COLUMBIA BASIN PROJECT, GRAND COULEE
SIPHON-BREAKER BUILDING
Grand Coulee
Grant County
Washington

HAER No. WA-139-D

HAER
WASH
13-GRACO,
1D-

BLACK AND WHITE PHOTOGRAPHS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street, NW
Washington, DC 20240

ADDENDUM TO:
COLUMBIA BASIN PROJECT, GRAND COULEE SIPHON
BREAKER BUILDING
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Grant County
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HAER WA-139-D
HAER WASH,13-GRACO,1D-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
PACIFIC WEST REGIONAL OFFICE
National Park Service
U.S. Department of the Interior
333 Bush Street
San Francisco, CA 94104

HISTORIC AMERICAN ENGINEERING RECORD

COLUMBIA BASIN PROJECT, GRAND COULEE SIPHON-BREAKER BUILDING

HAER No. WA-139-D

Location: Grand Coulee
Grant County
Washington

The Grand Coulee Siphon-Breaker Building is located at latitude: 47.9535, longitude: -118.9919. The latitude and longitude coordinates were converted from the UTMs via Montana State University and Yellowstone National Park RCN Utilities and Tools web site on November 18, 2013.

Dates of Construction: 1948-50

Engineers: Bureau of Reclamation

Original Owner: Bureau of Reclamation

Original Use: Siphon-breaker building

Present Owner: Bureau of Reclamation

Present Use: Siphon-breaker building

Significance: The Siphon-Breaker Building played a small but critical role in the process of delivering water from the Columbia River to the irrigation system. Its main function was to manage the flow at the top of the pump discharge line, where water ran into the stilling pool at the head of the Feeder Canal. When a pump stopped, the flow would reverse and the water would be siphoned back to the Pumping Plant unless there was a mechanism to prevent this action.

Project Information: This documentation study was initiated by the Bureau of Reclamation's Pacific Northwest Regional Office in Boise, Idaho. Joseph Pratt was the contracting officer; Derek Beery, Mike Flowers, Sean Hess, Pei-Lin Yu, and Lynne MacDonald served as contracting officer representatives. Hess, Roise and Company, a historical consulting firm based in Minneapolis, Minnesota, was the prime contractor for the project, with photography and delineation completed by subcontractor Clayton Fraser of FraserDesign,

Loveland, Colorado. Charlene Roise, principal of Hess Roise, was the project manager and historian, with research assistance from staff historian Elizabeth Gales and staff researcher Penny Petersen. CH2M HILL'S Boise office provided editorial and other assistance, under the supervision of Mark Bransom, as a subcontractor to Hess Roise.

Introduction

The Siphon-Breaker Building is situated on the west side of the Columbia River, on the crest of the bluff above the Pump-Generating Plant (since dedicated to John W. Keys III) (HAER No. WA-139-C). The building marks the upper terminus of twelve 12'-diameter discharge pipes that carry water from the plant to the Feeder Canal (HAER No. WA-139-E) for Banks Lake. The pipes initially run underground from the widely spaced pumping plant outlets, then come above ground about half way up the incline, angling together as they rise towards the Siphon-Breaker Building.

The Siphon-Breaker Building comprises two sections: the reinforced-concrete control house and the siphon breakers (see photograph HAER WA-139-D-1). The siphon breakers are mostly below grade, with a long, low, above-ground concrete pedestal running north to south, directly east of the control house. Housing for the twelve units is spaced at regular intervals along the pedestal. The control house, which is situated by Units No. 5 and No. 6, was originally equipped with two oil accumulators (A-1 and A-2), an air compressor and receiver (C-1 and C-2), and two wet vacuum pumps (P-3 and P-4), with locations provided for two additional wet vacuum pumps. A permanent access road from the Industrial Area (HAER No. WA-139-H) crosses the reinforced-concrete outlet structure where the pipes discharge into the Feeder Canal.[1]

A Low Priority

Although Reclamation's original mission was to provide irrigation to the arid lands of the West, it discovered soon after its founding in 1902 that power generation was a natural complement to this activity. Sometimes, in fact, generating hydroelectricity became the chief driver of a project. Conflicting demands for irrigation and power are interwoven through the early history of Grand Coulee, with power emerging as the victor (for an in-depth discussion of this subject, see HAER No. WA-139-A). As a result, Reclamation's first priority was building the dam and powerplants at Grand Coulee.

Although planned from the beginning, the pumping plant came later when sufficient demand justified the cost of developing the irrigation system. Reclamation had to decide on the number of pumps for the plant before surveys of the irrigation project's land were completed, so it erred on the side of caution in estimating water needs. The pumping plant was designed to allow the installation of twelve pumps. Even as late as 1952, a Reclamation report speculated that "ten may prove to be sufficient, on account of planned economies in the use of water."[2]

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[1] Bureau of Reclamation, "Siphon Breaker House, Pump Discharge Outlet, Siphon Breaker Operating Diagram," Drawing 222-D-15719, May 15, 1951, revised November 2, 1973; Bureau of Reclamation, "Grand Coulee Pumping Plant Feeder Canal Sta. 0+00, Pump Discharge Outlet, General Plan and Sections," Drawing 222-D-12550, May 1, 1947.

[2] Bureau of Reclamation, "Description of the Power Plant at the Grand Coulee Dam," April 1952, 16, in "Appendices to Substantiating Materials, Columbia Basin Project-Washington, Coulee Dam Field Division, Third Power Plant, Grand Coulee Dam," May 1953; Alvin F. Darland, "The Columbia Basin Project," *Electrical Engineering* 56 (November 1937): 1342.

The plant would lift water 280' up the west side of the Columbia River canyon from the reservoir behind the dam (now Lake Roosevelt). The water would flow through a canal for about 1.5 miles to a reservoir (Banks Lake) formed by damming both ends of a large and ancient ravine: Grand Coulee. Distribution canals extending from the reservoir would feed an irrigation system serving more than 1 million acres of land.

The Siphon-Breaker Building played a small but critical role in this process. Its main function was to manage the flow at the top of the pump discharge line, where water ran into the stilling pool at the head of the Feeder Canal. When a pump stopped, the flow would reverse and the water would be siphoned back to the pumping plant unless some mechanism prevented this action. As Reclamation engineers explained in a 1945 paper, "The siphon limits pumping head to that computed from the water level in the canal and the siphon breaker prevents backflow from the canal when a pump is shut down."[3]

The Water Stops Here

To address the siphon issue, Reclamation engineers considered installing a valve to seal off the end of the discharge line. For the Grand Coulee facility, though, they preferred another alternative: using a solenoid-operated air valve to introduce air into the pipe to break the vacuum. The valve was activated automatically by a float switch; the circuit closed when the level of water rose past the float ball, and it opened again when the water dropped. A siphon elbow incorporating the air valve would be fitted to the upper end of each discharge line. The other end of the elbow would empty into the Feeder Canal, where its outlet would remain submerged. "The elbow," a Reclamation report explained, "is designed similar to a draft tube, which accomplishes the twofold result of recovering velocity head and releasing the water with a low velocity into the canal."[4]

Reclamation's Hydraulic Machinery Laboratory conducted model tests related to the design of the siphon elbow from 1939 to 1941. A 1940 drawing based on the model showed the crest at elevation 1588', slightly higher than the ultimate design, with a correspondingly higher

[3] C. B. Brown and E. M. Tomsic, "Pumping-Generating Units for the Grand Coulee Pumping-Generating Plant," *IEEE Transactions on Power Apparatus and Systems* 92 (May 1973): 1059.

[4] F. Tessitor and D. J. Hebert, comps., "Hydraulic Model Study of a Siphon Elbow Proposed for the Grand Coulee Pumping Plant Discharge Line, Columbia Basin Project," Bureau of Reclamation, Hydraulic Laboratory Report No. 163, Denver, March 1, 1945, 1-2, at Record Group (RG) 115, Records of the Bureau of Reclamation, Engineering and Research Center, Project Reports, 1910-55, 8NN-115-85-019, Box 329, National Archives and Records Administration-Rocky Mountain Region, Denver (hereafter cited as NARA-RMR); Bureau of Reclamation, "Siphon Breaker House, Pump Discharge Outlet, Siphon Breaker Operating Diagram," Drawing 222-D-15719, May 15, 1951, revised November 2, 1973; Bureau of Reclamation, "Grand Coulee Pumping Plant," July 25, 1940, 2, at RG 115, Engineering and Research Center, Project Reports, 1910-55, 8NN-115-019, Box 329, NARA-RMR.

maximum water elevation of 1585' in the Feeder Canal.[5] (See ILLUSTRATION 1: Model study for pumping plant, pump intake, elbow and siphon discharge.)[6]

Although the summary report containing this drawing was released in 1940, the main report of the laboratory's findings was not issued until 1945. "Urgency of other work prevented an earlier compilation of the report," the foreword explained. The delay was also caused because Reclamation was considering outfitting the Pumping Plant with pump-generator units. In this case, flow reversal would be desirable. Water would be pumped from the plant to the canal during the irrigation season in the late spring and summer, when power use was relatively low, and redirected from the canal to generators in the plant during periods of peak power demand, typically in the winter. This would require controlling the flow in the discharge pumps in two directions rather than one. Before the laboratory's final report was issued, this concept had been dropped, but it was later to return.[7]

Even for the single direction, the laboratory's results were not completely reliable. The lower end of the discharge line and pump—important components of the system—could not be included in the 1:24-scale model. In addition, the model represented only a generalized condition rather than a reproduction of specific features for individual discharge lines; while all were 12' in diameter, the length and alignment of each were unique. Despite these limitations, the tests did lead to some useful conclusions. Among other things, engineers found that the design of the elbow worked efficiently for the reverse flow, but not the normal flow. The good news, though, was that the air valve appeared to be a reliable option, with various designs functioning with equal effectiveness.[8]

After this report was issued, Reclamation conducted more tests at its hydraulic laboratory in Denver. A report of findings was dated March 1949. The tests considered the characteristics of

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[5] F. Tessitor and D. J. Hebert, comps., "Hydraulic Model Study of a Siphon Elbow Proposed for the Grand Coulee Pumping Plant Discharge Line, Columbia Basin Project," Bureau of Reclamation, Hydraulic Laboratory Report No. 163, Denver, March 1, 1945, foreword, and Grand Coulee Pumping Plant, Pump Intake, Elbow and Siphon Discharge Model Study, Drawing 222-D-6909, June 28, 1940, appended to Bureau of Reclamation, "Grand Coulee Pumping Plant," all at RG 115, Records of the Bureau of Reclamation, Engineering and Research Center, Project Reports, 1910-55, 8NN-115-85-019, Box 329, NARA-RMR; C. B. Brown and E. M. Tomsic, "Pumping-Generating Units for the Grand Coulee Pumping-Generating Plant," *IEEE Transactions on Power Apparatus an Systems* 92 (May 1973): 1059.

[6] "Grand Coulee Pumping Plant, Pump Intake, Elbow and Siphon Discharge Model Study," Drawing 222-D-6909, June 28, 1940, appended to Bureau of Reclamation, "Grand Coulee Pumping Plant," at RG 115, Records of the Bureau of Reclamation, Engineering and Research Center, Project Reports, 1910-55, 8NN-115-85-019, Box 329, NARA-RMR.

[7] F. Tessitor and D. J. Hebert, comps., "Hydraulic Model Study of a Siphon Elbow Proposed for the Grand Coulee Pumping Plant Discharge Line, Columbia Basin Project," Bureau of Reclamation, Hydraulic Laboratory Report No. 163, Denver, March 1, 1945, 2, at RG 115, Records of the Bureau of Reclamation, Engineering and Research Center, Project Reports, 1910-55, 8NN-115-85-019, Box 329, NARA-RMR.

[8] F. Tessitor and D. J. Hebert, comps., "Hydraulic Model Study of a Siphon Elbow Proposed for the Grand Coulee Pumping Plant Discharge Line, Columbia Basin Project," Bureau of Reclamation, Hydraulic Laboratory Report No. 163, Denver, March 1, 1945, 2-3, at RG 115, Records of the Bureau of Reclamation, Engineering and Research Center, Project Reports, 1910-55, 8NN-115-85-019, Box 329, NARA-RMR.

the flow beyond the Siphon-Breaker Building: "The proposed straight 140-foot-long transition connecting the pump outlet structure to the feeder canal was too short to give smooth flow," the study concluded. Instead, a curved, 193'-long transition with a circular siphon outlet "was the simplest to construct and had the lowest overall loss for a wider operating range than either the branching siphon or the floating radial gate." The study also developed a different design for the circular outlet of the siphon to reduce the number of pumps needed to prime the siphons from six to two.[9]

In the end, 30" siphon breakers, shaped like broad, inverted "V"s, were installed at the terminus of the discharge lines. The crest of the siphons was at elevation 1570±. They discharged below the surface of the water in the Feeder Canal, which ranged in elevation from 1557 to 1571.[10]

The Pumping Plant's Turn

The first step toward installing the Pumping Plant discharge pipes was taken in 1938 when Reclamation awarded a contract for excavating the plant's foundation to Consolidated Builders. The contract included removing rock from the back wall for the twelve pump discharge tunnels. The first 36' of the tunnels were 21' in diameter; they were 17' thereafter. As the 1938 project history explained, "From the portal the tunnels were excavated horizontally for distances of 61 to 141 feet, then through a vertical curve of 60' radius upward to intersect the surface on the left abutment at elevations ranging from elevation 1480 at tunnel No. 1 to elevation 1535 at tunnel No. 12." The excavation was finished in April 1939.[11]

World War II intervened, bringing most progress to a halt. A sign of renewed activity came in July 1945 when Reclamation began excavating an access road to the planned site of the Siphon-Breaker Building. The road curved up the bluff from just west of the Assembly Building in the Industrial Area (see photograph HAER No. WA-139-49).[12]

Another hiatus then ensued until the fall of 1948 when Reclamation selected a contractor to complete the Pumping Plant, excavate the Feeder Canal, install the pump discharge pipes, erect the Siphon-Breaker Building, and other items. The $13.8 million contract went to a joint venture of the Morrison-Knudsen Company and Peter Kiewit Sons' Company, which had received a $2.8 million contract earlier in the year for work on the Right Powerplant and Right Switchyard. The schedule for the Pumping Plant was accelerated in the following year as the United States sought to increase food production, a goal that would be furthered by irrigating land in the Grand Coulee Project. Reclamation also had another motive in rushing to get the plant in operation: it

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[9] Bureau of Reclamation, "Hydraulic Model Studies of the Siphon and Feeder-Canal Transition for Grand Coulee Pumping Plan—Columbia Basin Project," Hydraulic Laboratory Report No. Hyd. 224, March 11, 1949, 1-2, at RG 115, Engineering and Research Center, Project Reports 1910-55, 8NN-115-85-014, Box 327, NARA-RMR.
[10] C. B. Brown and E. M. Tomsic, "Pumping-Generating Units for the Grand Coulee Pumping-Generating Plant," *IEEE Transactions on Power Apparatus and Systems* 92 (May 1973): 1059.
[11] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 6, 1938, 193; Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 7, 1939, 36.
[12] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 13, 1945, 40.

was under increasing pressure to repay the federal treasury for project costs allocated to the irrigation component. The aim was to start filling the reservoir and testing irrigation canals early in 1951 so that water could be delivered to 80,000 acres in spring 1952, with another 60,000 acres added to the system annually through 1958.[13]

Subcontractor Consolidated Western Steel Corporation was responsible for installing the twelve discharge pipes, which were put in place in sections from the ends to the middle. "Installation began from the bottom of the tunnel up the steep incline to 'combined bend No. 2,' and from 'combined bend No. 3' downward to meet 'combined bend No. 2,'" the 1950 project history explained. "When the pipes were in place, concrete was pumped to fill the space between the pipes and the excavated rock in the tunnel section, and exposed pipes were encased in reinforced concrete." In the vicinity of the Siphon-Breaker Building, "reinforced concrete also formed substantial anchor blocks over the bends at the crest and was used for the pipes extending from the bend section to the outlet structure, which provided a transition from the cylindrical form of the pipes to the rectangular outlets into the trapezoidal-section feeder canal." The contractor started installing the pipes in March 1949, and Tube No. 1 was finished by the end of the year. By May 1950, all of the pipes were in place.[14]

Reclamation did not succeed in starting irrigation in 1951. Instead, that year saw the beginning of pumping to fill the reservoir. The final inspection of the pump and motor for Unit P-1 was completed on May 5, and the unit went into operation two days later. Pump P-2 followed on July 5. Both of the 65,000-horsepower pumps continued in service until the pumping season ended September 20. Because the water level in Lake Roosevelt was high enough in October, the pumps were put to work again for most of the month. Together, they pumped 671,000 acre-feet of water into the reservoir during their inaugural year.[15]

The flow of water during the season revealed a flaw in the floor slab between the headwall and entrance of the Feeder Canal. Damage to the slab required its removal and replacement. This work was started in mid-February 1952 and rushed to completion by mid-April, before the start of the pumping season in May. Contractor Cerf Brothers of Ephrata, Washington, accomplished the job.[16]

The push to get the system back in service paid off. In 1952, pumping capacity exceeded irrigation needs for the first time. The plant met the minimum pumping requirements for the year on August 25. The plant's output was boosted on July 25 when the first two units were joined by

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[13] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 16, 1948, 39-41; Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 17, 1949, 56-57, 65.
[14] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 17, 1949, 213, 219, 220, 278; Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 18, 1950, 111-112, 152-153.
[15] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 18, 1950, 44; Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 19, 1951, 2, 16, 18.
[16] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 20, 1952, 36.

Pump P-4. In the same month, work began on the installation of Units P-5 and P-6. They, along with Pump P-3, began operation in May of the following year.[17]

A construction-related accident almost delayed the startup of P-5. In December 1952, "scaffolding and canvas wind breakers, ignited by spars from a welder's torch set fire to the coal-tar enamel paint in the discharge pipe," the project history reported. "Traveling quickly up the pipe the fire escaped through the siphon breaker and, fed by the stack-like draft, burned off the enamel, warped the pipe in places and cracked an anchor block." Reclamation held the contractor responsible for making necessary repairs to the P-5 pipe, which were apparently completed by the following spring.[18]

More trials were to come. On July 25, 1953, another section of the Feeder Canal floor slab failed, apparently because of unstable foundation rock. The pumping season was abruptly terminated. By November, Reclamation had a contractor starting repairs. Harsh weather slowed progress during the winter months, but by April the contractor was running two to three shifts a day, six or seven days a week, to complete the repairs before the beginning of the pumping season. On May 21, with the work almost finished, Reclamation was able to start up the pumps, and the Siphon-Breaker Building was back in business.[19]

Operations ran smoothly for the next decade. In 1964, for example, when the irrigation season started in late April, only three pumps were needed to maintain the level of Banks Lake. All six pumps ran from May 1 to July 23. For the next couple of months, "pumping continued periodically to meet irrigation demands." All in all, the pumps handled around 2.1-million acre-feet of water during the year.[20]

By this time, though, the ability of the six pumps to supply future needs was being questioned. Reclamation engineers began exploring the feasibility of installing more pumps in the plant, which was designed to hold twelve units, and the possibility of installing a different type of unit. They issued a report in August 1963 entitled "Justification of Accelerated Construction of Pumping Units P-7 and P-8." The report noted that "consideration has been given to construction of the remaining 6 pumping units as reversible pump-turbine units which could be used to help meet peaking power requirements when such peaking capability is required in the relatively near future." A "Plan of Development" issued in September 1964 asserted: "Irrigation will require

[17] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 20, 1952, 31, 63; Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 21, 1953, 50, 61.
[18] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 20, 1952, 39; Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 21, 1953, 60.
[19] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 21, 1953, 50, 58; Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 22, 1954, monthly summary for January, 1, monthly summary for March, 2, and monthly summary for May, 1.
[20] Bureau of Reclamation, Annual Project History, Columbia Basin Project, Vol. 32, 1964, 47.

pumps 7 and 8 by 1973. Power demands in the Pacific Northwest will justify the installation of units P7 and P8 as pump-turbine units." [21]

The issue became more urgent in the late 1960s as more land was irrigated and the six pumps at Grand Coulee strained to supply sufficient water. At the same time, Banks Lake was becoming a popular recreational destination, so wide fluctuations in the level of its surface were less acceptable. By the early 1970s, Reclamation began actively pursuing plans to add more units, and the rising demand for electricity convinced engineers to advocate for pump-generating units. Even though these units were about 35 percent more expensive than standard pumping units, the higher price was easily offset by the value of their electrical production. Reclamation engineers asserted "that these units would be among the most economical sources of peaking power available in the area."[22]

The pumping-generating facilities, the engineers explained, "are designed to utilize the top 2 feet (60 cm) of Banks Lake for pumping-generating use"—although the water level would typically fluctuate less than 1'. "The units would be operated for peaking power for about 3 hours per day with the water pumped back offpeak every night. However, in case more peaking operation is required, it is estimated that with the initial two units in operation, 100,000 kilowatt (kW) could be delivered 9 hours per day for 5 days per week, refilling during the weekend."[23]

Advocates of the pump-generating units were victorious. In January 1972, the Scott-Buttner Corporation started modifying the pumping plant and related structures for two pump-generating units, P/G7 and P/G8. The units were substantially completed by November 1973, with the remaining details finished by the following January. The contractor's scope included "installation of pump-turbines, reverse-flow wheel-mounted gates, and appurtenant equipment" and "electrical installations and modifications of outlets to existing discharge lines" to accommodate the new units. In August, the project history reported, "the power and control circuits between the siphon breaker building and the pumping plant were installed." Also during the summer, stiffener rings were attached to the discharge tubes. In the fall, the Westinghouse Electric Corporation began delivering components for the 50,000 kW units to Grand Coulee. [24]

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[21] Bureau of Reclamation, "Justification for Accelerated Construction of Pumping Units P-7 and P-9, Grand Coulee Pumping Plant, Columbia Basin, Washington," typescript, August 1963, 1, at Bureau of Reclamation-Boise, third floor; "Plan of Development," September 1964, 2, at Bureau of Reclamation-Boise, third floor.
[22] C. B. Brown and E. M. Tomsic, "Pumping-Generating Units for the Grand Coulee Pumping-Generating Plant," *IEEE Transactions on Power Apparatus and Systems* 92 (May 1973): 1057, 1060.
[23] C. B. Brown and E. M. Tomsic, "Pumping-Generating Units for the Grand Coulee Pumping-Generating Plant," *IEEE Transactions on Power Apparatus and Systems* 92 (May 1973): 1057.
[24] Bureau of Reclamation, Annual Project History, Grand Coulee Third Powerplant-Columbia Basin Project, Vol. 6, 1972, 118, 146-148; C. B. Brown and E. M. Tomsic, "Pumping-Generating Units for the Grand Coulee Pumping-Generating Plant," *IEEE Transactions on Power Apparatus and Systems* 92 (May 1973): 1057; Bureau of Reclamation, Annual Project History, Grand Coulee Dam Third Powerplant-Columbia Basin Project, Vol. 7, 1973, 80; Bureau of Reclamation, Annual Project History, Grand Coulee Dam Third Powerplant-Columbia Basin Project, Vol. 8, 1974, 65.

The introduction of pump-generator units required modifications to the Siphon-Breaker Building, which had not been used during the winter because the pumps had operated only during the growing season. The building received its first heating system, and drain lines were moved below the frost line.[25]

"The transition from the penstocks to the canal is the only part of the existing water conveyance system to be modified to permit operation of the units as turbines," a Reclamation engineer noted. "Based on model studies, the ceiling of the closed transition is being lowered from elevation 1555± to elevation 1550±, and a deflection vane is being placed in the open transition. These are to prevent drawing air from the canal into the penstock during generator operation." [26]

After the pump-generating units were in service, Reclamation continued making changes to improve their performance. In the Siphon-Breaker Building, on-off toggle switches were installed in 1975: "In the 'ON' position, these switches bypass their respective siphon-breaker float switches and vacuum switches, close the siphon breakers and open the valve to the vacuum header to water up the discharge tubes for a generate mode start. This avoided using the P/G rapid reversal sequence."[27]

By 1976, Reclamation had received authorization to proceed with the final four pump-generator units. It awarded a $6.8 million contract for furnishing and installing the units to Mitsui and Company (USA), a contractor based in San Francisco. The generator/motors were provided by Hitachi America under a separate contract. Labor disputes and other problems delayed the schedule. It was not until April 1978, that Reclamation hired Venture Construction of Auburn, Washington, to remove some materials in the Pump-Generating Plant to make room for the new units and to place second-stage concrete for the units.[28]

The outlets for the discharge lines for Units P/G9 through P/G12, all dating from when the first pumping units were installed, were modified to meet the revised specifications for the pump-generating units. Reclamation hired the Martin K. Eby Construction Company of Wichita, Kansas, to complete this work as well as to alter the Feeder Canal to accommodate the increased volume of water. "The headworks transition block," the project history reported, "had settled and had to be replaced." Just beyond the headworks, about 6,100' of the canal's 50'-wide base was enlarged to 80'. The next section was replaced by a 2,700'-long flume with a bottom width of 90'.

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[25] Bureau of Reclamation, Annual Project History, Grand Coulee Dam Operations Office-Columbia Basin Project, Vol. 4, 1973, 9.
[26] C. B. Brown and E. M. Tomsic, "Pumping-Generating Units for the Grand Coulee Pumping-Generating Plant," *IEEE Transactions on Power Apparatus and Systems* 92 (May 1973): 1059.
[27] Bureau of Reclamation, Annual Project History, Grand Coulee Project Office-Columbia Basin Project, Vol. 1, 1975, 33.
[28] Bureau of Reclamation, Annual Project History, Grand Coulee Third Powerplant-Columbia Basin Project, Vol. 4, 1978, 49; Bureau of Reclamation, Annual Project History, Grand Coulee Third Powerplant-Columbia Basin Project, Vol. 6, 1980, 26-27, 44-46, 48.

The contractor started the project towards the end of 1977 and was virtually finished by December 1980. The cost totaled about $30 million.[29]

The Harder Mechanical Contractors received the contract to furnish and install a heating system for the siphon breakers in April 1980. The contractor was also responsible for a number of other items related to the activation of the new pump-generating units, including installing stiffener rings on the four discharge pipes. The work was scheduled to be finished in 1982.[30]

[29] Bureau of Reclamation, Annual Project History, Grand Coulee Third Powerplant-Columbia Basin Project, Vol. 6, 1980, 22-25.
[30] Bureau of Reclamation, Annual Project History, Grand Coulee Third Powerplant-Columbia Basin Project, Vol. 6, 1980, 32-34.

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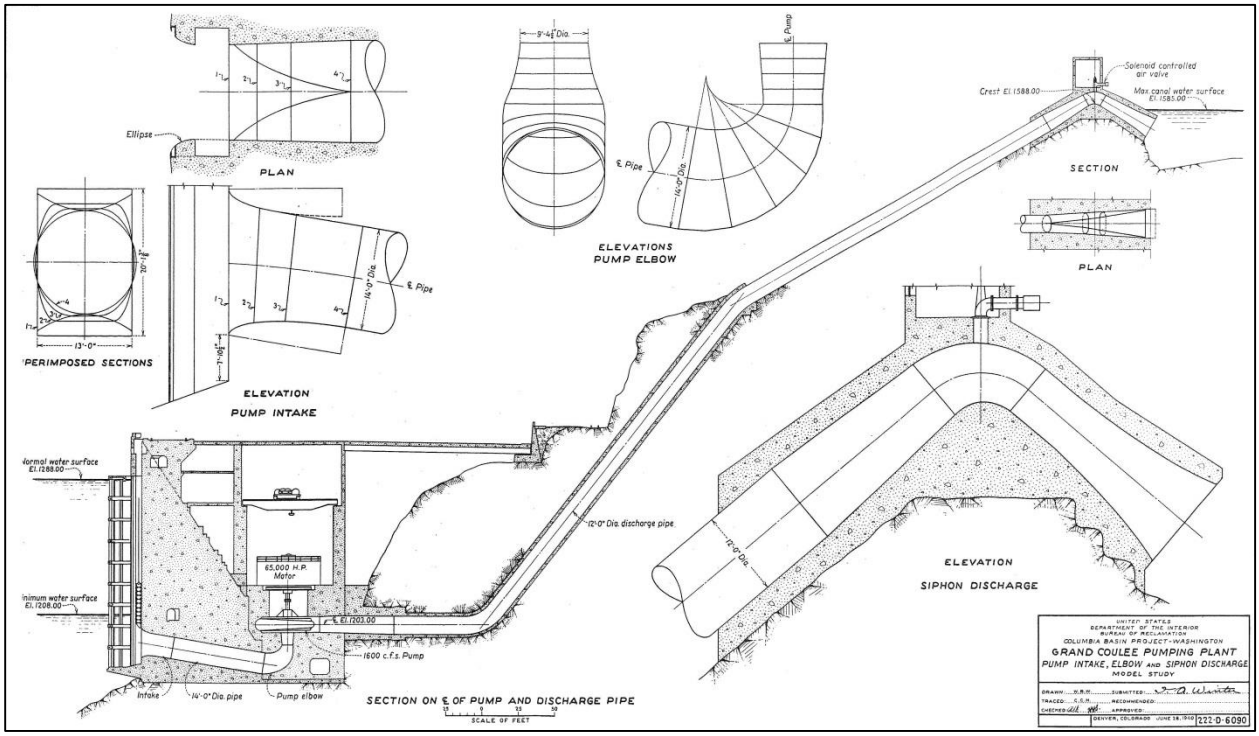

ILLUSTRATION 1: Model study for pumping plant, pump intake, elbow and siphon discharge.

("Grand Coulee Pumping Plant, Pump Intake, Elbow and Siphon Discharge Model Study," Drawing 222-D-6909, June 28, 1940, appended to Bureau of Reclamation, "Grand Coulee Pumping Plant," at RG 115, Records of the Bureau of Reclamation, Engineering and Research Center, Project Reports, 1910-55, 8NN-115-85-019, Box 329, NARA-RMR.)