

Bonneville Power Administration Ross Complex Testing Facilities Historic Context

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Cover Photo: Aerial view of the Testing Facilities District at the BPA Ross Complex, 1979. (*Bonneville Power Administration's Test Facilities* U.S. Department of Energy, 1979)

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Acronyms

AC	alternating current
BPA	Bonneville Power Administration
DC	direct current
DOE	Determination of Eligibility
EHVDC	extra high voltage direct current
HAER	Historic American Engineering Record
HVDC	High-Voltage Direct Current
kV	kilovolt
MPD	Multiple Property Documentation Form
NRHP	National Register of Historic Places
UVH	ultra-high voltage

1. Introduction

Bonneville Power Administration's (BPA) history includes the development of high-voltage testing facilities, high-voltage and ultra-high voltage (UHV) technologies, and over 15,000 miles of high-voltage transmission BPA's service area that spans eight states (Oregon, Washington, Idaho, Montana, Wyoming, California, Nevada, and Utah).¹ Transmission lines are the primary element in BPA's system, and high-voltage transmission lines transport electricity quickly and efficiently to customers. To develop this high-voltage and UHV technology, testing facilities were established to create and test new transmission equipment. These high-voltage testing facilities are highly significant within the development history of the BPA Transmission System and are a primary reason why BPA operates one of the world's largest networks of long-distance, high-voltage lines.^{2 3}

BPA has completed previous National Register of Historic Places (NRHP) eligibility evaluations for its historic substations and other facilities with historic buildings, as well as for individual transmission lines. BPA has identified a need for a historic context to use in a widespread identification and evaluation effort for its historic high-voltage testing facilities, specifically at the Ross Complex. A historic context and Multiple Property Documentation Form (MPD) prepared by George Kramer in 2010 and 2012, respectively, provides a basis for evaluating historic resources in BPA's transmission system.⁴ This BPA High-Voltage Testing Facilities Historic Context incorporates and builds on the historic context and MPD with a more detailed focus on high-voltage testing facilities, specifically within the Ross Complex.

The BPA Ross Complex Testing Facilities Historic Context provides an overall summary of the following:

- The need for and development of BPA's testing facilities
- How high-voltage differs from UHV
- Development of testing facilities and equipment at the Ross Complex
- Development of BPA's testing facilities outside of the Ross Complex, including Big Eddy Substation High Voltage Direct Current (HVDC) Test Center, Lyons Test Facility, and Moro Test Facility
- Descriptions of BPA's past and present testing capabilities

Additionally, the historic context provides the foundational material for a future evaluation framework to determine the eligibility of BPA's high-voltage testing facilities for inclusion in the NRHP. The historic context establishes the evaluation criteria for an individually eligible testing facility, and supports the Determination of Eligibility (DOE) report's finding of an NRHP-eligible historic district for the Ross Complex's testing facilities.⁵

¹ BPA.gov, "Energy & Services," accessed June 18, 2023, <https://www.bpa.gov/energy-and-services>.

² BPA, *Living and Working Safely Around High-Voltage Power Lines*, April 2022, <https://www.bpa.gov/-/media/Aep/lands/lusi-Living-and-working-safely-around-high-voltage-power-lines.pdf>.

³ George Kramer, *Bonneville Power Administration [BPA] Pacific Northwest Transmission System*, National Register of Historic Places, Multiple Property Documentation Form, Washington, D.C.: United States Department of the Interior, National Park Service, 2012.

⁴ George Kramer, *Corridors of Power: The Bonneville Power Administration Transmission Network, Historic Context Statement*, Portland, OR: Prepared for the Bonneville Power Administration under Master Agreement #38010, 2010; Kramer, *Bonneville Power Administration*.

⁵ AECOM, *Updated J. D. Ross Complex District Determination of Eligibility*, prepared for Bonneville Power Administration, 2023.

1.1 General Information: Bonneville Power Administration in the Pacific Northwest

BPA is a nonprofit federal power administration that markets wholesale hydroelectric energy throughout the Pacific Northwest and is part of the U.S. Department of Energy. BPA's transmission system, which provides nearly one-third of the region's electric power, operates primarily in Idaho, Oregon, Western Montana, and Washington; as well as sections of California, Eastern Montana, Nevada, Utah, and Wyoming; and interconnects with systems in British Columbia, Canada.⁶

BPA has had an integral role in the development of communities and industries throughout the Pacific Northwest since its creation in 1937. President Franklin Roosevelt's "New Deal" included a plan to market power from Bonneville Dam, the Columbia River's first federal dam. The construction of BPA's "Master Grid" transmission network (1938-1945) enabled the transmission of inexpensive power from the Bonneville and Grand Coulee Dams in Oregon and Washington to urban and rural communities. The network also attracted major industries to the region.^{7 8} BPA held an important role in national defense in its first years, supplying electricity that brought massive industrial development to the region and supporting the U.S. war effort. After World War II, as defense industries closed or converted to peacetime uses, BPA power continued to facilitate the significant development of the region's aluminum, agriculture, and timber industries. Since its inception, BPA has continually adapted to evolving regional and national priorities by incorporating new electric distribution, management, and communication technologies through system upgrades and expansion.⁹

1.2 Research Methodology

This context was developed through research in a variety of BPA source documents and incorporates past research. Research used primary and secondary sources, including—but not limited to—the BPA Library, internal BPA records, historic newspapers, BPA Annual Reports, engineering technical reports, engineering design manuals, historic photographs and films in BPA's collection, and historic planning documents.

Existing BPA Historic Contexts incorporated as secondary materials include the following:

- BPA Pacific Northwest Transmission System MPD¹⁰
- *Corridors of Power: The Bonneville Power Administration Transmission Network. Historic Context Statement*¹¹
- BPA Historic Built Resources Field Guide¹²
- BPA Manual for Built Resources¹³
- HVDC Test Facility Big Eddy Substation Historic American Engineering Record (HAER)

This document relies on the MPD as a foundation for historic context and expands the historic overview and evaluation framework. The context also incorporates more detailed research and

⁶ BPA.gov, "About Us," accessed June 18, 2023, <https://www.bpa.gov/news/AboutUs/Pages/default.aspx>.

⁷ Christine Ann Curran, "A Historic Context for the Transmission of Hydroelectricity by the Bonneville Power Administration, 1939-1945," Master's thesis, University of Oregon, 1998.

⁸ Kramer, *Bonneville Power Administration*.

⁹ Kramer, *Bonneville Power Administration*.

¹⁰ Kramer, *Bonneville Power Administration*.

¹¹ Kramer, *Corridors of Power*.

¹² AECOM, *Historic Built Resources Field Guide*, Portland, OR: Prepared for the Bonneville Power Administration, 2021.

¹³ AECOM, *Bonneville Power Administration Manual for Built Resources*, Portland, OR: Prepared for the Bonneville Power Administration, 2019.

an expanded identification typology for characterizing BPA's high-voltage testing facilities and their components. A detailed identification and evaluation framework addresses significance and integrity considerations that are unique to determining the NRHP eligibility of BPA's high-voltage testing facilities. Treatment strategies lay out the approach for BPA to identify, evaluate, and manage historical high-voltage testing facilities within the Ross Complex Testing Facility District.

1.3 Geographic Boundaries

The geographic boundary for this context is the Ross Complex in Vancouver, Washington. Additional testing facilities are in Oregon, including in The Dalles, Lyons, and Moro. This context briefly discusses those testing facilities, but focuses on the testing activities in the Ross Complex (Figure 1).

1.4 Temporal Boundaries

The context considers a period of significance of 1953 to 1972 for the Ross Complex testing facilities, consistent with the construction dates for the oldest and most recent contributing resources. The period begins with the construction of the Blacksmith Shop (Medium Voltage Testing) and ending in 1972 with the construction of the J. J. Mangan Mechanical Electrical Laboratory (Mangan Lab). The following timeline provides a high-level chronology of the development of the Ross Complex testing facilities. Per BPA's MPD, BPA's Period of Significance consists of the Master Grid (1938-1945) and System Expansion (1946-1974) periods. BPA's assets constructed during the Master Grid period represent BPA's initial development to provide hydropower from the Bonneville and Grand Coulee Dams to the region, enable rural electrification, and support the World War II-era defense industry. The System Expansion Period encompasses BPA's efforts to support population growth and the development of a new industrial base during the Pacific Northwest's postwar expansion.¹⁴ The MPD's Period of Significance ends at 1974 with the dedication of the Dittmer Control Center's computer-based management systems for power transmission and implementation of Public Law 93-454 that transformed BPA's funding and operation.¹⁵ However, BPA's period of significance for the Ross Complex Testing Facilities Historic District ends in 1972 following the completion of the Mangan Lab. An overview of key events within the development timeline of BPA's testing facilities is provided in Table 1.

¹⁴ Kramer, *Bonneville Power Administration*.

¹⁵ Kramer, *Bonneville Power Administration*.



Figure 1. Ross Complex Testing Facilities, depicting contributing and noncontributing resources to NRHP-eligible historic district.¹⁶

¹⁶ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

Table 1. BPA Testing Facilities Development Timeline

Date	Event
1937	BPA was created by an act of Congress as part of President Roosevelt's New Deal.
1939	First laboratory-type functions occurred at BPA in the form of calibration and scaling of switchboard instruments and testing of meters, instrument transformers, and relays used on the BPA system. ¹⁷
1947	Current testing processes began at Ross Complex, and a broad range of maintenance and acceptance testing was completed. ¹⁸
1953	Construction of the Blacksmith Shop (now the Medium Voltage Testing Building).
1955	Construction of the High Current Test Lab (demolished by 2016).
1958	Construction of the Surge Generator Control Building.
1961	Construction of the Motor Generator / High Voltage Lab.
1961	Construction of the Carey High Voltage Laboratory to facilitate a testing program to define the insulation, hardware, and conductor requirements for BPA's 500-kV transmission lines.
1961	Columbia River Treaty prompted the need for a high-voltage transmission line and high-voltage testing.
1962	Construction of the High-Voltage Direct Current Test Center at the Big Eddy Substation, initiating BPA's high-voltage research.
1964	Establishment of the Pacific Northwest-Pacific Southwest Intertie.
1964	The BPA HVDC Development Program, which employed new facilities at the EHVDC Test Center, was launched.
1965	The 1965 BPA annual report mentioned that the testing program at Big Eddy Substation will eventually be moved to the Charles E. Carey Test Lab at Ross.
1972	Laboratory capabilities at Ross were increased with the addition of the J.J. Mangan Mechanical Electrical Laboratory.
1972	Construction of the Fog Test Chamber and the Mangan Lab at Ross Complex was completed. ¹⁹
1974	The Carey High Voltage Laboratory was added to the existing Charles E. Carey Laboratory.
1975	Supported by the Department of the Interior and Congress, BPA began a program to develop and test prototype UHV transmission. ²⁰
1975-1976	Construction of the UHV test yard and installation of a \$1 million impulse generator designed to simulate irregularities and other characteristics of existing and future transmission lines. ²¹

¹⁷ Stig A. Annestrand and Alvin R. Batiste, "Bonneville Power Administration's High Voltage and Mechanical Test Facilities," Reprinted from Volume 38-Proceedings of the American Power Conference, 1976.

¹⁸ Kramer, *Bonneville Power Administration*.

¹⁹ BPA, *1973 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1973.

²⁰ BPA, *1975 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1975.

²¹ BPA, *1976 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1976.

Date	Event
1979	A visitors' center opened at the Lyons test facility, informing visitors about the newest UHV technology.
1986	BPA continued its 1,100-kV testing program, studying three principal areas consisting of electric performance, mechanical performance, and environmental effects through 1986, with the program moving on to the demonstration phase and testing of equipment in 1987. ²²
1996	HVDC Test Center in The Dalles closes.

Notes:

BPA = Bonneville Power Administration; EHVDC = extra high voltage direct current; HVDC = high-voltage direct current; kV = kilovolt; UHV = ultra-high voltage

²² BPA, *1981 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1981.

2. Bonneville Power Administration Testing Facilities Historic Context

The operation and management of BPA's transmission network is dependent on their testing facilities. Historically, BPA's testing facilities provided space for ensuring the functionality of the transmission network and exploring opportunities for development and innovation in design and technologies. This section provides an overview of BPA's history (Section 2.1), development of BPA's testing facilities (Section 2.2), and high-voltage versus UHV electricity (Section 2.3). The history of specific BPA testing facilities is discussed in Section 2.4.

2.1 Brief History of Bonneville Power Administration and Testing Facilities

BPA, part of the U.S. Department of Energy, is a nonprofit federal power administration that markets wholesale hydroelectric energy throughout the Pacific Northwest. BPA's transmission system provides nearly one-third of the region's electric power. A broader and more detailed discussion of BPA's history and development is found in the Ross Complex DOE report, Curran (1998), Kramer (2010), and Kramer (2012).²³

BPA was created in 1937 by an act of Congress as part of President Franklin Roosevelt's "New Deal" to market power from Bonneville Dam, the Columbia River's first federal dam. In 1938, BPA's first administrator James Dalmage Ross proposed a "Master Grid" transmission network to connect Bonneville Dam and the newer Grand Coulee Dam with the Portland, Oregon and Puget Sound, Washington areas. In May 1938, Congress's first appropriation of \$3.5 million enabled BPA to begin Master Grid network construction, beginning an era of development known as the "Master Grid Period" (1938-1945).

As part of the development and maintenance of the Master Grid transmission network, BPA began calibrating switchboard instruments and testing meters, instrument transformers, and relays used throughout the BPA system in 1939.²⁴ Testing capabilities increased throughout the early 1940s, and by 1945, field testing up to 150 kilovolt (kV) was possible in BPA facilities.²⁵ At the end of the Master Grid Period, testing expanded to include a broad range of maintenance and acceptance testing, primarily conducted at the Ross Complex.

The System Expansion Period (1946-1974) is characterized by transitioning away from war industries, diversifying revenue sources, and focusing on expanding BPA's transmission line network. As BPA expanded its transmission and communication network during the 1950s and 1960s, it implemented technological innovations to increase capacity and reliability. Although testing of transmission equipment at the Ross Complex began as early as 1939, the first dedicated testing facility, the High Current Test Lab, was constructed in 1955.²⁶ Additional facilities at the Ross Complex were developed in the late 1950s, 1960s, and 1970s.²⁷ Testing during the early years of the System Expansion Period included materials testing in a dedicated materials laboratory, as well as increased staff expertise in the areas of chemical and

²³ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*; Curran, "A Historic Context"; Kramer, *Corridors of Power*; Kramer, *Bonneville Power Administration*.

²⁴ Annestrand and Batiste, "Bonneville Power Administration's."

²⁵ Annestrand and Batiste, "Bonneville Power Administration's."

²⁶ Carl Williams, Z0329, *BPA Ross High Current Test Lab*, Historic Property Report, Olympia, WA: Washington Department of Archaeology and Historic Preservation, 2015.

²⁷ BPA, *1973 Annual Report*.

mechanical testing.²⁸ Between 1954 and 1964, BPA laboratories began implementing dielectric tests, preventative maintenance programs, and insulation evaluations.²⁹

The Columbia River Treaty (1961) between the U.S. and Canada, in addition to the establishment of the Pacific Northwest-Pacific Southwest Intertie (Intertie) in 1964, enabled BPA to further expand its network and begin marketing surplus power to southern California.^{30 31} Construction on a new \$2 million extra-high voltage direct current (EHVDC) test center at the Big Eddy Substation near The Dalles, Oregon, began in 1963 (Figure 2). Big Eddy Substation was energized and dedicated on November 5, 1963. BPA constructed the substation with the purpose of gathering information for best practices for the Intertie project, which relied on UHV to transport power from the Pacific Northwest to California.

During the second half of the 1960s, BPA continued the expansion of its transmission network through the Pacific Northwest, replacing older lower-voltage transmission lines with 500-kV lines, and experimenting with higher-voltage 800-kV transmission lines.³² A joint 3-year research and development project with Edison Electric Institute began, providing operating information on HVDC transmission up to 600-kV.³³ Completion of the William A. Dittmer Control Center in 1974 marked the end of BPA's System Expansion Period. Dittmer housed new computer-based management systems that relied on microwave communication facilities to gather and transmit massive amounts of data.³⁴

Supported by the Department of the Interior and Congress, BPA initiated a program to develop and test prototype UHV transmission in 1975.³⁵ BPA constructed two 1.1-million-volt test facilities, which opened in late 1976. The first opened in Moro, Oregon, to mechanically test “worst case” physical conditions, such as loads, wind-induced oscillations, and vibrations on various hardware.³⁶ The second test facility opened near Lyons, Oregon, to study electrical impacts of the UHV line on the well-being of people nearby using a 1.3-mile UHV mechanical test line.³⁷ In June 1976, the 1.1-mile UHV mechanical test line was completed near Moro, Oregon, to measure the ability of bundled conductors to withstand icing and wind stress.³⁸ A visitor center opened at the Lyons test facility in 1979, informing visitors about the newest UHV technology.

²⁸ Annestrand and Batiste, “Bonneville Power Administration’s.”

²⁹ Annestrand and Batiste, “Bonneville Power Administration’s.”

³⁰ Kramer, *Corridors of Power*.

³¹ Kramer, *Bonneville Power Administration*.

³² BPA, *1970 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1970.

³³ BPA, *1973 Annual Report*.

³⁴ BPA, *1972 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1972, 24.

³⁵ BPA, *1975 Annual Report*.

³⁶ BPA, *1975 Annual Report*.

³⁷ BPA, *1975 Annual Report*.

³⁸ BPA, *1978 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1978.



Figure 2. UHV testing equipment at Big Eddy HVDC Test Site, 1963.³⁹

To support the UHV testing program, BPA constructed a 3-acre test yard at the J.D. Ross Complex in 1976. The yard contained an impulse generator that can test UHV air gaps, insulator configurations, and conductor mounting assemblies.⁴⁰ BPA continued its 1,100-kV testing program, studying three principal areas including electric performance, mechanical performance, and environmental effects through 1986. The program transitioned to the demonstration phase and testing of equipment in 1987.⁴¹ Today, many of the testing facilities at the Ross Complex are still in use, and engineers use much of the original equipment to perform tests.

2.2 Development of BPA's Testing Facilities

Testing facilities have played a substantial and important role in BPA's history. BPA has been a leader in the creation and introduction of new electrical technology in the U.S., and BPA testing facilities have contributed to the innovation of electricity and high-voltage transmission. Testing facilities were developed for multiple reasons. First, testing facilities were and are still used to improve the designs of current systems. Secondly, testing facilities have played an important role in BPA's preventative maintenance and safety programs. Finally, testing facilities have been used to improve efficiency of power transmission which is economically and environmentally beneficial. See Section 3 for a description of tests performed at testing facilities.

The main objectives of BPA test programs were:

³⁹ BPA Archives, E67364, Portland, OR: Bonneville Power Administration of Multnomah County, 1963.

⁴⁰ BPA, 1976 *Annual Report*.

⁴¹ BPA, 1981 *Annual Report*.

- To verify that design requirements for components and the entire system are met;
- To verify that system performance requirements are realistic;
- To verify that the environmental impact of the system is acceptable; and
- To ensure that the system is safe for both the public and BPA.⁴²

Considering the large investments in transmission facilities, BPA recognized the need for testing to obtain design data and to verify the adequacy of new and improved designs in order to minimize the risk of system failures.⁴³ The performance of transmission facilities is dependent on the electrical and mechanical withstand capabilities and the stresses to which they are subjected to.⁴⁴ Laboratory tests were used to determine withstand capabilities, and transmission system tests were used to determine stresses.⁴⁵ Various facilities, which are discussed in Section 2.4.1 and Section 2.4.2, were built for laboratory tests to complement the tests performed on the BPA transmission system.⁴⁶

To identify and assess conservation and economic benefits of both direct current (DC) and alternating current (AC) high-voltage transmission, BPA continued testing and experimentation in both fields.⁴⁷ Because AC techniques were used for the majority of transmission line applications, BPA continued its testing and experimental work to optimize AC designs and operations. This included testing capability and performance of switchgear, transformers, and insulation. As system complexity and maximum voltages continued to increase, testing requirements changed and laboratory facilities were improved to test new methods and measuring techniques.⁴⁸ BPA determined that even a small reduction of transmission line cost could result in substantial savings for consumers, particularly at the UHV level.⁴⁹

Testing facilities also played an important role in BPA's preventive maintenance and safety programs.⁵⁰ By testing operations and technology in various types of weather, the durability of certain materials, and the effects of high voltage on people and animals, testing facilities have helped ensure the safety of the public and BPA workers.

2.3 High-Voltage versus Ultra-High Voltage

BPA began operating high-voltage transmission lines as early as 1939. High-voltage electricity was the preferred method to move electricity across greater distances due to less electricity being lost in transit.⁵¹ High-voltage electricity is too powerful to be used in traditional consumer methods, like to operate household appliances, and therefore must be transformed into a lower voltage prior to distribution to consumers. High-voltage electricity is transmitted using direct current, which does not require as much equipment in comparison to AC. AC requires more substations, whereas DC can travel greater distances before requiring a substation to transform the power. DC towers are also smaller and lighter, thus requiring less materials and less cost to construct. BPA's Intertie, completed in 1964, was the first high-voltage DC transmission line in

⁴² Annestrand and Batiste, "Bonneville Power Administration's."

⁴³ Annestrand and Batiste, "Bonneville Power Administration's."

⁴⁴ Annestrand and Batiste, "Bonneville Power Administration's."

⁴⁵ Annestrand and Batiste, "Bonneville Power Administration's."

⁴⁶ Annestrand and Batiste, "Bonneville Power Administration's."

⁴⁷ BPA, *Bonneville Power Administration Justification for Appropriations Fiscal Year Ending June 30, 1965*, Washington D.C.: U.S. Department of the Interior, 1965.

⁴⁸ Annestrand and Batiste, "Bonneville Power Administration's."

⁴⁹ Annestrand and Batiste, "Bonneville Power Administration's."

⁵⁰ Annestrand and Batiste, "Bonneville Power Administration's."

⁵¹ BPA.gov, "Transmission: From Dam to Doorstep," accessed September 20, 2023, <https://www.bpa.gov/learn-and-participate/community-education/hydropower-101/transmission>.

the U.S. and one of the world's largest networks of high-voltage transmission lines. It transported high-voltage electricity from the Pacific Northwest to California.^{52 53}

Increasing need for greater amounts of electricity grew with voltage requirements. BPA began transmitting UHV in the 1970s. Compared to high voltage, UHV offered more energy saving across transmission lines and greater savings to consumers.⁵⁴ With support from the Department of the Interior and Congress, BPA began a program in 1975 to construct a new outdoor facility and develop and test prototype UHV transmission equipment using the Carey High Voltage Lab.⁵⁵ A 1979 publication discussing the savings of UHV, stated that BPA "would save 8,000 acres of land for every 200 miles of [UHV] constructed, and power [losses] would only be one fifth as great per megawatt-mile," which is equivalent to saving 1.75 million barrels of oil per year.⁵⁶

UHV continued to be a primary area of study at BPA throughout the late 1980s. Three areas of UHV were studied through BPA's 1,100-kV test program: electrical performance, mechanical performance, and environmental effects.⁵⁷ UHV research findings from BPA's test facilities has been shared with utility corporations around the world.⁵⁸

As BPA's transmission system complexity and maximum voltage increased, test requirements changed.⁵⁹ Laboratory facilities with improved functions and new test methods were added, and new measuring techniques developed.⁶⁰ Today, BPA testing facilities accommodate most electrical testing required on systems extending from low voltage into the UHV range.⁶¹

2.4 BPA High-Voltage Testing Facilities

BPA operates several testing facilities where they conduct numerous tests on transmission equipment. The majority of BPA's testing facilities are at the Ross Complex and are discussed in Section 2.4.1. Testing facilities outside of the Ross Complex are discussed in Section 2.4.2. A list of specific tests conducted at these facilities is provided in Table 2.

Table 2. Testing Categories Based on Facility Type and Location⁶²

Test Category	Test Facility Type	Facility Location/s
Laboratory Tests: Impulse Tests	High Voltage Impulse Test Facility	Charles E. Carey High Voltage Laboratory, Ross, Vancouver, WA
Laboratory Tests: Direct-Voltage Tests	UHV 60 Hz Test Facility	Charles E. Carey High Voltage Laboratory, Ross, Vancouver, WA
Laboratory Tests: Direct-Voltage Tests	EHV 60 Hz Test Facility	Charles E. Carey High Voltage Laboratory, Ross, Vancouver, WA
Laboratory Tests: Low Frequency	Environmental Test Facility	Fog Test Chamber, Ross, Vancouver, WA
Laboratory Tests: Direct Voltage Tests	High Current Test Facility	High Current Test Installation Lab, Ross, Vancouver, WA

⁵² Libby Burke, "An Introduction to BPA's HVDC Test Center at Big Eddy" [Presentation]. September 4, 2019, accessed September 20, 2023, <https://bonpow2.ent.sirsi.net/custom/web/content/HVDC%20Test%20Center%201963-2017.mp4>.

⁵³ United States Department of Energy, *Bonneville Power Administration's Test Facilities*, Washington D.C.: U.S. Department of Energy, 1979.

⁵⁴ Annestrand and Batiste, "Bonneville Power Administration's."

⁵⁵ BPA, *1975 Annual Report*.

⁵⁶ *The Columbian*, "More Power to Us," April 15, 1979.

⁵⁷ BPA, *1980 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1980.

⁵⁸ *The Columbian*, "More Power to Us."

⁵⁹ Annestrand and Batiste, "Bonneville Power Administration's."

⁶⁰ Annestrand and Batiste, "Bonneville Power Administration's."

⁶¹ Annestrand and Batiste, "Bonneville Power Administration's."

⁶² Annestrand and Batiste, "Bonneville Power Administration's."

Test Category	Test Facility Type	Facility Location/s
Laboratory Tests: Low Frequency	Capacitor Test Facility	Ross, Vancouver, WA
Laboratory Tests: Direct Voltage Tests	EHVDC Test Center	The Dalles, OR (near Celilo HVDC Converter Station)
Laboratory Tests: Mechanical Tests	Mechanical Test Facilities	Mangan High Voltage Lab, Ross, Vancouver, WA
Prototype Testing	1200-kV Mechanical Test Lines	Moro Mechanical Test Facility, Moro, OR Lyons UHV Test Facilities, Lyons, OR
Laboratory Tests	Chemical Laboratory	Ross Complex, Vancouver, WA
Laboratory Tests	Instrumentation and Standards Laboratory	Ross Complex, Vancouver, WA

Notes:

EHVDC = extra-high voltage direct current; HVDC = high-voltage direct current; Hz = Hertz; kV = kilovolt

2.4.1 Ross Complex Testing Facilities

Construction of testing facilities at the Ross Complex occurred during the System Expansion Period, beginning with the High Current Test Lab in 1955 (demolished by 2016). In the High Current Test Lab, engineers conducted state-of-the-art analysis by exposing a variety of high-voltage switch gear to large magnitudes of current for specific amounts of time. This testing facilitated engineers' ability to improve equipment design and operation.⁶³ The Charles E. Carey Laboratory (Carey Lab), constructed in 1961, facilitated testing programs that defined insulation, hardware, and conductor requirements for BPA's 500-kV transmission lines.⁶⁴ The Blacksmith Shop/Medium Voltage Testing Building, constructed in 1953, was converted to a testing facility in the mid-1960s. The Surge Generator Building was constructed in 1958 as a workshop and storage area. Testing facilities were added to the Ross Complex throughout the late 1960s and into the 1970s, including a Fog Test Chamber and the John J. Mangan Mechanical-Electrical Laboratory (Mangan Lab) in 1972.⁶⁵ The Mangan Lab was designed to evaluate the tensile, compressive, shear, and impact strength, vibration characteristics, and mechanical-electrical-thermal characteristics of a broad range of static and dynamic loads at various current and voltage levels under various controlled weather conditions.⁶⁶ The High Voltage Lab was added to the Carey Test Lab in 1974 and the Outdoor Test Yard was constructed in 1976 (Figure 3). By 1979, a chemistry lab was established in the Ampere South building and has collaborated with the Carey Test Lab, High Voltage Lab, and Mangan Lab for testing oil form breakers and transformers.^{67 68}

Presently, almost all BPA testing is conducted at the Ross Complex, which has the only laboratories of its type on the Pacific Coast.⁶⁹ BPA tests almost all of its materials and supplies in either the Mangan or Carey Lab prior to installation. The only items not tested in these labs are large transformers, which are too cumbersome to move. BPA uses its mobile test trailers to examine this equipment on location.

⁶³ Williams, Z0329.

⁶⁴ Annestrand and Batiste, "Bonneville Power Administration's."

⁶⁵ BPA, *1973 Annual Report*.

⁶⁶ BPA, *1973 Annual Report*.

⁶⁷ Rolando Dizon and Joshua Powers, interview with AECOM at BPA Ross Complex Testing Facilities, Vancouver, WA, February 14, 2023.

⁶⁸ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

⁶⁹ *The Columbian*, "More Power to Us."



Figure 3. Aerial view of BPA Ross Complex testing facilities in 1979.⁷⁰

Charles E. Carey Test Laboratory and High Voltage Test Laboratory

Constructed in 1961, the Carey Lab was designed for maintenance electrical testing of BPA's 345-kV and above equipment.⁷¹ The Carey Lab is the main electrical laboratory in BPA's network of testing facilities.⁷² In 1965, a new 4-million-volt impulse generator was purchased for the lab to conduct special test projects and investigations.⁷³ Purchase of additional equipment planned for 1965 included "a vertical surge generator for extra high-voltage surge testing, an impulse capacitance divider, heat and cooling cycling equipment, a metallograph, a 6 channel recorder, and various meters and instruments used in making tests, repairs, measurements, and calibrations."⁷⁴

The Carey High Voltage Laboratory was added in 1974 to the existing Carey Lab to host testing for BPA's 500-kV transmission lines, including testing the insulation, conductor requirements, and hardware for the lines as well as other electrical equipment in connection with operating and maintenance problems (Figure 4).⁷⁵ ⁷⁶ In 1977, the lab added a Swiss-built surge generator, rain racks, and a test section of a complete transmission line to the outdoor test facility. The outdoor high-voltage test yard added a mesh grounding mat, a \$1-million-dollar impulse generator designed to simulate irregularities in transmission lines, and a 400-foot high-voltage test span.⁷⁷

⁷⁰ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

⁷¹ *The Columbian*, "Lab Expansion Money Asked," May 20, 1970.

⁷² United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

⁷³ BPA, 1965 Report: *U.S. Columbia River Power System*, Washington D.C.: U.S. Department of the Interior, 1965.

⁷⁴ BPA, *Bonneville Power Administration Justification for Appropriations*.

⁷⁵ Annestrand and Batiste, "Bonneville Power Administration's."

⁷⁶ *The Columbian*, "Lab Expansion Money Asked."

⁷⁷ *The Columbian*, "Olson Given Contract Nod," July 30, 1976.

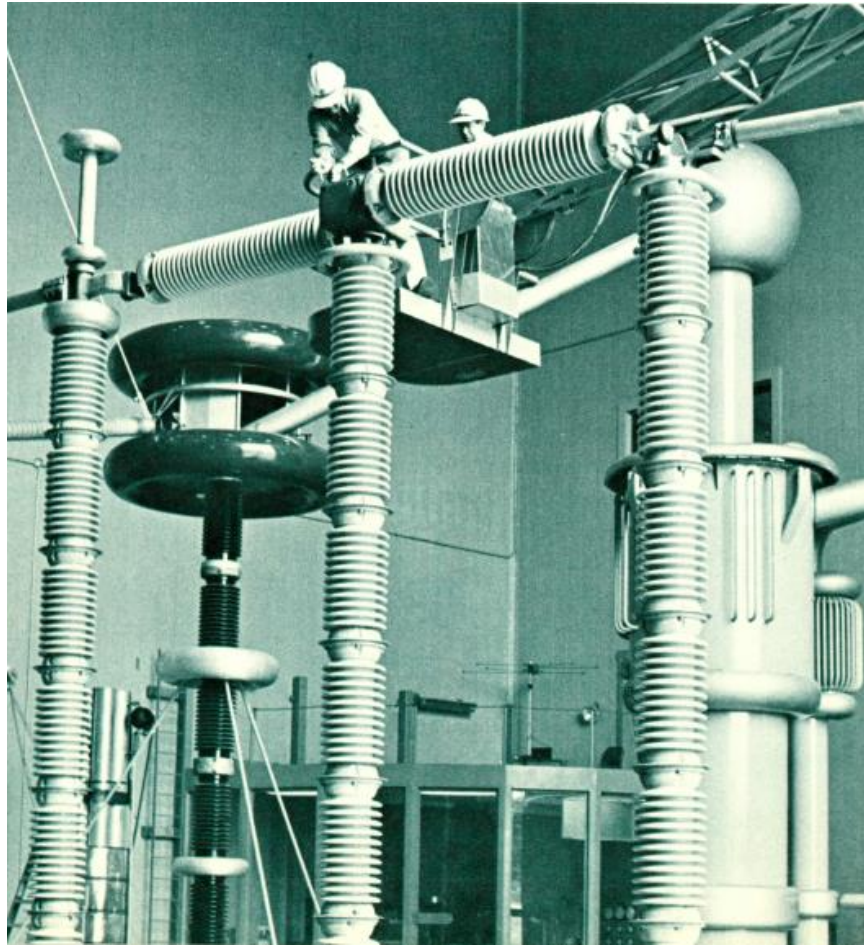


Figure 4. Laboratory personnel assembling a circuit-switcher for testing in front of the cascade transformer in 1979.⁷⁸

The complex was the largest such government facility in the country in the 1970s and also the biggest energy lab on the West Coast.⁷⁹ Since the late 1970s, testing has been completed both for BPA's internal use and for manufacturers, foreign governments, universities, and U.S. government agencies like the U.S. Coast Guard.⁸⁰ Today, the Carey Lab continues to test electrical stresses and is composed of several sections, including the High Voltage Lab, the now-defunct Extra-High Voltage Hall, and the UHV Outdoor Test Yard.^{81 82} The Extra-High Voltage Hall was previously used as a high-voltage testing area, but a fire in the 1990s damaged the hall, and it transitioned to a training area with classroom areas and a library.

Carey High Voltage Test Laboratory

Due to the lack of adequate test facilities on the West Coast capable of handling increased amounts of UHV testing, BPA expanded the Carey Lab in 1974 to house the new Carey High Voltage Test Laboratory (High Voltage Lab).^{83 84} Built to house specific testing machines, the High Voltage Lab was designed with a floor area of 25 by 37 meters, an unobscured vertical

⁷⁸ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

⁷⁹ *The Columbian*, "BPA Engineers Simulate Lightning Bolts," February 23, 1977.

⁸⁰ *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

⁸¹ Sources differ on the name of this hall, with some calling it the Ultra-High Voltage Hall and some calling it the High Voltage Lab.

⁸² *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

⁸³ Annestrand and Batiste, "Bonneville Power Administration's."

⁸⁴ *The Columbian*, "Lab Expansion Money Asked."

clearance of 25 meters, and thick walls to act like a giant faraday cage.⁸⁵ The walls minimized electromagnetic interference due to a steel structure inside the walls that provided a controlled and safer test area for BPA engineers by grounding the area against any electricity.⁸⁶ The walls were also designed to attenuate sound. The interior featured aluminum siding and copper plates on the floor of the lab to act as a grounding grid. Troughs for conductors were placed underneath the floor grates for use during testing, similar to what is found in BPA substations. Sixty-foot-tall doors on the north and south elevations of the room were specially designed to allow the transportation of large pieces of testing equipment. The bridge crane with two 55-kilonewton hoists attached to the lab's 90-foot ceiling was used to erect and move test specimens and equipment.

Much of the equipment found in the Carey Lab is original to the building and is still in operation. Outdated testing equipment has been decommissioned and removed from the facility.⁸⁷ For a full list of testing capabilities and equipment, see Table 3 and Table 4 in Section 3. Extant historical equipment is discussed in the following paragraphs.

The Hafely brand cascade transformer in the Carey High Voltage Lab can produce up to 1.1 million volts using AC (Figure 5).⁸⁸ The stepped appearance of the transformer aids in the creation of a high amount of voltage (Figure 6).⁸⁹ Each "step" produces 200,000 volts at a time, making the transition from low voltage to 1 million volts easier.

⁸⁵ *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

⁸⁶ *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

⁸⁷ Dizon and Powers, Interview.

⁸⁸ Dizon and Powers, Interview.

⁸⁹ Dizon and Powers, Interview.

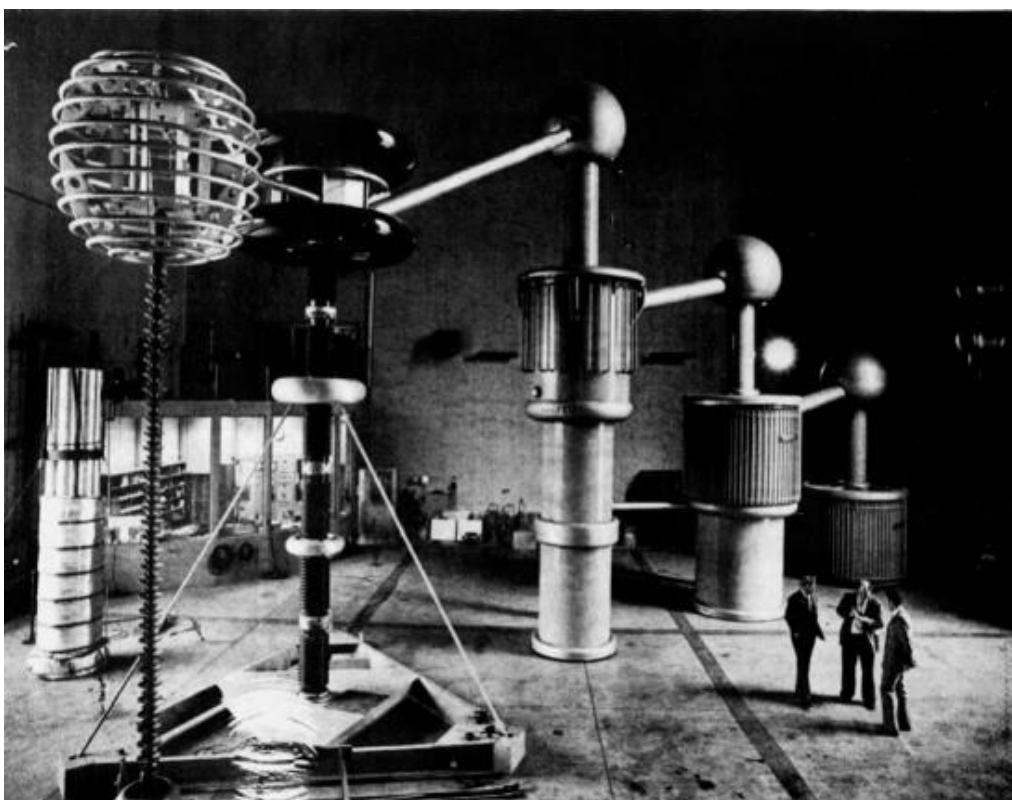


Figure 5. The cascade transformer (right) and a long insulator being tested (left).⁹⁰



Figure 6. The cascade transformer and large 60-foot utilitarian doors (background).⁹¹

⁹⁰ *The Columbian*, "More Power to Us."

⁹¹ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

The Carey High Voltage Lab's impulse generator uses 2 million volts of electricity to stimulate switch impulses and lighting impulses (Figure 7). The machine can create lightning that reaches up to 12-15 feet. The machine is currently used to test bucket trucks at least once a year to ensure the fiberglass-insulated boom lift meets safety standards for BPA line workers.⁹² The DC Voltage Divider and Capacitor provide up to a million volts of DC capability for testing.⁹³ A splice shunt suspended on the wall of the High Voltage Lab is used to increase the thermal capacity of existing transmission lines by testing for corona (the electrical field surrounding conducting wires).⁹⁴ Currently, the High Voltage Lab primarily tests for corona. The various testing equipment in the lab harness up to 1.1 million volts of AC, and engineers evaluate materials using a night vision scope to ensure all materials are corona-free. The lab tests BPA bucket trucks, surge arrestors, failure analyses, conductors, and many other materials.⁹⁵



Figure 7. Impulse generator (underneath blue tarp) and DC voltage divider and capacitor (two red towers to the left of the impulse generator).⁹⁶

⁹² Dizon and Powers, Interview.

⁹³ Dizon and Powers, Interview.

⁹⁴ Joel Scruggs, "Lightning, Corona, and Cameos: A Peek into BPA's High Voltage Lab," November 4, 2014, accessed June 19, 2023, <https://www.tdworld.com/grid-innovations/transmission/media-gallery/20969760/lightning-corona-and-cameos-a-peek-into-bpas-highvoltage-lab?id=20969760&slide=12>.

⁹⁵ Dizon and Powers, Interview.

⁹⁶ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

UHV Outdoor Test Yard and Testing Equipment

The UHV Outdoor Test Yard was developed directly north of the Carey Lab in 1976 to support the Carey and Mangan Labs as part of a 1970s BPA program to test prototype UHV transmission (Figure 8).⁹⁷ The facility was designed to house an impulse generator, voltage divider, and portal test tower to conduct low-frequency high-voltage tests, including tests to eliminate corona and evaluate different weather conditions (Figure 9). Due to the outdoor environment and level of clearance required, the outdoor yard was capable of testing higher voltages, handling up to 5 million volts—over double the voltage of indoor test facilities.^{98 99} Installed in 1977, the impulse generator in the UHV Outdoor Test Yard is a larger version of the impulse generator inside the Carey Lab (Figure 10). The large white tower is a glass-laminated polyester tower enclosing the 448-kilowatt impulse generator. The impulse generator has a capacity of over 5 million volts and can generate lightning bolts up to 40 feet.¹⁰⁰ Inside the tower is a large HVAC system that runs 24/7, dehumidifying the internal working of the generator and preventing rust (Figure 11).¹⁰¹ The impulse generator is capable of testing UHV air gaps, insulator configurations, and conductor mounting assemblies.¹⁰² The generator works with other equipment in the yard, including the voltage divider and portal test tower, to simulate irregularities and other characteristics of existing and future transmission lines and provides engineers the space to evaluate equipment, tools, and techniques in a realistic environment.¹⁰³
^{104 105} The 36-by-36-meter portal test tower is equipped with adjustable ground plane panels and a water spray rack (Figure 12).¹⁰⁶ The mobile outdoor voltage divider is used for voltage measurements (Figure 13).

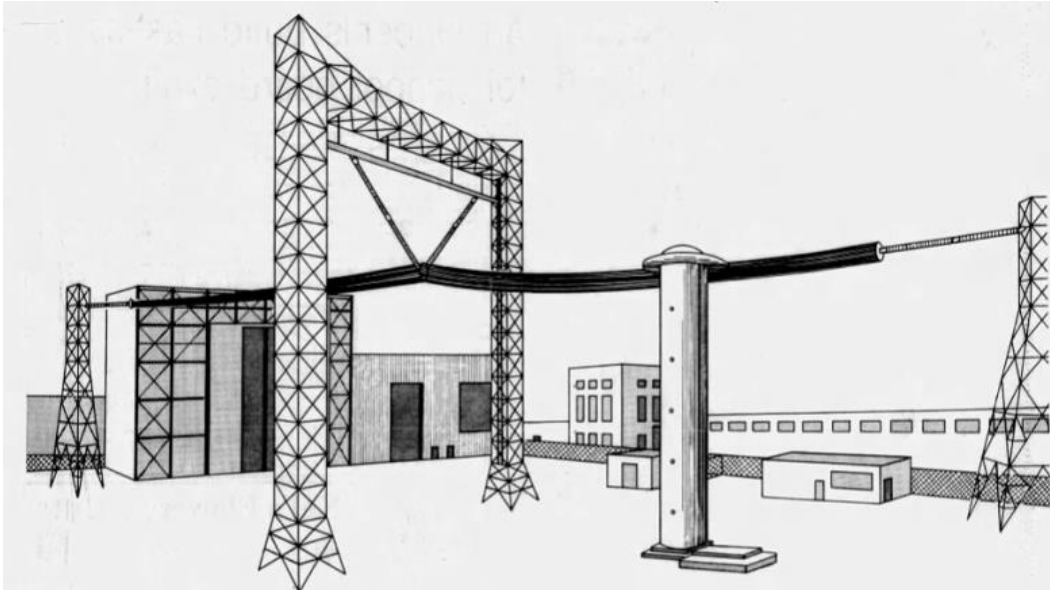


Figure 8. Historic drawing of the UHV Outdoor Test Yard prior to completion.¹⁰⁷

⁹⁷ BPA, 1975 Annual Report.

⁹⁸ BPA.gov, "It's Alive! High-voltage Lab Sparks Halloween Frankenstein Fantasies," October 27, 2022, accessed June 19, 2023, <https://www.bpa.gov/about/newsroom/news-articles/2022/20221027-its-alive-high-voltage-lab-sparks-halloween-frankenstein-fantasies>.

⁹⁹ Dizon and Powers, Interview.

¹⁰⁰ Dizon and Powers, Interview.

¹⁰¹ Dizon and Powers, Interview.

¹⁰² BPA, 1975 Annual Report.

¹⁰³ *The Columbian*, "Olson Given Contract Nod."

¹⁰⁴ *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

¹⁰⁵ Scruggs, "Lightning, Corona, and Cameos."

¹⁰⁶ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

¹⁰⁷ *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

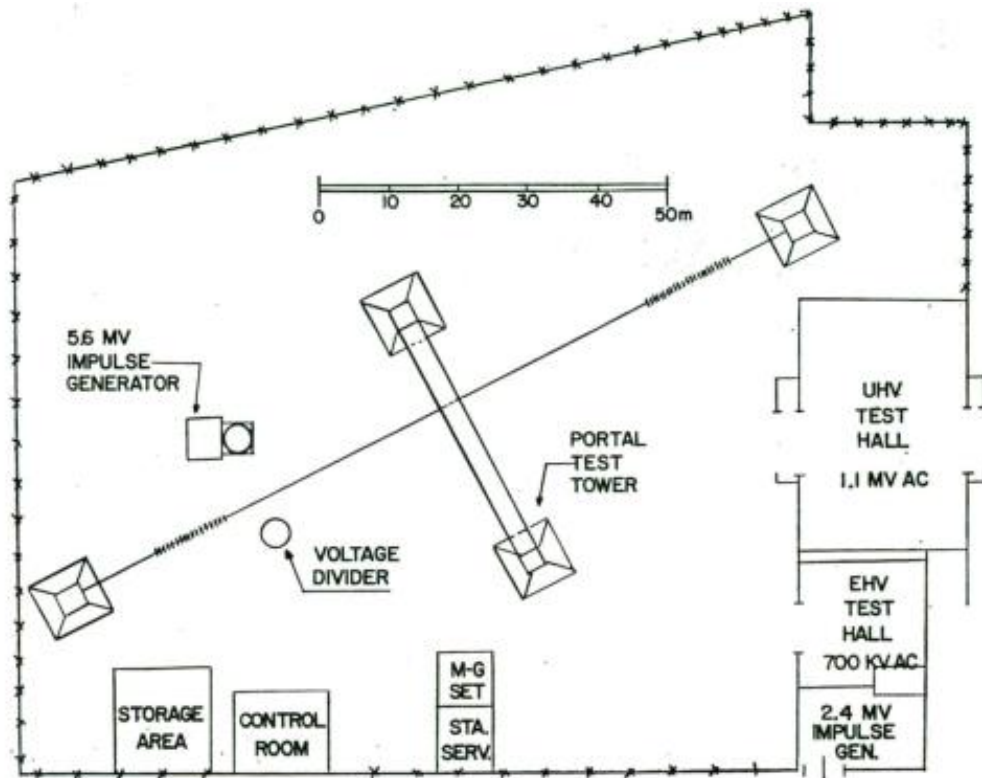


Figure 9. 1976 diagram of the UHV Outdoor Test Yard.¹⁰⁸



Figure 10. Impulse Generator (left) in the UHV Outdoor Test Yard. The Portal Test Tower is visible to the right.¹⁰⁹

¹⁰⁸ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

¹⁰⁹ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.



Figure 11. Interior of the outdoor pulse generator.¹¹⁰



Figure 12. Portal test tower with Carey UHV Lab visible in the background.¹¹¹

¹¹⁰ *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

¹¹¹ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.



Figure 13. Voltage Divider.¹¹²

John J. Mangan Mechanical-Electrical Laboratory

The John J. Mangan Mechanical-Electrical Laboratory (Mangan Lab) is an 80- by 120-foot building constructed in 1972 to conduct mechanical tests on transmission equipment (Figure 14). Prior to 1964, BPA experienced a minimal number of mechanical failures on its transmission systems; however, after 1965, with the installation of 550-kV lines, hardware failures increased due to increased vibration and oscillation.¹¹³ The Mangan Lab joined the Carey Laboratory to provide “a variety of sophisticated testing facilities which ultimately optimize the reliability, performance efficiency and cost of the entire transmission grid.”¹¹⁴

¹¹² AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

¹¹³ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

¹¹⁴ BPA, *1975 Annual Report*.

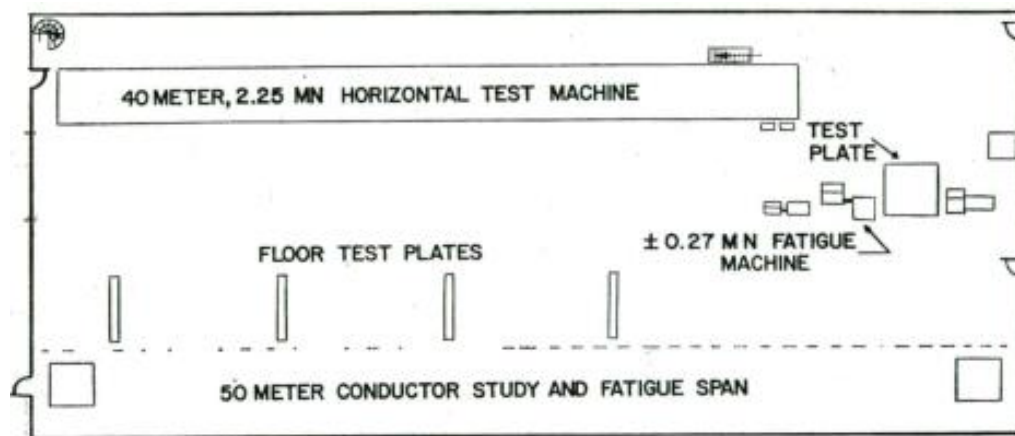


Figure 14. 1976 floorplan of Mangan Lab.¹¹⁵

Its modular construction, large exterior doors, and 80-foot interior clearance facilitated the easy movement of large and unique equipment and testing elements. The first piece of equipment to occupy the lab was a machine that tested transmission hardware, insulators, and conductors.¹¹⁶

¹¹⁷ Constructed by Ametek Corp for approximately \$200,000, the machine was the widest of its length and capacity in the U.S. at the time of its installation.¹¹⁸

On the facility's dedication in June 1973, BPA reported that the laboratory could "simulate a broad range of static and dynamic loads at various current and voltage levels under controlled weather conditions. Properties to be evaluated included tensile, compressive, shear and impact strengths, vibration characteristics, mechanical-electrical-thermal characteristics, and the effects of environmental influences."¹¹⁹ Historical machines inside the Mangan Lab include a tension test machine, a weather test machine, a universal testing system, and an AC high-current power supply. An internal crane helped to lift weights and test safety functionality.

The Mangan Lab's 100-foot, 400,000-pound horizontal tension test machine is mounted in a pit equipped with environmental components to simulate weather conditions under which transmission equipment and materials operate (Figure 15). The machine was designed to accommodate a wide variety of special test projects. The machine allowed engineers to stretch and compress materials such as lifelines for BPA line workers to determine if the materials were expanding or contracting.

¹¹⁵ Annestrand and Batiste, "Bonneville Power Administration's."

¹¹⁶ *The Columbian*, "Laboratory Bid is Won," July 14, 1970.

¹¹⁷ *The Columbian*, "Bonneville Power Administration has Number of Projects on the Fire," January 29, 1971.

¹¹⁸ *The Columbian*, "BPA Accepts Equipment Bid," June 24, 1970.

¹¹⁹ BPA, 1973 *Annual Report*.



Figure 15. Tension Test Machine and pit below.¹²⁰

The Mangan Lab originally featured four environmental test chambers for testing various weather conditions on high-voltage equipment (Figure 16). Only one chamber remains today but is still used for testing heat, moisture, controlled temperature, or the effects of UV rays on materials. The Baldwin brand Universal Testing System was designed to use vibration, heat, and cold to evaluate conductors (Figure 17). Outdated testing equipment has been decommissioned and removed from the facility.¹²¹ For a full list of testing capabilities and equipment, see Table 3 and Table 4.

¹²⁰ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

¹²¹ Dizon and Powers, Interview.



Figure 16. Environmental Test Chamber.¹²²



Figure 17. Universal Testing System.¹²³

Fog Test Chamber

Built in 1972, the 10-by-10-by-10-meter Fog Test Chamber was primarily designed for testing contaminated insulators in fog, rain, or humidity but was capable of testing specific weather impacts on various materials.¹²⁴ The Fog Test Chamber is part of a larger Environmental Test

¹²² AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

¹²³ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

¹²⁴ Annestrand and Batiste, "Bonneville Power Administration's."

Facility which contains the Fog Test Chamber, a 35-by-60-meter test yard, and a step voltage regulator rated at 13.2 kV.¹²⁵ (Figure 18). Historically, engineers controlled the type of water to manipulate the mineral and pH levels of the water for testing.¹²⁶



Figure 18. The Fog Test Chamber and attached test yard.¹²⁷

Blacksmith Shop/Medium Voltage Testing Building

The Medium Voltage Testing Facility was constructed in 1953 as a blacksmith shop. In the mid-1960s, the building was transformed into Medium Voltage Testing Facility. Unlike the Carey Lab, which uses high voltage and low current, and the Capacitor Test Facility (a small substation outside of the main Ross Testing Complex), which uses low voltage but high current, the Medium Voltage Testing Facility uses medium current and medium voltage when performing tests (Figure 19).¹²⁸ The Medium Voltage Testing Facility uses approximately 115,000 volts in comparison to the millions of volts used in the Carey Lab.¹²⁹ Historically, the Medium Voltage Testing Facility has been used for battery testing and vibration testing. The facility remains operational.

¹²⁵ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

¹²⁶ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

¹²⁷ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

¹²⁸ Dizon and Powers, Interview.

¹²⁹ Dizon and Powers, Interview.



Figure 19. Medium Voltage Testing Building.¹³⁰

Surge Generator Control Building and Motor Generator Lab

The Surge Generator Control Building was constructed in 1958 to provide a workshop and storage space for the Ross Complex testing facilities. The building was heavily altered in 1976, including the reconfiguration of the façade, installation of a shed addition on the south elevation, replacement plate glass windows on the east elevation (rear), and infill of a secondary entrance on the rear elevation. The Motor Generator Building was constructed in 1961 to provide operating space for the power generating equipment that powers the Carey Test Lab and High Voltage Lab. Neither historical documents or newspaper articles mention the Surge Generator Control Building and the Motor Generator Lab acting as primary testing facilities at the Ross Complex. Research indicated both buildings have served a supportive role to the larger testing facilities at the Ross Complex (Figure 20).

¹³⁰ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.



Figure 20. Photo inside the Motor Generator Lab looking out to the UHV Outdoor Test Yard.¹³¹

2.4.2 Other BPA Testing Facilities

Testing facilities outside the Ross Complex consist of the HVDC Test Center at the Big Eddy Substation in The Dalles, Oregon, a 1.3-mile test line in Lyons, Oregon, and a test center in Moro, Oregon. These facilities evaluated the effects of high-voltage power on radio interference, tested different insulator designs for durability and safety, and compared ground electrodes and ground currents, among many other tests.¹³² Each of these facilities is discussed in the following sections.

High-Voltage Direct Current Test Center at Big Eddy Substation

After the establishment of the Columbia River Treaty in 1961, BPA administrators recognized the need to develop new methods to transport large amounts of power over great distances. To support development of the Intertie, BPA approved plans for development of a new test center at the Big Eddy Substation in The Dalles, Oregon in 1962. The new HVDC Test Center would provide important data on the transmission of high voltage and help prepare BPA to construct the largest high-voltage line in the United States.¹³³

The test center had one main goal: to test the conversion of electricity to DC in order to safely send currents at high voltages.¹³⁴ DC would be a much more efficient and economical method to transport electricity over long distances. To use DC current, it would be transported using high-voltage power lines that would then be converted to the lower-voltage AC for traditional electrical uses.¹³⁵ DC power had been tested and used in other countries prior to completion of the HVDC Test Center, but the use of DC power at this scale in the U.S. was groundbreaking

¹³¹ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

¹³² Burke, "An Introduction to BPA's."

¹³³ Burke, "An Introduction to BPA's."

¹³⁴ *The Capital Journal*, "BPA Testing New Tricks, Old Current," February 29, 1964.

¹³⁵ Burke, "An Introduction to BPA's."

and propelled BPA to experiment “with direct current technology to gather a baseline of data that did not exist yet.”¹³⁶

Construction of the HVDC Test Center began in 1963 and consisted of a 5-mile test line, large domed power-supply, and flashover and insulator test areas. Building a nonconductive structure large enough to contain the testing equipment required innovative construction methods. An expansive polyvinyl-coated nylon bubble was erected at a cost of approximately \$2 million.¹³⁷ The bubble was 200 feet long, 100 feet wide, and 58 feet tall, held up by 5 to 7 pounds of air pressure (Figure 21).¹³⁸ The HVDC Test Center was the first of its kind in the U.S.¹³⁹ Several congressmen, along with many scientists and scholars, attended the dedication ceremony in November 1963. Testing at the DC test center included a program designed to learn about the effects of transmission lines energized up to 1.1 million volts DC and testing ground transmission through buried electrodes. Tests at the HVDC Test Center gave BPA the information it needed to design a system to transmit power from what would become BPA’s Celilo Converter Station, near The Dalles, Oregon, to the Sylmar Converter Station at Los Angeles Water and Power in California.¹⁴⁰



Figure 21. HVDC Test Center in The Dalles, Oregon, 1963.¹⁴¹

Inside the bubble, testing equipment included voltage dividers, filter capacitors, rectifier transformer units, insulators, and corona rings. In addition to testing DC, the testing facility had a fog chamber, test line, and three test areas that all used a single point of control to operate. The first area—the flashover test area—was used to evaluate test equipment for line-to-line tower clearance, including how corona and radio interfered. This test area also used simulated lightning to explore how high voltage interacted with equipment. The long-term test area was

¹³⁶ Andrea Blaser, *Historic American Engineering Record: Bonneville Power Administration Big Eddy Substation, High Voltage Direct Current Test Center*, HAER No. OR-186-A, 2016.

¹³⁷ Burke, “An Introduction to BPA’s.”

¹³⁸ *The Capital Journal*, “BPA Testing New Tricks.”

¹³⁹ Blaser, *Historic American Engineering Record*.

¹⁴⁰ BPA.gov, “Special Exhibit Visits BPA before Touring the Region,” 2019, accessed June 18, 2023, <https://www.bpa.gov/news/newsroom/Pages/Special-Exhibit-Visits-BPA-before-Touring-the-Region.aspx>.

¹⁴¹ BPA, E67378 [Photograph], on file at National Archives and Records Administration, Seattle, Washington.

used for testing types of insulators, including their spacing and design. Key aspects that were evaluated by engineers included leakage tests under various conditions, materials tests, pesticides tests, and the testing of multiple imported insulators. Lastly, the 5-mile test line evaluated weather variables, safety, and ground electrodes on an outdoor line. In addition, the transmission line tested methods of controlling corona which causes radio noise and television interference. The fog chamber, a later addition to the facility, was used to stimulate and test materials in various climates.¹⁴²

In 1965, BPA proposed to move the high-voltage testing equipment to the Charles E. Carey Test Center at the Ross Complex.¹⁴³ This move was proposed due to the Big Eddy 5-mile test line being absorbed into the John Day-Keeler transmission line, as well as the completion of the Intertie.¹⁴⁴ Seeing a growing need to test AC techniques, BPA planned to continue testing at the Ross Complex to optimize AC designs and operations, including proving the capability and performance of switchgear, transformers, and insulation.¹⁴⁵

Testing experiments still continued at Big Eddy throughout the 1970s and 1980s. In 1972, a joint 3-year research project with the Edison Electrical Institute was initiated. The project tested operating equipment on HVDC up to 600kv, and added new lines and facilities to the test center.¹⁴⁶ Additional cooperative test programs occurred, including cooperative funding with the Electric Power Research Institute and the American Public Power Institute. The Big Eddy substation was used by BPA until 1996 when the building became obsolete. The HVDC Test Center existed from 1963 until its demolition in 2017 to make way for future development around the Big Eddy Substation. The HVDC Center was documented as part of a HAER in 2016 prior to its removal.¹⁴⁷

Lyons Test Facility

The Lyons Test Facility was constructed in 1976 and energized in 1977. The facility was used to evaluate the electrical effects of 1,200-kV transmission, including the impact on radio and television interference as well as ecological effects on plants and animals.¹⁴⁸ The Lyons site included a substation and a 1.3-mile electrical test line with towers averaging 200 feet tall strung with two overhead ground wires and eight conductor lines for each of three phases of 1,100-kV AC. At the time of its construction, the line was the most powerful in the world. The 1.3-mile electrical test line was installed to prepare for testing the high capacity (10 million kilowatts per circuit) needed to transmit power in the late 1980s.¹⁴⁹ In 1979, a \$100,000 visitor center opened at the Lyons test facility.¹⁵⁰ The visitor center featured interactive exhibits including “slide shows, push-button quizzes, and demonstration equipment,” as well as an outdoor exhibit allowing visitors to feel the presence of an electric field (Figure 22). Testing at the Lyons facility in the late 1970s included testing the effects of high-voltage transmission on cattle, honey bees, plants, and other wildlife.¹⁵¹ In 1982, the Lyons facility transitioned its testing to include a greater emphasis on substation equipment, specifically gas-insulated equipment, which would aid in the development of more cost effective and reliable equipment.¹⁵²

¹⁴² *The Capital Journal*, “BPA Testing New Tricks.”

¹⁴³ BPA, *Bonneville Power Administration Justification for Appropriations*.

¹⁴⁴ Blaser, *Historic American Engineering Record*.

¹⁴⁵ BPA, *Bonneville Power Administration Justification for Appropriations*.

¹⁴⁶ BPA, *1972 Annual Report*, Washington, D.C.: U.S. Department of the Interior, 1972.

¹⁴⁷ Blaser, *Historic American Engineering Record*.

¹⁴⁸ BPA, *1976 Annual Report*.

¹⁴⁹ BPA, *1976 Annual Report*.

¹⁵⁰ *Albany Democrat-Herald*, “Come Visit Us, Urges BPA,” October 5, 1979.

¹⁵¹ United States Department of Energy, *Bonneville Power Administration's*.

¹⁵² *The Columbian*, “BPA: Voltage Risk Unfounded,” October 4, 1977.



Figure 22. A child at the Lyons Test Facility visitor center playing with a vandograph generator.¹⁵³

Moro Mechanical Test Facility

The Moro Mechanical Test Facility (Moro Facility) in Moro, Oregon, was constructed in 1976. The 1.1-million-volt test facility was built to mechanically test “worst case” physical conditions like wind-induced oscillations, ice impacts, vibrations on hardware, and load capacity.¹⁵⁴ ¹⁵⁵ The facility used 1100-kV, 1.8-kilometer-long transmission lines for testing.¹⁵⁶ The self-supporting towers for the line were designed to allow simultaneous mechanical testing.¹⁵⁷ Testing consisted of monitoring and analyzing performance of conductor bundles, insulator hardware, and tower structures when exposed to both artificially induced and naturally occurring weather.¹⁵⁸ The test program at the Moro Facility had four main goals: to optimize mechanical design of UHV transmission lines, to develop and verify analytical procedures, to refine design loads and criteria, and to develop construction and maintenance techniques for UHV lines.¹⁵⁹

¹⁵³ *Albany Democrat-Herald*, “Come Visit Us, Urges BPA.”

¹⁵⁴ BPA, 1975 Annual Report.

¹⁵⁵ BPA, 1976 Annual Report.

¹⁵⁶ United States Department of Energy, *Bonneville Power Administration’s Test Facilities*.

¹⁵⁷ Annestrand and Batiste, “Bonneville Power Administration’s.”

¹⁵⁸ Annestrand and Batiste, “Bonneville Power Administration’s.”

¹⁵⁹ Annestrand and Batiste, “Bonneville Power Administration’s.”

3. Characteristics of BPA's High-Voltage Testing Facilities at Ross

Each of BPA's testing facilities serves a unique testing function and consists of a set of characteristics that collectively define the facility. These character-defining features include the following:

- Purpose-built building, structure, or yard
- Utilitarian design
- Testing equipment
- Testing capabilities

Each of these character-defining features is discussed with examples in the following sections.

3.1 Purpose-Built Building, Structure, or Yard

Many BPA testing facilities, including structures, buildings, and yards, were developed and constructed for the purpose of laboratory experimentation or trial installation of electrical transmission equipment.¹⁶⁰ As testing stations occur with varied designs, construction materials, and locations, their unifying design feature is the testing purpose for which they were constructed. This is seen throughout Ross Complex testing facilities in multiple areas, including the following:

- Carey UHV Lab: Large, 60-foot doors accommodate the movement and installation of large equipment like the cascade transformer; the walls and floor of the building act as a giant faraday cage; the extensive ceiling height provides ample space for cranes and bucket trucks to maneuver in the facility (Figure 23).
- Mangan Lab: Wide entrances, similar to the Carey UHV Lab, allow for the movement of big pieces of equipment to and from the building; a pit built into the floor accommodates the 40-meter tension test machine; the building structure does not act as a faraday cage, indicating it was purpose-built for mechanical rather than electrical testing.

The size and scale of the Mangan and Carey Labs indicate the advancement in testing technology. New test equipment today is much smaller, and the mobile test trailers near the Mangan Lab can hold almost all of the testing tools needed. As such, the Mangan and Carey Labs evoke their historic purpose clearly through the use of wide entrances, specialized materials, and purpose-built designs.

¹⁶⁰ Kramer, *Bonneville Power Administration*.

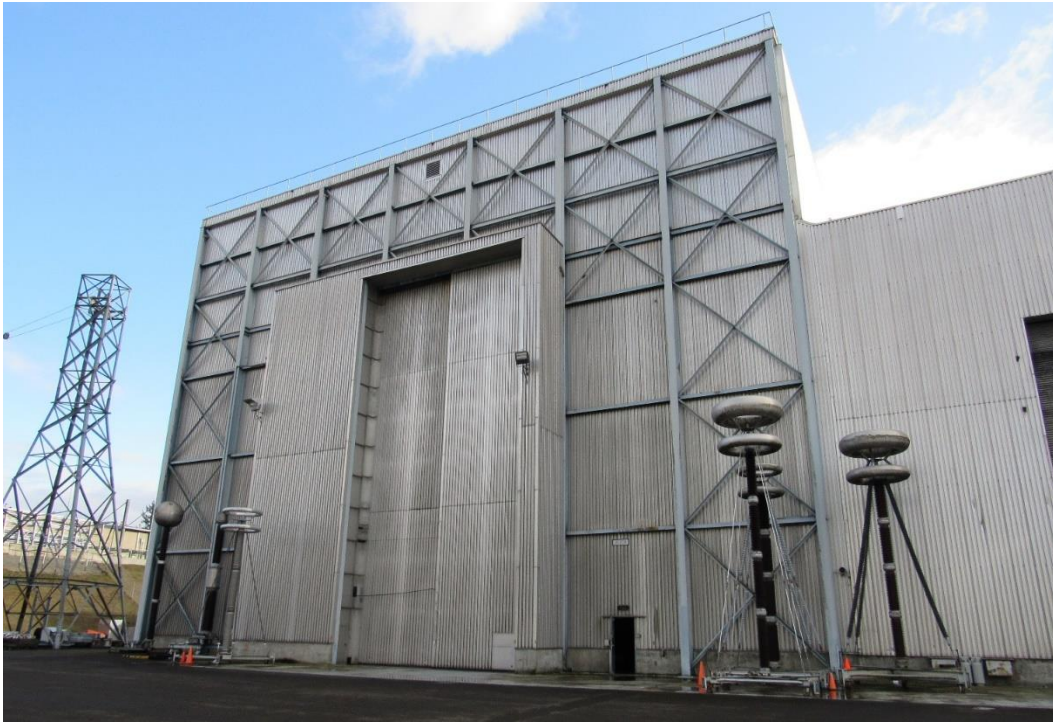


Figure 23. Large, purpose-built utilitarian doors of the Carey Lab.¹⁶¹

3.2 Utilitarian Design

In order to accommodate the testing equipment and facilitate experimentation, most testing facilities have minimal fenestration. The lack of windows is apparent and functional, providing a controlled environment for testing. Garage-style doors allow equipment to be moved, and single-leaf metal doors provide access. Cladding is often simple metal panels, with structural elements exposed on either the interior or exterior of the structure. Hardy materials, including concrete and steel, are used on the floors and walls and withstand heavy testing. Observation areas are also a key feature of the design of the test facilities. The Carey High Voltage Lab contains an enclosed, protected control room with large, reinforced windows and a metal control panel (Figure 24). The outdoor test yard is connected to the Surge Generator Control Building which was altered in 1976 to provide a viewing area for the outdoor testing. The Mangan Lab does not contain specifically designated observation areas, as the purpose of the lab is to perform mechanical rather than electrical testing. Thus, the Mangan Lab has smaller observation areas that are near each machine and not one dedicated observation room. The lack of ornamentation is also a feature of utilitarian design, indicating that the building or structure is purpose-built and is dictated by the building's function.¹⁶²

¹⁶¹ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

¹⁶² National Park Service, *Architecture: Utilitarian (1860 to the present)*, February 28, 2015, accessed September 20, 2023, <https://www.nps.gov/prsf/learn/historyculture/utilitarian.htm>.

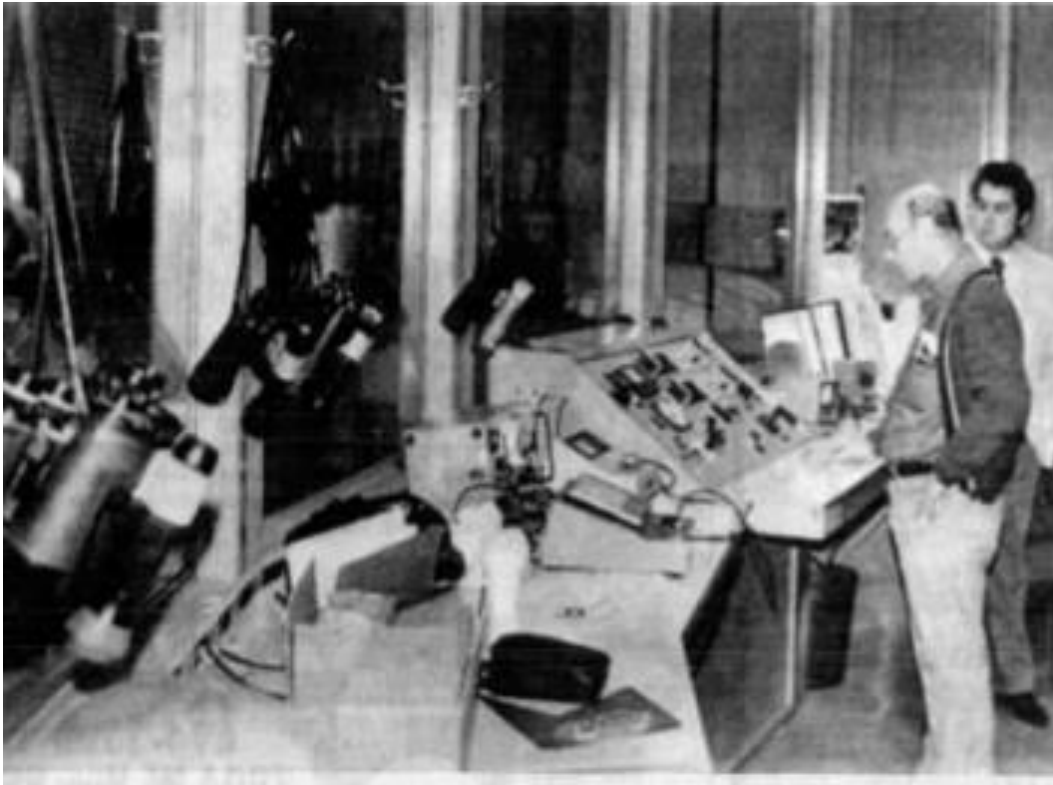


Figure 24. Control room in the Carey High Voltage Lab in 1977; note the binoculars hanging from the windows to closely view testing results.¹⁶³

3.3 Testing Equipment

Each testing facility at the Ross Complex contains a variety of testing equipment used to perform numerous experiments. Equipment is kept in the facilities only if it is still functional and relevant. As many of the buildings contain original testing equipment, the functionality and presence of the historic equipment is a character-defining feature. The testing equipment often dictated the design of its facility. Testing equipment found in the testing facilities at Ross is listed in Table 3.

Table 3. Testing Equipment Throughout the Ross Complex Testing Facilities

Location within Ross Complex	Equipment Name
Carey Lab and High Voltage Laboratory	Vertical surge generator Impulse capacitance divider Heat and cooling cycle equipment Metallograph Cascade transformer Impulse generator DC voltage divider and capacitor Splice shunt
UHV Outdoor Test Yard	Impulse generator Voltage divider Portal test tower

¹⁶³ *The Columbian*, "BPA Engineers Simulate Lightning Bolts."

Location within Ross Complex	Equipment Name
Mangan Mechanical-Electrical Laboratory	Horizontal tension test machine Fatigue test machine Weather test machine/Environmental test chamber Universal testing system AC high-current power supply Crosshead and grip precision actuator Insulator testing machine High-current transformers Crane
Fog Test Chamber	Spray and steam fogging systems Rain racks Step voltage regulator

Notes:

AC = alternating current; DC = direct current; UHV = ultra-high voltage

3.4 Testing Capabilities

The testing capabilities, or functions, of each facility fulfill the purpose of the testing facilities. Testing capabilities are broadly divided into two categories: Laboratory Testing and Prototype Testing. Laboratory Testing can be further subdivided into Impulse, Mechanical, Low Frequency, and Direct Voltage tests. The types of equipment tested and tests performed at BPA facilities are listed in Table 4.

Table 4. Major Types of Tests Conducted at BPA Test Facilities ¹⁶⁴

Equipment To Be Tested	Types of Tests Performed
Transformers and Shunt Reactors	Lightning impulse tests Switch impulse tests Power frequency dielectric tests Induced voltage tests with increased frequency Partial discharge measurements Temperature rise tests Short circuit tests at full voltage Low-voltage impulse diagnostic tests Determination of the operating characteristics (losses, voltage regulations, etc.) Transformer fault gas analyses Vibration analysis Sound level measurements Stress analysis Mechanical and electrical tests on expulsion links
Circuit Breakers	Lightning impulse tests Partial discharge tests Dry and wet power frequency dielectric tests Dry and wet switching impulse tests Vibration analysis Sound level measurements Stress analysis Temperature cycling tests

¹⁶⁴ United States Department of Energy, *Bonneville Power Administration's Test Facilities*.

Equipment To Be Tested	Types of Tests Performed
Fuses	Insulation tests Temperature rise tests Check of the operating features Short circuit tests for the checking of the breaking capacity Environmental tests
Surge Arresters	Lightning impulse sparkover tests Switching impulse sparkover tests Power frequency sparkover tests Contamination tests High current 60 Hz tests
Disconnecting Switches	Lightning impulse tests Dry and wet switching impulse tests Dry and wet power frequency dielectric tests Partial discharge tests Open gap tests with and without bias voltages Stress analysis High current tests
Insulators	Lightning impulse tests Dry and wet switching impulse tests Dry and wet power frequency tests Partial discharge tests Contamination tests Power arc tests Mechanical-Electrical tests Vibration tests Tensile-Torsional-Environmental tests Fatigue tests Flexural tests Impact tests
Cables	Lightning impulse tests Switching impulse tests Power frequency dielectric tests Partial discharge measurements DC voltage tests Power factor measurement Tension tests Flexure tests Environmental tests
Capacitors	Power frequency dielectric tests Power factor measurements Partial discharge measurements Life tests High current tests on series capacitor assembly Environmental tests
Current Transformers and Busbars	Checking of thermal and electrodynamic behavior under short-circuit conditions Stress analysis Vibration analysis Sound level tests

Equipment To Be Tested	Types of Tests Performed
Hardware and Conductors for Overhead Lines	Temperature rise tests Visual corona and partial discharge measurements Short-circuit stress tests Power arc tests Tension tests Compression tests Flexure tests Vibration tests Hardness tests Impact tests Shear tests Fatigue tests Environmental tests High speed x-ray on armor grip suspension assemblies
Line Construction Equipment	Tension-compression tests Flexure tests Hardness tests Hydraulics tests Magnetic particle inspection
Conduit	Impact tests Flexure tests Compression tests
Structures	Vibration tests Tension tests Flexure tests Magnetic particle inspection
Conductors	Tensile tests Vibration tests Torsion tests Stress analysis Hardness tests Dye-penetrant inspection
Vehicles	Stress analysis Vibration tests Sound level tests
Substation Bus	Temperature rise test Flexure tests Vibration tests Radiography
Materials	Insulating oil testing Industrial water analysis Paint formulation and analysis Domestic water analysis General chemical analysis Adhesive formulation and consultation Wood pole inspection and treatment development Metallographic examination and analysis General physical tests General electrical tests

Equipment To Be Tested	Types of Tests Performed
Instrumentation and Standards	Watt-hour meter tests Relay tests Transducer tests Instrument evaluations Potential transformer tests Current transformer tests Galvanometer testing Battery chargers, inverters and power supply Substation and control center recorders

Notes:

BPA = Bonneville Power Administration; DC = direct current; Hz = Hertz

4. Identification and Evaluation of Historic Resources Associated with High-Voltage Testing Facilities

The vast majority of BPA's testing facilities are at the J.D. Ross Complex substation in Vancouver, Washington. The Ross Complex contains seven of BPA's 10 testing facilities. The MPD states that testing stations may occur at varied locations, both in association with substations and independently, and include structures developed to test new equipment, especially in connection with the development of the HVDC Intertie or related to new transmission line technologies. Testing stations may include a variety of resources throughout the BPA network, including either buildings or structures, developed and constructed for the purpose of experimentation or trial installation of electrical transmission equipment. In the MPD, testing stations are highly significant within the development history of the BPA Transmission System through their relationship to the implementation of new technologies and technique in transmitting electricity. The MPD also describes the eligibility and integrity requirements of BPA's historic testing facilities.¹⁶⁵ In order for a testing facility to be eligible, it must, at minimum, meet all of the following standards:

- Be designed by or purchased at the direction of BPA
- Be owned and operated all or in part by BPA during some portion of the period of significance
- Its construction must have been initiated prior to 1975

The integrity requirements of testing stations, set forth by the MPD, include the following:

- Location and Setting: - In general, testing stations are independent and often temporary elements that derive minimal significance from their location. Resources that meet the minimum eligibility requirements meet integrity for location and setting.
- Design, Materials and Workmanship: Testing stations occur in multiple designs and configurations. Resources that maintain essential integrity with their design and construction during the period of significance retain integrity in design/materials and workmanship. Given the temporary nature of testing, ongoing operation or function is not essential to the retention of integrity for testing-related resources.
- Feeling: Testing stations demonstrate integrity of feeling when they effectively convey their original construction and role in the development of the BPA Transmission System.
- Association: Testing stations reflect the technological innovations and experimentation associated with the development of the BPA Transmission System and, as such, have strong association with its significance.

4.1 Criteria for Evaluating Historic Test Facilities

The evaluation framework incorporates portions of the MPD that address criteria, minimum eligibility requirements, and historical integrity, and include refined significance and integrity considerations for BPA's historic high-voltage testing facilities.

The NRHP is the official list of historic properties recognized as significant to the history of the U.S. at the national, state, or local level. A property is eligible for the NRHP if it meets one of four criteria (listed below) and maintains sufficient historic integrity based on its location, setting,

¹⁶⁵ Kramer, *Bonneville Power Administration*.

design, materials, workmanship, feeling, and association. In order to be recognized as significant, a property must:

- A. be associated with events that have made a significant contribution to the broad patterns of our history;
- B. be associated with the life of a person significant in our past;
- C. embody the distinctive characteristics of a type, period or method of construction, or represent the work of a master or display high artistic values; or
- D. yield, or be likely to yield, information important in prehistory or history.

BPA's historic high-voltage testing facilities found to be significant and retaining historic integrity are eligible for the NRHP under Criterion A. Criterion B and D are generally not considered applicable to BPA's historic resources. Criterion C is also considered not applicable but is addressed later in this section. Significant resources associated with this historic context are eligible at the national and/or state levels and may be individually significant and/or a contributing resource to the greater Ross Complex Testing Facilities Historic District.

The Ross Complex Testing Facilities Historic District is significant under NRHP Criterion A for its association with BPA's implementation of new technologies and techniques in transmitting electricity.¹⁶⁶ The increase in maximum system voltage over time has necessitated the creation of testing laboratories to identify and solve associated technical problems. These test facilities meet a series of objectives essential to BPA's continued function, including verifying component and system design requirements are met, assuring system performance requirements are realistic, determining whether environmental impact of the system is acceptable, and ensuring the system's safety for both BPA and the public.¹⁶⁷ The testing facilities at the Ross Complex provide the majority of BPA's testing capabilities, including low-frequency hardware testing, direct high-voltage testing, impulse testing, mechanical testing, system testing, and prototype testing. Thus, the Ross Complex Testing Facilities Historic District is significant under Criterion A in the following areas of significance:

- Engineering – association with the development of equipment, structures, or machinery to serve human needs. BPA's testing facilities are the first of their kind in the United States and contain machinery specifically built to test BPA materials. The development of these facilities created new technology that brought faster and more efficient power to BPA customers throughout the western United States.
- Science – association with the study of natural law and scientific phenomenon. BPA contributed greatly to the knowledge and development of high-voltage transmission in the United States. BPA's development of testing facilities furthered scientific discovery and innovation, particularly in relation to DC and high-voltage testing.
- Politics/Government – association with federal programs or activities, political issues, or the development or expansion of government impacts. BPA's pivotal role in the development and expansion of public power in the Pacific Northwest is significant and led to the establishment of testing facilities to increase expansion in the region.

The Ross Complex Testing Facilities is not historically significant under Criterion B, C, or D of the NRHP.

Although multiple BPA engineers contributed to BPA's high-voltage testing throughout the period of significance, no one individual is individually significant within a specific historic context. BPA engineers that contributed to BPA's high-voltage testing during the period of significance include Sol Schultz (1939 to 1954), Eugene Starr (1954 to 1961), Eugene White (1961 to 1965),

¹⁶⁶ Kramer, *Bonneville Power Administration*.

¹⁶⁷ Annestrand and Batiste, "Bonneville Power Administration's."

Kenneth Klein (1965 to 1970), and George Bingham (1970 to 1977). Additional individuals who are significant for their contributions to BPA's transmission and engineering advancements include Florence Ango, Abraham Osipovich, Matt Marjerrison, and Ralph Gens. Although these individuals contributed to the development of testing facilities at the Ross Complex, the facilities are not eligible under Criterion B.

Regarding Criterion C, the testing stations are "associated with the development and technology of the HVDC Intertie line" but must also be "[e]xemplar of a particular significant technology" and retain a "HIGH level of integrity to relate that technology."¹⁶⁸ This technology associated with the development of the Intertie was better exemplified in the HVDC Testing Facility at the Big Eddy Substation and thus, the Ross Complex testing facilities are not eligible under Criterion C.

Criterion D is not applicable to BPA's historic resources because they have not yielded, nor are they likely to yield, information important in history.

4.1.1 NRHP Criteria Considerations

Only one NRHP criteria consideration (G) could be applicable to BPA's testing facilities. Criteria Consideration G may be applicable when a testing facility has achieved significance within the past 50 years and is of exceptional importance.¹⁶⁹ Although the majority of BPA's NRHP-eligible testing facilities achieved significance within the period of significance (1953-1972) outlined in this historic context, some testing facilities may have achieved significance after this period. This includes the UHV Outdoor Test Yard at the Ross Complex that abuts the Carey Lab. Several pieces of the testing equipment, including the impulse generator, were added after 1973. However, the UHV Outdoor Test Yard does not function independently of the Carey Lab or Mangan Lab and thus the implementation of Criterion Consideration G is not used in this case.

BPA's historic high-voltage testing facilities do not include any religious properties (Criteria Consideration A), relocated properties (Criteria Consideration B), birthplaces or graves (Criteria Consideration C), cemeteries (Criteria Consideration D), reconstructed properties (Criteria Consideration E) or commemorative properties (Criteria Consideration F).

4.2 Significant Historic Testing Facilities

Using the framework detailed in the MPD, the historic testing facilities listed in Table 5 have been identified as possessing individual significance associated with BPA's historic context. The individually significant testing facilities have been evaluated for integrity; however, determinations have not been made regarding the NRHP eligibility of each testing facility except the HVDC Test Center. BPA determined the HVDC Test Center eligible for listing in the NRHP under Criteria A and C in 2013. Archaeological Investigations Northwest, Inc., completed a HAER report to mitigate the demolition of the HVDC Test Center in 2016.¹⁷⁰

The testing facilities located at the Ross Complex were evaluated by AECOM in 2022 as part of an updated DOE report on the complex. These resources were recommended as significant at the national and/or state levels. For full discussions of the integrity of each building, see the DOE report.¹⁷¹ Two testing facilities, the test lines at the Moro Test Facility and the Lyons Test Facility, have not been evaluated for NRHP eligibility.

¹⁶⁸ Kramer, *Bonneville Power Administration*.

¹⁶⁹ National Park Service, *National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation*, Washington, D.C.: U.S. Government Printing Office, 2005.

¹⁷⁰ Blaser, *Historic American Engineering Record*.

¹⁷¹ AECOM, *Updated J. D. Ross Complex Determination of Eligibility*.

Table 5. Significant Historic Testing Facilities

Testing Facility	Construction Date(s)	NRHP Criteria	Notes
Ross Complex Testing Facilities Historic District	1953-1972	A	Significant for powering the Victor Chemical Works
Carey Test Lab	1961	A	Contributes to Ross Complex Testing Facilities Historic District
Carey UHV Lab	1972	A	Contributes to Ross Complex Testing Facilities Historic District
Mangan High Voltage Lab	1972	A	Contributes to Ross Complex Testing Facilities Historic District
Fog Test Chamber	1972	A	Contributes to Ross Complex Testing Facilities Historic District
Blacksmith Shop/Medium Voltage Testing Building	1953	A	Contributes to Ross Complex Testing Facilities Historic District
Motor Generator Lab	1961	A	Contributes to Ross Complex Testing Facilities Historic District

Notes:

HAER = Historic American Engineering Record; HVDC = high-voltage direct current; NRHP = National Register of Historic Places; UHV = ultra-high voltage

5. Treatment Strategies

Recommended treatment strategies for the Ross Complex historic testing facilities focus on gathering more information on the types of historic equipment, types of tests performed, and institutional knowledge harbored by BPA testing facility employees.

5.1 National Register Nomination

This historic context, combined with the DOE report, could be used to generate a NRHP nomination for the Ross Complex Testing Facilities Historic District. The historic context could also serve as a comparative analysis for other BPA testing facilities if such facilities are ever nominated or evaluated.

5.2 Oral History

Several BPA employees have recently retired from working in the testing facilities, and several more are still with BPA and contain a wealth of knowledge about how these facilities operated. An oral history could be recorded to document the employees' recollections of the tests these facilities performed over time and how technology has advanced since the establishment of these facilities. The BPA employees could share details about the more minute pieces of equipment and smaller tests performed and provide more information on the types of historic equipment in the facilities. An oral history could help document workers' experience and knowledge of these facilities and their equipment.

5.3 Inventory of Historic Equipment

The testing facilities at the Ross Complex contain historic test equipment dating to the period of significance. Although several of the larger and most important pieces of equipment were documented in this historic context, documentation of all equipment could supplement this or future historic contexts and assist in comparative analyses of the Ross Complex testing facilities with other BPA testing facilities. An inventory of historic equipment could also yield more information on the types of tests performed in these facilities and whether these tests have changed over time.

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