BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code: 86-68560 Date: August 11, 2016

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

Subject: Travel to Granby Dam for flow and vibration testing of modified outlet works

1. Travel period: 19 and 26 – 27 July 2016

2. Places or offices visited: Granby Dam, Granby CO

3. Purpose of trip: The purpose of this trip was to acquire discharge and vibration data for a 30-inch hollow jet valve and 12-inch jet flow gate that have recently been reconfigured due to the addition of a new 36-inch penstock and hydropower plant below Granby Dam. The test procedure was written and administered by Northern Colorado Water Conservancy District (Northern) and measurements were recorded by Reclamation's Technical Service Center - Hydraulic Investigations and Laboratory Services Group.

4. Synopsis of trip: On Tuesday July 19th Josh Mortensen and Joe Kubitschek (86-68560) travelled to Granby Dam to evaluate the outlet works and equipment to be tested in preparation for field measurements the following week. The modified outlet works consist of a new 30-inch steel pipe with a vertical bifurcation. The top bifurcation transitions into a 36-inch steel penstock for the powerplant. The bottom ends about 28-ft downstream of the bifurcation with the original 30-inch hollow jet valve (recently refurbished) which discharges below the penstock into the circular tunnel (11.5-ft dia.). A separate outlet connection consists of a 14-inch steel pipe that ends with a 12-inch jet flow gate which discharges into the tunnel at the same location as the hollow jet valve.

On Tuesday July 26th, Josh returned to Granby Dam with Mike Rauh (86-68410) to install test instrumentation. After reviewing a JHA and special work permit, test equipment was installed. Acoustic flowmeter transducers were installed on the 30-inch and 14-inch pipes approximately 8-ft upstream from the hollow jet valve and jet flow gate. Accelerometers were mounted on the hollow jet valve, the 36-inch penstock transition, and both the 30-inch and 14-inch pipes near the flowmeter installation to measure vibration. Pressure transducers were installed on an air vent line from the 30-inch pipe and the fill line for the butterfly valve on the penstock. More detailed information on locations and instrumentation is shown in Figure 1 and Table 1.

On Wednesday July 27th testing was performed according to the procedure prepared by Northern. During testing, flow measurements were recorded every five seconds for a minimum of 90 seconds at each valve and gate position. Vibration and pressure signals were acquired using an IOTech Personal DAQ 3000 data acquisition system and laptop computer at a rate of 10k samples per second, again for at least 90 seconds at each test condition. Video cameras were located near the hollow jet valve and at the tunnel outlet to observe flow conditions throughout the test.

The hollow jet valve was operated at openings in 10 percent increments from zero to full open. Once the jet valve was 100 percent open the jet flow gate was then opened in 20 percent increments. Finally, with both the valve and gate fully open Northern attempted to bring the powerplant online to allow flow through the penstock. However, this was unsuccessful due to a glitch with the powerplant programming. At that point, the outlet works were shut down and the test was concluded. All instrumentation and test equipment was packed up and then Josh and Mike returned to Denver.

5. Test Data: All testing was performed at a reservoir elevation of 8,278.75 ft and no flow through the 36-penstock. For the hollow jet valve, acoustic flowmeter data were recorded at 10, 20, 30, 40, 50, 60, and 70 percent valve openings. Discharge measurements at openings greater than 70 percent had to be made using stream gaging in the downstream river channel as flow velocities were outside of the range of the acoustic flowmeter. All discharge results were less than 7 percent from the original discharge curve from 1950 (Table 2 and Figure 2). Jet flow gate measurements were recorded at 20, 40, 60, and 70 percent gate openings as shown in Table 3 and Figure 3 (again limited by flow range at greater openings).

Vibration data are shown as the Root Mean Square (rms) of the acceleration which indicates the typical magnitude of vibration at each measurement location (Table 4). Figure 4 shows that vibration levels on the hollow jet valve and penstock remained steady throughout the entire operational range of the valve. However, there was an increase in vibration on the 30-inch pipe at valve openings greater than 70 percent. Also, vibration remained constant at the penstock and 14-inch pipe during the entire operational range of the jet flow gate (Figure 5).

Video recordings of the stilling basin show that the flow did not reach the crown of the tunnel for all discharge conditions (Figures 6 through 9).

6. Conclusions: Successful collection of test data.

7. Action correspondence initiated or required: N/A

8. Client feedback received: N/A

cc:

Noble Underbrink (nunderbrink@northernwater.org)
Karl Thiel (EC-1800)
Bill McStraw (86-68410)
Mike Rauh (86-68410)

SIGNATURES AND SURNAMES FOR:

Travel to: Granby Dam, Granby, CO

Dates of Travel: 19 and 26 – 27 July 2016

Names and Codes of Travelers: Josh Mortensen & Joe Kubitschek, (8560) and Mike Rauh, (8410)

Travelers:

JOSHUA MORTENSEN Digitally signed by JOSHUA MORTENSEN
Date: 2016.08.12 09:54:03 -06'00'

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

MICHAEL RAUH Digitally signed by MICHAEL RAUH
Date: 2016.08.12 10:12:13 -06'00'

Michael Rauh Date
Mechanical Equipment Group

Reviewed:

JOSEPH KUBITSCHEK Digitally signed by JOSEPH KUBITSCHEK
Date: 2016.08.15 09:17:48 -06'00'

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

Noted and Dated by:

TONY WAHL Digitally signed by TONY WAHL
Date: 2016.08.15 10:38:46 -06'00'

Tony L. Wahl, P.E., Acting Manager Date
Hydraulic Investigations and Laboratory Services Group

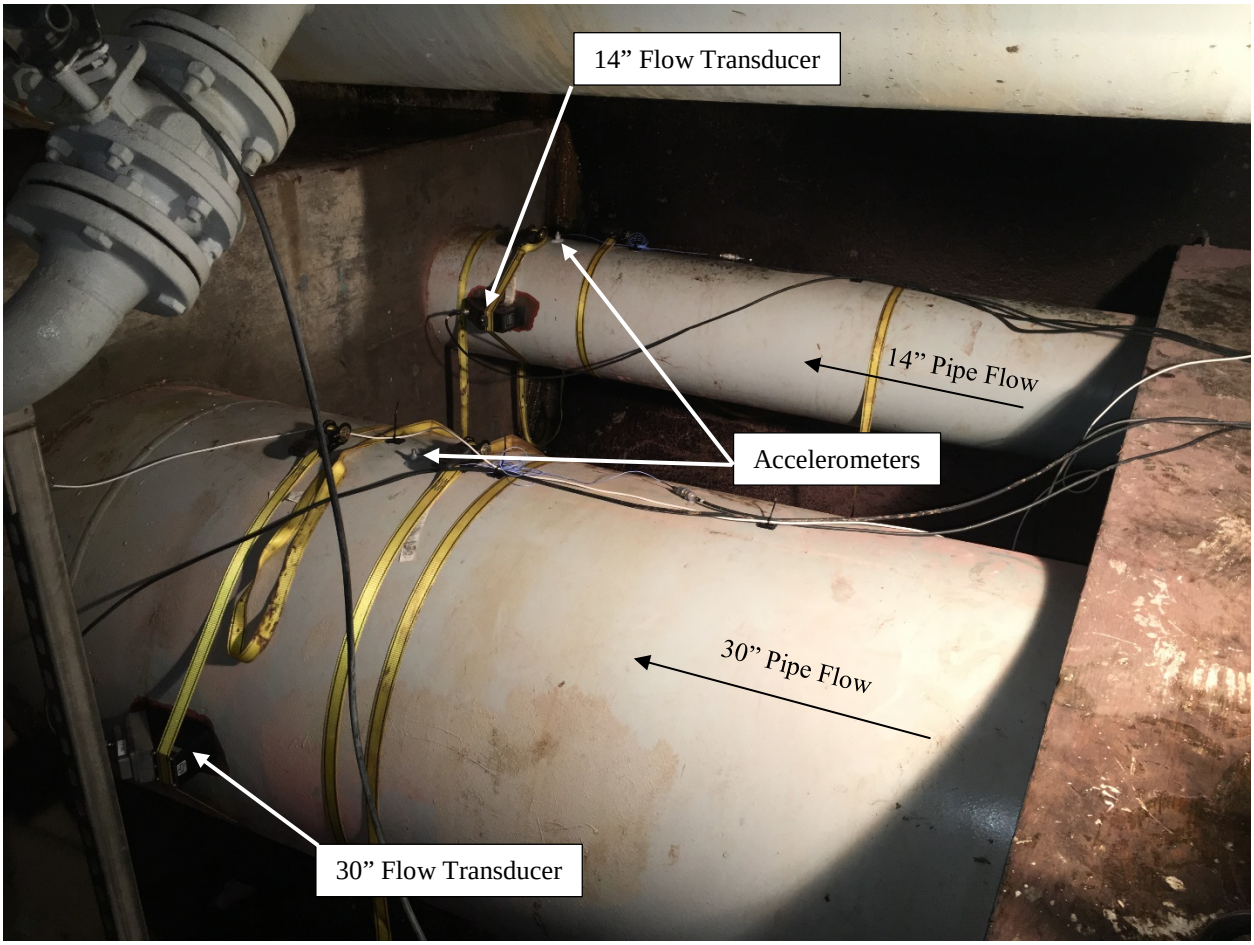

Figure 1 Acoustic flow transducers and accelerometers mounted on the 30-inch and 14-inch pipes upstream of the hollow jet valve and jet flow gate (between the concrete encasements). Flow is from right to left.

Table 1 Measurement locations and instrumentation used for data collection.

MEASUREMENT	LOCATION	INSTRUMENT	SAMPLING RATE
Flowrate (ft^3/s)	30" pipe, 28” upstream from downstream most concrete encasement	Siemens acoustic flowmeter, 991 Universal size 5 transducers, mounted in "direct" mode, ±2% accuracy	1/5 sec
	14" pipe, 12.5” upstream from downstream most concrete encasement	Siemens acoustic flowmeter, 1011 Universal size E2 transducers, mounted in "direct" mode, ±2% accuracy	1/5 sec
Vibration (acceleration - g)	Top of 30" pipe, 28” upstream from downstream most concrete encasement	Vibrametrics Accelerometer, model 1000	10k/sec
	Top of 14" pipe, 12.5” upstream from downstream most concrete encasement	Vibrametrics Accelerometer, model 1000	10k/sec
	36" penstock, top of transition, 25” downstream from weld connection (STA 0+42.13)	Vibrametrics Accelerometer, model 1000	10k/sec
	30" HJV, top of bonnet, about 4.5” from downstream edge	Vibrametrics Accelerometer, model 9001A	10k/sec
Pressure (psi)	30" Pipe, about 35 ft upstream from HJV, air vent line	Omega pressure transducer, model PX309-500G5V, ±0.25% accuracy	10k/sec
Pressure (psi)	36" Penstock, fill line	Omega pressure transducer, model PX309-500G5V, ±0.25% accuracy	10k/sec

Table 2 Discharge measurement data from the 30-inch hollow jet valve.

30" HOLLOW JET VALVE MEASUREMENTS - Reservoir El. 8,278.75 ft				
Valve Position	**Measured Discharge**	**Discharge Curve from 1950**	**Percent Difference**	**Measurement Method**
% open	*avg cfs*	*cfs*	*%*	-
10.22	42.0	45	-6.6	Acoustic pipe flow
20.15	84.8	85	-0.2	Acoustic pipe flow
30.05	127	130	-2.6	Acoustic pipe flow
40.09	170	180	-5.7	Acoustic pipe flow
49.99	209	220	-4.9	Acoustic pipe flow
59.93	247	255	-3.2	Acoustic pipe flow
70.01	282	292	-3.5	Acoustic pipe flow
79.98	335	320	4.7	stream gaging
99.71	385	375	2.7	stream gaging
45.20	191	200	-4.6	Acoustic pipe flow
20.04	84.7	85	-0.3	Acoustic pipe flow

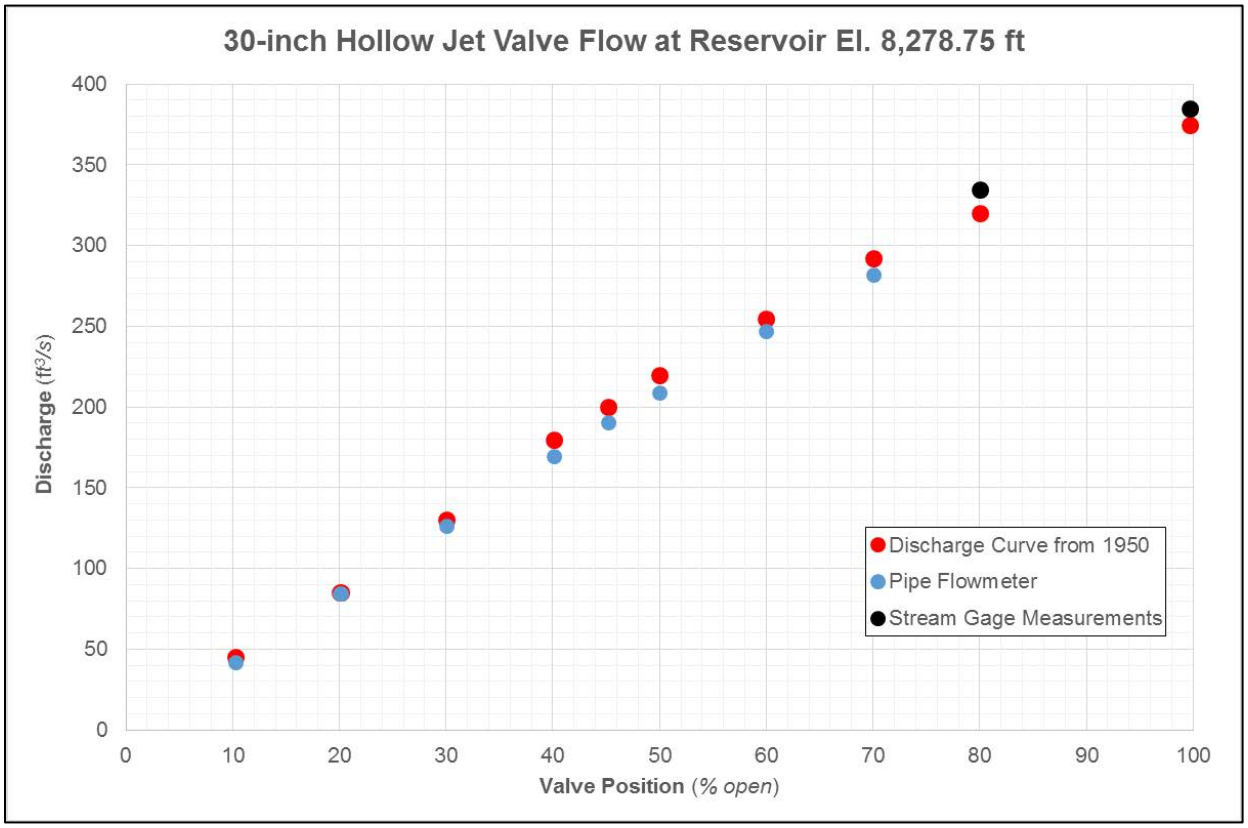

Figure 2 Comparison of discharge vs. valve opening measurements with the original 1950 discharge curves for the 30-inch hollow jet valve.

Table 3 Discharge measurement data from the 12-inch jet flow gate.

12" JET FLOW GATE MEASUREMENTS - Reservoir El. 8,278.75 ft		
Gate Position	**Measured Discharge**	**Measurement Method**
% open	*avg cfs*	-
20	7.1	Acoustic pipe flow
40	22.8	Acoustic pipe flow
60	40.7	Acoustic pipe flow
70	48.5	Acoustic pipe flow

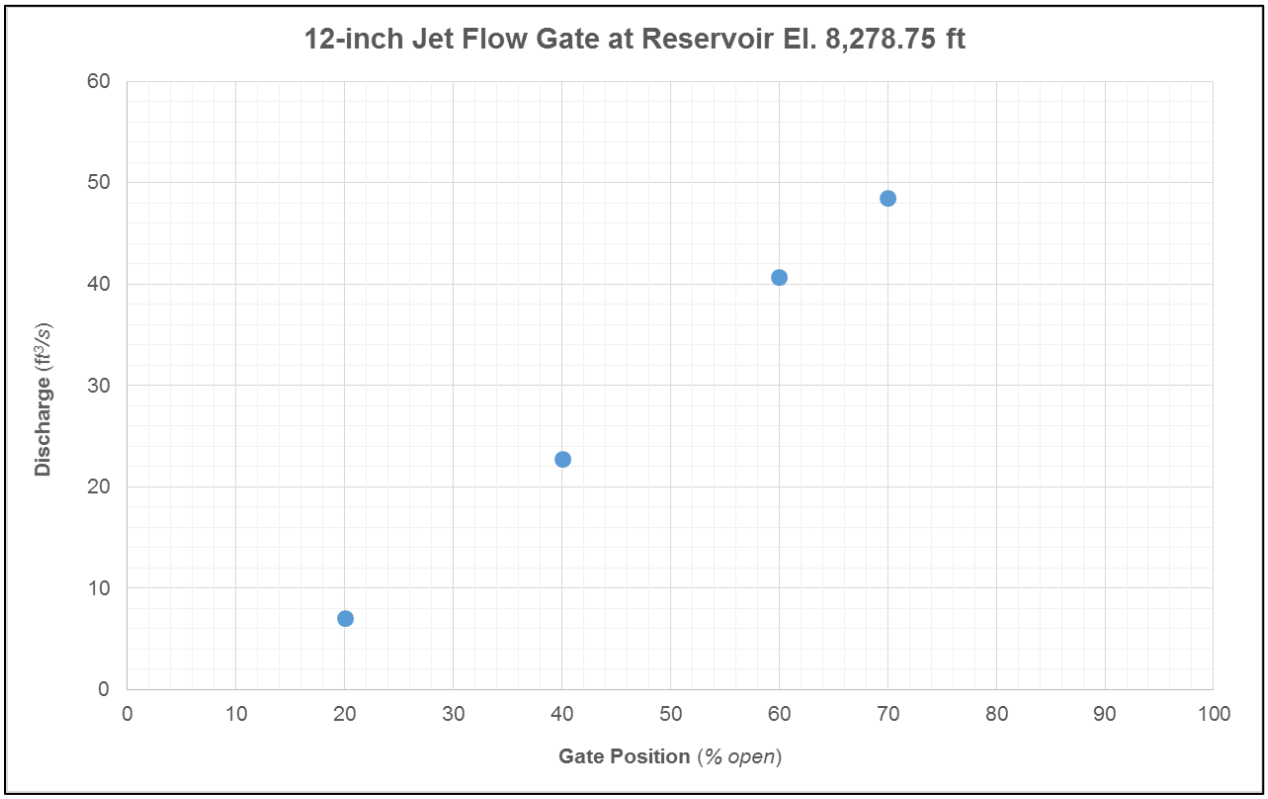

Figure 3 Plot of discharge vs. gate opening for the 12-inch jet flow gate. No original data curves were provided for comparison.

Table 4 Vibration data for the penstock, 30-inch pipe, 14-inch pipe, and 30-inch hollow jet valve.

VIBRATION MEASUREMENTS					
30" Hollow Jet Valve Position	**12" Jet Flow Gate Position**	**36" Penstock**	**30" Pipe**	**14" pipe**	**30" Hollow Jet Valve**
% open	*% open*	*rms (g)*	*rms (g)*	*rms (g)*	*rms (g)*
0	0	0.018	0.02	0.026	0.07
10.22	0	0.154	1.28	0.083	5.37
20.15	0	0.234	2.07	0.206	5.96
30.05	0	0.285	2.18	0.267	5.58
40.09	0	0.252	2.30	0.255	5.74
49.99	0	0.255	2.18	0.237	5.37
59.93	0	0.260	2.10	0.230	5.36
70.01	0	0.231	2.08	0.237	5.40
79.98	0	0.254	2.65	0.302	5.32
89.95	0	0.309	3.66	0.400	5.34
99.70	0	0.443	4.90	0.515	5.49
99.71	20	0.489	5.30	0.540	5.57
99.71	40	0.466	5.03	0.572	5.54
99.71	60	0.481	4.98	0.600	5.54
99.71	70	0.455	5.04	0.586	5.55
99.71	100	0.467	4.86	0.512	5.53

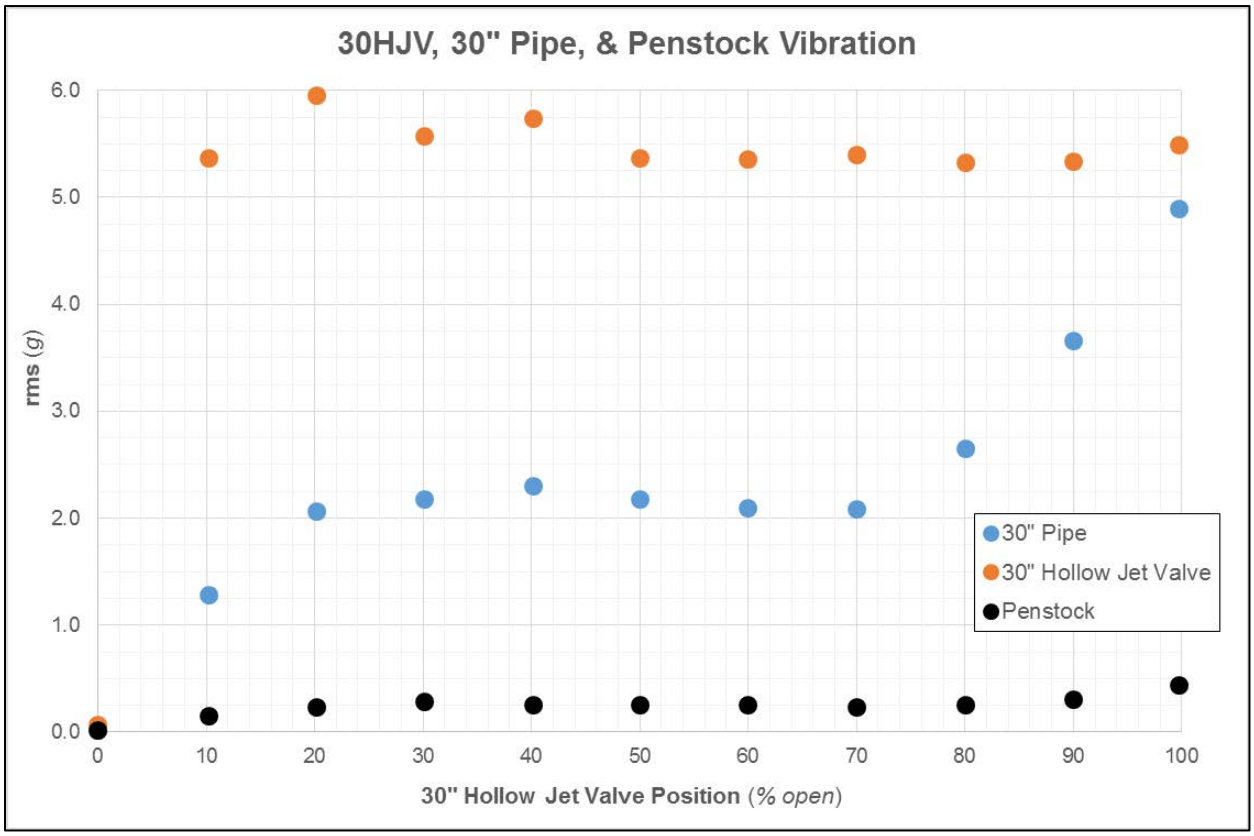

Figure 4 Plot of rms vibration levels for the 30-inch pipe, hollow jet valve, and penstock vs. valve position over the range of test conditions.

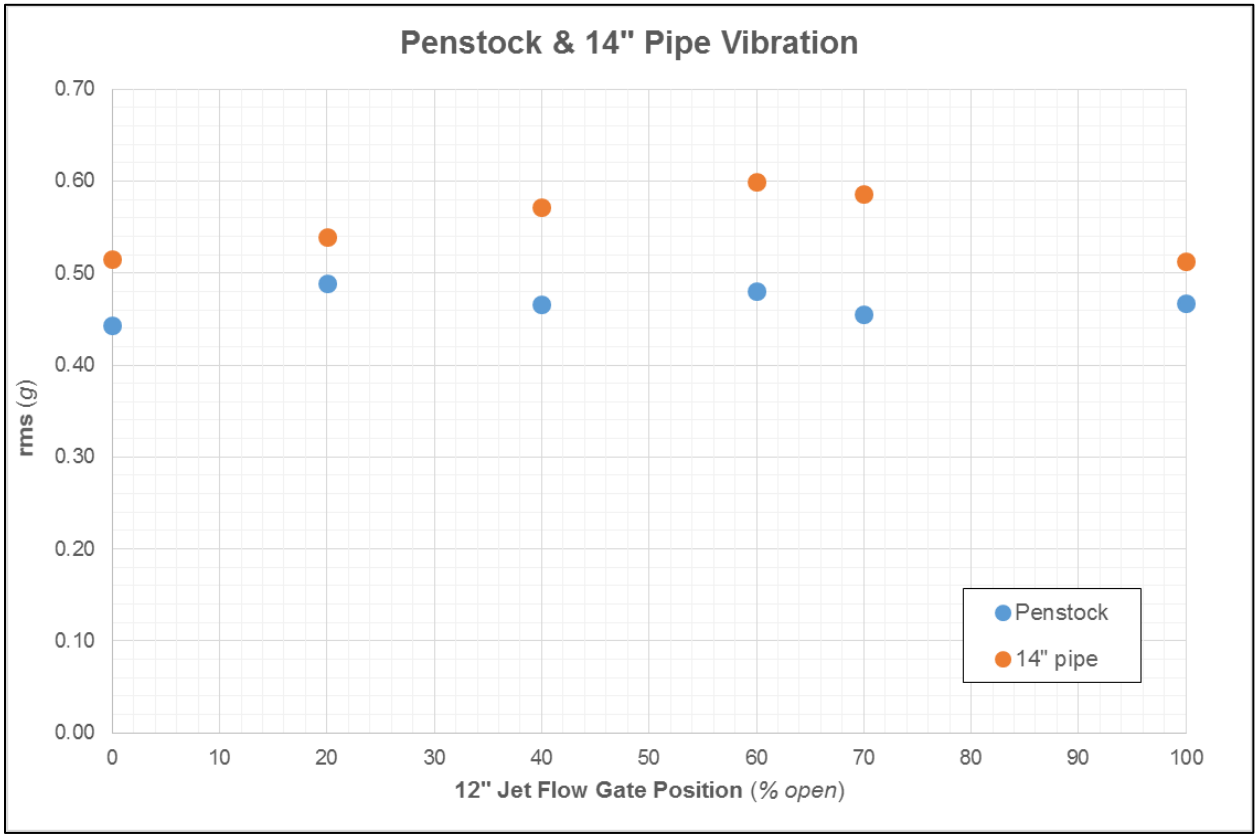

Figure 5 Plot of rms vibration levels for the 14-inch pipe and penstock vs. gate position.

Figure 6 Discharge into stilling basin with the hollo jet valve at 50 percent open. Flow is about 220 ft^3/s (flowing left to right).

Figure 7 Discharge into stilling basin with hollow jet valve at 100 percent open. Flow is about 380 ft^3/s (flowing left to right).

Figure 8 Discharge into stilling basin with both hollow jet valve and jet flow gate 100 percent open. Flow is greater than 430 ft^3/s (flowing left to right).

Figure 9 Flow discharging from the hollow jet valve into the tunnel at 50 percent open (about 220 ft^3/s).