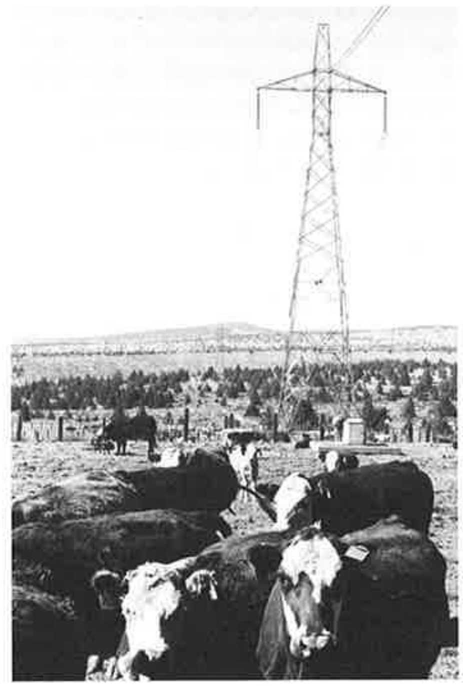
# The Grizzly Mountain HVDC Transmission Research Facility

**by Jack M. Lee, Jr., Vernon L. Chartier, and Robert J. Raleigh**

***"D-C transmission lines can be more efficient and more economic than A-C lines under certain circumstances."***



***Beef cattle under study at the Grizzly Mt. HVDC Research Facility. Each animal is individually identified by the use of color-coded ear tags.***

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This article is about d-c transmission lines and the Grizzly Mountain HVDC Research Facility, where some important new studies are underway. They were begun by Bonneville Power Administration (BPA) and are partly sponsored by a group of utilities interested in finding out more about environmental and electrical effects of a high-voltage, direct-current (HVDC) electrical transmission line. The research facility is located in central Oregon, about 12 miles southeast of Madras. Why the studies were begun, and what they hope to accomplish, are outlined below along with a basic introduction to d-c transmission lines.

## Why a D-C line?

Transmission lines provide power from generation sources to load centers. Since they were first used, improvements have been made to carry more power over the lines, to move it more efficiently, and to move it at less cost. Throughout the United States electricity is consumed primarily as alternating current (a-c), and, therefore, most transmission lines carry a.c. The current passing over this line rapidly shifts direction and alternates charges from negative to positive. By contrast, the current in direct current (d-c) lines flows in only one direction; and the charge on the lines' two conductors therefore stays either positive or negative. This results in different electrical effects, including the production of air ions (electrically-charged molecules) by d-c lines. There has been some speculation that different environmental effects might therefore occur around a d-c line.

Actually, the first electrical station in the United States, built by Thomas Edison in 1882, was a d-c system. However, soon after, the development of the transformer and other equipment made a-c systems more practical for most applications. D-c transmission lines can be more efficient and more economical than a-c lines under certain conditions: over a long (several-hundred-mile) distance, where a large power transfer is taking place, and where the power is not tapped off the system at intermediate stations.

The first commercial high voltage d-c line constructed in the United States was the Celilo-Sylmar line. That line, energized in 1970, is part of the Pacific Northwest-Pacific Southwest Intertie. This D-C Intertie transmits large amounts of surplus electrical power from the Northwest over a long distance (846 miles) to the Pacific Southwest. It has brought benefits worth millions of dollars to consumers in both regions. Since the Celilo-Sylmar line was energized, two other d-c lines have been built in the Midwest, and additional d-c lines have been built in the Midwest, and additional d-c lines are under construction or have been proposed.

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### Increased Interest in Environmental Effects

In recent years, there has been increased public and scientific interest in the possible environmental effects of high-voltage transmission lines. Most interest and research has involved a-c lines. However, as additional d-c lines have been constructed or proposed, interest in these lines has also developed. A controversial ±400-kV d-c line energized in Minnesota in 1978 is a well-known example.

Changes in the operating capacity of the D-C Interstate prompted decisions to undertake new research. From 1970 until 1985, the line operated at ±400-kV and carried up to 1,600 megawatts of power.[1] During that time, there were no indications that the line had caused any adverse environmental effects. In early 1985, the Intertie voltage was increased to ±500-kV, with a new capacity of 2,000 megawatts. This is approximately the output of two large power plants. The line's good operating record is expected to continue.

This expectation is based on results of electrical research with BPA's ±600-kV d-c test line at The Dalles, Oregon, and successful operation since the late 1970s of a ±400-kV d-c line in North Dakota and a ±450-kV d-c line in Canada. (These latter two lines operate at lower voltage. However, because of their design, the electrical characteristics near the ground are similar to those of the D-C Intertie.) In 1988, more terminal additions may be connected to the Intertie, so the current could be increased to 3,100 amperes, with a new capacity of 3,100 megawatts.

Because few environmental studies of d-c transmission lines have been made, BPA initiated a study to coincide with the 1985 increase in voltage. The study consists of two parts. BPA engineers began to study the electrical environment of the d-c line in 1984. An agricultural study involving cattle and crops, raised on and near the d-c line right-of-way, began in 1985. It is being carried out be scientists from Oregon State University, through an intergovernmental agreement between OSU and BPA. Because the agricultural study is widely applicable, it is being co-sponsored by eight other utility organizations from throughout the United States.

### The Grizzly Mountain Facility

The Grizzly Mountain HVDC (high-voltage, direct-current) Research Facility is located next to the D-C Intertie in central Oregon, approximately 12 miles southeast of Madras and 2 miles east of Highway 26. It is very near the BPA Grizzly Substation, which is located along the A-C Intertie lines. The site is on the Crooked River National Grassland, administered by the U.S. Forest Service. In 1984, the Forest Service issued a permit to BPA to begin the electrical monitoring program. After preparing an Environmental Assessment, the Forest Service issued BPA a land use grant for conducting the agricultural study. The study area has been used for livestock grazing. In past years, it had been cleared and seeded with crested wheatgrass and dryland alfalfa. Stands of western juniper are adjacent to the study area on the south and west. Elevation is around 3,500 feet above sea level. Average annual precipitation for Madras is 9.4 inches, and the average high and low temperatures for January and July are 40°/20°F, and 87°/44°F, respectively.

### Study Objectives and Approach

The overall objective of the study is to assess whether the electrical properties of a ±500-kV d-c transmission line result in any significant effects on cattle or crops, under simulated farming and ranching conditions. It is a scientific study using treatment and control groups with large sample sizes, and conducted in a natural environment. It is also the largest experimental agricultural study ever conducted for any transmission line.

The study design compares data collected on cattle and crops living near the d-c line (the treatment group) with data on cattle and crops living in a control area away from the line. The comparison is used to test the hypothesis that the d-c line has no significant effect on the treatment group. Statistical tests are used to see if there are differences, not due to chance, between the two groups. If there are no observed differences between groups, this increases the scientists' confidence in the hypothesis. This would not, however, prove there are absolutely no effects. There could still be subtle effects of the line not detected by this particular study design. This is generally true of any study. However, this study is using large sample sizes so possible effects on key growth and reproduction factors, large enough to be noticeable in a commercial agricultural operation, can be detected.

If the treatment and control groups do perform differently, this would indicate that the hypothesis may be rejected. In this case, the scientists would analyze the data and, perhaps, conduct further studies to verify whether the d-c line, or some other factor, was responsible for the differences.

**Sponsors of the Joint HVDC Agricultural Study**

Bonneville Power Administration, Portland, OR
Central and Southwest Services, Inc., Dallas, TX
Empire State Electric Energy Research Corp., New York, NY
Houston Lighting and Power Co., Houston, TX
Los Angeles Department of Water and Power, Los Angeles, CA
Pacific Gas and Electric Co., San Francisco, CA
Salt River Project, Phoenix, AZ
Southern California Edison Co., Rosemead, CA
Western Area Power Administration, Golden, CO

### Cattle study

About 100 head of beef cows and their calves are maintained in four pens under the d-c line. The four pens enclose a total area of approximately 11 acres. A similar group is maintained in identically-sized control pens. Both groups are fed and cared for using identical procedures: the animals are fed chopped hay year-round; water, salt, and minerals are provided in each pen.

The cows used in the study were all purchased from a single rancher in eastern Oregon. The animals are crossbred from Hereford, Angus, and Charlois stock, and are typical of a western range operation. Bulls are placed with the cows during the breeding season: two bulls with groups of 50 cows. The calves are born in the spring and weaned in the fall.

Individual records are kept on each animal. Large color coded ear tags on the cattle allow the researchers to identify individual animals at a distance.

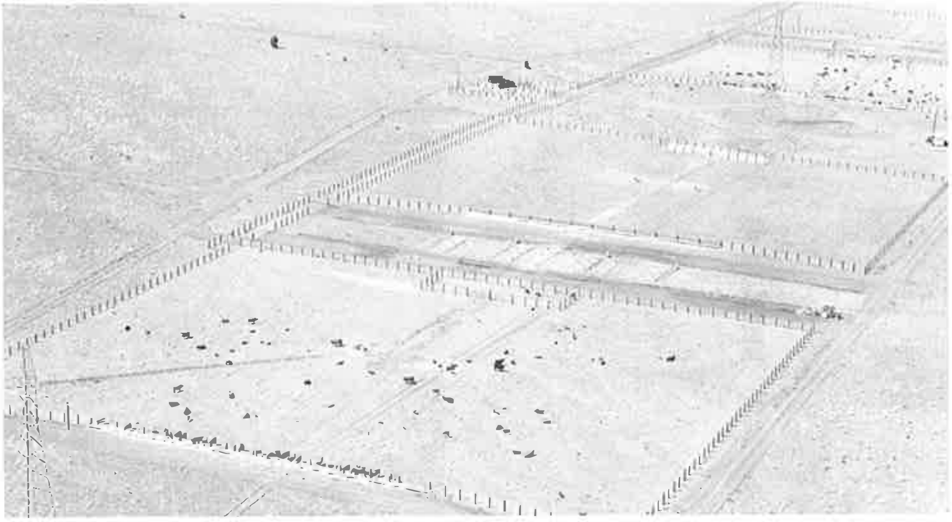
During the study, a large amount of data is collected. The most important data are conception rate, calving interval, calf weight, and number of calves weaned. Data on behavior and herd health are also obtained. Most of the data is processed by computer, using standard OSU procedures employed in other agricultural studies. For this study, additional procedures were also developed to take into account the unique aspects of the d-c line.

The cattle study is designed to simulate a "worst-case" condition. That is, the treatment animals are confined year-round to pens under the line. Also, the water, minerals and hay are placed beneath and near the line, where electric fields and air ion levels are greatest. Range cattle normally would not spend such long periods of time directly beneath the line. However, by using the more extreme exposure conditions, any effects should be more evident.

Preliminary results of the study show no effects of the d-c line on growth or reproduction of cattle. However, no final conclusions will be reached until the study is completed.

### Crop study

Wheat and alfalfa plants are grown in adjacent 12-by-400 foot strips. The 400-foot-long strips are perpendicular to and centered on the d-c line right-of-way. There are eight such strips for the line (four for each crop) and eight in the control area. Alfalfa, a perennial, was planted once, in the summer of 1985. Wheat, an annual, was first planted in the fall of 1985 and must be planted each



***One hundred beef cows and their calves (in two groups of 50) are rotated through four pens beneath the ±500-kV d-c line. Instruments to monitor d-c electric fields and air ions can be seen between the first two pens. Crops are also grown in strips near the instruments. Groups of cattle and crops are also raised under similar conditions in a control area 2,000 feet from the line.***

year. The plots were fertilized and rototilled before planting. An underground irrigation system is used to supply water to each of the crop plots.

Data on growth and condition of the crops will be collected throughout the growing season beginning in 1986. Yield and quality are most important. Alfalfa will be harvested several times during each growing season, and wheat is harvested each fall. After harvesting, yield is determined on both a fresh and dry weight basis, and protein content is determined. A small plot combine will be used to collect wheat seeds which will later be tested for weight and protein content.

It is common practice for farmers to raise crops on the right-of-way of the d-c line. The electrical exposures in the crop part of the agricultural study, therefore, do simulate typical conditions. By raising the crops under controlled experimental conditions, however, any effects should be more detectable than would be the case if data were collected at random in fields growing near the line elsewhere.

## Electrical Characteristics of D-C Lines

Before we describe the electrical study, you will need to understand some basic properties of d-c lines. All electrical equipment, including household wiring, produces electric and magnetic fields. Most transmission lines, like household wiring, produce alternating-current fields at the power frequency of 60 Hertz (60 cycles per second). By contrast, the "static" fields produced by d-c lines are of the same type as those produced by the earth, by batteries, and by some manufacturing processes that use d.c. such as aluminum smelters.

With both a-c and d-c lines, the strong electric fields can break down air right next to the conductors. This is called corona. Corona causes hissing and crackling sounds. It can also produce high-frequency noise, which may interfere with radio reception.

Corona also causes air ions to be formed. Ions carry positive or negative electrical charges, and occur naturally in the atmosphere. (They are also produced by natural phenomena such as waterfalls, wind, and thunderstorms.) Some scientists have suggested that air ions at concentrations differing from normal levels can have various beneficial or adverse effects on plants and animals.

Near a-c lines, air ions tend to be "caught" by the alternating positive and negative charges on the line, so they stay within a few inches of the conductor surface. A d-c line, however, has one positive conductor and one negative conductor. Negative ions produced by corona are repelled by the like charge on the negative conductor and are attracted by the opposite charge of the positive conductor. Similarly, positive ions are repelled from the positive conductor. Most ions are attracted to the opposite conductor or to the ground beneath the line. Some ions, however, are carried away from the d-c line by wind. These windborne ions can attach to water droplets or dust particles and form-charged aerosols, which may be measurable up to one-half mile or more downwind from the line.

For an a-c line, the electric field strength in the air and near the ground is primarily due to the voltage on the conductors. With d-c lines, the electric field is due to the voltage plus the air ions. Therefore, the d-c electric field is highly variable, and is greatly influenced by weather (especially wind).

## Electrical Monitoring Program

BPA engineers have installed instruments to measure the variations in electric field strengths and air ion levels on and off the right-of-way of the d-c line. The study began in 1984 so data could be collected while the line was still operating ±400 kV. Long-term monitoring will be done so that the d-c electrical environment can be described for different weather conditions. This study will allow the engineers to develop better models to predict the operating characteristics of a d-c line. Results of the study will also be used to describe the electrical environment existing in the agricultural study areas.

The electrical test station near two spans (three adjacent towers) of the d-c line uses four special types of instruments. Space-charge cages, developed at EPRI's High Voltage Transmission Research Facility, are used to measure total space charge (ion and charged aerosol concentrations) at 500 feet and 1,000 feet from the line. Field mills, developed by the Institute de Recherche Hydro Quebec (IREQ), are used to measure the d-c electric field. Aspiration type ion counters measure the small ion concentrations under the line. Wilson plates measure the ionic current density (ions flowing to ground). Audible and radio noise is also measured as part of the program. A complete analysis of meteorological conditions complements the study and will allow engineers to correlate electrical changes with weather conditions.

*Cattle at the Grizzly Mt. Facility are fed a mixture of chopped hay year-round. Each day, the cattle consume approximately 3 tons of hay and 2,000-3,000 gallons of water.*

Data are recorded at 1-minute intervals, stored at the site, and periodically transferred to the BPA Ross Complex in Vancouver, Washington, where they can be analyzed. An electrical monitoring station is also located in the control area of the agricultural study. Because of prevailing winds, the control area is generally upwind from the d-c line.

**Study schedule**

The electrical monitoring study began in the fall of 1984; the agricultural study began in the spring of 1985. Studies are scheduled to continue through the fall of 1987. During this time, data for the agricultural study will be obtained on two crop-growing cycles, and on two cattle-reproduction cycles in which calves will be conceived and raised to weaning age near the d-c line. Data collection and analysis for the electrical monitoring program will take place throughout the study. These data will be used to support the agricultural study, and will provide better predictions for future d-c lines. A final project report is expected to be available by late 1988.

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**Footnotes**

1. ***Technical notes:*** The voltage of a ***bipolar*** d-c line is usually designated with a $\pm$. For example, with a $\pm$400-kV d-c line, the voltage between one pole (conductor) and ground is +400-kV, and the voltage between the other pole and ground is -400 kV. The same line could also be called an 800-kV d-c line. This is the voltage measured between the negative and positive poles. The "kV," stands for kilovolts with 1 kV = 1,000 volts. A megawatt is 1 million watts.