Nooksack Falls Hydroelectric Plant
Puget Sound Power and Light Company
7 miles E of Glacier on Rt. 542
Glacier Vicinity
Whatcom County
Washington

HAER No. WA-18

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

MEASURED DRAWINGS

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HISTORIC AMERICAN ENGINEERING RECORD

NOOKSACK FALLS HYDROELECTRIC PLANT

HAER No. WA-18

Location: The Nooksack Falls Hydroelectric Plant is located eight miles northeast of Glacier, Whatcom County, Washington; along the North Fork of the Nooksack River.

UTM: 10.587025.5417750
Quad: Mt. Baker
Scale: 1:62,500

Date of Construction: Construction began in 1903, and the plant went on line in 1906.

Present Owner: Puget Sound Power and Light Company.

Present Use: The Nooksack plant continues to generate electricity for Puget Power's electric system.

Significance: With a generating capacity of 1,500 kilowatts, the Nooksack plant is the second oldest operating hydroelectric facility in western Washington (only the Snoqualmie Falls plant (1899) is earlier--the Electron plant, although completed in 1903, was rebuilt in 1939 after a landslide completely destroyed the power station). Some modifications have been made to this facility through the years (most notably the replacement of the turbine in 1910 and the installation of a new dam and water conveyance system in 1931); but much of the Nooksack plant has remained unchanged for the eighty years of its existence. Importantly, the power plant retains its original Westinghouse generator and the Pelton wheels installed in 1910.

Historian: Kenneth D. Rose, September 1987

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A special word of thanks goes to Doug Hamilton, Nooksack plant operator. Doug's knowledge of the Nooksack facility, his enthusiasm, and his constant willingness to help the team members in any way possible made this project a real joy to work on.

Kenneth D. Rose
Historian
Seattle, Washington
1987

Introduction

The Nooksack Falls powerhouse, containing a relatively small generating capacity of 1,500 kilowatts, is, nevertheless, one of the oldest operating hydroelectric facilities in the state of Washington. Completed in 1906 and designed to serve the electrical needs of Whatcom County, it presently provides power for the nearby small town of Glacier and its sparsely populated environs.[1] Despite some modifications through the years--most notably the replacement of the original Francis turbine with a Pelton impulse wheel in 1910, and the replacement of the penstocks and relocation of the diversion dam in 1931--the plant and machinery have remained largely unchanged since its construction. The Nooksack plant is an excellent example of early twentieth century high-head hydroelectric development in the Pacific Northwest.

Early Hydroelectric Development

In the Eastern states, the typical hydroelectric plant at the turn of the century was low head, that is, the water dropped only a short distance from the forebay to the turbines, and high volume (meaning a large quantity of water was available.) Electricity generated by Eastern hydroelectric plants was typically transmitted over relatively short distances. The hydroelectric technology developed for conditions in the East, however, was often inadequate when applied to the West. In a region characterized by high elevations, low quantities of water, and long transmission distances, engineers had to modify existing technology, and sometimes invent new technologies, to meet the Western challenge. Their success in finding solutions to such problems is embodied in the Nooksack plant, a typical high-head hydroelectric facility of the early 1900s that continues to function with few problems some eighty years after its completion.

As Louis C. Hunter observed in his seminal study of water power in the United States, the application of the principles of the hydraulic turbine were greatly advanced in France and the United States beginning in the 1820s through the 1840s. While the French engineers stressed mathematics and the mechanical sciences in their experiments with the hydraulic turbine, their American counterparts approached the same subject in a more empirical fashion, consistently with an eye towards its practical use. Not surprisingly, in the United States much of the work in developing turbine design and materials for fabricating this new kind of water wheel was centered in New England, specifically in the textile mills along the Merrimack River, where innovations in turbine technology found immediate application in the powering of textile machinery. The foremost hydraulic engineer in the United States, James B. Francis, working in one of the nation's industrial centers, Lowell, Massachusetts, is generally credited with perfecting the inward flow turbine, an innovative wheel that, by the late nineteenth century, was widely used in the burgeoning hydroelectric power industry.[2]

The second significant development in the realm of water wheel design in the nineteenth century was the perfection of the "impulse" wheel. Commonly called the Pelton wheel, its design and application was a by-product of mining activities in the American West during the 1860s and 1870s. Mining, especially the underground mining of hard-rock ore, required huge quantities of power both to operate the mine and to crush and extract the minerals from the rock.

While many of the mining companies in the East employed steam power, those in the West found that, owing to the scarcity of fuel, steam power was most often prohibitively expensive.[3] One possible solution was the use of water power, but again the geologic and hydraulic conditions of the West were radically different from those of the East. The Western terrain was rugged and mountainous, typically with sudden changes in elevation. But what Western streams lacked in volume of flow they made up in velocity and rate of drop. Indeed, Louis C. Hunter has pointed out that whereas the water wheel streams of New England characteristically had drops of five to ten feet per mile, in the West streams often dropped from 100 to 250 feet per mile. In the East heads of forty to fifty feet were uncommon, while heads in the West were usually measured in hundreds of feet.[4] The damage a debris-carrying stream dropping hundreds of feet in a mile could inflict on a turbine water wheel could be severe, and it soon became apparent that the Eastern-bred turbine was too delicate for the rigors of the West. Turbines commonly used in the East acquired such a bad reputation in the West that one engineer declared in 1884 that, as far as he knew, of the 800 water wheels then in operation in California, there was not a single conventional-type turbine at work.[5]

What Westerners were using instead was the Pelton wheel--a special type of turbine not nearly as efficient as the more widespread low-head a turbine (by 1900 some turbines were approaching a maximum efficiency of ninety per cent while the efficiency of most Pelton wheels was about forty per cent)--but a wheel whose versatility more than compensated for its lack of efficiency. The Pelton wheel was of simple, open construction and consisted of a series of "buckets" bolted around the perimeter of a wheel. These buckets were easily accessible, and should one of them become damaged, it was a simple matter to unbolt it for either repair or replacement. In addition, the Pelton wheel did not require the complex gearing that usually characterized low-head turbine installations. The Pelton-type wheel (and the nozzles used to direct water at the buckets) underwent as many transformations in design as had the turbine, and the efficiency of the best Pelton wheels was approaching that of the older well-established turbines by the late nineteenth century.[6]

By the 1880s, practical demonstrations of the viability of hydroelectric power were being made, but steam power continued to be the dominant technology for producing electricity. The earliest electric power stations used direct current (DC) equipment, and one of the great debates among electrical engineers during the 1880s centered on whether direct current or alternating current (AC) was most efficient. Though DC power was the older and more developed technology, AC advocates pointed out one of the serious drawbacks of DC power: it could only be efficiently transmitted the relatively short distance of about ten miles or less. By the late 1880s, Westinghouse was producing single-phase alternating current equipment, and in 1889 the Willamette Falls Electric Company in Portland, Oregon, became the first power company in the U.S. to install the new AC equipment.[7] But while single-phase was adequate for lighting purposes, it was often inadequate for powering motors. When Nikola Tesla demonstrated that two or more AC currents generated in phase with one another could produce a magnetic field that could easily power electric motors, the stage was set for the long distance transmission of versatile polyphase AC power. Three-phase transmission would eventually emerge as the industry standard, because two-phase systems required four wires while three phase systems required only three. Over a long distance, the savings in copper wire was considerable.[8]

Just as the mountainous and semi-arid environment of the West had spurred the development and refinement of the Pelton wheel, so did the rugged terrain as well as the great distances between hydro sites and Western population centers mandate new approaches in the transmission of hydroelectric power. Only in the West (and parts of the American Southeast) were engineers faced with such formidable transmission distances, and the work done by electrical engineers, especially in California, revolutionized the hydroelectric industry. The lack of precedent for the high voltage long distance transmission of electricity often meant that practice exceeded theory; and in fact, as Thomas P. Hughes has pointed out, "the combination of large capacity and transmission distances of a hundred miles or more was a California phenomenon."[9]

As California hydroelectric plants were being constructed, engineers drew on experience gained from providing hydraulic power for local mining activities. As was the case with mining hydraulics, water was gathered using elaborate diversion systems, and the plants often operated under very high heads. (The Fresno hydroelectric plant, for instance, which was built in 1896, operated under a head of 1410 feet--at the time the highest in the world by far.)[10] Engineers in California were often working with transmission distances and voltages never before attempted. One example was the Colgate plant, a high-head facility completed in 1899 and designed to provide power for local mines and for Sacramento sixty miles away. In 1901 the Yuba Power Company, owners of the Colgate plant, decided to extend power transmissions to the San Francisco Bay area. The Yuba Power Company succeeded not only in building the world's longest transmission line--some 140 miles--but also in transmitting at 60,000 volts, double the voltage recommended by both General Electric and Westinghouse.[11] By 1912 Western states had created the most extensive transmission system in the world and were routinely operating at 100,000 volts or more.[12]

Early Hydroelectric Power in Washington State

The development of hydroelectric power in Washington paralleled its growth in California. Washington, like California, is a geologically rugged state. Two mountain ranges, the Cascades and the Olympics, dominate the topography. As in California, mining was the activity in Washington which provided much of the impetus for experimentation in the use of water wheels and in other practical applications of hydraulic engineering. When gold discoveries were made in the 1880s and 1890s in the upper Skagit River region of eastern Whatcom County, most large mining concerns built hydraulic plants to provide power for the mines, even though bringing in the necessary materials was often quite difficult. In 1906, for instance, the Ruby Creek Mining Company went so far as to built a small sawmill to provide the lumber needed to build the four-mile flume for its hydraulic plant. Everything for this plant had to be brought in by pack train--including the hydraulic plant's nozzle which was mounted on a block of cast iron. In neighboring Slate Creek, an even more elaborate project was constructed the same year at the Chancellor Mine. There a sawmill and a flume were built, as well as a powerhouse. A 240-horsepower generator was installed in the powerhouse, and once again everything had to be brought in by pack animals.[13] The stamp mills that crushed the ore used much of the power in any mining operation, and it is estimated that in the vicinity of Barron on the upper Skagit there were at least six large stamp mills operating at the turn of the century.[14]

Important mineral discoveries were also being made in eastern Whatcom County in the area of Nooksack Falls. The richest strike in what would eventually become the Mount Baker mining district was the Lone Jack claim of 1897. Before it closed in 1924 some $500,000 in gold would be taken out of the Lone Jack mine. The success of the Lone Jack claim produced a proliferation of mining claims in the Mount Baker mining district, and some 5,000 claims were made between 1890 and 1937.[15] One of these claims resulted in the Great Excelsior mine, ten miles southwest of the Lone Jack mine and only one mile from the current Nooksack Falls powerhouse. A 20-stamp mill was built in 1902 to crush the ore, and a water-powered turbine provided the power. The water for the turbine was routed through a 2,200 foot flume and into a 500 foot penstock under a head of 300 feet. When the Excelsior mill was rebuilt in 1914, a powerline was extended from the Nooksack Falls powerhouse, and electrically powered machinery was used to grind the ore.[16]

The Bellingham Bay Improvement Company

One of the mining claims made on the Nooksack was by the "Power House Group"--an association of investors led by Pierre B. Cornwall with no real interest in the mineral wealth of their claim but a great interest in developing a hydroelectric facility in the area. This group, better known to local residents as the Bellingham Bay Improvement Company (BBIC), was comprised of wealthy California businessmen who were investing heavily in Bellingham properties because they believed that the coastal town would someday become an important urban center. With the aim of speeding along Bellingham's metamorphosis into a great metropolis, the BBIC was incorporated in 1889. The BBIC invested in such diverse enterprises as shipping, coal mining, railroad construction, real estate sales and utilities.[17] Although the dreams of these investors were never realized (it was Seattle, 100 miles to the south, that became the Northwest's major economic and population center), the BBIC did contribute a great deal to the economic development of Bellingham.

The BBIC had the franchise for providing power for the city of Bellingham (and here as in other municipalities the earliest use of electricity was for street lighting and street railways), and maintained a small generator for that purpose. This generator was often inadequate for the job, however, and in 1903 the BBIC began developing a hydroelectric facility on the North Fork of the Nooksack River, below Nooksack Falls (see HAER photo WA-18-24). In 1904, the BBIC's electrical franchise with the city was up for renewal, and the City Council made it clear that it was not totally pleased with BBIC's performance. The City, in fact, threatened to build a municipally-owned hydroelectric plant at Whatcom Falls, however, it subsequently backed away from this proposal after a survey disclosed that the BBIC was supplying Bellingham with electricity cheaper than could be had by a municipal operation. Despite some disagreement among members of the City Council, it responded to the survey by awarding the BBIC a three-year extension of its franchise.[18]

In addition to the hostility of the City Council, the BBIC was also encountering some construction problems at Nooksack Falls. In 1903 the BBIC had been able to bore six tunnels at the Nooksack site for the flume and penstocks, but the generator and transformers for the plant were waiting at Whatcom some fifty miles away.[19] (In 1903 voters from the cities of Whatcom and Fairhaven voted to consolidate their municipalities into a single city: Bellingham.) Moving heavy hydroelectric equipment through the mountains to the Nooksack site presented formidable problems. The heaviest equipment was shipped to the rail head at Glacier, then loaded on sleds and pulled by steam donkey to the site. The first piece of heavy equipment to be brought in and mounted in the powerhouse was a crane with a 40,000 pound capacity. Once the crane was installed, it was used to lift and install the rest of the powerhouse equipment. The lighter pieces of equipment were brought in by pack animals, and many local residents were able to make extra money by hiring out their animals.[20] The difficulties encountered by the BBIC in maintaining its small generator and in trying to construct a hydroelectric facility at Nooksack prompted the Board of Directors to announce in 1905 that it was selling its utility holdings. In October of 1905 the BBIC announced that it had sold its entire power holdings to the Boston firm of Stone & Webster.[21]

Stone & Webster

Charles Stone and Edwin Webster first met in 1884 while studying electrical engineering at the Massachusetts Institute of Technology. The two became close friends and in 1890, only two years after graduating, they formed their own business, the Massachusetts Electrical Engineering Company (in 1893 the company's name was changed to Stone & Webster.)[22] Their company was one of the earliest electrical engineering consulting firms in the United States. One of Stone & Webster's first projects was the testing of all electrical materials for the Underwriter's Union--a job held by the firm until 1895 when the Underwriters established their own laboratories. Stone & Webster was awarded its first major contract in 1890: designing and constructing a hydroelectric plant for a New England paper company.[23]

The Panic of 1893 brought financial difficulties for many electrical manufacturers when the securities they had accepted from utility companies as payment for their equipment proved inadequate to meet the demands of banks for repayment of the manufacturers' loans. J.P. Morgan played a leading role in rescuing the newly formed General Electric company by buying G.E.'s utility stocks and establishing a syndicate to manage these holdings. Stone & Webster was retained to appraise these properties. The Stone & Webster partners not only gained great insight into the development and management of utilities through this experience, but also

invested profitably in the utilities they were appraising. Stone & Webster was able to gain control of one such utility, the Nashville Electric Light and Power Company, for a few thousand dollars and later sold it at a profit of $500,000.[24]

During the next ten years Stone & Webster acquired financial interest in a large number of other utilities, while at the same time offering engineering, financial and managerial consulting services to independent utilities. Though Stone & Webster was not technically functioning as a holding company, since these various utilities maintained their own officers and board members, Stone & Webster's financial and managerial presence in these utilities meant that the firm always had considerable influence in policy decisions. Often, in fact, Stone & Webster would be paid for its services in utility stock. By 1912 the firm had divided itself into three specialized subsidiaries: Stone & Webster Engineering Company, Stone & Webster Management Association and Stone & Webster and Blodget, Inc., the financial wing of Stone & Webster.[25] The result was that Stone & Webster not only became one of the nation's most important engineering firms, but acquired in the process financial interests in a large number of properties--especially railway and utility properties.[26]

By 1908, Stone & Webster listed thirty-one railway and lighting properties as being under its management. These included five properties in Washington State: Puget Sound Electric Railway, Puget Sound International Railway and Power Company, Puget Sound Power Company, The Seattle Electric Company, and the Whatcom County Railway and Light Company.[27] Stone & Webster was sensitive to the increasing public criticism of large holding companies, and was careful to emphasize the "complete independence" of these properties. Indeed, when J.D. Ross, superintendent of Seattle City Light, issued a report that was hostile to Stone & Webster's presence in Seattle, one of his prominent exhibits was a list taken from Moody's Manual of 1916 showing the 49 companies then under Stone & Webster management.[28]

Washington state was attractive to those with an interest in developing hydroelectric power because of its great water power potential. The U.S. Geological Survey of 1928 found Washington to have the greatest hydroelectric power potential of any state. The survey, in fact, credited Washington with having some 18.9 percent of the total water power resources of the United States.[29] Perhaps more important was the fact that the concentration of water power (meaning water power per square mile of land area) was twice as great in Washington as in its nearest competitor, the state of Oregon.[30] Some understanding of the vast extent of Washington's water resources can be gained if one considers the fact that by 1981 Washington had already developed the largest hydroelectric capacity of any state in the union--yet still ranked third among all states in hydroelectric potential.[31]

The availability of such natural resources, coupled with a widely held belief that the economic and developmental potential of the area was almost limitless, attracted such firms as Stone & Webster to Washington. Edwin S. Webster, for one, believed that outside capital was the "thing most needed" to develop the resources of Washington, and chided those localists who thought otherwise:

> In a new country with such great resources as the Puget Sound Country outside capital is the thing most needed. Of course the business interests of that section are perfectly aware of this, but there are a good many persons in other walks of life who seem

> to forget it. I think, however, that if the demand for the resources of the Northwest increases in the way it should the need of further supplies of outside capital will be so imperative that even these persons will see the wisdom of making conditions easy rather than hard for the Eastern investor.[32]

As we have seen, outside capital was already a presence in Bellingham in the form of the Bellingham Bay Improvement Company; but the BBIC was not the only outside firm with an interest in Bellingham utilities. The General Electric Company of New York purchased Bellingham's Fairhaven and New Whatcom street rail line in 1897, and when this utility metamorphosed into the Northern Railway and Improvement Company in 1898 the Electric Corporation of Boston purchased a large block of shares.[33] Stone & Webster was also involved in Puget Sound area street railways, and in 1900 had taken control of, and merged, eight small rail lines in Seattle. Shortly thereafter Stone & Webster also took over the street railway systems of Tacoma and Everett.

In December 1902, Stone & Webster acquired the Fairhaven and New Whatcom. Over the next several months Northern Railway and Improvement sold Stone & Webster the rest of its Bellingham holdings. This included the Fairhaven Electric Light, Power and Motor Company, and the Whatcom-Fairhaven Gas Company. Stone & Webster organized these concerns under the umbrella name of the Whatcom County Railway and Light Company.[34]

One of the most pressing problems facing Stone & Webster in Bellingham was a shortage of power. Power for the 149 electric light customers was provided by a steam engine running a single phase generator, while four steam engines driving direct-current generators produced the power for the rail system. All steam engines were fueled by wood. The inadequacies of this system were often painfully obvious--especially when power to the railway would drop to a point where cars along the line would simply come to a stop until normal power generation could be resumed.

To remedy this situation, Stone & Webster bought out the power and lighting properties of the Bellingham Bay Improvement Company in 1905. These included the York Street steam plant, and the partially completed Nooksack hydroelectric project (see HAER photo WA-18-25). Stone & Webster Engineering Corporation took over the construction of the plant, and on 21 September 1906, Bellingham received its first power from the Nooksack plant via a 47 mile transmission line.[35]

Stone & Webster was becoming heavily involved in electric utilities and hydroelectric projects elsewhere in western Washington. As has already been noted, Stone & Webster had assumed control of the street rail lines in Seattle, Tacoma and Everett. In Seattle, the Stone & Webster-owned Seattle Electric Company was building new steam plants, adding new rail tracks, and scouting the region for possible hydroelectric sites. After the state's first large hydroelectric facility was built at Snoqualmie Falls in 1898, the Seattle Electric Company contracted with the Snoqualmie Falls Power Company to buy half of the plant's output--about 3,000 horsepower.[36] This was an era of fierce competition among power companies--precipitated largely by an incredible boom in population (Seattle's population nearly tripled between 1900 and 1910) and by a great increase in demand for electricity.

Competition was especially keen between the Seattle Electric Company and the Seattle-Tacoma Power Company (a company formed from a merger among the Snoqualmie Falls Power Company, the Tacoma Cataract Company and the Seattle Cataract Company in 1904.) The Seattle-Tacoma Power Company increased the output at its existing Snoqualmie plant in 1905, and constructed a second power plant there in 1910. In 1904, Stone & Webster completed its Electron plant on the Puyallup River under the corporate name Puget Sound Power Company. This hydroelectric facility utilized ten and one fourth miles of flume, operated under a head of about 870 feet, and was capable of generating 24,000 kilowatts (kw) transmitting at 55,000 volts. With the service area of the Seattle-Tacoma Power Company threatened by the Electron plant, the Seattle-Tacoma Power Company bought the rights to the projected White River hydroelectric development in 1906. The purchase price ($1,250,000) was ruinously high, and in 1908 the Seattle-Tacoma Power Company sold its White River rights--for under $600,000--to a subsidiary of the Seattle Electric Company. Stone & Webster Engineering began construction of the plant in 1909, and in 1911 the White River facility went on line generating 20,000 kw (later enlarged to 60,000 kw) under a head of 400 feet.[37]

In 1912 Stone & Webster merged the Seattle-Tacoma Power Company and the Pacific Coast Power Company, and combined them with the Seattle Electric Company, the Puget Sound Power Company, and the Whatcom County Railway and Light Company, to form the Puget Sound Traction, Light & Power Company. Eventually renamed Puget Sound Power & Light, the new company now owned four hydroelectric plants (Snoqualmie, Electron, White River and Nooksack) and an integrated transmission system.[38] Upon completion of the White River project in 1911, Stone & Webster controlled all but one of western Washington's premier hydroelectric plants.[39]

Eighty Years at Nooksack Falls

Shortly after the Nooksack plant was placed on line L.H. Bean, writing for the Stone & Webster Public Service Journal, boasted that "the Whatcom [County Railway and Light] Company congratulates itself upon securing a power plant intelligently planned and economically constructed."[40] The earliest years of the Nooksack plant, however, turned out to be some of the most difficult. The most serious problem stemmed from the sand and debris entering the hydraulic system from the swiftly flowing river. Sand was clogging the water passages "to such an extent that large quantities of the volume practically impasses the wheel, unused, or detrimentally." Sand was also wearing the gates to the turbine, producing a condition in which "the clearance between the gates and the wheel is rapidly being destroyed and may eventually result in the destruction of the turbine by reason of the gates dropping into wheel blades."[41]

Most deleterious, however, was the effect of sand on the turbine itself. The Nooksack plant was operating with a 3,300 horsepower Victor Turbine of the Francis type manufactured by Platt

Iron Works. As we have seen, Francis turbines had never enjoyed great success in the West, and this pattern was repeated at the Nooksack plant. Sand was destroying the turbine's bearings, and by 1908 the Stone & Webster Public Service Journal was reporting that "sand and grit of one kind and another have so worn these bearings as to make them practically useless."[42] One side effect of this bearing wear was excessive end thrust on the turbine, and Samuel L. Shuffleton, Stone & Webster's chief engineer for the Puget Sound region, had tried to compensate for this phenomenon by installing a special thrust cylinder and piston on the generator pedestal and shaft.[43] By late in 1909, however, Stone & Webster had decided that the turbine at Nooksack should be replaced by an impulse wheel. Though repairing the turbine would have been cheaper, Stone & Webster noted that "it is altogether likely that in three years from now the wheel would require replacement anyway."[44] In 1910, the turbine was replaced by six Pelton impulse wheels--a job that took about ten days to complete.[45]

The Nooksack plant experienced other problems in the early days, including the frequent failure of the commutator.[46] There were problems with the armature at the Nooksack plant as well, and in the winter of 1908-09 the armature burned up, and it was necessary to install a new one. The new armature came in two sections, one weighing 22,000 pounds, the other 26,000 pounds, and had to be dragged the seven miles from Glacier by a crew of men and a steam donkey engine.[47]

The Nooksack plant was also plagued with electrical problems, namely voltage variation and "when the plant was first started the voltage variation was so bad as to jam the Tirrill regulators in both directions, causing much trouble and poor service."[48] In 1913 the original bank of transformers was replaced by a new bank of water-cooled transformers, and an auxiliary motor driven exciter was installed. In 1922 the generator was completely rewound.

The new Pelton wheels quickly developed problems of their own. The wheel buckets were constantly being chipped, cracked and broken by river debris. The Nooksack plant log book in 1912 is full of references to problems associated with the Pelton buckets: July 7-"putting on buckets," July 27-"shutting down broken buckets," August 11-"putting on buckets," August 20-"loose bucket."[49] Aside from cracking and chipping, the Pelton buckets developed further problems as the pins holding the buckets to the spider began to wear out.[50] In 1913 the six Pelton wheels were removed and replaced with new ones.[51] In October 1924 the Pelton wheels were replaced once again.[52] The six-Pelton-wheel configuration at Nooksack was finally abandoned in 1940 in favor of a four-wheel system. Skagit Steel and Iron removed the old wheels, and installed four new Pelton wheels of an improved design. At the same time larger nozzles were installed to replace the old ones.[53] A test run in 1922 revealed that the six Pelton wheels had picked up an average load of 300 kw each.[54] According to plant operator Doug Hamilton the four Pelton wheels currently in service average 400 kw each.[55]

Some of the most extensive modifications to the Nooksack plant were completed in 1931. Throughout its history, the Nooksack plant had experienced problems with slides damaging the penstocks. In 1930, work began on building a new penstock and creating a new route for it. The old penstocks consisted of one 44-inch wood-stave penstock with iron bands and steel riveted elbows at curves, and a 47-inch steel penstock.[56] These penstocks had passed through four tunnels between the forebay and the plant. In 1931 the two original penstocks were replaced by a single 60 inch welded steel penstock built above grade, and a new path was chosen for the penstock to avoid slide areas.

While work was progressing on the penstock, a new dam was being constructed a thousand feet upstream from the old one. Built with large Douglas fir logs and anchored by mass concrete, the new dam would raise the head from 176 feet to 206 feet. The addition of this dam meant that other major alterations would have to be made to the water conveyance system, including the building of a concrete flume, 450 feet in length, a settling basin, a wood-stave pipe, measuring six feet in diameter and extending 560 feet, a rock tunnel with a length of 1,025 feet, and a reinforced concrete forebay, 35 feet long.[57] These additions quickly improved the operations of the Nooksack plant. By December 1931, the plant operator was noted that, "The most outstanding events in connection with the plant this year has been the remarkable and phenominal [sic] all around increased efficiency, not only from an operative point of view, a transmission system corrective, but also increased K.W. production. This is due solely to the new water power system."[58]

Working at Nooksack

Keeping a hydroelectric plant functioning is a constant struggle against the forces of nature. The troubles experienced at Nooksack with sand and debris damaging both the turbine and water wheels, and slides damaging the penstocks, have already been alluded to. One maintenance activity frequently performed at Nooksack is the removal of debris from the intake and forebay trashracks. The swift-flowing Nooksack River is capable of carrying quite heavy objects in its current, which can not only clog the intakes, but hit the trashrack bars with sufficient force to bend them. Consequently, not only must trashracks be cleaned frequently, but even trashrack bars must occasionally be replaced. The region around the Nooksack plant is also heavily forested, and trees occasionally fall across the transmission lines cutting off power.

The river itself has wild seasonal fluctuations. Former plant operator Don Blackman remembers that during the winter and spring months "the river used to get high--high as the devil."[59] Bridges would occasionally wash out, and in 1962 heavy rains had swollen the river to such a point that the island south of the plant was washed away.[60] During the summer the Nooksack River can be reduced to a trickle. Often the plant cannot pull a full load, and water pressure can be reduced to the point where the plant must be operated on only one valve.

The operators at Nooksack have brought a variety of skills to the job. David Harrison, for instance, who was an operator at Nooksack in the 1930s, had a degree in electrical engineering and later became chief operator at Grand Coulee hydroelectric facility. Don Blackman, however, notes that a technical education in electricity was not really necessary to performing the duties of a plant operator. Blackman himself had no practical training in electronics, and was trained at the Nooksack site by chief operator Pat Miller.[61] Art Bennett, who began his stint as chief operator in the 1920s, was described by his son Alastair as a "self-styled engineer" who learned about electrical engineering through correspondence courses.[62] Doug Hamilton believes that few operators had even this much technical background, and that most learned the skills of a hydro operator through "hands on" experience. Most useful to the Nooksack operator was mechanical skills to keep old machinery operating.[63]

Relations between labor and management at Nooksack have, for the most part, been harmonious. This pattern did not change when workers voted to affiliate with the International Brotherhood of Electrical Workers in 1934. Keeping the plant operating full time normally required three eight-hour shifts. But during the Depression the company sometimes cut back operations to the point where, at times, only one eight-hour shift was run and occasionally the plant was shut down altogether. During these down periods, Nooksack operators were reassigned rather than layed off.[64]

Community Life at Nooksack

For much of its history, the plant at Nooksack served not only as a commercial hydroelectric facility, but also as the center of a small community. Because of its remote location, the rugged landscape surrounding it, and the primitive transportation conditions which existed in the vicinity of the Nooksack plant, the only practical way to operate the plant in the early days was for workers to live on the premises with their families. After the plant came on line, the utility company employed one chief hydro-operator and two assistant operators, and the company built three frame cottages (ca. 1906) on the hill above the powerhouse to house these workers and their families. In addition, a school teacher was hired to educate children of the workers, and a hotel was built about 1905 to house company officials, construction workers, and others visiting the plant. A section of the two-story wood-frame hotel also served as a school room. Employment at Nooksack was at its peak between 1906 and the mid-1920s, with five operators, hotel manager, cook, assistant cook, and teacher all on the payroll.

Alastair Bennett began living at Nooksack at age two, when his father Art assumed the duties of chief operator in 1924. The younger Bennett remembers that the company considered the plant a showcase, and that it took great pains to maintain carefully the plant, housing, and grounds. When he began attending school at Nooksack, the only students sharing the hotel classroom with him were his older sister and Maxine Lang, daughter of operator Max Lang and wife Lila. Alastair Bennett speaks highly of this school, and notes that teachers were certified by the state, and that Whatcom County officials made periodic inspections of the Nooksack school. After his second grade, however, his mother pulled his sister and himself from the Nooksack school and enrolled them in school at Glacier. By 1930, the company had closed the Nooksack school, and never reopened it.[65]

In 1948, operator Don Blackman and his wife Rose moved into the westernmost cottage at Nooksack and became the last people to live in the plant cottages. Though their home was generally well-maintained by the company, and Puget Power did not charge them rent, the Blackmans discovered several drawbacks to life at Nooksack. Rose Blackman especially can still vividly recall the feeling of isolation she experienced during the Blackmans' two year stay. The winters could be especially lonely, and the fact that the cottage relied on wood and coal for heat meant that a winter at Nooksack could be quite cold.[66]

The cottages were demolished in the early 1970s to discourage squatters from taking up residence. Though Puget Power considered turning the hotel into a company ski lodge in the late 1930s, this idea never came to fruition, and the hotel was finally demolished in the mid-1960s.[67] In addition to the powerhouse, early buildings still standing at the Nooksack site include the machine shop at the base of the hill, and the original concrete transformer house on the hill above the plant.

Today there is little evidence of the small community that once existed at Nooksack, because the plant no longer requires the manpower it once did. In 1978 the plant was partially automated with emergency equipment that can shut all four water valves in 12 seconds. An "annunciator" now activates the operator's pager if the plant develops a problem. A plant that once required five operators can now be managed by Doug Hamilton alone. Major maintenance on the plant is done once a year, when the Nooksack plant is shut down for a month to weld the Pelton wheels, check the bearings, and do whatever else might be necessary to keep the plant functioning smoothly.

The future of the Nooksack plant remains uncertain. In 1982 Puget Power applied to the Federal Energy Regulatory Commission to build a new hydroelectric facility at Nooksack Falls. If Puget Power's application is approved, the old plant will be shut down. Until then, the tiny Nooksack Falls plant will continue to serve Whatcom County as it has for over eighty years.

Notes

1.The Nooksack Falls plant was not always the smallest Stone & Webster facility in Washington. One Puget Sound Power & Light Company publication from 1923 lists six hydroelectric plants with smaller capacities than Nooksack. These include the Jim Creek, Granite Falls, Entiat, Dryden, Sylvia and Kalama plants, with power ranging from the 1,600 horsepower at the Dryden plant to the 80 horsepower at the tiny Granite Falls facility. See Puget Sound Power & Light Company, Handbook of Puget Sound Power & Light Company, March 1923, p. 14.

2.The inward-flow or center-vent turbine represented a departure from the French-engineered Fourneyron turbine in that it permitted water to enter at all points along the circumference of the wheel where, after passing through the buckets, was discharged downward through the wheel's center. Debate over Francis's contributions to the innovative inward-flow turbine has existed for some time--Samuel A. Howd, a mechanic from Ontario County, New York, is seen by Louis C. Hunter as introducing in the 1840s the first inward-flow turbine that was put in practical use, while another Massachusetts engineer and a colleague of Francis, Uriah A. Boyden, is credited by Hunter as having played a major role in the development of the inward-flow turbine through his experiments with the Fourneyron turbine. See Louis C. Hunter, A History of Industrial Power in the United States, 1780-1930, Volume One: Waterpower in the Century of the Steam Engine (Charlottesville, Virginia: University Press of Virginia, 1979), pp. 313-42.

3.Louis C. Hunter, A History of Industrial Power in the United States, p. 398. For a detailed discussion on the operations of power plants see Robert H. Fernald and George A. Orrok, Engineering of Power Plants (New York: McGraw-Hill, 1927).

4.Louis C. Hunter, A History of Industrial Power in the United States, p. 397.

5.Louis C. Hunter, A History of Industrial Power in the United States, p. 400.

6.For a discussion on the development of the Pelton wheel and other turbines in the late-nineteenth century West see Louis C. Hunter, A History of Industrial Power in the United States, pp. 396-415.

7.David B. Rushmore and Eric A. Lof, Hydro-Electric Power Stations (New York: John Wiley and Sons, 1923) p. 7.

8.Donald C. Jackson, "Theory and Practice in the Development of a Technological Style: California's Early 3-Phase AC Power Systems," unpublished paper from a University of Pennsylvania graduate seminar, a copy of which is available from the author, pp. 4-5. See also Harold C. Passer, The Electrical Manufacturers 1875-1900: A Study in Competition, Entrepreneurship, Technical Change, and Economic Growth (Cambridge, Mass.: Harvard University Press, 1953).

9.Thomas P. Hughes, Networks of Power: Electrification in Western Society, 1880-1930 (Baltimore: Johns Hopkins University Press, 1983) p. 264.

10.Donald C. Jackson, "Theory and Practice in the Development of a Technological Style," p. 10.

11.Thomas P. Hughes, Networks of Power, pp. 272-275.

12."Western Transmission Systems," Electrical World, v. 59 (1 June 1912) p. 1191. The editors of Electrical World also emphasized the close association in the West between irrigation and electrical energy transmission: "In many cases the transmission undertaking would have been impractical had not the irrigation project been a necessity."

13.JoAnn Roe, The North Cascadians (Seattle: Madrona, 1980), p. 61. In western Washington sawmills also made extensive use of water power. The first sawmill in the Puget Sound area was built in 1847 and powered by the falls at the De Chutes River at Tumwater,Washington. By 1892 the falls was providing water power for a flour mill, a shingle mill, a box factory and an ice factory. See Arthur Kramer, Among the Livewires: 100 Years of Puget Power (Edmonds, WA: Creative Communications, 1986) pp. 8-9.

14.Paul C. Pitzer, Building the Skagit: A Century of Upper Skagit Valley History 1870-1970 (Portland, Ore.: The Galley Press, 1978) p. 5.

15.Wayne S. Moen, "Mines and Mineral Deposits of Whatcom County, Washington," in Washington State, Division of Mines and Geology: Bulletin No. 57, (Olympia, Washington: 1969), p. 63.

16.Moen, "Mines and Mineral Deposits of Whatcom County, Washington," p. 87.

17.Beth Kraig, "A Slow Game: The Bellingham Bay Improvement Company and the Economic Development of Bellingham, 1900-1912," unpublished M.A. thesis, Western Washington University, 1981. pp. 1-2.

18.Kraig, "A Slow Game," pp. 88-89.

19.Shuffleton, S.L. Letter of 27 November 1903 to Stone and Webster Management. Puget Sound Power and Light Company files.

20.Doug Hamilton, current chief operator at the Nooksack plant, remembers his grandfather telling him that he and his team of horses helped move equipment to the Nooksack plant. Hamilton, Doug. Interview with Kenneth Rose, 24 July 1987.

21.Kraig, "A Slow Game," pp. 89-90.

22.Hughes, Networks of Power, p. 386.

23.Whitney Stone, "History of Stone & Webster 1889-1966," company reprint, 1966.

24.Hughes, Networks of Power, p. 387.

25.Hughes, Networks of Power, p. 387-90.

26.For a complete listing of Stone & Webster construction projects that had been completed or were in progress as of January 1916, see the Stone & Webster Journal, v. 18, 1916, p. 41. These included twelve gas plant construction contracts, forty-six building construction contracts, and 698.4 miles in railway construction, and 1,194 miles in transmission lines. In addition Stone & Webster was involved in water power developments producing a total of 262,450 KW, steam power developments producing a total of 408,920 KW, and sub-stations producing a total of 299,450 KVA.

27.Stone & Webster, "Electric Railway and Lighting Properties," 1908, p. 3.

28.City of Seattle Lighting Department, J.D. Ross, Superintendent, "The Power Situation in the Puget Sound District in 1918," p. 36. University of Washington Libraries, Pacific Northwest Collection.

29.C. Edward Magnusson, "Hydro-Electric Power in Washington," The Washington Historical Quarterly, v. 19, no. 2 (April 1928) p. 90.

30.Magnusson, "Hydro-Electric Power in Washington," p. 97.

31.Washington State, Department of Ecology, Washington State Energy Office, Developing Hydropower in Washington State: A Guide to Permits, Licenses, and Incentives, January 1985, p. 50.

32.Edwin S. Webster, "Impressions of the Puget Sound Country," Stone and Webster Journal, March 1917, p. 189.

33.Daniel E. Turbeville 1lI, "The Electric Railway Era in Northwest Washington 1890-1930," Occasional Paper #12, Center for Pacific Northwest Studies, Western Washington University, 1978. Turbeville notes that General Electric purchased many small rail lines and utilities in the mid and late 1890s, but because of public fears of unchecked corporate growth G.E. took great pains to disguise its acquisitions. In Bellingham, G.E. ordered that company executive S.Z. Mitchell appear as "owner" on all forms dealing with the Bellingham railway. See especially pp. pp. 4-5. and 43-45.

34.Daniel E. Turbeville, III, "The Electric Railway Era in Northwest Washington 1890-1930," pp. 50-51.

35.Turbeville, "The Electric Railway Era in Northwest Washington 1890-1930," pp. 52-53.

36.Kramer, Among the Livewires, p. 19.

37.Henry L. Gray, "Report on the Puget Sound Traction Light & Power Company, 30 June 1915, pp. 35-48. A copy of their report is available at the office of Puget Sound Light & Power Company in Bellevue, Washington. The Electron plant operated under a head of 870 feet and was capable of generating 24,000 kilowatts, transmitting at 55,000 volts. The White River plant went on line in

1911 and generated 20,000 kilowatts (later enlarged to produce 63,000 kw) operating under an average head of 440 feet. See Kramer, Among the Livewires, pp. 26-28.

38.Kramer, Among the Livewires, p. 36. By 1919 Puget Power had interconnected its transmission system with other power companies including Western Canada Power Company, the City of Tacoma, and Washington Water Power Company. Some 1,500 miles of transmission lines were integrated. Puget Power and Seattle City Light signed an interchange of power agreement in 1937, and in 1942 the power systems of Washington, Oregon, Idaho, Montana and Utah were all interconnected into a single power pool. See Puget Sound Power & Light Company, Hand Book of Puget Sound Power & Light Company, March 1923, p. 87.

39.The only important hydroelectric plant that Stone & Webster did not control was Seattle's municipal plant on the Cedar River.

40.L.H. Bean, "Nooksack Falls Development, Bellingham, Wash.," Stone & Webster Public Service Journal, November 1907, p. 3411.

41."Report on Power Requirements of the Whatcom County Railway & Light Company," ca. 1909, in W.E. Herring papers, Puget Sound Power & Light Company files.

42.Stone & Webster Public Service Journal, October 1908, p. 276.

43.Stone & Webster Public Service Journal, October 1908, p. 349.

44."Report on Power Requirements of the Whatcom County Railway & Light Company," pp. 358-359.

45.At the same time the Pelton wheels were installed, six 20" gate valves were also installed. Unfortunately, the valve bodies were cast in concrete, which later necessitated chiselling away the concrete so that maintenance could be performed on the valves. John F. Wallin to G.C. Sears, 30 November 1950. Puget Sound Power & Light Company files.

46.Stone & Webster Public Service Journal, March 1908.

47.Stone & Webster Public Service Journal, July 1909. pp. 428-429.

48.Stone & Webster Public Service Journal, October 1908. p. 275.

49.Nooksack Falls plant log book. Puget Sound Power & Light Company Files.

50."Preliminary Report-Proposed Nooksack Extension," ca. 1929. Puget Sound Power & Light Company files, pp. 1-2.

51."Nooksack Falls Plant," 11 October 1934. Puget Sound Power & Light Company files.

52.Log Book for Nooksack Falls Power Plant, October 1924.

53.Log Book for Nooksack Falls Power Plant, entries of January 1-6, 1940 and 9 February 1940.

54.Log Book for Nooksack Falls Power Plant, entry of 7 May 1922.

55.Hamilton, Doug. Personal communication with Kenneth Rose. 26 August 1987.

56.Earl Jacob Beery, "The Electrical Development in the State of Washington," unpublished M.A. thesis, University of Washington, 1915. p. 18.

57.Puget Sound Power & Light Company, "Before the Federal Energy Regulatory Commission Application for License for Major Unconstricted Project, Nooksack Falls Project No. 3721, February 1982," pp. E-54, E-58.

58.Log Book for Nooksack Falls Power Plant, December 1931.

59.Blackman, Don. Interview with the author. Bellingham Washington, 1 July 1987.

60.Bennett, Alastair. Interview with Gray Fitzsimons, HAER, 2 May 1988; Log Book for Nooksack Falls Power Plant, November 1962.

61.Blackman, Don. Interview with Gray Fitzsimons, 2 May 1988.

62.Bennett, Alastair. Interview with Gray Fitzsimons, HAER, 2 May 1988.

63.Hamilton, Doug. Interview with Gray Fitzsimons, 2 May 1988.

64.Bennett, Alastair. Interview with Gray Fitzsimons, HAER, 2 May 1988

65.Bennett, Alastair. Interview with Gray Fitzsimons, HAER, 2 May 1988.

66.Don Blackman interview with Gray Fitzsimons, 2 May 1988. Alastair Bennett notes that during his father's tenure as chief operator (from 1924 to late 1940s) there was a relatively high turnover of employees--a phenomenon he attributes in part to the isolation of life at Nooksack. Doug Hamilton believes that the high employee turnover was related to the fact that operators' salaries were not commensurate with local logging wages. Alistar Bennett interview with Gray Fitzsimons, HAER, 2 May 1988.

67.Log Book for Nooksack Falls Power Plant, 3 November 1939.

Appendix I

Technical Information: Nooksack Falls Hydroelectric Project, Powerhouse

Dam: The original dam was located 80' above Nooksack Falls and consisted of a single log, four feet in diameter. Concrete piers anchored the log into the rock on either side of the river. The intake was cut out of solid rock and consisted of two concrete walls 18' long, 16' deep and 2' thick. The walls were held in place a wooden frame for two 3 1/2" thick 4' wide gates operated by a motor from the powerhouse. A trash rack consisting of ten 56-pound T-rails, 18' long, protected the intake. The present dam, which was built in 1931, is located 1,050' above the original and consists of two fir logs, 65' long and 36" in diameter. Concrete piers anchor the dam to the banks, and a single concrete pier anchors it in the middle. The dam is sheathed with two layers of 6" x 12" planks, with spaces between the toe and the logs filled in with rock. A new intake leads to a concrete flume.

Flume: In the original water-conveyance system, water from the intake flowed through an 8' x 10' rock tunnel, 260' in length and lined with 2" plank to the forebay. In the present configuration, water from the intake enters a reinforced concrete flume 8-1/2' wide and 6-1/2' high. The flume is 450' long and is supported on a solid rock foundation. Water from the flume enters a settling basin through a gate on the river side.

Wood Stave Pipe: From the settling basin, the water enters a wood stave pipe 6' in diameter and 560' long supported by cedar cradles.

Rock Tunnel: A steel nipple at the end of the wood stave pipe is concreted into an unlined rock tunnel 1,025' in length. In the 1931 configuration the tunnel was 7' to 8-1/2' wide and 8-1/2' to 10' high. The tunnel was recently excavated to increase its height 2'-9", and it was lined with shotcrete.

Forebay: The original forebay was 12' x 60' x 22' deep and was constructed of timber. 8" x 8" posts and 8' x 10" sills were used spaced every three feet with six 3/4" x 14' tie rods. The sides and bottom were 2-1/2" x 12" tongue and grooved plank spiked to the posts. A trash rack was placed on the outlet end. Attached to the forebay was a wooden spillway 42' long which took the sediment from the water and returned it directly into the Nooksack River. The present forebay and surge tank is constructed of reinforced concrete 10' to 24' wide, 35' long and 25-1/2' high. The bottom slopes to a steel side gate so that sediment can be flushed out.

Penstock: Originally two penstocks issued from the forebay: one a 44" diameter wood stave pipe with 5/8" iron bands with steel riveted elbows at curves, and one a 47" diameter steel riveted pipe. The total length of each pipe was 1,380'. These penstocks travelled through four tunnels of 196', 28', 79', and 80' in length. At various intervals the penstocks were embedded in concrete blocks

and anchored to the hillsides. Because of occasional landslides, protective walls were built into the hillsides. These penstocks were replaced in 1931 by a single 60" diameter welded-steel penstock placed above grade.

Powerhouse: Originally the powerhouse measured 40' x 42'; three of the four walls were constructed of reinforced concrete. Perhaps with the idea of future expansion in mind, the west wall had been built of corrugated iron on a wood frame. Instead, when the plant was altered in 1910 to accommodate the new Pelton wheels, it was the east wall that was knocked down and extended 15'. The original 20-ton, hand-operated traveling crane made by Northern Engineering Works of Detroit, Michigan remains in place in the plant. It spans 36'-8".

Water Wheel: Originally the Nooksack plant was equipped with a Francis-type turbine. It was replaced in 1910 with a horizontal, tangential Pelton water wheel with six runners (serial no. 13165). Six backshot nozzles and four undershot nozzles drove the turbines. In 1940 this six-runner configuration was replaced by an improved four-runner system, and larger nozzles were also installed.

Generator: The original AC Westinghouse generator remains in service. It is a three-phase, 60-cycle, 1,500 kw unit.

Exciter and Governor: The exciter and governor are both original equipment. The belt-driven exciter is rated at 45 kw. The exciter supplies current to produce the generator field, and provides electricity for the plant lights and the motor at the headgates. The Nooksack plant also has an auxiliary exciter which appears to date from 1906 and is rated at 60 cycles, 25 horsepower, and 220 volts. The governor, which controls the speed of the water wheels, is a Lombard type Q (serial no. 938.)

Oil Pump: The oil pump dates from 1906. It is a double 3" x 3" Lombard pump with a vertical tank. It was originally operated by a five-horsepower motor and supplied oil for the operation of the governor. The oil circuit breaker is a General Electric type FK-43.

Appendix II

Operator's Instructions in the Event of a Power Outage: Bringing the Nooksack Plant on Line

Some appreciation of the skills required of Nooksack employees can be gained by taking note of the operations which must be performed when power from the plant is terminated. Power outages are typically caused by trees falling across power lines--an event which occurs on average of eight to ten times per year. "Jacks out!" is the call given by the operator when, as the result of a power outage, the switch is thrown taking the plant off line. To return the plant on line the operator has to perform the following procedures (Source: Douglas N. Hamilton, "Basic Procedures, Nooksack Hydro" [1984], pp. 1-2.):

1. Turn off excitation rheostat and pull oil circuit breaker down.

2. Turn governor control nut down 1/4 turn.

3. Close all water valves (oil pressure permitting) except #2.

4. Allow time for machine to calm down, check oil slinger rings.

5. Inspect board to determine cause of outage. Remedy any problems causing outage (such as the removal of a tree and repairing of a broken line, if necessary.

6. Obtain clearance from main office to synchronize.

7. Open main oil supply valve, and start auxiliary oil pump.

8. Double check emergency oil tank and open manual oil valve X.

9. Close disconnects.

10. Open governor oil supply valves and set up governor. Check dashpot.

11. Open water valve #2 slowly.

12. At approximately 126 r.p.m. give governor control nut a 3/4 turn down and lock it.

13. Assist governor engagement with slight upward pressure on speed lever. Hold snap lever up, it will engage at 180 r.p.m.

14. When governor has steady control of speed (198-202 r.p.m.) check oil slinger rings.

15. Check breaker 86N.

16. Put synchroscope plugs in board.

17. Check line voltage and put voltage plug in machine position.

18. Match machine voltage to line voltage by increasing excitation. (Between red marks on volt meter.)

19. Adjust cycles to 60 with governor control nut. Allow time for machine to adjust.

20. Synchronize.

21. Release governor control lock nut and turn governor control full open.

22. Adjust governor control to barely open, and turn 1/4 more.

23. Check Var meter and adjust excitation until meter shows 1 1/2 points leading.

24. Remove synchroscope plugs from board and move voltage plug to line position.

25. Oil pressure permitting, begin opening water valves one by one to carry maximum load.

26. Arm automatic shutdown system. Close manual valve X, open valve Y, and turn key switch to on. Check to make sure the red light comes on, and that oil supply valves to cylinders are open.

27. Shut off auxiliary oil pump.

28. Recheck governor.

29. Check oil slinger rings, log action, and readings, call load off

APPENDIX III

Oral Interviews

Interview with Alastair Douglas Westbrooke Bennett
by Gray Fitzsimons, Historic American Engineering Record,
at a Visitor's Information Center on Interstate 5,
near Arlington, Washington, May 2, 1988

This interview discusses the career of Alastair Bennett's father, Arthur Westbrooke Bennett for many years the chief operator at Nooksack.

Arthur W. Bennett was born in Arlington, Oregon, about 1895. He received a high school education but did not attend college. His first job was as a telegrapher with the Canadian Pacific Railroad. During the First World War Bennett was a conscientious objector, for he believed this conflict was immoral, a clash between competing economic interests. He remained in Canada through much of the war. In 1919 Arthur obtained work on the construction of the large Thompson River hydroelectric project in British Columbia. After its completion he remained at the powerhouse as a plant operator for its owner, Revelstoke City Power & Light. He married a Canadian woman, Leslie Aleanor Ferne, during his years in British Columbia. About 1923 Arthur and Leslie Bennett returned to the United States where they settled in Sumas, Washington. For about one year Arthur worked as an electrician for the Olympic Portland Cement Company. In 1924 he obtained a job with the Puget Sound Power & Light Company as a hydro-operator at Nooksack. Arthur began as a hydro-operator 2nd class, and became Chief Operator by 1928. According to his son, Arthur was a "self-styled engineer" who took correspondence courses in electrical engineering through the International Correspondence School (ICS). Arthur received a diploma from ICS in 1926.

At Nooksack operators worked a single eight-hour shift, for ten consecutive days, followed by four days off. When Arthur Bennett came to work at Nooksack in 1924 there were three operators: Les Hayden, Walter Mann (Mann came shortly after Bennett arrived), and Max Lang. Near the plant were three company houses, a hotel, and a machine shop. The machine shop contained a drill press, a lathe, blacksmiths tools, and a forge. These tools were belt-driven off a central line shaft powered by an electric motor. (Alastair Bennett believes that the spare metal parts for the hydro-system and the machine tools were contributed to the United States during World War II. The machine shop was never re-equipped.)

Arthur and his wife had two children, a boy and a girl; The son, Alastair Douglas Westbrooke Bennett was born in Revelstoke, British Columbia, in 1922. Two years later the Bennett family was living at Nooksack. Alastair and his sister attended school in a room in the hotel. The school had one teacher and only a few students. During Alstair's two years at the Nooksack school there were only one two other children there: his older sister and Maxine Lang, the daughter of hydro-operator Max Lang and his wife Lila.

Puget Power paid the salary of the school teacher and provided the classroom with books and other educational materials; Alastair Bennett has fond memories of the school and noted that the teacher, though hired by Puget Power, had to be certified by the State; the Nooksack school was inspected periodically by Whatcom County school officials. The Nooksack school employed only single female school teachers; many stayed for a year or two before moving on. If a teacher married she was dismissed from her job. (Alastair notes that this was a statewide policy of Washington's School Boards.)

Classes in the Nooksack hotel were held in one room on the first floor; About 1929-30 Mrs. Bennett pulled her two children out of the Nooksack school and sent them to school in Glacier. The company-sponsored school at Nooksack closed at this time never re-opened.

Alastair Bennett recalls that Puget Power considered the plant a show case and carefully maintained the grounds and buildings at Nooksack. Many visitors came to the plant for tours. Company houses were assiduously maintained by Puget Power. The houses were periodically painted and re-roofed and the Plant and grounds were carefully maintained. Puget Power rented the three houses to its employees. Access to the old Excelsior mine on the south side of the Nooksack River was provided by an old timber truss bridge downstream from the power plant. It was washed out in freshet in winter of 1934-35.

Arthur Bennett and his family continued to live at Nooksack during the 1930s. According to his son, Arthur was "a closet Democrat" and favored union organization but he did not campaign vociferously for it. Arthur was a "nonconfrontational man" who was opposed to violence. Arthur Bennett's son recalled an incident at Nooksack that illustrates his pacifistic nature. One of the hydro operators was an emotionally unbalanced young man who became angry with Arthur and tried to strike him. Arthur was physically much larger than his antagonist; however, he refused to strike back. He simply grabbed the irate fellow and held him in a bear hug. John Methven, another hydro operator at Nooksack saw this fracas and ran up to Arthur, shouting in his Scottish brogue, "Let him go Arthur and I'll pop him one." Arthur declined Methven's help and the young hydro operator calmed down after which Arthur promptly fired him.

Workers at Puget Power voted to affiliate with the International Brotherhood of Electrical Workers in 1934. This brought no significant change in the relations between the company and its employees. Alastair Bennett noted that relations between management and the union were relatively harmonious. The company did not lay off many workers during the economic depression of the 1930s. At Nooksack, however, operations of the plant were cut back. Only one shift was run during part of the 1930s and occasionally the plant was entirely shut down. Hydro-operators were reassigned rather than discharged. Arthur Bennett retained full-time employment at Nooksack during the 1930s and oversaw the rebuilding of the headworks and penstock. In the 1940s Arthur Bennett and his family left the Nooksack plant, though Arthur remained with Puget Power's Bellingham Division.

Interview with Donald Blackman at the Blackman Residence,
by Gray Fitzsimons, Historic American Engineering Record,
1535 Iron Street, Bellingham, Washington, May 2, 1988

Donald Blackman was a hydro operator at the Nooksack plant about 1948-50. He as born in 1903, in Mackinac City, Michigan. Blackman had one sister. About 1919, he and his family moved to Wickersham, Washington, where his father worked for the Moore Logging Company. Blackman's father later worked for a logging company at Dorn Spur, Washington.

Donald Blackman did not finish high school; he married Rose Cook in 1924. With the help of Rose Cook's father, Donald Blackman got a job at Kendall State Fish Hatchery and worked there about two years; he then went to Sumas to work for the Olympic Portland Cement Company as a truck driver. Blackman operated a truck at the company's quarry for four years. In 1933 he joined the Civilian Conservation Corps and worked on various road building projects in Shuksan area for six months. Blackman then worked as a ranger with the Forest Service for approximately ten years. During World War II he worked as a crane operator in the Bellingham ship yards. Blackman began working for Puget Power in Bellingham around 1945; he and his wife purchased their house on Iron Street in 1945.

Blackman's first trip to Nooksack plant was around 1919-20, but he remembers very little about it. When he began working as an hydro-operator in 1948, there were three other operators: Don Nims, Pat Miller (chief operator), and Bill Barnes (Barnes was an operator for only a short time). They were all members of International Brotherhood of Electrical Workers (IBEW) Local No. 77. Hydro-operators worked three eight-hour shifts.

Pat Miller trained Blackman in the skills required for a hydro-operator. Blackman, though experienced as a crane operator and mechanic, had no training in electronics; Blackman observed, however, that a knowledge of electronics was not extremely necessary to become a hydro-operator. Most of the work involved monitoring the hydraulic and electrical equipment.

About 1948, Donald and Rose rented their Bellingham house and moved into the westernmost house at Nooksack. Rose did not care for life at Nooksack; she felt very isolated, particularly in winter. The house was heated with coal and wood, and was often very cold during the winter. The Blackmans were the last people to live in the company houses. As Rose Blackman noted, by the late 1940s Puget Power did not charge rent and was "glad to have people living there 24 hours a day." Donald Blackman noted that relations between IBEW and the company were good. There were no strikes during Blackman's twenty years with Puget Power. Blackman noted that most operators stayed only a short while at Nooksack; some found higher paying jobs with logging companies.

Blackman went from Nooksack to the Baker hydro-electric project around 1951. Like other employees, he had to 'bid' on jobs as they became available. Blackman's wife, Rose, wanted to leave Nooksack. Blackman worked as hydro-operator at Baker for approximately two years and he and his wife lived in nearby Concrete. They did not care for Concrete, feeling the townsfolk to be "clannish" and some were prone to violence. The Blackmans witnessed a terrible brawl outside a tavern in Concrete. Rose Blackman did not want to stay in the town and her husband put in a bid for a job as a mechanic at the Puget Power garage in Bellingham. The Blackmans moved back to Bellingham around 1954, returning to the house on Iron Street.

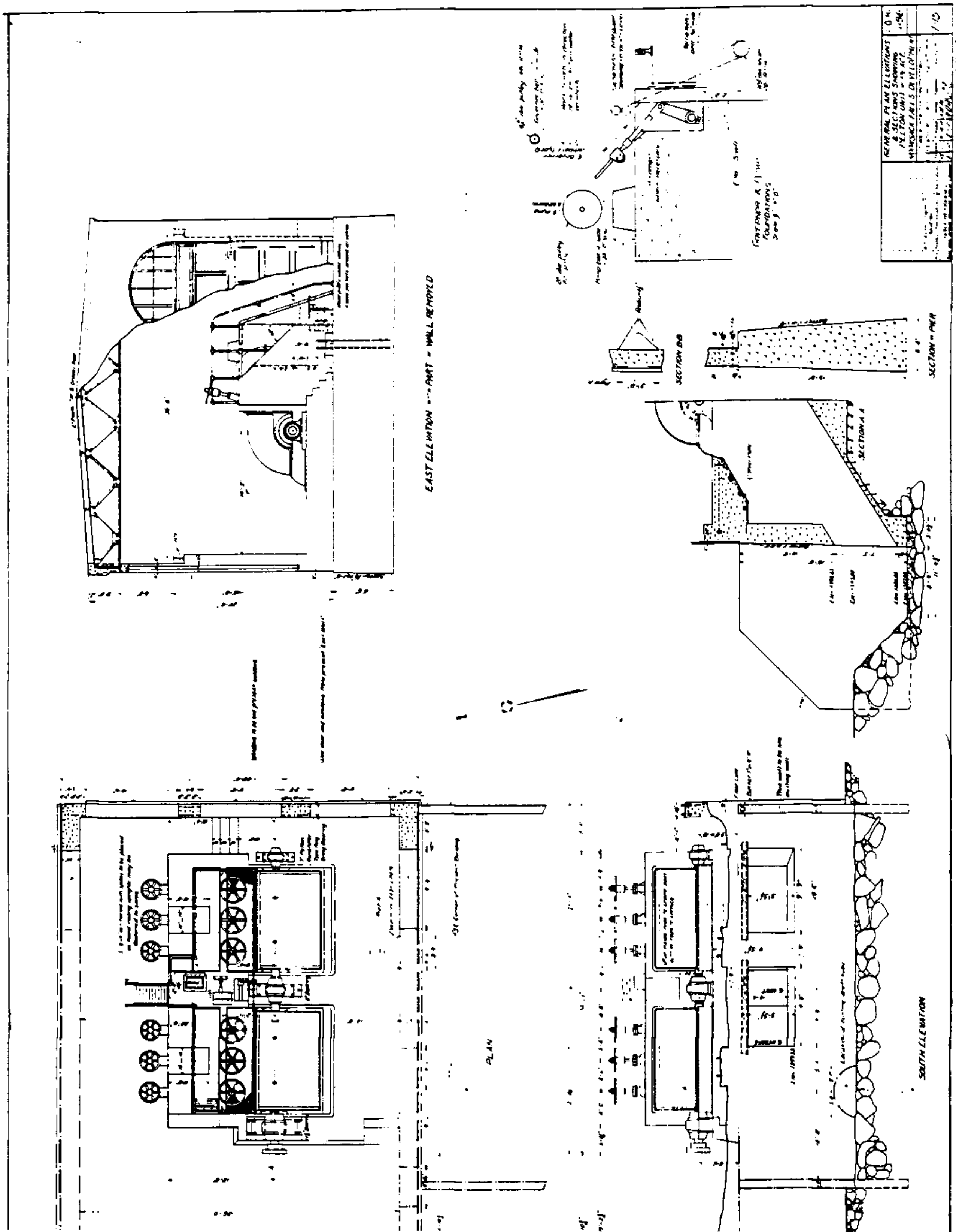
Don Blackman retired from the garage at Bellingham in 1965. He was brought back by the company for about two weeks in February 1966 to teach Doug Hamilton the necessary skills to work as a hydro-operator at Nooksack. Blackman has remained retired ever since.

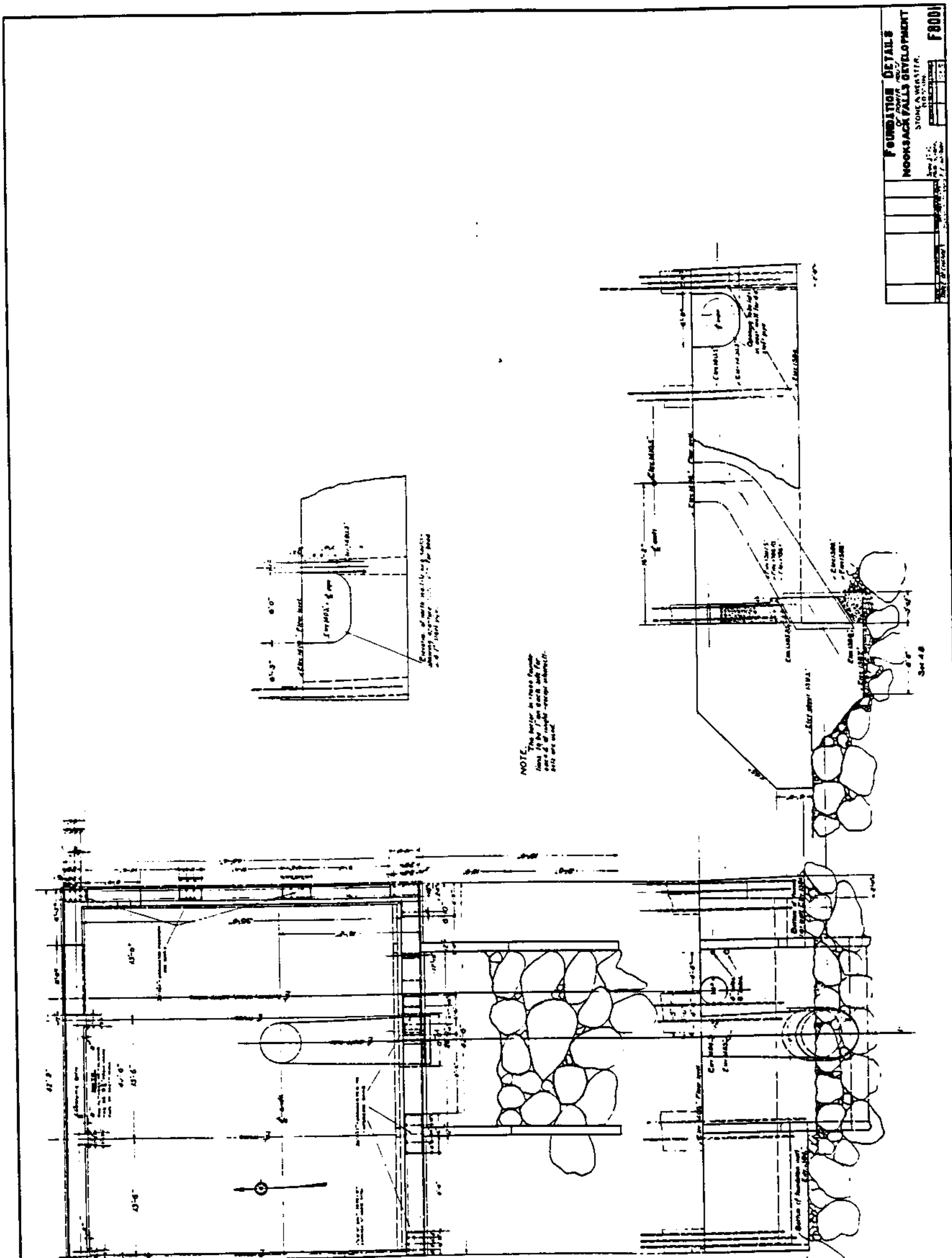
Standing 5'-5", Blackman was called the "strongest little man" at Nooksack. He was also called "Baldy" (he went bald as a fairly young man) and was considered very easy-going. He was especially well liked by the CCC boys whom he directed as a Forest Service ranger during the 1930s.

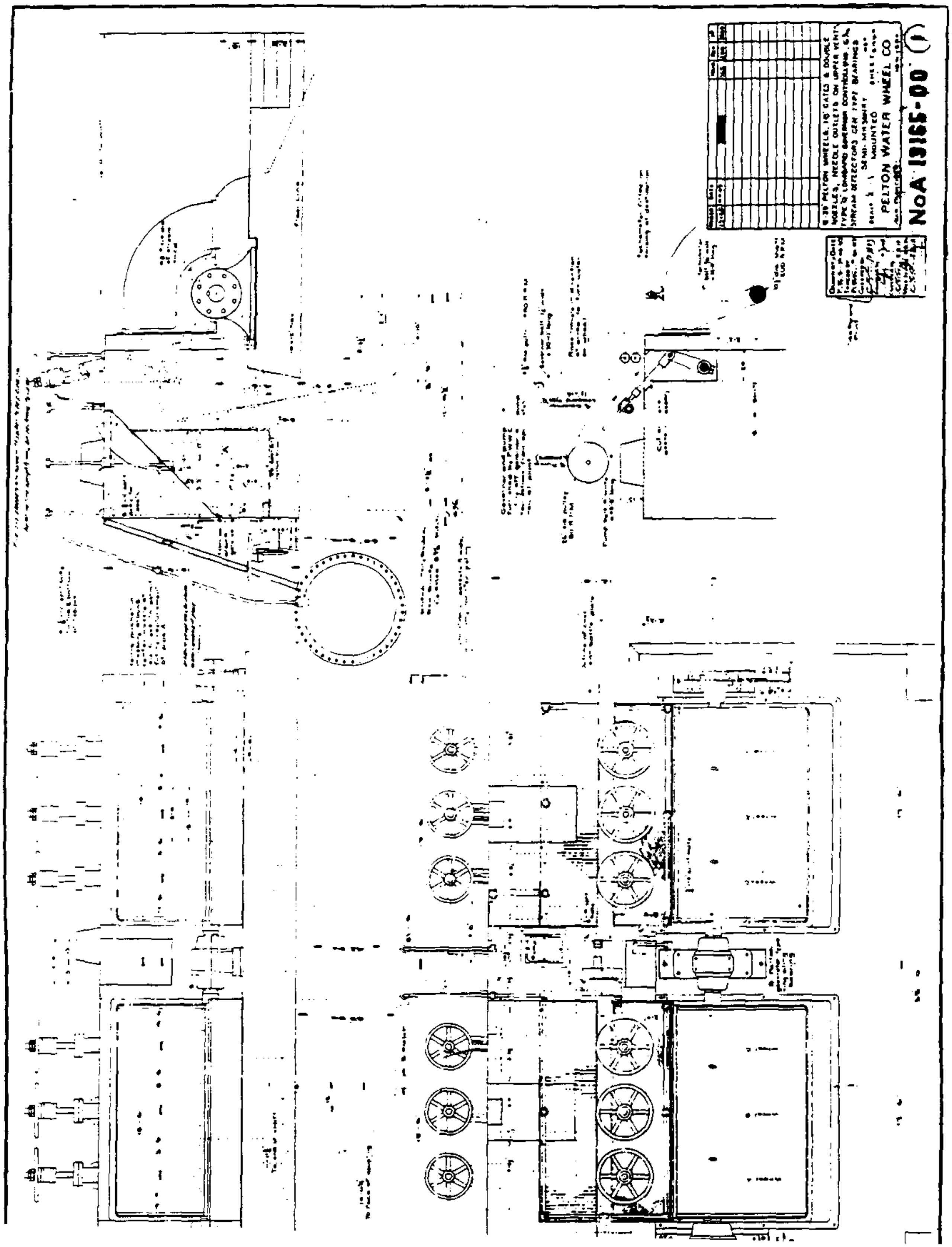
APPENDIX IV

Reduced Copies of Original Drawings of Nooksack Falls Development

Courtesy of Puget Sound Power & Light Company.




FOUNDATION DETAILS
NOOKSACK FALLS DEVELOPMENT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