observed unusual noises emanating from Turbine No. 1 ("T1") and that the turbine speed was not increasing as expected. The unit was stopped pending further investigation. On December 18th, the draft tube was removed and numerous cracks were discovered in the runner blades of T1. The stationary sealing ring in the bottom cover of the scroll case was also found to be loose. Further assessment of the generating unit revealed the generator shaft had been damaged as well.

The report titled *Rose Blanche Hydro Plant Turbine No. 1 Refurbishment* included as Schedule C provides detailed information on the capital expenditures needed to rectify the damage and return T1 to service.

Justification

The Plant went into service in 1998 and has provided 19 years of reliable energy production. The normal annual plant production is approximately 23.5 GWh of energy, or about 5.4% of Newfoundland Power's total hydroelectric production.

Engineering assessments of the turbine generator have revealed that the damage is such that operation of both turbines to produce maximum generation from the Plant is no longer possible. Returning the Plant to its normal operating condition will require the manufacturing of a new runner and stationary seal components, procurement of a replacement generator shaft, as well as disassembly and reassembly of the existing, new and refurbished equipment. The project is justified upon the need to provide reliable and least cost electrical service to customers.

This project was not included in the 2017 Capital Budget Application as the work requirements resulted from unforeseen damage that occurred in December 2016. Delaying the project and including it in the 2018 Capital Budget Application would result in unnecessary spill in the 4th quarter of 2017 and reduced generation available from the Plant in the winter of 2017/2018.

Projected Expenditures

Table 1 provides a breakdown of the proposed expenditures for 2017 and a projection of expenditures through 2021.

Table 1
Project Cost
(000s)

Cost Category	2017	2018	2019 - 2021	Total
Material	$1,265	-	-	$1,265
Labour – Internal	160	-	-	160
Labour – Contract	-	-	-	-
Engineering	42	-	-	42
Other	320	-	-	320
Total	**$1,787**	**$0**	**$0**	**$1,787**

Costing Methodology

The budget estimate for this project is based on an engineering cost estimate of the required work.

Future Commitments

This is not a multi-year project.

Project Title: **Rose Blanche Rockfall Remediation**

Project Cost: **$1,494,000**

Project Description

Newfoundland Power's (the "Company") Rose Blanche hydroelectric generating plant (the "Plant") is located in southwestern Newfoundland, near the community of Rose Blanche, approximately 45 kilometres east of Port aux Basques.

On the morning of November 23, 2016, while performing routine surveillance of the Plant site, power plant maintenance staff observed the remnants of a rockfall near the main dam. The rockfall had caused damage to the penstock and deposited a large amount of rock material in the access road, effectively blocking vehicular access to the main dam. It is estimated that approximately 500 to 1,000 tonnes of material were displaced in the rockfall, including stones as large as five tonnes. The penstock sustained dents and damage to the coating paint as a result of falling rock striking the penstock in 4 locations.

The project will involve the repair and burial of the penstock to avoid future damage and relocation of the access road to the opposite side of the valley. A ditch will also be excavated to catch any falling rocks and ensure the safety of users of the new road.

The report titled *Rose Blanche Hydro Plant Rockfall Remediation,* included as Schedule D, provides detailed information on the project.

Justification

The Plant went into service in 1998 and has provided 19 years of reliable energy production. The normal annual plant production is approximately 23.5 GWh of energy, or about 5.4% of Newfoundland Power's total hydroelectric production.

Remediation of the damage caused by the rockfall, along with improvements to prevent damage associated with future rockfalls, is required to ensure the safe and reliable operation of the Rose Blanche Hydroelectric development.

Vehicular access to the main dam is essential to the safe, reliable operation of the Plant. If a future rockfall were to result in rupture of the penstock, Plant staff may not be able to access the main dam quickly enough to shut off the water to the penstock and avoid rapid drawdown of the reservoir. The resulting uncontrolled release of water could result in damage downstream, including washout of roads and other infrastructure, interference with fish habitat, and an interruption in production from the Plant until the penstock is repaired and water levels are restored.

This project was not included in the 2017 Capital Budget Application as the work requirements resulted from unforeseen damage that occurred in November 2016. Delaying the project and including it in the 2018 Capital Budget Application would result in an unacceptable risk of further damage to the penstock, as well as unacceptable risk to employee and public safety.

Projected Expenditures

Table 1 provides a breakdown of the proposed expenditures for 2017 and a projection of expenditures through 2021.

Table 1
Projected Expenditures
(000s)

Cost Category	2017	2018	2019 - 2021	Total
Material	$1,095	-	-	$1,095
Labour – Internal	21	-	-	21
Labour – Contract	-	-	-	-
Engineering	83	-	-	83
Other	295	-	-	295
Total	**$1,494**	**$0**	**$0**	**$1,494**

Costing Methodology

The budget estimate for this project is based on engineering estimates.

To ensure this project is completed at the lowest possible cost consistent with safe and reliable service, all material and contract labour will be obtained through competitive tendering.

Future Commitments

This is not a multi-year project.

Rose Blanche Hydro Plant
Turbine No. 1 Refurbishment

April 2017

Prepared by:

Monty Hunter, P.Eng.

REGISTERED PROFESSIONAL ENGINEER
M. C. HUNTER
SIGNATURE
April 19, 2017
PROVINCE OF NEWFOUNDLAND

NEWFOUNDLAND POWER
A FORTIS COMPANY

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Appendix A: Rose Blanche Turbine Layout

Appendix B: Runner and Bottom Ring Damage Analysis

Appendix C: Generator Shaft Damage Analysis

1.0 Background

1.1 General

Newfoundland Power's (the "Company") Rose Blanche hydroelectric generating plant (the "Plant") is located in southwestern Newfoundland, near the community of Rose Blanche, approximately 45 kilometres east of the Town of Port aux Basques. The Plant went into service in 1998 and has provided 19 years of reliable energy production. The normal annual plant production is approximately 23.5 GWh of energy, or about 5.4% of Newfoundland Power's total hydroelectric production.

The Plant contains one 7,625 kVA General Electric generator and 2 Sulzer Francis turbines on a common shaft operating under a rated net head of 114.2 m. The turbine-generator is known as a dual Francis compact turbine with a single generator and a turbine located on each end of the generator shaft.[1] The generator with both turbines operating has a combined nameplate capacity of 6.0 MW.

The Rose Blanche hydroelectric development is a true run-of-river operation with water flows varying seasonally. The single-generator, dual-turbine configuration allows for a single turbine unit to be utilized at lower inflows, thus maintaining high efficiency. When only one turbine is operating, the inlet valve to the other turbine remains closed and the second turbine spins in air with no water present. At times of high inflow into the reservoir, both turbines are utilized to provide production at the maximum capacity of the Plant.[2]

Appendix A provides an illustration of the turbine layout of the Plant.

1.2 December 2016 Event

On December 14, 2016, maintenance personnel were dispatched to the Plant to reset the unit following a trip due to high bearing temperature. The high bearing temperature resulted from the oil pump operating in DC mode as opposed to the normal AC mode.[3] Following reset of the system alarms and a visual check for damage, a unit start was initiated with Turbine No. 2 ("T2") in lead.[4]

During run-up, the onsite maintenance personnel noticed unusual noises coming from Turbine No. 1 ("T1") and observed that the turbine-generator shaft speed was not increasing as would normally be expected. The unit was stopped pending further investigation. On December 18th, the draft tube was removed to allow inspection of the turbine. The inspection revealed numerous

[1] Unit drawing is shown in Appendix A.
[2] Water flow is required to be maintained in Rose Blanche Brook downstream of the Plant for fish habitat.
[3] The DC mode is a backup mode in the event of failure of the AC power supply. It preserves oil flow to the bearings to prevent damage, and the lower than normal oil flow triggers a unit shutdown when the bearing temperature rises as a result.
[4] Single-turbine operation is alternated between the two turbines to equalize the amount of usage of each turbine. The unit currently selected for operation is referred to as the "lead" turbine. In this case, water was directed to T2 while T1 rotated in air with no water applied.

cracks in the runner blades of T1. The inspection also found that the bottom stationary sealing ring was loose.

A mechanical maintenance crew was dispatched from St. John's on December 20th to assist in further disassembly. This further inspection revealed that the key securing the T1 runner to the shaft was "rolled" in the keyway and the generator shaft rotated inside the runner bore. These findings indicated that the runner had encountered rotation resistance. Attempts were made to remove the runner, but it could not be pulled off from the shaft.

A contractor was retained and arrived at the Plant on January 6, 2017 to assist in removing the turbine runner. When the runner was removed, it was found that the generator rotor shaft keyway was deformed. In addition, the preliminary indications were that the shaft was bent in the area where the runner was fitted.

The runner and associated components were sent to turbine manufacturer American Hydro on January 16th for a repair assessment.[5] On February 8th, inspection of the generator shaft was completed.

1.3 March 2016 Event

In March 2016, the T1 runner had been subjected to an event where the runner had come in contact with the bottom seal ring. At that time, the T1 unit was operating in air when cooling water was lost to the runner band seal areas due to blockage in the cooling water supply line. This resulted in overheating and expansion of the components. When the runner contacted the stationary seal ring, the resulting heat caused the rotating runner to fuse to the stationary component.

Repairs were undertaken in the spring of 2016, and the unit was returned to service in June. To lessen the chance of a similar occurrence in future, the stainless steel stationary ring was replaced with a cast bronze ring. Bronze is a softer material than steel, and therefore more forgiving than steel in the event of contact between the rotating and stationary components. At the time, the T1 runner blades were inspected using liquid penetrant, and no cracks were found. The unit operated without any problems until the event on December 14, 2016.

2.0 Damage Assessment

2.1 Turbine

American Hydro's January 2017 assessment of the T1 runner concluded that the runner had been previously subjected to a high-temperature event, followed by a rapid cooling that caused the stainless steel runner material to become brittle.[6] It is believed that the March 2016 contact between the rotating runner and the stationary stainless steel bottom seal ring exposed the runner to sufficiently high temperatures to render the material brittle. As a result of the weakening of

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5 American Hydro is a turbine manufacturer with offices in Canada and the United States.
6 The cooling procedure for cast stainless steel to avoid brittleness involves slow, controlled lowering of the metal's temperature through staged cooling.

the runner material, fatigue cracks formed during the relatively short period of time between the reinstallation of T1 in June 2016 and its failure in mid-December.[7] These cracks would have been caused by normal loading on the runner blades while T1 was operating, and would have made the runner susceptible to the failure and damage that occurred in December 2016.

American Hydro's report on their damage analysis of the runner and bottom seal ring is Appendix B to this report.

Figure 1 – T1 Turbine Runner Showing Blade Cracks

2.2 Main Generator Shaft

The generator shaft was inspected on site by American Hydro and Acuren to determine the extent of the damage and whether the shaft could be repaired on site.[8] The original equipment manufacturer, General Electric, was unable to provide the necessary inspection services within an acceptable timeframe.

The indications from the onsite testing are that the shaft end has a bend of 0.017". It is also likely, based on the deformation of the runner key and keyway, that the shaft was also twisted and plastically deformed, although this cannot be definitively established without destructive testing. Although no cracks in the shaft were found using magnetic particle, ultrasonic and liquid penetrant inspection methods, American Hydro are of the opinion that the stress to which the shaft was exposed in the December 2016 incident has drastically reduced the fatigue life of the shaft, and have recommended that the shaft be replaced.

7 Testing completed following the March 2016 event would not have identified the changes at the molecular level that resulted in the brittleness that ultimately caused the cracks later observed in the runner. Testing for brittleness would have required removing samples of metal from the runner for destructive testing that would have essentially required it be replaced by a new runner.

8 Acuren is a non-destructive inspection company. Their inspection report on the Rose Blanche turbine shaft is included in American Hydro's report (Appendix C to this report).

American Hydro's report on their damage analysis of the generator shaft is Appendix C to this report.

Figure 2 – Rolled Key and Shaft Keyway Damage

2.3 Auxiliary Systems

To prevent future overheating of the mechanical components of the runner assembly, a new cooling water system supplying the seal areas, complete with dedicated flow switches, will be installed. In addition, a more sensitive non-contact shaft vibration monitoring system will be installed for improved protection of the unit.

2.4 Current Status

Following removal of the T1 runner, the remainder of the generating unit was inspected and found to be in good order. The unit can be safely operated using the T2 turbine only. This enables continued production from the Plant while the new runner and shaft are being manufactured.

With only the T2 turbine running the generator, the Plant provides a maximum capacity of 3 MW, or only half its nameplate capacity. During periods of high water inflow, spill will occur, as the available water cannot all be utilized by the T2 turbine.[9] The T1 turbine needs to be reinstated so efficient operation of the Plant can be restored.

[9] Inflow typically exceeds the T2 capability during the months of April, May, October, November and December.

3.0 Project Proposal

3.1 Project Description

The refurbishment project involves:

(i) the manufacture of a new runner,
(ii) the manufacture of stationary seal components,
(iii) the manufacture of a replacement generator shaft,
(iv) disassembly of the Rose Blanche generator,
(v) shipping of the existing generator shaft to the manufacturer for salvage of the flywheel and generator poles,
(vi) installation of salvaged generator components on the new shaft,
(vii) shipping of the new generator rotor with salvaged components assembled,
(viii) shipping of the new runner and stationary seal components,
(ix) replace the cooling water piping, provide additional instrumentation and replace the vibration monitoring system, and
(x) the reassembly and commissioning of the new and refurbished equipment.

3.2 Project Cost

The total project cost for the refurbishment of the Plant, including the upgrades to the cooling water system is estimated at $1,787,000. Table 1 below provides the cost breakdown.

Table 1
Project Cost
($000s)

Cost Category	**Cost**
Material	1,265
Labour - Internal	160
Labour - Contract	-
Engineering	42
Other	320
Total	**$1,787**

3.3 Project Schedule

The estimated schedule for turbine delivery from order is in the 32 week range, with the generator shaft delivery being 28 weeks. The following project milestones have been established.

April 2017	Establish contracts for supply of turbine and generator shaft
August 14, 2017	Shut down plant to remove existing generator shaft

August 28, 2017	Ship generator shaft to manufacturer for salvage of reusable components
October 16, 2017	Receive new generator shaft from manufacturer and start installation
November 6, 2017	Receive turbine from manufacturer and start installation
November 17, 2017	Turbine installation complete
November 24, 2017	Commissioning complete and unit returned to service

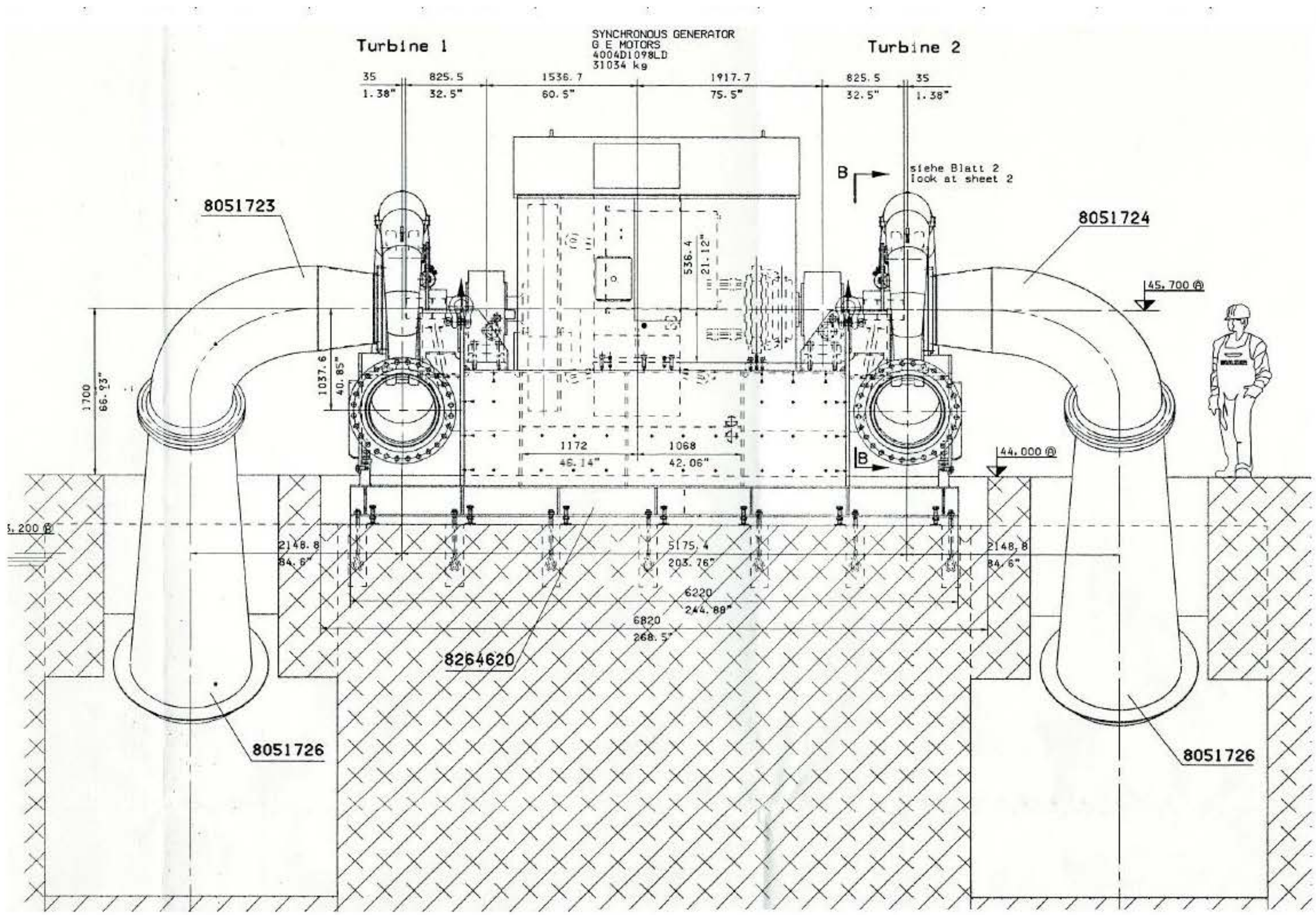
4.0 Conclusion

The T1 turbine operation is required for the full and efficient production of energy at the Plant. It is recommended that the necessary work described in this report be carried out as soon as possible.

Most of the project cost will be covered by insurance, subject to a deductible amount of \$250,000. Additional expenditures include an estimated \$25,000 for spare seal rings and \$50,000 to replace the cooling water piping, provide additional instrumentation and replace the vibration monitoring system with a more sensitive system.

The project should proceed in 2017. The project was not included in the 2017 Capital Budget Application as the work requirements arose as a result of unforeseen damage sustained by the unit in mid- December 2016. Delaying the project and including it in the 2018 Capital Budget Application will result in unnecessary spill of water in the 4^{th} quarter of 2017 and a reduction in the generation available in the winter of 2017/2018.

Appendix A
Rose Blanche Turbine Layout


Turbine 1
SYNCHRONOUS GENERATOR
G E MOTORS
4004D1098LD
31034 kg
Turbine 2
35
1.38"
825.5
32.5"
1536.7
60.5"
1917.7
75.5"
825.5
32.5"
35
1.38"
siehe Blatt 2
look at sheet 2
8051723
8051724
45.700
536.4
21.12"
1700
66.93"
1037.6
40.85"
1172
46.14"
1068
42.06"
44.000
2148.8
84.6"
5175.4
203.76"
2148.8
84.6"
6220
244.88"
6820
268.5"
8264620
8051726
8051726

Appendix B
Runner and Bottom Ring Damage Analysis

American Hydro
A Wärtsilä Company | WÄRTSILÄ

Runner and Bottom Ring Damage Analysis

Rose Blanche Unit 1

33109-TD Rev. B

March 23, 2017

Newfoundland Power

American Hydro Contract No. 64038

Authored By:

Michael A. Little
Supervisor of CAD Design

Reviewed by:

Joseph M. Druck, P.E.
Chief Engineer

Introduction

American Hydro (AH) was contracted by Newfoundland Power (NP) to evaluate the damage caused by an operational incident that occurred with Rose Blanche Unit 1 (U1). The scope of this document is limited to the runner and the bottom ring.

It is AH's understanding that U1 experienced a galling failure of the interface between the runner and the lower stationary seal in the bottom ring. The first incident occurred in March of 2016 and the second incident occurred in December of 2016.

After the first galling incident, the stainless steel lower stationary wearing ring was replaced with an aluminum bronze material. In spite of more favorable materials, the unit galled again after approximately five months of service.

Initial work and action plan development

Upon arrival at AH, the runner buckets were sequentially numbered 1-13 in a clockwise direction beginning at the shaft key way (Figure 1 below). A long crack was immediately noted in the middle of the discharge section of bucket #4. Major deformation of the key way was also observed.

As a result of this readily visible damage, AH determined that a two-pronged approach would be required to properly assess the runner's current condition. The first phase would involve the use of our FARO ARM coordinate measuring machine. The second phase would use established visual (VT) and dye penetrant (PT) methods to determine the true extent of the cracking.

A comprehensive inspection instruction drawing 33095 was generated and it is included in the appendix at the end of this document.

FIGURE 1 – BUCKET IDENTIFICATION PATTERN

Runner FARO ARM inspection results

A full copy of the report is included in the appendix at the end of this document. Note that the report letters A thru J coincide with A thru J as shown on drawing 33095.

Highlights –

The runner seals at datums D, E, F and G have run outs consistent with a new runner. The largest observed run out is .0032" (.08mm) at the outer crown seal D.

All of the shaft bore run outs exceed industry standards. This is assumed by AH to be a direct result of the visually distorted keyway. At datum A the run out is .0047" (.12mm), at datum B the run out is .0078" (.20mm) and at datum C the run out is .0093" (.24mm)

The bottom plane of the band and the top plane of the crown are parallel within .003" (.08mm) which is in line with original equipment manufacturer tolerances.

FIGURE 2 – RUNNER SET UP IN FARO ARM WORK STATION

Runner NDT results

A full copy of the report is included in the appendix at the end of this document. Please note that buckets 7 and 10 had no recordable defects.

Highlights –

It appears that the key way cracking is only in the flame sprayed coating on the surface perpendicular to the bore.

In addition to the nine readily apparent cracks in the band discharge fillets, eight of the thirteen buckets also exhibit crown discharge fillet cracks.

Runner material properties

The colors shown in the photo below (Figure 3) accurately capture the temperatures involved in the first incident. Colors such as pale or straw yellow indicate heating in the area of 600 F (316 C). Blue or dark blue is 1,150 F (621 C) to 1,200 F (649 C) and grey or darker areas are even higher. Locations that have any scale formation indicate a temperature of 1,580 F (860 C). Where the material experiences the most distress is the cooling from these temperatures which will typically have two effects. One, if the material is not cooled slowly cracking may occur prior to any physical stresses being applied. Or two, if no cracking occurs the material will likely form un-tempered martensite. This then presents a microstructure that exhibits a brittle characteristic. With a brittle structure in place, once load and fatigue come back into play the cracking that we observe on this runner will typically occur.

FIGURE 3 – RUNNER HEAT DAMAGE DURING THE FIRST INCIDENT

Runner crack discussion - (Added as Revision A – 2/16/17)

Please refer to figures 4 thru 6 below. Input for this discussion section was prepared by Eric Russell, P.E.

The cracking seen at the intersection of the blade discharge edges and the crown is typical of Francis runners. This location is usually the highest stressed area in a runner, and fatigue cracks may begin to form as a result of the start/stop cycles of the unit. The cracking seen at the intersections of the blade discharge edges and the band can occur on high specific speed Francis runners where the acute angle between the blade discharge edge and band forms a stress concentration. The stresses seen in this area typically result from the rotational speed of the unit (operating and runaway). The crack on blade 4 is not in a location that typically sees high stress. The first 1 inch of this crack length shows a smooth texture typical of fatigue crack propagation with some smearing of the surface that corresponds to shearing between the crack faces. This smearing most likely occurred after the brittle fracture. The remaining 3.5 inches of crack length shows a grainy texture typical of brittle fracture, which would have occurred after the crack propagated beyond the slow growth region. The most probable cause of a crack initiating in this abnormal location is a localized impact causing a crack initiation site. However, there is not a clear indication of such an impact on this blade. Given that, we think that once this blade had cracked and separated from the band, this allowed the blade to repeatedly flex at the now-cracked location. This caused a fatigue crack to form and propagate for the first 1 inch, then transition to fast growth and fracture for the remaining crack length.

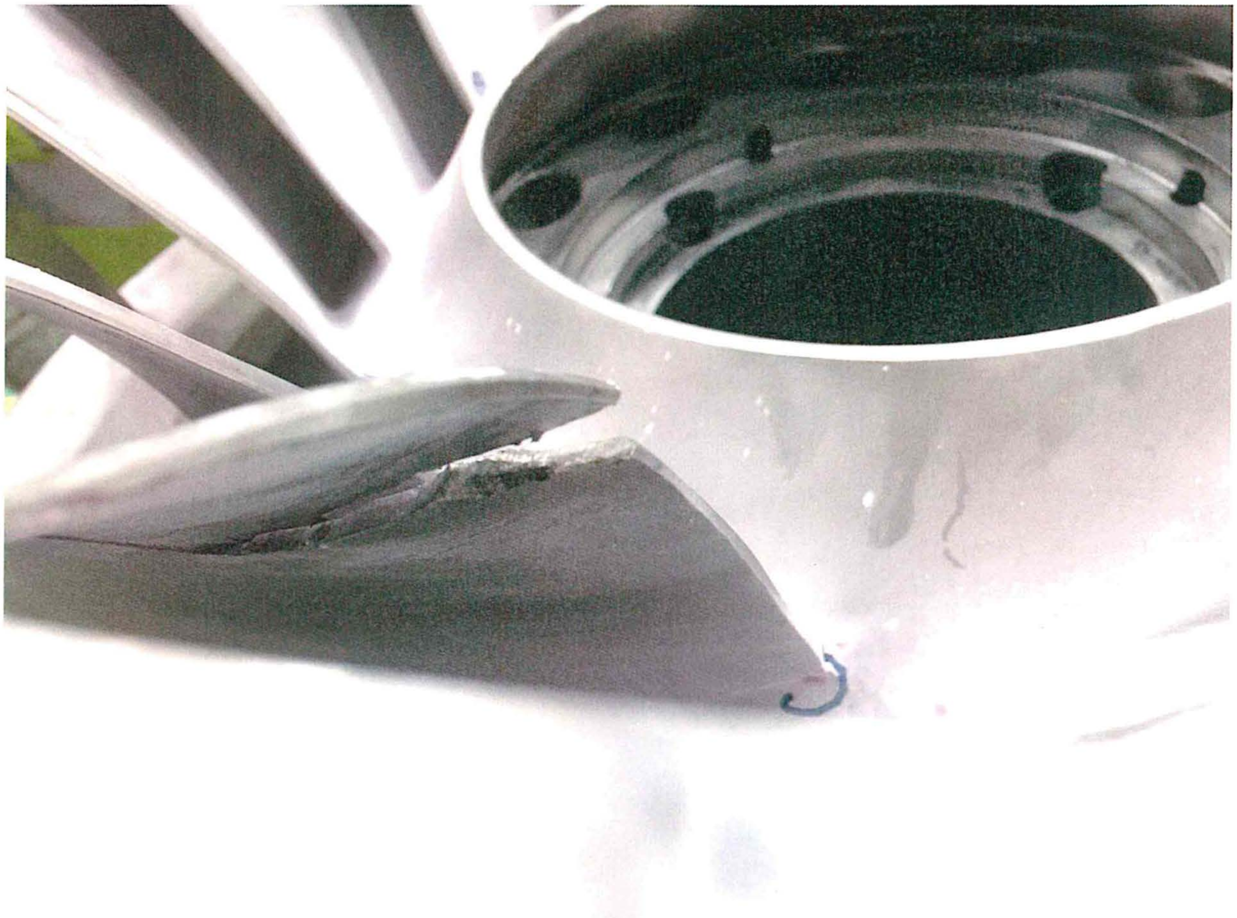


FIGURE 4 – BUCKET #4 PRESSURE SIDE

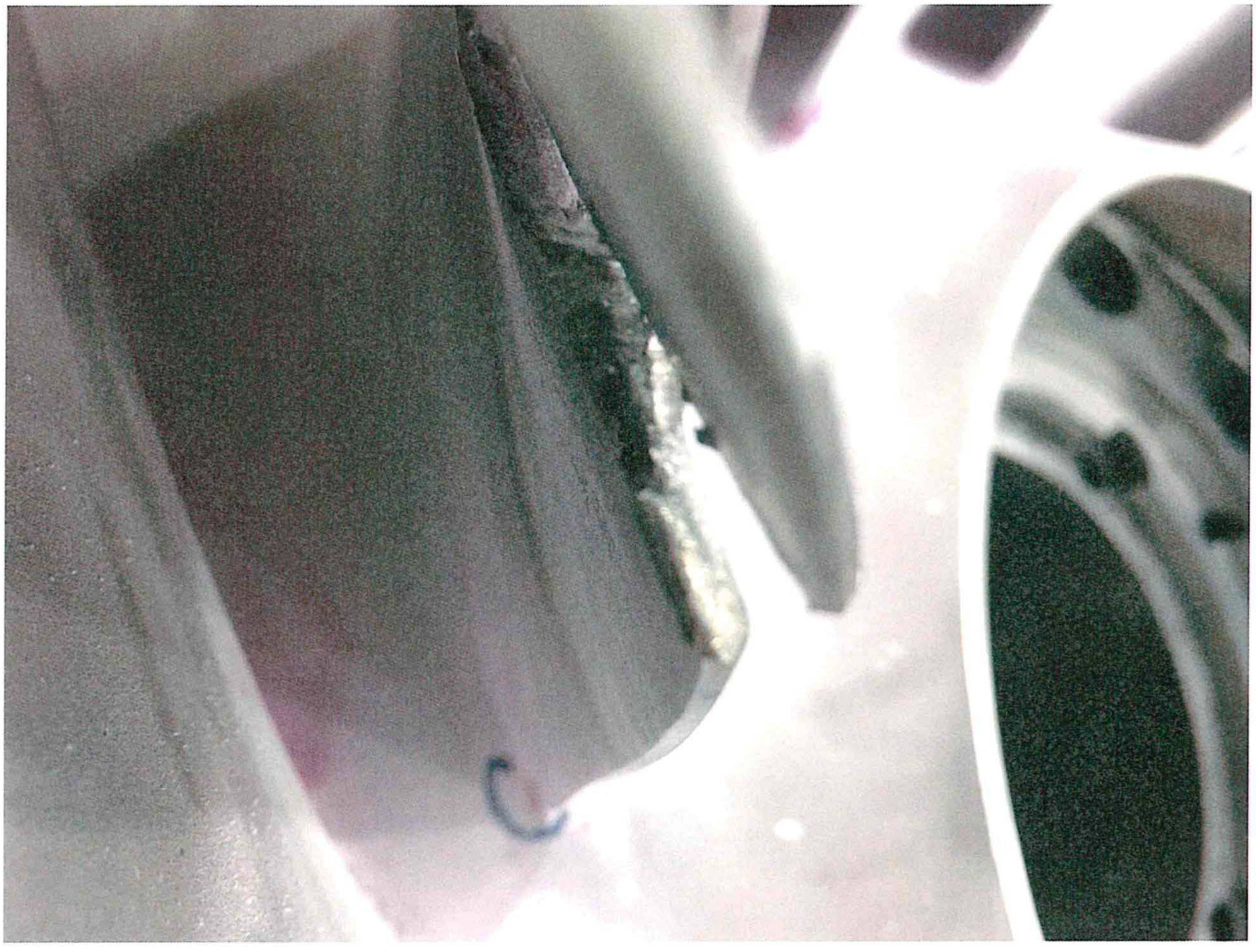


FIGURE 5 – BUCKET #4 LOOKING PARALLEL TO DISCHARGE EDGE

FIGURE 6 – BUCKET #4 SUCTION SIDE

Bottom ring inspection

While inspecting the runner it was noted that substantial aluminum bronze material has transferred to the rotating seals. The aluminum bronze sealing surface exhibits heavy scarring and large burrs are turned up on the edges. Further inspection revealed that a .010" (.25mm) feeler gauge can readily be inserted behind the seal (Figure 8 below). AH shop personnel noted during the handling process that the ring appears to be loose in the bore. Burrs on the OD of the seal (Figure 9 below) confirm that the ring rotated in the bottom ring bore during the incident. The torque of the runner and generator rotor acting through the galled interface exceed the resistance of the designed press fit.

Bottom ring rehabilitation

The bottom ring could be readily repaired with a new aluminum bronze stationary wearing ring.

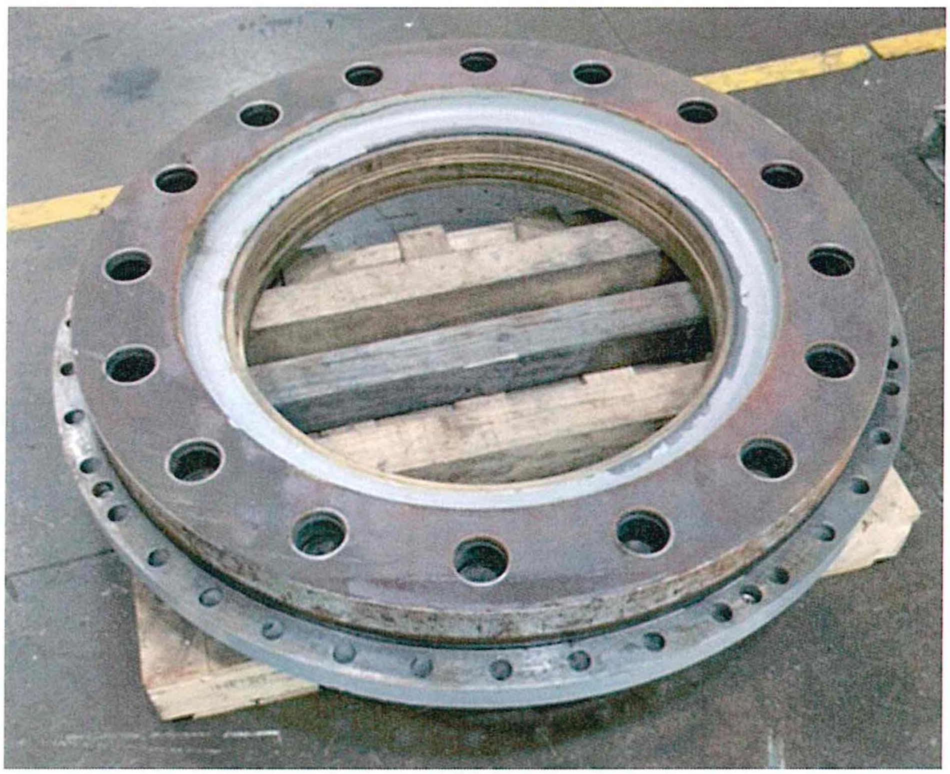


FIGURE 7 – AS RECEIVED BOTTOM RING

FIGURE 8 - .010" (.25mm) FEELER GAUGE INSERTED BEHIND SEAL

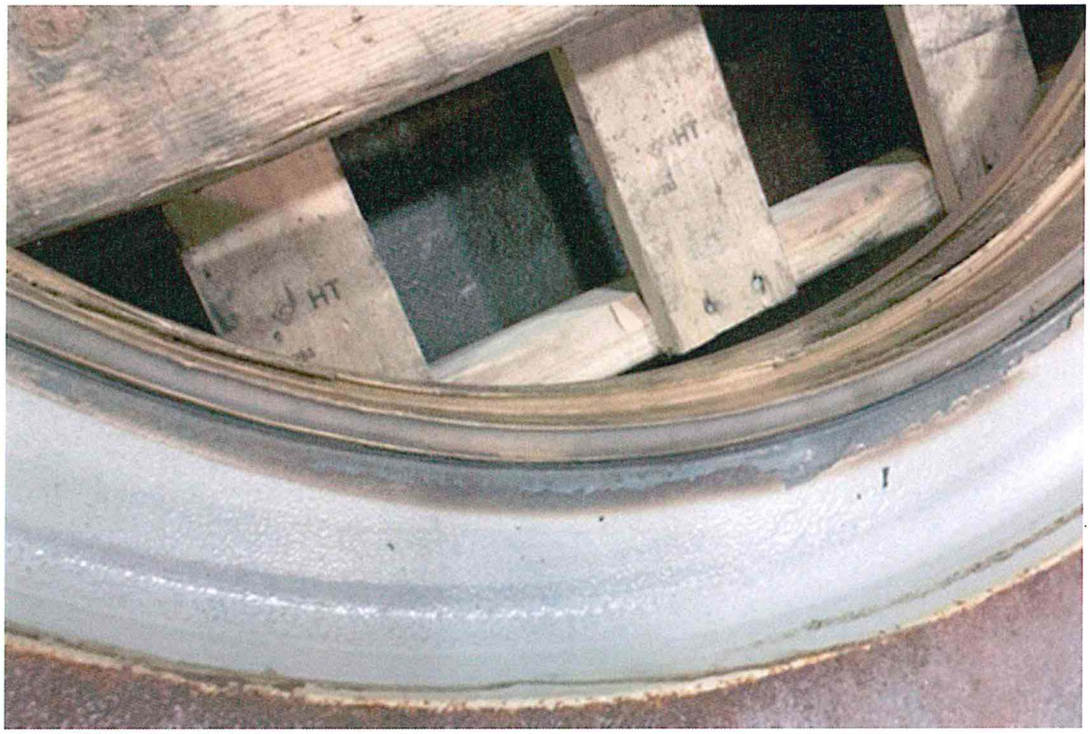


FIGURE 9 – BURRS ON ID AND OD OF THE WEARING RING AND BLISTERED PAINT

Potential runner rehabilitation

This runner has been subjected to a rapidly occurring, extremely high temperature event followed by instantaneous cooling on two separate occasions. Rapid heating and cooling is extremely detrimental to the mechanical properties of martensitic stainless steel.

If this runner were to be rehabilitated, a series of carefully monitored events would need to occur.

1 – A material sample would need to be sent out for testing to determine the exact chemical composition. Assuming the materials are able to be welded work would continue.

2 – The entire runner would need to be thermal stress relieved to mitigate the residual stresses that occurred during the previous two incidents.

3 – The large tear on bucket number four would need to have a weld joint generated and a full penetration repair weld would need to be performed.

4 – After bucket number four is stable, its profile would be reshaped to match the other twelve buckets.

5 – All of the cracks on the other buckets would be excavated and a full penetration repair weld would be performed.

6 – Once all of the buckets are stabilized a vent check would need to be performed to assure that the hydraulic imbalance is within the industry standard guidelines.

7 – Every critical surface would then need to be machined undersize and have a weld build up applied. This step prevents the newly machined features from being generated directly in the root of the weld build up.

8 – After all of the weld repairs are complete, the entire runner would then be thermally stress relieved to remove all of the newly generated residual weld stresses.

9 – After stress relief all of the runner's critical surfaces would be machined to OEM dimensions.

10 – As significant welding and machining would have occurred, the runner would need to be rebalanced.

Conclusion

Based on our experience, the basic work outline described above would most likely result in a repair expense that approaches the cost of a new runner. There are also many opportunities for unintended consequences to occur during the execution of the repair. Although extreme care would be used in the above rehabilitation process American Hydro would not be able to provide a warranty. We assume that other turbine manufacturers would take a similar stance.

As such, American Hydro strongly recommends that the damaged Rose Blanche runner be replaced with a new runner. Doing so would provide an engineered solution to the issues that the plant has been experiencing. A new runner would also benefit from the advances in both CFD and FEA that have been developed over the last twenty years.

Please contact American Hydro for clarification or discussion on any aspect of our report.

APPENDIX –

Section 1 – Drawing 33095 Runner Evaluation

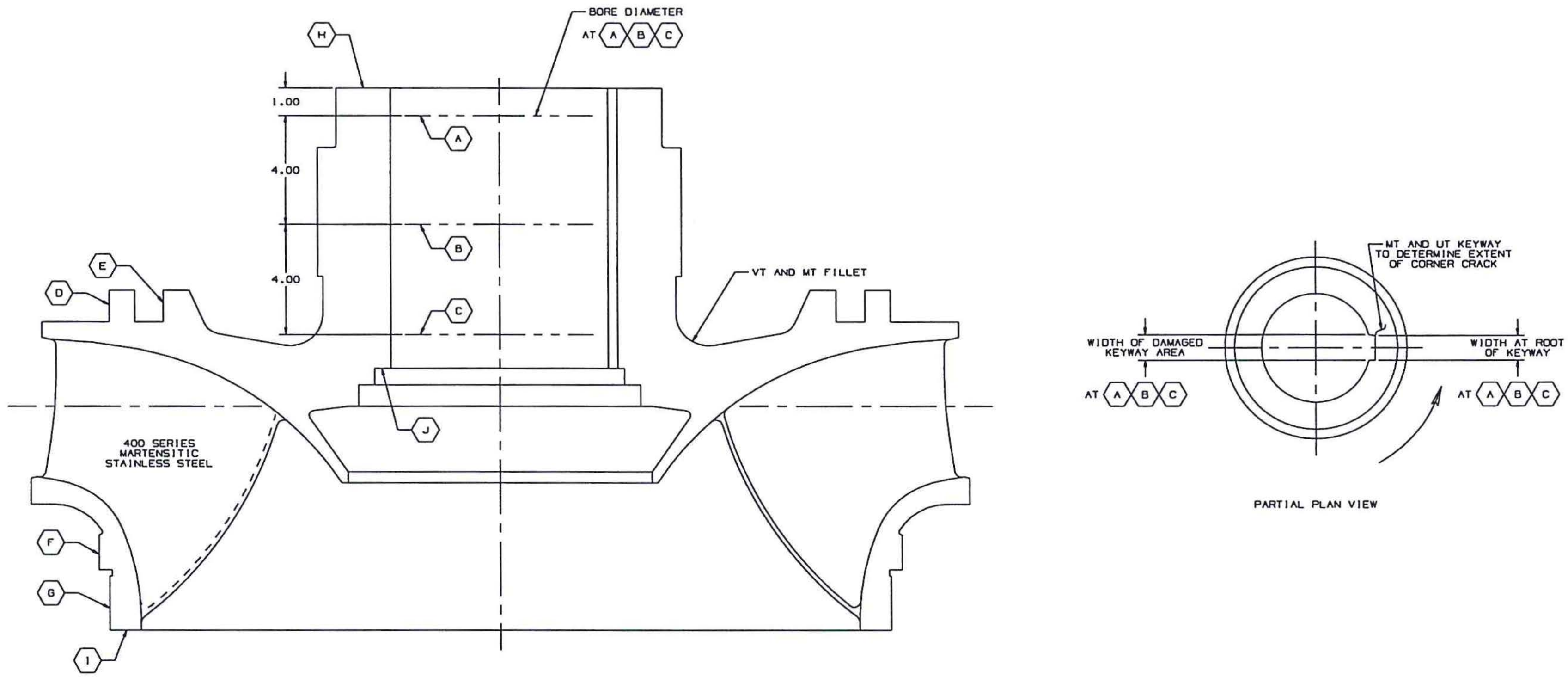
Section 2 – FARO ARM report

Section 3 – VT and PT report with photos

SECTION 1 – DRAWING 33095 RUNNER EVALUATION DRAWING

DWG NO 33095 SIZE D REV -

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED



64038	1
ORDER & UNIT	QTY
USED FOR	

CAD DRAWING
NO MANUAL REVISIONS

DIMENSIONING PER
ASME Y14.5-2009

UNLESS OTHERWISE NOTED:
DIMENSIONS ARE IN INCHES,
DIMENSIONS IN [ ] ARE IN MM
MACHINING TOLERANCES ARE:
1 PLACE DECIM ±.062
2 PLACE DECIM ±.031
3 PLACE DECIM ±.010
ANGLES ±0.500°
REAMED HOLES +.0015/-.0005
BREAK ALL EDGES .015 MIN

CONTRACT: ROSE BLANCHE

American Hydro
A Wärtsilä Company

AMERICAN HYDRO
CORPORATION
YORK, PA, USA

DRAWN: M. LITTLE 2/8/17
CHECKED:
HYD ENG APP: NOT REQUIRED
APPROVED:

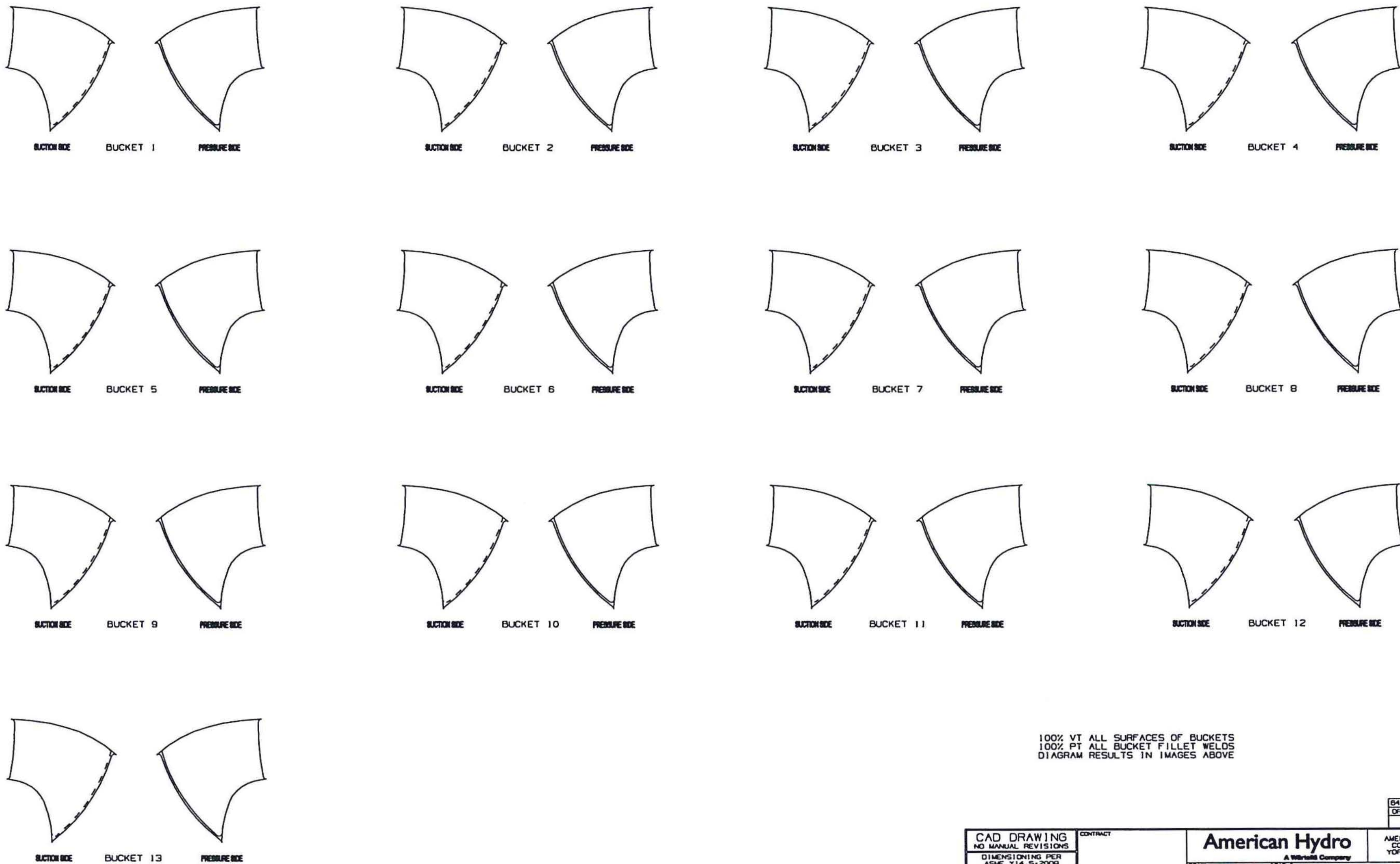
TITLE: RUNNER EVALUATION

DWG NO 33095 SIZE D REV -

SCALE 1:2 ORDER NO 64038 SHEET 1 OF 2

DWG NO 33095 SIZE D REV -

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED



100% VT ALL SURFACES OF BUCKETS
100% PT ALL BUCKET FILLET WELDS
DIAGRAM RESULTS IN IMAGES ABOVE

64038	1
ORDER & UNIT	QTY
USED FOR	

CAD DRAWING
NO MANUAL REVISIONS

DIMENSIONING PER ASME Y14.5-2009

UNLESS OTHERWISE NOTED:
DIMENSIONS ARE IN INCHES,
DIMENSIONS IN [ ] ARE IN MM
MACHINING TOLERANCES ARE:
1 PLACE DECIM ±.062
2 PLACE DECIM ±.031
3 PLACE DECIM ±.010
ANGLES ±0.500°
REAMED HOLES +.0015/-.0005
BREAK ALL EDGES .015 MIN

CONTRACT: ROSE BLANCHE

American Hydro
A Wärtsilä Company

AMERICAN HYDRO CORPORATION
YORK, PA, USA

DRAWN: M. LITTLE 2/8/17
CHECKED
HYD ENG APP: NOT REQUIRED
APPROVED

TITLE: RUNNER EVALUATION

DWG NO 33095 SIZE D REV -

SCALE 1:4 ORDER NO 64038 SHEET 2 OF 2

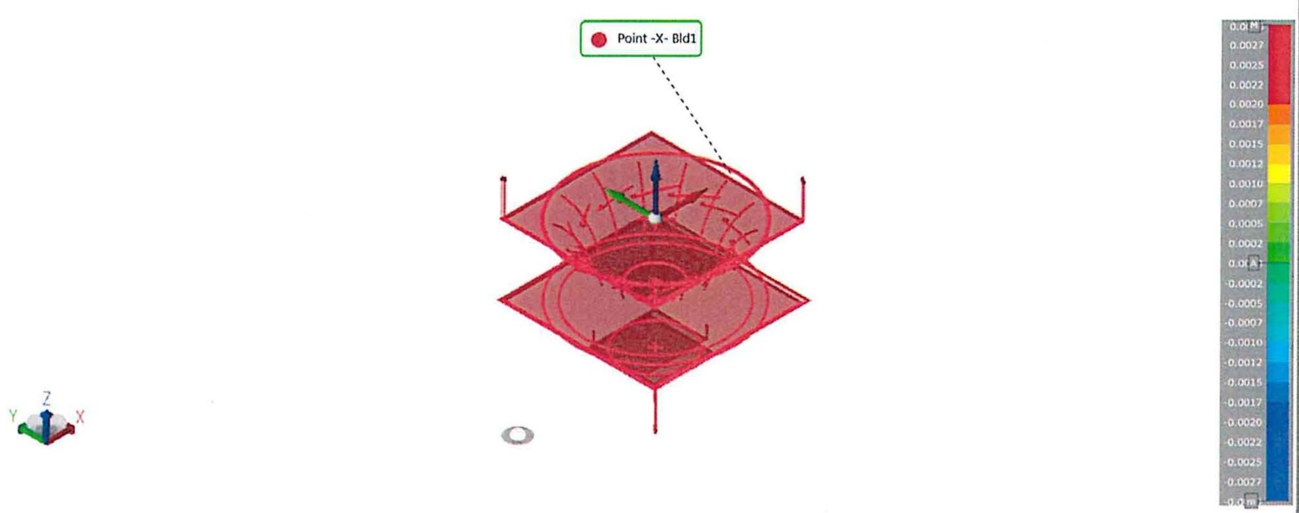
SECTION 2 – FARO ARM REPORT

FARO Technologies Inc.

125 Technology Park	http://www.faro.com
FL 32746	support@faro.com
Lake Mary	(407) 333-9911
USA	08 Feb 2017 01:21 PM

Session Information

Program Name	
File Name of FCD	Rose Blanche 2-8-17 Final I.fcd
Part Name	
Session Name	
Note	
Operator	
Company Name	
Address	
Telephone No.	
Email Address	
Date	2/8/2017
Time	1:21 PM
Ambient Temperature	
Active Alignment Error	
Active Device	P08-05-04-03143
P08-05-04-03143 -> Device Position 1 Device Error	



Circle A

Readings:8.

	actual	nominal	dev	- tol	+tol	oot
Center.x	0.0004in			-0.0200in	0.0200in	
Center.y	0.0023in			-0.0020in	0.0020in	
Center.z	-9.4833in			-0.0020in	0.0020in	
Diameter	7.8802in			-0.0020in	0.0020in	
Circularity	0.0016in		0.0016in	0.0000in	0.0020in	0.0000in
Concentricity B	0.0047in		0.0047in	0.0000in	0.0020in	0.0028in

Circle B

Readings:15.

	actual	nominal	dev	- tol	+tol	oot
Center.x	-0.0007in			-0.0200in	0.0200in	
Center.y	0.0039in			-0.0020in	0.0020in	
Center.z	-9.4833in			-0.0020in	0.0020in	
Diameter	7.8800in			-0.0020in	0.0020in	
Circularity	0.0016in		0.0016in	0.0000in	0.0020in	0.0000in
Concentricity B	0.0078in		0.0078in	0.0000in	0.0020in	0.0058in

Circle C

Readings:6.

	actual	nominal	dev	- tol	+tol	oot
Center.x	-0.0011in			-0.0200in	0.0200in	
Center.y	0.0045in			-0.0020in	0.0020in	
Center.z	-9.4833in			-0.0020in	0.0020in	
Diameter	7.8805in			-0.0020in	0.0020in	
Circularity	0.0011in		0.0011in	0.0000in	0.0020in	0.0000in
Concentricity B	0.0093in		0.0093in	0.0000in	0.0020in	0.0073in

Circle D

Readings:11.

	actual	nominal	dev	- tol	+tol	oot
Center.x	-0.0009in			-0.0200in	0.0200in	
Center.y	-0.0014in			-0.0020in	0.0020in	
Center.z	-12.3165in			-0.0020in	0.0020in	
Diameter	28.3400in			-0.0020in	0.0020in	
Circularity	0.0015in		0.0015in	0.0000in	0.0020in	0.0000in
Concentricity B	0.0032in		0.0032in	0.0000in	0.0020in	0.0012in

Circle E

Readings:8.

	actual	nominal	dev	- tol	+tol	oot
Center.x	-0.0001in			-0.0200in	0.0200in	
Center.y	-0.0012in			-0.0020in	0.0020in	
Center.z	-12.3165in			-0.0020in	0.0020in	
Diameter	24.4048in			-0.0020in	0.0020in	
Circularity	0.0015in		0.0015in	0.0000in	0.0020in	0.0000in
Concentricity B	0.0025in		0.0025in	0.0000in	0.0020in	0.0005in

Circle F

Readings:7.

	actual	nominal	dev	- tol	+tol	oot
Center.x	-0.0008in			-0.0200in	0.0200in	
Center.y	-0.0007in			-0.0020in	0.0020in	
Center.z	0.0000in			-0.0020in	0.0020in	
Diameter	28.8420in			-0.0020in	0.0020in	
Circularity	0.0016in		0.0016in	0.0000in	0.0020in	0.0000in
Concentricity B	0.0022in		0.0022in	0.0000in	0.0020in	0.0002in

Circle G

Readings:7.Datum:B.

	actual	nominal	dev	- tol	+tol	oot
Center.x	0.0000in			-0.0200in	0.0200in	
Center.y	0.0000in			-0.0020in	0.0020in	
Center.z	0.0000in			-0.0020in	0.0020in	
Diameter	28.2899in			-0.0020in	0.0020in	
Circularity	0.0017in		0.0017in	0.0000in	0.0020in	0.0000in
Concentricity	0.0000in		0.0000in	0.0000in	0.0020in	0.0000in

Plane H

Readings:15.

	actual	nominal	dev	- tol	+tol	oot
Flatness	0.0015in		0.0015in	0.0000in	0.0020in	0.0000in
Parallelism A	0.0031in		0.0031in	0.0000in	0.0020in	0.0011in

Plane I

Readings:12.Datum:A.

	actual	nominal	dev	- tol	+tol	oot
Flatness	0.0012in		0.0012in	0.0000in	0.0020in	0.0000in

Plane J

Readings:11.

		actual	nominal	dev	- tol	+tol	oot
Flatness	⏥	0.0007in		0.0007in	0.0000in	0.0020in	0.0000in
Parallelism A	//	0.0010in		0.0010in	0.0000in	0.0020in	0.0000in

SECTION 3 – VT AND PT REPORT WITH PHOTOS

American Hydro
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LIQUID PENETRANT EXAMINATION REPORT

(Procedure # YK-QA-SOP-001)

Job #: 64038	U1	2/1	**Oper.:** 30	**Project:** ROSE BLANCHE

Part Description: RUNNER	**AH#:** 1	**Cust. #:** 1

Drawing #: 33095	**Part #:**	**Rev:** -	**Quant. #:** 1

Part Serial or Heat # (When Applicable): N/A

Acceptance Standard:	☒ 20003-A		☐ 20015-A	☐ Other
Examination Method:	☐ Fluorescent		☐ Water Washable	
Type:	☒ Visible		☒ Solvent Removable	
Manufacturing Stage:	☐ Before PWHT	☐ After PWHT	☐ Rough Machined	☐ Final Machined

Other (specify): AS RECEIVED

Examination Area (s) Identification	Accept	Reject	Inspector	Date
PT BKT. TO BAND & CROWN FILLETS		X	T.SMITH	2/10/17
"SEE ATTACHED SHEETS"				

Attach Record of Indications/Excavations as required.

Witnessed ______________________ Date ____________

Reviewed Mike [signature] Date 2-13-17 Page: 1 of 1

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VISUAL EXAMINATION REPORT

Job # 64038 U 1 2/1 Unit # 1 Project Rose Blanche

Operation # 30 Part Description Runner

Drawing # 33095 Part # ______ Rev ______ Qty 1

Part Serial or Heat # (when applicable) n/a

Order Quantity 1 Lot Quantity 1 Inspected Quantity 1

Supplier customer PO # n/a

Inspection Type: ☐ Source ☐ Receiving ☐ In Process ☐ Final

Manufacturing Stage: ☑ As Received ☐ After Blast Cleaning ☐ Before PWHT

☐ After PWHT ☐ As Welded ☐ Ground ☐ Rough Finished

☐ Other - Specify: ______

Procedure YK-QA-SOP-007 Surface Finish as received

Acceptance Standard no cracks , damage

List Specific Examinations 100 % exam

Record: Flaw Type, Size, Location, Orientation and Frequency On A Sketch or Drawing, Also May Photograph and Attach to This Report.

Examination Results: ☐ Accept ☑ Reject

Comments: GALLING (ML) ~~gaulding~~ on band seal 360 deg.,& on crown seal @ 41",crack @ key way appears to be only the sprayed on coating, no cracking going down the key way, cracking on the bkts see photos

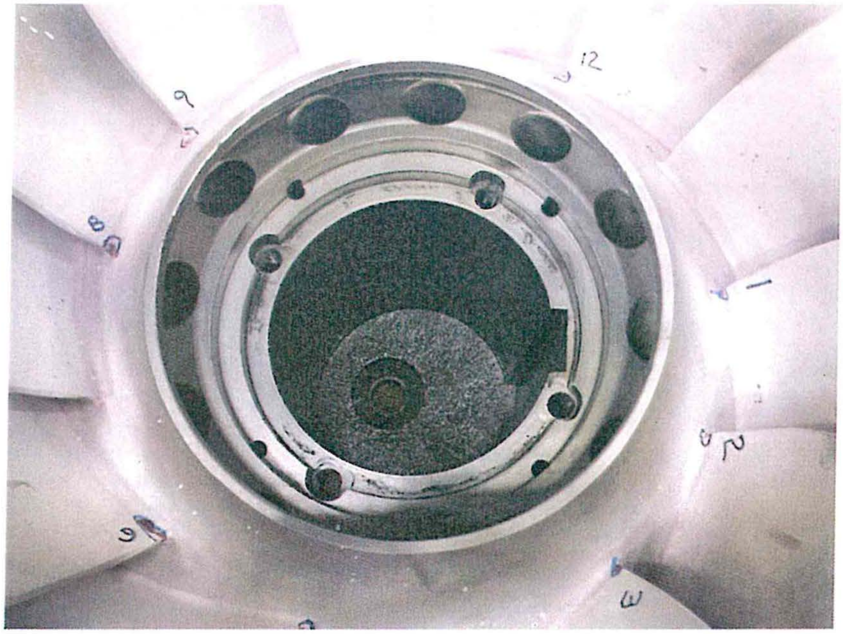
Disposition of Rejected Component:

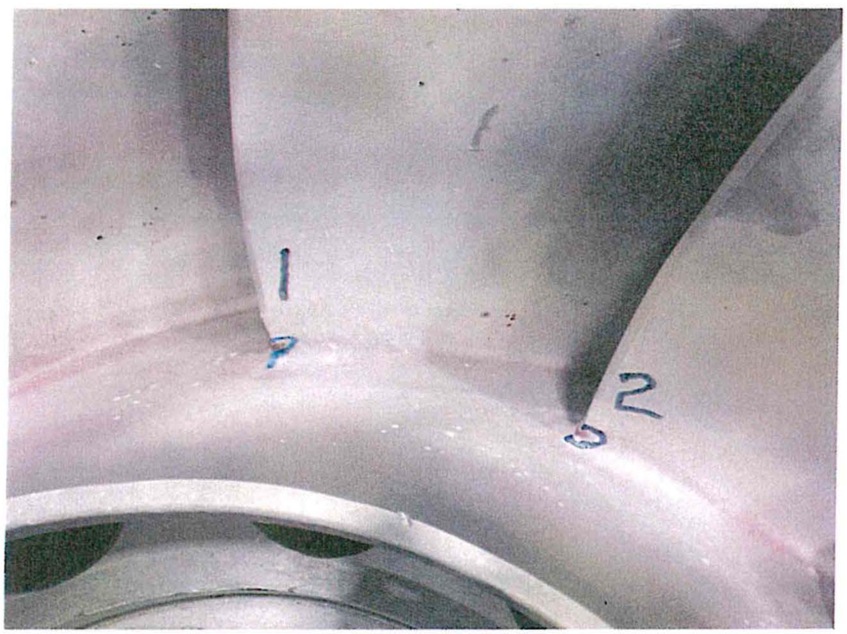
☐ Accept As Is ☐ Rework ☐ Repair ☐ Customer Approval

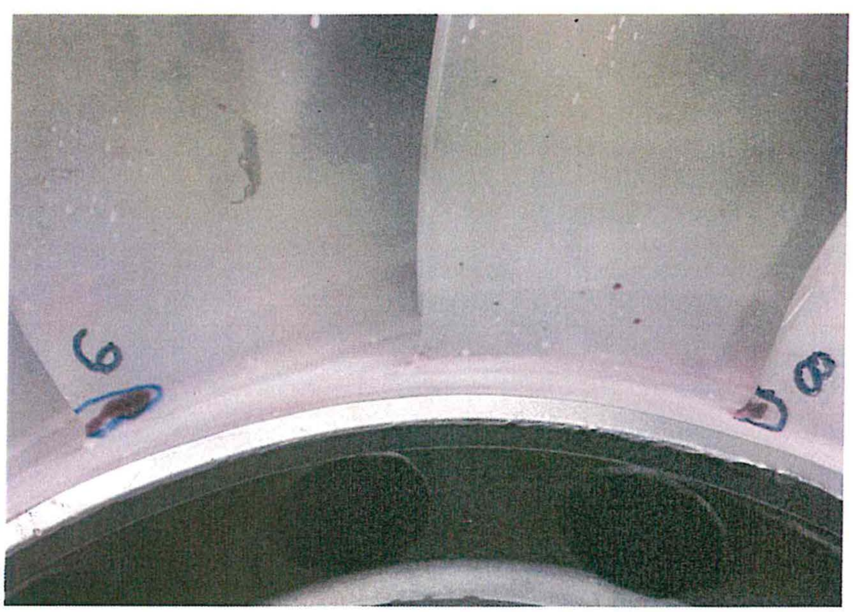
Instructions: ______

Inspector	Lee Anderson TLS	Date	2/10/17 2-10-17
Engineering (if specified)	Mike [signature]	Date	2-13-17
QA Review		Date	

64038 - Rose Blanche Runner - Visual Supplement

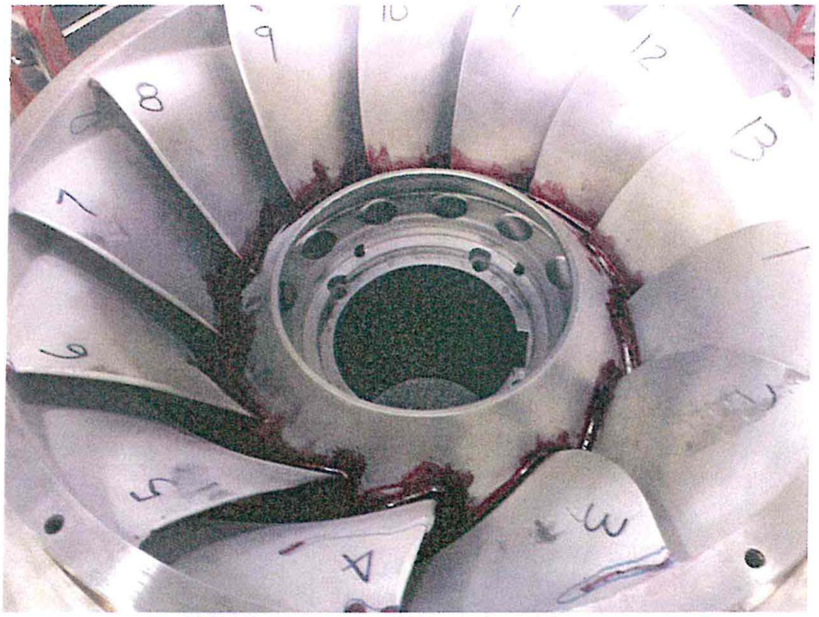






64038 - Rose Blanche Runner - Visual Supplement

64038 - Rose Blanche Runner - Visual Supplement



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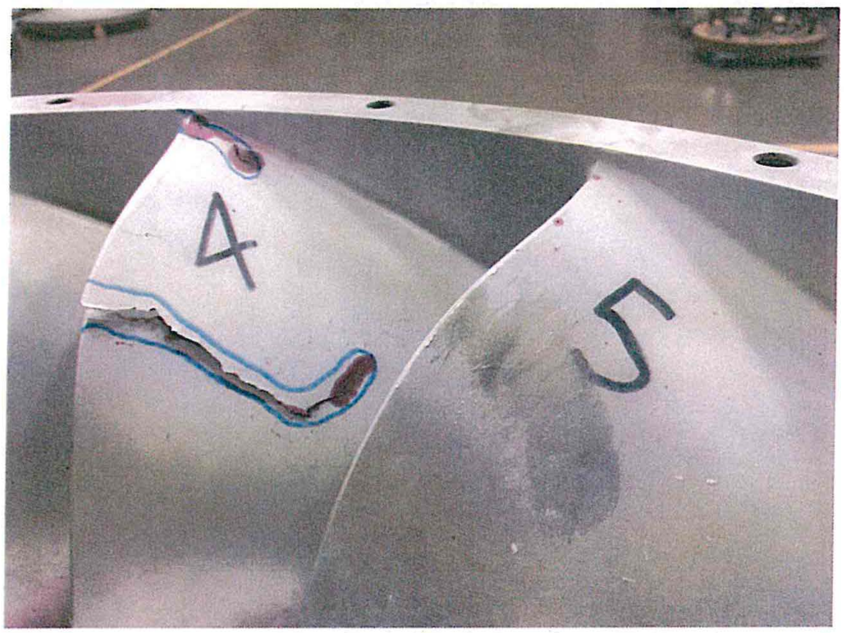

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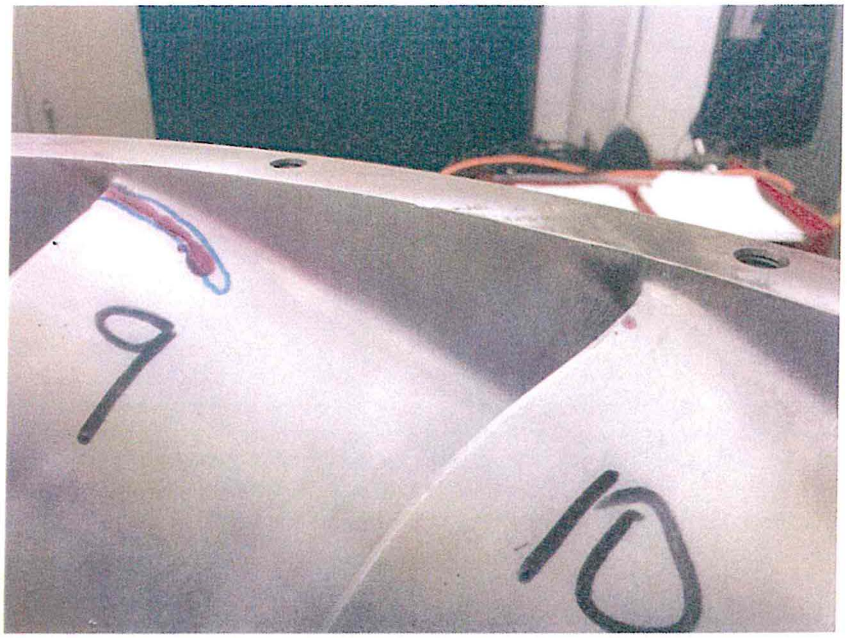
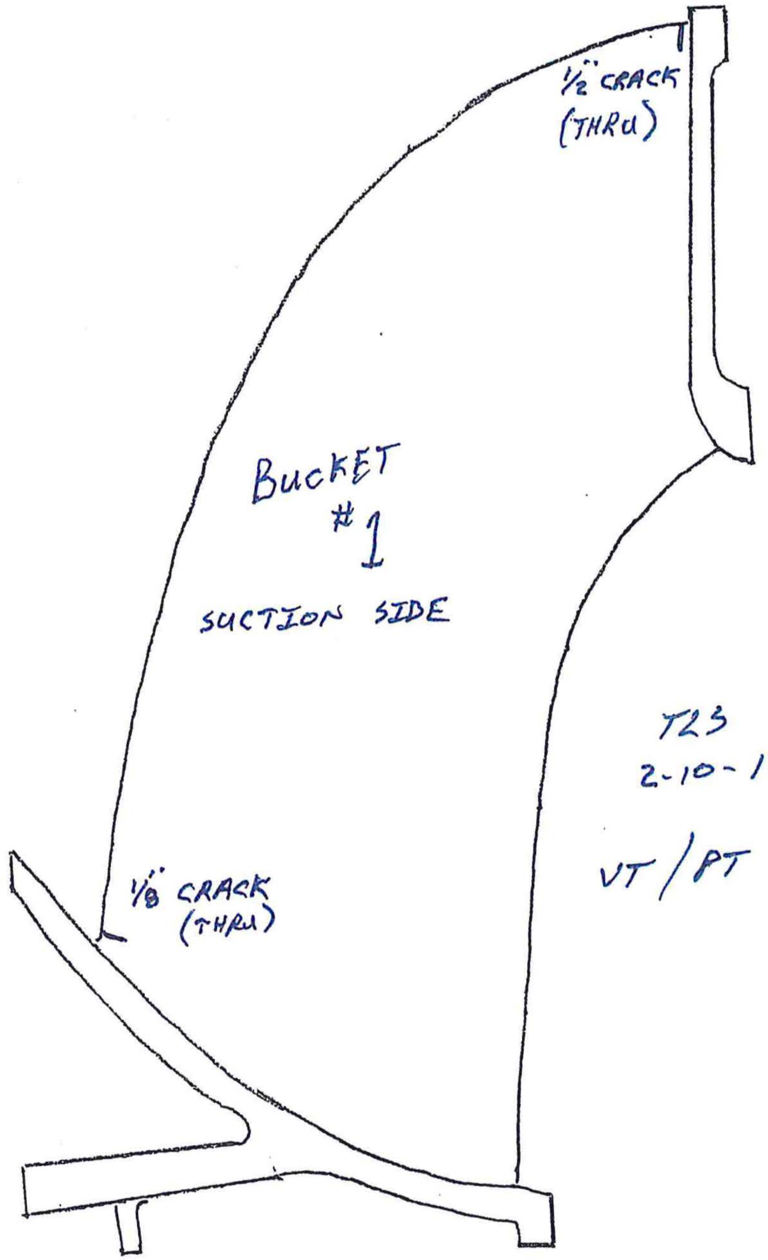
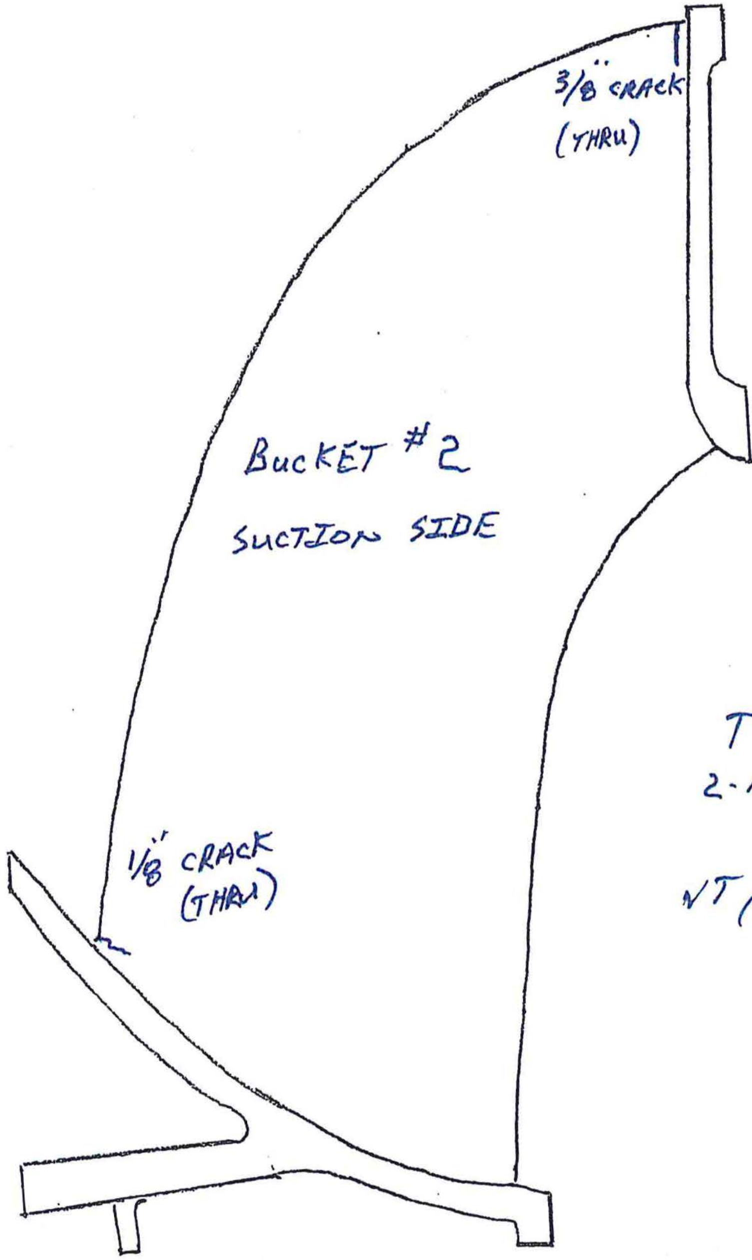




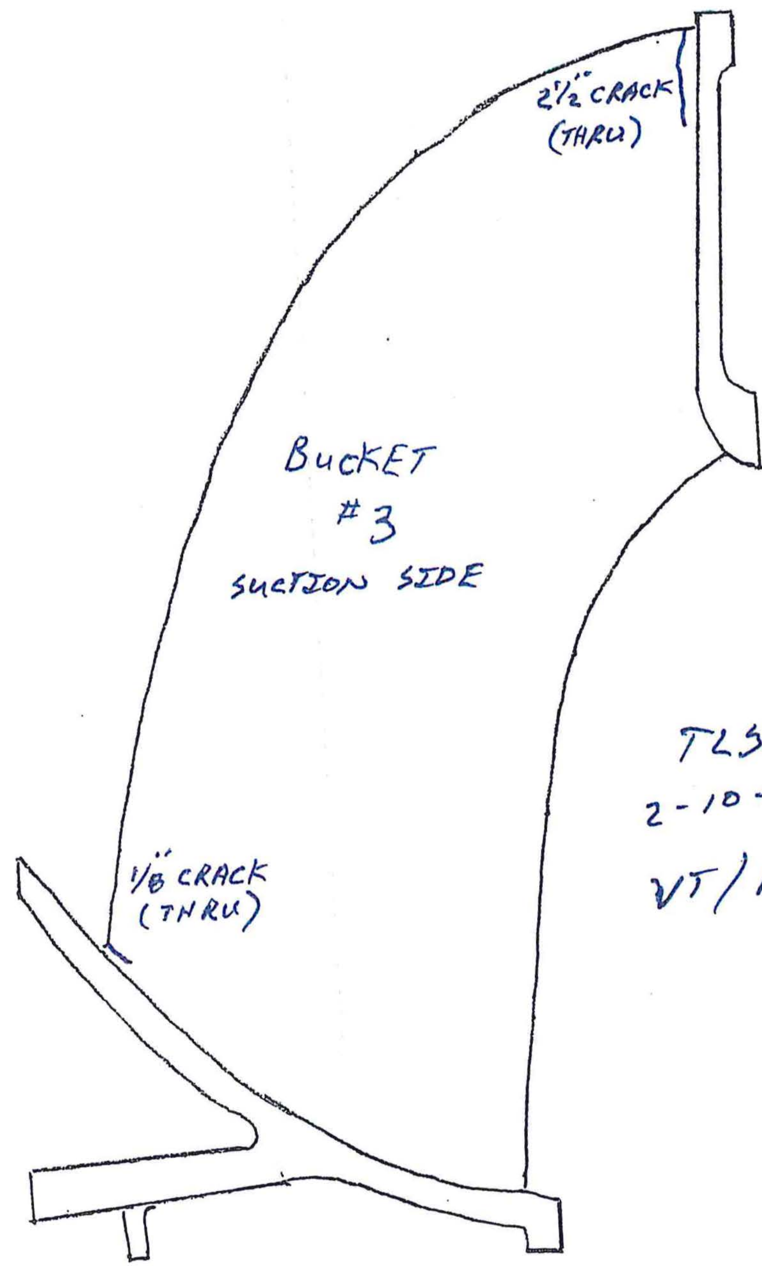
T23
2-10-17

VT/PT REJECTS

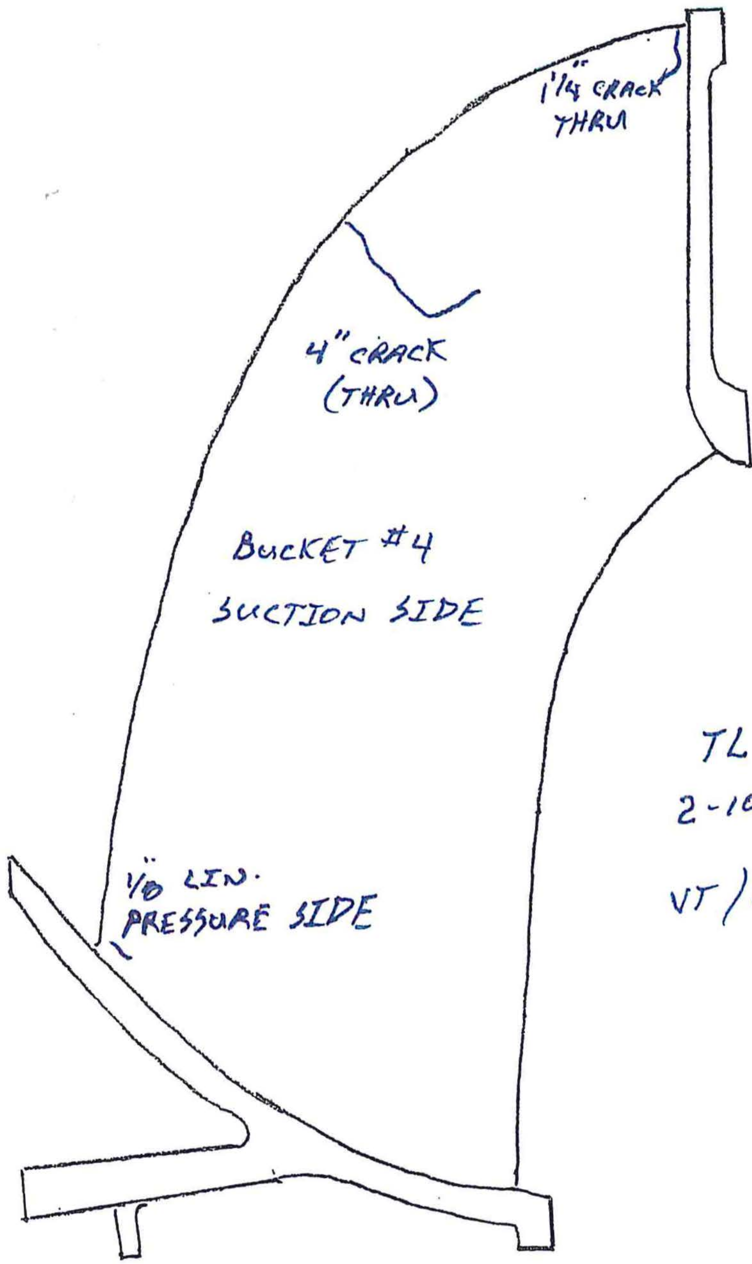


TLS
2-10-17

NT/PT REJECTS



TLS
2-10-17
VT/PT REJECTS



TLS
2-10-17
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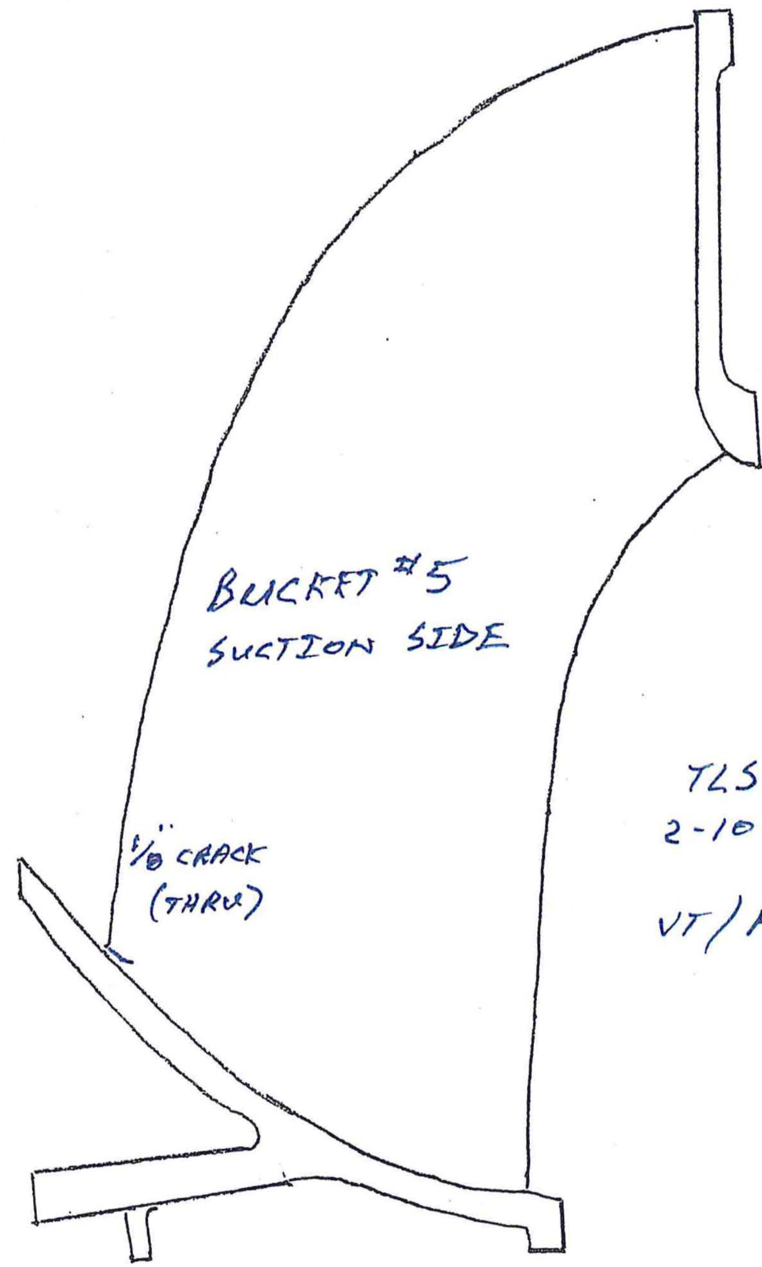

TLS
2-10-17

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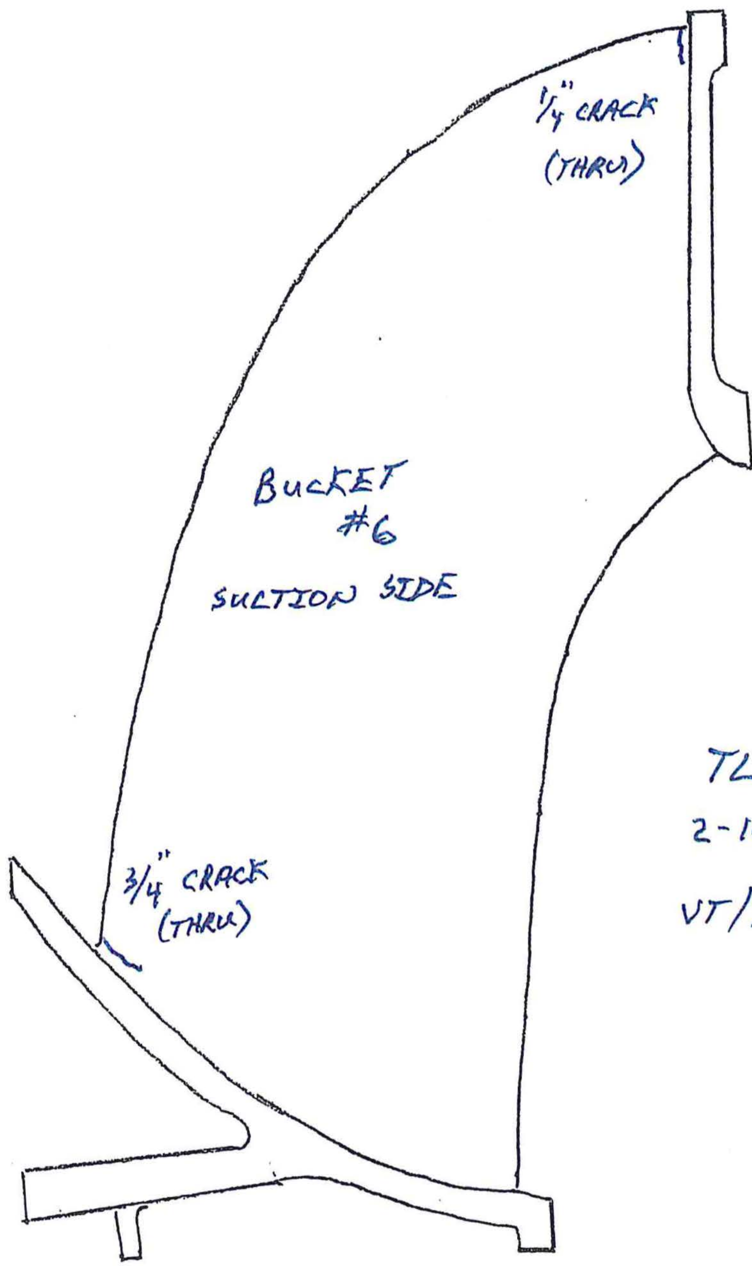
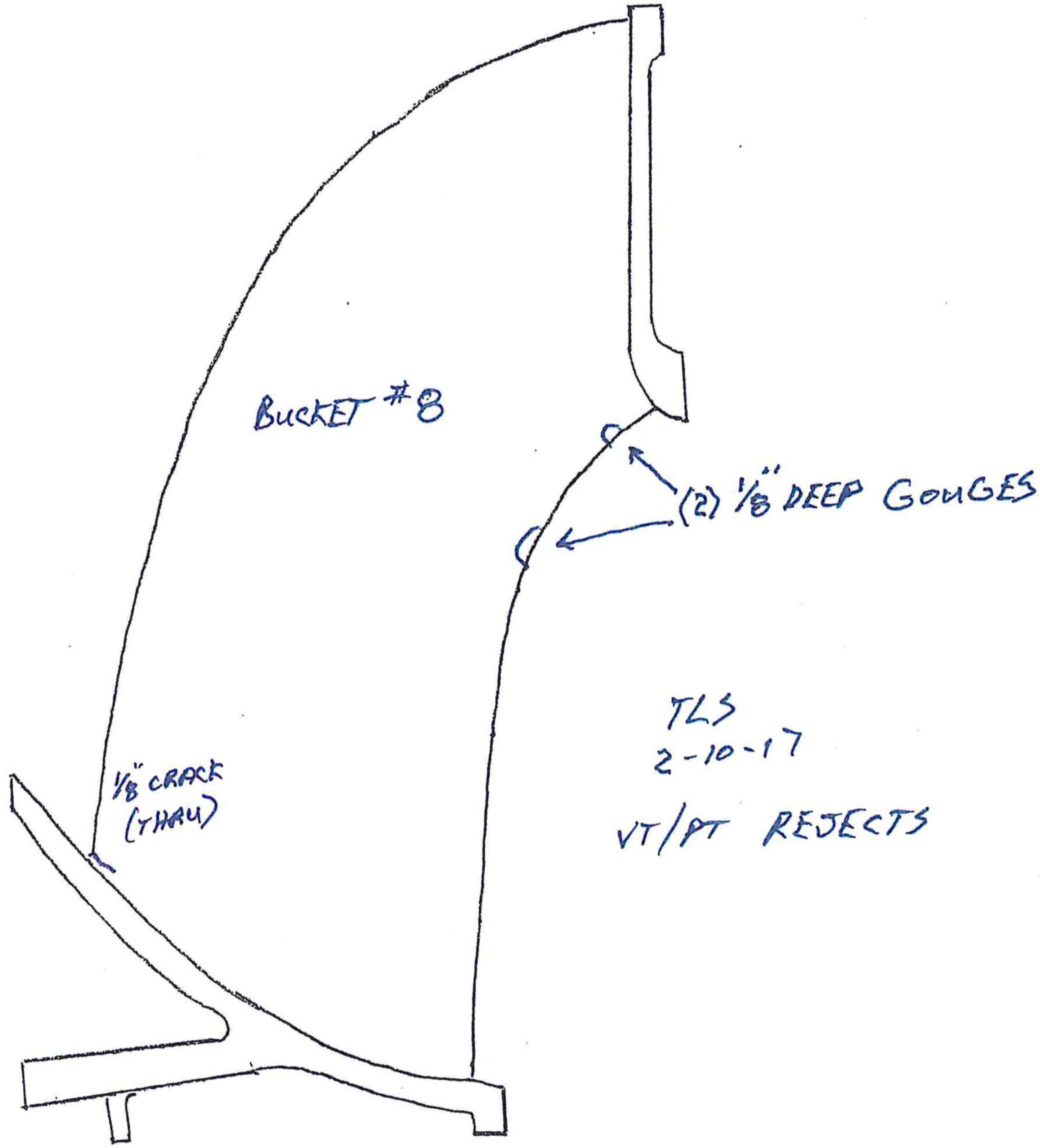
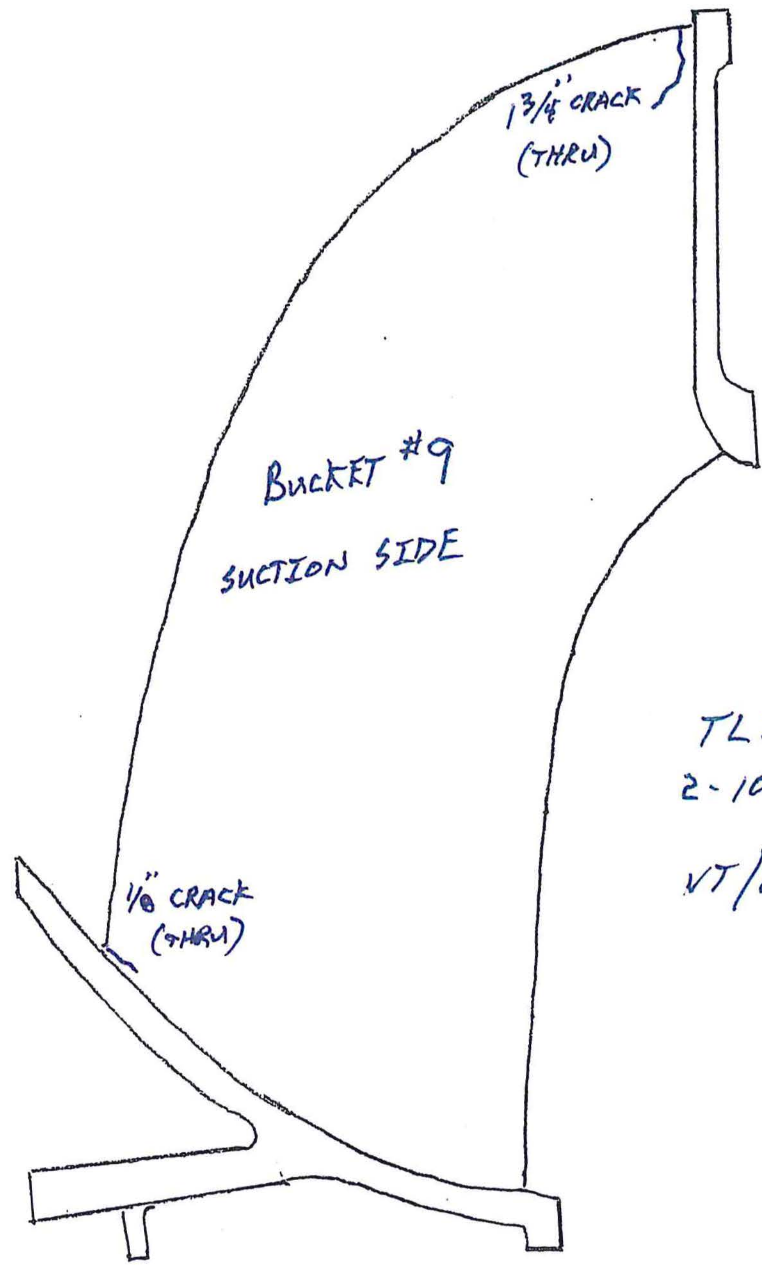


TLS
2-10-17
VT/PT REJECTS


BUCKET #8
(2) 1/8" DEEP GOUGES
1/8" CRACK
(THRU)
TLS
2-10-17
VT/PT REJECTS



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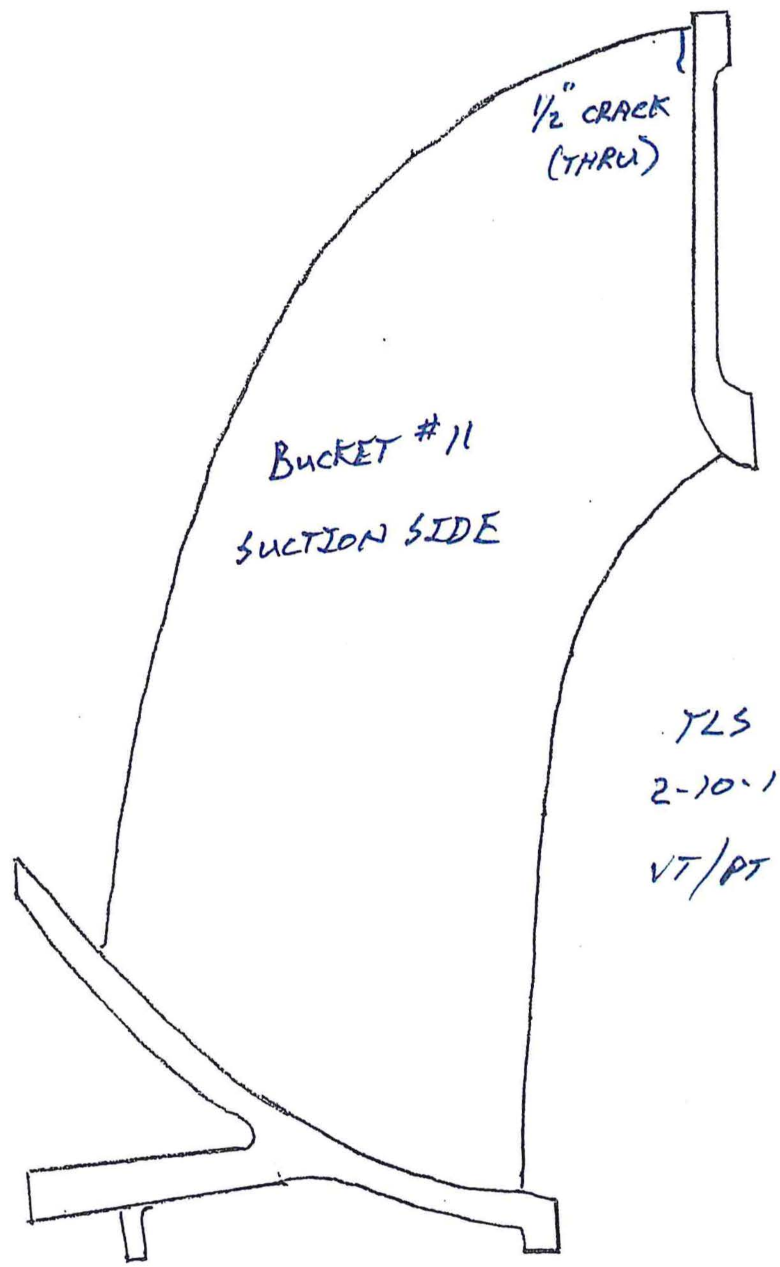
2-10-17
VT/PT REJECTS



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2-10-17
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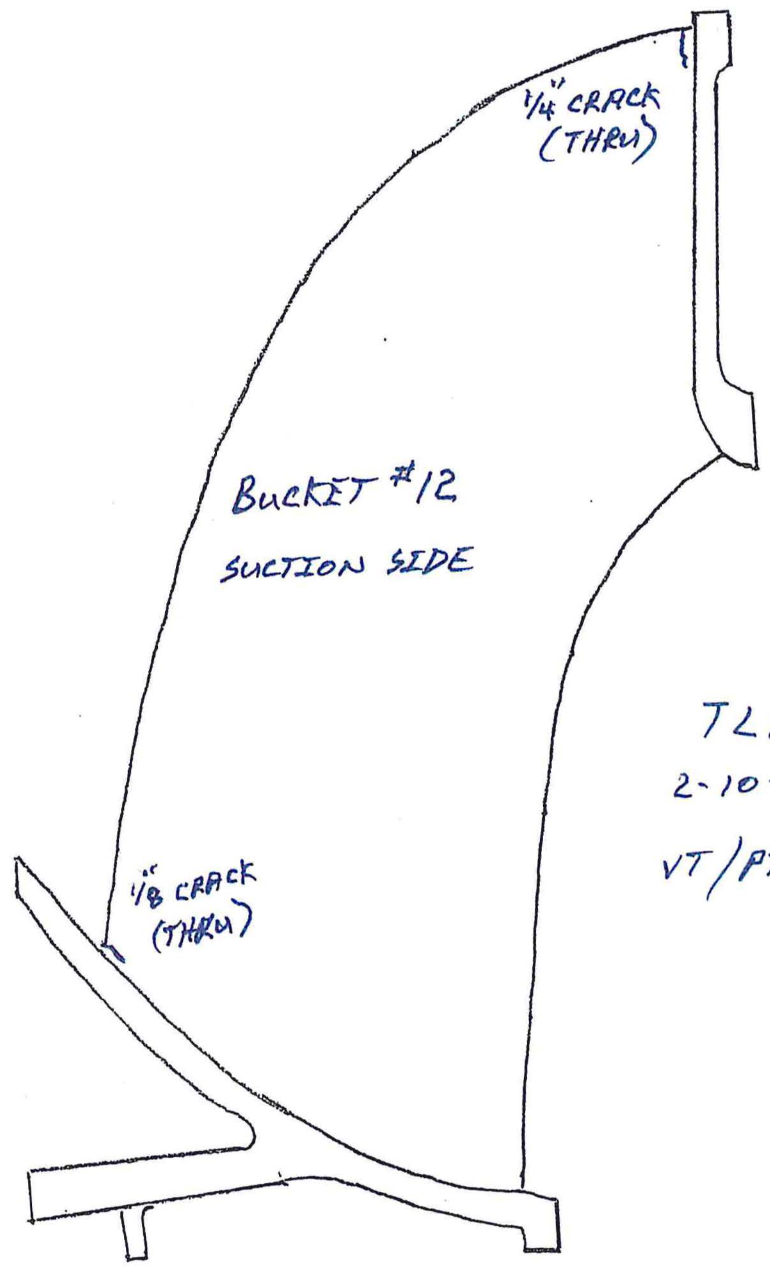

TLS

2-10-17

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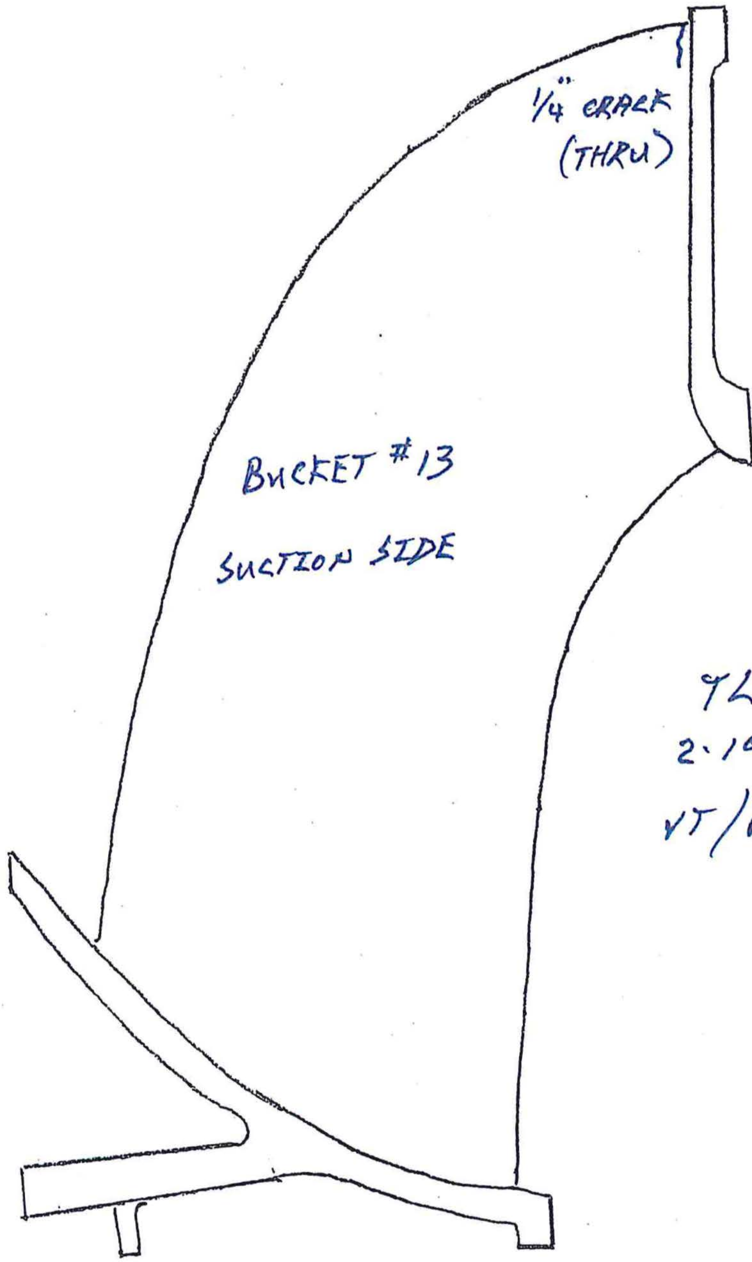

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2-10-17
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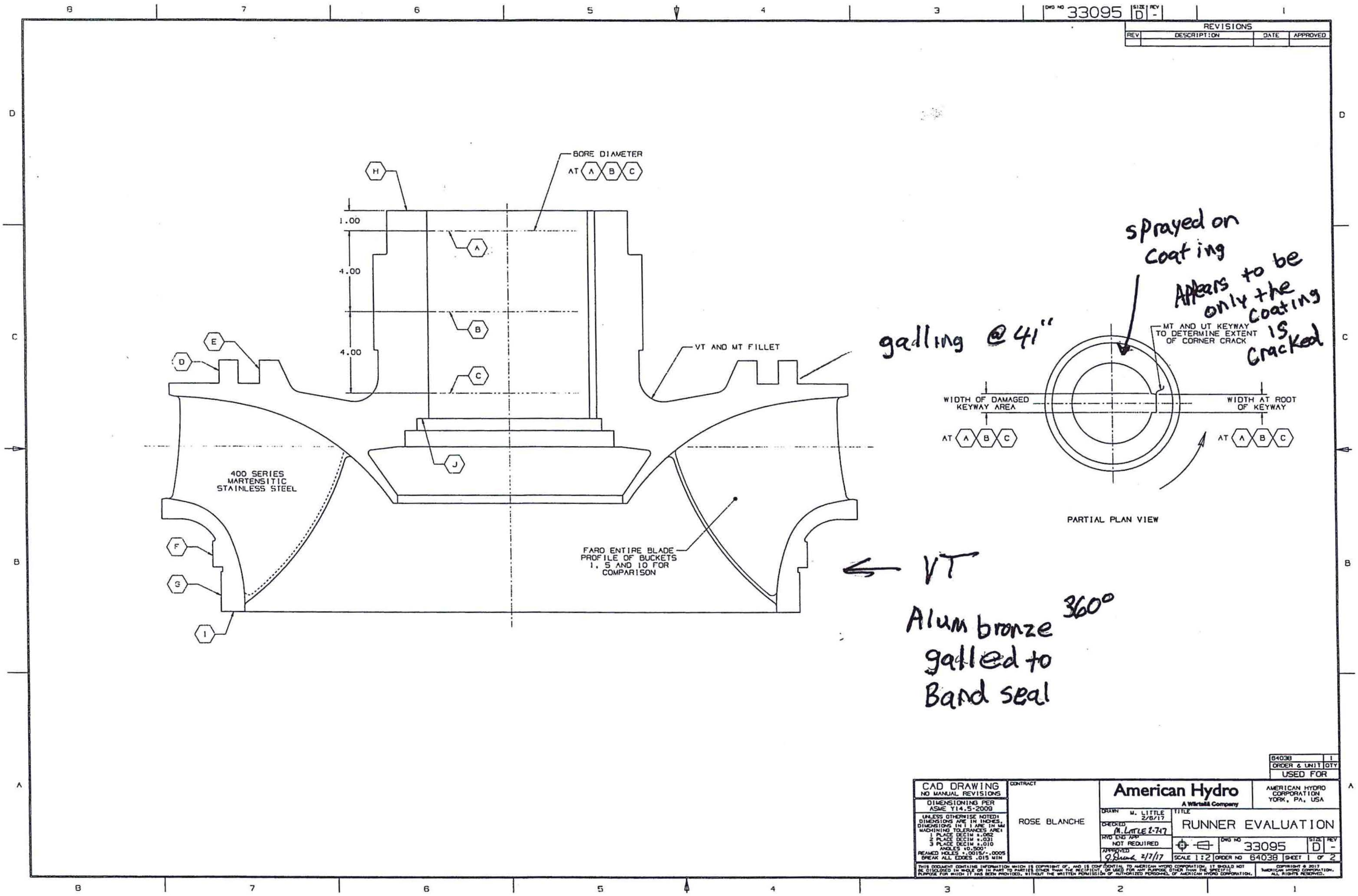
DWG NO 33095 SIZE D REV -
REVISIONS
REV
DESCRIPTION
DATE
APPROVED
BORE DIAMETER
AT A B C
H
1.00
4.00
4.00
A
B
C
D
E
VT AND MT FILLET
J
400 SERIES MARTENSITIC STAINLESS STEEL
F
G
I
FARO ENTIRE BLADE PROFILE OF BUCKETS 1, 5 AND 10 FOR COMPARISON
sprayed on coating
Appears to be only the coating is cracked
galling @ 41"
MT AND UT KEYWAY TO DETERMINE EXTENT OF CORNER CRACK
WIDTH OF DAMAGED KEYWAY AREA
WIDTH AT ROOT OF KEYWAY
AT A B C
AT A B C
PARTIAL PLAN VIEW
VT
Alum bronze gallED to Band seal 360°
64038
1
ORDER & UNIT
QTY
USED FOR
CAD DRAWING NO MANUAL REVISIONS
DIMENSIONING PER ASME Y14.5-2009
UNLESS OTHERWISE NOTED: DIMENSIONS ARE IN INCHES. DIMENSIONS IN [ ] ARE IN MM
MACHINING TOLERANCES ARE:
1 PLACE DECIM ±.062
2 PLACE DECIM ±.031
3 PLACE DECIM ±.010
ANGLES ±0.500°
REAMED HOLES +.0015/-.0005
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CONTRACT
ROSE BLANCHE
American Hydro
A Wärtsilä Company
AMERICAN HYDRO CORPORATION YORK, PA, USA
DRAWN M. LITTLE 2/6/17
CHECKED M. LITTLE 2-7-17
HYD ENG APP NOT REQUIRED
APPROVED 2/7/17
TITLE
RUNNER EVALUATION
DWG NO 33095
SIZE D
REV -
SCALE 1:2
ORDER NO 64038
SHEET 1 OF 2
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Appendix C
Generator Shaft Damage Analysis

American Hydro

A Wärtsilä Company

Generator Shaft Damage Analysis

Rose Blanche Brook – Compact Dual Francis Turbine

On-site Inspection (02-08-2017) & Recommendation Report

Work performed under standby agreement SA-2016-058

Client: **Newfoundland Power – A Fortis company**
Location: **55 Kenmount Road, St-John's, NL, A1B 3P6**

Confidential Distribution: CLIENT

March 23, 2017

Proprietary Information

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1. INTRODUCTION

Rose Blanche generating station is located on the southwest corner of Newfoundland about 45 km inland from Port Aux Basques. The plant was commissioned in 1998 and has two generating units, each with a capacity of 3.0 MW. The twin Francis turbines (Sulzer Hydro) are connected to a single generator (GE Industrial).

The single generator is able to operate with one or both turbines in service. There is no formal time keeping record of which side operates, but is supposed to have an alternate sequence where one is the prime and the other operates only on demand. During single turbine operation, cooling water must be supplied to be labyrinth of the turbine rotating in air to prevent the runner from overheating and seizing.

Past history (AH understanding):

- During the commissioning (1998), the shaft was found bent (30 to 40 mils) and the supplier corrected the run-out on site by controlled heating and cooling. No formal report of this event has been provided but the unit was put in service and operate without any problems for several years.

- Recently (2015/2016), the shaft seal bushing began to loosen and was turning on the shaft. At that time the unit was stopped and a quick fix was done using shims and O-rings. (turbine #1 side)

- The first major catastrophic failure happened at the beginning of 2016 sometime after the shaft seal bushing fix. The failure originated from stainless steel galling between the runner and the lower stationary seal and the bottom ring. Partial refurbishment at the time did not include the shaft seal bushing, which was left as is. (turbine #1 side)

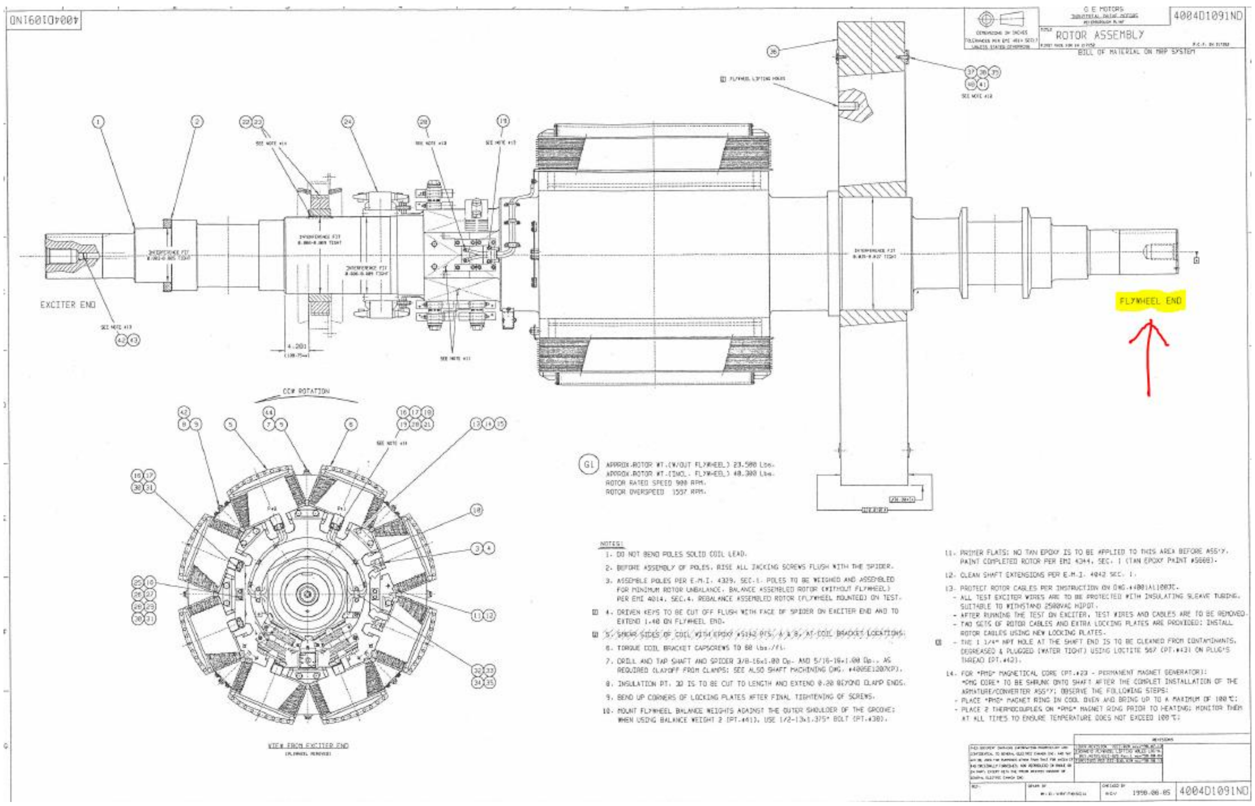
- The second catastrophic failure happened in December 2016 when the turbine tripped off and came to an abrupt stop. The runner, bottom ring, stationary seal and related components were sent to York for damage assessment. (turbine #1 side)

The document herein was prepared at the conclusion of the on-site inspections performed February 8, 2017 on the generator shaft to summarize the findings and make recommendations on reparability.

2. Observations

2.1. Damages location (General orientation)

All the observations are related to turbine #1 on the flywheel end.



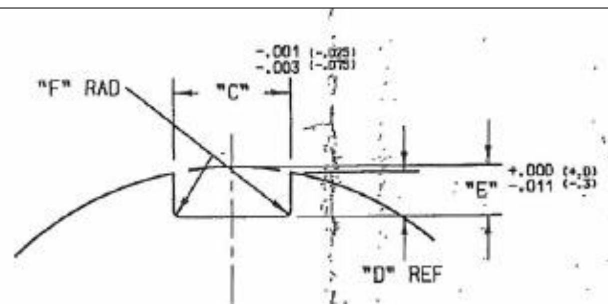
 Turbine #1	

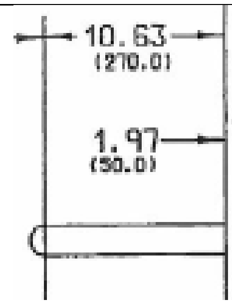
2.2. Damages to the shaft keyway

The following pictures were taken during the runner removal process.

<table>
<tr>
<td>
Before runner removal
(the key roll in the keyway)</td>
<td>
Plastic deformation on one side
(was ground off)</td>
</tr>
</table>

For the keyway damage assessment we use the following dimensions.

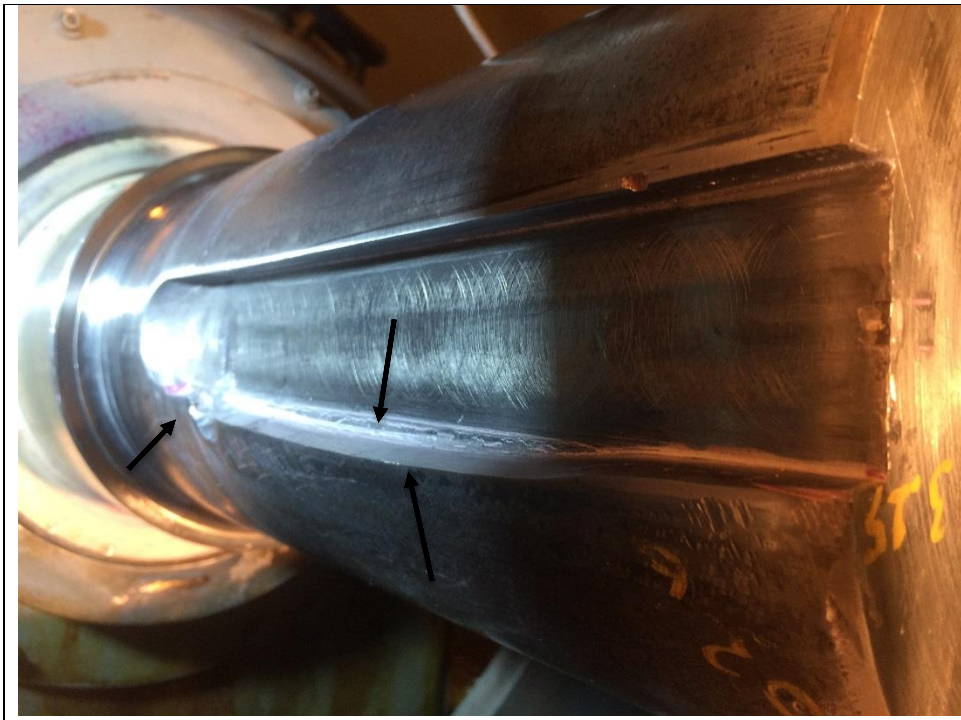




SECTION	"C"	"D"	"E"	"F"
"B"-"B"	1.772 (45.0)	.54 (13.7)	.591 (15.0)	.04 (1.0)

Shaft key according to OEM drawing design

The following picture show the shaft keyway damaged areas.



Actual state of the keyway

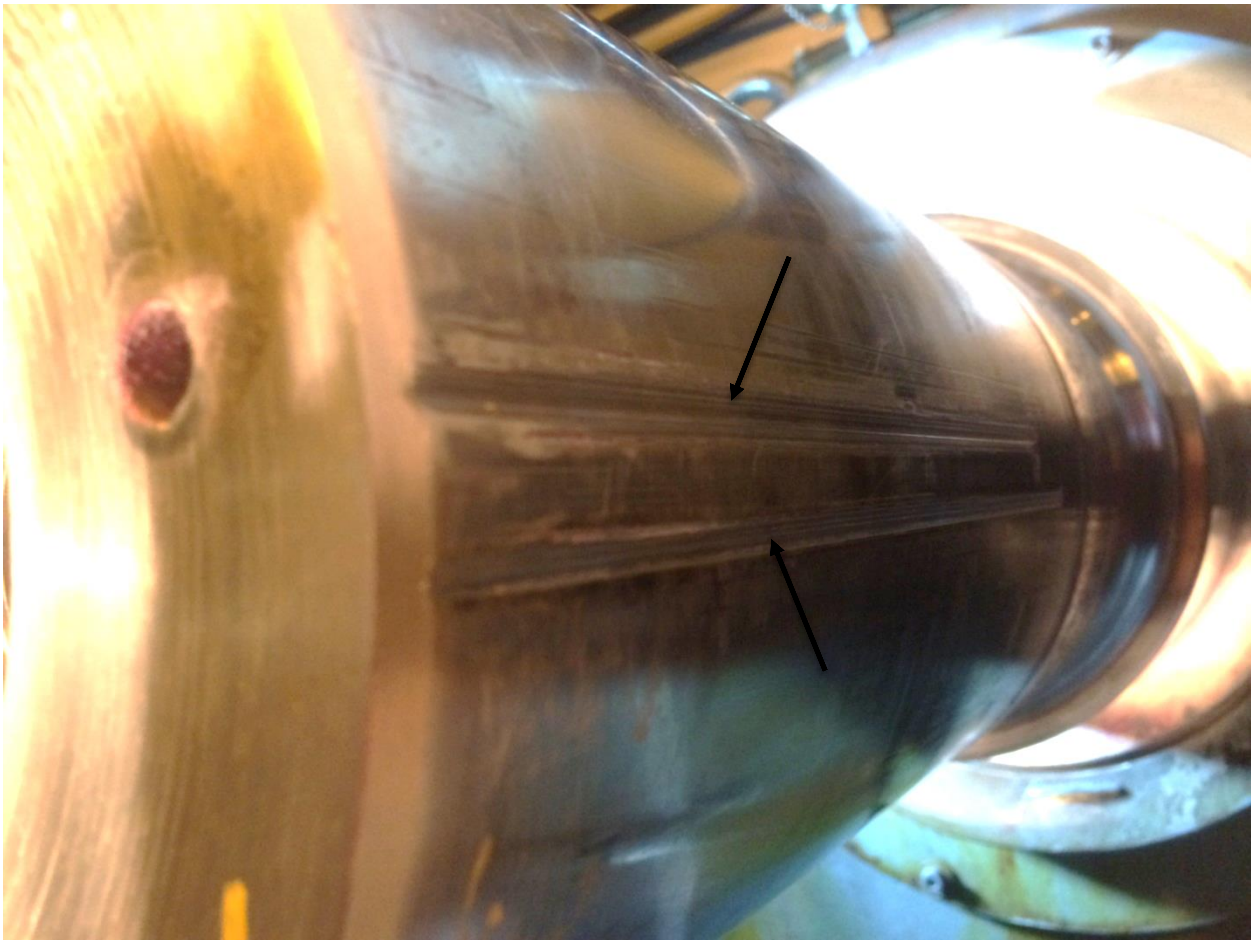
In the keyway area, we performed a dye penetrant inspection to verify if surface cracking could be detected. We also performed an ultrasonic inspection that confirmed that the key area was free of reportable defects.

We estimate that if we have to machine a keyway oversize free from stress riser, the value C will need to be increased from 1.772 (original) to approximately 2.250. The depth will also need to be slightly increased.

To assess machinability of the material and possible hardness increase due to heat or deformation, hardness testing was performed. The results (196 to 220 HB) confirmed the machinability of the steel if on-site machining should be performed.

2.3. Damage to the runner fit

We observed two scratches on the runner fit that possibly originated from the runner removal operation.



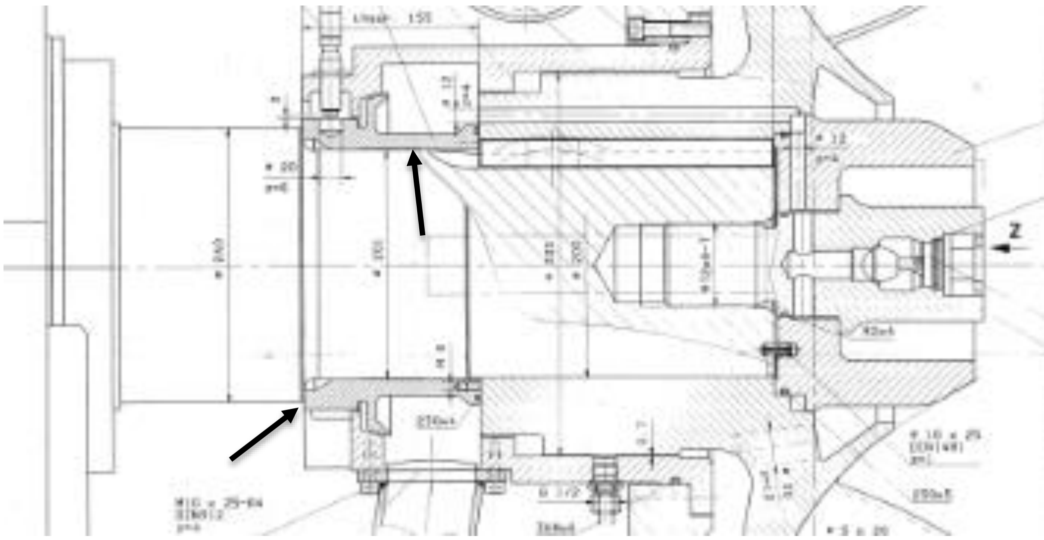
Two scratches of approximately 0.0625” depth x 9” long

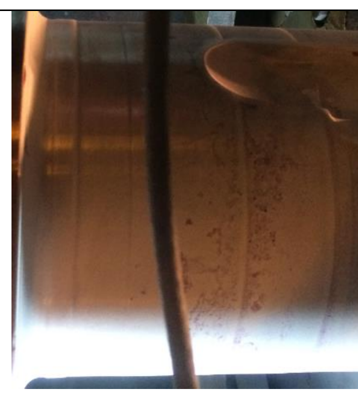
We perform an NDT inspection that confirmed the runner fit was free from reportable indications.

The actual shaft diameter for the runner ID area was measured at 7.874” and conforms to what the general shaft drawing show.

2.4. Damage to the shaft seal bushing fit

The following cross section of the shaft end indicates damage where the shaft is in contact with the seal bushing.



 Seal	 Seal area on shaft

The NDT inspection report confirmed that the surface was not cracked but does have some indications of fretting and wear.

Shaft measured 7.914” towards thrust bearing for a small area on the shaft, and 7.901” towards the runner side. General shaft drawing shows 7.913”.

This section provides some information recorded by the customer on the seal condition.

Picture #1

Picture #2

Picture 1 (end), is towards the bearing.
Seal is worn 0.020” and more is gone from the shaft.
ID bore at this end which is 7.950”.
Shaft measured highest point at 7.914” which is a 0.036” (7.950”-7.914”) difference.

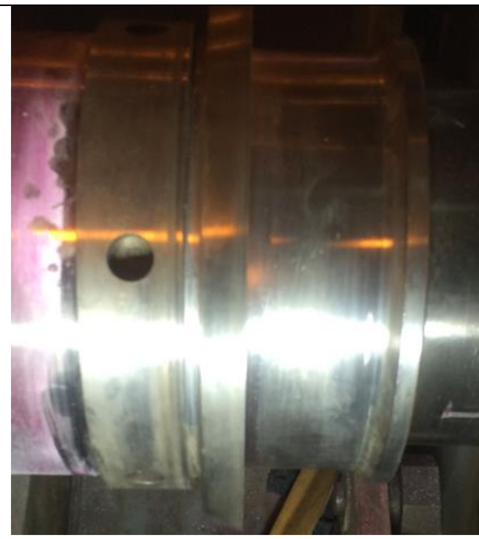
Picture 2 (end), is toward the runner hub.
O-ring is worn.
ID bore at this end which is 7.925”.
Shaft measured at 7.901” which is 0.024” (7.925” – 7.901”) difference.

The seal is showing a 0.025” (7.950” – 7.925”) difference on 6.5” front to back.

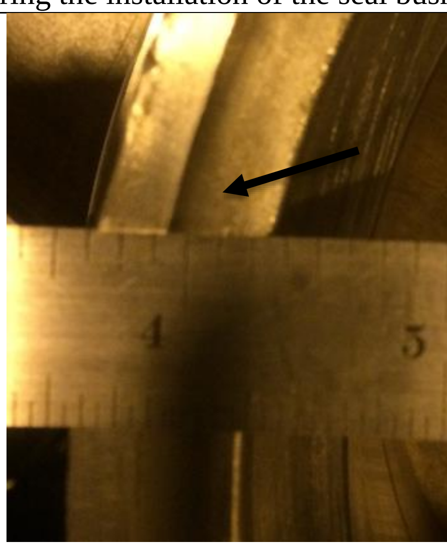
2.5. Damages to the contact area of the seal bushing and the shaft shoulder

For validation purpose, the shaft bushing was installed in position. The wear area on the bushing matches the worn area on the shaft shoulder.

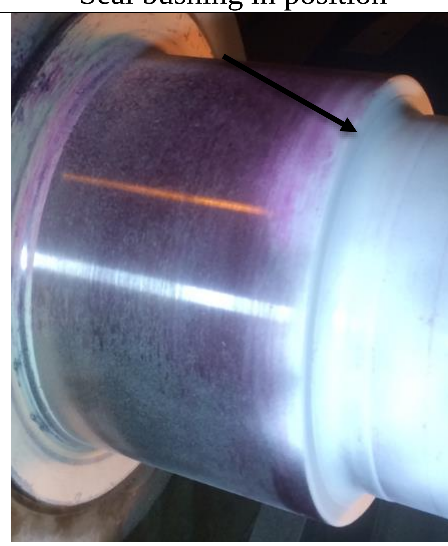
During the installation of the seal bushing



Seal bushing in position



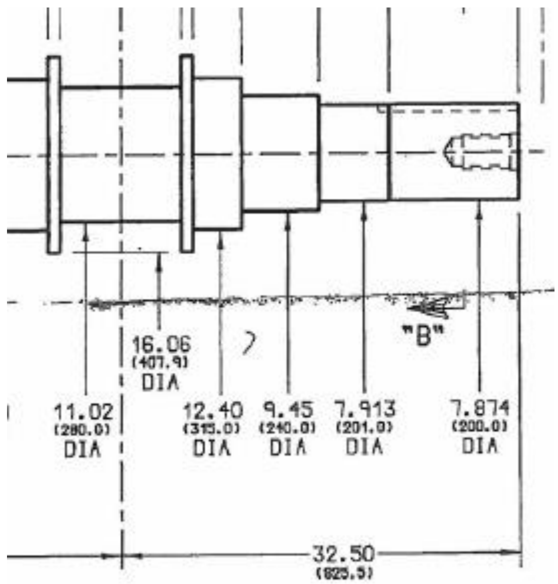
Worn area on the bushing



Worn area on the shaft shoulder

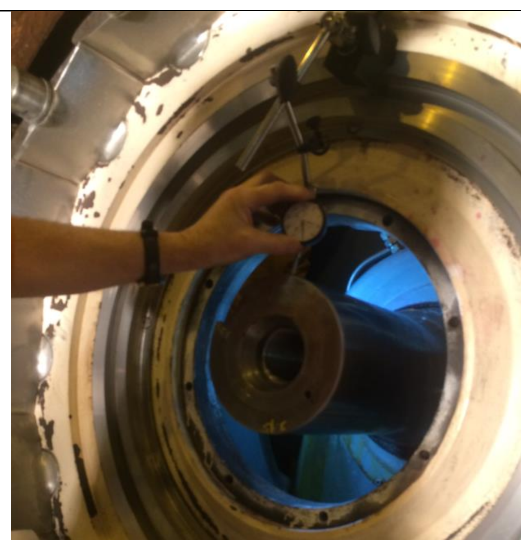
2.6. Shaft run-out

To get some information about the shaft geometrical condition, we performed basic runout measurements.



The total indicator runout measured on the seal fit was 0.004 mils and at the end of the shaft was 0.017 mils.


Dial indicator on the shaft seal bushing fit


Dial indicator at the end of the shaft

This may be an indication of some shaft bending but will need further verification.

3. RECOMMENDATIONS

3.1 Potential on-site repair of the shaft

Considering the actual state of degradation of this generator shaft, we concluded that the piece cannot be repaired on-site back to original specifications.

In addition to the above noted bending of the shaft, there is reason to believe the shaft may also have twisted and plastically deformed.

During the runner evaluation it was noted that the keyway and various features appear to be twisted about the axis of rotation. This twisting was likely caused as the runner seal seized with the bottom ring resulting in a shock loading from the inertia of the entire generating assembly passing through the shaft into the runner. As the runner twisted, it is likely that the shaft also experienced enough stress to cause similar effects.

While no evidence of cracking is currently present, the fact that the shaft has experienced a stress above the yield point for that material will drastically reduce the fatigue life of the shaft. Being a horizontal shaft, the shaft sees more fatigue loading than a vertical unit and this event could have caused irreparable damage to the shaft.

It is for this reason that American Hydro must recommend replacement of this shaft and that it not be repaired for continued use.

3.2 .Manufacture of a new shaft

This is our recommendation for operational reliability.

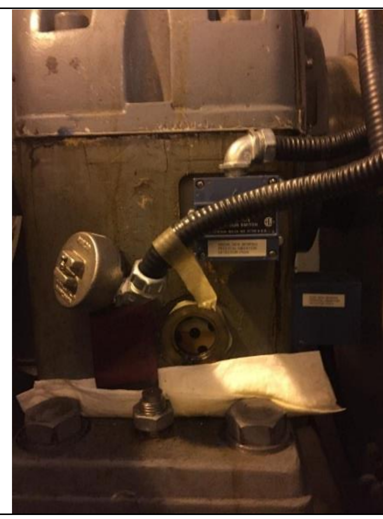
3.3 Other recommendations / observations

1. The shaft seal bushing and drawing should be sent to American Hydro for assessment.

2. Engineering review of the cooling system operation and design (used when the turbine is running in the air)

3. Special consideration (engineering review) should be given to the key material and design of the locking system.

4. Both bearings have "Vibraswitches" (see photos). While these do not monitor vibration per se they do trip the unit if vibration exceeds a pre-set limit. More sensitive monitoring equipment using non-contact probes should be considered.



5. Keeping a formal register of operating conditions and hours of each runner.

Report written by: Mario Gariepy, PEng. Engineering Manager, American Hydro (Canada)

Reviewed by: Brent Masek, Mechanical Engineer, American Hydro (USA)

4. APPENDICES

Liquide penetrant testing - Acuren report # PT-SS020817 RD
Ultrasonic testing - Acuren report # UT-SS020817-001 RD
Hardness measurement - Acuren report # QF-151

Appendix attached as separate file.

Acuren Group Inc.
1 Austin Street
St. John's, NL, Canada A1B 4C2
www.acuren.com
Phone: 709.753.2100
Fax: 709.753.7011

NDT, Inspection and Engineering

NONDESTRUCTIVE EXAMINATION

TO: **AMERICAN HYDRO**

DATE: **FEB 08/17** **(NA)**
ACUREN JOB #: **183-17-10WAR003-0001**
REPORT #: **PT-SS020817-001 RD**
PO: **10799429** WO:NA

ATTENTION: **SCOTT PARSONS**
WORK LOCATION: **ROSE BLANCHE**
Project: **ROSE BLANCHE TURBINE STATION**
Item(s) Examined: **TURBINE # 1**

PART #: **SEE BELOW** MATERIAL: **CS** THICKNESS: **VAR**
SCOPE: **PERFORM LPI AS PER CLIENT REQ.**
TYPE OF INSPECTION: **LIQUID PENETRANT**

TEST DETAILS:

ACCEPTANCE STANDARD: **CLIENT INFO** REVISION: **NA**
PROCEDURE/TECHNIQUE: **CAN-PT-14P001** REVISION: **07 NOV 17/16**

TYPE: **WATER WASHABLE**	METHOD: **VISIBLE**
FAMILY BRAND: **MAGNAFLUX**	LIGHTING EQUIPMENT: **HEADLAMPS/FLASHLIGHT**
PENETRANT: **SKL-WP** DWELL TIME: **30** Min.	BLACKLIGHT MAKE: **NA** S/N: **NA**
PENETRANT REMOVER: **H20** DRY TIME: **15** Min.	LIGHT METER S/N: **150803707** CAL DUE: **APR 06/17**
DEVELOPER: **SKD-S2** DWELL TIME: **15** Min.	LIGHT INTENSITY: **OUTPUT > 100 FC**
DEVELOPER TYPE: **NON-AQUEOUS**	

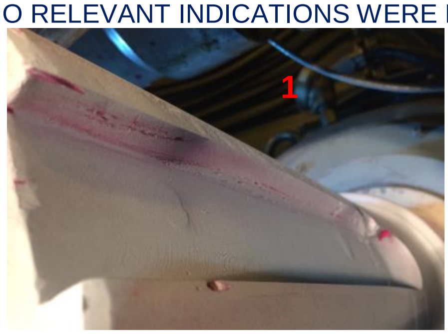
BATCH NOS. (WHEN REQUIRED): PENETRANT: **13F15K** REMOVER: **H2O** DEVELOPER: **SKD-S2**

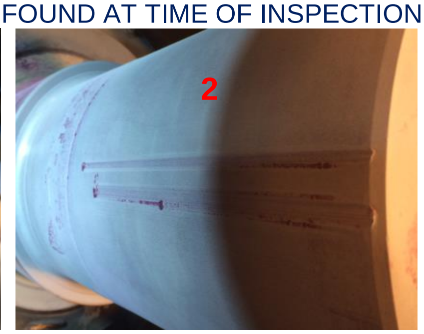
TEST SURFACE CONDITION: **CLEAN BARE METAL** TEST SURFACE TEMPERATURE: **10 C/50 F TO 52 C/125 F**

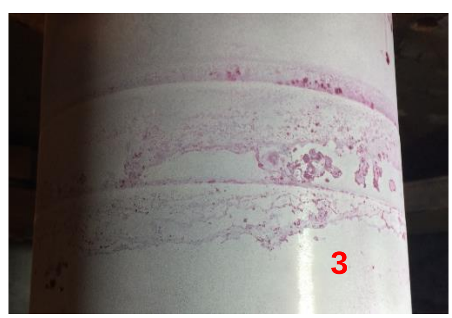
RESULTS: LPI INSPECTION WAS PERFORMED ON THE END OF THE SHAFT AS SHOWN BELOW. SEE ITEMS 1-3 FOR RESULTS.

1. Area where keyway was damaged showed some tool marks but no relevant indications with dye penetrant.
2. Area on opposite side of keyway showed some tooling marks but no relevant indications with dye penetrant.
3. Area on back end of shaft where hub came loose and spun around causing non relevant indications due to surface flaking from mating surfaces.

NO RELEVANT INDICATIONS WERE FOUND AT TIME OF INSPECTION.







CLIENT REPRESENTATIVE: N/A
TECHNICIAN:

SCOTT STACEY
1st Technician
CGSB Reg. #II 9804

2nd Technician

REVIEWER:

(Generated Using: CAN-QUA-02F007 R02 - 12/15/2015)

Acuren Group Inc.
1 Austin Street
St. John's, NL, Canada A1B 4C2
www.acuren.com
Phone: 709.753.2100
Fax: 709.753.7011

NDT, Inspection and Engineering

NONDESTRUCTIVE EXAMINATION

TO: **AMERICAN HYDRO**

DATE: **FEB 08/17** **(NA)**
ACUREN JOB #: **183-17-10WAR003-0001**
REPORT #: **UT-SS020817-001 RD**
PO: **10799429** WO:NA

ATTENTION: **SCOTT PARSONS** WORK LOCATION: **ROSE BLANCHE**
Project: **ROSE BLANCHE TURBINE STATION**
Item(s) Examined: **TURBINE # 1**

PART #: **SEE BELOW** MATERIAL: **CARBON STEEL** THICKNESS: **VAR.**
SCOPE: **PERFORM UT AS PER CLIENT REQUEST.**
TYPE OF INSPECTION: **Ultrasonic**

TEST DETAILS:

ACCEPTANCE STANDARD: **CLIENT INFO** REVISION: **NA**
PROCEDURE/TECHNIQUE: **CAN-UT-17P001** REVISION: **06**
TYPE: **Flaw Detection** METHOD: **Contact**
INSTRUMENT: **Olympus** MODEL: **Epoch 600** S/N: **130534509** CAL DUE: **SEP.14/17**
CAL. BLOCK: **IIW** S/N: **4875** CABLE-TYPE: **COAXIAL** LENGTH: **6'**
CAL. BLOCK: S/N: COUPLANT: **SONOTECH UTX**

Probe & Technique Details:

	Test Angle (°)	Probe Type	Crystal Size	Freq. (MHz)	Serial Number	Damping Ω	Test From	Reference Reflector	Transfer Value	Reference dB	Reference % FSH	Scan dB	Range
1	**0**	**OLYMP.**	**½"**	**2.25**	**16040**	**NA**	**A**	**SBW**	**NA**	**45**	**40-60**	**+14**	**125mm**
2	**70/45/60**	**OLYMP.**	**½"**	**2.25**	**863142**	**NA**	**A/B**	**1.5mmSDH**	**+2**	**45.6**	**40-60**	**+14**	**100mm**

TEST SURFACE CONDITION: **As Welded** TEST SURFACE TEMPERATURE: **0°C to 50°C**

RESULTS: Shear wave and longitudinal ultrasonic testing were utilized to inspect the end of the # 1 turbine shaft around the keyway after it was damaged.
Longitudinal 0 degree inspection was performed from the end of the shaft as well as around the keyway to determine if any cracking had occurred transverse or parallel to the shaft keyway. Shear wave inspection was also performed around the keyway from multiple directions to detect any subsurface cracking not detectable using the 0 degree.

Red arrows show areas for 0 degree inspection and yellow arrow shows the area for the shear wave inspection.

NO RELEVANT INDICATIONS WERE FOUND AT TIME OF INSPECTION.

CLIENT REPRESENTATIVE: N/A
TECHNICIAN:

SCOTT STACEY
1st Technician
CGSB II Reg. #9804

2nd Technician

REVIEWER:

HARDNESS TEST REPORT
QF-151

ACUREN

HTR#:SS020817-001 RD

PAGE: 1 **OF** 1

Date : Wednesday, February 08, 2017

Client	AMERICAN HYDRO	**Acuren Job No.**	183-17-10WAR003-0001
Attention	SCOTT PARSONS	**PO/WO No.**	10799429
Address	DARTHMOUTH NOVA SCOTIA	**Work Location**	ROSE BLANCHE
		Acceptance	CLIENT INFO
Project	ROSE BLANCHE TURBINE SHAFT	**Standard**	CLIENT INFO
Item(s) Tested	END OF SHAFT FOR TURBINE # 1	**Acuren Procedure No.**	CAN-HT-15P001 R02

JOB DESCRIPTION

Item Description	END OF TURBINE SHAFT	**Material**	CS
Scope	PERFORM HARDNESS TEST AS PER CLIENT REQ.		

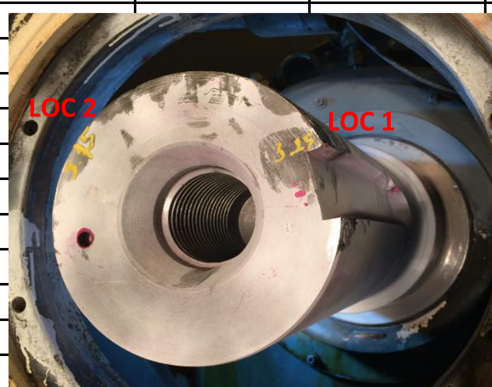
EQUIPMENT DETAILS

Instrument	TELEBRINELL	**Model**	HAMMER	**S/N**	NA	**Cal. Due Date**	NA
Check Std. (s)	BRINELL BAR	**Check Std. Value(s)**	241			**Measured Value**	NA

Acuren Marking **Low Stress Stamp** ☐ **Ink** ☐ **None** ☑ **Hardness Scale** **HV** ____ ☐ **HB (Bar Value)** ☑ **HR** ____ ☐

RESULTS

Component/Location	Base Metal	BAR	HB		
LOCATION 1	3.25	3.60	196		
LOCATION 2	3.15	3.25	220		



NOTE:

COMMENTS:

SIGNATURES

[signature]	CGSB LV II #9804		
Technician Name	**Title**	**Technician Name**	**Title**

Client ____________________ ____________________ **Acuren Review** ________ INITIAL

Rose Blanche Hydro Plant
Rockfall Remediation

April 2017

Prepared by:

David Ball, P.Eng.

REGISTERED PROFESSIONAL ENGINEER
PEG Newfoundland and Labrador
DAVID S. BALL
SIGNATURE
2017/04/20
DATE
NEWFOUNDLAND & LABRADOR

NEWFOUNDLAND POWER
A FORTIS COMPANY

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Appendix A: Rockfall Inspection Report (Prepared by MECO)

1.0 Background

1.1 General

Newfoundland Power's (the "Company") Rose Blanche hydroelectric generating plant (the "Plant") is located in southwestern Newfoundland, near the community of Rose Blanche, approximately 45 kilometres east of the Town of Port aux Basques. The Plant went into service in 1998 and has provided 19 years of reliable energy production. The normal annual plant production is approximately 23.5 GWh of energy, or about 5.4% of Newfoundland Power's total hydroelectric production.

The Plant has a nameplate capacity of 6.0 MW and operates under a rated net head of 114.2 m. Water is transferred from the forebay dam to the powerhouse through a 1,257 m long, 1,676 mm diameter steel penstock. The 15.3 m high concrete faced rock filled main dam and penstock are situated in a narrow, rocky, steep sided valley.

1.2 Rockfall Event

On the morning of November 23, 2016, while performing routine surveillance of the Plant site, power plant maintenance staff observed that a rockfall had occurred near the main dam. Nobody witnessed the event, and it did not disrupt operations at the Plant. Based on the observations of the maintenance staff, the rockfall had likely occurred within the preceding 24 hours.[1]

The rockfall damaged the penstock and blocked vehicle access to the main dam. The approximate direction of the rockfall, location of the road blockage and penstock damage in relation to the main dam and reservoir are shown in Figure 1.

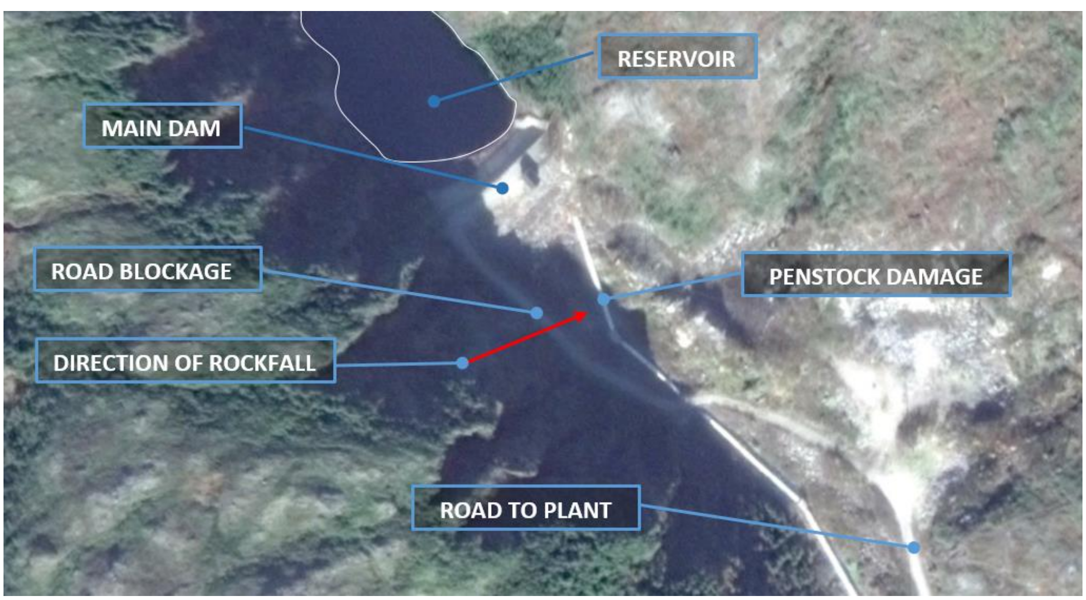

Figure 1 – Location Map

[1] The rockfall appeared fresh when observed, as fresh mud was evident on the rock. Heavy rain that occurred on November 22nd would likely have washed the mud off the rock had the rockfall occurred prior to that time.

It is estimated that approximately 500 to 1,000 tonnes of rock material were displaced in the fall, including stones as large as 5 tonnes. The source and path of the rockfall are shown on Figure 2.

Figure 2 – Rockfall Path

2.0 Damage & Risk Assessment

Newfoundland Power engaged Mitchelmore Engineering Company Limited ("MECO"), an engineering consultant with expertise in geoscience and civil engineering, to complete an inspection, provide advice on the likelihood of further instability of the rock mass and suggest risk mitigation measures to protect against future rockfall hazards. MECO completed a site visit on December 8, 2016 to facilitate the assessment. The observations arising from the site visit are set out in the report attached as Appendix A and summarized below.

2.1 Access Road Damage

The rockfall has completely obstructed vehicle access to the main dam. As shown in the photograph in Figure 3, a significant portion of the rock debris came to rest in a mound on the road. Due the instability of the slope, MECO recommended that removal of the material blocking the road should not be immediately undertaken and that the dam be accessed only from the opposite side of the valley. Access is currently limited to pedestrian traffic. Due to the steep rocky slopes of the valley, vehicular access cannot be established without major capital works.

Figure 3 - Road Blockage

2.2 Penstock Damage

The Penstock was struck by rock in 4 locations resulting in dents in the penstock and damage to the paint.[2] The largest boulder to strike the penstock was estimated to weigh approximately 5 tonnes. The location of some of the impacts also indicates that the boulders were bouncing significantly at the time of the impact. All welds appear to be intact, and the penstock does not appear to have been displaced. MECO has advised that the penstock may be expected to operate without incident in the near term; however, in light of the damage sustained, further assessment will be undertaken to confirm the long-term integrity of the penstock.

Figure 4 – Overview of Damaged Area

Figure 5 – Typical Dent & Scratch

[2] The damage to the penstock could lead to accelerated rusting and deterioration of the penstock in the damaged area.

2.3 Operational Impact and Risk

Vehicular access to the main dam is essential to the safe, reliable operation of the Plant. Staff must be able to access the dam with vehicles and equipment to perform routine maintenance, such as trashrack debris removal.[3] Access is also required to provide response in the event of a dam safety, public safety or employee safety emergency.[4] Due to the instability of the rock slope, MECO has recommended avoiding work in the area until summer. With access currently limited, the Company's ability to respond to normal operational and maintenance requirements is also limited. The associated risk is acceptable in the short term; however, remediation of the rockfall site and the access road must be undertaken as soon as it is safe to do so. The photographs in Figures 6 and 7 show the unstable rock slope.

Figure 6 – Unstable Rock Slope

Figure 7 – Unstable Rock Slope

Although the November rockfall event did not rupture the penstock, it is possible that a subsequent rockfall of similar magnitude could do so. With vehicle access to the main dam impeded by the rockfall, Plant staff may not be able to access the gatehouse of the main dam quickly enough to shut off the water to the penstock and avoid rapid drawdown of the reservoir. The resulting uncontrolled release of water could result in damage downstream, including washout of roads and other infrastructure, interference with fish habitat, and an interruption in production from the Plant until the penstock is repaired and water levels are restored.

3.0 Assessment of Alternatives

As part of their assessment, MECO presented 3 alternative design concepts for mitigation of the risk of future rockfalls. The 3 alternatives presented are:

1. Active Protection
2. Passive Protection
3. Reinforcement and/or modification of rock slope

[3] Trashrack debris removal is required every 1-2 years to avoid plugging the intake. Loss of the ability to remove debris will render the plant inoperable within 1-2 years.

[4] The main dam is classified as "Significant Consequence" based on the guidelines prepared by the Canadian Dam Association.

To identify the least-cost alternative, Newfoundland Power completed cost estimates for each alternative. The alternatives and associated costs are described below. Further details of the alternatives are set out in Appendix A.

3.1 Alternative 1: Active Protection - $1,494,000

The primary feature of active protection is the burial of the penstock to avoid damage from future rockfalls. With this alternative, the road would be relocated to the opposite side of the valley and a ditch provided to prevent any falling rocks from reaching the new road.[5] MECO noted that, as an alternative to relocating the road, a roof could be constructed over the existing access road. However, this suggestion was dismissed, as the costs were estimated to be significantly higher, and it would provide no greater benefit to long term safety and reliability.

This alternative would entail minimal increase in operating expenditures beyond current levels.

3.2 Alternative 2: Passive Protection - $2,135,000

The primary feature of passive protection is the provision of catch nets to manage rockfalls. The penstock would not be buried.

Smaller rockfalls could be managed with this approach. However, larger events may overwhelm the nets and damage the penstock. As with the first alternative, the road would be relocated to the opposite side of the valley to ensure the safety of users under any rockfall scenario.[6]

This alternative involves higher capital costs than Alternative 1. In addition, operating expenditures associated with this alternative would be higher due to the requirement to inspect and maintain the catch nets.

3.3 Alternative 3: Reinforcing and/or Modifying the Rock Slope - $2,040,000

This alternative would require either (i) the addition of rock anchors, mesh and cables to stabilize the rock face, or (ii) the removal of significant quantities of rock to flatten the slope.

Cost estimates indicate that using rock anchors, mesh and cable to stabilize the rock face would be more costly than removing rock to reduce the slope. In addition, it would entail higher operating expenditures associated with ongoing inspection and maintenance requirements.

Removing rock to reduce the slope would allow the current configuration of the road and penstock to be maintained; however, significantly more work would be required on the cliff face than for either Alternatives 1 or 2.

This alternative involves higher capital costs than Alternative 1. Operating expenditures associated with this alternative would be similar to those for Alternative 1.

---

[5] During detailed design, the exact alignment of the road and configuration of the ditch will be finalized, taking detailed survey data and final penstock burial details into account.

[6] As with Alternative 1, during detailed design, the exact alignment of the road will be finalized, taking detailed survey data into account.

4.0 Project Proposal

4.1 Project Description

It is recommended that Newfoundland Power proceed with Alternative 1. Active Protection will provide long-term, safe access to the main dam and ensure the reliability of the penstock at a lower cost than the other 2 alternatives.

As soon as weather permits, work can commence to obtain the necessary field data to adequately assess and address safety risks, as well as facilitate detailed design and optimization of the chosen solution.

Stabilization of the rock face will be required to facilitate a safe worksite prior to remediation activities.[7] Remediation of the damage to the penstock will be completed to ensure its long-term integrity. The penstock will then be buried, protecting it from future rockfalls. An access road will be constructed on the other side of the valley, ensuring the safety of employees using the road and ensuring Plant maintenance and emergency response requirements are not impeded.

4.2 Project Cost

The total project cost for Alternative 1is estimated at $1,494,000. Table 1 provides the cost breakdown.

Table 1
Project Cost
($000s)

Cost Category	Cost
Material	1,095
Labour - Internal	21
Labour - Contract	-
Engineering	83
Other	295
Total	**$1,494**

[7] The rock face stabilization measures required to ensure worker safety in connection with Alternative 1 are much less extensive than the slope modifications contemplated for Alternative 3.

4.3 Project Schedule

During and following the engineering inspection in December 2016, snow has been present at the site. As a result, to date, field investigation has been limited to visual observation only. The necessary field data required to advance the engineering of this project, including a precision survey, will be obtained as early as possible in the spring, after the snow has melted.

Due to the specialized nature of the work, Newfoundland Power will require third party expertise to assist in the development of detailed design and advancement of the risk mitigation strategies associated with the potential for falling rock both during construction and in the longer term.

Detailed engineering will proceed as soon as data becomes available and will include optimization of the access route to minimize the quantities of material required. It is anticipated that construction will take approximately 12 weeks, with the Plant being out of service for 8 to 10 weeks to facilitate the work. Any outage related to the rock remediation work will be coordinated with the outage required for the Turbine No. 1 refurbishment, to be undertaken at approximately the same time.

Table 2 shows a proposed preliminary high level schedule for the project.

Table 2
High Level Schedule

April 2017	Prepare RFP for Consulting Services
May 2017	Award Consulting Contract
May - June 2017	Obtain Field Data
June - July 2017	Complete Detailed Engineering
August 2017	Project Tendering
September-November 2017	Construction

5.0 Conclusion

With vehicle access to the dam totally blocked as a result of the November 2016 rockfall, there is a significant risk that the normal operation and maintenance of the Plant may be disrupted. There is also a potential for future rockfalls which could cause greater damage to the penstock than was experienced in November.

Remediation of the damage caused by the November rockfall, along with improvements to prevent damage associated with future rockfalls, is required to ensure the safe and reliable operation of the Plant. The necessary remediation work described in this report should be carried out as soon as possible. As noted in the MECO report, the work should not proceed in the winter and spring, due to the higher potential for instability. However, it should proceed as soon as seasonal conditions permit.

The project should proceed in 2017. The project was not included in the 2017 Capital Budget Application because the failure was not foreseen. Delaying the project for inclusion in the 2018 Capital Budget Application would result in an unacceptable risk of further damage to the penstock, as well as an unacceptable risk to employee and public safety.

Appendix A
Rockfall Inspection Report

Innovation | Reliability | Performance

Rose Blanche Hydroelectric Development
Rockfall Inspection Report

Rose Blanche, Newfoundland
Contract #15-001

FINAL | January 2017

Report On

Rockfall Inspection Report
Rose Blanche Hydroelectric Development
Contract #15-001

Prepared For

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January 2017

Mitchelmore Engineering Quality System Checks	
Project No.: 10385	Date: January 23, 2017
Issue Status: Final	Revision No.: 2
Prepared By: Perry Mitchelmore, P.Eng.	
Reviewed By: Roger Boychuk, P.Eng.	

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SECTION 1
Introduction

1. Introduction

The Rose Blanche Hydroelectric (RBH) development is located on the southwest corner of Newfoundland, approximately 45 kilometres east of Channel-Port aux Basques. The plant was commissioned in 1998 and has an installed capacity of 6.1 MW at a net head of 114 meters.

The system consists of a 93 hectare reservoir (0.93 km^2) impounded by Main Dam, a 27 metre high concrete faced rock fill structure. Water is diverted through a 1.5 metre diameter above ground steel penstock, 1.3 kilometres in length, to a metal frame powerhouse. A concrete overflow spillway is located about 500 metres east of the Main Dam with a discharge channel that merges with the original river below the powerhouse. The project drainage area is estimated at 52 km^2. The generator plant is remotely operated and maintained from Channel-Port aux Basques.

In describing observations, references to left and right refer to an observer on or above the dam, viewing in a southeasterly direction. Upstream and downstream refer to direction of flow, which is generally from the northwest towards the southeast.

1.1 Scope of Work

On or before November 23rd 2016, a landslide occurred near the Main Dam, on the downstream and right hand side. There was nobody in the vicinity when the event occurred. Newfoundland Power initiated a process to investigate and respond to the risk to equipment and personnel.

Meco had performed previous engineering work at RBH, are familiar with the geological environment and possess expertise in rockfall risk assessment and management, including assisting with previous stabilization work at the rock face behind the RBH powerhouse. Meco was retained to participate in a site visit to inspect the landslide with Newfoundland Power personnel and prepare a report on the likelihood of further instability in the rock mass and advise of risk mitigation measures to protect against future landslide hazards. The purpose of the current report is to document observations from the site visit and provide a recommendation for further tasks to achieve the overall objective of a safe work area.

SECTION 2

Site Inspection

2. Site Inspection

A site visit was completed on December 8th, 2016. The site visit was performed by

Mitchelmore Engineering

Perry Mitchelmore, P.Eng.

Newfoundland Power

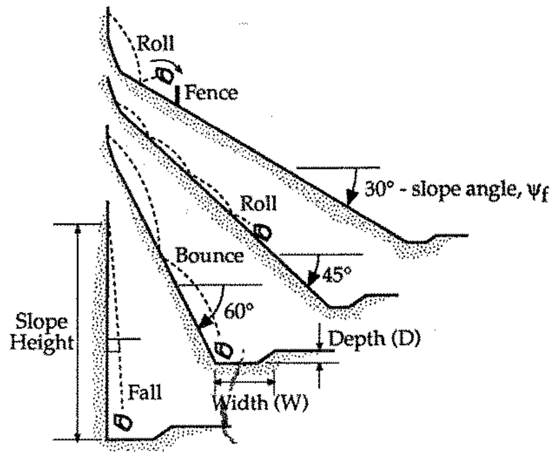
Gary Humby, P.Eng.
David Ball, P.Eng.
Dean Oake
John Collier
Barry Furlong

The site visit consisted of a walkover survey along the access road closed by debris from the landslide, an inspection of the penstock impact areas and a traverse of the opposite side of the valley. In describing observations from the site visit, upstream and downstream refer to the direction of flow in the system, generally from northwest to southeast. Reference to right and left, when describing locations, are always referenced to an observer looking downstream. The area was photographed with select photographs included in Appendix B.

2.1 Rockfall Description

The landslide occurred below the Main Dam, on the right side (looking downstream) of the valley, and closed the access road to the dam (Photo #1-5, Appendix B). The land slide is technically described as a rockfall, which was likely very rapid. A rock block, approximate insitu dimensions of 6-8 metres wide, by 8-10 metres high and 3-5 metres deep, failed on a joint surface that dipped at about 70 degrees. The volume is estimated at between 500 and 1,000 tonne, with a talus rubble pile of stones varying in size from under one tonne to over five tonne, at a visual average of about one tonne (Photo #5, Appendix B).

An opinion on the failure sequence is that the rock mass likely fell for the first few metres, then broke apart and bounced to the road, at which point it accumulated, with some stones rolling over the road and into the penstock below, as illustrated in Sketch 1.



Sketch 1: Rockfall Descriptors (Ritchie 1968)

2.2 Observations of Rock Formation

The bedrock geology is massive and described in the literature as metamorphosed schist with multiple deformation events, principally from the Harbour Le Cou group. The structural geology is dominated by two orthogonal joint sets that are near vertical, the primary feature forming the river valley and the orthogonal set running cross valley. The upper rock slope is jagged, blocky and contains many loose rock fragments.

Geological mapping was not completed during the December site visit. Previous work conducted at RBH involved geological mapping of discontinuities near the powerhouse, consisting of 21 discontinuity surfaces, with results presented in stereographic projection in Figure 1, Appendix A, along with published regional geology mapping. While the geological pattern may vary slightly between sites, the variance will be minor as structural geology is a more regional than local. The joint sets are not corrected for magnetic declination, which is 18 degrees and 46 minutes west of north for Rose Blanche. The scatter in the drawing is a result of the low number of measurements. There are three significant patterns that control the overall slope geometry as listed in Table 1.

Table 1: Discontinuity Description

Discontinuity Set	Dip Direction	Dip	Comments
Shear surfaces	260 - 290 080 - 100	70 - 90 80 - 90	Potential Toppling
Cleavage joints	025 - 045 205 - 235	80 - 90 80 - 90	
Foliation	330 - 030 260 - 300 140 – 205	20 - 40 40 - 60 40 – 60	Mid dip slopes represent potential wedge and plane slides.

The recent landslide appears to be a wedge type failure and there is evidence of remnant slides in the area. The failure mechanism is unknown but, given the time of year of the event, it is possible the recent landslide may have been initiated by water in the joint surface that expanded on freezing and wedged the rock mass to failure. The inspection team was unable to get close enough to the failure surface to verify the failure mechanism, and given the time lapse from failure to the site visit, evidence is likely to have disappeared at any rate.

The right side rock escarpment appears steeper for a distance of about 250 metres upstream and downstream of the Main Dam. The escarpment extends downstream to the powerhouse and beyond but is generally less steep for most of that length, with occasional overhanging.

2.3 Observations of Impact Damage to Penstock

The rock talus impacted the steel penstock at four locations, identified as Impact Areas 1 through 4 in the photographs in Appendix B, causing damage in the form of denting and paint damage. The penstock does not appear to have displaced during the impact (Photo #25-26, Appendix B), but there was undoubtedly a severe impact. The welds appear intact, and the penstock does not appear out of line or plumb. Failing a future incident, the penstock should continue to operate without incident in the near term.

Impact areas 1 and 2 are the furthest upstream and damage is primarily related to damage of the paint, with minor indentation. Impact areas 3 and 4 sustained both paint damage and indentation. The indentation for impact area 3 was about a metre long and occurred over about 5% of the perimeter, or 250mm width. The indentation for impact area 4 was about only about a half a metre long and occurred over about 15% of the perimeter, or 750mm width.

SECTION 3

Risk Assessment and Mitigation

3. Risk Assessment and Mitigation

The landslide that occurred in late November 2016 appears to be a result of unfavorable structural alignment of discontinuities in the rock mass. Stereographic methods were used to assess the potential for wedge, planar and toppling failure modes in the rock mass. The slope was modeled as a moderately steep 70 degree slope and results of a kinematic analysis suggest that the slope is at risk of wedge failure in combination with toppling type failures. The prevalent subset that formed the wedge for the current landslide is a sub-horizontal joint set, identified as a foliation fabric although it could be isostatic rebound tension relief, combined with near vertical orthogonal set. All kinematic analysis was performed assuming an angle of internal friction of 35 degrees for all discontinuity surfaces and by ignoring cohesion and water pressure.

The theoretical wedge identified in kinematic analysis is comparable with observations at site. There are other potential overhangs in the rock mass that have similar geometries and there is a risk of further rockfall activity, some of which are identified in Photo #'s 1, 2, and 9 in Appendix B. The timing of future instability is not quantifiable without intense monitoring, and only slightly more predictable with monitoring. That said, regular monitoring of the rock face for micro-movement does provide a means to warn of future instability, which may be required for rehabilitation construction work.

The landslide occurred near the Main Dam and warranted consideration of potential impacts on dam safety. The structural risk of a direct hit to the Main Dam is insignificant. However, indirectly, a wave generated from a rockfall upstream of the dam will have an impact on freeboard requirements, particularly by reducing available minimum freeboard during a flood condition. Also, a ruptured penstock will cause a rapid drawdown of the reservoir, estimated at about three (3) metres per day. Neither of these risks to dam safety constitute an emergency, but they should be specifically assessed as part of a future dam safety review of the dam.

3.1 Mitigation

In the immediate near term, winter and spring 2017, there is a risk of ongoing instability of the rock slope. Environmental conditions may increase risk of instability during these times and capital works in the vicinity of the rock slope should be avoided until summer. Remedial work in the near term should be limited to observation and planning.

Prior to start of remedial work in and around the area of rock instability, spot scaling or removal of overhanging rock may be required to facilitate a safe work site. The amount and degree of initial stabilization required should be based on field observations, analytical assessment and judgement of a qualified professional engineer in collaboration with Newfoundland Power safety standards.

To remediate the site and provide for future safe access and operations, Newfoundland Power will need to provide protection for the penstock and provide access for maintenance and operations staff to work at the dam. To achieve this, the following three (3) options are available to manage risk of rockfalls.

1. Provide Active Protection against Future Rockfalls
2. Provide Passive Protection against Future Rockfalls
3. Reinforcing and/or modifying the Rock Slope

3.1.1 Option 1 – Active Protection

Active protection may include relocating the access road to the opposite side of the slope in combination with ditching, or as an alternative, installing a roof over the current access road. A schematic section of both options is provided in Figure 2, Appendix A.

The roof option will likely involve greater capital cost and may only apply if ditching is technically not feasible. Either option will be done in concert with direct burial of the penstock. In lieu of installing a roof, relocating the access road to the left side, over the buried penstock, and using a ditch at the toe of the slope is likely more cost effective to mitigate risk due to falling rock. The required dimensions of the ditch are a function of slope height and angle of the face. A ditch is designed to catch bouncing and rolling rock and depth and width dimensions can be determined by using published design charts or computer simulation programs. A preliminary review indicated a ditch excavated at the current access road location will need to be at least six (6) metres wide and about 2.5m deep to capture bouncing rock.

3.1.2 Option 2 - Passive Protection

Newfoundland Power may choose to leave the slope as is, and relocate the Main Dam access road to the left abutment. A schematic section is provided in Figure 3, Appendix A.

Future instability of the right rock slope will be allowed to occur, and the damage assessed at the time of the event. Smaller rock falls can be managed with catch nets at the abandoned access road to isolate the penstock. However, a large rockfall will likely overwhelm the catch nets and impact the penstock.

Relocating the access road to the left abutment will likely require retaining structures to support the road and prevent the constructed fill from encroaching on the penstock. An abandoned construction access road at the left side is identified in Photo #3, Appendix B. The old access road could be reinstated but access is limited and will likely require controlled blasting or retained fill solutions to complete. Access will be challenging and construction difficult. Newfoundland Power will need to engage specialist engineers and contractors for design and construction to improve opportunities for success.

3.1.3 Option 3 - Reinforcing / Flattening the Slope

The overall slope can be flattened to achieve stability, or by reinforcement of the rock slope with post tensioned anchors at the large rock wedges. A schematic section of both options is provided in Figure 4, Appendix A.

For the reinforced rock option, identifying individual blocks at risk may be more cost effective and technically effective than pattern bolting the rock face. Regardless of whether using a pattern or discrete bolting method, the post tensioned anchors should be supplemented with wire mesh draped over the face to catch smaller rock fragments.

For the flattened slope option, scaling will likely involve a form of drilling and blasting to remove large boulder fragments and rock overhangs. The risk of further damage to the penstock during slope flattening is significant and the penstock will likely require burial, or be removed as part of a repair option, to avoid being further damaged. The finished slope should be draped with steel mesh as further protection from falling rock.

Draped mesh is suitable for controlling rock sizes of about 0.5 tonne size and up to 2.5 tonnes size if woven wire rope is used. It is generally most effective on vertical, or very steep slopes, such as at Rose Blanche. A wire mesh solution, if used, should use woven wire to protect against larger rock sizes. The wire mesh presents challenges with installation and finding anchor locations for the top support.

The advantages of reinforcing the rock slope are limited to maintaining the current configuration of access road and penstock. Making the slope flatter will require removal of large rock masses and will almost certainly require the penstock be either removed or buried during construction so as not to cause more damage. So flattening offers little economic advantage. A decision to stabilize the rock face with anchoring will present significant construction challenges, and the work can only be completed by specialized contractors.

SECTION 4

Conclusions & Recommendations

4. Conclusions and Recommendations

Conclusions and recommendation provided are based on a one day visual inspection of a rock fall, a desktop review of previously available information, and a degree of professional judgment. The assumptions and qualified analysis should be considered preliminary and conceptual.

4.1 Conclusions

The RBH development has operated without a serious rockfall incident for nearly 20 years, but the structural geology of the area indicates potential for instability. Observations at the site indicate that, in the current condition, certain areas of the right escarpment extending from the dam to the gate are potentially unstable with respect to landslides. This area in particular, should be considered unstable and removal of the talus debris that resulted from the landslide should be avoided. If required, access to the dam should be overland on the left side of the valley. The current access road should be closed beyond the access gate until further notice.

The RBH development did not stop generation as a result of the landslide and continues to operate without incident. The penstock received a direct impact, but the anchor bolts are intact and the structure does not appear to have displaced. Continuing to generate power in the current state should not cause additional damage to the facilities.

There are engineering methods and technologies available that can mitigate the risk of further damage due to landslide activity at RBH. The methods and technologies include providing active protection of facilities, passive protection of facilities and stabilization of the rock slope. A conceptual level discussion of all three approaches is provided for consideration by Newfoundland Power.

Future instability may further damage the penstock, but immediate remedial work to mitigate that risk is not practical or safe during the winter/spring season. The summer period provides a more appropriate time for construction as the rock face is more likely to be dry, free of ice overhangs, or other supplemental loading, and there will exist a better observation environment for unexpected movements. In the interim, signage should be posted to inform the general public of the risk and advise them to avoid the risk areas.

4.2 Recommendations

There is limited field data available to make informed decisions on risk and advance cost estimates for the remedial options beyond the conceptual level. To develop planning beyond the conceptual level, additional field data needed include additional topographic survey, precision survey of the rock slope, additional geological mapping of the local geology and further assessment of functionality of the penstock. Acquiring field data may not be safe or practical during winter conditions, but Newfoundland Power should acquire the information in the Spring when conditions improve.

There is limited physical data of the unstable rock face, and topography of the region is from the geomatics database provided by the Government of Newfoundland and Labrador. Newfoundland Power should acquire survey of the rock face, as well as video and a photographic record of the top of slope. This data should be acquired by remote aerial vehicles, a solution commercially available in the area. The purpose is to establish topography for remedial design, as well as establish a baseline to monitor future movement of the rock face, which will be required prior to any construction activity at the base of the rock slope.

Detailed geological mapping of the rock formation will provide a more reliable assessment of potential unstable areas. This data will be more applicable for option 3, and also option 2, but to a lesser extent. Given the potential for instability, geological mapping should not be performed in the area of the recent landslide.

The indentation damage to the penstock may, over time, cause premature degradation of the steel shell. If the long term repair solution is to leave the damaged section of penstock in service, a “Fit for Service” assessment should be performed to determine if the penstock is adequate as is or if replacement of damaged sections are required. The assessment should be completed in phases, starting with a desktop study that may be supplemented with some field testing, such as dye penetration, magnetic particle, etching, or residual stress measurements, if required.

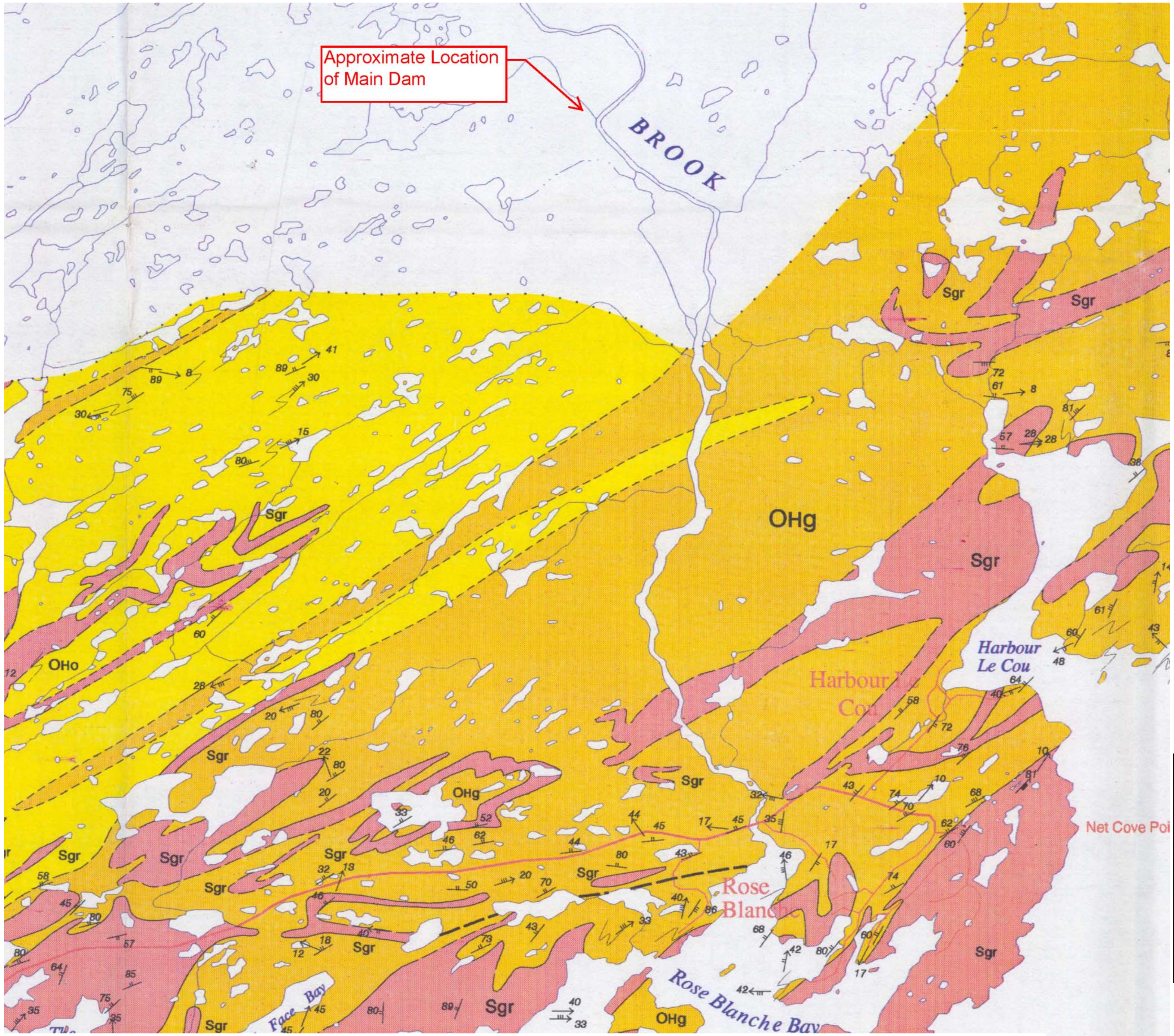
The area from the vehicle gate to the Main Dam will need to be modified to mitigate potential for damage to existing infrastructure and the risk to life safety. Modifications include two components; (1) reinstating the access road, and (2) protecting the steel penstock. Newfoundland Power should develop the conceptual engineering methods and technologies presented to a preliminary level to determine technical feasibility of each option and prepare order of magnitude estimates of probable construction cost to assess the best applicable technological solution.

Special provisions are required during construction to manage the temporary risks to workers completing the work. Prior to commencing construction, Newfoundland Power should complete a risk management assessment and prepare appropriate risk mitigation strategies.

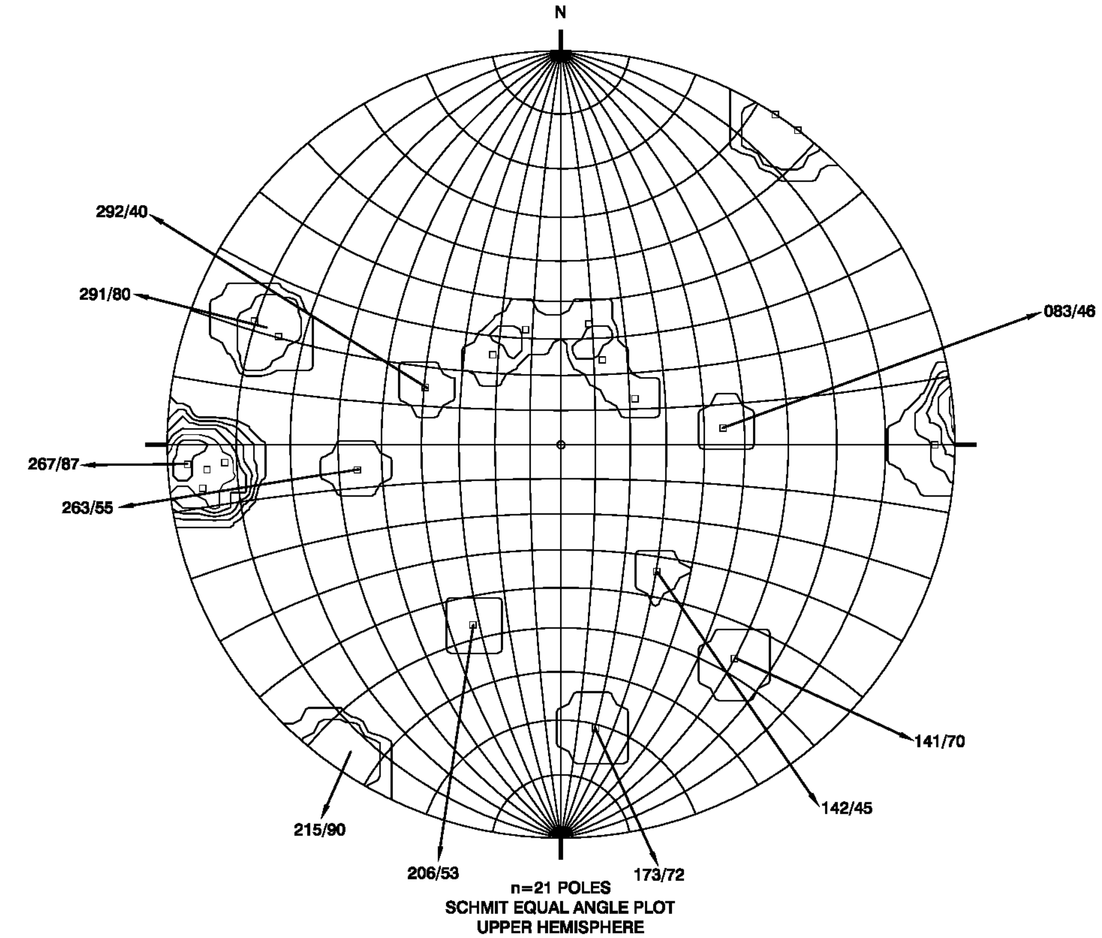
Risk to dam safety is related to a lack of access to the headgate and results in a dam safety deficiency. Other potential dam safety issues include risk of a wave reducing freeboard and risk of an uncontrolled reservoir release as a result of a penstock rupture. Reinstatement of access and protection of the penstock should be given a high priority as a result of the risk to dam safety. Other risk should be considered in the next Dam Safety Review for the Main Dam.

A

Figures



Van Staal, C.R.,, Lin S., Hall L., Valverde P. and Genkin M. "Geology, Rose Blanche, Newfoundland, GSC Open File 3219 (1996)



Discontinuity	Dip Direction	Dip	Comments
Shear Surfaces	260 - 290 080 - 100	70 - 90 80 - 90	Potential Toppling
Cleavage	025 - 045 205 - 235	80 - 90 80 - 90	
Foliation	330 - 030 260 - 300 140 – 205	20 - 40 40 - 60 40 – 60	Mid dip slopes represent potential wedge and plane slides.

Magnetic Declination -18.75 degrees to be added to dip direction

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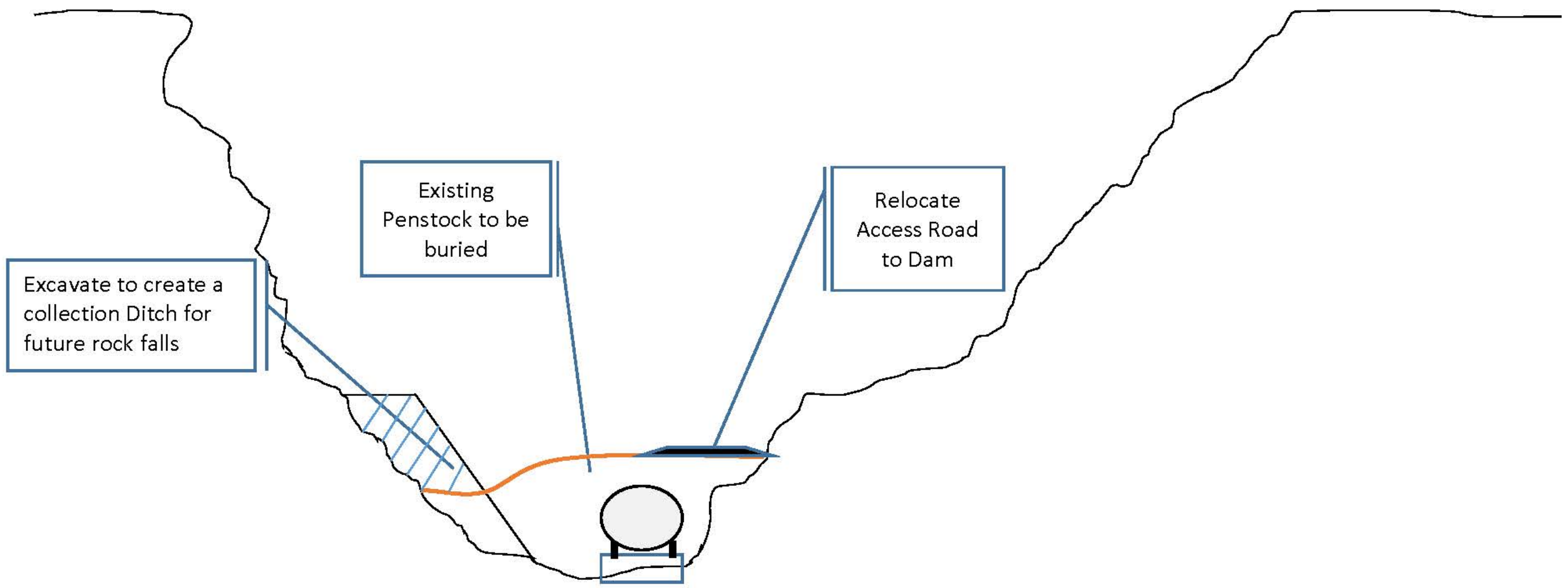
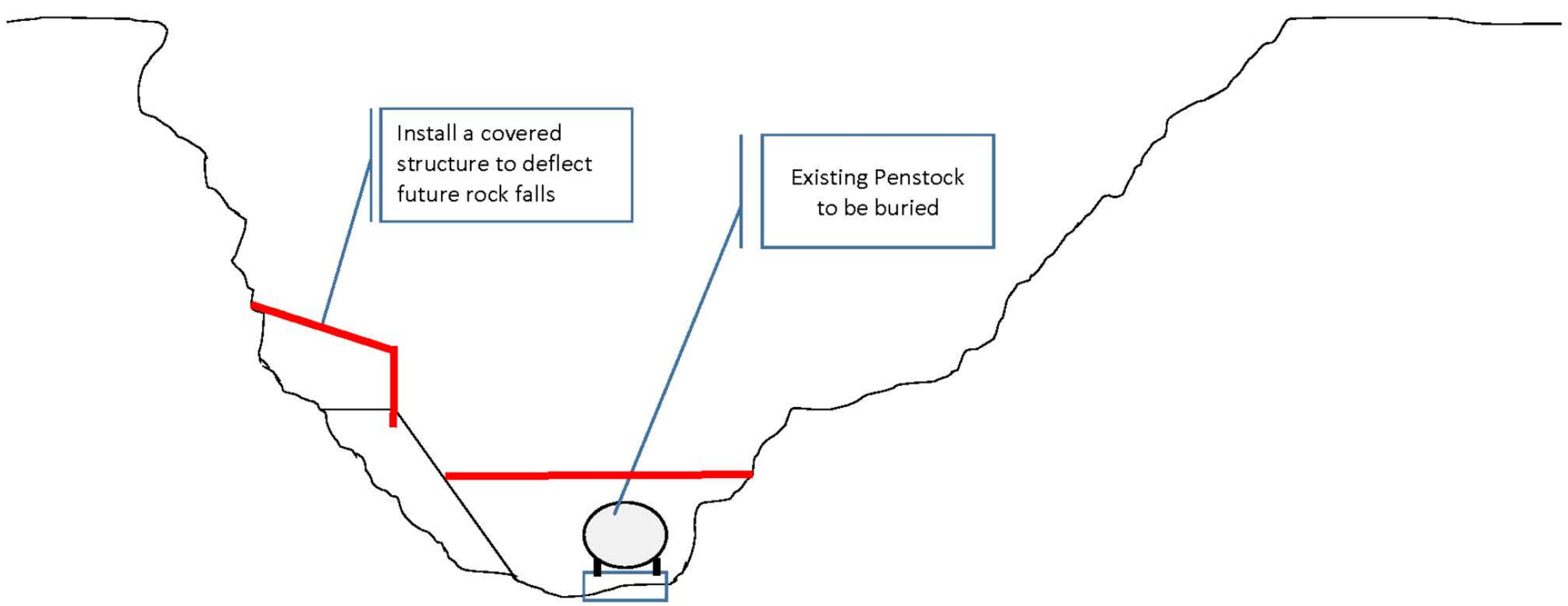
Rose Blanche Hydro

Rockfall Hazard Assessment

Figure 1

Regional and Structural Geology





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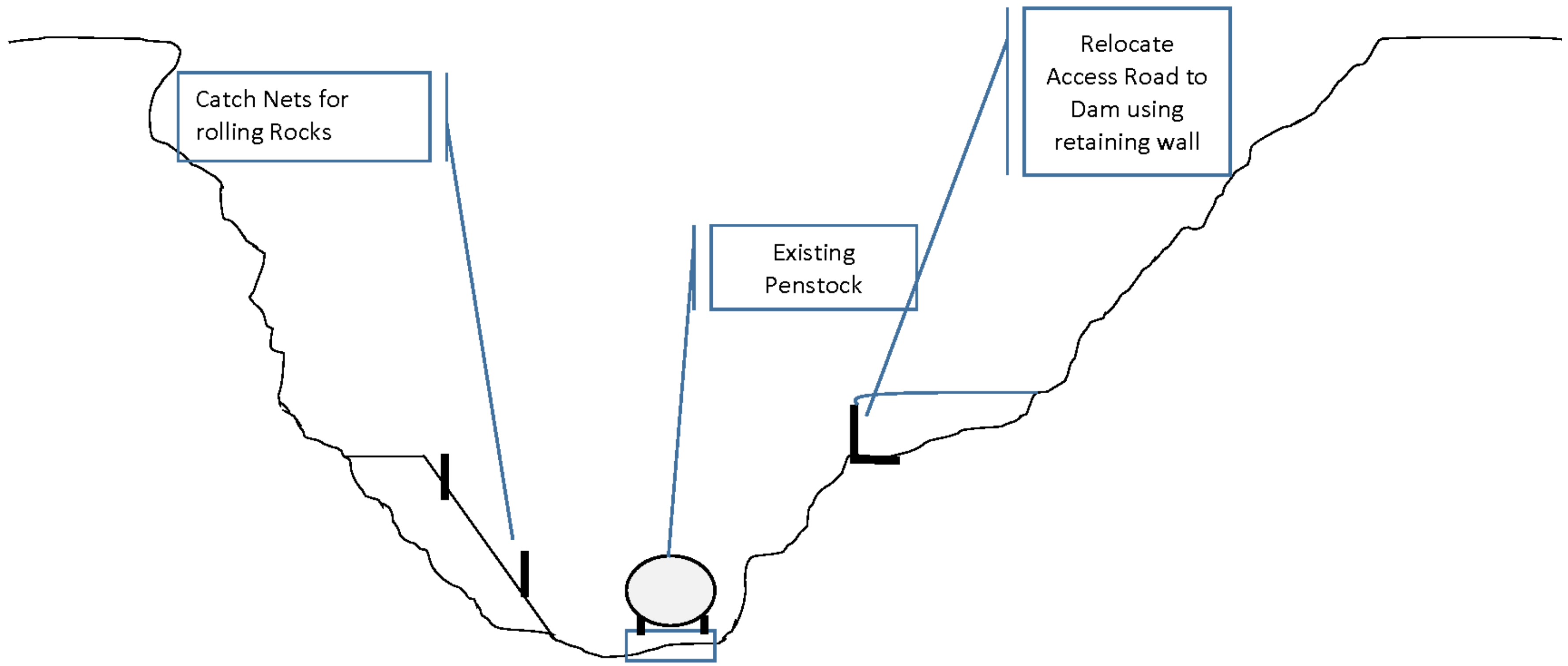
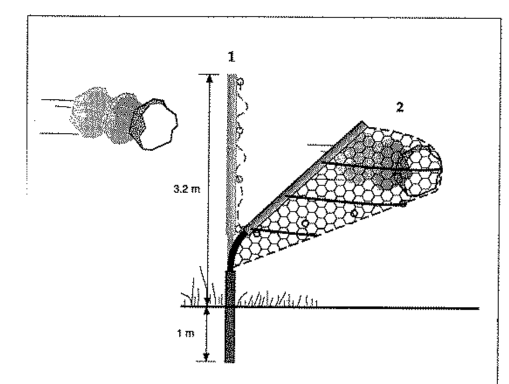
Rockfall Hazard Assessment

Figure 2
Risk Mitigation – Option 1
Direct Burial





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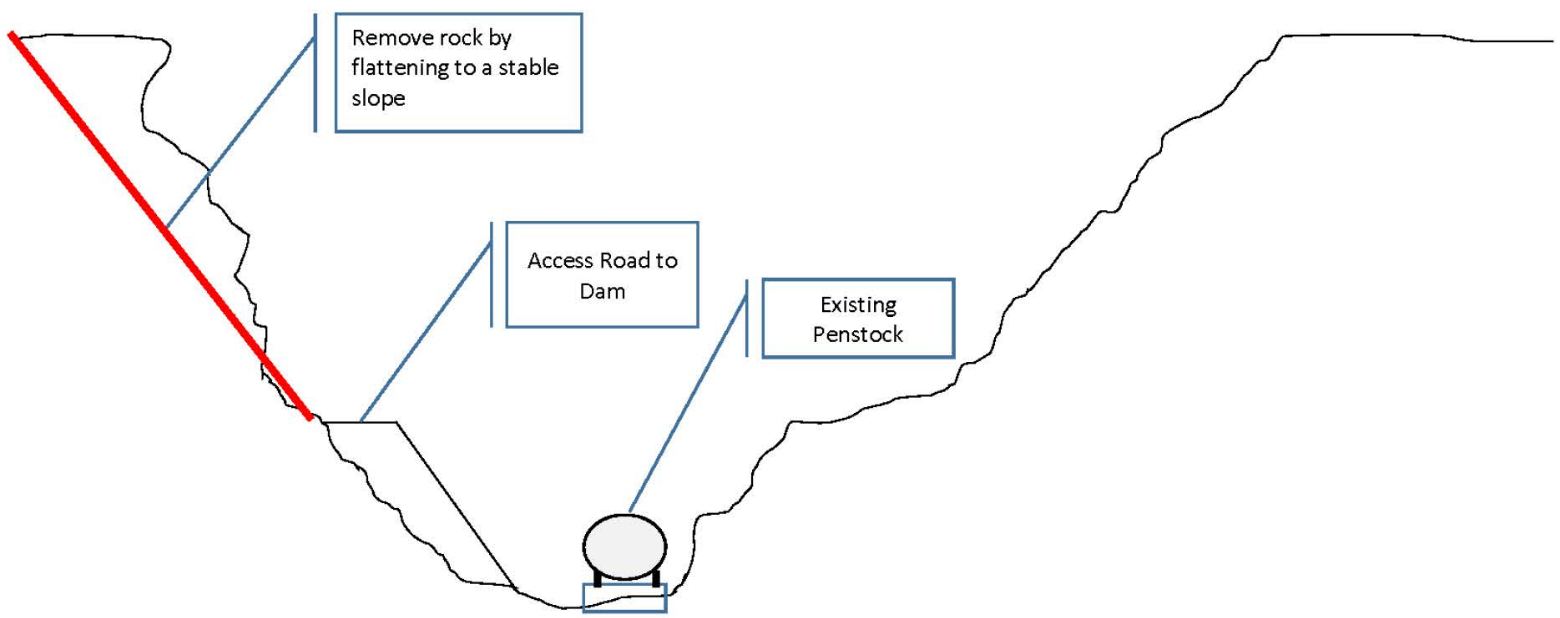
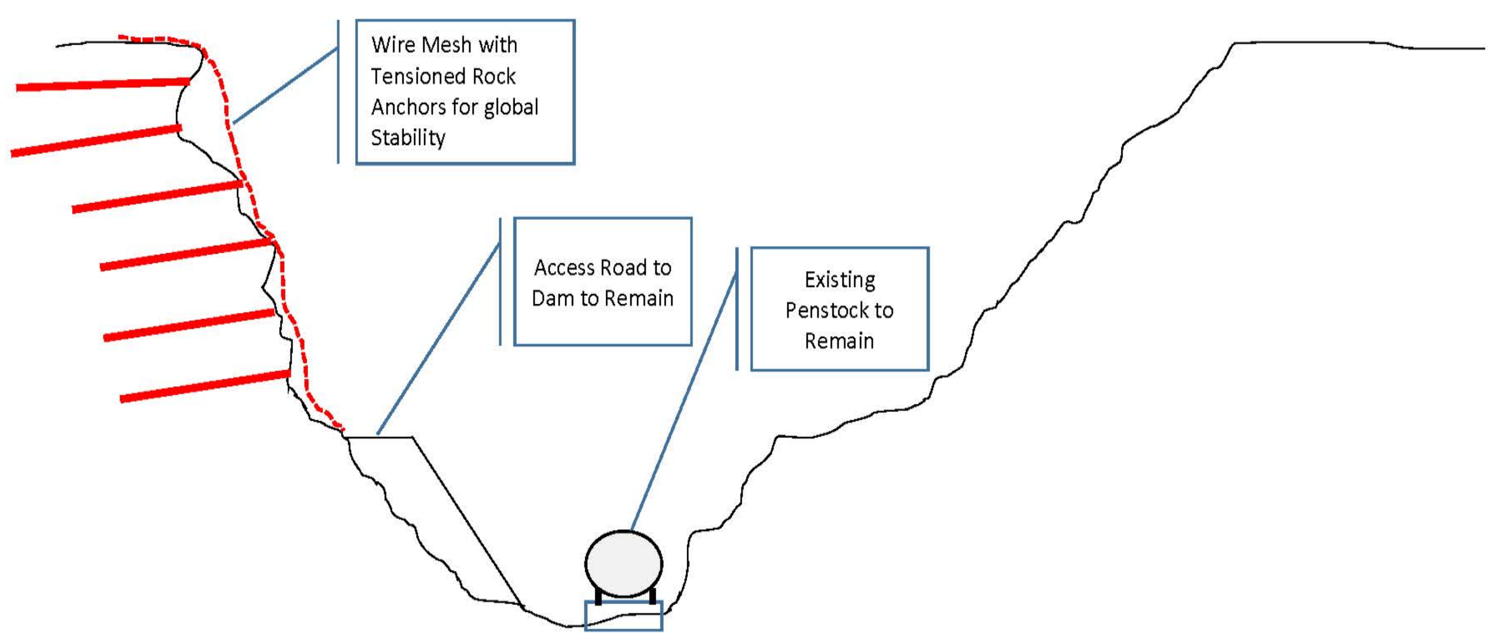
Rose Blanche Hydro

Rockfall Inspection Report

Figure 3

Risk Mitigation – Option 2
Passive Approach





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Rockfall Inspection Report

Figure 4
Risk Mitigation – Option 3
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B

Photographs

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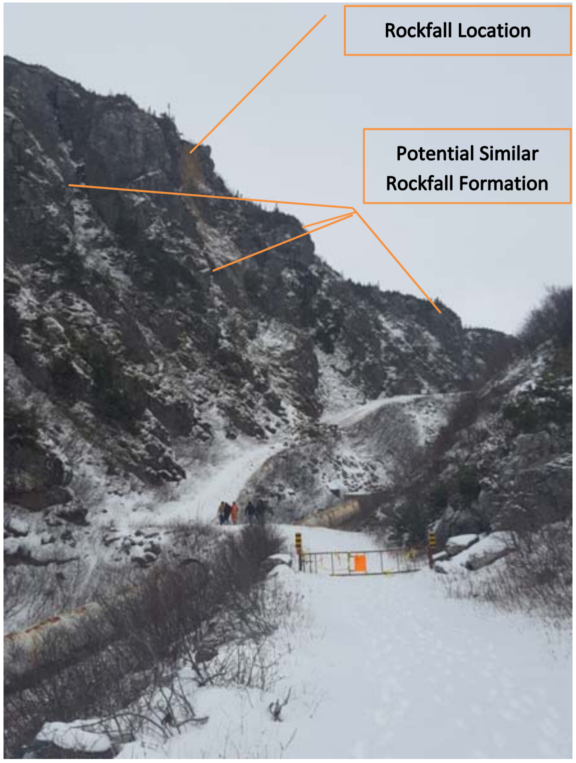

Photo 1 – View of the Rockfall Zone looking North.

Photo 2 – Rockfall area from the culvert crossing.

Photo 3 – Rockfall area looking south from the top of dam.

Red lines show potential area of alternate access road. Work will require relocation of the power poles, as well as drilling and blasting. It is likely a retaining wall will be required to support the new road.

Photo 4 – Access road blocked by debris field.

Photo 5 – Debris field on access road looking towards dam.

Photo 6 – Scarp on rock slope of fall area.

Photo 7 – Fall zone showing trace of detritus.

Photo 8 – Rock slope geology.

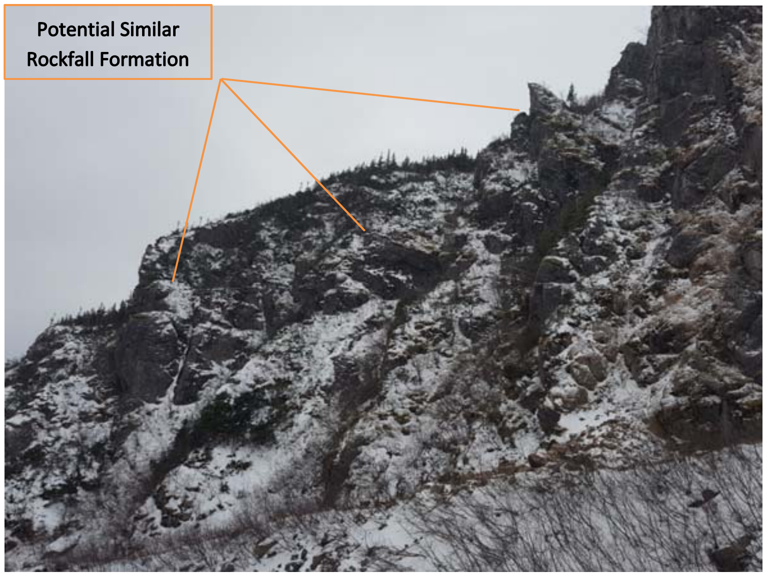

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Photo 22 – Paint Damage.

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NEWFOUNDLAND AND LABRADOR

AN ORDER OF THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES

NO. P.U. ___ (2017)

IN THE MATTER OF THE PUBLIC
UTILITIES ACT, R.S.N. 1990,
CHAPTER P-47 (THE "ACT")

AND

IN THE MATTER OF AN APPLICATION
BY NEWFOUNDLAND POWER INC. (THE"APPLICANT")
FOR (1) APPROVAL OF A SUPPLEMENTAL CAPITAL
EXPENDITURE FOR THE CONSTRUCTION
AND PURCHASE OF CERTAIN IMPROVEMENTS
AND ADDITIONS TO ITS PROPERTY PURSUANT
TO SECTION 41 (3) OF THE ACT.

WHEREAS the Applicant is a corporation duly organized and existing under the laws of the Province of Newfoundland and Labrador, is a public utility within the meaning of the Act, and is also subject to the provisions of the Electrical Power Control Act, 1994, and

WHEREAS the Applicant operates transmission lines, distribution lines and substations to deliver electricity to customers throughout its service territory on the island portion of the Province of Newfoundland and Labrador, and

WHEREAS the Applicant's Rose Blanche (the "Plant") is a 7,625 kVA hydro plant located in the community of Rose Blanche, approximately 45 kilometres east of the Town of Port aux Basques, and

WHEREAS following a trip of the Plant difficulty was encountered restarting the generator, and subsequent condition assessment of Turbine No. 1 revealed damage to the turbine runner, shaft and associated equipment, and

WHEREAS the damage has resulted in the Plant operating at reduced capacity with only Turbine No. 2 in service, and

WHEREAS the most cost-effective option to enable the Plant to be returned to full cacpacity is to refurbish the turbine runner, shaft and associated equipment, at a cost of $1,787,000, and

WHEREAS in November 2016 a rockfall at the Plant site near the main dam caused damage to the penstock and blocked vehicular access to the main dam., and

WHEREAS the lack of access to the main dam presents significant risk to the safe and reliable operation of the Plant and there is also potential for further damage to the penstock from future rockfalls, and

WHEREAS the most cost-effective option to enable the continued safe, reliable operation of the Plant is to bury the penstock, construct a ditch to contain future rockfalls, and relocate the main dam access road, at a cost of $1,494,000, and

WHEREAS the proposed capital expenditures are necessary for the Applicant to provide service and facilities which are reasonably safe and adequate and just and reasonable pursuant to Section 37 of the Act, and

<u>IT IS THEREFORE ORDERED THAT:</u>

1) Pursuant to Section 41 (3) of the Act, the Board approves the capital expenditures in excess of $50,000 associated with the improvements and additions to the Applicant's property as proposed in the Application.

DATED at St. John's, Newfoundland and Labrador, this ______ day of   , 2017.

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____

G. Cheryl Blundon

Board Secretary