THEODORE ROOSEVELT DAM, EASTERN MINING AREA TRANSMISSION LINE (115kV SYSTEM)
Salt River
Roosevelt vicinity
Gila County
Arizona

HAER AZ-6-C
AZ-6-C

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
INTERMOUNTAIN REGIONAL OFFICE
National Park Service
U.S. Department of the Interior
12795 West Alameda Parkway
Denver, CO 80228

THEODORE ROOSEVELT DAM,
Eastern Mining Area Transmission Line

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AZ-6-C

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(page 1)

Location:	The Eastern Mining Area transmission line is a 130 mile loop located in the Superstition Mountains, east of the Phoenix metropolitan area in eastern Maricopa, northern Pinal and Gila Counties, Arizona. It passes through the vicinities of Goldfield, the Roosevelt Dam, Miami, Superior, and spurs off to Ray. At selected vertices, the UTM coordinates are:
	USGS Quad: Apache Junction, UTM: 12/ 1,485,663.25/12,144, 933
	USGS Quad: Mormon Flat Dam , UTM: 12/ 1,503,028.25/12,175,147
	USGS Quad: Horse Mesa Dam, UTM: 12/ 1,554,856.375/ 12,175,147
	USGS Quad: Inspiration,UTM: 12/ 1,678, 282/ 12,131, 832
	USGS Quad: Superior, UTM: 12/ 1, 618, 439.25/ 12, 101,886
	USGS Quad: Teapot Mountain ,UTM: 12/ 1, 638, 743.125/12, 040, 121
Date of Construction:	1907-1909, 1912-13, 1922-25, 1927.
Designing Engineers:	Orville H. Ensign, Charles C. Cragin.
Supervising Engineer:	Louis C. Hill.
Construction Engineers:	A. H. Demerick, Irving C. Harris, William Cone.
Manufacturers:	United States Wind Engine and Pump Company, Batavia, Illinois.
	Muskogee Iron Works, Muskogee, Oklahoma.
	Pacific Coast Steel Company, San Francisco, California.
Present Owner:	Salt River Project.
Present Use:	The Eastern Mining Area transmission line delivers hydroelectric power to the towns and mines in the Eastern Mining District.
Significance:	The Eastern Mining Area transmission line was first built to carry hydroelectric power generated at Roosevelt Dam, the United States Bureau of Reclamation's first large scale work, into Phoenix. It soon expanded to serve the area mines the southern portion of Gila County. The sale of power to these mines provided revenue to expand the Salt River Project's hydroelectric system and furnish Salt River Valley farmers with electricity.
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Date:	June 1996

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I. Introduction

The 115.000 volt Eastern Mining Area (EMA) transmission line, constructed in segments from 1907-1927, traverses the Superstition, Apache, and Pinal mountains east of metropolitan Phoenix in Arizona (*(see AZ-6-C-30, 31)*. The line was first built to convey power generated by Roosevelt Dam, the Bureau of Reclamation's first large-scale work, to Phoenix and the rest of the Salt River Valley.[1] It soon expanded to serve the area mines in the southern portion of Gila County. The sale of power to these mines provided the revenue to expand the Salt River Project's hydroelectric system and furnish Salt River Valley farmers with electricity (*see figure #1*).

The system remained relatively untouched until the 1950s when technological development and the increased use of electrical power demanded a significant frequency change. In recent years, the Salt River Project has added lines and replaced towers and portions of the system off the original right of way. Today the system is a complex multi-line network serving much of central Arizona, including Phoenix and the mining towns of Globe, Miami, and Superior. The 115, 000 volt (115kV) EMA lines connects to the Valley's 230kV system at the Silver King and Goldfield receiving stations.

The development of the original 115kV line followed industry standards.[2] However, these transmission structures still maintain their original design integrity, feeling, and function. They stand today as representations of early long distance electrical transmission ingenuity and design. In addition, the towers also serve as a testament to the federal government's role in bringing electrical power to remote areas in order to produce agricultural products and extract mineral resources from the country's western territories.

II. Local Historical Background

The area surrounding Globe, Superior, and Ray first attracted gold and silver prospectors in the 1870s. As these minerals became depleted, miners soon discovered large copper deposits beneath the silver layers. Initially, copper was primarily used to manufacture kitchen utensils and roofs. However, as industrial enterprises expanded, copper became an essential material for

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[1] The history of the construction of the Theodore Roosevelt Dam is described by Donald Jackson in "Theodore Roosevelt Dam,"(National Park Service, Historic American Engineering Record , No. AZ-6), 1992. For additional information on the first few years of the Salt River Project, see Karen L. Smith, *The Magnificent Experiment: Building the Salt River Reclamation Project, 1890-1917* (Tucson: University of Arizona Press, 1986).

[2] Industry standards were dictated by groups such as the American Institute for Electrical Engineers (AIEE) and shared at conferences and in journal publications.

conducting electricity. When the railroad arrived in the 1880s, it emerged as one of the Arizona territory's most important exports.[3]

Farther west, Phoenix and the Salt River Valley too had experienced tremendous economic growth. Beginning in the 1860s, Mexican and Anglo settlers dug canals to irrigate lands north and south of the Salt River. These cultivated lands yielded highly profitable crops and grains. A scarce and poorly controlled water flow, however, hampered further agricultural expansion. By the late 1890s, a series of floods and intermittent droughts waterlogged much of the area. In addition, as the amount of irrigated land increased, competition for the limited water supply grew increasingly fierce. The only existing process for determining water rights was through litigation. Continuous legal challenges indicated the need for a comprehensive water storage plan.[4]

On June 17, 1902, the United States Congress passed the National Reclamation Act. The purpose of the act was to utilize streams and rivers to irrigate arid lands in the western United States through large water storage projects, thus opening the way for settlement to expand the United States economy. Valley farmers responded by forming the Salt River Valley Water Users' Association to lobby for a federal water storage project. The government agreed with local surveyors that the Tonto basin site was an ideal location for a dam. On March 12, 1903, Secretary of Interior Ethan Allen Hitchcock selected the Salt River Project to be one of the first five reclamation projects in the country. In 1904, the government began to build Roosevelt Dam sixty miles northeast of Phoenix.

A temporary power plant constructed at Roosevelt provided 1,200 horsepower needed to run machinery, operate the cement mill, and provide lighting for constructing the dam. However, government officials soon realized the high potential for the commercial sale of hydroelectric power to the Salt River Valley. Although the government intended that the electricity generated at Roosevelt Dam be used for pumping groundwater, they also realized it had commercial possibilities. In 1906, Congress authorized the Secretary of Interior to sell excess power generated at federal reclamation projects, with customer priority given to municipalities.[5] The receipts from these power sales would go to the reclamation fund as credit toward repaying the cost of building reclamation projects.

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[3] Bisbee, Jerome, Clifton, and Clarkdale were other places where copper was heavily extracted. Thomas Sheridan, *Arizona: A History* (Tucson: The University of Arizona Press, 1995), 161-186.

[4] Christine Lewis, "A History of Irrigation on the Tempe Area," (M.A. Thesis, Arizona State University, 1963).

[5] In The *1906 Townsite Act, Statutes at Large* 34, sec. 5, 116 (1906), Congress authorized the Reclamation Service to sell surplus power not needed for irrigation purposes to municipalities.

Throughout the United States, and particularly in the west, large hydroelectric power projects capitalized on advances in high voltage, long distance electrical transmission. In doing so, rural farms and remote mining communities opened up as new economic markets. While electrical machines optimized production and reduced labor costs, electrical pumping maximized water supply and delivery. The government persuaded Valley farmers to consider selling hydroelectric power for revenue, as long as the power production did not decrease the Roosevelt Dam's water supply.[6] In 1907, Secretary of the Interior James R. Garfield agreed to the future sale of 1500kW (kilowatts) generated at Roosevelt Dam to the Phoenix based Pacific Gas and Electric Company (later Central Arizona Light and Power Company (CALAPCO)) for subsequent distribution to the city of Phoenix and to various Salt River Valley businesses.[7] A permanent hydroelectric plant began operating in June 1909.[8]

III. Electrical Transmission: A Historical Overview

When electrical power transmission was in its early developmental stage, federal auspices over public utilities was rare. At the turn of the century, most Americans considered electricity a commodity for private enterprise, rather than a government service, and thus privately owned companies motivated and determined the evolution of electrical technology. Initially, urban centers were the power companys' primary market.[9]

In the late nineteenth century, although electrical service was generally limited to the Northeast and Midwest, American companies lead the world in electrical system development. Rapid and independent innovations in electrical technology characterized the period. Scientists experimented with electricity as early as the 1700s, but the invention of arc lights in the 1840s enticed commercial interest and henceforth rapid technological development. Throughout the 1880s, Thomas Edison issued several licenses to various companies to utilize his discoveries. These included incandescent lights and direct current circuit equipment. The Westinghouse Electric and Manufacturing Company, established by George Westinghouse in 1884, was his

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[6] David Nye, *Electrifying America: Social Meanings of a New Technology 1880-1940*, (Cambridge, MA: The MIT Press, 1990), 300.

[7] For a more thorough discussion on the Project's hydroelectric development, see David M. Introcaso, "Mormon Flat Dam," (National Park Service, Historic American Engineering Record, No. AZ-14, 1989), 1-20: James M. Gaylord, "Power and Pumping System of the Salt River Project, Arizona," (Phoenix: Salt River Project Archives, 1 January 1914), 6.

[8] For an historical overview of the Theodore Roosevelt Dam power plant and transformer house and the development of the Salt River Project power system, see Christine Pfaff, "Theodore Roosevelt Dam, Power Plant," (National Park Service, Historic American Engineering Record, No. AZ-6-A), 1996.

[9] Nye, 139-141.

strongest competitor. Because of the corporate competition and subsequent push for technological advancement, the electrical industry did not standardize its equipment and had few compatible systems. The controversy over direct and alternating current contributed to the industry's incongruity.

Throughout the 1880s, the most popular debate in the electrical industry concerned the best mode of electrical transmission, direct or alternating current (DC or AC). Unlike direct current, the electrical impulses in alternating current oscillated at back and forth intervals, rather than flowing in one direction. The rate of the alternating current is known as *frequency*. Frequency (measured in *cycles*) allowed for an increase in the force of the electrical current (*voltage*) and a decrease in the amount of electricity transmitted at a time. Transformers or converters stepped voltage up or down through a set of coils. This flexibility allowed electricity to travel over significantly greater distances than direct current. The AC system, however, lacked an efficient corresponding motor. The dispute pitted the Edison Company, which advocated DC, against Westinghouse which advocated AC.

While American companies pioneered many forms of electrical technology, Europeans made more significant advances in the area of long distance transmission. In 1883, Nikola Tesla of Yugoslavia patented a simply-constructed polyphase AC motor. Westinghouse secured the manufacturing rights. A multi-phase motor meant that the current experienced more than one burst of energy for every encounter with an electromagnet. This greatly increased the efficiency of the AC system. Advances in the development of AC fueled the development of longer transmission lines.

By 1892, AC transmission lines served remote western mining operations like Telluride's Gold King mine in western Colorado.[10] However, the most significant advances in hydroelectric and transmission technology developed in California during a period of corporate mergers and industry consolidation. Consequently, throughout the 1890s, electrical equipment became more standardized.[11]

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[10] Vernon E. Lynch, Jr., "Entrepreneurship and the Development of Electrical Power in Southwestern Colorado," *Essays in Economic and Business History* 8 (1990): 270.

[11] A three-phase circuit meant that three bursts of energy, rather than one, resulted from each encounter with an electromagnet, surpassing the efficiency of direct current for the purposes of electrical transmission. For a comprehensive description of the development of electrical transmission and hydroelectric power see Mark T. Swanson, "Santa Ana River Hydroelectric System," (National Park Service, Historic American Engineering Record, No. CA-130), 1992.

Reclamation engineers based the design for the transmission line from Roosevelt to Phoenix on the standards of the industry. These included the techniques their colleagues had used to design the hydroelectric systems at Niagara Falls, New York and Santa Ana, California.[12] California's engineers and businessmen applied their knowledge and expertise to Arizona. To direct the development of Arizona's system, the government hired Orville Hiram Ensign, who worked for the Redlands Electric Light and Power Company when it built the first long distance, three phase, alternating current electrical system in the United States.[13]

The Santa Ana line was the longest transmission line in the country at the time of its construction. It was also one of the most powerful. Built from 1894-1897, it carried 33,000 volts (33kV) of electrical power down the Santa Ana Canyon for 82 miles into the San Bernardino Valley. The ambitious project was Ensign's brainchild. One of the keys to the line's success was his development of the so called "Redlands type" insulator. Insulators encase the conductor wire and protect the other electrical equipment, including the transmission tower or pole, from high voltages. They are made of a material, such as porcelain or glass, that does not conduct electricity. Prior to Ensign's glazed porcelain design, those that could withstand voltages higher than 10kV were rare. Porcelain was much stronger than glass, and the flared-out edges (referred to as a "petticoat"), further strengthened the insulator. The arrangement of wires and insulators on the poles was also important to the line's success. At certain intervals across the line, maintenance workers rotated and transposed wires to reduce the static noise of an unbroken electromagnetic field.[14]

From 1902 to 1907, Edison Electric built a series of hydro plants on the Kern River to electrify Southern California. Former General Electric engineer James A. Lighthipe designed a 118 mile long, 75kV line. Not only was Kern River the highest voltage line in the nation, it was also the first in the country not supported on wood poles. Instead, steel towers designed by a windmill company carried the conductor wires.[15]

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[12] The first all steel transmission line was built in 1903 from Michoacan, Mexico to Guanajuanto on forty foot towers, 400-1600 feet apart. Norman Rowe, "Lightning-Rods and Grounded Cables as a Means of Protecting Transmission Lines Against Lightning," *Proceedings of the American Institute of Electrical Engineers* (6 June 1907): 1239-1248.

[13] For a comprehensive description of the Santa Ana system, see Swanson, "Santa Ana River Hydroelectric System."

[14] William A. Myers, *Iron Men and Copper Wires* (Glendale: Trans-Anglo Books, 1984), 38-39; For considerable detail on Orville Ensign and the development of the Santa Ana transmission line, see Swanson, "Santa Ana River Hydroelectric System Transmission," 79-87.

[15] Until that time, the only time steel towers had been used to carry transmission lines were in special cases like river crossings. Myers, 47.

Electrical engineers considered a variety of factors to determine the best tower design. These included wind, sleet, terrain, temperature, and the probability of accidents, such as breaking cables. The structures most resembling the conditions and purposes for transmission structures were windmill towers of pyramidal form. Designers of high voltage electrical lines often turned to these manufacturers to design transmission towers.[16]

In Central Arizona, the terrain, wind pressure, arid weather conditions, and high voltage required the strength and stability of steel towers, rather than wood or steel poles. A large portion (30 miles) of the transmission line from Roosevelt Dam's hydroelectric plant to Phoenix, traveled through the desert mountain region known as the Superstition, Apache, and Pinal Mountains. There, soil conditions are often loose and rocky. The surface is extremely uneven and among the most rugged areas in Central Arizona. The vegetation is typical of the Sonoran desert and includes dense areas of palo verde and mesquite trees, amidst cholla, saguaro, prickly pear, barrel, and pin cushion cactus. After Ensign assessed the topography and determined certain specifications, Reclamation officials solicited bids from various companies to manufacture the towers. Local (Los Angeles based) agents represented most of the firms.[17]

Though the designs of other towers were stronger, a windmill company from Illinois offered the lowest bid at $23,021.50.[18] The United States Wind Engine and Pump Company was the primary manufacturer of the most popular American windmill, the Halladay Standard. In 1863, the Connecticut based U. S. Wind Engine and Pump Company purchased the Halladay Windmill Company and moved to Batavia, a popular center of windmill production, in the Fox River Valley 35 miles west of Chicago. Windmills made from iron and steel began to appear in the 1870s. However, manufacturing steel was quite expensive and did not become commercially profitable until the turn of the century. The U.S. Wind Engine and Pump Company produced galvanized steel towers. They marketed their products through their own descriptive catalogs, dealers, agents, or in exhibitions. Towers were sold in intervals of five feet. Braces, which ran

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[16] "Load" is a term used to describe various types of stresses on a structure including electrical voltage, physical pull, wind pressure, and climate. D. R. Scholes, "Fundamental Considerations Governing the Design of Transmission-line Structures," *Proceedings of the American Institute of Electrical Engineers* (29 June 1908): 1011-1018; P.M. Downing, "Foundations for Transmission Line Towers and Tower Erection," *Proceedings of the American Institute of Electrical Engineers* (20 June 1915): 1227-1233.

[17] The U.S. Wind Engine and Pump Company was represented by local agents Pearson, Roeding, and Company. File marked "Roosevelt Dam Construction: Materials and Construction," Salt River Project Archives.

[18] Ibid. Ensign was suspicious about the strength of these towers because they lacked horizontal braces. He did prefer the arrangement of pins. The final decision, however, was based on price. Their 40 foot galvanized steel towers ran $68.00 each. The company was responsible for securing the appropriate insulators and crossarms for their towers. Once the price of crossarms and insulators were added to the bill, the total estimate came to $58,971.50, still far below the other bids.

diagonally, were specially adapted for various height requirements. While the windmill company supplied the towers, the Reclamation engineers specified parts, materials, and measurements.[19]

IV. Construction of the Transmission Line from Roosevelt to Phoenix

Like the Roosevelt Dam, the United States Reclamation Service also directed the construction of its hydroelectric generating unit. The generating facility contained six, 900kW turbine units.[20] This equipment generated a three phase alternating current at 2,300 volts and 25 cycles, which the electrical industry considered the best frequency to operate heavy industrial equipment required by the mines. The current then traveled to a transformer house that stepped up the voltage to 45kV for the sixty mile transmission into the Valley.[21] The line from Roosevelt to the city of Phoenix ran from the dam to the town of Mesa, where it would meet the distribution system for the Valley. Additional lines continued to the Gila River Indian Reservation, and into the town of Chandler as well.[22] Louis C. Hill was the Supervising Engineer. A. H. Demerick was the electrical engineer in charge of construction.[23]

Most of the labor force at the Roosevelt Dam was under Demerick's supervision. A group of 35-50 men, mostly Indians, constructed the transmission line. Beginning in 1906, six to eight men from Demerick's camp surveyed the transmission line from the Tonto Basin to Phoenix. They completed the survey in February. Workers began constructing the transmission line from Roosevelt Dam to Mesa on July 4, 1907. Engineers tested the completed double circuit, three phase, 44kV line in August 1909.[24]

Workers were able to lay five miles of tower foundations a month. This activity took longer than originally anticipated, especially in the mountainous segment east of the Goldfield mine.

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[19] Ensign even made requests as to the level of phosphorus used in the steel. T. Lindsay Baker, *A Field Guide to Windmills* (Norman: The University of Oklahoma Press, 1985), 7-10, 22, 70; File marked "Roosevelt Dam Construction: Materials and Construction."

[20] See Donald C. Jackson, "Theodore Roosevelt Dam," (National Park Service, Historic American Engineering Record, No. AZ-6), 87-89.

[21] The transformer house was built in 1908. For a description on the transformer house, see Pfaff, "Theodore Roosevelt Dam, Power Plant."

[22] The Sacaton project was a failed attempt to irrigate 10,000 acres on the north side of the Gila River.

[23] Demerick died in May of 1909. He was succeeded by both Irving Harris and William Cone.

[24] Louis Hill, Supervising Engineer, United States Reclamation Service (USRS) to A. P. Davis, Acting Chief Engineer, USRS, 7 February 1907, Files, Salt River Project; *Arizona Republican*, November 27, 1906, Newsclippings, Salt River Project Archives.

According to engineering practices, foundations had to have the strength to resist horizontal forces at the ground level. This was determined by their holding power and the density of the soil. While in the open desert, tower feet were planted in five foot deep holes on steel anchor plates, bricks, cement, and rocks were needed to secure them in the mountains *(see AZ-6-C-2).* These materials had to be hauled over long, rough distances. The *Arizona Republican* estimated that 500 barrels of cement and twelve tons of anchor bolts (to which the tower frames are attached) comprised the tower foundations *(see AZ-6-C-56).* Crews marked each foundation with the height of the tower required. When the towers arrived from the factory in groups of varying heights, the bundles of uprights, braces, and crossarms, were numbered with a metal tag to correspond with the foundations. A wagon, or even mules when necessary, could then carry them directly to their proper locations. Workmen completed the foundations by January 1908.[25]

The U.S. Wind Engine and Pump Company towers were made of rectangular angle iron braces of galvanized steel. They had four legs and two crossarms made of "channel" iron. Four wires hung across the upper arm, and two across the lower. The towers were either mounted on the concrete bases or anchored in solid rock *(see AZ-6-C-35).* Legs and foundations were altered in accordance with uneven surfaces. They were single braced, unless they ran at an angle, and then they were double-braced. According to a 1911 engineering article, the tower heights were chosen "to give the minimum number and degree of vertical angles consistent with economical construction."[26] Most towers were about 35 feet tall, but heights ranged from 15 to 90 feet *(see AZ-6-C-11).* The tallest were in depressions, and the shortest on mountain crests *(see AZ-6-C-12).*[27]

Anticipated in January 1908, the first shipment of the 600 tons of steel for the towers did not arrive from Illinois until March. The manufacturer sent the towers with numbered parts and instructions for assembly. They also pre-punched holes for brace rods and special fixtures and provided anchor rods. Despite some initial problems with less than perfect fittings, workers raised the first tower on Monday, March 2nd, and completed over half a mile in the next three days. Assembly, performed on location, required twelve men. About half were needed to raise the towers with a gin pole (two wooden poles configured in such a way as to act like a crane) operated by horse power, a practice commonly used to raise windmill towers. On flatter

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[25] *Arizona Republican*, 9 October 1907, 20 October 1907, 25 November 1907, 8 December 1907, 16 December 1907, 17 January 1908, 2 February 1908, 27 March 1908, Newsclippings, Salt River Project Archives.

[26] "Construction of a Transmission Line in Arizona," *Engineering Record* (28 January 1911): 109-110; W. E. Mitchell, "Tower Foundations for Transmission Line Towers and Tower Erection: The Alabama Power Company," *Transactions of the 32nd Annual Convention of the American Institute of Electrical Engineers* (20 June 1915): 1225.

[27] "Construction of a Transmission Line in Arizona," 109.

surfaces, workers first assembled towers on the ground as suggested by both engineers and the manufacturer *(see AZ-6-C-3, 4, 5, and 6)*. On the steeper inclines, workmen built the towers from the ground up *(see AZ-6-C-7)*. Eventually, they were raising an average of seven towers per day, with fourteen of them per mile.[28]

Soon, a shipment of 1,400 barrels of insulators arrived, about half the amount required for the whole line. Manufactured by the Locke Company, they were made of porcelain, the proven material for withstanding harsh climatic conditions, in the "triple petticoat" style. The pins to the three-part, pin-type insulators were assembled on site and were cemented into the cross arms with a special frame. Wire to conduct the electricity was tied to the insulators by two pieces of cable and two brass clamps *(see AZ-6-C-13)*. [29]

Two work camps of 20-30 men hung six-strand hemp core copper wires (known as standard No. 1 B&S) across the towers. They began stringing the line in April 1908 at the Highland Canal just east of Mesa. The top crossarm carried four wires, and the bottom carried two. Wire angles were spaced at a four foot equilateral triangle. By July 1908, workers had completed 20 miles. They finished the job by November.[30] The *Arizona Republican* described the process:

> Their mode of operation is to have a rope the required two miles in length with block attachments. These are taken ahead two miles and one end attached to an engine at that point; then the rope is stretched back with the aid of mules to where the coils of cable are and fastened to the end of same one at a time. A pulley is placed on each tower to run the cable along on and keep it from contact with the ground. The engine then stretched it to place and the operation is repeated until all six cables are in place and they are ready to move up to the next bunch of reels. . .[31]

The newspaper also noted that knowing how tight to stretch wire over rough hills, so that it neither breaks nor sags too much, "takes considerable technical information and a whole lot of natural horse sense" *(see AZ-6-C-8)*. [32]

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[28] *Arizona Republican*, 5, 11, 20, 27 March 1908; Downing, 1230-1232, "Steel Towers for Windmills," Catalog of *U.S. Wind Engine and Pump Company*, Windmill Manufacturer's Trade Literature Collection, Historical Research Center, Panhandle Plains Historical Museum, Canyon, Texas, 1909-1911.

[29] See footnote #10 for an explanation on insulators. *Arizona Republican* , 27 March 1908, 27 May 1908, 6 July 1908, and 26 November 1908.

[30] Ibid.

[31] *Arizona Republican*, 26 July 1908.

[32] *Arizona Republican*, 6 July 1908.

Once completed, the entire line stretched 65 miles from Roosevelt Dam to the Pacific Gas and Electric Company's plant in Phoenix *(see AZ-6-C-14)*. When the line reached Mesa near the Highland Canal, steel tripartite poles carried the wires, instead of towers, into the Salt River Valley. This 19 mile long branch took off from a switching station northeast of Mesa. It consisted of two, three phase circuits.

At the time, Project engineers believed the line from Roosevelt to Phoenix, built according to the most up-to-date practices, was "one of the best pieces of transmission line construction of its type in existence."[33] Yet soon after its completion, hawks decided that crossarms made attractive perches. Along with lightning strikes, they were responsible for most service interruptions.[34] At first, engineers attached a cast iron guard to each tower to remedy the industry wide problem with large birds. Other problems resulted from hunters, who shot out insulators, or from people, who for reasons equally puzzling, threw baling wire across the lines. The *Engineering Record* featured the relatively reliable Arizona line in 1911. However, by the following year, a contract to sell power generated at Roosevelt to the Inspiration Consolidated Copper Company not only offered additional revenue to repay SRVWUA's debt to the government, but provided an opportunity to rehabilitate the line.

V. Line Reconstruction and System Expansion

The Reclamation Service's contract with the Inspiration Consolidated Copper Company, signed on August 2, 1912, stipulated the construction of a new line which would run from Roosevelt Dam to Inspiration's mine and smelter near Miami. In addition to the agricultural resources in Central Arizona, the nation's economic interests also turned to the region east of the Salt River Valley for rich mineral deposits. By 1910, Gila County's Miami, Inspiration, Old Dominion, and Magma mining companies were among of the nation's leading producers of copper.[35]

Although there were a number of hydroelectric sites in the West, most were too far from the mines to supply energy prior to the advancement of long distance transmission technology.

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[33] "Will Revise Power Line," *The Arizona Republican*, November 5, 1912; SRP Annual History 1912-13, Salt River Project Archives.

[34] Ibid.

[35] Copper production in Central Arizona began as early as 1881, when the Old Dominion Copper and Smelting Company began its operations at Globe. By 1908, Arizona led the nation in copper production and pretty much held that title until at least 1981. Melissa Keane and A. G. Rogge, "Gold and Silver Mining in Arizona 1848-1945," Prepared for the Arizona State Historic Preservation Office, December 1992. For more information on the activities of the mines, see Frank Tuck, "History of Mining in Arizona," Department of Mineral Resources, Phoenix, Arizona, 1963.

Some mines generated electrical power with coal and steam. Those located in the rough western regions had difficulty shipping these materials to their remote locations. Yet, the mines had many uses for electricity. Electricity lit the shafts without any danger of exhausting oxygen supplies. Wires carrying electrical current were considerably less cumbersome than pipes carrying steam or compressed air. This made some equipment, like drills and pumps, more portable and easier to maneuver in tight shafts and tunnels. Electricity drove hoists, air compressors, ventilation equipment, mills, and tramming machinery. Finally, small and powerful locomotives replaced mules for transporting minerals and equipment. The new energy source made mines much more efficient in their production.[36]

As early as 1908, Reclamation's Supervising Engineer Louis C. Hill notified SRVWUA President Benjamin A. Fowler that he had received numerous applications for power from the Globe area. Residents realized that power would allow the mining regions to develop rapidly while cutting operation expenses considerably. In response, Fowler agreed that selling power to such districts made sense. "Personally," he commented to the *Arizona Republican*, "I have no doubt at all that the policy of the board will be to dispose of such power as can be wisely sold without detriment to the interests of the valley. . ." [37] On January 8, 1909, Globe Attorney George Stoneman reported that "Globe is anxious to secure power from the dam. . . I am very confident that there will be an electric line built from Globe to Roosevelt." Stoneman further claimed that Globe was booming with building improvements. The railroad to Miami was complete, the Old Dominion Mine was flourishing, property values were up, and the population was on the rise. Therefore, it was naturally the first place entitled to power following the Salt River Valley.[38] Despite the compelling argument, the nearby mining town of Miami, Globe's chief competition, secured this privilege for their more profitable company.

The 1912 agreement with the Inspiration Consolidated Copper Company meant a revenue stream of at least $400,000 a year to the Salt River Project. This income was extremely helpful to the Salt River Valley farmers trying to pay off their Roosevelt Dam construction debt to the government. In addition, the copper companies would pay for the construction of the new 38 mile line from Roosevelt to the Miami-Globe mining district, but the United States would own it upon completion. Reclamation officials, however, would design the line in order to ensure uniformity with the rest of the hydroelectric system that extended to Phoenix. Inspiration could

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[36] Nye, 204; Frederic Quivik, "Early Steel Transmission Towers and Energy for Montana's Copper Industry," *Montana: The Magazine of Western History* 38 (Fall 1988): 67-69.

[37] Hill to Benjamin A. Fowler, 21 December 1908, 4 January 1909, Files, Salt River Project Archives.

[38] *Arizona Republican*, 8 January 1909.

secure a minimum of 3,000 kilowatts (kW) of power for its plants two miles east of Miami, near Globe.[39]

Meanwhile, since 1907, the technology of high voltage transmission had grown rapidly. Engineers offered various solutions to common problems. As the use of electricity increased, power customers demanded larger amounts of power to be transmitted over longer distances. This required greater emphasis on the role of the insulator. By 1907, Electrical Engineer E. M. Hewlett declared that, "It has approached, if not already passed, the limits of good construction."[40] While the "pin type" insulator had become larger to meet greater voltage demands, Hewlett and his colleague, H. W. Buck, developed a new type of insulator more suitable for high voltages. They introduced it at the annual meeting of the American Institute for Electrical Engineers (AIEE) on July 26, 1907.

Suspension and strain insulators, argued Hewlett and Buck, were safer and more reliable than the pin-type. Suspension insulators hang vertically beneath the cross-arm. The strain variety, which stretched between two points, could be used at intervals to dead end the line, or anchor it at angles and curves *(compare figure #3 and AZ-6-C-13).* The first designs were ten inch individual units which were flanged, or petticoated, discs to protect the bundled (known as "tie") wires, from rain. The units interlocked through the center to insulate bundled wires. Conductor wires would pass through the discs' holes exerting pressure on the porcelain. The discs were arranged in a series so that if any one broke, the tie wire remained intermeshed. When a conductor supported by a suspension insulator breaks, as it retreats from the breaking point, it will stop at the next disc. The conductor remains protected. Each disc could handle about 25,000 volts, thus the level of voltage carried on the line determines the number of discs in a series. Hewlett and Buck suggested using these insulators with material properties (i.e. degree of moisture absorption) appropriate to the climate of the line's location. A 140 mile, 100,000 volt line in California built by the Stanislaus Power Company was the first to use suspension insulators exclusively.[41]

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[39] The transmission line's length later revised to about 32 miles. "Water Board Approves the Power Sale," *The Arizona Republican*, 2 August 1912.

[40] E. M. Hewlett, "A New Type of Insulator for High Tension Transmission Lines," *Proceedings of the American Institute of Electrical Engineers* (26 June 1907), 1259. For a discussion of the development of insulators prior to this time see Swanson, 81-84.

[41] For more information see E. M. Hewlett, "A New Type of Insulator for High Tension Transmission Line;" H. W. Buck, "Some Methods in High-Tension Line Construction;" D. R. Scholes, "Fundamentals Considerations Governing the Design of Transmission-line Structures," *Proceedings of the American Institute of Electrical Engineers* (26 June 1907), 1231-1237, 1259-1271; Downing, 1227-32.

Suspension insulators solved a variety of problems in transmission line construction. They carried the wire beneath the crossarm so large birds were less likely to touch it and short circuit a wire. Together with overhead ground wires and aluminum cell arresters, they reduced the threat of lightning. Finally, because they were able to carry higher voltages, these insulators allowed electricity to be carried over greater distances. Longer spans were of minimal concern in a climate where heavy snow and sleet conditions were rare. On double circuit towers, the most distance between towers was 800 to 1000 feet, approximately twice the span of the original tower locations.[42] Lines could therefore have fewer towers, making construction more economical.

In October 1912, linemen tested towers for the reconstruction of the Roosevelt-Mesa transmission line. Engineers drew specifications according to the most recent innovations.[43] Project engineers determined that they could rebuild the line according to recent industry advances by reconstructing the tower tops to carry suspension insulators and support ground wires, and by removing every other tower since the new design would allow for larger spans between the taller towers. The materials and towers taken from the old line would be salvaged and used to build the new Inspiration line. The money the Inspiration Copper Company provided for the new line would fund both projects. This solution not only offset costs, but at the same time, ensured a uniform and contemporary transmission system. This notion of saving money through the process of line reconstruction was ten years ahead of common practice.[44]

Chief Reclamation Service Engineer Irving C. Harris directed reconstruction efforts from 1912-1914. A crew surveyed the line from August through September of 1912 while Ensign oversaw the sample tower testing. A detailed report in November described the construction process. Workers began to set foundations for the new line in January 1913, and relocation for the old began in April.[45] Tower materials arrived in the summer. Workers removed 260 towers from the Roosevelt-Mesa line. They left many foundations in place. They replaced the crossarms with three new angle iron crossarms on top of each of the remaining towers. These new extensions

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[42] Downing, 1228-1229.

[43] Files, Salt River Project Archives; Department of the Interior, Reclamation Service, *Twelfth Annual Report of the Reclamation Service*, (Washington D. C.: Government Printing Office, 1912-13), 52.

[44] P. O. Reyneau and H. P. Seelye, "Transmission-Line Reconstruction," *Electrical World* 75, (3 January 3 1920), 7.

[45] The bases of the towers remain the same as the originals. Each tower foot was anchored to concrete footing. By 1915, engineers had determined that this was still a much more reliable method of securing steel towers against vertical and horizontal loads. All steel footings, although cheaper, required a perfectly flat surface on which to rest, or there would be unequal stresses on different legs of the anchor. J. B. Leeper, "Foundations for Transmission Line Towers and Tower Erection: II- Transmission Tower Steel Anchors Set in Earth," *Transactions of the 32nd Annual Convention of the American Institute of Electrical Engineers* (20 June 1915): 1213-1219.

carried conductor wire by suspension insulators (*see AZ-6-C-15, 57-59*). When towers were taller, the span, or space between them, could be increased and the number of towers reduced.[46] The length of the extensions varied from three to fifteen feet above the original towers' height in order to accommodate any increased line sag caused by the increased distance between towers. In the mountains, workers removed 40% of the towers. Most of these were taller towers. They placed the shortest possible extension on those remaining. Engineers strung telephone wire six feet below the power wires for inter-Project communication.[47]

The government sold the bulk of the removed tower material to Inspiration and subsequently used it to build the line from Roosevelt to Miami. They were essentially the same towers, but with shorter extensions, and double braced because a more level terrain allowed longer spans. The salvaged material not used on the Miami line was saved for use at a later date. These parts included 3500, 40kV porcelain pin-type insulators, tie-clamps used to tie wire, 142 cast iron anchors for scrap cast iron or guy anchors, and 272 pounds of twelve foot galvanized channel iron.[48]

Work was completed in January 1914, and Inspiration's substation received power on March 21.[49] The reconstruction went relatively smoothly, except at least three inexperienced workers died from falls or electrocution.[50] A severe September storm blew down two miles of the new line. Wood poles were used as temporary replacements. Engineers insisted that the tower failures were not due to a fault in design, but to highly unusual and unanticipated violence in the weather.[51] The following year, SRP's Annual History reported that the new line design had, for the most part, remedied the hawk and lightning problems of the past. The stretch from Mesa to Phoenix, which still carried pin insulators, continued to experience interruptions.

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[46] D. R. Scholes, "Transmission Line Towers and Economical Spans," *Transactions of the American Institute of Electrical Engineers* (26 June 1907):1221-1237.

[47] Telephone lines were used for inter-Project communication only. SRP never ran a public telephone service. "Construction of a Transmission Line in Arizona," 109.

[48] Foundations of removed towers can still be seen along the right of way. Gaylord, *Power and Pumping*, 113-118; File labeled "Miami-Roosevelt 1913," Salt River Project Archives. This file contains detailed instructions regarding reconstruction, work order for parts, hand-written instructions, and maps of the line locations.

[49] SRP Annual History, 1912-13.

[50] Investigators of these accidents determined that the workers' inexperience and their misunderstanding of instructions caused these accidents. *Phoenix Gazette*, 23 December 1913, *Arizona Record*, 15 January 1914.

[51] File labeled "Miami-Roosevelt 1913," Salt River Project Archives.

In 1919 and 1920, six towers near Fish Creek failed because of a lightning and wind storm. By 1922, due to a number of tower downings, most towers were side guyed with three-fifths galvanized strands and attached to seven inch channels or rock anchors. According to accepted standards, a guy anchor was placed about one- third the distance of the tower's height from its foot.[52] Power workers periodically replaced faulty and broken insulators up and down the line.[53] However, after ten years, the SRP Power Division only needed to replace 250 out of 12,000 insulators.[54]

In November 1913, engineers had estimated a cost of $60,000 to reconstruct the line. The number included materials for towers (300,000 pounds), 2,800 insulators and fittings, ground wire, telephone wire, tower fittings, and labor charges. The Reclamation Service contributed $10,763 for materials, yet by the project's completion the price reached almost $125,000.[55] Nevertheless, other mines in the area followed Inspiration's lead.

VI. Striking it Rich with the Mines

Between 1913 and 1914 the Magma Copper Company in Superior built a concentrator with a capacity of 200 tons per day. Under arrangements with Inspiration, Magma constructed a substation and a 14.72 mile single circuit steel tower line over rough terrain from Miami to Superior in order to receive some of Inspiration's power to operate its concentrator and smelter. Constructed from spare parts, towers were essentially identical to those on the Roosevelt-Mesa and Roosevelt -Miami lines. Spans as large as 1000 feet between towers were common. Magma financed the construction in order to receive a portion of the power coming to Inspiration from the Roosevelt Dam powerhouse. Although it connected to the government system, Magma owned the line *(see AZ-6-C-60).*[56] On June 12, 1917, the United States signed its first contract with Magma. The company agreed to construct a power plant, transmission, and telephone lines from Roosevelt Dam to Magma's new substation at Superior via Goldfield. A 50% credit on

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[52] Connery, F. C. "Foundations for Transmission Line Towers: V. Toronto Power Company," *Proceedings of the American Institute of Electrical Engineers*,(July 1915): 1233-1241 .

[53] SRP Annual History, 1919-20, 1921-22

[54] Twice, conductor lines broke at a point near the insulator. The copper may have been weakened by the continuous bending due to swinging lines. SRP Annual History, 1917, 1922-1923.

[55] "Will Revise Power Line," *Arizona Republican*, 5 November 1912; Norman Rowe, "Lightning Rods and Grounded Cables as a Means of Protecting Transmission Lines Against Lightning;" A. Bang, "Four Years' Operating Experience on a High-Tension transmission Lines," *Transactions of the American Institute of Electrical Engineers*, (26 June 1915): 1243-1245; Gaylord, 116; File marked "Miami-Roosevelt Line, 1913," Salt River Project Archives.

[56] Gaylord, 113-118.

Magma's monthly power bills reduced the estimated construction cost of $125,000 by $60,000. Upon completion, the structures would become the property of the United States.[57]

The following April, the Association built a single circuit line from Goldfield to Superior along with the hydroelectric power plant at Chandler. Like the line from Mesa to Miami, Goldfield-Superior was 44kV at 25 cycles, but because of cost, it was carried by wood poles (*see AZ-6-C-67*). This stretch of the transmission system was the most vulnerable line to lightning strikes, and the section between Queen Creek and Superior experienced an excessive number of outages. In 1922, the Magma Railroad Company had to relocate some of the poles that were running through its right of way.[58]

VII. Completing the Circuit: "The Loop"

During World War I, industries came to the Salt River Valley in Arizona to produce Egyptian long staple cotton used for the production of tires and airplane fabric. As the war came to an end, however, the demand for cotton and other products dropped. This imposed a significant financial hardship on Salt River Valley farmers. In November 1917, the government had turned over the Project to the Salt River Valley Water Users' Association. The Association still needed to pay off its ten million dollar debt for the construction of Roosevelt Dam. By the early 1920s, economic conditions forced it to defer its repayments. In addition, the potential load demand on the power system increased as electric service became available to farmers and the mines expanded with the growing copper industry.[59] The Salt River Valley Water Users' Association instructed newly elected Chief Engineer Charles C. Cragin, together with civil engineer F. J. O'Hara and electrical engineer H. J. Lawson, to investigate economical ways to secure additional power development and power sales, particularly to the copper mines.[60]

Cragin's report, completed in 1922, concluded that regulating the Verde River could generate over 50,000kV of additional hydroelectric power. The report recommended increasing the

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[57] Another agreement on October 12, 1920 modified the 1917 contract. The government completed part of the construction at a cost of $66,000 which Magma was to pay back. Sheridan, xvi; Glenn W. Brandow, "Historical Documents Pertaining to Power Contracts and Agreements of the Salt River Project," (Phoenix: Salt River Project, 1961): 8-9.

[58] File labeled "25 Cycle Conversion," Salt River Project Archives; SRP Annual History 1917-18, 1921-22.

[59] The Magma Copper Company was organized in 1910 to work the Silver Queen Mine. Eventually, it mined primarily copper. From 1917-1920, they renewed activity on the Silver King Mine as well. Tuck, "History of Mining in Arizona."

[60] Charles Cragin, a graduate of New York University had worked as a consulting water supply in numerous cities across the country. Introcaso, 22-23.

storage capacity of Roosevelt's reservoir, remodeling the existing power plant to correct sources of interruption, and constructing the Mormon Flat Dam for additional hydroelectric power. Cragin also suggested building another dam, between Mormon Flat and Roosevelt. Horse Mesa's construction would be the focus of the Salt River Project's expansion.[61]

Finally, in order to deliver the additional power generated at the new Mormon Flat power plants, the Project would need to convert the transmission system to a 110kV single circuit connecting Goldfield, Roosevelt Dam, Mormon Flat, Miami-Inspiration, and Superior through new substations at Goldfield and Superior (*see figure #2*).[62] The Cragin report proposed that the present 44kV line could be modified to a 110kV loop through economical reconstruction; they worked from what they had and recycled parts from old projects. The old windmill towers in the area, made of galvanized steel and anchored on concrete foundations, still satisfied industry standards.

By the 1920s, steel towers were the most accepted type of transmission structure for high voltage lines. E. F. Gemmill wrote a series of articles for the *Electrical Review* explaining the latest practices in designing steel tower lines. Unlike steel poles, or flexible steel frames, rigid towers could withstand loads at angles and from a number of directions. The loop would operate as a closed system. The amount of electrical power delivered, known as "loading," would be equally divided on both sides. With two lines entering the circuit from separate routes at every point of use, Cragin's report boasted that "with the changes contemplated for the new development, it will be one of the most reliable transmission systems in existence." [63]

Like the 1913 alterations, the tops of the steel windmill towers would again be reconstructed to convert the line to a single circuit. This would eliminate half of the wind pressure on the wires and reduce their dead load by about 800 pounds per tower. Parts would again be salvaged and

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[61] In 1928, the Board of Governors also approved the Stewart Mountain Dam Project. Frank Martos and Jerry D. Smith, "History of SRP's Electric System: A Phase 1 Study Report Long Range Electric System Plan, Power System Analysis, Salt River Project," (Phoenix: Salt River Project, July 1986), 7. Copy located in the Salt River Project Archives; Also see Introcaso.

[62] A voltage of 110kV was selected because structures and conductors could be adapted and the voltage was an appropriate level at which to handle the amount of power. The Goldfield substation would provide duplicate autotransformers to regulate voltage to the Valley and to the dam sites, while at Superior and Miami , the substations would reduce the voltage to 40kV so that the transformers already at Magma and Inspiration could handle the load. For a more detailed description of the entire transmission system, see C.C. Cragin, "Report on Proposed Additional Hydroelectric Power Development of the Salt River," (Phoenix: Salt River Valley Water Users' Association, February 1922): 34-39.

[63] E. L. Gemmill, "Steel Transmission Line Structures," *Electrical Review* 76, (March-May 1920); 385-390, 555-560. 645-651, 719-723; Cragin, 34-35.

reused. Cragin also presumed that the wood pole line from Goldfield to Superior could be adapted to the higher voltage by resetting the poles and by using the salvaged copper from the two circuit Roosevelt-Miami line. The only new construction the engineers predicted was 4.6 miles of line connecting the new Mormon Flat Power Plant to the existing line. Conductors would be "#00 B& S Gauge Stranded" copper cable throughout the entire loop, except between the Roosevelt Power Plant and Dam where one of the existing "#1 S & S Gauge" copper lines was removed. Meanwhile, workers relocated towers from the Mormon Flat reservoir site and built 1.25 miles of 110kV line to the Mormon Flat Power plant. Construction for the 4.5 mile long transmission line into Horse Mesa, over particularly rough terrain, was completed between October 1924 and May 1925 *(see AZ-6-C-21, 22-23, 36-40, 65-66).*[64]

With expansion, the Association renegotiated its power contracts with its biggest customers. On January 3, 1924, Magma Company near Superior transferred its line to the Inspiration substation. Magma could use up to 2,000kW of power off the line for 50 years without cost. On June 14, Inspiration, then one of the largest industries in Arizona, signed a contract with the Association to purchase all the hydroelectricity generated from the new dam, Horse Mesa, in order to power its new six million dollar leaching plant. This agreement essentially funded the dam's construction. It also required the Association to build two new transmission lines to carry that power to the copper company's Miami operations. Along with paying the cost of construction and operations, the revenue would further aid the farmers in the Salt River Valley in repaying the government for the Roosevelt Dam project, as well as provide funds for electrifying the Valley.[65] The Association also secured ownership of the Magma's line from Miami to Superior.

From April 1925 through at least November 1925, workers built brand new steel towers from Goldfield to Superior along the old wood pole line which they removed and salvaged. The Muskogee Iron Works Company of Muskogee, Oklahoma provided the new towers.[66] Unlike the square windmill-type towers that made up much of the loop, these were rectangular transmission

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[64] There is almost no information available as to the manufacturer of these towers to Horse Mesa, and perhaps Stewart Mountain Dam. However, they are almost identical to several types seen and advertised in engineering journals during this time period. Their particular pyramidal design was appropriately chosen for the particularly steep and rocky terrain near Horse Mesa Dam. SRP Annual History, 1924-25; See also Bang, "Four Years' Operating Experience on a High -Tension Transmission Line," *Proceedings of the American Institute of Electrical Engineers* (26 June 1907):1241-1245.

[65] The agreement was supplemented and modified in November 1924. A copy of this agreement was reproduced in the July 15, 1924 issue of *The Associated Arizona Producer*. The entire 110kV loop cost just over $100,000. Introcaso, 60-78; "Agreement Between the Salt River Valley Water Users' Association and the Inspiration Consolidated Copper Company," (14 June 1924). Copy available at the Secretary's Office, Salt River Project.

[66] These towers are also on the transmission line to Mormon Flat. SRP Annual History 1924-25.

towers. Tower designs had become increasingly sophisticated since the windmill model. Although engineers decided the best arrangement of wires, calculated loadings under various local climactic and topographic conditions, and assessed the dimensions and strength required of the structures, the manufacturers with the best bid often determined the actual design of transmission towers.[67] Muskogee employed slight alterations depending on the function of the tower. Intermediate towers were the most common. They placed an extra arm on angle towers. Transposition towers, which come in pairs, had additional elevations in order to transpose the wires in order to decrease the electromagnetic field. Each new tower took workmen about eight hours to erect *(see AZ-6-C-24, 25-26, 41-47, 67-71).* [68]

The Association purchased additional parts from the United States Steel Products Company in San Francisco, California for the existing steel tower lines from Goldfield to Miami via Roosevelt. These consisted of cross arms, diagonals, plates, galvanized poles, and washers. On each tower, workmen removed or sawed off the middle cross arm and placed three sets of insulators on the remaining ones *(see figure #3, AZ-6-C-18, 19, 61, 62).* All the older towers required new tops and crossarms to gain higher clearance for the higher voltage.[69] They replaced all the conductors with the larger #2/0 copper conductor wire. Workers relocated 27 and added 23 towers on the Superior-Miami line. They also moved two and a half miles of the Roosevelt-Miami line to release storage space for the new leaching plant at Inspiration. Finally, they relocated five towers near Roosevelt to allow the Apache Trail to reach the Horse Mesa reservoir site. A few years later in 1928, for unknown reasons, engineers found it necessary to install 29 miles of overhead ground wires from Goldfield to Superior. They also added ground wires and changed out steel crossarms with wood ones from Superior to Roosevelt via Miami, and from Roosevelt to Mormon Flat *(see AZ-6-C-63, 64).* [70] Engineers may have made the latter decision because unlike steel, engineers could calculate the precise strength of wood regarding its ability to hold heavier conductor wires. The 110kV loop began operating on August 5, 1926 with the Mesa Switching Station and Superior Substation *(see AZ-6-C-19, 28-29).* [71]

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[67] For more detailed description about the factors determining steel transmission tower design, see Gemmill, 719-723.

[68] SRP Annual History 1924; "A Story Without Words," (photo series) *The Associated Arizona Producer* 4 (1 November 1925), 5.

[69] Engineers used some of the old 44kV line Locke 5800 insulators, but replaced others with the new ones from Westinghouse, insulator no. 601.

[70] Other subsequent changes are noted on referenced drawings AZ-6-C-62, 63.

[71] SRP Annual History 1925-1926, 1928; File marked "Miami-Roosevelt 1913," Salt River Project Archives.

In 1926, workers began constructing Horse Mesa Dam. That same year, the Association signed a contract to sell power with the new Nevada Consolidated Copper Company at Ray. The agreement added $250,000 dollars a year to the Association's income. It allowed for the sale of power from Horse Mesa that was produced in excess of the amount contracted to Inspiration. Also like the Inspiration agreement, Nevada's contract stipulated that the transmission line, valued at $153,000, would become the Association's property after twenty-five years. As well, the Association supervised construction at the company's expense, and was allowed to purchase power from the mine's auxiliary equipment in times of water shortage.[72] From March through June of 1927, the Project constructed a new 13 mile, 110kV steel line from Superior to Ray off the 110kV loop. The 87 towers were rectangular, similar to those from Goldfield to Superior, but the Pacific Coast Steel Company in San Francisco supplied a slightly different design (*see* AZ-6-C-27, 72).

VIII. The Linemen

The men who built the 110kV loop worked out of four camps located at Horse Mesa, Miami, Superior, and Roosevelt. Like the linemen who had worked on the first reconstruction, these workers were primarily young single men, some local, or often drifters or miners, who sought temporary jobs. Often they had little, if no experience in linework. They earned about three dollars a day, approximately 50 cents less than the mines paid. However, strikes often plagued the mines so laborers could not always rely on steady work. The Project provided tents for linemen to live in, but they slept in their own bedrolls. Cooks provided their meals for one dollar a day.

Jess Stoker, a long time Salt River Project employee, began as a lineman in 1926 building the steel Muskogee towers from Goldfield to Superior. He lived at the "Top of the World" camp, located halfway between Superior and Miami, with about fifty other men. Bob Ward was the line foreman, but Charles Keats, who worked at the Miami-Pinto Creek camp, supervised the loop's construction. Jess Fulton was in charge of wiring, and Ira Levin supervised the telephone line. Additional crews removed the telephone line from the towers and, according to Stoker, strung it

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[72] The mines produced 10,000 tons of ore daily, meaning 70,000 tons of refined copper valued at $17,000,000. Nevada Consolidated Copper Company took over the Ray Consolidated Copper Company in 1926. Inspiration also received power for its mills, concentrators and smelters from a power house that utilized reverberatory waste heat and also produced power from oil-fired boilers. Drawing F-12-50, Salt River Project; "Salt River Valley Farmers to Realize $250,000 Yearly Income From Power Furnished Ray Mines," *The Associated Arizona Producer* 5 (15 December 1926), 3-4; Martos and Smith; For detailed information about their equipment see G. R. Rubley, "The Story of the Miami-Inspiration Copper District," Arizona Historical Foundation, Arizona State University.

on 18 foot boiler tubes with crossarms 100 feet away from the power line. The boiler tubes were probably salvaged parts from a substation and re-used for the telephone lines.[73]

Stoker described an atmosphere where "everybody was working to enjoy themselves and get the job done."[74] They drove to work in old trucks which could only reach 18-20 miles an hour on the rocky dirt roads. Although they often graded the road, it was at times even too rough for mules. Sometimes it was just easier to walk to a tower's designated location. Once at the erection site, explained Stoker,

> We started from the bottom right up and built them piece by piece. We didn't have any equipment or nothing, only just a handline. That's a pulley, a hook, on the end of a rope hanging up on the end of the steel and start the construction . . . We had everything in those days that was available that we needed. We could have used other stuff but we didn't have it and didn't know anything about it. We had one winch truck, that is, with a pulley on it so you could pull the wire in.[75]

Except for an occasional mashed finger, there were few, if any, reported accidents. Once the Ray line was completed, the system reconstruction was for the most part finished, and most of the linemen were laid off.[76]

IX. Epilogue

Since the 1920 alterations, the Salt River Project has made few alterations to the transmission line in the Eastern Mining Area. Most modifications consisted of maintenance, part replacement, or tower relocation. Some towers were removed. One of the most significant developments resulted from yet another voltage increase, but more significantly, a frequency change as well. In 1949, the Project introduced a new 60 cycle frequency system to the Valley.

Although electrical lines and appliances operating at 60 cycles were becoming the national standard, the Salt River Valley still operated at the 25 cycles required by the mines, the largest power customers. After World War II, however, the Salt River Valley's urban areas and population significantly grew. The electrical service at 25 cycles and 45,000 volts was far below contemporary industry practice, especially for modern urban areas. By the 1950s, manufacturers

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[73] A Mr. Munster was foreman at Horse Mesa camp, and Azell Henshaw, one of three linemen brothers, directed the stretch from Roosevelt to Pinto Creek. Jess Stoker, Interview by Harriet Haskell, (Transcript: SRP Historical Research and Archives Project, 10 April 1981), 1-10.

[74] Stoker, 3.

[75] Stoker, 7.

[76] Stoker, 6, 10.

were no longer making 25 cycle equipment and appliances. In addition, the low frequency caused household lights to flicker. Finally, the old system could no longer sustain the loads required by Phoenix's industrial development. SRP recruited experienced personnel from California and began plans to convert the entire transmission system.[77]

Frequency conversion required four main stages. First, the electrical equipment itself, the generating plants, substations, and transmission system, would need to be changed. Next, the Project would have to replace the equipment for the mines, commercial establishments and residential areas. Unlike the 50 to 60 cycle change in California, the increase from 25 to 60 cycles required the replacement of operating equipment. The mines, however, who were the largest power customers, still preferred 25 cycle which most of the industry considered ideal for industrial use. SRP purchased frequency changers and placed them at Mesa in order to isolate everything east of the Mesa Switching Station, which was essentially the 110kV mining loop, to 25 cycles.[78] For years, the Project sought to persuade the mining area to upgrade. They were finally successful in 1955. In order to bring 60 cycles to the mining towns, the Project built a new 115kV, 60 cycle line from Goldfield to Superior, parallel to the old one. This way the mines could use either or both frequencies depending on the age and capabilities of their equipment. Perhaps aside from changing out the conductor wires, the old transmission lines or towers needed no major alterations for the frequency change.

In 1955, SRP contracted with the Kennecott Copper Company at Ray, increasing services to Ray and Superior from 110kV to 115kV at 60 cycle. The Project converted the lines from Mesa to Goldfield, Goldfield to Superior, and Superior to Ray. The Superior-Miami line followed in 1958 when Inspiration's contract required the company rebuild a mill with 60 cycle equipment.[79] By the mid-1960s, SRP management was eager to upgrade the frequency in the mining area. They considered the 25 cycle loads inefficient and obsolete and urged new contracts with the

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[77] About 1948, Salt River Project administrators Searles, Best, and Floyd Smith recruited people from California to direct the Project's frequency conversion. The four main managers from California included Rod McMullin, Henry Shipley, Stan Ward, and Thomas Morong. Morong's former Supervisor at the Southern California Edison Company, C. L. Sidway also worked for Westinghouse in Arizona. He often toured the mining areas and advised the copper companies on electrical equipment. When the Los Angeles consulting firm of Leeds, Hill, Barnett, and Jewett was asked to prepare an economic survey of the Salt River Project, Sidway was enlisted for the electrical section. The resulting report strongly suggested the need for a Project wide frequency conversion. Having frequently consulted with Sidway about the Arizona situation, Tom Morong became chief engineer for the Salt River Project. Tom Morong, Interview with Harriet Haskell (Salt River Project Historical Research and Archives Project, 1981), 18-23.

[78] "Mesa Switching Station," *The Current News*, (1954), 3-5.

[79] In 1957, the Project built a 115kV, 60 cycle line from Ray to Hayden, and in 1962, they built similar lines from Hayden to Coolidge and from Goldfield to Stewart Mountain.

mining companies to force out the 25 cycle system. Their hopes turned urgent when the hydro plant equipment needed rebuilding in order to adequately supply the mining load when water conditions restricted hydrogeneration. Inspiration held out longer than the other mining industries, and its general manger, Bud Neal, agreed to use a frequency changer at the mine so that the rest of the loop could be converted. Finally, by 1969 the last phase of the Hydro Expansion and Frequency Unification project (HEFU) completed the frequency conversion for the entire Salt River Project electrical system.[80]

Project maintenance did not check the 110kV loop tower by tower until 1954. At that time, engineers Max Seaton and Clem Allen and estimator George Shanks found weakened crossarms, metal corrosion, damage to foundations, and defective down guys and anchor rods. However, most of the forty year old towers could continue to effectively transmit electricity to the mines. The engineers recommended adding a special armor rod to prevent damage to clamps that were pinching the conductor wires, as well as some replacements of guy wires and crossarms. They also suggested replacing the galvanized steel guys and anchor rods with copper clad steel. Maintenance workers have replaced insulators on many towers, but some still operate with the originals. The Project has also added to the line, or replaced a number of the older towers, with wooden "H-frames."[81] The original steel towers from Goldfield to Superior and from Superior to Ray remain essentially untouched since their construction in the 1920s.

A long-range study conducted in 1983 predicted that mining loads in the eastern mining area would probably "never reach historical peak levels."[82] However, future plans focused on the individual needs of particular areas and companies. In 1980, the Project built its first EHV (Extra High Voltage) transmission lines; a 500kV current traveling from Cholla to Silver King and 230,000kV connected Silver King to Goldfield and Kyrene.[83]

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[80] Fred Henshaw, Interview by Harriet Haskell, (Transcript: SRP Historical Research and Archives Project, 3 February 1981, 31 March 1981), 17, 37; Morong, 22; Martos and Smith, 30-34; T. M. Morong, Manager, Power Operations to G. W. Brandow, Assistant General Manager, Power Operations, 8 December 1966, Salt River Project Archives.

[81] Henry F. Unger, "Close-up of a Check Up," *The Current News* (September 1954), Salt River Project Archives.

[82] Memo, William G. Breyer to Executive Planning Committee, (7 December 1983), Salt River Project Archives.

[83] "Eastern Mining Area Transmission System: Summary Report," (July 1983), Salt River Project Archives.

X. Conclusion

The early EMA transmission line delivered the energy needed to produce two of Arizona's most valuable economic resources, cotton and copper. Arizona provided these essential raw materials for industrial America throughout the early 20^{th} century. Revenue from the sale of power to the mines, the Project's largest customers, funded the building of power dams that in turn brought electrical power to the Salt River Valley. The transmission system enabled a large-scale government water storage project to become a complex hydroelectric system serving most of central Arizona. Thus, the long distance transmission of hydroelectric power to farms and mines transformed the region into an area of great wealth and prosperity.

Finally, although the Salt River Project has modified and, in some cases, relocated the original towers, it completed most changes early. Today, the 115kV towers illustrate the rapid development in long distance, high voltage electrical transmission technology and tower design in response to society's needs.

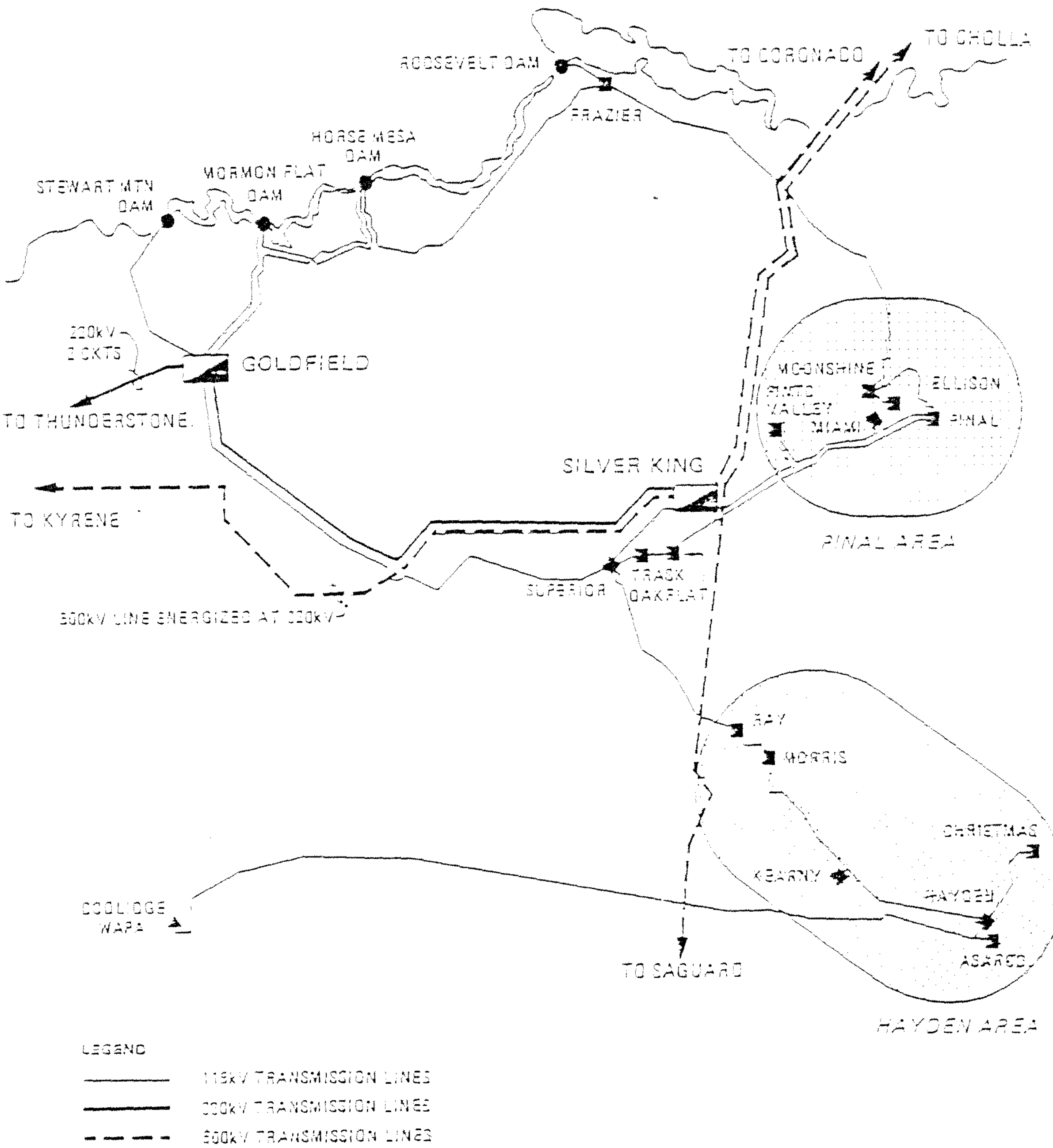


Figure 1

EXISTING EASTERN MINING AREA TRANSMISSION SYSTEM
provided by the Salt River Project, Phoenix, Arizona

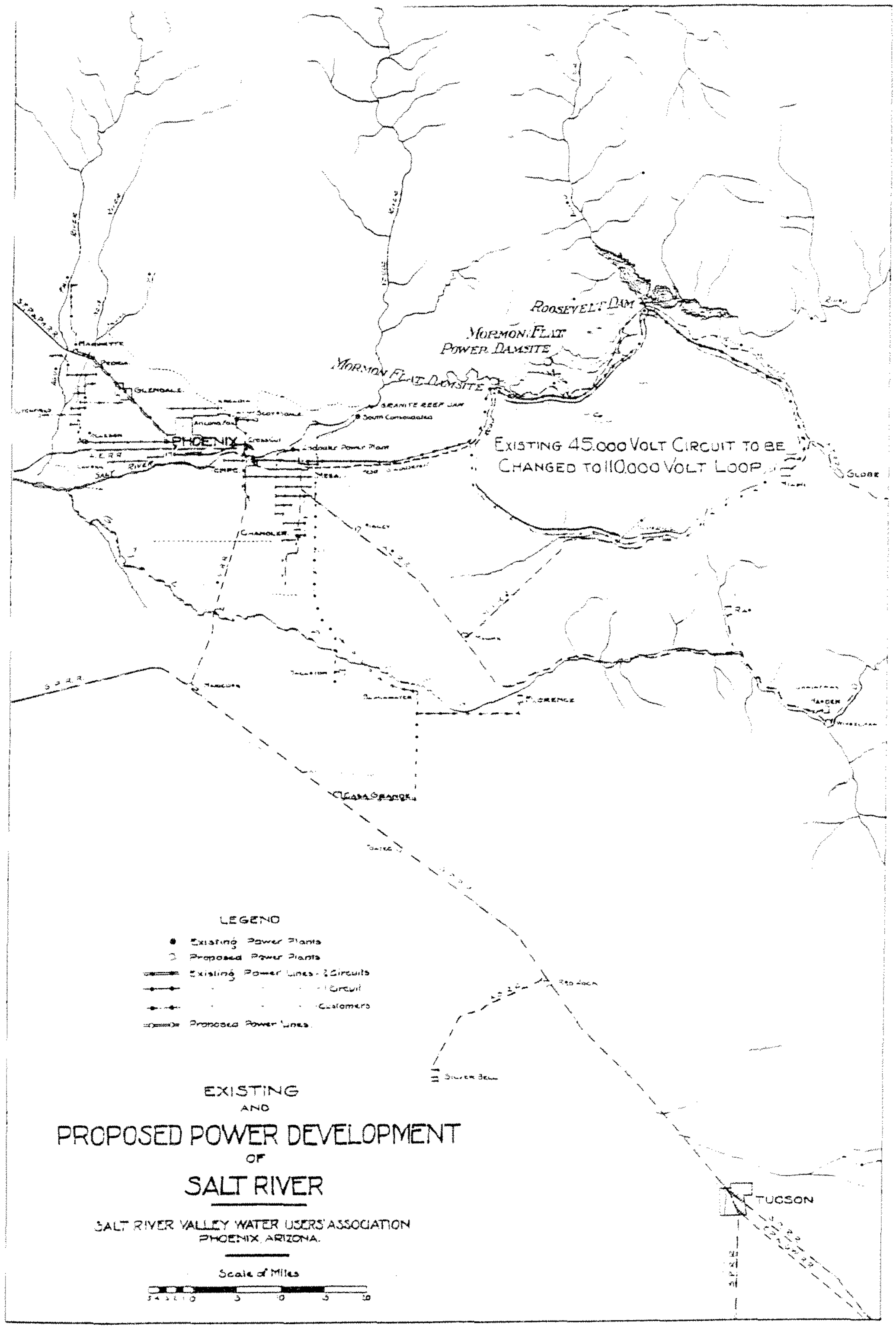
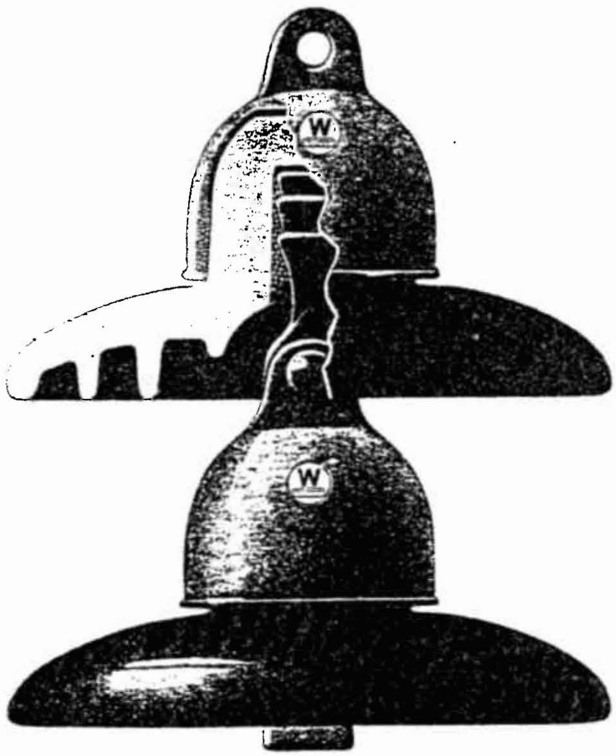


Figure 2

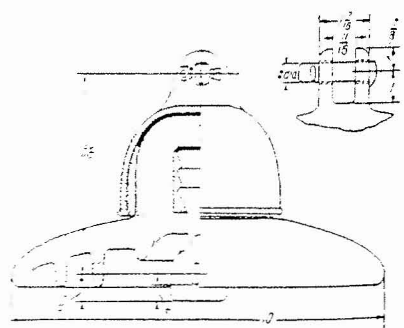
From C.C. Cragin, "Report on Proposed Additional Hydroelectric Power Development of the Salt River," Salt River Valley Water Users' Association: Phoenix, AZ, February 1922.

PORCELAIN SUSPENSION-TYPE INSULATORS—Continued



Two of Insulator No. 601

Insulator No. of one unit	601
Trade voltage rating per unit	20000
Dry arc-over voltage	80000
Leakage distance, inches	11½
Wet arcing distance, inches	3¼
Diameter of insulator, inches	10
Distance between center of eyes, inches	5⅜
Approximate net weight per 100 in pounds	1050
Approximate weight packed per 100 in pounds	1335
Packed ... 3, 4, 5, or 6 per crate as desired.	
List price per 100 units	$363 00



Note: For transmission line fittings refer to catalogue section 6-E.

Figure 3

From "Westinghouse: Catalogue of Electrical Supplies 1923-24." Pittsburgh: Westinghouse Electric and Manufacturing Company, 794. Copy in the Salt River Project Research Archives.

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