Electron Hydroelectric Project (Puyallup Project)
Along 10 miles of the Puyallup River
Electron
Pierce County
Washington

HAER No. WA-12

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

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Historic American Engineering Record
Western Region
National Park Service
Department of the Interior
San Francisco, California 94102

HISTORIC AMERICA ENGINEERING RECORD

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(Puyallup Project)

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Location: Approximately 23 miles southeast of Tacoma, Washington. It is situated along a 10-mile stretch of the Puyallup River, which has its source in the glaciers of nearby Mount Rainier. A low timber crib diversion dam and intake are located in the Northwest 1/4, Section 3, T16N, R6E, W.M., at an elevation of approximately 1,600 feet amsl. The flume extends 10.1 miles from the intake in a northwesterly direction, along a steep valley wall on the south side of the river, to the forebay in the Southeast 1/4, Section 4, T17N, R5E, W.M. The elevation of the forebay pond is approximately 1,538 amsl. The Electron flume appears on the USGS's Kapowsin, Washington, quadrangle.

Date of Construction: 1903-1904. The flume was built during 1903 and was first put into commercial operation on April 14, 1904.

Engineer: Samuel L. Shuffleton of the Stone and Webster Engineering Corporation of Boston supervised the surveying, engineering and construction of the project.

Present Owner: Puget Sound Power & Light Company
P. O. Box 97034
Bellevue, Washington 98009-9734

Present Use: Hydroelectric power generation

Significance: The Electron Project, originally known as the Puyallup Project, is characteristic of the turn-of-the-century Pacific Coast hydroelectric development in having a high head/low volume plant, impulse waterwheels, a long water-gathering network, and relatively long distance power transmission. The project is also a transition between a run-of-the-river project and a storage project. The wood flume at the Electron Project is likely the largest flume used in hydroelectric development in the country.

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HISTORICAL NARRATIVE

Introduction

The Electron Hydroelectric Project is noteworthy in being one of the first projects in the Northwest to use the considerably high head of 872 feet. The project uses Pelton waterwheels which, at the time of their installation, were reported to be the largest of their kind.[1] The General Electric generators installed at the project were reported to be second in size in the United States only to those installed at Niagara Falls.[2] As a water-gathering network, Electron utilizes an approximately 10-mile-long wooden flume built on trestle work which carries water from the point of diversion to the reservoir. This is likely the largest flume used in hydroelectric development in the country. Smaller flumes carry additional water from small tributaries into the main flume. A standard gauge railroad track is laid along the top of the main flume and is used by hand cars and motor-operated vehicles for inspection and maintenance of the flume. Two transmission lines were installed to convey electrical energy from the project to Seattle, 48 miles away, and to Tacoma, a distance of 32 miles.[3] The project is an example of he state-of-the-art in turn-of-the-century Pacific Coast hydroelectric development. It now operates essentially the same as when it was originally constructed (see sketch of Electron Project, page 26 and HAER drawing 1 of 6).

The project is also a transition between a run-of-the-river project and a storage project. A small reservoir, which has a storage capacity of 120 acre-feet, is situated on the plateau above the powerhouse. The reservoir was constructed with discharge elevations arranged to allow for about 2 hours of normal power generation, thus permitting the continued use of the powerhouse in the event of a temporary interruption of water supply. The reservoir is also useful in providing maximum flows to the powerhouse at times when the flow in the flume is low due to low river flows or icing.[4] This feature is particularly useful for accommodating short-term fluctuation in load, regardless of river conditions, and represents a first step toward the large storage projects of later years.

Background of Development

The first stage of hydroelectric development in the Northwest occurred during the 1880s and 1890s, when a multitude of small steam electric plants were constructed. Owned and operated by small private companies, these plants were normally inefficient and costly, serving only a small circle of customers.[5] During the first decade of the twentieth century in western Washington, population growth and a corresponding increase in the demand for electrical power led to a second stage of development. This was characterized by the consolidation of the many small electric companies and the establishment of electric service on a regional basis.[6]

The second stage of development saw a shift from the construction of small urban steam plants to relatively large hydroelectric projects located away from city centers. This change was motivated by a need for more cost-effective and reliable generating facilities. Improved technology in the construction and operation of hydroelectric systems, along with the ability to transmit electric power over greater distances, made feasible the development of mountain streams with hydroelectrical potential.

Technological Innovations

A number of technological innovations emerged in the late 1800s which made possible the development of low volume/high head Pacific Coast hydroelectric projects like the Electron Project. These innovations included the development of alternating current, the transformer, the Pelton waterwheel, and the use of long water-gathering networks.

In 1903, the electric power industry was still in its infancy. Thomas A. Edison had invented the first commercially practical incandescent lamp on October 21, 1879. On September 4, 1882, the first central station to furnish current for the Edison-type lamp was put into operation at Pearl Street in New York City. Early electric stations utilized direct current which was not cost effective when transmitted over long distances. Transformers, introduced in the mid-1880s, were used to step up the voltage before it was transmitted and then step it down again prior to distribution.[7]

A number of innovations grew out of the California mining industry which were essential to hydroelectric developments like the Electron Project. The mining industry of California emerged following the discovery of gold in the mid-1800s. The mining industry utilized large volumes of water for cleaning debris from the desired minerals or for the use of waterwheels. As miners were not always located close to a convenient source of water, water-gathering and storage systems were developed to bring water to the mine. By the 1880s, there were reported to be over 8,000 miles of artificial watercourses in the State. Many of these were later utilized in the hydraulic systems of hydroelectric plants.[8]

In the late 1800s, water conveyance systems were also utilized in the Pacific Northwest. Early system in Washington were primarily used for irrigation. Later, these systems combined ditches with wood flume structures and were often used in conjunction with hydroelectric generation. Early systems which utilized wood flume structures include the Yakima Valley Canal, the Lewiston-Clarkston Company system, and the Olympia Light and Power Company flume at the Deschutes River.

The first, and one of the most important irrigation canals to be developed in the Yakima Valley, was the Yakima Valley Canal, constructed in 1894-1895 by the Chicago-Duluth mining magnate Chester A. Congdon. This was a 15-mile-long wood flume which diverted water from the Naches River and conveyed it to land south of the river. The flume consisted of a wooden trapezoidal flume box supported by a trestle situated along the rock wall above Cowiche Canyon. In 1903, the flume was substantially enlarged and its capacity was increased to approximately 80 cubic feet per second.[9]

In 1896, a group of Boston investors, headed by Charles Francis Adams, formed the Lewiston Water and Power Company to irrigate land in northeastern Asotin County, Washington. The proposed project included a 15-mile-long canal for the irrigation of 3,000 acres. In the center of the land to be irrigated, a new town named Clarkston was formed. The irrigation project was also to provide water and electricity. Work on the project began in the summer of 1896. Completed during that year were a diversion dam and headworks on Asotin Creek, and the canal, which consisted of open earth ditches and a timber flume mounted on trestles. In selecting the particular designed used in constructing the canal, the company gave up its ability to generate electricity as sufficient head was not developed.[10]

In 1905, a wood flume was used in conjunction with a hydroelectric project on the Deschutes River in Washington. This project was built by the Olympia Light and Power Company. The flume diverted water from an upper falls over a 90-foot drop to a lower falls, where the powerhouse was constructed in 1905.[11]

In addition to its role in the early development of West Coast canal systems, the California mining industry was also responsible for the development of the tangential impulse waterwheel.[12] In the late 19th century, California mines relied on water power as its primary source of energy. Traditionally, the form of waterwheels included the wooden overshot and undershot situations. For high head applications, vertical waterwheels were developed with triangular wooden blocks arranged around the circumference of the wheel. These blocks were enclosed on the sides with rims. Water in the form of a jet was directed against the face of those blocks. The water jet was created by passing water through a hole drilled in a wooden block at the end of a pipe or hose. This wheel was gradually modified and improved. Bronze or brass tapered nozzles replaced the wooden blocks first used to direct the jet of water. By the 1870s, millwrights began replacing the triangular wooden blocks of the wheel with cup-shaped buckets of iron. Water flowing in the cups discharged laterally, causing less interference to incoming water. Gradual experimentation led to the Pelton waterwheel. Around 1880, a California millwright named Lester Pelton developed a waterwheel that used a double bucket type of arrangement. The buckets arranged around the wheel were twin buckets shaped like a "W". These were provided with curved bottoms, inclined sides, and a raised center which was used to split the incoming jet of water. This allowed for less interference between incoming and outgoing water, thus doubling the efficiency of the wheel. The tangential impulse wheel was to become the characteristic water turbine used for the Pacific Coast high head hydroelectric developments.[13]

The Financial and Managerial Framework

The construction of large hydroelectric generating facilities required large amounts of capital, which at the turn of the century was not readily available in the State of Washington. Similar to other West Coast hydroelectric developers, local Northwest entrepreneurs looked to the East for financial backing. Accompanying East Coast financing came East Coast management and engineering expertise. In Washington State, as in other parts of the country, this was provided by the Stone and Webster managerial association.[14]

To understand how the development of the Electron Project came about, it is useful to briefly examine the role played by the Stone and Webster managerial association in the early growth of the utility industry in Washington. At the turn of the century, Stone and Webster was a rapidly-growing, Boston-based company with expertise in engineering, management and finance. The company was founded by Charles A. Stone and Edwin S. Webster, who met in 1884 while enrolling for one of the first electrical engineering courses offered by the Massachusetts Institute of Technology. A partnership was formed between Messrs. Stone and Webster in 1889, although it was not until 1893 that their company took the name of Stone and Webster.[15] The growth of this company paralleled the development of power and electric plants, telephone systems, traction lines, electrochemical works, and other electrical projects that came into existence with the commercial viability of electrical power transmission. Stone and Webster rapidly gained experience both in acquiring electric properties and in managing the electric properties of others. The companies that normally came under Stone and Webster's management were small and could not afford the range of skills and experience which Stone and Webster could provide.[16]

At the turn of the century, there existed in Seattle numerous street railway companies, electric light and power companies, and steam heating companies. Seattle businessmen brought this condition to the attention of eastern investors who formed a banking syndicate to acquire, manage and consolidate these electric properties. The syndicate hired a young firm of Stone and Webster to assess the situation and recommend changes. Mr. Stone visited Seattle in the fall of 1898, and the Stone and Webster firm was hired by the syndicate in 1899.[17] Under a plan devised by Stone and Webster, the Seattle Electric Company was organized on January 19, 1900, for the purpose of taking over properties associated with electrical utilities. Agents of the banking syndicate played a key role in the acquisition of the plants or securities o the many small electric companies, as they either purchased controlling interests in them or bought their property outright. An agreement was made between the syndicate and the Seattle Electric Company such that, as properties were acquired and put into good operating condition, they would be turned over to the company, which then issued its own securities in payment.[18] In this way, sixteen electric railway, light and power companies operating in Seattle were, by 1903, consolidated under Stone and Webster management. Although Stone and Webster served as general manager of the

Seattle Electric Company, they never actually owned more than a small percentage of the company.[19] This small percentage was sufficient to control the many companies under the Seattle Electric Company umbrella. Such an arrangement was typical of the early holding company system. As Stone and Webster expanded its influence in the State of Washington, it organized companies in other cities along the lines of the Seattle Electric Company.

To provide electrical energy to the local companies under its management, Stone and Webster decided to construct a hydroelectric plant on the Puyallup River. The Puget Sound Power Company was formed by Stone and Webster to construct and operate the Electron Project. To raise the substantial amount of new capital required to construct the project, the Puget Sound Power Company issued $4,000,000 worth of bonds and $3,000,000 worth of stock. The bonds were guaranteed as to principal, interest and sinking fund by the Seattle Electric Company.[20]

In 1912, Stone and Webster merged the Puget Sound Power Company with the Seattle Electric Company and numerous other companies organized, managed or acquired by Stone and Webster to form the Puget Sound Traction, Light and Power Company. This electric company, which later changed its name to the Puget Sound Power & Light Company, was and still is the largest privately-owned utility in the State of Washington. Other companies included in the 1912 merger were the Whatcom County Railway and Light Company, the Seattle-Tacoma Power Company and the Pacific Coast Power Company. As a result of this reorganization, the three major hydroelectric projects of western Washington, the Snoqualmie Falls, Electron and White River projects came under the management of one company which could then operate them as a single generating system.

Project Construction

Actual construction of the Electron Project was carried out by the Columbia Improvement Company. Stone and Webster formed this company to systematize reports from men in the field and to standardize methods of construction. In effect, the Columbia Improvement Company served as the construction department of Stone and Webster.and, thus, was the precursor of the Stone and Webster Engineering Corporation.[21] S. Z. Mitchell, who built the first electric plant in Seattle in 1885, managed the company.[22] Initial surveys and studies for the Electron Project were made in 1901 by Samuel L. Shuffleton. A renowned civil engineer, Shuffleton managed all of Stone and Webster's operations west of the Mississippi. Shuffleton was born and raised in Shasta County, California, and educated as a civil engineer. He joined Stone and Webster in 1890 upon his arrival in Seattle and was later made manager of all of Stone and Webster's operations west of the Mississippi.[23] Construction for Electron began in March 1903.[24] The first generator unit of 5,000 hp was put into commercial operation, delivering power to Seattle and Tacoma on April 14, 1904, less than 14 months after work commenced.[25] By September 1904, three additional units were put into operation.

During construction, hundreds of men were housed in camps along the flume. Teams of horses hauled wagonloads of supplies up a tote road leading to the headworks. Much of the lumber used in constructing the project was cut on the spot. One sawmill was located at Camp 6 near the reservoir, and another two miles below the headworks. The Tacoma Eastern and the Northern Pacific railroads passed within three miles of the powerhouse site, and a branch railroad named Pierce County Improvement Company was built to haul in materials and machinery. Materials for the construction of the reservoir and flume were hoisted up by means of a standard gauge cable incline, lifting an elevation of 950 feet from the railhead to the reservoir[26] (see construction photographs, HAER No. WA-12-58 to WA-12-89).

PROJECT DESCRIPTION

The plant was designed to operate on the differential in head between the forebay pond elevation and the elevation of the turbines located in the powerhouse. According to plans, water is diverted from the Puyallup River about 0.6 mile below its confluence with the Mowich River and carried a distance of 10.1 miles by means of a wooden flume to the forebay. Additional water is utilized by means of smaller flumes that divert water into the main flume from a number of creeks which once included Neisson and Kellogg creeks (see HAER drawing 3 of 6). From the forebay, located on a high plateau overlooking the powerhouse, plans called for the discharge of water by means of woodstave and steel penstocks into Pelton waterwheels housed in the powerhouse below. The turbines were designed to operate under a head of 872 feet and a total flow of 400 cubic feet per second. Total plant capability is 26.4 megawatts (see HAER Photographs No. WA-12-68, WA-12-74, WA-12-80, WA-12-82 and WA-12-89).

The diversion dam and intake, which serve to divert and control the river flow into the flume, were located at the upper end of the flume at approximately the 1,600-foot elevation.[27] The dam was originally constructed as a low timber crib dam, 200 feet long and 5 feet high, covering the bed of the river longitudinally for a distance of 60 feet, exclusive of the downstream apron[28] (see HAER Photographs No. WA-12-1, WA-12-63, WA-12-64, WA-12-72, WA-12-76, and WA-12-88).

Built upon an impervious bottom of clay, the dam was made watertight by the installation of three rows of triple lap sheet piling set into the hardpan bottom and embedded in concrete. The dam was faced with 6x12" timber and covered at the crest with 1/4-inch boiler plates. In addition to the 30-foot-wide spillway which confined scour at the intake end, the whole dam was designed to operate as a spillway. The intake was set at right angles to the dam and constructed of concrete masonry. This was built 62 feet wide at the river bank and was protected by a screen grating made of iron. A steel frame was erected across the intake for the insertion of needle boards, used to regulate or shut off entirely the flow of water through the intake. A radial gate was also installed at the junction of the masonry intake and the flume for the purpose of quickly controlling the amount of water delivered to the flume[29] (see HAER Photograph No. WA-12-81).

At its lower end, the flume terminated in a reservoir which was situated on the plateau overlooking the powerhouse and the Puyallup River. The reservoir was constructed by removing material from the higher side of the site and using it to form an embankment on the lower side of the reservoir. This was accomplished by first building a trestle and piling material over it. The trestle was gradually buried until an embankment was formed (see HAER Photograph No. WA-12-69). The material was from a glacial boulder formation of clay-like consistency which required blasting before it could be handled with a steam shovel. The material puddled well and formed a watertight fill which set hard, almost like concrete.

The reservoir covered an area of 12-1/2 acres and, at the time of construction, had a capacity of 6,000,000 cubic feet. To remove glacial silt carried through the flume, an 8-foot sand pump having a maximum capacity of 30 cubic yards of solid matter per hour, was mount on a scow. The pump was driven by a 40 hp induction motor and pipe mounted on pontoons which carried the discharge over the reservoir bank. A settling basin was eventually built about halfway between the headworks and reservoir. This was put into operation in 1941 (see HAER drawings no. 4 of 6 and 5 of 6). Before the settling basin was built, it was necessary to have three shifts a day running the pump to keep the reservoir from filling with silt. Now, only one shift is used to run a 125 hp motor-operated pump.[30]

The flume entered one end of the reservoir and originally continued to a point where it discharged into a concrete basin located in front of the forebay (see HAER Photograph No. WA-12-78). This allowed the reservoir to be emptied for inspection or cleaning without interrupting the delivery of water to the powerhouse. The flume now terminates at the edge of the reservoir and empties directly into it.

The forebay structure, divided into eight separate gate chambers leading to the main penstocks, was constructed of concrete. Iron racks or screens with stop boards were installed at each gate to permit inspection or repairs of the forebay structure.[31] Although the forebay was originally built to house eight main penstocks, only four were ever installed (see HAER Photographs No. WA-12-67, WA-12-69 and WA-12-78).

The upper portions of the four main penstocks, originally constructed of woodstave pipe covered with concrete, were carried through the reservoir embankment from the forebay (see HAER Photograph No. WA-12-68). The four woodstave pipes joined four steel penstocks approximately 345 feet below the embankment where surge pipes were also provided. In 1984, the woodstave portions of the pipes were replaced with steel. In addition to the lower portions of the main penstocks, a similar but smaller penstock, used to supply water for two exciters, was also made of steel. The penstocks were furnished by the Risdon Iron and Locomotive Works. These five penstocks were each approximately 1,700 feet in length and followed the incline at an average of 30 degrees from the top of the plateau to the powerhouse located on the riverbank below (see HAER

Photograph No. WA-12-89). The larger penstocks were built of steel 1/4-inch thick at the top and 3/4-inch thick at the lower end; the diameter of the pipes tapering from 4 feet at the top to 3 feet at the bottom. The smaller penstock for the exciters had an 18-inch diameter. This smaller penstock was taken out of use in 1982 and, presently, static exciters are used. The penstocks were anchored by concrete abutments, designed to drain all surface water away from the pipes. After construction, the pipes were also protected with backfilling of earth, on which was planted quick-growing vegetation.[32]

The powerhouse, built into the bank of the river on a foundation of bedrock and piling is of concrete, brick and steel construction. It measures 90x150 feet and is divided into a generating, transformer and switching house. One end wall of the powerhouse was constructed of corrugated iron to allow for future expansion with the intention of doubling the capacity. This expansion never occurred, and the powerhouse remained with the original installation of four units (see HAER Photographs No. WA-12-73, WA-12-74, and WA-12-83). Each unit consisted of two overhung Pelton waterwheels (10 feet, 6 inches in diameter), mounted one on each end of the shaft of a 5,000 horsepower, two-bearing General Electric generator. The Pelton waterwheels, which were the primary turbines used in Pacific Coast development, were reported to be the largest of their kind at the time of their installation, while the General Electric generators were second in size in the United States only to those installed at Niagara Falls. The generating units were arranged parallel to and along the river side of the building; the penstocks being brought to the river side of the building; the penstocks being brought to them under the main floor from the rear (see HAER Photographs No. WA-12-73, WA-12-74, WA-12-83 and WA-12-84). The transformers were grouped in isolated rooms of concrete in the basement of the switch house; the switching apparatus and wiring being in compartments overhead.

The Electron Project utilized long distance power transmission, a characteristic unique to Pacific Coast hydroelectric development at the turn of the century. Two parallel transmission lines originally ran a distance of 22 miles from the powerhouse to Bluffs, a station on the line of the Puget Sound Electric Railway, located approximately 9 miles northeast of Tacoma and 25 miles southeast of Seattle. From Bluffs, one line ran to Seattle, for the most part, parallel to the transmission line of the Puget Sound Electric Railway. The other line, which extended to Tacoma, also paralleled that of the Puget Sound Electric Railway[33] (see HAER Photograph No. WA-12-62).

A private right-of-way secured from the powerhouse to Bluffs contained two pole lines, which ran 50 to 80 feet apart. The minimum length of poles used was 45 feet, with a minimum top diameter of 10-1/2 inches. The standard spacing was 125 feet on straight lines and 90 to 100 feet on curves. The main crossarms, measuring 5x7 inches by 7 feet, 4 inches, were made from fir. These were boiled in raw linseed oil, a common practice at the time, which gave the crossarms a longer life than untreated arms. At the top of the pole was a 5x7x18-inch arm.

The main arm supported two insulators and the top arm one insulator, giving a equilateral triangular spacing of 72 inches between wires.[34]

Presently, a single 115 kV transmission line leaves the Electron Project and ties into the Electron Heights substation located approximately one-half mile away. From this substation, two 115 kV lines head in a northerly direction to the White River transmission substation located approximately 16 miles to the north. These lines are called the White River-Electron Heights #1 and #2 lines. A 55 kV line leaves the Electron Heights substation in a northeasterly direction and passes through Buckley to the Krain Corner Substation near Enumclaw. This line is called the Electron Heights-Krain Corner 55 kV line. A 115 kV line also leaves the Electron Heights substation in a westerly direction and ties into the Blumaer substation located approximately 34 miles away in Tenino. This 115 kV line is called the Electron Heights-Blumaer 115 kV line.

FLUME CONSTRUCTION

The water-gathering network of the Electron Project utilized a 10.1-mile-long wooden flume, with additional smaller flumes feeding the main flume. The main flume, which conveys water from the dam to the reservoir, was first put into commercial operation on April 14, 1904. Built on a uniform grade of approximately seven feet to the mile, the flume consisted of a framed flume box built on trestle work. The supporting trestle work was of bents spaced 16 feet between centers. Additional bents were later added, making the spacing eight rather than 16 feet between centers. Typically, each bent consisted of rough sawn mudsills of fir resting on cedar mud blocks. The mudsills supported three timber posts, on top of which rested a bent cap. These components were fastened together with iron dowels, and sway bracing for lateral support was provided by diagonally positioned planks[36] (see HAER Drawing no. 6 of 6, and HAER Photographs no. WA-12-23, WA-12-24 and WA-12-71).

The description given above is of the standard bent. In many cases where the hillsides were steep, cripple bents, or bents in which each post had a separate foundation, were used; and where the height was over 40 feet, double deck bents were used[37] (see HAER Photographs No. WA-12-25, WA-12-59, WA-12-70, WA-12-75 and WA-12-87).

The bents were spanned with six 6-inch by 12-inch by 18 feet sawed stringers on edge, the ends of which lapped on each bent and which were fastened to the bent caps with 3/4-inch drift bolts. After additional bents were put in place, making the spacing eight rather than 16 feet between centers, some half-length, 9-foot stringers were used to replace some of the 18-foot stringers.[38]

The flume box consisted of 6-inch by 6-inch by 9-feet posts bolted at the bottom between two 4-inch by 8-inch by 14-feet sills and held together at the top by a cap which is notched to take the post. Braces extended from below the middle of the post down through the outer end of the sill, where they were fastened by two 3/8-inch by 8-inch square spikes driven through the sills on either side. These frames were originally spaced four feet between centers and lined on the inner sides with tongue and groove siding, the first five boards being 2-1/4-inch by 12-inch and the upper boards being 2-inch by 12 inch.[39] The box, originally constructed only five boards high to a height of 5 feet, was raised in 1905 to a height of 8 feet. The bottom of the box consisted of 2-inch by 12-inch boards, surfaced on one side laid rough side up, with 1-inch x 12-inch boards surfaced on one side laid rough side down with joints broken. To prevent leakage at the corners, a 3-inch by 3-inch strip with heavy tarred felt was placed along each corner and spiked in place.[40]

A train track of standard gauge was laid along the top of the flume for inspection and maintenance purposes. This was constructed of rails supplied by the Illinois Steel Company, Joliet Works, dated 1890. Hand cars were originally used along this track until gasoline-powered vehicles, called speeders, were introduced in 1910.[41] Maxwell engines with a reversing box were used in the original engine-driven speeders. Saxine speeders with friction drive were later used. Crews would normally be carried along the flume in engine-powered speeders and then used hand cars that were pushed or pulled manually at the work site. Most speeders were constructed in the shop at the forebay. Later, these were installed with 4-cylinder Ford or 6-cylinder Chevrolet engines. A specialized bent maintenance machine was constructed and used in the 1970s[42] (see HAER Photographs No. WA-12-50, WA-12-51, WA-12-52, WA-12-53, WA-12-54, WA-12-55, WA-12-56 and WA-12-57).

A standard gauge incline cable railway, built on a 68-percent grade, was constructed for hoisting materials and workers to the reservoir. The lower end was located near the powerhouse and the upper end near the reservoir. This was taken out of operation on June 22, 1971, after the cable car broke away from its line and smashed at the bottom of the hill, killing Clarence A. Bransteitter, who was one of 19 workers returning from work in the car at the time[43] (see HAER Photograph No. WA-12-58).

A series of spillways constructed at intervals along the flume facilitated the drainage of water from the flume box for shutdown or repair. The last spillway, located near the terminus of the flume at the reservoir, employed needle boards which could be used to control the amount of water engineering the reservoir (see HAER Drawing no. 2 of 6, and HAER Photographs No. WA-12-39 and WA-12-79).

Sixteen landings were also constructed along the flume that were used as areas to store supplies for flume maintenance work. Some of these were covered and served as eating areas for flume workers (see HAER Photographs No. WA-12-9, WA-12-10, WA-12-11, WA-12-35 and WA-12-36).

FLUME MAINTENANCE HISTORY

The flume was originally framed with 9-foot-high posts, although the box was only built up to a height of 5 feet. In September 1905, side boards were added to the flume box, raising it to a height of 8 feet. This box then remained in use until the late 1930s.[44]

The flume right-of-way passes through steep, heavily-wooded hillsides, commencing at approximately the 1,600-foot elevation on the south side of the Puyallup River. As timber was not cut to a sufficient distance from the flume, problems arose during the first two years of operation by trees falling or sliding onto the flume. In 1905 and 1906, timber was cut back to give adequate clearance. To carry out this work in a manner which did not endanger the flume, trees were cabled either at the bottom or on the top before being cut. For trees cabled on top, it was necessary for men to climb up 75 to 150 feet and place the cable around the tree at that point. These trees were left to rot, lying on the hillside behind stumps and other obstructions. From time to time, it was necessary to remove some of the felled trees to prevent them from sliding into the flume.[45]

A great deal of flume maintenance work was required in the early years of the project. In 1909, the flume box began to show signs of stress, and extensive repairs were begun to strengthen the framing. Eight thousand additional frames were added, making the spacing between frames in many places 2 feet instead of 4 feet.[46]

The greatest item of expense during the first years of operating the flume was the maintenance of the structure. This was primarily due to poor foundations. In places, the substructure was built on clay that became soft and crumbled away due to flume leakage. In other places, the substructure was built upon dirt from cuts which, like the clay, would crumble from continuous leakage. Breaks in the flume occasionally occurred where the flume crossed canyons and draws. The bents were sometimes built on dirt foundations rather than rock. In these draws, the dirt would often slide, after being softened by rains or melting snow. Most of the breaks that occurred in the first ten years of operation happened between bents #500 and $1900, which are in the section of flume located on the steepest terrain.[47]

In 1910, a program was started to install additional bents every 8 feet. Substructure maintenance problems arose from using hemlock, which deteriorates rapidly when exposed to the weather. In 1910 and 1911, many of the hemlock posts were replaced. Where hemlock bent caps were used, additional bents had to be constructed on either side of the defective ones.[48]

In 1911, the operating superintendent, C. E. Quinan, and the superintendent of water power, J. Harrisburger, and others suggested that the flume be rebuilt.[49] S. L. Shuffleton prepared a report in August 1911, in which he proposed rebuilding the flume, constructing settling basins and reservoirs using tunnels i places, and increasing the capacity of the plant.[50] Shuffleton's plan, however, was never implemented.

Over the years, there has been a continuous maintenance program to replace the bent structures as needed. To accomplish this, it required a crew of approximately 40 to 50 men. Generally, the maintenance followed a five-year rotation plan from one end of the flume to the other. In a single year, the crew would replace from 700 to 900 bents. In April or May, one crew would dig out the foundations of the bents to be replaced, and another crew tore out the old bents. A finishing crew would then put in new mudblocks and prepare the foundation for the bent. A crew called the "donkey crew" would put in the new bents, which required jacking and shimming. A sway brace crew would sway brace the new bent posts together. Finally, a brush crew would clear the right-of-way, burning brush and old bents, and salvaging the reuseable bents. Maintenance work also including removing ice from the flume during the winter, stopping leaks, fighting fires, and removing moss.[51]

A number of major slides occurred through the years which took out large portions of the flume. The first major slide occurred in 1932 just below Neisson Creek. In 1933, 150 to 200 feet of flume were taken out by a landslide near Kellogg Creek. In 1934, 300 to 320 feet were taken out by a landslide near an area called Lions Head Rock, just below landing #16.

In 1933, a diversion of water from Neisson and Kellogg creeks was discontinued. Several smaller flumes, however, still diverted water into the main flume.

On November 23, 1936, a slide destroyed the powerhouse. This incident was described by Emmot Chase, a lifetime employee who was born at the project and lived on the hill above the powerhouse:

> It was November 1936. I believe it was on the 23rd day. I had gone to bed -- I lived right where I could look down on the powerhouse -- and it was right after about 10:30 at night we heard a terrible noise, and it was just like thunder getting louder and louder and louder. I wondered what it was. I jumped out of bed and looked out of the window. Just as I looked out the window -- it was a bright moonlight night -- I saw this massive wall of logs, mud and everything. The powerhouse just collapsed in the middle and then there was a terrible arc that just lit the skies up.[52]

The slide did not destroy the foundation, which remained intact, with the four turbine generator units damaged but still in place. Units No. 1 and No. 2 were repaired and returned to service in 1937, while Units No. 3 and No. 4 were returned to service in 1941.

After the slide of 1936, the flume box was reconstructed in two phases. The first 16,000 feet out to bent #1002 were rebuilt in 1938. The remaining 38,000 feet were replaced in 1941. In this rebuilding of the flume box, the two sections replaced in 1933 and 1934 were not rebuilt, but the new box was joined to these. The boards matched to the exact dimensions. These two sections were subsequently replaced in 1951.

At the time the flume box was reconstructed, a settling basin was installed about halfway between the headworks and the reservoir was approximately 1,700 feet long and 100 feet wide at the widest point and 15 feet deep. A discharge gate was provided at one side for removal of silt. Water can be diverted through the settling basin or the settling basin can be entirely bypassed by diverting water down the flume.

Other slides occurred in 1943 and 1964 which carried away approximately 200 and 130 feet of flume, respectively.

In 1929-30, Puget Power started a program of wood treatment. This consisted of soaking wood in a vat containing creosote. When the flume box was rebuilt in 1938, arsenic was used in place of creosote. In the 1960s, pentachlorophenol took the place of arsenic as the wood preservative used.

In the late 1960s, a program of lining the inside of the flume box with plywood and plastic was undertaken. This may have actually increased the rate of deterioration of the box by trapping moisture between the plywood and siding. However, this reduced the leakage of the flume box and thus reduced the washing out of the foundations. As a result, the overall life of the flume was increased.

1984-1985 FLUME REBUILD

In the summer of 1984, a program of rebuilding the entire flume was undertaken. This rebuilding was accomplished in two phases, approximately four miles in 1984 and the remaining six miles in 1985.

While the configuration and operation of the project remain essentially unchanged, new materials have been used in the flume construction. Steel stringers and frames replace the wooden ones used previously. New stringers are connected at either end and are staggered in a manner that allows for removal of the bent with water in the box. The new stringers are bolted to the existing bent caps. Prefabricated steel frames are welded to the striners and spaced with 4-foot centers. The flume box planks are bolted to the steel frames. Planks with splines are used in place of tongue and groove. A new rail track has been laid on top of the steel frames. The substructure for the most part has been left intact, although a number of wooden bents were replaced with steel bents. Through the course of normal bent maintenance, all wooden bents will be converted to steel bents.

Baugh Industrial Contractors, Inc. was contracted for the demolition of the old flume box, replacing bridges and construction of steel stringers and frames. Approximately 150 to 160 men were hired for these activities. National Erectors was contracted for the installation of the new wood liner. Approximately 60 to 70men were employed in this work.

The flume rebuild was carried out by several crews working in sequence, each having its own responsibilities. The first crew consisted of three workers responsible for removing the old rail from the top of the flume box. A second crew demolished the upper three-quarters of the flume box, leaving the floor and a stub side wall intact. A specially-adapted backhoe operating from the floor of the flume box pulled the caps of the frames off. Chain saw crews made horizontal cuts through the side posts, while other sawyers made vertical cuts up to the top of the side board. The backhoe operator would then grab sections of the sidewalls and cast the off to one side of the flume. A third crew removed the bottom of the flume in 4-foot sections. This same crew removed the old stringers and placed the new stringers in temporary positions (new stringers were prestocked in the old box prior to start of construction). A fourth crew would level the existing caps on the old bents and then arrange the stringers in their permanent positions. A fifth crew welded the stringers together and lug-bolted them into the caps of the old bent. A sixth crew installed the new frames and new rail. Seven frames and two 30-foot lengths of rail would be set out. The frames were then welded to the stringers and the rail bolted to the top of the frames. After being welded in place, the frames were cabled for additional stability. The next load would have eight frames and two 30-foot lengths of rail. Loads were taken out on flatcars by speeders along the new rail and installed by means of a carry deck crank positioned at the end of the new rail. A seventh crew was responsible for putting the flume floor in. Vinyl was clamped to the steel fraMes before the floor boards were bolted onto the steel frames. The eighth and ninth crews were responsible for putting in the side boards. Again, vinyl was clamped to the steel frames before the side boards were bolted in place. Wood splines were used at the top and bottom of each side board and a steel spline at each end. A sealant was also used at the end of each board to help initially seal the boards until they swelled from water. Wedges were placed between the top of the side wall plank and the frame to help press the wall against the floor. Another crew worked independently on rebuilding bridges where the flume crossed draws.

CONCLUSION

The Electron Hydroelectric Project represents the state-of-the-art in Pacific Coast hydroelectric development at the turn of the century. It is characteristic of Pacific Coast development for this period in having a high head/low volume plant, impulse (Pelton) waterwheels, a long water-gathering network and relatively long distance power transmission. The Electron Project is also associated with the second stage of electric power development in Washington. In this stage of development, small electric companies were consolidated and electric service on a regional basis arose. The consolidation were facilitated by the Stone and Webster managerial association. Through the 1912 merger which created the Puget Sound Traction, Light and Power Company, the Electron Project became part of a generating system that provided electric service on a regional basis. The wooden flume used at the Electron Project is an integral part of the project and may be the largest flume used in a hydroelectric development in the country. Many of the major structures of the Electron Project remain intact and, although some have been reconstructed, the project as a whole retains the integrity of the original project and still operates much the same as when it was first built.

FOOTNOTES

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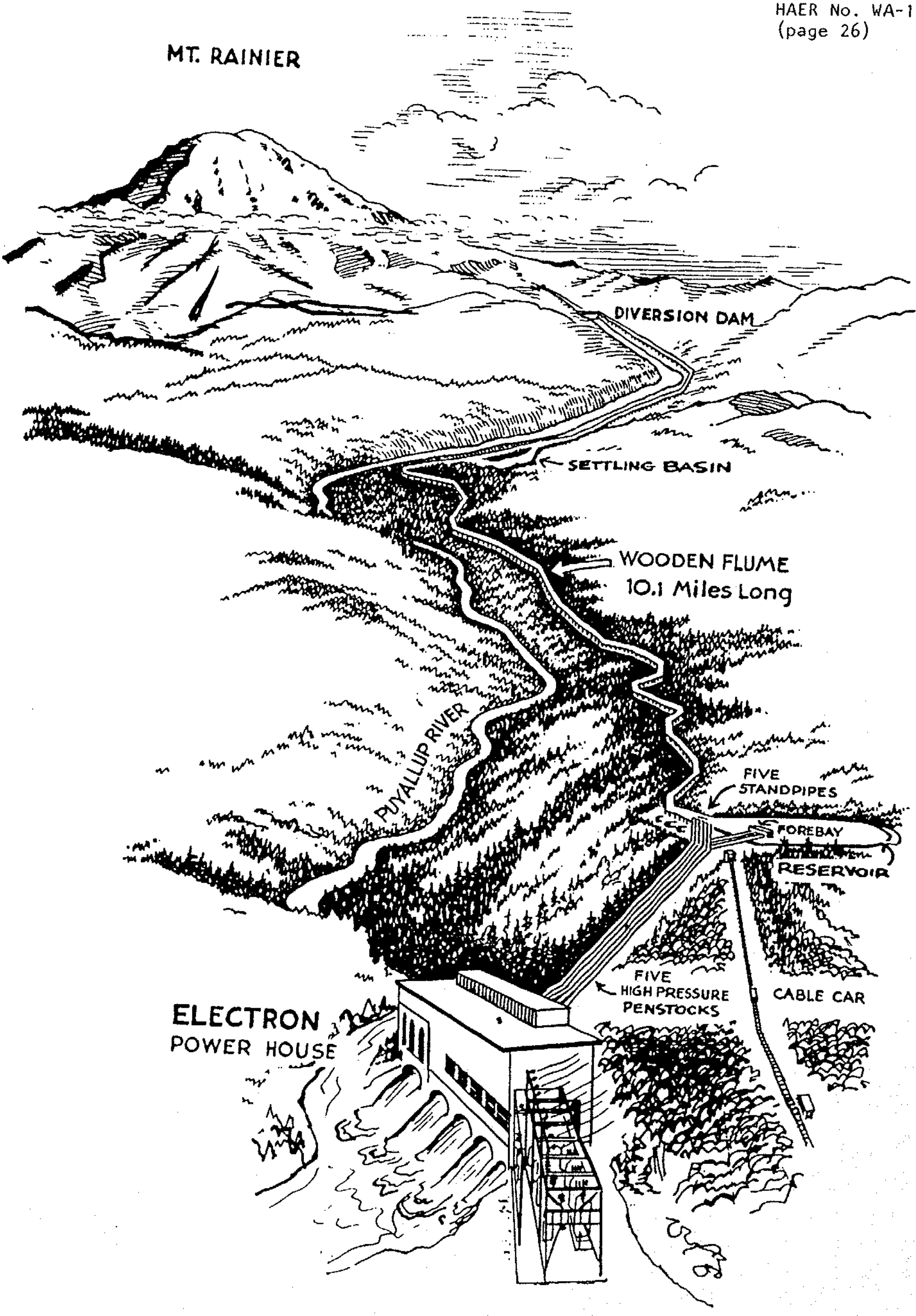
MT. RAINIER
DIVERSION DAM
SETTLING BASIN
WOODEN FLUME
10.1 Miles Long
PUYALLUP RIVER
FIVE STANDPIPES
FOREBAY
RESERVOIR
ELECTRON
POWER HOUSE
FIVE HIGH PRESSURE PENSTOCKS
CABLE CAR