BISHOP CREEK HYDROELECTRIC SYSTEM, PLANT 4,
POWERHOUSE NO. 4
Bishop Creek
Bishop vicinity
Inyo County
California

HAER CA-145-4-J
HAER CA-145-Z

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001

HISTORIC AMERICAN ENGINEERING RECORD

Bishop Creek Hydroelectric System, Plant 4, Powerhouse No. 4
Bishop Creek, Bishop vicinity, Inyo County, California
HAER No. CA-145-4-J

Location: The Bishop Creek Hydroelectric Powerhouse No. 4 (Powerhouse No. 4) is located on the southeast side of California State Route 168 in Inyo County, California. From the intersection of California State Route 168 (West Line Road) and U.S. Route 395 (Three Flags Highway) in the Town of Bishop, California, Powerhouse No. 4 is located approximately 5.28 miles southwest on California State Route 168 and 1.81 miles southwest on East Bishop Creek Road.

The approximate center of Powerhouse No. 4 is located at UTM Zone 11S, easting 366927.33m, northing 4131766.19m. Distances and coordinates were obtained on January 17, 2012, by plotting location using Google Earth. The coordinate datum is World Geodetic System 1984.

Present Owner: Southern California Edison Company
P.O. Box 800
Rosemead, California 91770

Present Use: Powerhouse No. 4 is a hydroelectric power generating facility that uses high-head impulse water wheels to generate electricity for transmission to distant customers, as it was originally designed and constructed to do. It is the largest and oldest in a chain of five similar power generating facilities located in the Bishop Creek system.

Significance: Powerhouse No. 4, a reinforced concrete industrial building originally constructed in 1905 by the Nevada Power, Mining and Milling Company, and expanded in 1908 by its successor, the Nevada-California Power Company, is a significant resource by virtue of its association with the earliest construction of the historic Bishop Creek Hydroelectric System and evidence it provides concerning the early expansion of the System.

The Bishop Creek Hydroelectric System Historic District is significant for its position in the expansion of hydroelectric power generation technology, its role in the development of eastern California, and its contribution to the development of long-distance power transmission and distribution. The System is significant under National Register of Historic Places criterion A (broad patterns of history) and C (distinctive characteristics of period and type of engineering and construction).). The Period of Significance for the

Bishop Creek Hydroelectric System is identified as 1905-1938.

Historian:

Matthew Weintraub, Senior Architectural Historian
Galvin Preservation Associates
231 California Street
El Segundo, CA 90245

Project Information:

The Historic American Engineering Record (HAER) is a long-range program that documents and interprets historically significant engineering sites and structures throughout the United States. HAER is part of Heritage Documentation Programs (Richard O'Connor, Manager), a division of the National Park Service (NPS), United States Department of the Interior. The Powerhouse No. 4 recording project was undertaken by Galvin Preservation Associates (GPA) for the Southern California Edison Company (SCE) in cooperation with Justine Christianson, HAER Historian (NPS). SCE initiated the project with the intention of making a donation to NPS. As recommended by Justine Christianson (NPS), the report describes how water flows in and out of the powerhouse to produce electricity, and a vital component of the report documents changes in operating machinery that have occurred over time. Archaeologist Crystal West (SCE) oversaw the project and provided access to the site. Historian Andrea Galvin (GPA) served as project leader. Architectural Historian Matthew Weintraub (GPA) served as the project historian. Jeff McCarthy, Supervisor of Operations (SCE), and Keith Inderbieten, Hydro System Operator (SCE), provided research assistance. Stephen Schafer produced the large format photographs. The field team consisted of Andrea Galvin (GPA), Matthew Weintraub (GPA), Crystal West (SCE), Neil Sliger (SCE), Stephen Schafer (photographer) and David Sanchez (photographer assistant).

Researchers can be directed to also see:
HAER No. CA-145-4, Bishop Creek Hydroelectric System, Plant 4;
HAER No. CA-145-4-A, Bishop Creek Hydroelectric System, Plant 4, Cottage No. 1;
HAER No. CA-145-4-B, Bishop Creek Hydroelectric System, Plant 4, Worker Cottage (Building 105);
HAER No. CA-145-4-C, Bishop Creek Hydroelectric System, Plant 4, Worker Cottage (Building 113);
HAER No. CA-145-4-D, Bishop Creek Hydroelectric System, Plant 4, Worker Cottage (Building 122);
HAER No. CA-145-4-E, Bishop Creek Hydroelectric System, Plant 4, Worker Cottage (Building 106);
HAER No. CA-145-4-F, Bishop Creek Hydroelectric System, Plant 4,

Worker Cottage (Building 115);
HAER No. CA-145-4-G, Bishop Creek Hydroelectric System, Plant 4, Worker Cottage (Building 116);
HAER No. CA-145-4-H, Bishop Creek Hydroelectric System, Plant 4, Worker Cottage (Building 117); and
HAER No. CA-145-4-I, Bishop Creek Hydroelectric System, Plant 4, Lightning Arrester Vault.

PART I. HISTORICAL INFORMATION

A. Physical History of Building:

The physical history of Powerhouse No. 4 was determined by reviewing available original construction drawings which were limited to a floor plan[1] and a machine foundation plan.[2] Also, drawings for alterations and additions to Powerhouse No. 4 which occurred after its original construction were reviewed.[3] These plans were retained by the power companies that successively owned and operated the plant (currently SCE). In addition, articles describing construction and operation of the powerhouse which originally appeared in the trade journals *Journal of Electricity Power and Gas*[4] and *Electrical World*[5] and reprinted by SCE were reviewed. They included a series of articles written by Charles O. Poole, who served as chief engineer of the Nevada-California Power Company. The building itself provided physical evidence of its history and development via field inspection,[6] as did historical photographs and contemporary drawings in the possession of SCE. Further information was found in previously completed HAER documentation[7] and evaluations of eligibility for listing in the National Register of Historic Places.[8] These sources provided thorough and detailed information regarding the historic design, construction, improvement and operation of the building.

Overview

Powerhouse No. 4 was constructed in 1905 by the Nevada Power, Mining and Milling Company, and it was expanded in 1908 by its successor, the Nevada-California Power Company. It was the first powerhouse to be constructed in the Bishop Creek system, and it is the third highest powerhouse at an elevation of 5,156 feet. Situated on the northwest

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[1] Nevada Power Mining & Milling Company, “Bishop Creek Power Plant Floor Plan Showing Arrangement of Machinery,” December 22, 1905.

[2] Nevada-California Power Company, “Foundation Plan Unit No. 5 for Power Plant No. 4,” April 22, 1908.

[3] Southern Sierras Power Company (SSPC), “Data for Roof of Power House No. 4 Area and Slopes,” May 11, 1928, revised July 27, 1928; California Electric Power Company, “Building Details Battery Room Plant No. 4 Bishop Creek,” November 29, 1956; SCE, “Building Roof & Wall Panel Details, Powerhouse No. 4,” June 12, 1991.

[4] Rudolph W. Van Norden, “System of Nevada-California Power Company and the Southern Sierras Power Company. Part 1 – Power Plants,” *Properties and Power Developments of the Nevada-California Power Company and the Southern Sierras Power Company*. Reprinted from the *Journal of Electricity Power and Gas*, Volume XXXI, Numbers 1-2, July 5-12, 1913, p. 1-20.

[5] C. O. Poole, “Hydraulic and electric features of stations Nos. 4 and 5 of the Nevada-California Power Company – Static head at the former station, 1100ft,” *Power Development and Transmission Systems of The Nevada-California Power Company and the Southern Sierras Power Company*, 1915, p. 27-31. Reprinted from *Electrical World*, New York, 1914.

[6] Field inspections were conducted on October 17 and December 7, 2011.

[7] Thomas T. Taylor, “Bishop Creek Hydroelectric System,” HAER No. CA-145, Historic American Engineering Record, National Park Service, U.S. Department of the Interior, 1994, p. 12-13.

[8] Robert Clerico and Ana Beth Koval, “An Architectural and Historical Evaluation of Structures Associated with the Bishop Creek Hydroelectric Power System, Inyo County, California,” Southern California Edison Company, December 1986, p. 24-29; Valerie Diamond, Stephan G. Helmich, and Robert A. Hicks, “Evaluation of the Historic Resources of the Bishop Creek Hydroelectric System,” Southern California Edison Company, July 1988, p. A-161-165.

bank of Bishop Creek, the powerhouse functioned as the main component of Power Plant 4, which included operational buildings, offices, residences, and accessory buildings. Powerhouse No. 4 was constructed as a single-story reinforced concrete industrial building in the Utilitarian early twentieth century industrial architectural style. As originally constructed, the building consisted of a large rectangular room that housed four impulse water wheel/generator units installed between 1905 and 1907, and a long wing that contained transformers. The power company expanded Powerhouse No. 4 in 1908-1909 in order to accommodate a fifth water wheel/generator and additional transformers. By 1927-1928, Powerhouse No. 4 operated with a combined capacity of 12,100 horsepower (h.p.) in water wheels and 6,750 kilowatts (kw) in generators. Transformers stepped up the voltage from 2,200 to 55,000 for long-distance transmission. Small additions to Powerhouse No. 4 were constructed between 1913 and 1928, and again more recently, and operations and machinery were incrementally improved over time. Currently, Powerhouse No. 4 operates as the oldest and largest powerhouse in the Bishop Creek system.

In 1913, the *Journal of Electricity Power and Gas* provided this general description of Powerhouse No. 4, which was originally constructed eight years previously and expanded five years previously:

> The power house building, while it has been added to to accommodate increased capacity, is substantially in construction like those of Nos. 2 and 3 [which were constructed after Powerhouse No. 4 in 1908 and 1913, respectively], being of reinforced column and curtain wall type, with corrugated iron roof of Fink steel trusses. There is a main bay for the generating units and a gable addition forming a bay almost as long as the main part, in which are placed the transformers. There are five main generating units placed with their shafts in line.[9]

In 1914, Charles O. Poole, chief engineer of the Nevada-California Power Company, described in *Electrical World* the economic factors that resulted in the expansion of the powerhouse and its facilities during and after its original construction:

> This station is the original station of the system, and the first units were installed in 1905, when the company was known as the Nevada Power, Mining & Milling Company. It was thought at that time that 3000 kw would be the maximum requirement, and the plant was designed accordingly. The original installation consisted of two 750-kw units, but the mining operations increased so rapidly that before the plant was put into operation a third unit of 1500-kw rating was ordered, and by the time

[9] Van Norden, "System of Nevada-California Power Company," p. 14.

that was installed a fourth unit was ordered, and so on until the development reached its present stage [with five units].[10]

1. **Date of Construction:**
According to Charles O. Poole, chief engineer of the Nevada-California Power Company: "Ground was broken on this plant in February, 1905, and on Sept. 20 electricity was delivered into Tonopah and Goldfield, a distance of 118 miles."[11] According to a history of the power company, *Iron Men and Copper Wires*, Powerhouse No. 4 was constructed during 1905 and: "On September 19, 1905, the first hydroelectric energy was delivered to Goldfield, and two days later, power went on in Tonopah."[12] Apparently Powerhouse No. 4 was already built and operating when a floor plan was drawn up in December 1905. The powerhouse was expanded at its north end in 1908 as indicated by a machine foundation plan for the addition of a fifth power generation unit dated April 1908.

2. **Architect/Engineer:**
The engineer of the original construction of Powerhouse No. 4 was John D. Galloway, who was listed as the civil engineer on a floor plan dated 1905. Galloway served as a consulting engineer for the Nevada Power, Mining and Milling Company. The engineers of the expansion of the powerhouse were (R. G.) Manifold & (Charles O.) Poole of Los Angeles, who were listed on a machine foundation plan dated 1908. Poole served as chief engineer of the Nevada-California Power Company. Other architects and/or engineers are not known.

3. **Builder/Contractor/Supplier:**
Powerhouse No. 4 was likely built by contractors and/or day labor force hired by the power company in 1905. "Ponderous generator parts were laboriously freighted up to the plant site, urged by long strings of mules. Pack trains and buckboard wagons carried material along an ever-lengthening road to where the power line was going up."[13] The powerhouse was probably expanded in 1908 by the Engineering-Contracting Co., which also constructed Powerhouse No. 3 in the Bishop Creek system that same year. Individual builders, contractors and material suppliers are not known.

4. **Original Plans:**
The powerhouse was constructed with concrete-over-aggregate foundation 10'0" deep and concrete walls 12" thick. The original building plan resembled a wide T-shape. The primary mass at the top of the T-shaped building had exterior dimensions of 82'0" x 32'0" and contained the main generator room. Concrete

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[10] Poole, "Hydraulic and electric features of stations Nos. 4 and 5," p. 27.
[11] Poole, "Hydraulic and electric features of stations Nos. 4 and 5," p. 27.
[12] Myers, William A., *Iron Men and Copper Wires: A Centennial History of the Southern California Edison Company*, 1986, p. 73.
[13] Myers, *Iron Men and Copper Wires*, p. 71.

columns that extended to the interior divided the long axis into five bays, of which the end bays were 15'0" wide and the middle three bays were 17'4" wide. Paired windows pierced the long walls of the generator room in the first, third, and fifth bays on the west side and the first and fifth bays of the east side (counting from south to north). The south end of the generator room was accessed by a man-door opening and it also contained a single window. The north end contained a large service opening and a pair of windows. At the building's west side, a small west wing projected from the fourth bay 7'0" in depth and 16'4" in width. The large east wing (the wide stem of the T-shaped building) projected from the center of the east elevation 23'3" in depth and 52'4" in width. The north wall of the east wing contained a large service door and a single window, the south wall contained two single windows, and the long east wall was blank.[14]

The powerhouse's generator room was originally designed and built with interior dimensions of 30'0" x 80'0" to house four water wheel/generator assemblies. Original specifications called for 750-kw generators, of which two were initially installed (at Units No. 1 and No. 2 in the south end) and of which the remaining two were substituted for larger and more powerful 1,500-kw generators during construction (at Units No. 3 and No. 4 in the north end), resulting in a total output capacity of 4,500 kw. The power generation units were installed in line with each other along the building's long axis, with the common centerline of the wheels, generators, and shafts located 11'8" from the interior west wall and 18'4" from the interior east wall of the generator room. The water wheels and direct-connected generators were mounted within pits that were cast into the poured concrete foundation. Units No. 1 and No. 2 were arranged with bilateral symmetry to each other so that the water wheels were located next to each other on the inside and the generators were located on the outside. Units No. 3 and No. 4 demonstrated the same bilateral arrangement. In the southeast quadrant of the generator room, the foundation contained a pair of exciter units arranged similarly to the main power generation units, with pit-mounted water wheels and generators (smaller than those used in the main units) center-aligned 8'4" from the interior east wall. The exciters produced direct current that was used to energize electromagnets within the main generators.

At the west side of the generator room, where the penstock feeder pipelines entered the concrete substructure, control pits housed the machinery that regulated the flow of water to the impulse water wheels. This regulating machinery, including gate valves, nozzles, power needles, and stream deflectors was operated primarily by hand-wheels. One bilateral set of pipelines, machinery, and wheel controls was located in a shared control pit at Units No. 1 and No. 2 and another

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[14] Contemporary sources widely report that Powerhouse No. 4 originated as an "L"-shaped structure that was later expanded into a "T"-shaped building. However, evidence indicates that the powerhouse originated as a "T"-shaped building that was first expanded into an "L"-shaped building and then shortly after that expanded into a larger "T"-shaped building.

bilateral set was located in the shared control pit at Units No. 3 and No. 4, which extended into a small west wing with interior dimensions of 6’0” x 14’4”. Additional machinery located within the generator room included a switchboard located to the east of the exciters, an oil pump located in the southeast corner, and another oil pump located in an open area along the east side. Along the long axis of the generator room, the rails of an overhead traveling crane (used to move heavy machinery within the building) ran on top of a reinforced concrete post-and-beam system that projected 12” into the generator room. At the east side of the generator room where the side wall opened into the large east wing, steel post-and-beam substituted for reinforced concrete beneath the crane rail. The large east wing, with interior dimensions of 21’9” x 50’4”, contained seven transformer units that stepped up the voltage of electricity for long-distance transmission. The transformers were installed close together in a row approximately 42’0” in length. Behind and above the transformers, an elevated concrete platform contained circuit breakers. Along the east side of the transformer wing, tracks for a transfer car (used to move transformers) ran the length of the room, aligned with the service opening at the north end.

Within three years of original construction and commencement of operation, the power company saw fit to expand the size and increase the generating capacity of Powerhouse No. 4. This expansion of the powerhouse may be considered a continuation of its construction because it occurred shortly after original construction and it was seamlessly integrated into the original building. According to photographic evidence, the powerhouse expansion of 1908 occurred in two separate phases. In the first phase, the north end of the transformer wing was extended by 14’10” the north, which filled in the recessed northeast corner of the original building, brought the north walls into the same plane, and resulted in an L-shaped building plan. However, a second phase of expansion which was completed in 1909 extended the generator room 19’0” to the north, which restored a T-shaped building plan to the powerhouse. The two phases of expansion involved the removal of the original north walls, reconstruction of north walls in new locations with windows and service openings in original configurations, and lengthening of side walls. At the generator room, the expansion added a sixth bay that was pierced at the east and west sides by pairs of windows that matched those installed in the original construction. The expansion resulted in an overall building length of 101’0” and a transformer wing that was 67’2” long at the east side. The original concrete post-and-beam wall section located in the fourth bay of the east wall of the generator room, which was enclosed by the expansion at the north end, was retained at the new interior as an open framed bay with an empty wall panel (which formerly contained a pair of windows) that allowed passage between the generator room and the transformer wing. The interior post-and-beam bay also supported the rails of the overhead traveling crane.

The expansion in 1908-1909 accommodated additional facilities that increased power generation and transmission capabilities. The expansion to the main generator room allowed for the installation of a fifth water wheel/1,500-kw generator assembly (Unit No. 5) located within the added bay and situated in line with the four previously existing units. A dedicated control pit with flow regulating machinery and controls was installed along the east wall next to the added power generation unit. It was arranged identically to the control machinery at Unit No. 4. Also, a third exciter unit was added near the center of the room in front of previously existing Unit No. 3. Also, three transformer units were added to the row of previously existing transformers within the east wing, which raised the total number of transformer units to ten (including one spare unit). The additional equipment resulted in a total generator capacity of 6,000 kw and transformers that stepped up the voltage from 2,000 to 55,000 for transmission on the Nevada-California and Southern Sierras systems.

Although available original construction plans do not provide complete information, photographic and physical evidence provide additional details of construction and early development. The powerhouse building was originally capped by a hipped roof at the main generator room and an intersecting gable roof at the transformer wing, both roofs with overhanging eaves. The small wing at the west side was covered by a shed roof that was an extension of the west eave. The roofs were originally sheathed in galvanized iron. At the primary hipped roof, a long gabled monitor straddled the length of the ridge with nine 3-light awning windows arranged in sets of three at each side. At the transformer wing, the upper wall of the east-facing gable end was pierced by a clerestory band comprised of six square windows regularly spaced. In 1908, the primary hipped roof was extended northward to cover the generator room addition and the rooftop monitor was lengthened to include a dozen awning windows on each side. Also in 1908, the transformer wing addition was capped by a second asymmetrical gable that was constructed next to the original gable and intersected with the primary hipped roof, resulting in a rather complex roof form. At the walls of the building, typical windows were double-hung wood sash, 6-light-over-1-light. At the interior, the long side walls contained recessed bays formed by the post-and-beam/curtain wall construction. The building was open vertically through the trusses.

5. Alterations and Additions:

Between approximately 1913 and 1928, three small exterior additions were constructed at Powerhouse No. 4 in order to accommodate improved operations and access. At the west side of the building, the existing small shed-roofed wing located in the fourth bay (counting south to north), which housed the control pit for Units No. 3 and No. 4 and valves for the penstock pressure line (No. 2), was extended 6’1” further from the west wall to 13’1” total. The extended wing contained a five-panel wood door in its south wall and a window in the north wall. At the second bay, a smaller shed-roofed addition was constructed 7’3” in depth and 10’0” in width, but it was not open to the interior of the powerhouse. This external addition housed valves for the penstock pressure lines (No. 1 and its by-pass connection to No. 2) and it was accessed by a two-panel wood door with diagonal boards in the panels and flat wood surround in its south wall. At the northeast recessed corner of the building, the construction of a small addition at the interior of the ell involved removal and covering of the large service opening at the north end of the east wing. The corner addition extended 8’5” along the north-south axis and 22’9” along the east-west axis, and it was set back 6” behind the existing east wall of the main building. It was capped by a sloped corrugated metal roof with overhanging eaves and it contained a two-panel wood door at its north side and a pair of 16-light-over-4-light, double-hung wood windows at the east side. The corner addition housed personnel work spaces and facilities and it was accessed at the interior through the east wing.

In 1928, steel sash replaced original wood sash in existing window openings. Also in 1928, the original metal roof was replaced with a new redwood roof covered by asbestos shingles. Between approximately 1928 and 1988, a gabled dormer with louvered metal vent was added to the south side of the larger roof gable, and the sloped roof at the northeast corner addition was replaced by a lower flat roof. Reroofing occurred again in 1991 when all roof surfaces were covered by metal panels with metal ridge caps. After 1988, two small additions were attached at the west wall, neither of which involved piercing or removing the original exterior wall. One of these additions was constructed at the original valve wing in the fourth bay which was previously expanded between 1913 and 1928. This newer shed-roofed addition with metal panel cladding and solid metal double doors was built onto the existing south side, though it did not open into the valve wing or the generator room. Adjacent to the small wing in the second bay that was added between 1913 and 1928, a similar, larger shed-roofed, metal-clad addition with double doors was constructed. These recent additions narrowed the open space between the small west wings but did not cover the windows located in the third bay. Over time, the original doors in the building were replaced, with the single exception of the wood door with diagonal boards located in the small west wing in the second bay which was constructed between 1913 and 1928.

Other changes at the interior have occurred. A major facilities change that was planned in 1914 and that occurred at about the same time involved removal of the transformers from the interior of the building as a fire prevention measure. This change allowed for repurposing of the internal volume of the east wing (the former transformer wing), including addition of equipment and partitioning over time. In the long east wall, which was previously blank except for clerestory windows in the original gable end, a window was added near the southeast corner. In 1956, a battery room measuring 8’0” x 12’0” was constructed in the southeast corner of the east wing. The battery room walls were 8’0” tall and constructed of 8” x 8” x 16” concrete-block. It was capped by a flat concrete slab roof 6” thick that projected 2” beyond the plane of the walls. The battery room was accessed from the interior of the powerhouse by a metal door with a louvered panel located in the west wall. The battery room was vented at the exterior by a metal louver that was installed in the south wall of the east wing. In 1965, a control room measuring approximately 24’0” x 23’6” was constructed within the north end of the east wing. The original concrete post-and-beam wall bay that was retained and enclosed when the north end was expanded in 1908-1909 became part of the west wall of the control room. The bay, which originally contained a pair of windows that opened to the exterior, was filled with a metal-framed office window above a stucco panel. The control room extended beyond the concrete post-and-beam and into the internal volume of the east wing as a rectangular framed enclosure with stuccoed walls and flat slab roof. Interior access to the control room was provided by doors located in the added west wall and in the southeast corner. The control room became the connection between the main volume of the powerhouse and the northeast corner addition, built between 1913 and 1928, which contained the north end entry vestibule, a communications room, and a lavatory (from east to west).

B. Historical Context:

The following historical context was included in previously completed documentation which established the eligibility of the Bishop Creek Hydroelectric System for listing in the National Register of Historic Places.[15]

The turn of the twentieth century saw a dramatic change in technological history. The production of cheap, dependable hydroelectric power, and the ability to transport the power over great distances, was perfected at this time. In short order, drainages with sufficient flow for hydroelectric power generation began to be developed. By 1923, the only suitable streams draining the east slope of the Sierra Nevada which were not being used for electricity production were the Carson and Walker river systems. The first hydroelectric power generation along Bishop Creek was a small plant operated by the Bishop Light and Power Company. The facility was reported to be a half mile west of the Standard Flouring Mills (present site of Plant 6) and two and a half miles from the town of Bishop. The plant consisted of a Stanley polyphase generator (capable of 150 horsepower) driven by a 48-inch Pelton wheel. The power was generated for local use.

Through the efforts of Loren B. Curtis, an engineer, and Charles M. Hobbs, a banker and financier, the Nevada Power, Mining and Milling Company was incorporated on December 24, 1904. The first facility built by the Nevada Power, Mining and Milling Company was put into operation in September, 1905, supplying hydroelectric power to the mining communities of Tonopah and Goldfield, Nevada. Executives of the power company had purchased controlling interest in the locally operated facilities in Tonopah and Goldfield, so that, when production began, there was a market ready for their

[15] Clerico and Koval, “An Architectural and Historical Evaluation,” p. 5-12.

product. The original transmission line extended east across Owens valley, the White Mountains, Fishlake Valley, and the Silver Peak Range to the town of Silver Peak in Clayton Valley. Here the line split, diverging northeast to Tonopah and due east to Goldfield. The line distance from Bishop Creek to Goldfield was 95 miles, and that to Tonopah was 118 miles. This was a new record for long distance transmission. On January 5, 1907, the Nevada-California Power Company, successor to the Nevada power, Mining and Milling Company, was incorporated; most of the original corporate officers remained with the new company.

Between 1905 and 1913, four more generating plants were placed on line, in tandem along Bishop Creek, and additional generators were placed in existing plants. As a result of this additional power generation, the “Tower Line” from Bishop to San Bernardino was completed in 1912 and put into operation, again creating a new record for long distance transmission (239 miles). The directors of the Nevada Power, Mining and Milling Company were well aware of the vicissitudes of the boom-bust mining industry and took steps to secure a more constant market for their product. In 1911, the Southern Sierra Power Company was incorporated with the main purpose of creating and servicing the power needs of southeast California. From then until 1918, several smaller power companies were purchased by the new company. The development of southern California's Imperial Valley corresponds directly with Bishop Creek's production of cheap, reliable electricity.

By the end of 1913, the Bishop Creek system was essentially complete with all five plants operating. In descending order down the drainage, the Bishop Creek facility then consisted of:

> Power Plant 2: Three Westinghouse generators, each capable of 2,000 kw of power (total output of 6,000 kw). Units 1 and 2 were driven by Pelton wheels and unit 3 by a Doble wheel.
>
> Power Plant 3: Three Crocker-Wheeler generators, each capable of 2,250 kw of power (total output of 6,750 kw). All three units were direct connected to Henry impulse wheels.
>
> Power Plant 4: Five generating units consisting of: two National Electric Company, 750 kw, generators connected to Pelton wheels; one Bullock, 1,500 kw, generator driven by a Pelton wheel; one Allis-Chalmers, 1,500 kw, connected to a Pelton wheel; and one Allis-Chalmers, 1,500 kw, machine driven by a Doble wheel (total output of 6,000 kw).
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> Power Plant 5: Two generating units, one of which was a 1,500 kw, Allis-Chalmers machine driven by a Doble wheel and the other a 1,850 kw unit connected to a Pelton-Francis wheel (total output of 3,350 kw).

Power Plant 6: A single generator capable of 2,250 kw driven by a Pelton-Doble wheel.

It is interesting to note that Power Plant 1 was to have been built at the present site of Intake No. 2, but the plant was never built due to the vulnerability of the site to avalanches. The plant number designators were not adjusted accordingly, so that there is no Power Plant 1, nor has there ever been.

In 1936, the Nevada-California Electric Corporation again was reorganized to become an operating company. The corporation became California Electric Power Co. and continued to operate under this name until 1964, when the company known as Calectric was subsumed by Southern California Edison Company. Since 1964, as a result of acquisition through merger consolidation, Southern California Edison (SCE) has owned and operated the Bishop Creek plants.

PART II: SITE INFORMATION

A. General Description of Building:

The following description of Powerhouse No. 4 incorporates information included in previously completed HAER documentation[16] and evaluations of eligibility for listing in the National Register of Historic Places.[17] This information was verified and new information was gathered via field inspection to inform the building description.[18]

Overview

Powerhouse No. 4 is a one-story, reinforced concrete industrial building resting on a deep concrete foundation and topped by a redwood-and-metal, combination hipped-gable roof. It was designed and constructed in the Utilitarian industrial architectural style. It has a slightly irregular T-shaped plan. The main volume houses five hydroelectric power generation units which are mounted in the concrete foundation and driven by impulse water wheels.

Exterior

Powerhouse No. 4 is a one-story, T-shape-in-plan, reinforced concrete industrial building resting on a deep concrete foundation. A tan, rough-textured stucco covers the exterior. The building is covered with a hipped roof over the primary rectangle of the building, which houses the generator room, and intersecting, asymmetrical east-facing double gables at the large east wing. The transition from side walls to roofs is accomplished with very simple, square-in-section, sheet metal cornices. Small wings that project along the west wall are capped by shed roofs in multiple planes, while the northeast corner addition is covered by a shallow hipped roof. All roofs are sheathed in pressed metal panels. The primary hipped roof is topped by a long, gabled monitor with a dozen 3-light, top-hinged metal windows per side, which straddles the length of the ridge. A smaller gabled dormer with a metal louvered vent is located atop the south side of the larger, original gable roof.

The long east and west walls of the powerhouse are six bays long as defined by internal post-and-beam construction. The large east wing occupies bays two through five on the east side (counting south to north). A series of four small, boxy shed-roofed wings project from the second and fourth bays of the west wall, and they cover portions of the third bay. The regular fenestration pattern at the long east and west walls consists of pairs of windows located in each non-wing bay, including the first, third, fifth, and sixth bays of the west wall and the first and sixth bays of the east wall. The somewhat irregular fenestration pattern at the rest of the building includes: a pair of windows in the north end wall of the generator room; a single window in the south end wall; a single window in the north wall of the original west wing; and single windows in the north, south and east walls of the large east wing. Typical windows are slightly recessed in openings with

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[16] Taylor, “Bishop Creek Hydroelectric System,” p. 9-11.
[17] Clerico and Koval, “An Architectural and Historical Evaluation,” p. 33-52; Diamond, Helmich, and Hicks, “Evaluation of the Historic Resources,” p. A-67-71, A-117-119.
[18] Field inspections were conducted on October 17 and December 7, 2011.

stucco surrounds, metal-framed, single and double 3-light-over-6-light-over-3-light wire glass. Upper and lower window sections are fixed and middle sections are center-hinged and covered by security grates. At the larger gable end, which is the original gable, the upper wall section is pierced by six square 6-light windows with top-hinged metal sash that form a horizontal band. Entrances to the building include: a solid, two-panel wood door located within a large, recessed stucco surround with well-defined wall angles at the south end (the original entrance to the powerhouse); a solid, two-panel wood door with diagonal boards in the panels and flat wood surround in the first west wing (counting from south to north) which appears to be the only extant original door; solid metal double doors in the second and third west wings; a solid metal single door in the fourth west wing; a corrugated metal roll-up door in the large service opening at the north end of the generator room; and a single-light metal door at the northeast corner addition.

The concrete foundation of the powerhouse extends to the east side of the building as a wide concrete apron with a substructure that is partially exposed by the downward slope of the creek bank in this direction. At the northeast and southeast corners of the concrete substructure, steps run from grade to subsurface metal doors/hatches that provide access to chambers within the substructure.

Interior

The interior of Powerhouse No. 4 is T-shaped and mostly open in plan, with partitioned rooms located within the north and south ends of the east wing. Several small additions at the west side are entirely walled off from the interior of the main building. The main rectangle of the building, the generator room, houses five water wheel/generator assemblies mounted within pits in the concrete floor and located in a line along the long axis of the room. In the southwest quadrant of the generator room, around the water wheel mountings for Units No. 1 and No. 2, the concrete floor is raised several feet above the main floor level and it is accessed by short flights of concrete steps at either side of the units. Around Units No. 3, No. 4, and No. 5, areas of the concrete floor are raised several inches above the main floor level. Along the west side of the room and located adjacent to the power generation units, machines related to their operation and control are installed in floor pits. Machinery pits are covered by bolted metal foundation plates that provide flooring in areas around the equipment. The east side of the power generation room is not occupied by machines or structures and it is open between the north and south ends of the building. The interior walls are finished in smooth stucco. The long side walls are subdivided into bays by structural pilasters that extend to the interior. An overhead traveling crane is mounted on rails supported by a post-and-beam system that is integrated into the structural system of the long walls. The building is open vertically through the Fink steel trusses and the underside of the redwood roof is exposed.

The generator room opens into the original small wing located in the fourth bay at the west side and into the larger wing located at the east side. At the west side, the small rectangular wing contains valves, pumps, and other mechanical equipment that is associated with the penstock pipelines and the water wheel units. At the east side, the volume of the large wing that originally housed transformers is partially partitioned. A small concrete-block battery room with metal door occupies the southeast corner and a stucco-clad control room projects into the volume from the north end. The control room provides access to other partitioned rooms at the north end, including a lavatory and a communications room. A section of the control room's west wall is comprised of a concrete post-and-beam bay that is filled with a metal-framed office window and a stucco panel. To the south of the post-and-beam bay, the west wall of the control room contains a glazed wood door with large transom. A second door, solid wood, is located at the southeast corner of the control room. Between the control room and the battery room enclosures, the east wing contains (from north to south): two rows of exciter units in metal cabinets; an open freestanding steel framework that supports electrical buswork; and an open area.

Forming a line along the middle of the generator room are found the five power generation units with original water wheel housings, original generator housings and rotors, and original shaft mountings. The wheel housings are semicircular, made of riveted cast iron, and bolted to the floor over the operating water wheels. The generator housings are donut-shaped with open interiors, also made of cast iron, and are suspended around the stator cores and rotors. At Units No. 1 and No. 2, the identical wheel housings contain pedestal-like bases with raised lettering that lists information about the original manufacturer: PELTON WATER WHEEL COMPANY, SF, 1905, NY. They also feature metal nameplates affixed to the exterior rims of the housings that are imprinted: THE PELTON WATER WHEEL CO, HYDRAULIC ENGINEERS, SAN FRANCISCO AND NEW YORK, USA. On the housings of the direct-connected generators at Units No. 1 and No. 2, metal nameplates attached to the rims are imprinted with the original manufacturer's information: NATIONAL ELECTRIC CO., MILWAUKEE, U.S.A., PATENTS PENDING; followed by original operating specifications. The wheel housing at Unit No. 3 is identical to those at No. 1 and No. 2, with the same Pelton-signature pedestal base and Pelton manufacturer's plate affixed to its rim. On the generator housing at Unit No. 3, an imprinted metal plate affixed to the rim is shaped like a shield and contains a stylized banner proclaiming the original manufacturer, BULLOCK, followed by: ELECTRIC MFG CO., CINCINNATI, O., U.S.A.; and its original operating specifications. The identical wheel housings at Units No. 4 and No. 5 feature raised lettering on their sides denoting the maker of the original wheels: DOBLE, SAN FRANCISCO. The identical generator housings at Units No. 4 and No. 5 retain original manufacturer's nameplates affixed to the rims, imprinted: ALLIS-CHALMERS CO., MILWAUKEE, WIS., U.S.A., BULLOCK TYPE.

1. **Character:**
   Powerhouse No. 4, the oldest and largest of the powerhouses of the Bishop Creek system, is significant primarily as a physical record of early development in the system. The physical characteristics of the building that reflect this character include (but may not be limited to): building/wing massing; complex hipped roof with intersecting double gables; fenestration and entrance pattern, steel-sash

windows; stucco wall cladding; generally open floor plan; interior side walls with post-and-beam recessed bays; and exposed interior roof volume and structure. Also, the original variously sized wheel housings, generator housings, and unit mountings that characterize the interior, and that are directly connected to the early development of the Bishop Creek system and the expanding power market, are extant. Although the wing that originally housed transformers was repurposed, including removal of all materials that were historically extant when long-distance transmission records were set, the volume of the original wing was retained even with interior partitioning. The material changes and small additions that have occurred at the exterior and interior are not necessarily characteristic, but they are subordinate to the essential historic character of Powerhouse No. 5, which remains evident. Powerhouse No. 4 continues to operate and it serves as an excellent example of a Utilitarian, early twentieth century California hydroelectric power plant.[19]

2. **Condition of Fabric:**
   Powerhouse No. 4 is in good physical condition. Visible damage/deterioration at the exterior is limited to a few isolated cracks in the stucco facing and localized areas of chipped stucco at window surrounds. Windows and doors are operable. The roof is intact, including the metal paneled exterior and the redwood under-siding. Likewise, the interior is in good physical condition. The concrete floor and foundation appear sound, with heavy operating machinery and metal foundation plates bolted into place. The stucco facing at the interior perimeter walls is intact.

B. Site Layout:

Powerhouse No. 4 is situated on the northwest bank of Bishop Creek, which runs off the steep eastern slopes of the Sierra Nevada. It is located on the southeast side of California State Route 168 and is accessible via East Bishop Creek Road. The powerhouse is part of a complex of buildings that comprise Power Plant 4, which is located primarily on the northwest bank and partially on the southeast bank of Bishop Creek. From the outset and continuing to the present, centrally located Power Plant 4 functioned as the operational headquarters of the Bishop Creek Hydroelectric System with the largest assortment of support buildings and the largest community of worker housing. The plant currently consists of 41 buildings, including: the powerhouse; a valve house; a transformer vault (originally a meter house); an administrative office building; a recreation hall (originally the office building); 12 residential buildings ("neat and tasty cottages for superintendent and operators and their families."[20]); and 24 accessory buildings including workshops, fire equipment houses, sheds and garages. Most of the buildings in the plant are located in and around the area circumscribed by East Bishop Creek Road and the County Road, which form an elongated loop through the complex and which involve two crossings of Bishop Creek. At the northern end of the complex, a third creek crossing provides access

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[19] Changes to Powerhouse No. 4 that occurred during the identified Period of Significance for features that contribute to the Bishop Creek system, 1905-1938, are considered significant.
[20] Van Norden, "System of Nevada-California Power Company," p. 15.

to a few buildings located on the southeast bank of Bishop Creek. The terrain surrounding Power Plant 4 consists of steep canyon walls covered with natural vegetation.

In 1913, the *Journal of Electricity Power and Gas* highlighted the unique and impressive scenic qualities of Power Plant 4 in this description of its site and setting, which generally remain accurate nearly a century later:

> Approaching the canyon from the town of Bishop, one rides some four miles between rich fields of alfalfa and more directly between stately rows of poplars before the first slope which is soon to rise very abruptly towards the mountain peaks, is reached. Another mile and the chauffeur (if you are so fortunate as to be riding in an auto.) puts in the intermediate gear, although the country looks fairly level, but the trees are missing and the granite boulders are thick among the clumps of sagebrush. The canyon is entered between two abrupt hills that would look very high were they not dwarfed by the snow covered peaks which seem to rise directly behind them. About a mile ahead as one looks up the canyon there appears a large and picturesque group of buildings, their red and green roofs interspersed with trees and shrubbery, a very bright and inviting spot nestled into a turn of the towering canyon. One might easily imagine it to be a well ordered summer watering place. The grounds are entered through a quaint lodge gate and the macadamized and concrete parapeted road lined with tasty electroliers divides, passing around both sides of the canyon to meet in a wide sweep above the buildings. The creek, rocky and precipitous, has been confined between heavy concrete walls, as is done in the Swiss Alps, and where it widens in the center of this settlement, a sort of sunken gardens, a triumph of the landscape artist, forms an island which dips into the little lake below it. And all this, because in its midst is No. 4 power plant, the first and oldest in this remarkable chain of plants.[21]

[21] Van Norden, "System of Nevada-California Power Company," p. 13.

PART III: OPERATIONS AND PROCESS

A. Operation:

This section describes the process that creates hydroelectric power at Powerhouse No. 4, in the context of Power Plant 4 and the chain of power plants that comprise the Bishop Creek Hydroelectric System. This section is divided into two subsections: (1) Basic Components of Hydroelectric Systems, which provides a general background for understanding the operations of hydroelectric plants; and (2) Operation of Plant 4, which describes how water moves through the power plant in order to drive turbines and generate electricity that is transmitted long distances.

Basic Components of Hydroelectric Systems

In a hydroelectric power generating unit, the force of moving water is used to spin a turbine (or "water wheel"). A turbine is connected via a shaft to a rotor, the moving part of an electric generator. The movement of the turbine spins the rotor within the generator and sweeps coils of wire past the generator's stationary coil, or stator, which produces electricity. Once electricity is produced, transformers raise the voltage to allow transmission over long distances through power lines.[22]

The following explanation of hydroelectric systems was included in a previously completed evaluation of eligibility for listing in the National Register of Historic Places.[23]

There are two basic types of hydroelectric systems. The first of these, low-head hydro, uses a large volume or mass of water from relatively low dams in order to turn the angled surfaces of screw-shaped turbines. The other type, high-head hydro, uses streams with relatively low volume flows, where water is diverted away from the natural stream course and elevated by artificially reduced fall far above the natural stream through a man-made canal or pipeline. At some point downstream the water is directed downslope were it achieves a very high pressure. The water at the base of the slope is directed against a bucketed wheel which receives an energy impulse by its impact.

The basic features of a high-head hydro system, of which the Bishop Creek Hydroelectric System is an example, are outlined below.

1. Water from a stream channel is separated from the natural stream using a diversion dam, headgates, screens and a spillway. The headgate regulates the flow of water, while the screens prevent debris from entering the water conduit. The reservoir behind the intake dam acts as the principal regulator of the water flow, allowing excess water to escape into the natural water channel. The dam,

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[22] U.S. Department of the Interior, Bureau of Reclamation Power Resources Office, "Reclamation: Managing Power in the West – Hydroelectric Power," July 2005, unpaginated. Found at http://www.usbr.gov/power/edu/pamphlet.pdf, accessed on January 30, 2012.
[23] Diamond, Helmich, and Hicks, "Evaluation of the Historic Resources," p. 10-11.

headgate, and regulating and cleaning apparatus are all known collectively as the *intake.*

2. Following intake, water is conducted by flumes or canal systems, pipes, tunnels or siphons (pipes in the case of Bishop Creek). The length of the system varies greatly, depending on the area's topography and amount of water-pressure desired. Sluices and sandboxes are usually built into the system to allow sand and gravel, which could clog or damage the downstream equipment, to settle out of the water. *Flowlines* generally incorporate pressure-relief valves, installed at regular intervals along their length. These open and permit outside air to enter the line to prevent the line from collapsing should there be an accidental break in the pipe. A large vacuum would normally be formed by the sudden acceleration of water through a break, which could easily destroy either wood or steel pipe.

3. At the end of the canal system, a pipe is installed as nearly vertical as conditions will allow providing the water pressure needed to operate the water wheel(s). This pressure pipe is known as a *penstock.* At the top of this pipe is a small reservoir, expansion tank or standpipe (standpipe in the case of Bishop Creek) which helps to regulate and smooth the flow of water within the penstock.

4. A *powerhouse* is located at the bottom of the penstock. This consists of a building within which is housed the power generation and distribution equipment. The machinery within the building includes water wheels, generators, batteries and exciters. Exciters provide direct current to energize the electromagnets within the larger alternating current generator(s). The powerhouse also includes the distribution equipment used to initiate transmission of electricity. This equipment consists of switches, circuit breakers and related controls which are connected to a nearby transformer. The transformer increases voltage so that power can be transmitted over long distances. The powerhouse also contains a variety of other apparatus used in the operation of the system. This often includes a small generating unit to operate the powerhouse lights and equipment, as well as telephone links with other system components. Other buildings associated with the operation of the hydro system are usually located in close proximity to the powerhouse(s). These may include such facilities as administrative headquarters, garages, housing for system personnel, equipment storage sheds, pump houses, and machine shops.

5. Where there is more than one power-generating source, it is not uncommon for there to be a *control station* where the transmission of energy may be monitored and regulated. If electrical generating facilities are close by, many functions may be automated or operated from a centralized control point; the control station may serve this additional function.

6. *Transmission lines* carry power to users. Normally a step-down transformer is used near the point-of-use to reduce the voltage to normal house currents.

Operation of Power Plant 4

At Plant 4, the static head of water (or vertical drop in elevation from intake to water wheel) is 1,112 feet. From Intake No. 4, an equalizing pond located immediately below the tailrace of Plant 3, the next highest plant in the system, water is transferred via Flowline No. 4, a metal pipeline (6,820 feet long) that runs along the crest of a moraine that comprises the northwest wall of Bishop Creek Canyon.[24] The next stage of water transfer involves two riveted steel penstocks that originate at the flowline and descend steeply down the face of the moraine, thereby delivering water at accelerated velocity to Powerhouse No. 4 located deep within the canyon. The penstock known as Pressure Line No. 1 (5,314 feet long) takes a more direct route to the powerhouse, while Pressure Line No. 2 (5,665 feet long) veers to the north.[25] After water passes through the powerhouse, it drops into tailrace channels located within the deep concrete substructure. The tailraces exit the substructure on the east side as large concrete-lined, square-bottomed channels that spill directly into Intake No. 5. A single tailrace exits from the south end of the substructure and a double-channel tailrace conveys water out of the north end.

At the powerhouse site, the No. 1 and No. 2 penstock lines converge in parallel and approach the concrete foundation below grade from the west side. Each of the main penstocks enters Powerhouse No. 4 at one of the small west wings which house valves that are used to control and potentially divert water flow before it reaches the water wheels. Pressure Line No. 1 enters at the southernmost wing, while Pressure Line No. 2 runs through the wing located near the center of the building. The small wing that receives the No. 1 line was constructed between approximately 1913 and 1928. It encloses a crossover valve on the No. 1 line that was originally located just outside of the west wall of the powerhouse. This crossover valve controls flow to a short header that connects the No.1 line, which does not contain a main valve or a bypass, to the No. 2 line, which features a main valve and bypass, as well as secondary valves and bypasses at its feeder pipes. The main valve and bypass valve on Pressure Line No. 2 are housed within the original, centrally located wing that was constructed at the west wall of the powerhouse in 1905. On its approach to the powerhouse, the No. 2 line originates two additional pipelines that branch off the main penstock and follow separate paths to the building: a penstock known as the No. 3 line; and a pressure line originally used for water-driven exciters and now discontinued. The No. 3 penstock line enters the foundation of the powerhouse at the north end that was expanded in 1908. Its main valve and bypass valve are located west of the powerhouse and within a small detached accessory structure known as the Valve House (Building No. 127), which is the only operating example of a dedicated valve house in the Bishop Creek system.[26]

[24] Flowline No. 4 was originally a redwood stave pipe that was replaced between 1958 and 1968.
[25] The original penstock pipelines were replaced between 1951 and 1953.
[26] The only other example of a dedicated valve house in the Bishop Creek system occurred at Plant 3, constructed in 1913. The building that served as the valve house at Plant 3 is extant but it currently functions as a battery house.

Within the substructure, the two main penstocks split into "Y" divisions that supply water to pairs of water wheels. At the south end of the building, the No. 1 penstock line (24" diameter) splits into two feeder pipelines that lead to the impulse water wheels of Units No.1 and No. 2. These paired units are arranged bilaterally in "A-B-B-A" configurations with the water wheels located at the "inside" along the penstock feeder lines and the generators located on the "outside". Similarly, the No. 2 penstock line (30" diameter) splits into separate pipelines that are directed to impulse water wheels at Units No. 3 and No. 4, which are also arranged with bilateral symmetry in the "A-B-B-A" configuration. The No. 3 penstock line (18" diameter) at the north end of the building runs directly to the impulse water wheel at Unit No. 5, which is not paired with another unit and which is arranged identically to Unit No. 4. Thus, the resulting pattern of generators ("A") and water wheels ("B") from south to north within the powerhouse is: "A-B-B-A-A-B-B-A-B-A". This pattern also applies to the arrangement of control pits and machinery at each unit that regulates the flow of water from the penstock feeder pipes to the impulse water wheels, including gate valves, nozzles and power needles, stream deflectors, and governors. At the paired units – No. 1 and No. 2; and No. 3 and No. 4 – the control pits and machines are arranged with bilateral symmetry around the "Y" divisions of the penstocks. At Unit No. 5, the control pit and machinery repeat the arrangement found at Unit No. 4.

Currently, Powerhouse No. 4 operates with solid-state exciter units which consist of non-moving electrical machinery housed within metal cabinets. The exciters are used to produce direct current that is used to energize electromagnets within the main water wheel-driven generators. Five exciter units, which correspond to the five power generation units, are installed in two parallel rows within the east wing of the building just outside of the control office. Originally, Powerhouse No. 4 housed water-driven exciters, which consisted of pit-mounted water wheels and direct-connected generators that were similar to those found at the main power generation units but smaller. The original two exciters installed in 1905 were located directly in front of Units No. 1 and No. 2. They were supplied water through the concrete substructure by feeder pipes from Pressure Line No. 1, which also supplied water to the power generation units. This internal pipework for the exciters followed a long "X" shape in plan, with feeder lines that captured water from the branches of the No. 1 line and joined into a single pipe that split again at the exciter wheels. The exciter pressure line contained valves at the main trunk and at each of the exciter feeds within the generator room. In 1908-1909, a third water-driven exciter was installed in front of Unit No. 3. The added exciter unit was connected to a dedicated penstock line that branched from Pressure Line No. 2 west of the powerhouse and ran between the No. 1 and No. 2 penstock lines. This added line was fitted with a valve near the exciter within the generator room. The water-driven exciters were retired between 1984 and 1987, when the modern solid-state exciters were installed.

The electricity that is produced by the water-driven impulse units at Powerhouse No. 4 is transmitted via cables to transformers located outside of the building. The transformers "step up" the voltage for transmission over long distances to distant customers. Originally, Powerhouse No. 4 contained the plant's transformers within its long east wing, one of only two powerhouses to keep in-door transformers in the Bishop Creek system.[27] It was constructed with seven transformer units in 1905 and expanded to ten transformer units in 1908. The transformers were located in a long row within the east wing. However, this arrangement changed in keeping with the designs of the later phase of power plants in the Bishop Creek system, as explained in 1914 by Charles O. Poole, chief engineer of the Sierra-Nevada Power Company: "It will be seen that the transformers are under the same roof as the generators, but arrangements are now being made to move the transformers outdoors, thus diminishing the fire hazard."[28] Consequently, the transformers were relocated from the interior of Powerhouse No. 4 to the broad concrete apron that extends to the east of the building above its substructure.

B. Machines:

This section provides an inventory of extant machinery within Powerhouse No. 4, including descriptions of purposes, manufacturer names and dates of installation (as available), and information regarding changed and removed machinery (as available). This section is divided into several subsections beginning with a general description of the power generation units, followed by detailed descriptions of individual machines and sets of machines. The individual machinery is described in the following order: turbines (water wheels); generators; control pits; exciters; transformers and switchwork; and additional machinery.

Power Generation Units

The main power generation units located within Powerhouse No. 4 were originally installed in phases between 1905 and 1909, resulting in a combination of machines that operated fundamentally in the same manner but that differed in specifications and capacities. According to a history of the power company currently known as Southern California Edison, *Iron Men and Copper Wires*, Plant 4 "originally was to have only one 750-kilowatt generator. Before long, however, it was seen that the Nevada load would overtax that one unit, so a second generator was installed by the time the transmission line to Nevada was completed."[29] Thus, Units No. 1 and No. 2 were installed in 1905 and originally contained identical water wheels manufactured by the Pelton Water Wheel Co. that operated at 450 r.p.m. (rotations per minute) and generators furnished by the National Electric Co. with 750-kw capacity. Unit No. 3, installed in 1906, was originally designed with a 400-r.p.m. Pelton-made wheel and a generator manufactured by the Bullock Electric Manufacturing Co. (which was apparently repaired/replaced as a 1,500-kw generator by the Allis-Chalmers Co. in 1913). Units No. 4 and No. 5 which were

[27] Powerhouse No. 5, which was the second plant to be constructed in the System in 1907, also originally contained transformers within the building. Powerhouse No. 2, which was the third plant to be constructed in the System in 1908, included a separate Transformer House that contained transformers within the building. The plants constructed after that, Powerhouses No. 3 and No. 6, were designed with transformers located outside of buildings.
[28] Poole, "Hydraulic and electric features of stations Nos. 4 and 5," p. 27.
[29] Myers, *Iron Men and Copper Wires*, p. 70.

installed in 1907 and 1909, respectively, featured identical 400-r.p.m. water wheels made by the Doble Co. and 1,500-kw generators made by Allis-Chalmers. In 1913, the power generation machinery specifications of Powerhouse No. 4 at that time were described in the *Journal of Electricity Power and Gas*:

> The first two units have 750 kw. National Electric Co. generators, operating at 450 r.p.m. and delivering 3-phase current at 2200 volts. These units have two bearings mounted on the castiron generator base frame. The waterwheels are single runner overhung, built by the Pelton Company. They have hand control needle nozzles which regulate by deflecting and are operated by Sturgiss governors…The remaining units are 1,500 kw. Allis-Chalmers generators with two bearings mounted on cast iron base. These operate at 400 r.p.m. and like all generators of this system deliver current at 2200 volts. The water wheels are overhung single runners equipped with governor deflecting, hand regulated needle nozzles…While the general specifications of the water wheels on all three machines are alike, two of the water wheels with their gate valves were furnished by Doble, while the third is a Pelton unit…The three larger units are controlled by Lombard type Q governors.[30]

While four of the power generation units at Powerhouse No. 4 were designed with typical single-nozzle systems that struck each impulse water wheel at a single point on the rim, Unit No. 5 was equipped with a primary nozzle and an auxiliary nozzle that provided two strike points on the water wheel. The dual nozzles/power-needles arrangement was described in 1914 by Charles O. Poole, chief engineer of the Nevada-California Power Company, in *Electrical World*:

> The fifth unit is equipped with a Doble auxiliary nozzle type of apparatus similar to the unit described in station No. 2 [which was constructed in 1908]. This apparatus has proved quiet efficient in conserving water and is used almost entirely in the governing of the system. It is exceptionally quick and accurate in its operations.[31]

The dual nozzles and power needles are extant at Unit No. 5.

Turbines (Water Wheels)

During the mid-twentieth century, the original water wheels on all of the units were upgraded with newer wheels furnished by the Pelton Water Wheel Co. This "modernization" occurred in 1946 at Unit No. 4, and in 1956 at Unit No. 3. The remaining original water wheels, located at Units No. 1, No. 2, and No. 5, were replaced in 1961. The first replacement wheel at Unit No. 4 was manufactured of cast iron and

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[30] Van Norden, "System of Nevada-California Power Company," p. 14.
[31] Poole, "Hydraulic and electric features of stations Nos. 4 and 5," p. 28.

later replacement wheels were made of cast steel. Generally the replacement wheels maintained original operating specifications. The newer water wheels operated at the same speed (450 r.p.m. at Units No. 1 and No. 2; 400 r.p.m. at Units No. 3, No. 4, and No. 5) and contained the same number of buckets at their rims (22 buckets at Units No. 1 and No. 2; 21 buckets at Units No. 3 and No. 5; and 17 buckets at Unit No. 4) as the original water wheels. While the pitch diameter of the replacement wheels at Units No. 3 (62") and No. 5 (68") remained the same as the originals, the pitch diameter of the replacement wheels increased at Units No. 1 and No. 2 (from 54" to 60") and Unit No. 4 (from 62" to 68"). Also, the rated shaft horsepower increased at Units No. 1 and No. 2 (from 1,700 hp to 3,000 hp), while original horsepower was maintained at Units No. 3 (3,000 hp), No. 4 and No. 5 (2,850 hp). More recently in 2009, the water wheel at Unit No. 3 was replaced again by a stainless steel model manufactured by Canyon Hydro with a larger pitch diameter of 66.5". All of these water wheel upgrades occurred within the original cast iron machine housings and mountings which are extant.

Generators

Similarly, the generators were upgraded over time. The first major change occurred in 1913 when the original generator manufactured by the Bullock Co. at Unit No. 3 was repaired, replaced and/or upgraded by the Allis-Chalmers Co., which furnished the generators installed at Units No. 4 and No. 5. In 1961, the stator cores within the generators furnished by the National Electric Co. at Units No. 1 and No. 2 were rewound/replaced, which increased their operating capacity from 750 kw to 1,000 kw. Likewise, the Allis-Chalmers generators at Units No. 3, No. 4, and No. 5 which originally operated at 1,500 kw and produced output at 2,200 volts were rewound for 1,985 kw and 2,400 volts in 1967 and 1969. More recently, the stator core within the generator at Unit No. 3 was rewound again in 1994. These rewinds occurred around the original rotors which are extant and within the original generator housings which are extant.

Control Pits

Directly to the west of the water wheels, control pits for the gate valves, nozzles/power needles, and stream deflectors are found. The control pits are covered with metal foundation plates that provide flooring. Bolted to the metal foundation plates of the control pits, and corresponding to individual units, is found equipment consisting of: governors (which can be used to control the positioning of power needles and/or stream deflectors); hand-operated needle controls and deflector controls; gate valve controls; and penstock valves. Originally, Sturgiss governors operated at Units No. 1 and No. 2 and Lombard type Q governors were used at the larger Units No. 3, No. 4, and No. 5. They were partially or entirely replaced by Pelton type 0-5 governors sometime during the twentieth century. More recently, the governors at Units No. 1 and No. 2 were replaced with newer, flat-panel models equipped with directional valves manufactured by Sperry-Vickers. The governors at Units No. 3 and No. 4 are made by the Woodward Governor Co. of Rockford, Illinois, including the distinctive bell-shaped heads and stylized meters. These governors are typical in the Bishop Creek system. The Unit No. 5 governor is a heavily altered machine with a large L-shaped cast iron base, a horizontally aligned hand wheel, a Pelton gauge, and an electrical control box.

Exciters

Water-driven exciters were originally installed within Powerhouse No. 4. The exciters operated as independent power generation units driven by impulse water wheels which provided the direct current initially needed to energize the electromagnets within the larger generators. In 1913, the exciter machines of Powerhouse No. 4 were described in the *Journal of Electricity Power and Gas*:

> There are three exciter sets. Two of these have National 60 kw., 140 volt, 850 r.p.m., 6-pole, d.c. generators, with single runner overhung Pelton water wheels equipped with needle nozzles. The latter are controlled by a hand wheel with a left hand screw, installed presumably to insure opening quickly by the natural right hand motion should the nozzle become plugged. One of these units has a National type I, 90 h.p., 2200 volt induction motor. The third exciter unit has a General Electric 55 kw., 125 volt, d.c. generator operating at 650 r.p.m. with Doble overhung waterwheel having a needle nozzle. The latter is controlled by what is claimed to be the first Replogle governor to be put in regular use. This unit has also one General Electric type I, 75 h.p., 2200 volt induction motor.[32]

In 1919, the exciter machines known as No. 1 and No. 2, which were the original exciters installed in a line with each other in 1905, were combined into a single machine. This was accomplished by merging the foundation pits, replacing the shafts with a common shaft, retiring one of the water wheels, and remounting the exciter with a single impulse water wheel (No. 1), two direct-connected generators (No. 1 and No. 2), and a motor. This change also resulted in disconnection of the north branch of the “Y” pipeline to the No. 2 unit, which no longer had a water wheel. Between 1984 and 1987, the water-driven exciters were retired and replaced by solid-state exciter units furnished by Basler Electric. After 1988, the water-driven exciter machines were removed from the powerhouse and the machine pits in the concrete floor were covered.

Transformers and Switchwork

Originally, the transformers and switchwork at Powerhouse No. 4 were installed along and within the east wing of the building. The *Journal of Electricity Power and Gas* in 1913 described the specifications of original machinery involved with transmitting and regulating electricity:

> The switchboard of blue Vermont marble, has five generator panels with oil switches mounted on back, two exciter panels and one voltage regulator panel. A full equipment of Westinghouse instruments follows the

[32] Van Norden, “System of Nevada-California Power Company,” p. 14.

> general practice of standardizing in use in this system. Back of and above the switchboard, placed on concrete platforms mounted on steel columns, are three sets of Pacific Electric, 60,000 volt oil switches on the high tension circuits from the transformers. There are 7 (one spare) Stanley-G, I., 500 kw. type W., 2200 to 30,000 volt water cooled transformers. Also 3 additional units of same make and capacity, Y connected on the high tension side for 55,000 volts through which the Nevada-California and Southern Sierras systems are paralleled.[33]

By 1914, plans were made to relocate the transformers outside of the powerhouse building, and this was accomplished soon afterwards. Switching panels remained in place along the plane between the main generator room and the east wing until after 1988. Switchboards were replaced with control panels that are currently located within the control room. A master circuit breaker unit in a large T-shaped metal housing topped by buswork, furnished by the Square D Company, currently occupies part of the area that was vacated by the transformer units.

Additional Machinery

Other notable details of operating machinery within the powerhouse include: the main valve for Units No. 3 and No. 4 (at Pressure Line No. 2) made by Doble and the accompanying double-hand-wheel bypass valve located in the small west wing; a gate valve furnished by the Eddy Valve Co. of Waterford, New York, located at the back of the west wing; a rotary oil pump that lubricates governors made by the Woodward Governor Co. of Rockford, Illinois, also located within the west wing; an oil pump made in 1966 by Scaife located against the third bay of the west wall; a governor oil sump pit located under the floor surface in the open area near the former location of the water-driven exciters; and a 15-ton overhead traveling crane manufactured by P&H (which is a replacement for the original 20-ton crane made by the Cyclops Iron Works of San Francisco).

C. Technology:

This section describes the technology of impulse turbines, also known as Pelton wheels, which are used to create hydroelectric power at Powerhouse No. 4.

Impulse Turbines (Pelton Wheels)

The "Pelton" or impulse wheel, the prime converter used for generating electrical energy on the Bishop Creek System, was designed and perfected in northern California during the last quarter of the nineteenth century (1872-1890). The Pelton wheel was named for its inventor Lester Allan Pelton who was based in California. All impulse water wheels are basically variations on the earliest Pelton concept, although impulse water wheels in the Bishop Creek System were also manufactured by the Doble, Henry, and Worthington companies as well as the Pelton company. With the application of a technology which

[33] Van Norden, "System of Nevada-California Power Company," p. 14-15.

evolved from the water monitor used in hydraulic mining, impulse wheels are driven by extremely high-velocity jets of water playing on buckets at the periphery of a high-strength iron or steel wheel. These wheels depend not on the mass of water falling the distance of the diameter of the wheel but on the velocity of the impacting jet of water. Impulse water wheels are especially well suited to high-head (high-pressure) but relatively low-volume water power resources. These wheels are also adaptable to streams with highly variable flow regimes. Current-day Pelton wheels, which are considered over 80-percent efficient, have bucket shapes which are slightly revised from those used originally on Bishop Creek – an improvement which increases the efficiency of energy transfer by a small percentage.[34]

The operation of an impulse turbine involves precise control over the high-velocity stream of water that strikes the wheel's buckets. This is accomplished by adjusting the position of a "power needle" that is located at the end of a penstock "nozzle" and that can variously restrict or permit water passage. Water passing through the end nozzle and past the power needle is directed with a "stream deflector" to strike the buckets at the proper angle for the desired rotation. Some impulse wheels are fitted with multiple nozzles and power needles, in which water under high pressure is directed against the wheel at multiple locations at the same time, which provides greater control and efficient use of water. After turning with the wheel, the water in the buckets falls to the bottom of the wheel housing and flows out. A typical impulse wheel turns the flow of water approximately 170 degrees from the point it receives the water pulse to the point that it drops the water into the tailrace.[35]

In the Bishop Creek system, which is typified by high-head, low-volume conditions, 12 of the 14 power generation units contained within four of its five powerhouses are driven by impulse turbines. Impulse turbines are installed in the three highest powerhouses at Plants 2, 3, and 4 and in the lowest powerhouse at Plant 6, which utilizes a dual-wheel, four-nozzle configuration with its single power generation unit in order to compensate for the low-head conditions found at the lower reaches of Bishop Creek. Other impulse turbines in the Bishop Creek system are configured with single nozzles, with the exceptions of Unit No. 2 at Plant 2 and Unit No. 5 at Plant 4, which operate with primary and auxiliary nozzles that provide greater control. The only powerhouse in the Bishop Creek system that does not use impulse wheels is located at Plant 5 which contains two units with reaction turbines.

[34] Diamond, Helmich, and Hicks, "Evaluation of the Historic Resources," p. 11-12.
[35] U.S. Department of the Interior, "Reclamation: Managing Power in the West – Hydroelectric Power," unpaginated.

PART IV: SOURCES OF INFORMATION

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__________. "Hydraulic Diagram – Bishop Creek No. 4." July 16, 1946, SCE Drawing No. 124217-0.

__________. "Plant 4 Water System." February 18, 1955, SCE Drawing No. 214539-0.

Nevada-California Power Company. "Foundation Plan Unit No. 5 for Power Plant No. 4." April 22, 1908, SCE Drawing No. 434477-0.

Nevada Power Mining & Milling Company. "Bishop Creek Power Plant Floor Plan Showing Arrangement of Machinery." December 22, 1905, SCE Drawing No. 72235-0.

Southern California Edison Company. "Bishop Creek Powerhouse No. 4 Overview and Area Map." November 18, 2003, SCE Drawing No. 722562-0

__________. "Bishop Creek Powerhouse No. 4 Plan." April 28, 2002, SCE Drawing No. 5166970-1.

__________. "Bishop Hydro Plant Four Area Map." Not dated; first revised August 8, 1972; most recent revision June 8, 1995, Sheet 1 of 4, SCE Drawing No. 5112345-3.

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Southern Sierras Power Company. "Data for Roof of Power House No. 4 Area and Slopes." May 11, 1928; revised July 27, 1928, SCE Drawing No. 214537-0.

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B. Secondary Sources:

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White, David R. M. "Management Plan for Historic and Archaeological Resources Associated with the Historic and Archaeological Preservation Plan for the Bishop Creek Hydroelectric Project (FERC Project 1394), Inyo County, California." Prepared for the Southern California Edison Company, Rosemead, California:

March 1989. Located in SCE company archives at 4000 Bishop Creek Road, Bishop, California.

C. Likely Sources Not Yet Investigated:

An inquiry was made to The Huntington Library, Arts Collections, and Botanical Gardens (The Huntington) located in San Marino, California, regarding the availability of construction drawings for Bishop Creek plants that may be stored in the Southern California Edison Records, 1848-1989 (SCE Records). According to The Huntington personnel and finding aids, the SCE Records do not contain indexed construction drawings. However, a vast volume of materials is indexed in the SCE Records in a variety of categories that include: Administrative Records; Department/Division Records; Financial Records; Generation, Distribution, and Transmission Records; Project Records; Research Files; Topical Records; and Oversize Materials. These materials could potentially yield additional information related to the historical development of Bishop Creek power plants and Powerhouse No. 4. This information could be gathered by conducting a thorough review of materials indexed in the SCE Records.

In addition, the Huntington maintains a Digital Library that includes a Southern California Edison Photographs and Negatives Collection (SCE Photograph Collection). This SCE Photograph Collection contains numerous historical photographic images of SCE facilities that could potentially yield additional information related to the historical development of Bishop Creek power plants and Powerhouse No. 4. This information could be gathered by conducting a thorough review of photographic images indexed in the SCE Photograph Collection.

Other potential sources of information that could be investigated include current and former power company employees, who may have knowledge of the historical development of Bishop Creek power plants and Powerhouse No. 4 which may not be contained in available documents, drawings, or other materials. This information could be gathered by contacting and conducting interviews with individuals who potentially have this knowledge.

Appendix A: Images

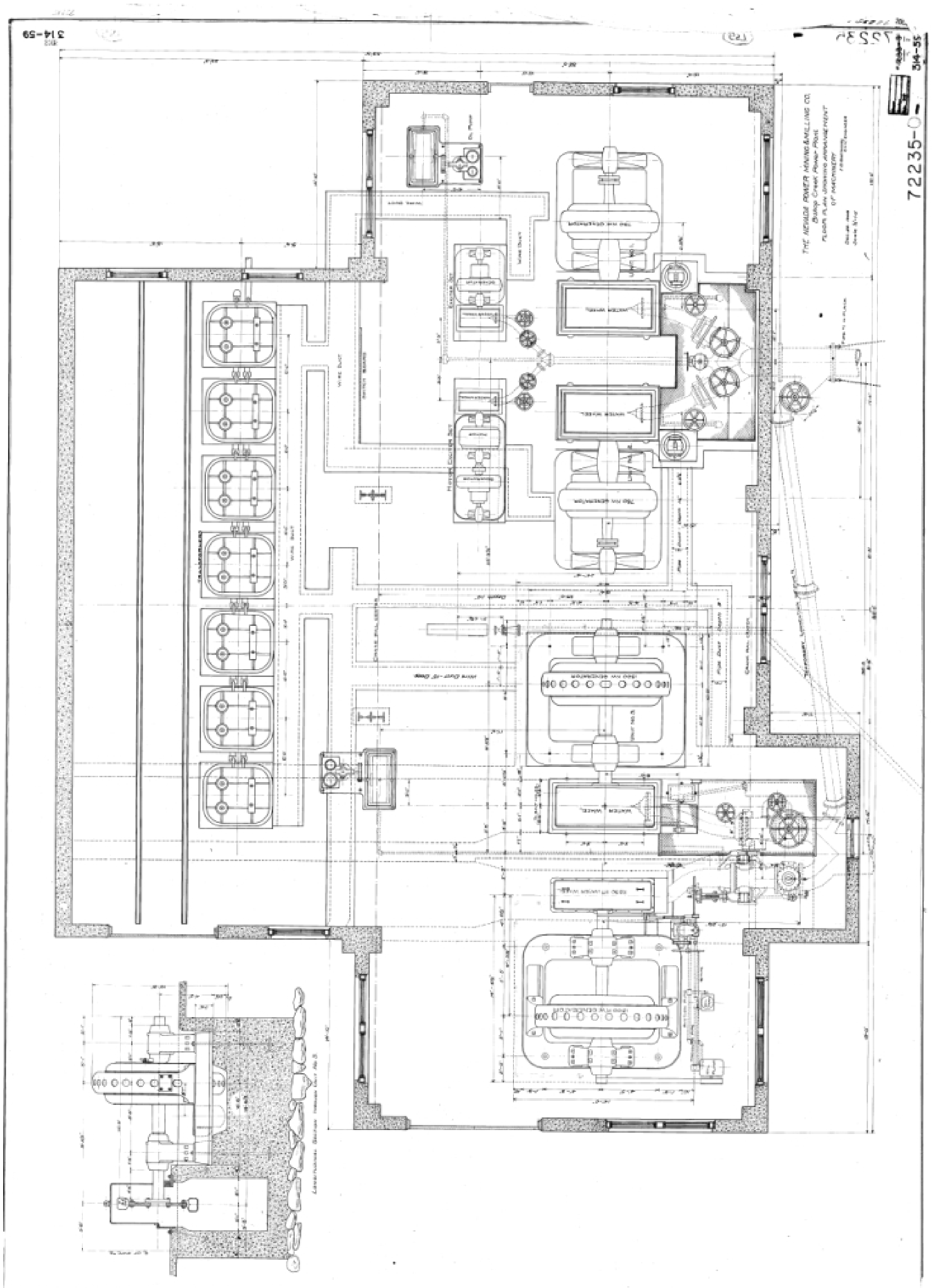

Figure 1: The Nevada Power Mining & Milling Company, "Bishop Creek Power Plant Floor Plan Showing Arrangement of Machinery," December 22, 1905. SCE Drawing No. 72235-0.

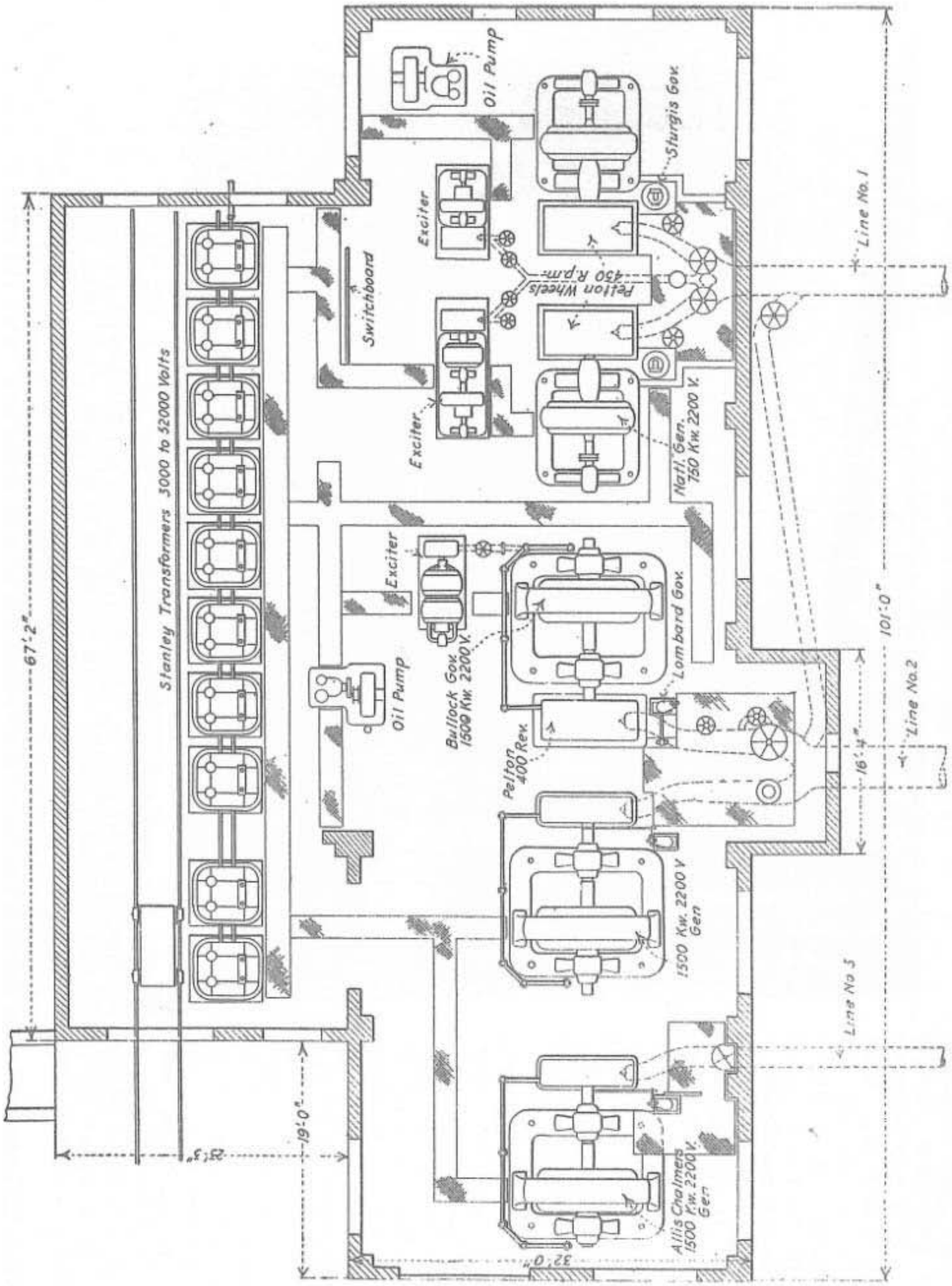

Figure 2: Floor Plan for Powerhouse No. 4 indicating the expansion that occurred in 1908-1909. Poole, C. O., "Hydraulic and electric features of stations Nos. 4 and 5 of the Nevada-California Power Company – Static head at the former station, 1100ft," *Power Development and Transmission Systems of The Nevada-California Power Company and the Southern Sierras Power Company*, 1915, Figure 43, p. 29; reprinted from *Electrical World*, New York, 1914.

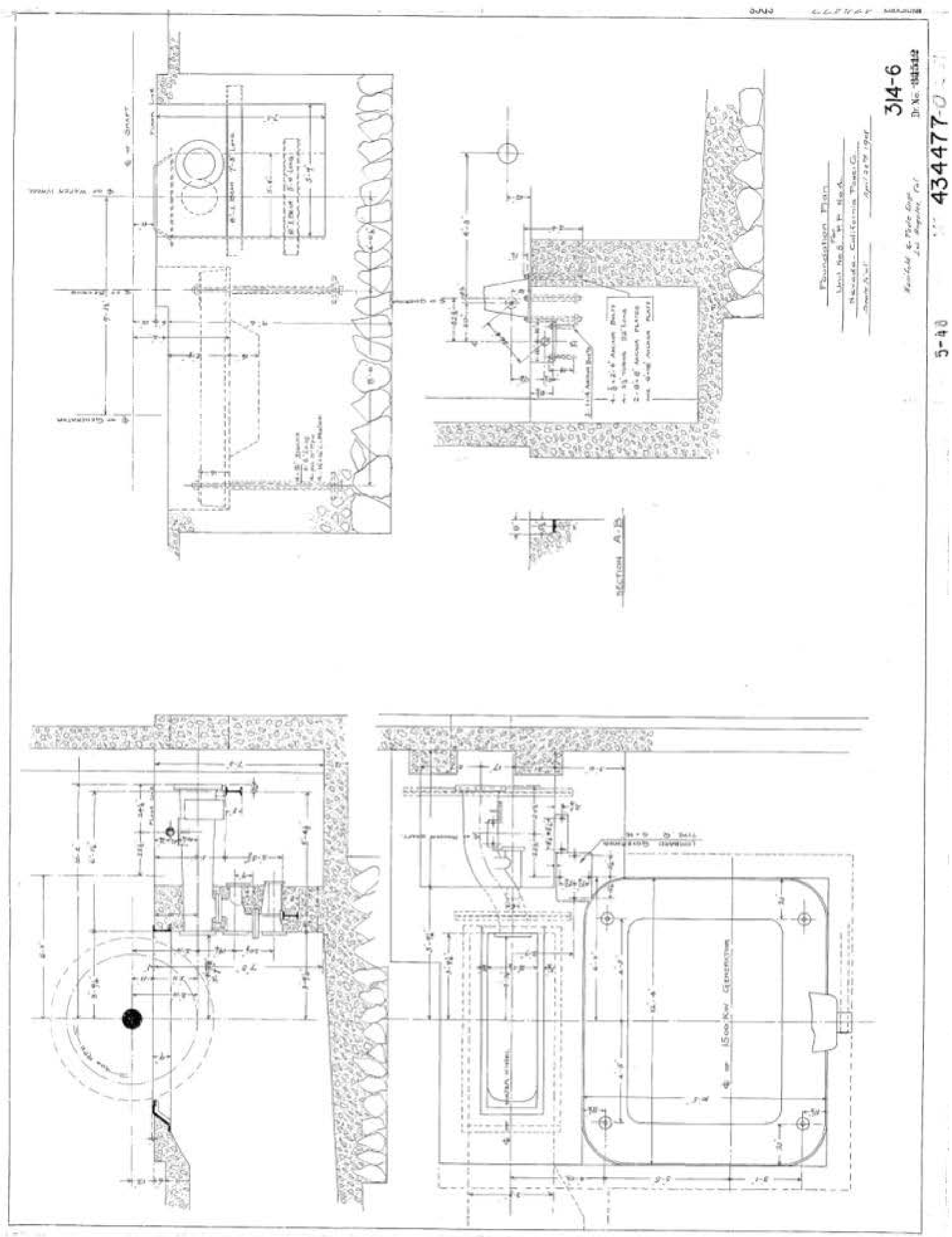

Figure 3: Nevada-California Power Company, "Foundation Plant Unit No. 5 for Power Plant No. 4," April 22, 1908. SCE Drawing No. 434477-0.

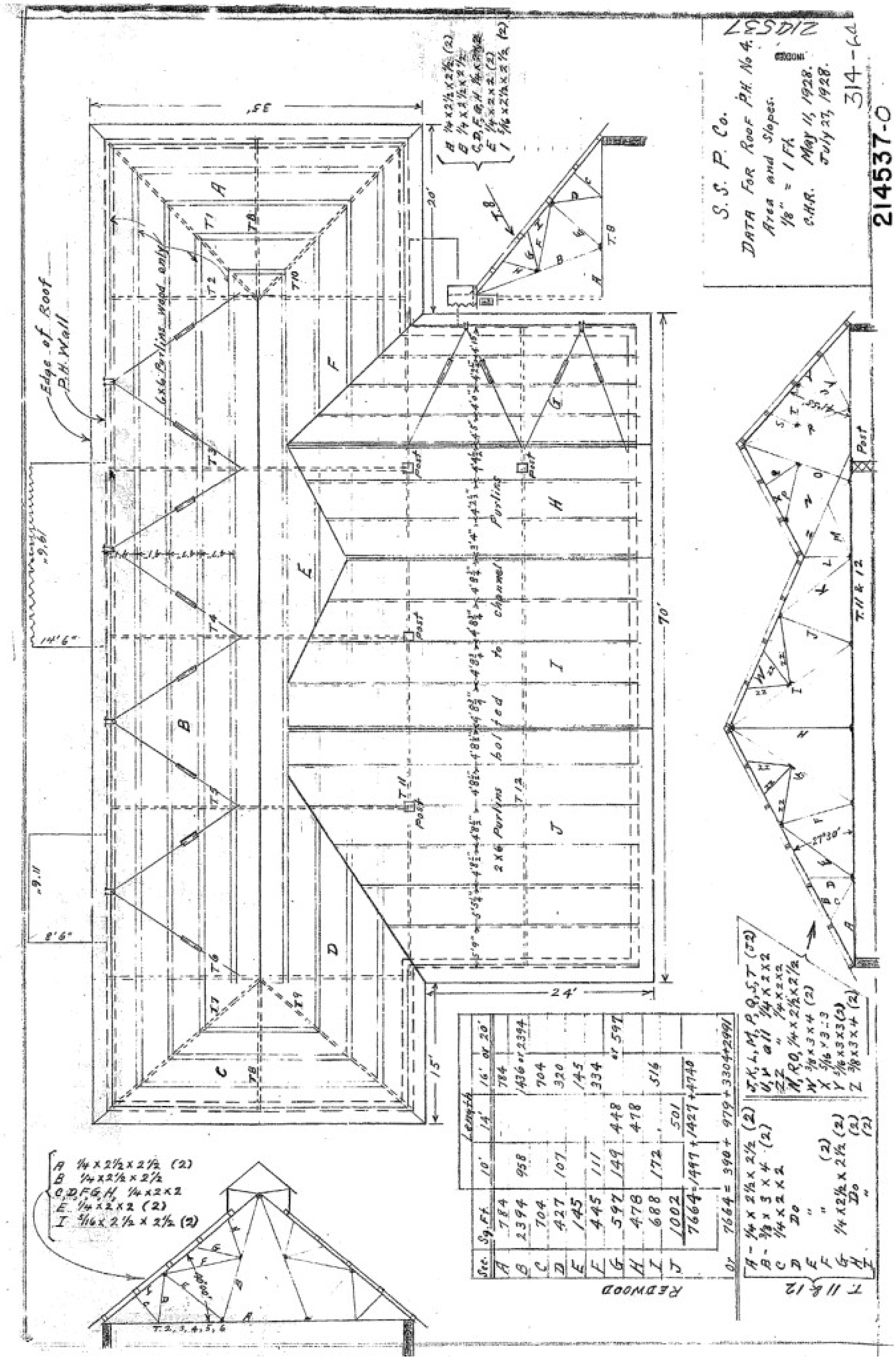

Figure 4: The Southern Sierras Power Company, "Data for Roof of Power House No. 4 Area and Slopes," May 11, 1928; revised July 27, 1928. SCE Drawing No. 214537-0.

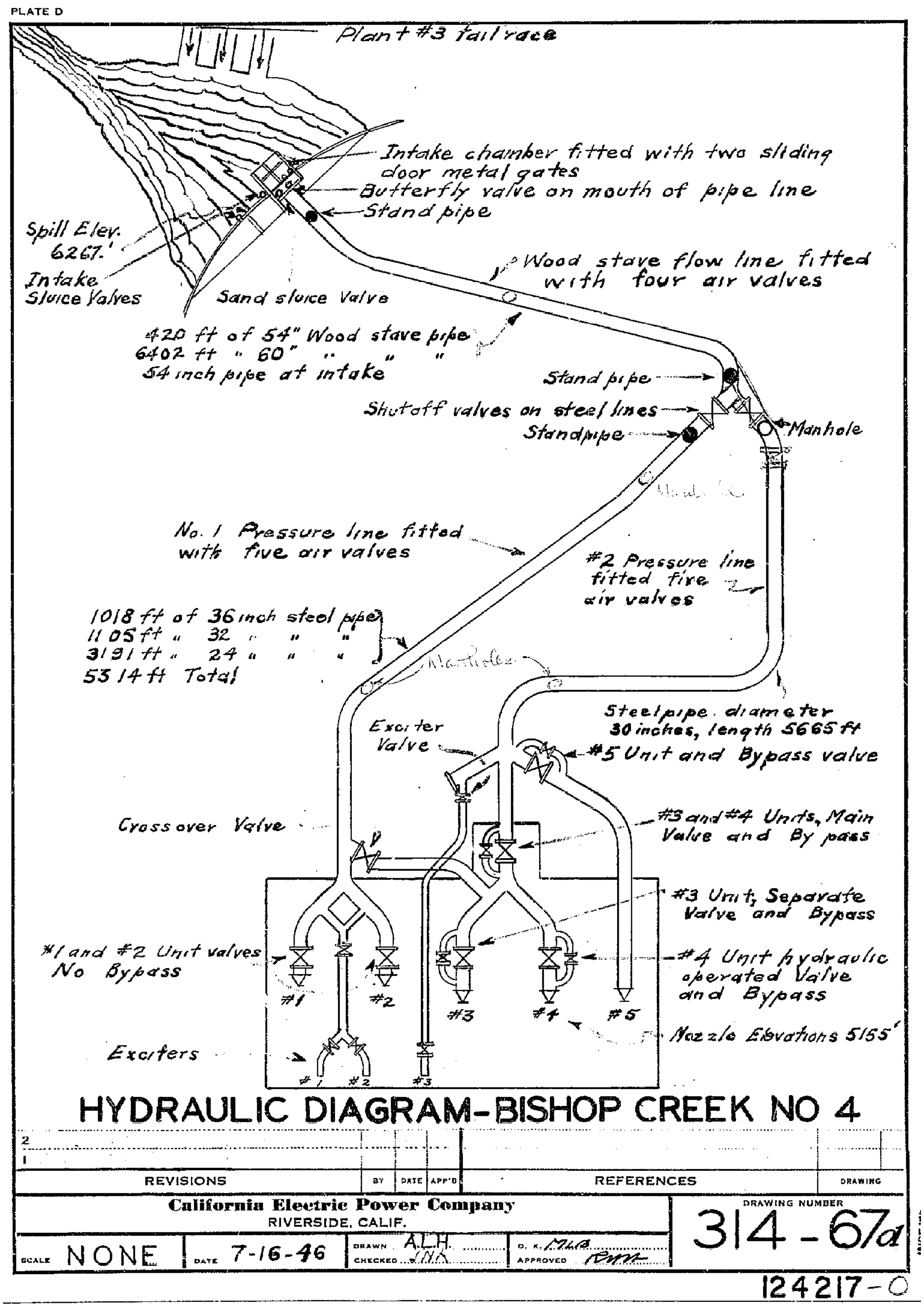

Figure 5: California Electric Power Company, "Hydraulic Diagram – Bishop Creek No. 4," July 16, 1946. SCE Drawing No. 124217-0.