RECLAMATION
Managing Water in the West

TR-2017-01

Travel to Senator Wash Pump-Generation Plant

Travel to Senator Wash Pump-Generation Plant to observe penstock vibrations

Date(s) of Travel: March 20 – 22, 2017

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code: 86-68560 Date: May 3, 2017

To: Manager, Hydraulic Investigations and Laboratory Services Group
From: Josh Mortensen, Hydraulic Engineer

Subject: Travel to Senator Wash Pump-Generation Plant to observe penstock vibrations

1. Travel period: 20 – 22 March 2017

2. Places or offices visited: Senator Wash Pump-Generation Plant

3. Purpose of trip:
The main purpose of this trip was to observe vibrations of the plant's main penstock that were identified during a facility review in February 2017. The Senator Wash Pump-Generation plant transports water to and from Senator Wash and Imperial reservoirs to allow flexible and efficient water delivery operations from Imperial Reservoir. The main penstock transports flow in both pump and generation mode for 6 Francis-type pump-generator turbines. The steel penstock is 10-ft diameter with ½-inch wall thickness, and is supported by ring stiffeners spaced approximately every 40-ft.

A new expansion joint was installed on the penstock in January 2017 and is thought to be a potential cause of increased vibration. Engineers from TSC's Hydraulic Investigations & Laboratory Services group (86-68560) were asked to travel to the plant and observe penstock vibrations during operation.

4. Synopsis of trip:
Josh Mortensen traveled to Yuma, AZ on Monday March 20th, observed operation of the penstock on Tuesday March 21st, and returned to Denver on Wednesday March 22nd. After a review of the Job Hazard Analysis the plant was observed to operate in generation mode with one, two, three, and then four units generating. The process was then repeated in pump mode with one, three, and four units pumping. Four was the maximum number of units that could operate simultaneously as units #1 and #4 were down for maintenance. Each operating condition was maintained for approximately 15 minutes to observe vibrations under steady state conditions.

For each test condition, a video of the expansion joint and penstock was recorded with a hand-held video camera. An accelerometer with a magnetic base was attached to the side of the penstock approximately 90° from the top to obtain preliminary acceleration data for each test condition. Other data collected included water surface elevations for Senator Wash Reservoir and Squaw Lake (tailbay) and video of the tailbay. Penstock flowrates were not measured but assumed to be approximately 200 ft^3/s per unit based on operator experience (max of 800 ft^3/s for four units).

Results from test runs in generator mode showed a maximum penstock displacement on the order of 1/16-inch, which did not vary significantly with the number of units generating. Dominant frequencies were in the range of 6-9 Hz, and 31 Hz. The blade passing frequency of 42 Hz (7 vanes, 360 rpm) was detected but not significant compared to the lower frequency vibrations (Figure 3). For one test with a single generating unit the accelerometer was moved up to approximately 45° from the top where displacement magnitudes where slightly higher but at similar frequencies compared to the side location at 90°. No unusual noises or sounds were observed. Jesse Alvarado, who observed the vibration last February, indicated that vibrations we observed on March 21st appeared the same as before. Similar vibrations were observed in other sections of the penstock up and downstream of the expansion joint.

For pump mode, no significant vibrations were observed. Displacement was not measurable and a single dominant frequency was recorded at 42 Hz (blade passing frequency, Figure 4). A slight sound was heard that seemed to be on the same order as the blade passing frequency but did not seem unusual or concerning.

5. Conclusions:

While it appears that there’s not an immediate concern with the current vibrations, observations from this trip could not confirm if the current vibrations are within an acceptable range to prevent long term issues for the penstock and associated equipment. Fatigue of the penstock from fluctuating stresses due to observed deflections does not appear to be a concern. The maximum fluctuating hoop stress is estimated to be about 3,510 psi [1] which is well below the endurance limit for steel. Conservative assumptions were used for this approximation which include full reservoir head (≈29 psi), maximum deflection of ¼-inch, and ASTM A283 steel pipe (since the actual steel is unknown). However, actual fluctuating hoop stresses are unknown and could vary depending on stress concentrations and mode of vibration. A field test with actual stress measurements (strain gage installation) would be needed to verify that hoop stresses are within the acceptable range.

The penstock and concrete at the ring supports would be the next potential location for problems. Periodic inspections for cracks in the penstock at the ring supports as well as cracking or spalling of the concrete piers are important.

It is unknown why the penstock vibrates only in generation mode. It could not be determined that the new expansion joint is the cause of vibration. This is unlikely as the estimated resonant frequency of the expansion joint is much higher than dominant frequencies identified with the accelerometer. While blade passing frequency remains the same for both pump and generating mode, potential operational differences include direction of the flow, pressure gradient, and discharge (which were not measured during observation tests) which could be a cause of exciting different modes when generating. Also, it was confirmed that the plant was designed to a standard for pumping efficiency but not a generating efficiency [2] which may result in generating operations that are rougher, less efficient, and more susceptible to vibrations.

6. Action correspondence initiated or required: A field test is recommended to further assess penstock vibrations. Physical data are needed to verify that fluctuating stresses in the penstock are within an acceptable range (i.e., below the endurance limit), which would be the main objective of the test. This could be done by installing strain gauges at strategic locations on the penstock to measure stresses during operation. A secondary objective of the test would include further investigation of the cause of vibration. This could be done by identifying longitudinal and circumferential modes with accelerometers and measuring penstock pressures and discharges during both pumping and generating operations. Testing could be performed by TSC’s Hydraulics Investigations and Laboratory services group.

7. Client feedback received: N/A

8. REFERENCES

[1] J. E. Shigley, C. R. Mischke and R. G. Budynas, Mechanical Engineering Design, New York: McGraw-Hill, 2004.

[2] Bureau of Reclamation, "Designer's Operating Criteria - Senator Wash Dam, Dikes, and Pumping-Generating Plan," Department of the Interior, Denver, 1968.

cc:

Nathaniel Gee (LC-6600)
Jesus (Jesse) Alvarado (YAO-2110)
Bill McStraw (86-68410)

SIGNATURES AND SURNAMES FOR:

Travel to: Senator Wash Pump-Generation Plant, Winterhaven, CA

Dates of Travel: 20 – 22 March 2017

Names and Codes of Travelers: Josh Mortensen 86-8560

Author:

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Josh Mortensen, P.E. Date
Hydraulic Investigations and Laboratory Services Group

Reviewed:

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Joe Kubitschek, P.E., PhD Date
Hydraulic Investigations and Laboratory Services Group

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Robert F. Einhellig, P.E., Manager Date
Hydraulic Investigations and Laboratory Services Group

Figure 1 Photo of the penstock and newly installed expansion joint, looking toward the reservoir.

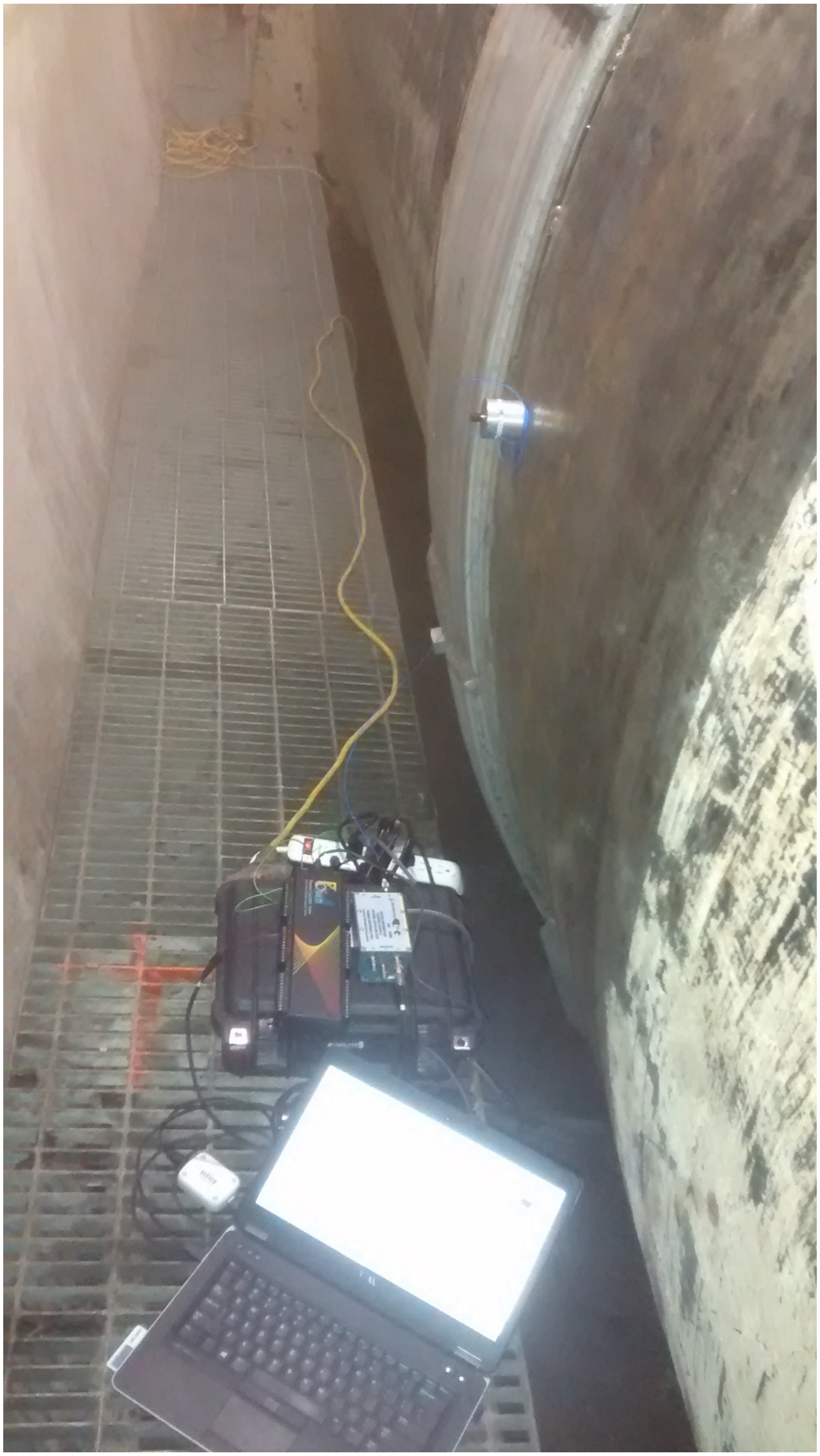

Figure 2 Photo of the accelerometer mounted on the penstock, on the reservoir side of the expansion joint during tests on March 21st.

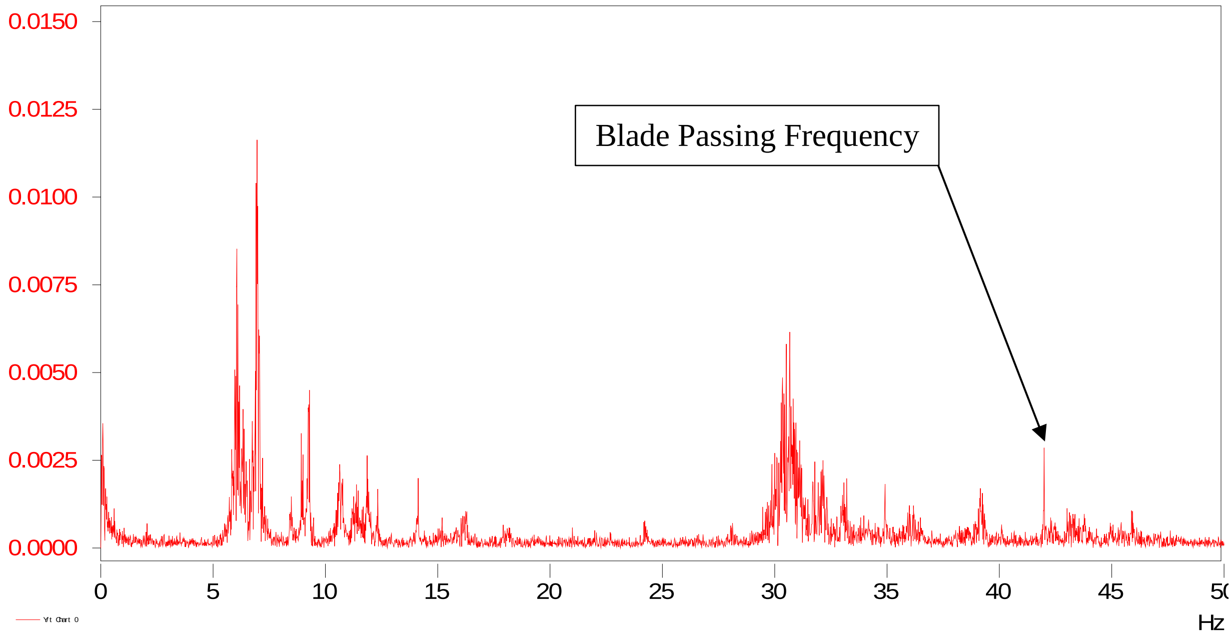

Figure 3 Plot of the acceleration signal in the frequency domain in generating mode. Dominant frequencies occurred in the range of 6-9 Hz and near 31 Hz. Blade passing frequency was detected but not significant.

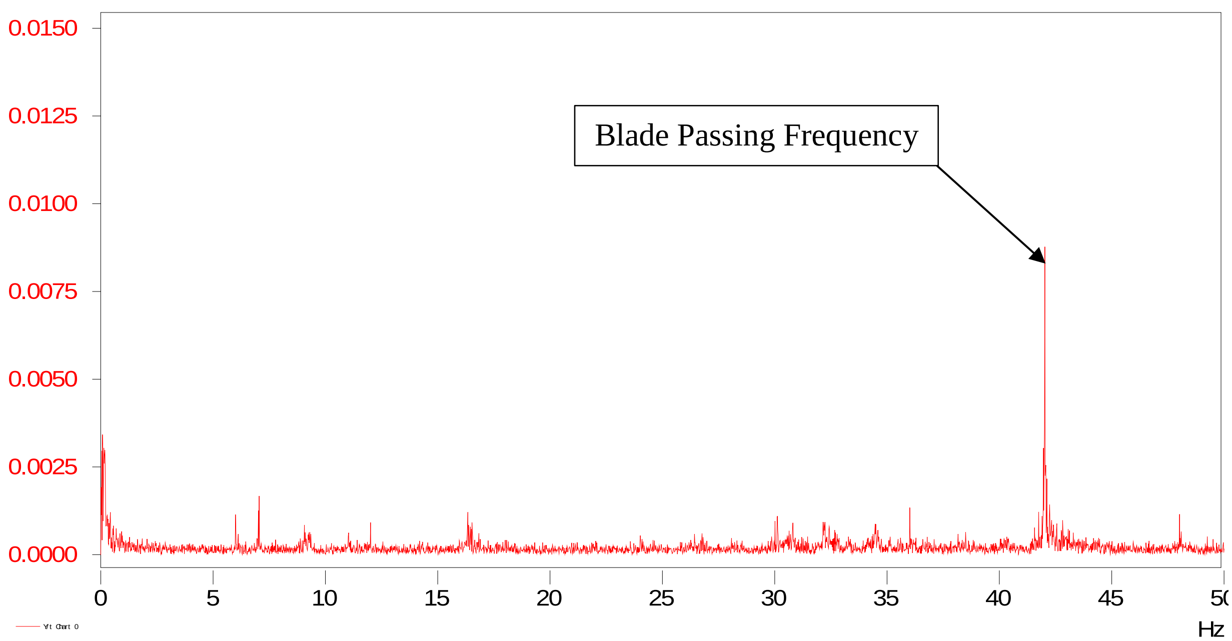

Figure 4 Plot of the acceleration signal in the frequency domain in pumping mode. Blade pass frequency (42 Hz) was dominant with no other significant vibrations.